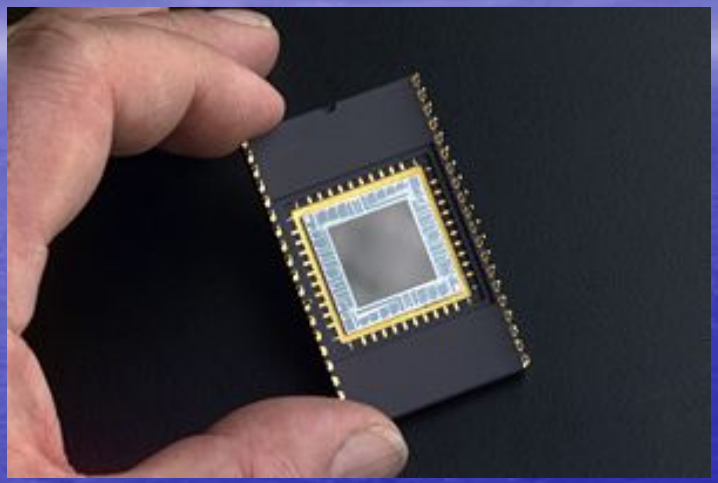
CHARGED-COUPLED DEVICE



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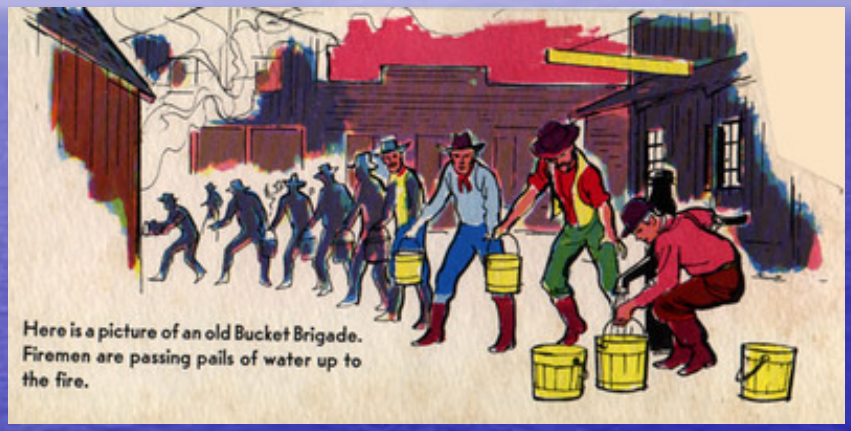
Dr. Doolittle

See resource/reference 1 for picture source.

Bucket-Brigade Device



In 1969 F. Sangster and K. Teer of the Philips Research Labs invented the Bucket-Brigade Device or BBD. This device basically transfers charge packets from one transistor to another. One year later, W. Boyle and G. Smith of the Bell Laboratories extended this concept by inventing a transport mechanism from one capacitor to another one. This new device got the name Charge Coupled Device or simply CCD.

Charged-Coupled Device

- A charged-coupled device is a light sensitive integrated circuit that stores and displays the data for an image in such a way that each pixel in the image is converted into an electrical charge the intensity of which is related to a color spectrum.
- Put another way, each CCD represents a single-image pixel.
- For a system supporting 65,535 colors, there will be a separate value for each color that can be stored and recovered.

See resource/reference 2 for picture source.

Charged-Coupled Device

- The CCD chip is an array of Metal-Oxide-Semiconductor capacitors (MOS capacitors), each capacitor represents a pixel. By applying an external voltage to the top plates of the MOS structure, charges (electrons (e-) or holes (h+)) can be stored in the resulting potential well. These charges can be shifted from one pixel to another pixel by digital pulses applied to the top plates (gates). In this way the charges can be transferred row by row to a serial output register. The picture is the display of the electron distribution.

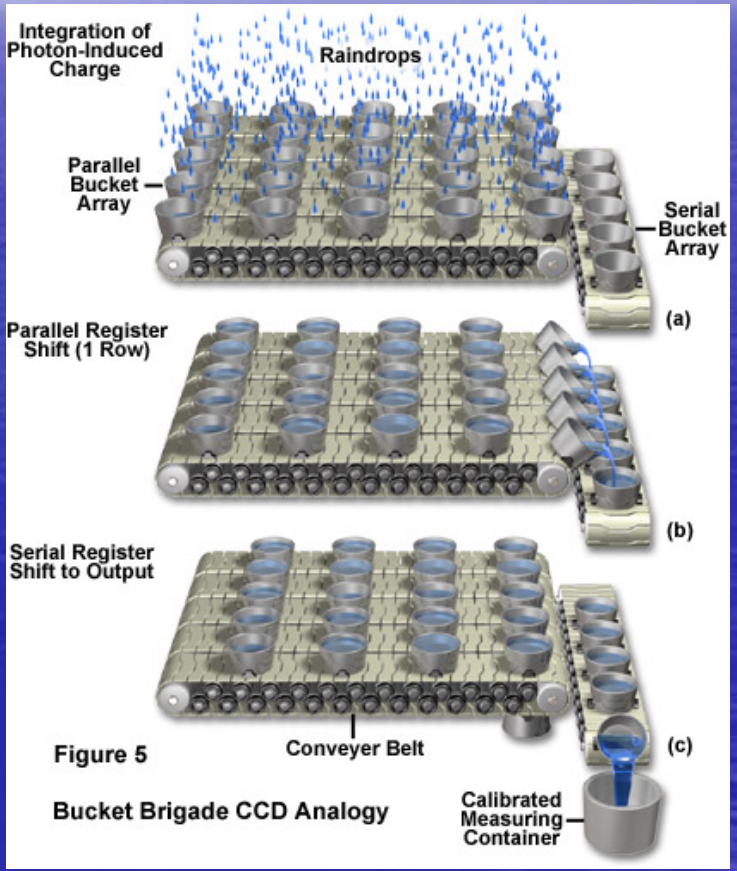


Figure 5

Bucket Brigade CCD Analogy

See resource/reference 3 for picture source.

Charged-Coupled Device

- Think of this process as something like a bucket brigade, where water in a bucket at the beginning of a line is transferred to the end of the line after being passed from bucket to bucket. This charge transfer occurs with an efficiency greater than 99.9% per pixel.

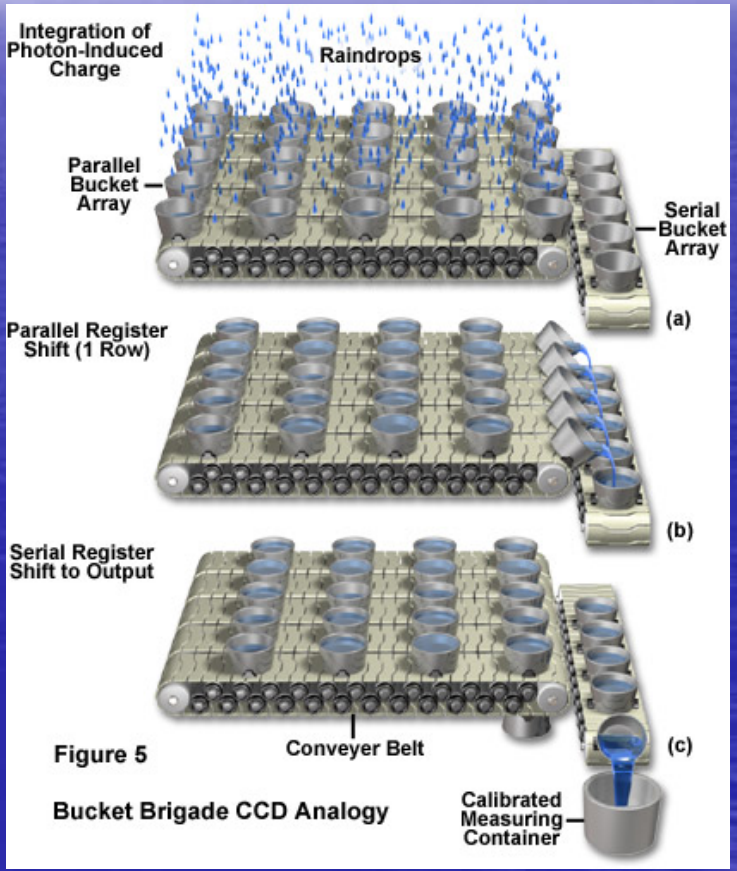
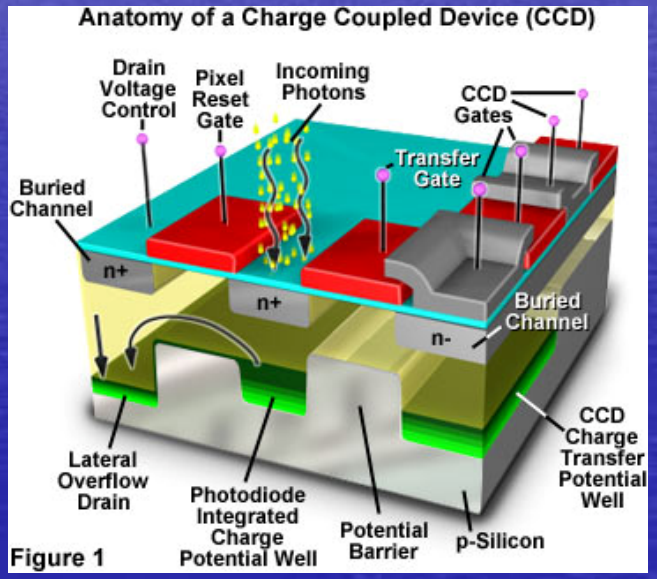


Figure 5
Bucket Brigade CCD Analogy

See resource/reference 3 for picture source.

Reading Charges

- The challenge lies in reading these charges out of the array so they can be digitized. To do this, each individual CCD detector, or pixel, consists of three transparent polysilicon gates over a buried channel of doped photosensitive silicon that generates the charge. The channel is flanked by a pair of channel stop regions that confine the charge.



See resource/reference 4 for picture source.

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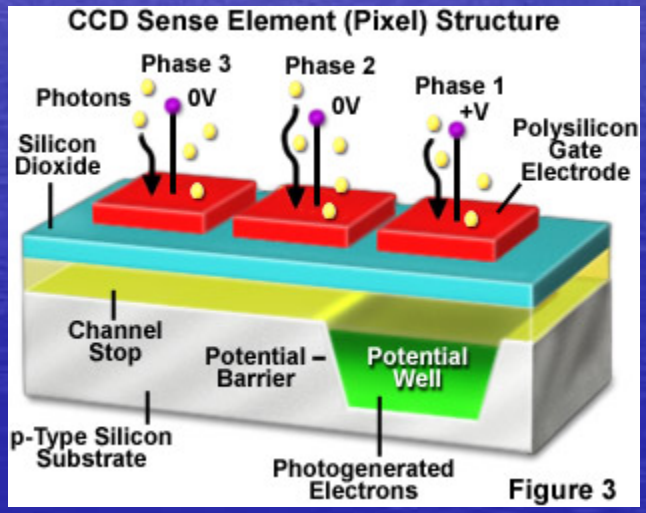
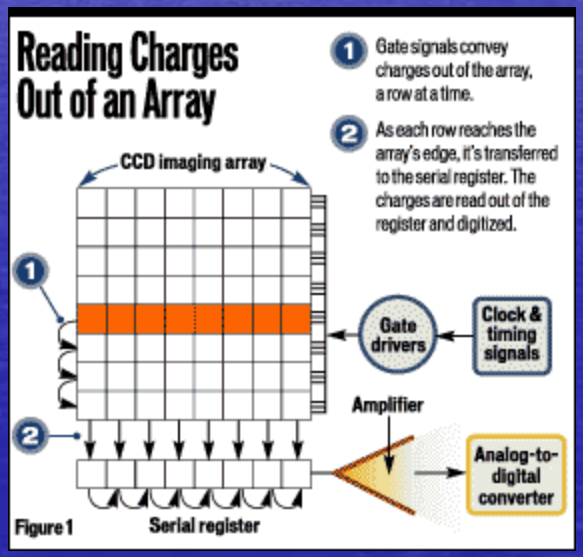


See resource/reference 3 for picture source.

Reading Charges

- To read and digitize a particular CCD's charge, the voltages of the three gates are cycled in a sequence that causes the charge to migrate down the channel to the next gate, then to the next pixel, and ultimately down the row until it reaches the end column, where it's read out into a serial register and ultimately sent to an analog-to-digital converter.



See resource/reference 5 for picture source.

Output Resolution

- The performance of a CCD is often measured by its output resolution, which in turn is a function of the number of photo sites on the CCD's surface
- The CCD employed in the EASYSHARE V1273, for example, contains 4088 photo sites on its horizontal axis and 3040 on its vertical axis (4088 x 3040 pixels) which gives it 12 million pixels or 12 megapixels of effective output resolution

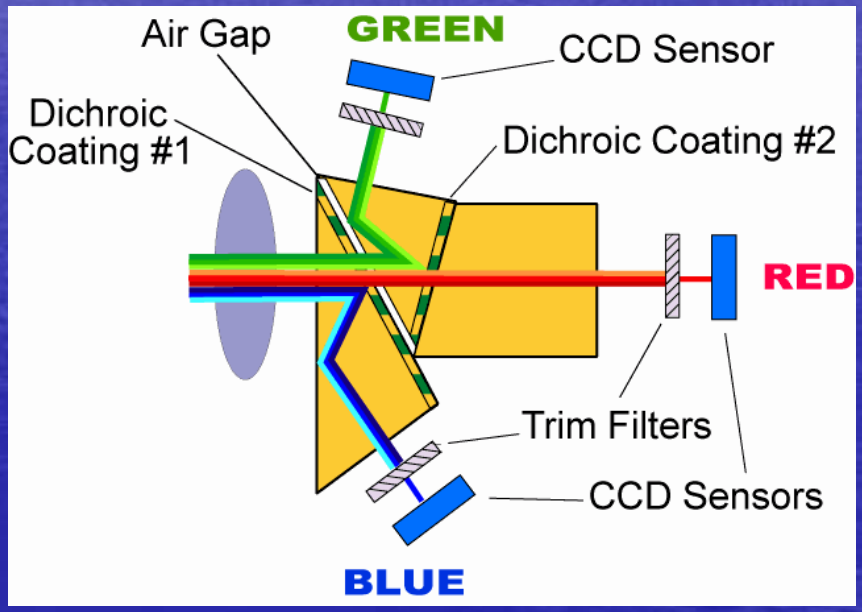
See resource/reference 6 & 7 for picture sources.

Capturing Color

- Because the CCD imaging array is only sensitive to light intensity, color has to be captured.
- The acquisition of color images with a CCD camera requires that red, green, and blue wavelengths be isolated by color filters, acquired separately, and subsequently combined into a composite color image.

Capturing Color (3CCDs)

- One way to capture a color image is to use three CCD arrays, each covered by a filter (usually produced by painting the CCD's surface with dye) that passes one of the three primary colors - red, green or blue. Onboard camera electronics merge these primary components into a color pixel. Because it requires three CCD arrays, this system is found only in high-end cameras and camcorders.



See resource/reference 8 for picture source.

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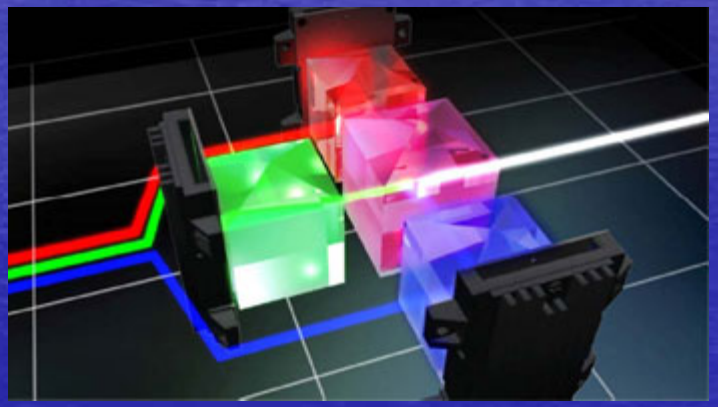

See resource/reference 9 for picture source.

Capturing Color (Frame-Sequental)

- Another approach is a frame-sequential method that employs a single CCD to sequentially capture a separate image for each color by switching color filters placed in the illumination path or in front of the imager.

See resource/reference 10 for picture source.

Capturing Color (Frame-Sequental)

- Because the same sensor is used for separate red, green, and blue images, the full spatial resolution of the chip is maintained, and image registration is automatically obtained.

See resource/reference 10 for picture source.

Capturing Color (Frame-Sequental)

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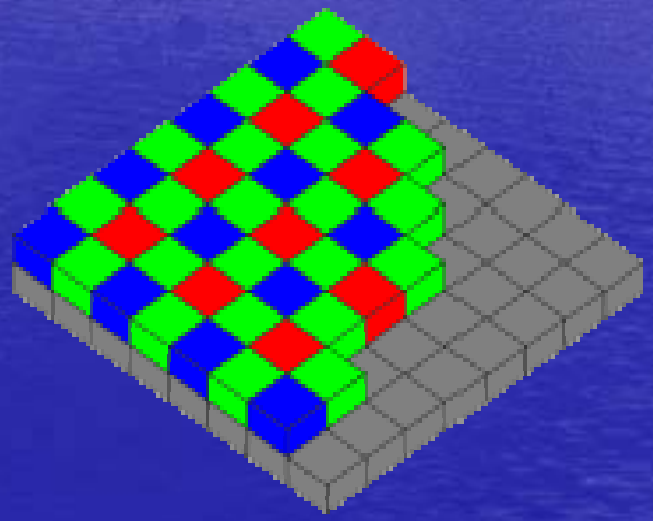
See resource/reference 10 for picture source.

Capturing Color (Bayer Mosaic Pattern)

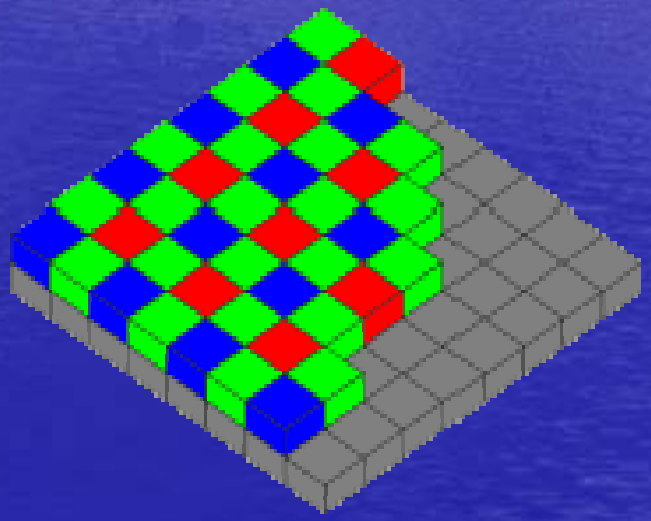
- The most common and low cost method is to blanket the CCD pixel array with an alternating mask of red, green, and blue (**RGB**) microlens filters arranged in a specific pattern, usually the **Bayer** mosaic pattern.



See resource/reference 1 for picture source.

Capturing Color (Bayer Mosaic Pattern)

- Half the filters in this layout are green because the human eye is most sensitive to that color.



See resource/reference 1 for picture source.

Disadvantages

- The CCD, invented at Bell Labs (now part of Murray Hill, N.J.-based Lucent Technologies Inc.) by George Smith and Willard Boyle in 1969, was originally intended to store computer data. But that function was taken over by faster technologies. By 1975, CCDs were being used in TV cameras and flatbed scanners. In the 1980s, CCDs appeared in the first digital cameras. CCDs are widely used today, but they do have some drawbacks:
  - Fading. Although the coupling process is quite efficient, moving the charges along a row of many hundreds or thousands of pixels adds up to a noticeable loss of charge.
  - Blooming. If too many photons strike a CCD element, it gets "filled up," and some of the charge leaks to adjacent pixels.
  - Smearing. If light strikes the sensor while a transfer is taking place, it can cause some data loss and leave streaks behind bright areas of the image.
  - Expense. CCDs require a different manufacturing process from other computer chips (such as CPUs and memory), so specialized CCD fabrication plants are necessary.

Resources/References

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2. http://www.cpaadvisor.us/sub/3_digitalimaging.htm
3. http://www.microscopyu.com/articles/digitalimaging/ccdintro.html
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