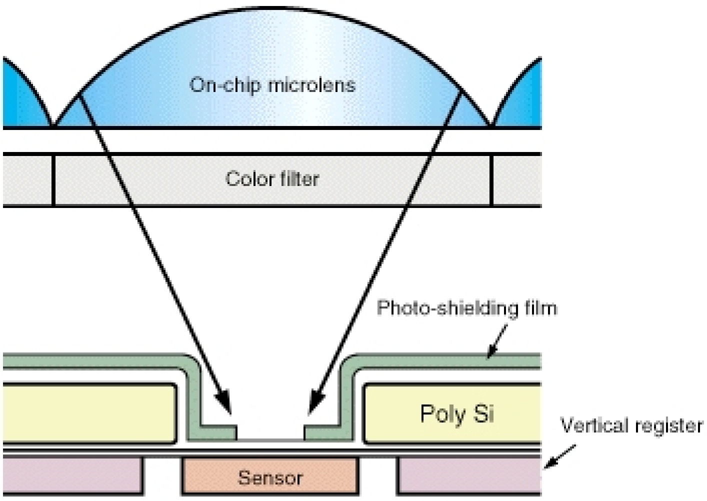
Charged Coupled Devices (CCD's)

An extremely mainstream digital imaging technology is the Charged Coupled Device (CCD). They are the imaging sensors that appear in nearly every type of digital camera on the market today. Essentially, a CCD consists of an array of small cells or pixels. Inside these cells are tiny photosensitive devices. These small devices are designed such that they will behave like "buckets" that will collect charge and hold it until it is drained out of the system (i.e. it is directly analogous to a capacitor). These cells are created out of a semiconducting material that will give off free electrons when a photon of light strikes its surface. The more photons that hit the cell (i.e. the brighter the light for a given amount of time), the more electrons there are in the bucket, however, these cells are only sensitive to the light's *intensity*, not its color (Thomson 1).

This brings up the very important point made in the "Attributes of Light" section - how to obtain a color image in the visible spectrum if you can't have a single cell that can automatically record the color of the light that's hitting it. The solution, as mentioned previously, is to utilize the colors red, green, and blue to create all the colors that the human eye can discern. This can be accomplished by grouping repeating patterns of two alternating cells. Each one of these cells has a one of three different color filters on it; either red, green, or blue. A diagram of a typical CCD pixel can be seen in figure one and a typical RGB CCD layout can be seen in figure two.

Figure One (Cross-sectional view of a typical CCD cell (or pixel))



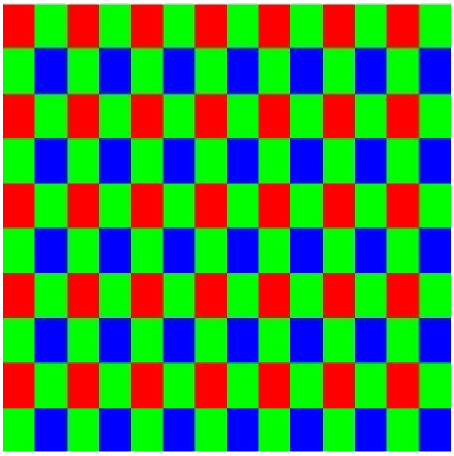
Super HAD CCD Sensor

(image courtesy of Sony Semiconductors)

From figure one, it can be seen that the small lens behaves very much like the glass lens discussed in the focal plane section, and indeed it does, however, it is essentially meshing a still infinite group of focal points onto a sensor that will merge them all into one. Ultimately, this is how and where most of the information is lost, as the microlens and sensor can not be made infinitely small. Hence, the sensor has to be made as small as is possible to produce an image with as much data in it as is possible. To sum up this point, the more CCD sensors that are on a single CCD array at the focal plane and the smaller the CCD pixels are, the higher the resolution of the resulting image and the more information the recorded image will contain. A good example of this is an earth orbiting weather satellite. If it took an image of the earth with a 6 RGB pixel CCD, the resulting image would look like six big blocks. However, if it's taken with a 5 million RGB pixel CCD, a beautiful picture of the earth will result.

Below in figure two can be seen a typical RGB CCD layout.

Figure Two (Diagram of a typical RGB pixel layout)

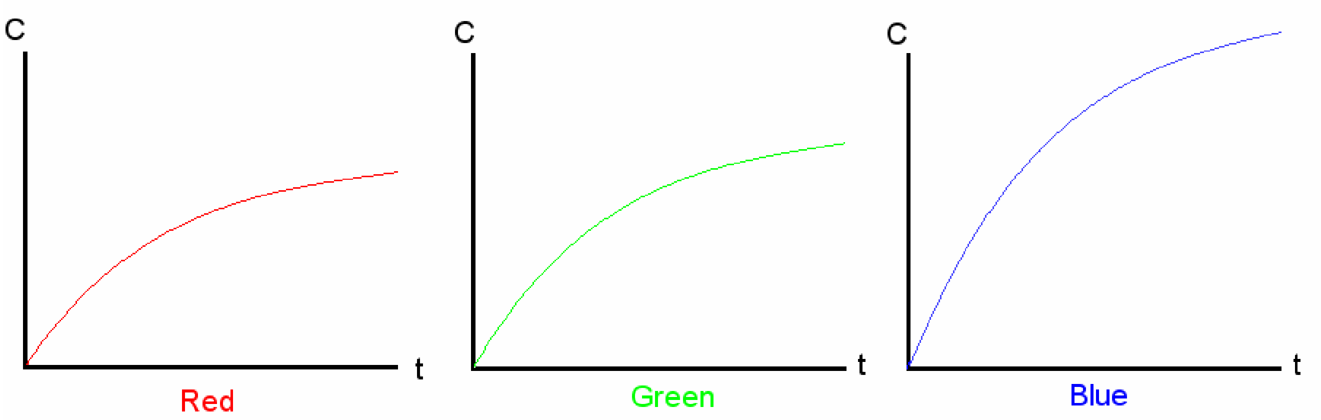


(image courtesy of duncantech.com)

As can be seen from figure two, the cells are situated in columns of alternating colors such that red, green, red, green is in one and blue, green, blue, green is in the one next to it before the column patters are repeated. This may be confusing at first, as there is 25% more green than there is red or blue in the system, however, this excess of green is advantageous, as our own eyes are much more sensitive to the color green than they are to blue and red (Spectral Configuration Guide, 4). Furthermore, the colors can be manipulated as much as is desired to make the colors appear correct, as once the CCD array is read by the hardware in the camera, software in the camera runs it through a set of algorithms in order to merge the intensity data from the CCD's pixels into color information that is then saved into a typical digital format, such as JPG or TIFF. Typically, one pixel in a JPG or TIFF file is comprised of four cells (one red, one blue, and two green) from a CCD array.

A simplified example of how these colors are combined through their intensities and how the cells might charge up for *one* pixel in a JPG or TIFF file is as follows: First, let's say each cell can have an intensity value of 0 - 255 (8 bits). Also, one pixel, as previously stated, has one red, one blue, and two green cells. Now, let's take a 1 second exposure of a blue river. At the beginning of the exposure, each cell and sensor within it will start out with zero charge in its bucket. As time increases, however, they will begin to charge up to a maximum value (maximum intensity = 255 - if all cells have an intensity of 255, the color output is white, if all zero, the color output is black), however, they will charge up at different rates due to the filters (in this case, blue will charge faster than green or red). The charge versus time graphs for each color would look something like figure three below.

Figure Three (Charge versus time graphs for an RGB pixel inside a CCD cell for the scenario listed above)



So after one second, there is more blue than red or green. For instance, after one second, the red sensor detected an intensity of 50, the green of 80, and the blue of 150. Once the intensities of the charges are read off from the sensor, the intensity is then registered inside the software of the camera. These intensities are then merged together to form a single pixel. From this example, the pixel would have this color: