How It Works: The Science of Digital Camera

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From the casual photographer's point of view, snapping a picture with a digital camera isn't all that different from taking the same shot with a traditional film camera. You look in the viewfinder, mentally and physically compose the shot, and press a button. But what's going on inside the two cameras is worlds apart.

We're going to tell you a little bit about how images get captured in a digital camera, how the camera turns the captured colors into data, and finally how the camera stores that data so that later it comes out as a crisp clear picture.

Image Capture

With traditional film cameras, light that bounces off a photographic subject-- say a bowl of fruit-- enters the cameras lens and gets focused by that lens onto light-sensitive film. The film holds that image until the film is developed using chemicals.

A digital camera begins its image-capture process the same way a film camera does; light enters the camera through a lens, but rather than focusing that light onto film, it focuses it onto a chip called a charged coupled device (CCD).

A CCD has a grid-like structure consisting of an array of photosensitive diodes (meaning they can capture light). Each diode represents one pixel, so in a three-megapixel camera there are over three million photodiodes on the surface of the CCD. Each photosensitive diode bears a color filter and can therefore only capture one color: red, blue, or green.

Often, these color filters cover vertical strips of the photodiodes that comprise the CCD, where every third strip picks up only red, blue, or green. Others use predefined patterns of color filters to cover individual pixels. The popular Bayer pattern, for example, consists of blocks of four cells where two green cells occupy a diagonal and one blue and one red cell occupies the remaining two diagonals (green filters typically comprise 50 percent of a digital camera's cells). High-end digital video cameras often have three separate CCDs, one for capturing each of the three primary colors.

Digitizing Color

Each photosensitive diode is attached to a transistor. The transistor measures the intensity of the light captured by the photodiode and produces a corresponding voltage. Very bright light carries a high voltage, dim light a low voltage. This electricity is sent to a chip called an analog-to-digital converter (ADC) as an analog waveform (there may be one ADC for each primary color). But to a computer, analog waveforms are meaningless. It's the job of the ADC to convert the analog waveform into its digital equivalent-- 1s and 0s-- through a technique called sampling.

Sampling is a continuous process of measuring the waveform and assigning a digital equivalent to each sampled slice. So if a photodiode captures an intensely bright shade of red, the transistor attached to it sends a strong voltage representing that bright red to the ADC in the form of an electrical wave.

The wave is sampled and the ADC determines that it has a very high voltage because it has a very high amplitude (a big tall wave). The ADC assigns a number to each sample ranging between 0 and 255. 255 is the most intense red possible; 0 is black. Of course, numbers ranging between 0 and 255 are as meaningless to a computer as analog waves. Binary equivalents of those numbers must be calculated.

In the case of our very intense red, the binary equivalent of 255 would be 11111111 (if we have 8-bit color depth). Black, previously represented by 0, would be 00000000. Every shade in between would be a number represented by a mix of 1s and 0s (5, for example, would be 00000101 or simply 101). Combined with 256 shades of blue and green, you can produce nearly 17 million colors.

Doing Something With 1s and 0s

From the ADC, the 1s and 0s move on to another chip called a digital signal processor or DSP. DSPs handle digital information that was born of analog information.

The DSP in a digital camera is specifically programmed to produce photographic images. The DSP is sort of like the dude who works at the PhotoMat. It adjusts the detail and contrast of the image, using algorithms to make sense of all the 1s and 0s. It also compresses all the digital information, filtering out extraneous data that our eyes couldn't see anyway, so that more pictures can be stored on the camera's storage medium.

When that process is finished, the DSP sends the slimmed-down data to the camera's storage medium, whether it is CompactFlash, SmartMedia, SD Card,MMC,Memory Stick, and so on.

Before the image can be displayed on a computer monitor, it needs to go through the reverse of this whole process within the computer's graphics card. CRT monitors are analog devices, and are as baffled by 1s and 0s as a computer is by analog waveforms.