Macro (close-up) Imaging

Extension Tubes

March 2009

Macro (close-up) Imaging using Extension Tubes

Every lens has a minimum focus distance, which dictates how close you can get to what you want to image. A lens that has a macro capability can be used as a close-up lens, bringing you closer than you can get in non-macro mode. However, a macro lens is expensive and there are alternatives, extension tubes or diopters. A diopter is a supplementary lens similar to a filter that is screwed on to the front of your lens. An extension tube attaches to your camera's lens mount on one end and the other end attaches to the lens, which alters the focusing distance and magnification ratio. Extension tubes are inexpensive and because there is no glass in the tube, the image quality is not compromised. Also, diopters can be used in combination with extension tubes for even higher magnification.

When using an extension tube with a lens, a lens with a long focal length will have a smaller amount of magnification than a lens with a shorter focal length. This is due to the difference in each lens minimum focus distance, which is modified by the extension tube. Hence, a long focal length lens has a larger minimum focal distance and a given extension tube will have less magnification than when compared to that of a shorter focal length lens. An extension tube has a focus zone, which greatly compresses the Depth-Of-Field (DOF) for an object to be in focus. As an example, a standard 50mm lens has a minimum focus distance that is reduced down to about 4 inches and the DOF is so small that the lens is very close to the subject for it to be in focus. You will find that short focal length lenses are more difficult to get an object in focus. Some patience and a fine adjustment of the working distance from the lens to the subject are necessary. Opening up the lens will increase the DOF when using an extension tube.

The total amount of extension you need in order to get to any given magnification depends on the focal length of the lens you are using. The amount of extension can be achieved by a combination of the lens focus range & the use of extension tubes. A simplified formula for calculating the magnification is shown below.

Magnification = Total extension used / Focal length used

As an example, if you want to magnify an object by 75% and you are using a 60mm lens, the total extension length needs to be the following:

Total extension used = Focal length used x Magnification = 60mm x .75 = 45mm

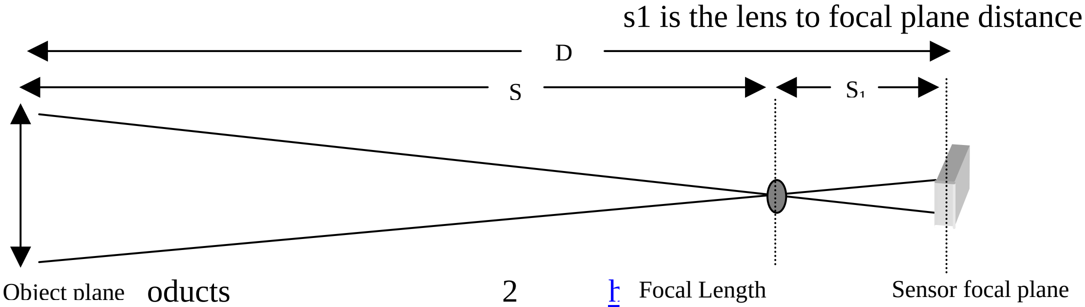
If you change the lens to a 200mm lens and kept the same total extension, the magnification would be:

Magnification = Total extension used / Focal length used = 45mm/200mm = 22.5%

This clearly illustrates why long focal length lenses when compared to a shorter focal length lens will not have as much magnification for a given extension distance. If you need to calculate the new Minimum Focus Distance (MFD) of a lens when an extension tube has been added, the following simplified lens formula:

$1/f = 1/s + 1/s_1$ (simplified)

Where
f is the lens focal length
s is the subject to lens distance
s1 is the lens to focal plane distance



As an example, a 300mm lens with an MFD of 1.46 meters (note- all units in mm):

$$1/300 = 1/1460 + 1/s_1$$

solving for s1 we have

$$s_1 = 377.6$$

Now let us add an extension of 20mm to the lens. We can now calculate the new focal plane distance s_1.

$$s1 = 377.6 + 20 = 397.6mm$$

Now use the new value for s_1 into the equation and solve for s, which is the new MFD for this example.

$$1/300 = 1/s + 1/397.6$$

s = MFD = 1222.13 mm or 1.222 m compared to 1.46 m without the extension tube.

More extension tubes can be added to magnify the object further.

The use of extension tubes will require an exposure adjustment due to the inverse square law for light. To calculate what compensation is required, we have the following calculation:

C = (log10 (1+ET/F)^2) / log10 (2)

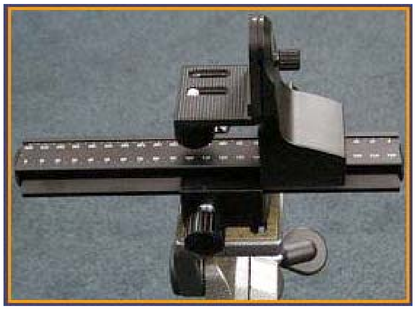
Where:
C is the exposure compensation
ET is the extension tube length in mm
F is the focal length of the lens in mm

To continue with the previous example:

C = (log10 (1+20/300)^2) / log10 (2) = 0.186 stops

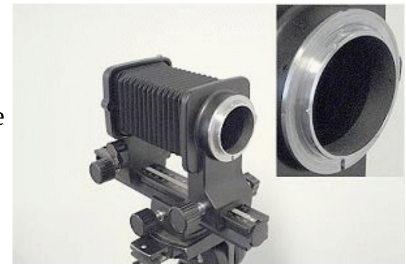
Such a small compensation is really negligible. Stacking the extension tubes may cause a greater amount of compensation

Using a tripod is a must with extension tubes. Keeping what is critical in focus can be made much easier if a focusing stage is used in conjunction with the tripod. The Nikon PG-2 focus stage shown below has a standard camera mount that sits on a set of rails, allowing the entire camera and lens set-up to be moved forward or backwards while mounted on a fixed-position tripod. The advantage of using a focusing stage is to eliminate the need of moving the tripod and losing the subject or composition while trying to get into that optimum position.



The Nikon focusing stage allows the normally mounted camera body to be rotated 90 degrees for a horizontal format shot. Other third-party models have various mechanisms for precise movement of the camera with a worm wheel system.

For very large lens-from-camera extensions, rather than using multiple extension tubes which can be difficult to support, bellows extensions are a better choice. The operation and calculations of the bellows works exactly the same as the extension tubes.



The difference is a much larger extension without fear of bending the tubes or causing damage to the camera mounts due to the over-hanging weight of the tubes and lens. The Nikon PB-4 and PB-6 bellows can be used with Nikon mounts.. The Nikon Bellows permit fully supported extensions up to 208mm (11x magnification) or 400 mm (22x magnification) respectively.

If you purchase extension tubes that are the same brand as your lens, most likely, the auto-functions will be passed through. However, for high-speed cameras, these auto-focus or stabilization functions are not used.

GENERAL COMMENTS

1. While close-up lenses and extension tubes provide some increase in magnification, they do so at the expense of loss of sharpness at the edge, greatly reduced working distances and very small depth of fields.

2. The distortions at the edges means these attachments are probably only good for small objects that fill the middle half of the frame.

3. The combination of 25mm extension tube with the 7-diopter Hoya lens stack provides a good compromise in magnification capability and image quality. It provides the greatest magnification with the least distortion, though the small working distance and depth of field.

4. To help keep the object in focus, try closing the lens down as much as possible to increase the DOF. Use low incident light (light from a low angle off the side) to bring the highlights out in the magnified image.

Mark Green from Digital West Imaging had this to say concerning Close-Up shots for high speed video:

> "In the case where the intrinsic motion of the object to be recorded is the primary focus and not its behavior in the overall space in which it travels, we use the Photron supplied C-mount flange (available for every Photron camera) and we use either Navitar or Infinity long focal lens assemblies to get the best images. When the object of interest is to be tracked within a larger area then a combination of F-mount long focal length lens, extension tubes, optical extenders and or magnification diaopters is used. The latter two additions will put extra demands on lighting the area of interest and may suggest the use of laser sheets or other lighting techniques to illuminate the subject or subjects in the area of travel. In either case you will have to insure the camera mounting provides a stable platform and micro-movement of the camera head is supported after the fashion of a microscope stage. There are many ways to accomplish this stability all of them dependent on the specific application". Mark Green (Mark@DigitalWestImaging.com Toll Free (866) 593-1900)

Semih Sinik from Itronx Imaging Technologies had these comments about Close-Up lenses:

"We have several infinity lenses. We prefer 105 mm lens with extenders, 2X adapter and close up lenses. We use GE fiber optic light for illumination". Semih Sinik (semih@itronx.com 818 865 0005)