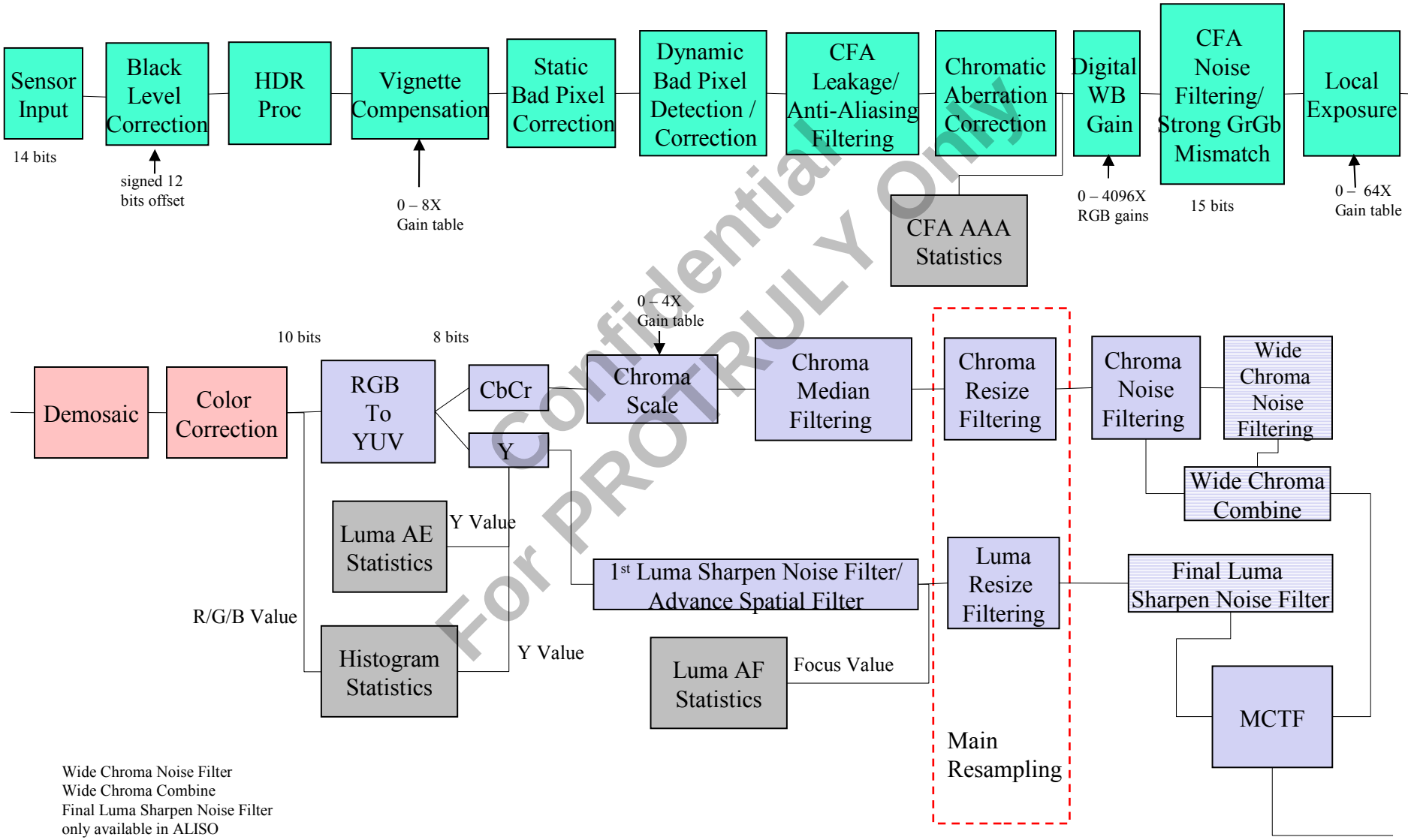
A12 Image DSP Pipeline

06/01/2016

V 1.0

A12 Image Pipeline Block Diagram



Wide Chroma Noise Filter
Wide Chroma Combine
Final Luma Sharpen Noise Filter
only available in ALISO

Static Bad Pixel Correction

- 1-bit per pixel “static bad pixel stream” indicates the good/bad status of pixels coming from the sensor.
- Correction applied as long as one or more same-color neighbors (out of the 8 available) is good.
- Correction is directionally oriented if enough neighboring pixels indicate directional structure.
- Otherwise correction is an average of the available good neighbors.

Dynamic Bad Pixel Processing

- Bad pixel detection is based on looking for the rank-ordered minimum and maximum outliers in neighborhood pixels same Bayer color.
- 1st order and 2nd order detection supported (based on expected amount of bad pixel clustering).
- 1st order detection can detect isolated pixel outliers.
- 2nd order detection can detect clusters-of-two pixel outliers.
- Independent dark and bright settings

Dynamic Bad Pixel Processing

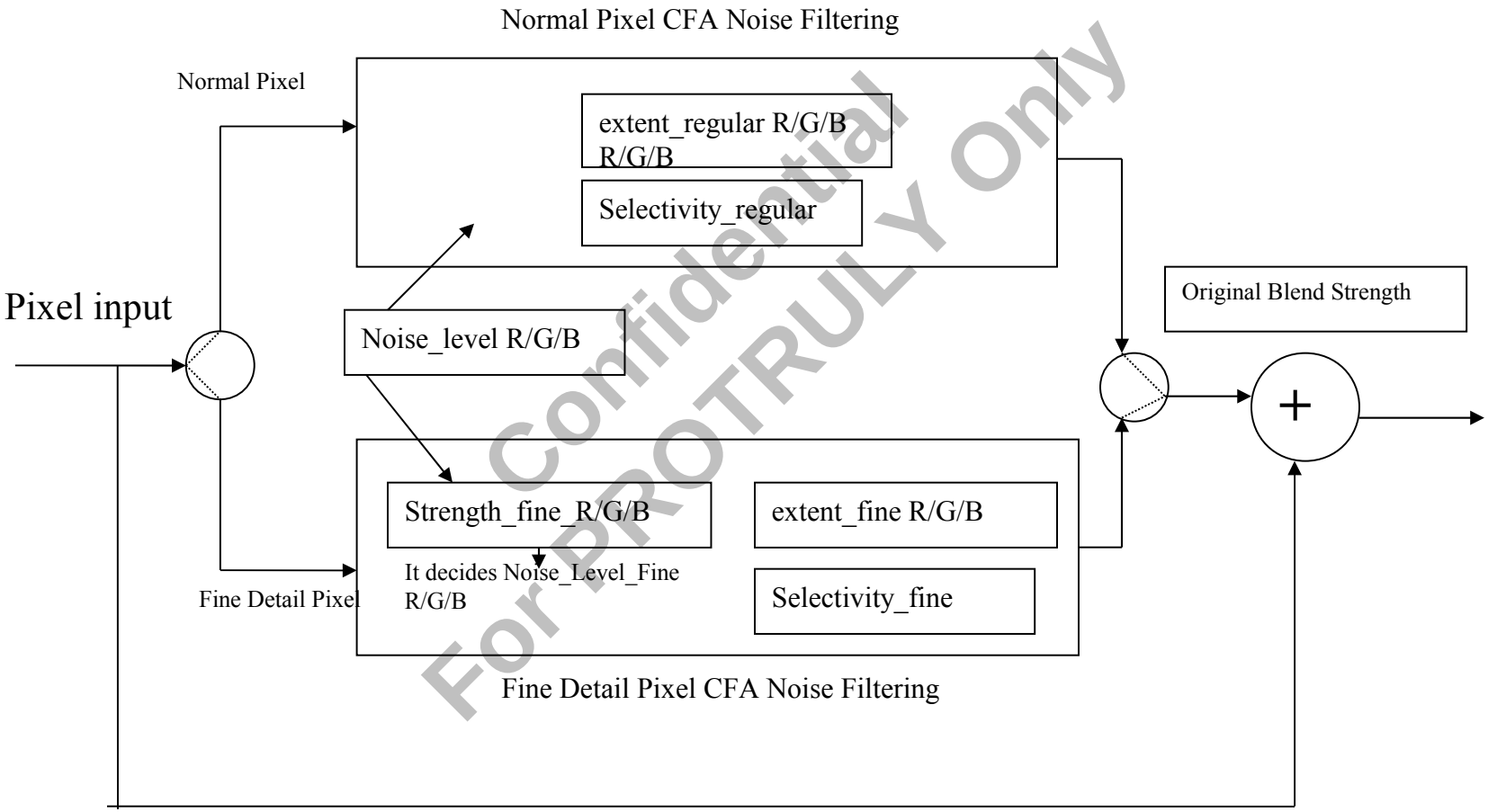
- Correct pixels that is very different from their eight closest same color neighboring pixels in CFA domain

idsp_dbp_correction_t		*bad_corr
u8	enable	0: disable 1:hot 1st order, dark 2nd order 2:hot 2nd order, dark 1st order 3:hot 2nd order, dark 2nd order 4:hot 1st order, dark 1st order
u8	hot_pixel_strength	Hot pixel correction strength, 0-10
u8	dark_pixel_strength	Dark pixel correction strength 0-10
u8	correction_mode	0: normal correction mode 1: aggressive correction mode: may be useful in extremely noisy situations.

CFA-domain Noise Filter

- Adaptively filters center pixel with neighbor pixels
- Separate controls for fine and coarse filtering
- Programmable R/G/B center weights for stronger / weaker filter

CFA-domain Noise Filter Block



CFA-domain Noise Filter

- There are two filters, the one is normal and the other is fine
- The two filters will run at the same time, but only one filter output will be chosen.
- Mostly the noraml filter output will be chosen. The noise level R/G/B is the threshold of normal filter
- The fine detail's noise level is decided by 'noise_level_RGB' and 'Strength_Fine_RGB'. If "Strength_Fine R/G/B = 0", then fine detail's noise level threshold is the same as normal noise level R/G/B threshold. If "Strength_Fine R/G/B" = 256, then the fine detail's noise level threshold will be aobut 10 times than normal noise level R/G/B

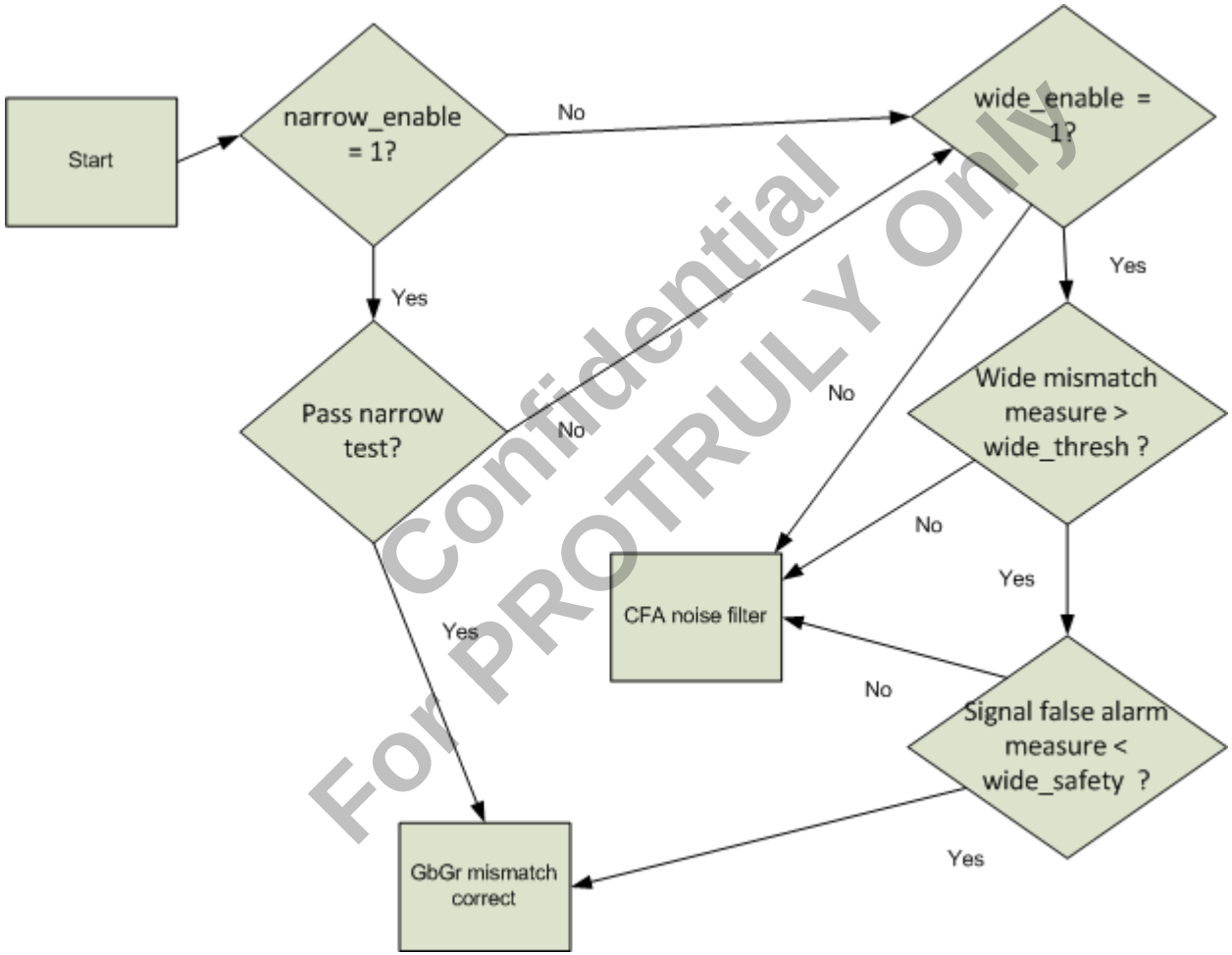
CFA-domain Noise Filter

- The extent regular R/G/B decides two things:
  - How large the area to find the match. If the value is 30, then it is 7x7 for R/B, 5x5 for G.
  - How many pixels within the match to judge it is successful to the filter output. The larger the number is, the more matching pixels are required
- Selectivity means the weighting of matching pixels for filtering
- The larger value of Selectivity means the stronger weighting in closer pixels. The value 0 means all the pixels are equal weighting.

CFA-domain Noise Filter

- The overall flow is
  - To judge if there is enough matching at the normal CFA filter output. If yes, then fine detail filter result won't be taken
  - If there is not enough matching at the normal coarse CFA filter output, then it will goes to fine detail filter output.

GbGr mismatch filter



GbGr mismatch filter

- Switch between correct (average with diagonal neighbors) and CFA noise filter
- GbGr correct if pass narrow test (close neighbors show mismatch) or wide (wide area shows mismatch)
- Narrow detection is just enable / disable

GbGr mismatch filter wide test

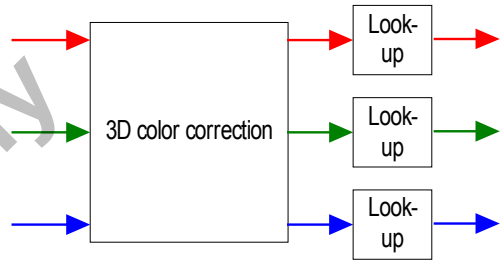
- Parameters:

gb_gr_mismatch_correct.narrow_enable	0-1
gb_gr_mismatch_correct.wide_enable	0-1
gb_gr_mismatch_correct.wide_thresh	0-256
gb_gr_mismatch_correct.wide_safety	0-256

- Wide detection passes is both of the following are true:
  - A measure of mismatch is greater than wide_thresh (so increasing wide thresh make the filter weaker)
  - A measure of how likely systemic mismatch is caused by true signal (i.e., Gbs should be higher or lower than Grs) is less than wide_safety (so increasing wide_saftey make the filter stronger)

Color Correction

- 3D correction “replaces” traditional matrix and gamma curves, allows for arbitrary correction



- Output tables can be used for “real time” modifications (like RGB auto-knee).
- Tools exist for programming based on color matrix and gamma curves and camera matching
  - Camera matching can be region-based
- Tools exist for taking in arbitrary mapping (spreadsheet), programming A7 registers
- Soft gamut clipping possible (color matrix uses hard clip)

Chroma noise filter

- Same structure as CFA noise filter, but works on chroma samples

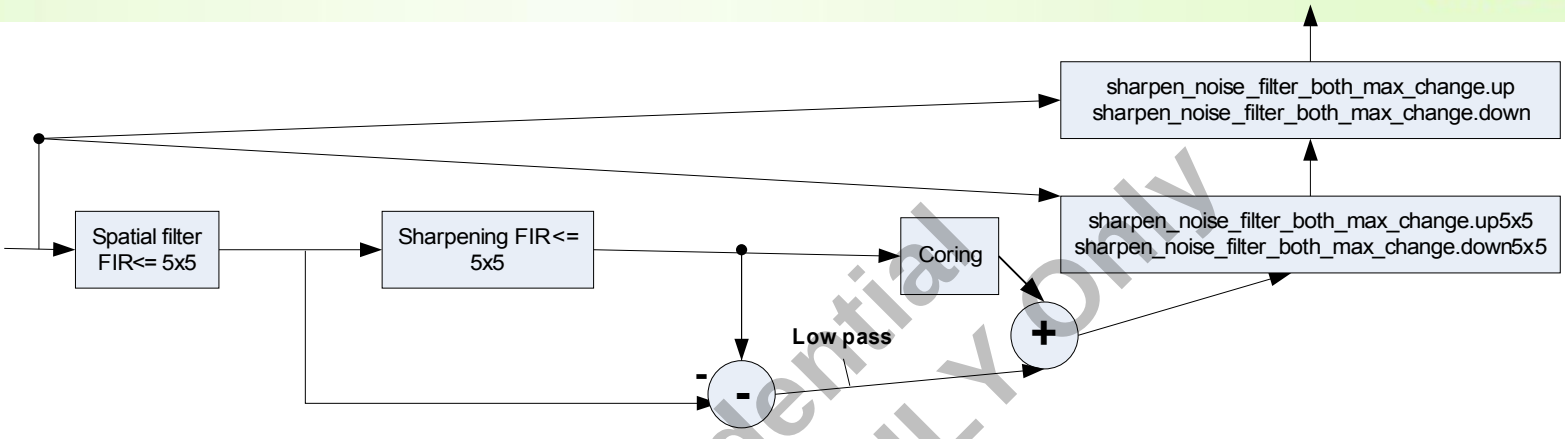
Chroma noise filter

- Noise_level
  - Increasing noise level increases filtering strength.
- Radius
  - Determine the spatial extent of the filter
  - Extent_fine (below) are increases as radius is increased.
  - Increasing radius increases filtering strength.
- Extent_fine
  - Determines the size of the filter support region.

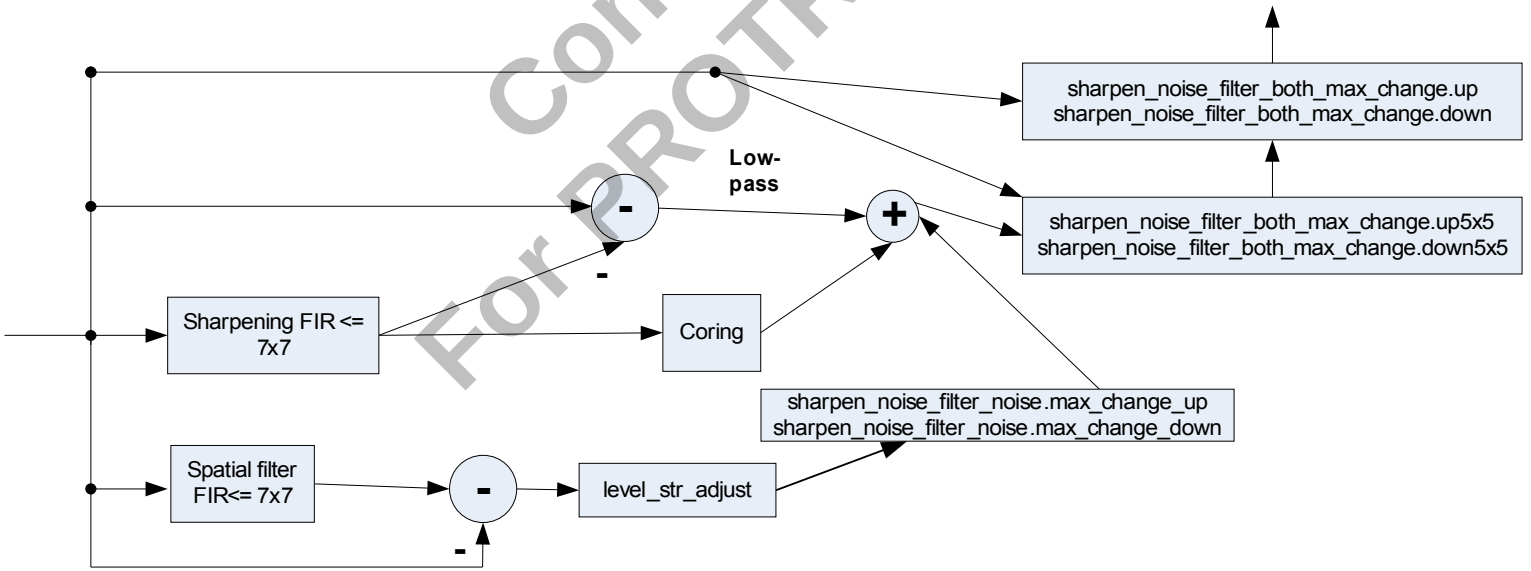
Luma spatial filtering and sharpening

- Flexible hardware
- Single pass can do spatial noise filtering (directional) and sharpening (video)

Luma spatial filtering and sharpening



Mode 0



Mode 2

Mode 0 and Mode 2

- See diagram on previous page. When sharpening is performed it is performed in conjunction with a spatial filter, which can either come before sharpening (mode 0) or work in parallel with it (mode 2).
- As in mode 0, the spatial filtering FIR is controlled by the sharpening_spatial_filter.fir* parameters.
- Level strength adjust is similar the same named parameters (*level_str_adjust_*) in advanced spatial filter, except that the max strength is 16 (not 64).

FIR

- Used in noise reduction and sharpening
- Supports isotropic and 8-directional FIR
- For sharpening and spatial filter FIRs, we decide to use directional or isotropic based on edge threshold

FIR Parameters

- When directional is chosen, the FIR coefficients are selected based on one of 8 chosen edge directions.
- The table below lists the parameters for a single FIR. All parameters except the last two are used to specify the FIR coefficients. In S2, edge_thresh and wide_edge_detect are often specified filter (e.g., sharpening) rather than per FIR.

Parameter	Number	Range
fir_specify	1	[0, 4]
fir_strength_iso	1	
fir_strength_dir	1	192 for 5x5, 256 for 7x7
fir_per_dir_fir_iso_strengt	9	
fir_per_dir_fir_dir_strengt	9	
fir_per_dir_fir_dir_amounts	9	[0, 256]
fir_coefs	variable	[-256, 256]
fir_edge_thresh	1	[0-2047]
fir_wide_edge_detect	1	[0, 8]

Fir_specify

- The table below lists the options for “fir_specify”, when option 1 or 4 is used, the user specifies the “fir_coefs” array contains the number of unique coefficients needed to fill in all FIRs

fir_specify	Directions	params used	Description
0	ISO only	fir_strength_iso	Single strength determines FIR size
1	ISO only	fir_coefs	Only isotropic but fully manual
2	ISO + dir	fir_strength_iso fir_strength_dir	One strength for isotropic, one for directional.
3	ISO + dir	fir_per_dir_fir_iso_strengths fir_per_dir_fir_dir_strengths fir_per_dir_fir_dir_amounts	For each direction, the user specifies an isotropic strength, a directional strength, and amount to blend isotropic and directional
4	ISO + dir	fir_coefs	Fully manual

Fir_specify (cont.)

- The charts below show the placement of the coefficients

fir_specify	FIR size	number of coefficients
1	7x7	10
4	7x7	9 (directions) *25

Option 1, 7x7

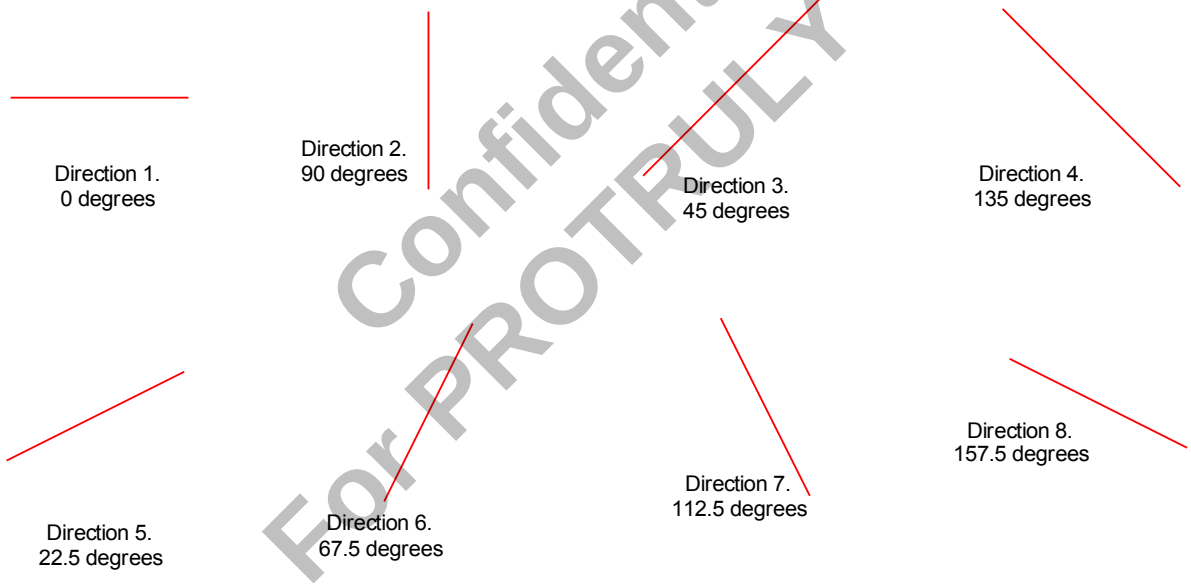
0	1	2	3	2	1	0
1	4	5	6	5	4	1
2	5	7	8	7	5	2
3	6	8	9	8	6	3
2	5	7	8	7	5	2
1	4	5	6	5	4	1
0	1	2	3	2	1	0

Option 4, 7x7

0	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
20	19	18	17	16	15	14
13	12	11	10	9	8	7
6	5	4	3	2	1	0

Fir_specify (cont. 2)

- For option 4, 25 coefficients are provided per edge, direction 0 is isotropic; the other 8 directions are show below:



Fir_specify (cont. 3)

- For option 0, 2 and 3, the FIRs used are interpolated from predefined FIRs. The FIRs are defined for strengths of 0, 64, 192 and 256
- For option 0, only the predefined isotropic (direction 0) FIRs are used.
- For option 2, each direction (0 … 8) is interpolated based on the strength; direction 0 (isotropic) uses fir_strength_iso and directions 1-8 all use fir_strength_dir.

Fir_specify (cont. 4)

- For option 3, the fir for direction “dir” is computed as follows:

A. fir_per_dir_fir_dir_strengths[dir] is used to interpolate a directional FIR with direction “dir”

B. fir_per_dir_fir_iso_strengths[dir] is used to interpolate an isotropic FIR

C. To define W = fir_per_dir_fir_dir_amounts[dir]/256

   Then [W× the result of “A”] + [(1-W) × the result of B] is the final FIR used

FIR edge

- fir_edge_thresh is the threshold used to determine if a directional or isotropic FIR is used.
- fir_wide_edge_detect is used to determine how wide of an area to use when determining an edge direction; the higher the value, the wider the area used.

Sharpening FIR

- User specifies 10 unique parameters, all others are inferred by symmetry
- FIRs should sum to 0
- Taps are specified in units of 1/256, with units as shown below

0	1	2	3	2	1	0
1	4	5	6	5	4	1
2	5	7	8	7	5	2
3	6	8	9	8	6	3
2	5	7	8	7	5	2
1	4	5	6	5	4	1
0	1	2	3	2	1	0

Coefficient	Bits	Range
9	9	[-256, 255]
8	8	[-128, 127]
7	7	[-64, 63]
4-6	6	[-32, 31]
0-3	5	[-16, 15]

“low-pass”

- Center pixel minus FIR is added to final output.
- FIR is a high-pass filter, center pixel minus FIR is a low-pass filter. So “low-pass” can be viewed as the unsharp mask in unsharp masking, with FIR programmed as inverse of unsharp mask
- Based on coring table programming and level control, sharpening can be used for sharpening, noise reduction, or both

Coring Tables

- The output of the FIR is applied to the coring table to get the coring multiplier. The multiplier is then multiplied by the FIR output
- There are 256 entries in the coring table to cover the full range of FIR outputs, with negative and positive outputs treated separately Interpolation is used between entries
  - 0: Smallest FIR output (i.e., largest negative value)
  - 128: FIR output = 0
  - 255Largest positive FIR output

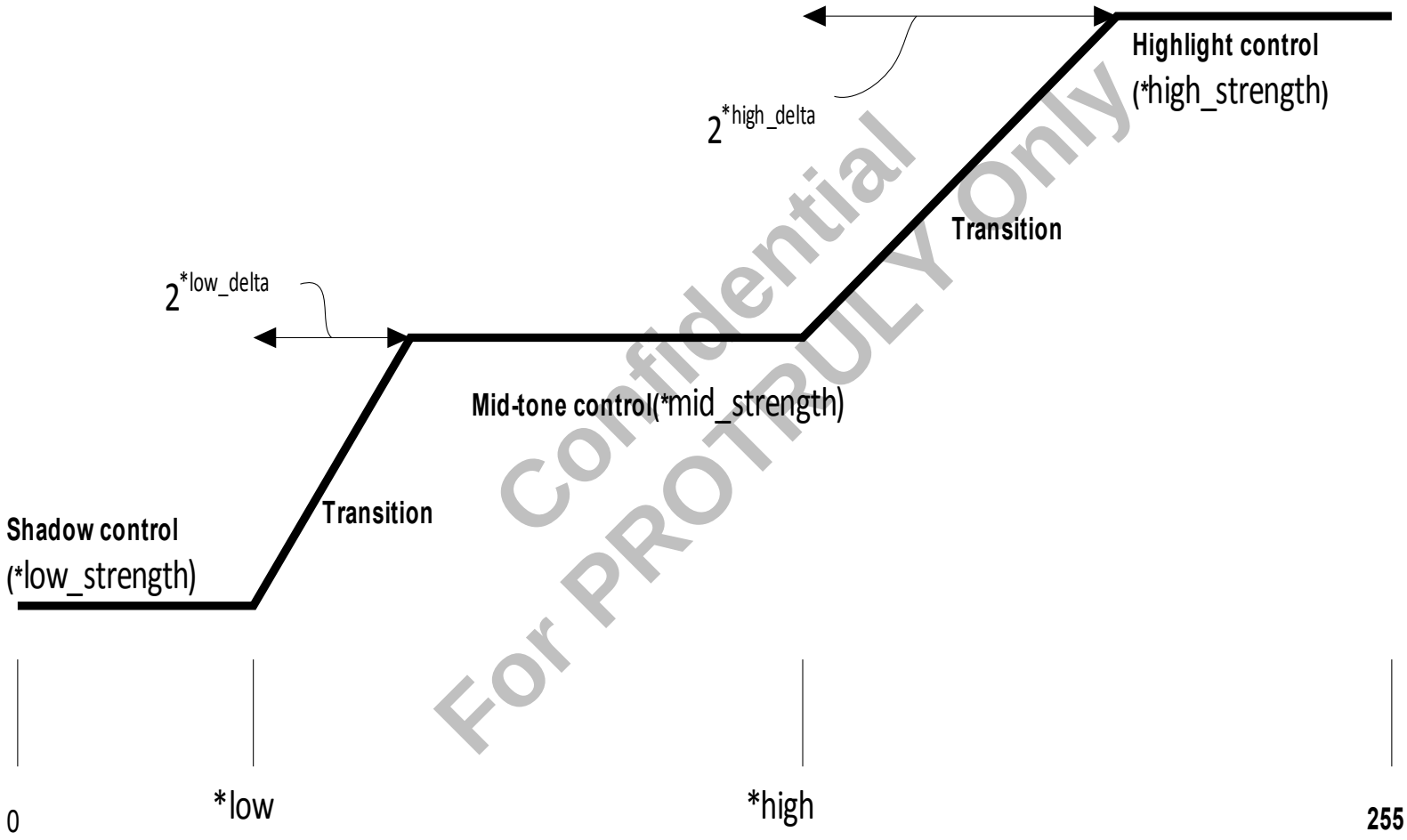
Coring Tables (continue)

- Coring table entries
  - A multiplier of 1 → FIR output is passed unchanged.
  - A multiplier of >1 → FIR output is increased. This will cause sharpening.
  - A multiplier of <1 → FIR output is decreased. This will cause noise reduction.
  - Unit is 8

Level Controls

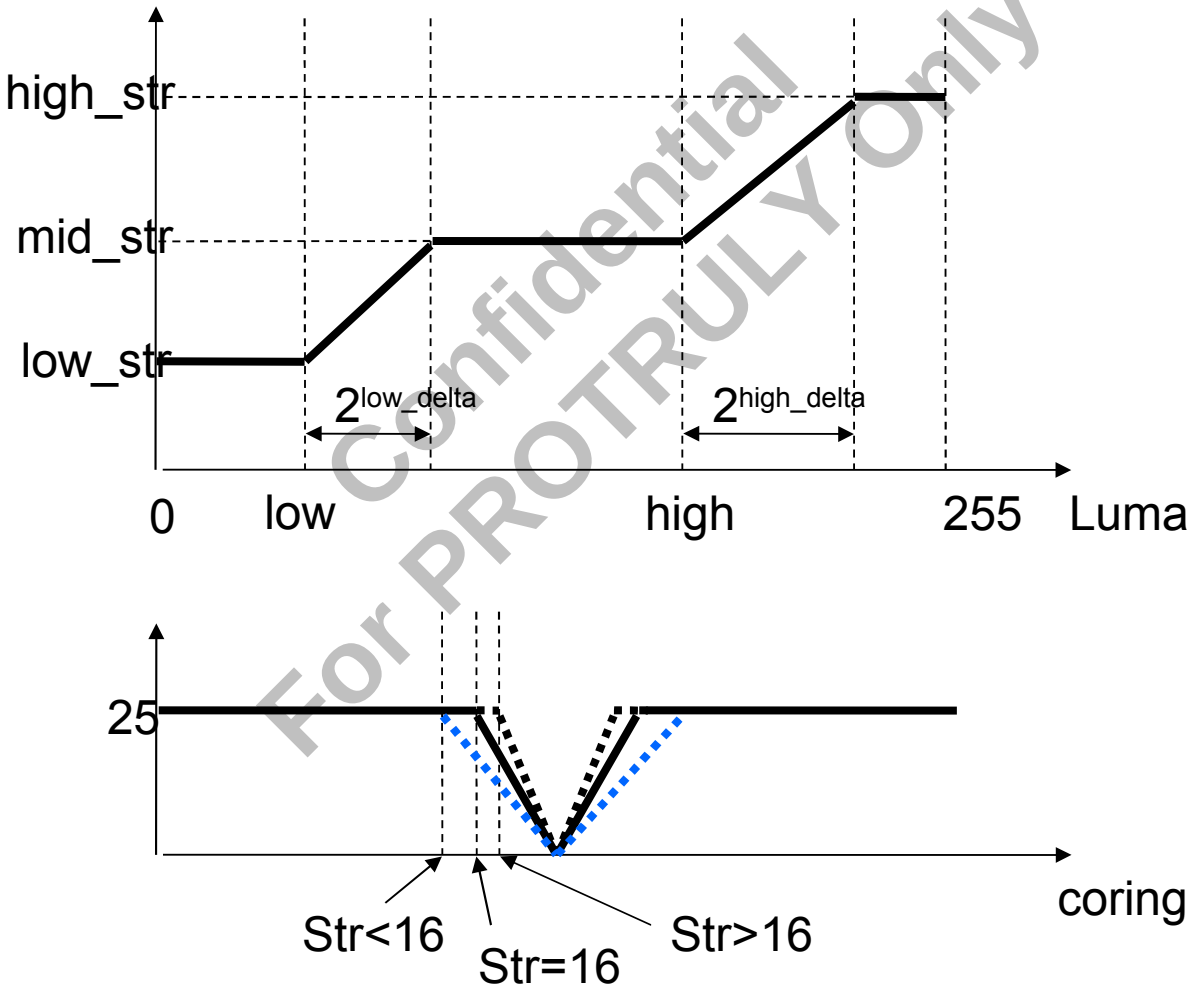
- The way coring multiplier computations are modified based on “level” as follows:
  a. sharpening_coring_index_scale.* scales the index way from the center. Strengths <16 move the index toward the center (entry 128) and strength > 16 move the index away from the center.
  b. The coring multiplier is multiplied based on the result of sharpening_scale_coring.*.
  c. The minimum coring multiplier is the result of sharpening_min_coring_result.*/8 (i.e., the strengths here have three more fractional bits than the coring table entries.)

Level Controls (continue)

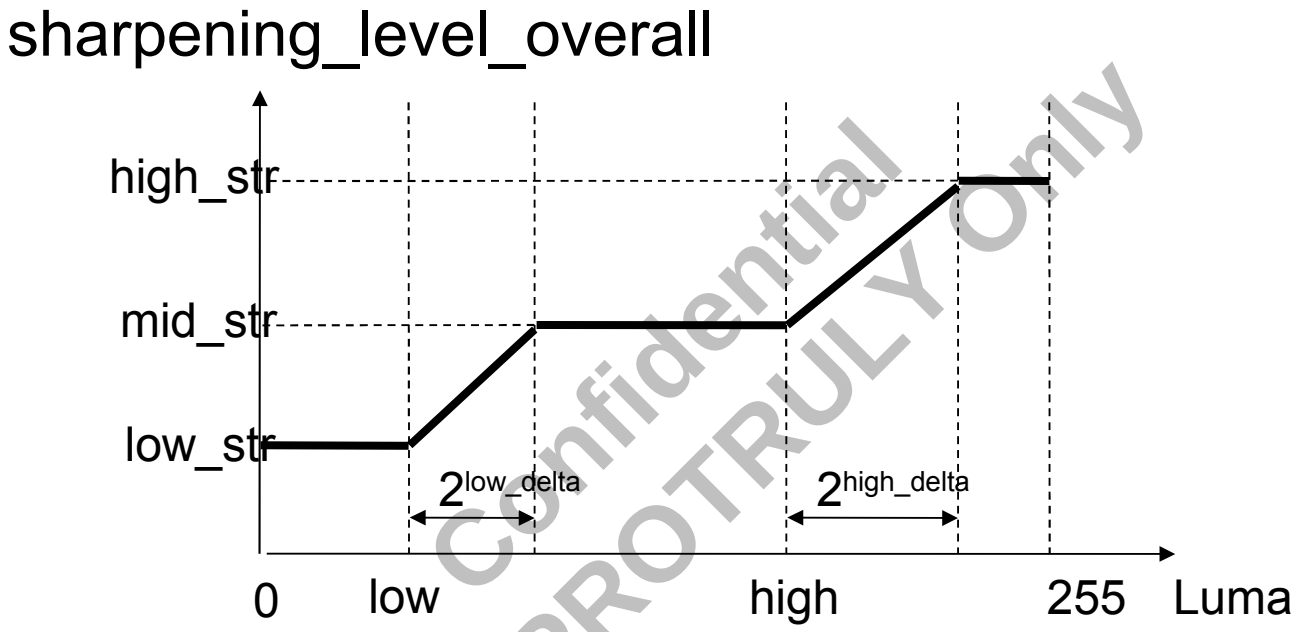


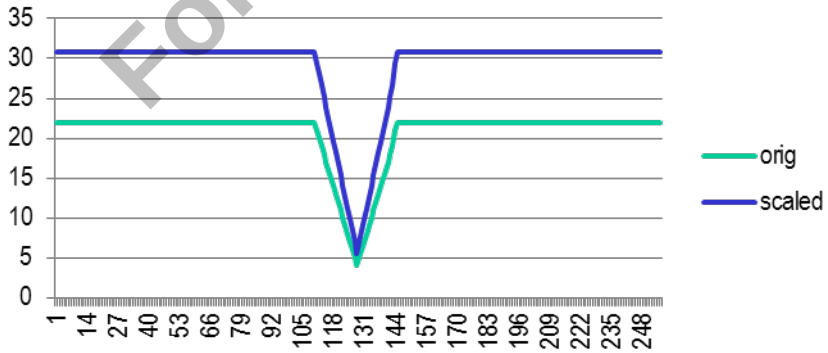
Coring Index Scale Level Controls

sharpening_level_overall

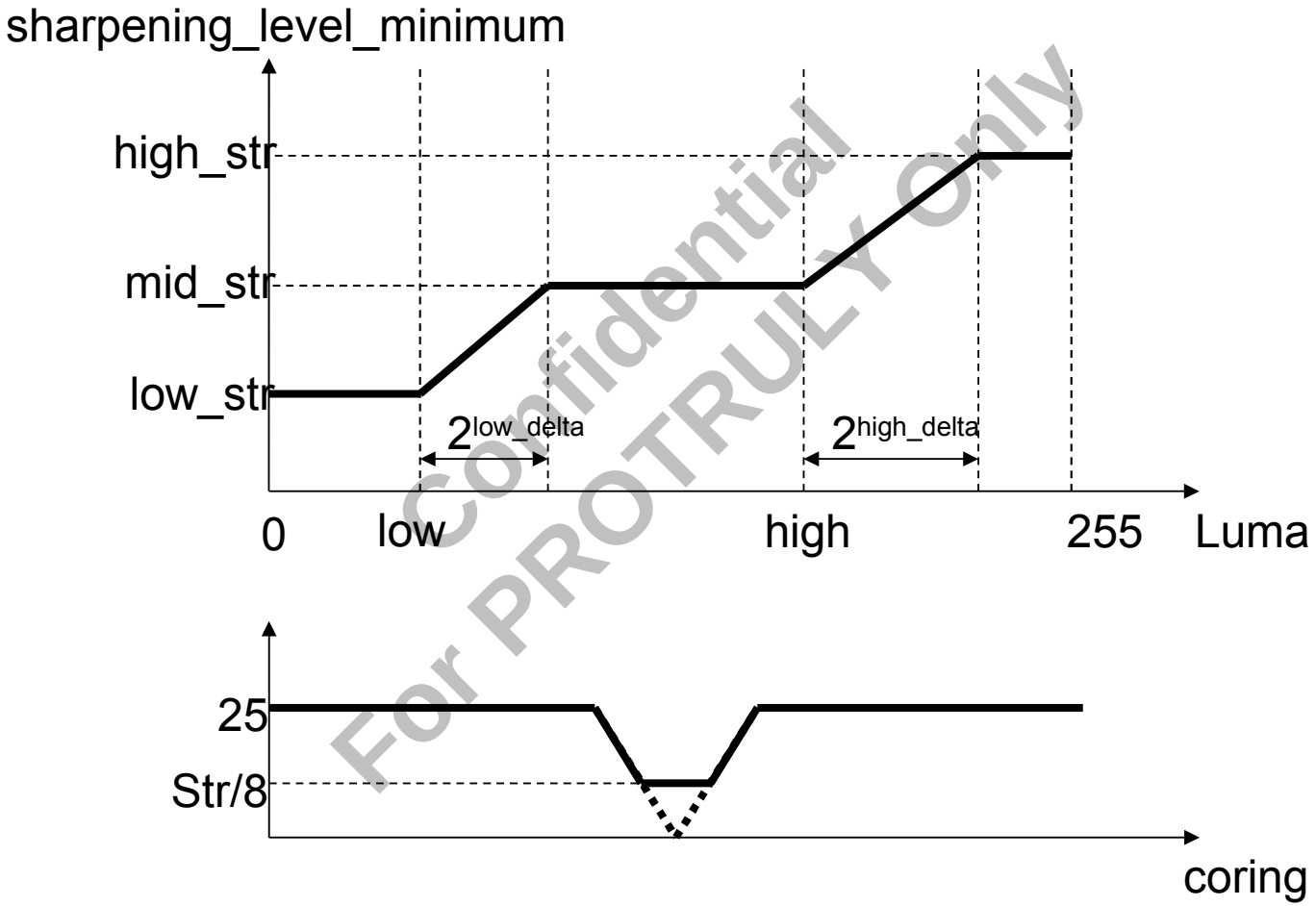


Coring Scale Level Controls

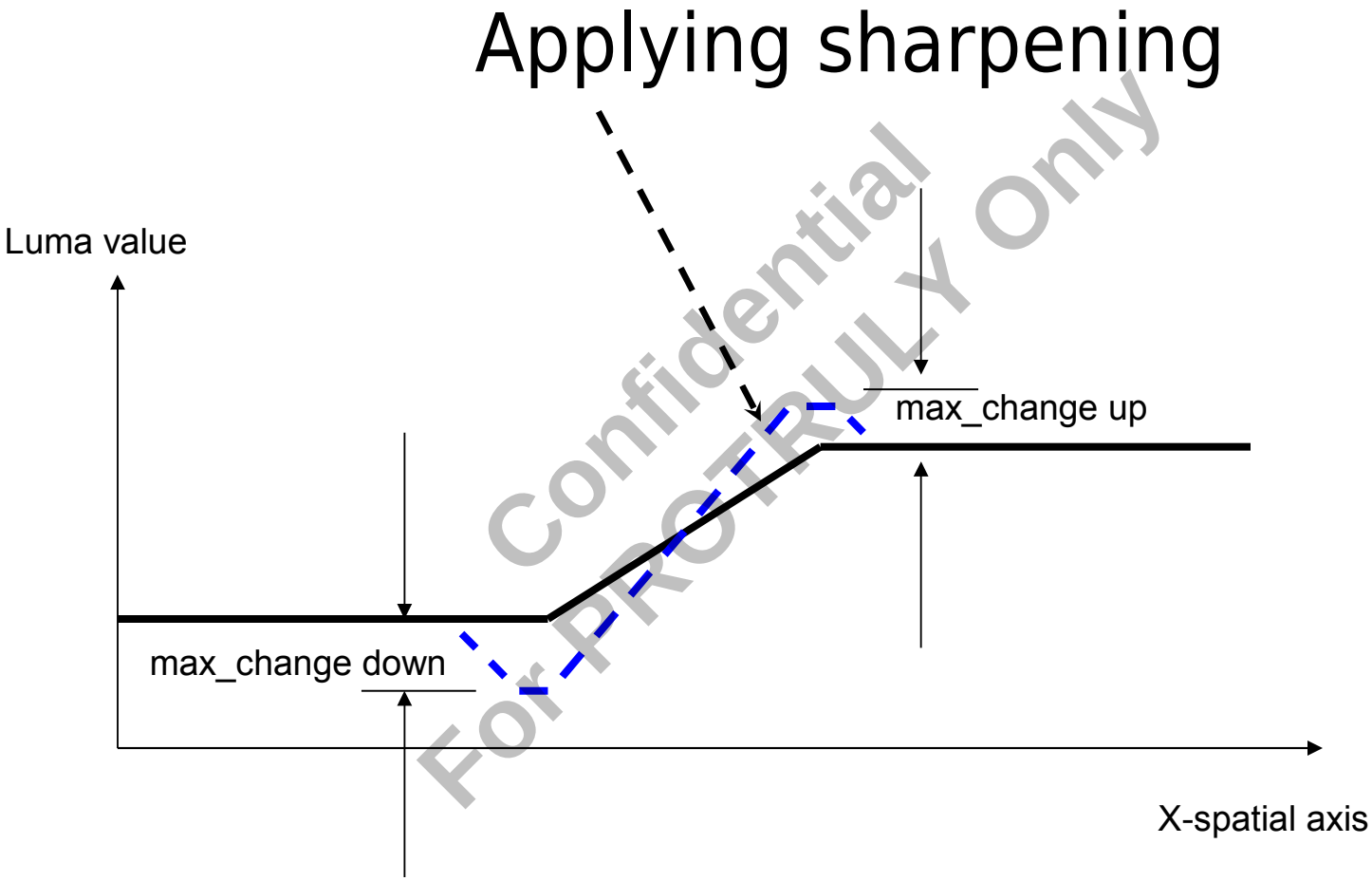




Minimum Sharpness Level Controls



Sharpening and Maximum Change



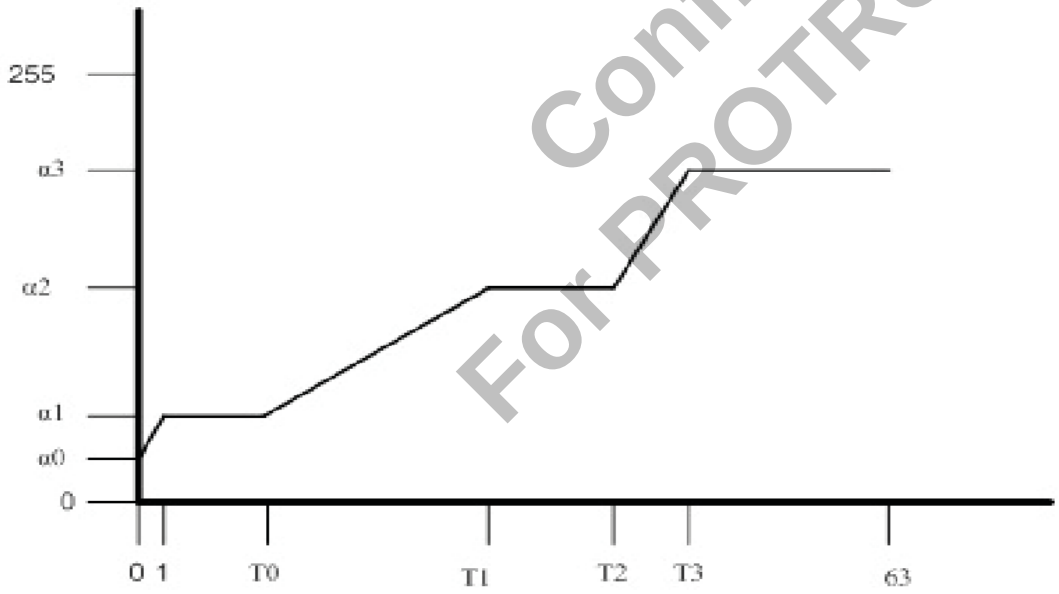
Video MCTF

- **Parameters:**

Type	Field	Description
UINT8	Enable	0: Disable Mctf function 1: Enable Mctf function
UINT16	YMaxChange	0-255. Larger value means stronger filter
UINT16	UMaxChange	0-255. Larger value means stronger filter
UINT16	VMaxChange	0-255. Larger value means stronger filter
UINT8	WeightingBasedOnLocalMotion	0:Disable Temporal Adjust 1:Enable Temporal Adjust
UINT8	Threshold[4]	0-63. Larger value means stronger filter
UINT8	Threshold1[4]	0-63. Larger value means stronger filter
UINT8	Threshold2[4]	0-63. Larger value means stronger filter.
UINT8	Threshold3[4]	0-63. Larger value means stronger filter
UINT16	Alpha1[4]	0-255. Smaller value means stronger filter
UINT16	Alpha2[4]	0-255. Smaller value means stronger filter
UINT16	Alpha3[4]	0-255. Smaller value means stronger filter

Video MCTF - Temporal control chart

- When Temporal Adjust disable, Threshold/Alpha[0-2], control Y, Cb and Cr channel, Threshold/Alpha[3] is invalid.
- When Temporal Adjust enabled, Threshold/Alpha[0-3] are used for different motion score, Y, Cb and Cr share same parameters.



MCTF Temporal controls

- Each sample is combined with a sample from the previous picture in a three-step process.
- In step 1, a weight W is computed using the following parameters:
  - **T0-T3**
  - **Alpha0 – Alpha3**
- In step 2, a preliminary filtered sample is computed as:
  - preliminary = ((255-W) * previous + W * current) / 255
- In step 3, the final filtered sample is computed as the preliminary filtered sample, but with change from the current sample limited to **maxchange**.