# Film & Sensor Size

## What Is Film?

Modern film is made of transparent plastic in a shape of a strip or sheet. That strip is coated on one side with light-sensitive silver halide crystals suspended into a gelatinous emulsion. The emulsion uses dye to hold it's ingredients together. When light strikes the film it creates a chemical reaction which causes the silver in the emulsion to activate. That reaction is controlled by the amount of light the film is exposed to. Films may have multiple layers containing silver based emulsions. Film can be b/w, color, positive (slide film) or negative like your standard print film. B/W film has one layer of coated emulsion. Color film has a minimum of three stacked layers; Red-Green-Blue. Each layer reacts separately to the light it is exposed to. Some color films use filters between the layers to remove excess green and keep the layers separate for cleaner images. Extreme overexposure can make the layers bleed into each other.

In order to bring out that image created by the silver halide's reaction, the film must be developed and the silver must be removed so that the film does not continue to react to light.

Projecting light thru film onto paper coated with light sensitive emulsion produces a print which must be developed in the same manner as film.

## What Is Grain?

Grain is the natural by-product of the chemical reaction in film. When the silver reacts to light it explodes the dye in the emulsion. That produces particles which appear as grain. Grain is noticeable when you enlarge your picture. The larger you make the print, the more noticeable the grain.

ISO or 'film speed' directly affects the visibility of grain in photos. In order for a film to be made more sensitive to light and thus 'faster' or 'higher ISO', the silver content must be increased. To react faster to light the reaction must be made more violent. With this more violent reaction comes more grain and larger grain.

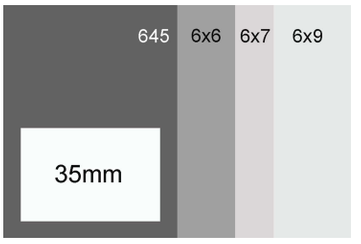
## Film Size Affects Visible Grain

Let's start this one with a question. Why did Ansel Adams use a large-format view camera. Let's take a look at the size of the film used in different camera systems.


Okay, you see the difference between an 8x10 view camera negative and a 35mm negative. Now, you want to make an 8x10 print and you have taken the same photo with both cameras. When you enlarge the image from the 35mm negative you have to enlarge it by 60x. So all the grain in the image is enlarged 60x. Now, make a print from the 8x10 negative. Yep, it's not enlarged at all. The grain remains tiny. It's that simple. We need to enlarge the image taken with our camera to make it comfortable to view, but by doing so, we make the grain more visible.

So, anytime you enlarge a photo you make the good more visible and the bad more visible. Remember this when we look at noise in digital images.

Why doesn't everyone use 8x10 view cameras if they are so much better. Simple, they are huge. It's not practical for an amateur photographer or most pro photographers to carry around a view camera. For the professional who needs to balance quality with portability, medium format cameras are the answer. Let's look at the comparison of film sizes between 35mm and medium format cameras.

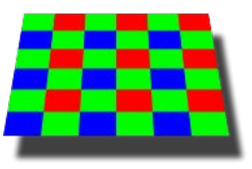



Once again, it's easy to see the difference in size. 645 film is 2.7x times larger than 35mm film. That means it only needs to be magnified 22 times to make an 8x10 print compared to the 60x a 35mm negative needs to be enlarged. Therefore, the grain is less visible in a print made from medium format film than from 35mm film.

So. why doesn't everyone carry a medium format camera? Simple, it's still too big for most people. And that's where 35mm comes in. 35mm is a good choice for amateur photographers, journalists and active people. A 35mm camera is much lighter than a medium format camera with much smaller lenses. A 35mm photographer can carry a camera body with several lenses without much hassle in a moderately sized camera bag. 35mm became the standard for photography for 80 years. In fact, it is still the standard when we look for something to compare digital sensors to.

## What Is A Digital Sensor?

Digital sensors record light by converting photons into electrical impulses. In order to do this a sensor is constructed like a grid, with millions of receptors distributed evenly across the frame. Each receptor collects photons when it is exposed to light. Those photons are converted into electrical impulses and interpreted for intensity by the processor. Colors are recorded by arranging red green and blue sensitive receptors next to each other in repetition. All three colors are represented equally.



This is the basic design for most sensors. Most digital sensors record images in 2 dimensions without layers. There are a couple of exceptions to this, though. The Foveon X3 sensor mimics film design and stacks its color layers. At low ISO's, it is the most accurate sensor made, but it is not versatile nor fast.

## What Is Digital Noise?

Digital noise is often compared to film grain but it is produced in a much different way. Digital sensors are electronically controlled and any electronic device creates electronic noise. Image noise is similar to static from a radio. It is always there and it usually happens in distinct patterns.

1. The image sensor can heat up and stimulate the production of stray electrons from each receptor site. Those rogue electrons can get mixed in with the photo electrons coming thru the lens and jump to neighboring receptors, causing errors in the interpretation and processing of the image.
2. Increasing ISO settings increases noise. In order to increase sensitivity the sensor needs more power, more amplification. Amplification makes every part of the signal more noticeable, including the noise.
3. Errors in processing or signal conversion can create white specks in black areas and black specs in white areas.
4. In long exposures, the receptors in sensors can leak current to a very noticeable level. That leakage of current, which usually doesn't have time to build up in a normal exposure becomes the major input source in long exposures. If you try to take a long exposure of the night sky you will see increased noise in the dark areas for this reason.
5. Sensor size. See the next section.

## Size Matters

Just like in film photography, the size of the recording medium directly impacts the quality of the enlarged image. In digital systems size is viewed in two ways. The number of pixels (receptors) the sensor contains and the size of the container which holds those pixels.

We know that digital noise is always there. We know what creates it. Then why does the sensor's size make a difference. Remember what I asked you to remember. No, okay, click here.

So, magnifying the image makes grain and noise more visible. Yes, it makes noise larger, too. Why? The camera sensor records images which could be considered less than dynamic compared to film. The image is flat. In that flat image, the noise is present, just like the grain in film. That flat image has a limited amount of information recorded in it. So, let's say the image has 5% noise. When the image is processed, either by the camera itself or the photographer, that flat image is tweaked to make it more vibrant. When the contrast is increased, the noise is also increased. When the colors are made stronger the noise is made stronger. When the image or file size is made larger the noise is made larger. All of this happens to the image file as it is adjusted.

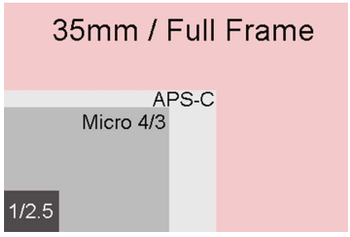
In digital photography, the more information that is recorded is directly proportional to the maximum size that it can be viewed at without loss of information or detail. A 2mb file will make a good 5x7, but if you make an 11x14 from it, it will look like something is missing. Something is missing; Information. So, more pixels let's us make bigger prints. A 23mb file let's us make a 16x20 poster without loss of detail. This is the reason why camera sensors have gotten more crammed with receptors over the last 15 years. We, as consumers aren't satisfied with tiny prints or images that can't be zoomed into. This sets us up for the problem of sensor size and it's relationship to noise.

Large sensors produce cleaner, sharper images than small sensors. This is a physical fact. The more receptors there are crammed into a small space, the more they interfere with each other and produce noise. In a large sensor, the receptors are larger, more energy efficient and spaced apart better. They interfere less with each other. The sensor itself is exposed to more light and light makes the image. Clutter in any medium means noise. Large sensors have a cleaner signal to noise ratio. So, a 20mp full frame sensor has less noise than a 20mp sub frame sensor. They hold the same amount of information but the full frame sensor has more actual photo, more useful information and less noise. The sub frame sensor with smaller receptors crammed into a smaller space creates more noise.

The severity of noise grows as ISO settings rise. The performance difference at ISO 100 can be barely noticeable but the difference in noise at ISO 800 is impossible to ignore and will be seen on monitors and in prints, especially enlargements. The file sizes may be the same, but the image is much cleaner from a larger sensor.

Imagine a photo taken with a smaller sensor. In order to get 20 megapixels into that sensor, they must be crammed in there so tightly that they interfere with each other to great extents. Feedback from one receptor affects 20 other receptors causing errors all across the sensor. It is like filling a room with mouse traps. They all react to each other when one is tripped. You don't want the trap next to the one that catches the mouse to respond but it is triggered to do so and before long, half of the room has tripped traps. When that happens in a digital photo, the noise becomes overwhelming. It is like looking at a static filled tv screen when the signal is weak.

Let's look at the sensor sizes of the most popular digital systems. 35mm/Full Frame is our reference size.




Okay, you can see that 35mm (full frame) is about twice the size of most D-Slr APS-C sensors. Micro 4/3 is slightly smaller. What is that little one doing in the lower corner? It is tiny. Why is that a popular size? That is the sensor in your bridge camera, phone, or compact point n shoot. Yes, that is why your pics from your phone are so noisy. In order to produce a viewable image from that sensor, it must be magnified many many times and with magnification comes more noticeable noise.

Why doesn't everyone use a full frame D-SLR? Simple, they are expensive and heavy.

Besides, the technical differences between different size sensors, there is also an aesthetic difference. Large sensors and /or large film formats produce more pleasing images than small sensor/film systems. If you view a photo of a tree in a field taken with an 8x10 view camera and compare it to the same image taken with a 35mm camera, you will notice that the tree stands out against the background and the entire photo has a feeling of depth. The out of focus areas are soft and similar to what the human eye sees. The 35mm photo looks flat and the out of focus areas are jagged and distracting compared to the photo taken with the larger negative. There is a technical explanation for this but it doesn't matter. Larger is better when you need your photo to feel real.

## Crop Factors

### Crop Factors on Digital Cameras

You may have noticed that when you bought your first point n click digital the lens had a rather strange lens size. Instead of 28-200mm lens, it says 4.6-33mm lens. It actually means the same thing. Since the sensor on that point n click is small, the lens needs to be small. 6x smaller than a 35mm camera's lens.

Let's use 35mm as a standard. A 50mm lens on a 35mm camera,, or full frame digital camera, is a normal lens. It doesn't magnify nor shrink the image.

In order to compare a lens from another system with a smaller sensor, say a Canon Rebel T5i, we need to correct for the difference in size by multiplying the Canon lens measurement by 1.6x. So, if you have a Canon Rebel T5i w/ a 17-55mm lens, you actually have the equivalent of a 28-90mm lens.

Why is this important. Well, it helps to know what type of magnification your lens has. A 50mm lens on a 35mm / full frame camera has no magnification. Any lens on a 35mm/full frame camera that is longer than 50mm is a telephoto. Any lens that is shorter then 50mm is a wide angle. So, if you put a 12mm lens on a Rebel T5i and you multiply 12 by the crop factor of 1.6x, you have the equivalent of using a 19mm on a 35mm/full frame camera. 19mm is an ultra wide angle lens.

This type of adjustment must be made for all cameras with a smaller sensor than a full frame camera. Here is a list of crop factors for popular

systems.

- 1/2.5 6x
- 1/1.7 4.55x
- Micro 4/3 2x
- Canon APS-C 1.6X
- Nikon APS-C 1.5
- Sony Alpha APS-C 1,5x

## Crop Factors on Film Cameras

Since 35mm is most familiar to us, the crop factors will be based on 24x36mm film.

Note: Crop factors are based on diagonal measurements of the film and therefore do not account for the change in ratio of ratio of length to width. In other words, 35mm film has a 2:3 ratio, but 5x7 doesn't, so the factor will be slightly off.

- 645 (6cm x 4.5cm)(2.25:3) .62X
- 6x6 (6cm x 6cm)(1:1) .55X
- 6x7 (6cm x 7cm)(2:2.33) .5X
- 6x9 (6cm x 9cm)(2:3) .43X
- 4x5" ( 10 x 12.5cm)(2:2.5) .25X
- 5x7" ( 12.5 x 17.5cm)(2:2.8) .20X
- 8x10"( 20 x 25cm)(2:2.5) .12X
- 11x14" ( 27.5 x 62.5cm)(2:2.55) .086X