

# Chapter 13: Raster

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## 13.1 Introduction

This chapter describes raster (bitmap) graphics. A raster image is composed of rows of dots or pixels. A pixel row is transferred to the printer as a string of bytes. Rows are organized from top to bottom: the first data row becomes the top pixel row of the image.

### Dot

A dot is the smallest mark a printer can make. Its size and spacing are device specific.

**Pixel**

The smallest definable picture element in the source image. At maximum machine resolution, a pixel consists of one dot. When scaling up, or at lower resolutions, a pixel may consist of more than one dot.

**Bit**

Bits refer to the binary 1's and 0's in the source data. In black and white printers, a single bit defines a pixel; a "1" bit prints a black pixel and a "0" bit prints a white pixel.

Bits	Pixel Rows
11111111	••••••••
10101010	• • • •

A color pixel may require more bits per pixel: e.g., two bits for four colors, three bits for eight, etc.

**Raster Mode**

Start Raster (*Esc\*r#A*) begins a restricted state called *raster mode*, which locks out commands that would affect rendering. Raster mode continues until an implicit or explicit End Raster (*Esc\*rC*). The Transfer Raster (*Esc\*b#V*, *Esc\*b#W*) and Raster Y Offset (*Esc\*b#Y*) commands can implicitly start raster mode, using the current raster resolution and left raster margin. Any text or non-raster command can implicitly terminate raster mode.

**Raster Area**

The PCL raster system uses the concept of a bounded raster picture, or *raster area*. Within the boundary, the printer zero-fills missing and incomplete rows and clips data that would fall outside.

Raster height extends vertically from CAP to one of the following:

- the distance specified by Source Raster Height if raster scaling is off (see section below).
- the row preceding an implicit or explicit End Raster (*Esc\*rC*).
- the lower edge of the printable area.

Raster width extends from the *left raster margin* (CAP or the left edge of the logical page), and is limited to one of the following:

- the distance specified by Source Raster Width (*Esc\*r#S*) if scaling is off (see section below).
- the right edge of the logical page.

DEVICE NOTE: LJs, DJ1200C, and PJXL300 clip at the right logical page boundary if Source Raster Width is specified, and at the right printable area boundary if width is not specified.

Raster is independent of text margins and perforation skip, and never causes a page eject: at the end of the page, CAP moves to the bottom logical page boundary and the rest of the graphic is discarded.

**Raster Scaling**

If scaling is on, the size of the raster picture is determined by Destination Raster Width (*Esc\*t#H*) and Destination Raster Height (*Esc\*t#V*). To use raster scaling, Source sizes (*Esc\*r#S*, *Esc\*r#T*) must be specified, but Destination sizes are optional (they default to logical page and printable area boundaries).

## Raster Resolution

*Machine resolution* is the dots per inch (dpi) a device is capable of printing. Some devices allow different *requested resolutions* up to the machine resolution. At lower requested resolutions, each pixel consists of more than one dot; but dot-spacing remains the same and the same number of dots-per-inch are printed. When 150 dpi is requested in a 300 dpi machine, 300 dpi is still printed; but the pixel is now composed of four dots and is twice as wide and twice as tall as a pixel printed at 300 dpi. Since dot spacing is always the same, changing the resolution changes the size of the printed raster image.

bit	300 dpi	150 dpi
1	•	••

Requesting a lower resolution does not by itself cause less detail to be printed. The printer still prints at its highest resolution; it just prints the image larger. Using the same data, a 150 dpi image is printed four times as large as a 300 dpi image. To keep the destination image the same size, it is necessary to send the printer one-fourth the information.

## Data Compression

Once a rectangular raster area is defined, data transfer can be minimized. The Raster Compression Method command (*Esc\*b#M*) provides several types of compression.

## Raster Command Sequence

The normal execution sequence for raster (without color) commands is shown below.

Raster Presentation	<i>Esc*r#F</i>	
Raster Resolution	<i>Esc*t#R</i>	
Source Raster Height	<i>Esc*r#T</i>	
Source Raster Width	<i>Esc*r#S</i>	
Destination Raster Height	<i>Esc*t#V</i>	(if using raster scaling)
Destination Raster Width	<i>Esc*t#H</i>	(if using raster scaling)
Configure Image Data	<i>Esc*v#W[data]</i>	(if using raster scaling)
Start Raster <i>Esc*r#A</i>		
Raster Compression	<i>Esc*b#M</i>	
Transfer Raster	<i>Esc*b#W[raster data]</i> or <i>Esc*b#V[raster data]</i>	
...		
Raster Y Offset	<i>Esc*b#Y</i>	
Raster Compression	<i>Esc*b#M</i>	
Transfer Raster	<i>Esc*b#W[raster data]</i> or <i>Esc*b#V[raster data]</i>	
...		
Raster Compression	<i>Esc*b#M</i>	
Transfer Raster	<i>Esc*b#W[raster data]</i>	
...		
End Raster	<i>Esc*rC</i>	

Note that presentation, resolution, height, and width are set outside the *start...data...end* sequence. The picture is sent, using the most effective compression method for each row, during *start...data...end*. Raster presentation, resolution, height, and width are all true PCL modes (see Chapter 4): they are not changed when raster mode is terminated; they remain in their specified state until explicitly changed by issuing the command again, or until reset to their default values by *EscE* or a power cycle. On the other hand, raster compression and left raster margin are reset when raster mode is terminated.

## 13.2 Raster Mode

The Start Raster command (*Esc\*r#A*) begins a restricted state called *raster mode*. Start Raster (*Esc\*r#A*) explicitly enters raster mode, and End Raster (*Esc\*rC*) explicitly ends raster mode. Implicit start and end raster is allowed, **but is not recommended and should not be documented externally**.

### Implicit Start Raster Mode

The Transfer Raster (*Esc\*b#V*, *Esc\*b#W*) and Raster Y Offset (*Esc\*b#Y*) commands implicitly start raster mode, using the current raster resolution and left raster margin.

### Implicit End Raster Mode

Text or non-raster commands end raster mode, retaining the current resolution and left raster margin.

### Raster Commands that are Ignored in Raster Mode

Raster mode locks out the following commands that might affect rendering of the image.

Assign Color Index ( <i>Esc*v#I</i> ) *	Render Algorithm ( <i>Esc*t#J</i> )
Color Component (first) ( <i>Esc*v#A</i> ) *	Scale Algorithm ( <i>Esc*t#K</i> )
Color Component (second) ( <i>Esc*v#B</i> ) *	Simple Color ( <i>Esc*r#U</i> ) * **
Color Component (third) ( <i>Esc*v#C</i> ) *	Source Raster Height ( <i>Esc*r#T</i> )
Configure Image Data ( <i>Esc*v#W</i> )	Source Raster Width ( <i>Esc*r#S</i> ) **
Configure Raster Data ( <i>Esc*g#W</i> )	Start Raster ( <i>Esc*r#A</i> )
Destination Raster Height ( <i>Esc*t#H</i> )	Download Dither Matrix ( <i>Esc*m#W</i> )
Destination Raster Width ( <i>Esc*t#V</i> )	Monochrome Print Mode ( <i>Esc&amp;b#M</i> )
Foreground Color ( <i>Esc*v#S</i> ) * **	Color Lookup Tables ( <i>Esc*l#E</i> )
Gamma Correction ( <i>Esc*t#I</i> )	Viewing Illuminant ( <i>Esc*i#W</i> )
Logical Operation ( <i>Esc*l#O</i> )	Pixel Placement ( <i>Esc*l#R</i> )
Push/Pop Palette ( <i>Esc*p#P</i> )	Select Palette ( <i>Esc&amp;p#S</i> )
Raster Presentation ( <i>Esc*r#F</i> )	Palette Control ID ( <i>Esc&amp;p#I</i> )
Raster Resolution ( <i>Esc*t#R</i> )	Palette Control ( <i>Esc&amp;p#C</i> )

\* DEVICE NOTE: DJ850C does not lock out these commands.

\*\* DEVICE NOTE: DJ540 does not lock out these commands.

### Raster Commands that are Allowed in Raster Mode

The following raster commands may be used in raster mode:

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

**Start Raster**    *Esc \* r # a/A*

Starts raster mode and specifies the starting position of the raster image.

Value(#)	= 0	Start raster at logical page left boundary (current vertical position)
	= 1	Start raster at CAP (current vertical and horizontal position)
	= 2	Turn on scale mode and start raster at logical page left boundary
	= 3	Turn on scale mode and start raster at CAP
Default	= 0	
Range	= 0 to 3	

DEVICE NOTE: Only Color LJ, DJ1200C, and DJ1600C use values 2 and 3.

This command sets the left raster margin (see the table below). A value of 0 starts the upper left raster at the current vertical position on the left edge of the logical page. A value of 1 starts the upper left raster corner at CAP (the current vertical and horizontal position). Values of 2 or 3 are equivalent to 0 and 1, but additionally enable resolution-independent scaling.

**NOTE:** To use raster scaling, send Configure Image Data (*Esc\*v#W*) before Start Raster (*Esc\*r#A*).

The default left raster margin is defined as:

Raster Presentation Mode	Orientation	Default Left Raster Margin
0	Portrait	Logical page left boundary
0	Reverse portrait	Logical page left boundary
0	Landscape	Logical page left boundary
0	Reverse landscape	Logical page left boundary
3	Portrait	Logical page left boundary
3	Reverse portrait	Logical page left boundary
3	Landscape	50 dots from the logical page top boundary
3	Reverse landscape	50 dots from the logical page top boundary

Using presentation mode 3 and landscape or reverse landscape orientation, each raster row runs along the vertical direction of the logical page.

This command locks out the commands listed on the previous page and clears the seed row for raster compression.

This command fixes raster height, width, resolution, and presentation mode until the next Start Raster command. If raster mode is started implicitly, the current left raster margin, height, width, compression, resolution, and presentation mode are used.

## **End Raster** *Esc \* r C*

This command ends Raster Mode. It signifies the end of the transfer of a raster image and ends the current raster row. It performs the following functions:

- Zeros the seed row (see Compression Method *Esc\*b#M*).
- Re-enables commands locked out of raster mode by *Esc\*r#A*.
- Defaults the compression method to 0.
- Resets the left raster margin to 0.
- Moves CAP to the row immediately following the end of the raster area and zero fills empty rows if source raster height was specified; otherwise to the next row.
- Resets the plane counter.

## **Raster Resolution** *Esc \* t # r/R*

Defines the resolution at which raster data is to be printed

Value(#) = Resolution in pixels per inch (ppi)  
Default = Device dependent  
Range = 0 to  $2^{32} - 1$

To assure that the picture is printed without data loss, an unsupported resolution maps to the next highest supported resolution.

This command is ignored during raster mode. If raster mode is entered with scaling ON (*Esc\*r2A*, *Esc\*r3A*), resolution is ignored but saved.

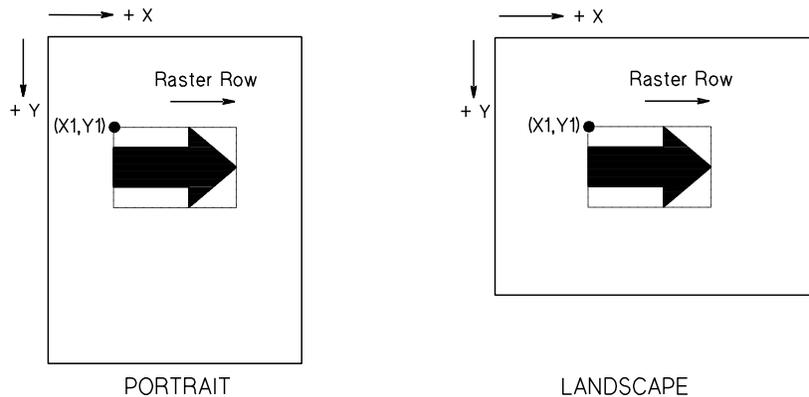
## Raster Presentation *Esc \* r #f/F*

Specifies the orientation of the raster image on the logical page.

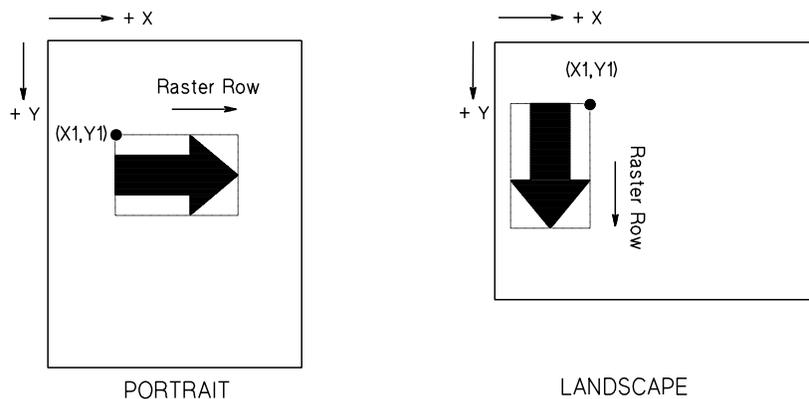
Value(#)	= 0	Prints in the orientation of logical page
	= 3	Prints along the width of the physical page
Default	= 3	
Range	= 0, 3	

A value of 3 prints the raster graphic 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, and the next raster row is printed in the positive Y-direction. In landscape orientation, a raster row is printed in the positive Y-direction, and the next row is printed in the negative X-direction.

**NOTE:** The (X1,Y1) location below is the position of CAP prior to the raster data transfer. The location of (X1,Y1) depends on the value specified by the Start Raster command (*Esc\*r#A*).



PRESENTATION MODE 0



PRESENTATION MODE 3

(X1,Y1) = current active position prior to the raster data transfer

## Source Raster Width *Esc \* r # s/S*

Specifies the width in pixels of the raster area.

Value(#) = Width in pixels of the specified resolution  
Default = Right logical page boundary minus the left raster margin (depends on raster presentation mode)  
Range = 0 to  $2^{32} - 1$  (clamped to the right logical page boundary minus the left raster margin)

This command specifies a distance from the left raster margin. The left raster margin may be set at CAP (implicit or explicit Start Raster) or at the left edge of the logical page (explicit Start Raster).

The printer clips data that would extend outside the specified width or beyond the right logical page boundary. In other words, raster data that would appear outside the intersection of the logical page, the printable area, and the raster width and height if specified is clipped.

Incompletely-filled rows are zero-filled to the specified width. The color of zero-filled areas depends on the color configuration (i.e. direct vs indexed, white/black references, the color at index 0, source transparency mode, etc).

Since width is in the direction that the raster rows are laid down, source raster width is relative to the current raster presentation mode.

This command is required for raster scaling and must precede a Start Raster command with a value of 2 or 3 (*Esc\*r2A* or *Esc\*r3A*).

This command is ignored after raster mode starts.

A specified source raster height or width of zero causes subsequent raster data to be ignored.

DEVICE NOTE: LJs, DJ1200C, and PJXL300 clip at the right logical page boundary if Source Raster Width is specified, and at the right printable area boundary if width is not specified.

DEVICE NOTE: LJs, DJ1200C, and PJXL300 zero-fill to the right printable area boundary if source raster width is not specified.

DEVICE NOTE: DJ540 does not lock out this command in raster mode.

DEVICE NOTE: DJs below 800 round Source Raster Widths that are not a multiple of 8 to the next higher multiple of 8 (i.e., the next byte boundary).

**Source Raster Height** *Esc \* r # t/T*

Specifies the height of the raster area in pixels.

Value(#) = Height in pixels  
 Default = NA  
 Range = 0 to  $2^{32} - 1$  (clamped to logical page length minus the Y position of CAP)

This command specifies a vertical distance from CAP.

If not specified, height extends either to the row preceding an implicit or explicit End Raster (*Esc\*rC*) or to the lower edge of the printable area.

The printer clips rows if they are outside the specified height or if the specified height extends outside the printable area with scale mode off.

The printer zero-fills unsent rows to the specified height; but no padding occurs if height is not specified. A specified height or width of zero clips the entire raster graphic. If raster mode is started and stopped before a non-zero specified area is filled, the unsent area is zero-filled. The printer zero-fills rows that incompletely fill the specified width. The color of zero-filled areas depends upon the color configuration (i.e., direct vs indexed, white/black references, the color at index 0, source transparency mode, etc).

"Height" is perpendicular to the direction that raster rows are laid down; therefore, height is relative to the current raster presentation mode (*Esc\*r#F*).

This command is required for raster scaling and must precede a Start Raster command having a value of 2 or 3 (*Esc\*r2A* or *Esc\*r3A*).

This command is ignored once raster mode starts.

**Raster Y Offset** *Esc \* b # y/Y*

Moves CAP vertically relative to CAP. Moves may extend outside the raster area. The amount of movement depends on the device resolution setting.

Value(#) = Number of raster lines of vertical movement  
 Default = NA  
 Range = 0 to  $2^{32} - 1$

This command zero-fills the offset area. The color of zero-filled areas depends upon the current color configuration (i.e., direct vs indexed, white/black references, the color at index 0, etc).

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 block of data.

## 13.3 Raster Data Transfer

The Transfer Raster commands (*Esc\*b#V*, *Esc\*b#W*) define how many bytes are to be interpreted as binary raster data, rather than as ASCII data.

Transfer Raster by Plane (*Esc\*b#V*) is used when the data is encoded by plane, as specified by Simple Color (*Esc\*r#U*), Configure Image Data (*Esc\*v#W*), or the HP-GL/2 *IN* command. Usually, *Esc\*b#V* sends each plane in the row except the last; then *Esc\*b#W* sends the last plane and advances the row.

The Transfer Raster by Row command (*Esc\*b#W*) moves CAP to the next pixel row after execution. It is used in single-color mode, for the last plane in a multi-plane row, or for color raster transfer when the data is encoded by pixel.

### Transfer Raster by Plane *Esc \* b # v/V [Data]*

Sends a plane of data to the printer and advances to the next plane, but not to the next row.

Value(#) = Number of bytes in the data field  
 Default = NA  
 Range = 0 to  $2^{32} - 1$

The number of planes per row is specified by Simple Color (*Esc\*r#U*), Configure Image Data (*Esc\*v#W*), Configure Raster Data (*Esc\*g#W*), or the HP-GL/2 command *IN*. The first plane sent represents the least significant bit in the pixel.

*Esc\*b#V* does not advance the row. Only *Esc\*b#W* can advance the row.

The amount of data sent is independent of raster width and may vary from plane to plane. Planes shorter than the raster width are zero-filled. Empty planes can be sent by *Esc\*b0V* except in Compression Methods 3 or 9 (*Esc\*b#M*). If fewer planes are sent than specified and the row ended early by *Esc\*b0W*, the undefined planes are zero-filled (except in compression methods 3 and 9). The color of zero-filled areas depends on the current configuration (i.e., direct vs indexed, white/black references, the color at index 0, source transparency mode, etc).

If more planes are sent than specified, the extra planes are ignored and the binary data discarded. If *Esc\*b#W* is one of the extra planes, its data is ignored and the row incremented.

If an End Raster command (*Esc\*rC*) is received before the row is completed, the output is not rendered and the row is incremented.

The data field is interpreted according to the current Compression Method.

This command implicitly starts raster mode if sent in the absence of a Start Raster command (*Esc\*r#A*).

DEVICE NOTE: Little "v" is not supported by LJs and DJ1200 and 1600.

## Transfer Raster by Row/Block *Esc \* b # w/W [data]*

Transfers the number of bytes specified in the value field to the printer in a row by row or block format, depending on the current compression method (*Esc\*b#M*), then moves CAP to the next row.

Value(#) = Number of bytes in the raster row/block  
 Default = NA  
 Range = 0 to  $2^{32} - 1$

This is the only data transfer command used in single-color devices, or in multi-color devices in which the data is not plane-encoded. This command increments the row pointer; therefore it is used to send the last plane in a multi-plane row.

In both *row* or *block* formats (see Compression Method 4), CAP is updated for each row. For row formats, CAP is reset to the left raster margin at the next raster row. For block formats, CAP is reset to the initial X-coordinate (left raster margin) of the block at the end of each row, and the Y-coordinate is incremented. For color data, the plane counter in a multi-plane row is reset to the first plane at the end of a row.

The data can vary from row to row and is independent of source raster width. If raster width is greater than data sent, the undefined area is zero-filled. The color of zero-filled areas depends upon the current color configuration (i.e., direct vs indexed, white/black references, the color at index 0, source transparency mode, etc). Data that would appear outside the intersection of the logical page, the printable area, and the specified raster width and height if specified, is clipped; however, the truncated data does affect the seed row.

The data field is interpreted according to the current Compression Method (*Esc\*b#M*).

The compression seed row is zeroed upon receipt and completion of a raster block.

DEVICE NOTE: Little "w" is not supported by LJs, and DJ1200 and 1600.

## 13.4 Raster Compression

Compressed data formats can improve data transfer throughput and efficiency (however, the amount of printer memory required to produce an image is not reduced). The Compression Method command (*Esc\*b#M*) provides several ways of compressing raster data.

**NOTE:** In addition to the compression methods described below, white-space transfer can also be reduced by sending empty rows and planes (*Esc\*b0W*, *Esc\*b0V*), or by offsetting the left graphic margin (*Esc\*rIA*) or vertical starting point (*Esc\*b#Y*); however, these methods are risky because the color of zero-fill depends on the current transparency modes and color configuration.

### Compression Method *Esc \* b # m/M*

Determines how raster data is interpreted in the Transfer Raster commands (*Esc\*b#V*, *Esc\*b#W*).

Value(#)	=	0	Unencoded
	=	1	Run-length
	=	2	Tagged Image File Format (TIFF) rev 4.0 "Packbits"
	=	3	Delta row
	=	4	Unencoded (block-based)
	=	5	Adaptive (block-based)
	=	6	CCITT Group 3 one-dimensional encoding (block-based)
	=	7	CCITT Group 3 two-dimensional encoding (block-based)
	=	8	CCITT Group 4 encoding (block-based)
	=	9	Compressed replacement delta row encoding
Default	=	0	
Range	=	0 to 9 (out-of-range values default to 0)	

DEVICE NOTE: On the HP5000 fanfold, Source Raster Width (*Esc\*r#S*) is not used; and clipping and zero-fill are not supported. Instead, the first four bytes (32-bit unsigned integer field) of Transfer Raster Data by Row (*Esc\*b#W*) specify the number of pixels in a row. The decompressed image must fit the dimensions bounded by this value and Source Raster Height (*Esc\*r#T*); otherwise, an error occurs. The range for the number of pixels per row that may be specified by this command is 0-5400.

The compression method remains in effect until explicitly changed to another method, a reset (*EscE*) occurs, or raster mode is terminated.

Compression can be turned on or off within a given raster image; and the compression method can be changed for each row.

Methods 6, 7, and 8 are currently defined as monochrome compression methods: data is sent for one plane only. If other planes are sent, all data planes except the first are assumed to be zeroed: the colors defined for indices 0 and 1 are always rendered for 0 and 1 bits respectively, regardless of how many planes were specified by byte two (number of bits per index) of the Configure Image Data command (*Esc\*v#W*).

## Method 0 - Unencoded

This is a simple binary transfer: no compression. Each bit has a one-to-one mapping to each pixel that is to be printed. Bit 7 of the first byte is the most significant bit. It corresponds to the first dot within the raster row. Bit 0 is the least significant bit and corresponds to the eighth dot.

## Method 1 - Run-Length Encoding

The raster data is sent as byte pairs: the first byte is the repetition count for the second byte. Thus, two bytes will be sent even if a byte is not repeated; however, if a byte is repeated, it need only be sent once, along with its repetition count byte. Therefore, method 1 is most useful if there are a large number of identical bytes within a raster row. The repetition count byte contains the total number of consecutive identical bytes minus 1. A count of 0 means the byte pattern occurs once and is not repeated; a count of 1 means the pattern occurs twice; and a count of 255 (the maximum) means the pattern occurs 256 times.

**NOTE:** Method 1 requires byte pairs: a Transfer Raster command (*Esc\*b#V*, *Esc\*b#W*) with an odd value field is ignored and the data discarded.

## Method 2 - Tagged Image File Format Encoding (TIFF revision 4)

Method 2 combines methods 0 and 1, with blocks of repeated bytes and blocks of unrepeated (*literal*) bytes. A control byte in two's complement format precedes each block; it indicates the number of succeeding bytes in the block, and whether they are repeated or literal.

If bit 7 of the control byte is set (byte = -1 to -127), the following bytes are repeated. The control byte's absolute value is the number of repetitions. The actual number of occurrences is the repetition count + 1. A control byte of -5 means the subsequent byte is repeated 5 times (6 occurrences).

If bit 7 of the control byte is zero (byte = 0 to 127), the following bytes are literal. The number of succeeding data bytes is 1 + the value of the control byte. A control byte of 0 means 1 literal byte follows; a control byte of 6 means 7 literal bytes follow.

A value of -128 represents a non-operative (NOP) control byte. This byte is ignored and the subsequent byte is treated as a new control byte.

It is more efficient to code two consecutive identical bytes as a repeated byte, unless these bytes are preceded and followed by literal bytes.

**NOTE:** The byte count value (#) or row length specified by the Raster Transfer commands (*Esc\*b#V*, *Esc\*b#W*) has precedence if it is met before the literal run count.

EXAMPLES OF METHODS 0-2

The following examples show how methods 0-2 can be used to send the raster row below:

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

Compression method 0 - Unencoded

```
Esc*r1A
Esc*b0m7WUUUUATT
Esc*rC
```

Compression method 1 - Run-length encoding

```
Esc*r1A
Esc*b1m6W(3)U(0)A(1)T
Esc*rC
```

Compression method 2 - TIFF encoding

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

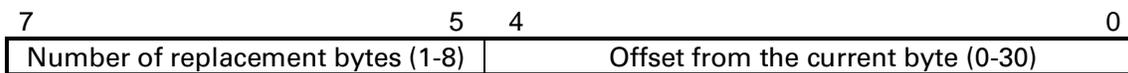
**Method 3 - Delta Row Encoding**

Delta row compression identifies bytes in a row that are different from the preceding row and then transmits only the data that is different. The previous row that has just been sent is called the **seed row**. The new row that reflects the changes is called the **delta** row. The delta row becomes the seed row when it is printed.

In delta row compression, a raster row consists of a command byte and one to eight replacement bytes:

[ Command byte ] [ replacement bytes ]

The command byte has two parts:



- Number of Delta Bytes: Bits 5-7 indicate the number of consecutive replacement bytes that follow the command byte. The actual number of replacement bytes is always one more than the value (000 = 1, 111 = 8).
- Offset: Bits 0-4 show where to position the replacement byte string. This is the *offset*: it specifies a byte placement, counting from left to right from the current byte position. The "current" byte is the first unaltered byte that follows the last replacement byte; at the beginning of a row, the current byte immediately follows the left raster margin.

An offset of 0 indicates the current byte; an offset of 1 indicates the byte following the current byte. For example, assume the current byte is the first byte in the row. An offset of 7 skips bytes 0 through 6, and a replacement count of 5 replaces bytes 7 through 11. The new current byte is 12. A second offset of 3 skips bytes 12, 13, and 14; byte 15 is the next byte to be replaced.

Bits 0-4 allow maximum value of 31; but larger offsets are possible. A value of 0 to 30 indicates the delta bytes are offset from the 1st to the 31st byte. A value of 31 indicates that an additional *offset byte* follows the command byte. To summarize, bits 0-4 have the following meanings:

- |         |  |
|---------|--|
| 0 to 30 | The offset is 0 to 30.   |
| 31      | The offset is 31 or greater. If the offset is 31, an additional <b>offset byte</b> follows the command byte. The offset in the command byte is added to the offset byte. If the offset byte is 0, the offset is 31; if the offset byte is 255, additional offset bytes follow. The last offset byte will have a value less than 255. All the offset bytes are added to the offset in the command byte to get the offset value. For example, if there are two offset bytes, and the last byte contains 175, the total offset would be: $31 + 255 + 175 = 461$ . |

If more than eight delta bytes are needed, additional "command byte/delta bytes" are added:

[ ( Command Byte) (1-8 Delta Bytes ) ] [ ( Command Byte) (1-8 Delta Bytes ) ] . . .

Upon entering raster mode, the seed row is zeroed and its width is set to the Source Raster Width (*Esc\*r#S*). Every raster transfer (*Esc\*b#V*, *Esc\*b#W*) affects the seed row, regardless of the compression method. For example, *Esc\*b0W* while in compression method 0 zeros the seed row. This allows method 3 to be combined with other methods in order to achieve better compression performance.

Method 3 operates on each plane independently; a separate seed row is maintained for each plane.

Raster Y Offset (*Esc\*b#Y*) zeros the seed row as well as skipped rows. Raster Y Offset affects all planes and rows simultaneously.

The following examples show the effects of some escape sequences in method 3 compression:

- |                |   |
|----------------|---|
| <i>Esc*b0W</i> | Repeat the previous row. The seed row is unchanged. |
| <i>Esc*b1Y</i> | Move down one raster row. Zero the seed row.        |
| <i>Esc*b0Y</i> | Zero the seed row.                                  |

The byte count in the value field of the Transfer Raster commands (*Esc\*b#V*, *Esc\*b#W*) has precedence over the byte count in the command byte. For example, if the byte count is 10, but the data field has 3 bytes, only 3 bytes are replaced. If the last byte indicated by the value field in a Transfer Raster command is a control byte, that byte is ignored; therefore, *Esc\*b1W* does not affect the seed row, but causes the previous row to be repeated.

## EXAMPLE OF METHOD 3:

The following binary raster data is compressed using method 3. Italicized bytes are those needing replacement — bytes different from the seed row. The seed row is zeroed upon raster mode entry.

Byte #:	1	2	3	4	5
Row 1	00000000	<i>11111111</i>	00000000	00000000	00000000
Row 2	00000000	11111111	<i>11110000</i>	00000000	00000000
Row 3	<i>00001111</i>	11111111	11110000	<i>10101010</i>	<i>10101010</i>

*Esc\*r1A*

*Start Raster* initializes the seed row to all zeros.

Row 1 - *Esc\*b3m2W(00000001)(11111111)*

The **3m** selects method 3, and **2W** indicates that two bytes of data will follow. The upper three bits of the command byte are zero, indicating one byte will be replaced. The lower five bits contain a relative offset of 1, indicating that the replacement occurs 1 byte in from the current position. The replacement byte follows and contains 11111111.

Row 2 - *Esc\*b2W(00000010)(11110000)*

The first three bits of the command byte are 0 indicating one byte will be replaced. The lower five bits contain a relative offset of 2; so the replacement will occur 2 bytes from the current position. The replacement byte 11110000 follows.

Row 3 - *Esc\*b5W(00000000)(00001111)(00100010)(10101010)(10101010)*

Three bytes are replaced using two commands. The first three bits of the first command byte are zero, indicating a single byte replacement, and the next five bits are zero, indicating a relative offset of zero. The replacement byte 00001111 follows.

The first three bits of the second command byte are 001, indicating the replacement of two bytes; and the lower five bits contain a relative offset of two. The two replacement bytes (10101010)(10101010) follow the command byte.

#### Method 4 - Unencoded (simple binary transfer by block)

Method 4 is the same as method 0 except that a single *Esc\*b#W* command may transfer all or any part of the raster data for the entire image.

Rows start on a byte boundary. The number of pixels per row is specified in the first four bytes of the raster data as a 32-bit unsigned integer binary value. This value must be a multiple of 8; otherwise, the next larger multiple of 8 is used. The row is padded to or clipped at the source raster width (*Esc\*r#S*). All planes for the first row are defined before the first plane of the second row, etc.

For both implicit and explicit row/plane divisions, the plane counter is incremented after the data for each plane is received. When the row is completely defined, the row counter is incremented, the plane counter is reset, and CAP is set to the left raster margin (i.e., CAP is reset to the initial X-coordinate of the block at the end of each row and the Y-coordinate is incremented).

If the last row of data specifies an incomplete row or if not all the planes have been defined, the unspecified data is assumed to be 0's. If source raster height ( $Esc*r\#T$ ) is specified, the same rules given for source raster width apply.

### Method 5 - Adaptive Compression

Adaptive compression enables the combined use of methods 0-3: when the row data within a block is no longer optimally compressed by one method, the method may be changed to "adapt" to the data. It can specify empty (all 0's) or duplicate rows to skip white space or replicate identical rows.

Adaptive compression interprets a raster image as a block of data, rather than as individual rows. When using this method, the Transfer Raster command ( $Esc*b\#W$ ) is sent only once, at the beginning of a raster transfer; its value field specifies the number of bytes in the entire block, rather than the number of bytes in a row. The block size of the compressed data is limited to 32767 bytes. To transfer more bytes, more blocks can be sent.

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 that row. The following two bytes specify either the number of bytes within the row or the number of duplicate or empty rows. The format of an adaptive compression raster row is shown below:

	msb	lsb	
<command byte>	<# of bytes/rows>	<# of bytes/rows>	<raster data>

As shown below, the command byte designates the compression method, empty row, or duplicate row:

Value =	0	Unencoded
	1	Run-Length Encoding
	2	Tagged Image File Format (TIFF) revision 4.0
	3	Delta Row
	4	Empty row
	5	Duplicate row
Range =	0 to 5 (out-of-range values and data are ignored, the remainder of the block is skipped, CAP is not updated, and the seed row is cleared)	

Command byte values 0-3 indicate the compression method to be used for a row. The two-byte field <# of bytes/rows> specifies the number of bytes in the row (**row length**). The most significant byte (high byte) of this field is sent first, followed by the least significant byte (low byte). The maximum value for the two-byte field is 65535, but the image will be clipped to the logical page; therefore.

A command byte value of 4 prints one or more rows containing zeros. The two-byte field <# of bytes/rows> identifies the number of empty or duplicate rows to be encountered after the current row, including the current row. An empty-row operation resets the seed row to zero and updates CAP.

A command byte value of 5 causes the previous row to be printed again the number of times contained in the two-byte field <# of bytes/rows>. A duplicate-row operation updates CAP, but does not change the seed row.

## USAGE GUIDELINES FOR ADAPTIVE COMPRESSION

- Compression methods cannot be mixed within one row.
- CAP is updated with each row of the raster block. CAP is also incremented for block counts less than 3.
- The Raster Y Offset command moves the entire block of raster data and zeros the seed row — even if the Raster Y Offset is zero.
- Block size takes precedence over row length. If the row length of any line exceeds the block size, the row size is truncated to the block size.
- For method 1, if the row length is odd, CAP is incremented and the row data is skipped (discarded), but the seed row is unchanged.
- For method 1, a row length of zero increments CAP and zeros the seed row.
- For method 2, CAP is always incremented and a new row started when row length is satisfied, regardless of the control byte value. "Extra" bytes following the control byte are used to start the next row.
- For method 2, a row length of 1 inputs one byte from I/O and increments CAP. The data is ignored and the seed row is zeroed.
- For method 3, CAP is always incremented and a new row started when row length is satisfied, regardless of the control byte value. "Extra" bytes following the control byte are used to start the next row.
- For method 3, a row length of zero duplicates the current row and increments CAP.
- For method 3, a row length of 1 inputs one byte from I/O, duplicates the current row, and increments CAP. The data is ignored.
- For duplicate and empty rows, a row length of zero does not update CAP; but the seed row is zeroed.
- An unsupported command byte for a row causes the remaining bytes in the block to be skipped and the seed row zeroed; CAP is not incremented.

## EXAMPLE OF ADAPTIVE COMPRESSION

The following example demonstrates adaptive compression.

<i>Esc*r3F</i>	Set presentation method to 3; and print along the width of the physical page, regardless of the logical page orientation.
<i>Esc*t300R</i>	Set raster resolution to 300 dpi.
<i>Esc*r1A</i>	Start raster at CAP. The seed row is initialized to all zeros.
<i>Esc*b5M</i>	Set compression method to 5, Adaptive Compression.

*Esc\*b84W* Transfer a raster block of data containing 84 bytes.

Ten rows of raster data are sent within the block. The first three rows are compressed using method 3, Delta Row, compression. The next row is compressed by compression method 1, Run Length Encoding. The next three rows of data are specified as duplicate rows of the previous Run Length Encode row. Finally, the last three rows are compressed using method 3. CAP is updated after each raster row within the block is processed.

The raster block has the following format and HEX data:

Row	Control byte	# bytes per row	Raster data
1	03 hex	00 09 hex	E0 FF F0 00 FF FF 00 0F FF
2	03 hex	00 09 hex	E0 00 00 FF F0 0F FF 00 00
3	03 hex	00 09 hex	E0 FF F0 00 FF FF 00 0F FF
4	01 hex	00 06 hex	00 FF 05 00 00 FF
5	05 hex	00 03 hex	
6	03 hex	00 09 hex	E0 FF F0 00 FF FF 00 0F FF
7	03 hex	00 09 hex	E0 00 00 FF F0 0F FF 00 00
8	03 hex	00 09 hex	E0 FF F0 00 FF FF 00 0F FF

*Esc\*rC* End raster session.

#### **Method 6: CCITT Group 3 One-Dimensional Encoding (Modified Huffman)**

CCITT Group 3 one-dimensional encoding is a block-based compression method that uses a statistical encoding similar to Huffman encoding. The length of alternating white and black (zero and one bit) runs are calculated, and then a table look-up is employed to output the corresponding binary codes. Refer to *CCITT Fascicle VII.3 Recommendation T.4* for details.

#### **Method 7: CCITT Group 3 Two-Dimensional Encoding (Modified READ)**

Method 7 is similar to method 6, except that the first row is sent using one-dimensional encoding followed by up to K-1 two-dimensional encoded rows, where K is the K-factor used when the data was encoded. Refer to *CCITT Fascicle VII.3 Recommendation T.4* for details.

#### **Method 8: CCITT Group 4 Encoding (Modified Modified READ)**

Method 8 is similar to method 7, except that all encoding is two-dimensional, does not include end of line delimiters, and does not allow padding to byte boundaries. Refer to *CCITT Fascicle VII.3 Recommendation T.6* for details.

## Method 9 - Compressed Replacement Delta Row Encoding

Like Method 3, this method replaces only bytes in the current row that differ from the preceding (seed) row. Unlike Method 3, the replacement (delta) bytes may be compressed.

The replacement byte string (delta compression string) consists of a command byte, optional offset bytes, optional replacement count bytes, and the replacement data.

Command Byte	Optional Offset Bytes	Optional Replacement Count Bytes	Data Bytes
--------------	-----------------------	----------------------------------	------------

The command byte itself has three parts:

Control Bit	Offset Count	Replacement Count
-------------	--------------	-------------------

**Control Bit** Determines whether the replacement data is compressed, and also the bit boundaries of the command byte's other two fields.

**Offset Count** The offset (number of bytes) the replacement data is offset from the current byte position in the seed row.

**Replacement Count** The number of consecutive bytes to replaced. One more byte than the replacement count is replaced (i.e., 6 bytes are replaced by a replacement count of 5).

Like compression method 3, The "current" byte follows the last replacement byte; at the beginning of a row, the current byte immediately follows left *raster margin*. An offset of 0 indicates the current byte; an offset of 1 indicates the byte following the current byte.

The size of the offset count and replacement count fields depends on the value of the control bit.

CONTROL BIT = 0

7	6	3	2	0
Control Bit = 0		Offset Count	Replacement Count	

If the control bit is 0, the replacement data is uncompressed. Bits 0-2 indicate the replacement count, and bits 3-6 indicate the offset count.

If the offset count is 15, an additional *offset count byte* follows and is added to total offset count. If the offset count byte is 255, another offset count byte follows. The last offset count byte is indicated by a value less than 255.

If the replacement count is 7, an additional *replacement count byte* follows and is added to the total replacement count. If the replacement count byte is 255, another replacement count byte follows. A value less than 255 indicates the last replacement count byte. One more than the total replacement byte count will be replaced. The number of data bytes immediately following the command and its optional bytes is replacement count+1. (That is, the replacement count is normalized from 0-7 to 1-8.)

CONTROL BIT = 1



If the control bit is 1, the replacement data is run length encoded. The bit boundaries are different than if the control bit is 0: bits 5-6 contain the offset count, and bits 0-4 contain the replacement count. As when the control bit is 0, optional offset bytes and replacement bytes may be added.

If the offset count is 3, an additional *offset count byte* follows and is added to total offset count. If the offset count byte is 255, another offset count byte follows. The last offset count byte is indicated by a value less than 255.

If the replacement count is 31, an additional *replacement count byte* follows and is added to the total replacement count. If the replacement count byte is 255, another replacement count byte follows. The last replacement count byte is indicated by a value less than 255. The single data byte to be replicated follows the command byte and its optional bytes; it is replicated *replacement count+1* times, for a total number of occurrences of *replacement count+2*. (That is, the replacement count is normalized from 0-31 to 1-32.)

## Seed Row Source *Esc \* b # s/S*

Specifies the plane of the seed row for multi-plane raster in compression methods 3 and 9.

Value(#) = 0    Use the corresponding plane of the previous row  
           = >0    Number of previous seed planes before the current plane.  
 Default    = 0  
 Range      = 0 to the number of currently active planes

For example, if the printer is in 3-plane mode and *Esc\*bOS* is sent, then:

1. The Cyan plane would use the Cyan plane from the previous row as a seed plane.
2. The Magenta plane would use the Magenta plane from the previous row as a seed plane.
3. The Yellow plane would use the Yellow plane from the previous row as a seed plane.

If the printer is in 3-plane CMY mode and *Esc\*bIS* is sent, then:

1. The Cyan plane would use the Yellow plane from the previous row as a seed plane.
2. The Magenta plane would use the Cyan plane from the current row as a seed plane.
3. The Yellow plane would use the Magenta plane from the current row as a seed plane.

## 13.5 Raster Scaling

Start Raster (*Esc\*r#A*) with a value field of 2 or 3 turns on scale mode. The raster image is rendered in the desired size independently of device resolution.

**NOTE:** Configure Image Data (*Esc\*v#W*) is necessary for raster scaling. It must be sent prior to Start Raster (*Esc\*r#A*). The Start Raster command must have a value field of 2 or 3.

Source Raster Width (*Esc\*r#S*) and Height (*Esc\*r#T*) define the source image size (the amount of data sent). Destination Raster Width (*Esc\*t#H*) and Destination Raster Height (*Esc\*t#V*) define the size of the destination image that is placed on the page. 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 raster margin and printable area boundaries. If the destination dimensions are not specified, isotropic scaling is maintained such that 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; in this case, clipping may occur.

### Destination Raster Width *Esc \* t # h/H*

Defines the width in decipoints of the destination raster picture.

Value(#)= Width in decipoints  
 Default = Right logical area boundary minus the left raster margin (CAP or left logical page boundary)  
 Range = 0 to  $2^{32} - 1$

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

A specified width that crosses the right printable boundary is clipped; but the scale factor is maintained.

### Destination Raster Height *Esc \* t # v/V*

Defines the height in decipoints of the destination raster picture.

Value(#)= Height in decipoints  
 Default = Bottom printable area boundary minus vertical CAP  
 Range = 0 to  $2^{32} - 1$

DEVICE NOTE: Color LJ, DJ1200C, and PJXL300 default to the logical page boundary minus CAP.

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

A specified height that crosses the lower printable area boundary is clipped; but the scale factor is maintained.

## Scale Algorithm *Esc \* t # k/K*

Selects an algorithm for enhancing details in downscaling color images with light or dark backgrounds. This command has no effect when scaling upward.

Value(#) = 0 Enhances color source images with a light background  
 = 1 Enhances color source images with a dark background  
 Default = 0  
 Range = 0,1

This command is valid only after the next Start Raster command (*Esc\*r#A*) is sent with the scale mode ON.

This command is ignored for scale factors greater than or equal to 1. For example, assume the source image is  $1024 \times 1280$  pixels and the destination image is  $2160 \times 2880$  decipoints (3"  $\times$  4"). At 300 dpi machine resolution, this means a destination size of  $900 \times 1200$  dots; so the specified scale algorithm would take effect.

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

