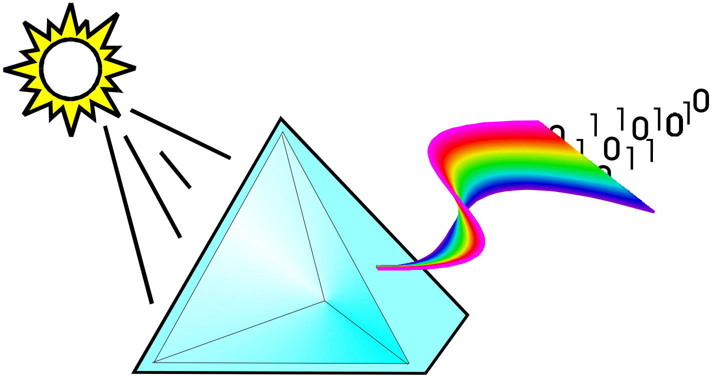
Color Processes

This chapter of the Core Technology Manual deals with color specific principles and processes. Discussions of monochromatic specific process or general subjects that are not affected by color will be found in other chapters.

Principles of Color

When discussing the processes involved in color copying, it is important to understand what light is and how just three basic colors can create a vast array of colors.



Electromagnetic Waves

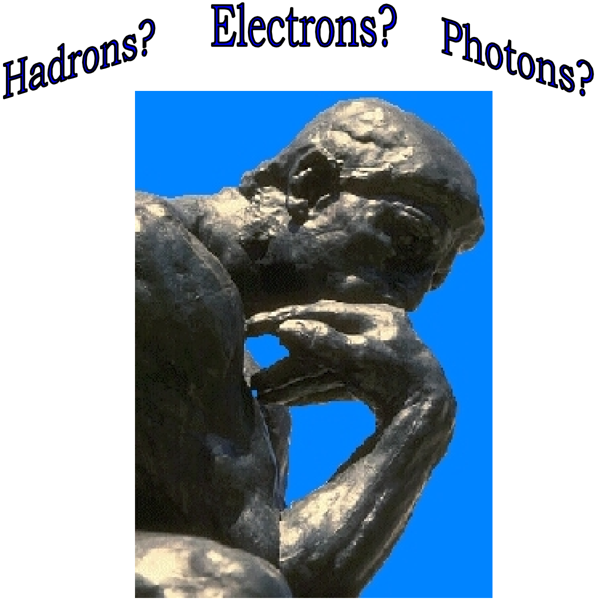
Once thought to be the smallest particles of matter—atoms—have over time been shown to consist of a variety of subatomic particles. These subatomic particles are organized into three groups—hadrons, leptons, and bosons.

The first group, the hadrons, includes among others the protons and neutrons that are found in the nucleus of the atom.

Of the second group, the leptons, the electron is the most important from the standpoint of color. Electrons are part of ordinary matter; the volume of an atom is nearly all occupied by the cloud of electrons surrounding the nucleus.

The final group the bosons, includes the particles responsible for carrying the fundamental forces of the universe such as electromagnetic energy and gravity. One of them is a particle of major interest here, the photon. You can think of the Boson group of particles as the universe's tiny energy transporters. Photons then, are particles that form a packet of electromagnetic energy and can transport this energy.

All matter and energy (as they are understood at present) consist of these particles. All matter that we normally deal with is made up of atoms. For our purposes, we will consider an atom to consist of a positively charged nucleus surrounded by a negatively charged cloud of electrons. These

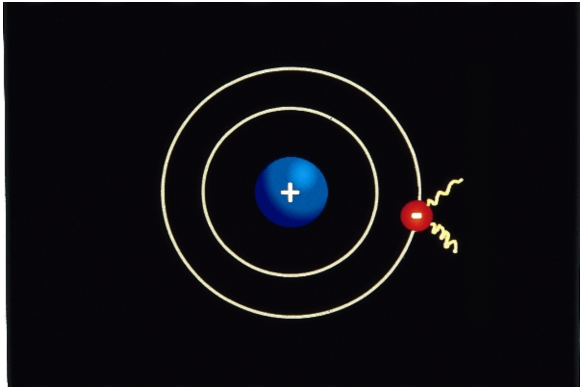


What do these particles have to do with color?

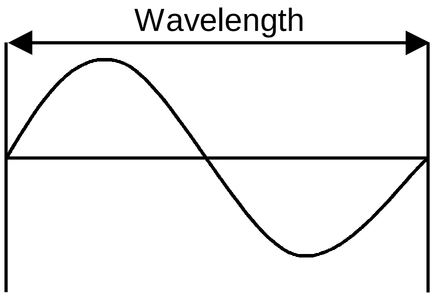
negatively charged electrons encircle the nucleus in fixed orbits or shells. Each shell has its own energy level, and when energy is to be released from the atom, we will call upon the boson group of particles to transport this energy outward.

If sufficient energy, say in the form of heat, is applied to the atom, one or more of the orbiting electrons will be forced to move to an outer shell. This process is referred to as *absorption*. An atom in which the electrons are boosted to higher energy levels is said to be in an excited state.

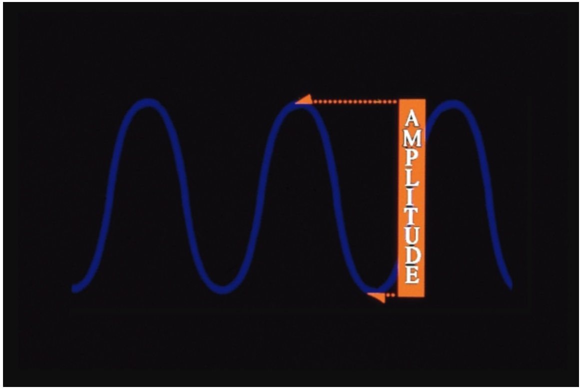
As the electron returns to its “normal” energy state, electromagnetic radiation is released. This process is referred to as *emission*. One type of electromagnetic radiation is visible light. The color of the visible light depends on the atom, how far the electron moved to return to its initial orbit, and how much energy was released.



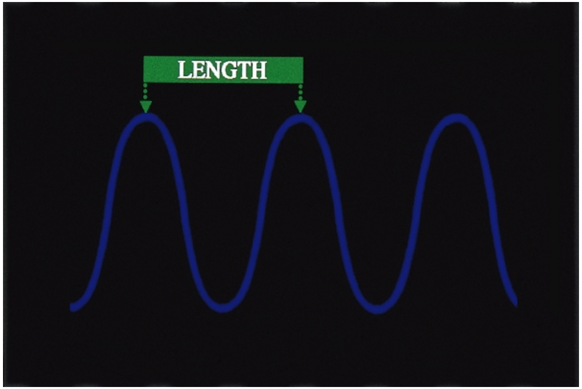
Electromagnetic radiation consists of rapidly changing electrical and magnetic fields, and is released from the atom in the form of particles or “packets” of energy. These tiny packets of electromagnetic energy are referred to as photons. These particles of radiation released in mass numbers take on the characteristics of a wave. The three wave characteristics of amplitude, wavelength, and frequency are described below. Photons are sometimes defined as particles of energy that behave like waves.



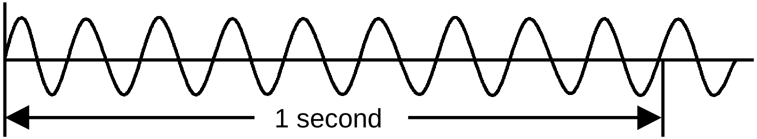
Along the radiation wave, the electric and magnetic fields oscillate or go up and down in strength. The amount that the wave varies in strength is the *amplitude*.

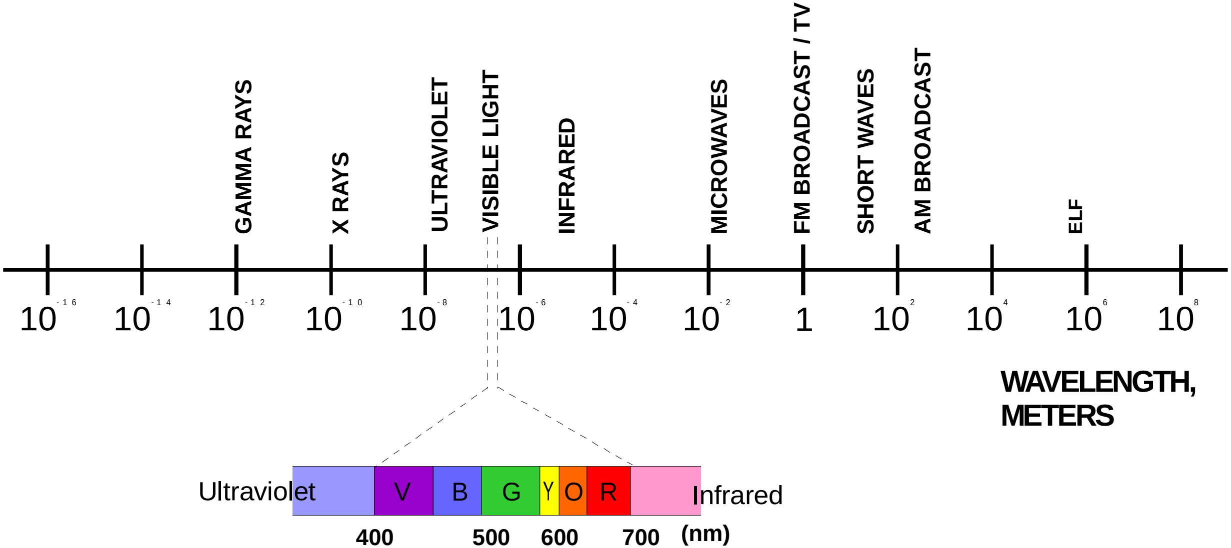


The distance between one peak of the wave to the next in either the electric or magnetic field is called *wavelength*, which is measured in meters.



And, the number of peaks that pass a given point in one second is called the *frequency*. Frequency is measured in Hertz (Hz).



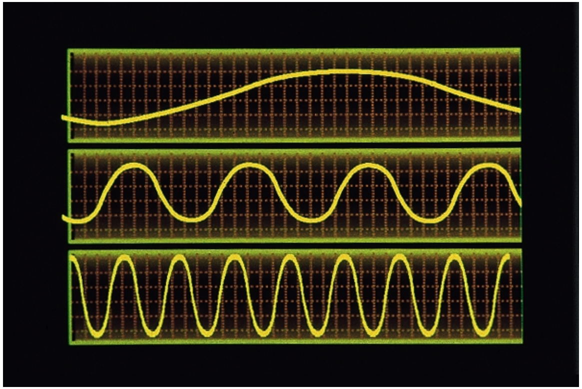


Electromagnetic radiation covers a very broad spectrum of wavelengths. From the longest—the extremely long frequency radio waves (ELF)—through radio waves, television, microwaves, radar, infrared, visible light, ultraviolet, x-rays and on down to the shortest waves—the gamma rays.

The principle difference between the various kinds of radiation is their differences in wavelength, frequency and energy. As the wavelength decreases, both the frequency and energy increases.

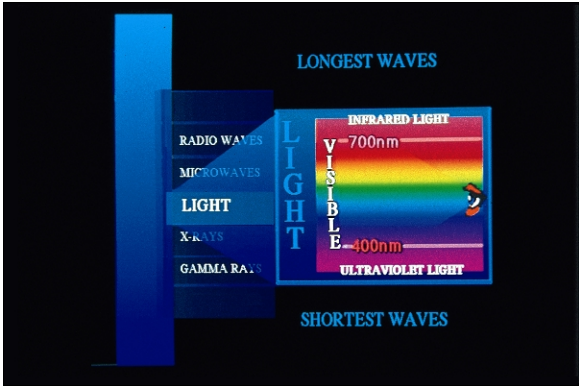
Notice that visible light occupies only a narrow band of the spectrum between about 400 and 700 nanometers.

- Some wavelengths are long and less frequent.
- Other wavelengths are short and more frequent.
- The longer the wavelength the lower the photon's energy.
- The shorter the wavelength the greater the photon's energy.
- A red photon of light (longer wavelength) has about half the energy as that of a blue photon of light (shorter wavelength).

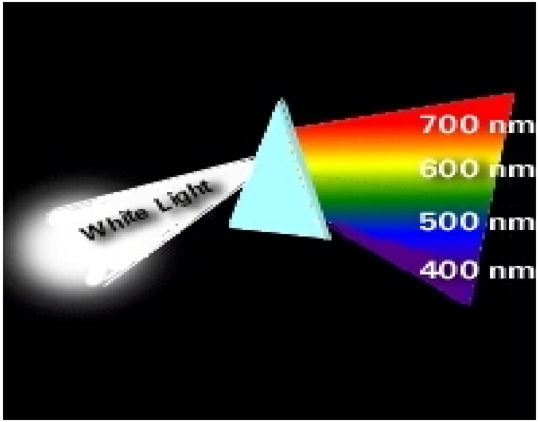


The Visual Spectrum

Visible light occupies a very small portion of this continuous spectrum. The electromagnetic energy with wavelengths of between about 400 nm and 700 nm makes up the entire visible light spectrum. (The abbreviation "nm" refers to a unit of measure called a nanometer. One nanometer is equal to 0.000000001 meters or written in exponential form 1×10^{-9} meters.) This range of wavelengths consists of all the colors of light that humans are able to perceive. White light contains all these wavelengths and hence, contains all the colors of the visible spectrum.



This can be demonstrated through the use of a prism. A prism works on the principle of refraction, or the bending of light. As light passes through dense matter (such as glass), longer wavelengths of color bend less than shorter ones. In this manner the various wavelengths of color bend differently from one another. The result is that all the individual colors that make up white light are separated from one another, producing a "rainbow" of colors.



As you can see in the previous illustration, the divisions between the colors are not pronounced or sharp. If you begin at the top, you may notice the color red, then going down through the spectrum you may be able to pick out a reddish-orange, then maybe an orange, a yellowish-orange and so on down through to the color violet.

We perceive certain colors based on the proportion of one color to another. For example, if the ratio of yellow light to orange is 1:1, we would perceive the color as yellowish-orange. If the ratio was increased to 2:1, we would perceive the color as yellow-yellowish-orange, and so on. There are, however, three primary colors of light that when any two are mixed together, in equal amounts, a new or secondary color is produced. And, when all three of these colors of light are blended together in equal amounts "white light" is produced. The three primary colors of light that best produce this effect are the colors red, green, and blue.

Range of Wavelengths	Color
400nm to about 500nm	Blue
500nm to about 600nm	Green
600nm to about 700nm	Red

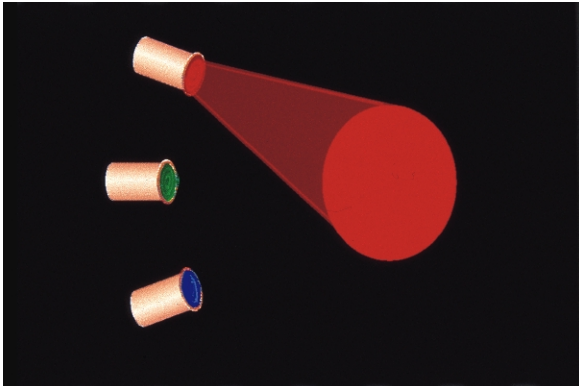
Since all the various colors of light, as well as white light, can be created by combining these three colors in varying amounts, it is then possible to categorize visible light (from about 400nm to about 700nm) into three basic categories

Reflection and Absorption

Luminous Color and Intrinsic Color

We see objects that create, reflect, or transmit, visible light. Objects that create light are said to be luminous. Luminous color is the color emitted by an object, and is dependent upon the wavelengths produced. Objects that reflect or transmit light are said to be intrinsic. Intrinsic color is the result of the wavelengths of light that are bounced off an object (reflected), or that are allowed to pass through a translucent or transparent object (transmitted color).

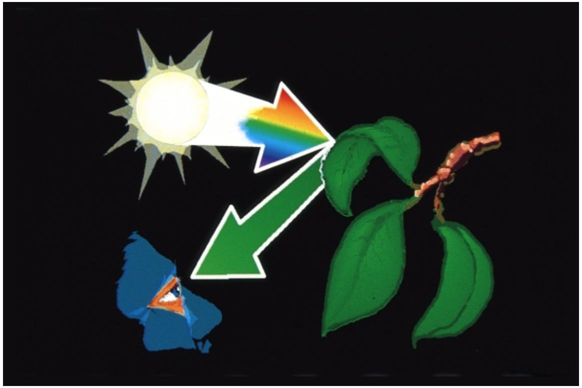
For example, the sun, a candle, a television or a red spotlight are all examples of luminous color. They all generate light.



Reflection and Absorption

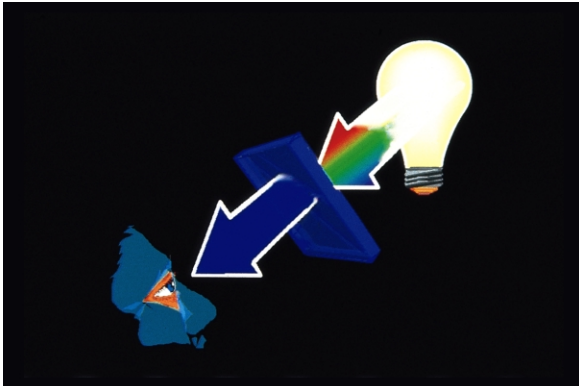
An orange, the pages in a book, a leaf or a transparent piece of blue glass have intrinsic color. The colors they produce are the result of absorbing or stopping some wavelengths of light, while reflecting or passing others.

As white light strikes the leaf, the green wavelengths are reflected, while the other wavelengths are absorbed.



When white light strikes the blue glass, the blue wavelengths pass through and all other wavelengths are stopped (absorbed). The eye perceives the color blue.

Substances which are colorless, such as air, are unable to absorb any of the wavelengths of light. Colorless substances either reflect all the wavelengths of light striking it, such as white clouds, or allow all the wavelengths to pass through, such as the glass in a window.

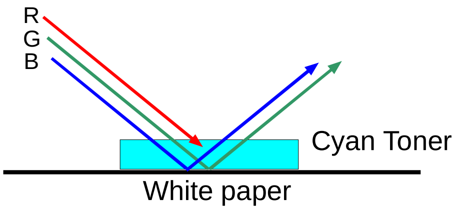


All the visible colors of light can then be expressed as some combination of three principle colors of light— red, green, and blue. It is this ability to reproduce all the colors of light using only three basic colors that is called *additive color mixing*. Red, green, and blue light are referred to as the three *additive primaries*.

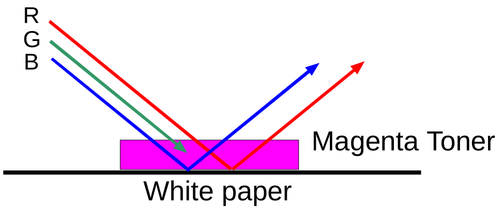
Light Reflective Characteristics of Color Toner.

The light reflective characteristics of color toner are of special interest to us. We will get into this in more detail later, but for now lets take a quick look at how color toner reflects light.

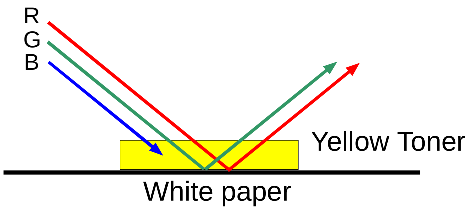
Cyan toner absorbs red rays and reflects blue and green rays. Reflected “B” and “G” rays are seen as cyan.



Magenta toner absorbs green rays and reflects blue and red rays. Reflected “B” and “R” rays are seen as magenta.



Yellow toner absorbs blue rays and reflects green and red rays. Reflected “G” and “R” light rays are seen as yellow.

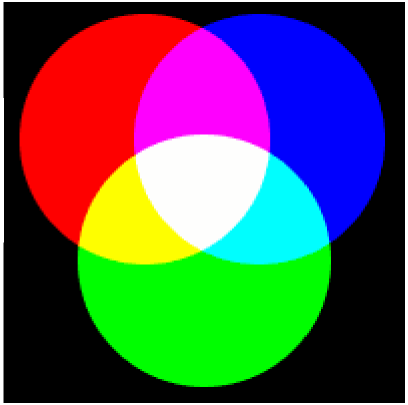


Color Mixing

The Primary Colors

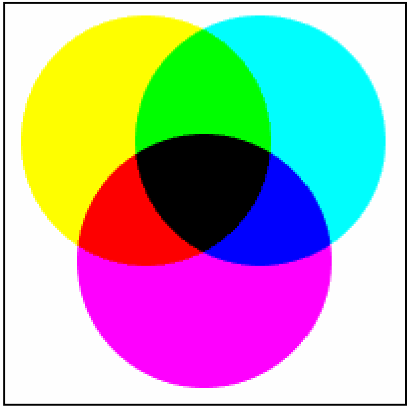
Colors can be created by mixing three primary colors in two basic methods. One is additive color mixing, which is the mixing of the three primary colors of light.

Additive color mixing uses red, green and blue.



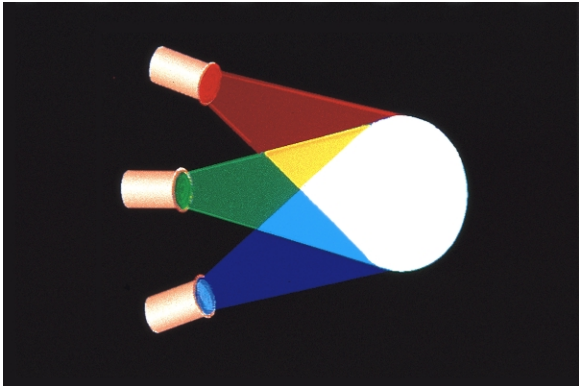
The other is subtractive color mixing, which is the blending of the three primary colors of pigment (such as ink, paint, or toner).

Subtractive color mixing uses cyan, magenta, and yellow.



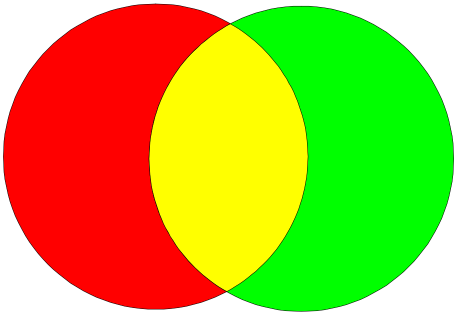
Additive Color Mixing

In additive color mixing red, green, and blue light are blended in various amounts to produce all other colors and white light. Additive Color Mixing is the process used by color televisions, and by color computer monitors.



As discussed earlier, if equal amounts of red light, green light, and blue light are mixed together, white light is produced. The resultant color created when mixing colors of light using the additive theory of color is “brighter” and lighter in color then either of its elements. The colors “ADD” together.

Red + Green → Yellow

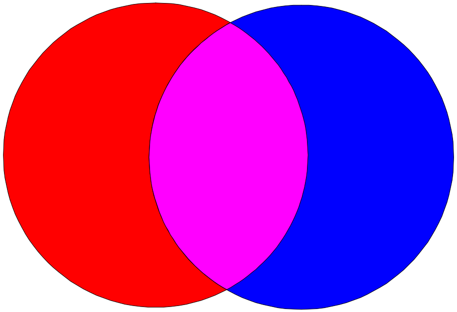


When only two of the three primary colors are mixed together, in equal amounts, the color created is referred to as a secondary color.

When equal amounts of red light and green light are mixed together, the color yellow is produced.

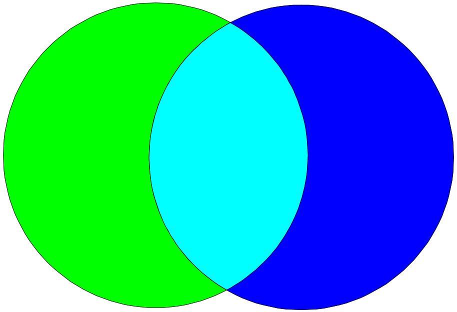
Mixing equal amounts of red light and blue light, produce the color magenta.

Red + Blue → Magenta



And when equal amounts of green light and blue light are mixed together, the color cyan is produced.

Green + Blue → Cyan



When one of the additive primary colors is combined with one of the secondary colors and the result is white or near-white light, the two colors are said to be *complementary*. For example, cyan light consists of green and blue light, adding cyan to red light would create white light. So, the color cyan and the color red are considered to be complementary colors.

By the same reasoning, the color magenta is formed by the mixing of equal amounts of blue light and red light. If these colors were added in the correct proportions to green light, white light would be the result. Magenta and green are complements.

The table lists the additive primaries and their complementary colors.

When mixing pigments, such as ink or dye, these complementary colors are used as the principle or primary colors in a process known as *subtractive color mixing*.

Additive Primary Color	Complementary Color
Blue	Yellow
Green	Magenta
Red	Cyan

Subtractive Color Mixing

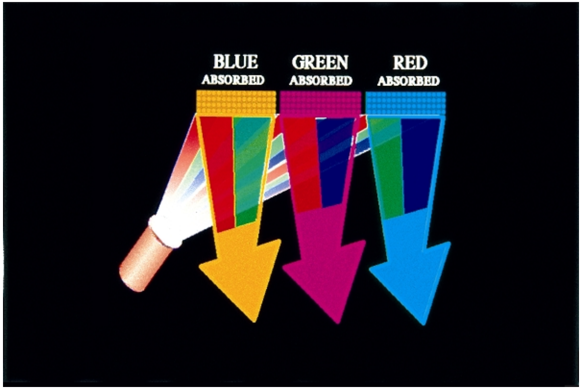
Mixing colors of light is one thing, but mixing opaque colors such as pigments or dyes is quite another. For example, red and green pigments will not blend to produce the color yellow no matter how hard you try. This is because these materials get their color by absorbing or “subtracting” certain amounts of red, green, and blue light, and reflecting what is not absorbed.

This means that a pure red pigment would absorb blue and green light and reflect only red light; a pure green pigment would absorb red and blue light and reflect only green light; and a pure blue pigment would absorb red and green light and reflect only blue light. The mixing of any two of these three pigments, red, green or blue would result in all three primary colors of light being absorbed, which is black. So as you can see, in a three color print process, using the colors Red, Green, Blue, as pigments would not work. What must be determined are the three principle or primary subtractive colors.

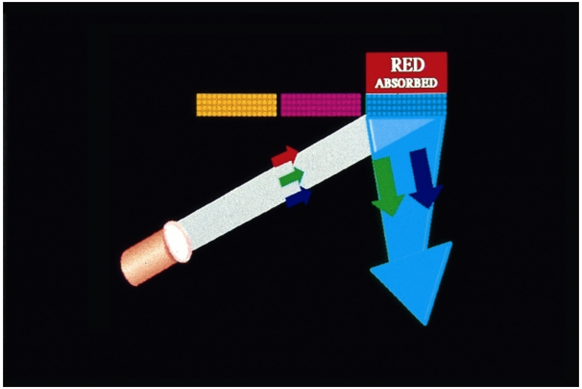
As you read the above paragraph you may have noticed that for each color pigment: pure red, pure green, and pure blue; two colors of light were absorbed or subtracted by each. If we had three different colors, colors that would each absorb only one color of light, then by mixing these three colors we could control the absorption of any combination of the three colors of light, resulting in the ability to create any color.

As we mentioned earlier three separate colors do exist that will each absorb only one of the three colors of white light, namely the complementary colors of red, green and blue which are *cyan, magenta,* and *yellow*. These three colors are referred to as the *subtractive primaries*.

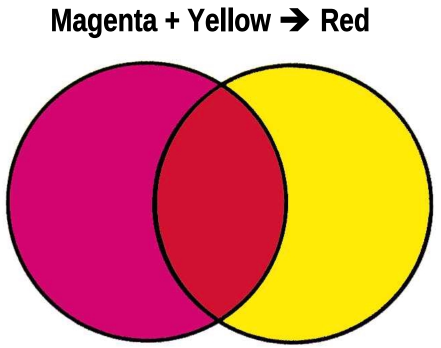
Cyan, Magenta and Yellow will each absorb a different additive primary and reflect the remaining two.



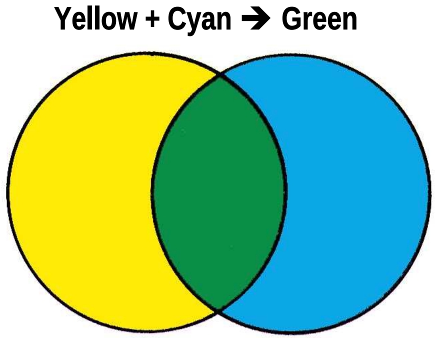
When white light strikes a pure yellow pigment the additive primary blue is absorbed and the remaining two additive primaries, red and green, are reflected. Remember, red and green light create yellow light. When white light strikes a pure magenta pigment, green is absorbed and red and blue are reflected. Red and blue light create magenta light. And as shown here, when a pure cyan pigment is used, red is absorbed and green and blue are reflected. (Green and blue = cyan)



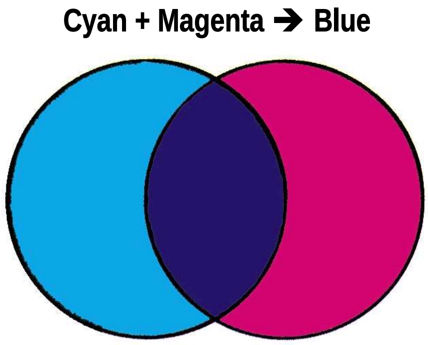
When magenta pigment (the circle on the left) is mixed with yellow pigment (the circle on the right) in equal proportions the color red is produced (center).



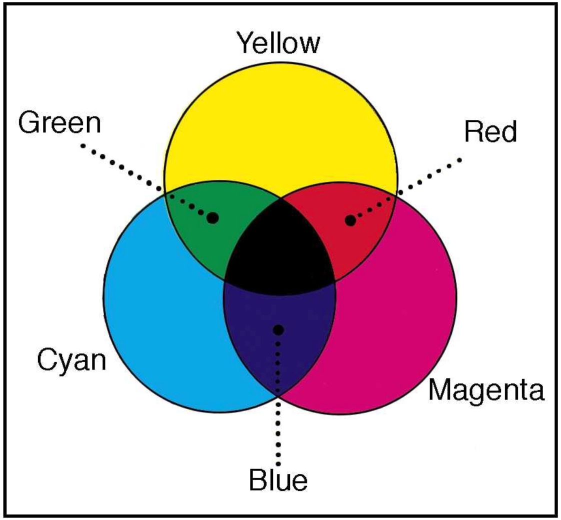
When yellow pigment and cyan pigment are mixed together in equal proportions, the color green is produced.



When cyan pigment is mixed with magenta pigment in equal proportions, the color produced is blue.



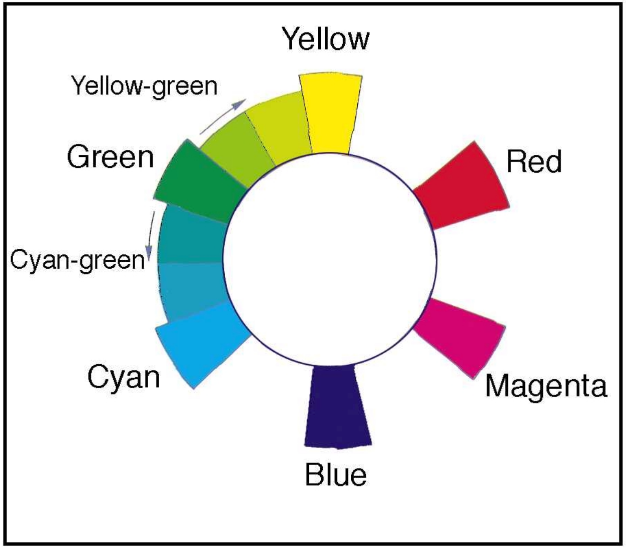
When all three colors: cyan, magenta and yellow are blended together in equal pro-portions, the result is that all the wavelengths of light are absorbed, and black is produced. This black color is referred to as “processed black,” and depending on the purity of the colors for cyan, magenta, and yellow will actually appear to be a very deep blue or brown.



The final color created, when mixing pigments using the subtractive theory of color, is always “darker” and deeper in color than either of its elements. The colors, when mixed together, “Subtract” light from being reflected.

The colors, cyan, magenta and yellow, known as the subtractive primaries, will be the colors used to print the images when using the three color print process.

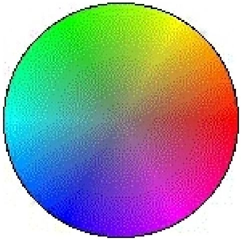
The illustration to the right is an example of a simple “color wheel.” Starting at the color green and following the top arrow, moving clockwise toward red is the color yellow. Remember, yellow is produced by mixing equal amounts of green and red light. Continuing clockwise past red is the color magenta, which is a mixture of red and blue light. Then comes cyan and so on... Notice that each portion of the color wheel points to its complementary color. For example the red “wedge” points to its complement cyan. The blue wedge to its complement yellow.



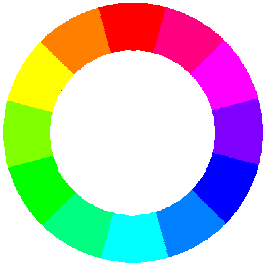
Not only does this color wheel show the relationships of the additive primaries, it also demonstrates the relationships of the subtractive primaries. For example, yellow and cyan pigments mixed in equal amounts create green. The color “green” sits between yellow and cyan on the color wheel. Green also points to its complement which is magenta. There are other, more elaborate color wheels, that can also demonstrate all the various “hues” of colors created as the proportions of the various colors mixed are changed.

Familiarizing yourself with the color wheel can be a strong aid to obtaining a specific color. For example, using the color wheel, when equal proportions of magenta and yellow pigments are mixed, red is produced. If the amount of magenta was reduced the color would take on a more orange look to it. Reduce the magenta even more and the color would begin to appear more and more yellow. Understanding these concepts of how cyan, magenta and yellow interact in forming all the printed colors are important in both operating and servicing any device using the three color print process, such as a full color copier.

Some Color Wheels



A continuous color wheel



An additive mixing color wheel

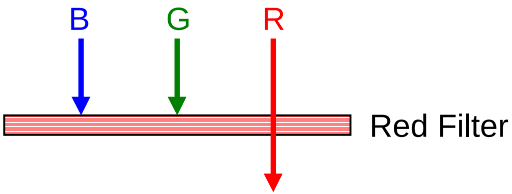
A subtractive mixing color wheel

Color Separation

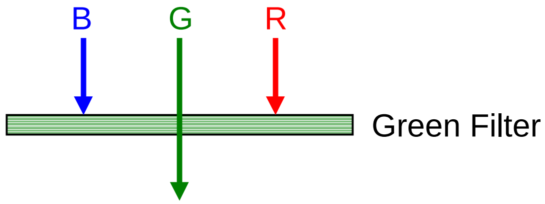
"Color Separation" can be thought of as the opposite of "Color Mixing." The process of color separation will take a full color image and "break it down" to its fundamental or primary components. This is accomplished using the intrinsic color transmission properties of optical filters. Although the process of color separation can be accomplished by using either the additive filters—Red, Green, or Blue (R,G,B), or subtractive filters—Cyan, Magenta, or Yellow, when used in the three color print process, such as used in color copiers, generally R,G,B filters are used. For this reason we will limit our explanation to the use of these three filters.

The Characteristics of Filters

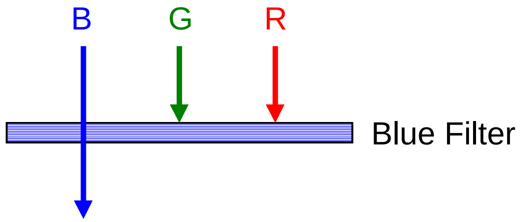
Red Filter—The "Red" filter allows "Red" light to pass through and absorbs "Blue" and "Green".



Green Filter—The “Green” filter allows “Green” light to pass through and absorbs “Blue” and “Red”.



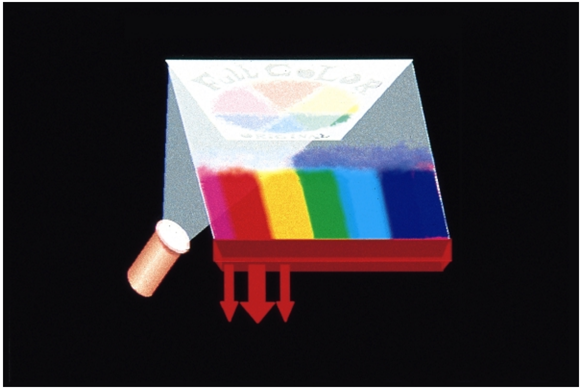
Blue Filter—The “Blue” filter allows “Blue” light to pass through and absorbs “Green” and “Red” rays.



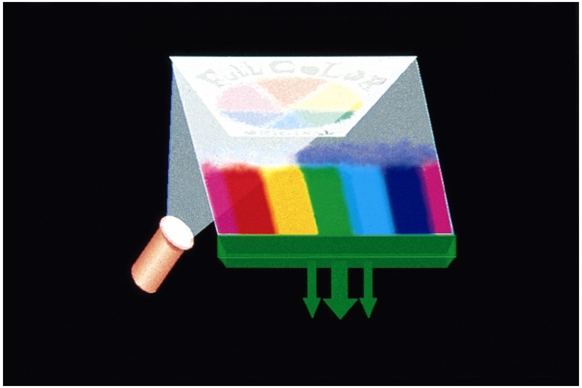
Let’s look at the separation process...

White light is first cast upon a full color image or object. Depending on the color of the image or object, certain wavelengths of light will be absorbed while others are reflected. The colors which are reflected can be considered as being composed of various proportions of the three primary colors: red, green, and blue.

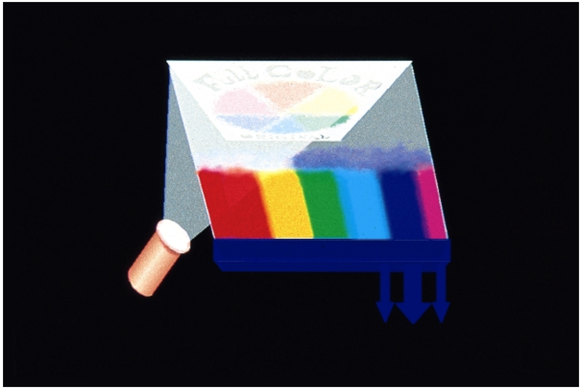
By passing the reflected light through a red filter, only the reflected light that consists of a red component will pass through. The intensity or amount of red that passes through is in direct proportion to the amount of red light reflected by the image. In other words, a pure yellow pigment would reflect red and green light in equal amounts. A red filter passes only the red element, hence the intensity of the light passed is only half of when the red and green light were combined.



White light is cast on the image again. This time the reflected light is passed through a green filter. The filter transmits only the green element of each color; the other colors are blocked.



Again, white light is cast on the image. This time a blue filter intercepts the reflected light. Only the blue element of each color from the image is allowed to pass.



These steps are basically what occur during the *color separation* process in a full color copier. Each time white light is cast on the image would be equivalent to one scan of the copier. For each scan, the reflected image is passed through a different color filter. The end result is that the image is “broken apart" into its R,G,B, components.

Image Scanning

The three-scan process has been replaced by a four-scan process in almost all modern full color copiers. The fourth scan is used to determine how much black pigment or toner should be added to the reproduced image. This is because the pigment or toner colors used are not necessarily pure. The magenta used may not be a *pure* magenta color, the cyan, not a *pure* cyan, and the yellow, not a *pure* yellow. This is due primarily to manufacturing, since the materials used to create the pigment color must also meet a range of requirements that are independent of color, such as: resistance to *caking* or *clumping*, consistency of particle size, or in the case of liquids the *flow rate*. The materials chosen to meet all the specifications may not wind up being pure in *hue*. For this reason black toner is used to produce a more true black, instead of the bluish or brownish look of a processed black. The amount of black used is usually a percentage of the C,M,Y ratio used—a process referred to as *under color removal*.

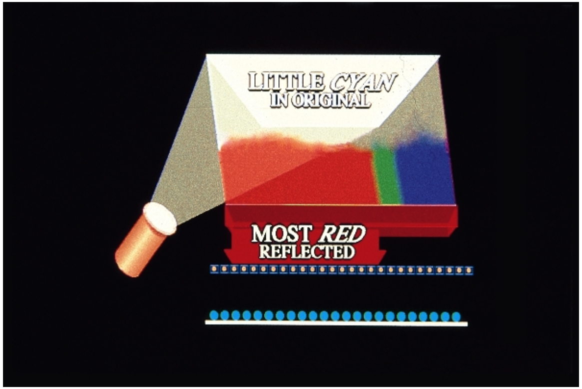
After scanning, the next process involves using the RGB separated color data and determining how much toner to apply. This is referred to as RGB to CMYK conversion (K = BLACK toner). This step is generally performed immediately after each scan before the next scan occurs. Since the subtractive primaries (C,M,Y) are the opposite or complements to the additive primaries (R,G,B), the amount of toner used is inversely proportional (or the opposite of) the amount of light transmitted through each filter.

Original image

CMYK separations after RGB to CMYK conversion

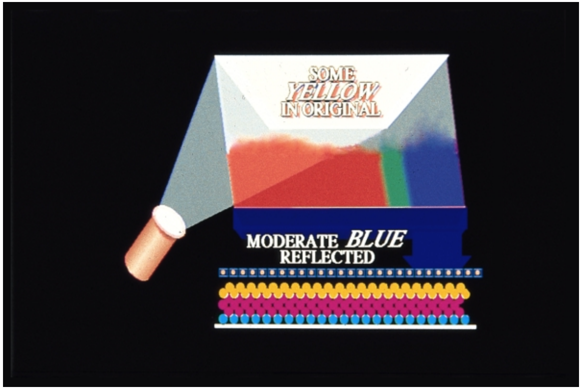
Let's examine the light transmission and toner selection for a solid pink original.

Since a large amount of red light is reflected from the pink image, then very little red light was absorbed. The color that absorbs red light is its complementary color cyan. Cyan pigment absorbs red light. Since very little red was absorbed by the image, the image must contain very little cyan pigment. So a very small amount of cyan toner will be used.

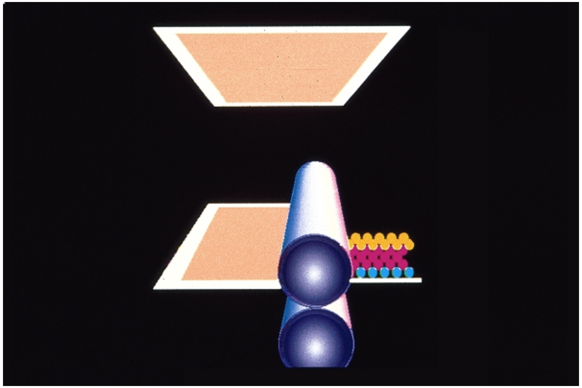


The pink original reflects only a very small amount of green light; so, a large amount must have been absorbed. The color pigment that absorbs green wavelengths of light is the complementary color of green, which is the color magenta. So, a large amount of magenta toner will be necessary to reproduce the color of this image.

Finally, the pink original reflects a moderate amount of blue light; so, a moderate amount must also have been absorbed. The color pigment that absorbs blue light is the complementary color yellow. And a moderate amount of yellow toner must be added to reproduce this image.



Blended together using heat and pressure, the end result is a copy or reproduction of the original image in full color. In this example the color "Pink" is reproduced.



By altering the proportions of cyan, magenta and yellow pigments used, based on the levels of red, green and blue light reflected, any color can be reproduced. Adding a fourth pigment, black, at the proper amount adds depth to the copy and improves black reproduction. And those are the basic processes surrounding light and color mixing.

Brightness, Saturation, and Hue

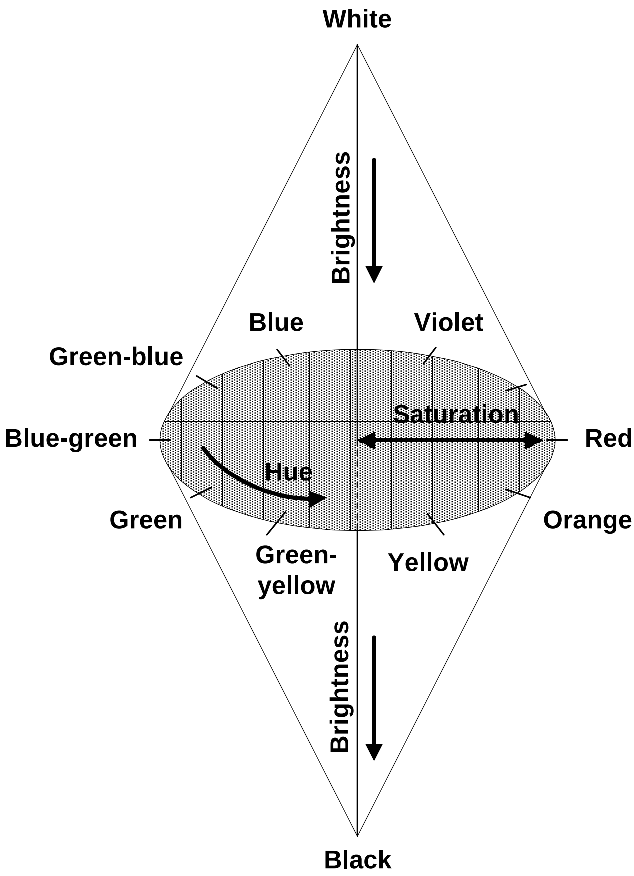
We will finish the section on the principles of color with a discussion of three important terms—*brightness, saturation, and hue*.

These color characteristics form one of the systematic models available for classifying colors. It is based on how the eye perceives shades of color.

Brightness: This is related to the amount of black or white in a color. It is also a measure of how much light the color is reflecting. Adjusting the lightness changes the intensity of R, G, and B but keeps their proportions the same. Brightness is also known as 'lightness'.

Saturation: Colorfulness with respect to a neutral gray (chroma is another term used). To adjust saturation, the intensity of the complementary RGB color is adjusted, keeping the dominant color the same.

Hue: This is the color of an object. It is a measure of the proportions of R, G, and B in the color.



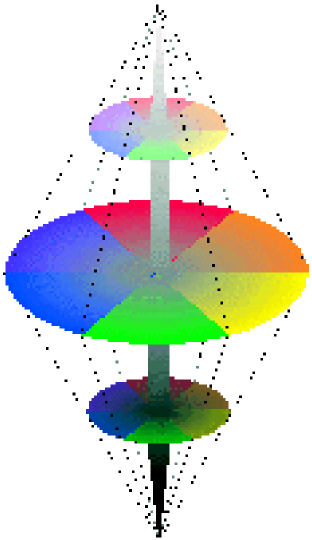
These three characteristics of color can be shown on a three-dimensional diagram as shown on the previous page. The illustration on this page is a color representation of this concept.

In this diagram, the *brightness* increases toward the top apex and decreases toward the bottom apex. All colors can be represented as a vertical color section in the solid, with a white apex at the top and a black apex at the bottom.

The colors going through the center of the solid from top to bottom are all shades of gray. Also, colors get brighter (more white) above the equatorial plane, and darker (more black) below it.

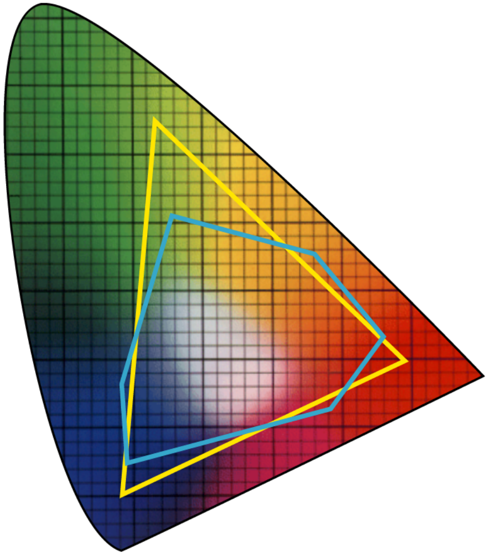
The colors get more intense as you move away from the vertical axis (the percentage of gray decreases). This represents increase in *saturation*.

Any horizontal slice through the solid yields our friend the color wheel. The *hue* changes as you move around the center.



A 3D “brightness, hue, and saturation” color diagram

Color Matching



In theory, color management is simple; the colors either match the original, or they don't. In practice, however, it is much more complex. While accurate color matching is a goal of almost every color process, it is not always possible. There are a number of technical elements that limit our ability to reproduce specific colors, as well as psychological elements that influence our perception of colors. Understanding these will help you create a close-as-possible color match.

Color Gamut

A color gamut is the maximum color range for a particular device. Different devices and different color processes have different gamuts.

The illustration on the right represents the entire visual spectrum—the color gamut visible to the human eye. The area inside the yellow triangle represents a typical RGB gamut. This is the color range that can be displayed on a typical monitor.

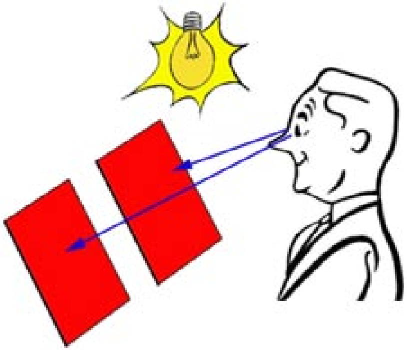
While the actual gamut will vary from monitor to monitor, it is always smaller than the visible range. There are always some colors that cannot be displayed.

The area inside the blue line represents a typical CMYK device. This, too, will vary depending on the quality of the printer or copier, but it is smaller than the RGB gamut. The unfortunate result is, some colors can be displayed on a monitor but cannot be printed. You can calibrate, adjust and manipulate the printer as much as you like—you won't get the desired color.

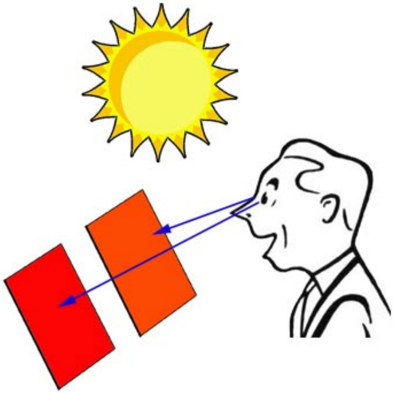
Dark blue shades are a common example. On some printers certain blues come out purple.

Metamerism

Metamerism is an illusion in which two or more colors appear identical under certain light sources, but are markedly different from each other under other lights. This is a common problem in the paint, printing and textile industries.



A typical example of metamerism occurs when you try to paint your living room to match your couch. You take a fabric sample with you to the hardware store, but while the paint chip and fabric sample match perfectly under the store's florescent lighting, they look quite different in your living room's blend of incandescent and natural light.



Metamerism is a particular problem for CMYK processes, where the colors are created from just three colorants.

Part of the problem is that, as we discussed earlier, light has color. Different light sources produce different colors—and these colors influence the appearance of fabric samples, paint chips and color copies.

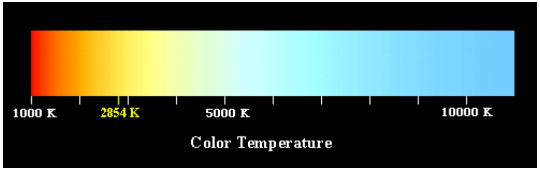
The color of a light source is described by its temperature. The temperature scale is calculated based on the amount of light emitted by a blackbody at any given temperature.

Blackbodies are theoretical objects that are perfectly black when cold. At zero degrees Kelvin they absorb all light cast upon them; however, as they heat up, they begin to emit light—first red, then yellow, then white and finally blue.

While perfect blackbodies do not exist, most solid objects are a good approximation of blackbodies. Think of the coils on an electric heater, the filament of an incandescent bulb, and even the sun and stars.

Color temperatures are measured using the Kelvin scale. Kelvin is similar to Celsius. The unit intervals are the same; however, zero K is equal to -273 degrees Celsius.

Note, hotter temperatures emit bluish light. Cooler temperatures emit reds. This runs contrary to most people's color intuition. Blue is usually seen as a cold color. Red as warm or fiery.



Color Temperatures	
12000 K	Clear blue sky at noon
11000 K	
10000 K	Graphics arts monitor
9000 K	
8000 K	North Sky Light
7000 K	Overcast Sky at noon
6000 K	Sunlight at noon
5000 K	Standard Color viewing lamps, Cool white florescent
4000 K	Photoflood tungsten, Warm white florescent
2854 K	Tungsten incandescent lamp
2000 K	Sunlight at sunset, Candlelight

Color temperature of standard light sources

When matching colors it is important to consider the light that the objects will be viewed under. Most professional color matching goes one step further—using strict lighting standards when comparing proofs. 5000 K is the default standard. This produces a completely neutral, white light source, similar to natural daylight. To be even more precise, the ANSI standard also defines the chromaticity, spectral power distribution, color rendering index, and intensity of the light for viewing different medium.

Color Memory

We are often disappointed with color reproduction, when the color does not live up to our memory of the scene. The truth is, colors that we remember are not always the colors we actually saw.

People tend to remember colors as being more vibrant, more rich than they actually where. If you take two prints of the same object, one with accurate coloring and one with over-saturated coloring, most people will pick the over-saturated one. It appears more alive and more interesting.

This is just one way in which psychology influences our definition of a “quality color image.”

For hands on experiments with interesting online applets, check out http://www.cs.rit.edu/~ncs/color

Normal colors

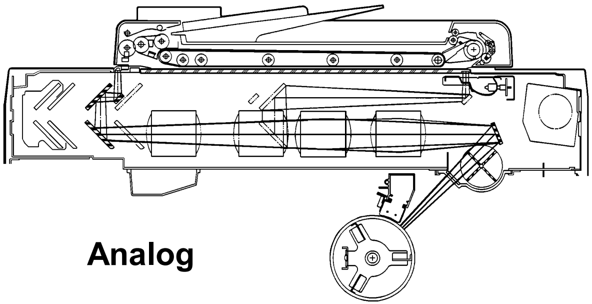
Over saturated colors

Color Scanning

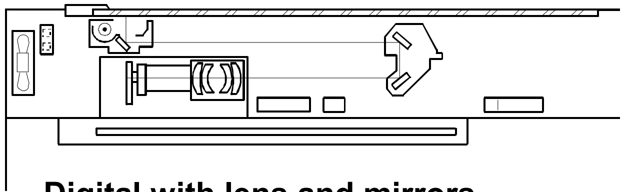
In this section we will look at the aspects of image scanning and photoconductor exposure that are unique to color systems. The details of processes that are common to both color and black/white systems are covered in *Photocopying Processes* and *Digital Processes* chapters.

Ricoh color products have used three different scanning methods, depending on the underlying basic architecture of the machines. These methods can be classified as color analog scanning/exposure, digital systems using lens and mirror scanning, and direct scanning digital systems using a fiber optic array. We will discuss and look at examples of each.

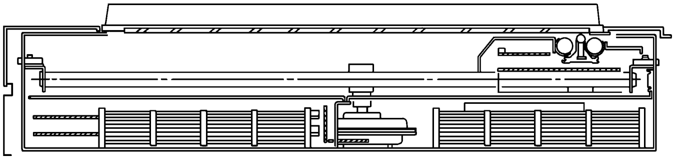
The number of scans that a color copier makes depends on the amount of memory it has. Most color copiers must make one scan per color. However, digital color copiers with a large amount of memory—for example *model A269*—can store the full image data for all colors and need only one scan per image.



Analog



Digital with lens and mirrors



Digital with fiber optic array

Analog Scanning

Most color machines are digital. However, there are some analog color machines in the field.

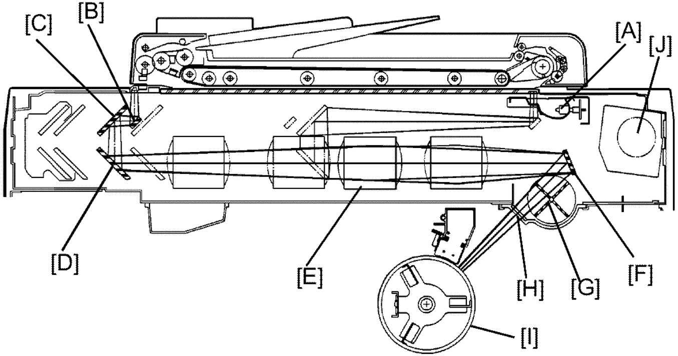
The color analog scanning and exposure is basically the same as the systems used for black and white analog copiers. (See and *Exposure* in the *Photocopying Processes* chapter.) The only difference is that filters have to be used to separate the colors and the original has to be scanned for each of the primary colors to be reproduced.

Example: Models A030 and A072

The illustration to the right shows the scanning mechanism of models A030/A072.

During the copy cycle, an image of the original is reflected onto the drum surface via the optics assembly.

Three *color filters* (red, green, and blue) and a neutral filter are mounted on a rotor. The three color filters are used when the full color mode is selected or single color erase mode is selected.

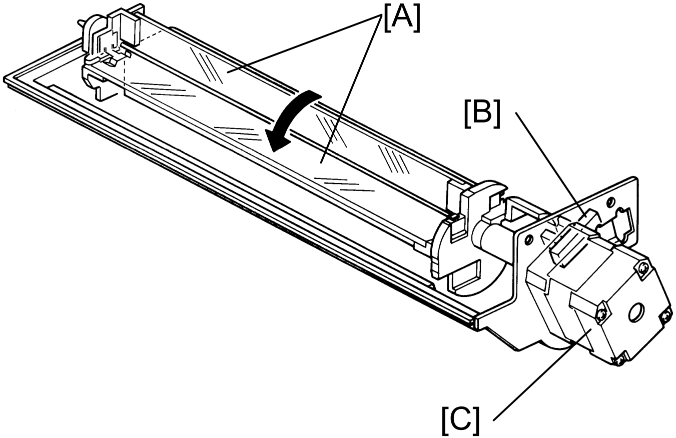


Exposure Light Path:
Exposure Lamp [A] ⇒ 1st Mirror [B] ⇒ 2nd Mirror [C] ⇒ 3rd Mirror [D] ⇒ Lens [E] ⇒ 4th Mirror [F] ⇒ Color Filter [G] ⇒ Toner Shield Glass [H] ⇒ Drum [I]

Optics cooling fan: [J]

The neutral filter is used when black copies or single color copies are made.

The filter rotor, which holds the four filters [A], is shown to the right. The rotor turns to bring the proper filter into the light path. A home position sensor [B] informs the CPU when the rotor is at the home position. A *stepper motor* [C] rotates the filter rotor the precise angle to bring the selected filter into the light path.



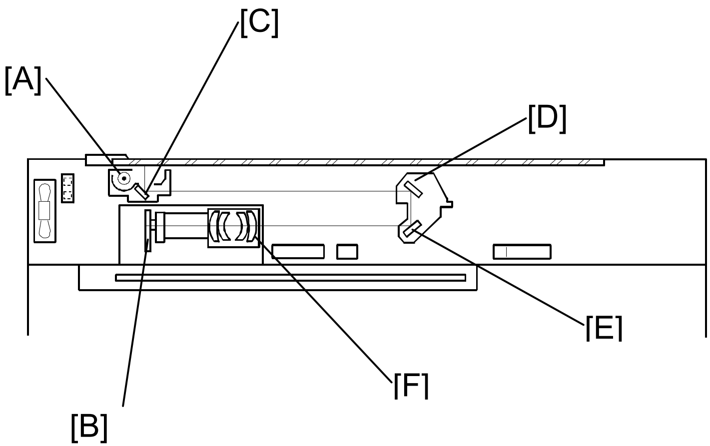
Lens and Mirror Digital Scanning

Most color digital machines use a lens and scanners with mirrors to reflect an image of the original to a *charge coupled device (CCD)*. This is very similar to the system used in most digital black and white copiers.

Example: Models A257 and A269

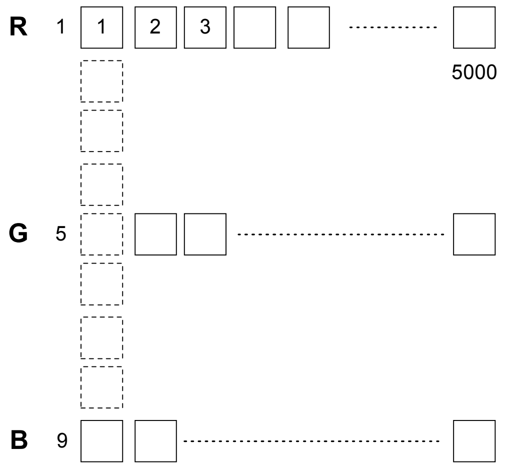
An image of the original illuminated by the exposure lamp [A] (a halogen lamp) is reflected onto a color CCD [B] (Charge Coupled Device) via the 1st [C], 2nd [D], and 3rd [E] mirrors, filter, and lens [F]. The filter removes infrared from the light reflected off the original; this is particularly important for glossy photos with black areas, which can appear reddish in copies.

For all copy modes except the "Auto Original Type" mode machine makes a single scan. The CCD is a one-chip color CCD with RGB color filters. The scanning resolution is 400 dpi (5,000 pixels).



The key element in digital color machines is the color *CCD*. The color CCD resembles the type of CCD used in black & white digital machines; however, it has three rows of light sensitive elements instead of one row. The color CCD converts light reflected from the original into three analog signals, one for each of the three basic colors Red, Green, and Blue. The signals are called the R, G, and B signals. A single scan generates a separate set of three signals (RGB).

The CCD consists of three lines of 5000 elements at a resolution of 400 dpi (15.7 dots/mm)—one line for each color. To make the R, G, and B signals, each line has a color separation filter (R, G, or B). The lines of CCD elements are very close together, but there is some space between them. In *model A269* the lines are spaced 4 pixels apart at full size magnification—illustrated to the right. (In many earlier models they are spaced 8 pixels apart.) To correct for the spacing, the R, G, and B signals must be synchronized. This is done by delaying the signals in memory buffers on the image processing unit (IPU) board. This process is called *scan line correction*.



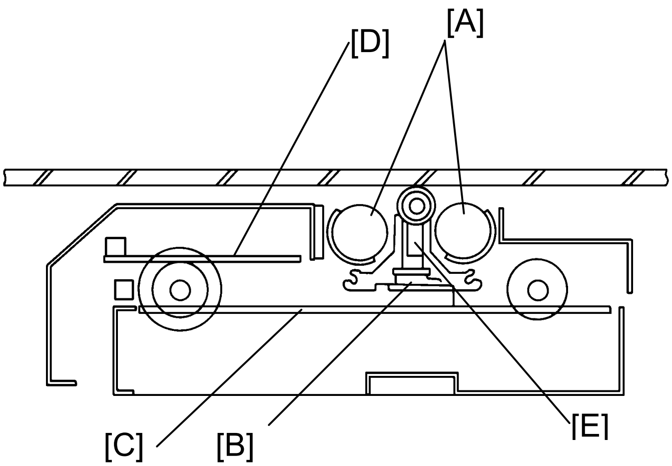
The CCD is mounted on the board with the lens block (the assembly is known as the SBU or Sensor Board Unit). Therefore, to replace the CCD, you must replace the SBU.

Direct Digital Scanning (SELFOC +CCD)

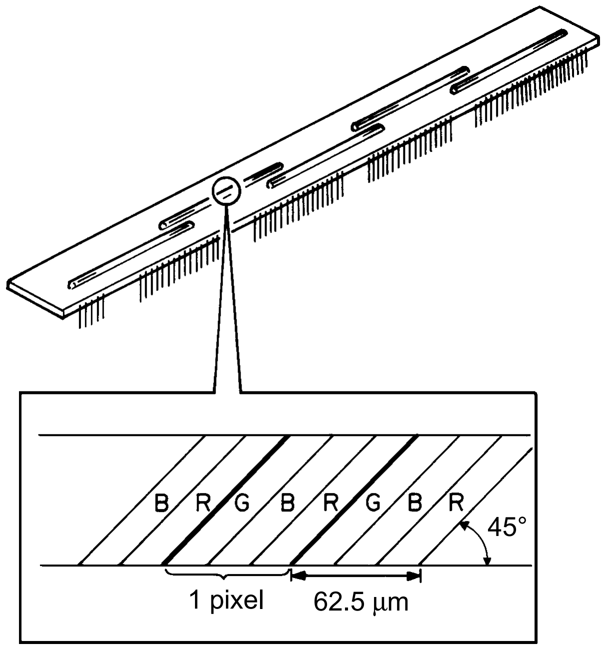
Color direct digital scanning systems use a self-focusing fiber optic array (SELFOC) and full-size CCD mounted together on a scanner. The basic principle of this method is quite simple. As the scanner moves across (scans) the original, a strip of the original is reflected through the fiber optic array to the CCD.

Example: Models A092 and A105

The scanner unit used in models A046 and A105 consists of two exposure lamps [A] (fluorescent lamps), the full-size CCD [B], the CCD drive board [C], the CCD pre-amp board [D] and the optical fiber array [E]. The light from the exposure lamps exposes the original and reflects on to the full-size CCD through the optical fiber array.



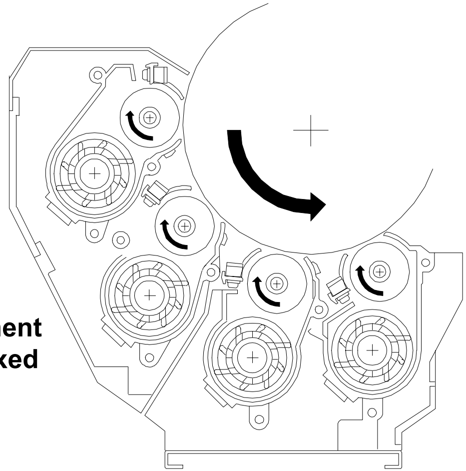
The full-size CCD board has an unusual design. There are 5 CCD chips on the CCD board, each CCD chip has 2,928 elements (2,880 elements for model A105). Each element has a tiny green (G), blue (B), or red (R) filter on top. This G.B.R. order is repeated along the full length of the CCD chips. One set of these G.B.R. elements is equal to one picture element or pixel. The CCD elements are angled 45 degrees, so that all three CCD elements of any pixel receive the same reflected light.



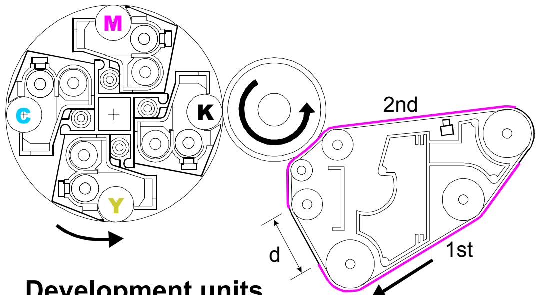
Color Development

Like black and white machines, color copiers and printers use *dual-component development* or *monocomponent development* systems. However, color systems require a separate development unit for each color, and they must make at least one development cycle per color.

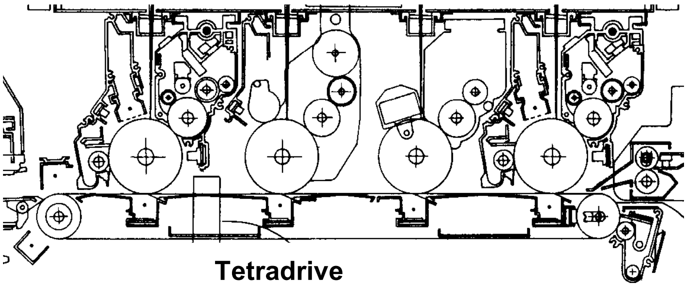
The development systems of Ricoh color products can be classified into three groups—(1) systems with the development units arranged in fixed positions around the photoconductor, (2) systems with a revolver that brings the development units to the photoconductor when needed, and (3) tetradrive systems. This section looks at representative examples of each group.



Development units in fixed positions



Development units on a revolver



Tetradrive

Fixed Position Development Systems

Many color copiers and printers have the four color development mechanisms (CMYK) arranged in fixed positions around the photoconductor. Such an arrangement is logical from a design point of view; however, such designs have two requirements that designers must address.

1. Photoconductor Surface Area

Four development mechanisms take up a lot of photoconductor surface. For this reason, color systems using fixed position development units must use a larger than normal photoconductor. One way is to increase the drum size; this is the approach used by model A109 as explained in example 1 below. Another method is to use a long photoconductor belt; this is the method used by model G033 (see example 2 below).

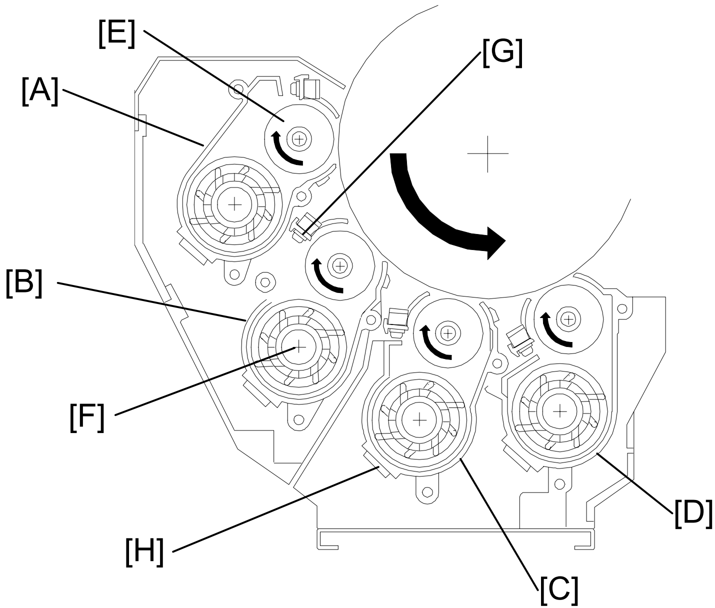
2. Prevention of Simultaneous Development

Although the development units are in a fixed position, only one color can be allowed to develop the image at a time. Examples 1 and 2 below show two ways to handle this requirement—model A109 removes the developer from the rollers that aren’t being used for development, and model G033 holds the development rollers away from the photoconductor when they are not in use.

Example 1: Model A109

This machine has one large development unit divided into four sections. From the left they are the black development section [A], the cyan development section [B], the magenta development section [C] and the yellow development section [D]. Each development section has a sleeve roller [E], dual mixing roller [F], doctor plate [G], and toner density sensor [H].

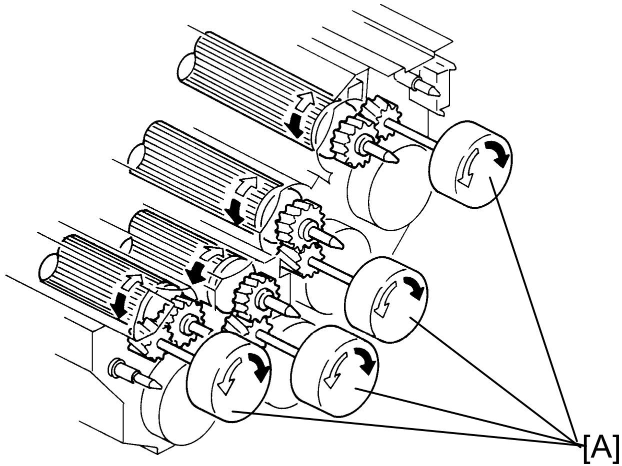
To make room for the four development sections, model A109 uses a drum with a diameter of 120 mm. (Other Ricoh color systems typically use a 90 mm diameter drum.)



Continued on next page.

One interesting feature of this machine is the use of six motors to drive the various development components. The color development drive motor drives the dual mixing rollers in the cyan, magenta, and yellow development sections. The black development drive motor drives those in the black development unit.

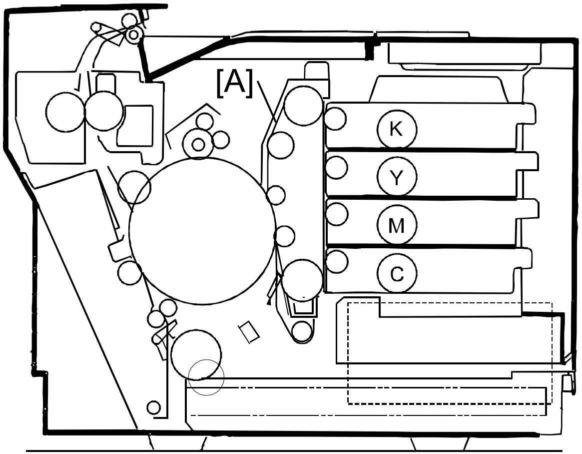
Each of the four sleeve rollers is driven by an independent, reversible motor [A]. When the sleeve turns as shown by the black arrows, developer is carried to the OPC drum. When the sleeve turns in the direction of the white arrows, all the developer left on the sleeve roller surface is returned to the development section. Only one color development section at a time carries developer to the drum.



Example 2: Model G033

This machine has the four color development units [K,Y,M,C] arranged along one side of an OPC belt [A].

When the printer is idle, none of the development units contacts the OPC belt. During printing, the machine moves the development units into contact with the belt one at a time. (Refer to the G033 service manual for details. The mechanism used is a standard mechanical system using a *solenoid*, a *spring clutch*, and a cam.)



Revolver Systems

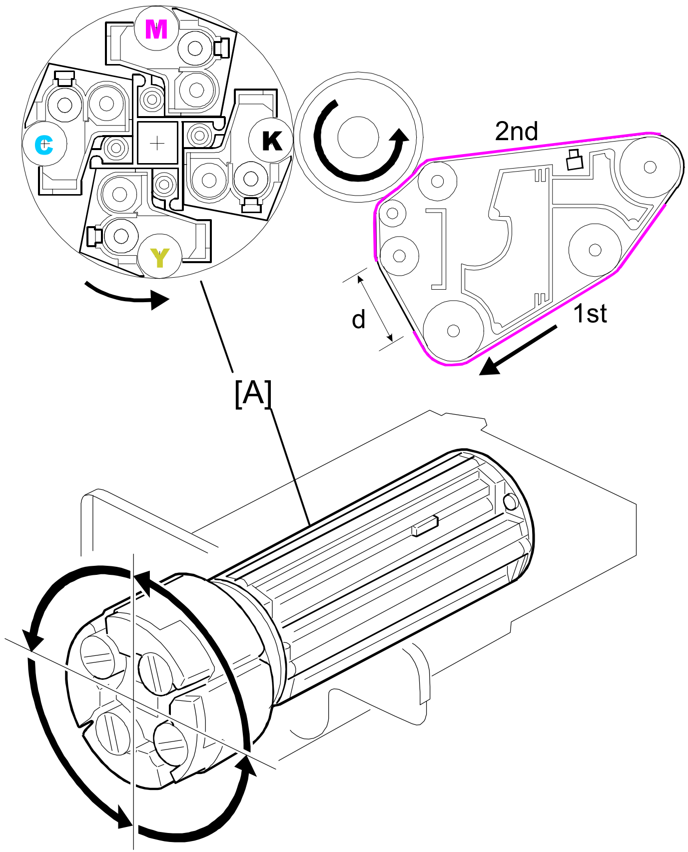
Revolver Operation Overview

Machines using the revolver system have the four development units (K, Y, C, and M) mounted around a rotating mechanism called the revolver. The revolver rotates to bring the proper color development unit to the drum. Revolver systems use a standard size OPC drum.

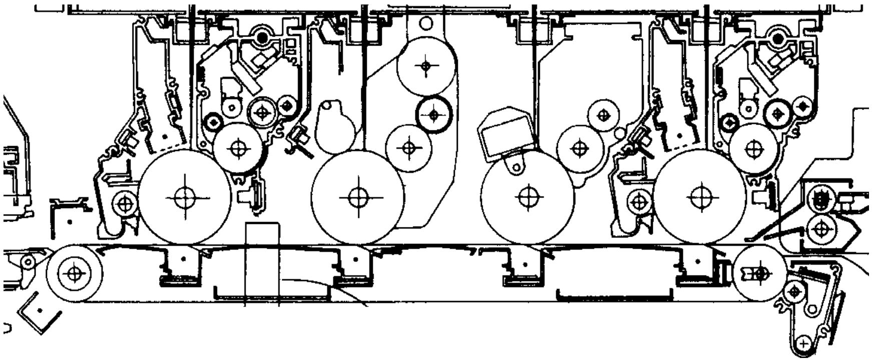
Example: Model A257/A269

The illustrations to the right show the revolver [A] used in models A257 and A269.

The revolver unit holds four development units, one for each color (KYCM). It develops colors by rotating the revolver counter-clockwise (as viewed from the front of the copier), 90 degrees at a time, in the order K, Y, C, and M. (In printer mode, this machine develops in the order Y, C, M, and K to improve the reproduction of black letters.)



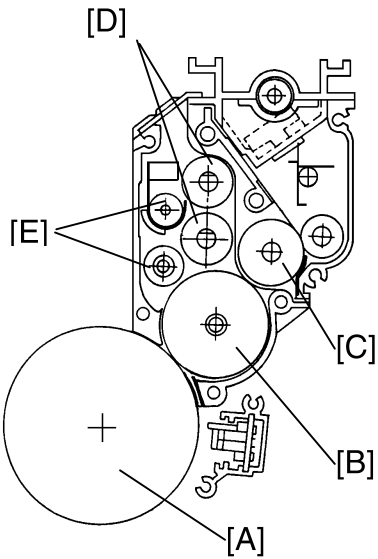
Tetradrive Systems

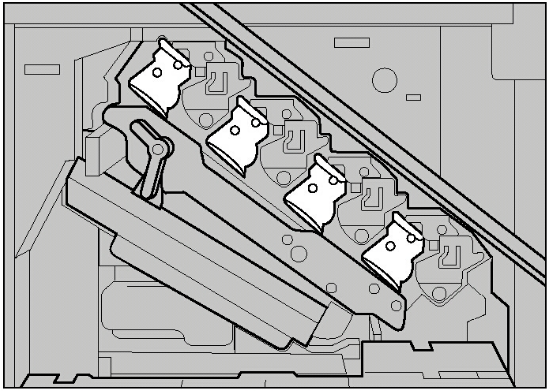


The tetradrive system uses four print engines lined up in a row. It has four drums, four laser beams, four charge corona units, four transfer corona units, and four development units. The four print engines allow the creation of the CMYK images simultaneously, thus greatly increasing the full color copy speed. The primary drawback of the tetradrive system is expense.

Examples of the original tetradrive system include models *A092* and *A105*. The development units of these products use a standard *dual component development* system. The components of the development units of model A105 are illustrated to the right.

[A] OPC drum
[B] Development roller
[C] Toner supply roller
[D] Transport rollers
[E] Mixing augers





Newer tetradrive systems (sometimes called four-tandem systems) have a number of improvements over the original.

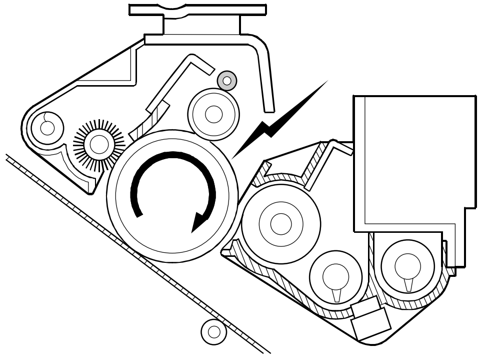
In the model *G060*, the paper path is inclined about 38 degrees to make the machine as compact as possible. The development units are redesigned, and there are four motors.

Development drive motor-K drives the development unit for black, the fusing unit, and the paper exit section.

Development drive motor-CMY drives the development units for magenta, cyan, and yellow, the registration roller and by-pass feed mechanism.

Drum drive motor-K drives the PCU for black and the transfer unit.

Drum drive motor-CMY drives the PCUs for magenta, cyan, and yellow.



Toner Supply Control

Current machines generally use fuzzy logic to control toner supply. Most use two inputs to the fuzzy control algorithm—the amount of toner attracted to the drum as sensed by the ID sensor and the calculated volume of toner used based on pixel count. (See example 1.) Higher end systems also use a toner density sensor. (See example 2.)

Note: While the explanation and examples in this section are given using machines with revolver development units, the basic information applies to other machines—both color and black and white.

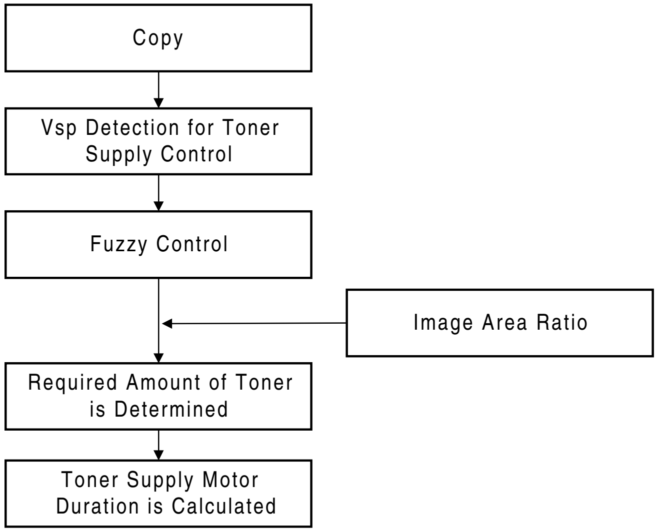
Example 1: Models A258/A259/A260

Fuzzy Control Mode

First, the machine assesses the amount of toner per unit area on the drum (M/A). This is determined from two sensor inputs: Vsg, and Vsp(toner).

The fuzzy logic algorithm then uses the most recent M/A values to assess current toner density conditions.

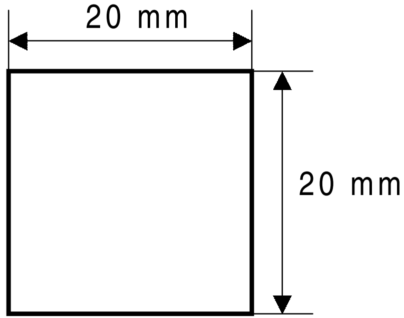
The output from the fuzzy logic process is then combined with the image area ratio obtained from the image data signal coming from the IPU board. The result of this calculation is the amount of



toner required, and from this, the machine determines the time that the toner supply motor must stay on in order to supply the correct amount of toner.

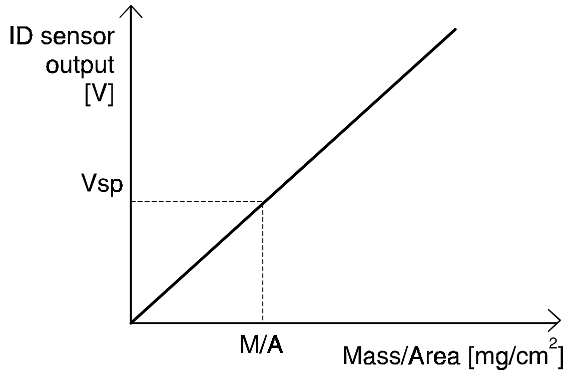
Vsp detection for toner supply control

The copier generates an ID sensor pattern using a standard laser diode power. The copier generates this pattern between the K, C, M, and Y images, and then detects the density using the ID sensor. The result is known as 'VSP for toner supply control', or 'VSP (toner)' to distinguish it from the other VSP, measured during potential control.



This process is done after

- Each color development cycle for odd-numbered copies when making continuous copies of A4/LT landscape size or smaller.
- Each color development cycle, every copy in all other modes.

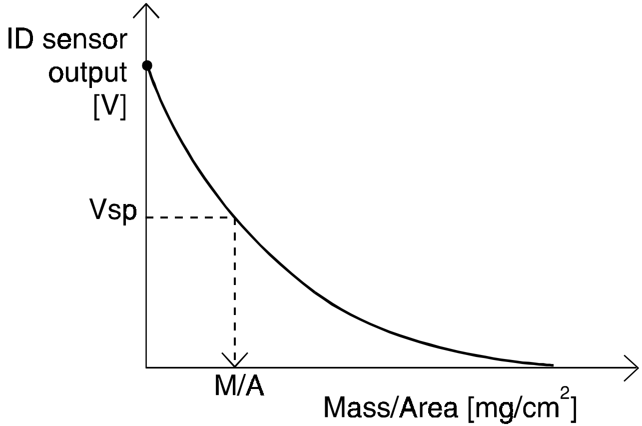


Calculating the amount of toner on the drum

First, the machine calculates a value from the current VSP (toner) value. Then, it refers to a table in the ROM to determine the toner density on the drum (M/A).

- M/A: Toner amount per unit area on the drum (mg/cm^2)

The target M/A for toner supply control is 0.4 mg/cm2 for the C, M, and Y toners and 0.3 mg/cm^2 for the K toner. M/A is calculated in the same way as for potential control.



– Fuzzy Logic Algorithm –

The fuzzy logic algorithm has two input factors which are related to the amount of toner on the drum. These are:

- The difference between the average of the previous 10 M/As and the target M/A
- The tendency of the previous 10 M/As

– Image Area Ratio –

This is a measure of how much toner will be needed for each color on a page. From the image data from the image processing unit (IPU), the machine determines the total amount of the color on the page. It takes into account the grayscale values for each pixel for that color.

Fixed Supply Mode

Models A258/A259/A260 normally use the fuzzy logic supply mode described above. The fixed supply method is used only when abnormal conditions occur during the process control self check. In fixed supply mode, the machine adds a fixed amount of toner to the developer every copy. Readings from the ID sensor are ignored.

The toner supply ratios for each color in fixed supply mode are determined by service programs (SP 2-208-005 to 008).

Example 2: Models A257/A269

Fuzzy Control Mode

The toner supply control of models A257 and A269 is similar to that described in example 1 above. However, in the fuzzy logic control mode, input from the toner density sensor (TD sensor) is also used in the calculation. Thus these machines use three input parameters as follows:

1. Density of the toner read by the TD sensor
2. Amount of toner attached to the drum sensed by the ID sensor
3. Pixel count (image area ratio)

The amount of toner supplied is determined by the toner supply clutch on time

Other Toner Supply Control Modes

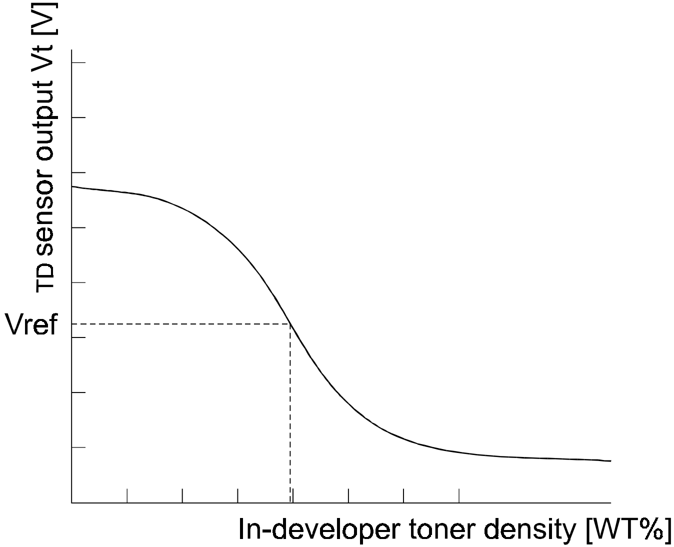
In addition to the default fuzzy logic control mode, these copiers have a proportional control mode and a fixed supply mode.

The proportional control mode is used if an ID sensor becomes faulty. Only the TD sensor is used to control toner supply.

The fixed supply mode is used if both the TD sensor and ID sensor become faulty.

TD Sensor Output

The relationship between the TD sensor output Vt and the toner density in the developer is shown in the figure on the right. The target toner density of this copier is 5 WT%. The TD sensor output for this toner density is referred to as Vref. Vref of this copier is adjusted to 2.5 ± 0.1 volts for a toner density of 5 WT% (brand-new developer) for each of the C, M, Y, and K toners. When developers are replaced, since TD sensor fluctuations can occur in such a case, it is necessary to initialize the TD sensor and adjust its gain using SP3-005-1 through SP3-005-5.



Relationship between toner density and TD sensor output

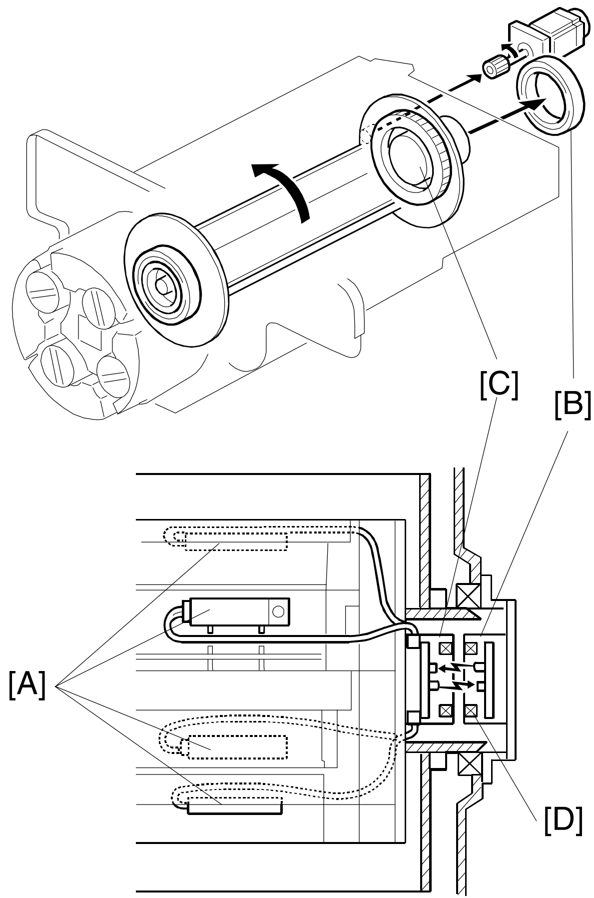
TD Sensor Noncontact Coupler

Interfacing the toner density sensors in a revolver mechanism presents a special design problem. Models A257 and A269 handle this with a mechanism called a *noncontact coupler*.

Each of the four development units has a TD sensor [A]. These sensors interface with the CPU through a single interface—the noncontact coupler. The noncontact coupler has two parts; one is mounted on the main unit [B] and the other [C] is inside the bearing ring of the revolver. These two sections are separated by an air-gap.

Power for the revolver side is provided through a circular coil [D] (a small transformer) inside the coupler sections. The power transformation is:
38 Vac (main unit) ➔ 12 Vac (revolver) ➔ 12 V (for TD sensor).

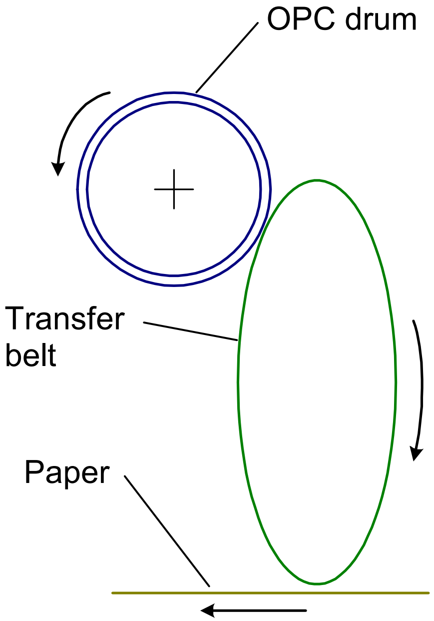
The TD sensor output is conveyed through optical communication. The CPU receives TD sensor output only from the development unit at the development position.



Color Image Transfer

Image transfer in color machines is more challenging than in single color copiers or printers. The image must be developed and then transferred once for each color. Each of the *color separations* must be transferred and overlaid to achieve the complete colored copy or print. Ricoh products have two basic methods of transferring the developed color separations.

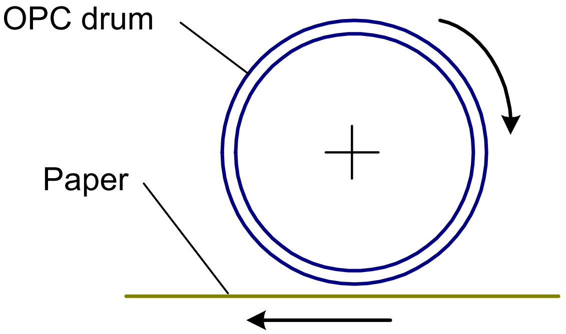
The most common method is a two step transfer system. In the first step, each of the color separations transfers from the OPC to an intermediate surface. The complete image builds on the intermediate surface one color at a time. Once the color image is complete, it is then transferred to the paper.
The OPC can be either a drum or a belt. When it is a drum, the intermediate surface is a "transfer belt". (Schematically illustrated to the right.) When it is a belt, the intermediate surface is a "transfer drum".



Two step image transfer

The other method is to transfer the color separations from the OPC drum the paper as they are developed much in the same way as in single color imaging systems. This is repeated for each color to build the complete image directly on the paper. This is the method used in analog color copiers and in tetradrive systems.

The following sections examine examples of both methods.

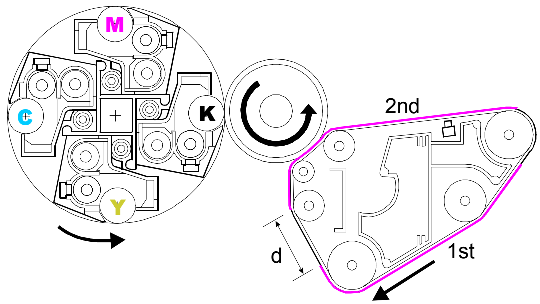


Direct-to-paper image transfer

Two-step Color Image Transfer

The two-step transfer method builds the complete color image before transferring it to paper. Each of the color images (color separations) is first developed on an OPC and then transferred from the OPC to an intermediate surface. Once the color image is complete, it is then transferred to the paper. This method has the following advantages over direct transfer to paper.

- It reduces paper handling (less chance for slipping, wrinkling, jamming, etc.)
- It allows greater control over the electrostatics of image transfer and more precise registration of the color separations.
- It is possible to increase the copy speed by designing the system so that more than one image can be made at a time. The illustration to the right (*model A269*) shows two images being created on the transfer belt.

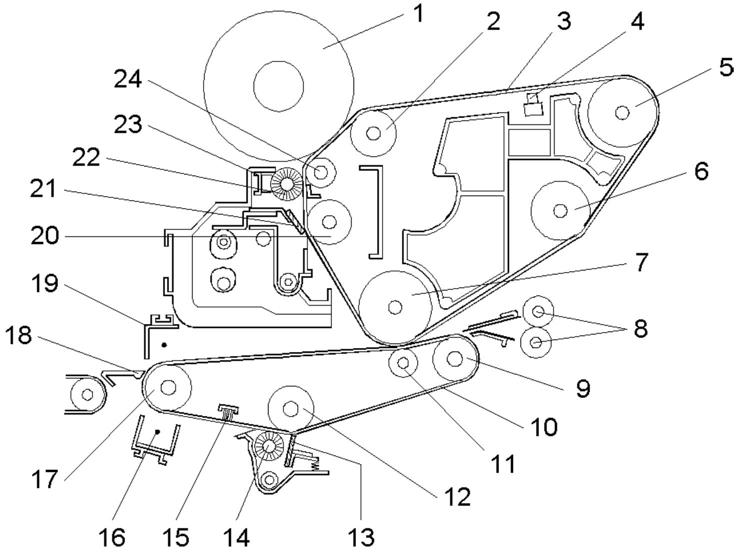


Two A4/LT images made in one revolution of the transfer belt

Example: Models A257/A269

The image transfer mechanism of models A257/A269 is illustrated to the right. This mechanism uses two transfer belts—an image transfer belt and a paper transfer belt. The copier transfer belt system first transfers the 4 color toner images from the drum to the image transfer belt and then later transfers the complete image onto the paper. This permits image transfer to the paper in a single operation.

For the paper transfer step, the copier employs an insulated transfer belt system to improve the efficiency of image transfer to the paper. The paper transfer belt also provides smooth paper transport as the paper passes through the image transfer area and receives the image.



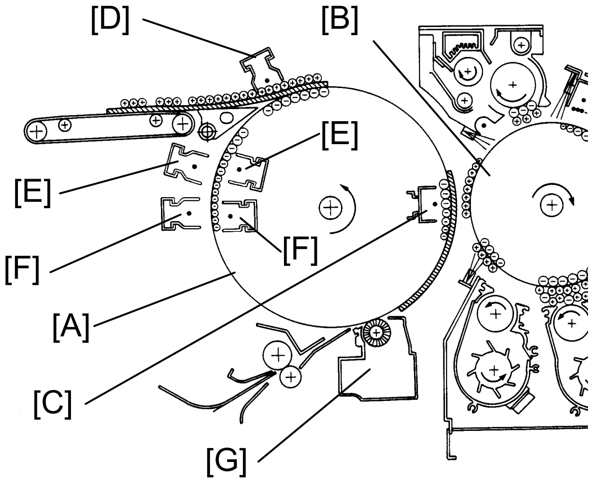
1. OPC drum
2. Transfer belt bias roller
3. Image transfer belt (ITB)
4. Belt mark sensor
5. Transfer belt drive roller
6. Transfer belt tension roller
7. Paper transfer counter roller
8. Paper registration rollers
9. Paper transfer tension roller
10. Paper transfer belt (PTB)
11. Paper transfer bias roller
12. PTB blade counter roller
13. PTB cleaning blade
14. PTB cleaning brush
15. PTB back brush
16. Belt discharge corona unit
17. Paper transfer drive roller
18. Pick-off plate
19. Separation corona unit
20. ITB blade counter roller
21. ITB cleaning blade
22. ITB lubricant brush
23. ITB lubricant bar
24. Ground roller

Direct-to-paper Color Image Transfer

Direct-to-paper transfer of color images is an older method that can be found in analog color copiers. It is also used in the unique tetradrive design.

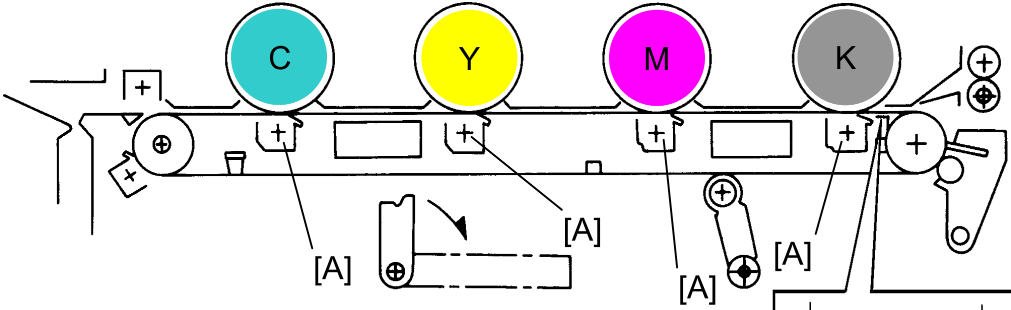
Example 1: Model A072 (Analog)

The illustration to the right shows the image transfer mechanism of model A072.
This model uses a transfer drum, which rotates in contact with the OPC drum. Copy paper is fed and clamped to the transfer drum. The transfer drum then makes the necessary number of rotations to transfer each color to the paper.
The transfer corona unit is located inside the transfer drum unit. A high negative charge is applied to the transfer corona wire and the corona wire generates negative ions. The negative ions are applied to the copy paper and the negative charge attracts the positively charged toner away from the drum and onto the paper. At the same time, the copy paper is electrostatically attracted to the surface of the transfer drum.
When full color image is complete, the clamp releases and the paper separates from the transfer drum.

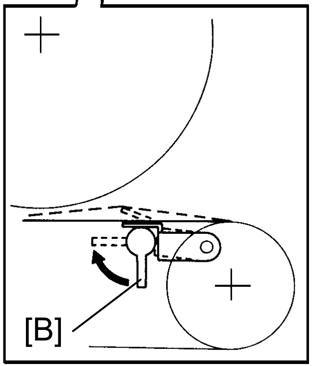


[A] Transfer drum
[B] OPC drum
[C] Transfer corona unit
[D] Separation corona unit
[E] AC discharge corona units
[F] DC discharge corona units
[G] Transfer drum cleaning unit

Example 2: Models A092/A105 (Tetradrive)



The image transfer method of the tetradrive system is different from all other color systems. It uses a standard *corona transfer* system repeated four times. Transfer coronas [A] are located below each drum to pull the toner image onto the paper.



The transfer belt position lever [B] raises the transfer belt to the drum to prevent void image problems under high humidity conditions.

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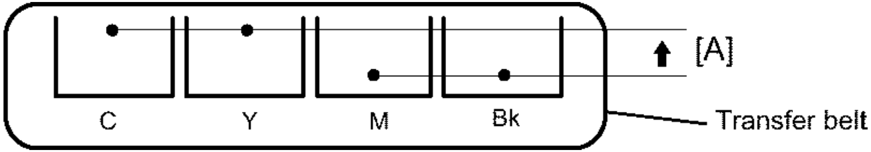
The transfer corona units for all four colors are the same, except for the corona wire height. The corona wires for yellow and cyan are installed closer to the drum than those for black and magenta [A].



The potential at the paper surface is increased in steps as each color is developed [B]. This is necessary because the top layers of toner require a stronger transfer force than the bottom layers.

The transfer corona current for each color is as follows:

- Black: 300 µA
- Magenta: 400 µA
- Yellow: 350 µA
- Cyan: 600 µA

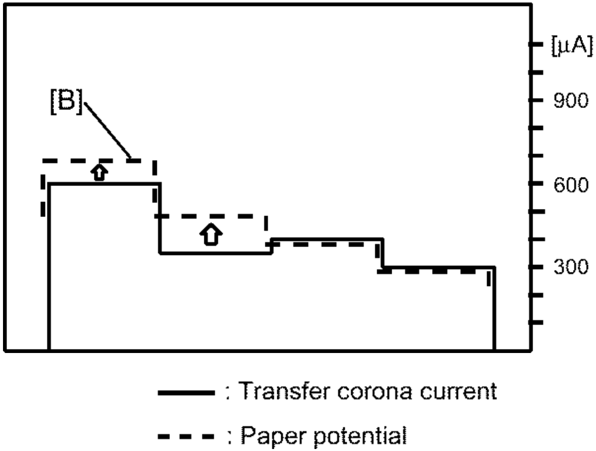


Image Files

Instead of being printed immediately, scanned data can be stored as an image file for later use. As a growing number of machines produce or use these image files, a basic understanding of file types becomes increasingly necessary.

Raster vs. Vector

There are two basic ways to create images. Rasters are created by defining color data for each dot in the image. Images are built from a grid of dots. A crude example can be seen at the football stadium. Fans holding up colored squares produce images for the television cameras.

Rasters are usually created by scanners or “paint” programs. They are particularly good at representing textures or photo-realistic images. On the down-side, the unmodified, physical size of the image varies depending on the resolution of the output device. Rasters are naturally displayed dot-for-dot on the output device. If an image is 600 x 600 pixels, it will be displayed as a 1 inch square on a 600 dpi printer. The same image will appear as an 8.3 inch square on a 72 dpi monitor.

While most applications can force the image to appear at a user-defined size, scaling the image can adversely affect its quality. Also, file sizes are based on the number of pixels and color depth of the image. Large, full-color raster images often result in mammoth files.

Vectors, on the other hand, do not try to define every dot. The image is created by building objects out of mathematically defined curves and lines. These objects can be further filled with various colors or patterns. Vector images are usually used for graphs, illustrations and technical drawings. They are created using “draw” programs. Vector images are easily resized without losing image quality. The file size depends on the number and complexity of the objects—not the image size. However, most output devices display images as rasters, so vector images need to be rendered (rasterized) before they can be displayed.

Metafiles represent a third option for storing image data. A metafile is not a new type of image—rather it is a composite. It is created from a combination of vector images, raster images and text.

The rest of this section will focus on raster images. Since most of our images will be created from scan data, raster images are the most important for our purposes.

Color Depth

Images are often described by their color depth—or the amount of information stored in each dot. The larger the color depth, the greater the variety of colors available. For example, in a 4 bit color image, each pixel must be one of 16 different colors. An 8 bit image allows 256 different colors. Most full color images are 24 bit (16 million colors) or greater.

Sometimes the color depth is listed as bits/channel. PhotoShop, for example, supports 8 and 16 bits/channel RGB images (x 3 channels = 24 and 48 bit color).

Color depth greatly affects the image file size. All other things being equal, a 24-bit color image will be three times larger than a grayscale image, and twenty-four times larger than a black and white bitmap.

Resolution

Raster images are also defined by their resolution, usually measured in dots per inch (dpi). Resolution depends largely on the device that will be used to display them. The typical computer monitor has a 72 dpi resolution. Images displayed at this resolution look natural to the eye—the pixels blend into a smooth image. However, if that same image is printed on a 300-dpi color printer, the pixels will appear as visible blocks, giving the image a jagged appearance.

On the other hand, an uncompressed 300-dpi image file is 17 times larger than a same-size 72-dpi image file. This means that, if the print-quality image was used on a web page, it could take 16 times longer to download.

Actually, the real-world difference would be greater still, since print-quality compression typically only reduces the file size by 1/2. Compression for web images often produces files 1/10 their original size or smaller.

For the best results, you should select an image resolution based on how the image will be used. Note, if you are using a single image for multiple purposes (for example, a web site and a brochure), it is usually best to create a separate image file for each.

Intended Use:	Recommended Resolution:
Internet Use (e-mail and web)	72 dpi
Halftone Printing	Printer's screen frequency multiplied by x 1.5 (good quality) to x 2 (best quality)
Other Printing	Printer's resolution

Halftone printing refers to printers that use dithering to produce grayscale images. These printers cannot produce true shading. Rather, they create dot patterns to give the appearance of grays. Since it takes multiple pixels to create one shaded pixel's worth of information, the image resolution should be less than the printer's true resolution. Anything over the printer's screen frequency x 2 is a waste of memory.

However, when printing bitmaps (pure black and white images) or printing to a device that can control the shading of individual pixels (through power modulation and pulse width modulation), each pixel-worth of information is important. The image file's resolution should equal the printer's.

Remember, an image's resolution and it's scale go hand in hand. A 1-inch, 100 dpi image stretched to fill 2 inches is the same as a 2-inch, 50 dpi image.

Resolution-based quality problems are often seen when people try to print images from the web or from a lower-resolution digital camera.

Lossy and Loss-less

Because raster images files can grow quite large, most image data is compressed. Compression reduces the amount of memory needed to store the file. But not all compression techniques are equal.

Loss-less compression techniques carefully maintain all the details of the original image. The compression ratio will vary depending on the complexity of the image, but most are around 2:1. They compresses images by combining strings of identically colored pixels.

For example, if the image has a row of 5 blue pixels the original sequence would appear as BLUEBLUEBLUEBLUEBLUE. The compressed image data could be reduced to BLUEX5.

Lossy compression, on the other hand, sacrifices some image detail in order to get a greater compression ratio, often up to 20:1. By using optical tricks that exploit limits in human vision, they create an image that is often indistinguishable from the original. However, depending on the amount of data sacrificed, the reduction in quality could become quite noticeable.

Lossy compression is usually used on the internet, where image size is crucial. When printing, the drop in quality is more noticeable. Loss-less images are therefor recommended.

Format Highlights

The following section looks at seven of the most common image formats. This, however, is just a small sampling. A lot of up-to-date graphics information is available on the web. If you are interested, I recommend looking at The Graphic File Format Page for technical information on a wide variety of image formats. The Graphic Formats frequently asked questions page provides a more detailed discussion of the advantages and disadvantages of the TIFF, PNG, JPEG and GIF formats.

BMP

The BMP file is one of the most commonly used formats for the Windows environment. It supports 24 bit color depth and loss-less compression. A very stable bitmap format; however, support is very limited on Apple or Unix systems. On Windows machines, it is used both for screen display (windows wallpaper) and printing. It is not typically used on the web.

EPS

Encapsulated PostScript (EPS) files use the Adobe PostScript language. They can store either bitmaps or vector information. The files are accepted on virtually all platforms, and virtually all graphics, illustration and page layout applications. The format also offers a variety of options for high-quality printing to postscript printers.

Most applications cannot read the postscript information directly—therefor the file also contains a low-resolution (often binary) thumbnail image. Thumbnails are usually TIFF or PICT format. These images are displayed as placeholders in many graphics and page layout programs.

There are three cautions when using EPSs. First, the PostScript may contain references to fonts. If the EPS was created on a different computer, those fonts may not be available on the current system. This can cause a variety of printing problems, from font replacements to print errors. Also, this may not be obvious when viewing the image in the page layout application.

Second, some thumbnail images are more accurate than others. What you see on the screen is not necessarily what you get out of the printer. Be sure to test print and check any EPSs.

Finally, EPSs are an excellent format when working with PostScript printers. However, if the printer cannot use PostScript information, the application will send the low-resolution thumbnail image instead. The result is very poor quality output from what was supposed to be a high-quality image format.

The bottom line is, EPSs provide an excellent format for high-quality printing when used properly. However, they require a bit more care and technical know-how.

GIF

An older format, the Graphics Interchange Format (GIF) only supports indexed color (8 bit, 256 colors) and LZW compression (loss-less compression). Once commonly used for online photographic images, it has largely been replaced by the JPEG. However, the loss-less compression, the limited color range, and the ability to have transparent backgrounds makes it an ideal choice for web-based icons, or any web-images requiring small, clear text or using only a limited number of colors. When saving rasterized line drawings, GIF files are often much smaller and much cleaner than JPEGs.

JPEG

The Joint Photographic Experts Group (JPEG) format is commonly used to display photographs and other continuous tone images on the web. It supports 24-bit color, and uses a lossy compression to greatly reduce the file size. While most loss-less compression averages around a 2:1 ratio, JPEGs can achieve 10:1 to 20:1, often without any visible loss in quality.

When saving a JPEG you can set variable amounts of compression. More compression results in a smaller file—but there is a greater loss in image quality. The maximum quality setting usually produces a result indistinguishable from the original.

While JPEGs are an excellent choice for screen-viewable photographs, it does not handle large areas of a single color or sharp edges very well. Blocks of color often develop odd distortions or squiggles, while text tends to appear blurry. It is also not recommended for binary (pure black and white) images.

Printing tends to bring out the worst in a JPEG. The optical tricks it uses to compress the data are more noticeable on the printed page.

One final note about JPEGS, they lose quality every time you open, edit and save them. While saving it once or twice may not be noticeable, continually editing and re-saving the file can result in a considerable loss of quality. If you are going to need to edit an image, create a master copy using a loss-less format. After you are done editing that copy, convert it to a JPEG.

PICT

The PICT format is popular with Macintosh graphics and page-layout applications. It supports 16 or 32 bit color and loss-less compression. It can also support various JPEG compressions. PICT files can store either raster or vector data. While well supported on the Macintosh, it has very limited support on other systems.

PNG

The Portable Network Graphics (PNG) format was developed as a patent-free alternative to the GIF. It supports up to 48-bit color and transparent backgrounds without jagged edges. Unfortunately, older browsers may not support PNG images.

TIFF

The Tagged-Image File Format (TIFF) is a flexible bitmap image format supported by virtually all paint, image-editing and page-layout applications. It is also platform independent—being well represented on Windows, Macintosh and Unix. This makes it an excellent choice for cross-platform or cross-application projects. If JPEG is the default web graphic format, TIFF is the default for printing. It supports up to 24-bit color and a variety of loss-less compression routines. Unfortunately, its flexibility can become a liability. There are many different flavors of TIFF, and not all applications support all formats.

If you run into TIFF compatibility problems, try re-saving the file without any compression. While this produces a larger file, it can be read by almost all image-handling applications.