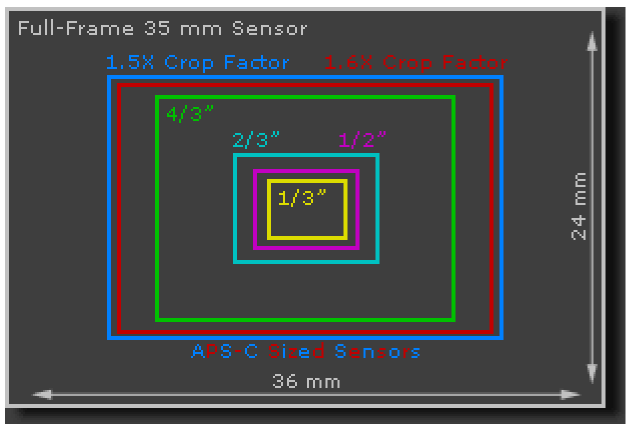
Kingston Photographic Club

Digital Cameras - Sensor Sizes

How does your digital camera's sensor size influence different types of photography? Confusion often arises on this topic because there are so many different size options, and so many trade-offs relating to depth of field, image noise, diffraction, cost and size/weight. See other KPC tutorials to explain depth of field.

OVERVIEW OF SENSOR SIZES

Sensor sizes currently have many possibilities, depending on their use, price point and desired portability. The *relative* size for many of these is shown below:

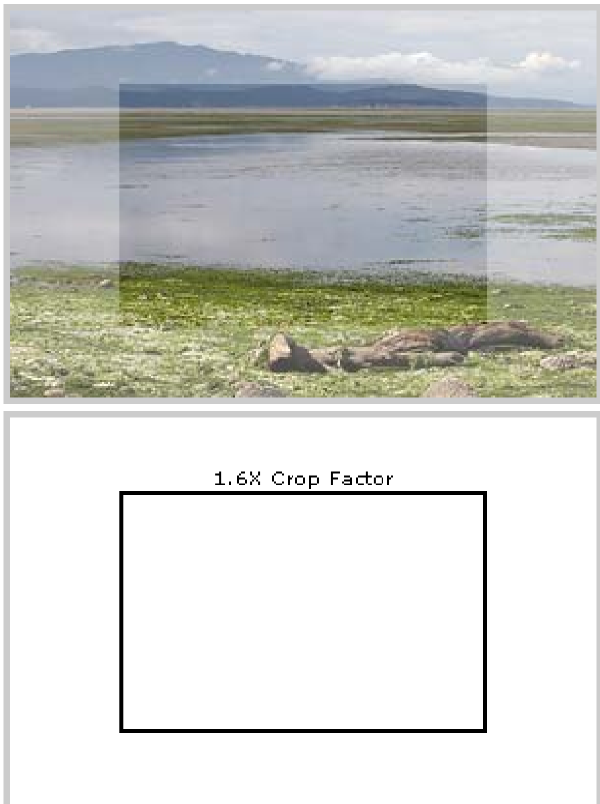


Canon's 1Ds/5D and Nikon D3 series are the most common full frame sensors, along with a couple of Sony cameras. Pentax and Olympus do not (2011) make them. Canon cameras such as the Rebel/60D/7D all have a 1.6X crop factor, whereas mainstream Nikon SLR cameras have a 1.5X crop factor. The above chart excludes the 1.3X crop factor, which is used in Canon's 1D series cameras.

Camera phones and other compact cameras use sensor sizes in the range of ~1/4" to 2/3". Olympus, Fuji and Kodak all teamed up to create a standard 4/3 system, which has a 2X crop factor compared to 35 mm film. Medium format and larger sensors exist, however these are far less common and currently prohibitively expensive – the most 'affordable' being the Pentax 645D at just under $10,000. Much as I'd love one, we won't deal with those here, but the same principles still apply.

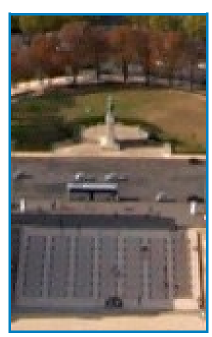
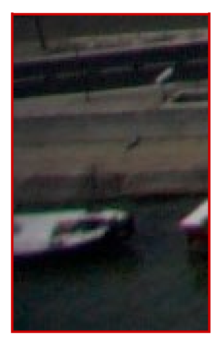
CROP FACTOR & FOCAL LENGTH MULTIPLIER

The crop factor is the sensor's diagonal size compared to a full-frame 35 mm sensor. It is called this because when using a 35 mm lens, such a sensor effectively crops out this much of the image at its exterior (due to its limited size).



35 mm Full Frame Angle of View

One might initially think that throwing away image information is never ideal, however it does have its advantages. Nearly all lenses are sharpest at their centres, while quality degrades progressively toward to the edges. This means that **a cropped sensor effectively discards the lowest quality portions of the image**, which is quite useful when using low quality lenses (as these typically have the worst edge quality).

Uncropped Photograph Centre Crop Corner Crop

On the other hand, this also means that one is carrying a much larger lens than is necessary — a factor particularly relevant to those carrying their camera for extended periods of time (see section below). Ideally, one would use nearly all image light transmitted from the lens, and this lens would be of high enough quality that its change in sharpness would be negligible towards its edges.

Additionally, **the optical performance of wide angle lenses is rarely as good as longer focal lengths**. Since a cropped sensor is forced to use a wider angle lens to produce the same angle of view as a larger sensor, this can degrade quality. Smaller sensors also enlarge the centre region of the lens more, so its resolution limit is likely to be more apparent for lower quality lenses.

Similarly, **the focal length multiplier relates the focal length of a lens used on a smaller format to a 35 mm lens producing an equivalent angle of view**, and is equal to the crop factor. This means that a 50 mm lens used on a sensor with a 1.6X crop factor would produce the same field of view as a 1.6 x 50 = 80 mm lens on a 35 mm full frame sensor.

Be warned that both of these terms can be somewhat misleading. The lens focal length does not change (and there is no extra magnification) just because a lens is used on a different sized sensor — just its angle of view. A 50 mm lens is always a 50 mm lens, regardless of the sensor type. At the same time, "crop factor" may not be appropriate to describe very small sensors because the image is not necessarily cropped out (when using lenses designed for that sensor).

LENS SIZE AND WEIGHT CONSIDERATIONS

Smaller sensors require lighter lenses (for equivalent angle of view, zoom range, build quality and aperture range). This difference may be critical for wildlife, hiking and travel photography because all of these often utilize heavier lenses or require carrying equipment for extended periods of time.

An implication of this is that if one requires the subject to occupy the same fraction of the image on a 35 mm camera as using a 200 mm f/2.8 lens on a camera with a 1.5X crop factor (requiring a 300 mm f/2.8 lens), one would have to carry 3.5X as much weight! This also ignores the size difference between the two, which may be important if one does not want to draw attention in public. Additionally, heavier lenses typically cost much more.

For SLR cameras, larger sensor sizes result in larger and clearer viewfinder images, which can be especially helpful when manual focusing. However, these will also be heavier and cost more because they require a larger prism/penta-mirror to transmit the light from the lens into the viewfinder and towards your eye.

DEPTH OF FIELD REQUIREMENTS

As sensor size increases, the depth of field will decrease for a given aperture (when filling the frame with a subject of the same size and distance). This is because **larger sensors require one to get closer to their subject, or to use a longer focal length in order to fill the frame** with that subject. This means that one has to use progressively smaller aperture sizes in order to maintain the same depth of field on larger sensors.

A shallower depth of field may be desirable for portraits because it improves background blur, whereas a larger depth of field is desirable for landscape photography. This is why **compact cameras struggle to produce significant background blur in portraits**, while large format cameras struggle to produce adequate depth of field in landscapes.

PIXEL SIZE: NOISE LEVELS & DYNAMIC RANGE

Larger sensors generally also have larger pixels (although this is not always the case), which give them the potential to produce lower image noise and have a higher dynamic range. Dynamic range describes the range of tones which a sensor can capture below when a pixel becomes completely white, but yet above when texture is indiscernible from background noise (near black). Since larger pixels have a greater volume — and thus a greater range of photon capacity — these generally have a higher dynamic range.

Further, larger pixels receive a greater flux of photons during a given exposure time (at the same f-stop), so their light signal is much stronger. For a given amount of background noise, this produces a higher signal to noise ratio — and thus a smoother looking photo.

This is not always the case however, because the amount of background noise also depends on sensor manufacturing process and how efficiently the camera extracts tonal information from each pixel (without introducing additional noise). In general though, the above trend holds true. Another aspect to consider is that **even if two sensors have the same apparent noise when viewed at 100%, the sensor with the higher pixel count will produce a cleaner looking final print**. This is because the noise gets enlarged less for the higher pixel count sensor (for a given print size), therefore this noise has a higher frequency and thus appears finer grained.

CONCLUSIONS: OVERALL IMAGE DETAIL & COMPETING FACTORS

Depth of field is much shallower for larger format sensors, however one could also use a smaller aperture before reaching the diffraction limit (for your chosen print size and sharpness criteria). So which option has the potential to produce the most detailed photo? Larger sensors (and correspondingly higher pixel counts) undoubtedly produce more detail if you can afford to sacrifice depth of field. On the other hand, **if you wish to maintain the same depth of field, larger sensor sizes do not necessarily have a resolution advantage**. Further, **the diffraction-limited depth of field is the same for all sensor sizes**. In other words, if one were to use the smallest aperture before diffraction became significant, all sensor sizes would produce the same depth of field — even though the diffraction limited aperture will be different.

Another important result is that **if depth of field is the limiting factor, the required exposure time increases with sensor size for the same sensitivity.** This factor is probably most relevant to macro and nightscape photography. Note that even if photos can be taken handheld in a smaller format, those same photos may not necessarily be taken handheld in the larger format.

On the other hand, exposure times may not necessarily increase as much as one might initially assume, because larger sensors generally have lower noise (and can thus afford to use a higher sensitivity ISO setting while maintaining similar perceived noise).

Ideally, perceived noise levels (at a given print size) generally decrease with larger digital camera sensors (regardless of pixel size).

No matter what the pixel size, larger sensors have more light-gathering area. Theoretically, a larger sensor with smaller pixels will still have lower apparent noise (for a given print size) than a smaller sensor with larger pixels (and a resulting much lower total pixel count). This is because noise in the higher resolution camera gets enlarged less, even if it may look noisier at 100% on your computer screen. Alternatively, one could conceivably average adjacent pixels in the higher pixel count sensor (thereby reducing random noise) while still achieving the resolution of the lower pixel count sensor. This is why images downsized for the web and small prints look so noise-free.

Overall: **larger sensors generally provide more control and greater artistic flexibility, but at the cost of requiring larger lenses and more expensive equipment**. This flexibility allows one to create a shallower depth of field than possible with a smaller sensor (if desired), but yet still achieve a comparable depth of field to a smaller sensor by using a higher ISO speed and smaller aperture (or when using a tripod).

So, is that all clear? I suppose the bottom line is that, if all cameras cost the same, and size and weight are not an issue, we would all have 60Mp Hasselblads. In the real world, a DSLR using a sensor with a 1.5 or 1.6 (or even a 2x) crop factor is sufficient for most of our needs, including quality large prints for exhibition and competition, unless we planned to print an image at around 4 x 5 *meters* in size! The effects of depth of field apply to all cameras – but small sensors (as in 'point and shoot' cameras) will not give the same blurring (or 'bokeh') that larger sensors can... and as you increase sensor size you won't get so much in focus (of relevance to the landscapers). Additionally, small sensors give more noise than large ones.

For most of us, the standard DSLR's sensor size is sufficient – and having an ambition to have a 'full-frame' sensor, or bigger, is understandable. And even then, some perfectly good photography can be achieved with a pocket-sized compact.