Variable cross-over points for multi-bit screening

Technical Note Hqn093

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1 Introduction

From HHR v4.1r0, when producing 2-bit or 4-bit deep output raster, it is now possible to influence how specific output pixel values (of all the possible non-zero output pixel values) are employed, including:

- using a subset of the output pixel values available at the given bit depth;
- limiting the maximum amount of an output value that the RIP employs;
- overlapping the introduction of a darker output value with the end of the preceding lighter output value.

This is achieved using the `/MixLevels` extension to `sethalftone`.

2 MixLevels

This section describes the `/MixLevels` extension in `sethalftone`.

In the PostScript language rendering model for 1-bit-per-pixel (bpp) output raster the screening information given to a RIP (frequency, angle and spot function, or thresholds) is used to determine when an output pixel is switched on (sometimes referred to as “lit”).

When producing 2 or 4-bpp output raster, the RIP can re-purpose such 1-bit screening information, so as to use it instead to determine when each output pixel should take on one of its several possible values. For an inkjet printer, each output pixel value may correspond to a different droplet size, or a different number of droplets ejected. For a laser printer, each output value may correspond to the degree of exposure at that point.

The `/MixLevels` key is a Harlequin extension that influences how the RIP does that.

In the absence of `/MixLevels`, the RIP will simply use the 1-bit screening information to determine when each output pixel takes on its next numerically-higher value, using it once to control the transition from 0 to 1, and then again from 1 to 2 and so on. This is similar to what the Red Book is referring to when it says “This scheme easily generalizes to monochrome devices with multiple bits per pixel” in section 7.4.5 “Threshold arrays”, except that the Harlequin Host Renderer can do the same with spot function screens, not just thresholds.

However, such simplistic behavior may be unsuitable for real-world output devices.

The /MixLevels key comprises an array of dictionaries, where each entry in the array influences how and when the RIP will employ one specific output pixel value out of all the possible non-zero output pixel values.

For example, in 2-bpp output raster, every pixel can take on one of three possible non-zero values: 3, 2 and 1 (from "darkest" to "lightest"). So, in its simplest form, /MixLevels for 2-bpp output will be an array that influences the use of the output pixel values 3, 2 and 1 (also in order from "darkest" to "lightest"). For example:

```
/MixLevels [
  << /Gradient 1.5 >>  % Output pixel value 3 ('Darkest')
  << /Gradient 1.0 >>  % Output pixel value 2
  << /Gradient 0.5 >>  % Output pixel value 1 ('Lightest')
]
```

where /Gradient (the only mandatory key in each dictionary) is a purely relative value that determines how "dark" one output value is, compared to another output value.

(The units used for /Gradient are irrelevant to the RIP—it evaluates how one /Gradient value compares with another. However, /Gradient values must reduce for each successive numerically-lower output pixel value.)

Another way to think of /Gradient might be the relative density contributions that an output pixel value has on the final output. So for example, if you measured the (paper-relative) densities of a patch of 100% of each of the three 2-bit pixel output values, you could probably enter those measured densities directly as the /Gradient.

2.1 Not using every possible output value

Some devices don't really employ all the possible output pixel values, so you can use fewer dictionaries in the /MixLevels array (and add a /Value key to each) to make the RIP produce just a subset of the values. For example, you could use something like this for a 2-bpp device that only actually uses pixel values 1 and 3:

```
/MixLevels [
  << /Value 3 /Gradient 1.75 >>  % Output pixel value 3 ('Darkest')
  << /Value 1 /Gradient 1.0 >>   % Output pixel value 1 ('Lightest')
]
```

Note: Currently there is a restriction that the "Darkest" pixel output value must be 3 for 2-bpp, or 15 for 4-bpp.

The dictionaries in the array must still be in descending order of /Value.

2.2 Not using 100% of every output value

You can use the `/Limit` key to prevent the RIP from using 100% of the given output value. That is, prevent it from setting every pixel in the output to the same value. For example:

```
/MixLevels [
  << /Limit 0.65 /Gradient 1.5 >>  % Output pixel value 3 ('Darkest')
  << /Limit 0.80 /Gradient 1.0 >>  % Output pixel value 2
  << /Limit 0.90 /Gradient 0.5 >>  % Output pixel value 1 ('Lightest')
]
```

Note: In current RIPs, a 100% black/solid color will always produce 100% of the darkest output pixel value even if the first entry in the `MixLevels` array has a limit less than 1.0. (This is due to a RIP-wide optimization, but can be avoided relatively easily using a suitable calibration that has **Force solids** turned off.)

2.3 Adding overlap between output values

There may be times when you want the pixels of a darker output value to start to appear before the pixels of the lighter output value have reached their specified maximum. This is achieved using the `/Overlap` key.

It is deducted from the `/Limit` of the current output value, to determine when the next darker output value will start to overlap with this one. In the following example the darker value will start to be used at the (defaulted) limit of 1.0 minus 0.2. That is, at 0.8 or 80% coverage of the lighter value:

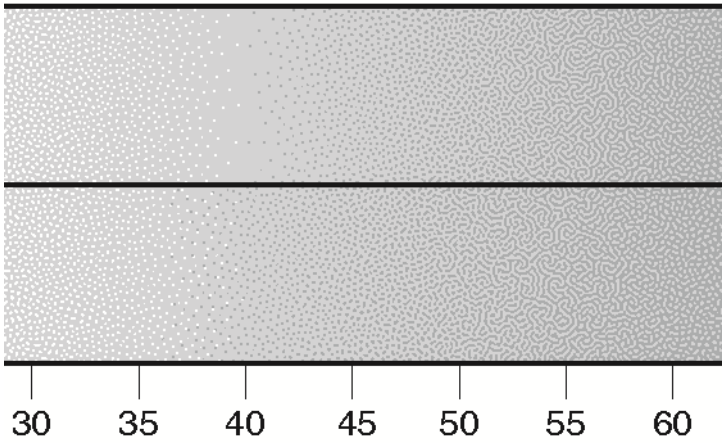
```
/MixLevels [
  << /Value 3 /Gradient 1.75 >> % Darker value
  << /Value 1 /Overlap 0.2 /Gradient 1.0 >> % Lighter value
]
```

2.4 Example 1

For Example 1 the screen is based on one of the RIP's HDS (dispersed) screens, but uses just 5 of the possible 15 non-zero output pixel values available in a 4-bpp output raster. (The coarse screen is chosen for illustration purposes.)

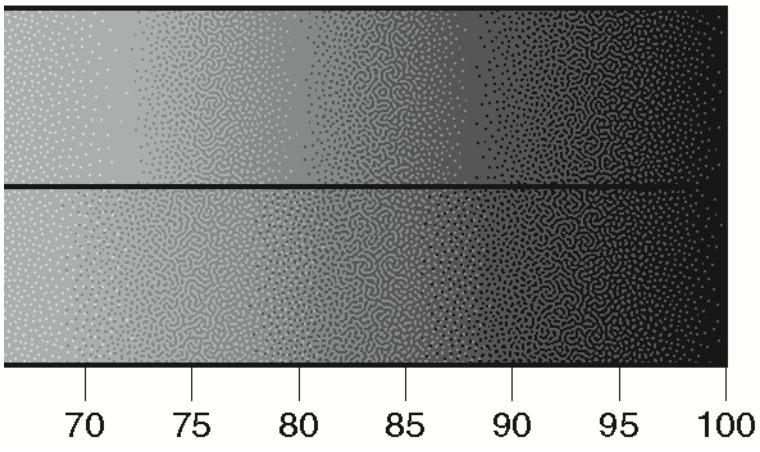
```
<<
  /HalftoneType 199 /Halftone /Hds-d-gen /HalftoneColor /D
  /HalftoneName /EG_HDS_FiveLevel
  /MixLevels [
    << /Value 15 /Gradient 2.5 >>
    << /Value 12 /Gradient 2.2 /Overlap 0.3 >>
    << /Value 9  /Gradient 2.0 /Overlap 0.3 >>
    << /Value 6  /Gradient 1.8 /Overlap 0.1 >>
    << /Value 3  /Gradient 1.0 /Overlap 0.1 >>
  ]
>>
sethalftone
```

In the absence of the `/Overlap` keys, the `/Gradient` numbers would cause the RIP to place the cross-over points at 40%, 72%, 80% and 88%. But with the `/Overlap` keys, the result is a smoother looking transition.



Example 1.a

Example 1.a shows the first cross-over point—in the upper part can be seen the result without the `/Overlap`; a distinct band can be seen wherein all the pixels are the same value. By contrast, the lower part shows the much smoother looking transition when `/Overlap` is added.



Example 1.b

Example 1.b shows the remaining cross-over points—again, the three noticeable bands in the upper part are far less obvious in the lower part because `/Overlap` is used.

Notes on example 1

Example 1 assumes 4-bit output raster (`/ValuesPerComponent 16`).

The last three cross-over points are very close together because of the relatively small difference in `/Gradient` of the darker output values.

This is also why the `/Overlap` numbers are higher for the last two output values—to stretch the overlap across a wider range.

`/HalftoneType 199` is a Harlequin extension that allows you to use a halftone dictionary declared elsewhere. In this instance we are "borrowing" one of the screens the GUI calls "HDS Coarse" (`/Halftone /Hds-d-gen`), and (for no particular reason) this example uses what HDS conventionally uses for its Black colorant (`/HalftoneColor /D`).

Note: See the file **SW\Screens\sf.ps** for the full definitions of the current HDS tile sets: `/Hds-a-gen` (also known as HDS Super Fine), `/Hds-b-gen` (HDS Fine), `/Hds-c-gen` (HDS Medium), `/Hds-d-gen` (HDS Coarse), and `/Hds-e-gen` (HDS Super Coarse). Each has six "colorants" named `/A` thru `/F`, plus two "inverse" tiles `/Ai` and `/Bi` which are the A and B tiles with their pixel order reversed.

This simple example uses a single halftone dictionary, which is effectively a `/HalftoneType 16` because that's what the type 199 alias is referring to (`/D` in `/Hds-d-gen`), but you can use `/MixLevels` in any subordinate dictionary of a `/HalftoneType 5` halftone as well.

`/HalftoneName` isn't mandatory, but it does appear in the screening "Dot-shape" messages in the RIP monitor, which can be useful. For example:

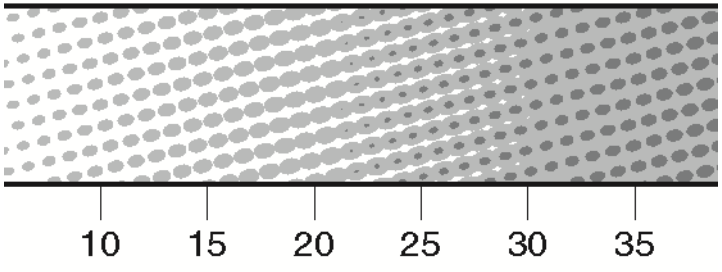
```
Dot shape: 'EG_HDS_FiveLevel'  Component: Cyan
Levels:  [15] 100.00 - 85.60  [12] 89.03 - 77.60  [9] 81.37 - 68.80  [6]
72.45 - 36.00  [3] 40.00 -  0.00
Tones used: 1024/1024
Colorants: 'Cyan' 'Magenta' 'Yellow' 'Black'
```

2.5 Example 2

Example 2 shows the use of `/MixLevels` on a normal spot-function AM screen.

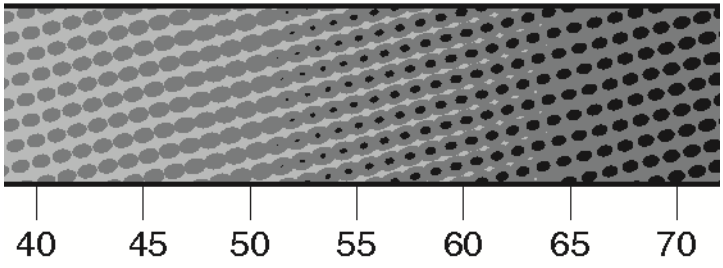
```
<<
  /HalftoneType 1
  /HalftoneName /EG_Spot_ThreeLevel
  /Angle 75
  /Frequency 12
  /SpotFunction { dup mul exch dup mul 0.5 mul add 1 exch sub } bind
  /MixLevels [
    << /Gradient 2.5 >>
    << /Gradient 1.5  /Overlap 0.3 >>
    << /Gradient 0.75 /Overlap 0.3 >>
  ]
>>
sethalftone
```

Note: The frequency value is very low for illustration purposes.



Example 2.a

Example 2.a shows the first cross-over point, and again illustrates how the use of `/Overlap` means the darker output value starts to appear as a darkening of the centre of the spot whilst the spots themselves still look like ellipses (albeit with one edge touching).



Example 2.b

Example 2.b shows the second cross-over point, and together these illustrations show how the screen retains its normal spot-shape feel over the whole range.

Notes on example 2

Example 2 assumes 2-bit output raster (`/ValuesPerComponent 4`).

The "Dot-shape" report for this example looks like this:

```
Dot Shape: 'EG_Spot_ThreeLevel', Frequency: 12.000000, Angle: 75.000000
Deviated Frequency: 12.000000, Frequency Inacc: 0.000000, Angle Inacc:
0.000000
Levels:  [3] 100.00 - 51.15  [2] 64.01 - 21.13  [1] 30.17 -  0.15
Tones used: 654/654
Colorants: 'Cyan' 'Magenta' 'Yellow' 'Black'
```

3 Definitions of keys

`/MixLevels`

(array, optional) An array of dictionaries, in descending order of (non-zero) output pixel value, each dictionary providing parameters that influence the RIP's use of that output pixel value.

3.1 Keys within the dictionaries in /MixLevels

`/Gradient`

(real, mandatory) The relative "darkness", as perceived on the output device, of one output pixel value, when compared with the other pixel values supported by the device.

Errors (other than typecheck)

The following will cause a `rangecheck` error:

`/Gradient` less than 0.0.

`/Gradient` greater than or equal to the `/Gradient` of the dictionary in the next lower index position within the `/MixLevels` array. That is, the `/Gradient` of the next "darker" output pixel value.

`/Value`

(integer, optional) The output pixel value this parameter dictionary applies to.

Range: 1 to 3 for 2-bpp output raster; 1 to 15 for 4-bpp output raster.

Default: One less than the `/Value` of the dictionary in the next lower index position within the `/MixLevels` array. That is, one less than the next "darker" output pixel value.

Errors (other than typecheck)

The following will cause a `rangecheck` error:

`/Value` less than 0.

`/Value` greater than or equal to the `/Value` of the dictionary in the next lower index position within the `/MixLevels` array. That is, the `/Value` of the next "darker" output pixel value.

`/Limit`

(real, optional) The maximum amount this output value is to be used, where 1.0 represents 100%.

Range: 0.01 to 1.0.

Default: 1.0.

Errors (other than typecheck)

The following will cause a `rangecheck` error:

`/Limit` greater than 1.0.

`/Overlap`

(real, optional) The amount before the `/Limit` of this output value that the next darker output pixel value will start to appear.

Range: 0.0 to the value of `/Limit`.

Default: 0.0.

Errors (other than typecheck)

The following will cause a `rangecheck` error:

`/Overlap` less than 0.0.

`/Overlap` greater than or equal to the `/Limit` value in the same output value dictionary.

`/Overlap` non-zero for the first dictionary in the `/MixLevels` array, because that always represents the “darkest” output value, so there can be no “darker” value with which it can overlap.

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