



Digital Photography

How it works

Meteorendag November 6, 2004
Roel Gloudemans



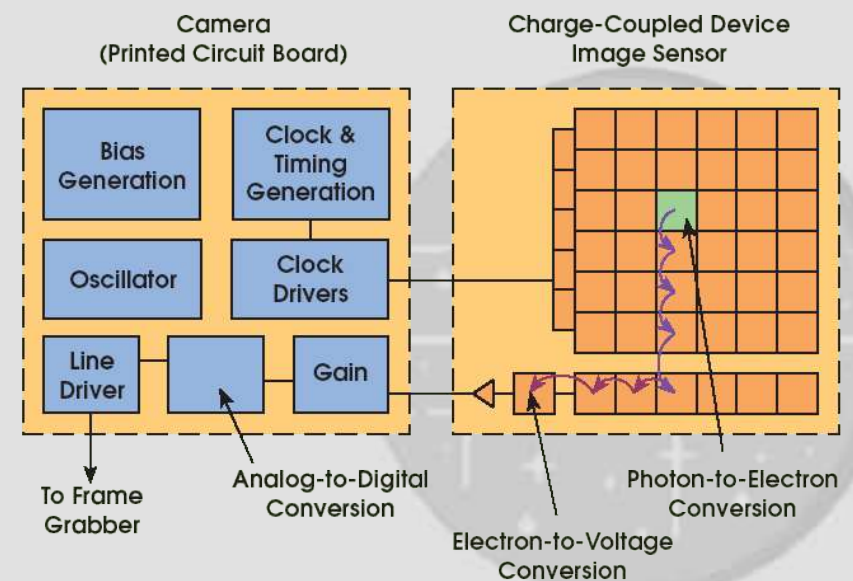
Agenda

- CCD sensors
- CMOS sensors
- CCD vs. CMOS a.k.a. Nikon vs. Canon
- Into the light
- MegaMegapixels
- Mine's bigger
- How colorful
- What's in store
- Overtime: Scientific processing of CCD images
- References

Charge Coupled Device (1)

- Array of photosensitive elements, each of which converts photons into electrons.
- Those electrons are stored in the photosensitive elements until read – A photon bucket...
- See image on how CCD is “read”

It may come as a shock; but a CCD is an **analog** instrument!!



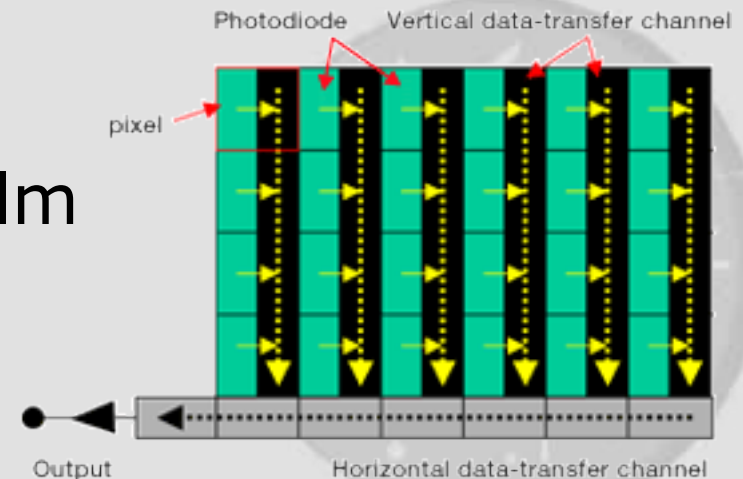
CCD (2)

- Disadvantages

- No exposure during readout
- Readout can take a long time. Solution: the interline CCD. But photosensitive surface is traded in. Hence smaller "light buckets". "Full Frame" camera's do exist e.g. Olympus E-1.
- Thermal noise in substrate (Dark signal) much higher noise on film

- Advantages

- Much higher efficiency than film
- No film used
- Instant result



CCD (3)

- The next few slides show images taken with a Nikon D100 SLR camera (interline CCD) which were taken in a totally dark environment. So:
 - Room with curtains drawn
 - Lens cap and viewfinder caps in place
 - Camera covered by a blanket
 - Room temperature about 22 degrees Celsius
 - Camera set to 200ASA
- Exposure times: 1,2,5,10,15 minutes





1 minute

2 minutes



5 minutes



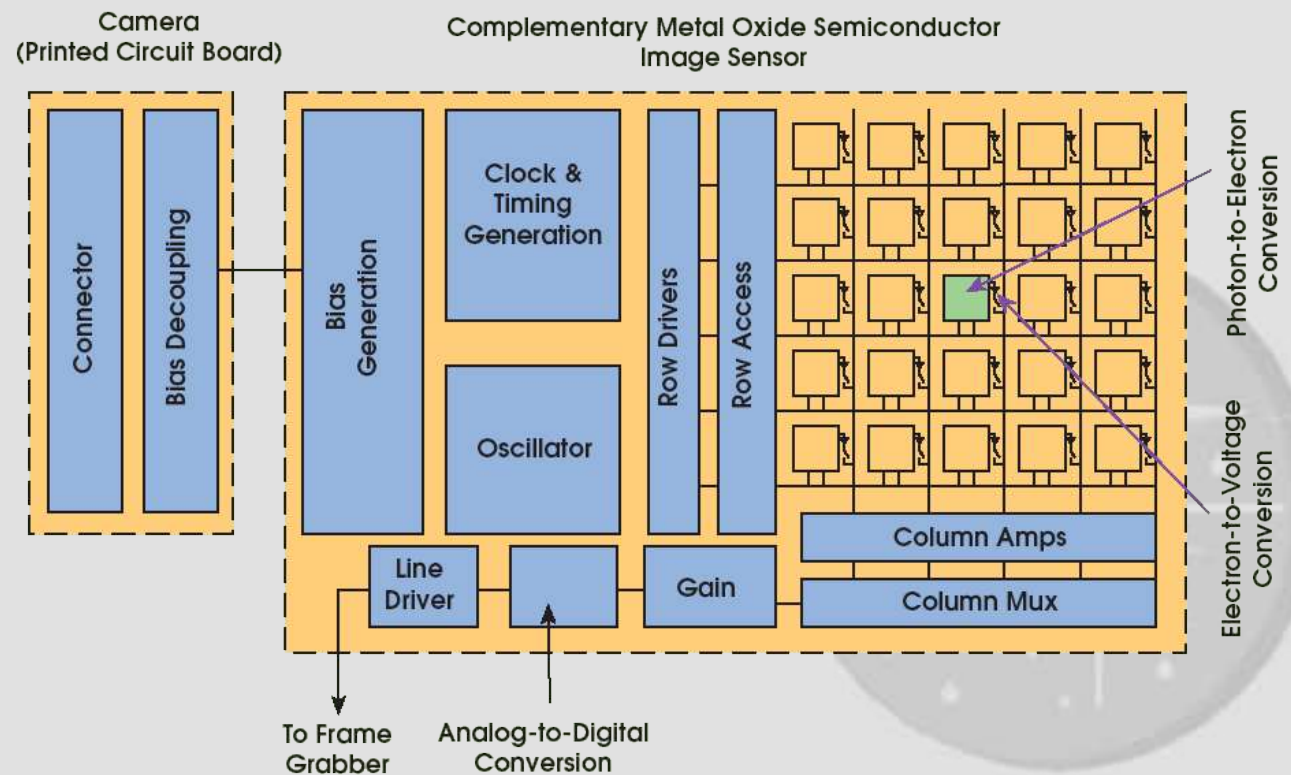
10 minutes



15 minutes

Complementary Metal Oxide Semiconductor (1)

- Photosensitive cells like the CCD, but each with it's own processing plant.
- CMOS sensors can be read per pixel
- CMOS is used in most consumer cameras



CCD vs. CMOS

a.k.a. Nikon vs. Canon

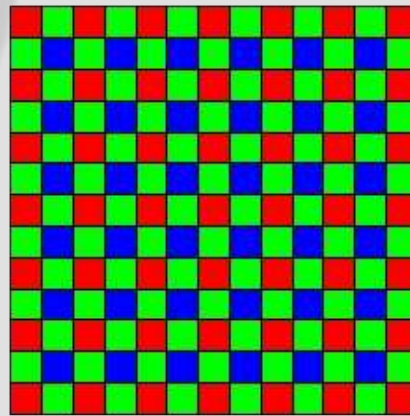
- Nikon SLR's tend to use CCD sensors. Canon's use CMOS.
- Which is better....

	CCD	CMOS
Responsivity	-	+
Dynamic range	+	-
Noise level	+	-
Uniformity	+	-
Anti blooming	-	+
Power use	-	+
Reliability	0	0

- It's a tie, but because of better dynamic range and noise levels the CCD is probably better suited for astronomical usage.

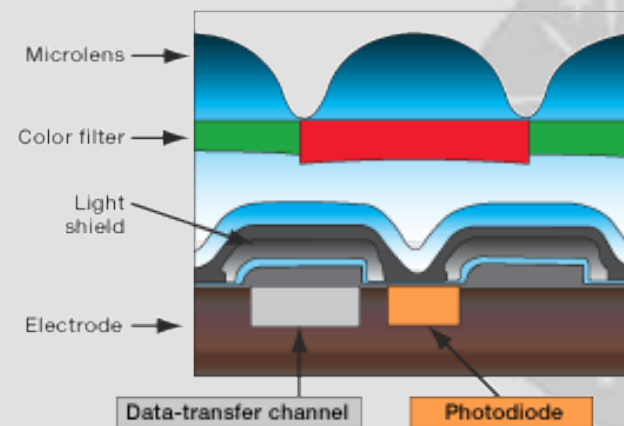
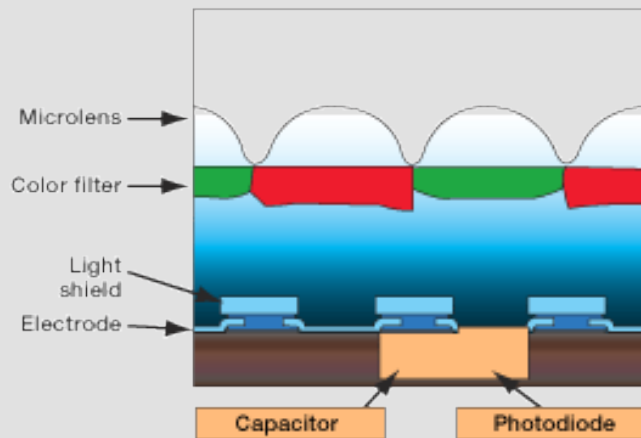
Into the light

- Until now, we've talked about photon buckets. What about colour?



Bayer filter

- Doing it better; the Foveon sensor (3 layered CCD) still lower on the pixel count though. Used in Sigma SD-10
- Microlenses, making it more sensitive



MegaMegapixels

- CCD and CMOS sensors still have not caught up with traditional film (still ways to go)
- However, CCD and CMOS are much more sensitive to light than film. Detection limit for meteors still unknown to me.
- High megapixel counts are not always good.
 - More circuitry onto a smaller area causes more noise
 - Smaller lightbuckets have smaller dynamical range
 - Today's optimum (for consumers) is about 6MP on an APS sized sensor

Mine's bigger



- With regard to sensor sizes: Up until a certain level; the bigger the better
- Most consumer cameras use small sensors.
 - Small sensors have a low SNR due to the small pixel sizes and the amount of electronic traffic going on on a small surface
 - Focal length of lenses must be much shorter for small sensors
- The big advantage of SLR's; large sensors.

Mine's bigger (2)

- Because of the large sensors your old lenses are still usefull
- Because the sensor is smaller than film, the virtual focal length increases by a factor of 1.5.
- Special DX lenses do exist. They project their complete image on the sensor.
 - Normal lens projects on a bigger area than the sensor itself. Hence less light is directed towards the sensor
 - Normal lens will probably produce a better image, since the whole of the picture is well away from the lens boundary

How colorfull

- White Balance
 - Identifying which mix of intensities of RGB make up white
 - This makes it possible to correct for non-white light sources, such as fluorescent light sources
- Color space
 - Camera's use the RGB color space (see Bayer filter)
- Contrast etc.



Color gamut

- Gamut: the way the primary colors from the color space combine into other colors.
- The gamut is defined by the colors which can be accurately represented in the color space.
- Most SLR's support 2 different color gamuts: sRGB and Adobe-RGB.
- Some camera's support several sRGB variants with slightly different gamuts. e.g. for portraits and landscapes (more green)
- Adobe-RGB has the widest gamut, but isn't supported for normal print.

Brushing up

- Camera's by default mutilate your pictures by applying:
 - Automatic white balancing
 - Sharpening
 - Auto contrast/brightness
- Think carefully on your settings



What's in store

- Most people use the JPEG format to store pictures. A 6MP shot results in a 3MB file
 - JPEG is a lossy compression algorithm
 - Do not use for scientific applications!!
- A few brave people use TIFF. A 6MP TIFF results in a 17MB file (8 bits per color per pixel)
- The intelligent use RAW. A 6MP RAW (Nikon) results in a 9MB file. (12 bits per pixel)
 - And now the fun part: RAW stores the raw CCD output and the camera settings. All can be adjusted afterwards! Warning: Except ASA/ISO (Why??)
 - There is no standard for RAW. (It is in the making)

Processing CCD images

- RAW images should be the basis
- Separate the RAW images into an image per color; this requires knowledge of the color filter
- Shoot bias frames throughout the night
 - These are to be subtracted from images
 - Can be used to find faulty pixels
- Shoot flat field images at start of the night
 - If you are using a telescope, use the inside of the dome; place a small light in the centre
 - Normalize these flat fields and divide images and bias frames by the normalized flat field

References

- http://www.dalsa.com/markets/ccd_vs_cmos.asp
- http://www.webcamsoft.com/en/faq/cmos_ccd.html
- http://www.reed-electronics.com/ednmag/archives/1997/100997/21df_02.htm
- <http://209.196.177.41/01/01-04.htm>
- <http://www.olympus-esystem.com/dea/technology/ccd.html>
- <http://electronics.howstuffworks.com/digital-camera1.htm>
- <http://www.dpreview.com/reviews/print.asp?review=nikond100&page=1>
- <http://www.photo.net/equipment/digital/sensorsize/>
- <http://www.digicaminfo.btinternet.co.uk/sensors2.htm>
- <http://www.dcresource.com/forums/archive/index.php/t-442.html>
- <http://encyclopedia.thefreedictionary.com/RGB%20color%20space>

