PCL 5
Color Technical Reference Manual

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Inside This Manual

What You Can Learn From This Manual

This manual describes the PCL 5 commands used to print color on the HP Color LaserJet and DeskJet 1200C printers. Some of the main topics include an overview of the color printing process, using palettes, choosing color modes, adjusting output color to meet your requirements, printing color raster graphics, and HP-GL/2 vector graphics. Examples are provided which demonstrate the use of the PCL 5 color commands.

Note

All commands described in this manual are not necessarily supported by both printers. See the *PCL 5 Comparison Guide* for feature support information for each printer.

This manual is written primarily for users that are already familiar with PCL 5 printer features. For information on using PCL 5, see the *PCL 5 Printer Language Technical Reference Manual*.

Manual Organization

This manual contains seven chapters. A brief description of each chapter is provided below.

Chapter 1. Color Printing Overview

This chapter explains background information about printing color documents using PCL 5. Topics include palettes, device-dependent vs. device-independent color, color selection, pixel encoding, color modes, and color matching.

Chapter 2. Using Color Modes

Chapter 2 defines the four color modes and describes how to use them, including descriptions of sending color raster data using different pixel encoding modes and color spaces.

Chapter 3. Using Palettes

This chapter describes the palettes associated with the four color modes and explains how palettes are created, saved, and modified.

Chapter 4. Modifying Output Color

This chapter explains how color can be optimized by compensating for different conditions, such as variations in color due to light sources, limitations of the original artwork and variations in viewing monitors. The chapter details the use of halftone rendering algorithms, color lookup tables, gamma correction, and viewing illuminant commands provided so that users can request and receive colored output that matches their expectations.

Chapter 5. The PCL Print Model

Chapter 5 describes the print model and how it determines the printed outcome when various patterns, colors, and images are applied together on a page. This chapter discusses the role that logical operations and transparency modes have on this process.

Chapter 6. Raster Graphics

This chapter describes the raster graphics commands and also compressing raster graphics images using various compression methods.

Chapter 7. Color Vector Graphics (HP-GL/2)

This chapter discusses printing color pages using HP-GL/2, the vector graphics language included on all PCL 5 printers. The chapter describes new and/or modified HP-GL/2 commands and how they are used to print with HP color printers.

Index

This manual includes an index for quick access to PCL command information.

Related Documents

The following documents provide related information about Hewlett-Packard PCL 5 printers.

PCL 5 Printer Language Technical Reference Manual

The *PCL 5 Printer Language Technical Reference Manual* provides a description of the printer command language that controls PCL 5 printers. The manual provides explanations of each PCL command, and examples demonstrating how the commands are used to manipulate the printer. A large portion of the manual is devoted to HP-GL/2, the vector-based graphics language in PCL 5 printers.

PCL 5 Comparison Guide

This document provides printer-specific information on paper handling, internal fonts, PCL command support, and control panel information. It identifies feature differences between the various PCL 5 printers, and how the printers implement the commands described in the *PCL 5 Printer Language Technical Reference Manual*.

Printer Job Language Technical Reference Manual

This manual describes PJL, the HP printer job language used on many of the Hewlett-Packard printers. PJL is used for switching printer languages, requesting status information, changing display messages, inquiring about feature settings, and other job-level functions.

PCL/PJL Technical Quick Reference Guide

This booklet is designed to provide quick access to the syntax of each PCL and PJL command. The commands are grouped by their function so that those familiar with PCL and/or PJL can find the syntax of a specific command without opening the manual.

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Color Printing Overview

Introduction

This chapter provides an overview of the way color is used in the HP Color LaserJet and DeskJet 1200C printers. It previews the remaining chapters, which describe the specific details of Hewlett-Packard color printing.

Note

The features described in this document are a superset of those supported by the Color LaserJet and DeskJet 1200C printers. Some features are supported on one or the other printers, but not on both. See the *PCL 5 Comparison Guide* for specific feature support for each printer.

Processing a color document involves specifying a palette or palettes, and then using the colors within the current palette to print. For non- raster printing, items such as text, rules, and vectors are simply printed in the currently active color, which is specified using the Foreground Color command or Select Pen command if in HP-GL/2. For raster printing, the color of each pixel is specified as either a direct color specification, or as an index into the palette, depending on the pixel encoding mode.

The PCL Print Model determines how color is applied to the page. The printed result can vary in background and texture depending on the source transparency mode, pattern transparency mode, and selected logical operation (ROP). Besides the pre-defined shading and patterns, users can define new monochrome or multicolor patterns.

When printing color pages, a user can choose one of several color modes, depending on the desired results. Each color mode has a palette associated with it. *Simple Color Mode*

provides a palette of fully saturated colors whose colors are similar to those of a plotter's pen colors. The palette is nonprogrammable, and is intended for simple printing of items such as bar and pie charts. For applications requiring different or more specific colors, the printer offers the *PCL Imaging* and *HP-GL/2 Imaging* Modes. The palette colors in these two modes can be modified to provide the desired result.

When choosing color for a particular application, the Color LaserJet printer provides *device-dependent* and *device-independent* color (the DeskJet 1200C supports only device-dependent color). *Device-independent* color provides accurate color matching based on an absolute color standard. It is preferred when users want a precise color to match the output from another device or to match the color on an existing page.

Besides providing device-independent color for precise color matching, the HP printers can modify color to compensate for various characteristics. The Color LaserJet printer supports the following methods of modifying color (the DeskJet 1200C printer supports halftone algorithms and gamma correction, but not color lookup tables or the Viewing Illuminant command).

- Halftone ren*der algorithms* determine how colors are rendered using the printers available colors. Halftone algorithms can be used to change apparent resolution, change the texture of images, reduce the number of colors, and change a color image to monochrome.
- Color look*up tables* can remap colors to compensate for various differences in input data, such as unwanted color casts caused by unbalanced photographic light sources.
- Gam*ma correction* provides a way to adjust for color differences in display monitors so that the display more closely matches the printed output.
- Since the appearance of colors changes under different viewing light sources, the *Viewing Illuminant* command allows the application to modify output color based on the light source used to view the printed page.

Color Concepts

This section describes some of the concepts and terminology used in this chapter, such as palettes, raster vs. non-raster color, device-independent vs. device-dependent color, black and white references, color selection, pixel encoding, and color modes.

Palettes

A palette is a collection of colors that are selected by their index numbers. You can create your own palette or choose from one of several fixed palettes. Although only one palette is active at any time, all palettes are assigned ID numbers and can be stored in the printer for later selection using the ID number. They can be deleted when desired. Palettes can also be saved (pushed) to a stack and later retrieved (popped) when needed.

Raster Mode

Raster mode is entered explicitly by the Start Raster command (Ec*r#A) or implicitly by a Transfer Raster command (Ec*b#V, Ec*b#W). Raster mode is exited explicitly by an End Raster command (Ec*rC) or implicitly by a non-raster command.

Raster Color vs. Non-Raster Color

Palettes are used differently depending on whether the printer is in raster mode.

- In non-raster mode, the palette is always used for color selection. The color of text or patterns is specified using the Foreground Color command (Ec*v#S).
- In raster mode, the palette is only used for indexed color selection; it is not used for direct color selection. (Indexed and direct color selection are explained later in this section.)

Device-Dependent vs. Device-Independent Color

Device-dependent color spaces are relative to the device's ability to produce specific colors. For example, if red is specified in a device-dependent color space, two different printers will combine the same amounts of cyan, magenta, yellow, and black toner to produce the color, but the results

will be different because of the different properties of the toner.

Device-independent color is specified absolutely, in a color coordinate system that is independent of any device. For example, if red is specified in a device-independent color space, two printers will always produce the same result, even though they may need to combine different amounts of cyan, magenta, yellow, and black toner. Printers that produce device-independent color are calibrated to precise color standards.

Black and White References

Device-dependent color specifications are based upon an arbitrary range of values for each primary color component. The range endpoints for each color component are called black and white references for that component. Colors relative to these predefined limits are derived by specifying the amount of each component.

For the Device RGB color space, the maximum limit is called the white reference and the minimum limit is called the black reference. Regardless of the number chosen, the white reference represents the maximum value of a primary color that a device can produce, and the black reference represents the minimum value of that primary color. For example, if 100 is chosen as the white reference for red in the RGB color model, it represents the reddest red the device can produce. If 10 were chosen instead, then 10 would represent the same red.

Example:

Assuming the white and black references are set as follows:

Scenario 1

White Reference	Black Reference
red = 63	red = 0
green = 63	green = 0
blue = 63	blue = 0

Scenario 2

White Reference	Black Reference
red = 63	red = 4
green = 127	green = 0
blue = 31	blue = 0

Using these reference values, 50% blue for scenario 1 is 31, and 50% blue for scenario 2 is 15.

Color Selection

The HP color printers offer two methods for selecting colors:

- Indexed selection
- Direct selection

In indexed selection, colors are chosen using their palette index numbers. For non-raster mode, the palette index number is specified using the Foreground Color command. In raster mode, the data bit combination for each pixel forms an index number. The example below shows how the index numbers for an 8-color palette are specified:

Three-bit combinations:	0 1 0 1 0 1 0 1
	0 0 1 1 0 0 1 1
	0 0 0 0 1 1 1 1
Palette index number:	0 1 2 3 4 5 6 7

The number of colors in the palette dictates the number of bits per pixel of raster data required to specify an index number. For example, to specify 256 colors you need to send 8 bits of raster data per pixel ($2^8 = 256$).

In direct selection, colors are specified using the proportions of their primary components. For example, using a 24-bit-per- pixel representation, the color specified by (0xff, 0xf0, 0x00) for red, green, and blue would print a slightly red-tinted yellow. A palette is not used for direct selection.

Pixel Encoding

Colors are encoded in a row of raster data using either *plane* or *pixel* format. In planar format, all the pixels in a row are partially specified by one plane (bit) before the next

plane is sent. In pixel format, each pixel is fully specified before sending the next pixel.

Encoding by Plane

Planar encoding uses successive data planes, each providing one bit for each pixel in a row. Each plane builds upon the preceding planes until the pixels in a row are fully defined. A pixel is not fully defined until it has received all the planes for that row.

The planes in a row form index numbers that define a pixel by selecting a palette entry. For example, an 8-entry palette requires 3 planes ($2^3 = 8$). The underlined bits below compose the index of the color of the third pixel in the first row.

Ec*b#V row 1	plane 1 (red)	b1 b1 **b1** b1 b1 b1 . . .
Ec*b#V	plane 2 (grn)	b2 b2 **b2** b2 b2 b2 . . .
Ec*b#W	plane 3 (blue)	b3 b3 **b3** b3 b3 b3 . . .
Ec*b#V row 2	plane 1 (red)	b1 b1 b1 b1 b1 b1 . . .

Encoding by Pixel

When encoding by pixel, each pixel is fully specified before any bits are sent for the next pixel. For example, if four bits are needed to define a pixel, then every group of four bits in the data stream defines a pixel. The underlined (c4 . . . c1) group below defines the second pixel in the first row.

Ec*b#W row 1 b4 b3 b2 b1 **c4 c3 c2 c1** . . .

Ec*b#W row 2 b4 b3 b2 b1 . . .

The table below shows the four PCL options for selecting colors and encoding color raster data.

	Planar Encoding	Pixel Encoding
Indexed Selection	Indexed planar	Indexed pixel
Direct Selection	Direct planar	Direct pixel

Color Modes

There are four PCL 5 color modes:

- Black and White mode
- Simple Color mode
- PCL Imaging mode
- HP-GL/2 Imaging mode

All four modes create a palette. The palettes used in the Black and White mode and Simple Color mode are not modifiable. You can, however, modify the palettes in the PCL Imaging and HP-GL/2 Imaging modes.

You can use more than one mode on the same page. For example, you could enter the Simple Color mode to print a headline and a bar chart, PCL Imaging mode to print a raster photograph, and Black and White mode to print some body text. Each mode is described in more detail in Chapter 2, “Using Color Modes.”

Device-Dependent Color Spaces

The following PCL commands can alter color processing for device-dependent color spaces:

- Rendering Algorithm (Ec*t#J)
- Gamma Correction (Ec*t#I)
- Color Lookup Tables (Ec*l#W)
- Configure Image Data (Ec*v#W)
- Simple Color (Ec*r#U)
- Monochrome Print Mode (Ec&b#M)

Color lookup tables or gamma correction (which are mutually exclusive) can modify the mapping of input to output.

Device-Independent Color Spaces

The following PCL commands can alter color processing for device-independent color spaces:

- Rendering Algorithm (Ec*t#J)
- Gamma Correction (Ec*t#I)
- Color Lookup Tables (Ec*l#W)
- Configure Image Data (Ec*v#W)
- Viewing Illuminant (Ec*i#W)
- Monochrome Print Mode (Ec&b#M)

Device-independent color spaces are supported under the following conditions:

1. The Configure Image Data command (Ec*v#W) configures the current palette and specifies a device-independent color space.
2. The Render Algorithm command (Ec*t#J) is set to one of the following:

- Nearest Intensity (Ec*t0J)
- Device Best (Ec*t3J, Ec*t5J)
- Error Diffusion (Ec*t4J, Ec*t6J)
- Cluster Ordered Dither (Ec*t7J, Ec*t8J)
- Ordered Dither (Ec*t11J, Ec*t12J)

Color processing reverts to device-dependent processing if the render algorithm is changed from one of the above. This is because extensive device characterization is necessary to achieve device-independence—calibration must be based on known parameters that affect the device's color gamut. Render algorithms such as Snap to Primaries (Ec*t1J), Snap Black to White and Colors to Black (Ec*t2J), or User-Defined Halftone (Ec*t9J) either limit the number of colors available, or are undefined to the extent that their performance is not as precise. These algorithms, therefore, produce device-dependent results. Device-independent color is again generated if the render algorithm changes to one of the 5 listed above and the color space has not changed.

Device-Independent Color

The PCL language characterizes color as either device-dependent or device-independent. Both categories encompass many color spaces, each with unique characteristics.

Device-Dependent Color

Device-dependent color is relative to the device's inherent characteristics. For example, the colors produced by plotters are relative to the color of the installed plotter pens. Pen color varies considerably, especially as pens wear out, changing the color of the output. Likewise, for monitor screens, the red, green, and blue screen phosphors determine the colors produced. Fully saturated colors can vary greatly between screens. For printers, the color produced on a page depends on the printer's subtractive inks or toner (cyan, magenta, yellow, and black).

When using device-dependent color, devices receiving relative color specifications for the same color frequently do not produce the same color. For example, a monitor's saturated red may be different than a plotter's. In short, the same color page may appear considerably different on different devices.

The HP color printers provide device-dependent color specified using either the Device RGB or CMY color spaces.

Device-Independent Color

In contrast with device-dependent color, device-independent color is based on an absolute color standard—the tristimulus values of human vision. The device, whether a printer or otherwise, is calibrated to match an independent color specification. The color specification is translated in such a way that the resultant color is independent of the device. Examples of color spaces based on absolute standards include Kodak Photo YCC, CIE L*a*b*, YUV, and the proposed YCrCb. Each is a transform from tristimulus CIE XYZ space.

With proper calibration, any device can provide a transform from device-independent color space to the device's own color space, producing output from different devices that have the same color appearance. For example, if a monitor's

parameters are known (gamma, gain, chromaticity coordinates for each primary, and the white point), the monitor's RGB pixel information can be transformed into device-independent color.

The Color LaserJet printer provides device-independent color specified using either the CIE L*a*b*, Colorimetric RGB, or Luminance-Chrominance color spaces.

Color Matching

When attempting to match color produced by different devices, it is important to know the difference between true color matching and appearance matching.

Proper device calibration can achieve true color matching, so that a side-by-side comparison of a printed page with the monitor on which the page was designed will show an exact match. However, true color matching is only satisfactory when using the monitor as a viewing reference. Viewed away from the screen, the printed page may appear flat and unsaturated because printers and monitors have different dynamic ranges. For example, black on the screen appears gray when compared to printed black, which is unacceptable if the intent is pure black. Likewise, the white produced on a monitor screen appears yellow or blue when compared to a white sheet of paper. True color matching would require that gray be printed in the black areas and colored dots be printed in the white areas.

Color Appearance Matching

Color appearance matching goes beyond true color matching by including adjustments for the dynamic ranges of the devices, so the user's intent is maintained. For example, the white areas of a page shown on a monitor display screen would be printed as white on a printed page because the user specified white, even though the screen cannot duplicate a white that truly matches white paper. Although the printed color does not exactly match screen color, color appearance does match, which is what users usually want. To maximize user satisfaction, the PCL language uses appearance matching when rendering device-independent color.

Color Lookup Tables

Color lookup tables, which provide additional control of the printed output, are transformations that map input data into a new output color range based upon point-by-point conversions.

Overhead transparencies provide one example of a good use for color lookup tables. Let's say a page is printed on plain paper and it matches the user's expectations. When printing the same document on overhead transparency film, the resulting image looks unsaturated and flat. To compensate, the user can send a color lookup table to increase color saturation without changing composition (for example, using the CIE L*a*b* color space to increase the a* and b* parameters in equal amounts).

Color lookup tables can also be used to adjust data from a Kodak CD-ROM, which uses the Photo YCC device-independent color space. The gamma correction table is complex and cannot be described by the traditional logarithmic expression. However, since the data can be mapped into new data values via tables, the user can provide a gamma correction table that essentially describes the complex correction factors.

Color lookup tables can be used to "neutral-balance" an image. For example, an underwater photograph produces a severe bluish cast when printed. The user can eliminate that cast from the image by providing a color lookup table that subtracts some color portion from each of the primaries.

Illumination Models

Illumination sources have different spectral distributions, causing colors to appear differently under one light source compared to another. For example, printed colors that look normal in natural sunlight shift in hue when viewed under fluorescent and tungsten lighting. The PCL language allows the user to compensate for the differences in viewing illumination using the Viewing Illuminant command. It allows the user to select different illuminations.

Processing Color Documents

To process a color page, PCL provides ways of specifying and modifying color so that the printed result appears as the user desires. This section provides a conceptual overview of the process.

Non-Raster Color vs. Raster Color

All color portions of a page consist of either:

- Page Marking Primitives (non-raster data)
- Color Raster Data

Page Marking Primitives

Non-raster data consists of HP-GL/2 and PCL page marking primitives such as glyphs, rules, polygons, circles, and vectors. Page marking primitives contain no color information about the image. They merely mark the page with attributes assigned to the current working environment (for example, colors, patterns, logical operation modes, etc.). Page marking primitives act as stencils through which color “paint” is poured, forming a homogeneous pattern.

Page marking primitives print in the currently specified color, which is specified using the Foreground Color command. For example, if you specify the color blue using the Foreground Color command, and then send some text to the printer, the text will be printed blue.

Color Raster Data

Unlike page marking primitives, each pixel of a color raster image contains color information. A color raster pixel may be defined by either:

- Palette Entry Indices
- Direct Color Specifications

User-defined color patterns are a form of color raster, but each pixel of a user-defined color pattern can be defined only by palette entry indices, not by direct color specifications.

Color Processing Functions

Given these two color uses, page marking primitives and color raster data, color processing must:

- Convert color attributes to an internal representation that can be poured through the page marking stencil onto the destination via some logical operation.
- Convert multiple-bit-per-pixel color raster to an internal representation that can be merged into the destination via some logical operation.

Color processing must have access to the following state variables, which indicate the form and attributes by which the two color groups are generated.

- Halftone (rendering algorithm)
- RGB gamma correction
- Device-dependent color lookup tables for each of the three primaries

Chapter 2 describes in more detail how color raster data is specified.

2

Using Color Modes

Introduction

The PCL printer language has four color modes:

- Black-and-White
- Simple Color
- PCL Imaging
- HP-GL/2 Imaging

PCL allows you to use any mode or combination of modes to accomplish your printing objectives most efficiently.

All four of the color modes create a palette. The palette for each mode is discussed in the section describing that mode, and also in Chapter 3 (“Using Palettes”).

Black-and-White Mode (Default)

Black-and-White Mode is the default color mode. PCL devices power up in this mode and revert back to it whenever the printer receives an ᴱᶜE reset.
Black-and-White mode is also selectable using the Simple Color command (ᴱᶜ*r1U). This mode creates an unmodifiable, default 2-pen palette, with white at index 0 and black at index 1 (compatible with existing monochrome PCL 5 printers).

Simple Color Mode

Simple Color Mode, entered by the Simple Color command (ᴱᶜ*r#U), creates a fixed-size, fixed-color, unmodifiable palette. Depending on the value field, ᴱᶜ*r#U can create a 2-pen Black-and-White palette, an 8-pen RGB palette, or an 8-pen CMY palette. When using the Simple Color mode, the pixel encoding mode is always indexed planar.

PCL Imaging Mode

PCL Imaging Mode, enabled by the Configure Image Data command (Ec*v#W), allows a maximum of 24 bits per pixel for color specification. Therefore, more colors (produced by halftoning) may be specified than are obtainable in Simple Color Mode. In the PCL Imaging Mode, pixel encoding mode, bits per pixel, bits per primary, white/black references, and the color palette are all programmable.

HP-GL/2 Imaging Mode

In HP-GL/2, the Initialize (IN) command starts color imaging and performs the following:

- Sets the pixel encoding mode to index by plane.
- Sets bits per index to 3.
- Creates an 8-pen palette that is reprogrammable in either PCL or HP-GL/2 contexts (see Chapter 3, "Using Palettes," for more information).

Although default HP-GL/2 palettes are different than default PCL palettes, an HP-GL/2 palette is modifiable in either PCL or HP-GL/2 (using the Assign Color Index [Ec*v#I] or Pen Color [PC] commands, respectively). Likewise, a PCL palette created by the Configure Image Data command (Ec*v#W) is modifiable in both PCL and HP-GL/2 using the same commands.

The active palette is always transferred between HP-GL/2 and PCL contexts. Since only one palette at a time can be active, a new palette created in either context overwrites the current palette.

Simple Color Mode

The Simple Color command (Ec*r#U) specifies color selection from a fixed palette. RGB or CMY raster data must be sent by plane (Ec*b#V) as well as by row (Ec*b#W). The last plane in each row is sent using the Ec*b#W command; all other planes are sent using the Ec*b#V command. In Simple Color mode, the pixel encoding mode is always indexed planar.

Simple Color Command

The Simple Color command creates a fixed-size palette, whose color specification cannot be modified.

Ec***r#U**

= –3 – 3 planes, device CMY palette

1 – Single plane K (Black) palette

3 – 3 planes, device RGB palette

Default = 1

Range = –3, 1, 3

The absolute value of the value field specifies the number of planes per row of raster data to be sent. The number of entries in the new palette is 2^n, with index values 0 to 2^n – 1. For example, a 3-plane palette has 8 entries, with index numbers 0 to 7.

This command destroys the active palette and creates a new palette, which becomes the active palette. When the Simple Color mode is active, PCL and HP-GL/2 commands that modify the palette are locked out (NP, PC, Ec*v#A, Ec*v#B, Ec*v#C, Ec*v#I). When a Simple Color palette is popped from the stack (Ec*p#P), it cannot be modified, and the pixel encoding mode reverts to indexed planar.

- A value field of **1** creates a 2-entry Black-and-White default palette.

- A value field of **3** creates an 8-entry Device RGB palette (compatible with a PCL Imaging Mode palette, but not an HP-GL/2 default (IN) palette).
- A value field of **–3** creates an 8-entry palette in Device CMY color space.

The Simple Color palettes are shown below:

Single Plane (value = 1)

Index	Color
0	White
1	Black

3-Plane RGB (value = 3)

Index	Color
0	Black
1	Red
2	Green
3	Yellow
4	Blue
5	Magenta
6	Cyan
7	White

3-Plane CMY (value = –3)

Index	Color
0	White
1	Cyan
2	Magenta
3	Blue
4	Yellow

Index	Color
5	Green
6	Red
7	Black

PCL Imaging Mode

The PCL Imaging mode, entered using the Configure Image Data (CID) command (Ec*v#W), creates a variable-sized programmable palette. It provides halftoning in the printer, with multiple color spaces, pixel encoding modes, and reprogrammable palettes.

Configure Image Data (CID) Command

The CID command provides configuration information for creating palettes and transmitting raster data. The CID command performs the following:

- Designates the color space for the default palette
- Designates the size of the palette to be created
- Provides data for transforming color-space-specific values into device-specific values
- Provides data for transforming device-dependent data (monitor RGB) to device-independent (Colorimetric RGB)
- Designates the format of raster data and how primary components are combined to yield the raster representation

Ec***v#W***[binary data]*

= Number of data bytes

Default = NA

Range = Short form: 6 bytes

Long form: >6 bytes

Invalid configurations of the CID command are ignored and the data discarded. Any signs in the value field are ignored.

The data fields in this command must contain byte-aligned binary data, not ASCII data.

This command has two forms: the six-byte short form described below, and the long form consisting of these six bytes, plus additional information specific to the color space.

Common 6-Byte Header

The short and long forms of the CID command use a common 6-byte header, regardless of which color space is specified. The header data fields, whose meaning may vary according to the color spaces, are present in all color space specifications. The short form and long form of the CID command are explained separately in the following pages.

Byte	15 (MSB) 8	7 0 (LSB)	Byte
0	Color space (UBYTE)	Pixel encoding mode (UBYTE)	1
2	Bits/index (UBYTE)	Bits/primary #1 (UBYTE)	3
4	Bits/primary #2 (UBYTE)	Bits/primary #3 (UBYTE)	5

Byte 0 (Color Space)

This byte specifies the color space. The range of values is 0 through 4. All other values are ignored.

Byte Value	Color Space
0	Device RGB (default)
1	Device CMY
2	Colorimetric RGB Spaces
3	CIE L*a*b*
4	Luminance-Chrominance Spaces

Note

Colorimetric RGB color spaces are based on the 1931 standard 2-degree observer and specified by CIE xy chromaticity coordinates. They use the standard D6500 viewing illuminant and a 45-degree illumination model with a 0-degree collector geometry for reflective data.

CIE L*a*b* is the CIE 1976 Uniform Color Space based on the 1931 standard 2-degree observer, and using a 45-degree illumination model with a 0-degree collector geometry for reflective data. The viewing illuminant is the standard D6500 illuminant.

Luminance-Chrominance spaces are a 3x3 linear transformation from Colorimetric RGB. Like CIE L*a*b*, achromatic data is contained in one channel and chromatic data shares the other two channels.

Byte 1 (Pixel Encoding Mode)

Byte number 1 designates the format in which raster data is to be transmitted and interpreted. The range of this value field is 0 to 3. All other values for this field are ignored.

Byte Value	Pixel Encoding Mode	Restrictions
0	Indexed by Plane (default)	Bits/index must be 1, 2, 3, 4, 5, 6, 7, or 8
1	Indexed by Pixel	Bits/index must be 1, 2, 4, or 8
2	Direct by Plane	1 bit per primary (RGB or CMY only)
3	Direct by Pixel	8 bits per primary (All Color Spaces)

You need one plane or one bit/pixel for each power of two colors in the palette. For example, a 256-color palette requires 8 planes or 8 bits/pixel ($2^8 = 256$).

MODE 0: INDEXED BY PLANE

In mode 0 (default), successive planes of data are sent for each raster row. A plane contains one bit for each pixel in a row. A pixel is not fully defined until it has received all the planes for that row. The planes in a row form index numbers that define a pixel by selecting a palette entry. Assuming 3 bits per index, the underlined column of bits below is the palette index for pixel 3 of row 1 (i1 is lsb; i3 is msb). Note that the Transfer Raster Data by Plane command (Ec*b#V) is used for all planes except the last plane of each row, which uses the Transfer Raster Data by Row command (Ec*b#W).

Ec*b#V	row 1	plane 1	i1	i1	**i1**	i1	i1
Ec*b#V		plane 2	i2	i2	**i2**	i2	i2
Ec*b#W		plane 3	i3	i3	**i3**	i3	i3
Ec*b#V	row 2	plane 1	i1	i1	i1	i1	i1

Example:

Ec*v6W 00 00 03 08 08 08	# Binary data for CID represented in hex. Sets color space to RGB, pixel encoding mode to 0, palette size to 8 (3 planes), last 3 bytes ignored.
Ec*r1A	# Start raster.
Ec*b1V10110000 . . .	# Transfer plane 1 (the first bit for each pixel in the first row). Combining each bit with its corresponding bit in the other planes forms the palette index number for that pixel.
Ec*b1V01110000 . . .	# Transfer plane 2 (the second bit for each pixel in the row).

^EC*b1W10101000 . . .	# Transfer plane 3 (the third bit for each pixel in the row) and move to the next row. Note that the ^EC*b#W command is used to send the last plane of each row.

MODE 1: INDEXED BY PIXEL

In mode 1, each pixel in a row is fully specified before any bits are sent for the next pixel. The bits for each pixel form a palette index number. Assuming 4 bits per index, the underlined block below is the palette index for pixel 2 of row 1 (i1 is lsb).

Esc*b#W row 1 i4 i3 i2 i1 **i4 i3 i2 i1** . . .

Esc*b#W row 2 i4 i3 i2 i1 i4 i3 i2 i1 . . .

Esc*b#W row 3 i4 i3 i2 i1 i4 i3 i2 i1 . . .

Example:

Esc*v6W 00 01 04 04 04 04	# Binary data for CID represented in hexidecimal. Sets color space to RGB, pixel encoding mode to 1, palette size to 16 (4 bits to address palette index). Last 3 bytes ignored.
Esc*r1A	# Start raster.
Esc*b1W45	# Most significant nibble selects palette index 4 for the first pixel. Second pixel is set to index 5. Move to the next row.
Esc*b1W6A	# First pixel is index 6, second pixel is index 10. Move to the next row.
Esc*b1W03	# First pixel is index 0, second pixel is index 3. Move to the next row.

MODE 2: DIRECT BY PLANE

In mode 2, the color raster data for each row is downloaded by sequential planes, but the pixel color is directly specified, rather than forming an index into the palette. The underlined block below defines the actual primaries for pixel 3 of row 1.

Ec*b#V	row 1	red plane	r	r	**r**	r	r
Ec*b#V		green plane	g	g	**g**	g	g
Ec*b#W		blue plane	b	b	**b**	b	b
Ec*b#V	row 2	red plane	r	r	r	r	r

Example:

Ec*v6W 00 02 01 01 01 01	# Binary data for CID represented in hex. Sets color space to RGB, pixel encoding mode to 2. Palette size is ignored because this is a direct selection, not indexed. Last 3 bytes are always 1 for this mode.
Ec*r1A	# Start raster.
Ec*b1V10110000 . . .	# Transfer plane for primary color 1. Each bit turns on or off the red primary for the pixel defined by the corresponding bits in each plane.
Ec*b1V01110000 . . .	# Transfer plane for primary color 2. Each bit turns on or off the green primary of the pixel.
Ec*b1W10101000 . . .	# Transfer plane for primary color 3 and move to the next row. Each bit turns on or off the blue primary of the pixel.

MODE 3: DIRECT BY PIXEL

In mode 3, the color raster data is downloaded pixel by pixel (as in mode 1), but each pixel directly specifies each color component (as in mode 2). Assuming Device RGB space with 8 bits per primary, the underlined block below defines the actual color primaries for pixel 1 of row 2.

Ec*b#W	row 1	r7–r0	g7–g0	b7–b0 . . .
Ec*b#W	row 2	**r7–r0**	**g7–g0**	**b7–b0** . . .
Ec*b#W	row 3	r7–r0	g7–g0	b7–b0 . . .

Example:

Ec*v6W 00 03 00 08 08 08	# Binary data for CID represented in hex. Sets color space to RGB, pixel encoding mode to 3. Palette size is ignored. Send 8 bits to address each primary value for a pixel.
Ec*r1A	# Start raster.
Ec*b3W 45 06 30	# Each byte sets a primary value for the first pixel and moves to the next row (45 specifies the red, 06 the green, and 30 the blue component value of that pixel).

Byte 2 (Number of Bits per Index)

In all pixel encoding modes, this byte sets the size of the palette to 2^n, where n is the number of bits per index.

- In pixel encoding modes 0 and 1 (indexed), where raster data is interpreted as indices into a palette, this value specifies the number of bits required to access all palette entries.
- In pixel encoding modes 2 and 3 (direct), this value determines palette size, but has no effect on the specification of raster data.

Byte 3 (Number of Bits for Primary #1)

This byte is ignored in pixel encoding modes 0 and 1, but affects the black and white references in device-dependent color spaces. In Device RGB, the black reference for primary #1 is set to 0 and the white reference is set to $2^n - 1$, where n is the number of bits for primary #1. These references are reversed in Device CMY color space.

- *In pixel encoding mode 2*, this byte is ignored except in Device RGB and Device CMY color space, where it designates the number of data bits needed to specify primary #1, as well as the number of data planes to be sent for primary #1.
- *In pixel encoding mode 3*, this byte designates the number of data bits needed to specify primary #1.

A value of 0 defaults the black and white reference values for primary #1 according to the color space.

Byte 4 (Number of Bits for Primary #2)

This byte is ignored in pixel encoding modes 0 and 1, but affects the black and white references in device-dependent color spaces. In Device RGB, the black reference for primary #2 is set to 0, and the white reference is set to $2^n - 1$, where n is the number of bits for primary #2. These references are reversed in Device CMY color space.

- *In pixel encoding mode 2*, this byte is ignored except in Device RGB and Device CMY color spaces, where it designates the number of data bits needed to specify primary #2, as well as the number of data planes to be sent for primary #2.
- *In pixel encoding mode 3*, this byte designates the number of data bits needed to specify primary #2.

A value of 0 defaults the black and white reference values for primary #2 according to the color space.

Byte 5 (Number of Bits for Primary #3)

This byte is ignored in pixel encoding modes 0 and 1, but affects the black and white references in device-dependent color spaces. In Device RGB, the black reference for primary #3 is set to 0, and the white reference is set $2^n - 1$, where n is the number of bits for primary #3. These references are reversed in Device CMY space.

- *In pixel encoding mode 2*, this byte is ignored except in Device RGB and Device CMY color space, where it designates the number of data bits needed to specify primary #3, as well as the number of data planes to be sent for primary #3.
- *In pixel encoding mode 3*, this byte designates the number of data bits needed to specify primary #3.

A value of 0 defaults the black and white reference values for primary #3 according to the color space.

Short Form of CID Command (Configure Image Data)

The Short Form of the CID command involves sending just the common 6-byte header. By changing the value of byte 0 (color space), the short form can specify the following five color spaces:

- Device RGB ^{E_C}*v6W[0x00, . . .]
- Device CMY ^{E_C}*v6W[0x01, . . .]
- CIE L*a*b* ^{E_C}*v6W[0x03, . . .]

The following data ranges are allowed in CIE L*a*b*. Hue is preserved when out-of-range data is clipped.

L* = 0.0 to 100.0

a* = –100.0 to 100.0

b* = –100.0 to 100.0

- Colorimetric RGB (SMPTE RGB) ^{E_C}*v6W[0x02, . . .]

Non-linear SMPTE RGB with a 2.2 gamma and 1.0 gain is the default Colorimetric RGB color space. The short form allows the following ranges:

R = 0.0 to 1.0

G = 0.0 to 1.0

B = 0.0 to 1.0

- Luminance-Chrominance (YUV) ^{E_C}*v6W[0x04, . . .]

YUV, which is a linear transformation from SMPTE RGB, is the default Luminance-Chrominance color space. The short form allows the following ranges:

Y = 0.0 to 1.0

U = –0.89 to 0.89

V = –0.70 to 0.70

Data Range Scaling

White and black references define the encoding range for device-dependent color spaces. However, device-independent color spaces require input data pre-scaled to the range 0 to 255. For example, to use the short form for the default YUV color space, the input data must have the following ranges:

Y = 0.0 to 1.0

U = –0.89 to 0.89

V = –0.70 to 0.70

The user must linearly scale (y = mx + b) the input data to the range 0 – 255:

Y = 0 (0.0) to 255 (1.0)

U = 0 (–0.89) to 255 (0.89)

V = 0 (–0.70) to 255 (0.70)

Long Form of CID Command (Configure Image Data)

In addition to the short form, there is also a long form of the CID command for each color space. In device-independent color spaces, the long form can specify primaries other than the defaults provided by the short form. For example, a Sony Trinitron RGB primary base can be selected for Colorimetric RGB instead of the default non-linear SMPTE RGB primaries.

Device RGB (Long Form)

The long form for the Device RGB color space (value field 18) provides explicit entry of black and white references (range is –32767 to 32767). Black and white references are used in the direct pixel encoding modes (2,3) to set relative limits for raster data; they are also used when specifying the primary components of new palette entries (Ec*v#A, Ec*v#B, Ec*v#C). Black and white references have no effect on CID default palette colors. The reference values are specified as 16-bit signed integers (sint16).

Note

The short form for the Device RGB color space defaults each primary's black reference to 0 and the white reference to 2^n–1, where n is the number of bits for that primary.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Color space	Pixel encoding mode	1
2	Bits per index	Bits per primary #1	3
4	Bits per primary #2	Bits per primary #3	5
6	White reference for primary #1 (sint 16)		7
8	White reference for primary #2 (sint 16)		9
10	White reference for primary #3 (sint 16)		11
12	Black reference for primary #1 (sint16)		13
14	Black reference for primary #2 (sint16)		15
16	Black reference for primary #3 (sint16)		17

Device CMY (Long Form)

The long form for the Device CMY color space (value field is 18) provides explicit entry of black and white references (range is –32767 to 32767). Black and white references are used in the direct pixel encoding modes (2,3) to set relative limits for raster data; they are also used when specifying the primary components of new palette entries (Ec*v#A, Ec*v#B, Ec*v#C). Black and white references have no effect on the default CID palette colors. The reference values are specified as 16-bit signed integers (sint16).

Note

The short form for the Device CMY color space defaults each primary's white reference to 0 and black reference to 2^n–1, where n is the number of bits for that primary.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Color space	Pixel encoding mode	1
2	Bits per index	Bits per primary #1	3
4	Bits per primary #2	Bits per primary #3	5
6	White reference for primary #1 (sint16)		7
8	White reference for primary #2 (sint16)		9
10	White reference for primary #3 (sint16)		11
12	Black reference for primary #1 (sint16)		13
14	Black reference for primary #2 (sint16)		15
16	Black reference for primary #3 (sint16)		17

CIE L*a*b* (Long Form)

The long form for the CIE L*a*b* color space allows a larger data range than the short form defaults:

L* = 0.0 to 120.0 (greater than the short form by 20.0)

a* = –159.0 to 128.0 (less than the short form by –32.0 and greater than the short form by 28.0)

b* = –120.0 to 80.0 (less than the short form by 20.0)

Note

Although the data ranges may extend beyond the default data ranges specified in the short form of the CID command, the printer will clip the data to the short form data ranges.

Maximum and minimum values are specified for each primary color. Floating point data must be linearly scaled (y = mx + b) to the range 0 – 255.

Since a* and b* have no theoretical limits, L*a*b* data may be sent outside CID constraints. Then data is clipped to preserve hue and compressed to the device's printable gamut.

The white point is based on the standard D6500 illuminant.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Color space	Pixel encoding mode	1
2	Bits per index	Bits per primary #1	3
4	Bits per primary #2	Bits per primary #3	5
6	Minimum L* value (most significant word)*		7
8	Minimum L* value (least significant word)*		9
10	Maximum L* value (msw)		11
12	Maximum L* value (lsw)		13
14	Minimum a* value (msw)		15
16	Minimum a* value (lsw)		17
18	Maximum a* value (msw)		19
20	Maximum a* value (lsw)		21
22	Minimum b* value (msw)		23
24	Minimum b* value (lsw)		25
26	Maximum b* value (msw)		27
28	Maximum b* value (lsw)		29

FLOATING POINT FORMAT*

The following format is used for device-independent color floating point specifications:

31	30 23	22 0
Sign	Exponent	Fractional Portion

The above single-precision, 32-bit floating point specification is fully compliant with the IEEE Floating Point Formats.

Colorimetric RGB (Long Form)

The long form for Colorimetric RGB allows specifications other than the default non-linear SMPTE RGB with a 2.2 gamma and 1.0 gain. Each RGB primary and the white point is specified in the CID data field by chromaticity coordinates (CIE xy). The tristimulus luminance Y value of the white point is assumed to be 100% and is therefore not specified. For color spaces that are linear transformations from CIE XYZ tristimulus coordinates, gamma and gain are set to 1.0; otherwise they are set appropriately. Colorimetric RGB spaces can be used for any monitor having primaries specified as CIE xy chromaticity coordinates with white point, such as the Sony Trinitron or Hitachi Color Monitor.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Color space	Pixel encoding mode	1
2	Bits per Index	Bits per primary #1	3
4	Bits per primary #2	Bits per primary #3	5
6	x Chromaticity for red primary (msw)		7
8	x Chromaticity for red primary (lsw)		9
10	y Chromaticity for red primary (msw)		11
12	y Chromaticity for red primary (lsw)		13
14	x Chromaticity for green primary (msw)		15
16	x Chromaticity for green primary (lsw)		17
18	y Chromaticity for green primary (msw)		19
20	y Chromaticity for green primary (lsw)		21
22	x Chromaticity for blue primary (msw)		23
24	x Chromaticity for blue primary (lsw)		25
26	y Chromaticity for blue primary (msw)		27
28	y Chromaticity for blue primary (lsw)		29
30	x Chromaticity for white point (msw)		31
32	x Chromaticity for white point (lsw)		33
34	y Chromaticity for white point (msw)		35
36	y Chromaticity for white point (lsw)		37

38	Gamma for red primary (msw)	39
40	Gamma for red primary (lsw)	41
42	Gain for red primary (msw)	43
44	Gain for red primary (lsw)	45
46	Gamma for green primary (msw)	47
48	Gamma for green primary (lsw)	49
50	Gain for green primary (msw)	51
52	Gain for green primary (lsw)	53
54	Gamma for blue primary (msw)	55
56	Gamma for blue primary (lsw)	57
58	Gain for blue primary (msw)	59
60	Gain for blue primary (lsw)	61
62	Minimum red value (msw)	63
64	Minimum red value (lsw)	65
66	Maximum red value (msw)	67
68	Maximum red value (lsw)	69
70	Minimum green value (msw)	71
72	Minimum green value (lsw)	73
74	Maximum green value (msw)	75
76	Maximum green value (lsw)	77
78	Minimum blue value (msw)	79
80	Minimum blue value (lsw)	81
82	Maximum blue value (msw)	83
84	Maximum blue value (lsw)	85

Luminance-Chrominance (Long Form)

The long form for Luminance-Chrominance allows color spaces other than the default YUV, such as Kodak Photo YCC, the proposed JPEG and TIFF 6.0 YCrCb standard, YES, and YIQ. These Luminance-Chrominance color spaces are derived from the Colorimetric RGB space using a 3x3 transformation matrix. The tristimulus luminance y value of the white point is assumed to be 100% and is therefore not specified.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Color space	Pixel encoding mode	1
2	Bits per index	Bits per primary #1	3
4	Bits per primary #2	Bits per primary #3	5
6	Encoding for primary #1 R (msw)		7
8	Encoding for primary #1 R (lsw)		9
10	Encoding for primary #1 G (msw)		11
12	Encoding for primary #1 G (lsw)		13
14	Encoding for primary #1 B (msw)		15
16	Encoding for primary #1 B (lsw)		17
18	Encoding for primary #2 R (msw)		19
20	Encoding for primary #2 R (lsw)		21
22	Encoding for primary #2 G (msw)		23
24	Encoding for primary #2 G (lsw)		25
26	Encoding for primary #2 B (msw)		27
28	Encoding for primary #2 B (lsw)		29
30	Encoding for primary #3 R (msw)		31
32	Encoding for primary #3 R (lsw)		33
34	Encoding for primary #3G (msw)		35
36	Encoding for primary #3 G (lsw)		37
38	Encoding for primary #3 B (msw)		39
40	Encoding for primary #3 B (lsw)		41
42	Minimum primary #1 value (msw)		43
44	Minimum primary #1 value (lsw)		45
46	Maximum primary #1 value (msw)		47
48	Maximum primary #1 value (lsw)		49

50	Minimum primary #2 value (msw)	51
52	Minimum primary #2 value (lsw)	53
54	Maximum primary #2 value (msw)	55
56	Maximum primary #2 value (lsw)	57
58	Minimum primary #3 value (msw)	59
60	Minimum primary #3 value (lsw)	61
62	Maximum primary #3 value (msw)	63
64	Maximum primary #3 value (lsw)	65
66	x Chromaticity for red primary (msw)	67
68	x Chromaticity for red primary (lsw)	69
70	y Chromaticity for red primary (msw)	71
72	y Chromaticity for red primary (lsw)	73
74	x Chromaticity for green primary (msw)	75
76	x Chromaticity for green primary (lsw)	77
78	y Chromaticity for green primary (msw)	79
80	y Chromaticity for green primary (lsw)	81
82	x Chromaticity for blue primary (msw)	83
84	x Chromaticity for blue primary (lsw)	85
86	y Chromaticity for blue primary (msw)	87
88	y Chromaticity for blue primary (lsw)	89
90	x Chromaticity for white point (msw)	91
92	x Chromaticity for white point (lsw)	93
94	y Chromaticity for white point (msw)	95
96	y Chromaticity for white point (lsw)	97
98	Gamma for red primary (msw)	99
100	Gamma for red primary (lsw)	101
102	Gain for red primary (msw)	103
104	Gain for red primary (lsw)	105
106	Gamma for green primary (msw)	107
108	Gamma for green primary (lsw)	109
110	Gain for green primary (msw)	111
112	Gain for green primary (lsw)	113
114	Gamma for blue primary (msw)	115
116	Gamma for blue primary (lsw)	117
118	Gain for blue primary (msw)	119

120	Gain for blue primary (lsw)	121

Examples Using the CID Command

The following examples illustrate using the CID command's short and long forms for each color space. For clarity, data is shown as ASCII, rather than binary and the CID command (Ec*v#W) is shown as "CID". The following format is used:

CID (data , data , . . .)

Device RGB or Device CMY

SHORT FORM

CID(0,1,8,8,8,8) Device RGB, 8 bits/pixel indexed

CID(1,1,8,8,8,8) Device CMY, 8 bits/pixel indexed

Example: The short form CID command, as a C function, can look like this:

```
short_cid(Color_mode, Pixel_mode, BitsperIndex,
    BitsperColor_1, BitsperColor_2, BitsperColor_3)
{
    int Color_mode, Pixel_mode, BitsperIndex,
    BitsperColor_1, BitsperColor_2, BitsperColor_3;

    printf("\033*v6W%c%c%c%c%c%c",Color_mode,
       Pixel_mode, BitsperIndex, BitsperColor_1,
       BitsperColor_2, BitsperColor_3);
}
```

LONG FORM

CID(0,1,8,8,8,8, Device RGB, 8 bits/pixel indexed
0,0,0 White reference
100,100,100) Black reference

CIE L*a*b*

SHORT FORM

```
CID(3,3,0,8,8,8)    L*a*b*, direct 8 bits/primary
```

LONG FORM

```
CID(3,3,0,8,8,8,    L*a*b*, direct 8 bits/primary
0.0, 100.0,         L* data encoding
–100.0, 100.0,      a* data encoding
–100.0, 100.0)      b* data encoding
```

Non-Linear SMPTE RGB, 2.2 Gamma, 1.0 Gain

SHORT FORM

```
CID(2,3,0,8,8,8)    RGB, direct 8 bits/primary
```

LONG FORM

```
CID(2,3,0,8,8,8,    RGB, direct 8 bits/primary
   0.64, 0.34,      |
   0.31, 0.60,      | Chromaticity coordinates
   0.16, 0.07,      | for RGB & White Point
   0.3127, 0.3290,  |
   2.2, 1.0,        *
   2.2, 1.0,        * Gamma and gain for RGB
   2.2, 1.0,        *
   0.0, 1.0,        |
   0.0, 1.0,        | Data range encoding
   0.0, 1.0)        |
```

Non-Linear Sony Trinitron

SHORT FORM

Not Applicable

LONG FORM

```
CID(2,3,0,8,8,8     RGB, direct 8 bits/primary
0.62, 0.34,         |
0.30, 0.58,         | Chromaticity coordinates
0.15, 0.09,         |    for RGB
0.2800, 0.2933,     | White Point
2.3, 1.19,          *
2.3, 1.19,          * Gamma and gain for RGB
2.3, 1.19,          *
0.0, 255.0,         |
0.0, 255.0,         | Data range encoding
0.0, 255.0)         |
```

YUV Chrominance-Luminance Color Space

SHORT FORM

```
CID(4,3,0,8,8,8)        YUV, direct 8 bits/primary
```

YUV Chrominance-Luminance with Sony Trinitron

LONG FORM

```
CID(2,3,0,8,8,8         YUV, direct 8 bits/primary
   0.30,0.59,0.11,      |
  –0.30,0.59,0.89,      | 3x3 YUV matrix
   0.70,–0.59,–0.11,    |
   0.0,255.0            *
  –227.0,227.0,         * Data encoding
  –179.0,179.0          *
   0.62,0.34,           |
   0.30,0.58,           | Chromaticity
   0.15,0.09,           | coordinates
   0.2800, 0.2933,      | chromaticity white point
   2.3,1.19,            *
   2.3,1.19,            * Gamma and
   2.3,1.19)            * gain for RGB
```

HP-GL/2 Imaging Mode

The HP-GL/2 Imaging Mode provides a way of using vector commands in printing documents. Although the default PCL and HP-GL/2 palettes are not the same, when transferring from PCL to HP-GL/2, active palette information does stay the same. You can switch between PCL and HP-GL/2 and use the same palette, and you can also modify palettes using either PCL or HP-GL/2.

Compared to monochrome printers, the Color LaserJet and DeskJet 1200C color printers have some commands that are new and/or modified for use with color printers. Chapter 7 describes the new or modified HP-GL/2 commands.

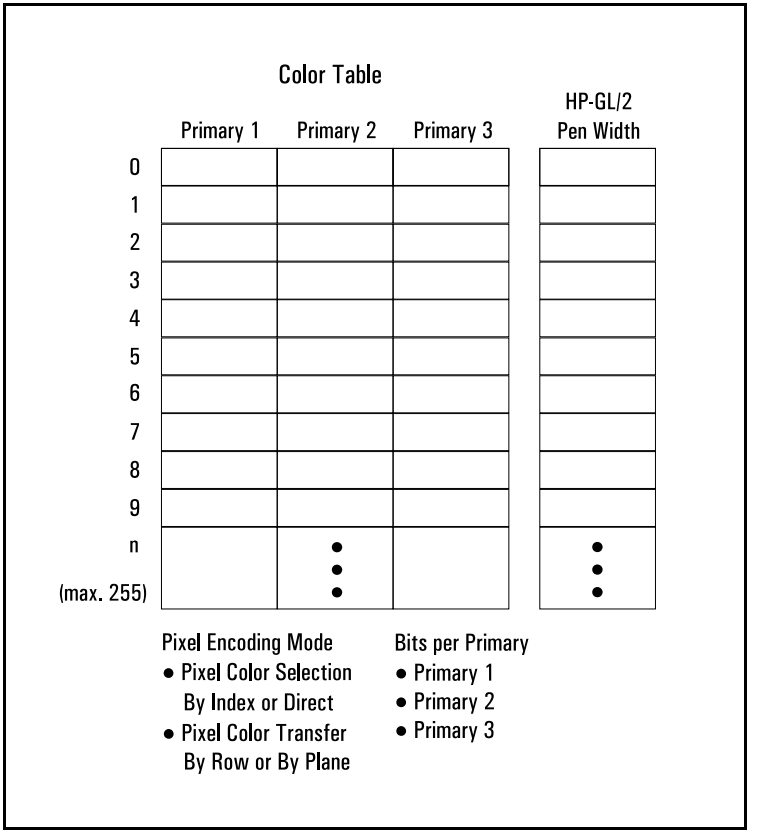
If you are not familiar with using HP-GL/2, see the *PCL 5 Printer Language Technical Reference Manual*. It provides a detailed explanation of using HP-GL/2.

3

Using Palettes

Introduction

A palette is a collection of color specifications selected using index numbers. The figure below illustrates a palette. Each palette entry associates an index number with three primary color components. For HP-GL/2 purposes only, a pen width is also associated with each palette entry.



In non-raster mode, the current palette contains all the colors available to the printer. In raster mode, indexed color selection uses the palette, but direct selection does not.

Default palettes are created by all the PCL color modes (Black and White, Simple Color, PCL Imaging, and HP-GL/2 Imaging). The active palette may be modified when in the PCL Imaging or HP-GL/2 imaging modes, but not when in the Simple Color or Black and White modes. When switching between PCL 5 and HP-GL/2 contexts, the active palette is automatically transferred.

Multiple palettes can exist in the system via the Palette ID and Palette Stack mechanism. However, only one palette at a time can be active. A palette created in the PCL context remains active and unchanged when switching to the HP-GL/2 context, and a palette created in the HP-GL/2 context remains active and unchanged when switching to the PCL context. Performing a reset or entering PJL overwrites the active palette with the default black and white palette.

Whenever a new palette is created, the currently or previously active palette is destroyed. A new palette is created by power-on and also by the following commands:

- PCL Reset (Ec E)
- Simple Color (Ec *r#U)
- Configure Image Data (Ec *v#W)
- HP-GL/2 Initialize (IN)

The active palette can be saved by pushing it onto the palette stack with the Push/Pop Palette command (Ec *p#P). Popping a palette from the stack destroys the active palette—the popped palette becomes the active palette.

Saving the Palette

The current palette is destroyed when a new palette is created. The Push/Pop Palette command (Ec*p#P) can save (push) the current palette and then restore (pop) it.

Push/Pop Palette Command

This command pushes or pops the palette from the palette stack.

Ec***p#P**

= 0 Push (save) palette
1 Pop (restore) palette

Default = 0

Range = 0, 1 (invalid values are ignored)

A value of 0 (Ec*****p0P) pushes a copy of the active palette onto the palette stack. When a palette is pushed, the active palette is not affected.

A value of 1 (Ec*****p1P) pops the most recently pushed palette and destroys the active palette; the popped palette becomes the active palette. As with any stack, the last item pushed is the first item popped.

Pushing a palette saves the following parameters:

- Color definitions for each palette entry
- Pen widths (for HP-GL/2 use)
- Color space specification
- Black and white references
- Number of bits per index
- Pixel encoding mode
- Number of bits per primary
- Gamma correction
- Viewing illuminant
- Color lookup tables

- Render algorithm
- Downloaded dither matrix

Pushing a palette does not save the following parameters.

- Foreground color
- Color components: 1st, 2nd, and 3rd
- Finish mode
- Monochrome print mode

The palette stack depth is limited by printer memory. Attempts to push a palette with insufficient memory cause an out-of-memory error. Attempts to pop from an empty stack are ignored.

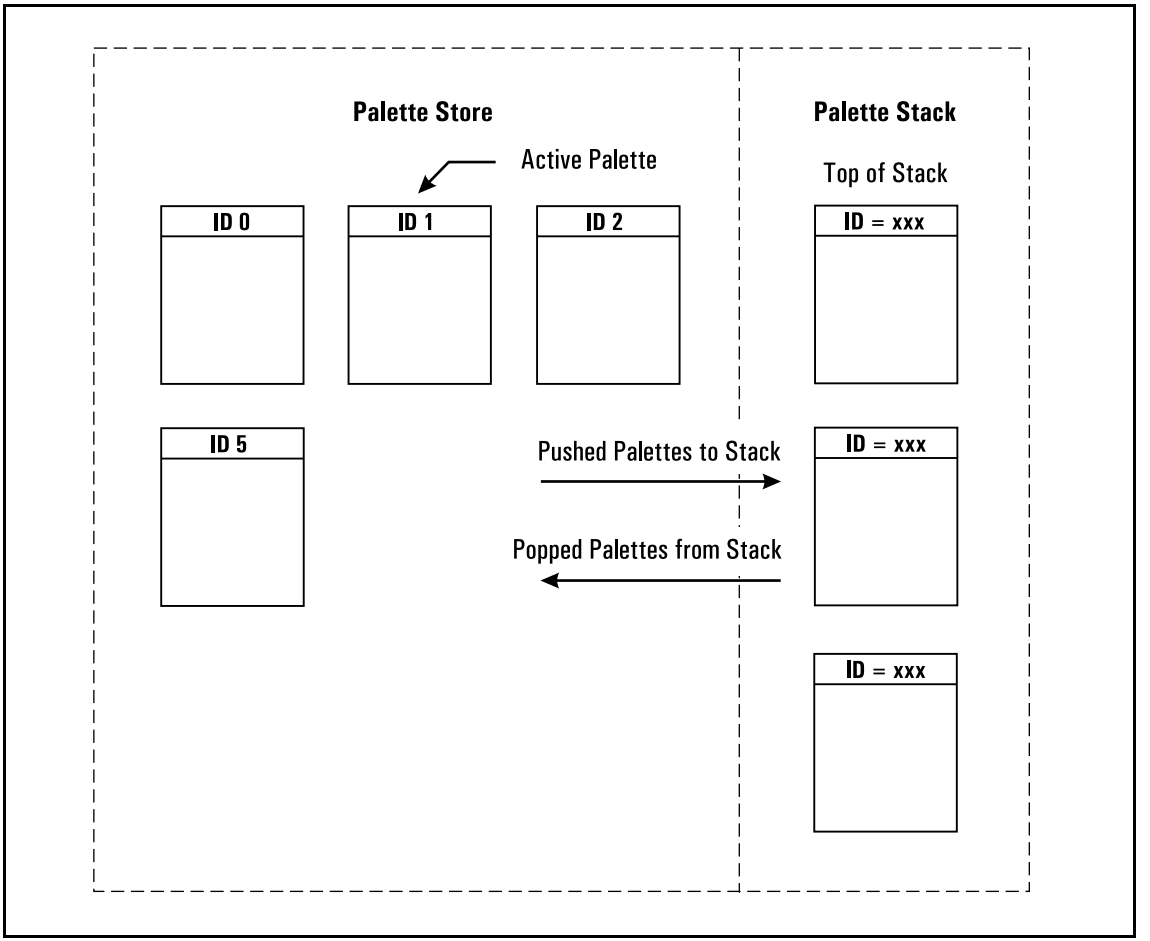
Macros can push and pop palettes. A palette that was popped in an *executed* macro remains in effect at the end of the macro (this is not true for “called” or “overlaid” macros).

PCL reset commands (EcE) and exits to PJL cause the printer to empty the palette stack and overwrite the active palette with a non-programmable black and white palette. The HP-GL/2 commands IN and DF have no effect on the palette stack, but they do destroy the active palette and replace it with the default HP-GL/2 palette.

Palette Management by ID

All palettes have a unique ID (identification number). The default black and white palette created on power-up or ^cE has an ID of 0.

Palette management by ID lets applications have multiple palettes. As shown below, multiple palettes can exist in two areas: the palette stack and the palette store. The stack holds palettes that are pushed via a Push/Pop Palette command; the store holds palettes having palette IDs.



Palettes on the stack may not be selected by ID, since only a copy of a palette is pushed onto the stack; the original palette and ID remain in the palette store. A palette popped from the stack goes into the palette store, becomes the new active palette, and assumes the ID of the previously active palette, which is overwritten. Only one palette at a time may be active.

Management by ID allows applications to tag data, have multiple raster configurations, and have palettes for different color spaces—all without reconfiguring the active palette. For example, one palette can be created for PCL text, one for HP-GL/2 primitives, one for simple raster, and one for 24-bit raster. The application can then switch between palettes according to what is being sent to the printer.

Selecting a new active palette changes the PCL graphics state. Besides color entries, a palette also contains the graphics state at the time the bitmap representation of the palette colors was created. This guarantees color reproduction integrity by insuring that the same color specification triplet always produces the same bitmap representation.

As described below, the Select Palette (Ec&p#S), Palette Control (Ec&p#C), and Palette Control ID (Ec&p#I) commands implement the three basic operations of management by ID.

- Selection of the active palette
- Deletion of palettes
- Copying of palettes

Select Palette Command

The Select Palette command selects a new active palette by specifying an ID number. The previously active palette is unchanged.

Esc&p#S

= Palette ID number

Default = 0

Range = 0 to 32767 (command is ignored for out-of-range values)

This command activates the designated palette in the palette store. The command is ignored if the specified ID matches the active palette's ID, or if no palette with that ID exists. The designated ID is saved as the palette select ID in the current modified print environment.

This command can be used to de-select the active palette and select as the new active palette a palette created by the Palette Control command (Esc&p#C). For example, to copy the active palette to an ID of 44 and select the new palette to use or modify, send Esc&p44i6c44S.

When a palette creation command is received such as Configure Image Data (Esc*v#W), Simple Color (Esc*r#U), or an HP-GL/2 IN, the created palette overwrites the active palette and is assigned the current palette select ID, which is unchanged.

A palette popped from the stack overwrites the active palette, and is assigned the current palette select ID, which is unchanged.

EscE resets the palette select ID value to 0 and deletes all palettes in the palette stack and palette store, including the active palette which is replaced by a default PCL fixed black and white palette with a palette select ID value of 0.

Macros affect the palette select ID value as follows:

- Calling or Overlaying a macro—saves the ID value and a copy of the active palette. Upon macro exit, the restored palette again becomes the active palette with the restored ID. An existing palette with this ID is deleted.
- Executing a macro—does not save the ID value or the active palette; changes remain in effect.

Palette Control ID

The Palette Control ID command specifies the ID number to be used by the Palette Control Command.

Esc&p#I

= Palette ID number

Default = 0

Range = 0 to 32767 (command is ignored for out-of-range values)

The ID number specified by this command is saved as the palette control ID in the current modified print environment and is used by the Palette Control command (Esc&p#C).

EscE or power-up resets the palette control ID to 0, which is then the default black and white palette ID.

Macros affect the palette control ID value as follows:

- Calling a macro—saves the value and restores the value at exit.
- Executing a macro—does not save the value; changes remain in effect at exit.
- Overlaying a macro—copies the value before resetting to 0, and restores at exit.

Palette Control

The Palette Control command provides a mechanism for marking and deletion of palettes.

Esc&p#C

= 0 - Delete all palettes except those in the stack (active palette deleted)

1 - Delete all palettes in the stack (active palette is not affected)

2 - Delete palette (specified by Palette Control ID)

6 - Copy active palette to ID specified by Palette Control ID

Default = 0

Range = 0, 1, 2, 6 (command is ignored for unsupported values)

- A value of **0** deletes all palettes except those on the palette stack. The active palette is replaced by the default black and white palette (ID 0). The palette control ID is not used.
- A value of **1** clears the palette stack. The active palette is unaffected, and the palette control ID is not used.
- A value of **2** deletes the palette with the specified palette control ID if it exists; otherwise the command is ignored. For example, to delete palette 53, send Esc&p53i2C. If the active palette's ID is specified the active palette is replaced by the default black and white palette. This option does not change the palette control ID value.

Note

When the active palette is replaced by the default black and white palette, the graphics state associated with the previous palette is also replaced.

- A value of 6 creates a copy of the active palette. The copy receives the ID specified by the last Palette Control ID command. For example, to copy the active palette to a palette with an ID of 14, send Ec&p14i6C. The copied palette overwrites any palette that already has an ID equal to the palette control ID. The copied palette does not become the active palette. The command is ignored if a palette is to be copied to its own ID.

The Palette Control command provides a way of managing system memory by deleting palettes in either the stack or store that are no longer in use.

Palette Control that is exercised during macros can have significant impact on palettes that exist within the system. Deleting all palettes, or those on the stack, or the current palette, or all those except on the stack can have adverse effects when the macro is exited. The adverse effect could be the deletion of the desired palette, and replacement with a black and white non-programmable palette.

Simple Color Palettes

The Simple Color command (Ec*r#U) provides a quick way to select colors from a fixed, non-programmable palette.

The Simple Color command overwrites the current palette with one of the fixed palettes below. When the Simple Color command is in effect, the PCL and HP-GL/2 commands that modify a palette entry (NP, CR, PC, Ec*v#A, Ec*v#B, Ec*v#C, Ec*v*I, Ec*t*I) are locked out. A popped simple color palette cannot be modified and the pixel encoding mode reverts to "index by plane". Only the IN or the CID (Ec*v#W) commands can create a modifiable palette.

As shown below, a value field of 1 (Ec*r1U) creates a black and white palette. A value of 3 creates an 8-pen palette in Device RGB color space. A value of –3 creates an 8-pen palette in Device CMY color space. All of these Simple Color palettes are fixed and non-programmable.

Single Plane (value = 1)

Index	Color
0	White
1	Black

3-Plane RGB (value = 3)

Index	Color
0	Black
1	Red
2	Green
3	Yellow
4	Blue
5	Magenta
6	Cyan
7	White

3-Plane CMY (value = –3)

Index	Color
0	White
1	Cyan
2	Magenta
3	Blue
4	Yellow
5	Green
6	Red
7	Black

CID Color Palettes

The Configure Image Data command, explained in detail in Chapter 2, creates a palette based upon the parameters in its data field. CID-created palettes are programmable: any entry can be reassigned a different color using PCL commands (Ec*v#A, Ec*v#B, Ec*v#C, Ec*v*I) or HP-GL/2 commands (CR, PC, NP). Default palettes vary by color space.

Device RGB Palettes

The black and white references specified by the CID command have no effect on the default palettes below. However, when a CID palette entry is reprogrammed with a different color, the black and white references are used to specify the primary components of the new color.

Bits/Index = 1

Index	Color
0	White
1	Black

Bits/Index = 2

Index	Color
0	Black
1	Red
2	Green
3	White

Bits/Index = 3 through 8

Index	Color
0	Black
1	Red
2	Green
3	Yellow
4	Blue
5	Magenta

6	Cyan
7	White
n > 7	Black

Device CMY and Device-Independent Palettes

A CID command specifying either a device-independent color space or the Device CMY color space creates the same default palettes. This is because device-independent colors are transformed into the printer's native space, Device CMY.

Bits/Index = 1

Index	Color
0	White
1	Black

Bits/Index = 2

Index	Color
0	White
1	Cyan
2	Magenta
3	Black

Bits/Index = 3 through 8

Index	Color
0	White
1	Cyan
2	Magenta
3	Blue
4	Yellow
5	Green
6	Red
7	Black
n > 7	Black

HP-GL/2 Palettes

Regardless of the color space, a default PCL palette is always different than a default HP-GL/2 palette. The following table shows the default palettes established in HP-GL/2. Like a default CID palette, a default HP-GL/2 palette can be modified in either PCL or HP-GL/2 contexts using the following commands:

PCL

- Color Components 1, 2, and 3 (Ec*v#A, Ec*v#B, Ec*v#C)
- Assign Color Index (Ec*v#I)

HP-GL/2

- Number of Pens (NP)
- Pen Color Assignment (PC)
- Set Relative Color Range (CR)

Note

The IN command always establishes the 8-pen palette.

Two Pens

Pen Number	Color
0	White
1	Black

Four Pens

Pen Number	Color
0	White
1	Black
2	Red
3	Green

Eight Pens

Pen Number	Color
0	White
1	Black
2	Red
3	Green
4	Yellow
5	Blue
6	Magenta
7	Cyan
n > 7	Black

Foreground Color

All PCL marking entities utilize “foreground” color, which is selected from the current palette using the Foreground Color command (Ec*v#S). Foreground color interacts with raster color depending on the print model commands in effect.

Foreground Color Command

The Foreground Color command sets the foreground color to the specified index of the current palette.

Ec***v#S**

= Index number into current palette

Default = 0

Range = 0 to $2^{(\text{current palette size})} - 1$

Specified values that are out-of-range of the current palette are mapped into a new index as follows:

Index = *Specified foreground index* modulo *palette size*

For example, specifying a foreground color index of 10 when the current palette size is 8 maps to 10 modulo 8, which is equal to 2. If the current palette was created under HP-GL/2, the index is mapped according to the HP-GL/2 mapping function.

Foreground color affects the following PCL page marking primitives:

- Text characters (they change to the foreground color, including underlining)
- Solid or monochrome patterned rectangular area fills (rules)
- Monochrome patterns (except HP-GL/2)
- Raster images

The following are not affected:

- User-defined color patterns (format 1 download patterns)
- HP-GL/2 marking primitives (HP-GL/2 uses “selected pen”, but ignores foreground color)

Note

Foreground color interacts with color raster images. In the printer, all color raster is resolved into three binary raster planes of CMY. Foreground color is applied to these planes, modifying the color image. For no interaction, set foreground color to black when sending color raster images.

After a foreground color is selected, changing any of the following will not change foreground color until a new Foreground Color command (Ec*v#S) is issued:

- Active Palette
- Configure Image Data (CID) command
- Render Algorithm
- User Defined Dither Matrix
- Gamma Correction
- Color Lookup Tables
- Viewing Illuminant

As an exception, Monochrome Print Mode (Ec&b#M) immediately maps foreground color to its equivalent gray. Similarly, deselection of Monochrome Print Mode immediately returns foreground color to its color equivalent.

Programming Color Palettes

Except for the default black and white palette or the Simple Color palettes (Ec*r#U), palette entries can be modified. The three primary components of a color are specified and the resulting color is assigned to the palette entry indicated by Ec*v#I.

In the explanation below, the term “component” refers to the color space primary colors. For example, if the current color space is CIE L*a*b*, component 1 indicates CIE L*, component 2 indicates CIE a*, and component 3 indicates CIE b*.

Color Component One

This command specifies the first primary of the palette entry designated by the Assign Color Index command (Ec*v#I).

Ec*v#A

= First Component

Default = 0

Range = –32767.0000 to 32767.0000 (up to 4 decimal places; command is ignored for invalid configurations)

The Assign Color Index command actually applies this value and then resets it to 0.

Color Component Two

This command specifies the second primary of the palette entry designated by the Assign Color Index command.

$^{E}_{C}$***v#B**

= Second Component

Default = 0

Range = –32767.0000 to 32767.0000 (up to 4 decimal places; command is ignored for invalid configurations)

The Assign Color Index command actually applies this value and then resets it to 0.

Color Component Three

This command specifies the third primary of the palette entry designated by the Assign Color Index command.

$^{E}_{C}$***v#C**

= Third Component

Default = 0

Range = –32767.0000 to 32767.0000 (up to 4 decimal places; command is ignored for invalid configurations)

The Assign Color Index command actually applies this value and then resets it to 0.

Assign Color Index

This command assigns the three current color components to the specified palette index number.

$^{E}_{C}$***v#I**

= Index Number

Default = 0

Range = 0 to $2^n - 1$, where n is the number of bits per index (no assignment for out-of-range values)

This command resets the color components to 0 after assignment. If the specified index number is greater than the palette size, no index assignment is made, but the three color components are set to 0.

4

Modifying Output Color

Introduction

The previous chapters of this manual have been concerned with giving an overview of the color printing process, choosing color modes, and using palettes. This portion of the manual explains how color can be modified to produce a desired result, from using halftone render algorithms to change the way color is rendered, to compensating for the yellow cast caused by a tungsten light source in a photograph. The HP color printers can modify colors using the following means:

- *Halftone render algorithms* provide a way to modify images based on a dither cell concept. The algorithm chosen determines how specified colors are "rendered" as dots on the printed page.
- *Color lookup tables* can remap palette colors to compensate for unwanted color characteristics of input data. For example, if a scanned photograph had a reddish cast, a color lookup table could be used to make the printed image look as if it were taken under a more balanced light source.
- *Gamma correction* provides a way to adjust for color differences in display monitors.
- The *Viewing Illuminant* command allows you to vary the xy chromaticity coordinates for the light source under which you will be viewing a printed piece. For example, if the printed document is to be viewed under a tungsten light, the command modifies colors so that they have the correct appearance when illuminated by a tungsten light bulb.
- The *Monochrome Print Mode* command converts each color to its grayscale equivalent for faster, draft printing.

- The *Driver Configuration* command provides a way for a driver to calibrate the output by adjusting color lightness, saturation, and color map information.

All of these methods of modifying output color are explained in the following sections.

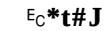
Halftone Render Algorithms

The HP color printers have the capability of applying different halftone render algorithms to achieve the desired output on the printed image. Render algorithms allow you to change the characteristics of the image by changing the way pixels are rendered. Each halftone render algorithm produces a different affect on the output, varying the texture and color appearance of the printed image.

To choose the type of rendering to be used, use the Render Algorithm command, described below. This command allows you to choose one of the existing rendering algorithms or to choose a user-defined pattern created with the Download Dither Matrix command.

Render Algorithm Command

The Render Algorithm command selects the algorithm to be used for rendering page marking entities on a given page.



Esc*t#J

=
- 0 - Continuous tone (device best dither)
- 1 - Snap to primaries
- 2 - Snap black to white and other colors to black
- 3 - Device best dither
- 4 - Error diffusion
- 5 - Device best (monochrome)
- 6 - Monochrome error diffusion

7 - Cluster ordered dither

8 - Monochrome cluster dither

9 - User-defined dither

10 - Monochrome user-defined

11 - Ordered dither

12 - Monochrome ordered dither

13 - Noise ordered dither

14 - Monochrome noise ordered dither

Default = 3

Range = 0 to 14 (invalid values are ignored; values 1 and 2 are ignored for device independent color)

Snapping to Primaries

This algorithm converts each component of a color specification to its corresponding primary color. For example, assuming 8 bits per primary, an RGB input value greater than 128 snaps to 255; a value less than or equal to 128 snaps to 0.

Snapping Black to White

Choosing this option converts black to white and all other colors to black. Input primary colors equal to a black specification are converted to a white specification, and other color specifications for the input primaries are converted to the black specification.

Device Best Dither

This dither pattern produces the best results for many images. Note, however, that the recommended dither pattern varies with the image, the intended use of the image, and the subjective judgements of the user.

Error Diffusion

The input primaries of a given pixel (x,y) are printed at the closest density available and the local error is propagated to

the unprinted neighboring pixels. Error diffusion applies only to raster data printed using the Configure Image Data command.

Ordered/Clustered Dither

The ordered dither or cluster ordered dither causes a pixel to be intensified at a point (x,y) depending on the desired intensity, I(x,y), and on an n x n dither matrix, D, where

i = x modulo n

j = y modulo n

For RGB color spaces, if I(x,y) < D(i, j), the point corresponding to (x,y) is intensified; otherwise it is not. The intensity of each primary color is determined according to this scheme. The relationship between I and D depends on the specified color space.

Monochrome Rendering

Monochrome rendering generates a gray value from the three primary colors. The gray value is computed according to the NTSC standard, which for the Device RGB color space is:

Gray = 0.3 x Red + 0.59 x Green + 0.11 x Blue

User-Defined Dithering

For a user-defined dither, the input primaries are compared against differently dimensioned dithers (e.g. MxN), which may vary for each primary color.

Note

Since it is impossible to characterize a printer for all possible dither algorithms, render algorithms 1, 2, 9 and 10 are not accessible when in a device-independent color space. If one of these render algorithms are selected when in a device-independent color space, the device best dither will be used instead.

User-Defined Dithers

The Download Dither Matrix command (Ec*m#W) can create a dither matrix for one or all three primary colors, in effect providing halftone screens. User-defined dither matrices can be used for optimizing the printer's output capabilities when using device-dependent color spaces. They are ignored for device-independent color spaces, since the printer cannot be calibrated as is necessary for device-independent color. User-defined halftones can be downloaded for each component of the color space.

A user-defined matrix is defined in additive colors (RGB values). The dither matrix pixels are defined in terms of device-dependent resolution.

When using the Download Dither Matrix command, you have several options:

- You can choose whether to define a separate matrix for each color plane, or use the same matrix for all three color planes.
- You set the height and width of the dither cell. When using separate matrices for each plane, you can use different size dither cells for each plane. For example, you can have a 4 x 4 pixel cell for red, a 4 x 6 cell for green, and a 6 x 8 cell for blue.
- You download the data bytes for each pixel of the cell. Each data byte determines a threshold—every pixel with a value greater than or equal to the threshold gets turned on and every pixel with a value less than the threshold does not get turned on.

Download Dither Matrix Command

The Download Dither Matrix command specifies a single matrix for all three primary colors, or three matrices (one for each primary), which may have different sizes and contents.

$^{E}_{C}$***m#W***[data]*

= Number of bytes of byte-aligned binary data in the data field

Default = 0

Range = 7 to 32767 (command is ignored for values of 0 – 6; values larger than 32767 or device limits are clamped; signs are ignored)

A downloaded user-defined dither will not take effect until after explicitly selecting it via a render algorithm command with a value of 9 or 10. However, if the current render algorithm (or last render algorithm received) was a user-defined algorithm (value 9 or 10), then a user-defined matrix will take effect as soon as it is downloaded. In this case, another render algorithm command (value 9 or 10) is not needed to "select" the downloaded user-defined dither matrix. This is due to the fact that the downloaded user-defined dither algorithm is the currently selected render algorithm.

If the command is sent before downloading a user-defined dither matrix, the device will use the device's user-defined dither default, if available, or, if no default is available, will use the default render algorithm.

Note

The user-defined dither matrix must be defined for processing with additive colors (RGB).

Since user-defined algorithms cannot be used when a device-independent color space is active, trying to specify a

user-defined algorithm in this situation causes the default algorithm to be used. The default is used until the algorithm is changed to something other than user-defined, or until you specify a device-dependent color space.

The table below shows the format for a dither matrix that is applied to all three color primaries. The format for "multiple dither matrices" is supplied after this explanation. ("uint 16" means unsigned 16-bit integer; "ubyte" means unsigned byte.)

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Format = 0	Number of planes = 1	1
2	Dither matrix height in pixels (uint 16)		3
4	Dither matrix width in pixels (uint 16)		5
6	byte #0 (ubyte)	byte #1 (ubyte)	7
8	byte #2 (ubyte)	byte #3 (ubyte)	9
	•		
	•		

Format

This byte should be set to 0.

Number of Planes

This byte designates how many dither matrices are specified by the command. The command is ignored and the data discarded for any value other than 1 or 3.

Byte Value	Value Description
1	One matrix applied to all primaries
3	Each primary has a separate matrix

Height and Width

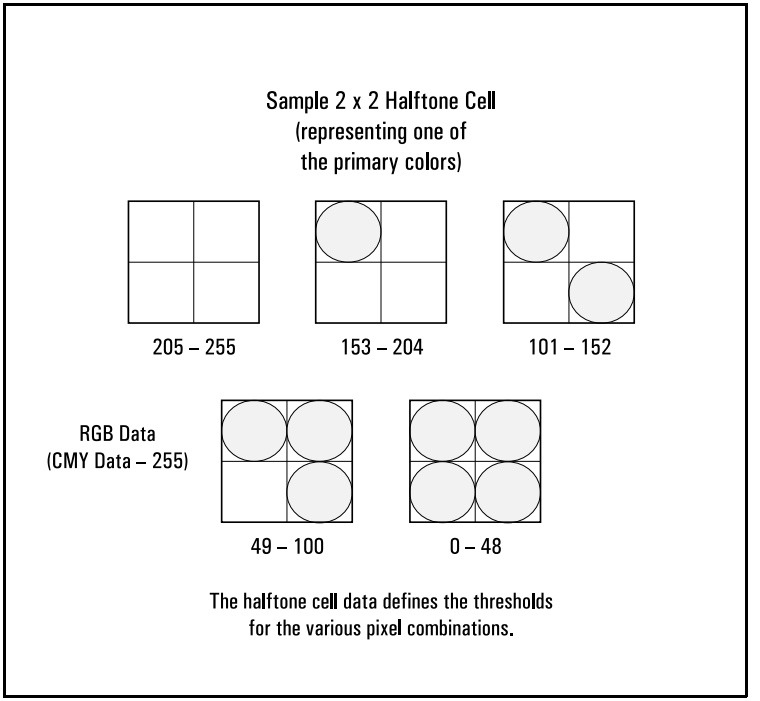
These bytes designate the size of the dither matrix in pixels. For example, a value of four for height and six for width produces a dither cell that is four pixels wide by six

pixels high. Values must be non-zero and sized so the matrix contains no more than 32767 bytes. Otherwise, the command is ignored and the data discarded. The minimum dither matrix size is 1 x 1.

Data Bytes

After specifying the height and width of the cell, data bytes are sent row-by-row (row-major order). Each data byte contains the normalized probabilities, ranging from 0 to 255, of one cell.

For example, a 2 x 2 cell could have no pixels print for RGB values of 205 through 255, one pixel for values of 153 through 204, two pixels from 101 through 152, three pixels for 49 through 100, and all four pixels between 0 and 48 (see the illustration below, which represents a halftone cell for one of the primary colors—note that the color data is in RGB values).



Each dither matrix must be completely specified. Otherwise, the width and height values may be misinterpreted if multiple matrices are sent.

If the width, height, and data specifications result in an odd number data bytes, the next matrix specification will begin on an odd byte boundary. No padding is provided for even-byte aligning.

Multiple Dither Matrices

As noted in the previous table, you set the number of planes field to 3 to send separate matrices for each primary. Each dither matrix must have its own width and height data fields. As shown below, the matrix specification for each primary follows the previous primary color's matrix specification.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Format = 0	Number of planes = 3	1
2	Dither matrix height in pixels (uint 16)		3
4	Dither matrix width in pixels (uint 16)		5
6	byte #0 (ubyte)	byte #1 (ubyte)	7
8	byte #2 (ubyte)	byte #3 (ubyte)	9
	•		
	•		
n	Dither matrix height in pixels (uint 16)		n + 1
n+2	Dither matrix width in pixels (uint 16)		n + 3
n+4	byte #0 (ubyte)	byte #1 (ubyte)	n + 5
n+6	byte #2 (ubyte)	byte #3 (ubyte)	n + 7
	•		
	•		
m	Dither matrix height in pixels (uint 16)		m + 1
m + 2	Dither matrix width in pixels (uint 16)		m + 3
m + 4	byte #0 (ubyte)	byte #1 (ubyte)	m + 5
m + 6	byte #2 (ubyte)	byte #3 (ubyte)	m + 7

Example This example produces a 4 x 4 dither matrix that is applied to all three color primaries (the number of planes is set to 1). The following command would be sent to create this dither matrix:

$^{E}_{C}$*m22W010404B0B1B2B3B4 . . . B15 (where the first 6 binary bytes are shown as ASCII here for clarity, and B1 . . . B15 indicate the binary byte data).

The byte-aligned binary data field (shown as ASCII for clarity) would be:

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	0	1	1
2	0	4	3
4	0	4	5
6	B0	B1	7
8	B2	B3	9
	•		
	•		
20	B14	B15	21

Note

Do not use downloaded dither matrices as patterns since the orientation of the pattern will not rotate with changes in orientation and page rotation.

Color Lookup Tables

Color lookup tables provide a way to re-map color data for the following types of applications:

- Highlight and shadow modification
- Saturation and desaturation
- Unique gamma correction curves
- Special effects for tonal correction
- Neutral balancing

Color lookup tables map input data for each primary color into a new output range based on point-by-point conversions. Color lookup tables can modify input data for both device-dependent and device-independent color spaces.

Like the CID command, the first byte of the data field identifies the color space to which the lookup tables will be applied. These tables specify on a point-per-point basis a transformation from an input space of 0 . . . 255 into an output space of 0 . . . 255. Figure 4-1 on the next page illustrates the concept.

The *unity lookup table* (see the following illustration) is the default for all color spaces; it performs a 1:1 mapping of input to output (that is, 129 is mapped to 129). The inversion lookup table performs a simple color inversion; for example, it inverts the red primary of a device-dependent RGB color space to create cyan output (from 255 red to 0 red, which is 255 cyan).

Color Lookup Tables Command

This command enables and specifies color lookup tables.

$^{E}_{C}$***l#W***[binary data]*

= Number of bytes of binary data

Default = 0

Range = 0 or 770 (command is ignored for other values; sign is ignored)

A value of 0 resets or initializes the color lookup tables for each primary to the unity curve (1:1). A value of 770 means the data for a color lookup table will be following. The command is ignored and the data is absorbed for any number of bytes not equal to 0 or 770.

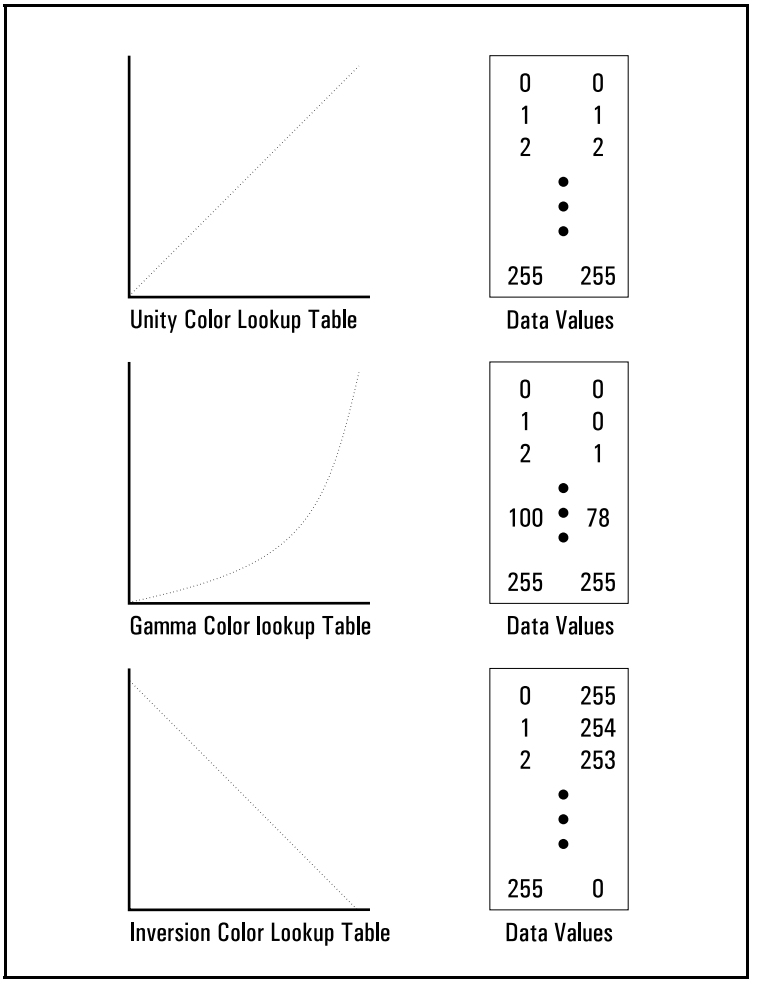


Figure 4-1. Color Lookup Tables

This command enables the color lookup tables until an ^[c]E, Configure Image Data (CID), or another Color Lookup Tables command with a 0 value field is received.

Note

RGB gamma correction (^[c]*t#I) and color lookup tables for device-dependent color spaces are mutually exclusive and overwrite each other.

As shown below, the 256 point-by-point transformation curve for each primary color is defined sequentially for a total of 768 bytes, with the additional 2 bytes for specifying the color space and reserved data field.

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	Color Space	Reserved Data Field	1
2	Color Component 1, Index 1	Color Component 1, Index 2	3
4	Color Component 1, Index 3	Color Component 1, Index 4	5
. . .			
256	Color Component 1, Index 255	Color Component 1, Index 256	257
258	Color Component 2, Index 1	Color Component 2, Index 2	259
260	Color Component 2, Index 3	Color Component 2, Index 4	261
. . .			
512	Color Component 2, Index 255	Color Component 2, Index 256	513
514	Color Component 3, Index 1	Color Component 3, Index 2	515
516	Color Component 3, Index 3	Color Component 3, Index 4	517
. . .			
768	Color Component 3, Index 255	Color Component 3, Index 256	769

Byte 0 (Color Space)

Value	Color Space
0	Device RGB (default)
1	Device CMY
2	Colorimetric RGB Spaces
3	CIE L*a*b*
4	Luminance-Chrominance Spaces

A color lookup table can be attached to one or more of the color spaces anytime after a CID command. For example, a Luminance-Chrominance space can have four lookup tables specified, namely:

- Device-Dependent space
- CIE L*a*b* space
- Colorimetric RGB space
- Luminance-Chrominance space

A reset (EcE), IN, or CID command sets each of the four levels of color lookup tables for each primary to the unity curve.

Gamma Correction

Color monitors, which are by nature non-linear, appear incorrect when given a linear ramp of some color. Gamma correction can significantly improve perceptual correctness by adjusting the brightness or darkness of the color data sent from the monitor to any other non-linear device.

Gamma Correction Command

$^{E}_{C}$***t#I**

= Gamma number

Default = 0 (gamma correction off)

Range = 0.0 to 32767.0 (command is ignored for invalid values) *

* The practical range for gamma values is 0.0 to 4.0.

Assuming 8 bits per primary (256 intensity levels per primary), the corrected intensity for each color primary is calculated as follows:

Intensity = ((1 + log (input / 255)) / gamma) * 255

Gamma correction is referred to in terms of device-dependent RGB. This command does not destroy the contents of device-dependent color lookup tables, but setting a gamma value supercedes any lookup table input in either Device CMY or Device RGB.

Note

The default value (0) gives the same result as a gamma value of 1.0, which results in a unity gamma curve.

Viewing Illuminant

Printed colors undergo a hue shift when viewed under different illuminations (for example, fluorescent, tungsten, or daylight). Colors with spectral characteristics outside the range of an illumination source are not received, changing the appearance of mixed colors. The Viewing Illuminant command (Ec*i#W) supports communication of standard illuminations to the printer to allow the printer to compensate for different lighting conditions when appearance matching.

Viewing Illuminant Command

The Viewing Illuminant command specifies the relative white point used in the determination of a viewing illuminant condition.

Ec***i#W***[binary data]*

= Number of binary bytes of data

Default = 8

Range = 8 (command is ignored for invalid values; signs in the value field are ignored

The binary data field is formatted as follows:

Byte	15 (msb) 8	7 (lsb) 0	Byte
0	x chromaticity white point (lsw)		1
2	x chromaticity white point (msw)		3
4	y chromaticity white point (lsw)		5
6	y chromaticity white point (msw)		7

The above format adheres to the IEEE floating point format as follows:

31	30 23	22 0
Sign	Exponent	Fractional Portion

The PCL default viewing illuminant is D65 (6500K). Below is a table of viewing illuminants and their chromaticity values.

Illuminant	x chromaticity	y chromaticity
Daylight (D65) (6500K)	0.3127	0.3290
Tungsten (3200K)	0.4476	0.4074
Cool White Fluorescent (5630K)	0.3904	0.3914

This command affects only device-independent color. The command acts like a state variable: it is ignored for White/Black, Device RGB, or Device CMY palettes, but it becomes active when a new CID command specifies a device-independent color space.

Monochrome Printing

The *Monochrome Print Mode* command converts each color value to its grayscale equivalent. This improves throughput, costs less to print, and eliminates waste by providing a draft mode.

Monochrome Print Mode Command

The Monochrome Print Mode command designates whether to print using the current rendering mode or a fast gray-scale equivalent. Pages printed using the gray-scale equivalent do not use any color and therefore print faster and more economically.

^EC**&b#M**

= 0 – Print in mixed render algorithm mode

1 – Print using gray-scale equivalent

Default = 0

Range = 0, 1 (command is ignored for invalid values)

This command must be sent prior to printable data; otherwise, the current page is closed and printed. It may be sent on a page-by-page basis.

Driver Configuration Command

This command specifies the Lightness, Saturation, and Scaling Algorithm to be applied to the document, and allows for the selection and downloading of Color Maps.

E_C***o#W***[device_id function_index Arguments]*

= Specifies the number of bytes to follow (device ID + function index + arguments)

Default = N/A

Range = see description below

device_id

Value	Printer
6	Color LaserJet printer

function_index

function_ index	Description	Argument Range	
0	Lightness	-100 to 100	
1	Saturation	-100 to 100	
3	Scaling Algorithm	0	Pixel Replication
		1	Bilinear Interpolation
		2	Modified Bilinear Interpolation

function_ index	Description	Argument Range	
4	Select Color Map	0	No Adjustment
		1	Process Blue
		2	Vivid Graphics
		3	Transparency
		4	Out of Gamut
		5	CIE Lab Match
5	Download Color Map	1	CMY Color Space
		3	CIELab Color Space
		See MapID List (14739 bytes)	

The following paragraphs describe the *function_index* values and their arguments.

Lightness Negative values darken (unlighten) the image, text or graphics color, but do not have any effect on black or white data. Positive values lighten the image. Zero turns the lightness adjustment off. This function index requires three data bytes.

Saturation Negative values desaturate (add gray to) the image, text or graphics color, but will not have any effect on black or white data. Positive values increase the amount of saturation, making the image more vivid. Zero turns the saturation adjustment off. This function index requires three data bytes.

Scaling Pixel replication is a backward-compatible scaling algorithm. Bilinear interpolation is a high-quality scaling algorithm for smooth-edge interpolated scaling. Modified bilinear scaling only interpolates when it is best to do so. This function index requires three data bytes.

Select Color Map

This value specifies which color treatment mode to use for rendering the next job.

No Adjustment

This setting provides linearization only (that is, the user sees the device as a linear device).

Process Blue

This setting provides the same results as Vivid Graphics (linearization plus user-preferred enhancements) with the addition of mapping process blue, which looks slightly purple, to a blue closer to that of a standard monitor.

Vivid Graphics

This setting adds color saturation to the resulting image.

Transparency

This setting uses a map to render the best color output on transmissive media.

Out of Gamut

This setting prints colors in an image that are out of gamut—all colors that are in gamut snap to white, all out-of-gamut colors are snapped to the gamut surface. This setting only supports the device-independent color map.

CIE L*a*b* Match

This map performs a true color match to the requested CIE L*a*b* input (there are no appearance matching adjustments). This setting only supports the device-independent color map.

Note

For screen matching, the long form of the Configure Image Data command is used and the color maps are generated internally dependent upon the monitor calibration data (the Driver Configuration command is not needed).

Download Color Map

The printer supports the downloading of color adjustment maps dependent upon the halftone requested, the type of color treatment desired (including device-dependent or independent), and the type of media.

Setting	Description	MapID
Device Dependent		
No adjustment	Cluster-No Adjust-DD	1
	Disperse-No Adjust-DD	2
	Scatter-No Adjust-DD	3
	ErrorDiffusion-No Adjust-DD	4
Process Blue	Cluster-Process Blue-DD	5
	Disperse-Process Blue-DD	6
	Scatter-Process Blue-DD	7
	ErrorDiffusion-Process Blue-DD	8
Transparency	Cluster-Transparency-DD	9
	Disperse-Transparency-DD	10
	Scatter-Transparency-DD	11
	ErrorDiffusion-Transparency-DD	12
Vivid Graphics	Cluster-VividGraphics-DD	13
	Disperse-VividGraphics-DD	14
	Scatter-VividGraphics-DD	15
	ErrorDiffusion-VividGraphics-DD	16
Out of Gamut	Cluster-OutOfGamut-DD	17
	Disperse-OutOfGamut-DD	18
	Scatter-OutOfGamut-DD	19
	ErrorDiffusion-OutOfGamut-DD	20

Setting	Description	MapID
CIELab Match	Cluster-TrueMatch-DD	21
	Disperse-TrueMatch-DD	22
	Scatter-TrueMatch-DD	23
	ErrorDiffusion-TrueMatch-DD	24
Device-Independent		
No Adjustment	Cluster-No Adjust-DI	51
	Disperse-No Adjust-DI	52
	Scatter-No Adjust-DI	53
	ErrorDiffusion-No Adjust-DI	54
Process Blue	Cluster-Process Blue-DI	55
	Disperse-Process Blue-DI	56
	Scatter-Process Blue-DI	57
	ErrorDiffusion-Process Blue-DI	58
Transparency	Cluster-Transparency-DI	59
	Disperse-Transparency-DI	60
	Scatter-Transparency-DI	61
	ErrorDiffusion-Transparency-DI	62
Vivid Graphics	Cluster-VividGraphics-DI	63
	Disperse-VividGraphics-DI	64
	Scatter-VividGraphics-DI	65
	ErrorDiffusion-VividGraphics-DI	66
Out of Gamut	Cluster-OutOfGamut-DI	67
	Disperse-OutOfGamut-DI	68
	Scatter-OutOfGamut-DI	69
	ErrorDiffusion-OutOfGamut-DI	70

Setting	Description	MapID
CIELab Match	Cluster-TrueMatch-DI	71
	Disperse-TrueMatch-DI	72
	Scatter-TrueMatch-DI	73
	ErrorDiffusion-TrueMatch-DI	74

5

The PCL Print Model

Introduction

The Print Model feature allows images and characters to be filled with color, with any of the printer's predefined shading or cross-hatch patterns, or with a user-defined pattern. Images include any raster graphic, such as one created with PCL raster graphics commands (as described in Chapter 6, *Raster Graphics*); a rectangular fill area (as described later in this chapter as *PCL Rectangular Area Fill Graphics*); or characters selected from any font.

Figure 5-1 illustrates the use of the print model. The following definitions are helpful in describing Print Model operation:

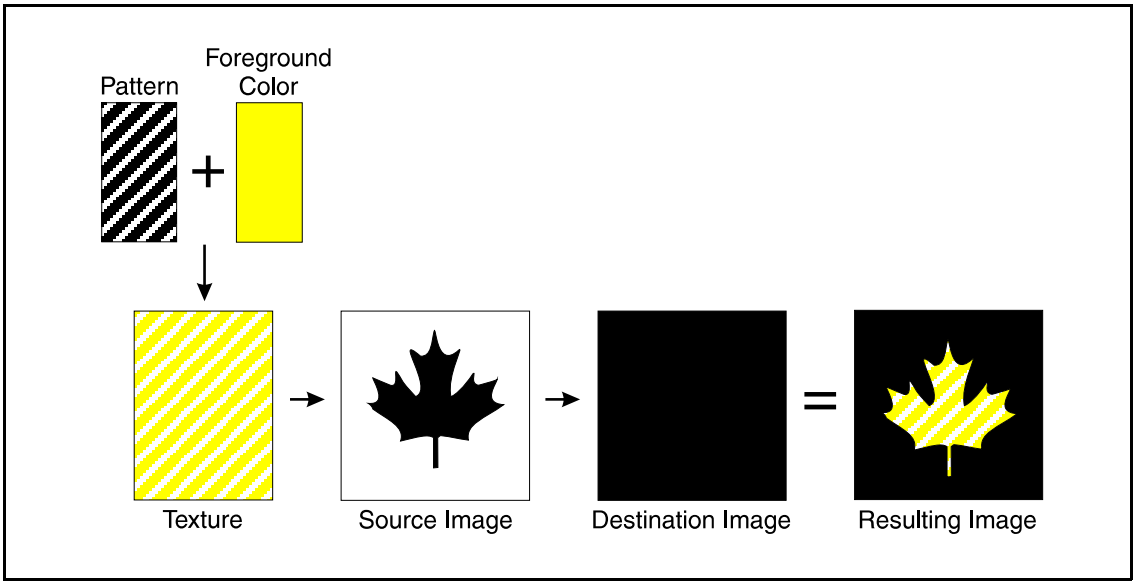


Figure 5-1. Print Model Imaging

- **Pattern**—The design which is "painted" through the non-white area of the source image onto the destination image. The pattern is defined by the Current Pattern (Ec*v#T) command. It may be a color pattern or a single-plane monochrome mask, such as the printer's internal predefined shading or cross-hatch patterns, or a user-defined pattern. Foreground color is not applied to a user-defined color pattern.

  When printing a page, text and raster images are printed using the **current pattern**. Once the current pattern is specified, it stays in effect until another is selected or the printer is reset. A reset returns the current pattern to its default value (100% black). The current pattern does not always apply to rectangular area fill, which uses patterns defined by the rectangular area fill pattern commands.

- **Foreground Color**—Foreground color is selected from the current palette using the Foreground Color command (Ec*v#S). Foreground color affects everything except user-defined color patterns and HP-GL/2 primitives. Raster color mixes with foreground color (see Chapter 6 "Color Raster Graphics").

- **Texture**—Texture is another name for the combination of pattern and foreground color, or for a color pattern which is not combined with a foreground color.

- **Source Image**—the Source Image is an image in which the non-white bits are replaced by the specified pattern. The source image functions like a stencil through which the pattern is applied to the destination image. The source image may be one of the following: HP-GL/2 primitives, rules, characters, or raster images (single plane mask or multi-plane color)

- **Destination Image**—The image onto which the source image/texture combination is placed. The destination image includes any images placed through previous operations.

- **Source Transparency Mode**—The transparency or opaqueness of the source image's "white" pixels as they

are applied to the destination image (see the note below). Setting the source transparency mode to 1 (opaque) applies the source image's white pixels to the destination image; with a setting of 0 (transparent), these pixels have no effect on the destination.

- **Pattern Transparency Mode**—The transparency or opaqueness of the "white pixels" in the pattern (see the note below). When set to 0 (transparent), these pixels have no effect on the destination; when set to 1 (opaque), they are applied through the black pixels of the source pattern to the destination.
- **Logical Operations**—the Print Model uses logical operations, such as AND, OR, XOR, and NOT when determining which bits of the source, pattern, and texture become part of the resulting image. The Logical Operations command (Ec*l#O) can vary the logical operation used, thus varying the outcome.

Note

For RGB color images, "white" pixels are those for which all color primaries are greater than or equal to their white reference values. For CMY color images, "white" pixels are those for which all color primaries are less than or equal to their white reference values.

When using Render Algorithm 2 (Ec*t2J) for halftoning, black pixels are affected by the transparency mode instead of white pixels.

For all rendering algorithms, white dots introduced in the dithering process are not subject to transparency modes.

Figure 5-2 illustrates the effects of the source and pattern transparency modes on the final image. (The transparency modes work a little differently with rectangular area fill—see "Pattern Transparency for Rectangular Area Fill" near the end of this chapter.)

This example uses the default ROP. The output may appear differently depending on the colors used.

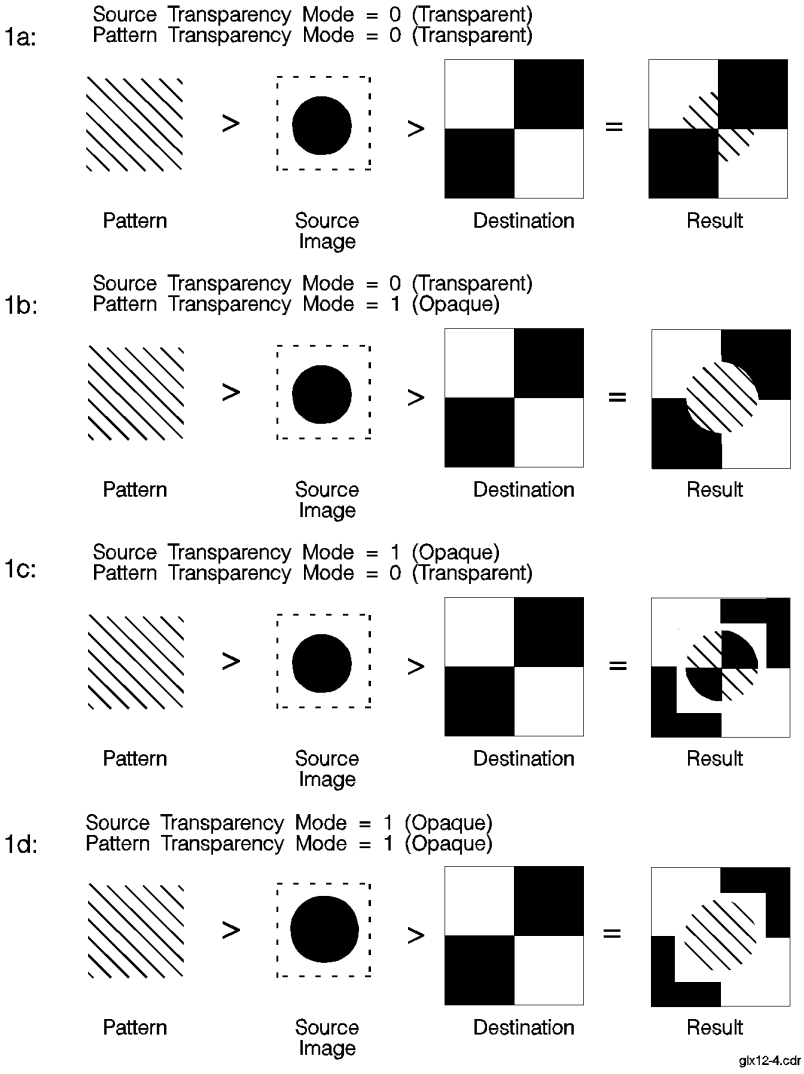
Figure 5-2. Opaque and Transparency Modes

Figure 5-3 demonstrates the transparency modes. In the first example (1a), the transparency mode for both the source image and the pattern is transparent. Since the source mode is "transparent," only the non-white region (the circle) of the source image is overlaid on the destination. Since the pattern mode is also transparent, the patterned source image is applied only to the white areas of the destination.

In the second example (1b), the source mode is still "transparent," but the pattern mode is "opaque" – so the pattern's white pixels are applied to the destination. The resulting image shows the entire circle region visible and patterned.

In the third example (1c), the source mode is "opaque" and the pattern mode is transparent. Since the source mode is opaque, the entire source image (the circle and the surrounding square) appears overlaid onto the destination. The pattern, however, is allowed to pour through only onto the white-pixeled area of the destination. The circle is visible in the result, but only two opposing quarters appear patterned.

In the fourth example (1d), both source and pattern modes are "opaque." The entire source image is overlaid onto the destination, and the entire circle is patterned.



In this example, the foreground color is black and the default ROP is used.

Figure 5-3. Effect of Transparency Modes on Images

Command Sequence

The table below shows the Print Model command sequence for selecting a current pattern and using it to fill a destination image. The commands for specifying transparency modes, logical operations, and patterns are discussed beginning on the following page. Foreground color is described in Chapter 3.

Operation	Comments
Download Page Data	Prior raster and character data downloaded to the page is considered destination image.
Select Transparency Modes	Esc*v#N (source) and/or Esc*v#O (pattern)
Specify the Logical Operation	If a logical operation other than the default (TSo-252) is desired, specify the operation with the Esc*ℓ#O command.
Select Specific Pattern ID	Pattern ID Esc*c#G
Download User-Defined Pattern	If using a user-defined pattern, it must be downloaded to the printer before using it.
Select Pattern	Esc*v4T (selects downloaded pattern)
Specify the Foreground Color	For color printers, specify a Foreground Color (Esc*v#S) if desired. (This step is unnecessary if a color pattern is used.)
Download Source Image Data	Raster image/characters
Return to regular print mode	Default *current* pattern and transparency modes: Esc*v0T (100% black pattern selected) and Esc*v0N Esc*v0O (transparency modes selected).
Download remaining page data	Transfer data for regular printing, or the above process may be repeated to produce another print model effect.
End of Page Data	

Source Transparency Mode Command

The Select Source Transparency Mode command sets the source image's transparency mode to transparent or opaque. This command determines whether the source's white pixels are applied to the destination.

Esc * v # N

= 0 - Transparent
1 - Opaque

Default = 0
Range = 0, 1 (other values cause the command to be ignored)

With a transparency mode of "0" (transparent), the white regions of the source image are not copied onto the destination. With a transparency mode of "1" (opaque), the white pixels in the source are applied directly onto the destination. White pixels are unaffected by pattern or foreground color; they are either white or transparent.

Note

For RGB color images, "white" pixels are those for which all color primaries are greater than or equal to their white reference values. For CMY color images, "white" pixels are those for which all color primaries are less than or equal to their white reference values.

When using Render Algorithm 2 (Esc*t2J), black pixels are affected by the transparency mode instead of white pixels. White dots introduced in the dithering process are not subject to transparency modes.

Refer to the preceding definitions and the discussion of Figure 5-3 for an explanation of the effects of source transparency.

Pattern Transparency Mode Command

The Pattern Transparency Mode command sets the pattern's transparency mode to transparent or opaque.

E_C *** v # O**

= 0 - Transparent
1 - Opaque

Default = 0
Range = 0, 1 (other values cause the command to be ignored)

A transparency mode of "0" (transparent) means that the white regions of the pattern image are not copied onto the destination. A transparency mode of "1" (opaque) means that the white pixels in the pattern are applied directly onto the destination.

Note

When printing white rules, the pattern transparency is treated as if it were "opaque"; white rules erase black rules regardless of the transparency mode.

For RGB color images, "white" pixels are those for which all color primaries are greater than or equal to their white reference values. For CMY color images, "white" pixels are those for which all color primaries are less than or equal to their white reference values.

When using Render Algorithm 2 (E_C*t2J), black pixels are affected by the transparency mode instead of white pixels. White dots introduced in the dithering process are not subject to transparency modes.

Refer to the preceding definitions and the discussion of Figure 5-2 and Figure 5-3 for an explanation of the effects of pattern transparency.

Logical Operations

The basic print model defines how a pattern, source image, and destination image are applied to each other using the print model's transparent and opaque modes to produce a resulting image. The Logical Operations (Ec*ℓ#O) command specifies which logical operation is to be performed on the source, texture, and destination to produce a new destination. Transparency modes should be specified before the logical operation is performed or printable data is sent.

The print model process consists of the following steps:

1. Specify source and/or pattern transparency modes, if desired.

2. Specify the logical operation (or use the default).

3. Define the desired operands (source, destination, pattern).

Definitions

Source: The source image may be one of the following:

- HP-GL/2 primitives
- Rules
- Characters
- Raster images (single plane mask or multiplane color)

Destination: The destination image contains whatever is currently defined on the page. It includes any images placed through previous operations.

Pattern or Texture: The pattern is defined by the Select Current Pattern command (Ec*v#T). The terms pattern and texture are used interchangeably in this section.

Transparency Modes: The white pixels of the source and/or pattern may be made transparent (source transparency 0, pattern transparency 0). The destination shows through these areas. Transparency modes are set by the Source Transparency (Ec*v#N) and Pattern Transparency (Ec*v#O) commands.

The Print Model allows logical operations, such as AND, OR, XOR, NOT, to be performed on source, texture, and destination images. Transparency modes and Logical Operation must be specified before printable data is sent.

Operators

- Source Transparency (specified before logical operation; default is transparent)
- Pattern Transparency (specified before logical operation; default is transparent)
- Logical Operators (default is Texture OR Source)

Operands

- Source objects: character cell, raster image, rule, HP-GL/2 vectors and polygons
- Texture: foreground color + pattern mask, color pattern (format 1).
- Destination: current page definition

Operation

- IF (source transparent && source == white) RETURN destination
- IF (pattern transparent && pattern == white) RETURN destination
- ELSE RETURN (logical op (source, texture, destination)

Assuming three bits per pixel, the following diagram shows the process.

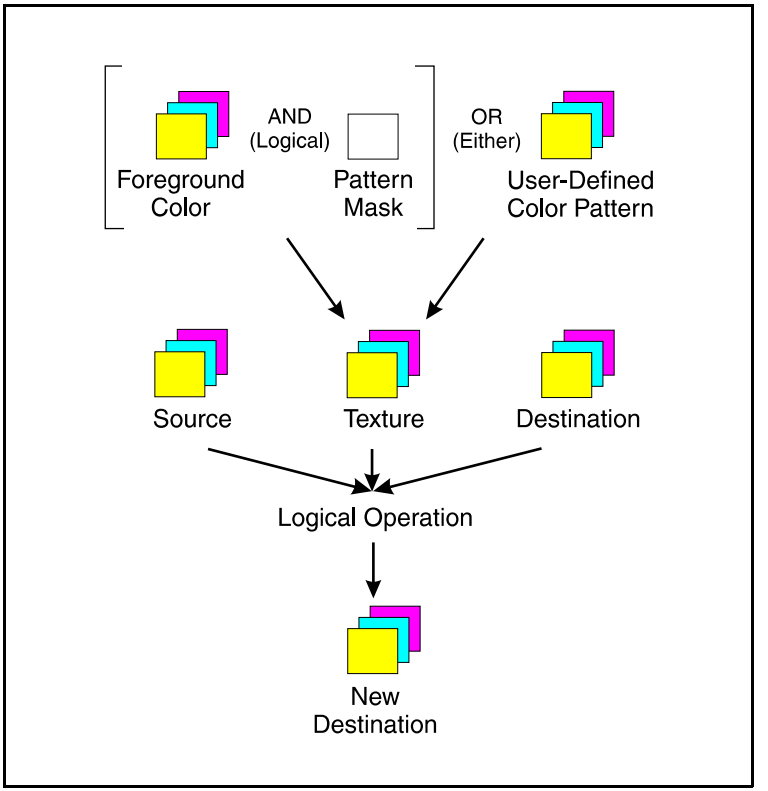


Figure 5-4. Logical Operations and the Print Model

Note

- The Logical Operation command (Ec*l#O) provides 255 possible logical operations. All of these logic operations map directly to their ROP3 (raster operation) counterparts (see the Microsoft Document, Reference, Volume 2, Chapter 11, Binary and Ternary Raster Operation Codes).
- The logical operations were defined for Microsoft Windows for an RGB color space. In RGB space, a "1" is white and a "0" is black.

Logical Operations and Transparency Interactions

As described above, transparency modes operate in addition to logical operations. The Logical Operations (ROP3) in Table 5-2 are true only if source and pattern transparency (for white pixels) are explicitly set to opaque (Ec*v1N and Ec*v1O). If source and/or pattern transparency modes are transparent (defaulted), the additional operations shown below must be performed to achieve the final result.

The four basic interactions are:

- **Case 1:** Source and Pattern are opaque.
  Texture = Color & Pattern.
  RETURN ROP3 (Dest, Src, Texture).

- **Case 2:** Source is opaque, Pattern is transparent.
  Texture = Color & Pattern.
  Temporary_ROP3 = ROP3 (Dest, Src, Texture).
  Image_A = Temporary_ROP3, & Not Src.
  Image_B = Temporary_ROP3 & Pattern.
  Image_C = Not Pattern & Src & Dest.
  RETURN Image_A | Image_B | Image_C

- **Case 3:** Source is transparent, Pattern is opaque.
  Texture = Color & Pattern.
  Temporary_ROP3 = ROP3 (Dest, Src, Texture).
  Image_A = Temporary_ROP3 & Src.
  Image_B = Dest & Not Src.
  RETURN Image_A | Image_B

- **Case 4:** Source and Pattern are transparent
  Texture = Color & Pattern.
  Temporary_ROP3 = ROP3 (Dest, Src, Texture).
  Image_A = Temporary_ROP3 & Src & Pattern.
  Image_B = Dest & Not Src.
  Image_C = Dest & Not Pattern.
  RETURN Image_A | Image_B | Image_C.

Logical Operation Command

Specifies the logical operation (ROP) to be performed in RGB color space on destination, source and texture to produce new destination data. Texture is defined as a combination of pattern and foreground color.

E_C*** ℓ # O**

= Logical operation value (see Table 5-2)

Default = 252 (TSo)
Range = 0 to 255

Note

Since PCL logical operations are interpreted in RGB space (white = 1, black = 0) rather than in CMY space (white = 0, black = 1), the results may not be intuitive. For example, ORing a white object with a black object in RGB space yields a white object. This is the same as ANDing the two objects in CMY space. It must be remembered that the printer operates in CMY space and inverts the bits. To convert from one color space to the other, write the ROP in binary format, invert the bits, and reverse the order.

When source and/or pattern transparency modes are set opaque (not defaulted), values specified by this command map directly to the ROP3 (raster operation) table values on the following page. However, when source and/or pattern transparency modes are set transparent, the additional operations shown on the previous page must be performed to achieve the final result.

Logical operations in the table are shown in RPN (reverse polish notation). For example, the value 225 corresponds to TDSoxn, the logical function of:

NOT (texture XOR (source OR destination))

Note

- Esc*ℓ # **O** is the PCL Version of the HP-GL/2 MC command.
- This command sets the ROP value which affects not only PCL operation but also the HP-GL/2 ROP value.

EXAMPLE

The Logical Operation default value is 252 (TSo), corresponding to a logical function of:

(texture | source)

The result is computed below (source and pattern opaque).

Table 5-1. Logical Operation (ROP3)

	Bits							
	7	6	5	4	3	2	1	0
Texture	1	1	1	1	0	0	0	0
Source	1	1	0	0	1	1	0	0
Destination	1	0	1	0	1	0	1	0
ROP3 (source & pattern)	1	1	1	1	1	1	0	0
	(decimal 252)							

Each column of destination, source, and texture values are the input to the logical function. The result, 252, is the value that would be sent to identify the logical operation (refer to page 5-12 for source/pattern transparency interactions).

Table of Logical Operations

The Logical Operations (ROP3) table (Table 5-2) shows the mapping between input values and their logical operations. Note that the logical operations are specified as RPN (reverse polish notation) equations. Here is a key to describe what the Boolean Function values mean;

S = Source	a = AND
T = Texture	o = OR
D = Destination	n = NOT
	x = EXCLUSIVE OR

Note

Since logical operations are interpreted in RGB space (white = 1 and black = 0) rather than in CMY space (white = 0 and black = 1), the results may not be intuitive. For example, ORing a white object with a black object in RGB space yields a white object. This is the same as ANDing the two objects in CMY space. It must be remembered that the printer operates in something similar to a CMY space and inverts the bits and reverses the order.

Table 5-2. Logical Operations (ROP3)

Input Value	Boolean Function	Input Value	Boolean Function
0	0	27	SDTSxaxn
1	DTSoon	28	TSDTaox
2	DTSona	29	DSTDxaxn
3	TSon	30	TDSox
4	SDTona	31	TDSoan
5	DTon	32	DTSnaa
6	TDSxnon	33	SDTxon
7	TDSaon	34	DSna
8	SDTnaa	35	STDnaon
9	TDSxon	36	STxDSxa
10	DTna	37	TDSTanaxn
11	TSDnaon	38	SDTSaox
12	STna	39	SDTSxnox
13	TDSnaon	40	DTSxa
14	TDSonon	41	TSDTSaoxxn
15	Tn	42	DTSana
16	TDSona	43	SSTxTDxaxn
17	DSon	44	STDSoax
18	SDTxnon	45	TSDnox
19	SDTaon	46	TSDTxox
20	DTSxnon	47	TSDnoan
21	DTSaon	48	TSna
22	TSDTSanaxx	49	SDTnaon
23	SSTxDSxaxn	50	SDTSoox
24	STxTDxa	51	Sn
25	SDTSanaxn	52	STDSaox
26	TDSTaox	53	STDSxnox

Table 5-2. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
54	SDTox	81	DSTnaon
55	SDToan	82	DTSDaox
56	TSDToax	83	STDSxaxn
57	STDnox	84	DTSonon
58	STDSxox	85	Dn
59	STDnoan	86	DTSox
60	TSx	87	DTSoan
61	STDSonox	88	TDSToax
62	STDSnaox	89	DTSnox
63	TSan	90	DTx
64	TSDnaa	91	DTSDonox
65	DTSxon	92	DTSDxox
66	SDxTDxa	93	DTSnoan
67	STDSanaxn	94	DTSDnaox
68	SDna	95	DTan
69	DTSnaon	96	TDSxa
70	DSTDaox	97	DSTDSaoxxn
71	TSDTxaxn	98	DSTDoax
72	SDTxa	99	SDTnox
73	TDSTDaoxxn	100	SDTSoax
74	DTSDoax	101	DSTnox
75	TDSnox	102	DSx
76	SDTana	103	SDTSonox
77	SSTxDSxoxn	104	DSTDSonoxxn
78	TDSTxox	105	TDSxxn
79	TDSnoan	106	DTSax
80	TDna	107	TSDTSoaxxn

Table 5-2. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
108	SDTax	135	TDSaxn
109	TDSTDoaxxn	136	DSa
110	SDTSnoax	137	SDTSnaoxn
111	TDSxnan	138	DSTnoa
112	TDSana	139	DSTDxoxn
113	SSDxTDxaxn	140	SDTnoa
114	SDTSxox	141	SDTSxoxn
115	SDTnoan	142	SSDxTDxax
116	DSTDxox	143	TDSanan
117	DSTnoan	144	TDSxna
118	SDTSnaox	145	SDTSnoaxn
119	DSan	146	DTSDToaxx
120	TDSax	147	STDaxn
121	DSTDSoaxxn	148	TSDTSoaxx
122	DTSDnoax	149	DTSaxn
123	SDTxnan	150	DTSxx
124	STDSnoax	151	TSDTSonoxx
125	DTSxnan	152	SDTSonoxn
126	STxDSxo	153	DSxn
127	DTSaan	154	DTSnax
128	DTSaa	155	SDTSoaxn
129	STxDSxon	156	STDnax
130	DTSxna	157	DSTDoaxn
131	STDSnoaxn	158	DSTDSaoxx
132	SDTxna	159	TDSxan
133	TDSTnoaxn	160	DTa
134	DSTDSoaxx	161	TDSTnaoxn

Table 5-2. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
162	DTSnoa	189	SDxTDxan
163	DTSDxoxn	190	DTSxo
164	TDSTonoxn	191	DTSano
165	TDxn	192	TSa
166	DSTnax	193	STDSnaoxn
167	TDSToaxn	194	STDSonoxn
168	DTSoa	195	TSxn
169	DTSoxn	196	STDnoa
170	D	197	STDSxoxn
171	DTSono	198	SDTnax
172	STDSxax	199	TSDToaxn
173	DTSDaoxn	200	SDToa
174	DSTnao	201	STDoxn
175	DTno	202	DTSDxax
176	TDSnoa	203	STDSaoxn
177	TDSTxoxn	204	S
178	SSTxDSxox	205	SDTono
179	SDTanan	206	SDTnao
180	TSDnax	207	STno
181	DTSDoaxn	208	TSDnoa
182	DTSDTaoxx	209	TSDTxoxn
183	SDTxan	210	TDSnax
184	TSDTxax	211	STDSoaxn
185	DSTDaoxn	212	SSTxTDxax
186	DTSnao	213	DTSanan
187	DSno	214	TSDTSaoxx
188	STDSanax	215	DTSxan

Table 5-2. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
216	TDSTxax	236	SDTao
217	SDTSaoxn	237	SDTxno
218	DTSDanax	238	DSo
219	STxDSxan	239	SDTnoo
220	STDnao	240	T
221	SDno	241	TDSono
222	SDTxo	242	TDSnao
223	SDTano	243	TSno
224	TDSoa	244	TSDnao
225	TDSoxn	245	TDno
226	DSTDxax	246	TDSxo
227	TSDTaoxn	247	TDSano
228	SDTSxax	248	TDSao
229	TDSTaoxn	249	TDSxno
230	SDTSanax	250	DTo
231	STxTDxan	251	DTSnoo
232	SSTxDSxax	252	TSo
233	DSTDSanaxxn	253	TSDnoo
234	DTSao	254	DTSoo
235	DTSxno	255	1

Pixel Placement

HP PCL 5 printers place pixels at the intersection of the squares of a theoretical, device-dependent grid covering the printable area on the page. Depending on the image and the logical operation in effect, a problem may occur when the sides of two polygons touch each other—the pixels along the common border may be printed twice or not at all. For example, a source rectangle consisting of all 1's that is XORed with a destination consisting of all 1's produces a white rectangle; but if another source rectangle is placed on the page touching the first rectangle, the two rectangles will be white-filled except at their common border ((1^1) ^1 = 1).

To correct situations where this problem occurs, the PCL printer language provides a choice of pixel placement models: grid intersection and grid centered. The grid intersection model is the default: pixels are rendered on the intersections of the device-dependent grid covering the page. In the grid-centered model, the number of rows and columns are each reduced by one, and pixels are placed in the center of the squares, rather than at the intersections.

The following example illustrates the concepts of the two models (see Figure 5-5). Assume a rectangle extends from coordinate position (1,1) to position (3,4). As shown below, for the same coordinates, the grid-centered model produces a rectangle that is one dot row thinner and one dot row shorter than the grid intersection model. Thus, the grid-centered model should be selected when two or more polygons on a page may share a common border.

Since PCL printers print only at the intersections of the grid, the actual implementation of the grid-centered model is shown on the right.

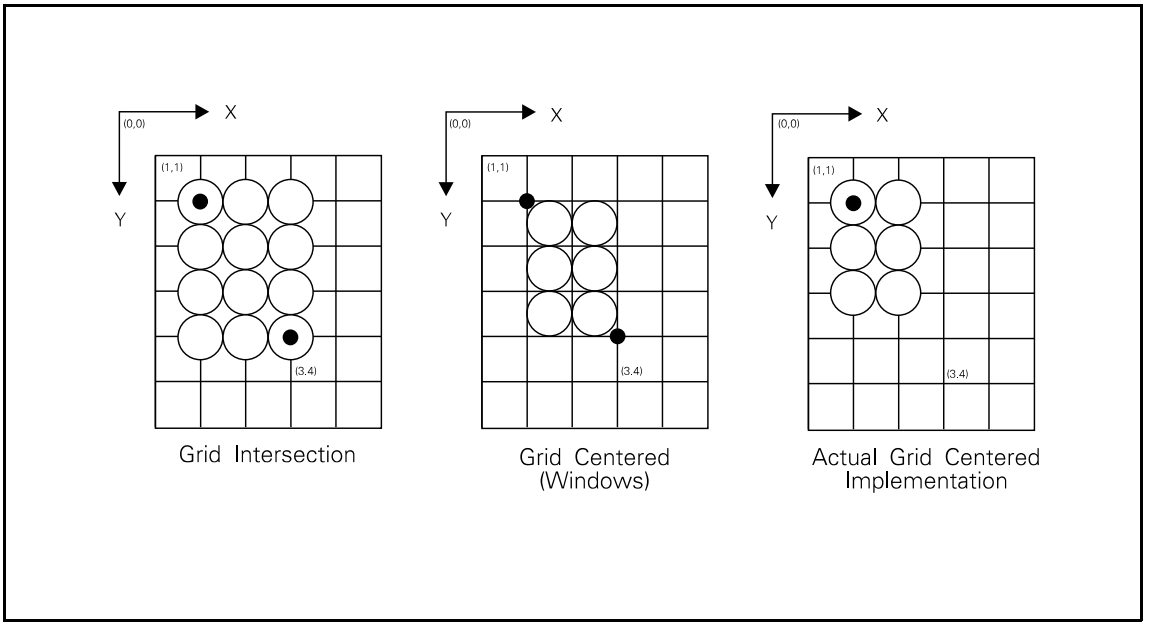


Figure 5-5. Pixel Placement

Note

The grid centered method is used by Microsoft Windows.

When rectangular area fills are used and grid intersection is used, an overlapping of pixels can occur if rectangular area fills are placed adjacent to one another (as shown below). Depending on the raster operation presently in effect, this overlap can produce undesirable results in the final printed image. To avoid this problem, use the grid centered method.

Note

Since PCL printers print only at intersections, grid-centered pixel placement is implemented as shown on the right.

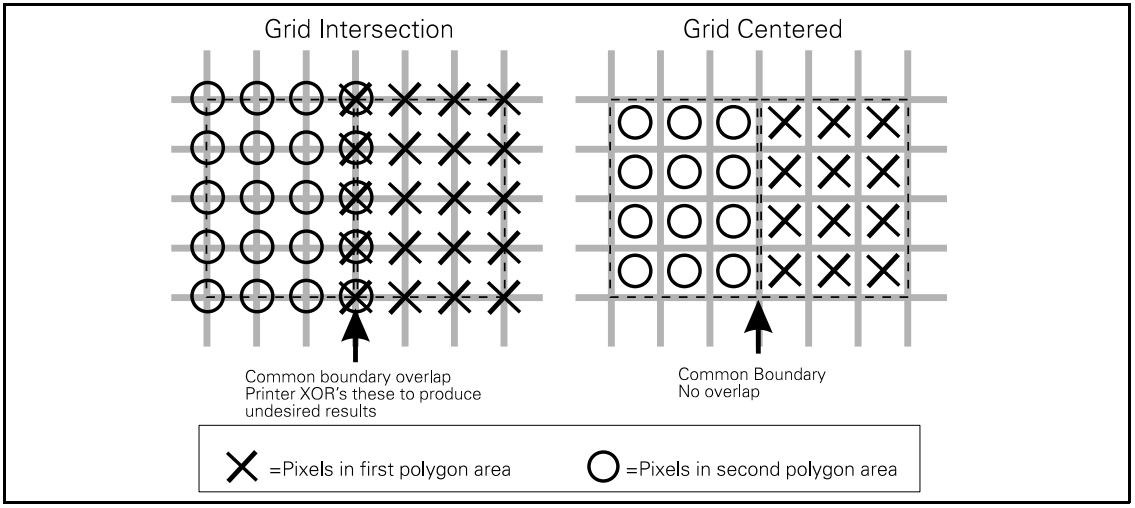


Figure 5-6. Pixel Placement Variations

There are two commands that modify the pixel placement function: the PCL Pixel Placement command (Ec*ℓ#R) and the HP-GL/2 Pixel Placement command (PP).

Pixel Placement Command

Determines how pixels are rendered in images.

$^{E}_{C}$***ℓ # R**

= 0 - Grid intersection
1 - Grid centered

Default = 0
Range = 0, 1 (command is ignored for other values)

Two models are used for rendering pixels when an image is placed on paper:

- Grid Intersection Model
- Grid Centered Model

This command can be used multiple times per page. It has no effect except to switch the model being used for imaging.

Note

- The PCL Pixel Placement command determines how pixels are placed for both PCL and HP-GL/2 operation.
- This command performs the same function as the HP-GL/2 PP command described in Chapter 7.

Filling with Patterns

The procedure for applying patterns to text, raster images, and rectangular areas is essentially the same, except that for text and raster images the Current Pattern (Ec*v#T) command is used, and for rectangular areas the Fill Rectangular Area (Ec*c#P) command is used. The procedures below describe how to fill with PCL and HP-GL/2 patterns.

Patterns for Text and Raster Images

Use the following general procedure to fill text and raster images with a non-solid pattern.

1. Specify the Pattern ID (Ec*c#G) command. For HP-defined patterns, select an ID that specifies the desired pattern.
2. Download the pattern (Ec*c#W). This step is for user-defined patterns only. The downloaded pattern adopts the current pattern ID.
3. Apply the pattern to all subsequent text and raster images. Specify the current pattern type (Ec*v#T).

Patterns for Rectangles

Use the following general procedure to apply a non-solid pattern to rectangular areas.

1. Specify the Pattern ID (Ec*c#G). For HP-defined patterns, select an ID that matches an HP-defined pattern.
2. Download the pattern (Ec*c#W). This step is for user-defined patterns only. The downloaded pattern adopts the current pattern ID.
3. Define the rectangle. Position the cursor and specify the rectangle size (Ec*c#A, Ec*c#B or Ec*c#H, Ec*c#V).
4. Apply the pattern to the rectangle. Send the Fill Rectangular Area command (Ec*c#P).

HP-GL/2 Patterns

PCL patterns can be used in HP-GL/2 mode, but HP-GL/2 patterns cannot be used in PCL mode. Using HP-GL/2, patterns are downloaded using the RF (Raster Fill) command, and applied using the FT (Fill Type) or SV (Screened Vectors) commands.

Pattern ID (Area Fill ID) Command

The Pattern ID command (formerly called Area Fill ID) identifies the specific shading, cross-hatch, or user-defined pattern. (This command is also used for rectangular area fill, described later in this chapter.)

E_C *** c # G**

Selecting Shaded patterns:

=
- 1 thru 2 = 1- 2% shade
- 3 thru 10 = 3-10% shade
- 11 thru 20 = 11-20% shade
- 21 thru 35 = 21-35% shade
- 36 thru 55 = 36-55% shade
- 56 thru 80 = 56-80% shade
- 81 thru 99 = 81-99% shade
- 100 = 100% shade

Selecting Cross-Hatch patterns:

=
- 1 - Pattern #1
- 2 - Pattern #2
- 3 - Pattern #3
- 4 - Pattern #4
- 5 - Pattern #5
- 6 - Pattern #6

Selecting User-Defined patterns:[1]

= ID number of user-defined pattern

[1] Not supported on all PCL 5 printers. Refer to the "PCL Feature Support Matrix" in Chapter 1 of the PCL 5 Comparison Guide for specifics.

Default = 0 (no pattern)
Range = 0 – 32767 (values outside the range are ignored)

For rectangular areas, the pattern "material" is determined by both the pattern ID and the value of the Fill Rectangular Area command. For other images, the pattern material is determined by the pattern ID and the value of the Select Pattern command.

Figure 5-7 and Figure 5-8 illustrate the HP-defined shading patterns and cross-hatched patterns, respectively.

Notes

- This command is used for both the Select Pattern and Rectangular Area Fill graphics.
- For user-defined patterns, this command, sent prior to downloading a user-defined pattern, assigns an ID pattern number to the downloaded pattern. (For more information, see "User-Defined Pattern Graphics," later in this chapter.)

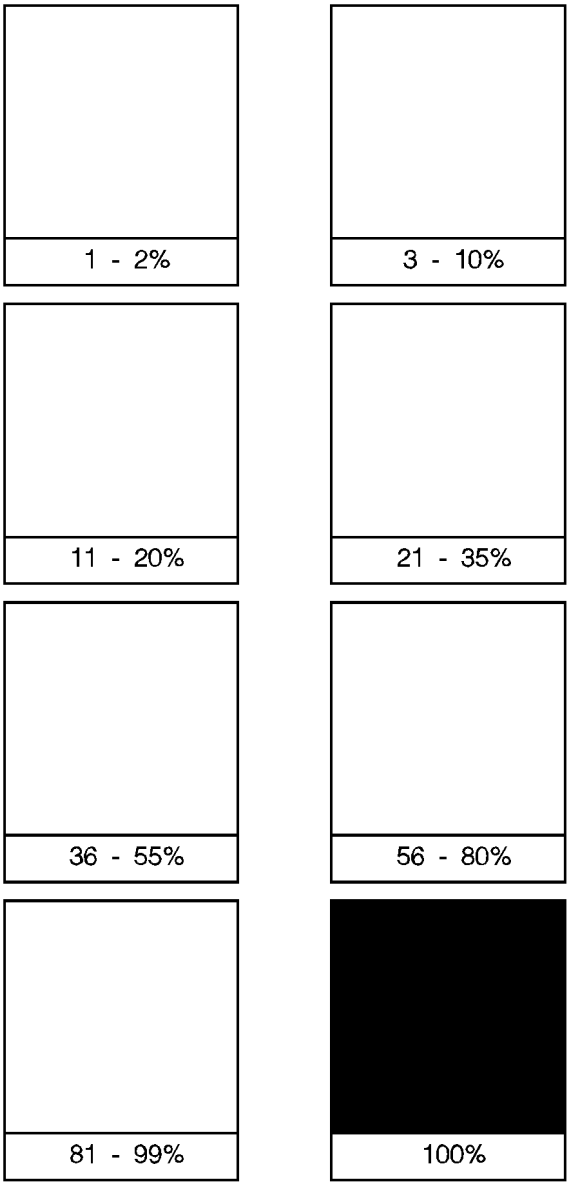


Figure 5-7. Shading Patterns

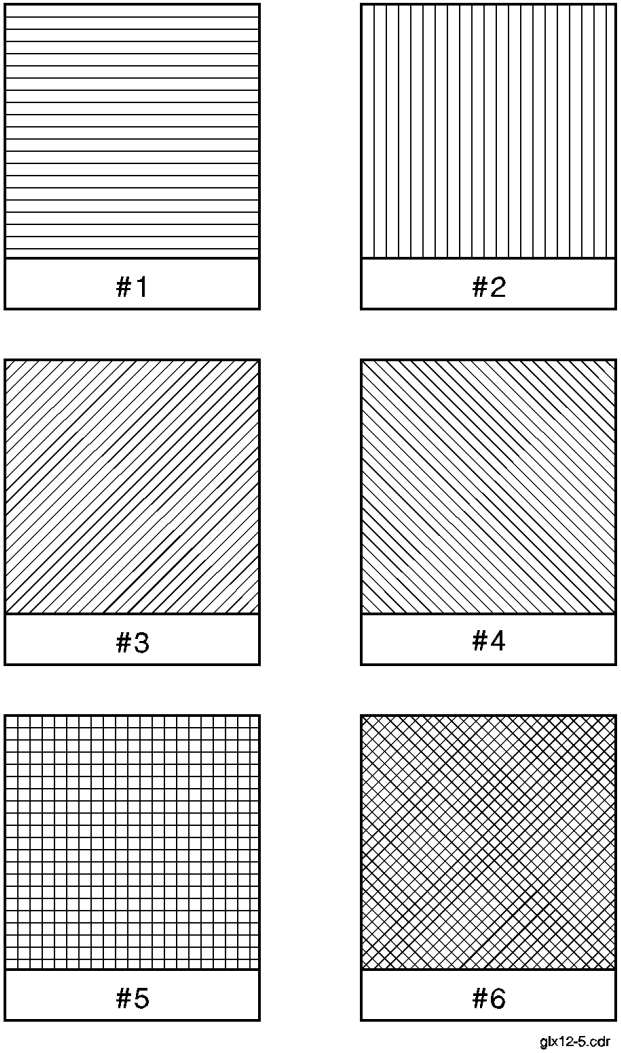


Figure 5-8. Cross-Hatch Patterns

Select Current Pattern Command

The Select Current Pattern command identifies the type of pattern to be applied onto the destination.

E_C *** v # T**

= 0 - Solid black or foreground color
1 - Solid white
2 - Shading pattern
3 - Cross-hatch pattern
4 - User-defined pattern

Default = 0
Range = 0 - 4 (values outside of range are ignored)

This command selects which type of pattern is applied. For values 2, 3, and 4, the desired shading level, cross-hatch pattern, or user-defined pattern number is identified by the Pattern ID command described earlier in this chapter.

Notes

- For selecting or changing the current pattern, the Select Current Pattern (E_C*v#T) and the Pattern ID (E_C*c#G) commands work together. **Sending the current pattern** (Select Current Pattern command) **alone does not change the current pattern; the Pattern ID must be sent first.** However, when selecting solid white (white rule) or solid black (black rule), only the Select Current Pattern command is required.
- Once a current pattern is selected, that pattern applies to all images placed on the page until a new pattern is selected.

User-Defined Pattern Graphics

In addition to the eight shading patterns and six cross-hatch patterns, users can design their own fill patterns. These **user-defined patterns** are downloaded to the printer and controlled using three commands:

- Download Pattern Ec*c#W [data]
- Set Pattern Reference Point Ec*p#R
- Pattern Control Ec*p#Q

Using User-Defined Patterns

To create a new pattern, a user defines a binary raster data image as a base pattern. This base pattern is downloaded to the printer using the User-Defined Pattern command. Prior to downloading the pattern, a Pattern ID command is sent to assign the user pattern an ID number. This ID number is used to select the pattern for printing and for pattern management.

To apply the pattern to an image, the printer duplicates or tiles (like placing ceramic tiles) the pattern across and down the page. This pattern can be applied to any image, including rectangular area fill.

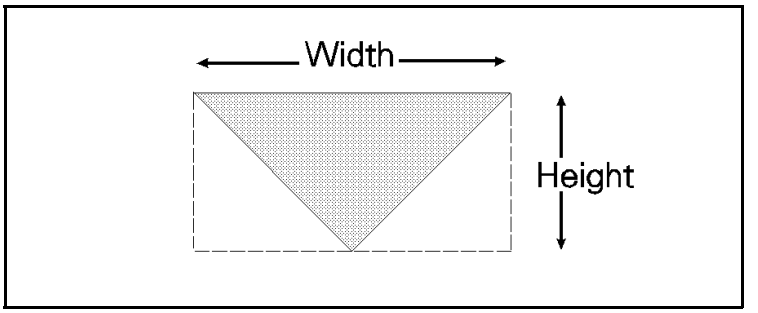


Figure 5-9. User-Defined Base Pattern Example

A user-defined pattern may be applied to any image in the same manner as the internal cross-hatch or shade patterns.

Note

For efficient memory usage and improved performance, it is strongly recommended that user-defined patterns should be 8x8, 16x16, or 32x32 in size. Specification of patterns that are either 1 pixel in height or width is strongly discouraged.

If user-defined halftones are also used, they need to be either the same size or multiples of each other to avoid render anomalies due to each pattern being rendered differently across the page (if tiled), or due to variations in xy position.

How the Printer Tiles a Pattern

A user-defined base pattern is a rectangular binary pattern stored in the printer. To apply the pattern to an image area on the page, the printer duplicates the base pattern across and down the page. This process is referred to as tiling. (The pattern is only applied to those areas on the page for which the pattern is required.)

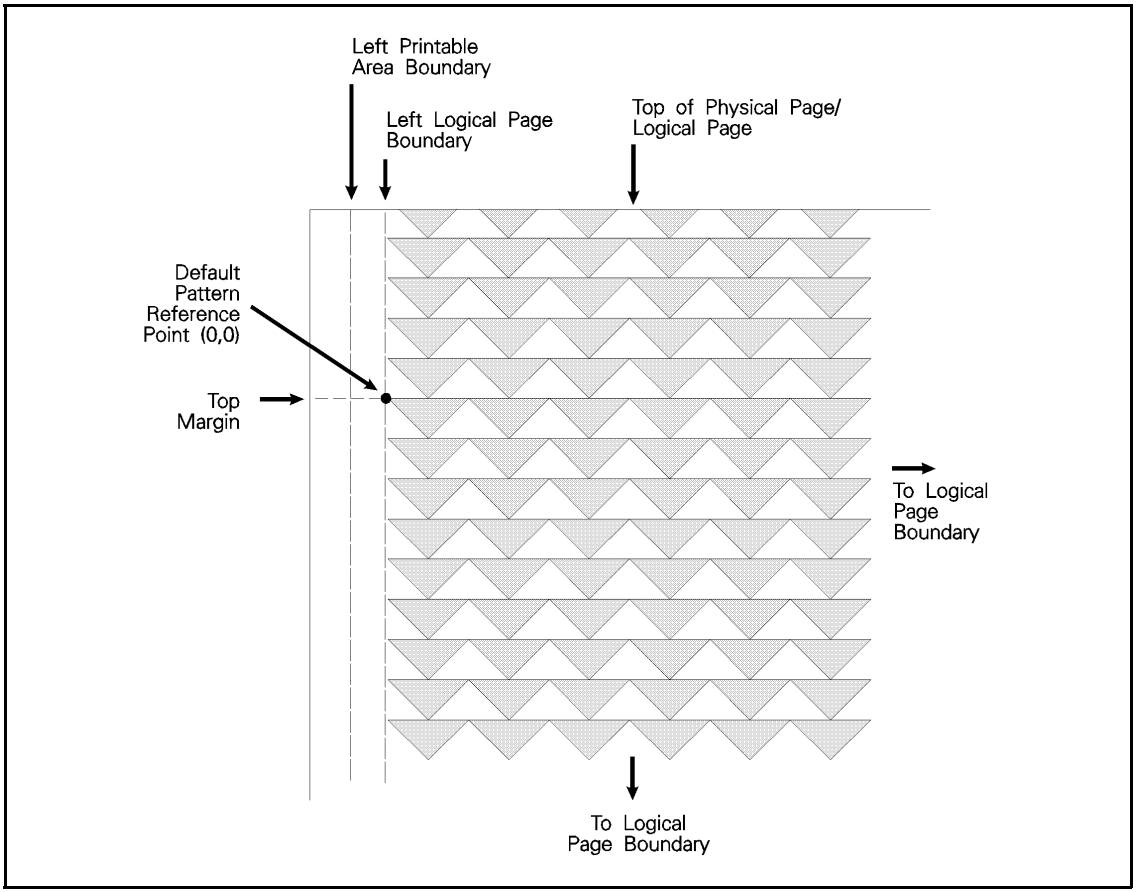


Figure 5-10. Pattern Layout Across the Printable Area

Pattern Reference Point

The pattern reference point is a position on the logical page at which the base pattern is positioned for tiling. The upper left corner of the base pattern is positioned at this point (see Figure 5-10). The default pattern reference point is position 0,0. However, it is possible to set the pattern reference point to the current cursor position. This allows the pattern to be positioned or adjusted for fill areas. The pattern reference point may be shifted more than once for as many fill areas as there are on a page (the area must be filled before the tile point is moved for the next fill area).

Figure 5-11 shows two areas filled with the pattern reference point fixed at the default (0,0) position. The lower portion of the illustration shows two areas in which the pattern reference point was moved to the upper left corner of each area and the area filled separately.

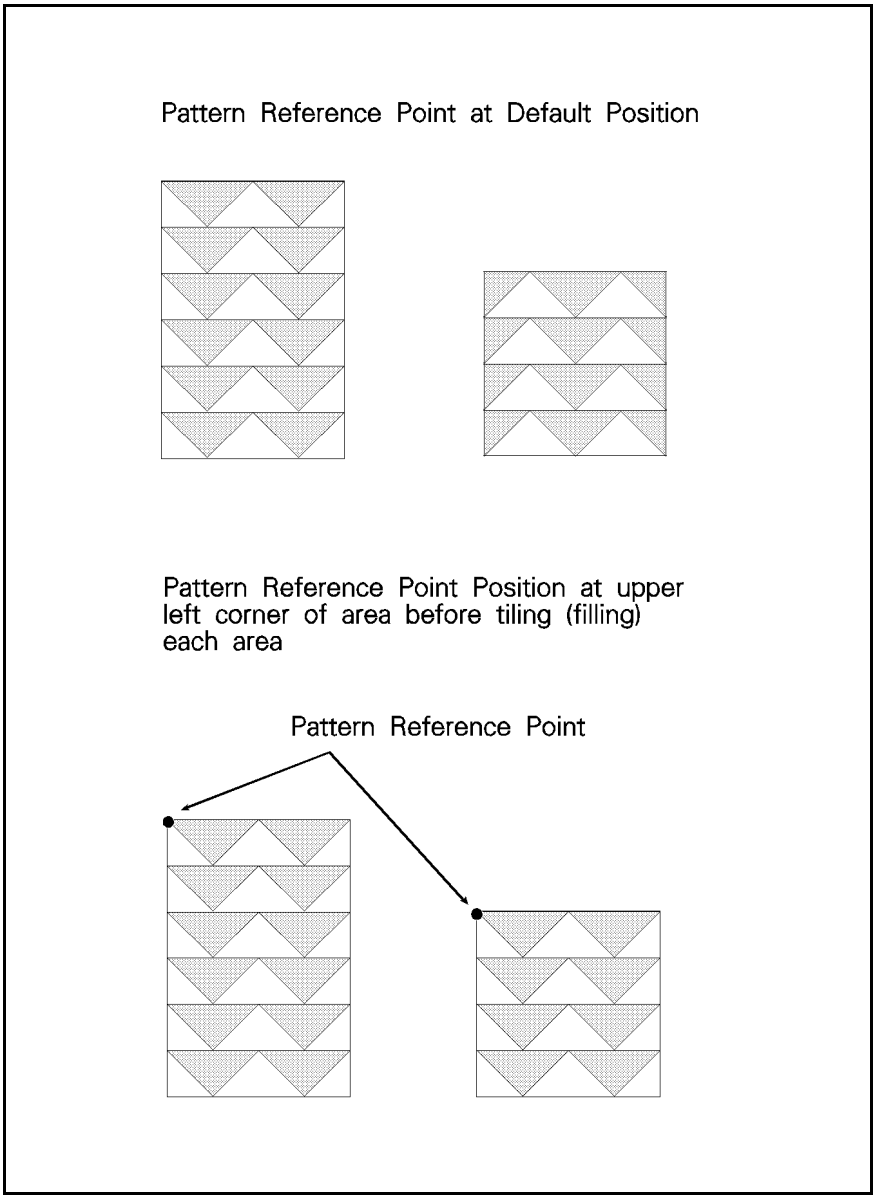


Figure 5-11. Moving Pattern Reference Point for Pattern Filling

Download Pattern Command

The Download Pattern command provides the means for downloading the binary pattern data that defines the user pattern.

$^{E}_{C}$ * c # W [pattern data]

= Number of pattern data bytes

Default = 0
Range = 0 – 32767 (values outside the range are ignored)

The value field (#) identifies the number of pattern data bytes that follow the Download Pattern command. In addition to the binary pattern data, there are eight bytes of pattern descriptor (header) information included in this pattern data. The format for a 300 dpi resolution header is shown in Table 5-3, below.

Table 5-3. User-Defined Pattern Header (300 dpi resolution)

Byte	15 - MSB 8	7 LSB-0	Byte
0	Format (0)	Continuation (0)	1
2	Pixel Encoding (1)	Reserved (0)	3
4	Height in Pixels		5
6	Width in Pixels		7
8	Pattern image		

Format (Byte 0)

This field indicates the downloadable pattern format:

Format 0	1 bit per pixel: black-and-white or foreground color. A "1" bit indicates black or foreground color for a color pattern. A "0" indicates either white or transparency, depending on the source and pattern transparency modes. A "0" cannot be colored.
Format 1	1 or 8 bits per pixel. This format uses the current palette. Data is sent pixel by pixel, and the bits/index field of the pixel encoding byte determines the number of bits defining a pixel.

Continuation (Byte 1)

This field, byte 1, must be set to "0." (This byte is for future printer support and does not currently provide any continuation operation.)

Pixel Encoding (Byte 2)

The bits/index field may be either 1 or 8. If the value is 1, the color of each pattern dot is specified by a single bit, supporting a two-color palette, which need not be black and white. If the value is 8, the color of each pattern dot is specified by one byte of data, allowing 256 colors. If the value of any byte is greater than the current palette size, the modulo function is applied when rendering.

7 5	4	3 0
000	Unused	Bits/Index

Reserved (Byte 3) This field, byte 3, is not currently used and must be set to 0.

Height in Pixels (Bytes 4 and 5) This field, bytes 4 and 5, identifies the number of raster rows (height) of the pattern, specified at device resolution. If the height is 0, the data is ignored and no pattern is defined. Pattern height must be less than 32767 pixels.

Width in Pixels (Bytes 6 and 7) This field, bytes 6 and 7, identifies the number of pixels (width) of the pattern, specified at device resolution. If the width is 0, the data is ignored and no pattern is defined. Pattern width must be less than 32767 pixels.

Pattern Image This field contains the raster data for the pattern. Data rows must be word-aligned. Pattern image data is formatted differently for each format type (see the data description under “Format Byte” on the previous page).

User-defined Pattern Example

This example shows how the user-defined pattern command is used to create new patterns. For this example, a pattern of triangles is used. The first step is to design the base pattern triangle (in this case, using 64 bytes of data). The base pattern binary data is shown below:

```
11111111111111111111111111111111
01111111111111111111111111111110
00111111111111111111111111111100
00011111111111111111111111111000
00001111111111111111111111110000
00000111111111111111111111100000
00000011111111111111111111000000
00000001111111111111111110000000
00000000111111111111111100000000
00000000011111111111111000000000
00000000001111111111110000000000
00000000000111111111100000000000
00000000000011111111000000000000
00000000000001111110000000000000
00000000000000111100000000000000
00000000000000011000000000000000
```

This translates into the following 64 bytes of hexadecimal values:

```
FF  FF  FF  FF
7F  FF  FF  FE
3F  FF  FF  FC
1F  FF  FF  F8
0F  FF  FF  F0
07  FF  FF  E0
03  FF  FF  C0
01  FF  FF  80
00  FF  FF  00
00  7F  FE  00
00  3F  FC  00
00  1F  F8  00
00  0F  F0  00
00  07  E0  00
00  03  C0  00
00  01  80  00
```

When using the 300 dpi User-Defined Pattern header (see Table 5-4), set the eight bytes of header information to the following values:

Byte 0 – Format 0 (00 hex)

Byte 1 – Continuation 0 (00 hex)

Byte 2 – Pixel Encoding 1 (01 hex)

Byte 3 – Reserved 0 (00 hex)

Byte 4/5 – Height in Pixels 0 / 16 (00 / 10 hex)

Byte 6/7 – Width in Pixels 0 / 32 (00 / 20 hex)

Byte 8 – Begins the first bytes of binary data.

The PCL code below downloads the user-defined pattern and assigns it an ID number of 3.

1. Specify the pattern ID number:

Ec***c3G** Assigns an ID number of 3 to the pattern data which follows.

2. Send the User-defined Pattern command:

Ec***c72W** Specifies that 72 bytes are to follow (8 bytes for the header plus 64 bytes of pattern data).

Send the pattern header and binary data:

```
00 00 01 00 00 10 00 20
FF FF FF FF
7F FF FF FE
3F FF FF FC
1F FF FF F8
0F FF FF F0
07 FF FF E0
03 FF FF C0
01 FF FF 80
00 FF FF 00
00 7F FE 00
00 3F FC 00
00 1F F8 00
00 0F F0 00
00 07 E0 00
00 03 C0 00
00 01 80 00
```

Notes

- There must be an even number of bytes in user-defined pattern data, hence the trailing zeros (“padding”) in the last eight data rows above.
- In the previous example, the raster data code is presented in hexadecimal, however, the numbers in the escape sequences are decimal.

Set Pattern Reference Point Command

The Set Pattern Reference Point command causes the printer to tile patterns with respect to the current cursor position (CAP). This command also specifies whether the pattern rotates with the print direction or remains fixed.

E_C *** p # R**

\# = 0 - Rotate patterns with print direction
1 - Keep patterns fixed

Default = 0
Range = 0,1 (values outside the range are ignored)

A value field of 0 rotates the patterns with changes in the print direction (see Print Direction command). For a value field of 1, patterns remain fixed for changes in print direction.

The default pattern reference point is the upper left corner of the logical page at the top margin (position 0,0). If the Set Pattern Reference Point command is not set, the pattern is tiled with respect to the default reference point.

Note

All patterns are rotated for changes in orientation, but the pattern reference point remains the same (refer to "Logical Page Orientation Command" in Chapter 5 of the *PCL 5 Printer Language Technical Reference Manual*).

This command applies to user-defined, shading, and cross-hatch patterns.

Pattern Control Command

The Pattern Control command provides a means for manipulating user-defined patterns.

E_C *** c # Q**

= 0 - Delete all patterns
(temporary & permanent)
1 - Delete all temporary patterns
2 - Delete pattern (last ID # specified)
4 - Make pattern temporary
(last ID # specified)
5 - Make pattern permanent
(last ID # specified)

Default = 0
Range = 0, 1, 2, 4, 5 (command is ignored for other values)

For value fields 2, 4, and 5, the Pattern ID (E_C*c#G) command is sent prior to the Pattern Control command to identify the specific pattern to which the Pattern Control command action is applied.

Rectangular Area Fills (Rules)

Rectangular area fills are a special case of source images—the source transparency mode has no effect, since the printer treats the rectangular area as a solid "black" (all 1's) source.

Rectangular areas may be filled using patterns or textures. The current Pattern ID (Ec*c#G) selects the pattern, and the Fill Rectangular Area command (Ec*c#P) tiles an area whose dimensions are specified by the Vertical and Horizontal Rectangle size commands (Ec*c#A, Ec*c#B, Ec*c#H, Ec*c#V). The rectangular area does not exist and cannot be printed until the Fill Rectangular Area command (Ec*c#P) has been issued, even though the rectangular area has been specified.

Filling a rectangular area does not change the current active cursor position (CAP). The filled rectangular area is not affected by end-of-line wrap, perforation skip mode, or margins. A rectangular area may extend beyond the margins, but it will be clipped to the printable area of the logical page. Rectangular areas are not affected by graphics resolution (Ec*t#R).

Except for the absence of white pixels in the source, pattern transparency operates the same way for rectangular area fills as for other sources. The non-white pixels of the pattern are poured through the entire rectangular area onto the destination. The white bits of the pattern are either applied or ignored, based on the pattern transparency mode. If foreground color is used, it is applied to the non-white bits of the pattern prior to pouring (except for user-defined color patterns).

Note

The Pixel Placement command (Ec*ℓ#R) affects rules.

The commands used to print rectangular area fills are described beginning on the next page.

Horizontal Rectangle Size (PCL Units)

This command specifies the horizontal rectangle size in PCL Units.

E_C *** c # A**

= number of PCL Units (valid to 4 decimal places).

The horizontal rectangle size is clipped to the bounds of the logical page. Values greater than the logical page boundary are acceptable; however, the final output is limited to the printable area of the logical page. Values outside the range of 0 - 32767 are ignored.

The default rectangle size is 0. Power-up and reset return this value to the default.

Horizontal Rectangle Size (Decipoints)

This command specifies the horizontal rectangle size in decipoints.

E_C *** c # H**

= number of decipoints (valid to 4 decimal places).

The horizontal rectangle size is clipped to the bounds of the logical page. Values greater than the logical page boundary are acceptable; however, the final output is limited to the printable area of the logical page. Values outside the range of 0 - 32767 are ignored.

Decipoints are converted into printer dot values, and any fraction of a dot is rounded up to the next full dot size.

The default rectangle size is 0. Power-up and reset return this value to the default.

Vertical Rectangle Size (PCL Units)

This command specifies the vertical rectangle size in PCL Units.

E_C *** c # B**

= number of PCL Units (valid to 4 decimal places).

The vertical rectangle size is clipped to the bounds of the logical page. Values greater than the logical page boundary are acceptable; however, the final output is limited to the printable area of the logical page. Values outside the range of 0 - 32767 are ignored.

The default rectangle size is 0. Power-up and reset return this value to the default.

Vertical Rectangle Size (Decipoints)

This command specifies the vertical rectangle size in decipoints.

E_C *** c # V**

= number of decipoints (valid to 4 decimal places).

The vertical rectangle size is clipped to the bounds of the logical page. Values greater than the logical page boundary are acceptable; however, the final output is limited to the printable area of the logical page. Values outside the range of 0 - 32767 are ignored.

Decipoints are converted into printer dot values, and any fraction of a dot is rounded up to the next full printable dot.

The default rectangle size is 0. Power-up and reset return this value to the default.

Fill Rectangular Area

The Fill Rectangular Area command determines the type of pattern used to fill the rectangle.

$^{E}_{C}$ *** c # P**

= 0 - Solid black or foreground color
1 - Solid white fill
2 - Shaded fill
3 - Cross-hatch fill
4 - User-defined pattern fill
5 - Current pattern fill

Default = 0
Range = 0 - 5 (out-of-range values are ignored)

Note

If a foreground color is selected, solid, shaded, and cross-hatch patterns are printed in the foreground color. User-defined patterns are not affected by the foreground color, but can contain color if they are defined as such. Solid white fills are not affected by foreground color.

Black fill—fills the rectangular area with black fill or with the current foreground color.

White fill—erases any fill in the rectangular area (it fills the rectangular area with white fill). Pertaining to white fills, the pattern transparency mode is always “opaque” (that is, the white pixels always have an effect on the destination).

Shaded fill—fills the rectangular area with one of eight shading patterns as specified by the Pattern ID command.

Cross-Hatch fill—fills the rectangular area with one of the six cross-hatched patterns as specified by the Pattern ID command.

User-defined fill—fills the rectangular area with custom pattern data as specified by the Pattern ID command and downloaded by the User-Defined Pattern command.

Current Pattern—fills the rectangular area with the current pattern.

Notes

- The current pattern is not applied to a rectangular area unless specified by this command.
- The order in which data (patterns/rules, text, raster) is received is the order in which it is processed during the rasterization of the page.
- The fill or pattern used as the current pattern is selected using the Select Current Pattern (Ec*v#T) command.
- Black fill (value field 0), also known as black rule, and the white fill (value field of 1) "patterns" do not have a choice of different patterns, and thus do not require a pattern specification using the Pattern ID command.

The upper left corner of the rectangular area is located at the cursor position when printing a rectangular area. After printing the rectangular area the cursor is returned to the upper left corner; the cursor position does not change positions as a result of printing a rectangular area.

Rectangular areas are independent of the text area and perforation skip mode; these boundaries are ignored (rectangles are not clipped at these boundaries). Addressable rectangular areas are limited to the logical page. Rectangular areas that extend outside the logical page are clipped at the logical page boundaries (refer to the *PCL 5 Printer Language Technical Reference Manual* for logical page and printable area boundary specifications).

The pattern transparency mode controls how the area fill pattern is applied to the page. Refer to the following section for a description of how the pattern transparency mode affects the rectangular fill area.

A white fill "erases" any data placed within the rectangular area, regardless of the transparency mode settings. However, after a white fill erases data within an area, data subsequently placed within that area will be visible.

Pattern Transparency for Rectangular Area Fill

Pattern transparency affects how a pattern is applied to the rectangular fill area. The pattern and pattern type are selected by the Pattern ID command (Ec*c#G) and the Fill Rectangular Area (Ec*c#P) command (described earlier in this chapter).

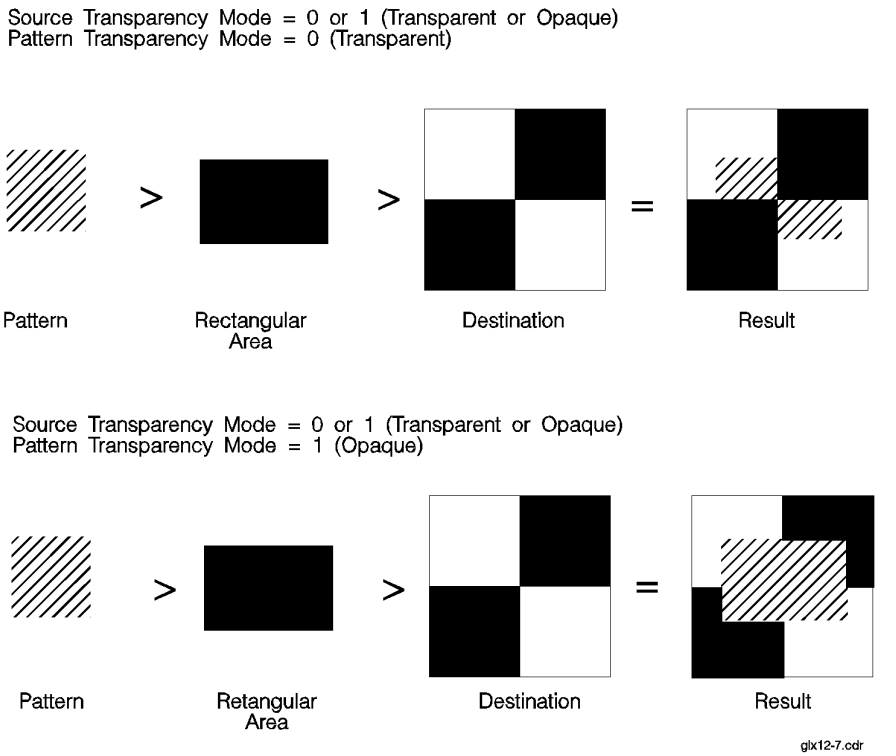
Note

Source transparency has **no effect** on the rectangular fill area since the rectangular area is viewed as all 1's (a solid black source image).

When applying a pattern (area fill) to the rectangular area, the pattern transparency mode affects the final result the same as it does when filling other images or text. The pattern transparency mode determines the effect white pixels of the pattern have on the destination for value fields 0 (black fill), 2 (shaded fill), 3 (cross-hatch fill), or 5 (current pattern fill) of the Fill Rectangular Area command.

The "0" bits of the fill pattern are either applied (opaque) or ignored (transparent) based on the transparency mode setting (see Figure 5-12). When a value field of 1 (white fill) is used, pattern transparency mode is **always treated as if it were opaque**.

The effect of transparency modes on rectangular areas is illustrated in Figure 5-12. In both examples, the source transparency mode is opaque regardless of the actual setting. In the first example, the pattern transparency mode is transparent; the white pixels in the pattern are not applied to the destination, so that the pattern is visible in only two quadrants of the destination. In the second example, the pattern transparency mode is opaque, and the pattern is visible in the entire rectangular area.



This example is a monochrome example and assumes the default ROP.

Figure 5-12. Effect of Transparency Modes on Rectangular Areas

Rectangular Fill Examples

Following are two examples that demonstrate the way to print and fill rectangular shapes. The first example demonstrates filling rectangles with solid fill and the second example demonstrates filling with a shading pattern.

Solid Fill (Black/White)

To print a 900 by 1500 Unit black rule (3 inches by 5 inches at 300 units-per-inch), then "white fill" a small area inside the black rectangle, perform the following steps.

1. Position the cursor:

Esc*****p300x400Y	This moves the cursor to PCL Unit position (300, 400) within the PCL coordinate system.

2. Specify the width of the rule:

Esc*****c900A	This sets the rule width to 900 PCL Units (3 inches at 300 units-per-inch).

3. Specify the height of the rule:

Esc*c1500B	This sets the rule height to 1500 PCL Units (5 inches at 300 units-per-inch).

4. Print the rule:

Ec*c0P	This example prints a black filled rectangular area.

5. Position the cursor inside the rectangular area:

Ec*p600x700Y

6. Specify the width and height for the smaller white fill rectangular area:

Ec*c300a600B

7. Select the white fill and print.

Ec*c1P

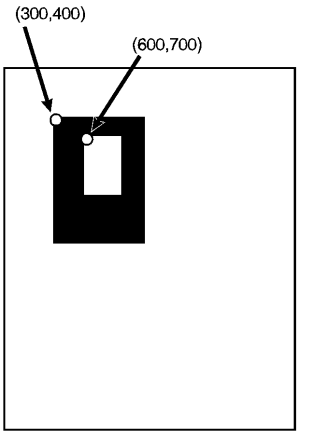


Figure 5-13. Solid Fill Example

Shaded Fill

To print a 900 by 1500 Unit 25% shaded rectangle (3 inches by 5 inches at 300 units-per-inch), perform the following steps.

1. Position the cursor:

Esc*p300x400Y	This moves the cursor to PCL Unit position (300, 400) within the PCL coordinate system.

2. Specify the width of the rectangle:

Esc*c900A	This sets the rectangle width to 900 PCL Units (3 inches at 300 units-per-inch).

3. Specify the height of the rectangle:

Esc*c1500B	This sets the rectangle to 1500 PCL Units (5 inches at 300 units-per-inch).

4. Specify the Pattern ID:

Ec*c25G	This sets the Pattern ID to 25.

5. Print the rectangular shaded area:

Ec*c2P	This example prints the following:

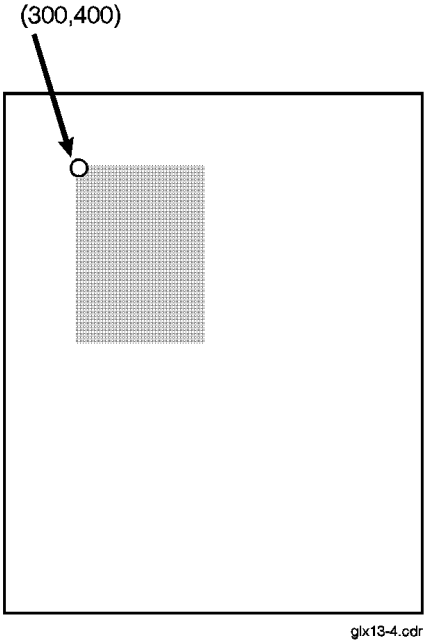


Figure 5-14. Shaded Fill Example

6

Raster Graphics

Introduction

A raster image is an image composed of pixels. Pictures in newspapers or on television screens (also, a page printed by this printer) are examples of raster images. The PCL language includes commands for printing raster graphic images. These commands enable PCL 5 printers to receive binary data and print the data as a raster image.

Note

When the printer receives the Start Raster command (Ec*r#A), it enters a restricted state called raster mode. Raster mode locks out commands that affect rendering of the graphics image. These commands remain locked out until the End Raster command (Ec*rC) is received. The only commands allowed in raster mode are:

- Raster Compression (Ec*b#M)
- Seed Row Source (Ec*b#S)
- Transfer Raster by Row/Block (Ec*b#W)
- Transfer Raster by Plane (Ec*b#V)
- Y Offset (Ec*b#Y)

The binary data used to create a raster image is divided into dot rows: a row describes a strip of the image that is one dot high. For monochrome printers, each dot position within a row is represented by a binary data bit. If a bit in a row is set to one, a dot is printed; if the bit is set to zero, no dot is printed for that position. A dot row of raster image data is transferred to the printer as a string of bytes containing a dot-per-bit representation of the row.

Color printers require more than one bit per pixel, since not only must the pixel be turned on or off, but the correct color must be selected.

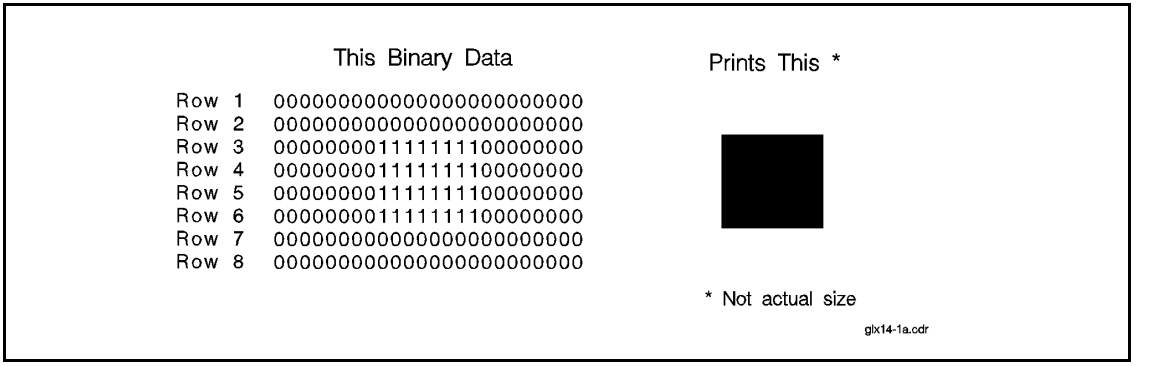


Figure 6-1. Binary Raster Data

Since it takes a considerable amount of data to create even a small raster image, several methods are provided to reduce the amount of data needed to define an image. (Note that the above illustration creates a rectangle 0.013 by 0.027 inches; a binary "1" = 1 dot = 1/300 inch.) These reduction techniques include several binary data compression methods, and additional reduction techniques associated with the **raster area** feature (see Figure 6-2).

Data compression methods include: run-length encoding, tagged image file format (TIFF), delta row, adaptive compression, and "compressed replacement" delta row compression. These techniques are described in detail later in this section, under the Set Compression Method command.

In addition to the compression methods, the raster area feature provides some other raster reduction techniques which utilize a defined raster area. The raster area is defined by a width and height which are set using the Raster Width and the Raster Height commands.

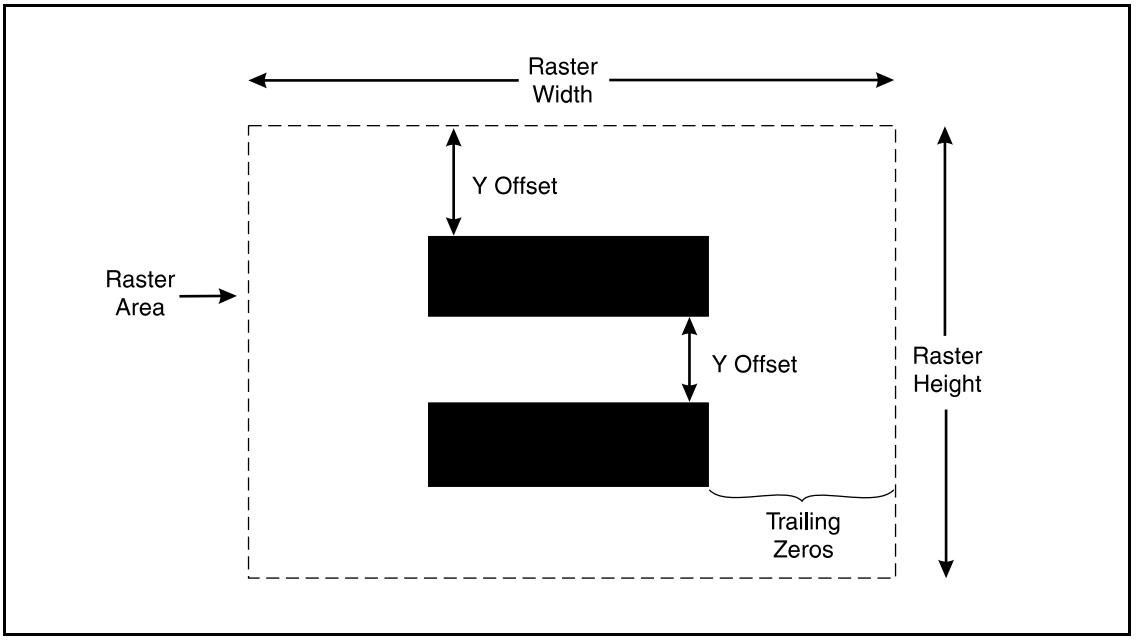


Figure 6-2. Raster Area

Zeroed rows at the top and within the raster image can be eliminated using the Y-offset feature. Y-Offset identifies how many rows to skip (index zero fill). The Y-offset command specifies the Y-offset or number of rows for the printer to fill with zeroed rows. This provides a reduction in data for increased efficiency, but depending on the color of index 0, it may produce unwanted results.

Full all-zero rows at the end of the raster image need not be sent. The printer automatically fills in any unsent zeroed rows from the end of the raster image (last raster row with any “1”s) to the bottom of the raster area.

The final data reduction technique provided by the raster area involves the printer’s ability to fill in trailing zeros to the edge of the raster area. Any zeros following the last “1” in the raster row to the edge of the picture area need not be sent. The printer automatically fills them. This technique eliminates the need to transmit raster data rows that are

all the same length, as required in a raster image which does not use the raster area feature.

The raster area represents a boundary. Within this boundary the printer zero-fills missing rows and fills in short rows to the edge of the raster area. However, in addition to filling to the boundaries of the raster area, the printer also clips any raster line which extends beyond the boundary. Thus, if an image extends beyond the raster area, then that portion of the image is not printed.

When the raster area reduction techniques are used in conjunction with the raster compression techniques, a considerable savings in transmitted data can be realized. This results in a saving of host storage requirements and data transmission time. However, these reduction techniques do not reduce the amount of printer memory required for page formatting.

Raster Graphics Command Sequence

PCL raster commands include: Start Raster Graphics and End Raster Graphics commands, Transfer Raster Data by Row, Raster Compression, Raster Presentation, Raster Resolution, Raster Height and Raster Width (which define the raster area), and Raster Y Offset commands. For printing well-behaved raster graphics, the normal sequence of execution for these commands is shown below. Hewlett-Packard strongly recommends that developers use this command sequence in their applications.

Note

Although the source raster height and width commands are not necessary, they improve memory efficiency.

```
Raster Presentation
Raster Resolution
Raster Height
Raster Width
Start Raster Graphics
Y Offset
Raster Compression
Transfer Raster Data
      …

Transfer Raster Data
Y Offset
Transfer Raster Data
      …

Y Offset
Raster Compression
Transfer Raster Data
      …

Raster Compression
Transfer Raster Data
End Raster Graphics
```

The emphasis in the previous command sequence is that the Raster Presentation Mode, Raster Resolution, Raster Height, and Raster Width are all set outside the *start..data..end* sequence of commands. Also, the entire image is sent during the *start..data..end* sequence, choosing the most effective compression method for each raster row of data.

Raster Presentation, Raster Resolution, Raster Height, Raster Width, and Raster Compression are all true modes. Once specified, the printer remains in that mode unless explicitly changed by issuing the command again, or reset to default values by a soft reset, self test, font printout, or power cycle.

Note

Only raster data appearing within the intersection of the logical page, the printable area, the raster width, and height is printed. If raster width and/or raster height have not been set (are defaulted), then the intersection of the logical page and the printable area determines where raster graphics appear; raster data is clipped to the printable area.

Raster Graphics Resolution Command

Raster graphics can be printed at various resolutions. This command designates the resolution of subsequent raster data transfers in dots per inch.

$^{E}_{C}$ *** t # R**

= 75 - 75 dots-per-inch
100 - 100 dots-per-inch
200 - 200 dots-per-inch
150 - 150 dots-per-inch
300 - 300 dots-per-inch

Default = 75
Range = 75, 100, 150, 200, 300

This command must be sent prior to the start graphics command. The factory default resolution is 75 dots-per-inch.

Note

Lower resolution graphics occupy less user memory. For example, the number of bits required to represent a two-inch by three-inch image at 75 dots-per-inch is 33,750. The same image at 300 dots-per-inch requires 540,000 bits.

When configured for 300 dpi resolution, the printer automatically expands raster graphics transferred at resolutions less than 300 dots-per-inch to 300 dots-per-inch during printing. Figure 6-3 illustrates how a single bit is translated into the corresponding printed dots in various graphics resolutions when the printer is configured for 300 dpi.

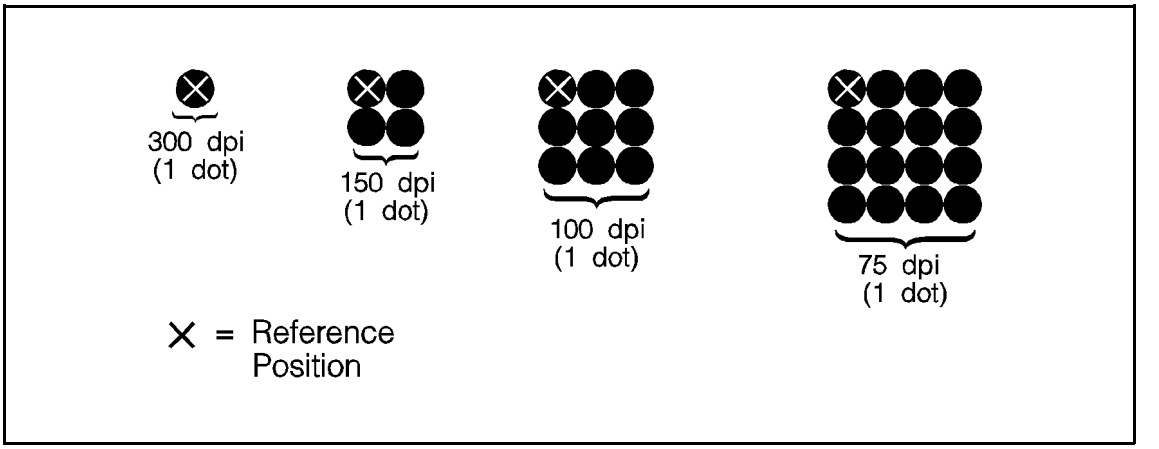


Figure 6-3. Raster Graphics Expansion - at 300 dpi

Note

Rectangular area fills and character data are not affected by changes in resolution. Rectangular Area fills and character data always print at the maximum resolution, regardless of the resolution setting.

Raster Graphics Presentation Mode Command

The Raster Graphics Presentation command specifies the orientation of the raster image on the logical page.

$^{E}_{C}$ *** r # F**

= 0 - Raster image prints in orientation of logical page

3 - Raster image prints along the width of the physical page

Default = 3
Range = 0, 3

- A value of **0** indicates that a raster row will be printed in the positive X-direction of the PCL coordinate system. (The print direction translates the PCL coordinate system.)
- A value of **3** indicates that the raster graphics will be printed along the width of the physical page, regardless of logical page orientation. In portrait orientation, a raster row is printed in the positive X-direction of the PCL coordinate system and a subsequent raster row is printed beginning at the next dot row position in the positive Y-direction. In landscape orientation, a raster row is printed in the positive Y-direction of the PCL coordinate system and a subsequent raster row is printed beginning at the next dot row position in the negative X-direction. Figure 6-4 illustrates presentation modes 0 and 3.

Raster Presentation Mode	Orientation	Default Graphics Margin
0	portrait	logical page left bound
0	reverse portrait	logical page left bound
0	landscape	logical page left bound
0	reverse landscape	logical page left bound
3	portrait	logical page left bound
3	reverse portrait	logical page left bound
3	landscape	50 dots in from the logical page *top* bound
3	reverse landscape	50 dots in from the logical page *top* bound

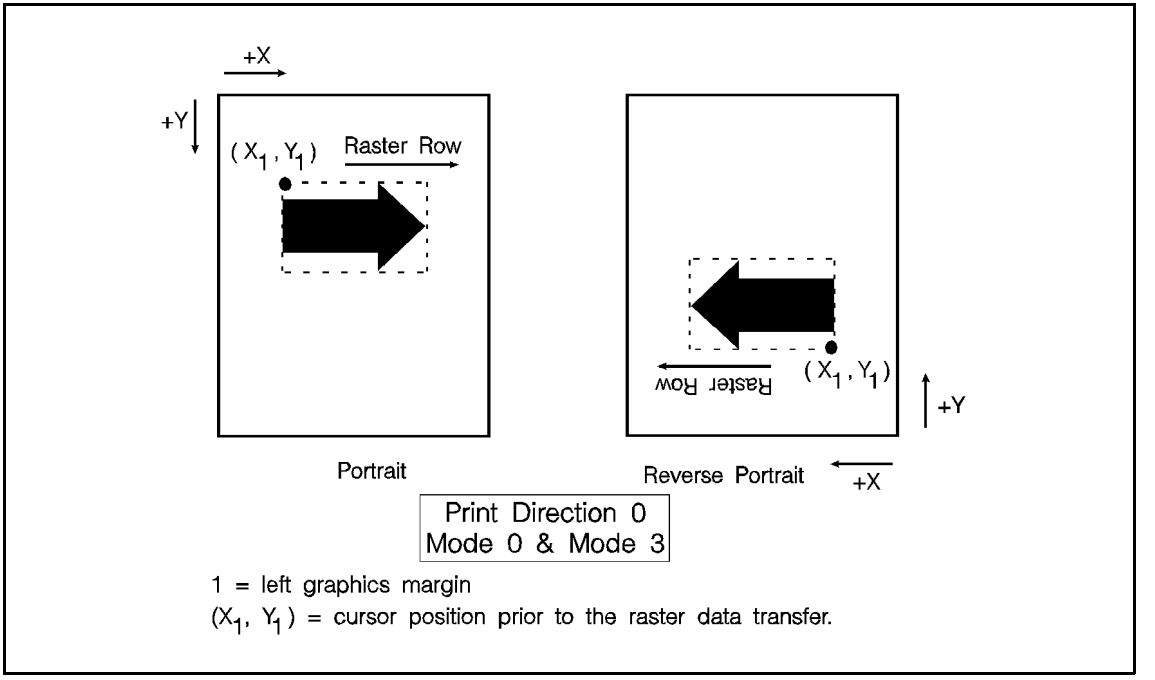


Figure 6-4. Raster Graphics Presentation Mode for Portrait Orientation

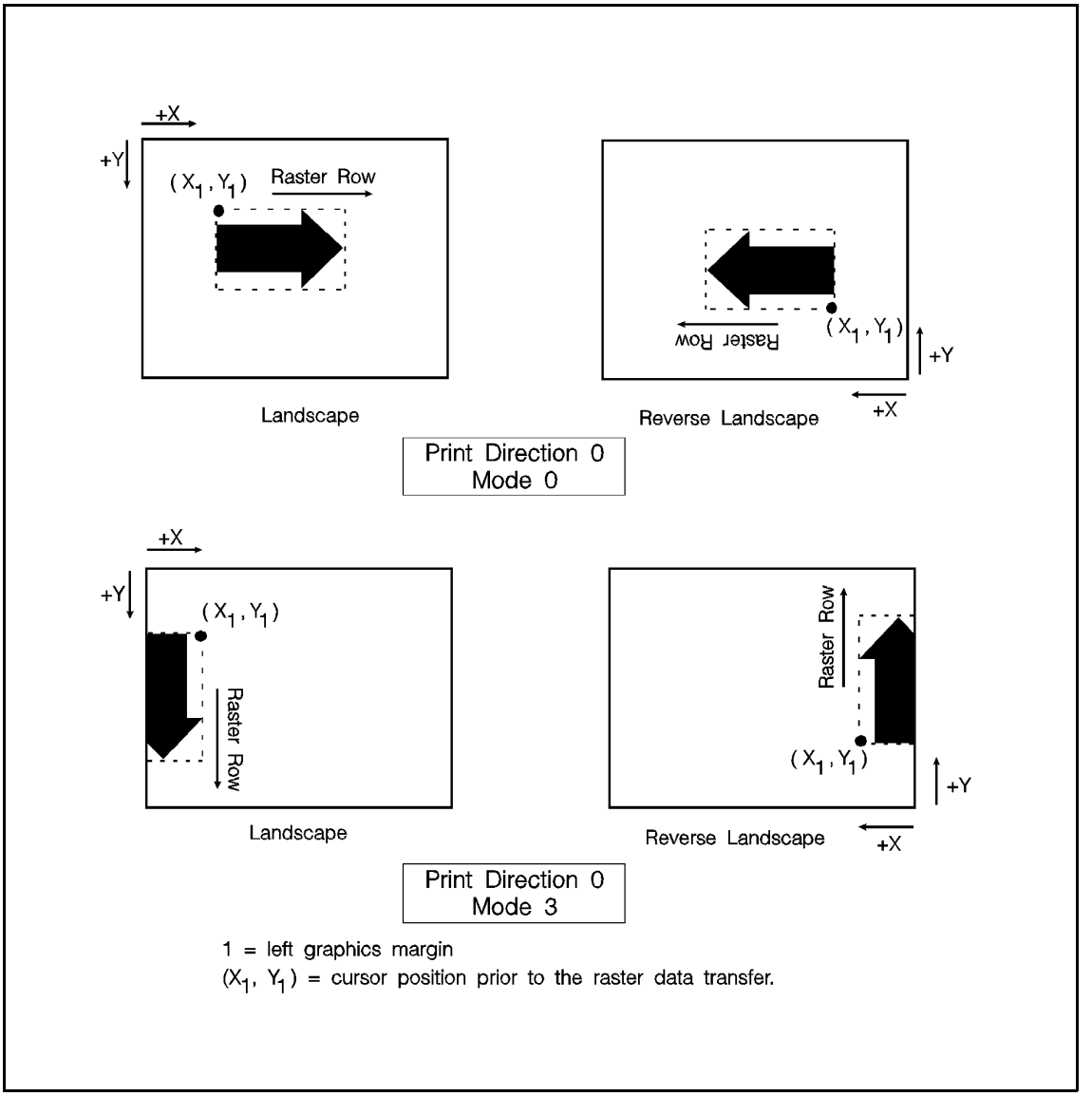


Figure 6-5. Raster Graphics Presentation Mode for Landscape Orientation

Source Raster Height Command

The Raster Height command specifies the height in raster rows of the raster area. Height is the direction perpendicular to the direction that raster rows are laid down, hence, height is subject to the current raster presentation mode and print direction (see Figure 6-6).

$^{E}_{C}$ *** r # T**

= Height in raster rows

Default = N/A
Range = 0 to (logical page length – current Y-position of the 0, cursor)*

* Greater values default to (logical page length - current Y cursor position).

Note

Specifying the raster width and raster height improves memory usage. Therefore it is highly recommended.

This command fills the raster area to the full raster height with zeroed rows. Unspecified rows map to either white or transparent depending on the source transparency mode (this is true only if index 0 is white).

When a Transfer Raster Data command is received that causes any raster row to extend beyond the row boundary set by the Raster Height command, the row outside the boundary is clipped. This includes the case where the cursor is moved beyond the height boundary with a Raster Y Offset command and the printing of raster data is attempted.

If you have specified either a raster height or a raster width of 0 and a Start Raster Graphics (or Transfer Raster Data) command is received, then the entire raster graphic is clipped. If both a raster height and a raster width are specified (non-zero) and a Start Raster Graphics (or

Transfer Raster Data) command is received, then the raster area is guaranteed to be logically zeroed-out.

Note

For color printers, a zero fill is not necessarily white.

If the raster height is not set, the raster height is ignored so that no padding or clipping of rows takes place.

This command is ignored after the Start Raster Graphics or Transfer Raster Data commands until the next End Raster Graphics command.

Note

Only raster data appearing within the intersection of the logical page, the printable area, and if set, the raster width and height, is printed. Data outside the intersection is clipped.

Upon receiving an End Raster Graphics (Ec*rC) command, the cursor position is set to the left graphics margin of the next raster row after the raster height boundary.

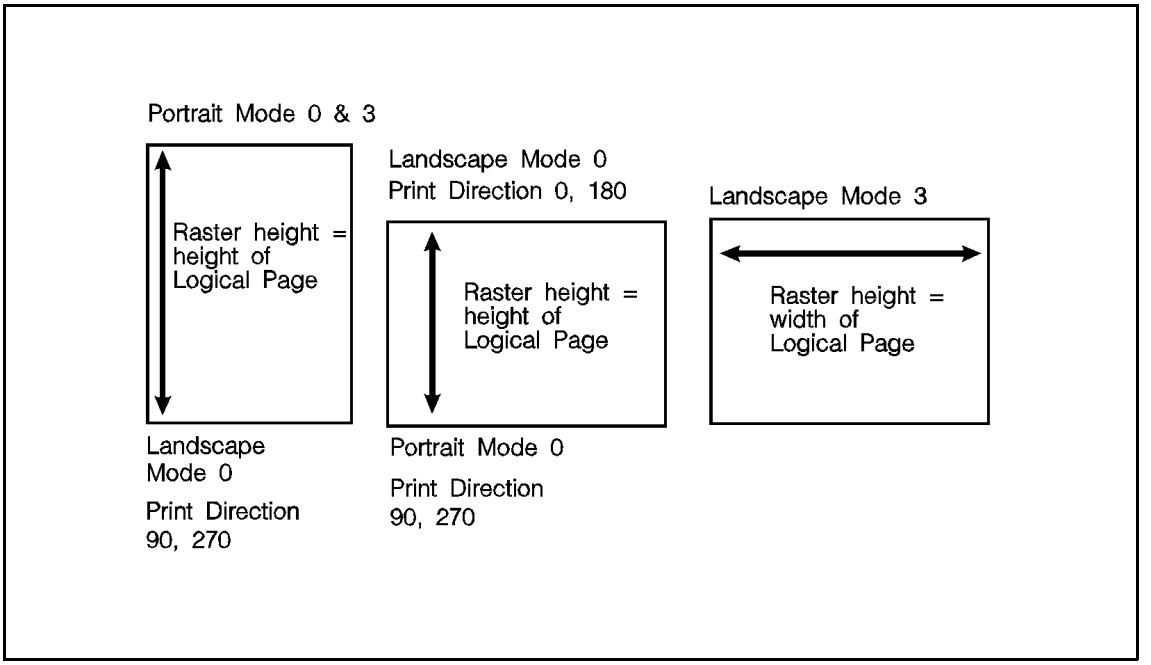


Figure 6-6. Maximum Raster Height

Source Raster Width Command

The Raster Width command specifies the width in pixels of the raster area. Width is in the direction that the raster rows are laid down, hence width is subject to the current raster presentation mode and print direction (see Figure 6-7).

$^{E}_{C}$ *** r # S**

= Width in pixels of the specified resolution

Default = depends on raster presentation mode: when presentation mode is 0 then width = width of logical page minus left graphics margin; when presentation mode is 3 then width = dimension of logical page along paper length minus left graphics margin.
Range = 0 to (logical page width minus left graphics margin)*

*Greater values default to the (logical page width – left graphics margin).

Note

Specifying the raster width and raster height improves memory usage. Therefore it is highly recommended.

This command allows you to implicitly tell the printer to pad raster rows that are not specified for the full raster width with zeros. Unspecified data maps to either white or transparent depending on the source transparency mode (this is true only if index 0 is white).

Note

For color printers, a zero fill is not necessarily white.

When a Transfer Raster Data command is received that specifies a row of data that is longer than the raster width, the data that extends beyond the raster width is clipped.

This command is ignored after the Start Raster Graphics or Transfer Raster Data commands, until the next End Raster Graphics command.

Note

Only raster data appearing within the intersection of the logical page, the printable area, and if set, the raster width and height is printed. Data outside the intersection is clipped.

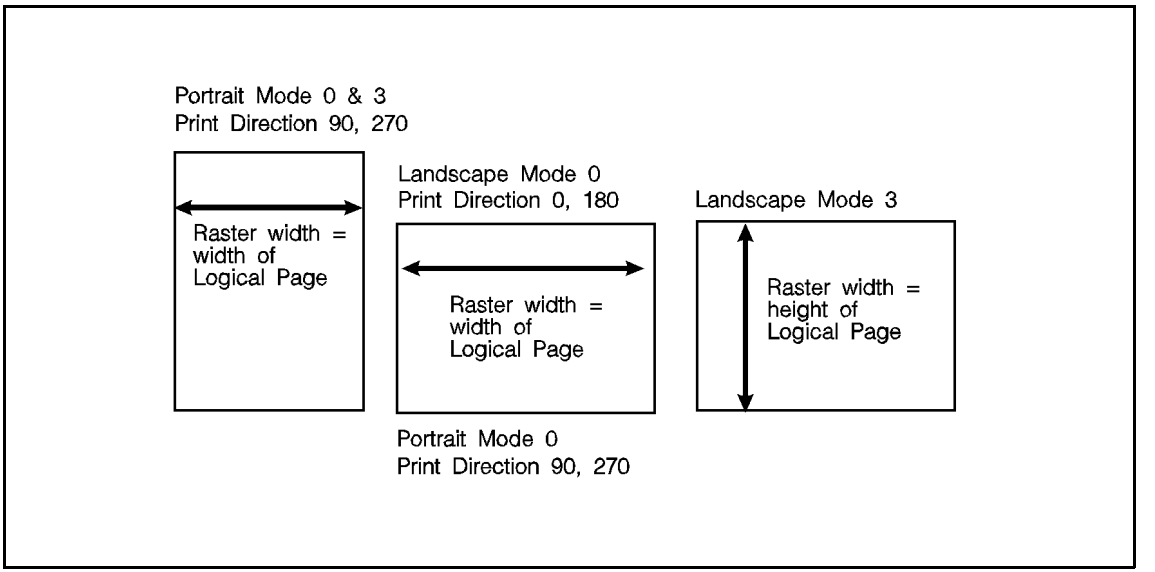


Figure 6-7. Maximum Raster Width

Start Raster Graphics Command

The Start Raster Graphics command identifies the beginning of the raster data and also specifies the left graphics margin.

Esc * r # A

= 0 - Start graphics at default left graphics margin (X-position 0).

1 - Start graphics at current cursor position (current X-position).

2 - Raster scaling on—start at left boundary.

3 - Raster scaling on—start at CAP.

Default = 0
Range = 0 - 3 (out-of-range values default to 0)

A value of 0 specifies that the left graphics margin is at the default left margin of the page (X-position 0). A value of 1 specifies that the left graphics margin is at the current X-position. Values of 2 or 3 are equivalent to 0 and 1, but also enable resolution-independent scaling. In presentation mode 3, the location of the left graphics margin varies depending on the orientation.

Once a Start Raster Graphics command is received by the printer, raster graphics resolution, raster graphics presentation mode, raster height, raster width, and left raster graphics margin are fixed until an end raster graphics command is received.

Once in Raster Graphics Mode, PCL commands and text imply an End Raster Graphics (Esc***rC**) except for the following commands:

- Transfer Raster Data
- Set Raster Compression Method
- Raster Y Offset

In addition, the following commands are ignored (i.e., locked out) while in Raster Graphics Mode and do not imply an End Raster Graphics command:

- Start Raster Graphics
- Set Raster Width
- Set Raster Height
- Set Raster Presentation Mode
- Set Raster Graphics Resolution

Notes

- An implied End Raster Graphics resets the Raster Compression Method 3 seed row, but does not reset the Raster Compression Method nor the left raster graphics margin.
- If source and/or transparency modes have been set, frequent start/end graphics commands in an image can result in a memory overflow condition.

Raster Y Offset Command

The Raster Y Offset command moves the cursor position vertically the specified number of raster lines from the current raster position in the raster area.

E_C *** b # Y**

= Number of raster lines of vertical movement

Default = N/A
Range = 0 - 32767

This command is recognized only while in raster graphics mode and only within the raster area.

This command zero-fills the offset area. For color printers, zero-fills are filled with the color of index 0, which is not necessarily white.

For Delta Row compression (methods 3 and 9), this command zeros the seed row. For Adaptive compression (method 5), this command applies to the entire raster data block.

Note

Movement by this command is based upon the Raster Resolution setting (E_C*t#R) and also the printer's resolution setting (75, 150, or 300 dpi).

Set Compression Method Command

The Set Compression Method command allows you to encode raster data in one of four compressed formats: Run-length encoding, Tagged Imaged File Format (TIFF) rev. 4.0, delta row compression, and adaptive compression. The choice of compression methods affects both the amount of code needed to generate a raster graphic image and the efficiency with which the image is printed.

$^{E}_{C}$ *** b # M**

= 0 - Unencoded
1 - Run-length encoding
2 - Tagged Imaged File Format (TIFF) rev. 4.0
3 - Delta row compression
4 - Reserved
5 - Adaptive compression

Default = 0
Range = 0 - 5 (values outside the range are ignored)

Unencoded (Method 0)

This is a simple binary transfer of data: no compression. Each bit describes a single dot. Bit 7 of the first byte corresponds to the first dot within the raster row, bit 0 corresponds to the eighth dot, and so on.

Note

Compressed data formats allow for efficient transfer of data from the host system to the printer. However, compressed data formats do NOT reduce the amount of printer memory required to produce an image.

Run-length Encoding (Method 1)

Run-length encoding interprets raster data in pairs of bytes. The first byte of each pair is the repetition count for the data in the second byte. The second byte is the raster data to be printed. A repetition count of 0 signifies the pattern in the data byte is not repeated (it occurs only once). A repetition count of 1 signifies the pattern occurs twice. The repetition count can range from 0 to 255 for a repetition of 1 to 256 times.

[(Repetition count byte 0-255)(pattern byte)] . [.] [ ]

Tagged Image File Format Encoding (Method 2)

Tagged Image File Format encoding interprets raster data as TIFF "Packbits." This format combines features of methods 0 and 1. A **control byte** precedes the raster data (pattern bytes). The control byte identifies whether the pattern byte(s) represent a byte that is to be repeated some number of times (up to 127), or represent some number of bytes (up to 127) which are to be printed as is (literally).

The sign of the number in the control byte identifies whether the byte or bytes that follow represent a literal pattern or byte to be repeated. A positive number (1 to 127) indicates that the bytes are literal. A negative number (-1 to -127), represented by the twos complement, indicates a repeated byte. The value of the number, if positive (literal), identifies the number of pattern bytes which follow the control byte; if negative (repeated), it identifies the number of times to repeat the following byte. A pattern byte may be repeated up to 127 times; or up to 127 literal bytes may follow the control byte.

As mentioned, for a byte to be repeated, the control byte must be a negative value as represented by the twos complement. For example, to repeat a pattern three times would require the twos complement of the number 3. The twos complement is computed as follows. The binary of 3 is 00000011. Complement each bit to get 11111100, then add one to this value to produce 11111101, the twos complement. The decimal value of this number, 253, used in the control byte, produces a repetition of 3 bytes for a total of 4 occurrences of the pattern.

The range of numbers for the control byte is shown below.

Literal Pattern Values

# of Bytes	Binary value	Decimal value
1	0000 0000	1
to	to	to
127	0111 1111	127

No Operation Value

NOP value	Binary value	Decimal value
128 (-128)	1000 0000	128

Repeated Pattern Values

# of Repetitions	Binary value*	Decimal value
1 (-1)	1111 1111	255
to	to	to
127 (-127)	1000 0001	129

* These negative values are represented by taking the twos complement of the value of the number.

Note

Another method to calculate the number needed in the control byte for some number of repetitions is to subtract the number of desired repetitions from 256. For example, the control value for 3 repetitions (4 occurrences) of a byte is 256 minus 3 = 253.

A zero or positive value in the control byte means that the subsequent byte or bytes are non-replicated bytes of data. The value of the control byte *plus one* indicates the number of data bytes that follow. For example, a control byte of 0 means the following 1 byte is literal raster data. A control byte of 6 indicates that the following 7 bytes are literal raster data bytes.

TIFF encoding also allows you to include a non-operative (NOP) control byte, represented by the value -128. This byte is ignored, and the subsequent byte is treated as the new control byte.

Note

It is more efficient to code two consecutive identical bytes as a repeated byte. If these bytes are preceded and followed by literal bytes, however, it is more efficient to code the entire group as literal bytes.

Examples: Run-length and TIFF Compression

The following examples show how a raster row can be coded using run-length and TIFF compression methods. Note that the compression examples use characters to represent the binary data stream.

Byte Number	#1	#2	#3	#4	#5	#6	#7
Bits	01010101	01010101	01010101	01010101	01000001	01010100	01010100
ASCII	U	U	U	U	A	T	T

Unencoded

^{Esc}***r1A**
^{Esc}***b0m7WUUUUATT**
^{Esc}***rC**

Run-length Encoding

^{Esc}***r1A**
^{Esc}***b1m6W(3)U(0)A(1)T**
^{Esc}***rC**

TIFF Encoding

^{Esc}***r1A**
^{Esc}***b2m6W(-3)U(0)A(-1)T or** ^{Esc}***b2m6W(-3)U(2)ATT**
^{Esc}***rC**

In the TIFF encoding example above, parenthetical expressions are used to identify control bytes. For example, the byte (-3) is shown to represent the control byte for a repetition (minus value) of 3. The actual value for this position is the decimal value 253. Additional “encoded” control bytes in this sequence include: (0) for decimal 0, (-1) for decimal 255, and (2) for decimal 2. The raster data (pattern) bytes are represented by the ASCII character.

Delta Row Compression (Method 3)

Delta row compression identifies a section of bytes in a row that is different from the preceding row, and then transmits only that data that is different (the delta data). If a row is completely different from its preceding row, then the entire row must be sent as the delta, which is not very efficient; if only one bit is different, then only one byte is identified and sent. To reassemble the raster data rows, the printer takes the current row (referred to as the seed row) and makes the changes indicated by the delta data, to create the new row. The new row (which becomes the new seed row) is used by the next delta compression data to create another row.

A delta compression row consists of two parts, a command byte and the replacement bytes, as shown below:

[(Command byte)(1 to 8 Replacement bytes)]

The command byte identifies two things: 1) the number of replacement (delta) bytes that follow; and 2) where to position the replacement byte string (the left offset). The replacement bytes are some number (up to eight bytes) of consecutive bytes that are used to create the new row from the seed row.

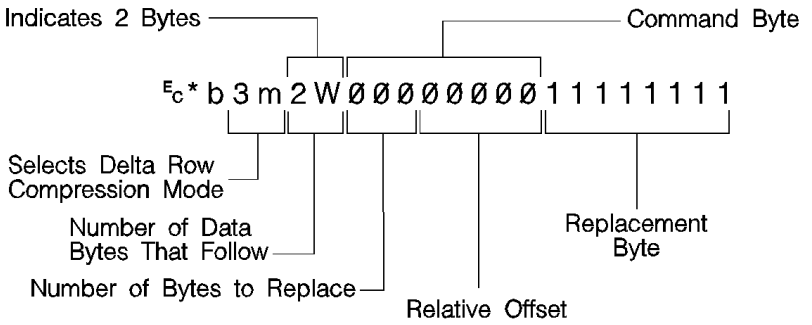
Command Byte	
7 5	4 0
Number of bytes to replace (1-8)	Relative offset from last untreated byte

If more than eight replacement (delta) bytes are needed, additional command byte/replacement bytes may be added, as shown below:

$^{E}_{C}$*3m#W [(Command Byte)(1 to 8 Replacement Bytes)][(Command Byte)(1 to 8 Replacement Bytes)]. . .

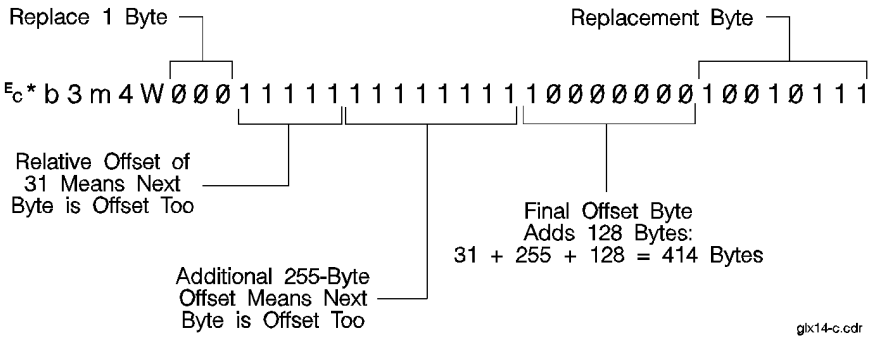
In the command byte, the upper three bits identify the number of replacement (delta) bytes (which can be 1 to 8 bytes). The lower five bits identify the location the replacement bytes are to be positioned. This position is identified as the **offset**, or the number of bytes from the treated byte. For example, if there are 5 replacement bytes and the offset is 7, then the replacement bytes replace bytes 7, 8, 9, 10, and 11 (the five bytes beginning at byte 7 from the seed row).

If there is more than one replacement in a row, the second offset is counted from the next untreated byte in the row: the first byte following the last replacement byte.



As mentioned, the offset contained in the lower five bits of the command byte allows for offset values from 0 to 31. Compression mode allows offsets larger than 31 bytes as follows:

- An offset value of 0-30 indicates that the replacement bytes are offset from the 1st byte to the 31st byte.
- A value of 31 indicates that the next byte following the command byte is an additional offset byte which adds to the first (32) offset value. This allows offset values larger than 31. Also, if this second offset byte is set to 255 (all ones), additional offset bytes follow until the required offset value is obtained. When the formatter detects an offset byte less than 255, it is assumed to be the last offset value and the offset bytes are then totaled (added). The following example shows an offset larger than 31:



The total offset is 414, which is the sum of the three offset values: 31 + 255 + 128.

Seed Row

The seed row is basically the current raster data row, the row being printed. It is maintained by the printer for use by delta row compression. The delta compression replacement bytes are applied to the seed row to create the new row. This new data row is printed and becomes the new seed row.

For color raster images, the printer operates on each plane independently, and a separate seed row is maintained for each graphic plane. A Y offset, however, affects all planes and seed rows simultaneously.

Note

For multi-plane graphics using compression modes 3 or 9, the Seed Row Source command determines which plane of the seed row to use. The Seed Row Source command is discussed later in this chapter.

The seed row is updated by every raster graphic transfer, regardless of the compression method. This allows the delta compression method to be mixed with other methods to achieve better compression performance.

Repeating a Row

^EC* b 0 W

When using the delta compression method, it is possible to repeat or copy the previous raster row using the Raster Data Transfer command. This is accomplished by setting the Raster Data Transfer command value field to zero.

Printing A Zeroed Row (Setting the Seed Row to Zero)

^EC* b 1 Y

It is possible to print a row of all zeros using the Raster Y-Offset command. Sending a Raster Y Offset command with a value field of 1 sets the seed row to zero and prints the zeroed row. Note that the next delta row is applied to a zeroed seed row.

Other cursor position moves set the seed row to zeros. (Remember, non-graphic cursor moves have the same effect as an end graphics command.)

Note

If the byte count of the Transfer Raster Data command value field is less than the number of bytes that can be replaced, the byte count has precedence. Also, if the last byte is a control byte, it is ignored. Therefore, Ec*b1W does not affect the seed row, but causes the previous row to be replicated.

Example: Delta Row Compression

The following example demonstrates how to compress the following data using the delta row compression. (The bytes highlighted in bold type indicate those bytes needing replacement – those bytes that are different from the previous row, the seed row.)

Byte No.	0	1	2	3	4
Row 1	00000000	**11111111**	00000000	00000000	00000000
Row 2	00000000	11111111	**11110000**	00000000	00000000
Row 3	**00001111**	11111111	11110000	**10101010**	**10101010**

Ec*r1A – The *start raster graphics* command initializes the seed row to all zeros.

Row 1 – Ec*b3m2W(00000001)(11111111)

The **3m** selects the delta row compression method and the **2W** indicates 2 bytes of data to follow. The first three bits of the first data byte, the command byte, signify a single byte replacement (all three bits are 0). The next five bits indicate an offset of 1 byte from the current position. The replacement byte follows and contains **11111111**.

Row 2 – $^{E}_{C}$*b2W(00000010)(11110000)

The first three bits of the command byte indicate that one byte will be replaced, and the next five bits indicate a relative offset of 2, so the replacement will occur 2 bytes from the current position. The replacement byte follows and contains 11110000.

Row 3 – $^{E}_{C}$*b5W(00000000)(00001111)(00100010)(10101010)(10101010)

As in the other rows, the first three bits of the command byte are zero, indicating a single byte replacement. The five offset bytes indicate a relative offset of zero bytes. The replacement byte follows and is 00001111. The third byte is another command byte and the first three bits signify the replacement of two bytes (the top three bits are 001). The offset bits indicate an offset of two bytes from the current position. The fourth and fifth bytes are the two replacement bytes.

Adaptive Compression (Method 5)

Adaptive compression enables the combined use of any of the four previous compression methods (0 through 3), and it includes the ability to print empty (all zeros) rows or to duplicate rows.

Adaptive compression interprets a raster image as a block of raster data rather than as individual rows. The result of this interpretation is that the Transfer Raster Data ($^{E}_{C}$*b#W) command is sent only once at the beginning of a raster data transfer, and the value field (**#**) identifies the number of bytes in the block (all rows). For the other compression methods, the Transfer Raster Data command is sent at the beginning of each row and the value field (**#**) identifies the number of bytes for that row only.

The size of a block is limited to 32,767 bytes. (32,767 bytes is the number of compressed bytes and not the size of the uncompressed data). To transfer greater than 32,767 bytes, send multiple blocks.

Adaptive compression uses three control bytes at the beginning of each row within the block. The first of these

bytes, the command byte, identifies the type of compression for the row. The two following bytes identify the number of bytes or rows involved. The format for adaptive compression raster rows is shown below:

<command byte><# of bytes/rows - upper byte><# of bytes/rows - lower byte> ...
... <first raster row byte> ... <last raster row byte>

The command byte designates the compression method, empty row, or row duplication. Command byte values are shown below.

Value	Compression Operation
0	– Unencoded
1	– Run-Length Encoding
2	– Tagged Image File Format (TIFF) rev 4.0
3	– Delta row
4	– Empty row
5	– Duplicate row

For command byte values 0 - 3, the two **<# of bytes/rows>** bytes specify the number of bytes (row length) for the row. For command byte values 4 and 5, these bytes identify the number of empty or duplicate rows to print. The maximum value for these two bytes is 65,535; however, the image is clipped to the logical page. Thus, the value of these bytes should not exceed the maximum number of bytes/rows that can be printed on the current logical page size.

If an out-of-range command byte is encountered, the remainder of the block is skipped, the cursor is not updated, and the seed row is cleared.

Compression methods 0 - 3 are the compression methods used by the Set Compression Method command. Value fields 4 and 5 are features for the adaptive compression method and are explained below.

Empty Row

A command byte of 4, empty row, causes a row of zero's to be printed. The number of rows printed depends on the value contained in the two **<# of bytes/rows>** bytes following the command byte. The empty row operation resets the seed row to zero and updates the cursor position.

Duplicate Row

A command byte of 5, duplicate row, causes the previous row to be printed again. The row can be duplicated the number of times indicated by the value contained in the **<# of bytes/row>** byte. Duplicate Row updates the cursor position but does not change the seed row.

Adaptive Compression Operation Hints

Note

Some HP LaserJet printers perform internal compression techniques to support full-page graphics. Refer to Chapter 1 of the *PCL 5 Comparison Guide* for specifics.

- The compression methods cannot be mixed within one raster row. A raster row must be compressed using only one method.
- The cursor position is updated with each row of the raster block. The cursor position is also incremented when a block count of less than 3 is sent.
- A Raster Y-Offset command moves the entire block of raster data and initializes the seed row to zeros. The seed row is set to zero even if the y-offset is zero.
- Block size takes precedence over row length. If the row length of any line exceeds the block size, the row length is truncated to the block size.
- For duplicate and empty rows, a row length value of zero does not update the cursor, however the seed row is initialized to zero.
- If an unsupported command byte for a raster row is encountered, the remaining bytes for the block are skipped, the seed row is cleared, and the cursor is not incremented.
- For method 1, run length encoded, if the row length is odd, the cursor is incremented, the row data is skipped (thrown away), and the seed row is left unchanged.
- For method 1, a row length value of zero increments the cursor and zero fills the seed row.
- For method 2, TIFF, if row length terminates the data before the control byte value is satisfied (literal byte count greater than row length), the data following the control byte, if any, is printed as text. The cursor is incremented.

- For Method 2—if row length is equal to one, the one byte is consumed from the I/O and the cursor is incremented. The data is ignored and the seed row is zeroed.
- For Method 3—delta row compression, within an adaptive compression block, the seed row is updated by every raster compression method or type of row. For example, a row compressed with Method 2, TIFF, updates the seed row, while the effect of an empty row initializes the seed row to zeros. Maintaining the seed row allows Method 3 to be mixed with other methods to achieve optimal compression performance.
- For Method 3—since delta row compression requires that the seed row be available whenever raster graphics mode is entered, the seed row is initialized to zeros upon raster graphics mode entry (EC*r#A). The seed row is also initialized upon receipt and completion of each raster block.
- For Method 3—if the row length terminates the data before the control byte value is satisfied (literal byte count greater than row length), the data following the control byte, if any, is printed as text. The cursor is incremented.
- For Method 3—if the row length is equal to one, the current row is duplicated and the cursor is incremented.

Transfer Raster Data Commands

There are two Transfer Raster Data commands: *Transfer Raster Data by Plane* and *Transfer Raster Data by Row*.

- **Transfer Raster Data by Plane**—This command (Ec*b#V) is used when the raster data is encoded by plane as specified by the Simple Color command (Ec*r#U) or the Configure Image Data command (Ec*v#W). The *Transfer Raster Data by Plane* command is used to send each plane in the row except the last; the *Transfer Raster Data by Row* command (Ec*b#W) must be used to send the last plane and advance the cursor to the beginning of the next row.
- **Transfer Raster Data by Row**—This command (Ec*b#W) moves the current active cursor position to the next pixel row after its execution. It is used for monochrome printers for the last plane in a multi-plane row, or for color raster transfer when the data is encoded by pixel.

Both commands are described in detail in the following paragraphs. Chapter 2 provides additional descriptions and examples using the Transfer Raster Data commands to print color images.

Transfer Raster Data by Plane

This command sends a plane of data to the printer and advances to the next plane (not to the next row).

Ec *** b # V** [*raster data*]

Default = N/A
Range = 0 to 32767

The value field (#) identifies the number of bytes in the plane. The number of planes per row is specified by the Simple Color command (Ec*r#U) or the Configure Image Data command (Ec*v#W), depending on which color mode is

used. The first plane sent represents the least significant bit in the pixel.

Since Ec*b#V does not advance the cursor to the beginning of the next raster row, it cannot be used for the last plane or for single-plane rows. Only Ec*b#W can advance the cursor to the next row.

The amount of data sent varies from plane to plane and is independent of raster width. Planes shorter than the raster width are zero-filled. Empty planes can be sent using Ec*b0V.

Note

For monochrome printers, zero indicates a white pixel. For color printers, the color indicated by zero depends on the current palette.

Transfer Raster Data By Row/Block Command

The Transfer Raster Data command is used to transfer a row of raster data to the printer. This command is used for sending all raster graphics data to monochrome printers. It is also used for color printers when encoding the raster data by pixel rather than by plane. When encoding color raster data by plane, this command is used for single-plane rows, or for the last plane in a multi-plane row, since this command advances the cursor position to the beginning of the next raster row.

Ec *** b # W** [*raster data*]

Default = N/A
Range = 0 to 32767

The value field (#) identifies the number of bytes in the raster row. These bytes are interpreted as one row of raster graphics data printed at the current Y position at the left raster graphics margin. Upon completion of this command,

the cursor position is at the beginning of the next raster row at the left raster graphics margin. At the end of each row, the plane pointer in a multi-plane row is reset to 1.

Within the raster data, each bit describes a single dot. Black-and-white printers interpret zeros as white; color printers interpret zeros according to the current palette. The most significant bit (bit 7 is the most significant, bit 0 is the least significant) of the first byte of data corresponds to the first dot within the row. If a bit is set to 1, the corresponding dot is printed. Each dot of the raster data is expanded according to the specified raster resolution.

Raster graphics is independent of the text area and perforation skip mode—these boundaries are ignored.

Raster graphic images, raster height, and raster width are limited to the printable area; images that extend beyond the printable area are clipped.

Byte Counts

The byte count of the value field in the Transfer Raster Data command has precedence over the literal, or the command byte, byte count. For example, the command,

$^{E}_{C}$*b2m3W [*binary data*]

sets compression method=2 and sends 3 bytes of raster data for the row. Suppose the binary data appears as follows:

00000010 00000001 00000001 00000001

The control (first) byte value of +2 indicates that 3 bytes of literal (unencoded) raster data will follow. The Transfer Raster Data command, however, specified only three bytes total (including the control byte) in the raster row. The control byte and the following two data bytes are read, and the remaining data byte is ignored.

If the last byte indicated by the value field in the Transfer Raster Data command is a control byte, that byte is ignored.

Note

If a Transfer Raster Data command is received without an accompanying Start Raster Graphics command, any preceding start raster values are used (such as left graphics margin, raster height and width, etc.).

End Raster Graphics Command

The End Raster Graphics command signifies the end of a raster graphic data transfer.

$^{E}_{C}$ * r C

Receipt of this command causes 5 operations:

- Resets the raster compression seed row to zeros.
- Moves the cursor to the raster row immediately following the end of the raster area (if a source raster height was specified).
- Allows raster commands which were previously locked out to be processed.
- Sets compression mode to 0 (no compression).
- Defaults the left graphics margin to X-position 0.

Note

- This command is a modified version of the $^{E}_{C}$*rB End Raster Graphics command. The newer version ($^{E}_{C}$*rC) performs two additional operations: it resets the compression mode to 0 and defaults the left graphics margin to 0.
- This command ($^{E}_{C}$*rC) is not supported by the HP LaserJet III or the HP LaserJet IIID printers. Use the $^{E}_{C}$*rB End Raster Graphics command to terminate raster graphic data transfers for these printers.
- Refer to the "PCL Feature Support Matrix" in Chapter 1 of the *PCL 5 Comparison Guide* for specific printers which support these commands.

Raster Scaling

Raster scaling provides the ability to enlarge or reduce raster images using the Destination Raster Width and Destination Raster Height commands. The Start Raster command (Ec*r#A) with a value field of 2 or 3 turns on scale mode. Scaling is independent of device resolution.

Note

To use raster scaling, the Configure Image Data command (Ec*r#W) must be sent prior to the Start Raster command (Ec*r#A), which must have a value field of 2 or 3 to enable scaling.

The Source Raster Width (Ec*r#S) and Source Raster Height (Ec*r#T) commands define source size. The Destination Raster Width (Ec*t#H) and Destination Raster Height (Ec*t#V) commands define destination size. The "scale factor" is implicitly determined from destination size, source size, and device resolution.

Specification of destination raster width and height is unnecessary for scaling, since these dimensions default to the graphics margin and printable area boundaries. If these dimensions are not specified, isotropic scaling is maintained so the entire image is rendered on the page without clipping. If only one destination dimension is specified, that dimension prevails and the other dimension is implicitly determined to maintain isotropic scaling.

Destination Raster Width

The Destination Raster Width command defines the width in decipoints of the destination raster picture denoted by the next Start Raster command, which must have a value field of 2 or 3 (Ec*r2A or Ec*r3A).

Ec *** t # H**

= Width (in decipoints)

Default = Right logical page boundary minus left graphics margin
Range = 0 – 32767 (values outside the range are ignored)

Zero or absent values default the destination width to a value that preserves isotropic scaling.

A specified width that would cross the right physical page boundary is clipped at the right physical page boundary, but the scale factor is maintained.

Destination Raster Height

The Destination Raster Height command defines the height in decipoints of the destination raster picture denoted by the next Start Raster command, which must have a value field of 2 or 3 (Ec*r2A or Ec*r3A).

Ec *** t # V**

= Height (in decipoints)

Default = Bottom logical page boundary minus vertical CAP
Range = 0 – 32767 (values outside the range are ignored)

Zero or absent values default the destination height to a value that preserves isotropic scaling.

A specified height that is longer than the physical page is clipped at the bottom of the physical page, but the scale factor is maintained.

Scale Algorithm

The Scale Algorithm command selects an algorithm for enhancing details when reducing color images with light or dark backgrounds. This command has no effect when enlarging an image

E_C *** t # K**

= 0 - Enhances color source images with a light background.
1 - Enhances color source images with a dark background

Default = 0
Range = 0, 1 (absent value field or values outside the range are ignored)

This command is valid only after a Start Raster command (E_C*r#A) with scale mode ON.

This command is ignored unless the scale factor is less than 1. For example, assume the source image is 1024 x 1280 pixels and the destination image is 2160 x 2880 decipoints (3" x 4"). At 300 dpi, this means a destination size of 900 x 1200 dots; therefore, the specified scale algorithm would take effect.

If the scale factor of either dimension is less than 1, the scale algorithm takes effect for that dimension only.

Raster Graphics Example

To transfer an unencoded arrow-shaped raster graphic image (see Figure 6-8) in the shape of an arrow, perform the following steps:

1. Position the cursor:

^[Esc]*p300x400Y	Move the cursor to PCL Unit position (300, 400) within the PCL coordinate system.

2. Specify Raster Presentation Mode 0:

^[Esc]*r0F	Print raster graphics in the orientation of the logical page.

3. Specify the raster graphics resolution:

^[Esc]*t75R	Set raster resolution to 75 dpi.

4. Specify the raster graphics height:

^[Esc]*r32T	Specify a raster height of 32 pixels (32 rows of raster data).

5. Specify the raster graphics width:

^[Esc]*r32S	Specify a 32-pixel raster width.

6. Specify the left raster graphics margin:

^[Esc]*r1A	Set the left graphics margin to the current X position (300).

7. Specify the Y offset:

^[Esc]*b0Y	This specifies a Y offset of 0 (this command is not necessary here but shows the proper command sequence).

8. Specify the raster compression mode:

^[Esc]*b0M	No compression (unencoded).

9. Transfer the raster data to the printer:

Divide the image into dot rows and transfer each dot row to the printer as a string of bytes, as illustrated on the following page.

10. Signify the end of the raster image transfer:

Ec*rC	This example prints the arrow as shown in Figure 6-8.

Example of Raster Graphic Image Data

Dot Row	Raster Image Data byte 1	byte 2	byte 3	byte 4	Command Data Decimal Equivalent
1	00000000	00000000	10000000	00000000	Ec*b4W[0, 0,128, 0]
2	00000000	00000000	11000000	00000000	Ec*b4W[0, 0,192, 0]
3	00000000	00000000	11100000	00000000	Ec*b4W[0, 0,224, 0]
4	00000000	00000000	11110000	00000000	Ec*b4W[0, 0,240, 0]
5	00000000	00000000	11111000	00000000	Ec*b4W[0, 0,248, 0]
6	00000000	00000000	11111100	00000000	Ec*b4W[0, 0,252, 0]
7	00000000	00000000	11111110	00000000	Ec*b4W[0, 0,254, 0]
8	00000000	00000000	11111111	00000000	Ec*b4W[0, 0,255, 0]
9	00000000	00000000	11111111	10000000	Ec*b4W[0, 0,255,128]
10	11111111	11111111	11111111	11000000	Ec*b4W[255,255,255,192]
11	11111111	11111111	11111111	11100000	Ec*b4W[255,255,255,224]
12	11111111	11111111	11111111	11110000	Ec*b4W[255,255,255,240]
13	11111111	11111111	11111111	11111000	Ec*b4W[255,255,255,248]
14	11111111	11111111	11111111	11111100	Ec*b4W[255,255,255,252]
15	11111111	11111111	11111111	11111110	Ec*b4W[255,255,255,254]
16	11111111	11111111	11111111	11111111	Ec*b4W[255,255,255,255]
17	11111111	11111111	11111111	11111111	Ec*b4W[255,255,255,255]
18	11111111	11111111	11111111	11111110	Ec*b4W[255,255,255,254]
19	11111111	11111111	11111111	11111100	Ec*b4W[255,255,255,252]
20	11111111	11111111	11111111	11111000	Ec*b4W[255,255,255,248]
21	11111111	11111111	11111111	11110000	Ec*b4W[255,255,255,240]
22	11111111	11111111	11111111	11100000	Ec*b4W[255,255,255,224]
23	11111111	11111111	11111111	11000000	Ec*b4W[255,255,255,192]
24	00000000	00000000	11111111	10000000	Ec*b4W[0, 0,255,128]
25	00000000	00000000	11111111	00000000	Ec*b4W[0, 0,255, 0]
26	00000000	00000000	11111110	00000000	Ec*b4W[0, 0,254, 0]
27	00000000	00000000	11111100	00000000	Ec*b4W[0, 0,252, 0]
28	00000000	00000000	11111000	00000000	Ec*b4W[0, 0,248, 0]
29	00000000	00000000	11110000	00000000	Ec*b4W[0, 0,240, 0]
30	00000000	00000000	11100000	00000000	Ec*b4W[0, 0,224, 0]
31	00000000	00000000	11000000	00000000	Ec*b4W[0, 0,192, 0]
32	00000000	00000000	10000000	00000000	Ec*b4W[0, 0,128, 0]

The brackets and commas are not part of the raster data command; they are used only to delineate the data.

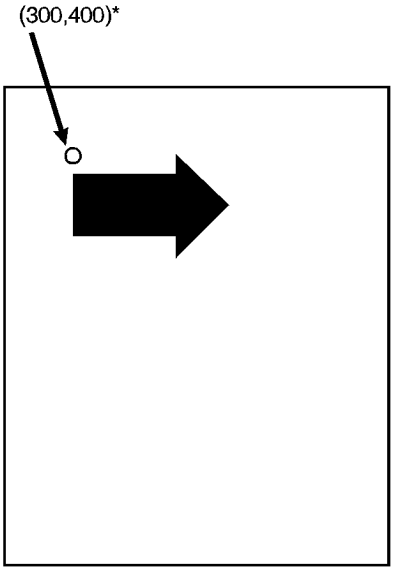


Figure 6-8. Example of Raster Graphic Image Data

Color Raster Graphics Example

This example demonstrates 24-bit RGB color specified directly by pixel using both the short and long forms of the CID command. It also shows reversing the black/white reference to get CMY color. The raster image is composed of blocks of different colors: red, green, blue, and several blocks of nonprimary colors.

The image is first sent as 24-bit RGB raster data. Then it is sent using the error diffusion and monochrome error diffusion digital halftoning algorithms. It is sent for a fourth time after using the long form of the CID command.

PJL Job initialization	
Send PJL commands to start the job and enter PCL	Ec%-12345X@PJL COMMENT ** Beginning of PCL Job** @PJL ENTER LANGUAGE=PCL
Initialize the printer	
Reset the printer	EcE
Specify portrait orientation	Ec&l0O
Set top margin to 0	Ec&l0E
Set graphics resolution to 300 dpi	Ec*t300R
Set raster height to 200 pixels	Ec*r200T
Set raster width to 1400 pixels	Ec*r1400S
Send Configure Image Data command (selects RGB color model, pixel encoding to direct by pixel, set bits per index to 0 [ignored parameter], and specify 8 bits for each primary color)	Ec*v6W00h 03h 00h 08h 08h 08h

Draw first raster image	
Position the cursor 1 inch from the left margin and 1 inch below top margin	Ec*p300x300Y
Start raster graphics with the current x position as the left graphics margin.	Ec*r1A
Specify mode 0 compression (no compression)	Ec*b0M
Transfer raster data by row with 4200 bytes/row (3 bytes/pixel * 1400 pixels/row=4200 bytes/row)	Ec*b4200W
(This section is shown in C code to show how Raster data is formatted.) for (i=0;i<200;i++) /* Red block */ fprintf(prn, "%c%c%c",255,0,0)	
for (i=0;i<200;i++) /* Green block */ fprintf(prn, "%c%c%c",0,255,0)	
for (i=0;i<200;i++) /* Blue block */ fprintf(prn, "%c%c%c",0,0,255)	
for (i=0;i<200;i++) /* Send 4 more blocks of color*/ fprintf(prn, "%c%c%c",216,218,50)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",249,120,15)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",158,81,200)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",45,120,249)	
Switch to mode 3 compression (delta row encoded) and send the remaining rows, which are identical	Ec*b3M
(Repeat the following command 200 times, which repeats the previous row each time)	
Repeat the previous row	Ec*b0W
Send End Raster Graphics command	Ec*rC

Draw second raster image (same image rendered using Error Diffusion)	
Position cursor 1" from left margin (absolute movement) and 1/3" below current position (relative movement)	^C*p300x+100Y
Select Error Diffusion Render Algorithm	^C*t4J
Start raster graphics with the current x position as the left graphics margin.	^C*r1A
Specify mode 0 compression (uncompressed)	^C*b0M
Transfer raster data by row with 4200 bytes per row.	^C*b4200W
(This section is shown in C code to show how Raster data is formatted.) for (i=0;i<200;i++) /* Red block */ fprintf(prn, "%c%c%c",255,0,0)	
for (i=0;i<200;i++) /* Green block */ fprintf(prn, "%c%c%c",0,255,0)	
for (i=0;i<200;i++) /* Blue block */ fprintf(prn, "%c%c%c",0,0,255)	
for (i=0;i<200;i++) /* Send 4 more blocks of color*/ fprintf(prn, "%c%c%c",216,218,50)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",249,120,15)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",158,81,200)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",45,120,249)	
Switch to mode 3 compression (delta row encoded) and send the remaining rows, which are identical	^C*b3M
(Repeat the following command 200 times)	
Repeat the previous row	^C*b0W
Send End Raster Graphics command	^C*rC

Draw third raster image (same image rendered using Monochrome Error Diffusion)	
Position the cursor 1" from left margin and 1/3" below current position.	Ec*p300x+100Y
Select Monochrome Error Diffusion Rendering Algorithm	Ec*t5J
Start raster graphics with the current x position as the left graphics margin.	Ec*r1A
Enter mode 0 compression (uncompressed)	Ec*b0M
Transfer data by row with 4200 bytes/row	Ec*b4200W
(This section is shown in C code to show how Raster data is formatted.) for (i=0;i<200;i++) /* Red block */ fprintf(prn, "%c%c%c",255,0,0)	
for (i=0;i<200;i++) /* Green block */ fprintf(prn, "%c%c%c",0,255,0)	
for (i=0;i<200;i++) /* Blue block */ fprintf(prn, "%c%c%c",0,0,255)	
for (i=0;i<200;i++) /* Send 4 more blocks of color*/ fprintf(prn, "%c%c%c",216,218,50)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",249,120,15)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",158,81,200)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",45,120,249)	
Switch to mode 3 compression (delta row encoded) and send the remaining rows, which are identical	Ec*b3M
(Repeat the following command 200 times)	
Repeat the previous row	Ec*b0W
Send End Raster command	Ec*rC

Draw fourth raster image (same image using long form of CID command)	
Send long form of the Configure Image Data command (select RGB color model, pixel encoding to direct by pixel, set bits per index to 0 [ignored parameter], and specify 8 bits for each primary color, followed by the white/black references)	Esc*v18W00h 03h 00h 00h 00h 00h 00h ffh 00h ffh 00h ffh 00h 00h 00h 00h 00h 00h (The black and white references are written as 2-byte values, requiring 12 bytes to write the 6 reference values. The white reference is 255=00000000 11111111 [binary] and the black reference is 0=00000000 00000000 [binary])
Position the cursor 1" from left margin and 1/3" below current position	Esc*p300x+100Y
Start raster graphics with the current x position as the left graphics margin.	Esc*r1A
Enter mode 0 compression (uncompressed)	Esc*b0M
Transfer data by row with 4200 bytes/row	Esc*b4200W
(This section is shown in C code to show how Raster data is formatted.) for (i=0;i<200;i++) /* Red block */ fprintf(prn, "%c%c%c",255,0,0)	
for (i=0;i<200;i++) /* Green block */ fprintf(prn, "%c%c%c",0,255,0)	
for (i=0;i<200;i++) /* Blue block */ fprintf(prn, "%c%c%c",0,0,255)	
for (i=0;i<200;i++) /* Send 4 more blocks of color*/ fprintf(prn, "%c%c%c",216,218,50)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",249,120,15)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",158,81,200)	
for (i=0;i<200;i++) fprintf(prn, "%c%c%c",45,120,249)	

Switch to mode 3 compression (delta row encoded) and send the remaining rows, which are identical	^C*b3M
(Repeat the following command 200 times)	
Repeat the previous row	^C*b0W
Send End Raster command	^C*rC
Reset printer and eject page	^CE
UEL command to end job	^C%-12345X

7

Color Vector Graphics (HP-GL/2)

Introduction

The process involved in using HP-GL/2 with the Color LaserJet or DeskJet 1200C color printers is nearly identical with using HP-GL/2 on other color printers or plotters. However, these two color printers add a few HP-GL/2 commands and expand the functionality of some existing commands. This chapter describes these commands and other pertinent points to keep in mind when using HP-GL/2 with these color printers.

The new or modified HP-GL/2 commands explained in this chapter include the following: The Merge Control (MC) command, which functions in a similar way to the PCL logical operation command. The Pen Color (PC) command, which modifies palette colors, the Number of Pens (NP) command, which changes the palette size, the Color Range (CR) command, which sets the range for specifying relative color data, and the Pixel Placement (PP) command, which determines how pixels are rendered in HP-GL/2 polygons.

In general, when using HP-GL/2 on the Color LaserJet and DeskJet 1200C color printers, keep in mind that:

- Palette information stays the same when switching between PCL 5 and HP-GL/2.
- The HP-GL/2 Initialize (IN) command sets the palette to the default eight-pen palette, and also resets the ROP code (see the MC command section later in this chapter) and the pixel placement command.
- As with color plotters, to specify a particular color, you use the SP (Select Pen) command.

If you are not familiar with using HP-GL/2, see the *PCL 5 Printer Language Technical Reference Manual.*

Enter HP-GL/2 Mode

This command causes the printer to interpret subsequent commands as HP-GL/2 commands, instead of PCL printer language commands.

$^{E}_{C}$**%#B**

= –1 - Stand-alone plotter mode (single context)

0 - Position pen at previous HP-GL/2 pen position

1 - Position pen at current PCL cursor position

2 - Use current PCL coordinate system and previous HP-GL/2 pen position

3 - Use PCL dot coordinate system and the current PCL CAP

Default = 0

Range = Range = –1 to 3 (unsupported negative values default to –1; all other unsupported values are ignored)

As soon as the printer receives this command, it switches to HP-GL/2 mode, interpreting commands as HP-GL/2 commands until it receives an Enter PCL Mode, $^{E}_{C}$E, or UEL command, or until the printer power is switched off and on.

The value field (#) determines the cursor position once HP-GL/2 mode is entered.

- **–1** — A value field of –1 creates a “single context” or “stand-alone plotter” mode which has the following effects:

— The current page is closed and printed and the HP-GL/2 environment is initialized (IN command).

— HP-GL/2 output begins on a new page.

— HP-GL/2 and PCL output cannot be combined on the same page.

— No PCL commands except ^[E]E, ^[E]%#A, and the PJL command ^[E]%-12345X are recognized by the printer.

— The PCL picture presentation directives are ignored.

— The ^[E]%#A command closes HP-GL/2, prints the current page, and performs an ^[E]E before entering PCL.

— The default HP-GL/2 orientation is reverse landscape.

— Hard-clip limits are equal to the printable area.

— The ^[E]E command functions as usual.

When the single-context mode is used (^[E]%–1B), the following steps should be followed:

1. Enter HP-GL/2 mode using the ^[E]%–1B command.
2. Transmit one or more HP-GL/2 drawings.
3. Exit HP-GL/2 mode (^[E]%#A).

- **0** — This parameter option (^[E]%0B) sets the pen position to the previous HP-GL/2 position; if this is the first time HP-GL/2 mode is entered in the present print job (assuming an ^[E]E has been sent), the pen position is at the lower left corner of the PCL Picture Frame (0,0).
- **1** — This parameter option (^[E]%1B) specifies that the pen position and the label carriage return point become the same as the current PCL cursor position.
- **2** — ^[E]%2B transfers the current PCL dot coordinate system to HP-GL/2, including the PCL origin and axes, but uses the previous HP-GL/2 pen position as the new pen position. Once the PCL coordinate system is established with this command, it is independent of the P1 and P2 positions.
- **3** — This parameter option (^[E]%3B) specifies that the pen position and the label carriage return point become the same as the current PCL cursor position. The current PCL dot coordinate system and axes are also transferred to HP-GL/2; once the PCL coordinate system is established with this command, it is independent of the P1 and P2 positions.

When HP-GL/2 is entered using any dual-context mode (any variation of the command except Ec%-1B), the HP-GL/2 and PCL contexts can be merged, resulting in the following:

- HP-GL/2 and PCL data can be combined on the same page.
- HP-GL/2 graphics can be integrated directly with text.
- The size and location of the PCL picture frame can be specified.
- HP-GL/2 graphics can be scaled to fit within the picture frame.
- The PCL palette and color configuration are transferred between contexts.
- The current logical operation and pixel placement settings are transferred between contexts.
- The current active position (CAP) is transferred between HP-GL/2 and PCL (for Ec%1B and Ec%3B only).
- The PCL orientation determines the HP-GL/2 orientation.

In PCL mode, the Enter HP-GL/2 Mode command must be executed, except when in display functions mode or within a binary data transfer. HP-GL/2 ignores this command.

Default Settings when Entering HP-GL/2

When you enter HP-GL/2 mode, most vector graphics variables retain their previous HP-GL/2 value. However, the following changes in the PCL environment can affect the HP-GL/2 environment:

- Resetting the printer (EcE or control panel reset):
  - — Executes an IN (Initialize) command
  - — Defaults the PCL Picture Frame size
  - — Defaults the PCL Picture Frame anchor point
  - — Defaults the HP-GL/2 plot size
  - — Defaults the PCL logical page orientation
- A page size, page length, or orientation command:
  - — Defaults the PCL Picture Frame anchor point

— Defaults the PCL Picture Frame

— Defaults the HP-GL/2 plot size

— Defaults P1 and P2 (IP, IR commands)

— Resets the soft-clip window to the PCL Picture Frame boundaries (IW command)

— Clears the polygon buffer (PM0, PM2)

— Updates the cursor to the lower-left corner of the picture frame (P1).

■ Redefining the PCL Picture Frame size or setting the anchor point:

— Defaults P1 and P2 (IP, IR commands)

— Resets the soft-clip window (IW) to the PCL Picture Frame boundaries.

— Clears the polygon buffer (PM0, PM2)

— Updates the current pen position to the lower-left corner of the picture frame (P1).

■ Setting an HP-GL/2 plot size:

— Changes the picture frame scaling factor.

■ Redefining the palette:

— Changes colors selected by the Select Pen (SP) command and used in patterns defined by the Raster Fill Definition (RF) command and/or used by the Fill Type (FT) command.

MC (Merge Control)

The MC command controls the color of pixels where two or more page marking primitives intersect on the page. This command supports all 256 Microsoft Windows ternary (ROP3) raster operation codes. A common application of the MC command is the rendering of complex polygon fill patterns. Raster Operations specify how source, destination, and patterns are combined to produce final images.

MC *mode, [opcode][;]*

Parameter	Format	Functional Range	Parameter Default
mode	clamped integer	0 or 1	0 (off)
opcode	clamped integer	0 to 255	252 (mode=0), 168 (mode=1)

- **Mode** — defines the merge control mode as follows:

  0 (off, default) Pixels in a primitive replace corresponding destination pixels. If no opcode is specified, 252 is used.

  1 (on) Pixels in a primitive merge with corresponding destination pixels, creating a new color based on the colors of the source data and the contents of the destination (frame buffer). If no opcode is specified, 168 is used.

Note

- This command is the HP-GL/2 version of the PCL Logical Operation command.
- This command sets a ROP value which affects not only HP-GL/2 operation but also the PCL ROP value.
- The MC command is defaulted by an IN command.

- **Opcode** — Specifies the logical operations performed on a source, destination, and pattern prior to drawing the final image. These raster opcodes (ROPs) are listed on the following pages in reverse polish notation (RPN) using the following abbreviations:

  D — Destination

  S — Source

  T — Texture

  a — and

  n — not

  o — or

  x — exclusive or

  For example, when mode = 0, the opcode default is 252, which is the logical function TSo (Texture OR Source).

  The operation code (opcode) specifies the logical operations that are performed on a source, destination, and patterned image prior to drawing the final image. The opcodes are created by listing all possible combinations of a single pattern, source and destination pixel, and constructing the desired final pixel values. The following table shows three common opcodes constructed by reading the output values bottom up.

Pixel Combinations			Desired Destination Values		
Pattern Pixel	**Source Pixel**	**Destination Pixel**	**Source Overwrite**	**Transparency (TR command)**	**Source Destination**
0	0	0	0	0	0
0	0	1	0	1	1
0	1	0	1	1	1
0	1	1	1	1	0
1	0	0	0	0	0
1	0	1	0	1	1
1	1	0	1	1	1
1	1	1	1	1	0
Resulting Opcode			204 (0xCC)	238 (0xEE)	102 (0x66)

Note

When using the MC command, some pattern types will not produce the expected ROP result. This only occurs when using the FT (Fill Type) command pattern types 1, 2, 3, and 4, and when the ROP includes an XOR operation. (This problem is due to the fact that these patterns are the result of a vector operation and do not produce raster data for use by a ROP operation.) All other Fill Type command patterns (types, 10, 11, 21, or 22) operate as expected.

The MC command supports all 255 Microsoft Windows ROPS, which are listed on the following page in reverse polish notation (RPN) using the abbreviation listed above (D for Destination, S for Source, etc.).

Table 7-1. Logical Operations (ROP3)

Input Value	Boolean Function	Input Value	Boolean Function
0	0	27	SDTSxaxn
1	DTSoon	28	TSDTaox
2	DTSona	29	DSTDxaxn
3	TSon	30	TDSox
4	SDTona	31	TDSoan
5	DTon	32	DTSnaa
6	TDSxnon	33	SDTxon
7	TDSaon	34	DSna
8	SDTnaa	35	STDnaon
9	TDSxon	36	STxDSxa
10	DTna	37	TDSTanaxn
11	TSDnaon	38	SDTSaox
12	STna	39	SDTSxnox
13	TDSnaon	40	DTSxa
14	TDSonon	41	TSDTSaoxxn
15	Tn	42	DTSana
16	TDSona	43	SSTxTDxaxn
17	DSon	44	STDSoax
18	SDTxnon	45	TSDnox
19	SDTaon	46	TSDTxox
20	DTSxnon	47	TSDnoan
21	DTSaon	48	TSna
22	TSDTSanaxx	49	SDTnaon
23	SSTxDSxaxn	50	SDTSoox
24	STxTDxa	51	Sn
25	SDTSanaxn	52	STDSaox
26	TDSTaox	53	STDSxnox

Table 7-1. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
54	SDTox	81	DSTnaon
55	SDToan	82	DTSDaox
56	TSDToax	83	STDSxaxn
57	STDnox	84	DTSonon
58	STDSxox	85	Dn
59	STDnoan	86	DTSox
60	TSx	87	DTSoan
61	STDSonox	88	TDSToax
62	STDSnaox	89	DTSnox
63	TSan	90	DTx
64	TSDnaa	91	DTSDonox
65	DTSxon	92	DTSDxox
66	SDxTDxa	93	DTSnoan
67	STDSanaxn	94	DTSDnaox
68	SDna	95	DTan
69	DTSnaon	96	TDSxa
70	DSTDaox	97	DSTDSaoxxn
71	TSDTxaxn	98	DSTDoax
72	SDTxa	99	SDTnox
73	TDSTDaoxxn	100	SDTSoax
74	DTSDoax	101	DSTnox
75	TDSnox	102	DSx
76	SDTana	103	SDTSonox
77	SSTxDSxoxn	104	DSTDSonoxxn
78	TDSTxox	105	TDSxxn
79	TDSnoan	106	DTSax
80	TDna	107	TSDTSoaxxn

Table 7-1. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
108	SDTax	135	TDSaxn
109	TDSTDoaxxn	136	DSa
110	SDTSnoax	137	SDTSnaoxn
111	TDSxnan	138	DSTnoa
112	TDSana	139	DSTDxoxn
113	SSDxTDxaxn	140	SDTnoa
114	SDTSxox	141	SDTSxoxn
115	SDTnoan	142	SSDxTDxax
116	DSTDxox	143	TDSanan
117	DSTnoan	144	TDSxna
118	SDTSnaox	145	SDTSnoaxn
119	DSan	146	DTSDToaxx
120	TDSax	147	STDaxn
121	DSTDSoaxxn	148	TSDTSoaxx
122	DTSDnoax	149	DTSaxn
123	SDTxnan	150	DTSxx
124	STDSnoax	151	TSDTSonoxx
125	DTSxnan	152	SDTSonoxn
126	STxDSxo	153	DSxn
127	DTSaan	154	DTSnax
128	DTSaa	155	SDTSoaxn
129	STxDSxon	156	STDnax
130	DTSxna	157	DSTDoaxn
131	STDSnoaxn	158	DSTDSaoxx
132	SDTxna	159	TDSxan
133	TDSTnoaxn	160	DTa
134	DSTDSoaxx	161	TDSTnaoxn

Table 7-1. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
162	DTSnoa	189	SDxTDxan
163	DTSDxoxn	190	DTSxo
164	TDSTonoxn	191	DTSano
165	TDxn	192	TSa
166	DSTnax	193	STDSnaoxn
167	TDSToaxn	194	STDSonoxn
168	DTSoa	195	TSxn
169	DTSoxn	196	STDnoa
170	D	197	STDSxoxn
171	DTSono	198	SDTnax
172	STDSxax	199	TSDToaxn
173	DTSDaoxn	200	SDToa
174	DSTnao	201	STDoxn
175	DTno	202	DTSDxax
176	TDSnoa	203	STDSaoxn
177	TDSTxoxn	204	S
178	SSTxDSxox	205	SDTono
179	SDTanan	206	SDTnao
180	TSDnax	207	STno
181	DTSDoaxn	208	TSDnoa
182	DTSDTaoxx	209	TSDTxoxn
183	SDTxan	210	TDSnax
184	TSDTxax	211	STDSoaxn
185	DSTDaoxn	212	SSTxTDxax
186	DTSnao	213	DTSanan
187	DSno	214	TSDTSaoxx
188	STDSanax	215	DTSxan

Table 7-1. Logical Operations (ROP3) continued

Input Value	Boolean Function	Input Value	Boolean Function
216	TDSTxax	236	SDTao
217	SDTSaoxn	237	SDTxno
218	DTSDanax	238	DSo
219	STxDSxan	239	SDTnoo
220	STDnao	240	T
221	SDno	241	TDSono
222	SDTxo	242	TDSnao
223	SDTano	243	TSno
224	TDSoa	244	TSDnao
225	TDSoxn	245	TDno
226	DSTDxax	246	TDSxo
227	TSDTaoxn	247	TDSano
228	SDTSxax	248	TDSao
229	TDSTaoxn	249	TDSxno
230	SDTSanax	250	DTo
231	STxTDxan	251	DTSnoo
232	SSTxDSxax	252	TSo
233	DSTDSanaxxn	253	TSDnoo
234	DTSao	254	DTSoo
235	DTSxno	255	1

PC (Pen Color)

This command changes the pen color in a palette created by the IN or CID command (Ec*v#W). The PC command defaults the colors of all pens as indicated in the table below.

PC *[pen [,primary1, primary2, primary3;]]*

or

PC *[pen;]*

or

PC*[;]*

Parameter	Format	Functional Range	Parameter Default
pen	integer	determined by NP	see table
primary1, primary2, primary3	clamped real	determined by CR	see table

- **pen** — specifies the number of the pen whose color is being defined. An out-of-range pen parameter sets error 3 and the command is ignored. (The range for the pen parameter is determined by the size of the current color palette.)
- **primary1, primary2, primary3** — specifies the primary component values which are to be associated with that pen. See the CR command description for the range associated with the values. If a primary color parameter is outside of the color range defined in the CR command, the value is clamped to the color range limits.

The "PC;" command defaults the colors of all pens as shown in the table below. The "PC pen;" command defaults the number of pens as shown in the table on the following page for an HP-GL/2 palette. When color device palettes larger than 8 pens default, the first 8 pen colors are as defined for a palette of 8; all remaining pen colors are device-dependent. If the palette is a non-default palette, it defaults in accordance with the default palettes in Chapter 4.

No. of Pens in Palette	Pen Number	Color
2 (“NP 2;”)	0	White
	1	Black
4 (“NP 4;”)	0	White
	1	Black
	2	Red
	3	Green
8 (“NP 8;”)	0	White
	1	Black
	2	Red
	3	Green
	4	Yellow
	5	Blue
	6	Magenta
	7	Cyan

For black and white printers that accept color descriptions and palettes, pen 0 defaults to white; all remaining pen colors default to “equivalent gray levels.” An equivalent gray level means that lighter colors (for example, yellow) are converted to light gray shades, and darker colors (for example, purple) are converted to dark gray shades. The mapping algorithm is device-dependent. However, equivalent gray levels represent solid colors, and any white pixels within them are not subject to transparency mode (TR).

Note

In the “shading” Fill Type command (FT10;), the shading levels are mapped between white (0% shading) and the equivalent gray level for the currently selected pen (100% shading). In the “HP-GL/2 user-defined” Fill Type command (FT11;), each pixel in the RF pattern is rounded to white or black based on the equivalent gray level of the pen number for that pixel. This rounding should use a low enough white/black threshold so that yellow will round to black.

For a black and white device, pen 0 defaults to white; all remaining pen colors default to black.

This command is ignored if the current palette was created by the Simple Color command (Ec*r#U). An IN command defaults pen colors as indicated in the previous table.

NP (Number of Pens)

The NP command resizes the palette after the IN or Ec*v#W commands.

NP *[n;]*

or

NP*[;]*

Parameter	Format	Functional Range	Parameter Default
n	clamped integer	2 to 32768	device-dependent *

* The default palette size for the HP color printers is 8.

- **n** — the parameter n denotes the size of the HP-GL/2 palette, where n is a power of two. If n is not a power of two, the next larger power of two is used. The palette is an array of virtual pens, each having an associated color value and an associated width. Pen colors are defined in terms of RGB components using the PC command. Widths are established using the PW and WU commands. A pen is selected with the SP command.

The maximum value for n is device-dependent, but is greater than or equal to the number of distinct colors the printer is able to produce. If n is larger than that maximum, the maximum-sized palette is allocated. If n < 2, error 3 is set and the command is ignored.

The "NP;" command defaults the palette size. Receipt of this command does not default pen colors and/or widths for

existing pen values. For example, if the palette size is initially 8 and is decreased to 4, pen colors and widths for the new palette are retained from the colors and widths of the first 4 pens of the old palette. If the palette size is increased from 8 to 16, the colors and widths for the first 8 pens remain the same, and the colors and widths of the remaining pens are defaulted. The pens are defaulted in accordance to how the palette was created (either CID or Simple Color palettes).

If the currently selected pen is outside the range of the new palette size, the SP command modulo function is applied to obtain a pen number which will index into the new palette; this clears the current residue (the unused portion of a pattern) and terminates any sequence of continuous vectors. For more information, see the descriptions of the Line Attribute (LA) and Line Type (LT) commands in the *PCL 5 Printer Language Technical Reference Manual*.

The number of pens is defaulted by an IN command.

This command is ignored if the current palette was created by the Simple Color command (ᴱC*r#U) or ᴱCE.

CR (Color Range)

The CR command sets the range for specifying relative color data.

CR *[b_ref_red, w_ref_red, b_ref_grn, w_ref_grn, b_ref_blue, w_ref_blue;]*

Parameter	Format	Functional Range	Parameter Default
b_ref (red, green, blue)	clamped real	–32768 to 32767	0
w_ref (red, green, blue)	clamped real	–32768 to 32767	255

Relative color is in reference to a range defined by a black and white reference value for each primary (red, green, and blue). For example, if the white reference is set as red=63, green=63, blue=63, and the black references are set as red = 0, green = 0, and blue = 0, then white = 63, 63, 63; black = 0, 0, 0; and medium blue = 0, 0, 31. However, if the white reference is set as red = 63, green = 127, blue = 31 and the black reference is set as red = 4, green = 0, and blue = 0, then white = 63, 127, 31; black = 4, 0, 0; and medium blue = 4, 0, 15.

The first two parameters set the black and white references (respectively) for red; the second pair sets the green references, and the final pair the blue reference values. If the black reference value for any primary is equal to the white referecne value for the same primary, the command is ignored.

The default for red, green, and blue “black references” is 0; the default for red, green and blue “white references” is 255.

This command is defaulted by the “CR;”and IN commands.

Execution of this command causes current pen colors to be remapped to the new range, so that current palette colors remain unchanged.

PP (Pixel Placement)

When printing, the printer places pixels at the intersection of the squares of a theoretical, device-dependent grid covering the printable area on a page. When the sides of two HP-GL/2 polygons touch each other, the pixels along the border may be printed twice or not at all—depending on the logical operation in effect. For example, if a source rectangle consisting of all 1's is XORed with a destination consisting of all 1's, a white rectangle is printed. If another source rectangle is placed on the page touching the first rectangle, the two rectangles are white-filled except at their common border: that is, (1^1)^1 = 1.

To correct this situation, two models of pixel placement are used: grid intersection and grid centered. The grid intersection model is the default: pixels are rendered on the intersections of the device-dependent grid covering the page. In the grid-centered model, the number of rows and columns are each reduced by one, and pixels are placed in the center of the squares, rather than at the intersections.

The following example illustrates the concepts of the two models. Assume a rectangle extends from coordinate position (1,1) to position (3,4). As shown below, for the same coordinates, the grid-centered model produces a rectangle that is one dot row thinner and one dot row shorter than the grid intersection model. Thus, when two or more polygons on a page share a common border, grid centering (value=1) can be turned on.

Since PCL printers print only at the intersections of the grid, the actual implementation of the grid-centered model is also shown in the following illustration.

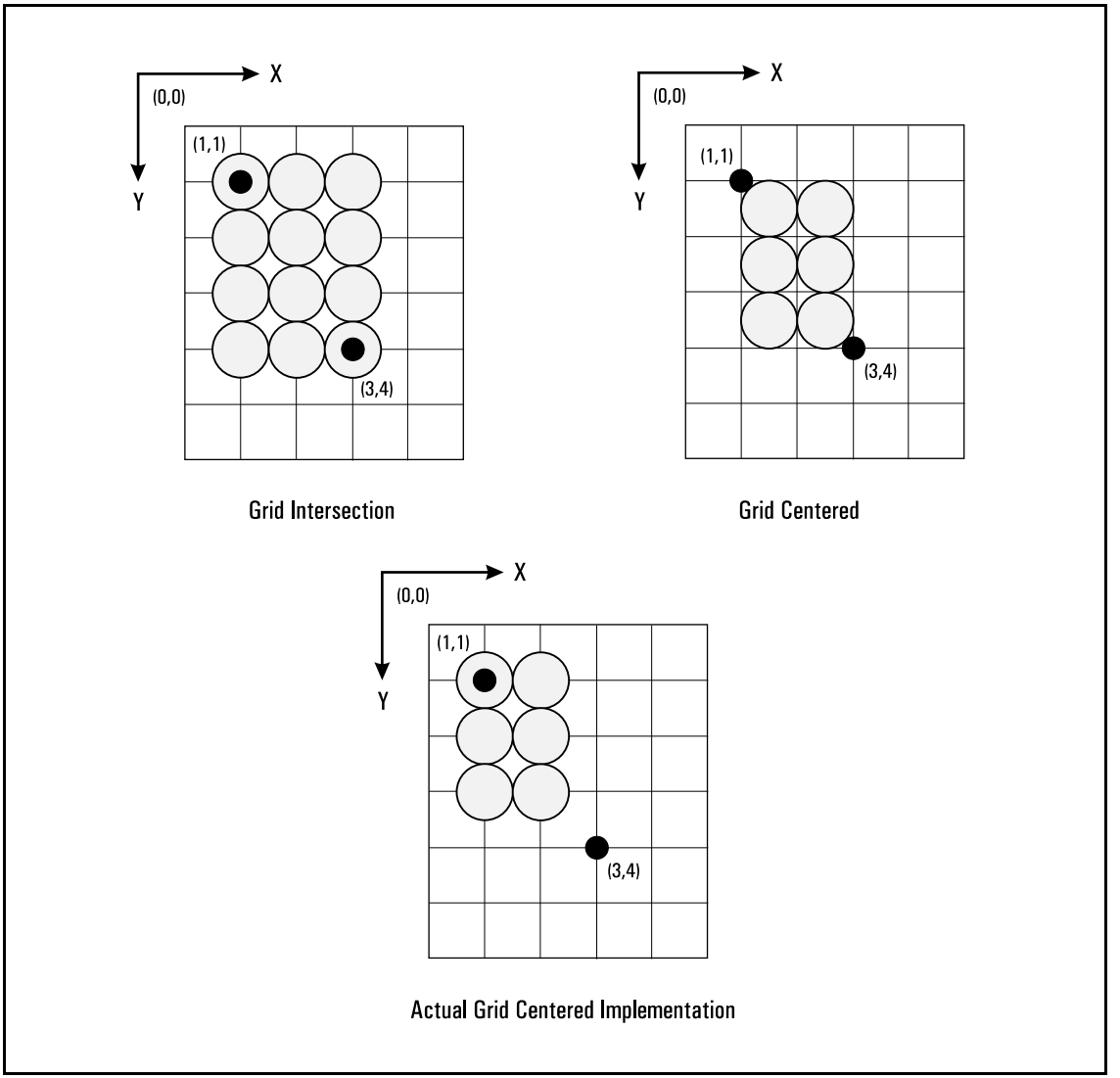


Figure 7-1. Pixel Placement

PP, Pixel Placement Command

The Pixel Placement (PP) command controls how pixels are placed on the layout grid during polygon fills. The two pixel placement modes are grid intersection or grid centered.

PP *[mode;]*

Parameter	Format	Functional Range	Parameter Default
mode	clamped integer	0 or 1	0 (grid intersection)

■ **mode**

0 grid intersection; device draws pixels centered at grid intersections (see Figure 7-1).

1 grid centered; device draws pixels centered inside the boxes created by the grid (see Figure 7-1).

When the printer is set to grid-centered mode (mode 1), portions of a polygon that are zero height or zero width are not rendered. When the printer is set to grid intersection mode (mode 0), portions that are zero height or width are rendered as lines. Portions that are both zero height and width are rendered as dots.

This command affects only HP-GL/2 polygons; it has no effect on characters, rules, or raster graphics. This command can be invoked multiple times during a page; it has no effect except to switch the model used for imaging.

This command is the HP-GL/2 version of the PCL Pixel Placement command. Whatever mode is selected, using the HP-GL/2 PP command also applies to PCL operation. Likewise the PCL Pixel Placement command also affects HP-GL/2 pixel placement.

Note

- Microsoft Windows fills polygons based on the grid-centered method.
- This command determines how pixels will be placed for both HP-GL/2 and PCL operation.
- The PP command is not defaulted by an IN command.

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