# Digital Processes

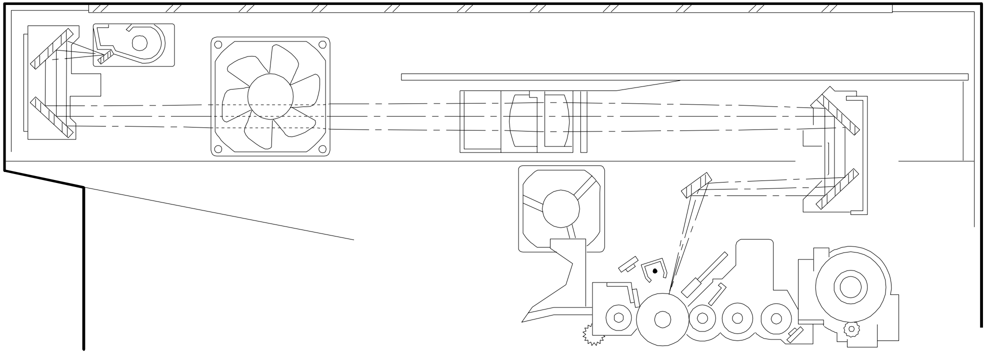
Digital Scanning
Image Processing
Printer Engines
Printer Interface Basics

## Digital Scanning

### *Basic concepts*

#### *Analog Machines*

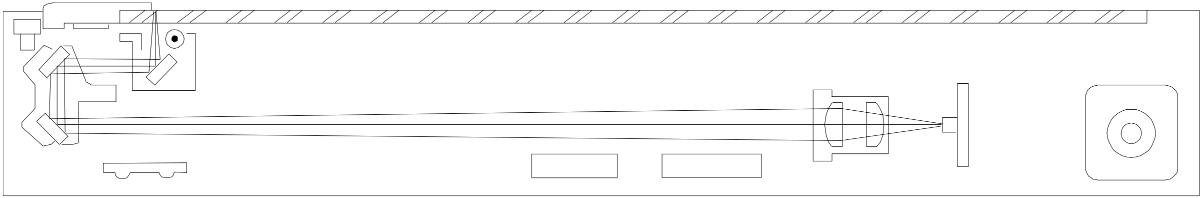
***Example: Model A219***



An exposure lamp illuminates the original. Mirrors reflect light from the original directly onto the photoconductor. This light writes a latent image on the photoconductor. This image is then developed with toner and transferred to the copy paper.

# Digital Machines

## Example: Model A193



The big difference with scanners in digital machines is that the light reflected from the original does not pass directly to the photoconductor.

The light is reflected onto a light-sensitive element, such as a CCD (Charge Coupled Device). This device converts the light into an analog electrical signal. Circuits inside the machine convert this signal into a digital signal. This signal then passes to a laser diode, which emits a laser beam to write a latent image on the photoconductor.

So, in a digital machine, there is a lot of electronics between the light reflected off the original and the light arriving at the photoconductor.

## *Digital Signals*

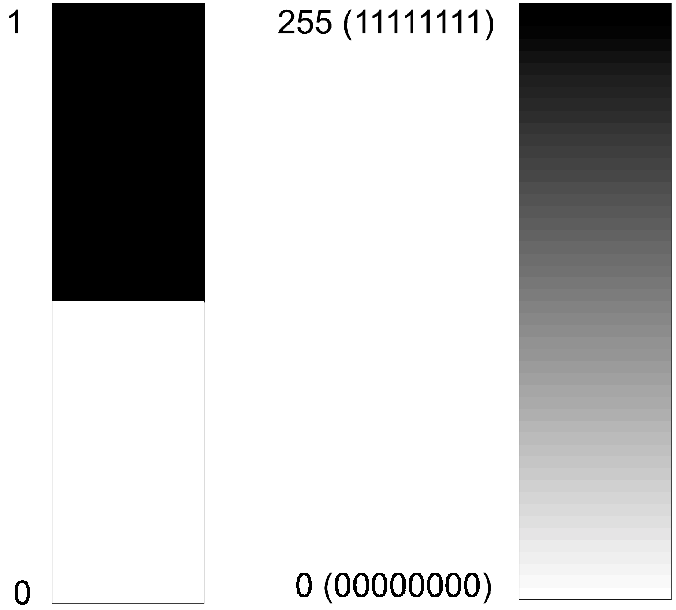
Digital signals consist of binary code. When scanning an original, binary code is used to represent the brightness of each pixel of the image.

In the most simple of systems, there are only two values for each pixel: 0 and 1, for black and white.

However, most machines use 4 or 8 bits.

In a four-bit system, there are 16 possible values for each pixel. This allows black, white, and 14 shades of grey in between.

Similarly, in an eight-bit system, there are 256 possible values for each pixel. This allows black, white, and 254 shades of grey in between (see the diagram).



# *Digital Images*

## *Overview*

Analog machines transfer an optical image of the original directly onto the photoconductor.

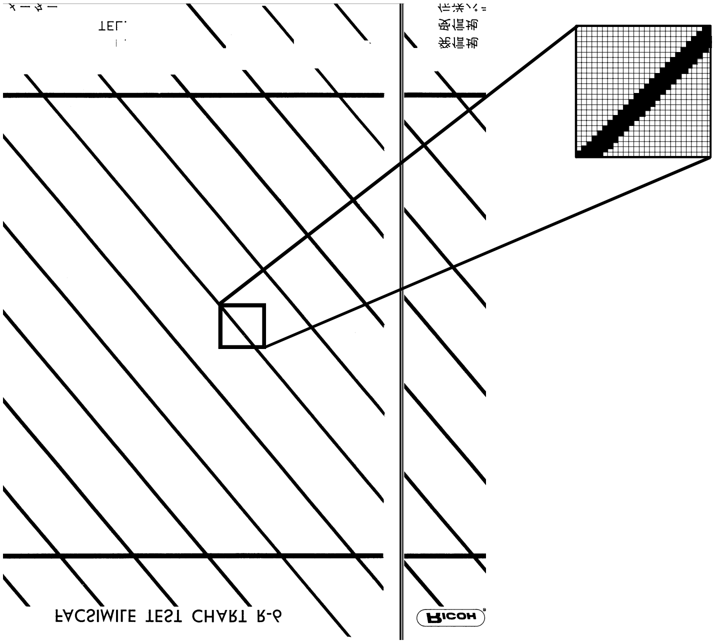
Digital machines break the image up into small dots, known as picture elements, or pixels for short.

The example shows the image that the machine builds up of a fax machine test chart.

This may seem to be a rather inaccurate representation. However, digital signals can be manipulated to enhance the image and create special effects.

Also, digital images can be used immediately, or stored for later use (see *Image Files*).

The size of the pixels (smaller pixels yield greater ‘resolution’) depends on several factors related to the scanner and printer hardware. (The software may also be set up to alter the resolution in various ways, but we shall look at hardware in this section.)

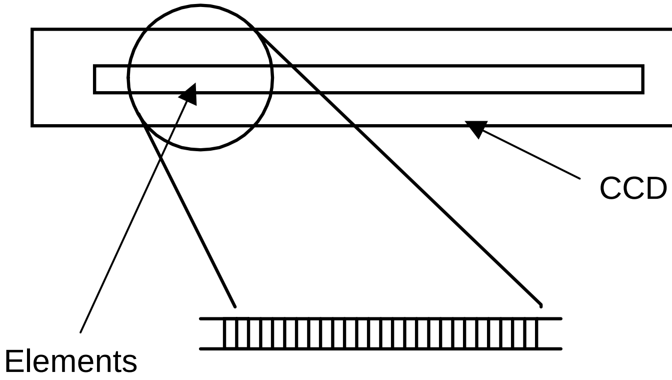


## *Scanner Resolution*

There are two points to consider: the image detector (typically a CCD) and the scanner motor

### *CCD*

The CCD (charge-coupled device) is a line of photosensitive elements. The output of the CCD represents one line across the page. Each element of the CCD generates one picture element of the line. So the CCD resolution is the resolution of the scanner across the page (this is also known as the ‘main scan’). The more elements there are per unit length, the finer the resolution. Typical CCDs have 200 or 400 elements per inch (or, for Group 3 fax machines operating in metric units, 8 or 16 elements per mm).

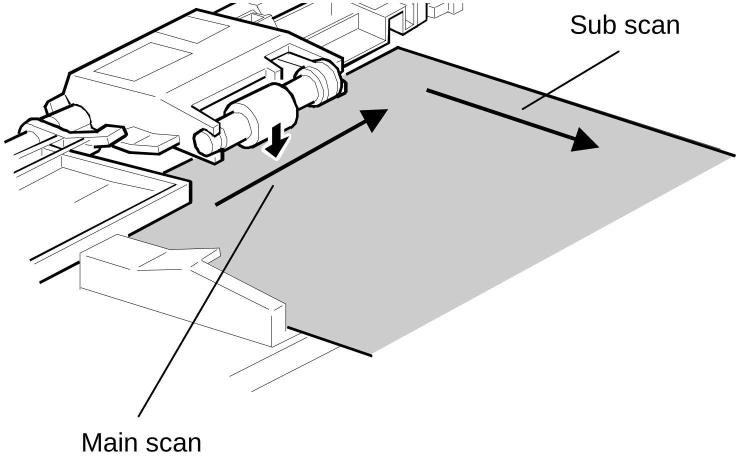


### *Scanner or ADF Motor*

#### *Example: Model A229, ADF mode*

The scanner or ADF motor is normally a stepper motor. The distance fed by each step of the motor determines the resolution of the scan down the page (also known as the ‘sub scan’ direction). Typical resolutions are 200, 300, or 400 lines per inch (or for Group 3 fax machines, 3.85, 7.7, or 15.4 lines per mm).

To scan an image, the CCD scans a line. Then the scanner motor feeds the page one line, and the CCD scans another line. This is repeated until the entire page has been scanned.



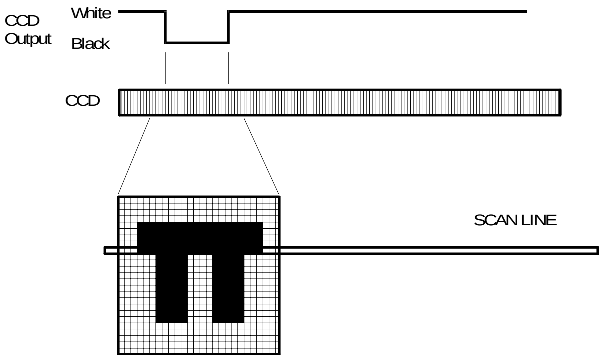
## *Scanner Output*

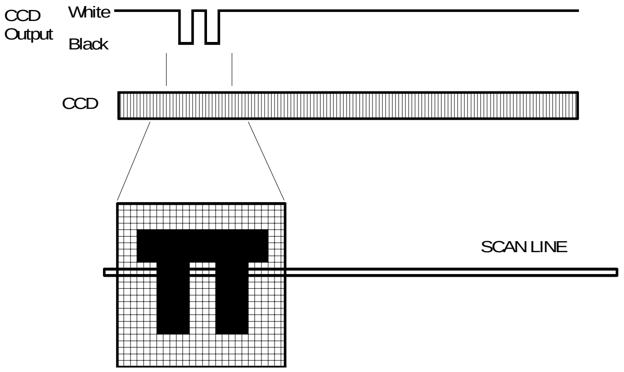
Each element of the CCD generates a voltage which represents the intensity of the light reflected onto it from the document. The signals from all the elements are output in sequence, to generate an analog signal that represents the line that is currently being scanned.

The upper diagram on the right shows an example of output from a line on a page which is all white except for a black shape on the left of the page.

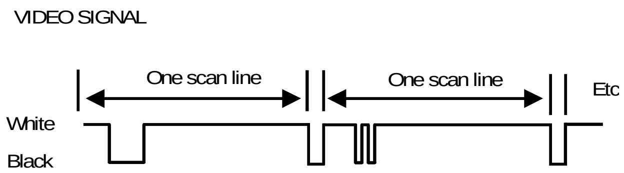
After the line has been scanned, the scanner moves the document forward one scan line width to move the next scan line into position. Then, the CCD reads the next scan line.

The bottom diagram shows the next line being scanned.



The signals from each consecutive scan line are strung together end to end, and sent out as an analog signal. The diagram opposite shows what the video signal would be like for the two consecutive scan lines shown in the previous two diagrams.




The output is then processed as described in Image Processing.

The next few pages show the basics about how the processed data is printed.

## *Printer Resolution*

The output from the scanner is converted to a laser diode drive signal. The laser beam then writes a latent image of the original on the photoconductor. There are two points to consider: the laser beam as it arrives on the photoconductor, and the speed of the photoconductor.

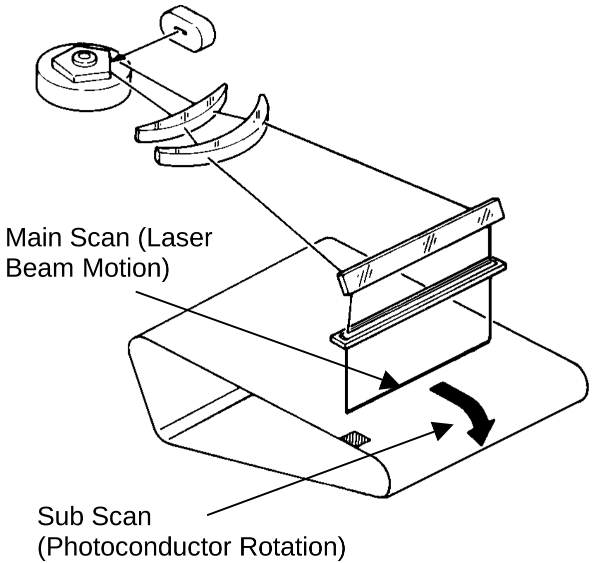
### *Example: Model H006, using a master belt*

Exposure of the photoconductor to the laser beam creates the latent image.

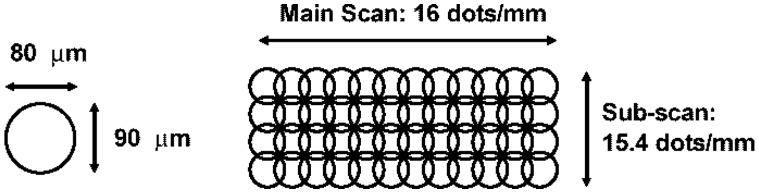
To make the main scan, the laser beam moves across the photoconductor. The resolution depends on the speed of the laser beam's motion across the photoconductor and on the frequency of the laser beam on/off switching clock.

To make the sub scan, the photoconductor rotates. The resolution depends on the speed that the photoconductor rotates.

In multifunctional machines, laser engines have to be able to print at a range of resolutions: 400 dpi for copying and Group 4 fax, 600 dpi for printing, and 16 x 15.4 dots per mm (391.2 x 406.4 dpi) for Group 3 fax.




For full details of the laser optic system, see the *Laser Printing* section.




The cross section of the beam on the master (i.e., the size of each printed dot) varies from model to model; it is roughly circular.

In the example shown, from a Group 3 fax machine, the diameter is about 80 µm. This means that the printed dots overlap each other slightly, as shown in the diagram. 80 µm is about 12 dots per mm, and 90 µm is about 11 dots per mm.

However, the printer resolution is 16 x 15.4 dots per mm for a Group 3 fax machine. The dots are larger than this resolution, so they overlap. This results in a better image than if there were no overlap.

Generally, the laser beam switches off between pixels, even between black pixels.

Note that, unlike the scanner/ADF motors, the motor that drives the photoconductor is normally a dc motor, not a stepper motor. Therefore, in theory, the main scan lines written across the photoconductor will be sloping very slightly.

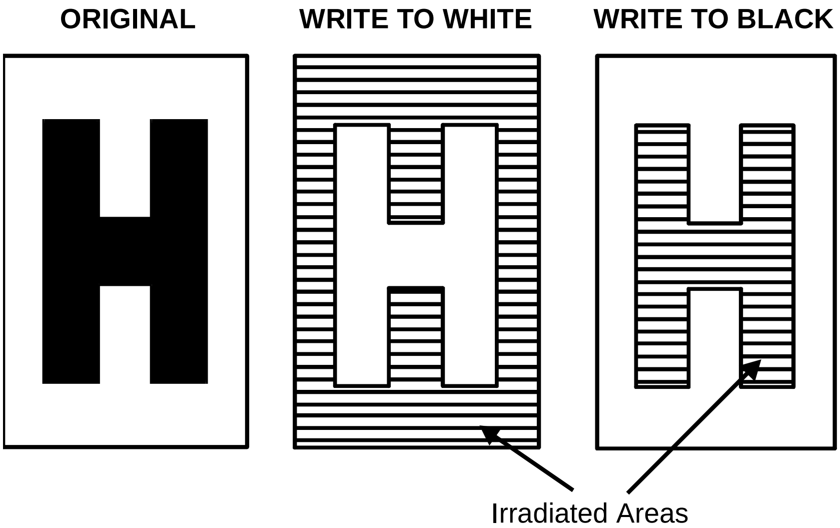
For more details, see the *Laser Printing* section.

## *Printer Output*

During the copy cycle, the photoconductor is charged to about -900 V (see *Photocopying Processes – Charge*). The laser beam writes a latent image on the photoconductor.

The charge on irradiated areas drops significantly, typically to between 0 and -100 V. (Voltage values differ from model to model.)

The area of the photoconductor that is irradiated depends on whether the ’write to white’ or ’write to black’ method is being used.



# Image Processing

## *Introduction*

This section describes how digital machines convert the image from a scanned original into digital data. This section also describes techniques for processing the digital data, so that the printout is as close to the original as possible. For example, techniques used to process a business letter will be different from those used to process an original containing photographs.

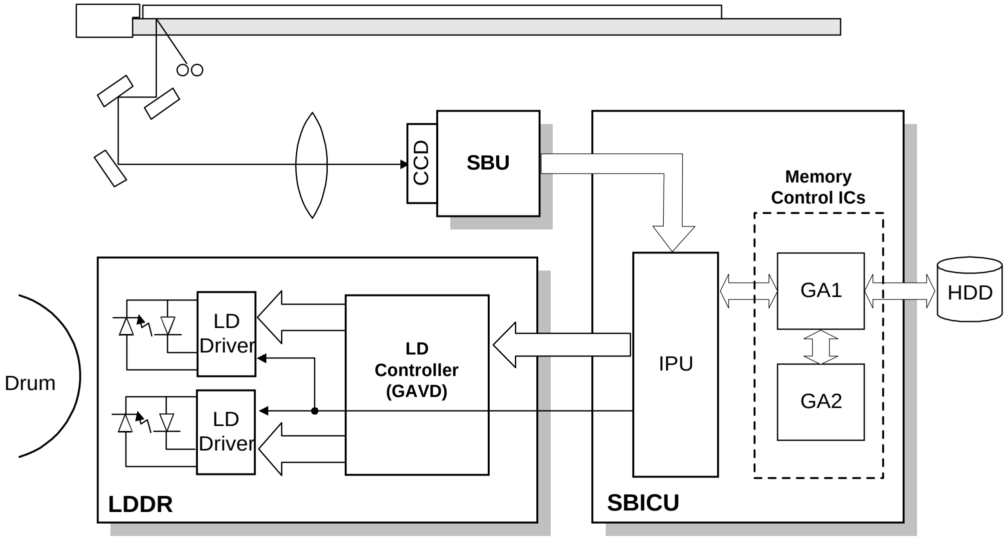
Each model implements these techniques in different ways, and some models do not implement all the techniques. In addition, the order of steps may be slightly different from that presented here. This section will provide a general description, with examples from various models.

The techniques used by black-and-white machines and color machines are different. Also, black-and-white machines can use two different types of image sensor in the scanner. As a result, this section will be divided into three sub-sections, as follows.

- Black and White Machines - CCD Systems
  This section describes black-and-white models that use a CCD (Charge Coupled Device). This is the standard method for mainstream digital machines.
- Black and White Machines - CIS Systems
  This section describes black-and-white models that use a CIS (Contact Image Sensor). This type of system is often used in lower-priced models.
- Color Machines
  This section describes image processing for color machines. These use a CCD of a different type, to generate data for the three primary colors.

# Black and White CCD Systems

## Overview




The diagram shows a typical example of an image processing circuit.

An exposure lamp illuminates the original. Light reflected from the original is reflected through a lens to the CCD.

The CCD generates an analog signal from the light. The voltage of the signal varies with the intensity of the light. The CCD is mounted on a board called the SBU (Sensor Board Unit). The analog output from the CCD must be converted to a digital signal. In the above example, the analog-to-digital conversion circuits are on the SBU board.

The digital signal is then processed, using large-scale integrated circuits, like the IPU (Image Processing Unit) in the above example. Some of the processes require enough working memory to store a page of image data. The data may then be stored temporarily on a hard disk until it is time for printing. The data then passes to the laser diode controller and laser diode driver.

After data processing, each pixel scanned from the original is represented by a number of bits (eight is a typical number), or only one bit (0: White, 1: Black), depending on the type of digital processing used. Also, the image may be enlarged or reduced. In this case, pixels will be deleted or artificially created to make the new image.

### *Scanner Lamps and the Shading Plate*

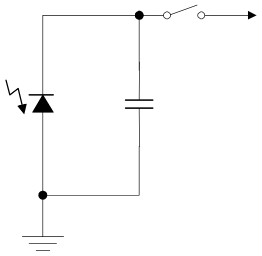
**Fluorescent lamp:** The ends of the lamp are not so bright as the center. To compensate for this, the light reflected from the original goes through a shading plate before it reaches the CCD. The shading plate allows more light to pass through from the ends of the lamp than from the center.

**Xenon lamp**: If a xenon lamp is used, the difference in brightness is smaller than with a conventional fluorescent lamp, but this problem still exists.

**LED array:** This is a strip of photodiodes. As all the diodes are equally bright, a shading plate is not needed.

## *CCD*

A CCD converts the light reflected from the original into an analog signal.



The CCD (Charge Coupled Device) consists of a row of photosensitive elements. The circuit of each element in the CCD is shown at the right. Light hitting the photodiode charges up a capacitor. The brighter the light, the more charge goes into the capacitor. There is more about CCDs in the *Standard Components* chapter.

The CCD has between 2,500 and 5,000 of these elements, depending on the maximum scanning width and number of pixels per unit length (i.e., the resolution across the page). A typical CCD in a high-end digital copier has 5,000 elements, at a resolution of 400 dpi (15.7 dots/mm).

A CCD in a G3 fax machine may have a resolution of 8 or 16 pixels/mm, to match ITU-T standards. However, as many machines are now multi-functional, such machines often employ a dpi-based CCD and convert the signal to mm format when sending a Group 3 fax.

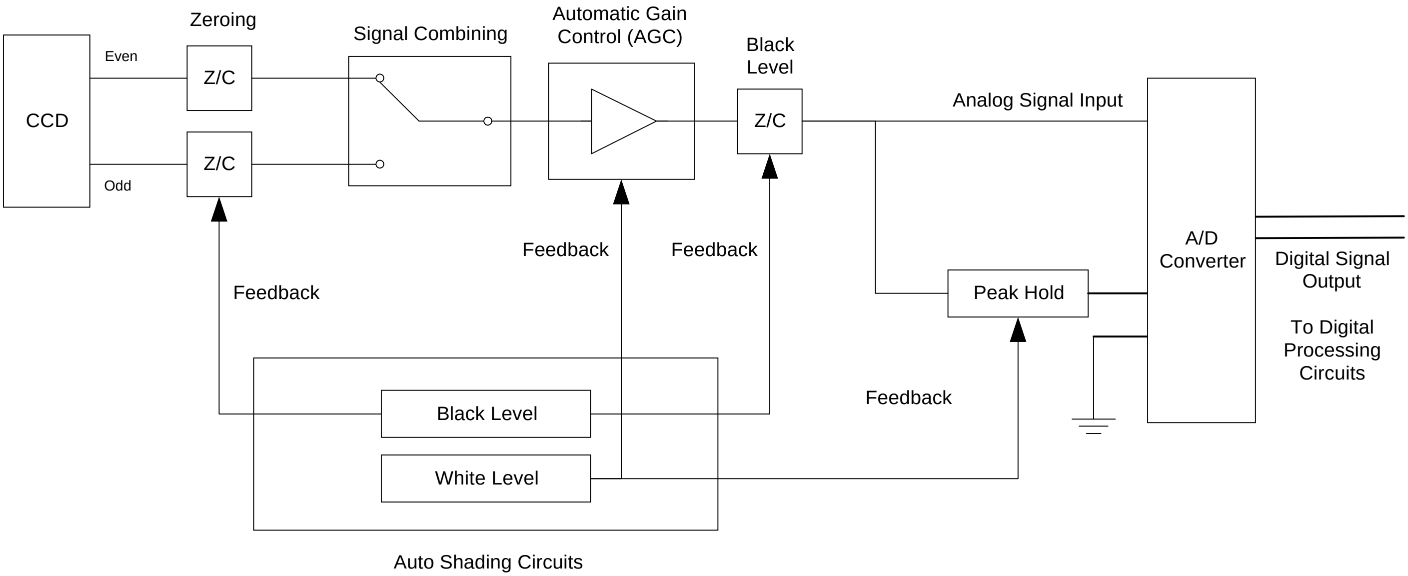
The voltage from each element depends on the intensity of the light reflected from the original onto the element; the intensity of the light depends on the darkness of the area of the document it was reflected from.

These charges are output from the CCD one after another, to make an analog video signal. Then the scanner moves to the next line of the original, and the CCD scans the next line.

The CCD scans the original one line at a time, and outputs an analog signal for each line.

# Analog Signal Processing

## Overview



This section describes:

- How the raw CCD output is prepared for conversion to digital data
- How the corrected CCD output is converted to digital data

The previous illustration shows the various steps and processes involved in preparing and converting the analog signal. The following table quickly summarizes each step.

| | |
|---|---|
| CCD output | How the raw data is output from the CCD. |
| Auto shading | A key part of analog signal processing. It affects most of the other steps and processes. |
| Zeroing | Black level correction prior to signal combination. |
| Signal combining | Merging of the odd and even picture elements. |
| Automatic gain control | Signal amplification and white level correction. |
| Black level | Black level correction after automatic gain control. |
| Auto image density | Removes background from the scanned image |
| Peak hold | Holds the peak white value for A/D conversion. |
| A/D conversion | Conversion of the analog signal to a digital signal. |

***CCD Output***

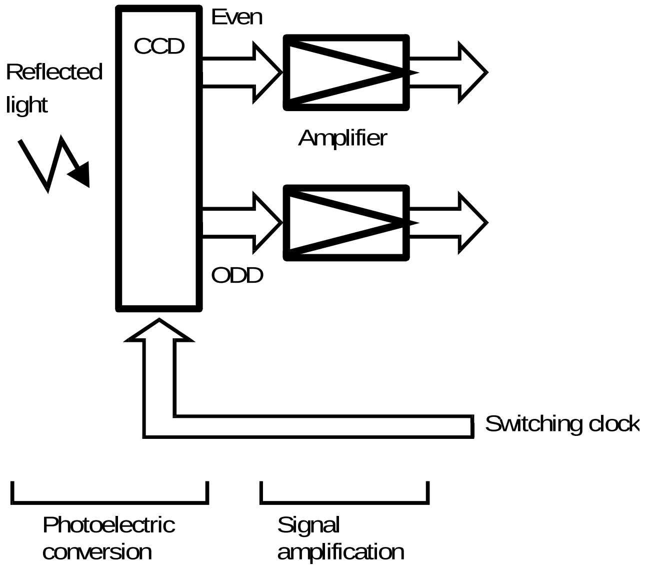
This diagram shows the CCD and its data output lines as a simplified block diagram.

There are two outputs from the CCD. One is for odd-numbered pixels, and the other is for even-numbered pixels. A clock switches the output for each pixel onto the odd or even output line alternately.

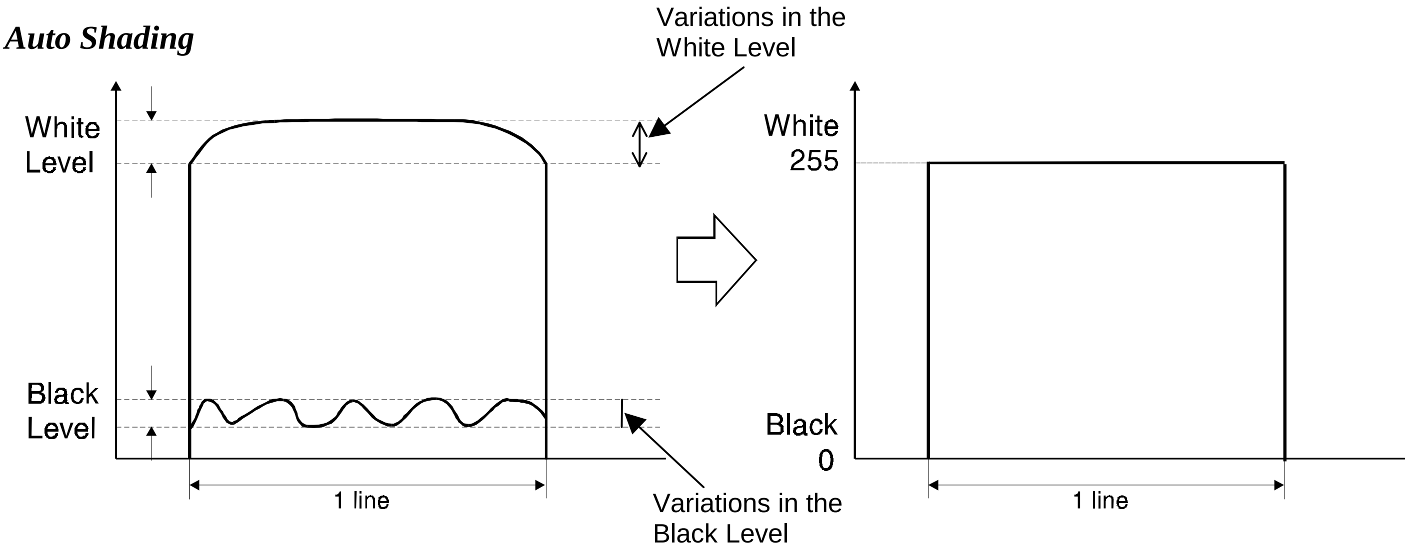
Having two outputs speeds up the image processing. CCDs in older models (mainly fax machines) only had one output line.

The two outputs are amplified before entering the analog signal processing circuits.

Details about the amplification of the raw CCD output signal are given in section 8 (Components).



### *Auto Shading*




Auto shading corrects errors caused by variations in the signal level for each pixel. Both the black level and the white level are corrected.

1) White Level Correction

The video signal information for each pixel obtained during image scanning is corrected by the image processing circuits.

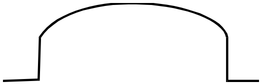
The data has to be corrected for variations in white level across the page. These variations are caused by the following factors.

- Loss of brightness at the ends of the exposure lamp with age or temperature (noticeable with fluorescent lamps and xenon lamps), or any bright and dull spots on the lamp
- Less brightness at the edges of the lens
- Variations in response among the CCD elements
- Distortions in the light path, such as differences in reflectivity across the scanner mirrors.

To correct for this, the machine scans a white plate before scanning each original. (This white plate is normally under the scanner cover or under the left scale of the exposure glass.) The white plate is uniform in color and in reflection.

The output from each element of the CCD is converted to digital and passed to a memory in the auto shading circuit. The waveform of the white platen cover from the CCD is not uniform, because of the factors mentioned above.

Ideal CCD output when the white plate is scanned



Actual CCD output when the white plate is scanned

In some models, there is a protection circuit which limits the white peak voltage. This is to prevent dark printouts resulting from an abnormally high reference voltage caused by strong light intruding into the scanner.

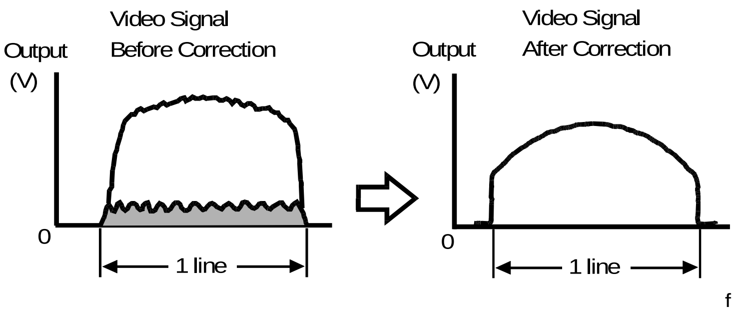
In models that have a built in ADF, continuous scanning of large originals can cause the scanner to heat up, which affects the CCD's response. Also, continuous exposure to light affects the CCD. Therefore, the white plate is scanned every 30 s to recalibrate the white level (it is done between originals; scanning is not interrupted).

After auto shading, the machine scans the page. The machine then uses the white waveform stored in the auto shading memory to correct the data. This is known as Automatic Gain Control (AGC). It is described later.

## 2) Black Level Correction

Method 1: Dummy Pixels

This zeroes the black level for each scanned line of data while scanning the original. To get the current black level, the CPU reads the dummy data elements at one end of the CCD signal (some pixels at the end are blacked off), and takes an average of the voltages read from these elements. Then, the CPU deletes the black level value from each image pixel.




This corrects the video signal for changes in response to the dummy black pixels as time passes.

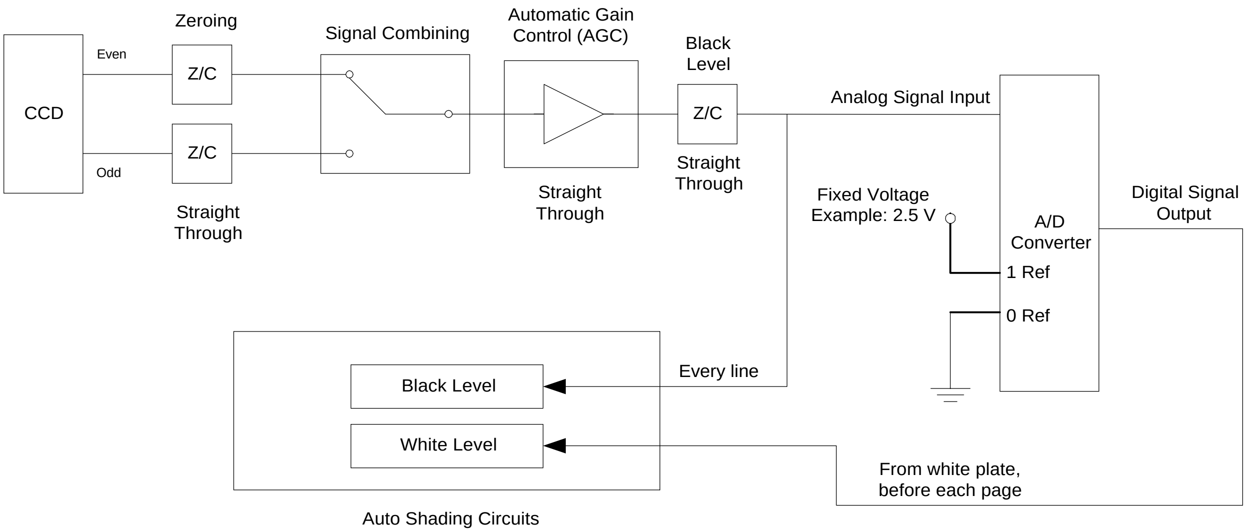
The black level is stored in the auto shading circuits (as a charge inside a capacitor, for example).

Method 2: Black Level Waveform

In some older models, the black level is done for every original, by shutting off the exposure lamp and reading a black level waveform across the page. This is stored in memory in the auto shading circuits in a similar way to that described earlier for the white level.

Method 3: Fixed Reference Voltage

Some models correct the black level using a standard reference voltage for the black reference (about 1.5 Volts)




When the machine scans the white plate before scanning the original, the odd and even pixel signals are combined. The resulting signal is converted to digital in the A/D converter, and stored in the memory in the auto shading circuits.

The auto shading circuits are normally inside the digital processing circuits, and signals from this feed back into the analog circuits when needed.

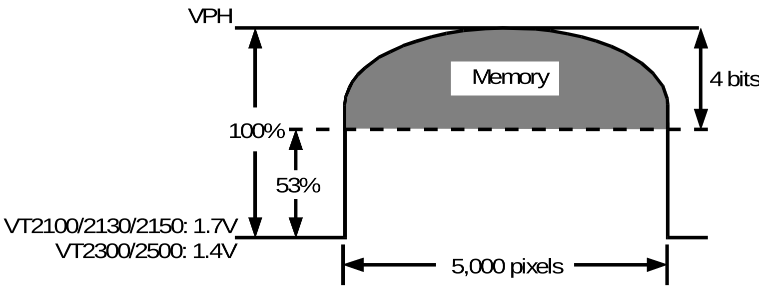
The black level goes to the auto shading circuit every line during scanning.

Peak white can be detected every scan line too - this is Auto Image Density mode (also known as ADS mode). This is described later in this section.

In the above diagram, the high level reference is arbitrarily fixed at 2.5 V and the low level reference at ground. In some cases, analog to digital (A/D) conversion is done using the peak value of the signal for the high reference, and half of the peak value for the low reference.

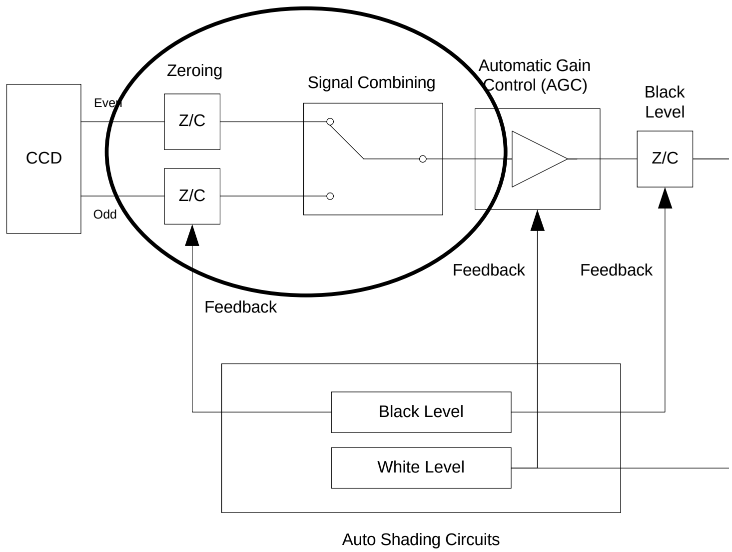
## *Example: Model C211*

The potential difference between the output of each pixel and the 53% level of the peak hold is converted by an A/D converter into 4-bit data.



## *Zeroing*

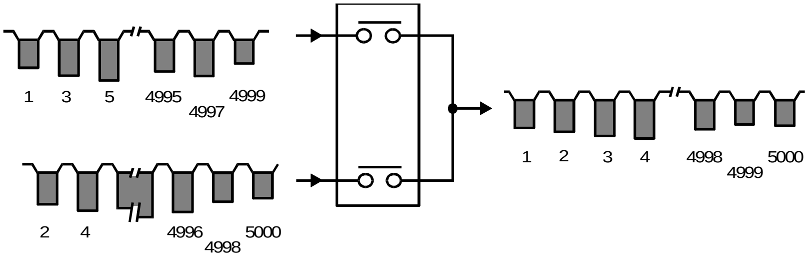
A zero clamp (Z/C) on each output adjusts the black level reference. The black level for the even pixels is adjusted to match the black level from the odd pixels. Feedback of the black level from the auto shading circuit is used.




## *Signal Combining*

A multiplexer merges the analog signals for odd and even pixels from the CCD.

In very high speed digital machines, the signals are not combined until the digital processing circuits. These machines have separate analog processing circuits for odd and even pixels.

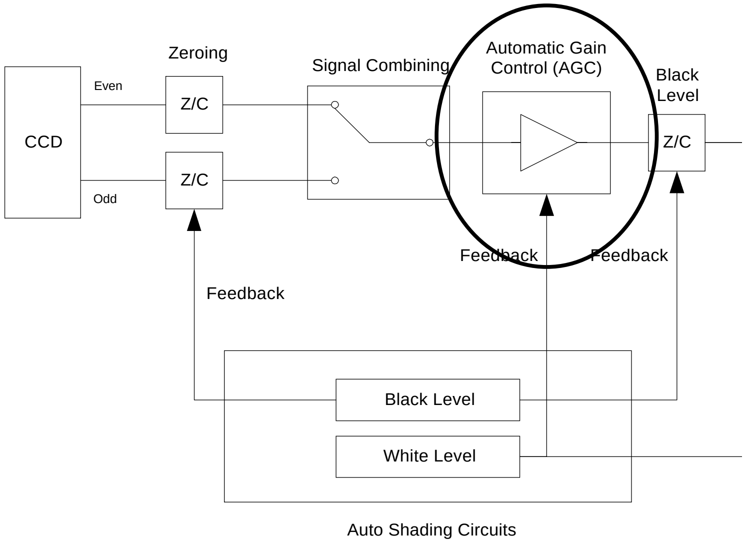


### *Automatic Gain Control (AGC)*

The analog signal is amplified by operational amplifiers in the AGC circuit.

When the original is scanned, the white level waveform is read back in from the auto shading memory. The AGC circuit uses the white level signal to correct the video data signal.

In effect, each element of the scan line is amplified by an amount that depends on the voltage of the same element in the white level signal. An example is shown on the next page

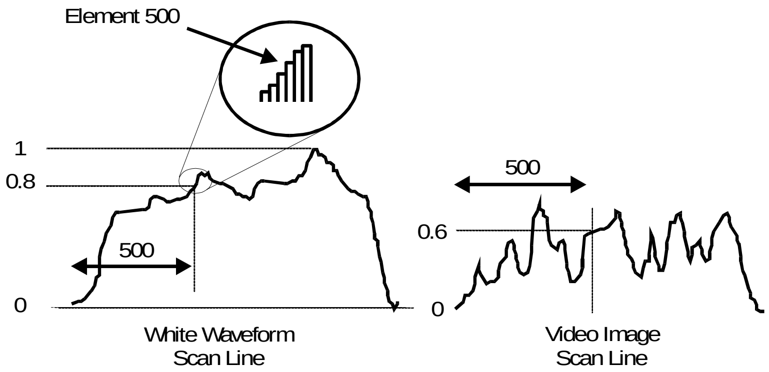


For shading correction, the peak of the scan from the white plate is set to 1. Let us take an example, in which the level of the 500th element of the white waveform is 0.8 (i.e., not perfectly white).

Then, at a point during scanning, say that element 500 in the video signal has a value of 0.6; it would be higher if there were no scanner irregularities.

So, element 500 in the video signal is corrected as follows: 0.6/0.8 = 0.75.

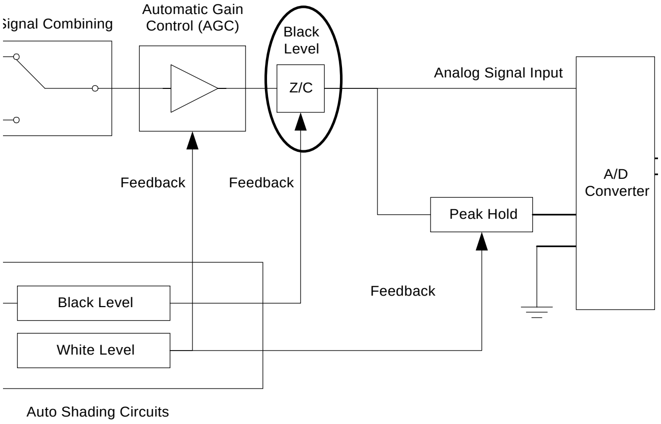
Each element in each video signal scan line is corrected in this way.




Also, if the platen cover is dirty, the values will be lower due to reduced reflection from the platen cover. This means that the image data will be overcorrected, causing pale bands in the image.

## *Black Level*

Before the data enters the A/D (analog-to-digital) converter, a zero clamp circuit again fixes the absolute value of the black level using feedback from the auto shading circuit.



***Auto Image Density***

In some machines, this feature is called Original Background Correction.

Auto Image Density (ADS) mode corrects for variation in background density down the page, to prevent the background of an original from appearing on copies.

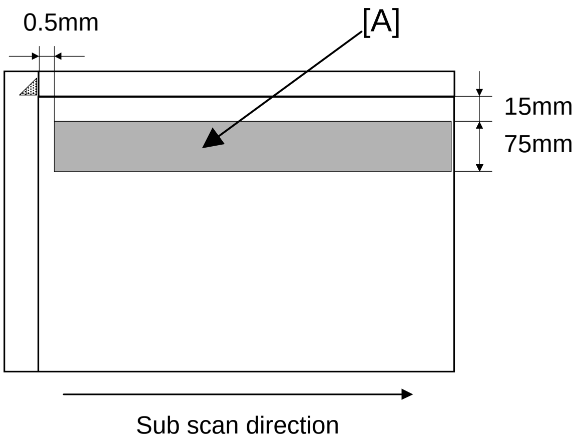
ADS mode detects the background level for the original, also known as the peak white level, and removes this from the image, to make a white background. The machine must ensure that it detects white level from areas of the original that are free from image data. There are two methods, which are explained on the next page.

When an original with a grey background is scanned, the density of the grey area becomes the peak white level density for that original. Therefore, the grey background will not appear on copies. Also, in machines where peak level data is taken for each scan line, ADS corrects for any changes in background density down the page.

Unlike with analog copiers, the user can select a manual image density when in auto image density mode, and the machine will use both the manual and auto settings when processing the original. This is useful when making copies of an original that has light image density with background; AD removes the background, and if the user selected a dark manual image density setting, the image will be brought out more clearly in the copy.

Method 1: Scanned from a narrow strip near the rear scale (***Example: Model A229***)

The copier scans the auto image density detection area [A]. This corresponds to a narrow strip at one end of the main scan line, as shown in the diagram. As the scanner scans down the page, the machine detects the peak white level for each scan line, within this narrow strip only.




Method 2: Scanned from a narrow strip at the center of the leading edge (***Example: C211 series***)

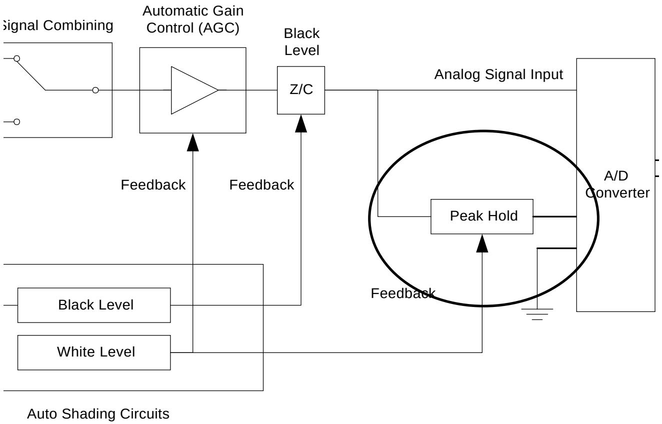
In this machine, the original is placed at the center of the original feed path, and not at one side like in the *A229*. Therefore, the peak level is read from the central 64 mm at the leading edge of the original.

One problem with this method is that, since scanning starts before the light intensity from the fluorescent lamp stabilizes, the light intensity tends to increase for a little while. The voltage from the CCD increases until the light intensity stabilizes. As a result, lighter image densities may not appear on prints after the light stabilizes. To prevent this, the peak voltage is changed when a higher (whiter) image signal is detected. If the peak voltage changes regardless of the output value, like in the A229, there is a chance of mistaking grey areas in the center of the image for peak white.

The peak hold circuit holds the peak white level.

From this peak white level, the machine determines the white reference value for A/D conversion.

The white level from auto shading is fed back to the ADS circuit to correct for fluctuations in the white level across the page.



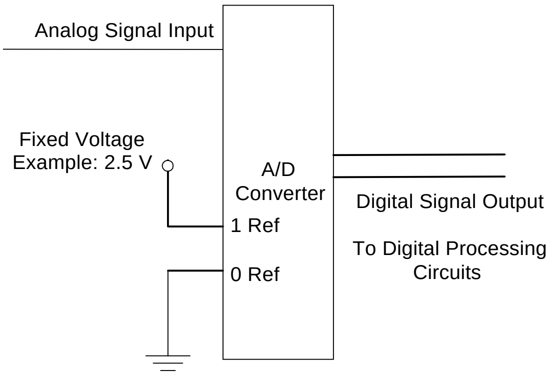
***A/D Conversion***

The A/D converter converts the analog signal to digital.

In a typical machine, the resulting digital signal has eight bits. This means that each pixel can have one of 256 values.

However, before this can be done, the A/D converter must be supplied with reference voltages that determine the black and white limits.

To do this, the A/D converter is supplied with a black reference voltage (0 Ref). For example, the input could be held to ground. This fixes the lowest of the 256 levels – any pixel with the same voltage as the black level will become black.

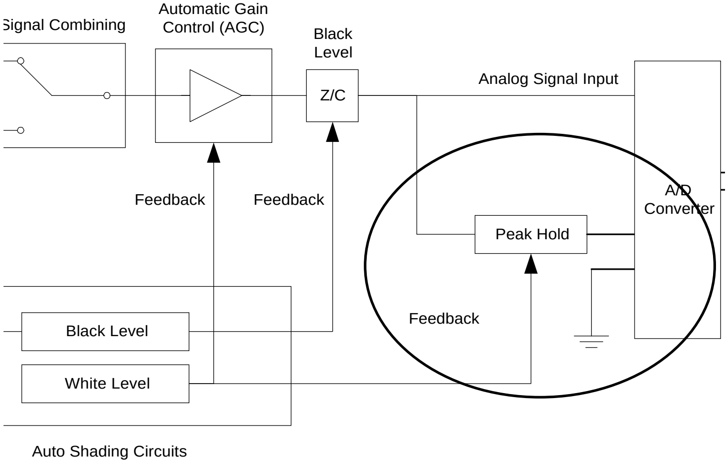



Also, the highest of the 256 values is fixed with a white reference voltage (1 Ref).

When the analog signal is digitised, 0 Ref and 1 Ref will serve as references for black and white, and the 256 levels of the grey scale will be distributed between these two levels.

If ADS is not being used, the white reference (1 ref in the diagram) is held to a fixed voltage.

If ADS is being used, the white reference voltage depends on the output of the peak hold circuit.




The A/D converter divides the range between the black and white reference voltage into 256 levels and digitizes the analog signal based on these levels. These 256 levels are known as grayscales.

The low reference voltage terminal stays constant. Only the high reference terminal voltage varies.

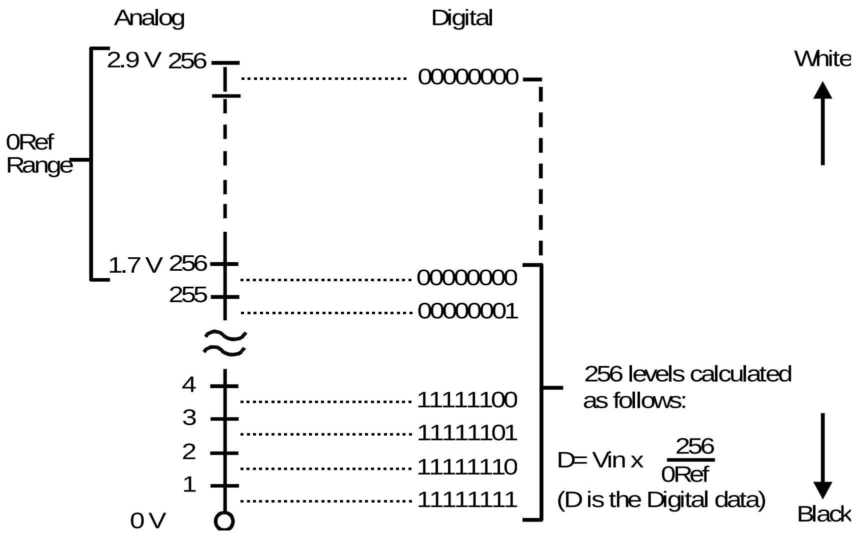
### *Example: Model A099*

In this example, the signal has been inverted so that digital 0 is white and 1 (0 Volts) is black.

The white level varies between 1.7 and 2.9 V, depending on the feedback from the peak hold circuit for ADS. (If ADS was not being used, the white level would remain fixed.)

The A/D converter divides up the range from black to the current white level into 256 levels.

The grey scale is based on the peak white level. The right side of the diagram shows how the range is divided up if the white level is 1.7 V. If the white level was 2.9 V, the spacing would be wider.




If the voltage for a pixel is between level 2 and level 3, this is converted into a digital value of 11111101.

Pure black (above level 255) becomes 00000000. Pure white (below level 1) becomes 11111111.

# *Digital Signal Processing*

### *Overview*

This section explains how the raw digital data from the A/D converter is processed to produce a faithful image of the original.

Digital fax machines, scanners, printers, and copiers use a wide range of digital image processing tools. The processes used are different in every machine, and so is the order in which they are done. Because of this, a comprehensive description is impossible. However, representative examples will be given. Many of the processes are proprietary, and in these cases, details cannot be given.

Digital processes can be broadly classified into the following types.

➢ Preliminary Image Enhancement: These processes prepare the data for processing by correcting the data for scanner characteristics, and removing unwanted data such as dots in the background.

- Scanner Gamma Correction
- Background Erase
- Independent Dot Erase
- Text/Image Separation

- Filtering: These processes enhance the data to suit the original mode (text or photo) selected by the user.
  - MTF (Modulation Transfer Function)
  - Photo mode Smoothing
- Magnification and Reduction: This enlarges and reduces the data, depending on the reproduction ratio selected by the user, or the paper size in the receiving fax terminal.
- Gradation Processing: The gradation processing methods used generally depend on the original type setting (text, photo, etc) selected by the user.
  - Grayscale Processing
  - Binary Picture Processing
  - Dithering
  - Error Diffusion
- Editing and Merging

  Using a memory work area, digital data can be manipulated to produce various effects, such as combining several images onto one copy.

  Also, multiple originals can be scanned into memory and several copies can be printed, already sorted, onto a single output tray. This is sometimes called electronic sorting. This feature allows low-volume sorted output without needing all the extra hardware.

Another benefit of digital processing with memory storage is faster duplex copying throughput, using a feature known as 'interleaving'. This feature uses a duplex tray with a one-page capacity, stores multiple originals in memory, and outputs the data in the order that is suitable for the fastest printing. This order is not necessarily the order in which the pages were scanned. This is covered more fully in the Paper Handling section (*Interleave Duplexing*).

The main benefits for most users are that a job with multiple originals can be scanned just once and stored in memory, then printed many times from memory without having to scan again. Also, printer jams can be recovered without having to scan the original again.

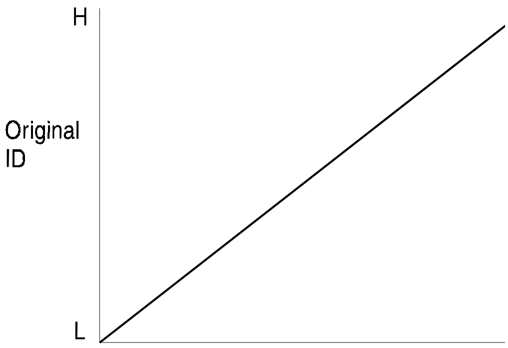
- Merging
- Make-up Mode
- Image Rotation
- Combining Images

➢ Final Image Enhancement

- Erasure of Irregular Dots
- Line Width Correction
- Edge Detection
- Sub-scan Resolution Conversion
- Inch-mm Conversion

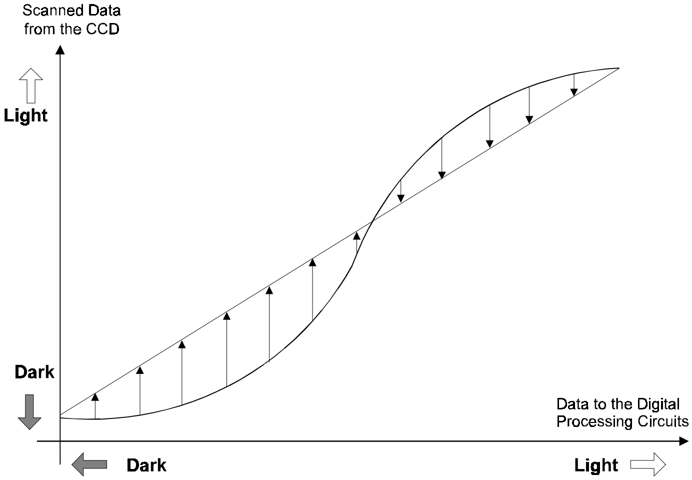
### *Scanner Gamma Correction*

Scanner gamma correction corrects the data to account for the characteristics of the scanner (e.g., CCD response, scanner optics). This ensures that the various shades in the grey scale from black to white on the copy match those on the original .




The relationship between original image density and analog circuit output should be linear as shown in the upper diagram. However, in reality, it is more like that shown in the lower diagram.

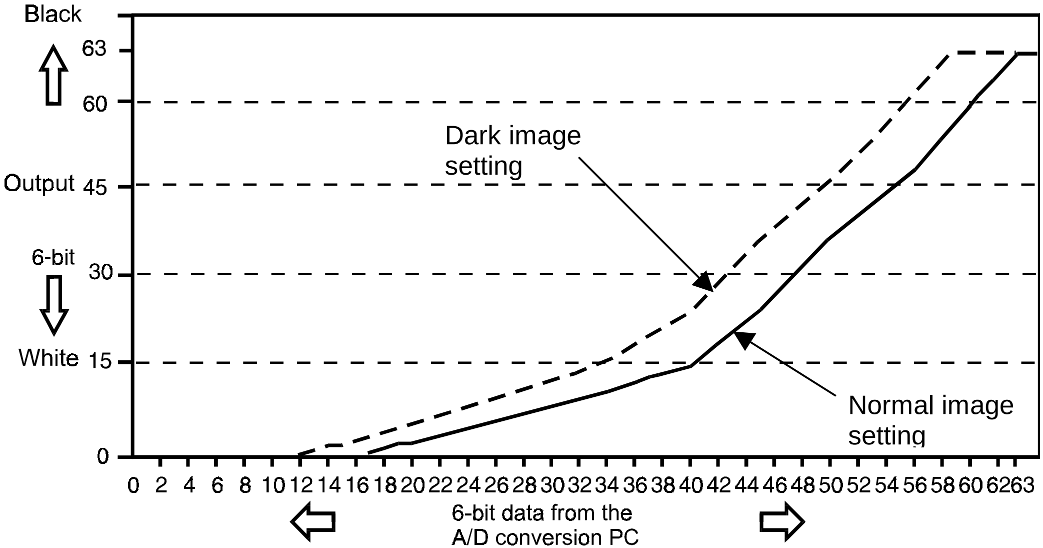
Gamma correction corrects the data for this deviation, as shown by the arrows in the lower diagram.



In some machines, the gamma curve can be changed with a service mode.

Also, some machines automatically adjust the gamma curve depending on the image density setting selected by the user.

### *Example 1: Model C222*



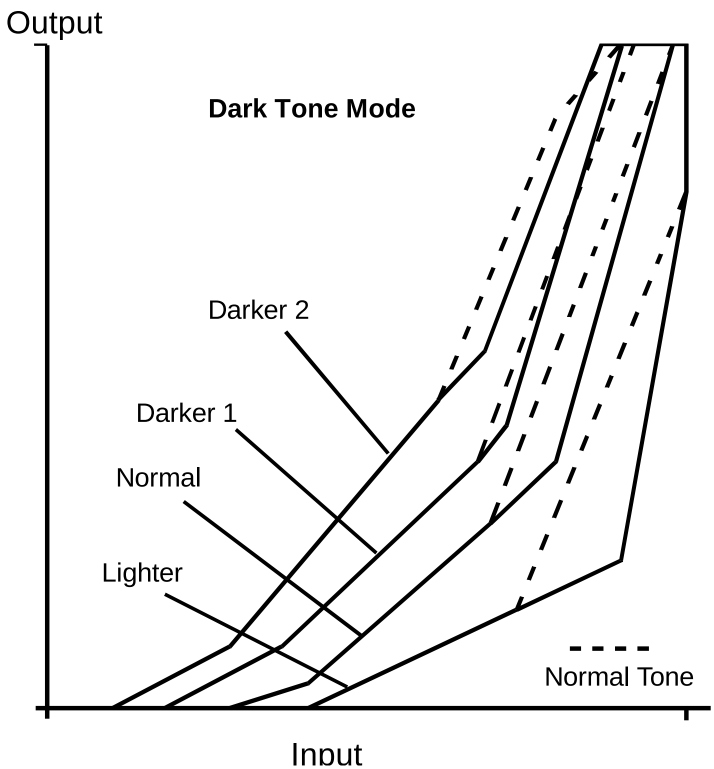

If the user selects ‘dark’ mode, the ‘dark image’ gamma curve is used and the output is darker.

## *Example 2: Model C210*

In this machine, there are four different image density settings, as shown (Darker 2, Darker 1, Normal, Lighter), There is an additional adjustment for tone. Using these, the user can emphasize better reproduction of pale or dark tones.

For example, if the user selects ‘dark tone’ mode (solid lines), the gamma curves change so that the output changes rapidly for small changes in input at the dark end of the scale. (The dotted lines show the curves for normal tone.) This causes shades of grey at the dark end of the scale to be reproduced.

There is also a printer gamma correction, to adjust the data for printer characteristics. This is discussed in the Laser Exposure section.



***Background Erase***

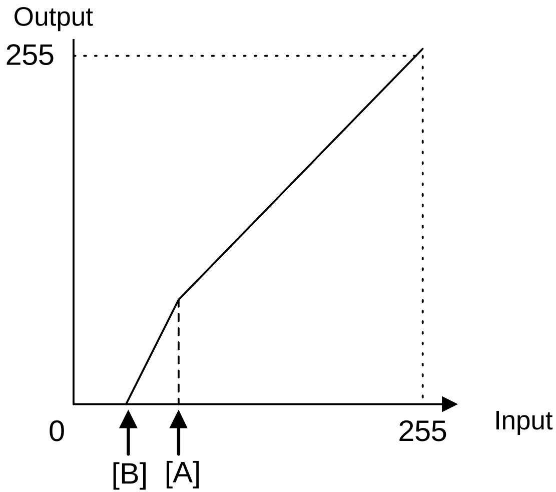
Usually, dirty background is erased using Auto Image Density (ADS). However, sometimes, dirty background areas will still appear. These can be erased by Background Erase.

If any low image density data which is lower than a threshold level remains after *auto shading*, this data will be treated as '0', which is equal to 'White'.

By adjusting the threshold to a larger value, darker backgrounds can be eliminated.

***Example: Model A229***

If there is a sudden cutoff at the threshold, sudden changes in the data around the threshold level area can cause errors during the MTF process. So, in the example shown, the image density does not cut off at the threshold [A], but gets paler more rapidly than usual, until at a certain point [B] it becomes white.



### *Independent Dot Erase*

This feature removes isolated black pixels from the image. It is normally not used in photo mode, to avoid deleting details from images.

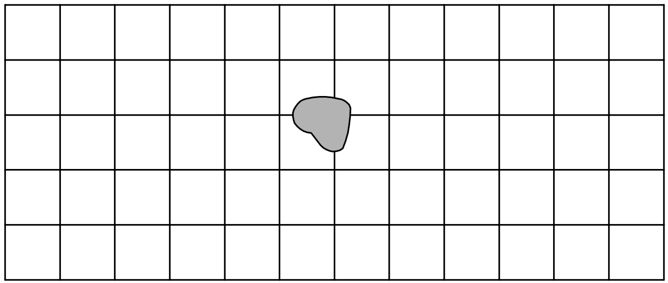
### *Example: Models A230/A231/A232*

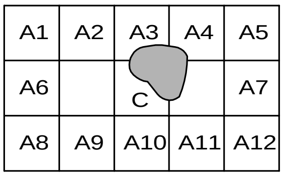
The software compares each pixel (C in the diagram above left) with the pixels around the edges of the surrounding 3 x 5 area. If the sum of the pixels at the edges is smaller than the threshold value, the object pixel is changed to 0 (white) or reduced in density to an average of the pixels around the edge, depending on an SP mode setting.

The threshold can also be adjusted.

In the example shown to the right, if the pixel is below the threshold value, it is either erased, or reduced to 3 (the average of the pixels around the edge, which is 37 divided by 12).

Original image






3 x 5 area

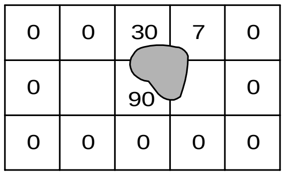



Image data

## *Text/Image Separation*

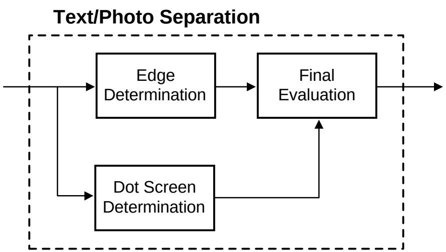
When the user selects Text/Photo mode, the machine processes text areas and image areas differently.

Some machines have only a simple text/image separation as part of the error diffusion process (described later), whereas others have a more sophisticated algorithm (described in this section).

Note that for some machines, “Letter mode” is used to refer to originals containing text. "Letter" refers to a type of image data, not Letter size paper or "correspondence". It means text and/or line art.

<u>Method 1: Edge and dot screen area detection</u>

Generally, text areas have strong contrast between the image and the background. In photo areas (dot screen areas), there is a less extreme range of contrast, and mid-range grey areas are common. By using these characteristics and the following separation methods, the original image is separated into text and photo areas.




1. Edge detection

Edges of letters and parts of images are detected by checking for strong contrast, continuity of black pixels, and continuity of white pixels around the black pixels.

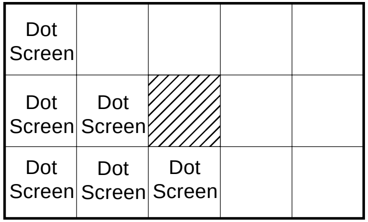
2. Photo area (dot screen) detection

Each pixel is tested to see if it is in a dot screen area by comparing with nearby pixels.

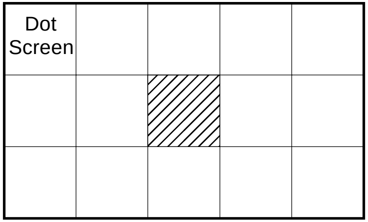
***Example: Model A229***

The page is divided into 4 x 4 blocks of pixels. Each block is placed at the center of a 5 x 3 array of these blocks, and becomes either text or photo, depending on the other blocks in the 5 x 3 area .

If the number of dot screen blocks in the 5 x 3 area exceeds a threshold, the central block is determined to be an image area. (The threshold is 2: if two or more of the blocks in the 5 x 3 area are dot screen, areas then all the pixels in the central block are determined to be in an image area.)




**Determined to be Photo**




**Determined to be Text**

## Final Evaluation

The machine decides whether each pixel is in a text or image area by looking at the results of the edge and dot screen detection processes.

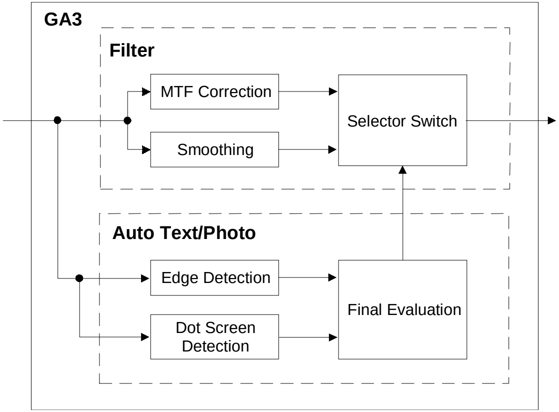
Example: Model A229

| Dot Screen | Edge | Final Evaluation |
|---|---|---|
| No | No | Photo |
| No | Yes | Text |
| Yes | No | Photo |
| Yes | Yes | Photo |

Text and image areas can then be processed differently.

***Example: Model A133***

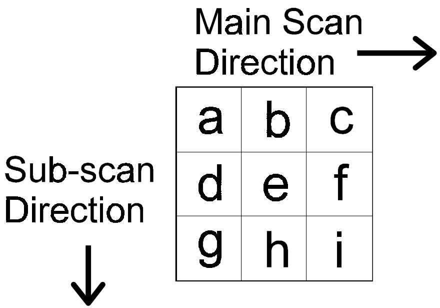
The image data is treated by *MTF* and by smoothing simultaneously. However, the result of the final evaluation controls a selector switch. For a text area pixel, the output from the *MTF* selector is selected. For an image area pixel, the output from the smoothing circuit is selected.



Method 2: Comparison of adjacent pixels

***Example: Model C226***

In the Letter/Photo mode, the machine checks each pixel of the original to see if the pixel is in a line area or in a photo area. To recognize a line area in a photo original, the CPU does the following calculation on the 6-bit pixel data.




$x = | (c + f + i) - (a + d + g) |$

$y = | (g + h + i) - (a + b + c) |$

If x or y is greater than 10, the machine recognizes that pixel e is in a letter area.

If the calculated number is 10 or less, the pixel is in a photo area.

In larger digital machines, this is a part of the error diffusion process, in addition to the main text/image separation process described earlier.

***MTF (Modulation Transfer Function)***

When the CCD converts the original image to electrical signals, the contrast is reduced. This is because neighboring black and white parts of the image influence each other as a result of lens characteristics. This symptom is typical when the width and spacing between black and white areas are narrow. MTF correction counters this symptom and emphasizes image detail.

Because of this, MTF is necessary for reproduction of details such as thin lines, points, and complex characters. Without MTF, such details may be lost, or only partly reproduced. Small dots and thin lines may be split up over more than one pixel. If the dot or line is small enough, the pixel output may fall below the threshold required to register a black pixel, and it would not be printed.

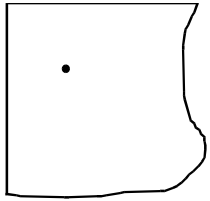
Because MTF sharpens the image, it is normally not used with photo mode. However, MTF can be useful in photo mode when putting more weight on improving the resolution when copying from continuous tone originals. Also, in text/photo or photo mode, MTF can be combined with error diffusion, which reduces differences in contrast.

The MTF algorithm generates a new value for the density of the element, using an algorithm that uses the density values of neighboring pixels in the image.

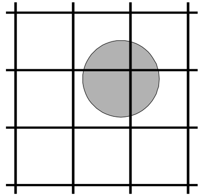
## *Example: Model C223*

Consider a small black point on a original as shown in the illustration (a) and (b). The 6-bit image data (range 0 to 63) for this section of the original is shown in (c). If the threshold level is 32, all the pixels in this area will become single-bit white data and the image will not be reproduced (d).

The MTF correction prevents this image loss by modifying the value of each pixel in the following manner



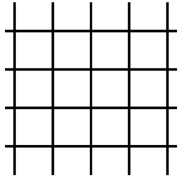
a) Section of original



b) Enlarged view of dot

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 12 | 4 | 0 |
| 0 | 30 | 12 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

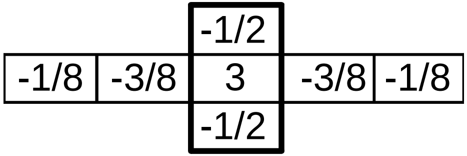
c) Image data after A/D conversion



d) Print without MTF correction (threshold level: 32)

C223d667.wmf

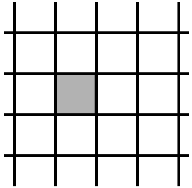
The value of the target pixel is multiplied by 3. Then, 3/8 of the values of the pixels to the left and right, 1/8 of the values of the pixels two steps to the left and right, and 1/2 of the values of the pixels above and below are subtracted from the new value of the target pixel. (If the result is less than zero, then the pixel value is set to zero.)



After the MTF correction is applied, the image data of the example is as shown in (e) and (f). The small black point is reproduced on the print.

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 19.5 | 1.5 | 0 |
| 0 | 63 | 22.7 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

e) Image data after MTF correction



f) Printout after MTF correction

The MTF algorithm can be strengthened by using higher values in the calculation. See the example on the right.

| | | | | |
|---|---|---|---|---|
| | | -2 | | |
| -1/8 | -3/8 | 6 | -3/8 | -1/8 |
| | | -2 | | |

In some machines, the MTF algorithm can be strengthened in either the main scan direction, sub scan direction, or both at once. For example, if the original has a lot of thin horizontal lines, MTF can be strengthened in the sub scan direction to preserve these lines, without applying an excessive MTF in the main scan direction.

A stronger MTF filter sharpens the image and leads to better reproduction of low image density areas, but may lead to the occurrence of moiré in the image. Also, stains, scratches, and other blemishes in the light path will appear on prints more easily.

***Photo mode smoothing***

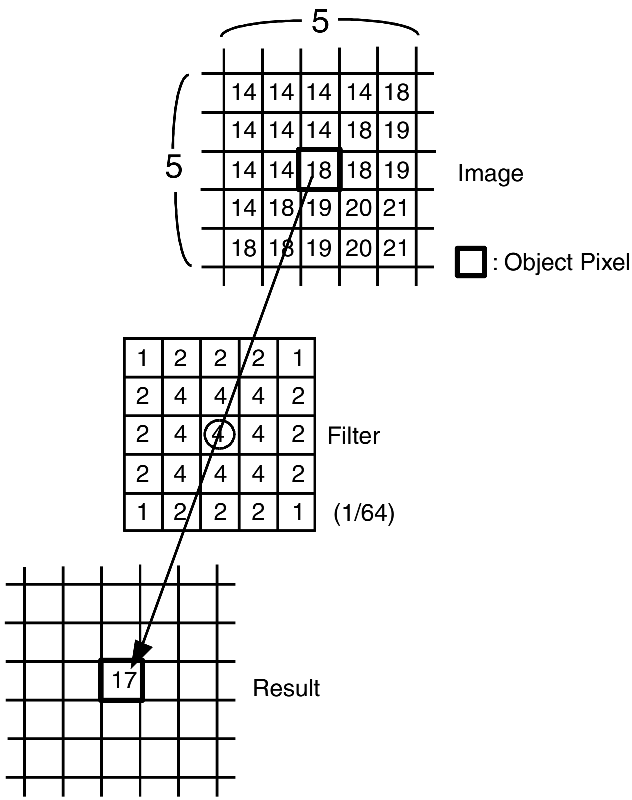
There are some different processes that use the name 'smoothing'. This section describes the image enhancement process that is used in photo mode to make a softer image. The other types of smoothing act on the final data to remove jagged edges from the image. They will be described later.

Smoothing acts in a directly opposite way to MTF. It smoothes the contrast between adjacent pixels, giving better reproduction for photos. Because of this, it will not normally be used in text mode.

### *Example: Model A099*

The smoothing algorithm is: the values of the 24 pixels surrounding the object pixel and the object pixel are multiplied by the values in a 5x5 filter matrix. Then the new values are added together. The result is then divided by 64 and rounded off to yield the new value of the pixel. If this procedure is applied to the example, the value of the pixel shown in the figure changes from 18 to 17.

This algorithm is applied to all pixels. If the pixel is on the edge of the image area, the missing data is assumed to be "0".



The filter can be changed using a service program to suit the type of original.

***Example: Model A099 again***

High-contrast originals

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 2 | 2 | 1 |
| 1 | 4 | 4 | 4 | 1 |
| 2 | 4 | 8 | 4 | 2 |
| 1 | 4 | 4 | 4 | 1 |
| 1 | 2 | 2 | 2 | 1 |

Normal originals

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 2 | 2 | 1 |
| 2 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 2 |
| 1 | 2 | 2 | 2 | 1 |

Low-contrast originals

| | | | | |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 |

## *Magnification and Reduction*

Overview

If the user selects a magnification or reduction ratio at the operation panel before copying, the image data must be enlarged or reduced.

Also, fax machines have to reduce the data if the paper in the machine at the other end is not wide enough to print the message. The machine determines whether reduction is necessary by comparing the received protocol signal with the document width sensor readings.

Sub Scan Direction

Method 1: Original transport speed

***Example: Model A229***

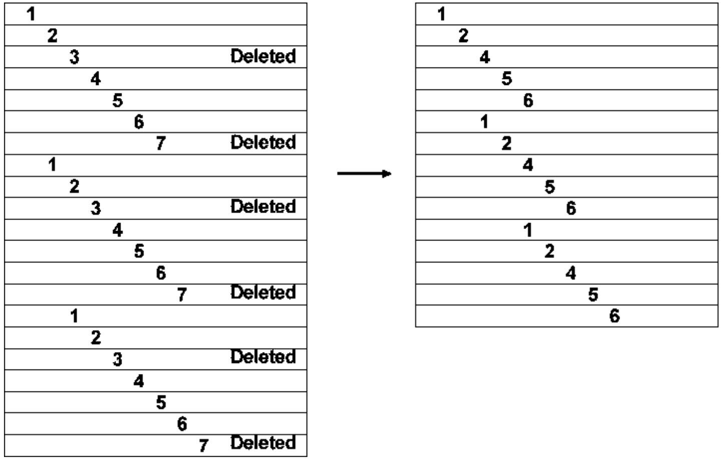
Reduction and enlargement in the sub scan direction are done by changing the scanner or ADF motor speed.

Method 2: Deleting scan lines

The cpu does sub-scan reduction by cutting out the 3rd and 7th scan lines in every 7 scan lines (for A3 [11.7" x 16.5"] to A4 [8.3" x 11.7"]), or the 6th and 13th scan lines in every 13 scan lines (for A3 [11.7" x 16.5"] to B4 [10.1" x 14.3"] and B4 [10.1" x 14.3"] to A4 [8.3" x 11.7"]).

This is only done by older fax machines. Recent models change the scanner motor speed.

Example: A3 to A4 reduction

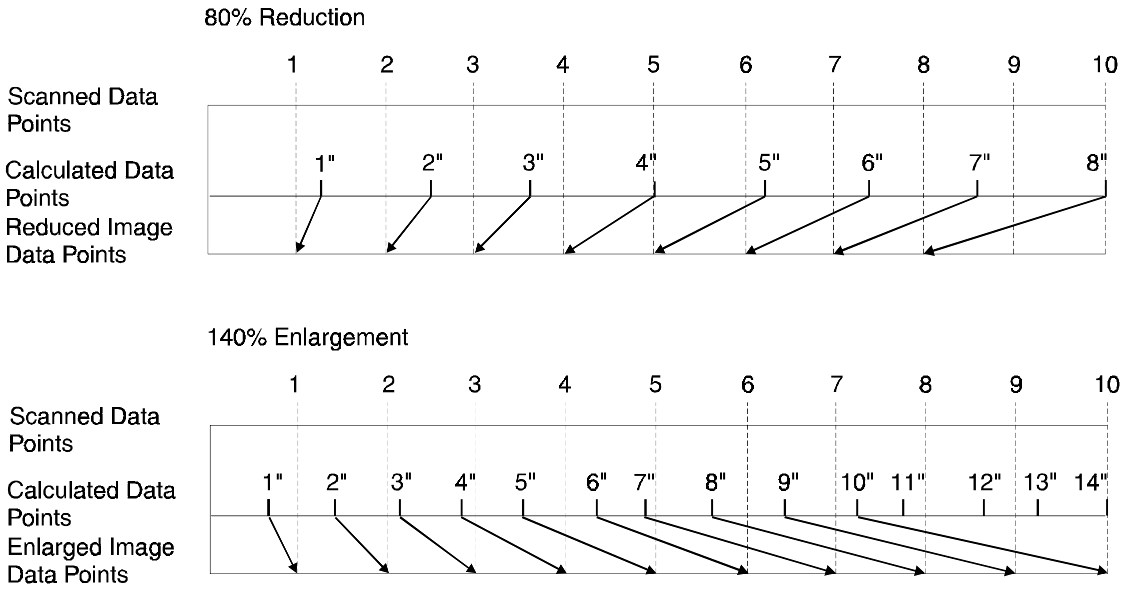



Main Scan Direction

Reduction and enlargement in the main scan direction are handled by digital image processing circuits.

Method 1: Calculation of Imaginary Pixels

## *Example: Model A229*




Scanning and laser writing are done at a fixed pitch (the CCD elements cannot be squeezed or expanded). So, to reduce or enlarge an image, imaginary points are calculated that would correspond to a physical enlargement or reduction of the image. The correct image density is then calculated for each of the imaginary points based on the image data of the nearest four true points. The calculated image data then becomes the new (reduced or enlarged) image data.

80 % Reduction

For example, data for 10 pixels in a main scan line are scanned by the CCD.

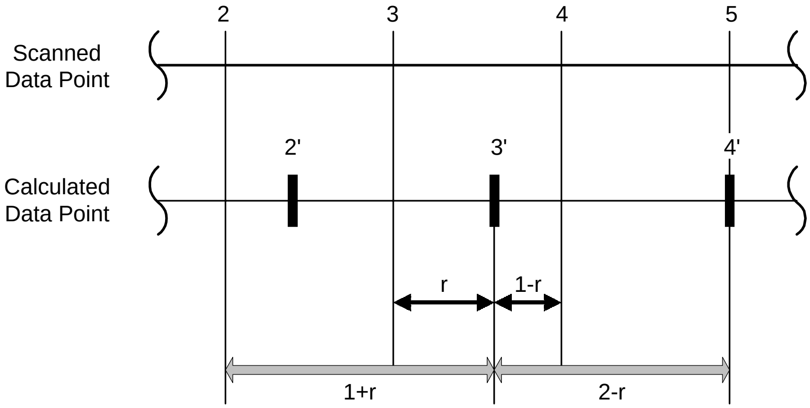
Those data are compressed into data for 8 pixels by the magnification processor. As a result, the image is reduced to 80 %.

140 % Enlargement

Data for 10 pixels of a main scan line are expanded into data for 14 pixels. As a result the image is enlarged with a 140 % magnification ratio.

The calculation method is described below in more detail.

To reduce or enlarge an image, imaginary points are calculated that would correspond to a physical enlargement or reduction of the image. The image density is then calculated for each of the imaginary points based on the image data of the nearest four true points. The calculated image data then becomes the new (reduced or enlarged) image data.




Here is an example of how the calculation is done.

In the example on the right, the density at point 3' (ρ3') is calculated from the densities at points 2, 3, 4, and 5 (ρ2, ρ3, ρ4, and ρ5) as follows:

$$(\rho 3') = \frac{\rho 2 \times h(1+r) + \rho 3 \times h(r) + \rho 4 \times h(1-r) + \rho 5 \times h(2-r)}{h(1+r) + h(r) + h(1-r) + h(2-r)}$$

The values of the weighting factors h(1+r), h(r), h(1-r), and h(2-r) depend on the value of r, as shown in the table on the right. The set for the nearest value of r is used.

| r | h(1+r) | h(r) | h(1-r) | h(2-r) |
|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 0 |
| 0.25 | - 0.25 | 1 | 0.375 | - 0.125 |
| 0.5 | - 0.25 | 0.75 | 0.75 | - 0.25 |
| 0.75 | - 0.25 | 0.375 | 1 | - 0.25 |

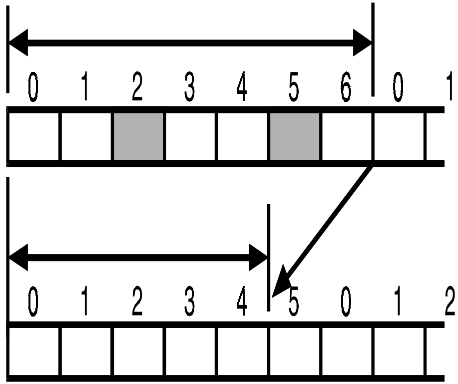
Method 2: Adding and Deleting Pixels

Another way to expand or shorten the main scan line is to add or delete pixels at regular intervals.

However, this method is not so flexible as method 1, because it does not allow the user to increase or decrease the magnification in 1% steps (the ‘zoom’ feature).

***Example: Model C226***

| Reduction Mode | Discarded Pixels | Remaining Pixels |
|---|---|---|
| 100% | 0 Pixels | All Pixels |
| 93% | 1/14 Pixels | 13/14 Pixels (0.929) |
| 82% (A4 version) | 3/11 Pixels | 9/11 Pixels (0.818) |
| 75% (LT version) | 1/4 Pixels | 3/4 Pixels (0.75) |
| 71% (A4 version) | 2/7 Pixels | 5/7 Pixels (0.714) |
| 64% (LT version) | 5/14 Pixels | 9/14 Pixels (0.642) |




71% reduction: 5 out of 7 pixels are used, 2 pixels are discarded (see the diagram).

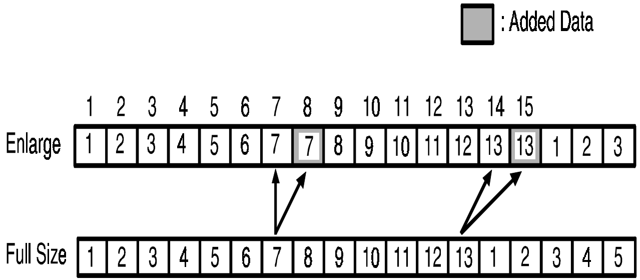
82% reduction: 9 out of 11 pixels are used, 2 pixels are discarded.

93% reduction mode: 13 out of 14 pixels are used, 1 pixel is discarded.

In some machines, there is one exception to this rule. If the pixel scheduled for deletion is darker than the pixel immediately to the right, the latter pixel is deleted instead.

| Enlarge Mode | Added Pixels | Pixel Ratio |
|---|---|---|
| 115% (LT/A4 Version) | 2 Pixels | 15/13 Pixels (1.154) |
| 122% (A4 Version) | 3 Pixels | 17/14 Pixels (1.214) |
| 127% (LT Version) | 3 Pixels | 14/11 Pixels (1.273) |
| 141% (LT/A4 Version) | 9 Pixels | 31/22 Pixels (1.409) |

115% enlargement mode: Every 7th pixel and 13th pixel are doubled to produce 15 pixels from every 13 pixels in the original (see the drawing).




122% enlargement mode: Every 5th, 10th, and 14th pixels are doubled to produce 17 pixels from every 14 pixels in the original.

127% enlargement mode: Every 4th, 8th and 11th pixels are doubled to produce 14 pixels from every 11 pixels in the original.

141% enlargement mode: Every 3rd, 5th, 8th, 10th, 13th, 15th, 18th, 20th, and 22nd pixels are doubled to produce 31 pixels from every 22 pixels in the original.

Some digital processes can cause *moiré* when used in conjunction with reduction or enlargement at certain reproduction ratios.

Because of this, the order of some processes depends on the reproduction ratio.

***Example: Model A229***

64% reduction or less: Main Scan Reduction then Filtering (MTF or Smoothing)

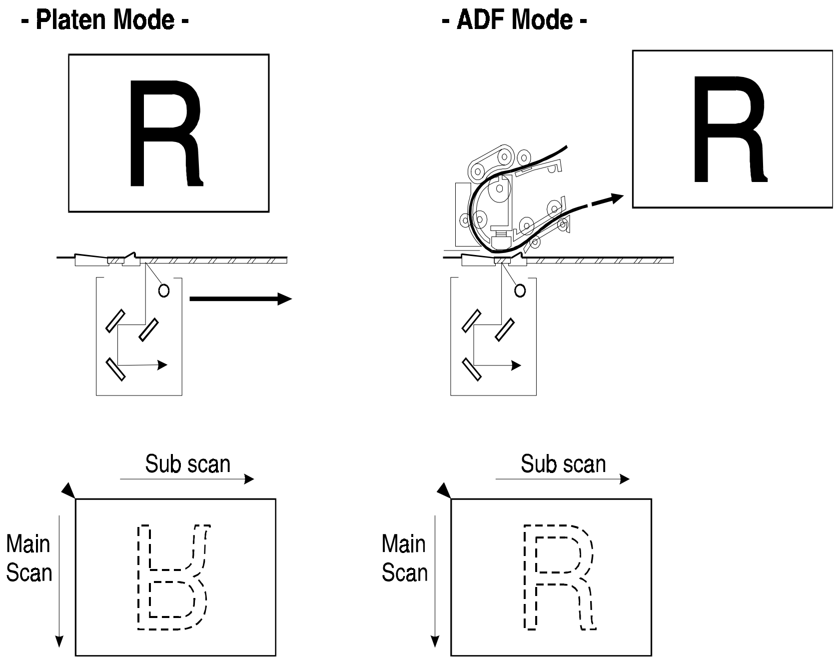
65% reduction or higher: Filtering (MTF or Smoothing) then Main Scan Magnification/Reduction

Method 3: Laser Diode Pixel Width

***Example: Model H523***

The CPU controls the magnification ratio by changing the interval between pulses in the laser clock signals. So, for example, the clock signal pulse interval for 200% enlargement is twice as long as the interval for normal (100%) image reproduction. This makes each image pixel for 200% enlargement become twice as long as each pixel for normal image reproduction.

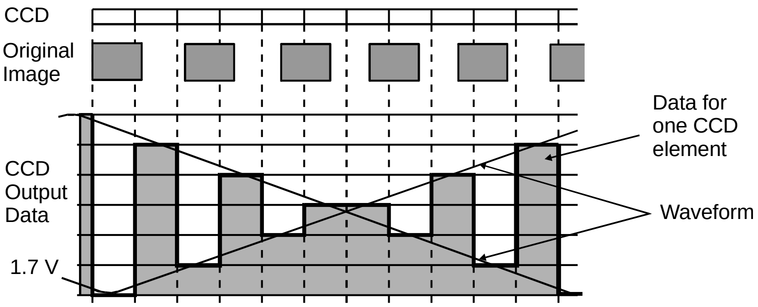
When using the ADF, the magnification circuit has to create a mirror image. This is because the main scan starts is at the other end of the scan line in ADF mode (as compared with platen mode). In platen mode, the original is placed face down on the exposure glass, and the corner at [A] is at the start of the main scan. The scanner moves down the page. In ADF mode, the ADF feeds the leading edge of the original to the DF exposure glass, and the opposite top corner of the original is at the main scan start position.




To create the mirror image, the CPU stores the main scan line data in a LIFO (Last In First Out) memory from the last pixel. When loading the main scan line data from the LIFO memory, the CPU loads the first pixel of the main scan line.

***Moiré***

When one pattern is imposed over another sometimes they interfere with each other and form a third pattern called a moiré pattern. In our products, MTF processing is a major cause of moiré patterns.




The illustration shows one of the moiré mechanisms. In this case, the pixel density of the CCD is the same as the density of the regular lines on the original. However, the regular lines are slightly out of step with the CCD pixels. As a result, each CCD pixel has a different value (as shown in the figure). Since the length of a CCD pixel is very short, the waveform from the CCD output looks like the cross lines in the figure. The moiré pattern appears when prints are made from this signal. The moiré pattern typically appears when the CCD pixel density is a multiple of the density of the regular lines on the original.

### *Grayscale Processing*

Grayscale processing uses many shades of grey to reproduce continuous tone originals, such as those containing photographs. A black and white photograph contains an unlimited number of shades of grey, but digital copiers and printers can normally only output a few shades, normally 64 or 256.

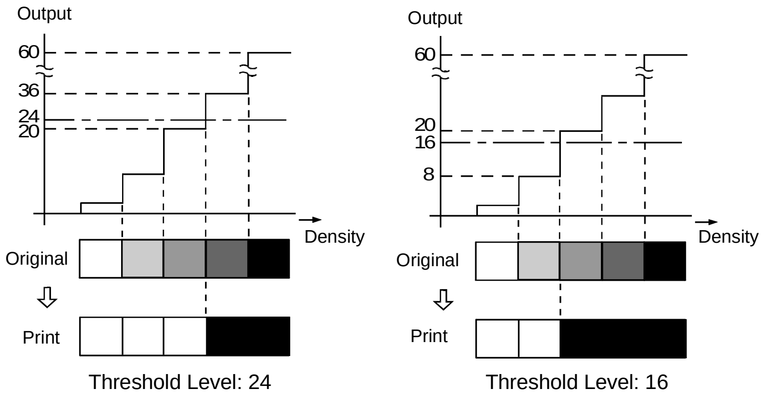
If grayscale processing is used, the digital image processing circuit outputs, to the memory or laser diode driver, the result of all the previous enhancement and filtering processes, without any error diffusion or dithering. The result is a multi-bit per pixel stream of digital data. For example, if there are 256 shades of grey, there are eight bits per pixel.

Note that grayscale processing needs a lot of memory. At eight bits per pixel (256 shades of grey), an A4 or LT page needs about 14 megabytes, without compression.

### *Binary Picture Processing*

In binary picture processing, the output data is one-bit only. There are no shades of grey. the output is black or white only.

The multi-bit per pixel data stream has to be reduced to single-bit data. To do this, a threshold level is used. If a pixel has a value that is brighter than the threshold, it becomes a white pixel. If it is darker than the threshold, it becomes a black pixel.



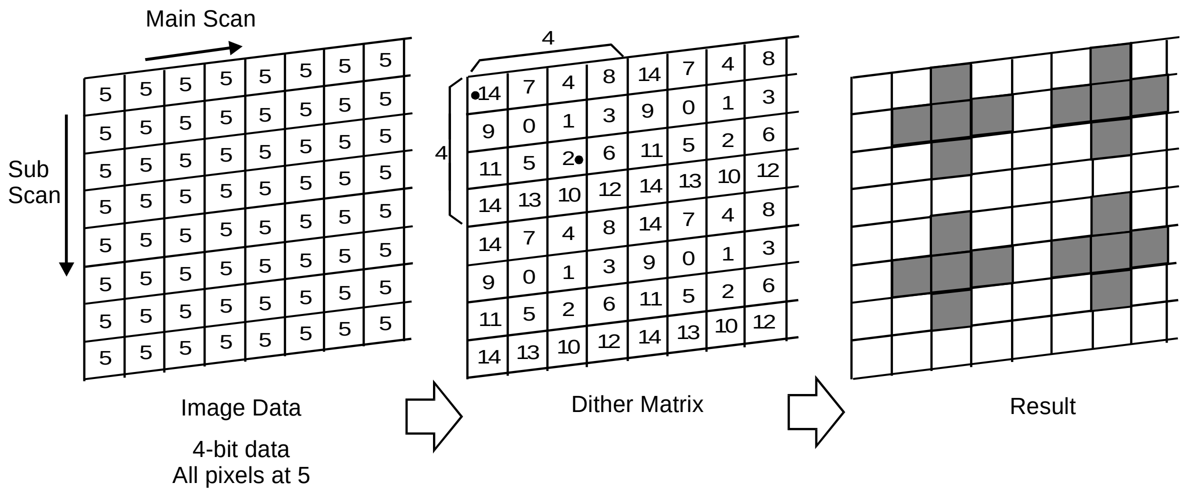

The threshold can usually be adjusted, and it often varies depending on modes selected at the operation panel. The example on the right shows how the threshold level affects the output.

If binary picture processing is used with dithering or error diffusion, then the threshold level for each pixel will be different, as described in later sections.

## *Dithering*

This is used to reproduce originals with continuous tones, such as photographs on machines that cannot output true grayscales. Dithering produces different shades of gray by making different patterns of black and white dots. There are no gray dots at all. Dithering is sometimes called half-toning, and the various shades of gray are called halftones.

## *Example: Model C211*




The diagram shows how a dither matrix is used. In this machine, a 4 x 4 dither matrix is used, repeated many times so that it becomes the same size as the data for the scanned original.

The dither matrix contains threshold levels. Each pixel of the scanned image is compared with the threshold level at the same location in the dither matrix. Then, each pixel changes to either black or white depending on whether the image data is greater or less than the threshold level. This procedure is repeated for the whole of the original. In the example, the original is a single tone of grey, and the repeated pattern output from the dither matrix appears grey to the human eye.

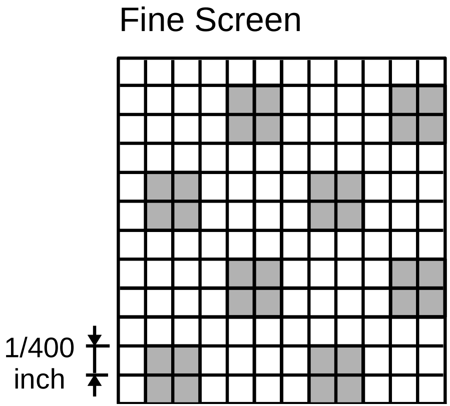
The thresholds in the dither matrix are designed so that half-tones can be reproduced on prints using only black and white pixels, by changing the ratio of black pixels to white pixels.

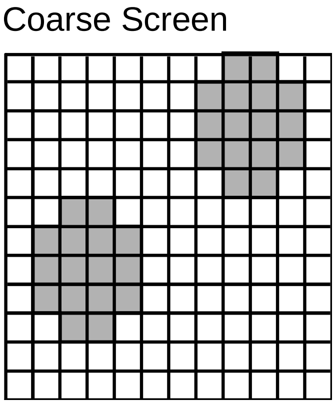
The matrixes can be adjusted in many machines to increase or decrease the detail on the copy. Also, the greater the number of lines in the matrix, the better the image quality in photo mode.

### *Example: Coarse and Fine Screen Mode in Model C223*

In this model a 12 x 12 dither matrix is used to convert 8-bit image data into single-bit data. The dither matrix for fine screen mode is different from the one for coarse screen mode.

The diagram shows what happens to an original with a constant grey tone of grade 55 (out of the possible 256).



### *Error Diffusion*

The error diffusion process reduces the difference in contrast between light and dark areas of a halftone image. Each pixel is corrected using the difference between it and the surrounding pixels. The corrected pixels are then compared with an error diffusion matrix.

Compared with dithering, error diffusion gives a better resolution, and is more suitable for "continuous toned" originals. On the other hand, dithering is more suitable for "screen printed" originals.

Error diffusion is often used in text/photo mode. Dithering reproduces text areas poorly, and with just a simple thresholding or grayscale process, photo areas do not come out well. Error diffusion is a good compromise because it reduces the contrast between light and dark areas of halftone images, while having no effect on letter areas.

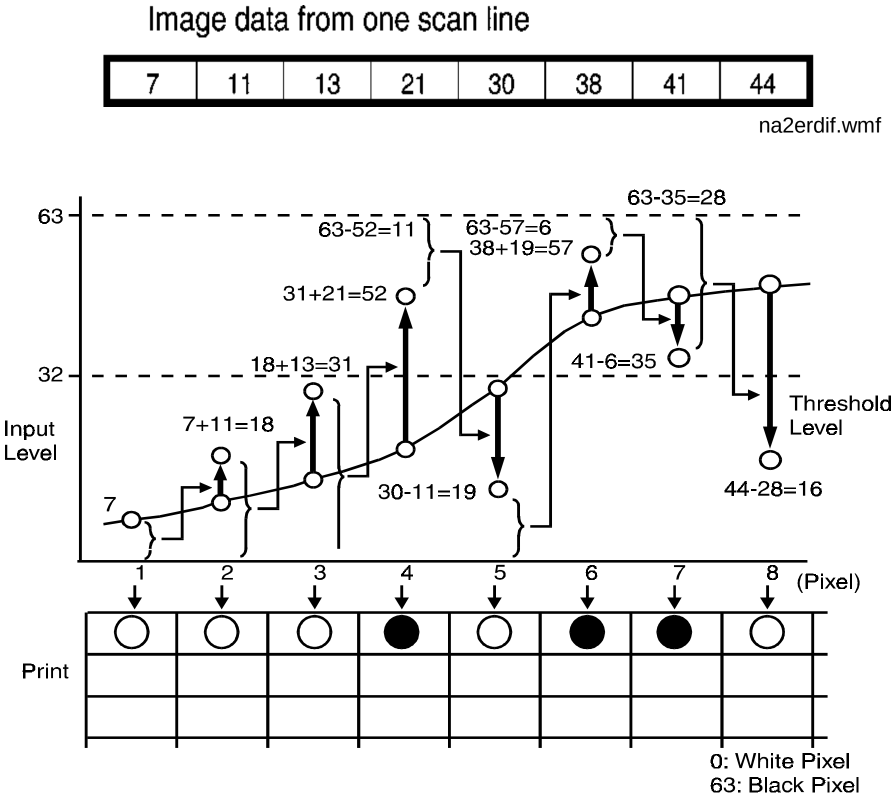
#### *Example: Model C226*

Before a 6-bit image signal is converted into a single-bit signal based on the threshold level, there is a difference between the image signal value and the complete black value (63 for a 6-bit signal) or white value (0). With the Error Diffusion process, the difference is distributed among the surrounding pixels. (The MTF process simply erases these differences.)

When considering Error Diffusion in one dimension only (across the page), the 6-bit data shown in the example below produces white and black data output as shown below. In practice, this one-dimensional Error Diffusion is done in all directions on each pixel (across the page, down the page, etc.).

In each dimension, the difference between the pixel value and the nearest extreme (0 or 63) is transferred to the next pixel. The 1st pixel in the row becomes either black or white, whichever is closest. Then, for the 1st pixel above, the difference between 7 and 0 is added to the 2nd pixel. The value of the 2nd pixel, which is now 18, is then added to the 3rd pixel. The 4th pixel becomes 52, which is closer to 63 than 0. In such cases, the difference is subtracted (not added) to get the next pixel value. In this example, the difference is 63-52=11, and the next pixel value (30-11) becomes 19.

These values will then be treated by an error diffusion matrix.



In Text/Photo Mode, the error diffusion matrix that is used may depend on the image area type (text or photo). Therefore, before error diffusion, a simple text/photo separation process is performed. This was described in Text/Image Separation - Method 2: Comparison of adjacent pixels.

If error diffusion is used with binary picture processing, the output image signal level has just 2 levels (white and black).

If it is used with grayscale processing, the output image signal level has a number of levels (from white to black). For example, in a machine with 256 grayscale output, the output from error diffusion may use a small selection of these values, which are selected to give a good print quality.

***Example: Model A229 (256 grey scales)***

***Photo mode – 17 levels per pixel***

Text areas in text/photo mode – 9 levels per pixel

Photo areas in text /photo mode – 17 levels per pixel

### *Merging*

Digital processing allows the user to combine other forms of data with the original before printing.

Common examples include printing the date and time, printing a message (such as 'Confidential'), or printing a background pattern.

### *Make-up Mode*

In make-up mode, the user scans command sheets before the original. Each command sheet specifies an area of the original. Before making the copy, the user then specifies which effects to use for the designated areas of the original. Typical effects include original type (text, photo, etc), use of various colored inks, reversed image, and background patterns.

This is a common feature in Priport machines. Color copiers achieve something similar using an editor touch screen on the operation panel.

### *Image Rotation*

If the machine has paper of the same size as the original but different orientation, the image will be rotated by 90 degrees in memory before printing. The machine must have enough working memory to do this. The amount of memory required for a certain paper size depends on the image resolution and the number of bits per pixel.

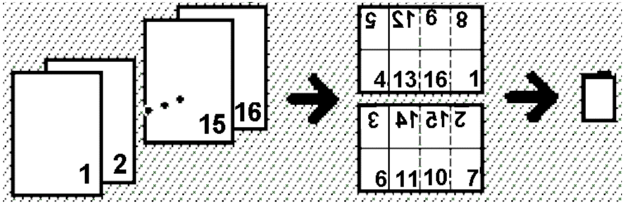
In the A229, 12 MB of DRAM is enough to hold two A4 images. This allows users to scan one original into the RAM while still copying from another. This only works for originals up to A4.

### *Combining Images*

Using the memory, digital machines can print reduced images up to eight pages on one sheet of copy paper, or 16 pages using duplex mode.

If the locations of the printed images are arranged suitably, the user can make a small booklet out of up to 16 originals, using duplex mode, then folding and cutting the copy.

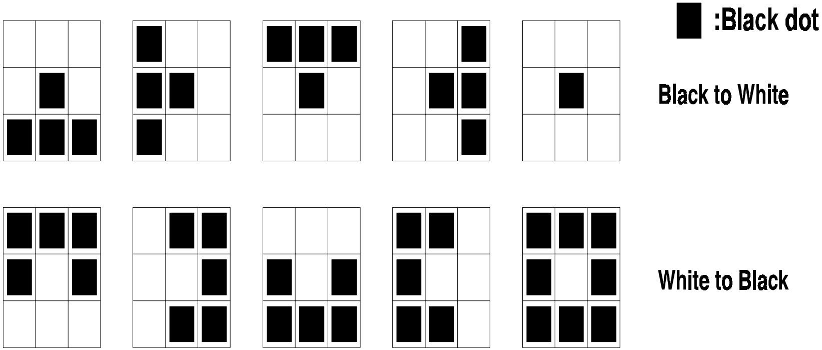
**Example: Model A133**




### *Erasure of Irregular Dots*

After the binary picture processing stage, some fax machines use pattern recognition to remove irregular dots.

### *Example: Model H515*



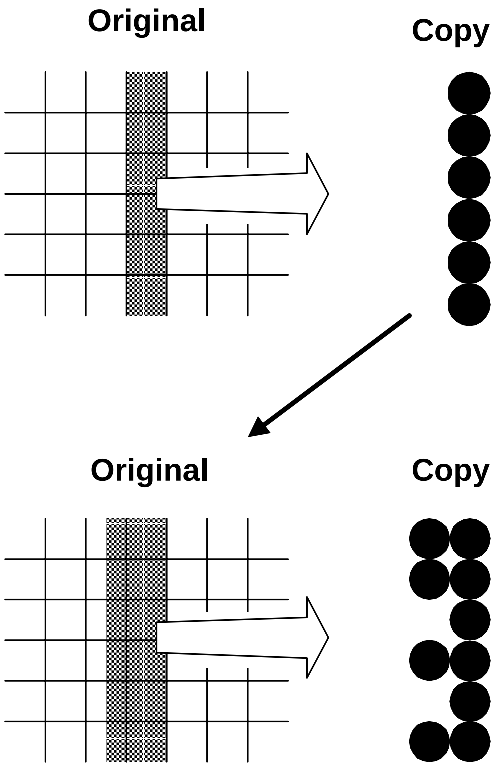

If an element after being converted to white or black by binary picture processing is irregular against the surrounding pixels, it is output in the opposite color. The central pixel is compared with the surrounding eight pixels to determine whether this process is necessary. There are ten cases, as shown above, in which conversion is done. This results in a cleaner image.

***Line Width Correction***

This is normally only used when the user selects Copied Original mode (making a copy of a photocopy). This mode is known as 'Generation Copy' mode in some machines.

Some copiers cause lines to bulge in the main scan direction as a result of the development system. So, pixels on edges between black and white areas are compared with adjacent pixels, and if the pixel is on a line, the line thickness will be reduced.

For example, if the line on the original is one pixel in width, the pixel on the copy may be slightly larger than one pixel width (as shown in the bottom diagram) due to the shape of the dot made by the laser beam and the amount of toner attracted to the pixel. If this copy is used as an original, image processing may then generate additional black pixels at the edges of the line, so the resulting printout will have slightly thicker vertical lines in places. Line width correction attempts to correct for this effect.



### *Edge Detection*

In some fax machines, this process preserves the sharpness of image outlines. Each element is tested to determine whether it is on a boundary of two areas of sharp contrast (such as the edge of a character on a white background). If the element is on a boundary, it goes straight to the cpu as a black (1) element. (Halftone processing on this element could lead to a fuzzy outline.)

Edge detection uses a threshold, which can be adjusted by RAM address in some models if edges of characters appear fuzzy.

### *Sub-scan Resolution Conversion*

Fax machines have to consider the resolution of the printer at the other end of the telephone line. The sending terminal learns the capabilities of the printer at the other end through exchanges of protocol signals.

If the printer cannot print at the same resolution as the scanned data, the sending terminal must modify the data. Two methods can be used: Line Skipping, and Or Processing.

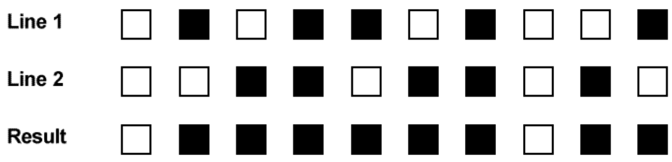
Line Skipping

***Example: Model H516***

If the user selects Fine resolution, the machine scans the document at a resolution of 15.4 lines/mm down the page. However, if the other terminal can only receive at Detail resolution (7.7 lines/mm; half the resolution in Fine mode), alternate lines are deleted before transmission.

# Or Processing

Or Processing combines two consecutive scan lines using a logical OR operation. An example is shown on the right.

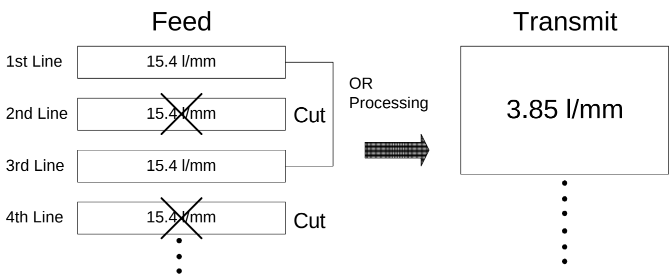



In this way, only one line is sent in place of the two lines of scanned data. OR processing ensures that the resulting single line accurately reflects the two consecutive lines that it is replacing, in that no black pixels are deleted.

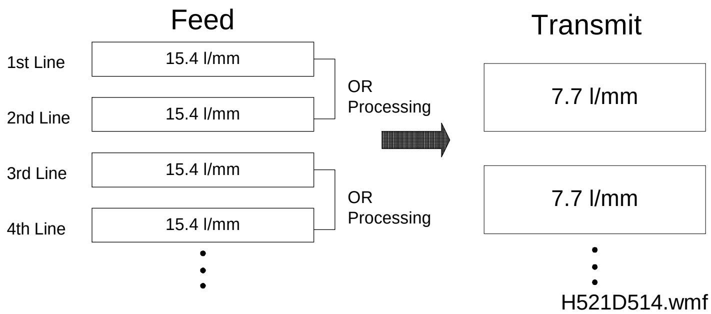
## *Example: Model H521*

The scanner always scans at 15.4 lines/mm, so the sub scan resolution has to be converted when transmitting to a terminal which is not capable of higher resolutions.

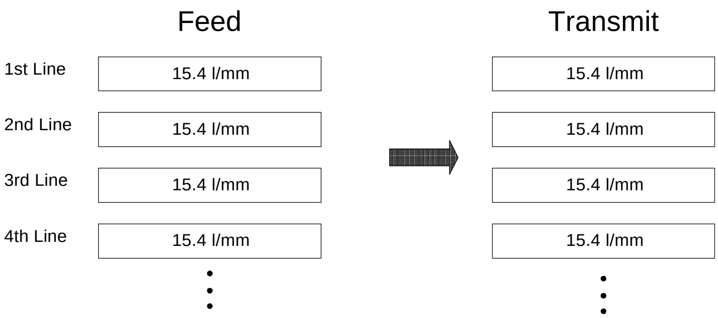
Standard (3.85 lines/mm): The first and third lines in each four-line group are OR processed for transmission. Other lines are deleted.



Detail (7.7 lines/mm): Pairs of lines are OR processed for transmission.




Fine: All the scanned lines are transmitted.



### *Inch-mm Conversion*

Multifunctional digital machines are usually designed to print in dot-per-inch format, to conform to international standards for office computer equipment.

However, in Group 3 fax standards, the data is transmitted in dot per mm format. If the scanner scans in dots per inch, the data must be converted to dot per mm format before transmission. The scanner hardware and image processing circuits can work together to get the right format.

### *Example: Models A639/A804*

Main Scan Direction

The base copier's scanner always scans at 400 dpi in the main scan direction.

Then, the image processor processes the scanned data to get the required resolution and data width. This is the same process as Reduction in copy mode.

**dpi:** dots per inch, **dpm:** dots per mm

| **Reduction** | **400 dpi** | **200 dpi** | **16 dpm** | **8 dpm** |
|---|---|---|---|---|
| No reduction | 100.0% | 50.0% | 101.5% | 51.0% |
| A3 to B4 | 86.5% | 43.0% | 88.0% | 44.0% |
| A3 to A4 | 70.5% | 35.0% | 71.5% | 36.0% |
| B4 to A4 | 81.5% | 41.0% | 83.0% | 41.5% |

## Sub Scan Direction

The base machine's scanner changes the motor speed to get the required resolution. However, if the reduction rate requires a faster speed than the scanner motor's maximum (37% reduction rate when using the ADF), the scanner and the image processor work together to get the required resolution as shown in the second table below.

**lpi:** lines per inch, **lpm:** lines per mm

| Reduction | 400 lpi | 200 lpi | 100 lpm | 15.4 lpm | 7.7 lpm | 3.85 lpm |
|---|---|---|---|---|---|---|
| No reduction | 100.0% | 50.0% | 25.0%[2] | 97.8% | 48.9% | 24.5%[7] |
| A3 to B4 | 86.5% | 43.2% | 21.6%[3] | 84.6% | 42.3% | 21.2%[8] |
| A3 to A4 | 70.5% | 35.2%[1] | 17.6%[4] | 69.0% | 34.5%[6] | 17.3%[9] |
| B4 to A4 | 81.5% | 40.8% | 20.4%[5] | 79.7% | 39.8% | 19.9%[10] |

Numbers in superscript – Scanner and image processor both work together; refer to the following table

| Case | Mode | Reduction by Scanner | Reduction by BiCU |
|---|---|---|---|
| Case 1 (35.2%) | | 52.8% | 66.7% |
| Case 2 (25.0%) | ADF | 50.0% | 50.0% |
| | Book | 25.0% | |
| Case 3 (21.6%) | | 43.2% | 50.0% |
| Case 4 (17.6%) | | 52.8% | 33.3% |
| Case 5 (20.4%) | | 40.8% | 50.0% |
| Case 6 (34.5%) | | 51.9% | 66.7% |
| Case 7 (24.5%) | ADF | 48.9% | 50.0% |
| | Book | 36.8% | 66.7% |
| Case 8 (21.2%) | | 42.4% | 50.0% |
| Case 9 (17.3%) | | 51.9% | 33.3% |
| Case 10 (19.9%) | | 39.8% | 50.0% |

Inch - mm conversion causes a slight enlargement in the main scan direction and a slight reduction in the sub scan direction. This can be seen from the above tables. For example, changing 400 x 400 dpi to 16 x 15.4 l/mm requires enlargement of 101.5% in the main scan direction and a reduction of 97.8 in the sub scan direction.

Similarly, if a dot-per-inch based machine receives Group 3 fax data, it has to convert it to dot-per-mm format. It can also change the polygon mirror speed.

***Example: Model A120***

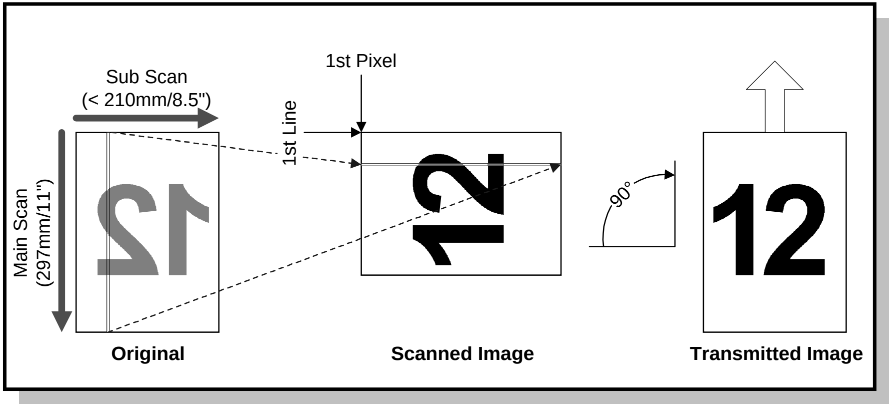
13132.44 rpm (dot-per-mm mode), 13385.83 rpm (dpi mode)

We will mention this again in the Laser Exposure section.

## *Image Rotation Before Transmission*

In copiers with fax boards, it is possible to place an A4 or Letter size original sideways on the exposure glass. In this case, the original will be treated as an A3 (DLT) width original, and reduced to A4 before transmission.

Also, if an A5 (half-letter) original is placed lengthwise on the exposure glass, the image will be sent as A4 (LT) with a lot of blank space at one edge.




However, the Image Rotation Before Transmission feature prevents these things from happening, by rotating the image before sending it out.

# *Black and White CIS Systems*

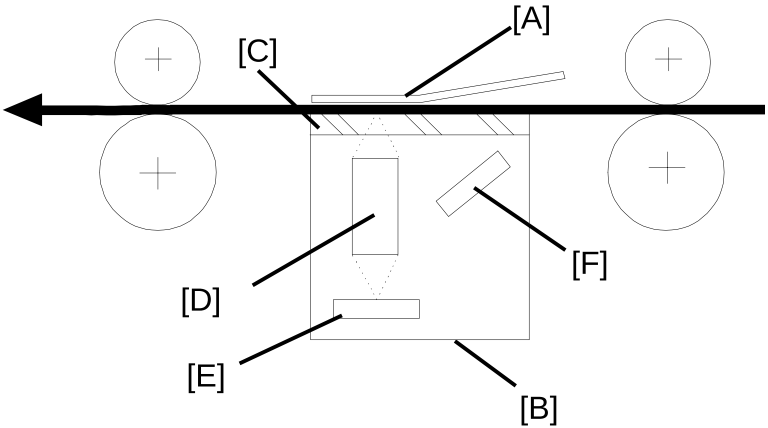
## *Contact Image Sensors*

Some low-price compact fax machines and Priports use a contact image sensor (CIS) instead of a CCD. A CIS consists of a strip of photodiodes to illuminate the document, and a strip of phototransistors covered by a row of self-focusing lenses. If a CIS is used, a long light path is not needed, because the CIS contacts the document directly, so the size of the scanner can be greatly reduced (no mirrors, lenses, or shading plates are needed). When using a fluorescent lamp/lens/CCD arrangement, the light path is about 300 to 500 mm. However, a CIS is positioned less than 0.1 mm above the surface of the paper.

However, the built-in analog processing circuits in CIS assemblies are inferior to the video processors of CCD models.

Originally, using a contact image sensor instead of a CCD removed the necessity of the complicated adjustments needed for a CCD scanner. However, CCD assemblies need no adjustments in the field nowadays, so they are used now only for cost and space reduction.

The diagram shows a typical CIS scanner.




The scanner consists of a shading plate [A] and a contact image sensor (CIS) assembly [B]. Inside the CIS are an exposure glass [C], a self-focusing lens array [D], an image sensor [E], and an LED array [F].

The image sensor is a row of 1728 photosensitive elements (A4 width, 8 dots/mm). The LED array illuminates the original. The self-focusing lens array focuses light reflected from the original onto the image sensor.

Because of the short optical path inside the CIS, the focal depth is much shorter than for a CCD type scanner. Because of this, a spring pushes the shading plate against the document so that the document surface always touches the exposure glass at the scan line, and the distance between the CIS and the original is constant.

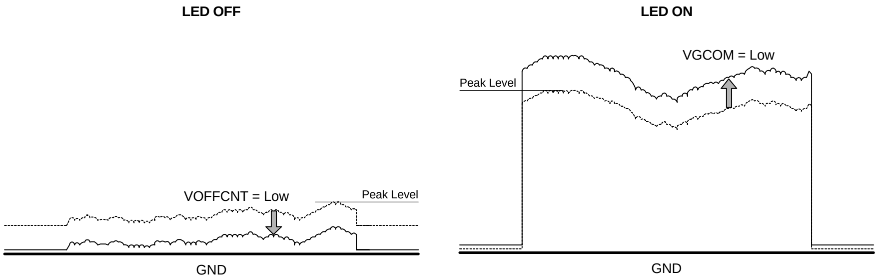
However in book scanning mode, if the original is out of the CIS focal range, the scanned image may get darker.

## *Analog Signal Processing*

Auto shading and other processes already described for the CCD are also used in CIS scanners. The only new ones are as follows.

### *Zeroing the Signal and Correcting the Amplification Ratio*

#### Example: Model H516




The image sensor generates a certain voltage even if the scanner lamp is not turned on. To correct for this, the machine automatically adjusts the ground level of the sensor output, if the peak voltage of the analog video signal exceeds 234 mV when the lamp is off.

Then, the machine adjusts the signal's amplification ratio if the peak output level of the analog video signal while the scanner lamp is on is lower than 1.72V.

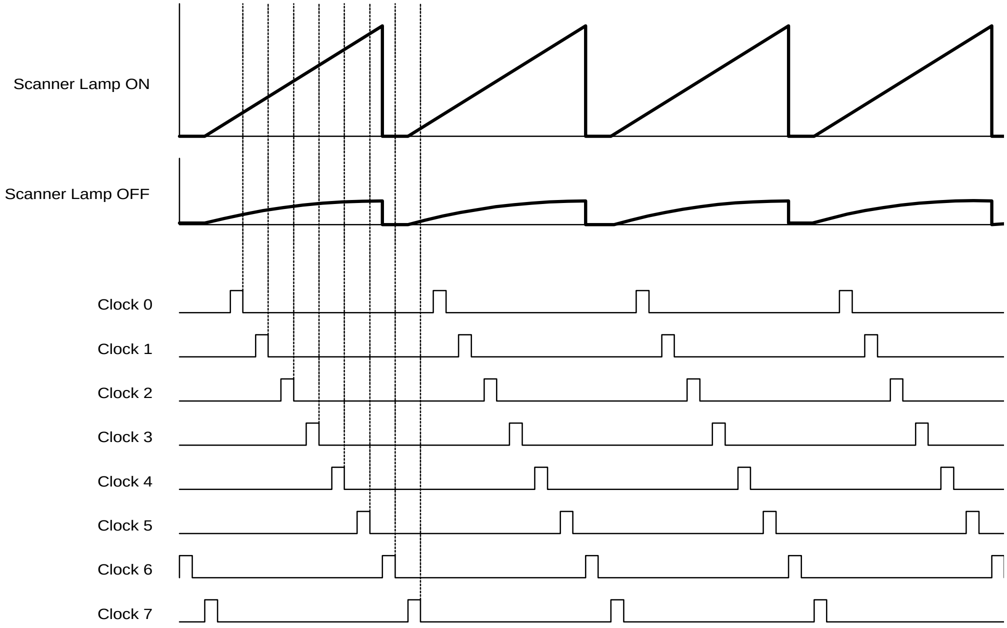
The machine will execute the above adjustments automatically, just before scanning the first page. Refer to the waveforms in the diagram to see how these adjustments work.

### *Sampling Clock Selection*

The image sensor output is a sawtooth waveform. So the sensor output level depends on the sampling clock selected as shown in the above diagram.

The clock is adjusted at the factory. But for some models, the clock should be reset using a service function whenever the image sensor is replaced.

**_Example: Model H521_**



## Digital Signal Processing

All the features discussed for the CCD apply here also. There is another one that appears in Priports that use a CIS.

### Paste Shadow Erase Mode

Due to the characteristics of the contact image sensor, shadows tend to appear on copies of paste-up originals. To counter this, pressing a key on the operation panel allows use of paste shadow erase mode.

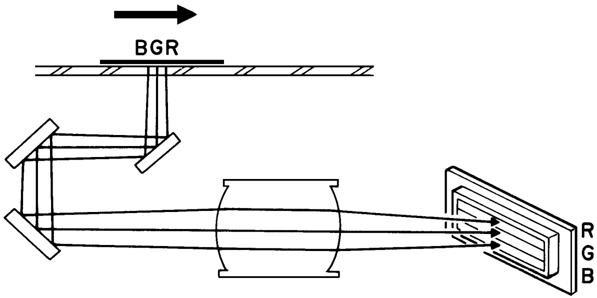
When this mode is selected, the black or white threshold level (used in binary picture processing) is slightly lowered. At the same time, the strength of the MTF process in the sub-scan direction is weakened to make the shadows inconspicuous.

# Color Systems

## Overview

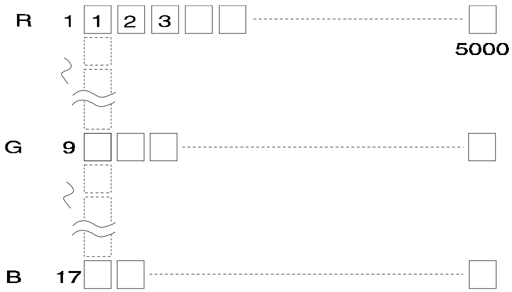
This section will explain image processing in color copiers.

## Color CCD




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. Each of the four scans (for toner colors YMCK) uses all three signals (RGB).

The CCD consists of three lines of 5000 elements at a resolution of 400 dpi (15.7 dots/mm). To make the R, G, and B signals, each line has a color separation filter (R, G, or B).




The lines are spaced 8 pixels apart for full size magnification. To correct for these spacings, the R, G, and B signals must be synchronized. This is done using a memory work area in the image processing circuits.

A filter removes infra-red; this is particularly important for glossy photos containing black areas, which can appear reddish in copies.

Most color copiers do not have enough memory for the scanned RGB data to be processed and converted to KCMY data all at once. Therefore, one scan is needed for each toner color that will be used in the copy. For example, for a full color copy, the original is scanned four times, as follows:

- First scan: The video processing circuits make K data from the scanned RGB data.
- Second scan: The circuits make C data from the RGB data.
- Third scan: The circuits make M data from the RGB data.
- Fourth scan: The circuits make Y data from the RGB data.

## *Analog Signal Processing*

These are similar to the processes for black-and-white copiers, except for the following.

### *Auto Shading*

This is done before the black scan.

# *Digital Signal Processing*

## *Scan Line Correction*

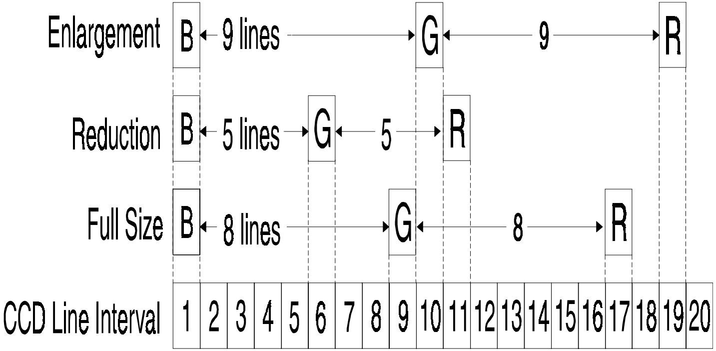
The three CCD lines providing the RGB signals are several scan lines apart (typically 8 scan lines apart) when full size magnification is used. To compensate for this discrepancy, the line correction circuits synchronise the output timing of the RGB signals to the digital processing circuits by storing the data for each line in memory.

The discrepancy between RGB video signals depends on the reproduction ratio, and this is taken into account in the correction.

### ***Example: Model A166***

- B: Standard (No correction)
- G: (8 lines) x (Reproduction ratio)
- R: (16 lines) x (Reproduction ratio)

If this calculation does not result in an integer (for example if the reproduction ratio is 90%), the correction factor is set to the closest integer, but further correction is needed (refer to Picture Element Correction).



### *Picture Element Correction*

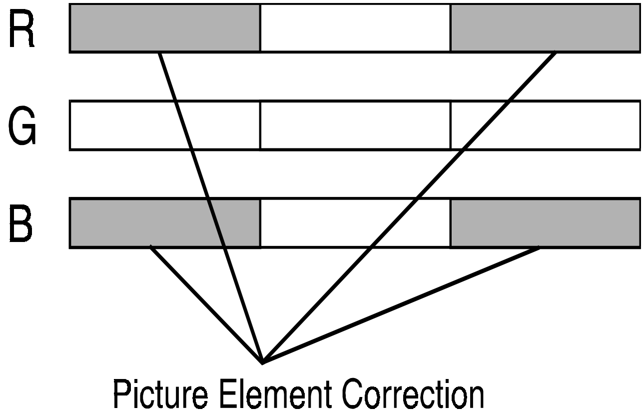
The target areas for this correction are shown in the diagram. The Picture Element Correction circuit does two things.

1. Completion of the Scan Line Correction process

This is done if the scan line correction process did not result in an integer.

2. Correction if the CCD is not perpendicular to the light

If the CCD board is not perpendicular to the light axis, the position of each pixel is different from the original image position. This difference becomes larger towards the ends. Under this condition, vertical black lines (in the sub-scan direction) at the left and right edges of the original are colored because the Y, M, and C toner dots are not properly positioned. (An example of this is the vertical lines at the right and left edges of the C4 color chart.)

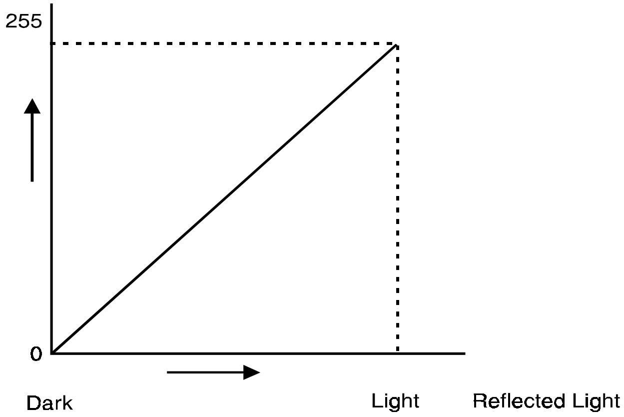


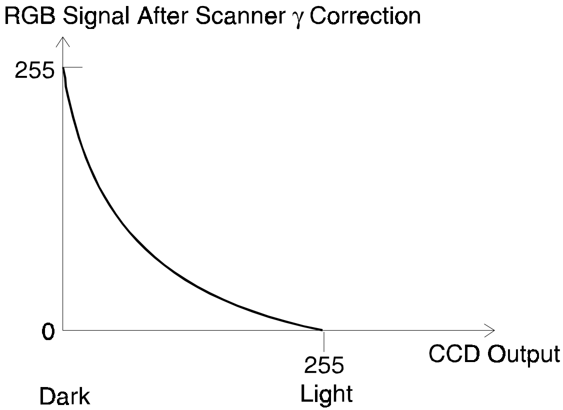

For this second stage, the green CCD line is taken as a standard, and the ends of the red and blue lines are corrected.

### *Scanner Gamma Correction*

The RGB video signals detected by the CCD are converted to 8-bit digital signals. These signals are proportional to the light intensity reflected from the original image (see the first diagram).

However, the image processor converts the signal levels as shown in the second diagram by using a gamma correction table. This table reverses the output of the video signal for each color, and this improves the accuracy of RGB to CMY color conversion, which is done later in the image process. The same table is used for R, G, and B signals.



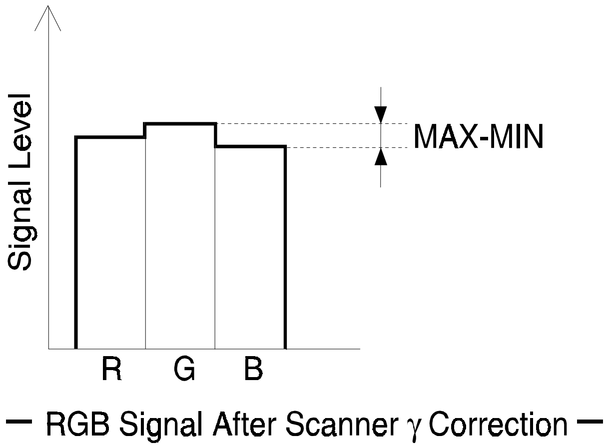
The scanner $\gamma$ correction converts the video signal levels as follows:

| | Dark (Black) | Light (White) |
|---|---|---|
| Scanner Input (RGB) | 0 | 255 |
| After $\gamma$ Correction (RGB) | 255 | 0 |
| ↓ Color Conversion | | |
| Printer Output (CMYK) | 255 | 0 |

The reversal is not linear. Dark areas need finer gradations for better copy quality.

### *ACS (Auto Color Selection)*

Auto color selection mode determines if an original is black/white or color. Then black copy mode or full color mode is automatically selected to match the original.




To recognize if the original has a colored area or not, the RGB video signals are compared. If the maximum difference among RGB signal levels (MAX-MIN in the above diagram) is within a certain range, the original is considered black and white.

Increasing the value of MAX-MIN makes it more likely that an original will be treated as a black-and-white original.

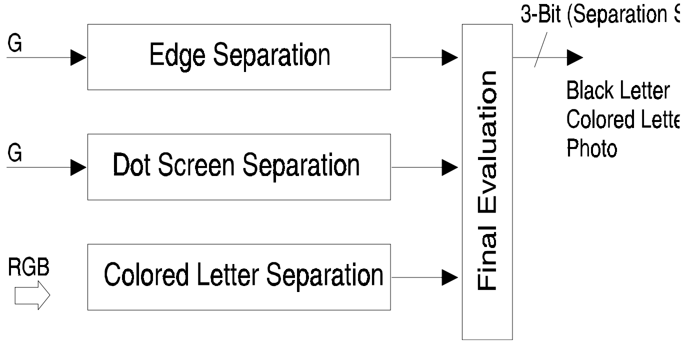
During the 1st scanning cycle, the latent image is developed with the amount of black toner as specified by the gamma-corrected RGB video signals. If the original does not have any color areas, the 2nd scanning is aborted and the developed image is transferred from the transfer belt to the copy paper. Then the black and white copy comes out. If the original has a colored area, copying resumes in the full color copy mode (4 scans).

Users can maximize the quality of their output by selecting priority for Black or Full color original when using ACS mode. This will be discussed in more detail later in the section on Under Color Removal (UCR)

### *Auto Text/Image Separation*

This is similar to the method already described for black-and-white systems. However, there is an extra step for determining which parts of text areas are black and which are colored.

Black pixels and color pixels in text areas are identified by determining the differences between the maximums of the RGB signals and by evaluating the output levels of the RGB video signals.



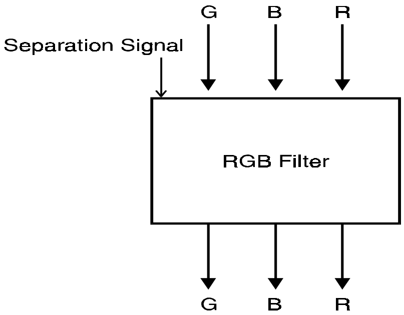

The edge separation and dot screen detection steps are similar to those described for black-and-white systems, but they are done using the green data signal only.

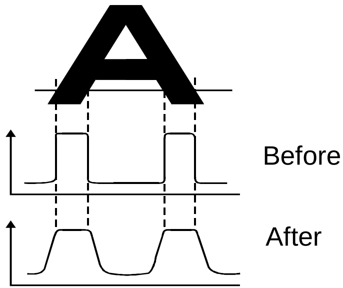
Auto letter/photo separation is mostly effective only for small letters or thin line diagram elements. If there are big letters or solid line drawing elements in the original, only the edges of these are processed using text mode; the inner regions are processed using photo mode.

### *RGB Filtering*

The appropriate filters are applied to the R/B/G video signals, depending on the selected image modes (text/image) or the result of Auto Text/Image separation.

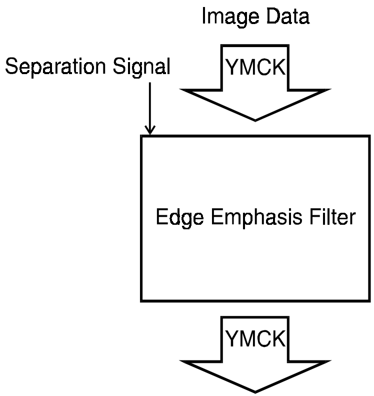
## Smoothing Filter

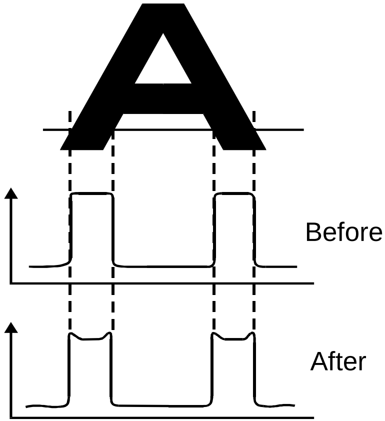



The smoothing filter improves the image by smoothing the gradient between pixels in half-tone areas.

Edge Emphasis Filter (High Contrast Filter)




The high contrast filter improves letters by making the edges of text and line art elements stand out more clearly.

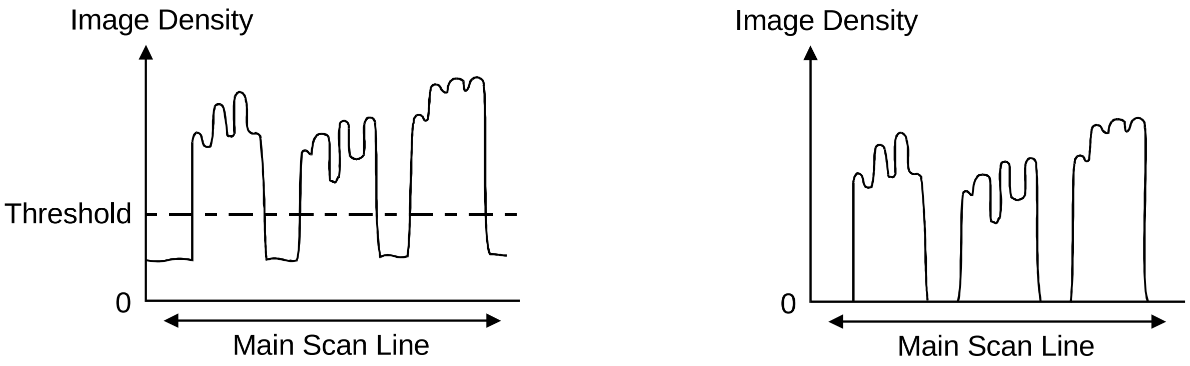
These two types of filter are applied again in some models after conversion from RGB to CMYK. (In the drawing, it is shown being used on CMYK data after color conversion.)

The user can adjust the strengths of these filters to make the image sharper or softer.

***Auto Image Density Control***

This prevents the background of an original from appearing on copies.

***Example: Model A166***

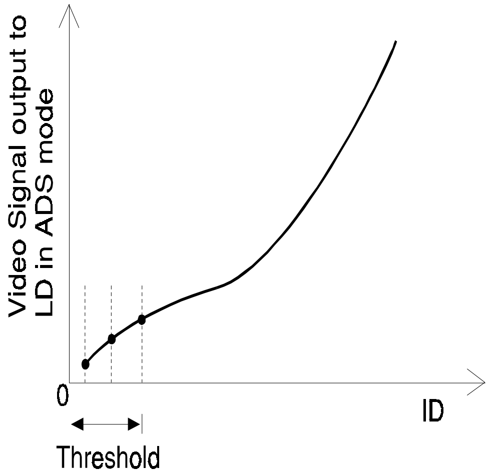



If the user does not select ADS mode, the machine removes low ID image signals (background) that are less than a certain threshold. The threshold that is applied depends on the color mode (single color or full color). If the threshold is too high, colored backgrounds could be erased.

If the user selects ADS mode, the machine calculates the threshold, guided by input from the user (there are 4 settings for black-and-white, and 4 for full color).

In full color mode, after the first scanning (Bk) the machine calculates the threshold for removing background by referring to the RGB data taken from the whole of the original.

In black and white mode, the machine calculates the threshold for each pixel by referring to neighboring pixels.

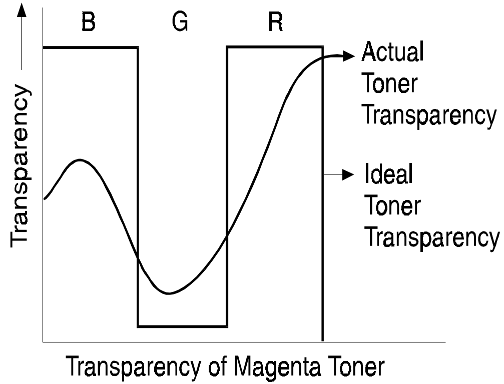


### *Color Conversion*

The transparency of each color toner is not ideal, as shown in the diagram.

Color conversion compensates for the difference between ideal and actual characteristics.

RGB video signals from each scanning cycle are converted to YMCK video signals using a matrix.



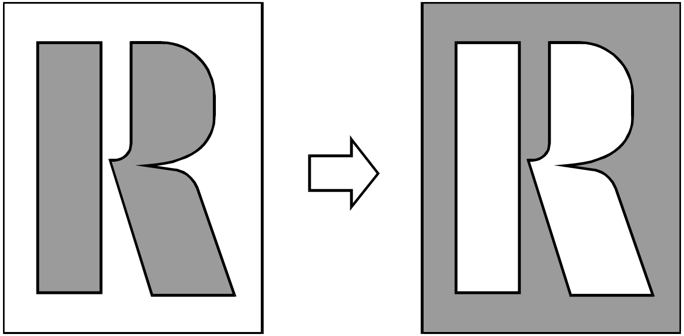

***Example: Model A166***

| | Original Color | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Toner | Bk | R | Y | G | C | B | M | W |
| Y | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| M | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| C | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| Bk | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

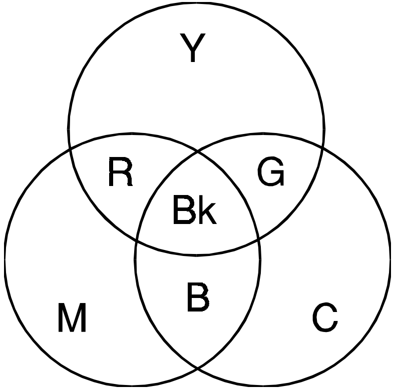
Some user and SP modes can change the contents of the matrix.

Examples: To change the color balance of the output, to allow three types of photo mode (Printed Photo, Glossy Photo, and Copied Photo).

### *Positive/Negative Reverse*



Posneg1.wmf

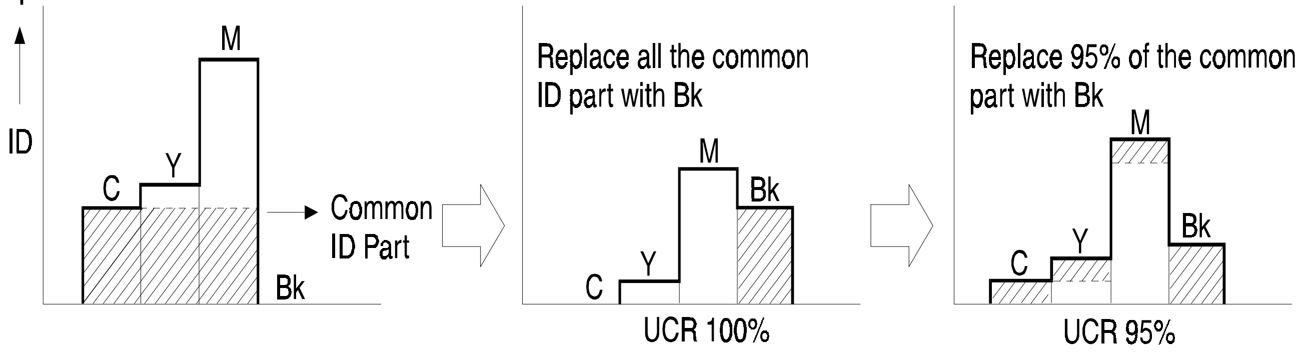



In the positive/negative image mode, colors are changed to their complements, as shown below:

Red – Cyan
Green – Magenta
Blue – Yellow
Yellow – Blue
Magenta – Green
Cyan – Red
Black – White
White – Black

***UCR (Under Color Removal)***

Principle




Getting the right colors using YMC toner addition does not always work perfectly. For example, equal amounts of Y, M, and C toner should give Black. However, the result is a dark blue.

UCR compensates for this by removing equal amounts of each color toner and replacing them with black toner.

The UCR ratio is the percentage of the common ID value for YMC that is subtracted and converted to Black. In the above example, where the UCR ratio is 100%; the entire common ID value is subtracted from Y, M, and C, and converted to Bk.

In actual use, the UCR ratio depends on the color mode and the image density. For example, when the UCR ratio is 95%, 95% of the entire common ID value is subtracted from Y, M, and C, and converted to Bk.

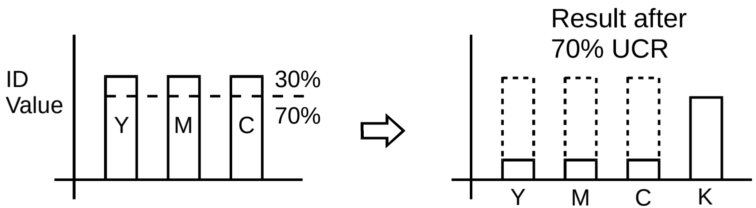
In the following examples, the UCR ratio is 70%.

For a Black Image

When a black image is copied, the ID values for all colors are equal (diagram on the left).

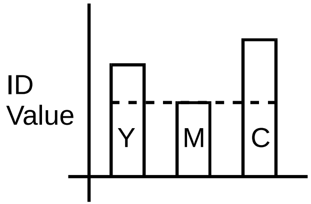
For each color, the ID value is reduced by the UCR ratio (70% in this example).

A black ID value equal to the 70% reduction is added to compensate for the color ID reduction (diagram on the right).

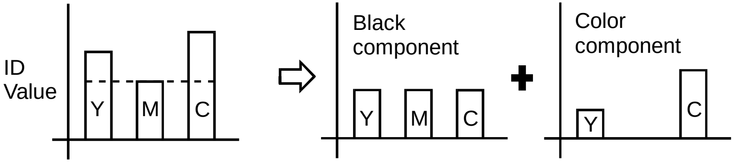



For a Color Image

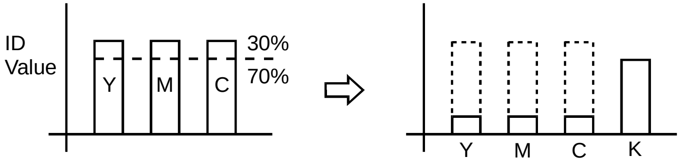
When a color image is copied, the color ID values are different from one another. It is treated in three steps.



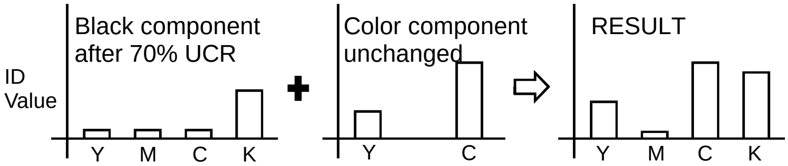
1. The ID value for this image is broken down into two parts: a set of values equal to the lowest color ID value, and the remainders of the two higher values.




2. The part with the equal values is treated as a black image (see “For a Black Image” on the previous page), using the 70% UCR ratio.

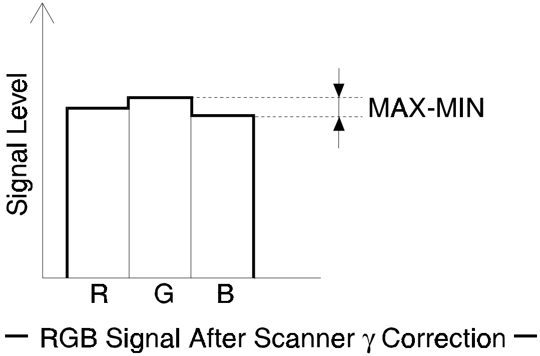


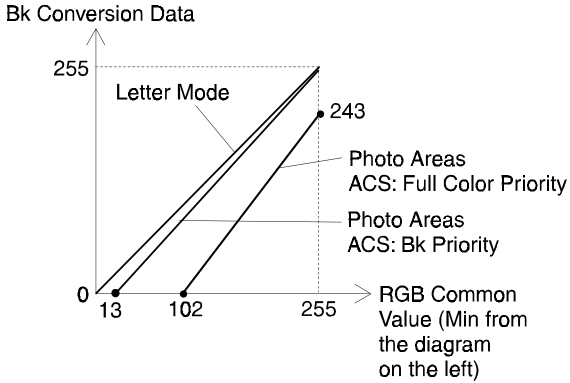

3. The resulting amounts are then added to the remainders from step 1. The final result gives us the ID value for each color and for black.



Changes in UCR Ratio with Image Density and Copy Mode

***Example: Model A166***




Also, the user can select either B/W Priority or Color Priority, to reproduce the B/W areas or Color areas well, when the ACS mode is selected.

- Letter Areas -

The UCR ratio in letter areas is always 100%. The UCR ratio is set to 100% to reproduce the letter areas well. Black toner is always used if MIN (RGB Common Data) is greater than zero, and the value of MIN determines how much black toner is used.

- Photo Areas, with ACS Priority set to Bk -

In photo areas, Bk toner is not used until MIN reaches a certain value.

When the user sets the ACS priority to Bk, UCR begins to replace color toner with Bk toner at low image densities (when MIN is about 13 – see the diagram on the previous page). This is to prevent the UCR process from reducing the image density too much in low image density areas.

At this point, the UCR ratio is zero. As shown in the graph above right (on the previous page), it gradually rises with image density, and the UCR ratio is about 100% when MIN is 255.

The UCR ratio changes with image density. The steeper the gradient in the above graph, the faster the UCR ratio increases with image density (as MIN increases).

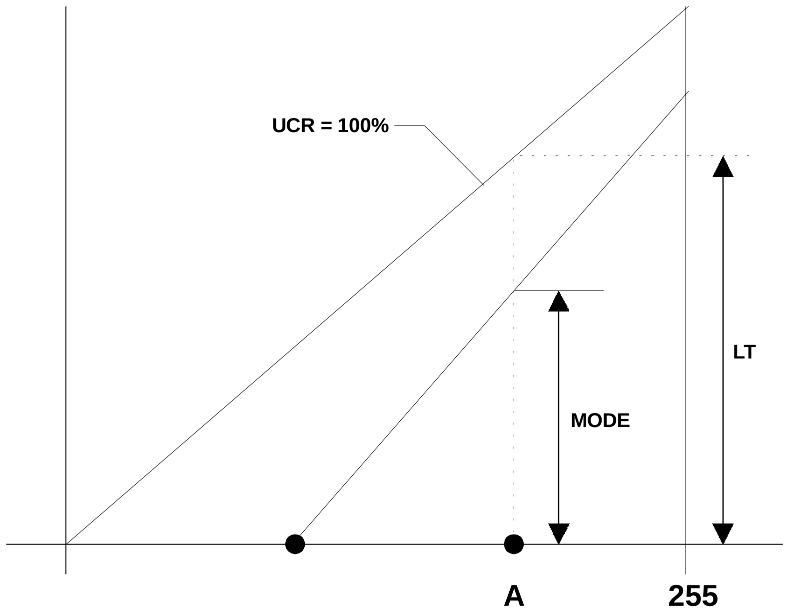
- Photo Areas, with ACS Priority set to Full Color -

When the user sets the ACS priority to Full Color, the UCR process does not begin to replace color toner with Bk toner until a low-medium image density (when MIN is about 102 – see the diagram).

At this point, the UCR ratio is zero. It gradually rises with image density, and the UCR ratio is about 95% when MIN is 255.

## Determining the UCR Ratio

To get the UCR ratio for any MIN value, draw a line up from the MIN value on the x axis until it reaches the line corresponding to Letter mode. Measure this length (LT), and measure the length (MODE) up to where this vertical line crosses the line for the copy mode being used. Because the UCR ratio for letter mode is always 100%, the UCR ratio for this MIN value with this copy mode is (MODE/LT) x 100%.

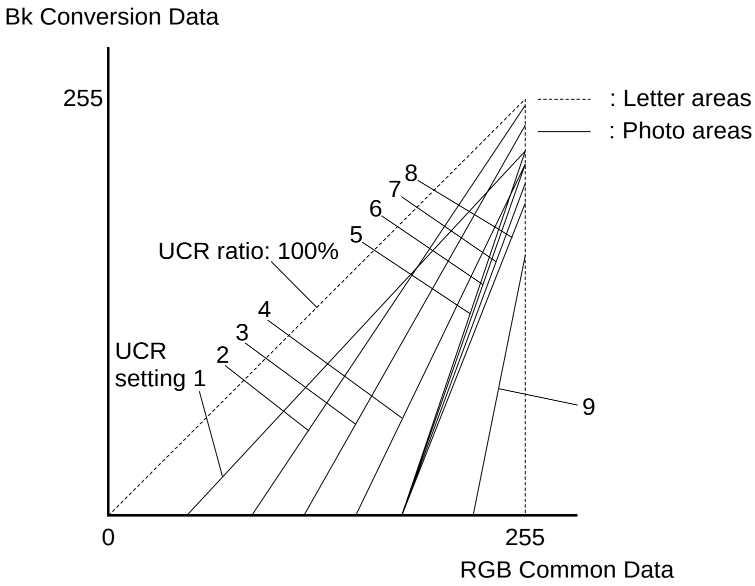



$$\text{UCR Ratio at A} = \frac{\text{Mode}}{\text{LT}} \times 100\%$$

When the user uses the UCR Adjustment User Tool, the UCR ratio for each image density will change, so the gradient and intercept of the line for color mode will change.

***Example: Model A172***

The diagram shows an example.

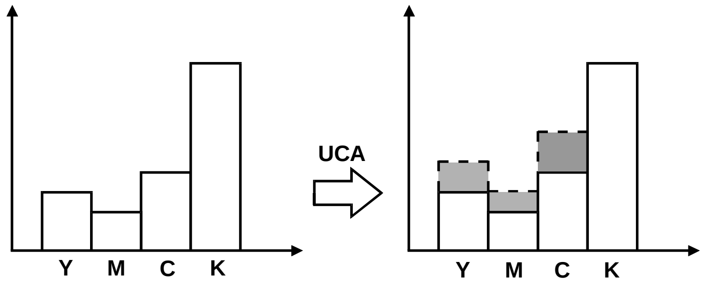


UCA (Under Color Addition)

Using only UCR processing, the copy lacks depth. So, a specified ratio of toner is added for each color (YMC only). The amount of additional toner is proportional to the density of that color on the copy.

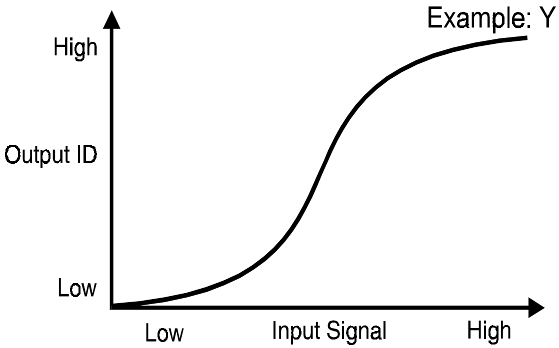
UCA is only done in text and line-art areas. In these areas, UCR is 100%, so some color may need to be added back. In photo areas, the UCR ratio changes with image density, so UCA is not needed.

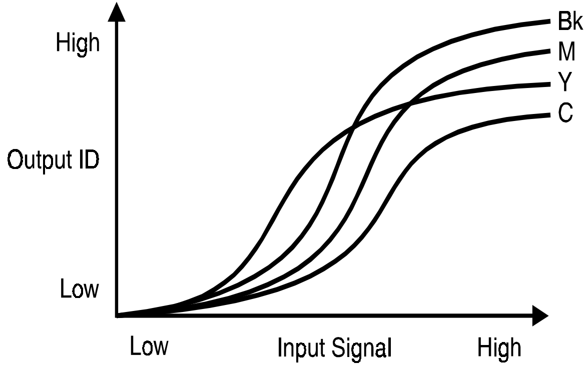
Increase the UCA level if dark colors are appearing black on the copy. Decrease the value if pure black on the original is not pure black on the copy.



### *Printer Gamma Correction and Auto Color Calibration*

KCMY Gamma




A gamma curve describes the relation between the image density of the original and that of the copy. The relationship is not linear: doubling the ID of an original does not double the ID of the copy.

The printer characteristics are much more variable than the scanner. Therefore, the printer gamma needs recalibration and adjustment from time to time.

Ideally, the gamma curves for Yellow, Magenta, Cyan, and Black should be identical, as shown in in the diagram above left. However, they are not, because electrical components always vary slightly, resulting in varying gamma curves, as shown in the diagram above right.

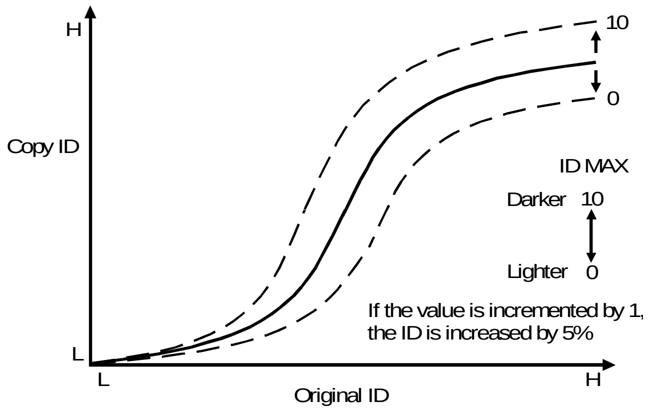
To compensate for this discrepancy, the Auto Color Calibration (ACC) procedure can be done if color reproduction is becoming unsatisfactory. ACC makes new gamma curves for each color in each mode (letter, photo, black letter, glossy photo). After ACC, the gamma curve for each color can be adjusted with service programs.

Using these programs, each gamma curve can be adjusted using 4 different modes: ID max., High ID, Middle ID, and Low ID, as shown on the following page. (ID = Image Density)

***Example: Model A109***

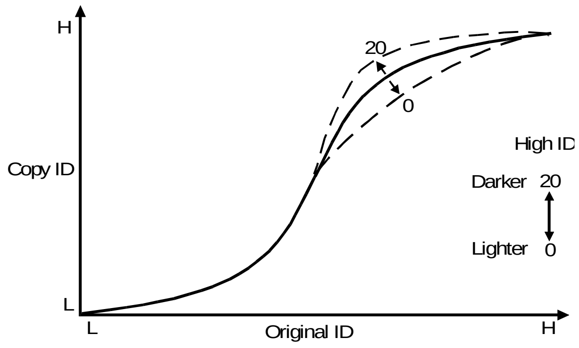
- ID max. -

This mode is used to adjust the total image density level.



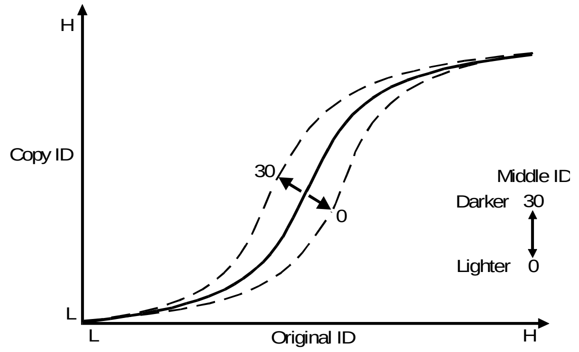
– High ID –

The High ID mode should be used to adjust the image density between Level 6 and Level 9 of the color gradation scale on the C-4 test chart.



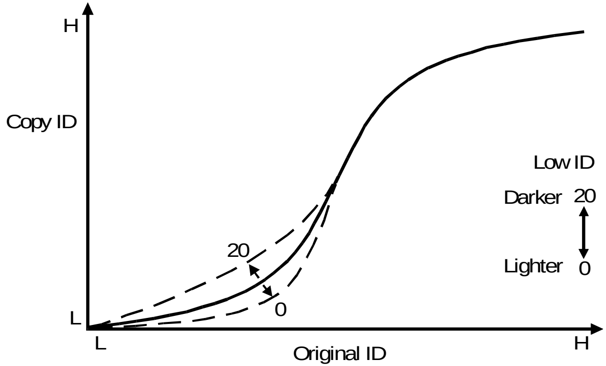

– Middle ID –

The Middle ID mode should be used to adjust the image density between Level 3 and Level 7 of the color gradation scale on the C-4 test chart.



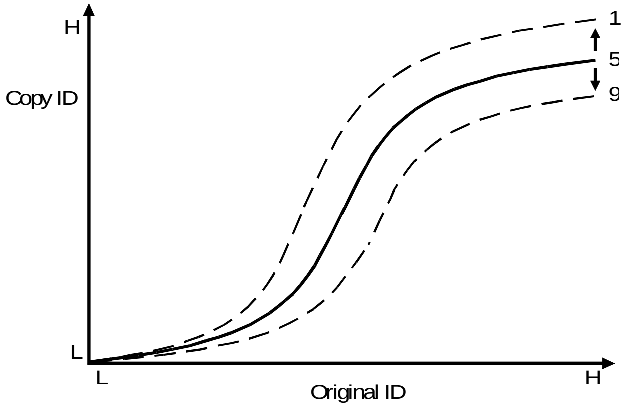
– Low ID –

The Low ID mode should be used to adjust the image density between Level 2 and Level 5 of the color gradation scale on the C-4 test chart.



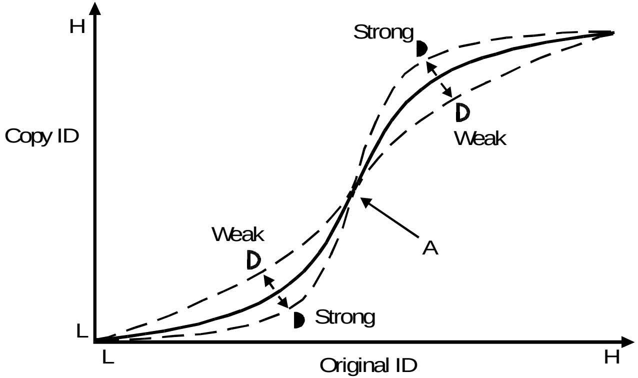
## Image Density

This shows how the gamma curve can be adjusted to change the image density.



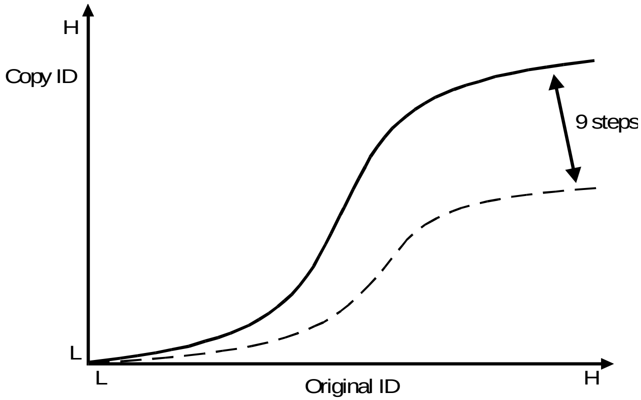

## Contrast

This shows how the gamma curve can be adjusted to change the contrast between light parts and dark parts of the image. The slope of the line in the graph changes, but stays centered around point "A".



## Pastel Mode

This shows how the gamma curves can be adjusted to produce pastel mode images. Another way to do this is by changing the parameters of the color conversion matrix.



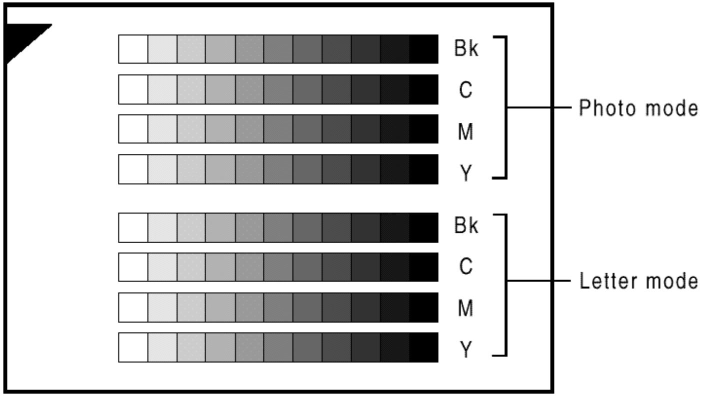

## Color Balance

The balance between the four colors CMYK can be changed by altering the gamma curves. Another way to do this is by changing the parameters of the color conversion matrix.

Auto Color Calibration (ACC)

***Example: Model A172***

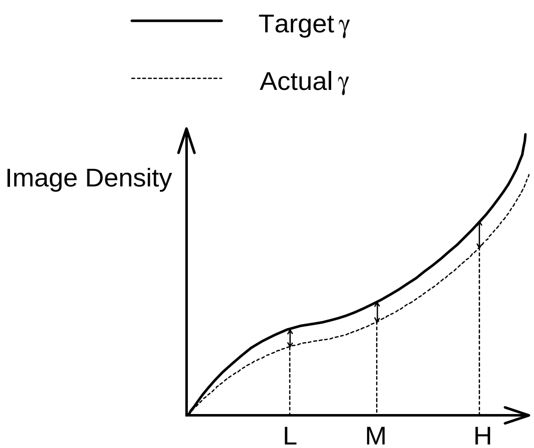
This machine automatically calibrates the printer gamma curve when the user selects ACC.




A test pattern, including the patterns for Letter mode and Photo mode, will be printed first. The user then scans the test pattern. and the machine corrects the printer gamma by comparing the ideal settings with the current image density.

The test pattern consists of eight lines, one for each color (KCMY) in letter mode, and one for each color in photo mode.

There are adjustment tables for L, M, H, and ID MAX values stored in the machine. The machine applies these to approximate the actual curve to the target curve as closely as possible. If needed, the printer gamma curve can be adjusted further manually using a procedure called Color Balance Adjustment.



# Printer Engines

## *Laser Printing*

### *Outline*

This section of the manual explains the optical and video data processing components of the laser printing system. It also explains how the printout data signal is generated from the received image data.

The machine uses a laser diode to produce electrostatic latent images on the photoconductor. This gives high print quality and enables high-speed writing.

The laser diode unit converts received image data into laser pulses, and the optical components direct these pulses to the photoconductor, where the laser beam forms a latent image.

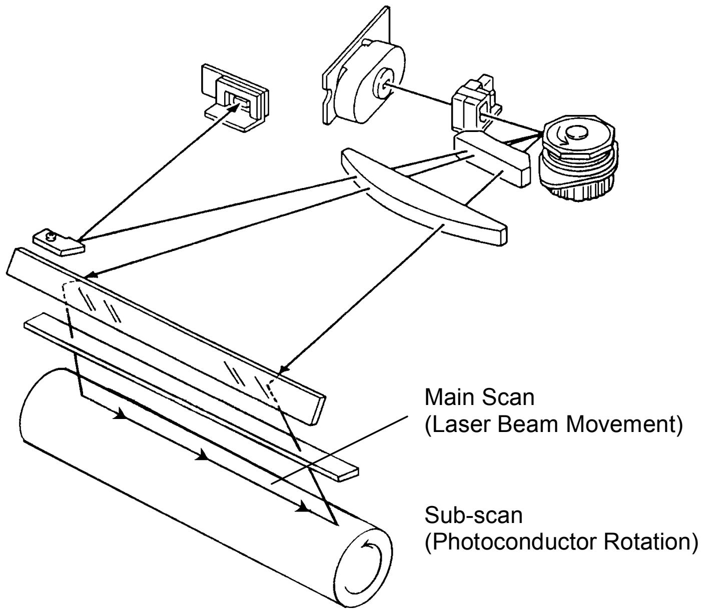
Notes

1. Every model has safety features to stop the laser if the photoconductor is not present or if certain covers are open. Interlock switches are normally used to ensure these safety conditions.
2. Always observe the following cautions when servicing a laser printer:
   - Never remove the laser unit cover while the main switch is on.
   - Never remove any components of the laser circuit when the main switch is on.
   - Never touch the surface of the optical components.

## *The Latent Image*

Exposure of the photoconductor to the laser beam creates the latent image. A rotating mirror moves the laser beam across the photoconductor to make the main scan while photoconductor rotation controls the sub-scan.

In this example, the photoconductor is charged to about -780 V. The charge on irradiated areas drops significantly, typically to between 0 and -100 V. (Voltage values differ from model to model.) The area that is irradiated depends on whether the 'write to white 'or 'write to black' method is being used. Most machines use the 'write to black' method. (See Digital Processes – Digital Images – Printer Output.)



## *Optical Path*

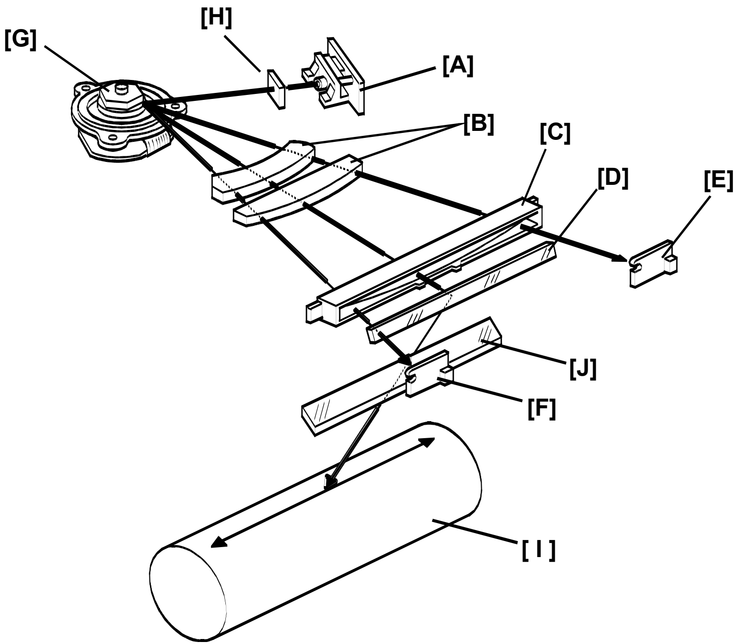
The diagram shows the typical optical components of a laser printer.

### *Example: Model A133*

The laser diode emits a thin pencil-like laser beam. This beam is reflected by a rapidly spinning polygonal mirror (a 5, 6, or 8-sided mirror is normally used). Each face of the mirror scans the laser beam across one main scan line on the photoconductor. The photoconductor then moves down one line, and the beam from the next face of the mirror writes the next main scan line.

The beam then passes to the photoconductor through the various optical components.

At the start of each main scan, the laser hits the laser synchronization detector. This detector then synchronizes the electronics for the start of a new scan line. This machine has two detectors; the reason for that will be explained later in this section.

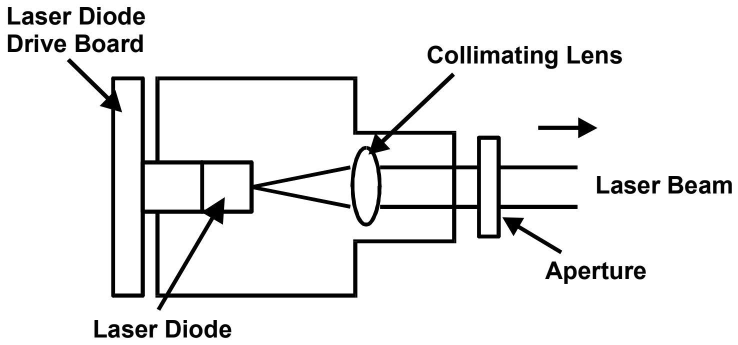



A: Laser Diode Unit
B: Fθ Lenses
C: BTL (Barrel Toroidal Lens)
D: Drum Mirror
I: OPC Drum
E: Laser Synchronization Detector Board-2
F: Laser Synchronization Detector Board-1
G: Polygon Mirror Motor
H: Cylindrical Lens
J: Toner Shield Glass

## *Optical Components*

The components of the optical path are described in the following pages. The actual components used and their names may differ from model to model.

### *Laser Diode Unit*



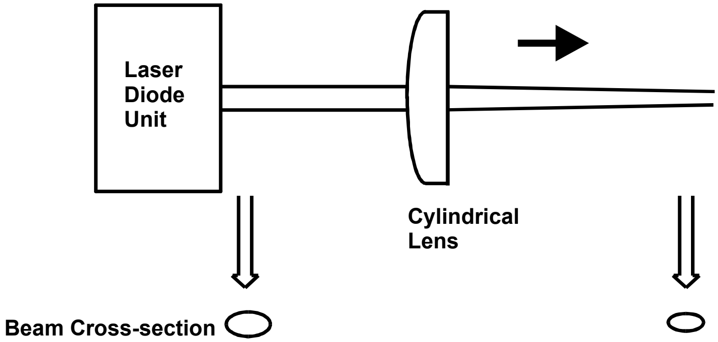

This consists of the laser diode, collimating lens, aperture, and laser diode drive board.

The laser diode (sometimes called LD for short) radiates laser beams of a wavelength of 780 nm, which is in the far red to near infra-red range of the spectrum.

The power of the laser beam depends on the type of photoconductor used, and on the paper feed speed (a faster engine needs a stronger laser, if the photoconductor type is the same). A typical example is 0.6 mW for the *A193*.

The collimating lens forms the radiating beams into a parallel flux, which passes to the cylindrical lens. The cross section of the beam at the aperture is an ellipse about 2.6 mm long by 0.5 mm wide.

Some models have two laser diodes. This is explained in “Dual Laser Beam Printing”.




### *Cylindrical Lens*

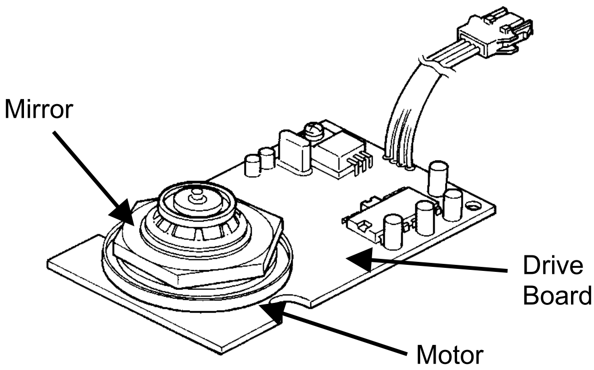
The cylindrical lens focuses the beam and sends it to the rotating polygonal mirror.

### *Polygonal Mirror*

The faces of the mirror are precision-ground for high reflectivity, and to prevent pixel misalignments in the main and sub-scan directions.

The mirror rotates at a constant speed, which varies from model to model. As the mirror reflects the laser beam, its rotation scans the beam across the photoconductor, via lenses and mirrors.

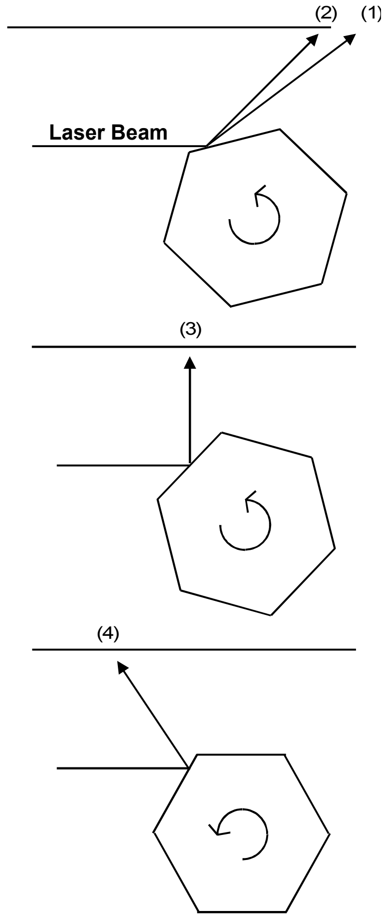
The beam reflected from one face of the polygonal mirror makes one main scan across the photoconductor. This is illustrated below.



The relation between mirror face orientation and scanning is as follows.

1. Laser synchronization (main scan start) detector position
2. Main scan start position
3. Main scan intermediate position
4. Main scan end position

(1) to (4) are repeated for each line.



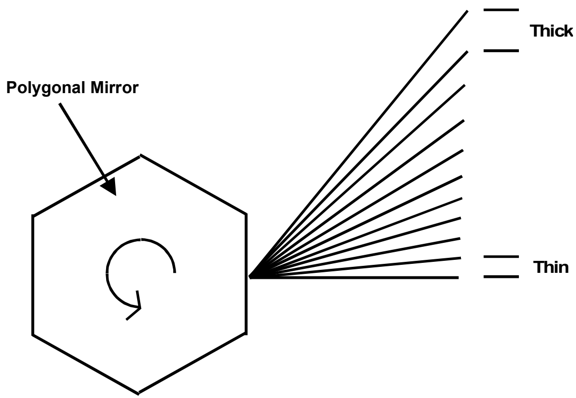

One scan line on the photoconductor is scanned by one face of the mirror.

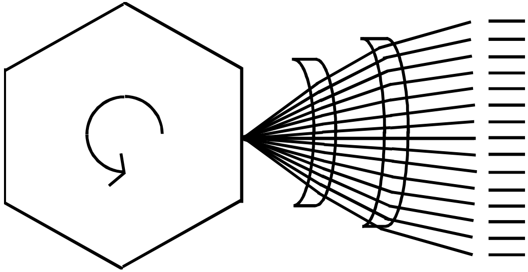
The above set of diagrams illustrates the main scan. When the beam hits the main scan start detector mirror (1), the CPU recognizes that a new line is about to be scanned. As the mirror rotates, the beam scans across the photoconductor [(2) - (3) - (4)]. Normally, there is no main scan end sensor at (4) because, as the mirror rotates and the beam hits the next face, the beam is instantly deflected to the vicinity of (1) and a new main scan begins. However, some machines have a sensor at the end of the main scan, and this will be explained later.

### *Fθ Lenses*

The angles between picture element beams are equal. However, the diameters of each element beam projected onto the photoconductor are different, being thicker at both ends of the main scan than in the center, as shown in the upper diagram. The Fθ (F-theta) lenses correct for this.

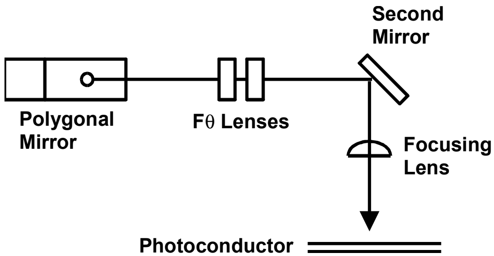
The Fθ lenses correct the laser beam so that it passes over the photoconductor at a constant speed. The lenses deflect the beam slightly inward to ensure that the diameters of all picture elements are equal.



### *Second Mirror*

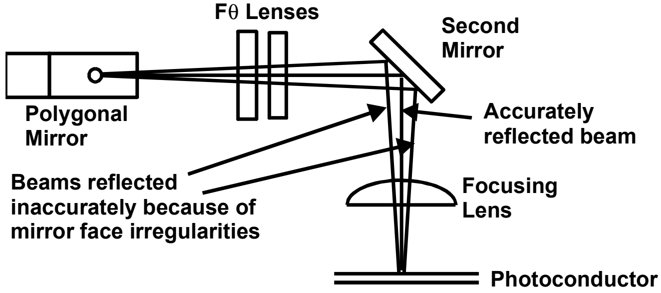
The second mirror reflects the corrected laser beam to the focusing lens. There may be more than one mirror in this position, if the optical path is not straight.



Lsrcmp7.wmf

### *Focusing Lens*

This lens corrects the beam for face irregularities on the polygonal mirror and second mirror, and focuses the beam onto the photoconductor.

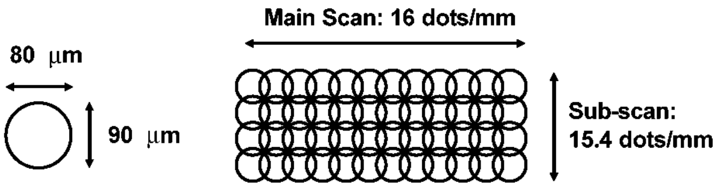



In printers where the photoconductor is close to the lens, a cylindrical lens is often used in this position. However, if the photoconductor is not close to the lens, a cylindrical lens would leave the left and right edges of the image blurred. In these models, a focusing lens (sometimes called a *barrel toroidal lens*) is used; this lens operates similarly to an Fθ lens. The barrel toroidal lens is also used when plastic Fθ lenses are used to reduce costs. With plastic lenses, it is difficult to get the required beam deflection with Fθ lenses only.

The cross section of the beam on the photoconductor (i.e., the size of each printed dot) varies from model to model; it is roughly circular, with a diameter in the region of 80 mm. This means that the printed dots overlap each other slightly, as seen below in a typical example.

### *Example: Model H006*

80 mm is about 12 dots per mm, and 90 mm is about 11 dots per mm. However, the printer resolution is 16 x 15.4 dots per mm. The dots are larger than this resolution, so they overlap. This results in a better image than if there were no overlap.



# *Laser Synchronization Detector*

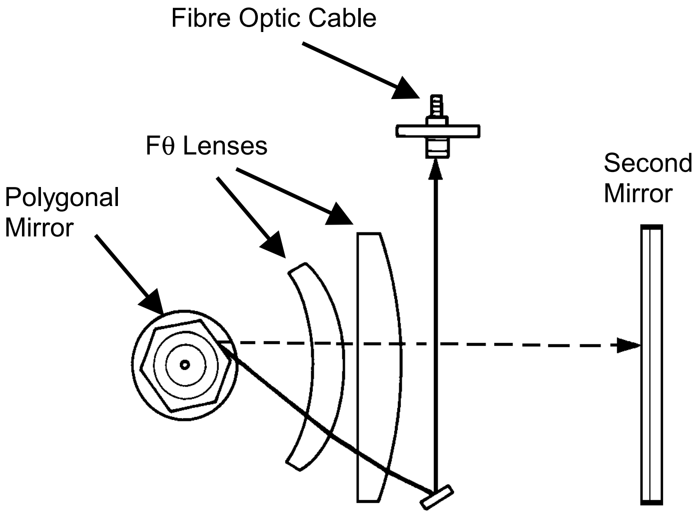
## *Single-detector System*

Mechanism

**Example: Model H006**

The laser synchronization detector (sometimes known as the main scan start detector) synchronizes the main scan start timing of the laser beam across the photoconductor.

Each face of the polygonal mirror scans the laser beam across the photoconductor for one main scan. Just before the laser beam starts scanning across the photoconductor, it hits the laser synchronization detector. The signal from the detector informs the cpu that a new main scan is about to start. The cpu then synchronizes the electronics for the start of the new scan line.




The laser synchronization detector is a phototransistor. In some models, it is connected with a fibre optic cable.

Circuit

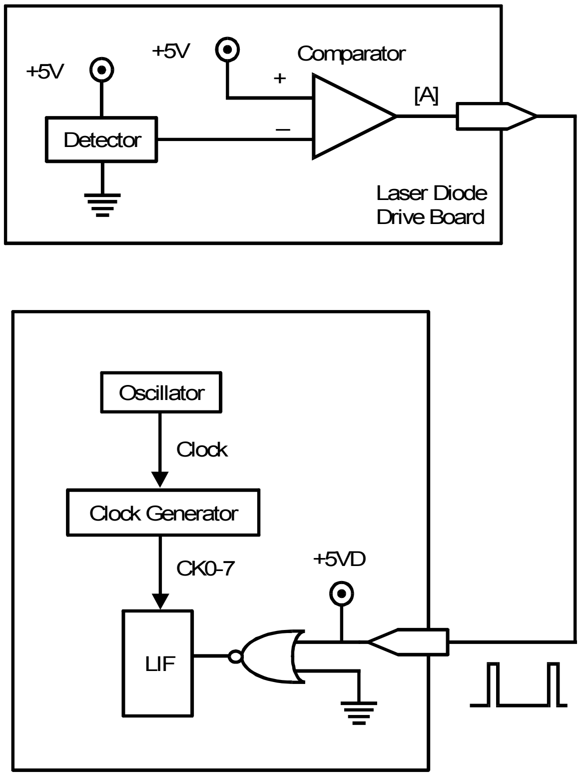
### *Example: Model H006*

Just before the laser beam starts scanning across the photoconductor, it hits the main scan start detector. An optic fiber or a mirror routes the laser beam to the detector.

The detector output passes to a comparator. The comparator output [A] goes high when activated by the laser beam. It remains high for a few microseconds. The signal passes to the Laser Interface (LIF).

An oscillator sends a clock signal to the clock generator. The clock generator generates eight clock signals (CK0 to CK7) from this clock. Each of these has the same frequency as the original clock signal, but there is a fixed phase difference of 30 to 40 nanoseconds (depending on the model) between each of the eight output signals. (A thousand million nanoseconds make one second.)

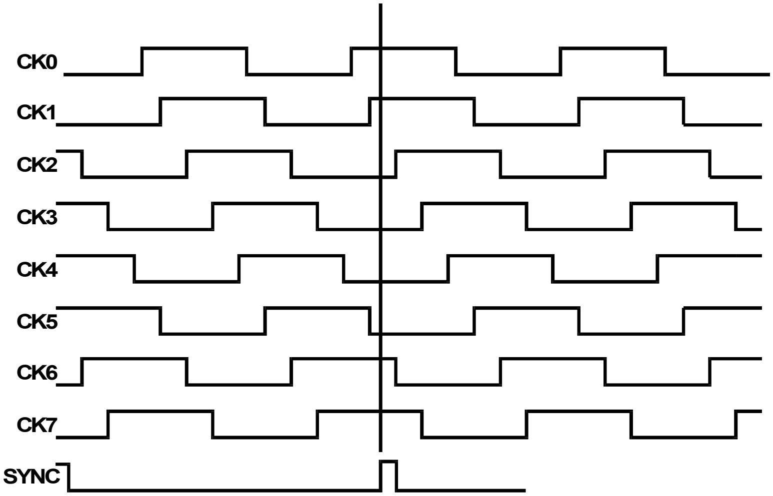
The LIF selects one of these eight signals to time data output for the main scan line that is about to start. The selection process is shown below.



As shown in the timing chart, the eight clock signals CK0 to CK7 have the same frequency but are out of phase with each other.

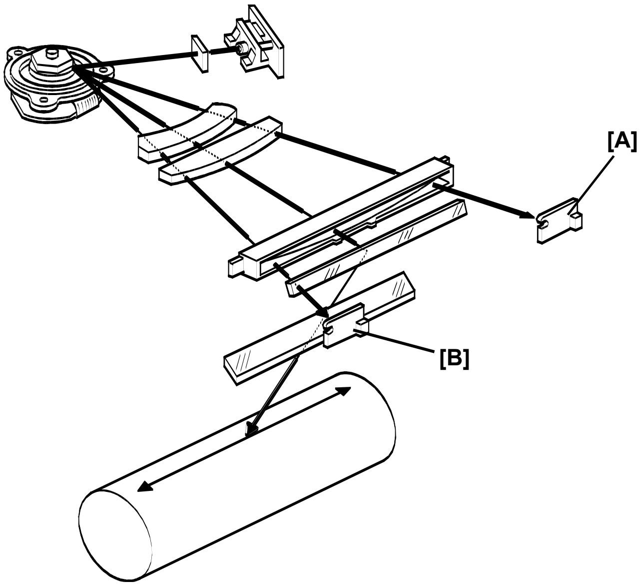
The signal chosen is the one that has the nearest rising edge immediately after the signal from the main scan start detector goes high. Here, CK2 is selected. The process is repeated at the start of each scan line.

In some models, the signal with the nearest rising edge before the main scan start signal is chosen; CK1 would be selected in the above example.



### *Double-detector System*

#### *Example: Model A133*




Some of the optical components are made of plastic, and may expand and contract with changes of temperature. If this happens, the number of pulses in the laser main scan across the photoconductor will vary. To counteract the effects of this, the machine adjusts the frequency of the laser pulses to keep the number of laser pulses in each main scan constant.

To do this, the machine has two laser synchronizing detector boards [A] and [B], one at each end of the main scan line. They measure the number of clock pulses between the start and end of each main scan. (These clock pulses are from the base clock, which is at a much higher frequency than the laser frequency.)

If the number of pulses is not correct, the machine adjusts the frequency of the laser to keep the number of laser pulses in each main scan constant.

The laser synchronizing detector board-1 [B] synchronizes the main scan start timing. At the other side, the laser synchronizing detector board-2 [A] counts the number of clock pulses since detector board-1 was activated.

## *Dual Laser Beam Printing System*

### *Overview*

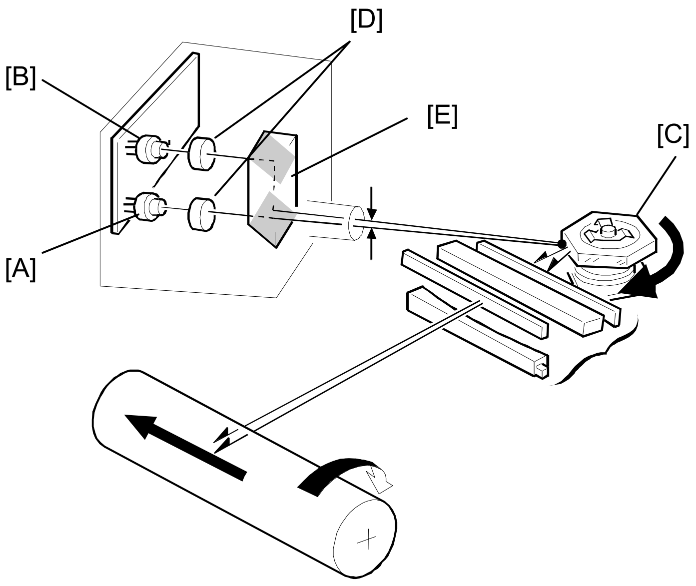
### Example: Model A230

This LD unit has two laser diodes, [A] and [B]. This means that each face of the six-sided polygon mirror writes two main scan lines, and twelve main scans are produced when the mirror rotates once.

This mechanism:

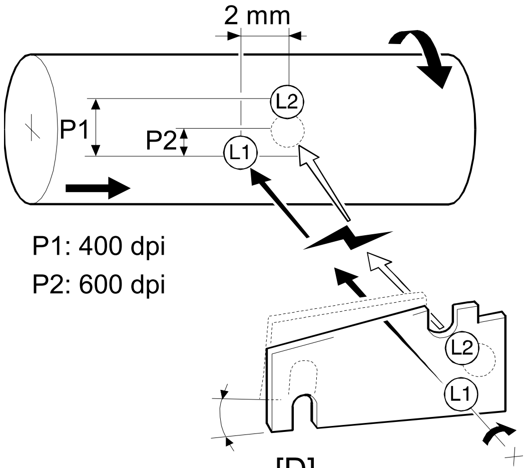
- Reduces the mirror motor rotation speed
- Reduces the noise generated by the polygon mirror motor
- Reduces the image data clock frequency, to allow high speed printing without costlier high-speed components

Two laser beams go to the polygon mirror [C] through collimating lens [D] and prism [E]. They arrive on the drum surface about 2 mm away from each other in the main scan direction and about 0.06 mm (at 400 dpi) in the sub scan direction.




A230D203.WMF

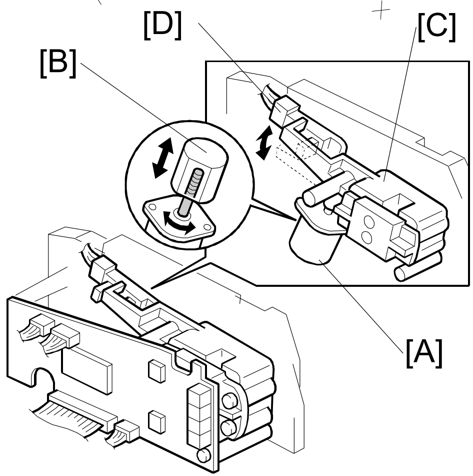
The reason for the two-mm difference in the main scan direction is so that the machine can detect a laser synchronization signal for each beam.




### *Laser Beam Pitch Change Mechanism*

#### *Example: Model A230*

When this machine receives data from a printer, it must print at 600 dpi. The machine changes the resolution between 400 and 600 dpi by rotating the LD unit.




When the LD positioning motor [A] turns, the metal block [B] (which contacts the LD unit housing [C]) moves up and down. This changes the position of the L2 laser beam (L1 does not move).

Both LD unit positions are at fixed distances from the LD home position sensor [D] (measured by motor pulses). Usually, the LD unit moves directly to the proper position. However, when the number of times that the resolution has changed reaches a certain value, the LD unit moves to the home position (the home position sensor activates), then it moves to the proper position. This recalibrates the LD unit positioning mechanism.

## *Laser Diode Power Control*

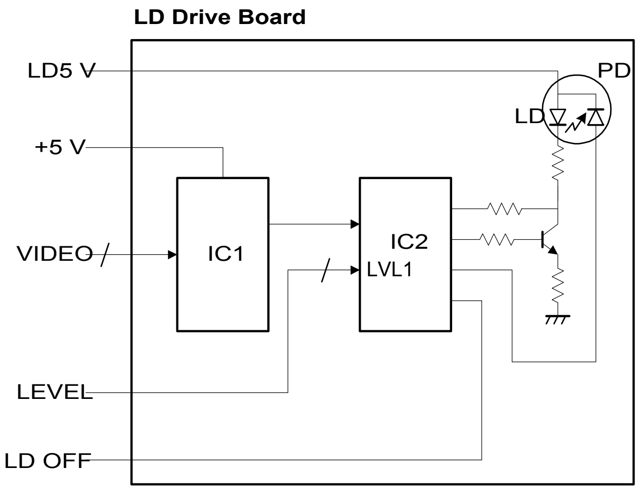
Even if a constant electric current is applied to the laser diode, the intensity of the output light changes with the temperature. The intensity of the output decreases as the temperature increases.

In order to keep the output level constant, the output light intensity is monitored through a photodiode enclosed in the laser diode. The photodiode passes an electrical current that is proportional to the light intensity. The output is not affected by temperature, so it faithfully reflects the changes in the LD output, without adding anything itself.

### *Example: Model A133*

Just after the main switch is turned on, and every pixel during printing, IC2 on the LD drive board excites the laser diode at full power and stores the output of the photodiode (PD) as a reference. IC2 monitors the current passing through the photodiode. Then it increases or decreases the current to the laser diode as necessary, comparing the output with the reference level.

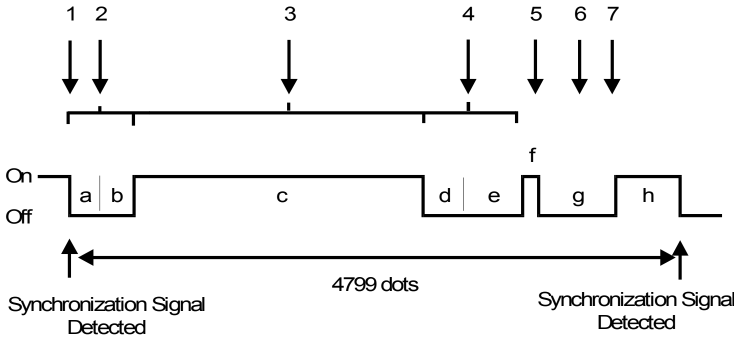
The laser power level is adjusted on the production line. Do not touch the variable resistors on the LD unit in the field.



## *Laser Signal Profile*

The cpu does not send a continuous stream of video data to the laser diode. If it did that, the start of each line of data would not be properly synchronized. The transfer of data to the laser diode is made line by line, using the signal from the main scan start detector to synchronize the signal. The following timing chart shows how each main scan line of data is sent to the laser diode. One page of data will consist of many repetitions of this basic signal profile.

When the CPU detects the main scan start synchronization signal, it turns off the laser beam.




(1) Main scan start synchronization signal detected
(2) Dummy bits ("a" and "b" on the diagram)
(3) One main scan line of data ("c" on the diagram)
(4) Dummy bits ("d" and "e" on the diagram)
(5) Dummy bits ("f" on the diagram)
(6) Dummy bits ("g" on the diagram)
(7) Laser on, ready to activate sensor ("h" on the diagram)

After a short while, it turns back on. The amount of white dummy bits marked "b" on the diagram depend on the paper width; the number of bits "a" are fixed. The main scan line data follows ("c" on the diagram), then more dummy bits (the amount of the dummy bits marked "d" depends on paper width; the bits marked "e", "f", and "g" on the diagram are fixed). During "c", the signal will switch between high and low in accordance with the data signal. It also switches on and off between pixels.

At point 7 on the timing chart, the laser beam turns back on so that it can activate the main scan start detector.

The signal profile on the previous page is for a "write to black" printing process. In a "write to white" process, the signal profile is similar, except that dummy bits "b" and "d" are high instead of low. Also, the polarity of the data signal during "c" is the reverse.

The duration of one cycle depends on the rotation speed of the polygon mirror.

***Example: Models A229 at 400 dpi***

Six-sided mirror, rotation speed: 25984 rpm

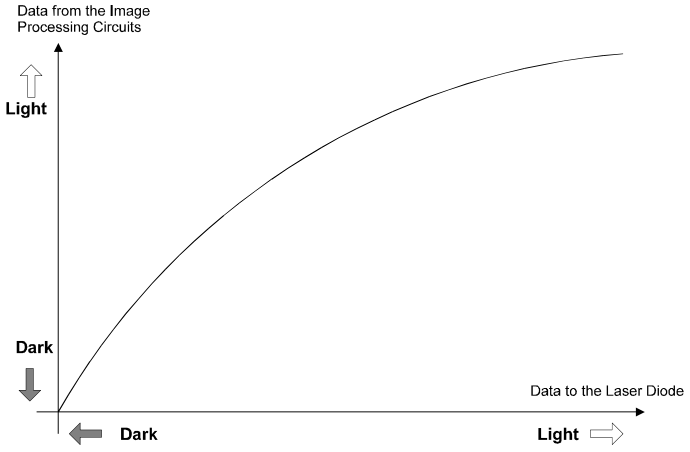
Duration: 60/(25984 x 6) s = About 0.38 ms

# Image Processing

## Printer Gamma Correction

Printer gamma correction corrects the data output from the image processing circuits to the laser diode to account for the characteristics of the printer (e.g., the characteristics of the drum, laser diode, and lenses).

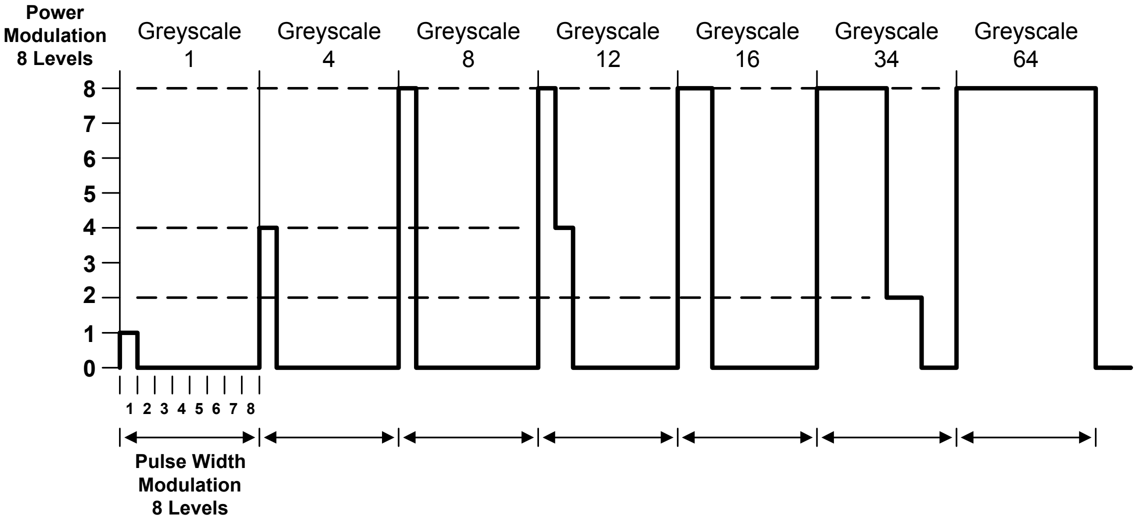
Printer gamma correction is done after image processing, before the data goes to the laser diode.



## *Gradation Processing*

This section explains how a laser printer reproduces grayscales.

To make the latent image, the laser beam illuminates the image area of the drum surface. The longer the laser is on and the brighter it is, the darker the developed pixel becomes.




Changing the duration (also called the width) of the pulse is known as Pulse Width Modulation (PWM). Models with this feature typically have 8 possible pulse width levels.

While the laser is on to make a dot, the laser can be made brighter or dimmer. This is known as power modulation (PM). The laser's intensity is controlled by the amount of current sent to the laser diode. Models with this feature typically have either 8 or 64 possible power levels.

The PWM and PM levels are combined to reproduce the various grades in the grey scale.

Examples

A193: 8 PWM levels, 8 PM levels, giving 64 possible greyscale levels per pixel

A229: 8 PWM levels, 64 PM levels, giving 256 possible greyscale levels per pixel

G020: 8 PWM levels, 0 PM levels, giving 8 possible greyscale levels per pixel

The power is modulated only on the final part of the laser pulse (example: see Greyscale 12 or 34 in the diagram).

For example: Greyscale 34 is made from PWM level 4 and PM level 2

Some machines having a high number of possible grayscales per pixel do not use them all.

## *Example: Model A229*

The 8-bit data from the image processing circuits (enough for 256 grayscales per pixel) are converted to 4-bit data for the laser diode drive board (only enough for 16 grayscales per pixel).

However, the machine emulates 256 grayscales by dealing with the output in blocks of 16 pixels (4 x 4), using the 16 grades per pixel in each of the 16 pixels in the block to produce 256 grayscales for blocks of 4 x 4 pixels.

The drawing shows an example of the principle. This data is not taken from any machine; it is just a fictitious example.

This technique is important for machines like the *G020*, which has only 8 grayscales per pixel. This machine emulates 256 grayscales in a similar manner.

**Greyscale 1**

| | | | |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 |

**Greyscale 50**

| | | | |
|---|---|---|---|
| 4 | 3 | 5 | 3 |
| 3 | 5 | 4 | 4 |
| 5 | 4 | 5 | 3 |
| 3 | 5 | 3 | 5 |

**Greyscale 100**

| | | | |
|---|---|---|---|
| 6 | 8 | 6 | 8 |
| 8 | 7 | 8 | 6 |
| 6 | 8 | 7 | 7 |
| 7 | 6 | 8 | 7 |

**Greyscale 200**

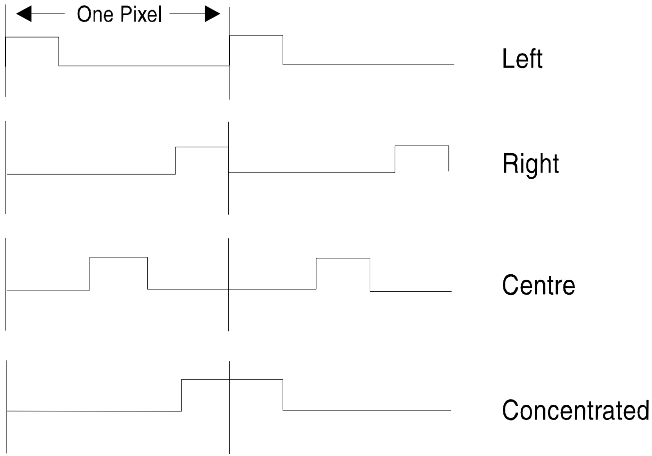
| | | | |
|---|---|---|---|
| 11 | 10 | 14 | 12 |
| 10 | 14 | 12 | 11 |
| 14 | 13 | 12 | 11 |
| 10 | 12 | 14 | 13 |

**Greyscale 256**

| | | | |
|---|---|---|---|
| 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 |
| 16 | 16 | 16 | 16 |

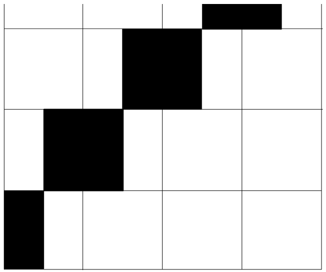
## *Laser Diode Pulse Positioning*

The laser pulse position (at the left side of the pixel, at the center, or at the right side) can also change depending on the location of the image pixel, so that the edges of characters and lines become cleaner. All the examples in the previous section (gradation processing) show the dot being reproduced at the left side of the pixel.




In the example on the right, the machine reproduces a thin diagonal line. At the left edge of the line, the dot is on the right side of the pixel, and vice versa.

In general, putting the pixel in the center gives better results for photo mode.

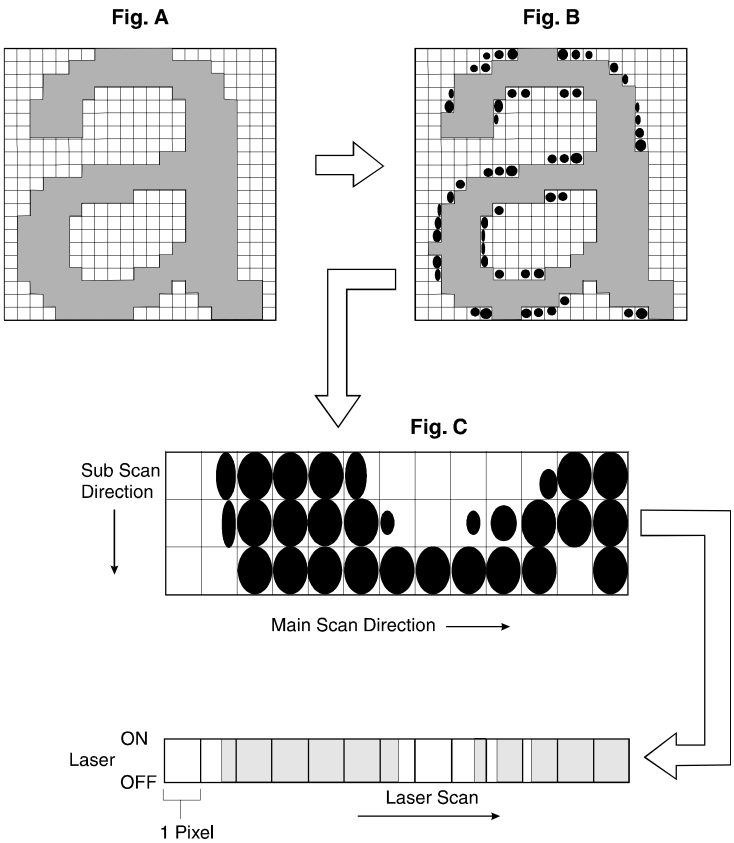


## *Edge Smoothing (Copiers and Printers)*

When binary picture processing mode is used, there are only two possible grey scales, black and white.

With this process, sudden changes from black to white mean that there might be jagged edges in the image. Smoothing attempts to remove these edges.

Using laser pulse positioning, dots on the left side of black areas are made with only a portion of the pulse width, and these dots are moved to the right side of the pixel. In a similar way, dots on the right edges are narrower, and at the left side of the pixel.

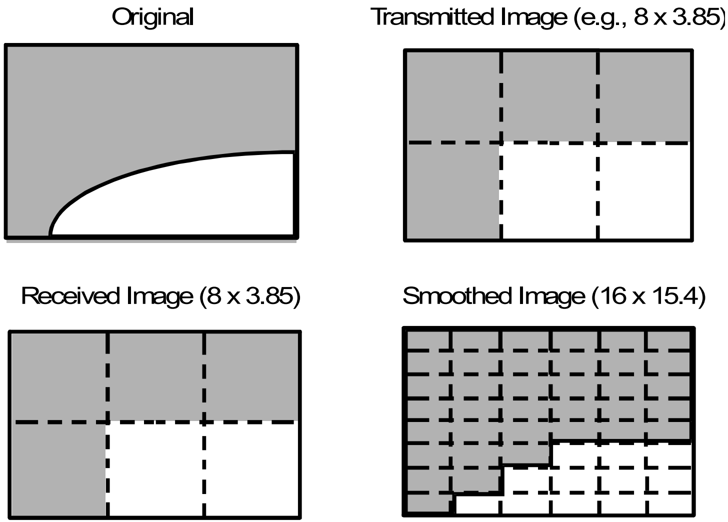


***Smoothing (Fax Machines)***

The resolution for printing depends on the resolution that was used for scanning; this is informed in the set-up protocol. It also depends on whether or not smoothing is switched on.

Smoothing is a digital processing technique that improves the resolution of the received message, reducing jagged edges on characters. Smoothing will change some bits from white to black, or vice versa, to round off jagged edges. A simple example is shown in the diagram.

If the image from the other end is in standard mode (8 x 3.85 dots/mm) and smoothing is on, the data is smoothed as shown in the diagram to give an effective resolution of 16 x 15.4 dots/mm. If smoothing is off, the same dot is printed twice across the page, and the same line is printed four times down the page.

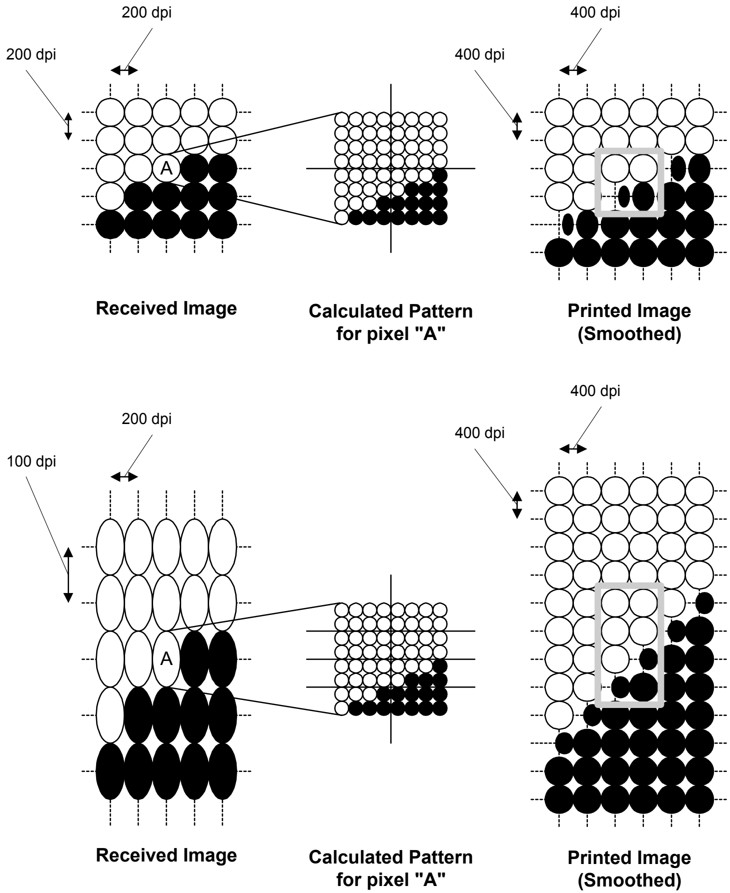



If the message was scanned in detail mode (8 x 7.7 dots/mm), and smoothing is on, the CPU smoothes the data to give an effective resolution of 16 x 15.4 dots/mm. If smoothing is off, the same dot is printed twice across the page, and the same line is printed twice down the page.

Fax machines that can print large numbers of gray scales can take advantage of that also.

### *Example: Models A639/A804*

When the fax unit prints a received fax image, the fax board converts the data into 400 x 400 dpi, 16 x 15.4 l/mm, or 15.4 x 16 l/mm (image rotation) resolution, and smoothes the image using the 64 gradation levels + 3 laser pulse positions format used by the base copier.



### *Print Density Adjustment (Fax Machines)*

In some fax machines, the laser pulse width depends on the mode (copy or fax) being used, the image density setting, and whether halftone is being used.

***Example: Model H515***

<table>
<tr><th colspan="2">Mode</th><th>Normal</th><th>Lighten</th><th>Darken</th></tr>
<tr><td rowspan="2">Copy Mode</td><td>Normal</td><td rowspan="2">80 %</td><td rowspan="2">40 %</td><td rowspan="2">160 %</td></tr>
<tr><td>Halftone</td></tr>
<tr><td rowspan="2">Fax Mode</td><td>Normal</td><td>100 %</td><td>40 %</td><td>160 %</td></tr>
<tr><td>Halftone</td><td>20 %</td><td>20 %</td><td>100 %</td></tr>
</table>

To change the pulse width, the duty cycle of the laser pulse is changed. For example, to make the print density 40% of normal, the laser is only kept on for 40% of the normal duration for each pixel.

### *Toner Saving*

In some machines, toner consumption can be reduced by omitting dots, as opposed to the use of a recycling mechanism or by adjusting development bias.

In toner saving mode, the image data is filtered through a matrix. The following example shows the principle.

```
1st line 1 0 1 0 1 0 1 0 1 0 . . . . . .
2nd line 0 0 0 0 0 0 0 0 0 0 . . . . . .
3rd line 0 1 0 1 0 1 0 1 0 1 . . . . . .
4th line 0 0 0 0 0 0 0 0 0 0 . . . . . .
```

(1: Actual data printed, black or white; 0: Always a white pixel)

In toner saving mode, the machine prints a black pixel whenever the data changes from white to black in the main scan direction. In this way, edges of black areas are printed more clearly. This feature is known as Edge Enhancement.

### *Enlargement (Fax Machines)*

Some  fax machines enlarge the received image by increasing the duration of each pixel in the laser signal. For example, to enlarge the image by 200%, the duration of each pixel is doubled.

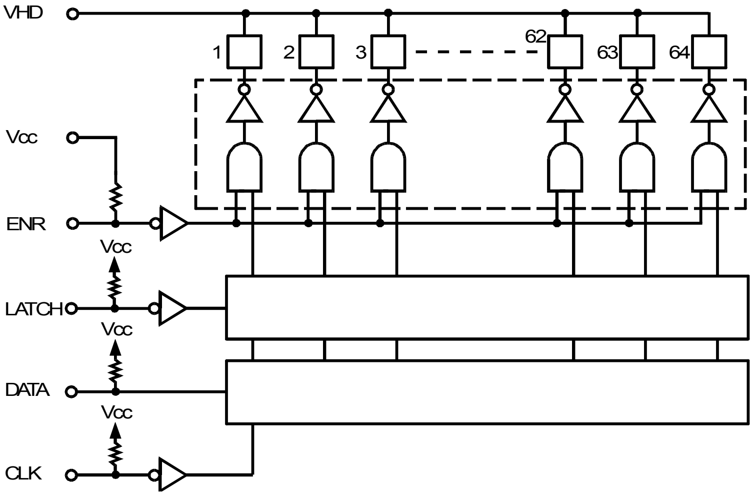
# Thermal Printing

## Thermal Head Overview

Thermal printers contain a thermal head. A thermal head consists of a row of heating elements, which are basically just resistors. If a heating element is turned on, it will heat up. The heat from the element will make a dot on thermosensitive printer paper (fax machines), or melt the over-coating and polyester film layers to make a hole in a master (Priports). Whether an element turns on or not depends on the image signal for each pixel

Fax machines have either 8 or 16 heating elements for each mm across the thermal head. Priport printers generally have 400 elements per inch.

The diagram shows a 64-element assembly. A typical thermal head, having 4608 elements (see Thermal Head Specifications), would have 72 of these assemblies.



Basically, the cpu clocks a line of data into a shift register in the thermal head. When the line is complete, the cpu sends a latch signal, then prints the line. Then the paper is fed forward one line, and the next line is printed in the same way.

There is normally an independent power supply for the thermal head, which applies power to the thermal heating elements.

For more details on how a thermal head works, refer to the chapter on *standard components*.

## *Typical Thermal Head Specifications*

### ***Example: Model C210***

Maximum Printing Width: 292.6 mm

Number of Thermal Heating Elements: 4608

Density of Thermal Heating Elements: 400 dots/inch

Size of Thermal Heating Element: 45 x 60 µm

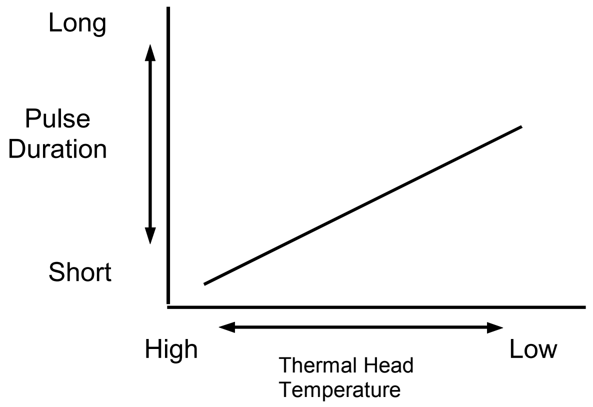
Average Resistance of Thermal Heating Elements: 1520 to 2300 W

Power Source: 15.1 to 18.6 V

# Thermal Head Energy

## Overview

Voltage to the thermal head is applied in 16 V pulses. The energy applied to the thermal head is changed by changing the duration of the pulses. The duration of the pulses depends on the thermal head temperature and resistance.




## Thermal Head Resistance

The resistance of each thermal head is different. Therefore, after installing a new thermal head, always recalibrate the power supply unit according to the ratings on the thermal head cover.

## Thermal Head Temperature

The thermal head contains a thermistor, which detects the thermal head temperature.

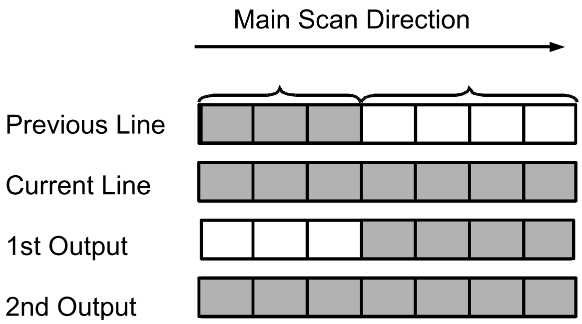
### *Maintaining Constant Element Temperature*

A thermal heating element may get too hot when there are consecutive black pixels in the sub-scanning direction. Conversely, a thermal heating element may not get hot enough to make a black dot or burn a hole in a master when there are consecutive white pixels in the sub-scanning direction.

To remedy this, each thermal element receives data twice for one line. The data depends on the state of each pixel for the previous line.

If the pixel at a certain position in the previous line was white, the first data for that pixel on the current line is black, to warm the element up. Then the actual black data is sent to the element.

If the pixel at a certain position in the previous line was black, the first data is white, to cool the element down to prevent overheating.



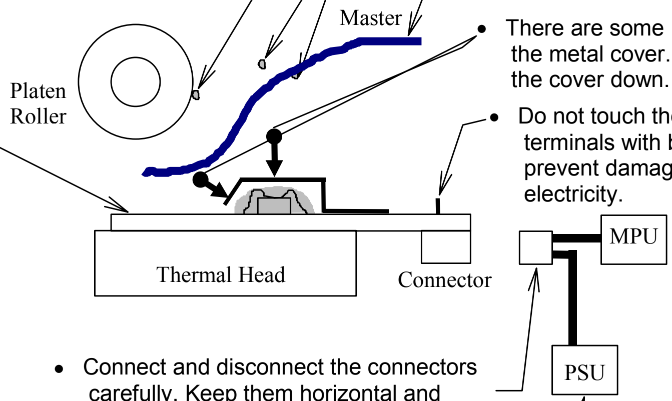

### *Overheat Prevention*

The thermistor on the thermal head provides thermal head protection, preventing the thermal head from overheating when processing a solid image.

## *Handling*

Pay careful attention to the following remarks when servicing:

- Do not touch the surface with bare hands. If this occurs, clean the surface with alcohol.
- Do not damage the heating elements.
- Remove any foreign materials from the platen roller.
- Remove foreign materials.
- Do not touch the master film surface with bare hands.
- There are some ICs inside the metal cover. Do not push the cover down.
- Do not touch the connector terminals with bare hands, to prevent damage from static electricity.




- Connect and disconnect the connectors carefully. Keep them horizontal and firmly reconnect them.
- Adjust the voltage supplied to match the specified value for the thermal head.

- Other Remarks -

Avoid using the machine under humid conditions. Moisture tends to condense on the thermal head, damaging the elements.

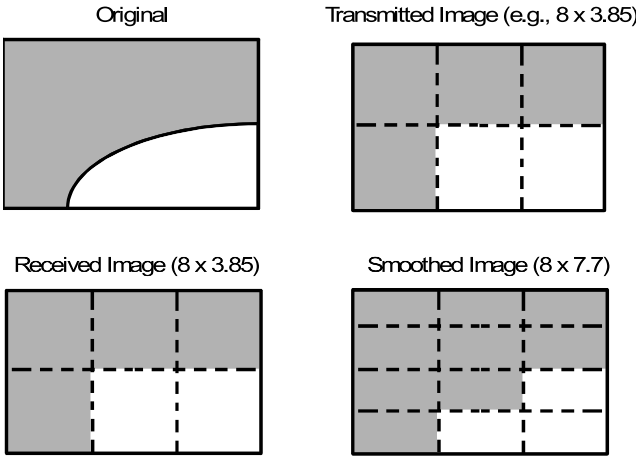
# Image Processing

## Smoothing (Fax Reception)

The principle behind smoothing is the same as for laser fax machines, except that incoming messages are smoothed to 8 x 7.7 or 8 x 15.4 dots per mm.

If the message was sent in standard mode (3.85 lines/mm) and smoothing is switched on, the cpu smoothes the data to give an effective resolution of 7.7 lines/mm. This smoothing is shown in the diagram. If smoothing is disabled, the same line is printed twice, and the image may appear jagged.

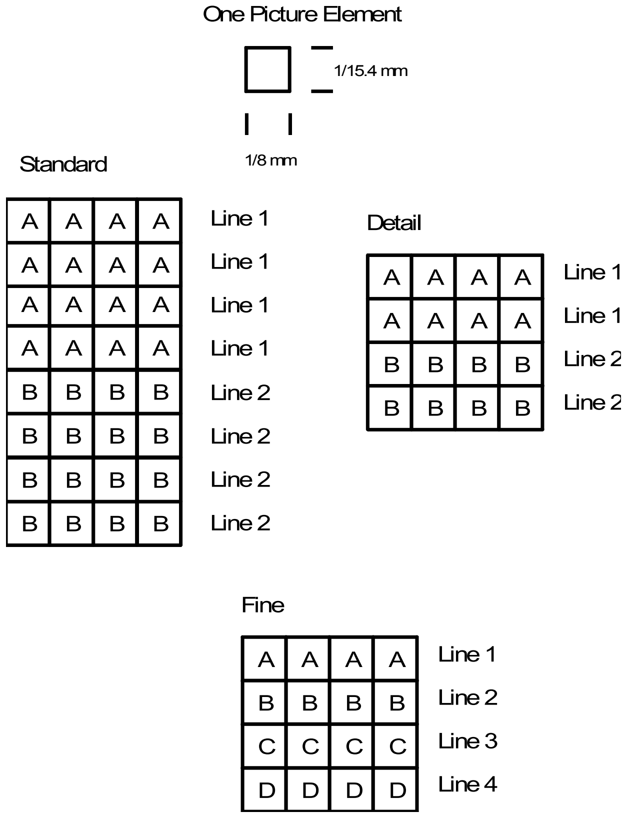
If the message was sent in detail mode (7.7 lines/mm), the data is printed unaltered.



### *Printing at Different Resolutions (Fax Machines)*

The printing density is 8 dots/mm across the page and 15.4 dots/mm down the page. To print in standard resolution (3.85 dots/mm down the page), each line of data is printed four times (the second of each pair of lines may be treated with smoothing - see the previous section). To print in detail resolution (7.7 dots/mm down the page), each line is printed twice.

To print in fine resolution (15.4 dots/mm down the page), each line is printed once. However, as printing is slow, the thermal head energy may have to be increased so that the heat of the printing elements does not drop, causing a pale printout.



### *Reduction (Fax Reception)*

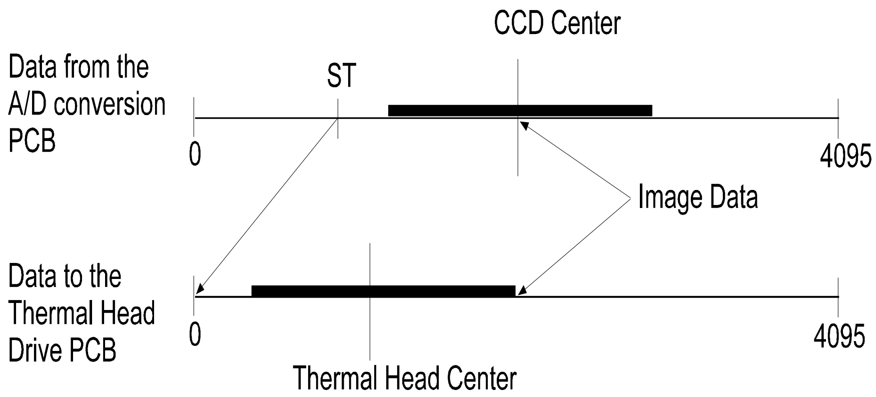
Normally, the transmitting terminal does reduction. However, if the receiving terminal can handle more than one roll width, it may reduce the incoming data in the following situation.

If the message is received by substitute reception and the user installs a roll which is less wide than the image, the machine will reduce the data after it comes out of the memory. The reduction process is the same as that explained for transmission.

### *Main-scan Direction Image Position Adjustment (Priports)*

To adjust the image position of the original across the printout, the image can be shifted ± 5 mm in the main-scan direction using SP mode.

The image is shifted in the main-scan direction by changing the relationship between the original main scan start timing and the master making main scan start timing.



# Ink Jet Printing

## Ink Cartridges

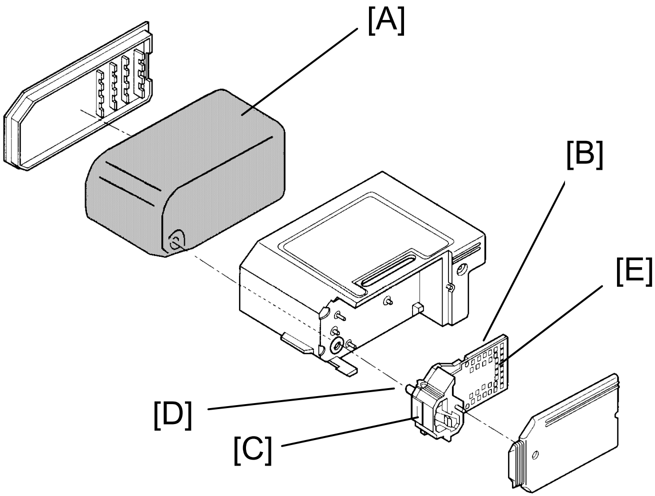
Ink cartridges consist of an ink sponge and a print head.

### Example: Model H504

**Ink Sponge [A]:** This contains about 20 grams of ink, which is enough for printing about 550 ITU-T #1 charts.

**Printer Head [B]:** The printer head faceplate contains a row of 64 nozzles [C], spaced at a resolution of 360 dots per inch. Ink passes to these nozzles through a pipe [D], which contains a filter. Printing signals arrive at the printer head at the signal contacts [E].

Color ink cartridges contain a sponge for each color of ink.



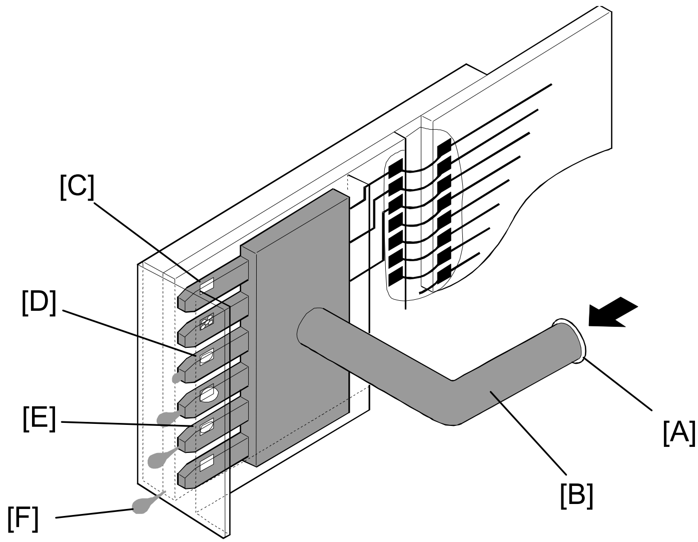
# *Print Head*

Small heating elements force ink out of the nozzles.

## *Example: Model H505*

Ink from the sponge is filtered at [A] to remove dust, and then passes to the nozzles through pipe [B]. When the head drive current flows through a nozzle's heater plate [C], the ink at the plate boils. The bubbles formed [D] eventually join into one large bubble [E]. The bubble forces a drop of ink [F] out of the nozzle.

Head drive current stops before the bubble is fully formed. The remaining heat of the heat plate completes the bubble. The plate cools by the time the ink drop is ejected, and fresh ink enters the nozzle from the sponge.

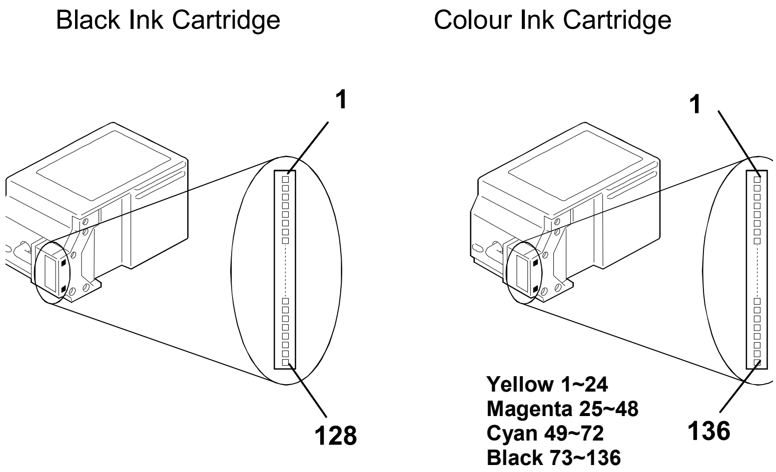


The nozzles are arranged in a straight line at intervals of 1/360 inch.

There are 128 nozzles in the black ink cartridge.

The color ink cartridge has a total of 136 nozzles: 24 yellow nozzles, 24 magenta nozzles, 24 cyan nozzles, and 64 black nozzles.

The drive circuit is explained in detail in section 8 (Components).



## *Purge Unit*

This unit does the following.

Capping puts a cap on the nozzles to prevent drying of the nozzle and ink leakage when the machine is not printing.

Cleaning: During cleaning, the wiper unit wipes the face plate to remove paper fiber and ink, and the ink pump in the purge unit sucks old ink from the capped cartridge and fills the nozzles with fresh ink.

In addition, the printer regularly ejects ink from all nozzles the cartridge to the purge unit to prevent ink from drying inside the nozzles and blocking them up. This is known as the maintenance jet function. The purge unit must absorb this waste ink.

The machine operates the purge unit at certain times automatically (for example, just after switching on, at the start of each page, every 60 s during printing, after a certain number of dots have been printed, or after a certain amount of time that the printer has been inactive).

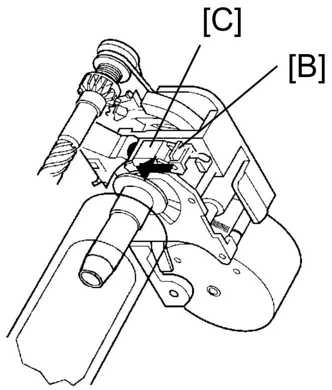
## *Example: H504*

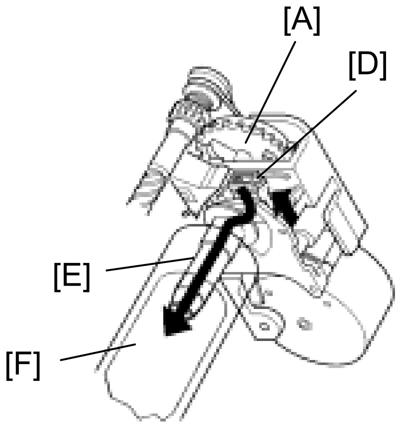
**Purge Unit Control Gear:** This gear [A] drives the purge unit wiper, cap, and pump.

**Wiper Arm:** This contains a rubber wiper [B] and the maintenance jet absorber [C]. The rubber wiper cleans the cartridge's face plate from top to bottom every 60 seconds during printing and when it is time for cleaning. The maintenance jet absorber absorbs ink ejected from the nozzles when power is switched on, before the start of printing, and every 12 seconds during printing. The ink absorber removes ink from the rubber wiper and the maintenance jet absorber when the wiper arm goes down.

**Cap:** The cap arm with its rubber cap [D] advances and caps the ink cartridge when the wiper arm goes down. The rubber cap connects to the ink pump. During cleaning, this pump sucks ink from the cartridge and fills the nozzles with fresh ink. The capping mechanism pushes the rubber cap against the face plate of the cartridge, to stop ink at the nozzles from drying up or leaking out.

**Pump:** The pump unit [E] sucks ink from the rubber cap and passes it to the waste ink absorber [F] in the paper feed roller.

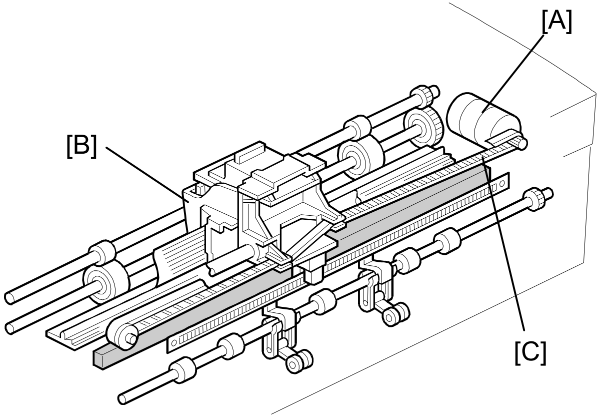


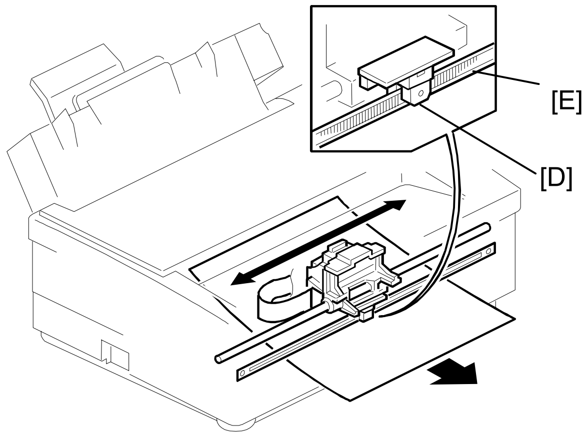



## *Carriage Drive Mechanism*

A motor drives the print head backwards and forwards across the paper. The carriage position is detected by counting stepper motor pulses, or by using an encoder, as in the following example.

### *Example: Model H905*




The carriage drive motor [A] drives the print head carriage [B] through the belt [C].

The sensor [D], located under the carriage generates a pulse signal while it moves along the encoder [E] , so that the printer engine can detect the horizontal location of the carriage.

## *Ink End Detection*

### *Example: Model H505*

To determine whether ink is present in the cartridge, the machine prints a black dot (known as the ink end mark) after printing the last line on a page. The ink end sensor reads the white level around the mark, and then it looks for the ink end mark itself. If the sensor cannot detect the mark, the machine determines that the cartridge is empty.

Some machines have no ink end sensor. The volume of ink used is monitored during printing by counting the number of dots made. The machine displays a warning when the ink has almost been all used up.

# Printer Interface Basics

## *USB (Universal Serial Bus)*

### *Introduction*

USB was designed to replace the serial and parallel ports, to provide a medium to high-speed port for a wide range of devices (such as mice, printers, speakers, digital cameras, & hard disks). Most computers and operating systems now support USB.

There are many similarities between USB and IEEE1394.

The computer acts as the host, and a chain of up to 127 devices can be connected to one host.

USB has the following advantages over older parallel and SCSI interfaces:

- ❐ Installation is very simple (no complex software or driver setup required). Just plug the device into the USB socket (a small rectangular socket) on the computer. The computer will automatically detect it (plug and play); in some cases, the user may have to install driver software.
- ❐ No terminators, device IDs (like SCSI), jumper, DIP switch, or IRQ settings are needed.
- ❐ Speed is much higher than the parallel port.
- ❐ Devices can be plugged in and disconnected at any time, without having to switch off the computer. This is known as ‘hot plugging’.

## *USB 1.1 vs USB 2.0*

USB 2.0 is a successor to the USB 1.1 specification. It uses the same cables, connectors, and software interfaces (USB 1.1 devices can be connected to USB 2.0 ports, and vice versa).

USB 2.0 provides a maximum data rate of 480 Mbps (high speed). This is particularly suitable for high-performance peripheral devices such as high-quality video conferencing cameras, high-resolution scanners, and high-density storage devices. However, the lower speeds supported by USB 1.1 will be enough to satisfy most printing requirements.

Mbps: megabits per second

Click here to see a comparative data rate table for various types of interface.

## *Specifications*

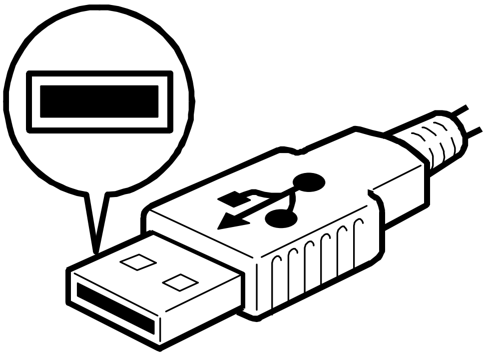
Data rates: 1.5 Mbps (low speed), 12 Mbps (full speed), 480 Mbps (high speed)

- Only USB 2.0 supports high-speed mode. The official logo is shown here.

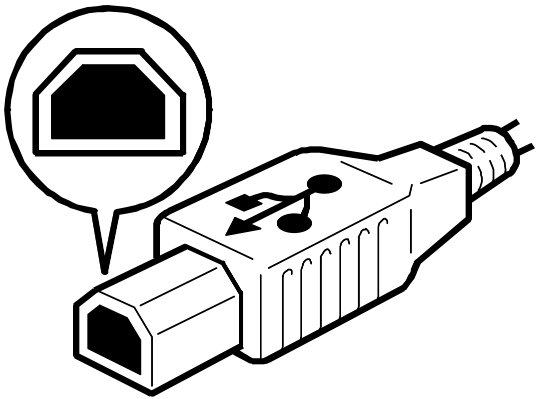
## *USB Connectors*

USB transmits all data on a single pair of wires. Another pair provides power from the host computer to downstream peripherals.

The USB standard specifies two types of connectors, type “A” connectors for upstream connection towards the host computer, and type “B” connectors for downstream connection to the USB device.



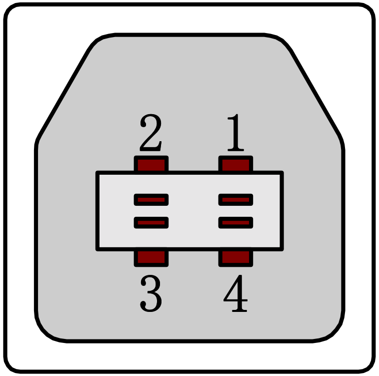
Type “A” connector



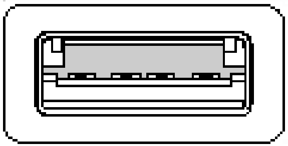
Type “B” connector

Printers and printer controllers inside MFP copiers have a type “B” receptacle.

| Pin No. | Signal Description |
|---|---|
| 1 | Power |
| 2 | Data – |
| 3 | Data + |
| 4 | Power GND |




Computers have a type “A” receptacle.
Pin 4 is at the left, and pin 1 is at the right.



To connect two PCs together, USB requires a special crossover cable.

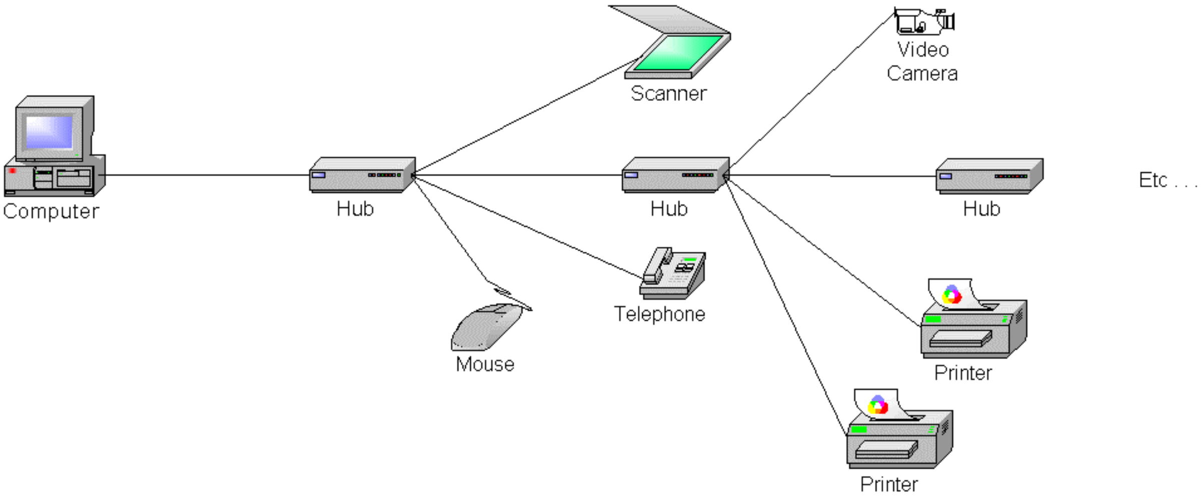
## *Connecting More Than One USB Device to a Computer*

Up to 127 devices can be connected to each USB controller inside the computer.

- ❒ Additional USB controllers can be installed inside the computer if required, by installing a card inside the computer.
- ❒ Note that many computers have two or more USB ports. In some computers, these are connected to separate USB controllers (so in theory, 254 devices can be connected if there are two ports). However, in other computers, the USB ports are connected to the same controller, so only 127 devices can be connected in total.
- ❒ Devices connected to the same USB controller all share the same bandwidth. Devices connected to another USB controller inside the same computer do not share the same bandwidth as those devices connected to the first USB controller. If a USB device, such as an audio speaker system, is taking up a lot of bandwidth, it might be a good idea to install another USB controller inside the computer and use it for that device only. Otherwise, other USB devices on the same bus, such as printers, may not work so fast.

The maximum cable length between each device is 5 meters.

- Using USB hubs (see the next page), chains of devices can be connected, as shown in the following example. However, there cannot be more than six ‘jumps’ between the PC and a device connected to a USB bus. In the following diagram, for example, there are three jumps between the computer and the video camera.



## *USB Hubs*

To connect a large number of devices to a computer, you can connect a USB hub to your computer's USB connector. Then, typically, you can connect four USB devices to this hub.

The diagram shows an example of a hub with four outlets.

If you need more USB ports, you can make chains using hubs, but the total number of devices (excluding hubs) must not exceed 127. Also, as shown earlier, there cannot be more than 6 cables ('jumps') between the PC and any device on the bus.

## *Power Supply to USB Devices*

The USB cable carries power from the computer. Devices that require a lot of power (such as laser printers) normally have their own power source, such as a mains power connection, and do not need to draw power from the USB connection. Generally, if a device needs to draw more than 500 mA, it has its own power source.

Low-power devices such as mice do not have their own power source, so they need to get power from the USB connection. In these cases, the power will come from the computer. If such devices are connected to a USB hub, the hub should have its own power source (the one shown above does not have a power cable). If the devices connected to the hub have their own power source, then the hub does not need a power source.

## *Protocol*

USB is bi-directional, allowing data, commands, and queries to flow both ways between computer and peripheral.

Just after the host computer is switched on, it checks what is connected to the USB controller and assigns an address to each device on the USB bus. New devices can be connected without switching the computer off; whenever a new device is connected to the bus, it is allocated an address immediately.

The computer also needs to determine what type of signalling each device will use to transfer data. There are three types:

- ❒ Bulk: Printers use this mode. The printer receives the data in packets, which are checked for errors.
- ❒ Isochronous: This mode is used by devices that require data transfer between host and device in real time, without interruption. An example would be a set of audio speakers. There is no error correction in this mode.
- ❒ Interrupt: Used by devices that do not send a lot of data, such as a USB mouse.

How does the USB controller inside the computer allocate bandwidth?

The controller assesses bandwidth demands whenever it checks what is connected to the bus.

The available bandwidth is divided into frames of 1-millisecond duration. During each frame, isochronous and interrupt devices get whatever bandwidth they need These devices are allowed to take up to 90% of the total bandwidth that is available. Bulk mode transfers and data flow control protocol requirements use what is left.

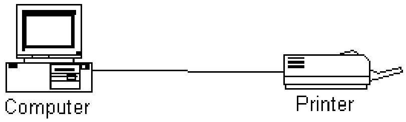
From this, it can be seen that connecting isochronous devices to the same USB controller as a printer can result in a loss of output speed. This could be a particular problem for USB 1.1. However, with the wide bandwidth available with USB 2.0, printing should still be fast enough for most users.

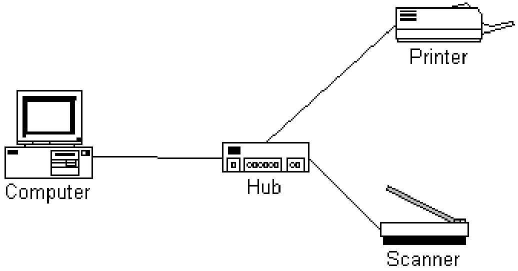
## *Connecting an MFP Product using USB*

This section explains how this company implements USB in its printers and MFP products.

### *Connecting Up*

Just connect the printer to the computer using a USB cable, either directly or through a hub (or chain of hubs). There are no settings to make on the computer or the printer.




Note that if either the computer, hub, or printer have only a USB 1.1 card, the maximum data rate will be 12 Mbps. 480 bps (high speed) will not be possible:

### *Operating Systems Supported by Ricoh Products*

- USB 2.0: Windows XP (Home Edition/Professional), Windows 2000 (Professional/Server/Advanced Server)
  - This may change depending on future support by Microsoft and Apple for USB 2.0.
- USB 1.1: Windows 98 (Second Edition), Windows Me, Mac OS 9.x, X (Classic Mode)
  - Mac OS X (Native Mode) and Mac OS 10.1 are not supported.
  - For Macintosh OS, only the built-in standard port is supported.
  - 'USB Printer Support' is required for USB printing on Windows 98 (Second Edition) or Windows Me. It is included on the CD-ROM for the printer. Follow the operating instructions.

### *Remarks concerning USB*

- ❒ The machine does not print reports specifically for USB.
- ❒ Using USB, the printer can only be connected to one computer.
- ❒ After starting a job using USB, do not switch the printer off until the job has been completed. When a user cancels a print job and data transmitted to the printer has not been printed at the time of cancellation, the job will continue to print up to the page where the print job was cancelled
- ❒ When the printer controller board is replaced, the host computer may recognize the machine as a different device.
- ❒ When printing from a Macintosh, PDL emulation may not be switched automatically. Please use the printer user tools to specify the PDL that will be used.
- ❒ Bi-directional communication is supported by the RPCS and PCL drivers. The condition of the paper trays and items in the Accessories tab of the printer driver can be monitored from the computer using a software utility such as SmartNetMonitor.

## *Related User Tools and SP Modes*

### *Data Transfer Rate*

This adjustment has two settings. The 'Auto' setting allows the machine to use either high-speed mode (480 Mbps) or full speed mode (12 Mbps) depending on the USB bus speed. The 'Full speed' setting restricts the machine to full speed (12 Mbps). The 12Mbps-only setting may be used for troubleshooting if data transfer errors commonly occur using the high-speed mode.

### Example: G081 series

SP mode 5-844

| | | | |
|---|---|---|---|
| 844 | **[USB]** USB settings | | |
| | 1 | Transfer Rate | Adjusts the USB transfer rate.<br>**HS/FS: High speed/Full speed auto adjust**<br>(480Mbps/12Mbps)<br>FS Fixation: Full speed (12Mbps fixed)<br>Do not change the setting unless there is a data transfer error using the USB high speed mode. |
| | 2 | Vendor ID | Displays the vendor ID. **DFU** |
| | 3 | Product ID | Displays the product ID. **DFU** |
| | 4 | Dev Release Num | Displays the development release version number. **DFU** |

User Tools – Host Interface Menu

| | |
|---|---|
| USB Setting | You can set the transmission speed for USB.<br>**Note**<br>❒ Default: Auto |

Do not change any other service mode settings unless instructed otherwise, or the machine may be out of compliance with local regulations

# IEEE 1394

## Introduction

IEEE1394 supports data transfer rates of up to 400 Mbps. It was originally developed by Apple.

- Apple uses the name ‘FireWire’ for IEEE1394 products. The FireWire logo is shown here.
- Other companies use other names, for example, Sony uses I-Link.

The concept of IEEE1394 is very similar to USB.

- It allows a lot of devices on the same bus (up to 63 can be connected to the same bus).
- No terminator or device ID, or dip switch/IRQ/jumpers to adjust
- Hot plugging
- Plug and play
- Provides power through the cable

IEEE1394 was developed before USB, and was for a long time much faster than USB.

- ❒ IEEE1394 has a maximum data rate of 400 Mbps, and USB 1.1 has a maximum rate of 12 Mbps.
- ❒ USB 2.0 has a speed of 480 Mbps, so there is currently not much difference between USB and IEEE1394.
- ❒ However, the IEEE1394 specification has been upgraded to ‘IEEE1394b’, which allows speeds of 800 Mbps, and using fiber optic cables, up to 3.2 Gbps.
- ❒ Click here to see a comparative data rate table for various types of interface.

The main difference from USB is that IEEE1394 is a peer-to-peer technology.

- ❒ This means that there can be more than one computer on the same IEEE1394 bus. Because of this, more than one computer can share the same printer. This is not possible with USB. For USB, there can only be one computer in the bus.
- ❒ Also, two devices can communicate without a computer; for example, you can copy from a camcorder to a VCR, or print a scanned image directly, without sending the data through a computer.
- ❒ Computers can also be connected together to form a high-speed network for copying files. No special cable or hardware is required to connect computers together.

## *Specifications*

IEEE1394-1995 supports data rates of 100, 200, and 400 Mbps (megabits per second) over a cable length of 4.5 m (15 ft).

- These speeds are actually 98.304, 196.608, and 393.216 Mbps. The figures are rounded up to 100, 200, and 400.

IEEE1394a-2000: Introduces improvements to the signalling protocols, to improve efficiency.

IEEE1394b: Includes more improvements, and supports data rates of 800, 1600, and 3200 Mbps. There is also support for long-distance cabling of up to 100 m. There is full backward compatibility with IEEE1394-1995 and IEEE1394a-2000.

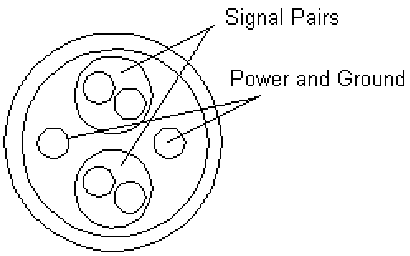
## *Data Rate Comparison Table*

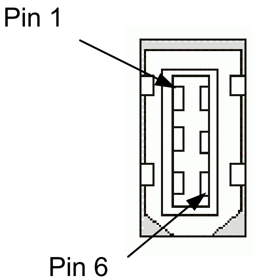
| Technology | Maximum Throughput |
|---|---|
| Serial Port (RS-232C) | 230 Kbps |
| Parallel Port (Centronics) | Standard: Up to 100 kbps<br>With ECP or EPP: Up to 2.5 Mbps |
| USB 1.1 | 1.5, 12 Mbps |
| USB 2.0 | 1.5, 12, 480 Mbps |
| IEEE1394a | 100, 200, 400 Mbps |
| IEEE1394b | 800, 1600, 3200 Mbps |
| Ethernet | 10 Mbps, or 100 Mbps |
| IEEE802.11b | 11 Mbps |
| Bluetooth | 720 kbps |

bps: bits per second

### *Connectors and Cables*

Six-pin: Four pins are for two twisted pairs, for a transmit-receive connection. The other two pins are for power (8-40V, 1.5A). Used for devices that need AC power, such as printers and external disk drives. The following diagrams show a cross-section of a six-pin to six-pin cable, and a view of a six-pin socket of the type commonly found on IEEE1394 interface boards.



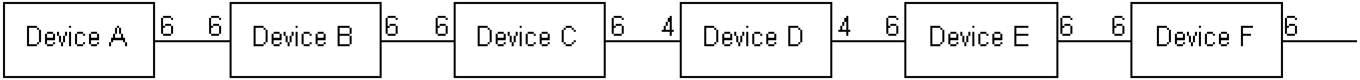

| Pin No. | Signal Description |
|---|---|
| 1 | Cable Power |
| 2 | GND |
| 3 | Receive strobe |
| 4 | Transmit data |
| 5 | Receive data |
| 6 | Transmit strobe |

Four-pin: Data only; does not carry power. Used for camcorders and small portable equipment.

Do not connect a 4-pin device between the device that supplies power to the bus and a device that needs to draw power from the bus.

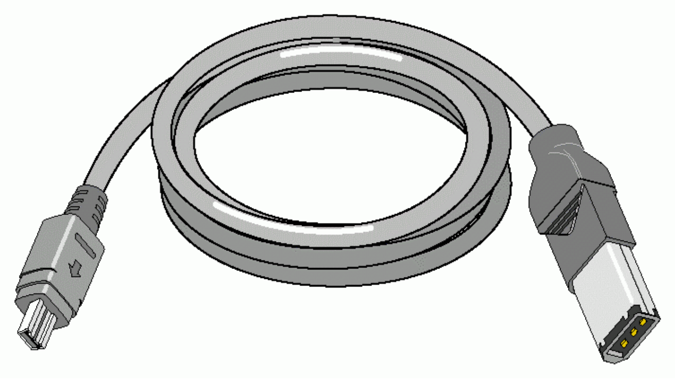
Including 4-pin devices in the middle of an IEEE1394 chain means that power is not carried to the units further along the chain, so it may not be convenient for some users.

In the example below, device A supplies power to the bus. Device D is a 4-pin device. Devices to the right of D in the diagram will not be able to get power from the bus, unless one of them is able to supply power from its own main power inlet through to the bus in a similar manner to device A.




If a device is connected to the bus with a 4-pin cable, it must have its own power source, such as batteries or a main power cable. However, using the 6-pin cable for battery-powered devices like video cameras ensures that the batteries are not drained while downloading data to the computer.

Here is an example of an IEEE1394 cable with a six-pin connector at one end and a four-pin connector at the other.



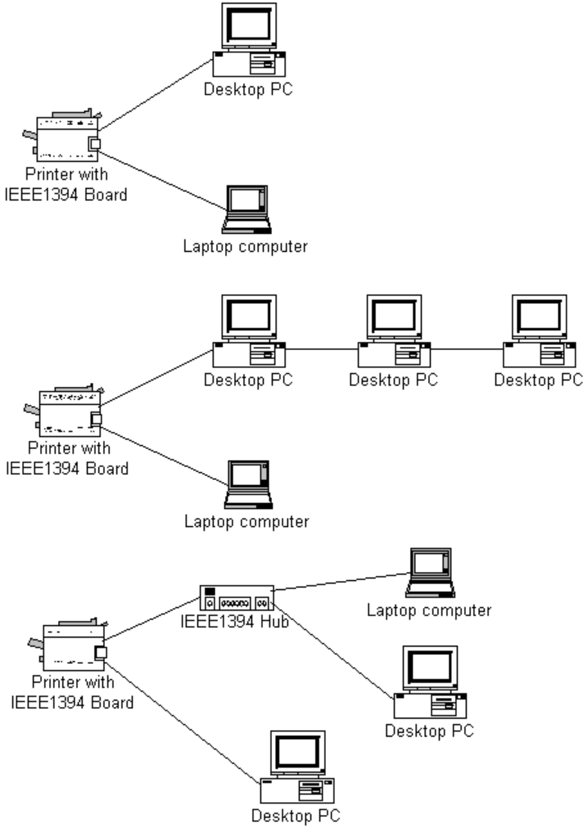
The cable length is limited to 4.5 m (15 ft). However, chains of devices can be connected, and there can be up to 16 ‘jumps’ between the devices on the bus. Up to 63 devices can be connected to an IEEE1394 network.

The reason for the 4.5 m limit on cable length and the 4.5 x 16 m (72 m) total bus length is signal attenuation. At the high speeds of IEEE1394, the signal would be attenuated too much if the cables were longer.

## *IEEE1394 Bus*

### *Topology: Chains and Trees*

- The drawings give three examples of how a printer containing an IEEE1394 card ports can be connected up. The ports are repeaters, allowing data to be passed on to the next device on the bus.
- The first example shows the printer connected to two computers; one on each port. The result is a chain of three devices, with a computer at each end and a printer in the middle.
- The second example shows one port on the printer being connected to a string of computers. The net effect is a chain of five devices, four computers and one printer.
- The third example shows a hub being used. Branching using hubs allows us to get up to 64 devices on the same bus, in a 'tree' structure.
- Some rules must be followed, as explained below.



***Rules***

- Up to 64 devices on each bus
- There must be no loops in the bus
- Max cable length between nodes: 4.5 m
- Max. number of cables between the ends of a bus: 16
  - Each cable is also known as a ‘hop’ or ‘jump’.

***Nodes***

- Each device on the bus is called a ‘node’.
- A device can contain more than one node.
- Each node can contain more than one port, allowing nodes to be chained together. Each port acts as a repeater, passing data packets on to other nodes on the bus.
  - Optional IEEE1394 boards for printers and MFP copiers commonly have two ports, so that another device can be connected after the printer, forming a ‘daisy chain’. See the previous page.
  - If the six-pin cables (carrying power for the physical layer signalling) are used, the repeater functions take place even if the node is switched off.

- On each bus, there is a ‘root node’, which controls the bus and manages the resources. This root node is often a 1394 interface board inside a PC.
- During a process called ‘tree identification’, the topology of the bus is determined. Each node is assigned an address, and the device that will be the root node is decided. It is also possible to force a particular node to become the root.
- Tree identification is done every time a device is added or removed, or whenever the bus is reset (by switching the root node off/on).

### *Cable and Backplane Connections*

- ❐ There are two types of IEEE1394 bus: cable, and backplane.
  - ➢ Backplane: Devices are plugged into a chassis, like boards plugged into a PC motherboard.
  - ➢ Cable: Devices are plugged into a root node, in a branching configuration, as described earlier
- ❐ In the backplane environment, devices do not contain repeaters, and their physical addresses may be determined by their slot positions
- ❐ In the cable environment, physical addresses are determined every time the bus is reset or a device is removed or added.
- ❐ Because of these differences, a bridge is needed to connect these two environments.

### *Addressing*

- ❐ The IEEE1394 bus appears as a large memory space shared between all the devices.
- ❐ Each node occupies a certain address range of this memory space.
  - ➢ Addressing is based on the IEEE1212 Control and Status Register (CSR) Architecture.

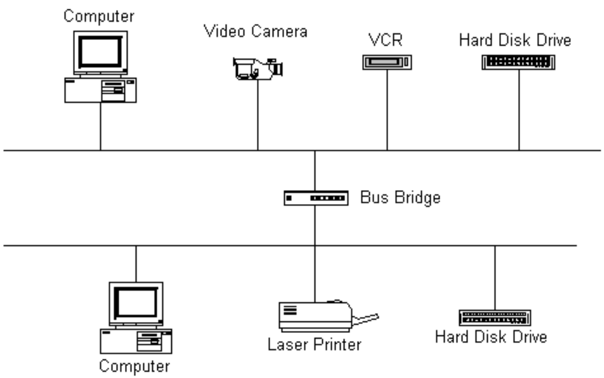
❒ The address is 64 bits.

- 10 bits are taken up by the network ID. This informs which IEEE1394 bus the signal is coming from.

**What do you mean, 'which bus the signal is coming from'? There is only one bus, isn't there?**

In theory, there can be up to 1024 buses in one IEEE1394 network (the number of the bus is specified by the 10 bit network ID). Two or more buses can only communicate with each other if they are connected together using a device called a bus bridge.

An example is shown below. The bus bridge isolates traffic in each IEEE1394 network.




Installing another IEEE1394 card inside a computer is also a way to make another bus.

- 6 bits are taken up by the node ID. This informs which device on the above bus the signal is coming from. As a result, up to 63 branch and leaf nodes can be connected to a single root node. The node ID is assigned automatically during tree identification.
- 48 bits are taken up by the memory address. This means that an IEEE1394 network can address up to 256 terabytes of memory in each node. This type of addressing views the devices on the bus as memory that can be accessed with processor-to-memory transactions.

In addition, each IEEE 1394 device has a unique identification code, similar to the MAC address on an Ethernet or IEEE802.11b interface card. The code for the IEEE 1394 device is called an EUI-64 code.

# Protocol Overview

## Isochronous and Asynchronous Transfer

*Overview*

- Both of these modes of transfer are supported.
- The mode that is used depends on the type of device. For example, a camcorder will use isochronous transfer, and a disk drive will use asynchronous transfer.
- Isochronous transport guarantees transfer of data at a certain rate and at a certain time, without interruptions. Data is considered to be useless if it arrives late. There are no retries.
- Contrast this with asynchronous, in which data can be broken up at irregular intervals, and where reliability is more important than timing, and where there can be retries if errors occur.
- Isochronous transport is ideal for devices such as video devices that need to transfer high levels of data within certain time constraints. For example, multimedia requires isochronous transport so that data is delivered as fast as it is displayed and so that the audio is synchronized with the video.
- In each IEEE1394 packet, bandwidth is allocated for both asynchronous and isochronous transfer. Up to 80% of a packet can be allocated to isochronous transfer.

*Isochronous*

- ❒ Broadcasts to channel numbers, not specific addresses
- ❒ No error correction or retransmission
- ❒ Time-critical applications, or applications that are tolerant of errors, such as linked video and audio
- ❒ Bandwidth and latency are guaranteed
  - ➢ The isochronous resource manager (often the same device as the root node or bus manager) allocates resources for a device wishing to make an isochronous transfer. Up to 80% of the bus bandwidth can be used for isochronous transfers. The amount a device can obtain depends on how many devices on the bus are also currently making isochronous transfers.

*Asynchronous*

- ❒ Transfers to a specific node with a specific address
- ❒ Transfers are acknowledged, so error correction and retransmission are possible
- ❒ Applications that are not time-critical but are not tolerant of errors, such as printers and hard disks
- ❒ There is no guarantee of a specific amount of bandwidth on the bus.
- ❒ The max data block size for an asynchronous packet depends on the transfer rate of the device.
  - ➢ 100 Mbps – 512 bytes; 200 Mbps – 1,024 bytes; 400 Mbps – 2,048 bytes

## *Connecting an MFP Product using IEEE1394*

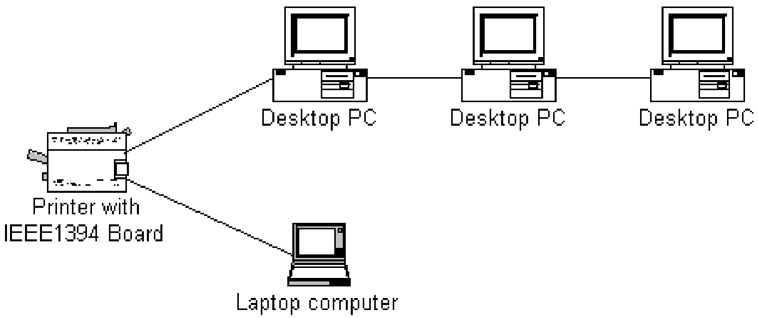
This section explains how this company implements IEEE1394 in its printers and MFP products.

### *Cables*

Normally, the printer only uses the 6-pin connectors. Use 6-pin cables to connect the printer to the computer.

### *Number of Ports*

The IEEE1394 option normally has two ports. These ports are repeaters. In the diagram on the right, the printer is part of a single chain of five devices (four computers and one printer).

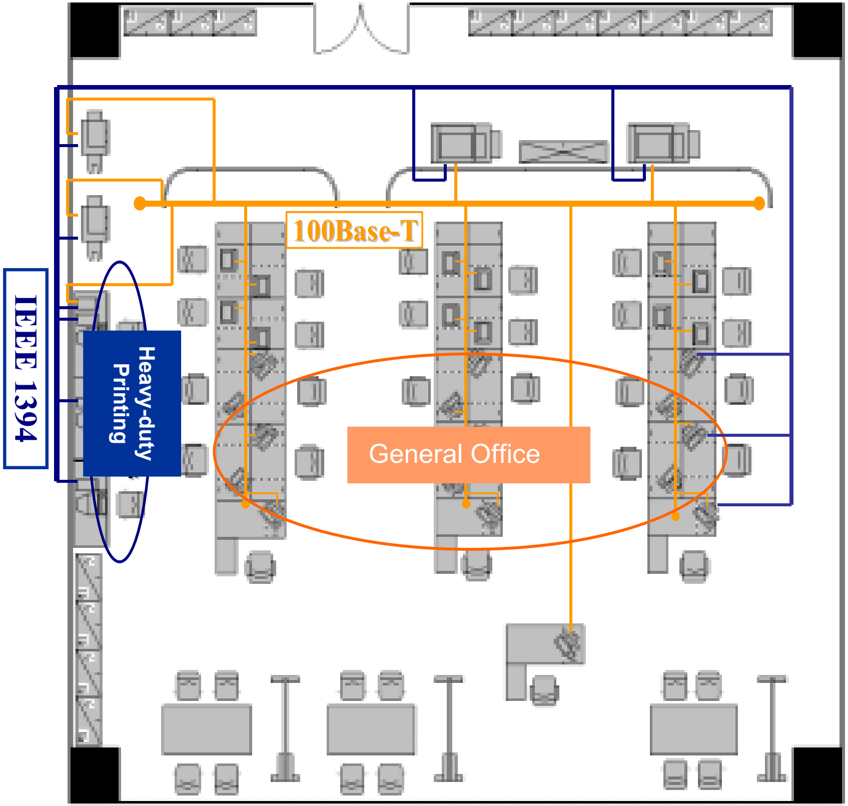



### *Data Speed*

IEEE1394 printer interface options still do not support IEEE 1394b, so the maximum speed is 400 Mbps.

### *Example of Use*

In the example shown opposite, traffic on the office LAN is reduced by connecting up heavy-duty printing workstations to the printers using IEEE1394 (up to 400 Mbps, as explained earlier). General office workers who do not have high-volume print jobs are connected up using the slower Ethernet LAN. The printers are shared by both sections of the office, and they contain Ethernet and IEEE1394 interfaces.



## *Two Ways to Set Up the Printer: SCSI Printing, and IP Over 1394*

*Overview*

There are two ways for a manufacturer to implement IEEE1394 in a printer.

- ❒ Implement SBP-2 (Serial Bus Protocol) and use the SCSI-2 printer command set: This is 'SCSI Printing'. Available for Windows 2000 or Windows XP.
- ❒ Use IP (Internet Protocol): This is 'IP over 1394'. Available for Windows Me or Windows XP.

For each of these methods, the printer is plugged into the computer in exactly the same way, using the IEEE1394 cable (do not try to use SCSI or Ethernet cables and hardware). The 'daisy-chain' or 'tree' bus configuration is acceptable for either of these methods. Also, there can be a mixture of protocols on the same bus. For example, if a computer is connected to a printer using IP over 1394, the other devices on the same bus do not all have to use IP; some of them can be using SBP-2 based signaling (such as a disk drive, or a printer set up for SCSI printing).

If using IP over 1394, the user must make additional settings to allow the IEEE1394 interface to use IP protocol.

Normally, SCSI printing and IP over 1394 cannot both be enabled at any one time. Select either one, using a user tool. Check the documentation for the product for details.

*SCSI Printing*

- Advantages -
The main advantage of SCSI printing is that it is easier to set up than IP over 1394.

- Disadvantages -
IP over 1394 is more flexible, and some applications cannot be used with SCSI printing, as we shall see later.

- Operating Systems -
Windows 2000 users must use SCSI printing. Windows XP users can use either SCSI printing or IP over 1394.

- Setup -
To set up the machine for SCSI printing, make sure that ‘SCSI print’ is enabled in the user tools.

- User Tools -
‘Bi-directional SCSI printing’ in the user tools allows the status of the items in the Accessories tab of the driver to be monitored at the computer using a software utility such as SmartNetMonitor.

*IP over 1394*

- Advantages -

IP over 1394 also allows scanning over IEEE1394. SCSI printing does not allow this. In addition, some document solutions applications such as Scan Router can work on an IP over 1394 bus, but not using SCSI printing.

In addition, the use of TCP/IP allows the printer to be connected to local networks, other subnets, and even to the Internet.

> Is it possible to connect a printer that uses IP over 1394 to a computer that is connected to an Ethernet LAN?
>
> Use of a 1394-Ethernet bridge or Media bridge (Windows XP) is not supported by GW products. Future products may support this.

- Disadvantages -

With IP over 1394, Plug and Play does not work, and the user must make IP settings at the operation panel during installation.

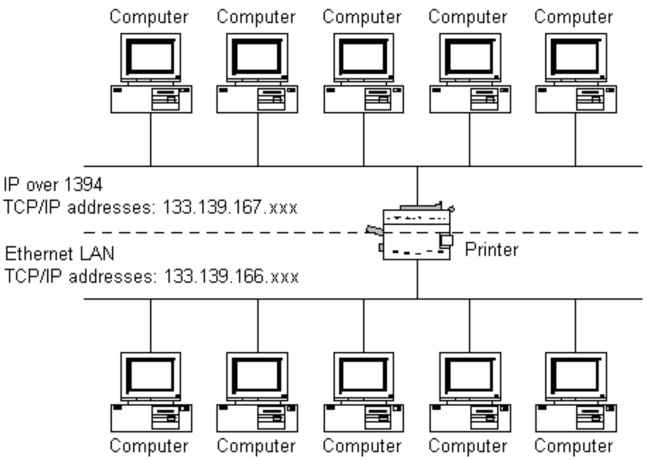
❒ However, Universal Plug and Play (UPnP) should allow the computer to find the printer. UPnP is provided with Windows XP and Me, but with Windows Me, it is not enabled by default.

- Operating Systems -

Windows Me users must use this method. Windows XP users can also use this method.

- Setup -

A Ricoh printer with an IEEE1394 board must have a separate IP address for IP over 1394; it cannot use its Ethernet IP address. In fact, as shown to the right, the subnet must be different, not just the IP address.




Because of this, there are separate IP settings for IP over 1394 in the user tools. The user tool TCP/IP settings for the Ethernet connection will not be used for IP over 1394.

❒ This specification may change in the future.

In addition, to set up the machine for IP over 1394, make sure that 'IP over 1394' is enabled in the user tools.

*Comparing SCSI Printing and IP over 1394*

| | **SCSI Printing** | **IP over 1394** |
|---|---|---|
| Available Functions | Printing | Printing, Scanning |
| PC Operating System Required | Windows 2000 Professional with Service Pack 1<br>Windows 2000 Server with Service Pack 1<br>Windows XP | Windows Me<br>Windows XP |
| Protocol Used | SBP-2 | TCP/IP |
| Bi-directional Communication | Yes | Yes |
| Number of Hops | 16 hops (Max.) | 16 hops (Max.) |
| Length of Cable | 4.5m between devices (Max.) | 4.5m between devices (Max.) |

- If Service Pack 1 is not installed in Windows 2000, there can be only one SCSI print device connected to an IEEE 1394 bus, and the client cannot install the printer driver without using an account with Administrator permission.
- Using IP over 1394 with Windows Me: Additional software may be required, such as SmartNetMonitor for Client. Check the documentation for the product.
- Using IP over 1394, some models support DNS, DHCP, and WINS, depending on the firmware version. Refer to the technical documentation for that model.
- When using the Scan to E-mail function on IP over 1394, an SMTP gateway may be required. Check the documentation for the printer.

### *Installing an IEEE1394 Option*

Extra memory may need to be installed in the printer/copier, or the IEEE1394 option will not work. Check your service or operation manuals to make sure.

After installation, some settings need to be made. Check your training documentation and operation manuals for the product for details on the procedures to follow.

### *Remarks concerning IEEE1394 Options*

Note the following general points about IEEE1394 interface options.

- ❒ The machine does not print reports specifically for IEEE1394. Print the Configuration Page during installation to check that the machine recognizes the card.
- ❒ There is no spooler or print queue. If a computer tries to print using IEEE1394 while the printer is busy, the IEEE1394 interface card inside the printer will return a busy signal.
- ❒ After starting a job using IEEE1394, do not switch the printer off until the job has been completed. Although the printer may appear to be inactive, it may be in the middle of an IEEE1394 protocol exchange with the computer.
- ❒ When using IEEE1394, it is not possible to check the printer status (busy/idle) from the computer with a utility such as SmartNetMonitor. However, when using SCSI print mode, if bi-directional communication is enabled in the User Tools for IEEE1394, the condition of the paper trays and items in the Accessories tab of the printer driver can be monitored from the computer.

### *Troubleshooting Notes*

If there are problems when printing using the IEEE1394 interface, check the following.

- ❐ Is the computer using Windows 2000 with service pack 1? If not, install service pack 1.
- ❐ Has the interface card been replaced recently? Each card has an individual address, similar to the MAC address in an Ethernet card. If the card was changed, the driver still looks for the old card. The new card is considered as another device and a new printer appears in the Windows Control panel. The new card must be configured in the same way as the printer that was replaced (the old printer icon in Windows Control Panel should be deleted).
- ❐ Is there a loop somewhere in the network? An IEEE1394 network must be a chain or a branched chain. There can be no closed loops. If there is a loop, just disconnect the devices and connect them up again in a chain. The bus will reconfigure itself.
- ❐ Try to find out where in the bus the problem is occurring. Test the machine one-to-one with the computer to determine if the printer is defective (when the printer's interface cable is plugged in, the computer should see "Printer Ready"; when the cable is disconnected, the computer should see "Offline").
- ❐ Does the device 'disappear' soon after installation? If a device switches itself off because of the Energy Star settings, it may disappear from Device Manager. If this is a problem, adjust the Energy Star settings in the printer.

- After installing the printer in the middle of a daisy chain, is a device after the printer on the bus suddenly unable to get power? This might happen if you use a 6-pin to 4-pin cable to connect up the printer. The 4-pin connection does not carry power to the next device in the bus. Do not connect a 4-pin device between the device that supplies power to the bus and a device that needs to draw power from the bus.
- If the device is slow, there may be a low-speed device (e.g., 100 Mbps) partway along the chain. Low-speed devices must be placed at the end of the bus. Otherwise, 400 Mbps devices may be forced to communicate at 100 Mbps.
- Earlier IEEE 1394 host adapters are not OHCI compliant, and because of this they are not compatible with Windows 2000. Make sure that the IEEE 1394 board inside the computer is OHCI compliant.

### *Related Service Modes*

Do not change the settings unless instructed otherwise, or the machine may be out of compliance with local regulations

### *Related User Tools*

Already discussed in the SCSI Printing and IP over 1394 sections.

Example: G081 series - Host Interface Menu - IEEE1394 Setup

| Menu | Description |
|---|---|
| IEEE 1394 Setup [*1] | You can make settings for using IEEE 1394. This menu appears only when the optional IEEE 1394 board is installed.<br>❖ **IP Address1394**<br>You can set the IP address for IEEE 1394 (IP over 1394).<br>**Note**<br>❒ Default: All zero<br>❖ **Subnet Mask1394**<br>You can set the Subnet Mask for IEEE 1394 (IP over 1394).<br>**Note**<br>❒ Default: All zero<br>❖ **IP over 1394**<br>You can activate IP over 1394.<br>**Note**<br>❒ Default: Active<br>❖ **SCSI print**<br>You can activate SCSI print.<br>**Note**<br>❒ Default: Active<br>❖ **Bidi-SCSI print**<br>You can activate bidirectional transmission for SCSI print.<br>**Note**<br>❒ Default: On |

To use IP over 1394, these values must be stored. They must be different from the TCP/IP settings used for the Ethernet network.

Make sure that IP over 1394 and/or SCSI Print are enabled

# Bluetooth

## Overview

Bluetooth (logo shown opposite) is one of the two widely-used wireless LAN technologies. The other is IEEE802.11b.

Bluetooth is a specification for short-range radio links between mobile PCs, mobile phones and other portable devices. It was designed for both voice and data communications. It aims for low cost and low power consumption. It can be thought of as a way to replace the cable between two devices. However, it can also be used to form small networks, as we shall see.

In addition to connecting a computer and printer, Bluetooth can be used to network a wide range of domestic appliances, such as stereo equipment and headphones in a home entertainment system, and a cordless telephone to its base. The technology is based on radio waves, so the devices do not have to be in line of sight. They can be in different rooms, for example.

There are no cables, and the user does not have to make any complex settings to get things working. In theory, if you have a Bluetooth device and walk up to another Bluetooth device, the devices will communicate automatically as soon as they are within range. The user does not have to press any buttons or input any commands.

Devices can establish a connection when they come between 10 metres of each other. 10 metres is considered to be a short range, and this short range is due to the radio frequency power output of 1 mW, which is very low (some cell phones emit up to 3 W). However, it will go through walls.

Higher-powered Bluetooth devices with a power output of up to 100 mW can have a range of up to 100 metres, but Bluetooth is mainly intended to work at low power.

## *Communication Speed*

The basic specification for printing is 720 Mbps (megabits per second).

A Bluetooth network has a total capacity of 1 Mbps. Protocol overhead takes up about 20% of this.

Voice: In a full-duplex (two-way) voice channel, such as a telephone, data can pass at 64 kbps. This is much more than enough to support a voice conversation.

Data: In a half-duplex (one-way) data link, such as printing from a computer, Bluetooth can transmit at up to about 720 kbps in one direction, with 57.6 Kbps in the other. For a full-duplex data link, the speed is about 430 kbps in each direction.

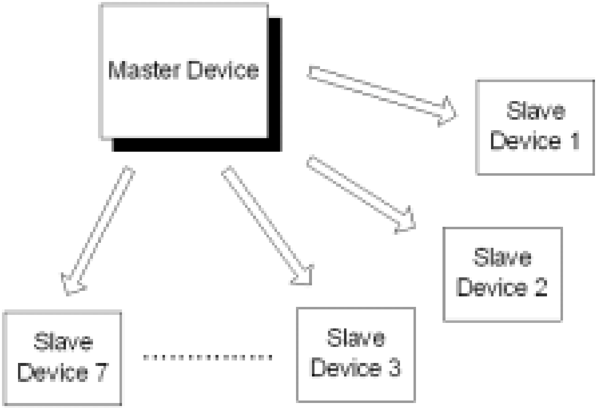
At 720 kpbs, Bluetooth is a lot slower than the other networking technologies discussed in this section. For example, IEEE802.11b, the other wireless technology, operates at 11 Mbps. However, an updated Bluetooth with higher data rates is being considered.

Click here for a table of data rates for various printer interfaces.

## *Bluetooth Networks*

A Bluetooth network is known as a 'piconet'. Another term for this is a personal-area network (PAN). Devices are connected to each other in an ad hoc fashion. (Loosely translated from the Latin, 'ad hoc' means 'on the fly').

A Piconet can start with two devices connecting to each other, and can expand until eight devices are connected. The connection is peer-to-peer, but one unit acts as the master, and the others act as slaves.




In addition to the seven active slaves, there can also be passive, or 'parked' slaves out in the piconet. These devices are not actively communicating at the moment, and enter a low power mode. Up to 255 slaves can be parked.

Slaves can participate in different piconets, and a master of one piconet can be the slave in another. This is known as a 'scatternet'. Up to 10 piconets can form a scatternet. In a scatternet, the piconets are not all synchronized with each other.

The master allocates the slots for the various communications taking place on the piconet, to control timing and avoid collisions. The clock and frequency hopping sequence of the master device synchronizes all other devices in the Piconet (frequency hopping will be explained later). It also stores the ID codes of the slave devices.

- Each device has a unique 48-bit ID code programmed into the ROM at the factory; this ID code normally appears as six two-digit numbers, such as 00:04:76:c5:fe:18. It is also known as the Bluetooth Device Address.
- Each active device in a piconet is also given a 3-bit address called the Active Device address.
- The user can also store a name for the device that is easy to recognize when using Bluetooth PC software to browse the Bluetooth devices in the piconet; this is known as a ‘friendly name’.

In a piconet, the master can support up to three synchronous ('voice') links of up to 64 kbps. Any free slots in the bandwidth can be used for asynchronous ('data') links. There can be up to seven of these in a piconet (one master, seven slaves). Asynchronous links can be either point-to-point (from master to one slave) or broadcast from the master to all slaves. In an asynchronous link, the slave can only transmit when the master requests it.

By connecting to a LAN access point, a Bluetooth device can also access LAN resources. However, if the LAN access point does not talk Bluetooth, the Bluetooth device will not be able to connect, unless it has TCP/IP.

## *Radio Frequency Control – Frequency Hopping*

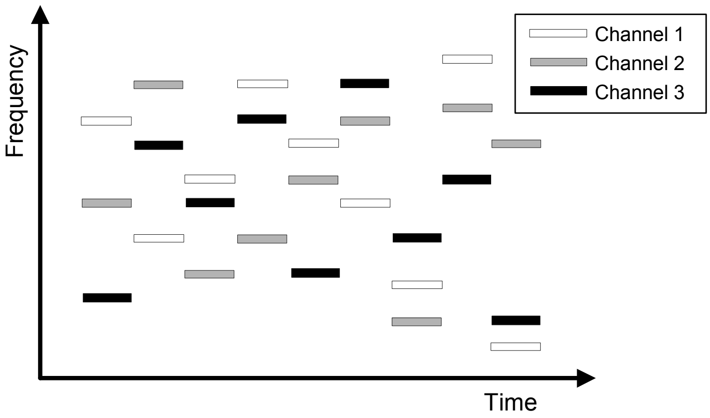
Bluetooth operates at 2.402 to 2.48 GHz. This waveband has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM), and is license free in most countries. Many types of devices, such as cordless phones, microwave ovens, and baby monitors, can use these frequencies.

Bluetooth breaks this waveband into 79 channels of 1 MHz width.

- ❒ In Japan, it is different. The frequency range is 2.472 to 2.497 GHz, and Bluetooth breaks it into 23 channels of 1 MHz width. France and Spain also use different frequencies.

Communications between devices change frequency to another channel 1,600 times a second. In the diagram opposite, there are three devices on the network. Notice how the devices all simultaneously change to another frequency at regular intervals (1,600 times a second, or once every 625 microseconds).

- ❒ Rapid frequency change helps prevent persistent interference between devices, not only Bluetooth devices but other types of device using the same frequency range. Interference on a particular frequency lasts only a fraction of a second.



- The low power signal used by Bluetooth devices also reduces the chances of interference.
- In the same area, there can be several piconets, perhaps making up a scatternet. To reduce the chances of interference, each piconet hops frequencies differently. Even if there is interference, it will probably be only for 625 microseconds, and Bluetooth contains software to automatically sort out confusion.
- This frequency switching technique is called ‘Frequency-Hopping Spread Spectrum’ (FHSS).

Each 625-microsecond interval is called a 'time slot'.

- According to Bluetooth specs, the master transmits in even-numbered time slots, slaves in odd-numbered time slots. Packets can be up to five time slots wide. Data in a packet can be up to 2,745 bits in length.

## *Bluetooth Profiles*

As stated earlier, a Bluetooth device will communicate with another automatically if within 10 metres. However, there are many different types of Bluetooth device, and because of this, there are a number of different connection protocols, known as 'profiles'. In order to work with each other, two devices must both be able to use the same profile.

Here is a list of profiles.

- Generic Access Profile
- Service Discovery Profile
- Cordless Telephony Profile
- Intercom Profile
- Serial Port Profile
- Headset Profile
- Dial-up Networking Profile
- Fax Profile
- LAN Access Profile
- Generic Object Exchange Profile
- Object Push Profile

- File Transfer Profile
- Synchronization Profile
- Hardcopy Cable Replacement Profile
- Basic Imaging Profile

Bluetooth devices also have a device type identifier to inform other devices on the network what type of device it is.

Using this information, Bluetooth devices within range of each other can form piconets among themselves and start working together. For example, a computer and a printer will form a piconet, stereo equipment and a set of headphones will form another piconet, and a cordless phone and its base will form a third piconet.

## *Security*

Bluetooth provides for several types of security, and the Bluetooth management software used by your PC may implement some or all of these.

### *Authorization*

If somebody tries to connect to your piconet, there is an alarm or warning, and you can then check who it is on the screen (the 'User Friendly' name and Active Device Address of the requesting unit appear). You can then allow or disallow the connection.

This security is not foolproof, because the user of the requesting device can change the User Friendly name. The only way to be sure is to keep a record of the device addresses of authorized devices.

### *Authentication*

Similar to Authorization (above), but the requesting user has to input a password as well.

Trusted devices can be allocated a link key, so that they do not have to keep inputting the password. Such devices are authenticated automatically, without needing operator intervention.

### *Encryption*

Bluetooth specs also allow some form of encryption using keys. It is thought to be adequate for most users, but those with high security requirements will need to use stronger algorithms. In addition, not all Bluetooth devices support encryption. If a Bluetooth device requests encryption but the other device does not have this feature, the communication may terminate unexpectedly.

### *Withdrawing the Availability of Services*

If a Bluetooth device offers more than one service, the user can disable some of them to prevent unauthorized access. However, this is a bit severe, because nobody can use these services in this case. So, Bluetooth provides for different passwords to be allocated to each service if required.

## *Connecting an MFP Product using Bluetooth*

This section explains how this company implements Bluetooth in its printers and MFP products.

### *Installing a Bluetooth Option*

To connect to the printer, follow the instructions provided with the computer's Bluetooth card.

### *Operating Systems Supported by Ricoh Products*

There are no limitations on operating system. If there is a driver for the operating system, the printer can be used with Bluetooth.

### *Bluetooth Profiles Supported by Ricoh Products*

Three profiles are supported. Communication from a PC must take place using one of these profiles.

Serial Port Profile (SPP)

- ❒ The printer shown by a Bluetooth search is connected to the serial port of the PC for printing.

Hardcopy Cable Replacement Profile (HCRP)

- ❒ The printer shown by a Bluetooth search is connected to the Bluetooth printer port of the PC for printing. This port is installed on the PC with the utility that comes with the PC's Bluetooth card.

Basic Imaging Profile (BIP)

- BIP is direct printing from a remote device without a printer driver. PostScript 3 may be required for this profile to be effective.

Notes

- HCRP supports Bi-directional communication, but SPP does not.
- HCRP is supported by Windows XP with the Service Pack 1 supplement.

### *Limitations on the Number of PCs that can Connect to the Printer*

- In brief, up to 3 PCs can connect to the printer at the same time.
- There cannot be more than one PC-to-printer connection using the same profile. For example, if a PC has connected using SPP, any other PC wishing to connect at the same time will have to use HCRP or BIP. SPP will only become available after the original PC has disconnected (or has been refused access for security reasons).
- Within the same piconet, only one computer can connect to the printer. This is because in the computer-printer relationship, the computer must be a master device, and a piconet can only have one master device.
- However, a PC from another piconet can connect to the printer. In this case, it must be using a different protocol from the printer that is already connected.

## *Security Features*

### *Public and Private Mode*

This can be set up either using a service mode or by the user (Telnet or Web Browser; refer to the operation manual for the product).

Public mode (default setting):

- ❒ The printer can be found by Bluetooth software on the PC. The printer is shown by its model name and Bluetooth active device address.

Private mode:

- ❒ The printer cannot be found by Bluetooth software on the PC. However, if the printer is specified using the PC's Bluetooth card, the printer can be used even if it is in private mode.

### *Password*

The printer contains a password made up of the last four digits of the printer's serial number. If the Bluetooth software in the PC is using a high security mode, this password will have to be input whenever printing to that printer.

However, at the moment, there is no high security mode option built into the printers to force the password to be input, so PC users can sidestep this by changing their security mode to a lower setting. This limitation may be addressed in the future. So for now, to ensure security at the printer side, use the 'Private mode' mentioned above.

### *Troubleshooting Notes*

If the printer does not print, try the following:

- Restart the computer and printer.
- Transmissions between the client PC and the printer can be blocked by obstructions. Move the printer and/or computer.
- If throughput is lower than expected, make sure that no IEEE 802.11b or other Bluetooth devices are in use. There may be some interference.
- Make sure that the versions of Bluetooth used by the printer and computer are the same. A device running Bluetooth 1.1 may not be able to work with a device running version 1.0.
- Make sure the printer you want to use can be found by the computer's Bluetooth software, and that the printer port has been set up correctly for the printer as described in the documentation for that software.

### *Related SP Modes*

Public and Private Mode: See above

Example: G081 series

SP 5-851

| | | | |
|---|---|---|---|
| 851 | [Bluetooth] | | |
| | 1 | Mode | Select the Bluetooth mode.<br>0: Public Mode<br>1: Private Mode<br>[ 0 or 1 / **0** / - ] |

User Tools - None

## *Other Questions*

Is anybody in charge?

- The Bluetooth Special Interest Group (SIG) controls the Bluetooth specification. The SIG started off with several leaders in telecommunications and computing, namely Intel, Ericsson, IBM, Toshiba, and Nokia. Other companies have since joined.
- In addition, the IEEE 802.15.1 standard is based on Bluetooth 1.1.
- Compatibility between Bluetooth 1.0 and 1.1 devices is poor.

Why 'Bluetooth'?

- Scandinavian companies have been important in developing wireless technologies, and have played a major role in setting up Bluetooth. In respect of that, this technology was named after Harald Bluetooth, king of Denmark in the 10th century, who united Denmark and introduced Christianity into that country.

Before wireless LAN technologies were developed, infra red ports (IrDA) were commonly seen on laptop computers. Why was an effective printing technology not developed from this?

- The main reason is that these infra red ports emit a beam of light in one direction, and this requires that the ports on the communicating devices point towards each other exactly. This also means that only two devices can communicate with each other; there cannot be a network of devices linked together at the same time.
- Also, there were incompatibility problems with some of the protocols used for IrDA.

## *Bluetooth vs IEEE 802.11b*

Why do we have two wireless technologies? Do they complement each other, or compete with each other? The following short series of notes addresses this in relation to printing.

Distance

- Bluetooth - 10 m (33.7 ft)
- 802.11b - hundreds of feet, but depends on the environment of installation (walls, metal objects, etc)

Application

- 802.11b is more a LAN type application, with a full range of networking features
- Bluetooth more a point to point type application, allowing small-scale networking, but not enough features for corporate-scale networking

Speed

- Bluetooth - 1 megabit per second bandwidth (700,000 bit per second throughput)
- 802.11b - 11 megabit per second bandwidth - throughput depends on distance - somewhat less than 11 megabit, but performance typically seems to be the same as a wired LAN connection.
- The throughput of Bluetooth is good enough for printing, but not for high throughput applications.

Cost

- Bluetooth is lower. It also consumes less power than IEEE802.11b.

Ease of use

- ❒ Bluetooth is much easier - 802.11b has more setup to do (like normal LAN management)

Conclusion

- ❒ The two technologies are complementary. IEEE802.11b is more suitable for corporate networks. Bluetooth is more suitable for home networks, and for use with PDAs and cell phones, but not for high-bandwidth devices such as digital cameras because it is too slow.

# *Interference between Bluetooth and IEEE 802.11b Networks*

## *Symptoms*

If throughput is reduced on either or both networks, interference may be the cause.

## *Causes*

Bluetooth and IEEE 802.11b devices both use the 2.4 GHz band. However, IEEE802.11b devices communicate on a single channel, which limits the frequency output of an IEEE802.11b device to about a third of the 2.4 GHz waveband at any one time. Bluetooth devices, on the other hand, rapidly hop frequencies all over the 2.4 GHz waveband. So intermittent interference between these two types of device is very likely.

IEEE802.11b stations check for radio activity before sending a frame. However, Bluetooth does not do this, and may begin transmitting at any time, even while an IEEE 802.11b station is sending.

On both types of network, interference causes lost packets, requiring retransmission of data, and reducing throughput.

In addition, IEEE802.11b throughput is reduced even more by the following factors (these factors do not affect Bluetooth):

- IEEE802.11b protocol requires acknowledgement of reception for each packet. If acknowledgement is not detected, the packet is resent.

- At the start of transmission, if Bluetooth interference is present, an IEEE802.11b transmitter may mistake the Bluetooth signals for carrier from another IEEE802.11b device, and think that the channel is busy.

### *Occurrence*

Interference happens only when Bluetooth and IEEE 802.11b devices transmit at the same time. Printing using Bluetooth will only cause radio activity for a short while, so an IEEE 802.11b network will only be affected temporarily, if at all.

Serious problems are more likely to occur if there are large-scale Bluetooth and IEEE 802.11b networks in the same building.

Also, Bluetooth devices only have a range of 10 metres, so if the IEEE 802.11b device is not nearby, interference is less likely. Studies show that interference is unlikely if the devices are more than 2 metres apart. Laptops with both Bluetooth and IEEE 802.11b cards may have problems, especially if the laptop is situated at the outer edge of the IEEE 802.11b network, where the signal is weaker.

### *Ways to Reduce Interference*

Limit the use of Bluetooth to applications that are only active for a short time, such as printing small documents, or synchronizing PDAs to computers.

Make sure that IEEE 802.11b signals can be picked up clearly in all areas that need them. If the signal is weak, any Bluetooth activity nearby could cause interference.

Wireless technologies in the 5 GHz band are becoming available. Critical devices that are experiencing intolerable interference could be moved to this waveband.

# IEEE802.11b

## Overview

IEEE802.11b is a wireless LAN technology. It is more powerful than Bluetooth, but harder to set up.

It is also known as 'Wi-Fi'. The Wi-Fi logo shown to the right is attached to products that have been certified by the Wi-Fi Alliance (formerly known as WECA: Wireless Ethernet Compatibility Alliance), which is supervising compliance with the IEEE802.11b standard.

Compared with Bluetooth, IEEE802.11b is faster and has a longer range. Also, IEEE802.11b devices can easily be integrated into existing Ethernet networks.

## Communication Speed and Effective Range

The top speed is 11 Mbps whenever possible. The speed automatically falls back to 5.5 Mbps, then 2 Mbps and finally down to 1 Mbps if there are communication problems caused by interference or low signal strength. This means that speed can fluctuate, but data transfer is reliable.

The range depends on the communication speed, as shown below.

| | |
|---|---|
| 11 Mbps | 100 m |
| 5.5 Mbps | 200 m |
| 2 Mbps | 270 m |
| 1 Mbps | 400 m |

However, these figures are for outdoor use. Indoors, the range depends on the layout of the building, and it is anything up to 100 m, but could be as low as 10 m in extreme cases. The maximum range also depends on which mode is being used (50 m for ad hoc, 100 m for infrastructure).

Throughput also depends on network topology and load. However, there is typically no difference in performance compared to a wired connection.

Note that some countries forbid the use of wireless LAN technology out of doors.

Click here for a table of data rates for various printer interfaces.

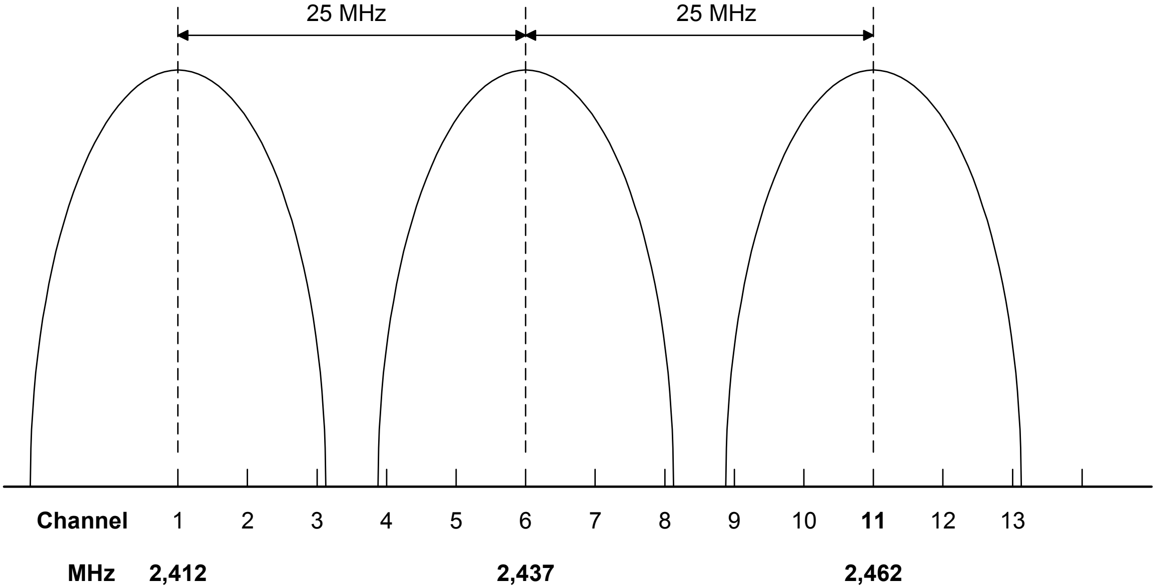
## *Radio Frequency Control*

IEEE802.11b operates in the 2.4 GHz band, which is the same as Bluetooth.

IEEE802.11b divides this waveband into 14 channels each of 22 MHz width. Devices on the same network must be tuned to the same channel. This method is known as DSSS (Direct Sequence Spread Spectrum).

The channels that can be used depend on the region.

- Europe: Channels 1-13 between 2412 and 2472MHz
- North America: Channels 1-11 between 2412 and 2464MHz
- Japan: Channels 1-14 between 2400 and 2497MHz
- Spain: 10, 11
- France: 10-13




To avoid interference with other radio frequency equipment, it is recommended to separate the frequencies by at least three channels. The diagram shows that a device using channel 11 may encounter interference if it is near a device using a frequency between channels 9 and 13. For example, if there are problems using channel 11 (default), try using channel 8.

The machines that are using the same channel are called a BSS (Basic Service Set).

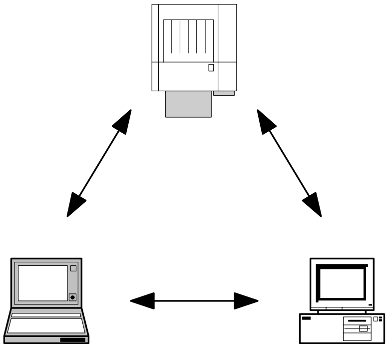
**What is Spread Spectrum Technology?**

This wideband radio frequency technique consumes more bandwidth than narrowband transmission, but produces a signal that is louder and easier to detect, if the receiver knows the parameters of the spread-spectrum signal. If a receiver is not tuned correctly, a spread-spectrum signal looks like background noise. There are two spread spectrum techniques: frequency hopping (used by Bluetooth) and direct sequence (used by IEEE802.11b).

## *IEEE802.11b Networks*

There are two types of IEEE802.11b network: ad hoc, and infrastructure.

### *Ad Hoc*



The ad hoc mode allows communication between each device in a simple peer-to-peer network. All devices must use the same channel.

The channel can be set at the printer’s operation panel.

The effective range between devices is about 50 m.

There are two types of ad hoc mode. One is “Ad hoc mode” and the other is “802.11b ad hoc mode”.

In 802.11b ad hoc mode, in addition to having the same channel, machines must also have the same SSID (Service Set ID) in order to communicate; see Infrastructure mode for more on the SSID.

802.11b ad hoc mode is also called ‘IBSS peer to peer mode’ (IBSS: Independent Basic Service Set).

Some operating system environments and some wireless LAN cards only support one of these ad hoc modes.

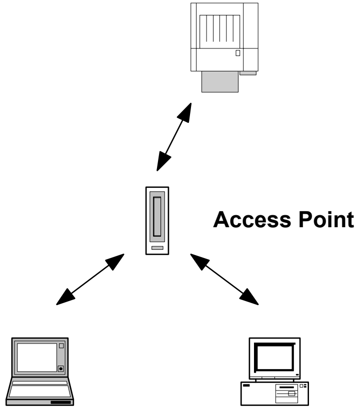
## *Infrastructure Mode*

In infrastructure mode, devices can only communicate through an Access Point.

Wireless LAN devices must use the same SSID (Service Set ID) as the access point in order to communicate.

The SSID is a case sensitive 32-byte code.

- Some device makers use a different name (NEC and Colega call it *ESS-ID*; Apple and IBM call it *Network name*).




If a device has the same SSID as the access point, the channel will automatically be set to the same as the one used by the access point.

If there is more than one Access Point, the client will connect to the access point that has the same SSID as the client.

Printers generally only have one SSID; check the documentation for the product.

Some access points support ‘ANY mode’, which allows devices to connect without comparing SSID codes, even if they have no SSID stored.

If the access point is also connected to an Ethernet LAN using an Ethernet cable, devices on the wireless LAN will be able to connect to devices on this Ethernet LAN, and to a WAN or the Internet.

The effective range between devices is about 100 m.

### *Allowable Number of Users*

There is no limit on the number of users in an IEEE802.11b network.

Also, if there are overlapping access points, people can move around a large area, such as a university campus, while remaining in contact with the network.

### *Advantages of Infrastructure or Ad Hoc mode*

Infrastructure mode

- ❒ Access points provide access to Ethernet, WANs, and the Internet.
- ❒ Wireless LAN range is almost double.
- ❒ An access point can optimize traffic on the network.

Ad hoc mode

- ❒ Easier to set up

# Protocol

## Protocol Layers

IEEE802.11b provides only two layers. These are the physical (PHY) layer and the medium access control (MAC) layer. The data transport layer (such as TCP/IP, IPX/SPX, Apple Talk, NetBEUI) must be supplied by the computer or device separately.

### *Physical Layer*

The physical layer describes how the data is sent between devices, as radio signals. This has already been discussed.

### *MAC Layer*

This is a CSMA/CA (carrier sense multiple access with collision avoidance) protocol. Compare this with a CSMA/CD (carrier sense multiple access with collision *detection*) protocol such as used by Ethernet.

- In a collision avoidance protocol, before device A sends a packet to device B, it checks to make sure that no other device is transmitting. If the channel is busy, device A waits for a short while before checking again. Device A also asks device B if it is ready to receive, because device B may be already receiving from another device C (if device C is out of wireless LAN range from device A, then device A will not detect that device C is transmitting).

- A collision detection protocol cannot be used on a wireless LAN because collisions cannot be detected. This is because when a device is transmitting, the signal that it sends will drown out any incoming signal, and collision will not be possible to detect.

In addition to collision avoidance, acknowledgement and cyclic redundancy check routines are also used.

Note that in contrast with IEEE802.11b devices, Bluetooth devices do not use a collision avoidance protocol, so they can cause radio interference.

### *Control of Infrastructure and Ad Hoc Modes*

In infrastructure mode, fixed access points control communication. When a client moves from the service area of one access point to another, the access points control the handoff to the next access point in a manner similar to a cellular network.

In ad hoc mode, there is no structure to the network; there are no fixed points; and the devices can all communicate with each other. To keep order in this type of network, one device is ‘elected’ as the master, while the other become slaves. This is similar to the Bluetooth piconet.

# *Security*

Several factors contribute to security, as described below.

## *Direct Sequence Spread Spectrum (DSSS)*

This type of radio frequency transmission technology is resistant to corruption, interference, jamming, and detection.

## *SSID (Service Set ID)*

Use of the SSID (either in 802.11b ad hoc or infrastructure mode) ensures that a device that does not have the same SSID as your network will not be able to gain access.

## *Encryption using the WEP (Wired Equivalent Privacy) Key*

### *What is the WEP Key?*

WEP is an encryption method using keys. There are 64 bit and 128 bit WEP keys. To unlock received encrypted data, the receiver must have the same WEP key as the sender.

### *Open and Shared Modes*

There are also two modes, called Open and Shared modes

- Open: Transmission data is encrypted.
- Shared: Handshaking protocol is also encrypted.

### *WEP Key Number*

Some LAN card utilities allow more than one WEP key, and give a 'key number' to each WEP key.

Most wireless LAN devices use 1 as the key number.

The WEP key ***and*** the WEP key number must be the same or communication will not be possible.

### ***MAC Address***

The MAC (Medium Access Control) address is similar to the MAC address used for Ethernet devices.

If infrastructure mode is used, access to the network can be limited at the access points using the MAC address. This type of security may not be available with some types of access points.

This feature has to be enabled at the access point. Then, the supervisor of the access point must register the MAC addresses of devices that are allowed to use the access point.

## *Connecting an MFP Product using IEEE802.11b*

### *Installing an IEEE802.11b Option*

In addition to IEEE802.11b settings, the data transport protocol must be set up properly, because IEEE802.11b does not supply a data transport protocol. Supported data transport protocols depend on the printer model and the operating system. Some common examples are TCP/IP, IPX/SPX, Apple Talk, and NetBEUI. For the following example, we shall assume TCP/IP is being used.

On the computer and printer, both TCP/IP and IEEE802.11b settings must be made. It does not matter in which order these are done. However, if you wish to use telnet or a web browser to set up the printer's IEEE802.11b settings, you must set up TCP/IP first.

After installing the wireless LAN card, some parameters have to be programmed. Briefly, these are as follows:

1. First, input the following TCP/IP settings at the printer's operation panel: IP address, Subnet Mask, Gateway Address, DHCP, Frame Type (NW), and Active Protocol.
   - Example: G080 printer
     Use the User Tools – Host Interface Menu – Network Setup Menu
   - Basic TCP/IP concepts are not covered in this section of the manual.
2. Make sure that the computer has its TCP/IP settings stored correctly.
   - The IP address must be on the same subnet as the printer.

3. At printer's operation panel (user tools) and at the computer, set up the IEEE802.11b parameters.
   - Communication mode for the PC and the printer must be set initially to the ad hoc mode, even if you will use the machine in infrastructure mode. The default for the printer is ad hoc mode.
   - The channel setting on the PC must be the same as for the printer.
   - When using a WEP key, set 1 as the WEP key number.
     Ricoh wireless products use 1 as a default WEP key number.
   - If 802.11 adhoc mode is being used, some vendor's utilities need an SSID of "ASSID".
4. At the printer's operation panel, set the LAN type setting (a user tool) to IEEE802.11b (wireless LAN).
   - This is only necessary in models where the IEEE802.11b and Ethernet connections cannot both be active at the same time. If the printer has both types of LAN card installed, one of them must be switched off with this user tool.
5. Try to 'ping' the printer from the computer.
6. If you wish to use ad hoc mode, you have finished. Make a test print.
   If you wish to use infrastructure mode, change the printer's IEEE802.11b settings (WEP key, SSID, Channel number) to match those of the access point. Then make a test print.

**Note:** After TCP/IP contact has been established between PC and printer, you can change the printer's settings with telnet (or a browser if the printer contains a web server such as Web Status Monitor).

### *Operating Systems Supported by Ricoh Products*

There are no limitations on operating system. If the wireless LAN card in the PC is supported by the operating system, the printer can be used over the wireless LAN interface.

### *Operating Modes Supported by Ricoh Products*

Infrastructure, ad hoc, and 802.11 ad hoc modes are supported. However, ad hoc is not supported with Netware.

Only one SSID can be stored. The default is ‘null’. If the operating mode is 802.11 ad hoc, then the default SSID automatically becomes “ASSID”. In such cases, if the printer’s default SSID is not changed, the SSID of the PC using the printer must also be “ASSID”. The SSID can be set at the machine’s operation panel, or with telnet, Web Status Monitor, or Web Image Monitor.

Some devices automatically change from ad hoc mode to infrastructure mode when the same SSID is used in ad hoc mode and infrastructure mode. If you wish to connect the printer to such a device, the device must have a specified SSID to use infrastructure mode and “ASSID” to use ad hoc mode.

### *Security Features*

Some models support 64-bit but not 128-bit WEP keys. Some models support both types. Check the documentation for the model.

Normally, only one WEP key can be stored in Ricoh printers. Check the documentation for the model.

## *Troubleshooting Notes*

*General*

1) Check the LED indicators on the wireless LAN card.

- Orange LED: Lit - IEEE 802.11b card is working
  Off - No power
  If the IEEE802.11b (wireless LAN) is not selected as the LAN type in the user tools, it does not light, even if the printer power is on.
- Green LED: Lit - It is connected properly to a network.
  Blinking - The machine is searching for devices.
  Off - No link established

2) Check if "IEEE802.11b" is selected in the LAN Type setting in the user tools.

3) Check for interference. If a Bluetooth network is nearby, there could be some intermittent interference. If there is persistent interference, try changing the channel setting (there should be a separation of at least three channels between interfering devices).

4) Make sure that the computer and printer are communicating on the same channel. If the computer cannot use the channel used by the printer (some client PC software has limitations on the channels that can be used), then change the channel setting in the printer.

5) WEP settings must be the same in the printer and the computer (Enable/Disable, WEP key and WEP key number)

*Ad Hoc Mode*

Move the devices closer together

Check that printer and computer are using the same ad hoc mode. If there are both *ad hoc* and *802.11 ad hoc* devices in the network, communication may not work correctly.

❒ Some operating system environments and some wireless LAN cards only support one of these ad hoc modes.

If the connection mode is 802.11 ad hoc mode, check that the SSID of the communicating devices is the same.

*Infrastructure Mode*

Bring the machine closer to the access point, change the antenna position, or check for obstructions between the machine and the access point.

Do the printer and access point have the same SSID?

If the Access Point has enabled MAC address security, check that the MAC address table has the printer's MAC address, and that the printer's MAC address is correct.

The Access Point probably has a list of wireless clients that are currently connected. If the printer is not in the list, the printer cannot connect. If the printer is in the list, the printer's IEEE802.11b settings should be correct (however, the PC's IEEE802.11b settings may be bad, the settings at the access point may be bad, or the printer's IP address setting may be incorrect).

Check the wireless communication status (use a user tool, telnet, or a web browser if the product contains a web server such as Web Status Monitor). This feature is only available with infrastructure mode. The status is described on a simple number scale.

| STATUS DISPLAY | COMMUNICATION STATUS |
|---|---|
| Good | 76~100 |
| Fair | 41~75 |
| Poor | 21~40 |
| Unavailable | 0~20 |

## *Related User Tools and SP Modes*

*User Tools*

Example: G080 printer
Maintenance menu

| | |
|---|---|
| WL.LAN Signal | You can check signal quality when using wireless LAN.<br>**Reference**<br>For more information about displaying signal quality, see p.147 "Displaying the Signal Quality". |
| WL.LAN Defaults | You can reset wireless LAN settings to the default. |

Check the wireless communication status (only works for infrastructure mode).

Host Interface menu – Network Setup – LAN Type

❖ **LAN Type**

You can select Ethernet or IEEE 802.11b as the LAN Type.

**Note**

- Default: *Ethernet*
- Appears only when the optional 802.11b interface unit is installed.

- Select either Ethernet or IEEE802.11b as the active network connection
- If you wish to use IEEE802.11b, select it with this user tool. Printing using the Ethernet LAN will be disabled

# Host Interface menu – Network Setup – IEEE802.11b

| Menu | Description |
| --- | --- |
| IEEE 802.11b *2 | You can make settings for using the wireless LAN. This menu appears only when the optional 802.11b interface unit is installed.<br>❖ **Comm. Mode**<br>You can set the transmission mode for IEEE 802.11b.<br>**Note**<br>❒ Default: *802.11 Ad hoc*<br>❖ **Channel**<br>The selectable channels are 1-11 (Inch version) and 1-13 (Metric version).<br>**Note**<br>❒ Default: 11<br>❖ **Trans. Speed**<br>You can set the transmission speed for IEEE 802.11b.<br>**Note**<br>❒ Default: *Auto* |

Transmission mode (ad hoc or infrastructure)

Channel number used for communication; depends on the location of the machine, as discussed earlier

Communication speed

# Host Interface menu – Network Setup – IEEE802.11b, continued

| Menu | Description |
| --- | --- |
| | ❖ **SSID**<br>You can make settings for SSID in Infrastructure mode and 802.11 Ad hoc mode.<br>**Limitation**<br>❒ Select "¥" if you want to enter "/" in the SSID. Also, "¥" appears when printing the configuration page, read it as "/".<br>**Note**<br>❒ Up to 32 ASCII characters in the range 0x20-0x7e can be used. The SSID setting is case-sensitive.<br>❒ An SSID value is automatically set to the nearest access point if the setting has not been made.<br>❒ If the setting has not been made for 802.11 Ad hoc mode, the same value for Infrastructure mode or an "ASSID" value is automatically set.<br>❖ **WEP Setting**<br>You can set the WEP encryption key for IEEE 802.11b.<br>**Note**<br>❒ Default: *Not Active*<br>❒ With 64-bit WEP, you can use a 10-digit hexadecimal key. With 128-bit WEP, you can use a 26-digit hexadecimal key.<br>❒ IEEE 802.11b communication is only possible when a WEP key has been specified. Set WEP to **[Active]**. |

SSID

WEP key: After setting to 'active', enter the WEP key that will be used for encryption by the PC

*SP Modes*

## Example: G080 printer, SP 5-840

| | | | | |
|---|---|---|---|---|
| 840 | **[IEEE 802.11b]** | | | |
| | 4 | Current SSID | *CTL | Enter a unique ID (up to 32 characters long) to identify the device. |
| | 6 | Channel Max | *CTL | Sets the maximum number of channels available for data transmission via the wireless LAN. **DFU**<br>[ 1 to 11 or 13 / 1 / 1 /step]<br>Europe/Asia: 1 to 13<br>USA: 1 to 11<br>**Note**: Do not change the setting |
| | 7 | Channel Min | *CTL | Sets the minimum number of channels available for data transmission via the wireless LAN. **DFU**<br>[ 1 to 11 or 13 / 1 / 1 /step]<br>Europe/Asia: 1 to 13<br>USA: 1 to 11<br>**Note**: Do not change the setting |
| | 10 | WEP key | *CTL | Enter the WEP key.<br>The maximum number of characters is determined by SP5-840-20. |
| | 11 | WEP key number | *CTL | Select the WEP key number.<br>[00~11 / 00 / 1 binary]<br>00: Key #1<br>01: Key #2 (Reserved)<br>10: Key #3 (Reserved)<br>11: Key #4 (Reserved) |
| | 20 | WEP mode | *CTL | Determines the operation mode of the WEP key.<br>[0~1/0/1]<br>0: Max. 64-bit (10 characters)<br>1: Max. 128-bit (10, 26 characters) |

SSID

WEP key

WEP key number (normally fixed at 1 in printers; this may change in the future)

Type of WEP key (64-bit or 128-bit)

Do not adjust other SP modes, or the machine may not be in compliance with local regulations.