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A Novel Dithering Algorithm for High Color Depth and High Color Performance: Hi-FRC

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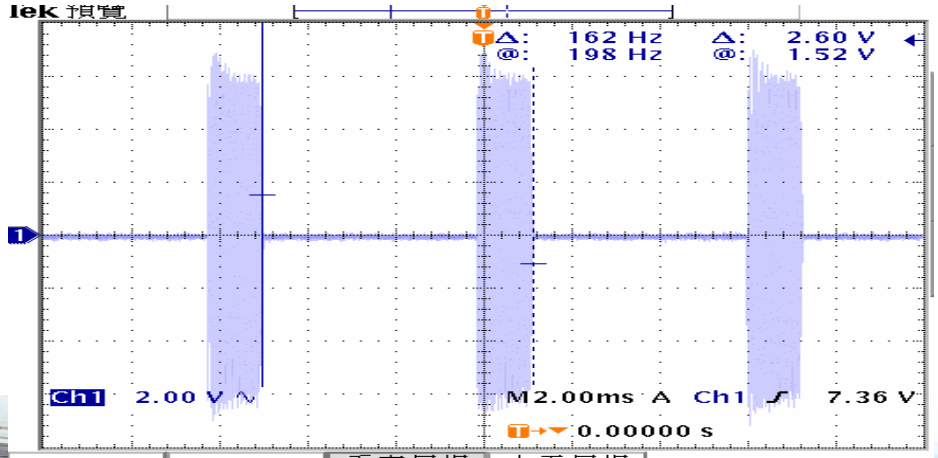
Abstract

- Conventional FRC can display only 16,194,277 colors with 6-bit source D-IC's.
- "Hi-FRC" enables full (16,777,216) color on an LCD panel.

Dimming Function

- Dimming
  - ⇨ The CCFL brightness is varied by varying the output current, etc. using an external or other signal. Dimming methods include pulse width modulation (PWM), voltage and current dimming.
- PWM(Pulse Width Modulation)
  - ⇨ This method uses a pulse signal to dim the lamp. The dimming range can be varied between 10 and 100%.

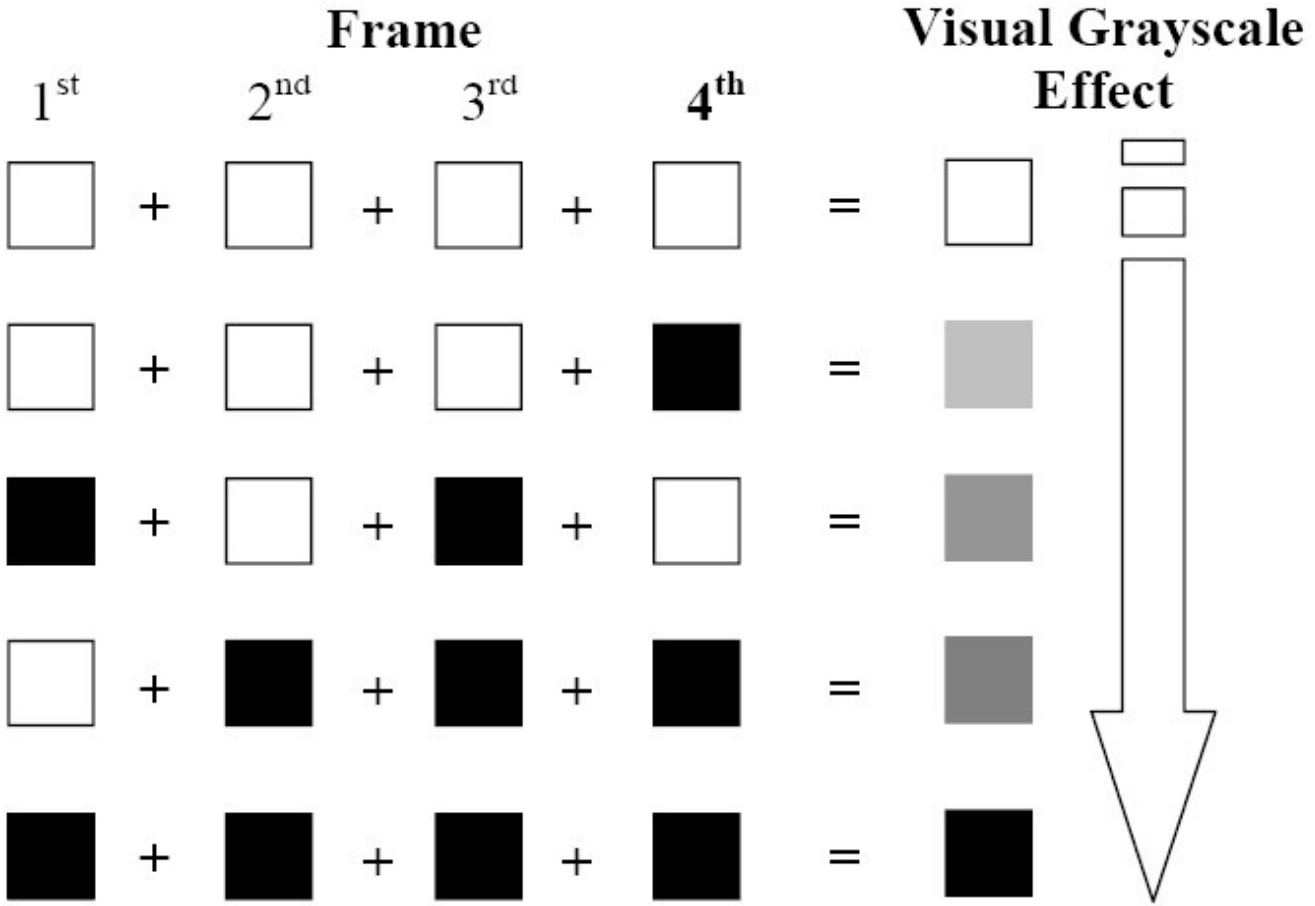


FRC and Dithering

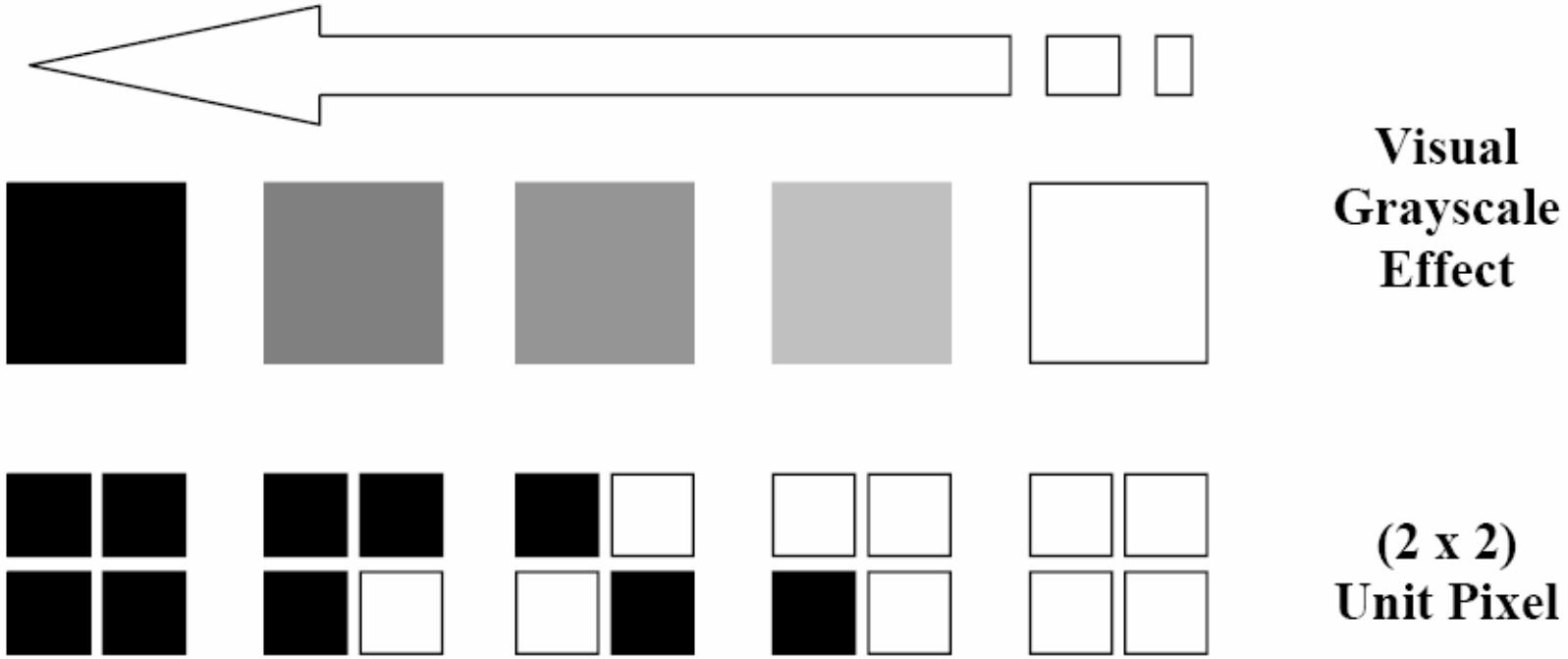
- FRC is achieved by controlling on and off pixels over multiple frames. *(Temporal)*

- Static dithering regulates the number of on and off pixels in a small defined pixel group. *(Spatial)*

FRC Driving Method

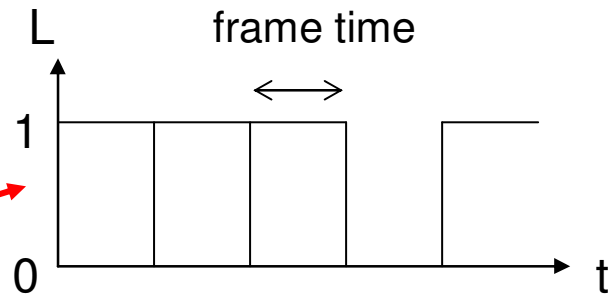


Dithering Driving Method



FRC

6bit	=>	8bit
0	=>	0
0.25	=>	1
0.5	=>	2
0.75	=>	3
1	=>	4
2	=>	8
3	=>	12
.		.
.		.
.		.
63	=>	252
		253
		254
		255



$$L = \frac{1}{4}(1+1+1+0) = 0.75$$

The human eyes average the luminance and feel the brightness is the same as grayscale “0.75”

Number of color of 6bit+FRC
$=(256\text{-}3)^3=(253)^3=16{,}194{,}277$

Temporal Average of FRC Algorithm

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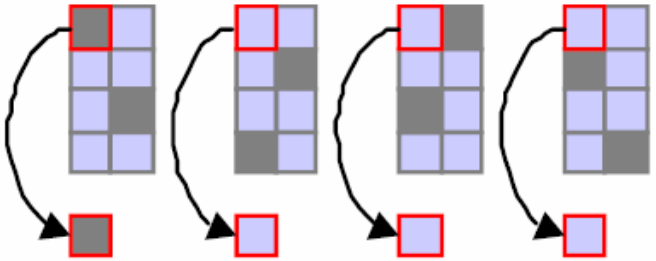
8 bits input => 6 bits output

11



$$\frac{124 + 128 + 128 + 128}{4} = 127$$

127 $(01111111)_2$ => 31,32,32,32

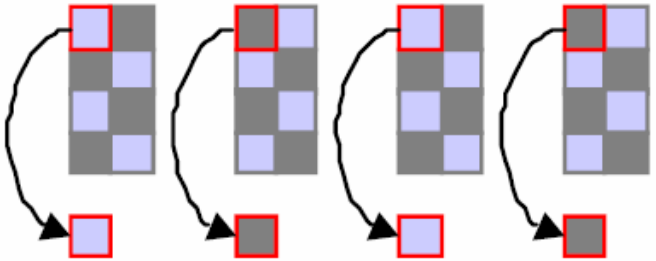
011111

100000

100000

100000

10



$$\frac{128 + 124 + 128 + 124}{4} = 126$$

126 $(01111110)_2$ => 32,31,32,31

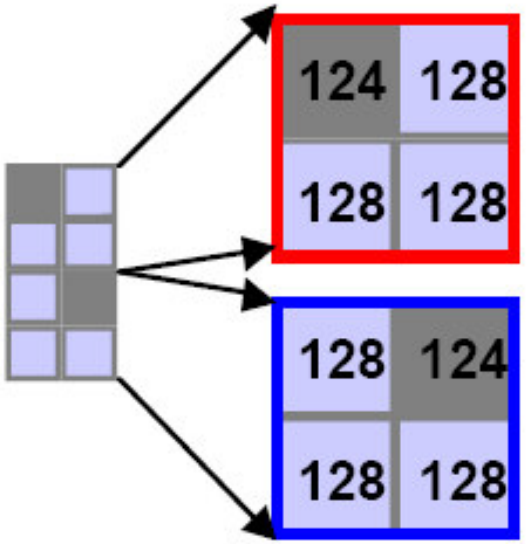
100000

011111

100000

011111

Spatial Average of FRC Algorithm



$$\frac{124 + 128 + 128 + 128}{4} = 127$$

$$\frac{124 + 128 + 128 + 128}{4} = 127$$

$127\ (01111111)_2 \ \Rightarrow\ 31,32,32,32$

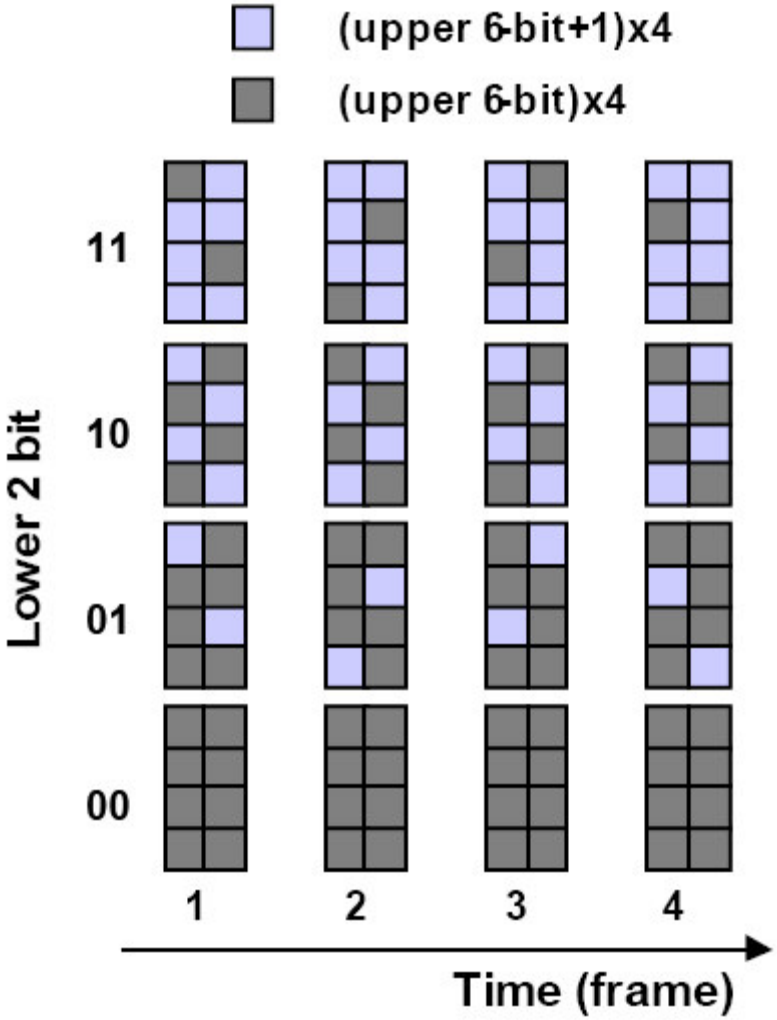
011111

100000

100000

100000

Spatial Dithering and Temporal Averaging Pattern



Conventional FRC is Limited to only 253 Luminance Levels

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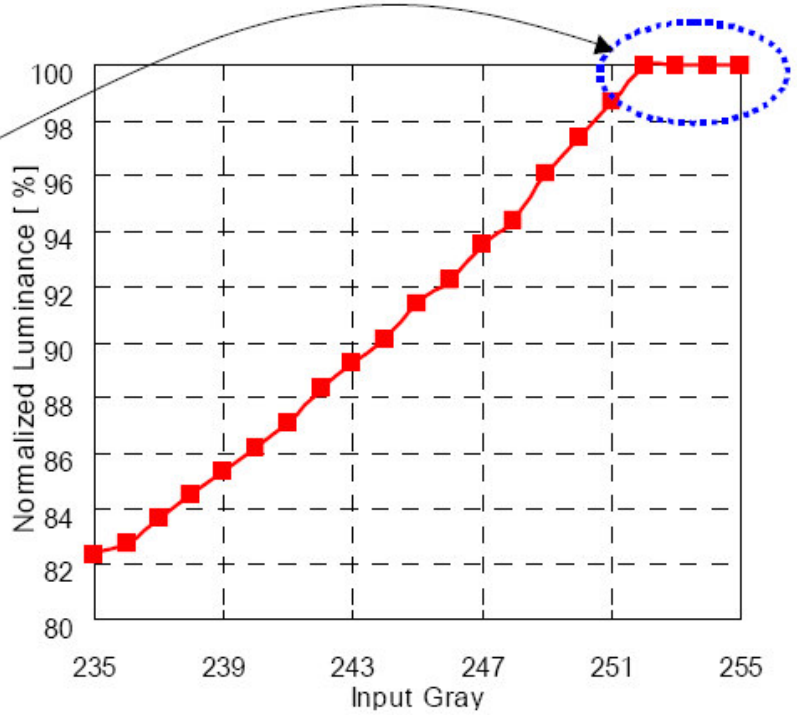
$255 = (11111111)_2 = 252+(11)_2$
$254 = (11111110)_2 = 252+(10)_2$
$253 = (11111101)_2 = 252+(01)_2$
$252 = (11111100)_2 = 252+(00)_2$
$251 = (11111011)_2 = 248+(11)_2$
$250 = (11111010)_2 = 248+(10)_2$
$249 = (11111001)_2 = 248+(01)_2$

$127 = (01111111)_2 = 124+(11)_2$
$126 = (01111110)_2 = 124+(10)_2$
$125 = (01111101)_2 = 124+(01)_2$
$124 = (01111100)_2 = 124+(00)_2$

$4 = (00000100)_2 = 4+(00)_2$
$3 = (00000011)_2 = 0+(11)_2$
$2 = (00000010)_2 = 0+(10)_2$
$1 = (00000001)_2 = 0+(01)_2$
$0 = (00000000)_2 = 0+(00)_2$



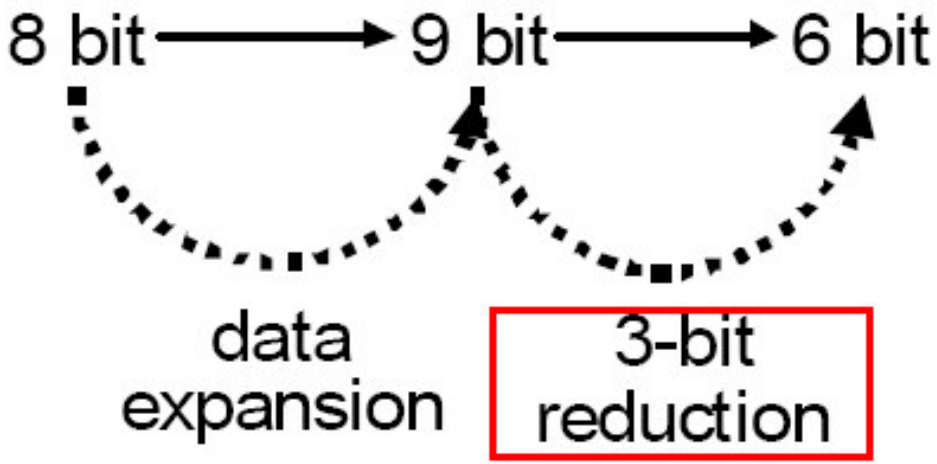
$$\frac{252 + 256 + 256 + 256}{4} = 255 \rightarrow \frac{252 + 252 + 252 + 252}{4} = 252$$

$$\frac{252 + 256 + 252 + 256}{4} = 254 \rightarrow \frac{252 + 252 + 252 + 252}{4} = 252$$

$$\frac{252 + 256 + 252 + 252}{4} = 253 \rightarrow \frac{252 + 252 + 252 + 252}{4} = 252$$

Ideal case *Real case*

Hi-FRC Enables a Higher Number of Available Colors



An Example of Hi-FRC for Higher Color Depth

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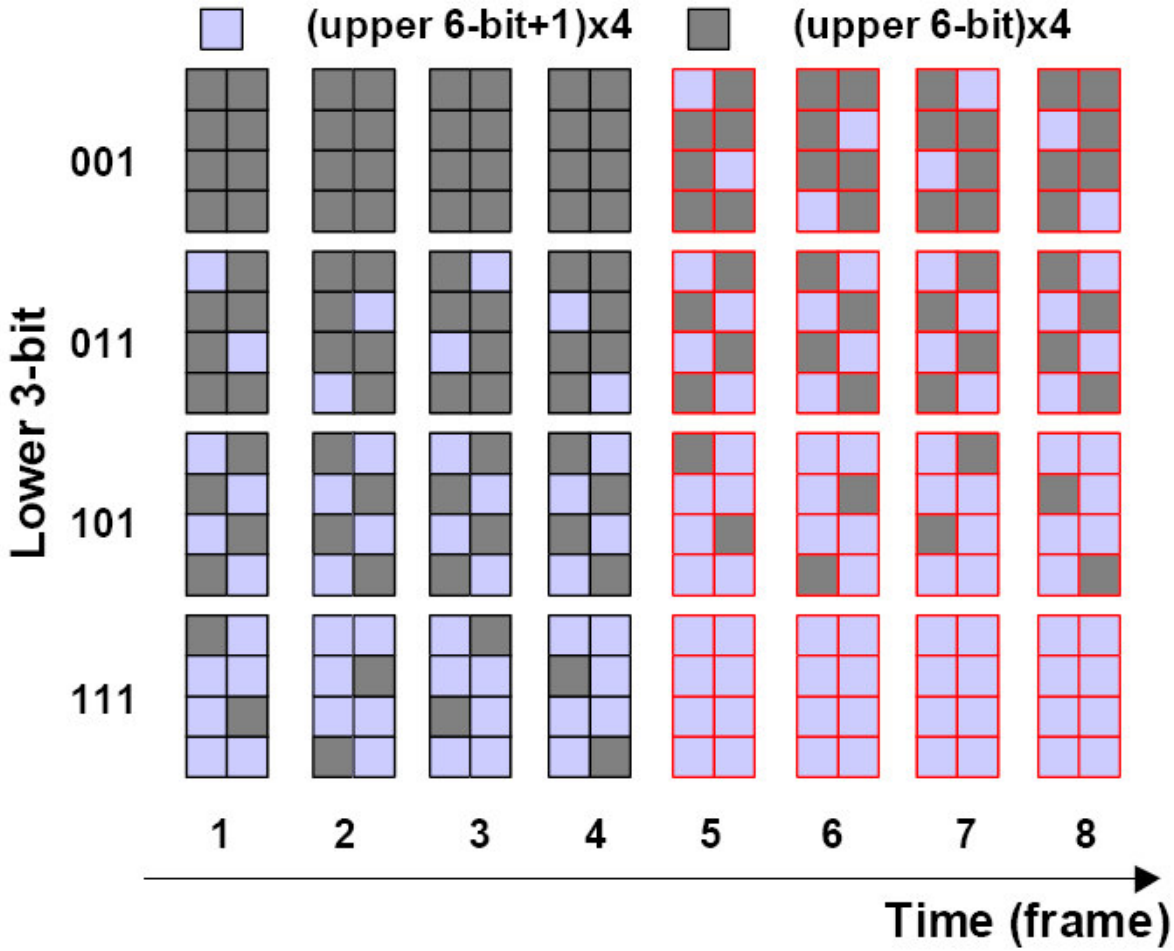
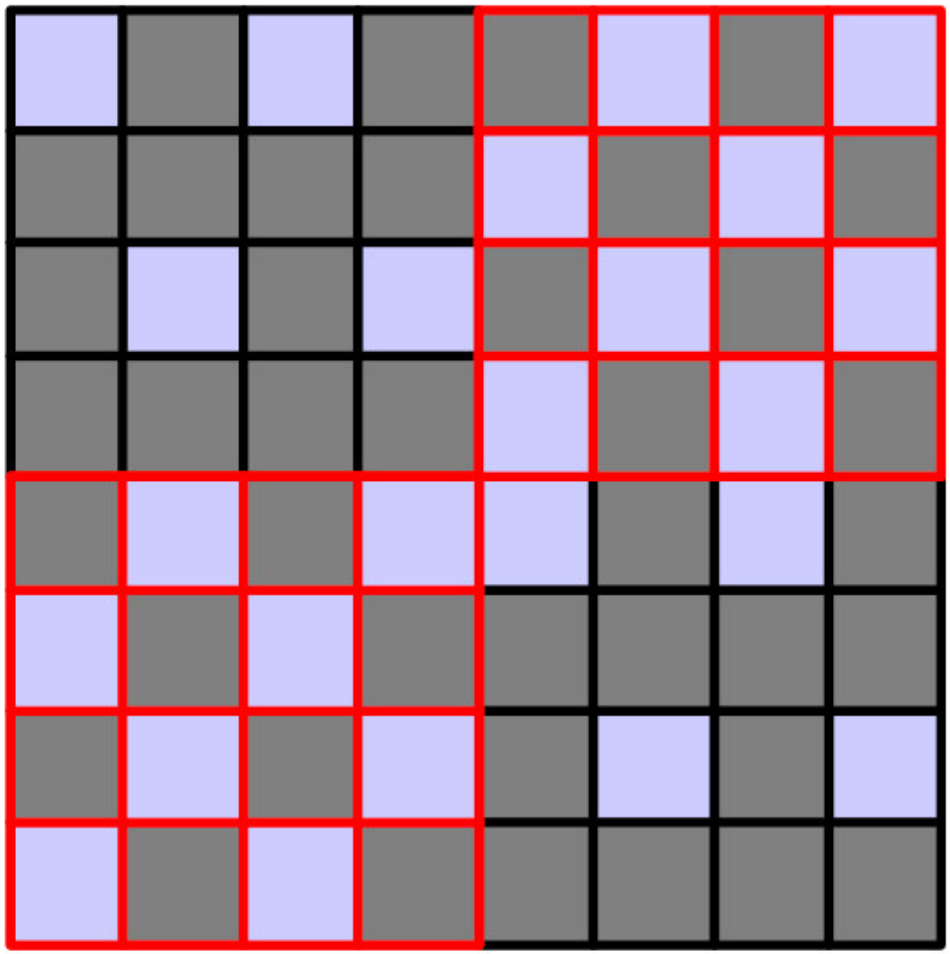
8bit	9bit	frame							
		1	2	3	4	5	6	7	8
255	**504 = 504+$(000)_2$**	504	504	504	504	504	504	504	504
254	**502 = 496+$(110)_2$**	496	496	504	504	504	504	504	504
253	**500 = 496+$(100)_2$**	496	496	496	496	504	504	504	504
252	**498 = 496+$(010)_2$**	496	496	496	496	496	496	504	504
251	**497 = 496+$(001)_2$**	496	496	496	496	496	496	496	504

cf) 504 = $(\mathbf{111111}000)_2$ = **63**x8, 496 = $(\mathbf{111110}000)_2$ = **62**x8

Temporal Averaging Concept of Hi-FRC



Spatial Dithering Concept of Hi-FRC (011)



The Measured Luminance