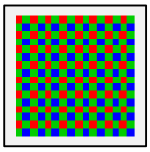
CCD or CIS: The Technology Decision

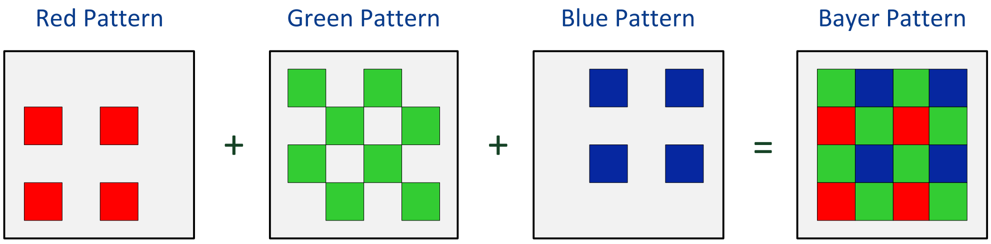
This White Paper will explain the two scanning technologies and compare them with respect to quality, usability, price and environmental aspects. The two technologies used in all document scanners are reduction type linear sensors (called CCD) and **C**ontact **I**mage **S**ensors (CIS). The abbreviation CCD actually stands for **C**harge **C**oupled **D**evice, which is the technology used in all image sensors, therefore using CCD as a synonym for reduction type linear sensors is incorrect from a scientific standpoint. But since everyone is using the term CCD for reduction sensors, we will also use it for reduction cameras to avoid confusion.

Bayer Pattern CCD



Digital cameras use area CCDs comprised of many extremely small pixels, which are covered with a **Bayer Pattern** consisting of two green, one red and one blue pixel side by side. This reduces resolution by a factor of two and increases noise compared to linear line sensors. These area CCD image sensors are not suitable for scanners since they do not scan but rather take pictures.

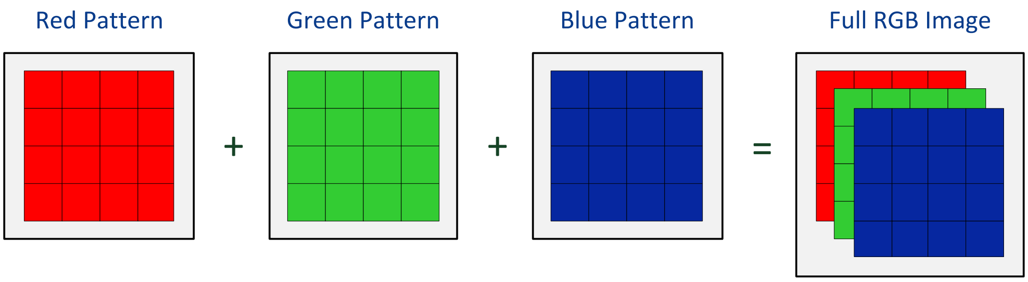
The following diagrams show, how a Bayer Pattern image from a digital camera is generated. This is good enough for pictures with many out-of-focus details but not for scanners.



If a vendor claims to sell a “scanner” with a one shot camera, a matrix camera or something similar, it will most likely be only an overpriced digital camera.

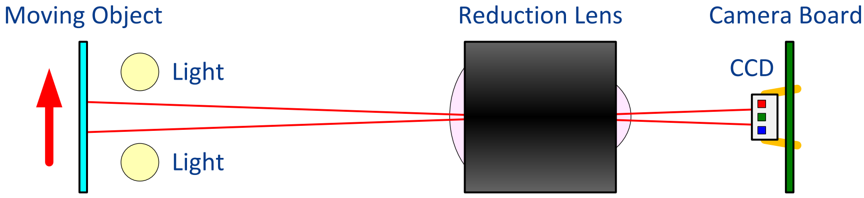
There is an exception from a French book scanner vendor. They are using a monochrome sensor and take **three exposures with different filters** in front of the sensor. Each exposure uses all pixels and afterwards they are composed to a full RGB image like all other ordinary scanners do. Since each exposure takes a few seconds it must be assured that absolutely no movement of the object or the scanner camera is present, otherwise the three images will not match. The best model of this vendor uses a 140MPixel chips to get 600dpi resolution on an area of DINA2.

The following diagram shows, how a full RGB Image is composed with three exposures done with red, green and blue color filters. Only **three shot cameras** with color filters have the same quality as scanners with lines sensors.



CCD based Scanners

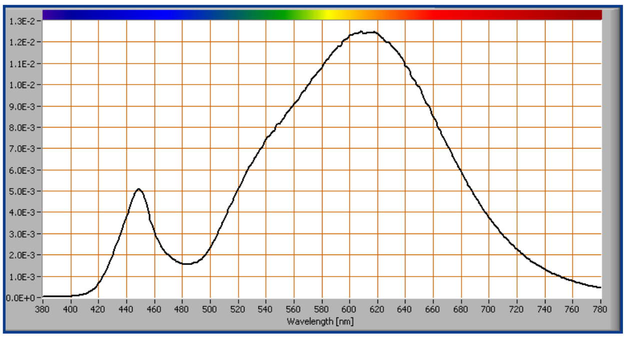
CCD based scanners have linear sensors capturing red, green and blue lines one after the other from a document illuminated with white light. The image is reduced by a reduction lens and projected on the linear CCD sensor. The object (document) is moving in synchronization with the exposure of the CCD elements. The red element will capture an image followed by a green element and a blue element. After the computer has shifted these lines in the correct order, the image will consist of RGB values at the full resolution without any Bayer pattern artifacts.



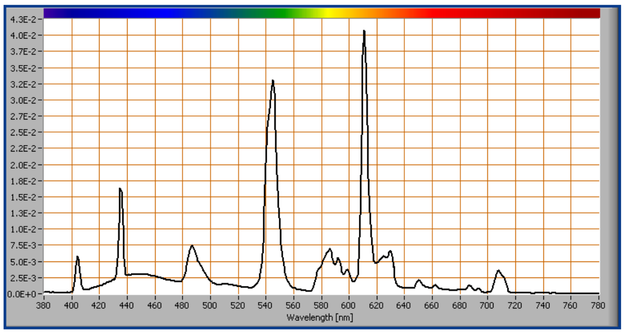
The quality of the white light determines the quality of the scan. Before white LEDs became available as a light source, wide format scanner vendors used fluorescent lamps for this purpose. The disadvantages of fluorescent lamps are many and because of the disadvantages, most scanner vendors no longer use fluorescent lamps.

One major difference is the color quality. The best tri-band fluorescent lamps with a CRI>95 are optimized for the highest lumen output and not for the response curve of the CCD elements. These tubes are emitting peaks in the green, red and blue area of the spectrum trying to get the most lumens per watt. The spectral response curve of a high quality LED is much more uniform and does not leave out as many colors as the fluorescent lamps do.

High quality LED in a WideTEK

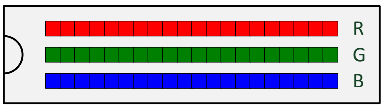


Fluorescent Lamp (competitor) CRI > 90



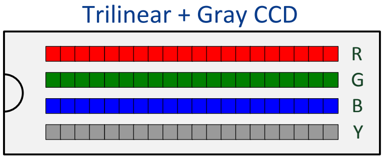
Trilinear CCD sensor

Trilinear CCD



Most high end scanners use trilinear CCD sensors. These sensors convert light on its surface into electrical signals. Color filters for red, green and blue on three consecutive rows of CCD elements provide a very high color gamut, which is typical for CCD scanners and cannot be reached by most CIS type scanners. Pixel sizes for high quality CCD sensors are rather large, 10µm x 10µm is a typical value. Larger pixels help to reduce noise and other image degrading effects. Readout speeds of linear CCDs can be as high as 120MPixel per second per color channel, therefore the fastest scanners all uses these kinds of sensors

Trilinear + Gray CCD

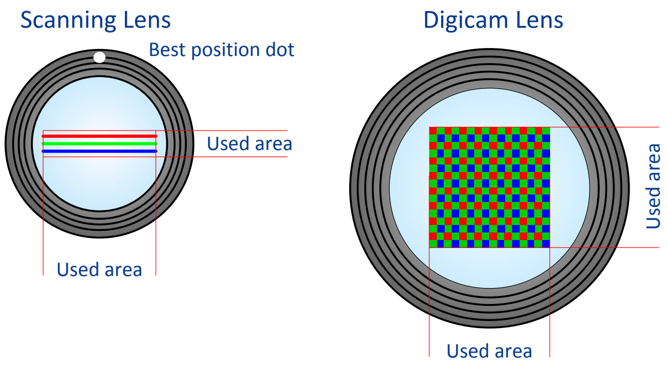


Some scanner vendors use trilinear sensors with a fourth row of sensors, which is not color sensitive. The reason for this is, that the image processing of a grayscale image is three times faster than processing a color image. In other words, these vendors use the fourth row of CCD elements to overcome their speed limitations. The tradeoff lies in the fact that they cannot perform a white balance in a grayscale image. The white balance process calibrates the red, green and blue channels independent of each other using a reference white target. A photometrically correct (for the human eye) grayscale image uses 30% of the red, 59% of the green and 11% of the blue to compute the image.

Image Access CCD based scanners use trilinear CCDs, always scan in full color and if necessary, convert to grayscale using the photometrically correct factors.

CCD Scanner Lenses

A pixel on the original at a resolution of 600dpi has a dimension of 64µm x 64µm, therefore a reduction lens 1:6.4 must be used in case the CCD elements are 10µm x 10µm. This results in a long track length, which is typically folded with a couple of mirrors to keep the size under control. The long track length is a disadvantage because of the higher cost involved but the large focal depth resulting out of a long focal depth is a clear advantage.



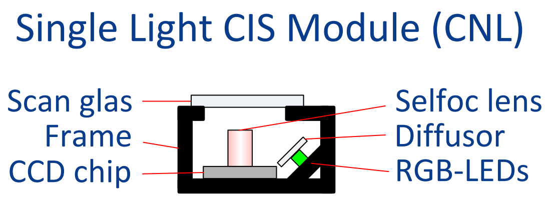
The quality of the reduction lens is a very important factor influencing the overall quality of the scanning system but constraints are a lot less compared with high quality digital camera lenses. The reason for this is the fact, that only the middle section of the lens is used due to the nature of the line sensor. Not only would a digicam lens have to be almost twice as big in diameter, it would also show significant color aberration, geometric inaccuracies like pin cushion distortions and a loss of intensity in the outer corners. Scanners are also used for quality control applications far beyond the point where only a picture has to be taken, therefore precision is a key factor. A “nice locking picture” is not a substitute for a precise scan.

Stitching in CCD Based Scanners

The fact that there is no lens or CCD available to capture 36 inch wide documents at high resolution all at once leads to a downside of wide format scanners, commonly referred to as “stitching”. The scanner has to be recalibrated on a regular basis because it consists of three or four independent CCD subsystems, each having their own lenses and mirrors. During this process, a high precision test target is scanned and the offset in the horizontal and vertical direction between the individual cameras is measured. These values are later used to “stitch” the three or four images from the individual CCD together.

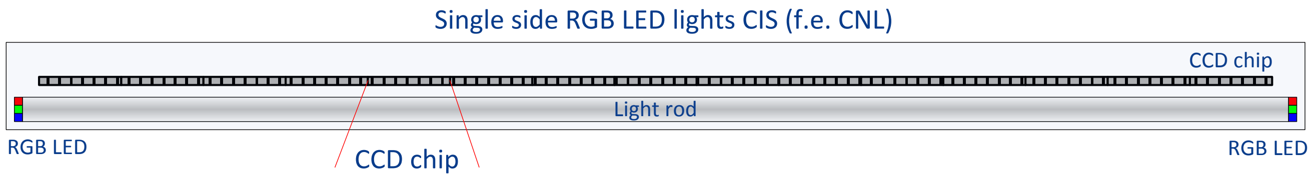
Image Access WideTEK scanners have their optical components such as lenses, mirrors, etc. mounted into one ultra-stable camera housing to avoid stitching errors introduced through thermal expansion of the scanner and its mounting parts. The patented process of calibrating out the remaining stitching offsets before every single scan makes stitching a “non issue”. There is no reference target or stitching procedure necessary, a great relief for every user, regardless of their technical background.

CIS Based Scanners (Consumer Quality)



Entry level scanners use sensors with CIS technology. The CCD is combined with a 1:1 Selfoc lens at a very close distance and an LED based illumination system, all assembled into a compact module. These modules are quite inexpensive and are produced in very high quantities for the flatbed consumer scanner market. The diagram to the right shows a cross section of a typical sensor found in wide format scanners. The lower diagram shows the same CIS module from the scanning side. The module consists of many individual CCD chips of 200-300 pixels each, which are butted side to side to form a long CCD line of typically 210mm (suitable for A4).

The light on these consumer level CIS modules is emitted through a light rod which carries a three color LED on each end. The light rod has cavities in varying distance, which are responsible for emitting the light, to insure a somewhat event distribution over the length of the module.



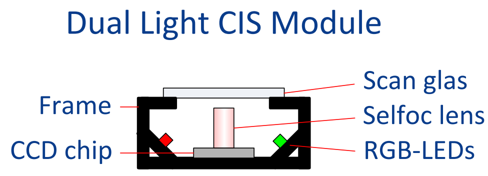
These LEDs are pulsed in a way that three exposures are made under the illumination of each color. These will be compiled into a single line of RGB pixels afterwards. Details about the design of a CIS sensor can be found here.

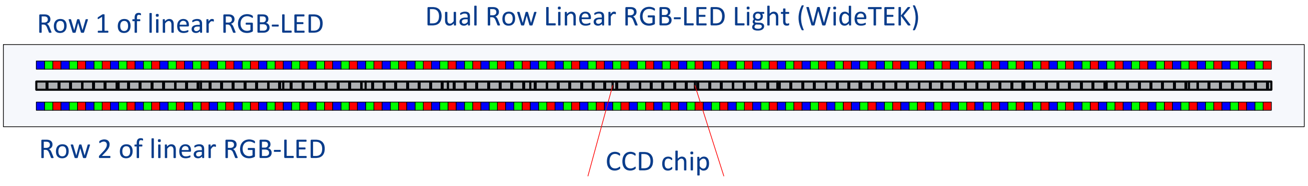
LED illumination typically has no warm up time but introduces some color artifacts because LED illumination systems typically consist of a red, a green and a blue LED that are each switched on for the duration of 1/3 of a scan line. This produces colored edges on black and white originals because each color image is taken from a slightly different position. Image Access uses advanced bilinear interpolation to reduce this effect to invisibility.

Most consumer level CIS modules have an LED illumination only on one side across the width, which amplifies all wrinkles and other surface distortions and produces good images only if the document surface is very even. This amplification effect can be reduced to a certain degree if a diffusor is used. The marketing department of a well-known wide format scanner vendor calls this “dual diffusion” hiding the fact, that their modules only have “single side illumination”

CIS Based Scanners (Professional Quality)

To overcome the problems with consumer level CIS modules, Image Access developed a new CIS module which has two rows of red, green and blue LEDs across the width of the module. The diagram to the right shows a cross-section of these CIS modules. Since they are completely symmetrical, there are no shadows visible even if documents are wrinkled or otherwise uneven.





The high quality LEDs used in WideTEK scanners also overcome another deficit CIS scanners have had over CCD scanners, the smaller color gamut. Our CIS scanners come very close to our CCD scanners with respect to color fidelity and gamut.

One issue remains and is a fundamental difference between the two technologies. The depth of focus of CIS sensors is very small, usually a fraction of a millimeter. This makes it mandatory to guide the original document against the scanning glass surface, resulting in all of the issues one can easily imagine: dirt, dust and scratches all degrade the image quality and can harm the original.

Stitching in CIS Based Scanners

Some large format scanner vendors use four or five of these consumer level CIS modules mounted side by side to achieve a scanning width of 36 inches or more. Stitching effects and geometric distortion are far less significant than with a CCD based scanner because of the 1:1 optical system and the fixed distance between the individual modules. This is not true for scanners that have CIS modules staggered in the transport direction as all wide format scanners have. Because of the large distance between the individual modules, which can be up to 1000 lines apart; stitching becomes dependent on the properties of the document and also requires a very stiff transport system.

Image Access WideTEK scanners have a software based automatic stitching algorithm which compares the overlapping images derived from each sensor and adjusts the stitching offset based on content analysis. As a result the CIS based WideTEK scanners only need an adjustment at factory or repair time and outside of this they behave like a solid single sensor behaves.

Wide Format Scanner Technology Comparison

Property	CCD (WideTEK)	CIS (WideTEK)	CIS (Other)
Speed	Very high	High	Low
Focal depth	3 - 5mm	0,3mm	0,1mm
Dual side illumination	Yes	Yes	No
Color gamut	Very wide	Wide	Narrow
Stitching	2D required	1D required	1D required
Plain paper with folds	Folds not visible	Folds not visible	Folds visible
Newspaper scans	Easy	Reasonable	Very difficult
Wrinkled or torn documents	Reasonable	Very difficult	Not possible
Lamp lifetime (typ.)	50.000h	50.000h	20.000h
Price	High	Low	Lowest
Included in warranty	Yes	Yes	No

Conclusion

There are heated arguments about CCD versus CIS technology in the wide format scanner business. The same arguments are used for each of the two, depending on the technology favored by the respective author or vendor. Is there really a “Technology Decision” to be made? Image Access sees advantages in both technologies and we think the decision depends on the customer’s needs and budget.

Many of the articles and advertisements we have read recently contained both misleading and incorrect statements. We read things like:

“CCD supports a wider color gamut/bit depth, capturing 48bit color compared to 24bit color for CIS, and this is why CCD is used in today´s digital cameras.”

Even a non-technical user will instantly come to the conclusion that the A/D converter´s resolution has nothing to do with the source of the signal. Both technologies produce an analog output signal that will be digitized in a later stage through the A/D converter. This can have any resolution between 8 bit and 48 bit but is independent of the CCD/CIS sensor.

The last part of the above statement has the highest score for nonsense we have found yet. Why would anyone in the world even consider using a **C**ontact **I**mage **S**ensor with a maximum focal distance of one tenth of a millimeter and a picture size of 1 by 5000 pixels for a digital camera? This logic remains the secret of its author.

Image Access does not favour one of the two technologies since they both have their strong and weak sides. We are convinced that the customer’s purchasing decision will largely be influenced by many more important criteria than the “Right Technology”.