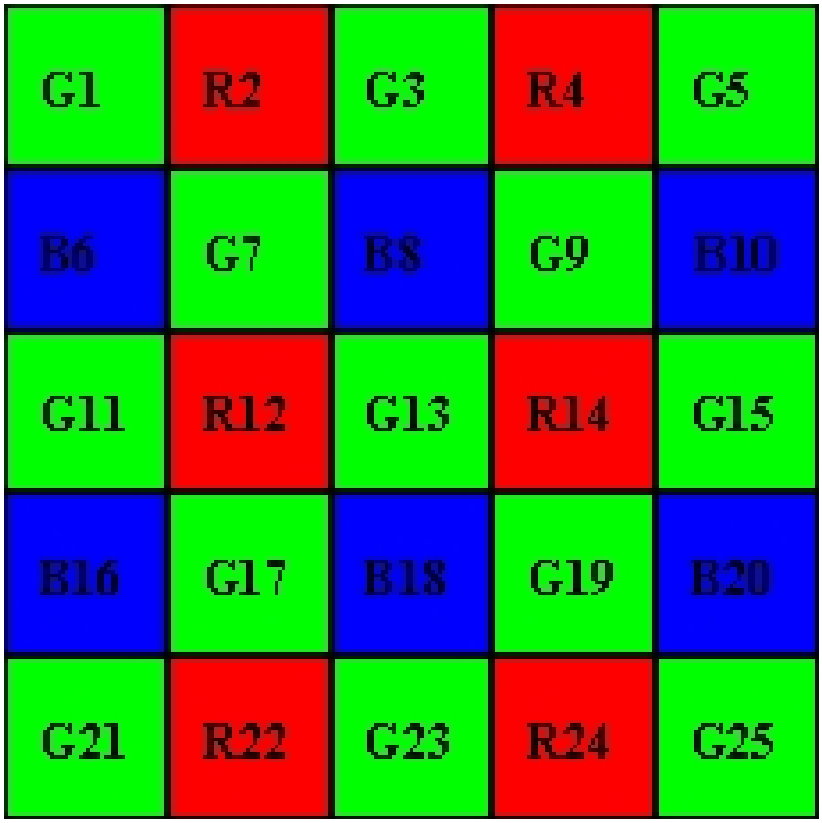

AN 60
COLOR PROCESSING AND BAYER COLOR

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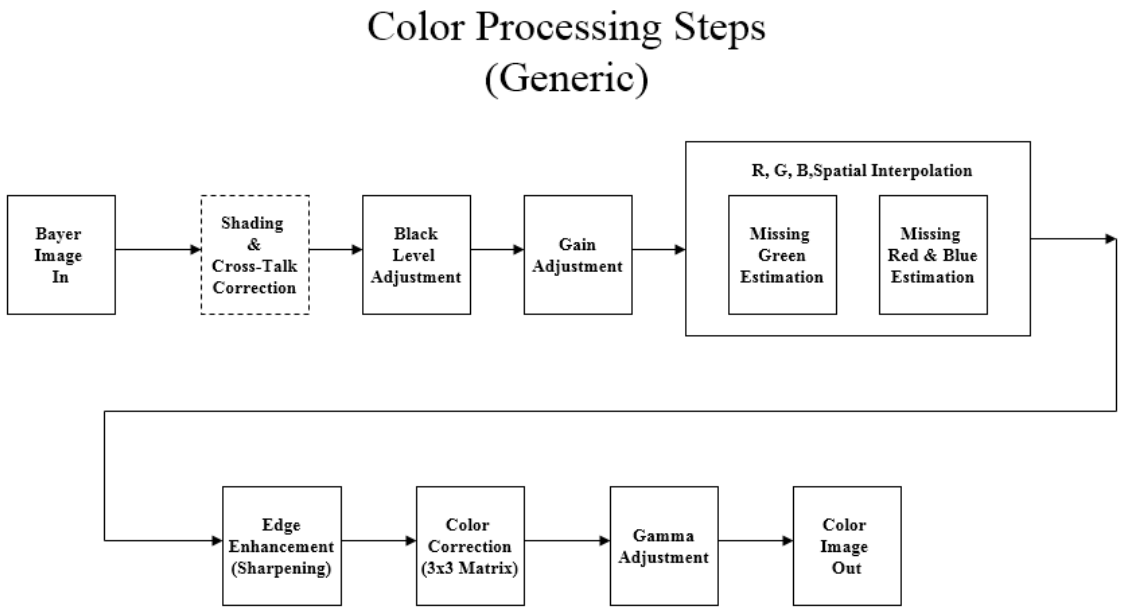
COLOR PROCESSING AND BAYER COLOR

The process of converting a RAW Bayer image into a color demosaic image is shown below in this block diagram. These steps are not always obvious to many that try to convert RAW images into brilliant color images. Much of the image science developed at Kodak was not published. The block diagram shown below defines how color conversion and correction was done in the 90's. A comprehensive paper published out of Standford **(A Study of Spatial Color Interpolation Algorithms for Single-Detector Digital Cameras, 1999**) gives detail of more alogrithms and suttle differences than shown here. In this app note, the intent is only to illustrate the Bilinear Interpoluation alogrithm.



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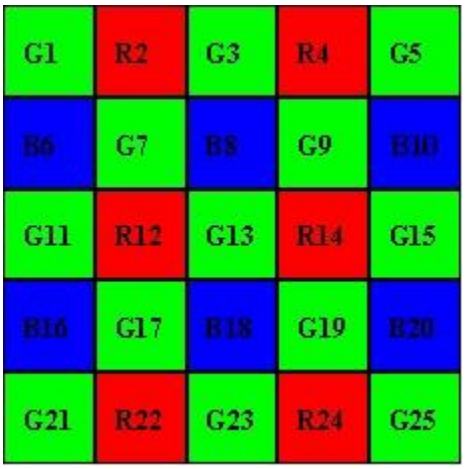
Bilinear Interpolation

This algorithm known as the Bilinear Interpolation has been published and is simple to convert RAW into Color for many cameras.

- For convenience, figure 1 is a small area off an array



- Interpolation of green pixels: the average of the upper, lower, left and right pixel values is assigned as the G value of the interpolated pixel. For example: G8 = (G3+G7+G9+G13) / 4

- Interpolation of red/blue pixels:
  - Interpolation of a red/blue pixel at a green position: the average of two adjacent pixel values in corresponding color is assigned to the interpolated pixel. For example: B7 = (B6+B8) / 2 ; R7 = (R2+R12) / 2

  - Interpolation of a red/blue pixel at a blue/red position: the average of four adjacent diagonal pixel values is assigned to the interpolated pixel. For example: R8 = (R2+R4+R12+R14) / 4 ; B12 = (B6+B8+B16+B18) / 4

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Color

To produce color, the sensor has a Color Filter Array [CFA]. This CFA will filter light into red, green and blue wavelengths for certain pixels. The filtered pixels are later interpolated into a full 24-bit or 30-bit color space.

Color Filter Array

A Color Filter Array (CFA) on the sensor produces full-frame, accurate-color images. Kodak was granted a U.S. Patent for this CFA called a Bayer pattern but since has expired. It is designed for progressive scan sensors. The array is composed of a kernel of 4 pixels. The filters are deposited during fabrication of the sensor. Two corner pixels are green while the opposite corners are blue and red. An interpolation is designed to take the Bayer pattern and interpolating the two missing color pixels. Three color values per pixel must be calculated, red-green (rmg), green (g), and blue-green (bmg). All of the green pixels, rmg and bmg must be calculated. At the red pixels, bmg must be calculated. At the blue pixels, rmg must be calculated. Color difference values are obtained from horizontal, vertical or bilinear interpolation of the color difference values at the chroma pixels. Solving for the missing green pixel, g' in the array is as follows:

line 1	B1	G1	B2	G2	B3
line 2	G4	R1	G5	**R2**	G6
line 3	B4	G7	B5	G8	B6
line 4	G10	R3	G11	R4	G12
line 5	B7	G12	B8	G13	B9

At a horizontal edge: missing green pixel (g') = 1/2(G5+G6) [1]

At a vertical edge: missing green pixel (g') = 1/2(G2+G8) [2]

Both edges or no edges: missing green pixel (g') = 1/4(G5+G6+G2+G8) [3]

Using the missing green pixel (g'), the rmg and bmg values are calculated as follows for a red line:

line 1	B1-g'	G1	B2-g'	G2	B3-g'
line 2	G4	R1-g'	**G5**	R2-g'	G6
line 3	B4-g'	G7	B5-g'	G8	B6-g'
line 4	G10	R3-g'	G11	R4-g'	G12
line 5	B7-g'	G12	B8-g'	G13	B9-g'

examples:

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horizontal interpolation

rmg @ G5 green pixel = 1/2 [(R1-g') + (R2-g')] [4]

vertical interpolation

bmg @ G5 green pixel = 1/2 [(B2-g') + (B5-g')] [5]

bilinear interpolation

rmg @ B5 blue pixel = 1/4 [(R1-g') + (R3-g')+ (R2-g') + (R4-g')] [6]

bilinear interpolation

bmg @ R2 red pixel = 1/4 [(B2-g') + (B5-g')+ (B3-g') + (B6-g')] [7]

Prior to these calculations, the pixels must have all offsets removed and be white balanced to achieve proper neutral tones. Other signal processing is done on the pixels after interpolation.

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