PRINCIPLES of DIGITAL PHOTOGRAPHY

COMPUTER BASICS – NUMBER THEORY

Computers are just large collections of electric switches that can be either on or off, resulting in a zero or a one. Series of numbers are codes that sometimes cause the computer circuitry to perform a specific task, such as add two numbers, or can stand for certain mathematical values, or even letters in written text. More complicated codes are known as applications (computer programs) which can turn a computer into many different tools, such as a painting machine, or a photographic processor, a paste-up board for page layout, or a video editor.

Binary Numbers work on the powers of 2, just as Decimal numbers work on the powers of 10. Each new digit added to a number increases the capacity of the number system by 1 power of the base. For example 1 digit decimal allows counting from 0 to 9, 10 numbers. 2 digits decimal allows counting from 0 to 99, 100 numbers, and so on.

In binary numbers, 1 digit can count from 0 to 1, 2 numbers

0, 1

2 digits can count from 0 to 3, 4 numbers

00, 01, 10, 11

3 digits can count from 0 to 7, 8 numbers

000, 001, 010, 011, 100, 101, 110, 111

4 digits can count from 0 to 15, 16 numbers

0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111,
1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111

2, 4, 8, 16 are the first, second, third, and fourth powers of 2.

$2^1 = 2$	$10^1 = 10$
$2^2 = 4$	$10^2 = 100$
$2^3 = 8$	$10^3 = 1{,}000$
$2^4 = 16$	$10^4 = 10{,}000$

Numbers in computers are usually grouped into packets of 8 digits or bits each, called bytes. The first desktop computers were based on 8 bit bytes. Then they built better systems based on 16 bits words made of 2 bytes each. The current systems are 32 bits wide. When you hear about the 64 bit PlayStation, now you know that this small game machine is actually more powerful than most desktop computer systems! Although, 128 bit computers will be here soon.

When larger numbers are used, many digits are involved. In this case shortcuts are made in the written language.

- KB stands for Kilobytes, thousands of bytes. $2^{10} = 1024$ = Kilobyte = 1000 bytes
  Most text files are in this range.
- MB stands for Megabytes, millions of bytes. 1 Megabyte = 1000 KB
  Most picture files are in this range.
- GB stands for Gigabytes, billions of bytes. 1 Gigabyte = 1000 MB
  Most hard drives have this capacity.
- TB stands for Terabytes, trillions of bytes. 1 Terabyte = 1000 GB
  Storage systems are on the way soon to work with those 128 bit computers.

ELECTRONIC IMAGING

TELEVISION and ELECTRONIC IMAGE DISPLAY

Television is the original electronic medium for visual images. It consists of a receiver and a CRT (cathode ray tube). The electron guns in the back of the CRT shoot electrons at a piece of glass coated on the inside with phosphors. An electromagnet controls the flow of electrons so that, at the beginning of a frame, electricity strikes the screen at the top left corner and make it glow at the appropriate level. Then the beam moves a bit to the right and makes the next location glow, and so on until a Line is complete. First the odd lines are "drawn", and then the even lines. All the odd lines together are called the odd field, and all the even lines together are called the even field. Both fields together are called a frame. Because our electrical system runs at 60 Hz (cycles per second), there are 60 fields drawn every second, yielding 30 frames per second.

When the CRT was utilized for digital images from computers the screen was divided into an exact number of lines and an exact number of locations. Each of these locations is called a pixel, short for "picture element". The resolution of digital images is measured in pixels. The original video standard is 640 by 480 pixels. Current computer displays are usually higher resolution than that.

VIDEO SCANNING and CCD's

Inside a Digital Still camera is essentially the same circuitry as inside a Video camera except that it works in reverse - inputting rather than outputting a signal. The light sensitive chip is called a CCD (charge-coupled device). A circuit looks at the light hitting the very upper left corner of the chip, measures the intensity with a sample and hold (S&H) circuit. An analog to digital converter (DAC) then gives that voltage a numerical value. This is a movement from physical energy to electrical energy to numerical information. This number is stored in the camera's memory. The circuit then looks at the next location across on the surface of the chip and does the same thing, and so on, and so on. When the end of that row of locations if finished, the circuitry moves down a little and scans across the chip again, and so on, and so on, until the entire surface of the CCD has been measured and the light intensity values have been assigned numbers.

The same interlacing technique is used as in the television display. Realize that if an screen has a resolution of 640 x 480 (usually only a 14" screen) it will draw 307,200 pixels per second. Higher resolution displays have to draw even more pixels per second. And to create the display, the numerical information in the source signal must be converted from digital data to voltages (using an ADC). Now you know why computer monitors are that much more expensive that television sets.

It is this last step of converting the measurement to numbers that makes these cameras "digital". The original video cameras stored their measurements as voltages on a moving magnetic tape. This is a very inaccurate system, and when making a copy of a tape, the energy patterns cannot be exactly duplicated. When a digital representation of a picture (still or video) is duplicated, every copy is an exact duplicate of the numbers in the first copy, so there is no signal degradation, and the output looks as good as the original. Essentially, listening to an audio CD is the same as listening to the studio master.

DIGITAL PICTURE DATA

RESOLUTION

The resolution of a digital camera is the number of pixels (picture elements) the device is capable of recording. Most digital still cameras made presently are called mega-pixels cameras because they have over one million pixels or resolution. The most common resolutions are 1280 x 960 and 1600 x 1200, which are aspect rations of 4:3. This varies from any previous camera aspect ratio, such as 2 x 3 for 35mm film, 2 $^{1}/_{4}$ square for medium format, and 4 x 5 for large format films. The newest cameras have a resolution of 1600 x 1200, containing over 2.1 million pixels.

1280 wide x 960 high x 24 bits deep = 29,491,200 bits (1.3 Megapixels)
divided by 8 bits per byte = 3,682,400 bytes

1600 wide x 1200 high x 24 bits deep = 46,080,000 bits (2.1 Megapixels)
divided by 8 bits per byte = 5,760,000 bytes
an increase of 156.42%, approx. 1 $^{1}/_{2}$ times

COMPRESSION

To store this much data on a storage device, digital cameras employ various types of compression. The most common compression is JPEG that has a range of settings to create picture files of varying sizes. JPEG compression works by losing the least important details of the photograph. The more the picture is compressed the more detail is lost. When a JPEG compressed picture file is loaded back into a computer, those details are recalculated, sometimes with poor results. Compression, then, is always a compromise between size and image quality. JPEG is a good compression scheme for the Web where speed of download is more important that the actual picture quality. This is also the format of choice for digital cameras because of its small file size. Files created in this format usually have an extension .jpg attached to the end of the filename.

PhotoShop employs its own compression scheme that does not lose any data. In addition, it retains all information about layers, channels, and paths. This is the best way to save working master files of pictures. Files created in this format usually have an extension .psd attached to the end of the filename.

When saving pictures after image processing in PhotoShop, the TIFF format also provides lossless data storage with LZW compression. This format retains only the pictures information (but none of the layers, channels or paths), and makes the files relatively small without losing any picture detail. This is the best format for saving manipulated files for printed output. Files created in this format usually have an extension .tif attached to the end of the filename.

STORAGE SPACE

Each digital cameras can store various numbers of pictures in their standard removable memory cards. Two types of cards are currently used - Compact Flash and Smart Media. This variance in capacity is usually a function of compression. Olympus uses the terms Super High Quality, High Quality, and Standard, and can store 18, 36 and 122 pictures in each mode respectively. Nikon on the other hand uses the terms Fine, Normal, and Basic modes, storing 8, 16, and 32 pictures respectively. Obviously Nikon is more conservative and will only compress their pictures a small amount rather than compromise image quality. Only the newest and most expensive 2.1 Megapixel cameras provide lossless TIFF compression. Very few pictures can be stored on a standard 8MB memory card with this format, but the quality is outstanding.