In the past twenty years, most of the major technological breakthroughs in consumer electronics have really been part of one larger breakthrough. When you get down to it, CDs, DVDs, HDTV, MP3s and DVRs are all built around the same basic process: converting conventional analog information (represented by a gradually fluctuating wave) into digital information (represented by 1s and 0s, or bits). This fundamental shift in technology totally changed how we handle visual and audio information -- it completely redefined what is possible.

The digital camera is one of the most remarkable instances of this shift because it is so truly different from its predecessor. Conventional cameras depend entirely on chemical and mechanical processes -- you don't even need electricity to operate one. All digital cameras have a built-in computer, and all of them record images in an entirely electronic form.

The new approach has proved monstrously successful. It may be decades before digital cameras completely replace film cameras, if they ever do, but they will probably account for around half of the U.S. market within the next few years.

In this article, we'll find out exactly what's going on inside these amazing digital-age devices.

Understanding the Basics

Let's say you want to take a picture and e-mail it to a friend. To do this, you need the image to be represented in the language that computers recognize -- bits and bytes. Essentially, a digital image is just a long string of 1s and 0s that represent all the tiny colored dots -- or pixels -- that collectively make up the image. (For information on sampling and digital representations of data, see this explanation of the digitization of sound waves. Digitizing light waves works in a similar way.)

If you want to get a picture into this form, you have two options:

- You can take a photograph using a conventional film camera, process the film chemically, print it onto photographic paper and then use a digital scanner to sample the print (record the pattern of light as a series of pixel values).
- You can directly sample the original light that bounces off your subject, immediately breaking that light pattern down into a series of pixel values -- in other words, you can use a digital camera.
At its most basic level, this is all there is to a digital camera. Just like a conventional camera, it has a series of lenses that focus light to create an image of a scene. But instead of focusing this light onto a piece of film, it focuses it onto a semiconductor device that records light electronically. A computer then breaks this electronic information down into digital data. All the fun and interesting features of digital cameras come as a direct result of this process.

In the next few sections, we'll find out exactly how the camera does all this.

A Filmless Camera
The key difference between a digital camera and a film-based camera is that the digital camera has no film. Instead, it has a sensor that converts light into electrical charges.

The image sensor employed by most digital cameras is a charge coupled device (CCD). Some low-end cameras use complementary metal oxide semiconductor (CMOS) technology. While CMOS sensors will almost certainly improve and become more popular in the future, they probably won't replace CCD sensors in higher-end digital cameras. Throughout the rest of this article, we will mostly focus on CCD. For the purpose of understanding how a digital camera works, you can think of them as nearly identical devices. Most of what you learn will also apply to CMOS cameras.

The CCD is a collection of tiny light-sensitive diodes, which convert photons (light) into electrons (electrical charge). These diodes are called photosites. In a nutshell, each photosite is sensitive to light -- the brighter the light that hits a single photosite, the greater the electrical charge that will accumulate at that site.

Image Sensors
One of the drivers behind the falling prices of digital cameras has been the introduction of CMOS image sensors. CMOS sensors are much less expensive to manufacture than CCD sensors.

Both CCD and CMOS image sensors start at the same point -- they have to convert light into electrons at the photosites. If you've read the article How Solar Cells Work, you already understand one of the pieces of technology used to perform the conversion. A simplified way to think about the sensor used in a digital camera (or camcorder) is to think of it as having a 2-D array of thousands or millions of tiny solar cells, each of which transforms the light from one small portion of the image into electrons. Both CCD and CMOS devices perform this task using a variety of technologies.
CCD vs. CMOS Sensors

Once the light is converted into electrons, the differences between the two main sensor types kick in. The next step is to read the value (accumulated charge) of each cell in the image. In a CCD device, the charge is actually transported across the chip and read at one corner of the array. An analog-to-digital converter turns each pixel's value into a digital value. In most CMOS devices, there are several transistors at each pixel that amplify and move the charge using more traditional wires. The CMOS approach is more flexible because each pixel can be read individually.

CCDs use a special manufacturing process to create the ability to transport charge across the chip without distortion. This process leads to very high-quality sensors in terms of fidelity and light sensitivity. CMOS chips, on the other hand, use completely standard manufacturing processes to create the chip -- the same processes used to make most microprocessors. Because of the manufacturing differences, there are several noticeable differences between CCD and CMOS sensors.

- CCD sensors, as mentioned above, create high-quality, low-noise images. CMOS sensors, traditionally, are more susceptible to noise.
- Because each pixel on a CMOS sensor has several transistors located next to it, the light sensitivity of a CMOS chip is lower. Many of the photons hitting the chip hit the transistors instead of the photodiode.
- CMOS sensors traditionally consume little power. Implementing a sensor in CMOS yields a low-power sensor. CCDs, on the other hand, use a process that consumes lots of power. CCDs consume as much as 100 times more power than an equivalent CMOS sensor.
- CMOS chips can be fabricated on just about any standard silicon production line, so they tend to be extremely inexpensive compared to CCD sensors.
- CCD sensors have been mass produced for a longer period of time, so they are more mature. They tend to have higher quality pixels, and more of them.

Based on these differences, you can see that CCDs tend to be used in cameras that focus on high-quality images with lots of pixels and excellent light sensitivity. CMOS sensors usually have lower quality, lower resolution and lower sensitivity. However, CMOS cameras are less expensive and have great battery life.

Resolution

The amount of detail that the camera can capture is called the resolution, and it is measured in pixels. The more pixels your camera has, the more detail it can capture. The more detail you have, the more you can blow up a picture before it becomes "grainy" and starts to look out-of-focus.

Some typical resolutions that you find in digital cameras today include:

- **256x256 pixels** - You find this resolution on very cheap cameras. This resolution is so low that the picture quality is almost always unacceptable. This is 65,000 total pixels.
- **640x480 pixels** - This is the low end on most "real" cameras. This resolution is great if you plan to e-mail most of your pictures to friends or post them on a Web site. This is 307,000 total pixels.
- **1216x912 pixels** - If you are planning to print your images, this is a good resolution. This is a "megapixel" image size -- 1,109,000 total pixels.

E-mailing Pictures

If you take pictures in JPEG format at 640x480 resolution, you can download them to your computer and e-mail them to friends without having to do anything to the picture. There’s no need to get film developed or scan the developed picture. Just take the picture, transfer it to the computer and e-mail it.
• **1600x1200 pixels** - This is "high resolution." Images taken with this resolution can be printed in larger sizes, such as 8x10 inches, with good results. This is almost 2 million total pixels. You can find cameras today with up to 10.2 million pixels.

**Resolution: Web and E-mail**

You may or may not need lots of resolution, depending on what you want to do with your pictures. If you are planning to do nothing more than display images on a Web page or send them in e-mail, then using 640x480 resolution has several advantages:

- Your camera's memory will hold more images at this low resolution than at higher resolutions.
- It will take less time to move the images from the camera to your computer.
- The images will take up less space on your computer.

On the other hand, if your goal is to print large images, you definitely want to take high-resolution shots and need a camera with lots of pixels. We'll talk more about print resolution in the next section.

**Resolution: Printing Pictures**

There are many different technologies used in printers. Here we'll talk about inkjet printers, which use many different methods in and of themselves. In general, printer manufacturers will advertise the printer resolution in dots per inch (dpi). However, all dots are not created equal. One printer may place more drops of ink (black, cyan, magenta or yellow) per dot than another.

For instance, printers made by Hewlett Packard that use PhotoREt III technology can layer a combination of up to 29 drops of ink per dot, yielding about 3,500 possible colors per dot. This may sound like a lot, but most cameras can capture 16.8 million colors per pixel. So these printers cannot replicate the exact color of a pixel with a single dot. Instead, they must create a grouping of dots that when viewed from a distance blend together to form the color of a single pixel.

The rule of thumb is that you divide your printer's color resolution by about four to get the actual maximum picture quality of your printer. So for a 1200 dpi printer, a resolution of 300 pixels per inch would be just about the best quality that printer is capable of. This means that with a 1200x900 pixel image, you could print a 4-inch by 3-inch print. In practice, though, lower resolutions than this usually provide adequate quality. To make a reasonable print that comes close to the quality of a traditionally developed photograph, you need about 150 to 200 pixels per inch of print size.

On this page, Kodak recommends the following as minimum resolutions for different print sizes:

<table>
<thead>
<tr>
<th>Print Size</th>
<th>Megapixels</th>
<th>Image Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wallet</td>
<td>0.3</td>
<td>640x480 pixels</td>
</tr>
<tr>
<td>4x5 inches</td>
<td>0.4</td>
<td>768x512 pixels</td>
</tr>
<tr>
<td>5x7 inches</td>
<td>0.8</td>
<td>1152x768 pixels</td>
</tr>
<tr>
<td>8x10 inches</td>
<td>1.6</td>
<td>1536x1024 pixels</td>
</tr>
</tbody>
</table>

**Capturing Color**

Unfortunately, each photosite is colorblind. It only keeps track of the total intensity of the light that strikes its surface. In order to get a full color image, most sensors use filtering to look at the light in its three primary colors. Once all three colors have been recorded, they can be added together to create the full spectrum of colors that you've grown accustomed to seeing on computer monitors and color printers.
Capturing Color: Beam Splitter

There are several ways of recording the three colors in a digital camera. The highest quality cameras use three separate sensors, each with a different filter over it. Light is directed to the different sensors by placing a beam splitter in the camera. Think of the light entering the camera as water flowing through a pipe. Using a beam splitter would be like dividing an identical amount of water into three different pipes. Each sensor gets an identical look at the image; but because of the filters, each sensor only responds to one of the primary colors.

The advantage of this method is that the camera records each of the three colors at each pixel location. Unfortunately, cameras that use this method tend to be bulky and expensive.

Capturing Color: Spinning Disk

A second method is to rotate a series of red, blue and green filters in front of a single sensor. The sensor records three separate images in rapid succession. This method also provides information on all three colors at each pixel location; but since the three images aren't taken at precisely the same moment, both the camera and the target of the photo must remain stationary for all three readings. This isn't practical for candid photography or handheld cameras.
Capturing Color: Interpolation
A more economical and practical way to record the three primary colors from a single image is to permanently place a filter over each individual photosite. By breaking up the sensor into a variety of red, blue and green pixels, it is possible to get enough information in the general vicinity of each sensor to make very accurate guesses about the true color at that location. This process of looking at the other pixels in the neighborhood of a sensor and making an educated guess is called interpolation. (You'll learn more about pixels later. For now, think of one photosite as a single pixel.)

Movies
Some cameras offer an "MPEG movie" feature, allowing you to take short movies with your camera. Look for the ability to change the resolution of the movie, and find out the maximum movie length you can record.

To see an example of a typical movie taken by a digital camera, click on the image below. This movie demonstrates a trick birthday candle:
Capturing Color: Bayer Filter

The most common pattern of filters is the **Bayer filter pattern**. This pattern alternates a row of red and green filters with a row of blue and green filters. The pixels are not evenly divided -- there are as many green pixels as there are blue and red combined. This is because the human eye is not equally sensitive to all three colors. It's necessary to include more information from the green pixels in order to create an image that the eye will perceive as a "true color."

The advantages of this method are that only one sensor is required, and all the color information (red, green and blue) is recorded at the same moment. That means the camera can be smaller, cheaper, and useful in a wider variety of situations. In other words, it makes it possible to create an affordable handheld digital camera. The raw output from a sensor with a Bayer filter is a mosaic of red, green and blue pixels of different intensity.

Capturing Color: Demosaicing Algorithms

If you took a close look at the image of the Bayer filter pattern, you might be wondering how a digital camera can achieve its full advertised resolution if it takes four separate pixels to determine the color of a single pixel. Digital cameras use specialized **demosaicing algorithms** to convert the mosaic of
separate colors into an equally sized mosaic of true colors. The key is that each colored pixel can be used more than once. The true color of a single pixel can be determined by averaging the values from the closest surrounding pixels.

Raw image

A demosaicing algorithm at work

There are other ways of handling color in a digital camera. Some single-sensor cameras use alternatives to the Bayer filter pattern. A company called Foveon has developed a sensor that captures all three colors by embedding red, green and blue photodetectors in silicon. This X3 technology works because red, green and blue light each penetrate silicon to a different depth. There is even a method that uses two sensors. Some of the more advanced cameras don't add up the different values of red, green and blue, but instead subtract values using the typesetting colors cyan, yellow, green and magenta. However, most consumer cameras on the market today use a single sensor with alternating rows of green/red and green/blue filters.

Digitizing Information

In the previous sections, we glossed over one of the important technical details so that we could simplify the explanation of color. You’ve learned that light is converted to electrical charge; but the electrical charges that build up in the CCD are not digital signals that are ready to be used by your computer. In order to digitize the information, the signal must be passed through an analog-to-digital converter (ADC). Interpolation is handled by a microprocessor after the data has been digitized.
Think of each photosite as a bucket or a well, and think of the photons of light as raindrops. As the raindrops fall into the bucket, water accumulates (in reality, electrical charge accumulates). Some buckets have more water and some buckets have less water, representing brighter and darker sections of the image. Sticking to the analogy, the ADC measures the depth of the water, which is considered analog information. Then it converts that information to binary form.

Photosites and Pixels

If you read digital camera claims carefully, you'll notice that the number of pixels and the maximum resolution numbers don't quite compute. For example, a camera claims to be a 2.1-megapixel camera and it is capable of producing images with a resolution of 1600x1200. Let's do the math: a 1600x1200 image contains 1,920,000 pixels. But “2.1 megapixel” means there ought to be at least 2,100,000 pixels. This isn't an error from rounding off, and it isn't binary mathematical trickery. There is a real discrepancy between these two numbers. If a camera says it has 2.1 megapixels, then there really are approximately 2,100,000 photosites on the CCD.

What happens is that some of the photosites are not being used for imaging. Remember that the CCD is an analog device. It's necessary to provide some circuitry to the photosites so that the ADC can measure the amount of charge. This circuitry is dyed black so that it doesn't absorb any light and distort the image.

Viewing Your Pictures

Most digital cameras on the market today have an LCD screen, which means that you can view your picture right away. This is one of the great advantages of a digital camera: You get immediate feedback on what you capture. Once the image leaves the CCD sensor (by way of the ADC and a microprocessor), it is ready to be viewed on the LCD.

Of course, that's not the end of the story. Viewing the image on your camera would lose its charm if that's all you could do. You want to be able to load the picture into your computer or send it directly to a printer. There are several ways to store images in a camera and then transfer them to a computer.

Creating Fun Photos

With the image-editing software that often comes with your camera you can do lots of neat things. You can:

- crop the picture to capture just the part you want
- add text to the picture
- make the picture brighter or darker

Batteries

Digital cameras, especially those that use a CCD sensor and an LCD display, tend to use lots of power -- which means they eat batteries. Rechargeable batteries help to lower the cost of using the digital camera, but rechargeable batteries are sometimes expensive. Here are some things to consider:

- Does the camera use standard-size rechargeable batteries (e.g., AA), or does it use special rechargeable batteries made by the manufacturer? If it uses the special ones, check to see what the price of another battery pack is.
- If the camera takes AA batteries, can you use normal alkaline batteries in a pinch?
- Are the rechargeable batteries removable, or are they permanently mounted in the camera? If they are not removable, it means that once the batteries go dead you can't use the camera again until you can get to a recharger and power supply. This can be a major pain in the neck if you want to take a lot of pictures at once.
Early generations of digital cameras had fixed storage inside the camera. You needed to connect the camera directly to a computer by cables to transfer the images. Although most of today's cameras are capable of connecting to a serial, parallel, SCSI, and/or USB port, they usually provide you with some sort of removable storage device.

There are a number of storage systems currently used in digital cameras:

- **Built-in memory** - Some extremely inexpensive cameras have built-in Flash memory.
- **SmartMedia cards** - SmartMedia cards are small Flash memory modules.
- **CompactFlash** - CompactFlash cards are another form of Flash memory, similar to but slightly larger than SmartMedia cards.
- **Memory Stick** - Memory Stick is a proprietary form of Flash memory used by Sony.
- **Floppy disk** - Some cameras store images directly onto floppy disks, or PCMCIA hard-disk cards, for image storage.
- **Writeable CD and DVD** - Some of the newest cameras are using writeable CD and DVD drives to store images.

In order to transfer the files from a Flash memory device to your computer without using cables, you will need to have a drive or reader for your computer. These devices behave much like floppy drives and are inexpensive to buy.

Think of all these storage devices as reusable digital film. When you fill one up, either transfer the data or put another one into the camera. The different types of Flash memory devices are not interchangeable. Each camera manufacturer has decided on one device or another. Each of the Flash memory devices also needs some sort of caddy or card reader in order to transfer the data.

**Storage: Image Capacity**

Right now, there are two main types of storage media in use today. Some cameras use 1.44-MB floppy disks, and some use various forms of Flash memory that have capacities ranging from several megabytes to 1 gigabyte. There are several other formats, but for now we'll discuss these two.

The main difference between storage media is their capacity: The capacity of a floppy disk is fixed, and the capacity of Flash memory devices is increasing all the time. This is fortunate because picture size is also increasing constantly, as higher resolution cameras become available.

The two main file formats used by digital cameras are TIFF and JPEG. TIFF is an uncompressed format and JPEG is a compressed format. Most cameras use the JPEG file format for storing pictures, and they sometimes offer quality settings (such as medium or high). The following chart will give you an idea of the file sizes you might expect with different picture sizes.
One thing that becomes apparent is that a 1.44-GB disk cannot hold very many pictures. In fact, at some image sizes you can't even fit one picture on the disk. But the floppy disk does have its uses. For Internet publishing and e-mailing pictures to friends, you almost never need a picture bigger than 640x480, and you will almost always save it in JPEG form. In this case, you might be able to fit 16 or so pictures on each disk.

If you are trying to store the biggest, highest quality images you can, then you will want the highest capacity medium. A 128-GB Flash memory card, for instance, could store more than 1,400 small compressed images or 21 of the uncompressed 1600x1200 images. You would probably never use the whole 128 GB if you were just taking small pictures, but if you were taking the big pictures this would be the only way to go. The large capacity might also come in handy if you were going on a long trip and wanted to be able to take lots of pictures.

Compression

Compression is a trickier issue. A digital camera records more information than is easily detected by the human eye. Some compression routines take advantage of this fact to throw away some of the more meaningless data. If you need smaller files, you need to be willing to throw away more data. Most cameras offer several different levels of compression, although they may not call it that. More likely they will offer you different levels of resolution. This is the same thing. Lower resolution means more compression.

Controlling Light

It is important to control the amount of light that reaches the sensor. Thinking back to the water bucket analogy, if too much light hits the sensor, the bucket will fill up and won't be able to hold any more. If this happens, information about the intensity of the light is being lost. Even though one photosite may be exposed to a higher intensity light than another, if both buckets are full, the camera will not register a difference between them.

Aperture

The aperture is the size of the opening in the camera. It's located behind the lens. On a bright sunny day, the light reflected off your image may be very intense, and it doesn't take very much of it to create a good picture. In this situation, you want a small aperture. But on a cloudy day, or in twilight, the light is not so intense and the camera will need more light to create an image. In order to allow more light, the aperture must be enlarged.

Your eye works the same way. When you are in the dark, the iris of your eye dilates your pupil (that is, it makes it very large). When you go out into bright sunlight, your iris contracts and it makes your pupil very small. If you can find a willing partner and a small flashlight, this is easy to demonstrate (if you do...
this, please use a small flashlight, like the ones they use in a doctor's office. Look at your partner's eyes, then shine the flashlight in and watch the pupils contract. Move the flashlight away, and the pupils will dilate.

### Shutter Speed

Traditionally, the shutter speed is the amount of time that light is allowed to pass through the aperture. Think of a mechanical shutter as a window shade. It is placed across the back of the aperture to block out the light. Then, for a fixed amount of time, it opens and closes. The amount of time it is open is the shutter speed. One way of getting more light into the camera is to decrease the shutter speed -- in other words, leave the shutter open for a longer period of time.

Film-based cameras must have a mechanical shutter. Once you expose film to light, it can't be wiped clean to start again. Therefore, it must be protected from unwanted light. But the sensor in a digital camera can be reset electronically and used over and over again. This is called a digital shutter. Some digital cameras employ a combination of electrical and mechanical shutters.

### Exposing the Sensor

These two aspects of a camera, aperture and shutter speed, work together to capture the proper amount of light needed to make a good image. In photographic terms, they set the exposure of the sensor. Most digital cameras automatically set aperture and shutter speed for optimal exposure, which gives them the appeal of a point-and-shoot camera.

Some digital cameras also offer the ability to adjust the aperture settings by using menu options on the LCD panel. More advanced hobbyists and professionals like to have control over the aperture and shutter speed selections because it gives them more creative control over the final image. As you climb into the upper levels of consumer cameras and the realm of professional cameras, you will be rewarded with controls that have the look, feel and functions common to film-based cameras.

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**Cool Facts**

- In the United States, there is roughly one camera for every adult.
- With a 3-megapixel camera, you can take a higher-resolution picture than most computer monitors can display.
- You can use your Web browser to view digital pictures taken using the JPEG format.
- The first consumer-oriented digital cameras were sold by Kodak and Apple in 1994.
- In 1998, Sony inadvertently sold over 700,000 camcorders with a limited ability to see through clothes.
- You can use various software programs to "stitch" together a series of digital pictures to create a large panorama.

---

**Lens and Focal Length**

A camera lens collects the available light and focuses it on the sensor. Most digital cameras use automatic focusing techniques, which you can learn more about in the article [How Autofocus Cameras Work](#).

The important difference between the lens of a digital camera and the lens of a 35mm camera is the
Focal length. The focal length is the distance between the lens and the surface of the sensor. You learned in the section on technical details that the surface of a film sensor is much larger than the surface of a CCD sensor. In fact, a typical 1.3-megapixel digital sensor is approximately one-sixth of the linear dimensions of film. In order to project the image onto a smaller sensor, it is necessary to shorten the focal length by the same proportion.

Focal length is also the critical information in determining how much magnification you get when you look through your camera. In 35mm cameras, a 50mm lens gives a natural view of the subject. As you increase the focal length, you get greater magnification, and objects appear to get closer. As you decrease the focal length, things appear to get farther away, but you can capture a wider field of view in the camera.

You will find four different types of lenses on digital cameras:

- **Fixed-focus, fixed-zoom lenses** - These are the kinds of lenses you find on disposable and inexpensive film cameras -- inexpensive and great for snapshots, but fairly limited.

- **Optical-zoom lenses with automatic focus** - Similar to the lens on a video camcorder, you have "wide" and "telephoto" options and automatic focus. The camera may or may not let you switch to manual focus.

- **Digital-zoom lenses** - With digital zoom, the camera takes pixels from the center of the image sensor and "interpolates" them to make a full-size image. Depending on the resolution of the image and the sensor, this approach may create a grainy or fuzzy image. It turns out that you can manually do the same thing a digital zoom is doing -- simply snap a picture and then cut out the center of the image using your image processing software.

- **Replaceable lens systems** - If you are familiar with high-end 35mm cameras, then you are familiar with the concept of replaceable lenses. High-end digital cameras can use this same system, and in fact can use lenses from 35mm cameras in some cases.

### Focal Length: 35mm Equivalents

Since many photographers that use film-based cameras are familiar with the focal lengths that project an image onto 35mm film, digital cameras advertise their focal lengths with "35mm equivalents." This is extremely helpful information to have. In the chart below, you can compare the actual focal lengths of a typical 1.3-megapixel camera and its equivalent in a 35mm camera.

<table>
<thead>
<tr>
<th>Focal Length</th>
<th>35mm Equivalent</th>
<th>View</th>
<th>Typical Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4 mm</td>
<td>35 mm</td>
<td>Things look smaller and farther away.</td>
<td>Wide-angle shots, landscapes, large buildings, groups of people</td>
</tr>
<tr>
<td>7.7 mm</td>
<td>50 mm</td>
<td>Things look about the same as what your eye sees.</td>
<td>&quot;Normal&quot; shots of people and objects</td>
</tr>
<tr>
<td>16.2 mm</td>
<td>105 mm</td>
<td>Things are magnified and appear closer.</td>
<td>Telephoto shots, close-ups</td>
</tr>
</tbody>
</table>

### Optical Zoom vs. Digital Zoom

In general terms, a zoom lens is any lens that has an adjustable focal length. Zoom doesn't always mean a close-up. As you can see in the chart above, the "normal" view of the world for this particular camera is 7.7 mm. You can zoom out for a wide-angle view of the world, or you can zoom in for a closer view of the world. Digital cameras may have an optical zoom, a digital zoom, or both.

An optical zoom actually changes the focal length of your lens. As a result, the image is magnified by the lens (sometimes called the optics, hence "optical" zoom). With greater magnification, the light is
spread across the entire CCD sensor and all of the pixels can be used. You can think of an optical zoom as a true zoom that will improve the quality of your pictures.

A digital zoom is a computer trick that magnifies a portion of the information that hits the sensor. Let's say you are shooting a picture with a 2X digital zoom. The camera will use half of the pixels at the center of the CCD sensor and ignore all the other pixels. Then it will use interpolation techniques to add detail to the photo. Although it may look like you are shooting a picture with twice the magnification, you can get the same results by shooting the photo without a zoom and blowing up the picture using your computer software.

**Macro**

If you plan to take close-up images, look for a camera that has a macro focusing capability. This feature lets you move the camera's lens very close to the subject. Here is an example of a macro photograph -- this is a picture of part of a small electric motor, and the white disk is about the size of a U.S. quarter coin:

If your camera is not equipped with a macro setting, there is no way for you to take an image like this.

**Summary**

If you've made it this far, you've learned a lot about digital cameras. Let's put it all together as we take a picture to send to friends.

- You aim the camera at the subject and adjust the optical zoom to get closer or farther away.
- You press lightly on the shutter release.
- The camera automatically focuses on the subject and takes a reading of the available light.
- The camera sets the aperture and shutter speed for optimal exposure.
- You press the shutter release all the way.
- The CCD is reset and then exposed to the light, building up an electrical charge, until the shutter closes.
- The ADC measures the charge and creates a digital signal that represents the values of the charge at each pixel.
- A processor interpolates the data from the different pixels to create natural color. On many cameras, it is possible to see the output on the LCD at this stage.
• A processor may perform a preset level of compression on the data.
• The information is stored in some form of memory device (probably a Flash memory card).
• The picture is transferred to a computer or a printer.
• The picture can be attached to an e-mail message or posted to a Web page.

When You Shop
We've created a feature comparison chart for you to use as you research various digital cameras. All you do is fill in the blanks for each model you are interested in.

The feature comparison chart is available to you as a PDF. You will need the free Adobe Acrobat Reader to view it.

• Download the comparison chart!

To give you an example of typical cameras, here are some popular ones:

Kodak Easyshare DX4900 Zoom
Sony Mavica MVC-FD100

Kodak DC3800
Canon PowerShot S100 Digital ELPH Camera Kit

Canon PowerShot S200 Digital Camera Kit
Nikon Coolpix 800

Olympus D460 Zoom
Sony Mavica MVC-FD97

Nikon Coolpix 990
Olympus Camedia D-360L

When You Shop: Look Out!
When purchasing a digital camera, there are several things you should keep in mind to avoid buying a camera that won't meet your needs. Here are some of the most common things to think about:

Make sure the camera has the right resolution for your needs.
If you are going to take snapshots and e-mail them to friends, then you don't need anything more than 640x480 pixel resolution. Buying the resolution that you need lets you save money (and hard disk space). On the other hand, if you want to print enlarged versions of your photos, you'll need a 2-megapixel or 3-megapixel camera.

Make sure the camera has enough memory.
There is nothing more frustrating that "running out of film" when there is a great picture sitting in your
viewfinder! The "film" for a digital camera is Flash memory, floppy disks, small hard disks, etc. Most cameras let you download pictures from the camera so that you can take more, but if you go on a week-long vacation you will be away from your computer and won't be able to download. So make sure you pick up enough extra memory when you buy your camera so you won't run out when you need it. CompactFlash cards now come with up to 1 GB of space, so it's definitely possible to get all the memory you'll need for a long trip.

Make sure the lens will handle the pictures you plan to take.
If you don't have the right lens, it can be hard to take the best pictures. For example, if your camera does not have a macro setting, you won't be able to take close-ups. If very crisp detail is important in your pictures, you'll probably want a high optical zoom number. Be sure to try out the lens system on a camera before you purchase it. Digital cameras come with a huge variety of lenses, so be sure to shop around.

Do not confuse digital zoom with optical zoom.
Many cameras advertise things like "100X zoom," but that is often misleading because only part of it is in the lens. The only part of a zoom lens that really matters is the "optical" part -- the part made out of glass lenses. This is the "zoom" that will increase the quality of the image. Any form of "digital zoom" is something you can do yourself outside of the camera. If you use your camera's software to crop out a small inner portion of a picture and blow it up, you are doing the same thing a digital zoom is doing. In most cases, the digital zoom simply makes the image fuzzy.

Do not confuse actual resolution with interpolated resolution.
Many cameras advertise that they have, for example, 1000x600 pixel resolution and 1200x800 interpolated resolution. Like digital zoom, interpolated resolution is an illusion. You can do the same thing yourself with the camera's software, and all it really does is make the image larger and slightly fuzzy.

See how long the batteries will last.
Many digital cameras eat batteries because they have to power an image sensor, an LCD panel and a microprocessor all at the same time, and sometimes there's a flash as well! See how long the batteries will really last in your camera. See if the camera will accept normal alkaline batteries in a pinch. If you plan on using your camera for long periods of time, think about purchasing an extra battery for it -- and be sure to check prices ahead of time. Some manufacturers charge an arm and a leg for their batteries, and if this is the case, you may want to consider a different manufacturer.

Lots More Information

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