Equivalent Focal Length

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ABSTRACT

In digital photography, a convention called "35-mm equivalent focal length" is used to allow comparison, across cameras of different format size, of the field of view implications of the use of a lens of a certain focal length on a particular camera.

This article describes the issues that are involved and the working of this convention.

FIELD OF VIEW

The *field of view* of a camera refers to the amount of the universe it "regards" when taking an image.

The field of view of a camera is dictated by two factors:

- The lens focal length. The greater the focal length, the smaller (narrower) the field of view.

- The camera's format size (the size of its film frame or digital sensor). With a lens of a given focal length, the smaller the format size, the smaller (narrower) the field of view.

If we wish to take in objects spanning a considerable angle, we must attain a large field of view, and thus on any given camera we must use a lens of relatively small focal length (a "wide angle" lens).

For photographing small objects, or larger objects at a substantial distance, it is desirable to have a small field of view. Among other things, this means that if the entire taken frame is printed (without cropping), the size of our "subject" on the print will be reasonable. It also in any event makes best use of the resolution of the film or digital image system. Thus, in such a situation we may wish to use a lens of relatively large focal length (a "telephoto" lens).

DESCRIBING THE FIELD OF VIEW

Field of view is actually described in terms of the angle embraced by the view (perhaps horizontally, or vertically, or even diagonally). But few photographers have ever been aware of the angular measure of the field of view given by any of their lenses (or zoom lens focal length settings). Rather, they came to know what focal lengths, **on**

their camera, produced a field of view that seemed best suited for a particular photographic situation.

Prior to the digital camera era, most photographers concentrated on the use of cameras of a single format size, or perhaps two format sizes. They could acquire the needed knowledge of the field of view behavior of different focal lengths for their format size(s) and keep using it.

For many decades, the camera *genre* of choice for many serious amateur photographers (and many professional photographers as well) was the 35-mm film camera. In that realm, awareness of focal length emerged with the availability of interchangeable lenses (such as on the famous Leica cameras) and, later, with zoom lenses (whose focal length could be readily changed).

Not surprisingly, the awareness of the focal length behavior of different focal lengths on a 35-mm film camera became very widespread (including through photographic guidebooks predicated on the 35-mm format)—probably more widespread than for any other format.

THE EMERGENCE OF DIGITAL CAMERAS

When digital cameras came to be generally available at a practical price, they sported quite a range of format sizes, even within a particular camera class. Most formats were dramatically smaller than the format size of the 35-mm film camera (36 x 24 mm)—often as small as 3.5 x 4.7 mm. Most had non-interchangeable zoom lenses.

It was recognized that photographers with experience with 35-mm film cameras could not easily grasp the significance (on field of view) of the focal length range of such a camera. And a user who learned through experience what focal length did what on his first digital camera would then find that knowledge obsolete when he moved up to a camera with a larger format size.

PRESERVATION OF OUR KNOWLEDGE

So a pragmatic convention was adopted to allow knowledge of focal length effect on field of view to remain useful in the face of a switch to a different camera. It revolves around this question, asked about a certain lens on a certain camera:

> What focal length lens, used on a 35-mm film camera, would give the same field of view **this** lens gives on **this** camera?

The numerical answer to this question came to be known (among other names) as the "35-mm equivalent focal length" of the lens of interest on its camera.

The significance of this is that any time we have a lens (or a zoom setting) whose 35-mm equivalent focal length on its camera is, for example, 80 mm, we will have the same field of view.

Now, even for photographers who had never used a 35-mm film camera, once they learned (perhaps on their first digital camera) that a lens with a 35-mm equivalent focal length of 80 mm worked out well in a certain portrait setting, that knowledge would still be valid when they upgraded to a camera with a larger format size.

On many cameras with non-interchangeable lenses, the lens (or the zoom lens focal length scale) was actually labeled with the applicable 35-mm equivalent focal length (rather than the actual focal length).

THE DIGITAL SINGLE LENS REFELX CAMERA

Today, an important genre of digital camera is the digital single-lens reflex (dSLR), often having interchangeable lenses. Important families of these fall alongside the manufacturer's line of 35-mm film SLR cameras, and are generally able to use all the lenses from the manufacturer's repertoire, most of those originally designed for use on the film cameras.

Typically, the digital cameras in these families include models with various format sizes, often including the same format size as a 35-mm film camera, plus one or two smaller ones. Thus, it would not be practical to label the lenses with a 35-mm equivalent focal length, since that would differ with the camera on which the lens was mounted.

CALCULATION ON THE FLY

To cope with this situation, a scheme emerged that would allow the user to easily reckon "on the fly" the 35-mm film equivalent focal length for any lens of interest when used on a particular camera.

The 35-mm equivalent focal length of a lens when used on a particular camera can be calculated this way:

$$f_{e35} = \frac{f}{k} \qquad (1)$$

where f_{e35} is the 35-mm equivalent focal length, f is the focal length of the lens (some would say "actual focal length" for emphasis), and k is the relative size of the format of the camera of interest compared to the format of the 35-mm film camera.[1] For example, if the camera has

[1] To deal with the possibility that the two formats do not have the same aspect ratio, k is customarily based on the diagonal dimensions of the formats.

a format size of 22.5 x 15 mm, then (recalling that the format size of a 35-mm camera is 36 x 24 mm) *k* would be 0.625 (22.5/36).

But, to take advantage of the fact that multiplying is usually easier than dividing, we recast the equation this way:

$$f_{e35} = j \cdot f \qquad (2)$$

where *j* is just 1/*k*. For our example, *j* would be 1.6.

Any given camera (with a certain format size) has a fixed value of *j*. [2] And in fact it has become popular to speak of a camera with a format size of 22.5 x 15 mm as a "1.6x" camera (since 1.6 is its value of *j*)—the 35-mm equivalent focal length of any lens used on such a camera is always "1.6 times" the lens' (actual) focal length.

The factor *j* has been given many names. The most explicit (but rarely used) is "35-mm equivalent focal length factor." Another name is "focal length multiplier". Finally, in recent times, there is an outlook that results in the factor *j* for a camera being called its "crop factor".

Since the use of the 35-mm film camera format size as the "reference" can be reasonably assumed in most contexts, the best term for general use is probably "equivalent focal length factor".

A CAUTION

It is important to note that the 35-mm equivalent focal length of a lens, as used on a certain camera, **is not a new focal length of the lens**. The focal length of a lens is a basic optical property (which the lens has even when in its carton), and does not vary depending on the format size of the camera on which the lens might be mounted.

Remember that the *35-mm equivalent focal length* is just the answer to the question:

> What focal length lens, used on a 35-mm film camera, would give the same field of view **this** lens gives on **this** camera?

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[2] Do not expect to see the notation *k* or *j* in camera specifications or technical literature; these are identifiers I adopted for the purpose of this article.