This lesson examines what lenses can do and how to use them.

- TYPES OF ZOOM LENSES
  Studio and field lenses, zoom range, and lens format
- OPTICAL CHARACTERISTICS OF LENSES
  Focal length, focus, light transmission (iris, aperture, and f-stop), and depth of field
- OPERATIONAL CONTROLS
  Zoom control, digital zoom lens, and focus control

TYPES OF ZOOM LENSES

When listening to production people talk about zoom lenses, you will most likely hear one person refer to a studio rather than a field zoom, another to a 20x lens, and yet another to a zoom lens that fits a 2/3-inch image format. The following is the different classifications of lenses on different basis.

STUDIO AND FIELD LENSES

As the name indicates, studio zoom lenses are normally used with studio cameras. Field zooms include large lenses mounted on high-quality cameras that are used for remote telecasts, such as sporting events, parades, and the like. They also include the zoom lenses attached to ENG/EFP cameras. The lenses of consumer camcorders usually come with the camera and cannot be exchanged. Some high-end prosumer models, however, allow you to attach a variety of zoom lenses. Because you can, of course, use a field lens in the studio and vice versa, a better and more accurate way to classify the various zoom lenses is by their zoom range and lens format, that is, what cameras they fit.

ZOOM RANGE

If a zoom lens provides an overview, for example, of the whole tennis court and part of the bleachers when zoomed all the way out and (without moving the camera closer to the court) a tight close-up of the player's tense expression when zoomed all the way in, the lens has a good zoom range. The zoom range is the degree to which you can change the focal length of the lens (and thereby the angle of view, or vista) during the zoom.

The zoom range of a lens is often stated as a ratio, such as 10:1 or 40:1. A 10:1 zoom means that you can increase the shortest focal length ten times; a 40:1, forty times. To make things easier, these ratios are usually listed as l0x (ten times) or 40x (forty times), referring to the maximum magnification of the image of which the lens is capable.

The large (studio) cameras that are positioned on top of the bleachers for sports coverage may have zoom ranges of 40x and even 70x. In the studio the cameras are well served by a 20x zoom lens. The smaller and lighter ENG/EFP camera lenses rarely exceed a 15x zoom range.

Optical and digital zoom ranges

You may have noticed that the zoom range on a consumer camcorder is rather limited; an optical zoom range of 15x is considered excellent even for high-end consumer cameras. This is why consumer cameras offer the option of increasing the zoom range digitally. During an optical zoom to a tighter shot, the image magnification is achieved by moving elements within the lens. In effect, you are continually changing the focal length during the zoom-in or zoom-out. In digital zooming such a change in focal length does not take place.

For a zoom-in, the electronics of the camera simply select the center portion of the long shot and enlarge the cropped area to full-screen size. The problem with digital zooming is that the enlarged pixels noticeably reduce the resolution of the image. At one point in digital zooming, the pixels can get so large that they look more like a special effect than a magnification of the original image. Higher-end camcorders, which have a digital zoom option, try to restore the full-pixel resolution of the original image by a process called interpolation. But despite this digital wizardry, the digital zoom does not achieve the crispness of the optical zoom.

Studio, field, and ENG/EFP lenses are all detachable from the camera. Most consumer camcorders have a builtin lens that cannot be detached.

Studio and large field lenses

Note that a 20x studio lens becomes a field lens if it is used "in the field," that is, for a production that happens outside the studio. Generally, however, field lenses have a much greater zoom range (from 40x to 70x) than studio cameras. Some field lenses have even a greater zoom range, allowing the camera operator to zoom from a wide establishing shot of the football stadium to a tight close-up of the quarterback's face. Despite the great zoom range, these lenses deliver high-quality pictures even in relatively low light levels. For studio use such a zoom range would be unnecessary and often counter-productive.

ENG/EFP lenses

These lenses are much smaller, to fit the portable cameras. Their normal zoom range varies between l l x and 20x. A 15x zoom lens would be sufficient for most ENG/EFP assignments, but sometimes you might want a closer view of an event that is relatively far away. You would then need to exchange the 15x zoom lens for one with a higher zoom range—such as 20x or even 30x. You can also use a range extender, which would let you zoom beyond the normal zoom range into a tighter shot.

A more important consideration for ENG/EFP lenses is whether they have a wide enough angle of view (a very short focal length), which would allow you to shoot in highly cramped quarters, such as in a car, a small room, or an airplane. Also, the wide-angle view is important for shooting in the wide-screen 1 6 x 9 format. Many lenses have digital or mechanical stabilizers that absorb at least some of the picture shakes resulting from operating the camera, especially when in a narrow-angle (zoomed-in) position. Realize, however, that such stabilizers cause an additional drain on the battery. Use this feature only if you don't have a tripod or are unable to stabilize the camera in any other way.

Consumer camcorder lenses

These zoom lenses generally have an optical zoom range of l0x to 18x. You may have noticed that the problem with zoom lenses on consumer camcorders is that the maximum wide-angle position is often not wide enough, despite their good zoom range. Most camcorders have some sort of image stabilization. Some high-end prosumer models, which have a built-in lens, let you attach elements that allow a wider angle or tighter close-ups.

Range extenders

If a zoom lens does not get you close enough to a scene from where the camera is located, you can use an additional lens element called a range extender, or simply an extender. This optical element, usually available only for lenses on professional cameras, does not actually extend the range of the zoom but rather shifts the magnification—the telephoto power—of the lens toward the narrow-angle end of the zoom range. Most lenses have 2x extenders, which means that they double the zoom range in the narrow-angle position, but they also reduce the wide-angle lens position by two times. With such an extender, you can zoom in to a closer shot, but you cannot zoom back out as wide as you could without the extender.

There is another disadvantage to range extenders: they cut down considerably the light entering the camera, which can be problematic in low-light conditions.

LENS FORMAT

Because camera lenses are designed to match the size of the CCD imaging device, you may hear about a lens format or image format of 1/3-inch, 1/2-inch, or 2/3-inch. This means that you can use only a lens that fits the corresponding CCD image format. Like film, the larger CCDs produce better pictures. The term lens format may also refer to whether a lens is used for standard NTSC cameras or HDTV cameras.

OPTICAL CHARACTERISTICS OF LENSES

Four optical characteristics of lenses are (1) focal length; (2) focus; (3) light transmission—iris, aperture, and *f*- s t o p ; and (4) depth of field.

(1) FOCAL LENGTH

Technically, focal length refers to the distance from the optical center of the lens to the point where the image the lens sees is in focus. This point is the camera's imaging device. Operationally, the focal length determines how wide or narrow a vista a particular camera has and how much and in what ways objects appear magnified.

When you zoom all the way out, the focal length of the lens is short and at the maximum wide-angle position; the camera will provide a wide vista. When you zoom all the way in, the focal length is long and at the maximum narrow-angle (telephoto) position; the camera will provide a narrow vista or field of view—a close-up view of the scene. When you stop the zoom approximately halfway in between these extreme positions, the lens has the normal focal length. This means that you will get a "normal" vista that approximates your actually looking at the scene. Because the zoom lens can assume all focal lengths from its maximum wide-angle position (zoomed all the way out) to its maximum narrow-angle position (zoomed all the way in), it is called a variable-focal-length lens.

On the television screen, a zoom-in appears as though the object is gradually coming toward you. A zoom-out seems to make the object move away from you. Actually, all that the moving elements within the zoom lens do is gradually magnify (zoom-in) or reduce the magnification (zoom-out) of the object while keeping it in focus, but the camera remains stationary during both operations.

Minimum object distance and macro position

You will find that there is often a limit to how close you can move a camera (and lens) to the object to be photographed and still keep the picture in focus. This is especially problematic when trying to get a close-up of a very small object. Even when zoomed in all the way, the shot may still look too wide. Moving the camera closer to the object will make the shot tighter, but you can no longer get the picture in focus. Range extenders help little, but while they provide you with a tighter close-up of the object, they force you to back off with the camera to get the shot in focus. One way to solve this problem is to zoom all the way out to a wide-angle position.

Contrary to normal expectations, the wide-angle zoom position often allows you to get a tighter close-up of a small object than does the extended narrow-angle zoom position (zoomed all the way in with a 2x extender). But even with the lens in the wide-angle position, there is usually a point at which the camera will no longer focus when moved too close to the object. The point where the camera is as close as it can get and still focus on the object is called the minimum object distance (MOD) of the lens. Although there are zoom lenses that allow you, without extenders, to get extremely close to the object while still maintaining focus over the entire zoom range, most zoom lenses have a minimum object distance of 2 to 3 feet.

High-ratio zoom lenses, such as 40x or 50x, have a much greater MOD than do lenses with a wide-angle starting position and a relatively low zoom ratio (such as l0x). This means that you can probably get closer to an object with a wide-angle field lens that can magnify the object only ten or twelve times than with a large field lens that starts with a narrower angle but can magnify the scene fifty or more times.

Despite the relative advantage of wide-angle field lenses, many field lenses on ENG/EFP cameras have a macro position, which lets you move the camera even closer to an object without losing focus. When the lens is in the macro position, you can almost touch the object with the lens and still retain focus; you can no longer zoom, however. The macro position changes the zoom lens from a variable-focal-length lens to a fixed-focal-length, or prime, lens. The fixed focal length is not a big disadvantage because the macro position is used only in highly specific circumstances. For example, if you need to get a screen-filling close-up of a postage stamp, you would switch the camera to the macro position, but then you cannot use the camera for zooming until you switch back to the normal zoom mechanism.

(2) FOCUS

A picture is "in focus" when the projected image is sharp and clear. The focus depends on the distance from the lens to the film (as in a still or movie camera) or from the lens to the camera's imaging device (beam splitter with CCDs). Simply adjusting the distance from the lens to the film or imaging device brings a picture into focus or takes it out of focus. In television zoom lenses, this adjustment is accomplished not by moving the lens or the prism block (beam splitter) but by moving certain lens elements relative to each other through the zoom focus control.

Focus controls come in various configurations. Portable cameras have a focus ring on the lens that you turn; studio cameras have a twist grip attached to the panning handle. Most consumer camcorders have an automatic focus feature, called auto-focus.

If properly preset, a zoom lens keeps in focus during the entire zoom range, assuming that neither the camera nor the object moves very much toward or away from the other. But because you walk and even run while carrying an ENG/EFP camera, you cannot always prefocus the zoom. In such cases you would do well by zooming all the way out to a wide-angle position, considerably reducing the need to focus.

(3) IRIS, APERTURE, A N D *f*- STOP

Like the pupil in the human eye, all lenses have a mechanism that controls how much light is admitted through them. This mechanism is called the iris or lens diaphragm. The iris consists of a series of thin metal blades that form a fairly round hole—the aperture, or lens opening—of variable size.

If you "open up" the lens as wide as it will go, or, technically, if you set the lens to its maximum aperture, it admits the maximum amount of light. If you close the lens somewhat, the metal blades of the iris form a smaller hole and less light passes through the lens. If you close the lens all the way—that is, if you set it to its minimum aperture—very little light is admitted. Some irises can be closed entirely, which means that no light at all goes through the lens.

f-stop

The standard scale that indicates how much light goes through a lens, regardless of the lens type, is the *f*-stop. If, for example, you have two cameras—a camcorder with a l0x zoom lens and a field camera with a large 50x lens—and both lenses are set at *f*/5.6, the imaging devices in both cameras will receive an identical amount of light.

Regardless of camera type, *f*- stops are expressed in a series of numbers, such as *f*/1.7, *f*/2.8, *f*/4, *f*/5.6, *f*/8, *f*/II, and *f*/16. The lower *f*-stop numbers indicate a relatively large aperture or iris opening (lens is relatively wide open). The higher *f*-stop numbers indicate a relatively small aperture (lens is closed down considerably). A lens that is set at *f*/1.7 has a much larger iris opening and therefore admits much more light than one that is set at *f*/1.6 . (The reason why the low *f*-stop numbers indicate large iris openings and high *f*-stop numbers indicate relatively small iris openings, rather than the other way around, is that the *f*-stop numbers actually express a ratio. In this sense *f*/4 is actually *f*/1/4; that is, / one over four.)

As mentioned, most lenses produce the sharpest pictures between *f*/5.6 and *f*/8. Some lenses extend the optimal focus to *f*/11.

Lens speed

The "speed" of a lens has nothing to do with how fast it transmits light, but with how much light it lets through. A lens that allows a relatively great amount of light to enter is called a fast lens. Fast lenses go down to a small *f*-stop number (such as *f*/1.4). Most good studio zoom lenses open up to *f*/1.6, which is fast enough to make the camera work properly even in low-light conditions.

A lens that transmits relatively little light at the maximum iris aperture is called a slow lens. A studio lens whose lowest *f*-stop is *f*/2.8 is obviously slower than a lens that can open up to *f*/1.7. Range extenders render the zoom lens inevitably slower. A 2x extender can reduce the lens speed by as much as two "stops" (higher *f*-stop numbers). This reduction in light transmission is not a big handicap, however, because range extenders are normally used outdoors, where there is enough light. The more serious problem is a slight deterioration of the original picture resolution. Because the amount of light that strikes the camera's imaging device is so important for picture quality, the continuous adjustment of the iris is a fundamental function of video control.

Studio cameras have a remote iris control, which means that the aperture can be continuously adjusted by the video operator (VO) from the camera control unit (CCU). If the set is properly lighted and the camera properly set up (electronically adjusted to the light/dark extremes of the scene), all that the VO has t o d o to maintain good pictures is work the remote iris control—open the iris in low-light conditions and close it down somewhat when there is more light than needed.

Most cameras, especially ENG/EFP and consumer camcorders, can be switched from the manual to the auto-iris mode. The camera then senses the light entering the lens and automatically adjusts the iris for optimal camera performance. This auto-iris feature works well so long as the scene does not have too much contrast. There are circumstances, however, in which you may want to switch the camera over to manual iris control.

(4) DEPTH OF FIELD

If you place objects at different distances from the camera, some will be in focus and others will be out of focus. The area in which the objects are in focus is called depth of field.

The depth of field can be shallow or great, but it is always greater behind the object than in front of it. If you have a shallow depth of field and you focus on an object in the foreground, the middleground and background objects will be out of focus. If the depth of field is great, all objects (foreground, middleground, and background) will be in focus, even though you focus on the middleground object only.

With a great depth of field, there is a large "sharp zone" in which people or objects can move toward or away from the camera without going out of focus or without any need for adjusting the camera focus. If they move in a shallow depth of field, however, they can quickly become blurred unless you adjust the camera focus. A similar thing happens when you move the camera. A great depth of field makes it relatively easy to move the camera toward or away from the object because you do not have to work any controls to keep the picture in focus. If you move the camera similarly in a shallow depth of field, you must adjust the focus continuously to keep the target object sharp and clear.

Operationally, the depth of field depends on the coordination of three factors: (1) the focal length of the lens, (2) the aperture, and (3) the distance between the camera and the object.

(1) Focal length

The focal length of the lens is the factor that most influences the depth of field. In general, wide angle lenses and, of course, wide-angle (short-focal-length) zoom positions (zoomed out) have a great depth of field. Narrow-angle lenses and narrow-angle (long-focal-length) zoom positions (zoomed in) have a shallow depth of field. A simple rule of thumb is depth of field increases as focal length decreases.

ENG/EFP Situation

When running after a fast-moving news event, should you zoom all the way in or all the way out? All the way out. Why? Because, first, the wide-angle position of the zoom lens will at least show the viewer what is going on. Second, and most important, the resulting great depth of field will help keep most of your shots in focus, regardless of whether you are close to or far away from the event or whether you or the event is on the move.

(2) Aperture

Large iris openings cause a shallow depth of field; small iris openings cause a large depth of field. The rule of thumb for apertures is that large *f*-stop numbers (such as *f*/16 or *f*/22) contribute to a great depth of field; small *f*-stop numbers (such as *f*/1.7 or *f*/2) contribute to a shallow depth of field.

(3) Camera-to-object distance

The closer the camera is to the object, the shallower the depth of field. The farther the camera is from the object, the greater the depth of field. Camera-to-object distance also influences the focal-length effect on depth of field.

Generally, the depth of field is shallow when you work with close-ups and low-light conditions. The depth of field is great when you work with long shots and high light levels.

OPERATIONAL CONTROLS

You need two basic controls to operate a zoom lens: the zoom control, which lets you zoom out to a wide shot or zoom in to a close-up, and the focus control, which slides the lens elements that lie close to the front of the zoom lens back and forth until the image or a specific part of the image is sharp. Both controls can be operated manually or through a motor-driven servo control mechanism.

ZOOM CONTROL

Most zoom lenses of professional cameras are equipped with a servo mechanism whose motor activates the zoom, but they also have a mechanical zoom control that can override the servo zoom at any time.

Servo zoom control

All types of professional cameras (studio and ENG/EFP) have a *servo zoom control for* their lenses, usually called *servo zooms.* The servo zoom control for studio cameras is usually mounted on the right panning handle, and you zoom in and out by moving the thumb lever, similar to a rocker switch. When pressing the right side of the lever, you zoom in; when pressing the left side, you zoom out. The farther you move the lever from the central position, the faster the zoom will be. With the servo system, the zoom speed is automatically reduced as the zoom approaches either of the extreme zoom positions. This reduction prevents jerks and abrupt stops at the ends of the zoom range.

The automation lets you execute extremely smooth zooms. Most servo mechanisms for studio cameras offer a choice of at least two zoom speeds: normal and fast. The fast zoom setting is used when fast zoom-ins are required for emphasis. For example, the director may call for a very fast zoom-in on a ringing telephone or a contestant's face. Normal zoom speeds are simply not fast enough to highlight such events.

ENG/EFP

The servo zoom control for ENG/EFP and prosumer cameras is directly attached to the lens; for consumer camcorders it is built into the camera housing. The rocker switch (similar to the thumb lever of studio cameras) is mounted on top of the box that surrounds the lens. It is usually marked with a *W* (for wide) and a T (for tight or telephoto). To zoom in, press the T-side of the switch; to zoom out press the W-side. The servo control housing has a strap attached, which lets you support the shoulder mounted or handheld camcorder while operating the zoom control. This way your left hand is free to operate the manual focus control.

Manual zoom control

ENG and EFP often require extremely fast zoom-ins to get fast close-ups or to calibrate the zoom lens as quickly as possible. Even fast servo settings are usually too slow for such maneuvers. ENG/EFP lenses (including the lenses on prosumer camcorders) therefore have an additional *manual zoom control.* The manual zoom is activated by a ring on the lens barrel. By moving the ring clockwise (to zoom in) or counterclockwise (to zoom out), you can achieve extremely fast zooms not possible with the servo control. Some zoom rings have a small lever attached to facilitate mechanical zooming. In addition to news coverage, this manual zoom option is especially important for sports, where getting quick close-ups is the rule rather the exception.

Digital zooming

In *digital zooming,* the magnification of the image is achieved not through optical means but by enlarging the image electronically. The gradual increase of image size in a digital zoom is similar to the gradual increase of the picture through the optical magnification of a normal zoom. As mentioned earlier, the problem with digital zooming is that the enlarged pixels noticeably reduce the resolution of the image and eventually show up as mosaic tiles. Professional cameras, which have a digital zoom option, add pixels during the zoom to avoid such negative pixalization of an image.

DIGITAL ZOOM LENS

The *digital zoom lens* has digital controls that allow you to preset certain zoom positions and then trigger the operation with the push of a button. This preset device, which also remembers focus calibration, is highly accurate, provided the camera and the subject are in exactly the same positions as during setup. It is most practical when using *robotic cameras* (cameras whose movements are controlled by computer and not by an operator), such as during studio newscasts.

FOCUS CONTROL

The *focus control* activates the focus mechanism in a zoom lens. For studio cameras, the focus control ordinarily consists of a twist grip similar to a motorcycle throttle, usually mounted on the left panning handle. Two or three turns are sufficient to achieve focus over the full zoom range. As with the servo zoom control, the focus operations are transferred by the drive cable from the panning-handle control to the lens, but the lens executes the focusing electronically.

ENG/EFP

These cameras and all camcorders have a focus ring near the front of the zoom lens. You focus the lens by turning the focus ring clockwise or counter-clockwise until the viewfinder shows the image sharply and clearly. You will notice when focusing this way that the front end of the lens, including its lens shade, rotates. This rotation is not problematic unless you want to attach a special-effects filter, such as a star filter that transforms light sources into star-like light beams. When focusing with the filter attached, the effect will rotate with the lens and may end up sideways when you have the picture in focus. *Internal,* or *inner, focus (I-F) lenses* do not rotate the front end when turning the focus ring. You can therefore focus I-F lenses without upsetting the filter effect.

The *servo focus control* lets you preset the lens so that it keeps focus during carefully rehearsed camera and/or subject movements. Because even the smartest servo focus control will not help you stay in focus if the camera or subject movements have not been carefully rehearsed, most camera operators prefer to use the manual focus controls.

Auto-Focus

The problem with *auto-focus* is that the camera does not know exactly on which object in the frame to focus. It usually settles for the object that is more or less in the center of the frame and closest to the camera. If you want to focus on part of the scene that is farther in the background and off to one side, the auto-focus will not comply. Also, if you do a fast zoom with a consumer camera, the automatic focus may not always be able to keep up; the picture will pop in and out of focus during the zoom. That is why manual focus devices are often preferred in critical camera work.

What Lenses See?

- The performance characteristics of wide-angle, normal, and narrow-angle lenses (zoom lenses adjusted to these focal lengths) include field of view, object and distance distortion, movement, and depth of field.
- A wide-angle lens (zoom lens in the wide-angle position) offers a wide vista. It gives a wide field of view with the camera relatively close to the scene.
- A wide-angle lens distorts objects close to the lens and exaggerates proportions. Objects relatively close to the lens look large, and those only a short distance away look quite small. The lens makes objects seem farther apart and makes rooms look larger than they actually are.
- A wide-angle lens is ideal for camera movement. It minimizes camera wobbles and makes it easy to keep the picture in focus during camera movement. It also exaggerates the perception of object speed toward and away from the camera.

- The normal lens gives a field of view that approximates that of normal vision. The normal lens (zoom lens in the midrange position) does not distort objects or the perception of distance. It is used when a normal perspective is desired.
- When a camera is moved with the lens in the midrange (normal lens) zoom position, camera wobbles are emphasized considerably more than with a wide-angle lens. The shallower depth of field makes it harder to keep the picture in focus.
- A narrow-angle lens (zoom lens in the telephoto position) has a narrow field of view and enlarges the objects in the background. Exactly opposite of the wide-angle lens, which increases the perceived distance between objects, the narrow-angle lens seems to compress the space between objects at different distances from the camera. It slows the perception of object speed toward and away from the camera.
- The magnifying power of a narrow-angle lens prevents any camera movement while on the air. Narrow-angle lenses have a shallow depth of field, which makes keeping in focus more difficult but allows for selective focus.