

# **Primjena digitalne fotografije u reprodukcijskim medijima**

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2. predavanje

## **Film vs. digital**

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# Digital versus film photography

[http://en.wikipedia.org/wiki/Digital\\_vs\\_film\\_photography](http://en.wikipedia.org/wiki/Digital_vs_film_photography)

**Digital versus film photography** is a topic sometimes debated by photographers. Between [digital](#) and [film](#), each format has advantages,<sup>[1][2]</sup> and the different natures of these two technologies usually render the question "Which is better, film or digital?" meaningless without the qualifier "...for what purpose?" Strictly speaking, neither technology is better or worse of itself. With that [caveat](#) in mind, this article attempts to compare some of the characteristics of both types of photography.

## 1. Quality

- **Spatial resolution**

There are many measures that can be used to assess the quality of still photographs. The most discussed of these is the [pixel](#) count, presumed to correlate with [spatial resolution](#).<sup>[3]</sup> This is measured by how many picture elements (pixels) the [image sensor](#) has, usually counted in the millions and hence called "[megapixels](#)".

The comparison of resolution between film and digital photography is complex. Measuring the resolution of both film and digital photographs depends on numerous issues. For film, this issue depends on the size of film used ([35 mm](#), [Medium format](#) or [Large format](#)), the [speed](#) of the film used and the quality of lenses in the [camera](#). Additionally, since film is an analogue medium, it does not have pixels so its resolution measured in pixels can only be an estimate.

Similarly, digital cameras have a variable relationship of resolution to megapixel count;<sup>[4]</sup> other factors are important in digital camera resolution such as the actual number of pixels used to store the image, the effect of the [Bayer pattern](#) or other sensor filters on the digital sensor, and the image processing algorithm used to interpolate sensor pixels to image pixels. In addition, digital sensors are generally arranged in a rectangular grid pattern, making images susceptible to [moire pattern](#) artifacts, whereas film is immune to such effects due to the random orientation of grains.<sup>[citation needed]</sup>

Estimates of the resolution of a photograph taken with a 35 mm film camera vary. It is possible for more resolution to be recorded if, for example, a finer grain film and/or developer are used or less resolution to be recorded with poor quality optics or low light levels. The digital megapixel equivalent of film is highly variable and roughly depends on film speed. Slow, fine-grained 35 mm B&W films with speeds of ISO 50 to 100 have estimated megapixel equivalents of 20 to 30 megapixels. Color films (both negative and slide types) are estimated between 8 and 12 megapixels. This would place film cameras (as of [2008](#)) well over almost all point and shoot digital cameras. However, different films with the same ISO speeds can have different linear resolutions, so a direct comparison to digital is not easy. Resolution for 35mm film drops drastically with higher ISO ratings, particularly above ISO 400.<sup>[citation needed]</sup>

While 35 mm is the standard format for consumer cameras, many professional film cameras use [medium format](#) or [large format](#) films which, due to the size of the film used, can boast resolution many times greater than the current top-of-the-range digital cameras. For example, it is estimated that a medium format film photograph can record around 50

megapixels, while large format films can record around 200 megapixels ( $4 \times 5$  inch)<sup>[5]</sup> which would equate to around 800 megapixels on the largest common film format,  $8 \times 10$  inches. However, the estimate above does not take into account lens sharpness.<sup>[citation needed]</sup>

When deciding between film and digital and between different types of camera you want to use for a given project, it is necessary to take into account the medium which will be used for display, and the viewing distance. For instance, if a photograph will only be viewed on a television or computer display (which can resolve only about .3 megapixels<sup>[6]</sup> and 1-2 megapixels, respectively, as of 2008. HD sets of 1080p are around 1.8mp), then the resolution provided by a low-end digital cameras may be sufficient. For standard  $4 \times 6$  inch prints, it is debatable whether there will be any perceived quality difference between digital and film when it comes to resolution.

- **Noise levels**

It should be noted that a special case exists for long exposure photography - Currently available technology contributes random noise to the images taken by digital cameras, produced by [thermal noise](#) and manufacturing defects. Some digital cameras apply noise reduction to long exposure photographs to counteract this. For very long exposures it is necessary to operate the detector at low temperatures to avoid noise impacting the final image. Film grain is not affected by exposure time, although the apparent speed of the film does change with longer exposures, a phenomenon known as [reciprocity failure](#).<sup>[citation needed]</sup>

- **Dynamic range**

The topic of [dynamic range](#) (DR) turns out to be more complicated than it sounds.<sup>[7]</sup> Any blanket claims that "digital has greater DR than film," or vice-versa, are not useful as they gloss over the many technical differences between film and digital photography. Any responsible comparison must consider:

- **What film?** For example, low-contrast print film has greater DR than slide film's low DR but richer gradation in recorded tones.
- **What film format?** Larger formats give greater film to image ratio so grain is less detectable at film's limits of exposure.
- **What sensor?** The more convenient pocket digicams use smaller sensors which generate more sensor noise.
- **What scanner?** Variations in optics, sensor resolution, scanner DR, and precision of the analog to digital conversion circuit can make a huge difference.
- **What counts as image and what is noise?** This question defines the limits of DR within a single photograph, and may vary with subject matter.

Since all of these issues affect DR, no one comparison can demonstrate that digital or film generally has more of it.

Different authors have performed tests with inconclusive results. R. N. Clark, comparing a professional digital camera with 35mm film, reached the conclusion that "Digital cameras, like the Canon 1D Mark II, show a huge dynamic range compared to either print or slide film, at least for the films compared."<sup>[8]</sup>

Ken Rockwell comes to a different conclusion: "CCDs and the related capture electronics will need about ten times more dynamic range (three stops) than they have today to be able to simulate film's shoulder....This is the biggest image defect in digital cameras today."<sup>[9]</sup>

Finally, Carson Wilson recently completed an informal comparison of Kodak Gold 200 film with a Nikon D60 digital camera, and concluded that "In this test a high-end consumer digicam fell short of normal consumer color print film in the area of DR."<sup>[10]</sup>

Much effort is currently being expended by the digital camera industry to address the problem of dynamic range. Some newer CCDs such as Fuji's [Super CCD](#), which combines photosites of different sizes, have increased dynamic range. Other manufacturers use in-camera software to prevent highlight blowout. Nikon's name for this process is "D-Lighting."

Drawing showing the relative sizes of sensors used in most current digital cameras.

- **Effects of sensor size**

All point and shoot digital cameras, and most [digital SLRs](#), have sensors that are smaller than a standard frame of 35 mm film. These smaller sensors have a number of effects on the captured image and the use of the camera:<sup>[11]</sup>

1. Increased depth of field.
2. Decreased light sensitivity and increased pixel noise.
3. For digital SLRs, cropping of the field of view when using lenses designed for 35 mm camera.
4. Lenses can be smaller, since they only need to project light onto a smaller image area
5. Increased degree of enlargement.

The [depth of field](#) of a camera/lens combination increases as the film/sensor size decreases, for a given [f-number](#). This is arguably an advantage for compact digital cameras since they are intended for taking snapshots. It means that more of the scene will be in focus than with a larger sensor, and the [autofocus](#) system does not need to be as accurate to capture an acceptable image. However, art photography often makes use of a limited depth of field to create special effects, such as isolating a subject from the background. In this case digital cameras with sensors smaller than a frame of 35mm film require a smaller f-number (same [aperture](#) diameter) on the lens to achieve the same degree of out-of-focus blur (sometimes referred to as "[bokeh](#)").

Light sensitivity and pixel noise are both related to pixel size, which is in turn related to sensor size and resolution. As the resolution of sensors increase, the size of the individual pixels has to decrease. This smaller pixel size means that each one collects less light and the resulting signal is amplified more to produce the final value. This amplification also includes an amount of noise in the signal. With a smaller signal, the [signal-to-noise ratio](#) decreases. Not only is more noise present in the image (relatively speaking), but the relatively higher [noise floor](#) means that less useful information can be extracted from the darker parts of the image.<sup>[11]</sup>

Most digital SLRs use [lens mounts](#) originally designed for film cameras, commonly [35 mm](#). If the camera has a smaller sensor than the intended film frame, the [field of view](#) of the lens is cropped. This [crop factor](#) is often called a "focal length multiplier" since the

effect can be simplified to that of multiplying the focal length of the lens. For lenses that are not "digital specific" (designed for a smaller sensor despite using the 35 mm-compatible lens mount) this has the slight beneficial side effect of only using the center part of the lens, where the image quality is normally best; the "soft edges" are cropped off. [\[citation needed\]](#)

Only a few of the most expensive digital SLRs have so-called "[full-frame](#)" sensors — a sensor the same size as a 35 mm film frame (36 × 24 mm). These larger sensors eliminate the issues of depth of field and crop factor when compared to 35 mm film cameras. [\[citation needed\]](#)

With compact digital cameras the sensors are tiny compared to DSLRs and frames of film. This means that prints are extreme enlargements of the original image, and that the lens has to perform outstandingly in order to provide enough resolution to match the tiny pixels on the sensor. Most digital compacts have sensors that exceed the maximum resolution that the lens is capable of delivering, increased sensor resolution may even have a negative effect on the overall resolution because of increased noise reduction. The use of a small sensor also has the effect of increasing depth of field to the extent of making images very "flat" looking because backgrounds can not be blurred except for subjects very close to the camera. [\[citation needed\]](#)

## 2. Convenience and flexibility



Digital photography is flexible to the extreme; a photographer can change anything about a photograph *after* it has been taken.



These two pictures are a before and after demonstrating the capabilities of the digital photographer.

This has been one of the major drivers of the widespread adoption of digital cameras. [\[citation needed\]](#) Before the advent of digital cameras, once a photograph was taken, the roll of film would need to be finished and sent off or taken to a lab to be developed. Only once the film was returned was it possible to see the photograph. However, most digital cameras incorporate an LCD screen which allows the photograph to be viewed immediately after it has been taken. This allows the photographer to delete undesired or unnecessary

photographs, and offers an immediate opportunity to re-take. When a user desires prints, it is only necessary to print the good photographs.

Another major advantage of digital technology is that photographs can be conveniently moved to a personal computer for modification. Many professional-grade digital cameras are capable of storing pictures in a [raw image format](#) which stores the output from the sensor directly rather than processing it immediately to an image. When edited in suitable software, such as [Adobe Photoshop](#) or the GNU program [GIMP](#) (which uses [dcraw](#) to read raw files), the photographer can manipulate certain parameters of the taken photograph (such as contrast, sharpness or color balance) before it is "developed" into a final image. Alternatively, users may choose to simply "touch up" the content of recorded [JPEG](#) images; software with which to do this is often provided with consumer-grade cameras. (See [Digital image editing](#).)

### **3. Price**

The two formats (film and digital) have different cost emphases. With digital photography, cameras tend to be significantly more expensive than film ones, <sup>[[citation needed](#)]</sup> comparing like for like. This is offset by the fact that taking photographs is effectively cost-free. The price of digital cameras continues to fall and it could be argued that film is more expensive than digital.

With film photography, good-quality cameras tend to be less complicated and, therefore, less expensive, but at the expense of ongoing film and in particular processing costs. The photographer will also only identify poor shots after paying developing and printing costs.

35mm film does offer the photographer much more control over the depth-of-field than a 'crop' body DSLR, and the entry cost differential to full-frame photography can therefore be very large - 35mm SLR's can be purchased for a tenth of the price of a full-frame DSLR. Since the lenses from the main brands are interchangeable between SLR and DSLRs, film can still be an attractive route into photography because of this.

There are also additional costs associated with digital photography, such as specialist batteries, memory cards, and long-term storage. However these combined are likely to be very much less than developing costs.

With many photographers switching to digital, many film cameras (and associated equipment like lenses) are now available on the second-hand market (especially online auction sites like [eBay](#)) at often very reduced prices.

### **4. Robustness**

Dust on the image plane is a constant issue for photographers. DSLR cameras are especially prone to dust problems because the sensor is reused for every shot, where a film SLR will effectively have a new "sensor" slid into place for every shot. A fresh, dust free film frame comes at risk of debris such as dust or sand in the camera scratching the film. A single grain of sand can damage a whole roll of film. Also as film SLRs age, they can develop burs in their rollers. With a digital SLRs dust is difficult to avoid, but easy to rectify if one has a computer with photo editing software available. Some digital SLRs have systems that remove dust from the sensor by vibrating or knocking the sensor. Some cameras do this in conjunction with software that remembers where dust is located on the sensor and removes dust-affected pixels from images. <sup>[[citation needed](#)]</sup> One advantage to

compact point and shoot digital cameras is that they are exclusively available with fixed lenses, so dust is not an issue for them. This is not true of point and shoot film cameras, which are often only light tight and not environmentally sealed.

## 5. Archiving

When choosing between film and digital formats, one may need to consider the suitability of each as an archival medium.

Films and prints processed and stored in ideal conditions have demonstrated an ability to remain substantially unchanged for more than 100 years. [Gold](#) or [platinum toned prints](#) probably have a lifespan limited only by the lifespan of the base material, probably many hundreds of years. <sup>[citation needed]</sup>

The archival potential of digital photographs is less well understood since digital media have existed for only the last 50 years. There exist three problems which must be overcome for archival usage: physical stability of the recording medium, future readability of the storage medium and future readability of the [file formats](#) used for storage.

Many types of digital media are not capable of storing data for prolonged periods of time. For example, magnetic disks and tapes may lose their data after twenty years, flash memory cards even less. Good quality optical media may be the most durable storage media for digital data. <sup>[citation needed]</sup>

It is important to consider the future readability of storage media. Assuming the storage media can continue to hold data for prolonged periods of time, the short lifespan of digital technologies often causes the drives to read media to become unavailable. For example, the first 5¼-inch [Floppy disks](#) were first made available in [1976](#). However, the drives to read them are already extremely rare just 30 years later.

It must also be considered whether there still exists software which can decode the data. For example, many modern digital cameras save photographs in [JPEG](#) format. This format has existed for only around 15 years. Whether it will still be readable in a century is unknown, although the huge number of JPEG files currently being produced will surely influence this issue.

Most professional cameras can save in a [RAW image format](#), the future of which is much more uncertain. Some of these formats contain proprietary data which is encrypted or protected by [patents](#), and could be abandoned by their makers at any time for simple economic reasons. This could make it difficult to read these 'raw' files in the future, unless the camera makers were to release information on the file formats. <sup>[12]</sup>

However, digital archives have several methods of overcoming such obstacles. In order to counteract the file format problems, many organizations prefer to choose an [open](#) and popular file format. Doing so increases the chance that software will exist to decode the file in the future. <sup>[citation needed]</sup>

Additionally many organizations take an active approach to archiving rather than relying on formats being readable decades later. This takes advantage of the ability to make perfect copies of digital media. So, for example, rather than leaving data on a format which may potentially become unreadable or unsupported, the information can typically be copied to newer media without loss of quality. This is only possible with digital media. <sup>[citation needed]</sup>

And, of course, the digital images can always be printed out and saved like traditional photographs although there are few, if any, commercial services available producing true silver halide prints from digital sources. All dye based prints, as noted above, have only limited permanence (with the exception of [Cibachrome](#)).<sup>[citation needed]</sup>

## 6. Integrity

Film produces a first generation image, which contains only the information admitted through the aperture of the camera. Film "sees" in color, in a specific spectral band such as [orthochromatic](#), or in broad [panchromatic](#) sensitivity. Differences in development technique can produce subtle changes in the finished negative or positive, but once this process is complete it is considered permanent.<sup>[citation needed]</sup>

Film images are very difficult to fabricate, thus in law enforcement and in cases where the authenticity of an image is important (passport or visa photographs), film provides greater security over most digital cameras, as digital files usually can be modified using a computer.

However, there are digital cameras that can produce authenticated images. If someone modifies an authenticated image, it can be determined with special software.<sup>[13][14]</sup>

In addition to digital cameras that can produce authenticated images, SanDisk claims to have a write-once memory stick for cameras. The images can be viewed, but they can not be deleted, altered, or changed in anyway. According to SanDisk its physically impossible. SanDisk also claims that the memory card has a life span of at least 100 years in proper storage conditions without any memory loss making it a viable archival option, and with a price that is substantially lower than that of prints.<sup>[15]</sup>



Nikon [film scanner](#), right, which converts 35mm film images to digital

## 7. Converting film to digital

Film photographs may be digitized in a process known as [scanning](#). They may then be manipulated as digital photographs.

There are currently three ways to scan or convert a film image to digital format.<sup>[citation needed]</sup> The first is through a reflective image scanner. Inexpensive flatbed scanners, depending upon the model used, can scan a paper-sized image from 8" x 14" to ledger size, 11" x 17". An expensive and very high resolution drum scanner can also be used to scan reflective and transparent images.

The second method is to use a dedicated [film scanner](#), such as the Nikon Coolscan (pictured) which can scan [35 mm](#) transparencies and negatives. Other film scanners can scan [120 film](#), typically up to 6 x 7 cm or 6 x 9 cm.



The third method is to take a digital photograph of the source image. One can mount a digital camera on a copy stand (or an old enlarger with its projection head removed) and photograph the source image. It is also possible to use a [slide projector](#) to project the image from a transparency and then take a digital photograph of the projection.

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## Film vs Digital - Practical differences

<http://www.digital-photography-tips.net/film-vs-digital.html>

The table below illustrates some of the practical differences of film vs digital cameras. Negative points are in red, positive in blue, neutral in green:

| Film:   | Digital:  |
|---|---|
| Image captured and stored on the film itself.   | Image captured on the image sensor and recorded onto a memory card.   |
| Once film is exposed to light it cannot be used again – more film has to be bought.                               | Once a memory card is full of images, they can be downloaded onto a computer. The memory card can then be wiped and used again.   |
| To view photographs the film has to be developed using special chemicals.   | Photographs can be viewed instantly, either on the digital camera or on a computer.   |
| Editing photographs is very difficult and requires a darkroom.  | Editing of photographs is easier and can be done on a home computer.  |
| Batteries last a long time in a film camera.  | Digital cameras eat batteries at a fair rate of knots!  |
| Film cameras are usually very responsive quick to start up, quick to focus and no delay on releasing the shutter. | Compact digital cameras take a couple of seconds to start up, can be slower to focus and some have a fraction of a second shutter delay. (NB: Digital SLRs suffer far less than compacts) |

It's worth having a look at these practical differences because the issue of film vs digital is not only about picture quality.

If a digital camera is slow to start and focus you may well miss photos that a film camera would have captured.

The quality of digital cameras may impress. But that's of little consequence if the subject you were photographing has moved on before the camera was ready to take the picture!

### *Film vs Digital – differences in quality*

It used to be the case, not that long ago, that digital cameras never matched the quality of film cameras.

**Slowly the gap narrowed.** Good (and very expensive!) digital cameras began to take better quality photos than cheaper film cameras.

Then the more affordable digital cameras improved. To get better quality with film you had to start spending more money on better equipment. **The film vs digital pendulum was swinging in favour of digital.**

These days the **quality of digital cameras outstrips all but the most specialized film cameras**. And by specialized I mean large and medium format cameras.

The evidence for this lies in the sale of cameras. Kodak has already pulled out of the film market. Even Nikon's professional film cameras are going, with the sole exception of the Nikon F6 – their highest spec film camera.

Professional photographers demand high quality. **If the professionals are leaving film cameras behind then it's safe to assume that digital cameras have come of age.**

If anyone thinks digital hasn't won the film vs digital competition, they must at least acknowledge that the finish line is near, and digital is edging ahead all the time.

### ***Film vs digital and the tonal range***

For a balanced film vs digital discussion we have to realise that there is more to quality than just producing a sharp picture. The **tonal range also matters**.

In simple terms, tonal range is the number of grades of light to dark in a photograph. Digital photography is generally limited to 256 grades. **Film** is effectively an analogue medium so theoretically **can produce limitless grades of light to dark**. In the issue of tonal range, film seems to win the film vs digital debate.

**How does this limited tonal range affect digital photography?** With a digital camera, bright areas of an image can record as pure white. Even though there are actually some shades within that area. These parts of an image are said to be **burnt out** or **blown highlights**.

The same applies to dark, but not quite black areas of pictures. Digital cameras will record the whole area as pure black. This is less of a problem as the human eye doesn't notice these dark areas so much.

I took the photograph below at the Chinese New Year Celebrations in London (great day out by the way!). The clouds in the photograph clearly show the differences in tonal range from film vs digital.

The first image shows what film can produce. The second shows the **blown highlights** that can sometimes result **from digital photography**.



Film - clouds properly exposed



Digital - clouds "blown"

## *Film vs Digital – "grain" vs "megapixels"*

Finally, you may be interested to find out how “megapixels” fit into the film vs digital debate.

Digital camera quality is often measured in megapixels. More megapixels means every individual pixel (or dot) in the final picture will be smaller. The smaller they are, the sharper the picture will be

Be careful though! Look at my page on [the megapixel race](#) to find out why **the number of megapixels alone doesn't always make a good camera**. There's also a table there showing you **how many pixels are enough**.

For film, the equivalent "pixels" are actually film "grains".

The size of the grains depends on the speed of the film used – faster film (more sensitive to light), has larger grains. These grains will be visible in the final print. Concerning film vs digital, **a good quality 4 megapixel digital camera equals fast film**, pixel for grain.

Most people would use slower film though, so this is what we should compare for a balanced film vs digital comparison. **For standard film it is generally considered that a good 8 megapixel digital camera is about equal**, pixel for grain.

Roger Clark has some graphs that illustrate the, [resolution differences between film vs digital](#) over on ClarkVision for those who really want to delve into the megapixel equation.

## *Film vs digital - conclusion*

Well, that's a tough one. No matter what people say, when it comes to film vs digital there will be fans on both sides of the fence.

One of the easiest ways to think about the film vs digital issue is to relate it to vinyl records and CDs.

CDs are convenient - easy to find a track, play well, no scratches or rumble. With CDs people have access to good quality music that's in a format that's easy to use.

But . . . vinyl records are still on sale. Hardened music fans insist that the quality of vinyl can never be matched by the quality of a CD. And in theory they are right. An analogue record has all the tones, the digital CD only has some.

Can the average person tell the difference? Nope! They prefer the convenience of CDs, and well, they sound just fine, don't they?

The same can be said of film vs digital. Film is analogue. It has all the tones. But digital is easier to use, and can most people tell the difference? Nope!

As a final conclusion about film vs digital then - film will always have its fans, but digital will be the most popular. And as for quality - only the really, *really* pickiest of photographers will ever notice the difference.

# Film vs. Digital

<http://www.clarkvision.com/imagetdetail/film.vs.digital.summary1.html>

## *Introduction*

Digital is Better than Film!  
No It's Not! Film is BETTER than Digital!  
No, You're wrong! **No, you're wrong!**

*Guess what? Flat statements like this are both wrong, and both right!*  
Why? There is no one single correct answer. Thus, depending on what you want to do, one tool may be better than another.

It is often asked if digital cameras meet or exceed the imaging quality of film and what are the advantages and disadvantages. Let me first consider 35mm versus digital.

I've done digital imaging and image processing in the scientific world since about 1977, so I am very familiar with the technology and its use. I set high standards for myself in all my work and play. Currently I use both film and digital.

Here are some of the issues in the Digital vs Film debate:

- The question really is film versus electronic sensors.
  - Both are analog capture.
  - Electronic sensors: an analog charge gets digitized in the camera.
  - Film can be scanned at high resolution.
- Image detail requires many megapixels.
  - Until recently, "digital" cameras could not meet film resolution.
  - Digital cameras only meet/exceed film cameras in some restricted areas.
    - E.g. Wildlife action photography.
- Images have tonality and dynamic range.
  - Both film and electronic sensors are good in this regard.
    - Electronic sensors have a larger dynamic range than film (at least the better sensors do).
  - Electronic sensors have lower image noise.
    - Noise in an image has a big impact on the perception of image quality.
    - The size of the pixels in the electronic sensor are directly related to the signal-to-noise in the image produced by the camera. Larger pixels are better.

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**More details: spatial resolution, dynamic range and signal-to-noise**

**So, how many megapixels do you need (Spatial Resolution)?**

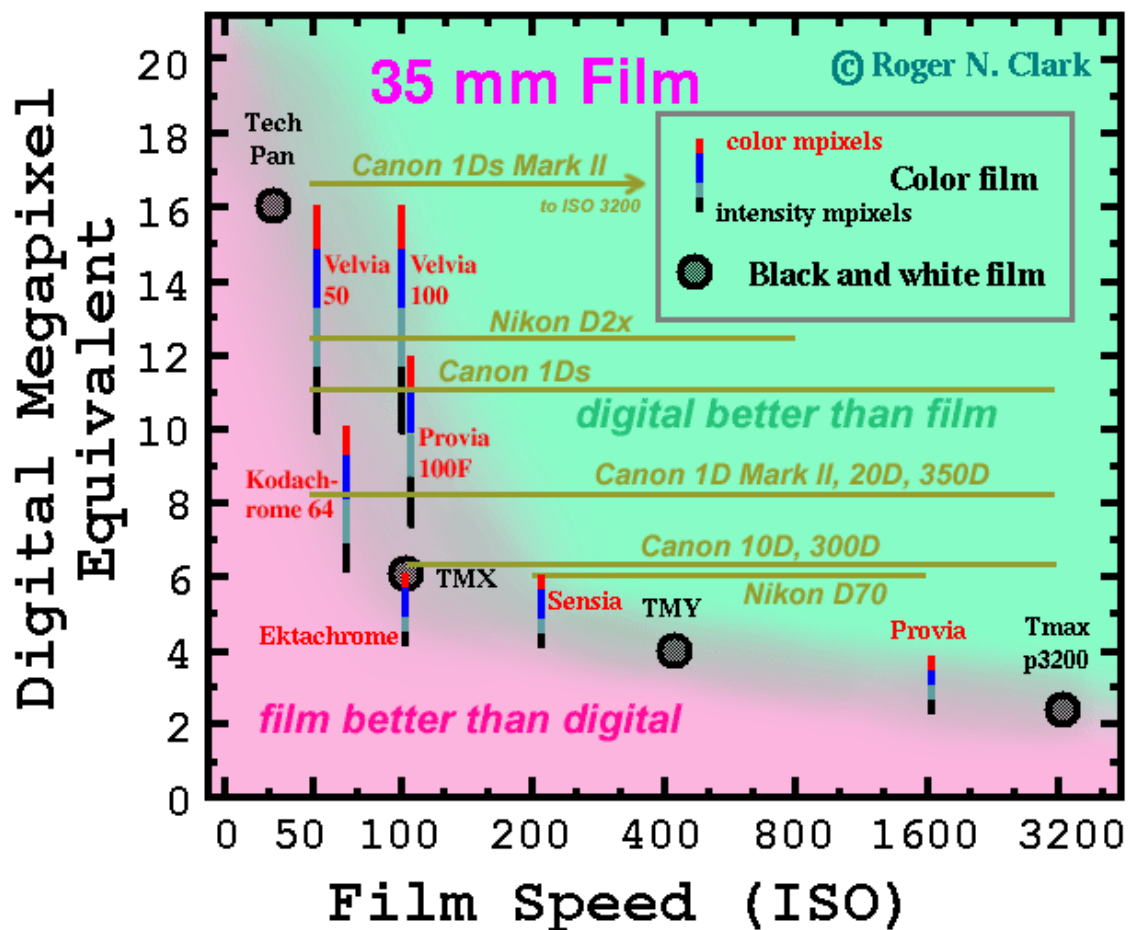


Figure 1. The spatial resolution of film in units equivalent to digital camera megapixels. "Better" refers to spatial resolution only. Signal-to-noise is similarly important to image quality and is discussed below. The grey band is where the spatial resolution of film and digital are similar.

The above plot is a summary of my research. This plot, digital megapixel equivalent versus film speed, refers to spatially resolved detail. In the experiments I've done, using a variety of films and digital sensors, my data and test results show quite a range of answers concerning whether film is better than digital with regard to spatial resolution. Remember, spatial resolution is only part of the story of perceived image quality. Detail of this research can be seen at:

[Film versus Digital Information](#),  
[An Image Detail Test: Scanned Fujichrome Velvia Versus 6-MPixel Digital](#),  
[Image Detail \(How much detail can you capture and scan?\)](#), and other articles at:  
<http://www.clarkvision.com/imagetail>.

Figure 1, above, shows the pink zone where film can give better results. If your digital camera works in the green zone, a quality digital camera can give better results. But that is not all, it really depends on WHAT you are trying to do.

In Figure 1 above, the derived digital megapixel equivalents are fuzzy numbers. For example, the Fujichrome Velvia 35mm equivalent is 10 to 16 megapixels. The 10 and 16 are soft. By soft I mean by several megapixels, like 10 meaning 8 to 12, and 16 meaning 14 to 18. You can see what I mean by trying to compare some of my test images yourself. The vertical bars for color represent the varying resolution one gets from Bayer Sensor digital cameras: color has less resolution than luminance. So the upper part of the bar

represents the megapixel equivalence for luminance information, and the bottom gives the color information.

Examples: If you want to do landscapes and use the finest grained films, like Fujichrome Velvia as ISO 50, current top end cameras like the 6.3 megapixel Canon 10D will not deliver the detail of fine grained film. The 11 megapixel canon 1Ds comes close to 35mm Velvia. Example 2: If you do wildlife or action photography, you want to record the image with fast shutter speeds. You need fast film/digital sensor speed and or fast lenses. Some stop action wildlife photography requires shutter speeds faster than about 1/2000 second. Slow speed film will simply not work in many lighting situations. Professional wildlife photographers often use 100 speed film pushed one stop to ISO 200. In the above plot, we see that a 6 megapixel camera operating at ISO 200 will deliver more image detail than the corresponding ISO film. So, determine what film you have been using for what conditions. Check the above plot and see what digital megapixel equivalent that corresponds to and choose a digital camera that would be better.

If you want to see the details of my research, including image comparisons for digital up to 200 megapixel equivalent and film, including 35mm, medium and large format (up to 8x10), go to [my image detail main page](#) and read the other articles. Specific articles on film versus digital camera spatial resolution include:

[Image Detail \(How much detail can you capture and scan?\)](#),  
[An Image Detail Test: Scanned Fujichrome Velvia Versus 6-MPixel Digital](#), and  
[How much to sample to record "all the detail?"](#)

But spatial detail is only part of the story.

### *Dynamic Range and Signal-to-Noise*

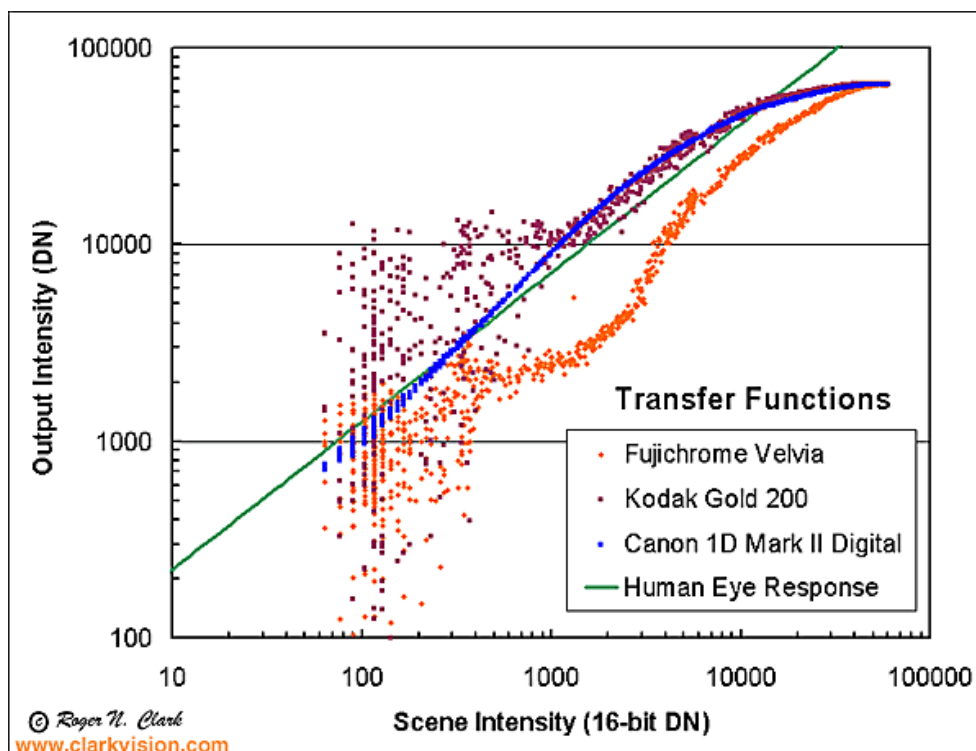


Figure 2. Example Transfer functions of one digital camera, one slide film and one print film.

There seems to be an urban legend that says digital cameras have less dynamic range than film. The legend is wrong. The above plot shows the comparison of a DSLR with print and slide film. The slide film records only about 5 photographic stops of information (a stop is a factor of 2, so 5 stops is 32). The print film shows about 7 stops of information. The digital camera shows at least 10 stops of information (this test was limited to 10 stops). Other tests show the Canon 1D Mark II camera has about 11.6 stops of information (a range of 3100 in intensity). Other DSLR cameras, like the Canon 10D have around 11 stops. Point and shoot digital cameras, somewhat less.

Examine the scatter in the data in the above figure. The scatter is due to noise. The digital camera has several times less noise at medium and high intensities, and dozens of times less noise at low intensities. The low scatter of the blue points shows the low noise of the digital camera, and it is lower at all scene intensities. For further information, see:

[\*\*Dynamic Range of an Image 2: Dynamic Range and Transfer Functions of Digital Images and Comparison to Film\*\*](#)

[\*\*Dynamic Range of an Image 1: How many bits do you need? \(Intensity Detail of an Image\)\*\*](#)

[\*\*The Signal-to-Noise of Digital Camera images and Comparison to Film.\*\*](#)

### ***Apparent Image Quality (AIQ)***

While most who have worked with digital camera images agree that because of the "smoothness" of digital images, they can be enlarged more than film images. My testing shows that fine grained film has higher spatial resolution than 8-MPixel digital camera images, but the digital camera images have several times higher signal-to-noise. People infer image quality as a function of both spatial resolution and signal-to-noise. While this is a subjective concept, I've started some experiments to test this "Apparent Image Quality," or **AIQ**. My initial results (example references below) are showing to first order that there is an approximate equal trade for signal-to-noise ratio versus spatial resolution. Thus, if you had a digital camera that produced 8 megapixels and twice the signal to noise as fine grained film, the apparent digital camera megapixels could be doubled when comparing to film. So that 8-megapixel image may have the "apparent image quality" of 16 megapixels if compared to the lower signal-to-noise film. Since my tests show the spatial resolution of fine grained 35mm film like Fuji Velvia is around 16 MPixels digital equivalent, then that 8-MPixel digital camera probably produces similar "apparent image quality" to 35mm fine-grained film.

But high end DSLRs, like the Canon 1D Mark II have several times the signal-to-noise ratio of film, so this boosts the apparent image quality by the same factor as the ratio in the signal-to-noise values, propelling the 1D Mark II images higher in "perceived image quality" than fine grained 35mm film. While my research is preliminary, it does seem to agree with what people are saying, and because people look at different things (image smoothness versus spatial detail), it shows there is a lot of room for interpretation.

Note, too, that there are differences in signal-to-noise ratio between different digital cameras, mainly due to their differing pixel sizes. Larger pixels, in general, produce higher signal-to-noise images because larger pixels collect more light. See:

[\*\*Digital Cameras: Does Pixel Size Matter? Factors in Choosing a Digital Camera\*\*](#)

I will continue testing on **AIQ** to further improve the AIQ concept. If my research trend holds, then the ~16 megapixel cameras with large sensors will have ~64 **AIQ** MPixel film equivalent, which is well into the higher medium format size range. Impressive! But small



pixel size cameras, typical of "point and shoot" models, will probably have AIQ values several times less than the large pixel size DSLRs, even given the same number of megapixels in each camera.

My working AIQ equation that fits my data so far is:

$$\text{AIQ} = \text{StoN18} * \text{MPix} / 20.0,$$

where **StoN18** is the signal-to-noise of the sensor on an 18% gray target, assuming a 100% reflective target just saturates the sensor, and **Mpix** is the megapixel equivalent. It is clear from existing data that the trends predicted in the equation are correct, but there is uncertainty in the magnitude of the differences as there are only a few data points so far. So to say camera X is twice as good as camera Y is taking the data too far, but to say camera X is better than camera Y based on the AIQ is clearly within the bounds of the data when there is a large difference in the AIQ value.

Here are typical parameters (consider the AIQ as a relative scale whose magnitude is relative and the numbers are fuzzy to about 30%). For example, to say the top DSLR in the table (AIQ = 76) is better than Medium format (AIQ = 70) is taking the numbers too far.

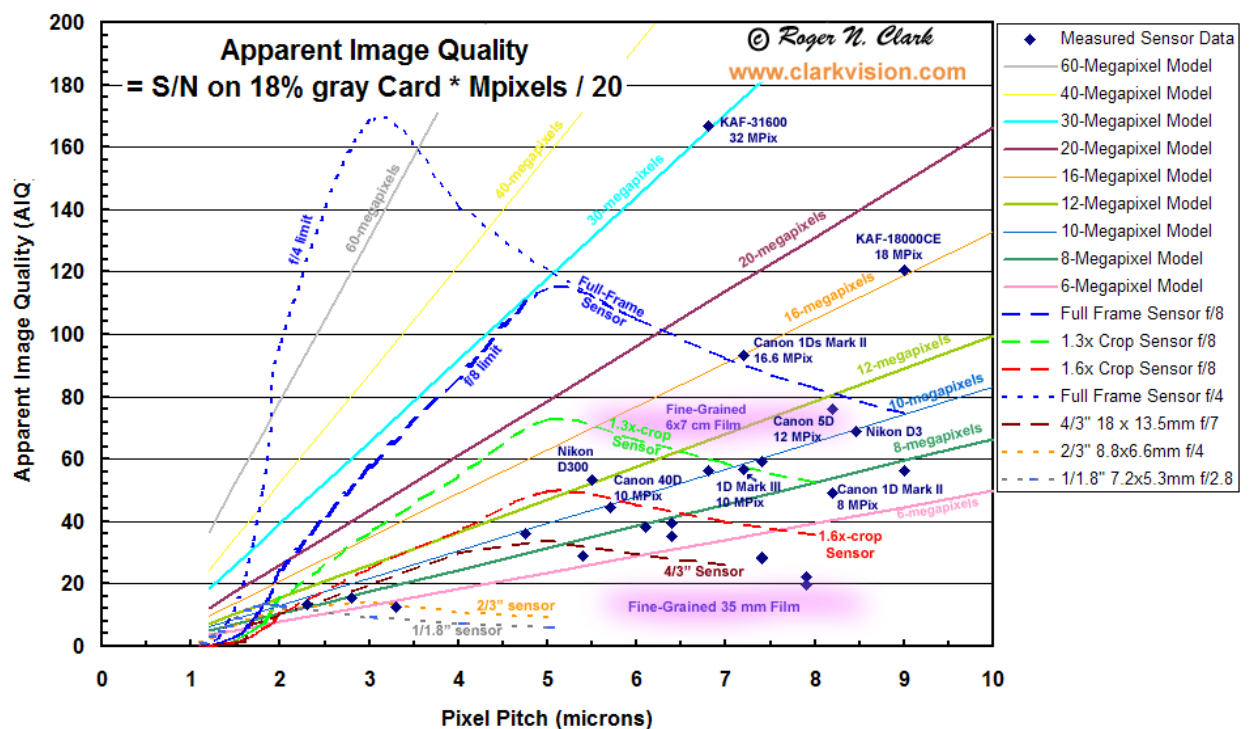
| Camera Examples        | Full Well Capacity (Electrons) | Pixel Spacing (microns) | signal-to-noise 18% Target (StoN18) | Millions of Pixels (MPix) | AIQ |
|------------------------|--------------------------------|-------------------------|-------------------------------------|---------------------------|-----|
| Digital MF* ISO 100    | 50,000                         | 6                       | 95                                  | 39                        | 185 |
| Digital SLR ISO 100    | 50,000                         | 8                       | 95                                  | 16                        | 76  |
| Digital SLR ISO 100    | 50,000                         | 8                       | 95                                  | 8                         | 38  |
| Digital SLR ISO 400    | 50,000                         | 8                       | 47                                  | 8                         | 19  |
| Digital P&S ISO 50     | 22,000                         | 2.8                     | 63                                  | 8                         | 25  |
| Digital P&S ISO 100    | 22,000                         | 2.8                     | 44                                  | 8                         | 18  |
| Digital P&S ISO 400    | 22,000                         | 2.8                     | 22                                  | 8                         | 9   |
| Digital P&S ISO 50     | 22,000                         | 2.8                     | 63                                  | 5                         | 16  |
| Digital P&S ISO 100    | 22,000                         | 2.8                     | 44                                  | 5                         | 11  |
| Digital P&S ISO 400    | 22,000                         | 2.8                     | 22                                  | 5                         | 6   |
| 35mm Film:             |                                |                         |                                     |                           |     |
| Film Fuji Velvia 50    | -                              | -                       | 18                                  | 16                        | 14  |
| Film Fuji Provia 100   | -                              | -                       | ~20                                 | 7                         | 7   |
| Medium format: 6x4.5cm |                                |                         |                                     |                           |     |
| Film Fuji Velvia 50    | -                              | -                       | 18                                  | 50                        | 45  |
| Medium format: 6x7cm   |                                |                         |                                     |                           |     |
| Film Fuji Velvia 50    | -                              | -                       | 18                                  | 78                        | 70  |
| 4x5 Film:              |                                |                         |                                     |                           |     |
| Film Fuji Velvia 50    | -                              | -                       | 18                                  | 240                       | 220 |
| 8x10 Film:             |                                |                         |                                     |                           |     |
| Film Fuji Velvia 50    | -                              | -                       | 18                                  | 960                       | 860 |

The above table shows Digital SLRs (DSLRs) with larger sensors have a clear advantage over digital point and shoot cameras, which are slightly above slow speed 35mm film.

Note that the digital advantage over film is smaller for small sensor P&S cameras than for DSLRs with larger pixel sizes.

\* The Digital MF is for a hypothetical medium format sensor. A 39 megapixel MF digital sensor has recently been announced, and if the sensor has full well capacities and sensor noise similar to existing Digital SLR cameras, it could have specifications like this.

The reason for the large increase in image quality with higher signal-to-noise ratio is that one can increase spatial resolution of an image by image restoration at the expense of signal-to-noise ratio. Here is one such example: [Image Restoration Using Adaptive Richardson-Lucy Iteration](#). In this example, a high end DSLR images showed about a factor of 2 increase in spatial resolution, thus an effective increase of 4 times the megapixel count, from 8 to about 32. Here is another example with a factor of 3 increase in spatial resolution using averaged images to increase the signal-to-noise ratio: [Saturn with a Telephoto Lens](#).



**Figure 3** Apparent Image Quality, measured for numerous digital cameras (diamond symbols), models of AIQ for digital sensors (lines) and fine grained film in two formats. See [Digital Camera Sensor Performance Summary](#) for more details.

### Other Considerations

If you want to do landscapes with maximum image detail, for the "feeling of being there," try large format view camera photography.

A MAJOR CONSIDERATION WITH DIGITAL CAMERAS: SHUTTER LAG. This is the time it takes for the camera to acquire, track and lock focus and trip the shutter. Many (most, all?) point and shoot digital cameras seem horrible in this regard. Those I've tried seem an exercise in frustration, taking one to several seconds to take a picture. Such long

delays make it difficult to get a candid picture of your kids at play, and make fast action like sports or wildlife pictures all but impossible.

Digital SLR cameras, like the Canon 1D Mark II, 10D, 20D, 1Ds, and Nikon D100, D200, D300, D3 have excellent (low) shutter lag and are equal to (or better than) 35mm film cameras concerning shutter lag.

**The Achilles heel of Digital Cameras!** Digital cameras, especially cameras with removable lenses have one major issue: **DUST ON THE SENSOR**. On such cameras, dust becomes very noticeable on images obtained with lens apertures of f/11 and smaller (higher number, like f/16, f/22). Thus for landscape or other photography requiring small apertures to maximize depth of field, film has the advantage. While you can clean the dust off, it is a short term solution, especially for long sessions in the field where it is impractical to clean the sensor multiple times each day. If you do not use small apertures, or only work indoors or clean environments, this may not be a problem.

I now use almost exclusively digital (DSLR) and occasionally film (4x5). I use Canon a 30D 8 megapixel camera and a Canon 1D Mark II 8-megapixel camera when I need fast speed with higher shutter speeds. For wildlife action photography, I feel can get better images with the digital than I can with 35mm film. For examples, see my [Birds and Birds in Flight](#), [Bears](#), or [Africa](#) galleries.

For landscapes, I use a 4x5 camera and Fujichrome Velvia film (more than 200 megapixel equivalent), then scan the film. See my [Landscape Favorites Gallery](#) for examples. If I do not have time to set up the 4x5, I'll use the DSLR at low ISO speed, and sometimes do multiple frames to mosaic a larger scene, effectively creating an image with more pixels. See: [Large Digital Mosaics as a Substitute for Large Format Film](#) for digital mosaics that surpass 4x5 film.

## ***References and Other Reading***

See Norman Koren's site, <http://www.normankoren.com/Tutorials/MTF7.html> where he concludes the Canon 10D 6-megapixel digital camera is equivalent to Fujichrome Provia 100F. Provia 100F plots a little higher on Figure 1 than Ektachrome, so Koren's testing regarding spatial resolution is in close agreement with mine.

This web site reaches similar conclusions: 8-megapixel DSLR cameras produce better (higher spatial resolution) images than 100 speed Fujichrome Astia film: [http://www.wlcastleman.com/equip/reviews/film\\_ccd/index.htm](http://www.wlcastleman.com/equip/reviews/film_ccd/index.htm).

Yet another film-digital comparison, this one showing an 11-megapixel digital camera produces clearly sharper images than Provia 100F film: [http://www.photographical.net/canon\\_1ds\\_35mm.html](http://www.photographical.net/canon_1ds_35mm.html).

The concept of signal-to-noise and its effect on apparent image quality is not new and is discussed at: <http://www.normankoren.com/Tutorials/MTF7A.html#Shannon> along with other references.

Another article about perceived image quality is at: <http://www.luminous-landscape.com/tutorials/dq.shtml>. Note when reading this that some of the signal-to-noise values are higher than possible from photon statistics alone.