

How Scanners Work

by [Jeff Tyson](#)

Scanners have become an important part of the home office over the last few years. Scanner technology is everywhere and used in many ways:

- **Flatbed scanners**, also called desktop scanners, are the most versatile and commonly used scanners. In fact, this article will focus on the technology as it relates to flatbed scanners.
- **Sheet-fed scanners** are similar to flatbed scanners except the document is moved and the scan head is immobile. A sheet-fed scanner looks a lot like a small portable printer.
- **Handheld scanners** use the same basic technology as a flatbed scanner, but rely on the user to move them instead of a motorized belt. This type of scanner typically does not provide good image quality. However, it can be useful for quickly capturing text.
- **Drum scanners** are used by the publishing industry to capture incredibly detailed images. They use a technology called a **photomultiplier tube** (PMT). In PMT, the document to be scanned is mounted on a glass cylinder. At the center of the cylinder is a sensor that splits light bounced from the document into three beams. Each beam is sent through a color filter into a photomultiplier tube where the light is changed into an electrical signal.



[Microtek's](#) Scanmaker flatbed scanner

The basic principle of a scanner is to analyze an image and process it in some way. Image and text capture (optical character recognition or OCR) allow you to save information to a file on your computer. You can then alter or enhance the image, print it out or use it on your [Web page](#).

In this article, we'll be focusing on flatbed scanners, but the basic principles apply to most other scanner technologies. You will learn about the different types of scanners, how the scanning mechanism works and what TWAIN means. You will also learn about resolution, interpolation and bit depth.

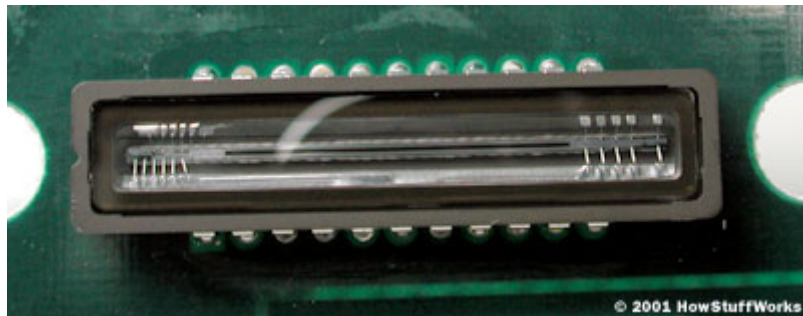
On the next page, you will learn about the various parts of a flatbed scanner.

Anatomy of a Scanner

Parts of a typical flatbed scanner include:

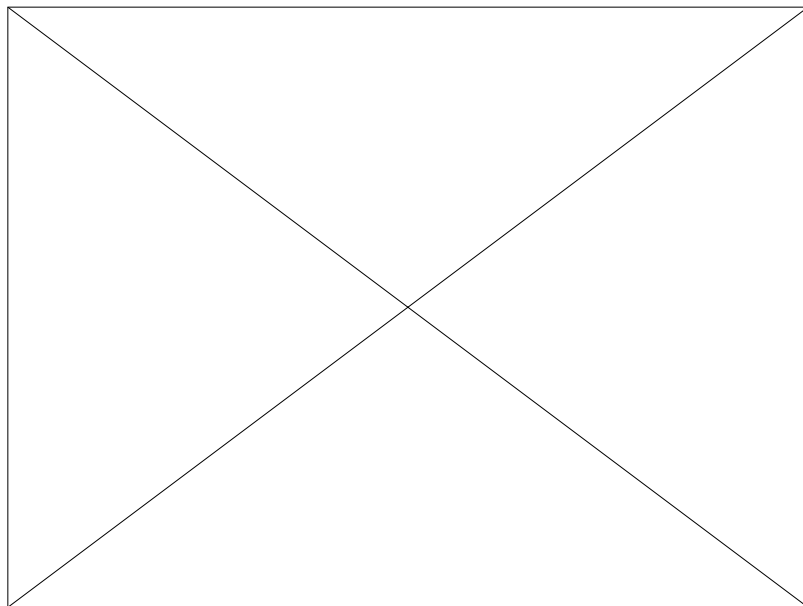
- Charge-coupled device (CCD) array
- Mirrors
- Scan head

- Glass plate
- Lamp
- Lens
- Cover
- Filters
- Stepper motor
- Stabilizer bar
- Belt
- Power supply
- Interface port(s)
- Control circuitry



Close-up of the CCD array

The core component of the scanner is the **CCD array**. [CCD](#) is the most common technology for image capture in scanners. 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.



Photons hitting a photosite and creating electrons

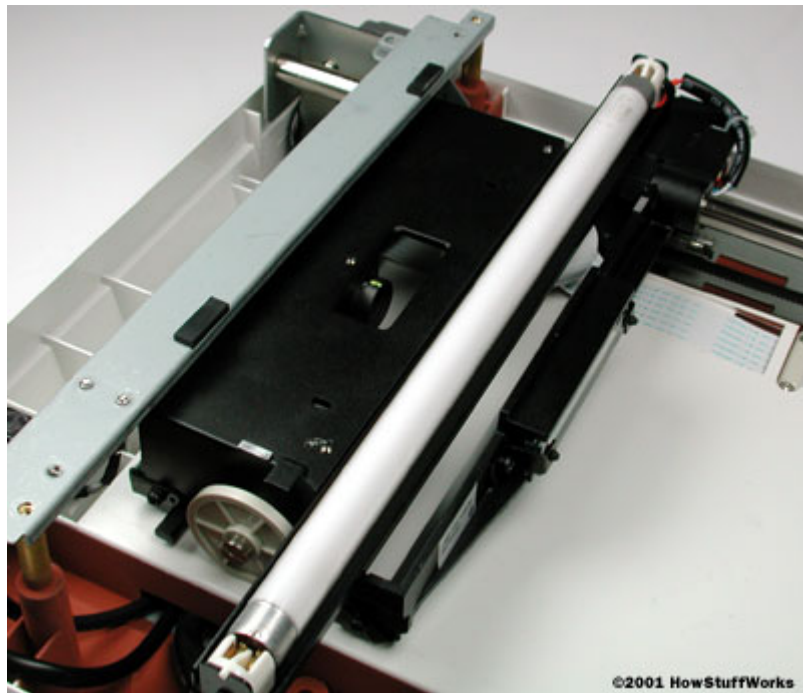
The image of the document that you scan reaches the CCD array through a series of mirrors, filters and lenses. The exact configuration of these components will depend on the model of scanner, but the basics are pretty much the same.

On the next page, you will see just how all the pieces of the scanner work together.

The Scanning Process

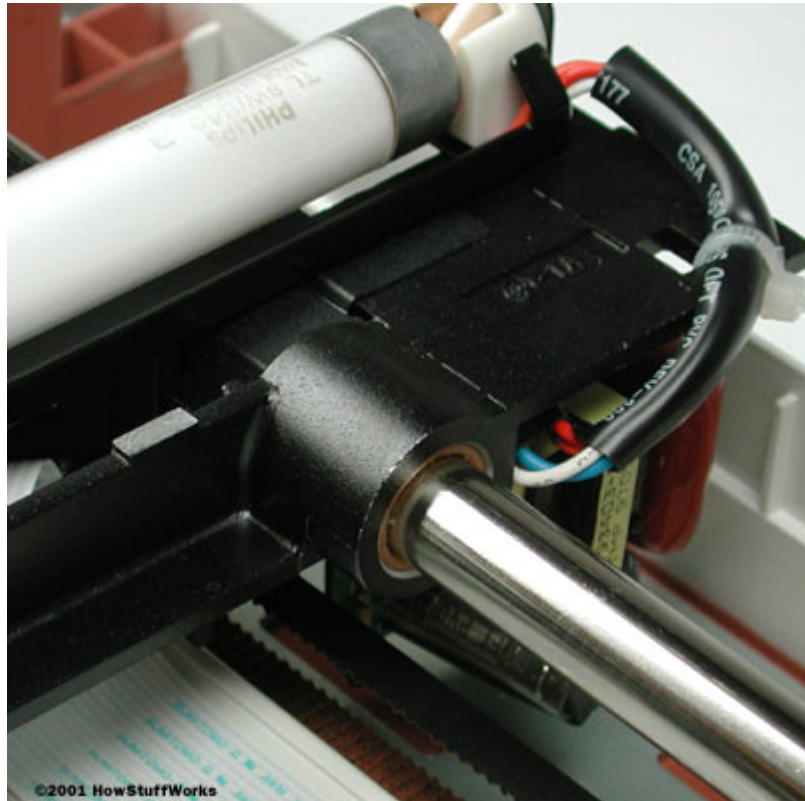
Here are the steps that a scanner goes through when it scans a document:

- The document is placed on the **glass plate** and the **cover** is closed. The inside of the cover in most scanners is flat white, although a few are black. The cover provides a uniform background that the scanner software can use as a reference point for determining the size of the document being scanned. Most flatbed scanners allow the cover to be removed for scanning a bulky object, such as a page in a thick book.



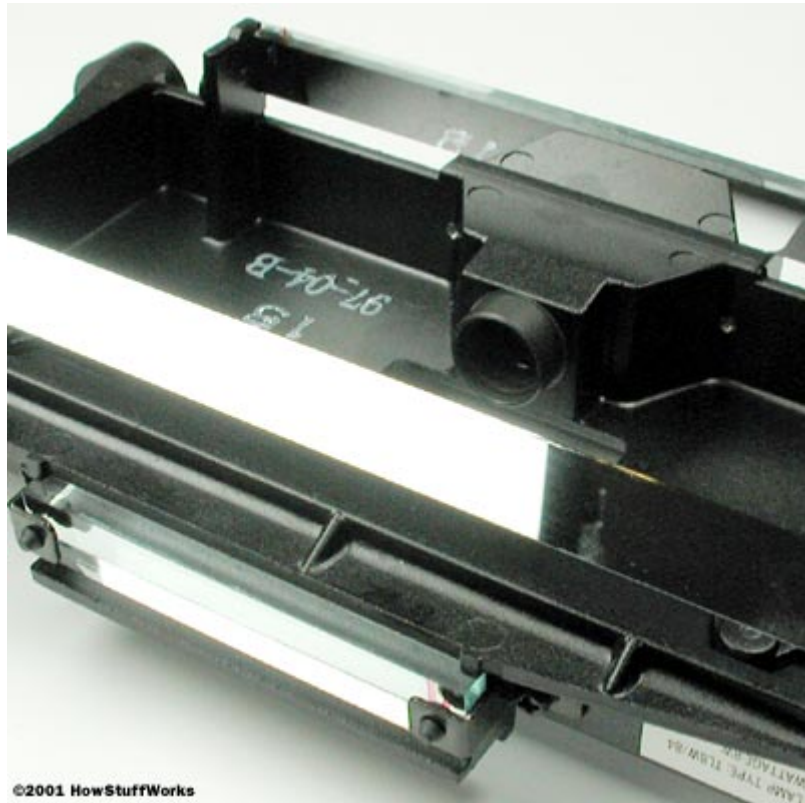
In the image above, you can see the fluorescent lamp on top of the scan head.

- A **lamp** is used to illuminate the document. The lamp in newer scanners is either a [cold cathode fluorescent lamp](#) (CCFL) or a [xenon lamp](#), while older scanners may have a standard [fluorescent lamp](#).
- The entire mechanism (mirrors, lens, filter and CCD array) make up the **scan head**. The scan head is moved slowly across the document by a **belt** that is attached to a [stepper motor](#). The scan head is attached to a **stabilizer bar** to ensure that there is no wobble or deviation in the **pass**. Pass means that the scan head has completed a single complete scan of the document.



The stabilizer bar is very durable and tightly secured to the body of the scanner.

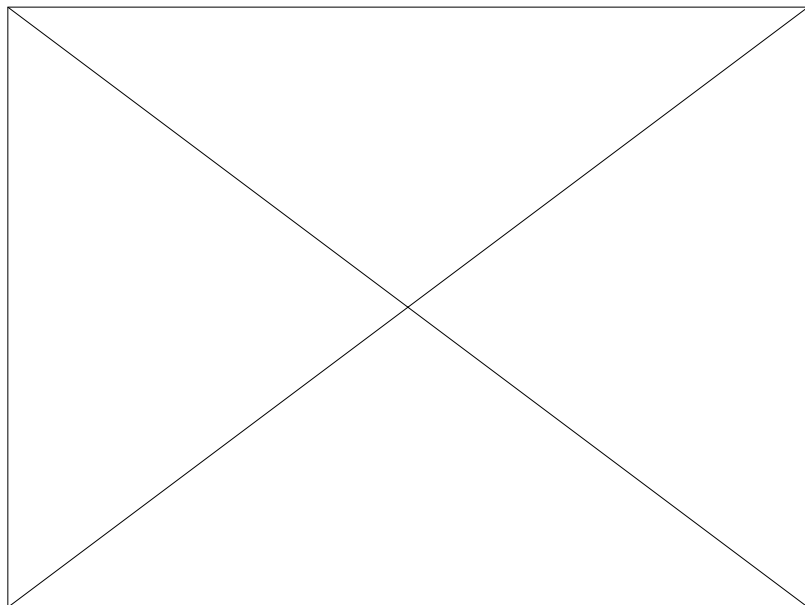
- The image of the document is reflected by an angled **mirror** to another mirror. In some scanners, there are only two mirrors while others use a three mirror approach. Each mirror is slightly curved to focus the image it reflects onto a smaller surface.
- The last mirror reflects the image onto a **lens**. The lens focuses the image through a **filter** on the CCD array.



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Look carefully at the image above and you can see all three of the mirrors plus the lens assembly in this scan head.

The filter and lens arrangement vary based on the scanner. Some scanners use a **three pass** scanning method. Each pass uses a different color filter (red, green or blue) between the lens and CCD array. After the three passes are completed, the scanner software assembles the three filtered images into a single full-color image.



Click on the green Scan button to see the scanning process.

Most scanners today use the **single pass** method. The lens splits the image into three smaller versions of the original. Each smaller version passes through a color filter (either red, green or

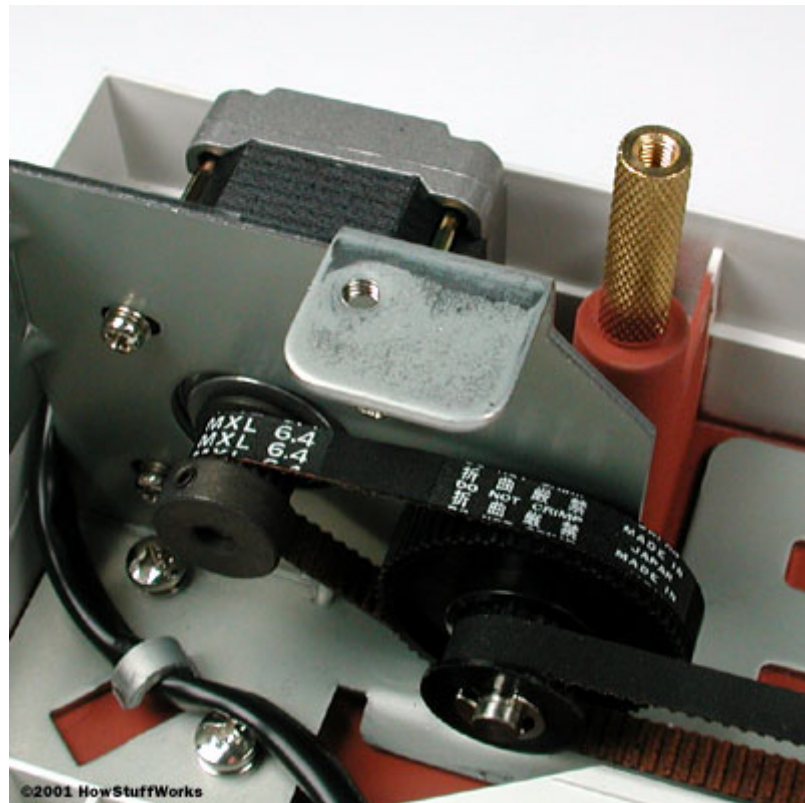
parts of the CCD array into a single full-color image.

Another imaging array technology that has become popular in inexpensive flatbed scanners is **contact image sensor** (CIS). CIS replaces the CCD array, mirrors, filters, lamp and lens with rows of red, green and blue **light emitting diodes** ([LEDs](#)). The image sensor mechanism, consisting of 300 to 600 sensors spanning the width of the scan area, is placed very close to the glass plate that the document rests upon. When the image is scanned, the LEDs combine to provide white light. The illuminated image is then captured by the row of sensors. CIS scanners are cheaper, lighter and thinner, but do not provide the same level of quality and resolution found in most CCD scanners.

We will take a look at what happens between the computer and scanner, but first let's talk about resolution.

Resolution and Interpolation

Scanners vary in **resolution** and **sharpness**. Most flatbed scanners have a true hardware resolution of at least 300x300 **dots per inch** (dpi). The scanner's dpi is determined by the number of sensors in a single row (**x-direction sampling rate**) of the CCD or CIS array by the precision of the stepper motor (**y-direction sampling rate**).



The precision of the stepper motor determines the y-direction sampling rate.

For example, if the resolution is 300x300 dpi and the scanner is capable of scanning a letter-sized document, then the CCD has 2,550 sensors arranged in each horizontal row. A single-pass scanner would have three of these rows for a total of 7,650 sensors. The stepper motor in our example is able to move in increments equal to 1/300ths of an inch. Likewise, a scanner with a resolution of 600x300 has a CCD array with 5,100 sensors in each horizontal row.



Most scanners have a scan area that is either letter size (8.5x11 inches, 21.6x27.9 centimeters) or legal size (11x14 inches, 27.9x35.6 centimeters).

Sharpness depends mainly on the quality of the optics used to make the lens and the brightness of the light source. A bright xenon lamp and high-quality lens will create a much clearer, and therefore sharper, image than a standard fluorescent lamp and basic lens.

Of course, many scanners proclaim resolutions of 4,800x4,800 or even 9,600x9,600. To achieve a hardware resolution with a x-direction sampling rate of 9,600 would require a CCD array of 81,600 sensors. If you look at the specifications, these high resolutions are usually labeled software-enhanced, interpolated resolution or something similar. What does that mean?

Interpolation is a process that the scanning software uses to increase the perceived resolution of an image. It does this by creating extra pixels in between the ones actually scanned by the CCD array. These extra pixels are an average of the adjacent pixels. For example, if the hardware resolution is 300x300 and the interpolated resolution is 600x300, then the software is adding a pixel between every one scanned by a CCD sensor in each row.

Another term used when talking about scanners is **bit depth**, also called [color depth](#). This simply refers to the number of colors that the scanner is capable of reproducing. Each pixel requires 24 [bits](#) to create standard *true color* and virtually all scanners on the market support this. Many of them offer bit depths of 30 or 36 bits. They still only output in 24-bit color, but perform internal processing to select the best possible choice out of the colors available in the increased palette. There are many opinions about whether there is a noticeable difference in quality between 24-, 30- and 36-bit scanners.

Image Transfer

Scanning the document is only one part of the process. For the scanned image to be useful, it must be transferred to your computer. There are three common connections used by scanners:

- **Parallel** - Connecting through the [parallel port](#) is the slowest transfer method available.
- **Small Computer System Interface (SCSI)** - [SCSI](#) requires a special SCSI connection. Most SCSI scanners include a dedicated SCSI card to insert into your computer and connect the scanner to, but you can use a standard SCSI controller instead.

- **Universal Serial Bus (USB)** - [USB](#) scanners combine good speed, ease of use and affordability in a single package.
- **FireWire** - Usually found on higher-end scanners, FireWire connections are faster than USB and SCSI. FireWire is ideal for scanning high-resolution images.



A scanner may have more than one way of connecting to your computer.

On your computer, you need software, called a **driver**, that knows how to communicate with the scanner. Most scanners speak a common language, **TWAIN**. The TWAIN driver acts as an interpreter between any application that supports the TWAIN standard and the scanner. This means that the application does not need to know the specific details of the scanner in order to access it directly. For example, you can choose to acquire an image from the scanner from within **Adobe Photoshop** because Photoshop supports the TWAIN standard.

In addition to the driver, most scanners come with other software. Typically, a scanning utility and some type of image editing application are included. A lot of scanners include OCR software. OCR allows you to scan in words from a document and convert them into computer-based text. It uses an averaging process to determine what the shape of a character is and match it to the correct letter or number.

The great thing about scanner technology today is that you can get exactly what you need. You can find a decent scanner with good software for less than \$200, or get a fantastic scanner with incredible software for less than \$1,000. It all depends on your needs and budget.

Did You Know?

TWAIN is not an acronym. It actually comes from the phrase "Never the twain shall meet" because the driver is the go-between for the software and the scanner. Because computer people feel a need to make an acronym out of every term, TWAIN is known as Technology Without An Interesting Name!