Film speed

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Film speed is the measure of a photographic film's sensitivity to light. Stock with lower sensitivity (lower ISO speed rating) requires a longer exposure and is thus called a *slow film*, while stock with higher sensitivity (higher ISO speed rating) can shoot the same scene with a shorter exposure and is called a *fast film*.

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ISO film speed scales

The standard known as **ISO 5800:1987** from the International Organization for Standardization (ISO) defines both a linear scale and a logarithmic scale for measuring film speed.

In the ISO linear scale, which corresponds to the older **ASA** scale, doubling the speed of a film (that is, halving the amount of light that is necessary to expose the film) implies doubling the numeric value that designates the film speed. In the ISO logarithmic scale, which corresponds to the older **DIN** scale, doubling the speed of a film implies adding 3° to the numeric value that designates the film speed. For example, a film rated ISO 200/24° is twice as sensitive as a film rated ISO 100/21°.

Commonly, the logarithmic (DIN) component is omitted from film speed ratings, and only the linear component is given (e.g. "ISO 100"). In such cases, the quoted "ISO" rating is in effect synonymous with the older ASA standard.

GOST (Russian: ГОСТ) is a pre-1987 linear standard used in the former Eastern Bloc. It was almost, but not quite identical to the ASA standard. After 1987 the GOST scale was aligned to the ISO scale. GOST markings are only found on pre-1987 photographic equipment (film, cameras, lightmeters, etc.) of Eastern Bloc manufacture.

The most common ISO film ratings are 25/15°, 50/18°, 100/21°, 200/24°, 400/27°, 800/30°, 1600/33°, and 3200/36°. Consumer films are generally rated between 100/21° and 800/30°, inclusive.

A film speed is converted from the linear scale to the logarithmic scale by this formula (plus rounding to the nearest integer):

$$\text{log-scale speed} = 3 \log_2 \left(\frac{128}{100} \text{linear speed} \right)$$

Conversion from the logarithmic scale to the linear scale is analogous, except that results must be rounded to the conventional values of the linear scale listed in the table below.

$$\text{linear speed} = \frac{100}{128} 2^{\left(\frac{\text{log-scale speed}}{3} \right)}$$

The following table shows the correspondence between these scales:

ISO linear scale (old ASA scale)	ISO log scale (old DIN scale)	GOST (Soviet pre-1987)	Example of film stock with this nominal speed
6	9°		original Kodachrome
8	10°		
10	11°		Kodachrome 8mm film
12	12°	11	Gevacolor 8mm reversal film
16	13°	11	Agfacolor 8mm reversal film
20	14°	16	
25	15°	22	old Agfacolor, Kodachrome 25
32	16°	22	Kodak Panatomic-X
40	17°	32	Kodachrome 40 (movie)
50	18°	45	Fuji RVP (Velvia)
64	19°	45	Kodachrome 64, Ektachrome-X
80	20°	65	Ilford Commercial Ortho
100	21°	90	Kodacolor Gold, Kodak T-Max (TMX)
125	22°	90	Ilford FP4, Kodak Plus-X Pan
160	23°	130	Fuji NPS, Kodak High-Speed Ektachrome
200	24°	180	Fujicolor Superia 200
250	25°	180	
320	26°	250	Kodak Tri-X Pan Professional (TXP)
400	27°	350	Kodak T-Max (TMY), Tri-X 400
500	28°	350	
640	29°	560	Polaroid 600
800	30°	700	Fuji NPZ
1000	31°	700	Ilford Delta 3200 (see text below)
1250	32°		
1600	33°	1400–1440	Fujicolor 1600
2000	34°		
2500	35°		
3200	36°	2800–2880	old Konica 3200
4000	37°		

5000	38°		
6400	39°		

Determining film speed

Film speed is found by referencing the Hurter–Driffield curve, or D–logE curve, for the film. This is a plot of optical density vs. log of exposure (lux-s). There are typically five regions in the curve: the base + fog, the toe, the linear region, the shoulder, and the overexposed region. Following the curve to the point where density exceeds the base + fog by 0.1, find the corresponding exposure. Dividing 0.8 by that exposure yields the linear ISO speed rating.

Applying film speed

Film speed is used in the exposure equation to find the appropriate exposure parameters. Four variables are available to the photographer to obtain the desired effect: lighting, film speed, f-number (aperture size), and shutter speed (exposure time). The equation may be expressed as ratios, or, by taking the logarithm (base 2) of both sides, by addition, using the APEX system, in which every increment of 1 is a doubling of exposure, known as a "stop". The f-number is proportional to the ratio between the lens focal length and aperture diameter, which is proportional to the square root of the aperture area. Thus, a lens set to $f/1.4$ allows twice as much light to strike the focal plane as a lens set to $f/2$. Therefore, each f-number factor of the square root of two (approximately 1.4) is also a stop, so lenses are typically marked in that progression: $f/1.4$, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, etc.

Exposure index

Exposure index, or EI, refers to speed rating assigned to a particular film and shooting situation, and used in the exposure meter or equation, to compensate for equipment calibration inaccuracies or process variables, or to achieve certain effects. Exposure index may or may not be the same as manufacturer's film speed rating for that particular film.

The exposure index is sometimes called the speed *setting*, as opposed to the speed *rating*.

For example, a photographer may choose to rate a 400 ISO speed film at 800 and then use push processing in order to get printable negatives from low-light conditions. In this case it is said that film has been shot at EI 800.

Another example of a situation when exposure index would differ from film manufacturer's rating is when a camera shutter is known to be miscalibrated and consistently overexposes or underexposes the film; similarly, a light meter can be known to understate or overstate lighting conditions. In such cases one could adjust EI rating accordingly in order to compensate for these effects and consistently produce correctly exposed negatives.

Film grain

Film speed is roughly related to granularity, the size of the grains of silver halide in the emulsion, since larger grains give film a greater sensitivity to light. Fine-grain stock, such as portrait film or those used for the intermediate stages of copying original camera negatives, is "slow", meaning that the amount of light used to expose it must be high or the shutter must be open longer. Fast films, used for shooting in poor light or for shooting fast motion, produce a grainier image. Each grain of silver halide develops in an all-or-nothing way into dark silver or nothing. Thus, each grain is a threshold detector; in aggregate, their effect can be thought of an a noisy nonlinear analog light detector.

Kodak used to use a Granularity Index (GI) to characterize film grain. Alternating images of the film under test and a standard grain were shown to test subjects who indicated when they perceived a match. The standard grain samples were the index. More recently, Kodak switched to a measurement of grain using an RMS measurement.

Granularity varies with exposure — underexposed film looks grainier than overexposed film.

Grainy high speed B/W film negative

Improvements in film

In the early 1980s, there were some radical improvements in film stock. It became possible to shoot color film in very low light and produce a fine-grained image with a good range of midtones.

Use of grain

In advertising, music videos, and some drama, mismatches of grain, color cast, and so forth between shots are often deliberate and added in post-production.

Altering film speed

Certain high-speed black-and-white films, such as Ilford Delta 3200 and Kodak T-Max P3200 (TMZ), are marketed with higher speeds on the box than their true ISO speed (determined using the ISO testing methodology). For example, the Ilford product is actually an ISO 1000 film, according to its data sheet (http://www.ilford.com/html/us_english/pdf/delta3200.pdf). The manufacturers are careful not to refer to the 3200 number as an ISO speed on the packaging. These films can be successfully exposed at EI 3200 (or any of several other speeds) through the use of push processing. The most sensitive sensor common in commercial photography may be the Silicon Intensified Target vidicon, at ASA 200,000, used in TV cameras.

Digital camera ISO speed and exposure index

The International Organization for Standardization (ISO) has a performance-based ISO speed standard for digital cameras, just as they have for film. ISO Standard 12232:2006 (http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=37777) ("Photography — Digital still cameras — Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index") defines ISO speed in terms of the amount of light needed to achieve a certain "quality" in the sense of a per-pixel signal-to-noise ratio.

However, this standard ISO speed "rating" for a digital camera is not necessarily very related to the ISO "setting" or "exposure index" used on the camera.

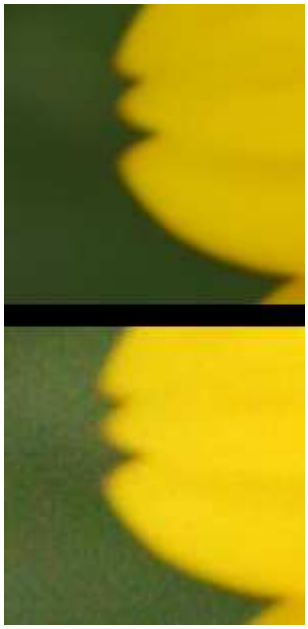
The image sensors in digital cameras can be adjusted, or can have their outputs adjusted, in sensitivity to function with metering at any given ISO setting. This is usually done by simply amplifying the output of the image sensor, which increases image noise, sometimes beyond the level that the ISO standard says is acceptable.

Just as with photographic film, greater sensitivity or exposure index comes with some loss of image quality, though this loss is visible as image noise rather than grain. The best digital cameras as of 2006 exhibit no perceptible noise at ISO 200 sensitivity, and some produce usable results up to ISO 3200.

Images of a flower taken at ISO 100 and ISO 1600 on a Canon 400D digital camera. Both images were shot under similar lighting conditions, varying only the ISO setting and shutter speed.

ISO 100, *f*/5.6, 1/350 s (click on image for larger version)

ISO 1600, *f*/5.6, 1/4000 s (click on image for larger version)



Comparison of both images. This is a crop of a small section of each image displayed at 100%. The top portion was shot at 100 ISO, the bottom portion at 1600 ISO.

References

- Leslie Stroebel, John Compton, Ira Current, and Richard Zakia. *Basic Photographic Materials and Processes*, second edition. Boston: Focal Press, 2000. ISBN 0-240-80405-8.

See also

- APEX system
- Lens speed

External links

- The official **ISO 5800:1987** (http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=11948).
- The official **ISO 12232:2006** (http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=37777).
- What is the meaning of ISO for digital cameras? (http://www.cs.duke.edu/~parr/photography/faq.html#isomeaning) Digital Photography FAQ
- understanding sensitivity (http://oemagazine.com/fromTheMagazine/jan02/testtalk.html) By Gloria Putnam

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