SDK6 AN A12 IQ Tuning

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Revision: V 1.0

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Revision History

Date	Version	Description
8 September 2015	V 1.0	Initial draft

Table of Content

1. Introduction

This document provides details on Ambarella's IQ tuning tool, iTuner for DSP cameras. The intent is for users to use the tool more effectively and with more flexibility. The Image Pipeline and iTuner Configuration section shows the image pipeline of A12 at both of Low ISO and Video flow and a list of iTuner configuration parameters corresponding to each of those pipelines. A user can easily find which processing block or parameter should be used in the pipeline. The Case Study and Examples section shows some typical case studies of image quality tuning with A12 and gives examples of how image processing blocks can be used effectively. The basic tuning flow section shows a typical workflow of the image quality tuning. Advanced users may be able to skip this section. For users who would like to know more on the environment and the operation of iTuner, they are requested to review the documents, *AMBARELLA_SDK6_UG_iTuner_Still* and *AMBARELLA_SDK6_UG_iTuner_Video*.

2. Image Pipeline and i-Tuner Configuration

2.1. Image Pipeline and i-Tuner Configuration: Low ISO and Video Flow

Note that **MCTF temporal Noise Reduction** is only available in Video flow.

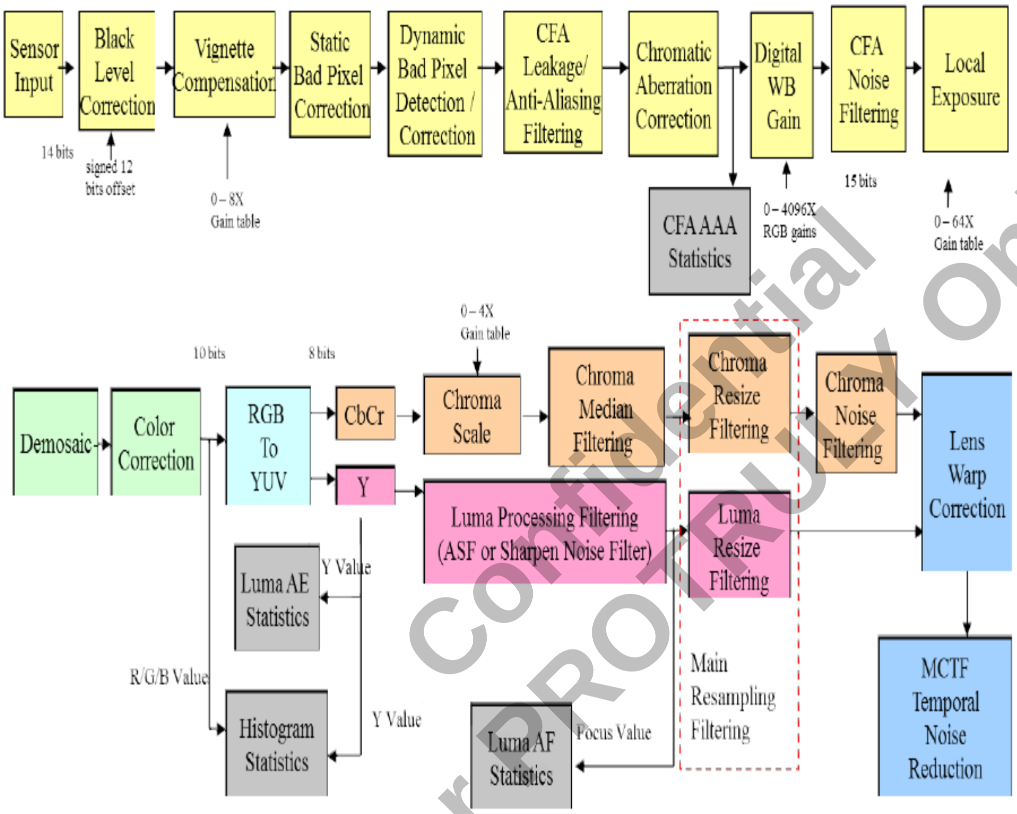
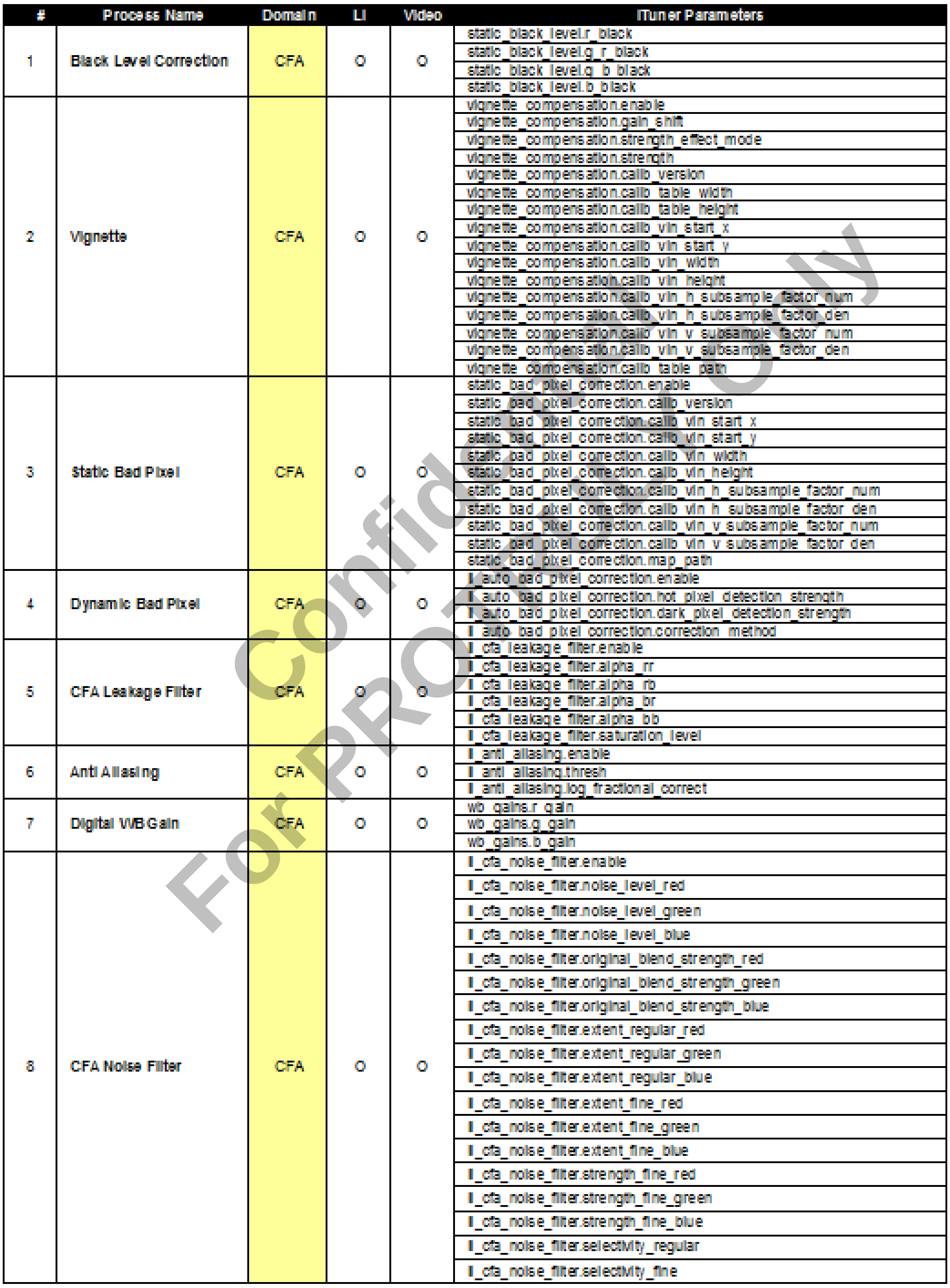
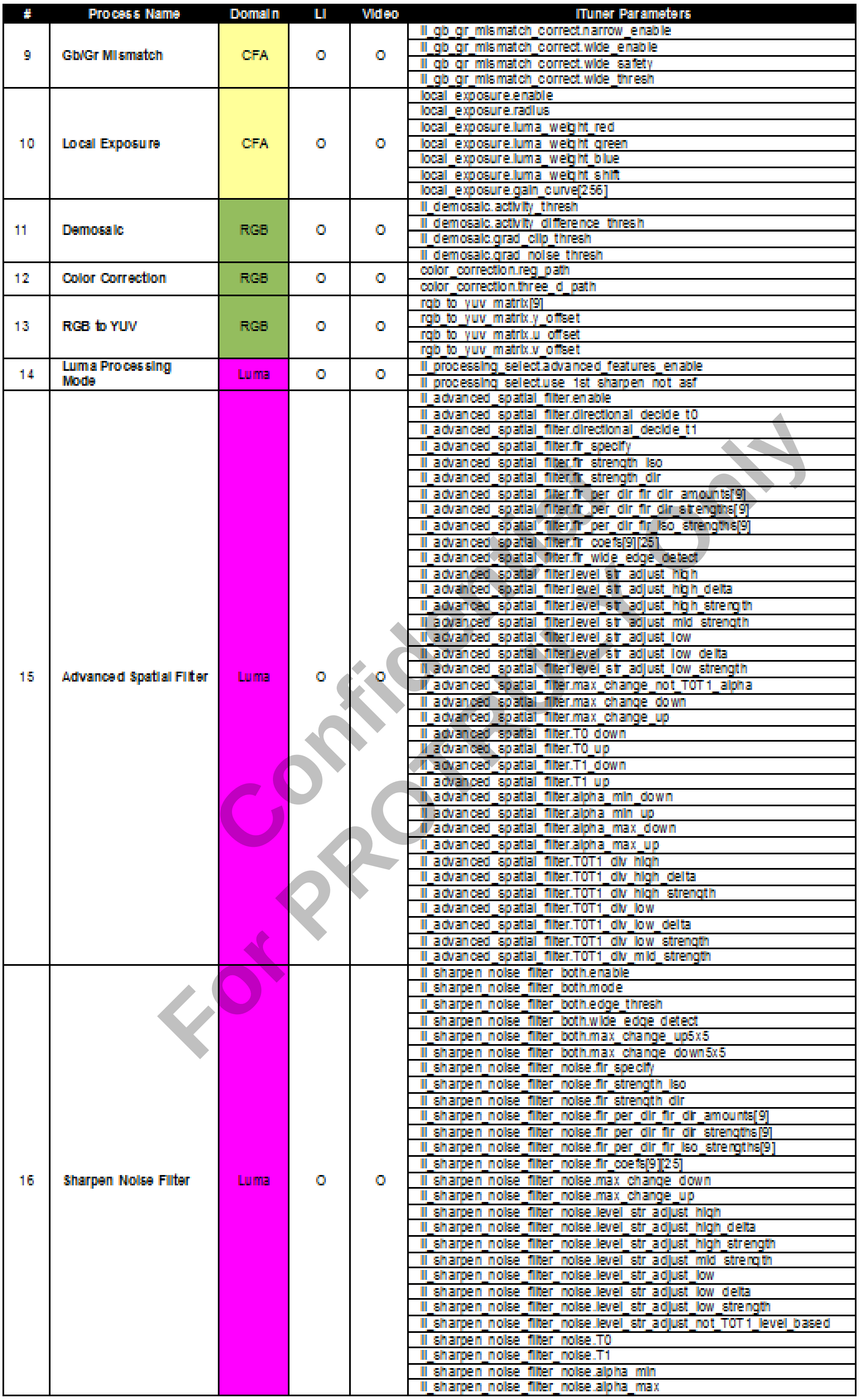


Figure 1: Video Flow.

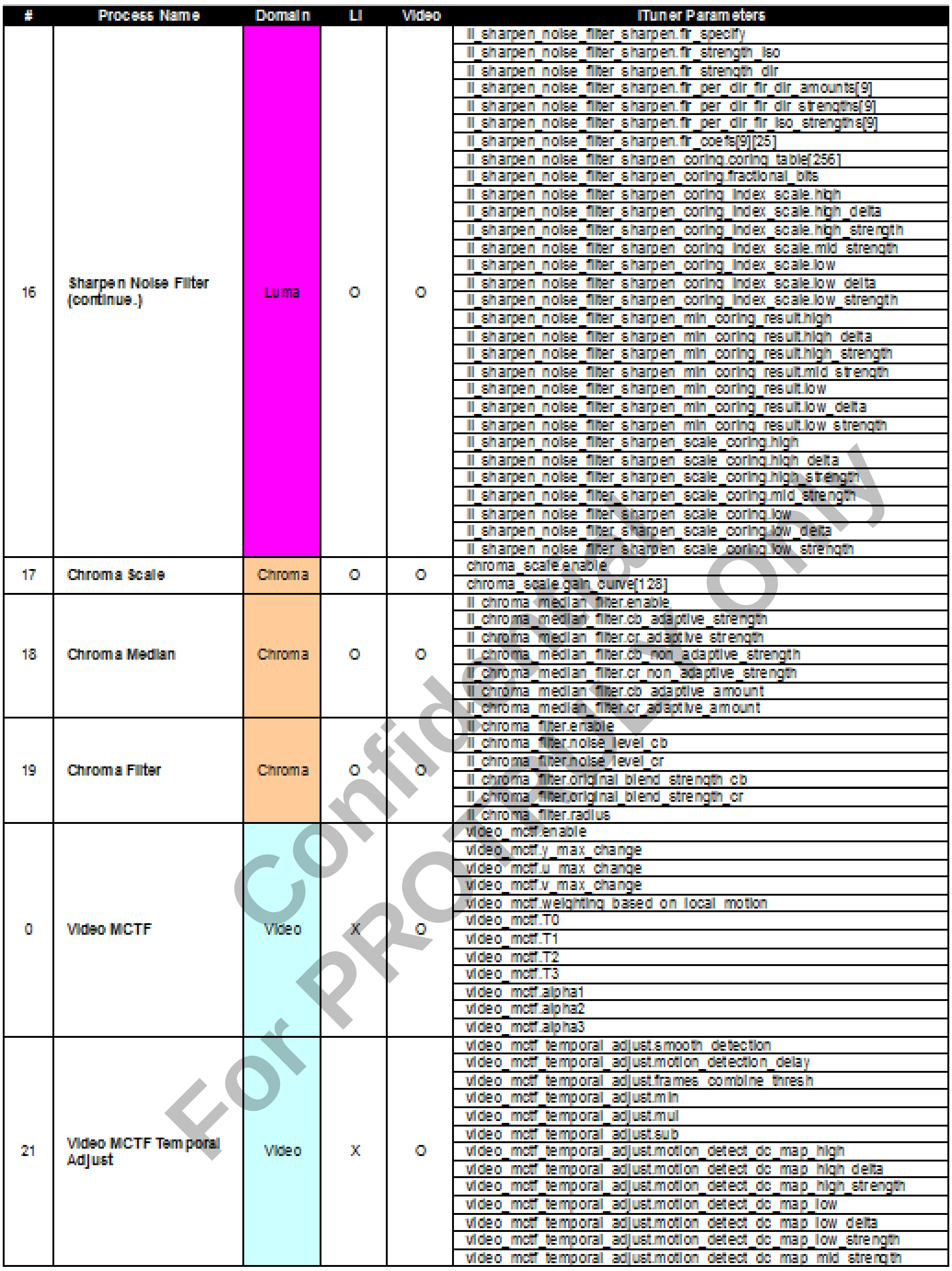
2.2. Image Pipeline and i-Tuner Configuration: iTuner Parameters Configuration



#	Process Name	Domain	LI	Video	ITuner Parameters
1	Black Level Correction	CFA	O	O	static_black_level.r_black
					static_black_level.g_r_black
					static_black_level.g_b_black
					static_black_level.b_black
2	Vignette	CFA	O	O	vignette_compensation.enable
					vignette_compensation.gain_shift
					vignette_compensation.strength_effect_mode
					vignette_compensation.strength
					vignette_compensation.calib_version
					vignette_compensation.calib_table_width
					vignette_compensation.calib_table_height
					vignette_compensation.calib_vin_start_x
					vignette_compensation.calib_vin_start_y
					vignette_compensation.calib_vin_width
					vignette_compensation.calib_vin_height
					vignette_compensation.calib_vin_h_subsample_factor_num
					vignette_compensation.calib_vin_h_subsample_factor_den
					vignette_compensation.calib_vin_v_subsample_factor_num
					vignette_compensation.calib_vin_v_subsample_factor_den
					vignette_compensation.calib_table_path
3	Static Bad Pixel	CFA	O	O	static_bad_pixel_correction.enable
					static_bad_pixel_correction.calib_version
					static_bad_pixel_correction.calib_vin_start_x
					static_bad_pixel_correction.calib_vin_start_y
					static_bad_pixel_correction.calib_vin_width
					static_bad_pixel_correction.calib_vin_height
					static_bad_pixel_correction.calib_vin_h_subsample_factor_num
					static_bad_pixel_correction.calib_vin_h_subsample_factor_den
					static_bad_pixel_correction.calib_vin_v_subsample_factor_num
					static_bad_pixel_correction.calib_vin_v_subsample_factor_den
					static_bad_pixel_correction.map_path
4	Dynamic Bad Pixel	CFA	O	O	I_auto_bad_pixel_correction.enable
					I_auto_bad_pixel_correction.hot_pixel_detection_strength
					I_auto_bad_pixel_correction.dark_pixel_detection_strength
					I_auto_bad_pixel_correction.correction_method
5	CFA Leakage Filter	CFA	O	O	I_cfa_leakage_filter.enable
					I_cfa_leakage_filter.alpha_rr
					I_cfa_leakage_filter.alpha_rb
					I_cfa_leakage_filter.alpha_br
					I_cfa_leakage_filter.alpha_bb
					I_cfa_leakage_filter.saturation_level
6	Anti Aliasing	CFA	O	O	I_anti_aliasing.enable
					I_anti_aliasing.thresh
					I_anti_aliasing.log_fractional_correct
7	Digital WB Gain	CFA	O	O	wb_gains.r_gain
					wb_gains.g_gain
					wb_gains.b_gain
8	CFA Noise Filter	CFA	O	O	I_cfa_noise_filter.enable
					I_cfa_noise_filter.noise_level_red
					I_cfa_noise_filter.noise_level_green
					I_cfa_noise_filter.noise_level_blue
					I_cfa_noise_filter.original_blend_strength_red
					I_cfa_noise_filter.original_blend_strength_green
					I_cfa_noise_filter.original_blend_strength_blue
					I_cfa_noise_filter.extent_regular_red
					I_cfa_noise_filter.extent_regular_green
					I_cfa_noise_filter.extent_regular_blue
					I_cfa_noise_filter.extent_fine_red
					I_cfa_noise_filter.extent_fine_green
					I_cfa_noise_filter.extent_fine_blue
					I_cfa_noise_filter.strength_fine_red
					I_cfa_noise_filter.strength_fine_green
					I_cfa_noise_filter.strength_fine_blue
					I_cfa_noise_filter.selectivity_regular
					I_cfa_noise_filter.selectivity_fine



#	Process Name	Domain	LI	Video	ITuner Parameters
9	Gb/Gr Mismatch	CFA	O	O	il_gb_gr_mismatch_correct.narrow_enable
					il_gb_gr_mismatch_correct.wide_enable
					il_gb_gr_mismatch_correct.wide_safety
					il_gb_gr_mismatch_correct.wide_thresh
10	Local Exposure	CFA	O	O	local_exposure.enable
					local_exposure.radius
					local_exposure.luma_weight_red
					local_exposure.luma_weight_green
					local_exposure.luma_weight_blue
					local_exposure.luma_weight_shift
					local_exposure.gain_curve[256]
11	Demosaic	RGB	O	O	il_demosaic.activity_thresh
					il_demosaic.activity_difference_thresh
					il_demosaic.grad_clip_thresh
					il_demosaic.grad_noise_thresh
12	Color Correction	RGB	O	O	color_correction.reg_path
					color_correction.three_d_path
13	RGB to YUV	RGB	O	O	rgb_to_yuv_matrix[9]
					rgb_to_yuv_matrix.y_offset
					rgb_to_yuv_matrix.u_offset
					rgb_to_yuv_matrix.v_offset
14	Luma Processing Mode	Luma	O	O	il_processing_select.advanced_features_enable
					il_processing_select.use_1st_sharpen_not_asf
15	Advanced Spatial Filter	Luma	O	O	il_advanced_spatial_filter.enable
					il_advanced_spatial_filter.directional_decide_t0
					il_advanced_spatial_filter.directional_decide_t1
					il_advanced_spatial_filter.fir_specify
					il_advanced_spatial_filter.fir_strength_iso
					il_advanced_spatial_filter.fir_strength_dir
					il_advanced_spatial_filter.fir_per_dir_fir_dir_amounts[9]
					il_advanced_spatial_filter.fir_per_dir_fir_dir_strengths[9]
					il_advanced_spatial_filter.fir_per_dir_fir_iso_strengths[9]
					il_advanced_spatial_filter.fir_coefs[9][25]
					il_advanced_spatial_filter.fir_wide_edge_detect
					il_advanced_spatial_filter.level_str_adjust_high
					il_advanced_spatial_filter.level_str_adjust_high_delta
					il_advanced_spatial_filter.level_str_adjust_high_strength
					il_advanced_spatial_filter.level_str_adjust_mid_strength
					il_advanced_spatial_filter.level_str_adjust_low
					il_advanced_spatial_filter.level_str_adjust_low_delta
					il_advanced_spatial_filter.level_str_adjust_low_strength
					il_advanced_spatial_filter.max_change_not_T0T1_alpha
					il_advanced_spatial_filter.max_change_down
					il_advanced_spatial_filter.max_change_up
					il_advanced_spatial_filter.T0_down
					il_advanced_spatial_filter.T0_up
					il_advanced_spatial_filter.T1_down
					il_advanced_spatial_filter.T1_up
					il_advanced_spatial_filter.alpha_min_down
					il_advanced_spatial_filter.alpha_min_up
					il_advanced_spatial_filter.alpha_max_down
					il_advanced_spatial_filter.alpha_max_up
					il_advanced_spatial_filter.T0T1_div_high
					il_advanced_spatial_filter.T0T1_div_high_delta
					il_advanced_spatial_filter.T0T1_div_high_strength
					il_advanced_spatial_filter.T0T1_div_low
					il_advanced_spatial_filter.T0T1_div_low_delta
					il_advanced_spatial_filter.T0T1_div_low_strength
					il_advanced_spatial_filter.T0T1_div_mid_strength
16	Sharpen Noise Filter	Luma	O	O	il_sharpen_noise_filter_both.enable
					il_sharpen_noise_filter_both.mode
					il_sharpen_noise_filter_both.edge_thresh
					il_sharpen_noise_filter_both.wide_edge_detect
					il_sharpen_noise_filter_both.max_change_up5x5
					il_sharpen_noise_filter_both.max_change_down5x5
					il_sharpen_noise_filter_noise.fir_specify
					il_sharpen_noise_filter_noise.fir_strength_iso
					il_sharpen_noise_filter_noise.fir_strength_dir
					il_sharpen_noise_filter_noise.fir_per_dir_fir_dir_amounts[9]
					il_sharpen_noise_filter_noise.fir_per_dir_fir_dir_strengths[9]
					il_sharpen_noise_filter_noise.fir_per_dir_fir_iso_strengths[9]
					il_sharpen_noise_filter_noise.fir_coefs[9][25]
					il_sharpen_noise_filter_noise.max_change_down
					il_sharpen_noise_filter_noise.max_change_up
					il_sharpen_noise_filter_noise.level_str_adjust_high
					il_sharpen_noise_filter_noise.level_str_adjust_high_delta
					il_sharpen_noise_filter_noise.level_str_adjust_high_strength
					il_sharpen_noise_filter_noise.level_str_adjust_mid_strength
					il_sharpen_noise_filter_noise.level_str_adjust_low
					il_sharpen_noise_filter_noise.level_str_adjust_low_delta
					il_sharpen_noise_filter_noise.level_str_adjust_low_strength
					il_sharpen_noise_filter_noise.level_str_adjust_not_T0T1_level_based
					il_sharpen_noise_filter_noise.T0
					il_sharpen_noise_filter_noise.T1
					il_sharpen_noise_filter_noise.alpha_min
					il_sharpen_noise_filter_noise.alpha_max



#	Process Name	Domain	LI	Video	ITuner Parameters
16	Sharpen Noise Filter (continue.)	Luma	O	O	li_sharpen_noise_filter_sharpen.fir_specify
					li_sharpen_noise_filter_sharpen.fir_strength_iso
					li_sharpen_noise_filter_sharpen.fir_strength_dir
					li_sharpen_noise_filter_sharpen.fir_per_dir_fir_dir_amounts[9]
					li_sharpen_noise_filter_sharpen.fir_per_dir_fir_dir_strengths[9]
					li_sharpen_noise_filter_sharpen.fir_per_dir_fir_iso_strengths[9]
					li_sharpen_noise_filter_sharpen.fir_coefs[9][25]
					li_sharpen_noise_filter_sharpen_coring.coring_table[256]
					li_sharpen_noise_filter_sharpen_coring.fractional_bits
					li_sharpen_noise_filter_sharpen_coring_index_scale.high
					li_sharpen_noise_filter_sharpen_coring_index_scale.high_delta
					li_sharpen_noise_filter_sharpen_coring_index_scale.high_strength
					li_sharpen_noise_filter_sharpen_coring_index_scale.mid_strength
					li_sharpen_noise_filter_sharpen_coring_index_scale.low
					li_sharpen_noise_filter_sharpen_coring_index_scale.low_delta
					li_sharpen_noise_filter_sharpen_coring_index_scale.low_strength
					li_sharpen_noise_filter_sharpen_min_coring_result.high
					li_sharpen_noise_filter_sharpen_min_coring_result.high_delta
					li_sharpen_noise_filter_sharpen_min_coring_result.high_strength
					li_sharpen_noise_filter_sharpen_min_coring_result.mid_strength
					li_sharpen_noise_filter_sharpen_min_coring_result.low
					li_sharpen_noise_filter_sharpen_min_coring_result.low_delta
					li_sharpen_noise_filter_sharpen_min_coring_result.low_strength
					li_sharpen_noise_filter_sharpen_scale_coring.high
					li_sharpen_noise_filter_sharpen_scale_coring.high_delta
					li_sharpen_noise_filter_sharpen_scale_coring.high_strength
					li_sharpen_noise_filter_sharpen_scale_coring.mid_strength
					li_sharpen_noise_filter_sharpen_scale_coring.low
					li_sharpen_noise_filter_sharpen_scale_coring.low_delta
					li_sharpen_noise_filter_sharpen_scale_coring.low_strength
17	Chroma Scale	Chroma	O	O	chroma_scale.enable
					chroma_scale.gain_curve[128]
18	Chroma Median	Chroma	O	O	li_chroma_median_filter.enable
					li_chroma_median_filter.cb_adaptive_strength
					li_chroma_median_filter.cr_adaptive_strength
					li_chroma_median_filter.cb_non_adaptive_strength
					li_chroma_median_filter.cr_non_adaptive_strength
					li_chroma_median_filter.cb_adaptive_amount
					li_chroma_median_filter.cr_adaptive_amount
19	Chroma Filter	Chroma	O	O	li_chroma_filter.enable
					li_chroma_filter.noise_level_cb
					li_chroma_filter.noise_level_cr
					li_chroma_filter.original_blend_strength_cb
					li_chroma_filter.original_blend_strength_cr
					li_chroma_filter.radius
0	Video MCTF	Video	X	O	video_mctf.enable
					video_mctf.y_max_change
					video_mctf.u_max_change
					video_mctf.v_max_change
					video_mctf.weighting_based_on_local_motion
					video_mctf.T0
					video_mctf.T1
					video_mctf.T2
					video_mctf.T3
					video_mctf.alpha1
					video_mctf.alpha2
					video_mctf.alpha3
21	Video MCTF Temporal Adjust	Video	X	O	video_mctf_temporal_adjust.smooth_detection
					video_mctf_temporal_adjust.motion_detection_delay
					video_mctf_temporal_adjust.frames_combine_thresh
					video_mctf_temporal_adjust.min
					video_mctf_temporal_adjust.mul
					video_mctf_temporal_adjust.sub
					video_mctf_temporal_adjust.motion_detect_dc_map_high
					video_mctf_temporal_adjust.motion_detect_dc_map_high_delta
					video_mctf_temporal_adjust.motion_detect_dc_map_high_strength
					video_mctf_temporal_adjust.motion_detect_dc_map_low
					video_mctf_temporal_adjust.motion_detect_dc_map_low_delta
					video_mctf_temporal_adjust.motion_detect_dc_map_low_strength
					video_mctf_temporal_adjust.motion_detect_dc_map_mid_strength

3. Case Study and Examples

3.1. Case Study and Examples: Dynamic Bad Pixel Correction

Dynamic bad pixel is aimed at finding pixels that grossly deviate from their closet same-color neighboring pixels in the current picture. There are two detection modes: first-order detection and second-order detection. First-order detection locates isolated bad pixels while second-order detection is a more aggressive mode which can detect clusters of up to two bad pixels. But, it may have a higher potential for false detection. And, the following sample images in Figure 2 show the different combinations of detection modes.

3.1.1 Dynamic Bad Pixel Correction: Tuning Example

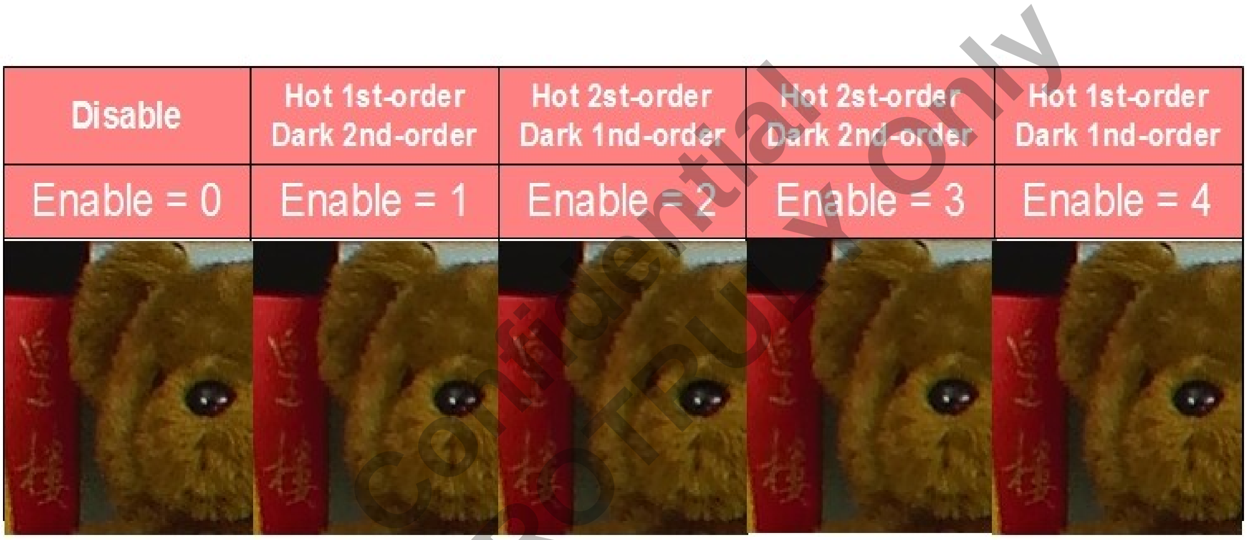


Figure 2: Sample Images at Low ISO.

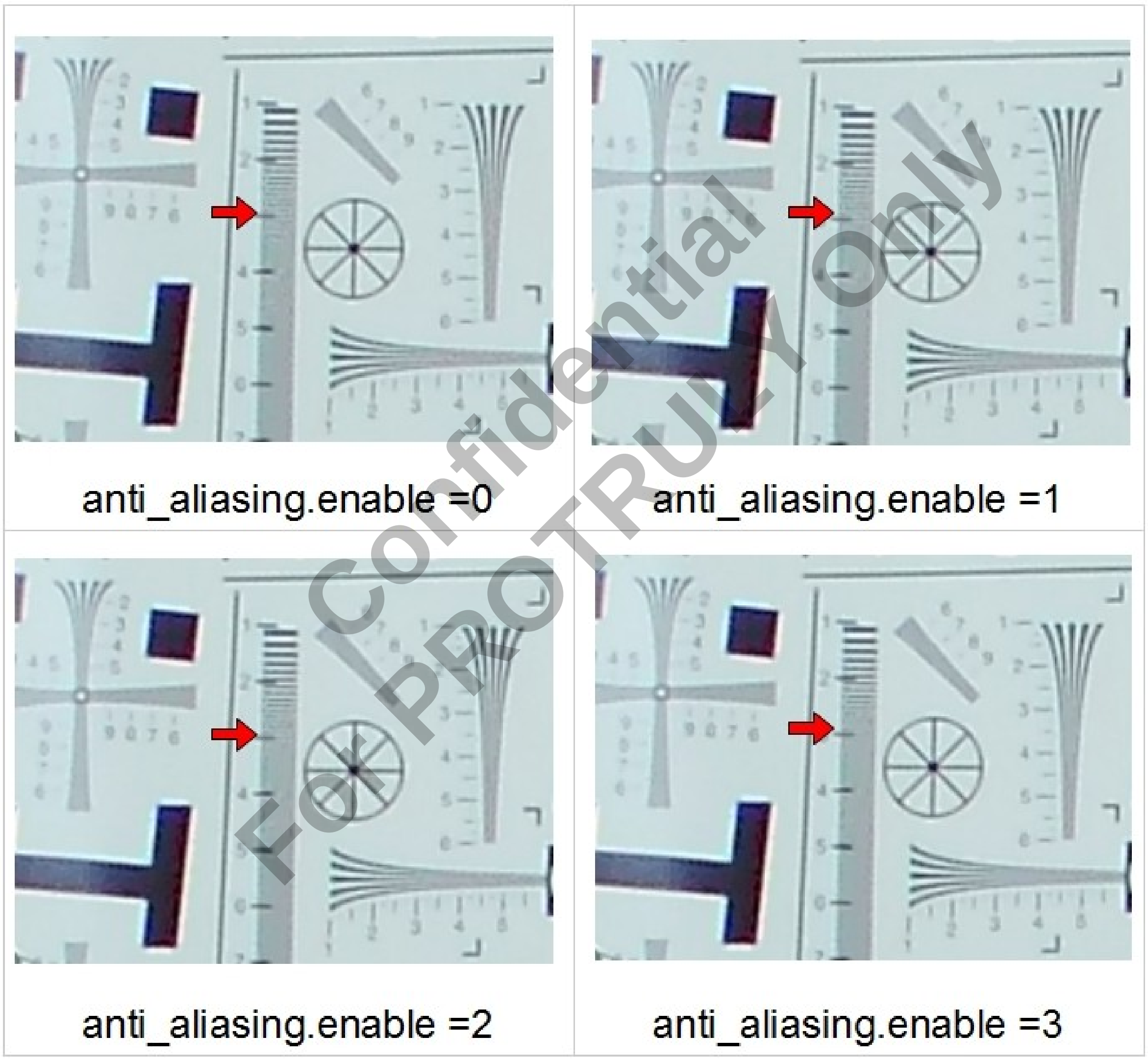
auto_bad_pixel_correction.enable	0,1,2,3,4
auto_bad_pixel_correction.hot_pixel_detection_strength	10
auto_bad_pixel_correction.dark_pixel_detection_strength	10
auto_bad_pixel_correction.correction_method	0

Table 1: Parameters.

3.2. Case Study and Examples: Anti-Aliasing Filter

3.2.1 Anti-Aliasing Filter: Tuning Example

Anti-Aliasing Filter is used to reduce aliasing. This filter can be tuned by strength from 0 to 3. And the following sample images in Figure 3 show the comparison of strength. The more the strength of anti-aliasing, the more the loss will be detailed.



anti_aliasing.enable =0

anti_aliasing.enable =1

anti_aliasing.enable =2

anti_aliasing.enable =3

Figure 3: Sample Images at Low ISO.

3.3. Case Study and Examples: CFA Noise Filter

3.3.1   CFA Noise Filter: Tuning Flow

The CFA noise filter tuning flow is shown in Figure 4. Users can refer to this diagram to confirm how to start the CFA noise filter tuning step by step. And, this section details typical tuning parameters and tuning results from Step 1 to Step 4 and options in Figures 5 ~ 9.

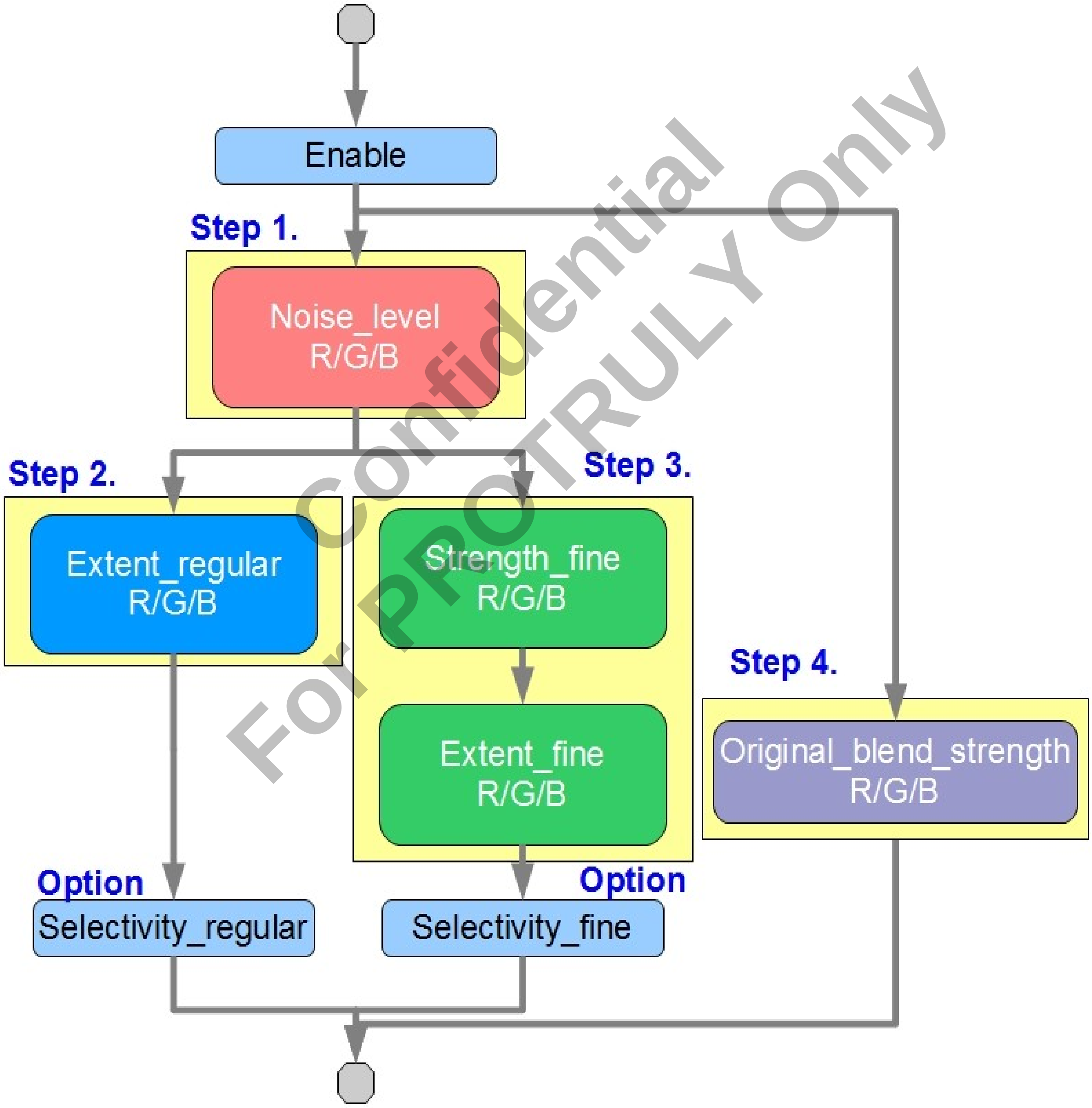


Figure 4: Tuning Flow.

3.3.2 CFA Noise Filter: Tuning Example

Step 1) noise_level R/G/B

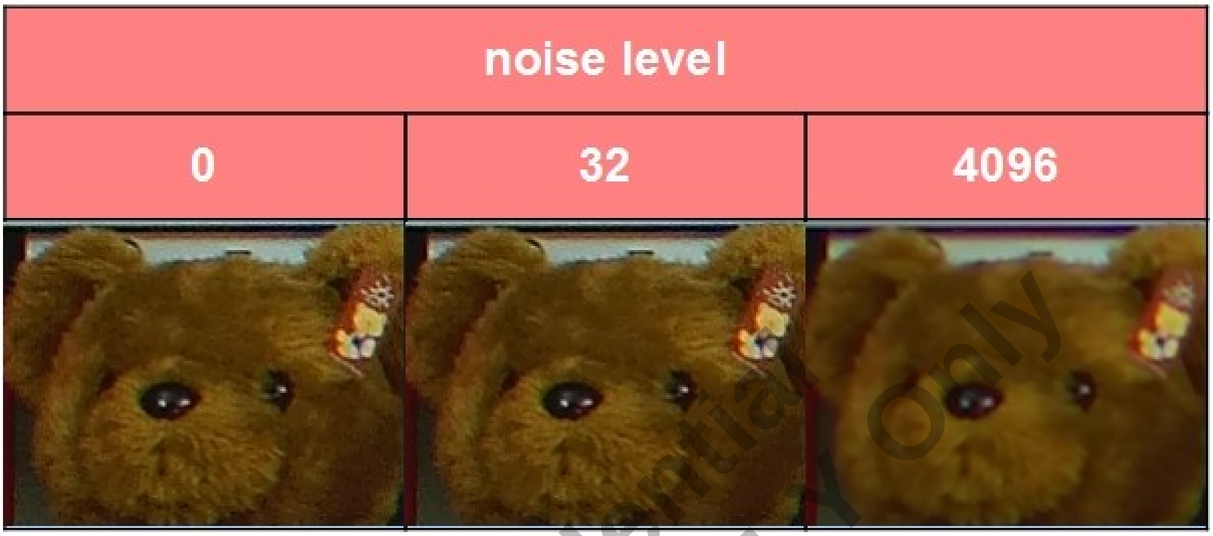


Figure 5: Sample Image at Low ISO.

Remarks

Noise level = 4096
Detail is disappeared by too strong Noise reduction.

Noise_level is set to the average noise level expected for the 14-bit sensor input (which is a function of the sensor settings). This value may be experimentally determined at each ISO level by measuring the noise standard deviation.

cfa_noise_filter.enable	1
cfa_noise_filter.noise_level_red	0, 32, 4096
cfa_noise_filter.noise_level_green	0, 32, 4096
cfa_noise_filter.noise_level_blue	0, 32, 4096
cfa_noise_filter.original_blend_strength_red	10
cfa_noise_filter.original_blend_strength_green	10
cfa_noise_filter.original_blend_strength_blue	10
cfa_noise_filter.extent_regular_red	36
cfa_noise_filter.extent_regular_green	36
cfa_noise_filter.extent_regular_blue	36
cfa_noise_filter.extent_fine_red	6
cfa_noise_filter.extent_fine_green	6
cfa_noise_filter.extent_fine_blue	6
cfa_noise_filter.strength_fine_red	71
cfa_noise_filter.strength_fine_green	71
cfa_noise_filter.strength_fine_blue	71
cfa_noise_filter.selectivity_regular	0
cfa_noise_filter.selectivity_fine	0

Table 2: Parameters.

Step 2) extent_regular R/G/B

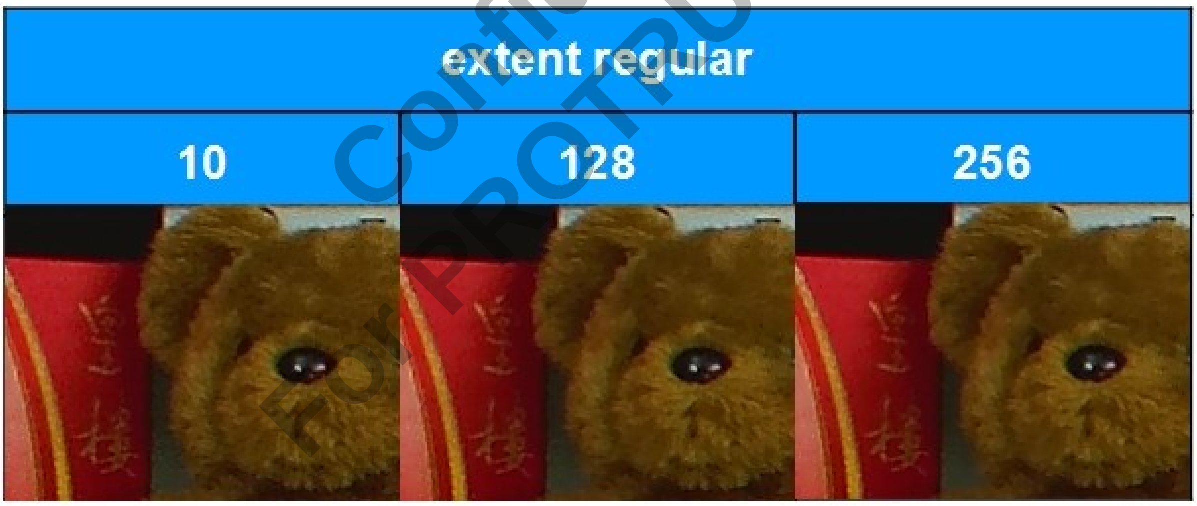


Figure 6: Sample Image at Low ISO.

Remarks

Extent regular = 256
Detail of wide area is disappeared by too strong Noise reduction.

Extent_regular determines the size of the support region for the filter. Using a larger region tends to increase the filter strength, therefore reducing the noise at the cost of reduced sharpness. The effect is not as direct as noise_level, because increasing the size of the supported region does not always result in more filtering; pixel values too different from the center value are not used by the filter.

cfa_noise_filter.enable	1
cfa_noise_filter.noise_level_red	32
cfa_noise_filter.noise_level_green	32
cfa_noise_filter.noise_level_blue	32
cfa_noise_filter.original_blend_strength_red	10
cfa_noise_filter.original_blend_strength_green	10
cfa_noise_filter.original_blend_strength_blue	10
cfa_noise_filter.extent_regular_red	10, 128, 256
cfa_noise_filter.extent_regular_green	10, 128, 256
cfa_noise_filter.extent_regular_blue	10, 128, 256
cfa_noise_filter.extent_fine_red	6
cfa_noise_filter.extent_fine_green	6
cfa_noise_filter.extent_fine_blue	6
cfa_noise_filter.strength_fine_red	71
cfa_noise_filter.strength_fine_green	71
cfa_noise_filter.strength_fine_blue	71
cfa_noise_filter.selectivity_regular	0
cfa_noise_filter.selectivity_fine	0

Table 3: Parameters.

Step 3) extent_fine R/G/B & strength_fine R/G/B

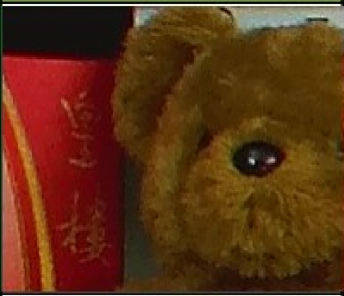
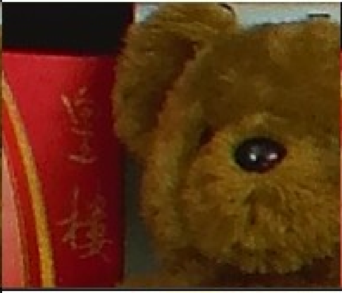
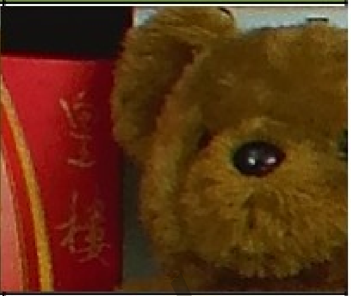
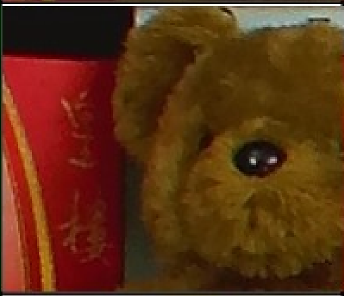
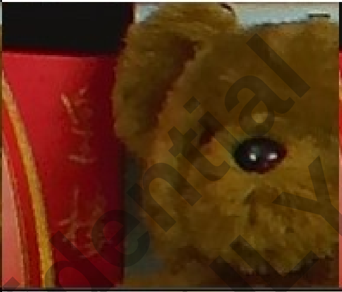
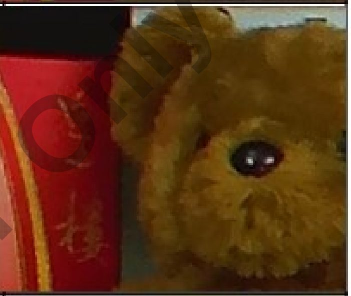
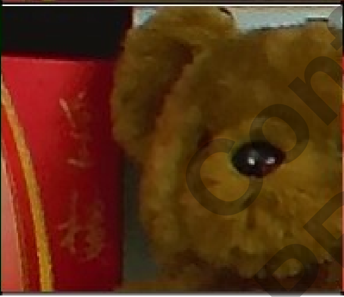
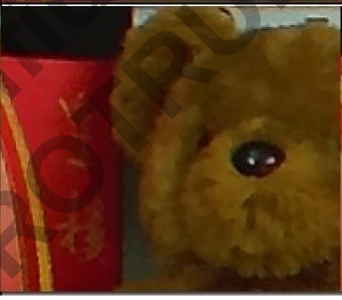
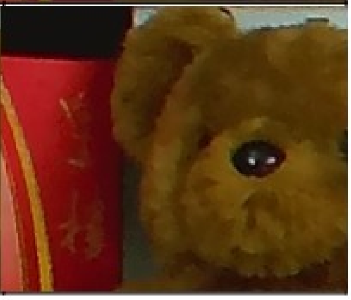
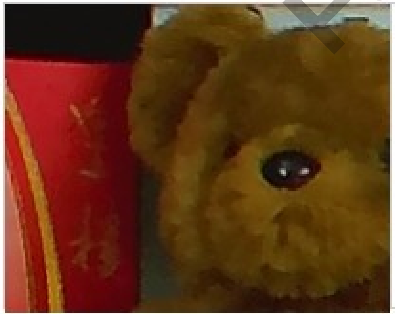
strength fine	extent fine		
	10	50	128
50			
128			
256			

Figure 7: Sample Image at Low ISO.

Remarks



Extent fine = 128, Strength fine = 256
Detail of wide area is disappeared by too strong noise reduction.

cfa_noise_filter.enable	1
cfa_noise_filter.noise_level_red	32
cfa_noise_filter.noise_level_green	32
cfa_noise_filter.noise_level_blue	32
cfa_noise_filter.original_blend_strength_red	10
cfa_noise_filter.original_blend_strength_green	10
cfa_noise_filter.original_blend_strength_blue	10
cfa_noise_filter.extent_regular_red	128
cfa_noise_filter.extent_regular_green	128
cfa_noise_filter.extent_regular_blue	128
cfa_noise_filter.extent_fine_red	10, 50, 128
cfa_noise_filter.extent_fine_green	10, 50, 128
cfa_noise_filter.extent_fine_blue	10, 50, 128
cfa_noise_filter.strength_fine_red	50, 128, 256
cfa_noise_filter.strength_fine_green	50, 128, 256
cfa_noise_filter.strength_fine_blue	50, 128, 256
cfa_noise_filter.selectivity_regular	0
cfa_noise_filter.selectivity_fine	0

Table 4: Parameters.

Strength_fine determines how the filter operates for pixels classified as “fine detail”. When strength_fine is zero, all pixels are treated the same way. This results in less filtering for pixels that are different from the surrounding pixels. As this value is increased, fine features or details are filtered more strongly.
When this parameter is being fine-tuned, it may be necessary to go back and re-tune noise_level and iterate.

Extent_fine determines the size of the support region for the filter. Using a larger region tends to increase the filter strength, therefore reducing noise at the cost of reduced sharpness. The effect is not as direct as strength_fine and noise_level, because increasing the size of the support region does not always result in more filtering; pixel values too different from the center value are not used by the filter.

Step 4) original_blend_strength R/G/B

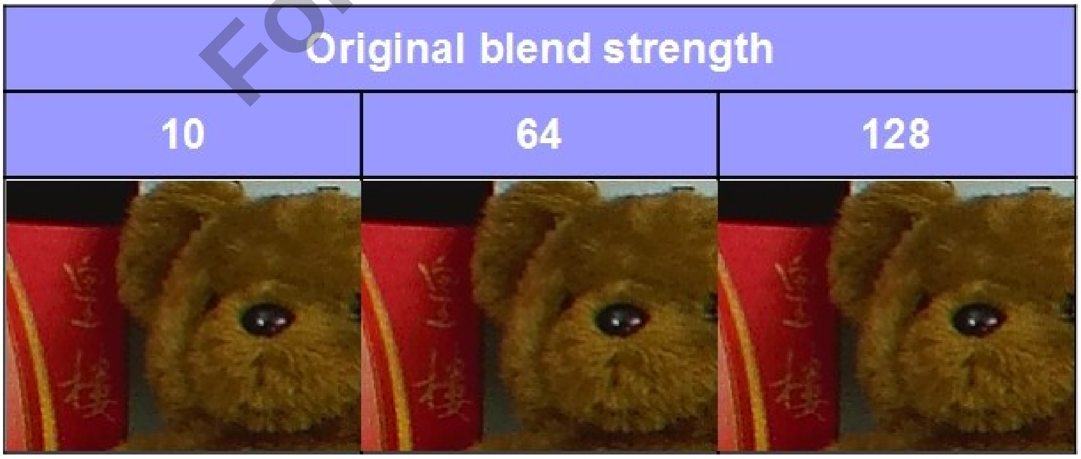


Figure 8: Sample Image at Low ISO.

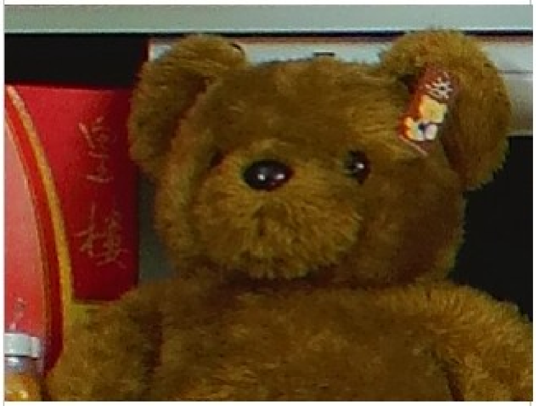
Original blend strength determines the weight of the center (original) pixel. Higher values increase the weight of the center pixel. It also means that it will increase the details but with more noise.

cfa_noise_filter.enable	1
cfa_noise_filter.noise_level_red	32
cfa_noise_filter.noise_level_green	32
cfa_noise_filter.noise_level_blue	32
cfa_noise_filter.original_blend_strength_red	10, 64, 128
cfa_noise_filter.original_blend_strength_green	10, 64, 128
cfa_noise_filter.original_blend_strength_blue	10, 64, 128
cfa_noise_filter.extent_regular_red	36
cfa_noise_filter.extent_regular_green	36
cfa_noise_filter.extent_regular_blue	36
cfa_noise_filter.extent_fine_red	6
cfa_noise_filter.extent_fine_green	6
cfa_noise_filter.extent_fine_blue	6
cfa_noise_filter.strength_fine_red	71
cfa_noise_filter.strength_fine_green	71
cfa_noise_filter.strength_fine_blue	71
cfa_noise_filter.selectivity_regular	0
cfa_noise_filter.selectivity_fine	0

Table 5: Parameters.

Optional) selectivity_fine/regular

Selectivity_fine/regular determines the frequency response of the filter. Higher values keep details of images instead of reducing noise. The following images show effects of this parameter. When selectivity_fine/regular = 250, it is noticed that the image and characters are more clear. It is recommended to tune this parameter after the other parameters have been tuned as fine tuning.

	Selectivity_fine = 0
	Selectivity_regular = 0

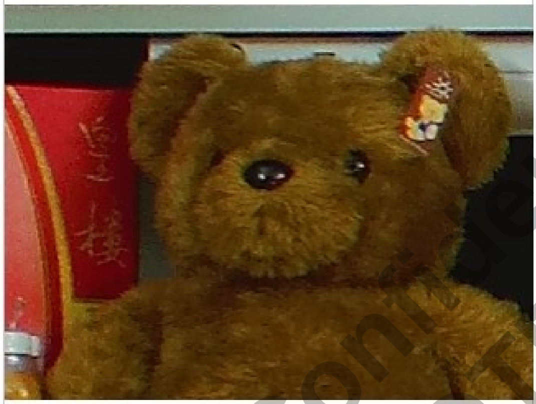
	Selectivity_fine = 250
	Selectivity_regular = 250

Figure 9: Sample Image at Low ISO.

3.4. Case Study and Examples: GbGr Mismatch Correction

Some image sensors have a characteristic showing a mismatch between the sensitivity of Gb pixels and that of Gr pixels. It is known that the mismatch causes maze noise (See Figure 10) after advanced de-mosaicing. Gb/Gr Mismatch Correction can smooth out this kind of noise.

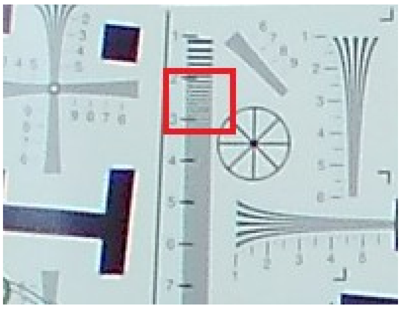


Figure 10: Maze Noise Caused by Strong Gb/Gr Mismatch.

3.4.1 CFA Noise Filter: GbGr Mismatch Correction: Tuning Flow

GbGr Mismatch correction flow is shown in Figure 11. First, it detects whether there is a consistent mismatch in a small area or in a wide area. If either condition occurs, the center pixels are averaged with the average of the neighboring four green pixels.

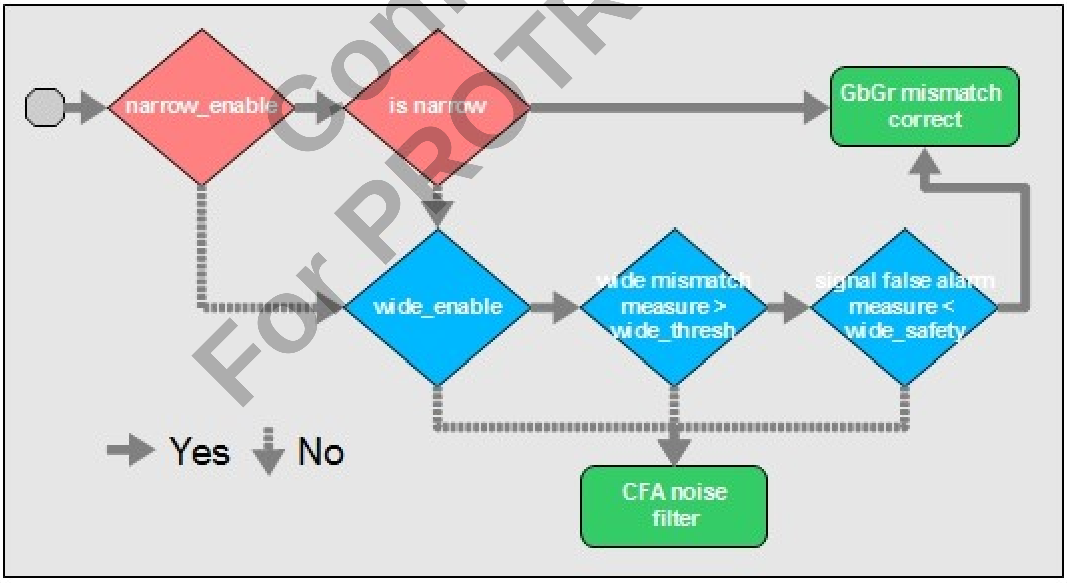

narrow_enable
is narrow
GbGr mismatch correct
wide_enable
wide mismatch measure > wide_thresh
signal false alarm measure < wide_safety
Yes
No
CFA noise filter

Figure 11: Gb/Gr Mismatch Correction.

Since the user has the narrow detection of mismatch followed by the wide detection, the recommended tuning flow should be in the same order.

Step A)

Enable narrow detection to see if the maze noise could be reduced nicely

Step B)

If Step A is not enough, go to step B to enable wide detection. There are two parameters, one is *wide_safety* and the other is *wide_thresh*. Users can tune the *wide_thresh* first while keeping *wide_safety* to be maximum (=256).

Step C)

Then, users can reduce *wide_safety* to keep the best balance between maze noise and sharpness. Sometimes it is necessary to go back to Step B to tune *wide_thresh.*

3.4.2 CFA Noise Filter: GbGr Mismatch Correction: Tuning Example

Step A)

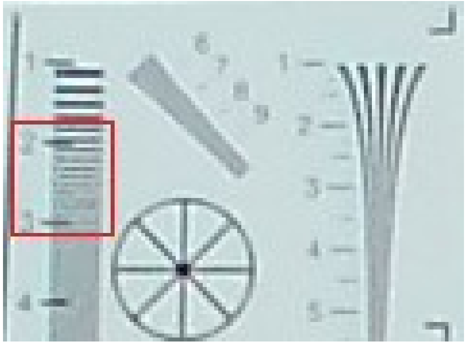
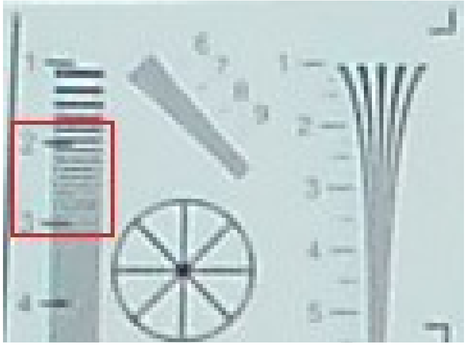


Figure 12: Enable Narrow Detection.

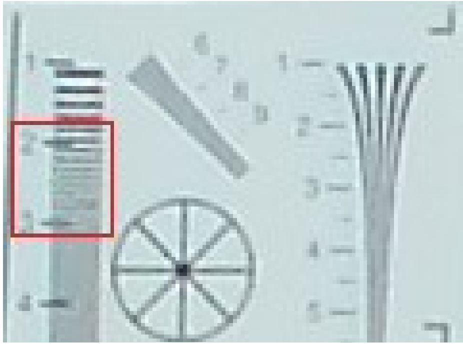
In this case, it seems not enough. Go to the next step.

Step B)



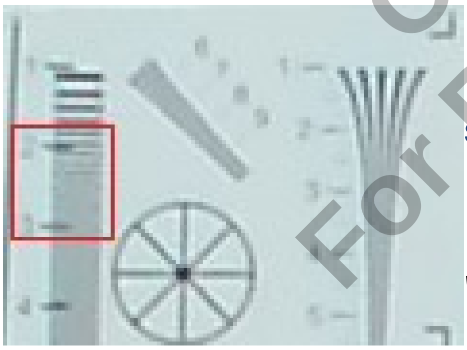
Not enough

wide_safety = 256, *wide_thresh* = 2



Not enough

wide_safety = 256, *wide_thresh* = 1

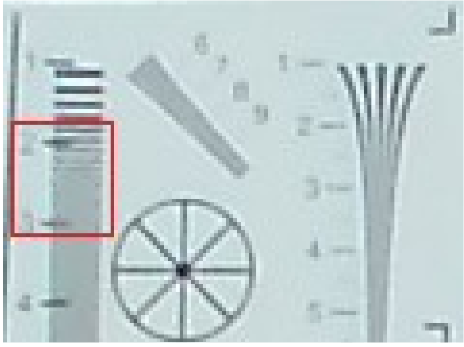


Slightly too blurred but good for de-noising, choose this one

wide_safety = 256, *wide_thresh* = 0

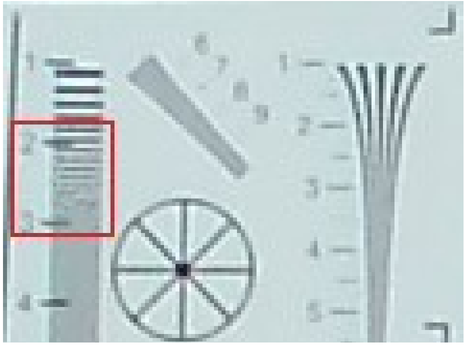
Figure 13: change wide_thresh.

Step C)



Enough effect

wide_safety = 16, *wide_thresh* = 0



Can see the maze noise, not good

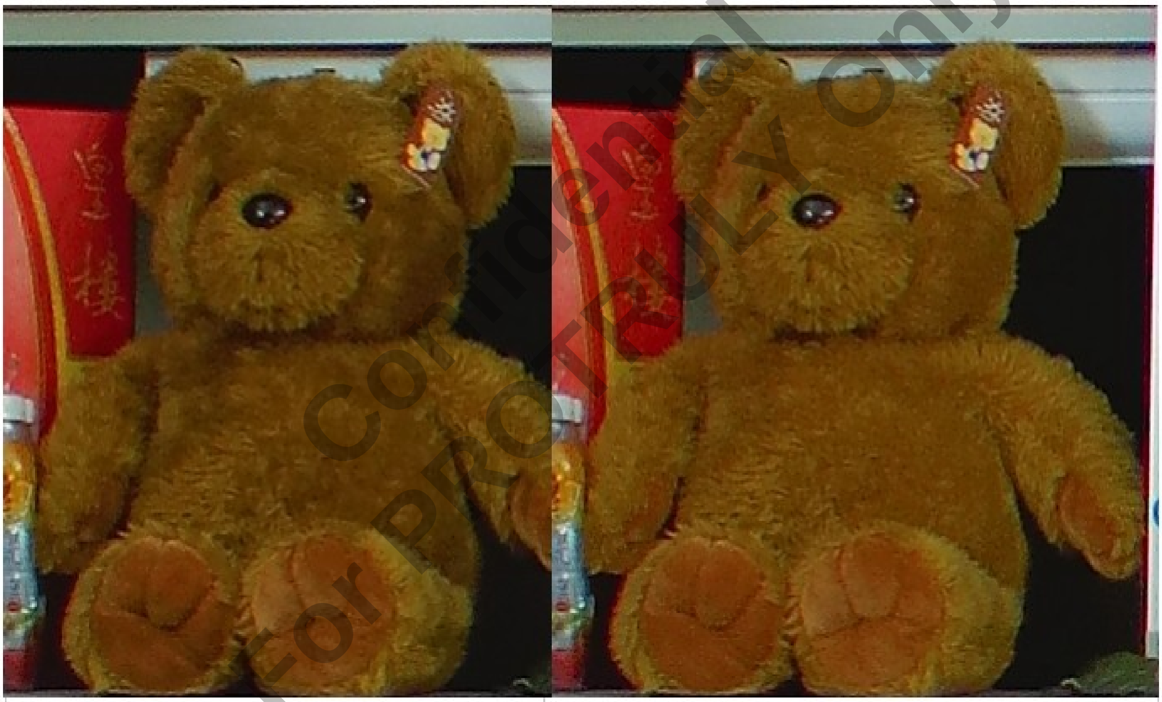
wide_safety = 8, *wide_thresh* = 0

The results of wide_safty= 16 can erase the maze noise and not be too blurred.

3.5. Case Study and Examples: Local Exposure

Local exposure can dynamically adjust the gain of the current pixel based on the average luma value around it. The visibility of shadow detail can be improved by increasing the local gain. A gain factor is applied on the pixels as a function of the local brightness value; this is controlled by programming a gain curve. And the following sample images at Figure 14 show the different gain curves to achieve the local exposure.

3.5.1 Local Exposure: Tuning Example



Gain curve table[256]	
Index	[0]-[255]
Value	1024

Gain curve table[256]							
[0]-[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
1024	1224	1536	2048	1843	1640	1536	1433

Gain curve table[256]							
[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]-[255]
1331	1280	1224	1178	1126	1075	1050	1024

Figure 14: Sample Images at Low ISO.

3.6. Case Study and Examples: Demosaic

Demosaic contains Gradient registers and Activity registers. The Gradient registers are used to select between isotropic and directional interpolation of the green channel. Interpolations for the red and blue components are dependent on the green channel's interpolation. When directional interpolation has been selected, the Activity registers are used to select the directional interpolation type: constant-hue or straight-average. Therefore, the possible combination of interpolations are: (1) directional, constant-hue (2) directional, straight-average (3) isotropic, always straight-average.

3.6.1   Demosaic: Tuning Example

Gradient - grad_noise_thresh
This value is used to select between directional interpolation and isotropical interpolation based on a Gradient measure. When the Gradient measure falls below grad_noise_thresh, isotropic interpolation is chosen to reduce noise. When the Gradient measure rises above grad_noise_thresh, directional interpolation is chosen to avoid zipper artifacts in edge areas.

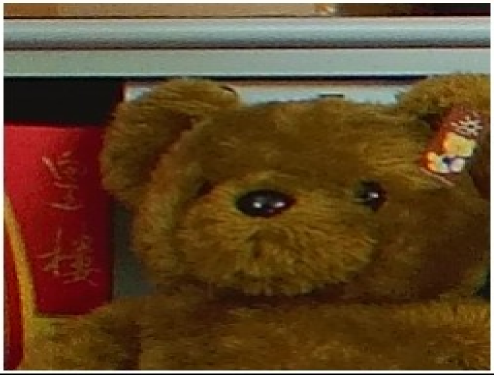
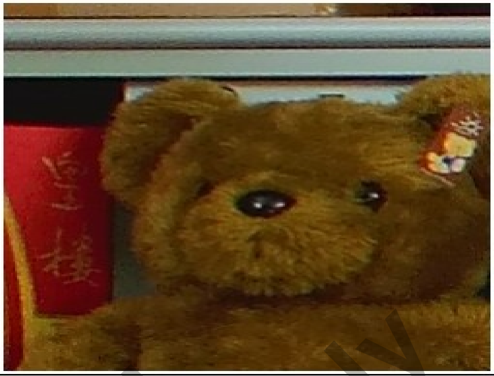
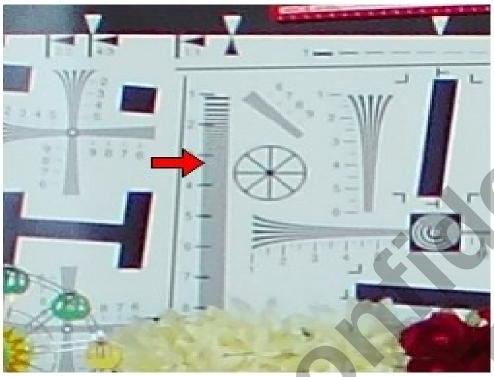
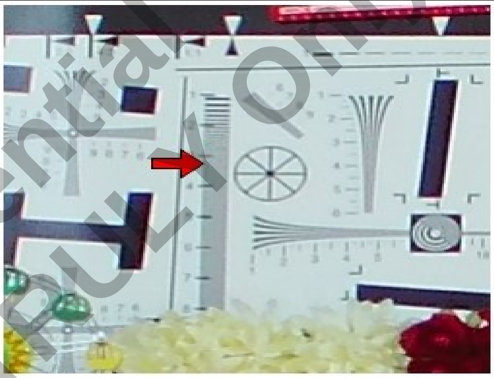
grand_noise_thresh	
16	64
	
	
Smaller grand_noise_thresh has more directional interpolation chosen. Therefore, it has more detail but more noise.	Larger grand_noise_thresh has more isotropic interpolation chosen. Therefore, it has less noise but less detail.

Figure 15: Sample Images at Low ISO.

li_demosaic.activity_thresh	31
li_demosaic.activity_difference_thresh	1365
li_demosaic.grad_clip_thresh	512
li_demosaic.grad_noise_thresh	**16, 64**

Table 6: Parameters.

Activity – activity_thresh

The value is used to determine if constant-hue interpolation or straight-average interpolation is to be used based on an Activity measure. If activity count is >= activity_thresh, constant-hue interpolation is used. If activity count is < activity_thresh, straight-average interpolation is used.

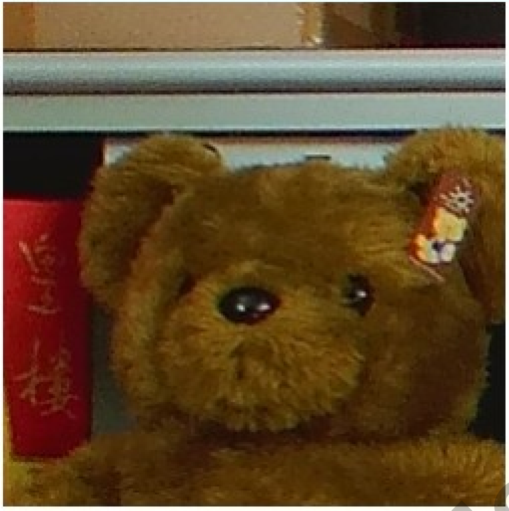
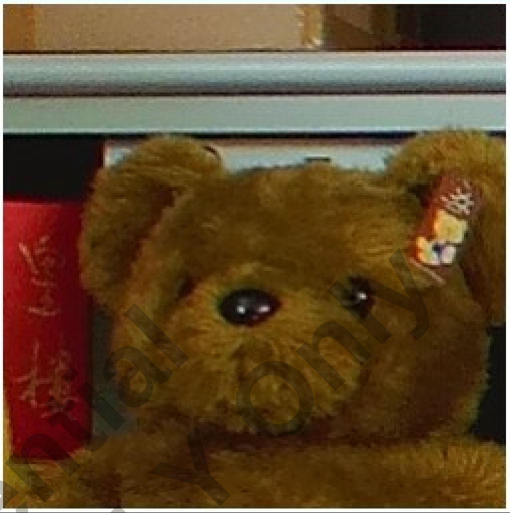
activity_thresh	
0	31
	
Smaller activity_thresh has more constant-hue interpolation used to achieve finer detail interpolation.	Larger activity_thresh has more straight-average interpolation used to achieve smoother and usually less noisy interpolation.

Figure 16: Sample Images at Low ISO.

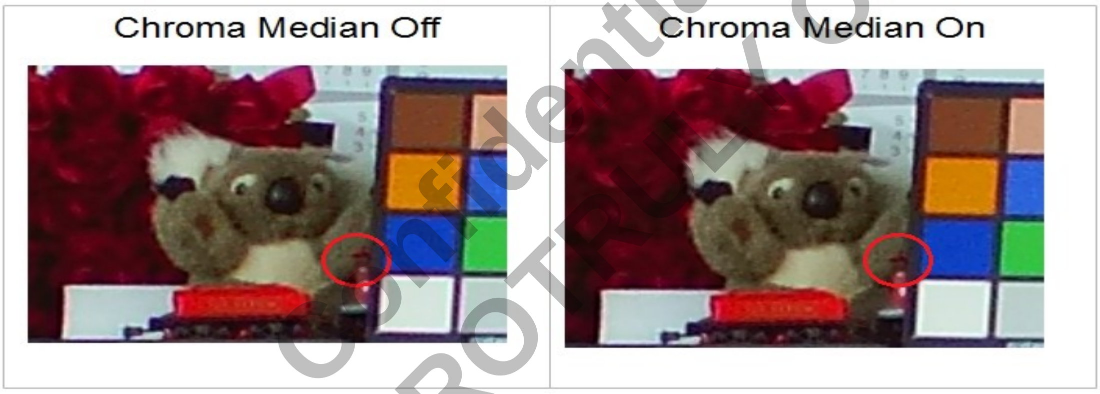
li_demosaic.activity_thresh	0, 31
li_demosaic.activity_difference_thresh	1365
li_demosaic.grad_clip_thresh	512
li_demosaic.grad_noise_thresh	5

Table 7: Parameters.

3.7. Case Study and Examples: Chroma Median Filter

Chroma Median Filter is used to reduce false color artifacts on the edge and is also effective for chromatic aberration. This filter has Cb and Cr strength parameters. Users can tune the strengths respectively.

The following sample images describe the effect of this filter.



Chroma Median Off

Chroma Median On

3.7.1 Chroma Median Filter: Tuning Example

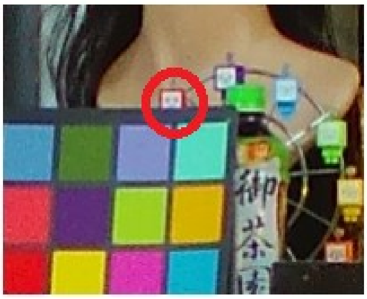
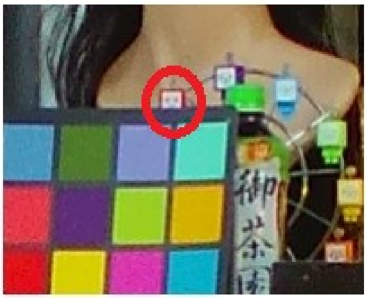
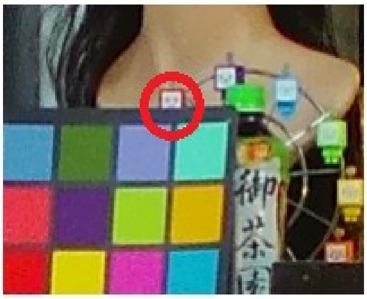
Strength		
0	128	256
		

Figure 17: Sample Image at Low ISO.

Remarks

	Strength = 256 Chroma saturation will decrease by too strong median filter.

chroma_median_filter.enable	1
chroma_median_filter.cb_adaptive_strength	0, 128, 256
chroma_median_filter.cr_adaptive_strength	0, 128, 256
chroma_median_filter.cb_non_adaptive_strength	0
chroma_median_filter.cb_non_adaptive_strength	0
chroma_median_filter.cb_adaptive_amount	256
chroma_median_filter.cb_adaptive_amount	256

Table 8: Parameters.

3.8. Case Study and Examples: Chroma Noise Filter

Chroma noise filter tuning flow is shown in Figure 18. Users can refer to this diagram to confirm how to start Chroma noise filter tuning step by step. Typical tuning parameters and tuning results are shown in Tables 9~11 and Figures 19~21.

3.8.1 Chroma Noise Filter: Tuning Flow

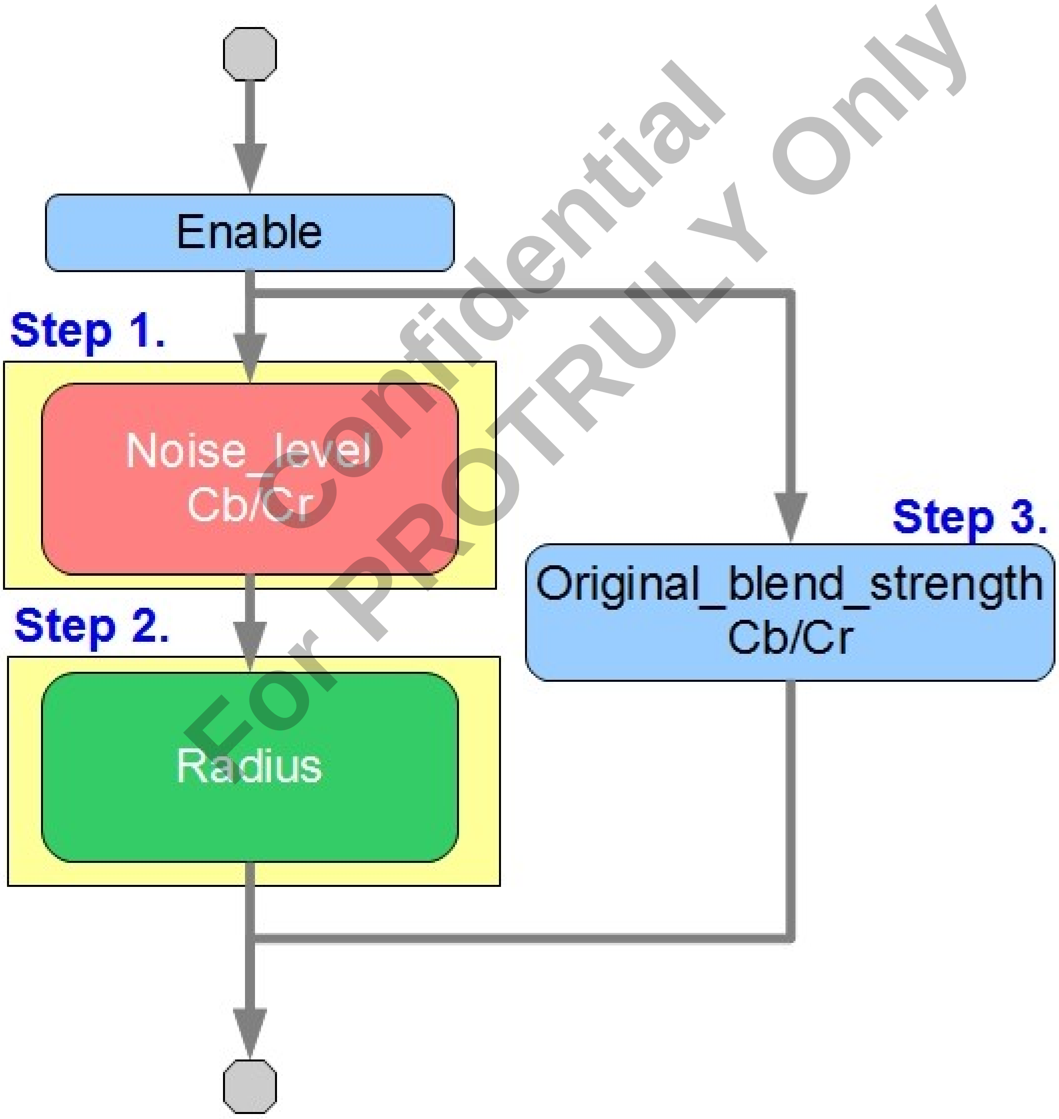


Figure 18: Chroma Noise Filter Tuning Flow.

3.8.2 Chroma Noise Filter: Tuning Example

Step1) noise_level Cb/Cr

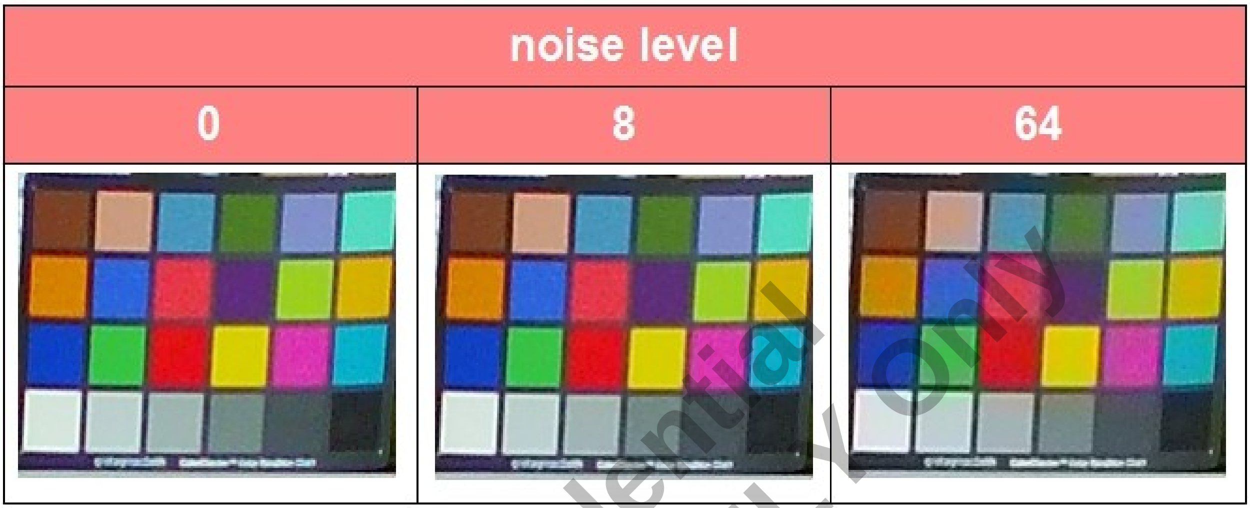
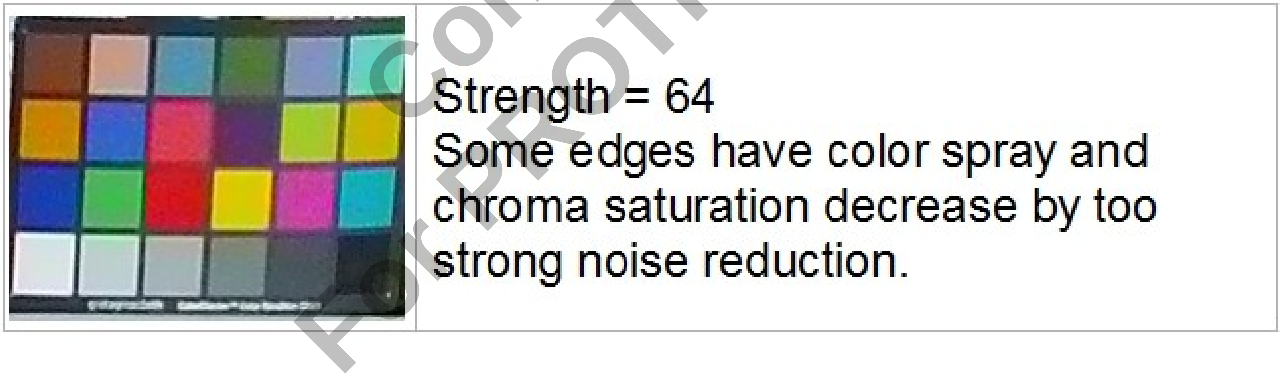


Figure 19: Sample Image at Low ISO.

Remarks



Strength = 64
Some edges have color spray and chroma saturation decrease by too strong noise reduction.

chroma_filt.enable	1
chroma_filt.noise_level_cb	0, 8, 64
chroma_filt.noise_level_cr	0, 8, 64
chroma_filt.original_blend_strength_cb	0
chroma_filt.original_blend_strength_cr	0
chroma_filt.radius	64

Table 9: Parameters.

Step 2) radius

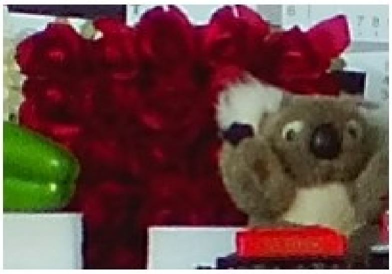
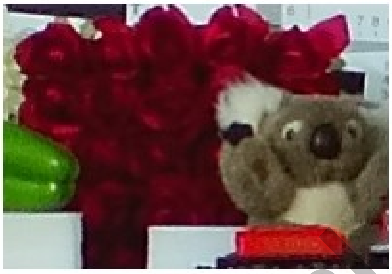
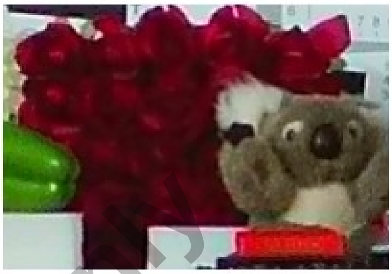
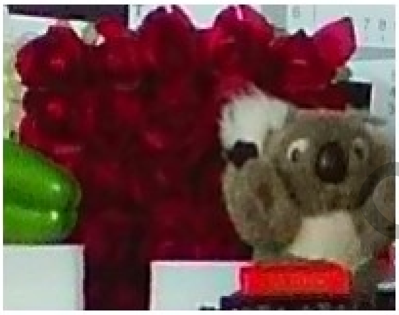
radius		
32	64	128
		

Figure 20: Sample Image at Low ISO.

Remarks

	Radius = 128 Sharpness are blurred and color of flowers is paled.

chroma_filter.enable	1
chroma_filter.noise_level_cb	8
chroma_filter.noise_level_cr	8
chroma_filter.original_blend_strength_cb	0
chroma_filter.original_blend_strength_cr	0
chroma_filter.radius	32, 64, 128

Table 10: Parameters.

Step 3) original_blend_strength Cb/Cr

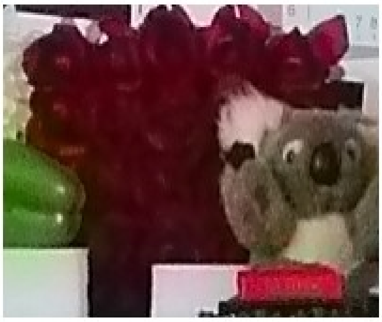
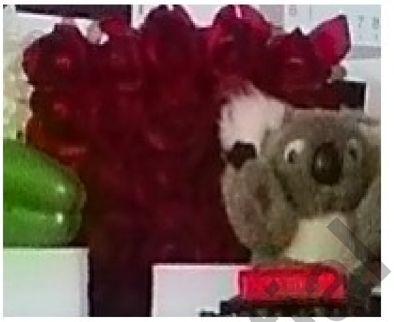
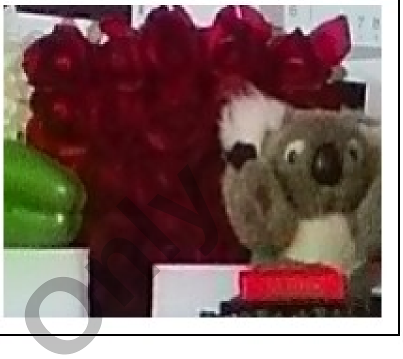
original blend strength		
10	128	256
		

Figure 21: Sample Image at Low ISO.

Remarks

	Original blend strngth = 256 The higher value of original blend strenght will keep the the original picture and less filter effect.

chroma_filter.enable	1
chroma_filter.noise_level_cb	64
chroma_filter.noise_level_cr	64
chroma_filter.original_blend_strength_cb	**10, 128, 256**
chroma_filter.original_blend_strength_cr	**10, 128, 256**
chroma_filter.radius	128

Table 11: Parameters.

3.9. Case Study and Examples: Advanced Spatial Filter

The advanced spatial filter is a luma noise filter. However, there is only one sharpen noise filter in A12, see Figure 1. Therefore, either the advanced spatial filter or the sharpen noise filter can be used. It can be set by "processing_select.use1st_sharpen_not_asf"=0 for advanced spatial filter or 1 for sharpen noise filter. It is not recommended to use only the advanced spatial filter. It will cause the image to be too blurred.

3.9.1 Advanced Spatial Filter: Tuning Flow

Step A) To tune advanced_spatial_filter.directional_decide_t0/t1 which configures the threshold.

The threshold is defined as follows:

- non-edge area < directional_decide_t0
- directional_decide_t0 < interpolation < directional_decide_t1
- directional_decide_t1 < edge area

Step B) To tune advanced_spatial_filter.fir_strength_iso which is applied for non-edge areas

Step C) To tune advanced_spatial_filter.fir_strength_dir which is applied for edge areas

Step D) To tune the maximum change value of filters which are used to restrict the effect of filters. The maximum change in other filters have the same meaning. Hence, tuning can be performed in the same way.

3.9.2 Advanced Spatial Filter: Tuning Example

Step A) directional_decide_t0/t1

directional_decide_t0 and directional_decide_t1 determines the pixel filtered isotropically or directionally. Therefore, it should be tuned fist. The values of T0 and T1 may be determined by using a high value of strenght_dir with a low value of strenght_iso to get the optimized value of T1, then a high value of strenght_iso with a low value of strenght_dir to get the optimized value of T0. In the Figure 22 example, strenght_dir = 256 and strenght_iso = 1 are used to verify T1 values. The users can get T0 values using the same method, a high value of strength_iso and a low value of strength_dir.

.

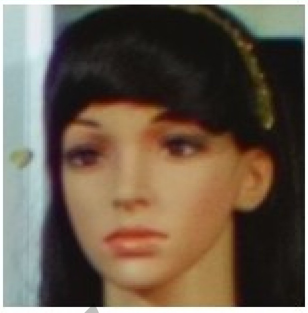
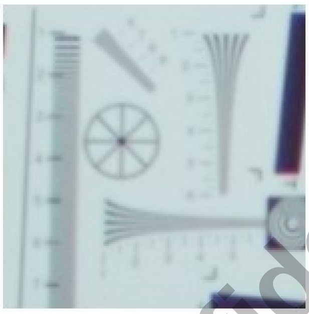
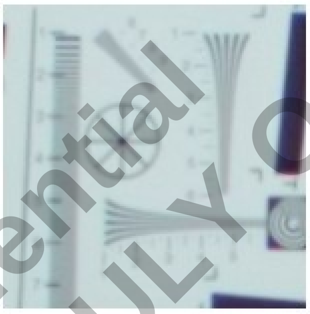
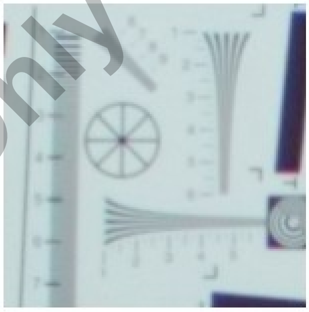
directional_decide_t0/t1			
	9/10	19/20	39/40
Non-edge area			
Edge area			

Figure 22: Sample Images at low ISO.

specify_firs	2								
dir_amounts	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
dir_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
iso_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
strength_dir	256								
strength_iso	1								
max_change_not_T0T1_alpha	5								
max_change_donw	5								
max_change_up	5								
directional_decide_t0	9, 19, 39								
directional_decide_t1	10, 20, 40								
wide_edge_detect	3								
level_str_adjust_low	5								
level_str_adjust_low_delta	5								
level_str_adjust_low_strength	64								
level_str_adjust_mid_strength	64								
level_str_adjust_high	110								
level_str_adjust_high_delta	5								
level_str_adjust_high_strength	64								

Table 12: Parameters.

Step B) strength_ iso

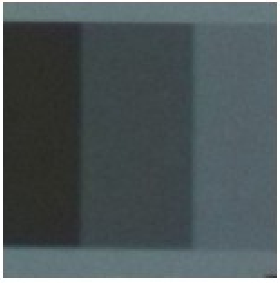
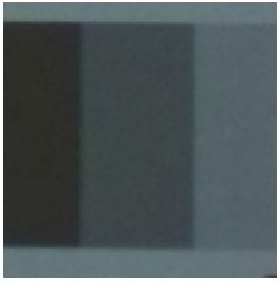
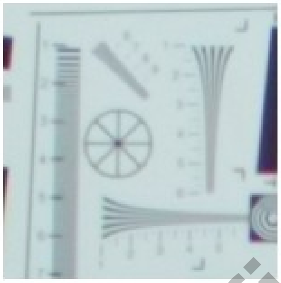
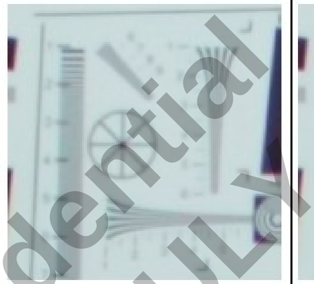
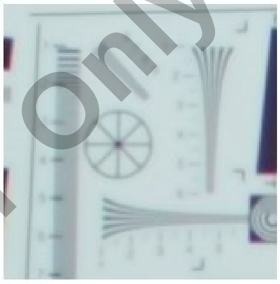
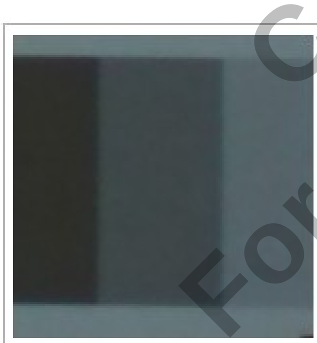
strength_iso			
	10	128	256
Non-edge area			
Edge area			

Figure 23: Sample images at low ISO.

Remarks

	strength_iso = 256 The noise of non-edge area is decreased, but continuous line is faded.

specify	2								
dir_amounts	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
dir_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
iso_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
strength_dir	50								
strength_iso	10, 128, 256								
max_change_not_T0T1_alpha	5								
max_change_donw	5								
max_change_up	5								
directional_decide_t0	5								
directional_decide_t1	10								
wide_edge_detect	3								
level_str_adjust_low	5								
level_str_adjust_low_delta	5								
level_str_adjust_low_strength	64								
level_str_adjust_mid_strength	64								
level_str_adjust_high	110								
level_str_adjust_high_delta	5								
level_str_adjust_high_strength	64								

Table 13: Parameters.

Step C) strength_dir

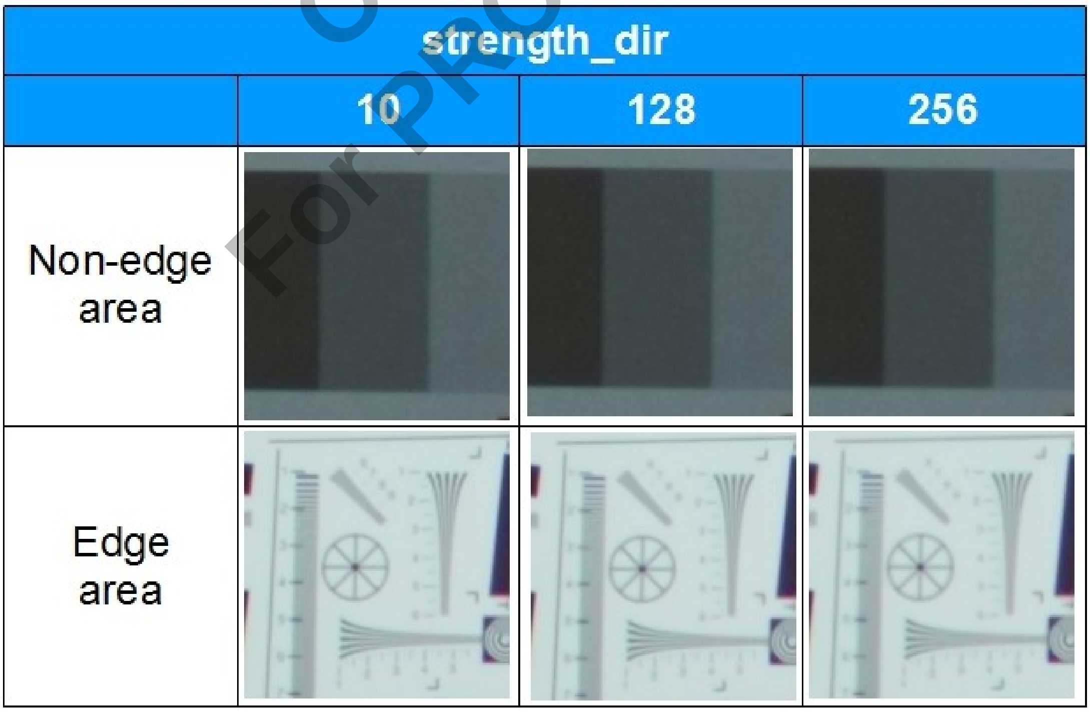
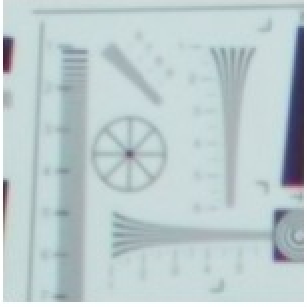


Figure 24: Sample Images at Low ISO.

Remarks



strength_dir = 256
Detail of characters is blurred.

specify_firs	2								
dir_amounts	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
dir_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
iso_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
strength_dir	10, 128, 256								
strength_iso	128								
max_change_not_T0T1_alpha	5								
max_change_down	5								
max_change_up	5								
directional_decide_t0	5								
directional_decide_t1	10								
wide_edge_detect	3								
level_str_adjust_low	5								
level_str_adjust_low_delta	5								
level_str_adjust_low_strength	64								
level_str_adjust_mid_strength	64								
level_str_adjust_high	110								
level_str_adjust_high_delta	5								
level_str_adjust_high_strength	64								

Table 14: Parameters.

In the advanced spatial filter, the value of max_change_not_T0T1_alpha decides max_change controlled by max_change_down/up or T0/T1/alpha_down/up. max_change_not_T0T1_alpha = 1 means it is controlled by max_change_down/up. max_change_not_T0T1_alpha = 0 means that it is controlled by T0/T1/alpha change.

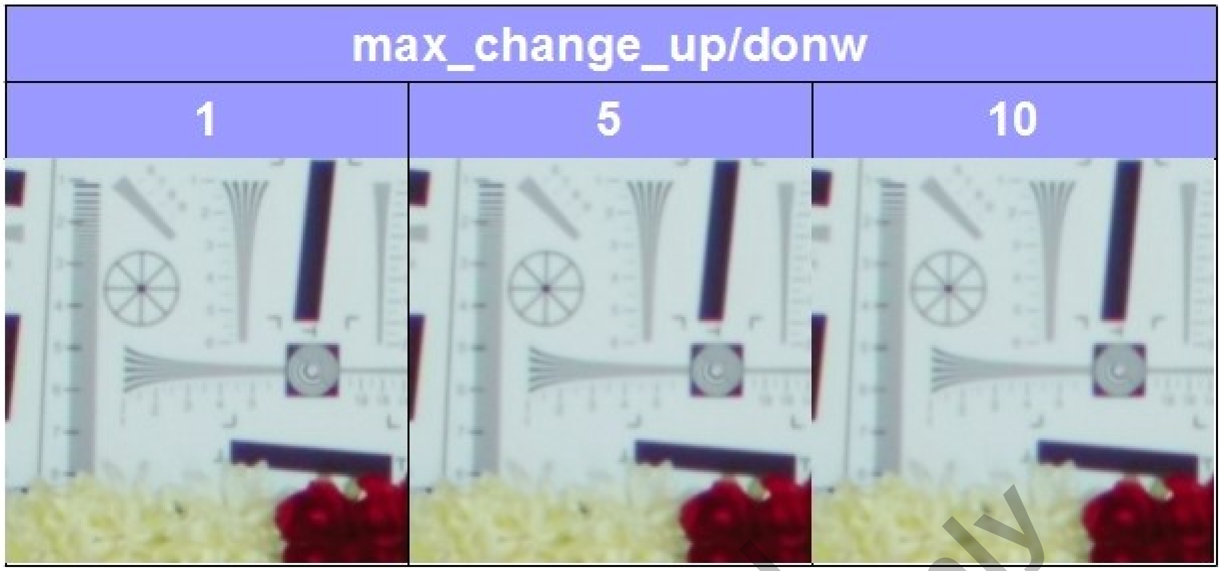


Figure 25: Sample Images at Low ISO.

Remarks

max_change_up/donw = 1
The effect of filter was restricted by the max change.

specify_firs	2								
dir_amounts	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
dir_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
iso_strengths	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	0	0	0	0	0	0	0	0	0
strength_dir	256								
strength_iso	128								
max_change_not_T0T1_alpha	1								
max_change_down	1, 5, 10								
max_change_up	1, 5, 10								
T0_down	5								
T0_up	5								
T1_down	5								
T1_up	5								
alpha_min_down	5								
alpha_min_up	5								
alpha_max_down	5								
alpha_max_up	5								
directional_decide_t0	2								
directional_decide_t1	40								
wide_edge_detect	3								
level_str_adjust_low	5								
level_str_adjust_low_delta	5								
level_str_adjust_low_strength	64								
level_str_adjust_mid_strength	64								
level_str_adjust_high	110								
level_str_adjust_high_delta	5								
level_str_adjust_high_strength	64								

Table 15: Parameters.

3.10. Case Study and Examples: Sharpen Noise Filter

Sharpen Noise Filter has two modes for noise reduction as shown below in Figure 26. When the user selects mode 0, Sharpening is applied after Spatial Noise Filter and FIR kernel is 5x5. When the user selects mode 2, Sharpening and Spatial Noise Filters are applied in parallel and FIR kernel is 7x7. Usually, it would not recommended that users use mode 0 as performing sharpening after de-noising is not meaningful. The image would have already lost details in the noise filter. Therefore, Mode 2 is usually used.

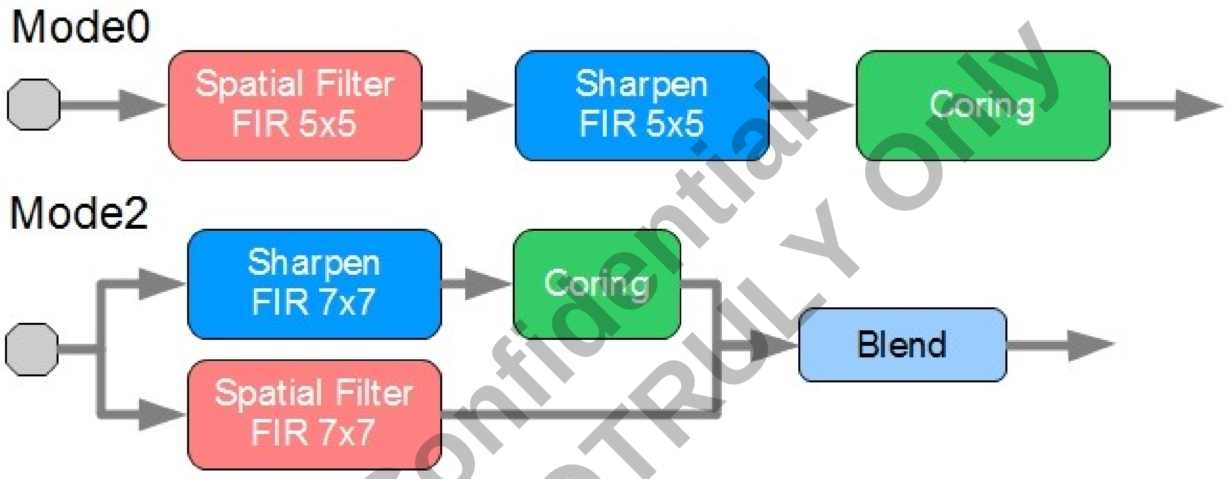


Figure 26: Difference of Mode Selection.

3.10.1 Sharpen Noise Filter: Tuning Flow

Step A) Tune spatial_filter.edge_threshold which configures the threshold between the non-edge area and the edge area. If users change the value of the edge_threshold, the noise level is changed for both non-edge and edge areas.

Step B) Tune sharpen_noise_filter_noise, this filter is a luma noise filter. The tuning methods are the same as mentioned for the advanced spatial filter.

Step C) Tune sharpening_fir.fir_strength_iso/dir which can tune strength of FIR. Higher value gives higher sharpness.

Step D) Tune sharpening_coring.coring_table which configures the coring table of the Sharpen filter. This table multiplied by the FIR output.

3.10.2 Sharpen Noise Filter: Tuning Example

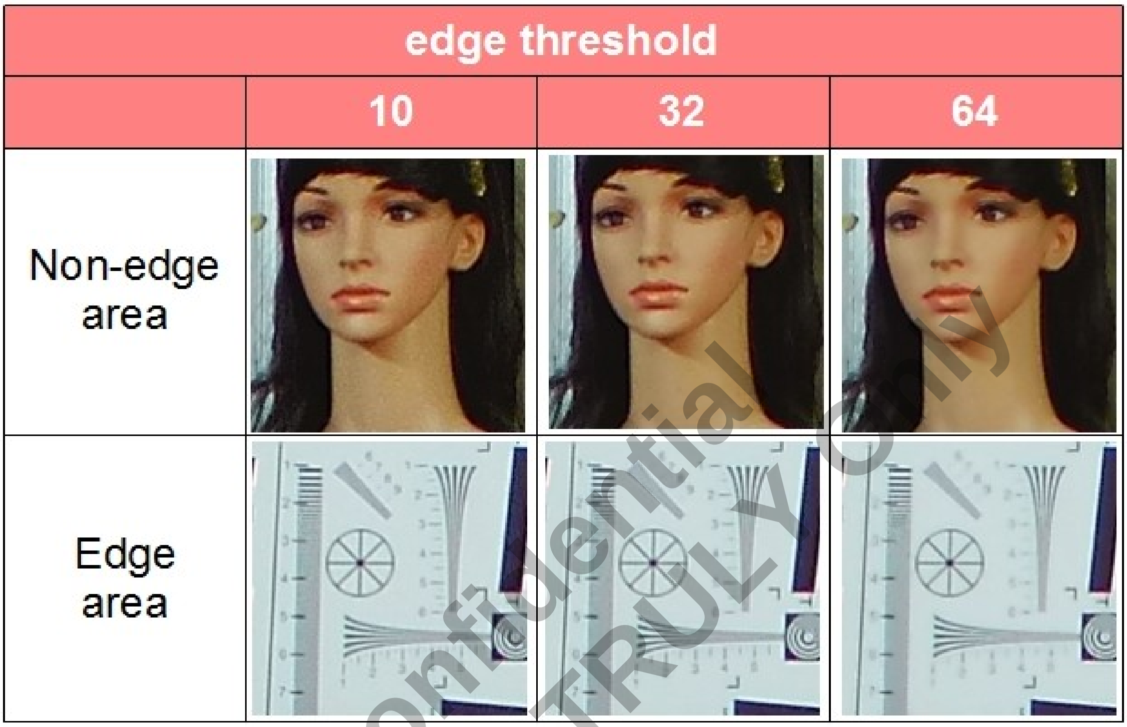


Figure 27: Sample Images at Low ISO.

Remarks

both.mode	2
both.edge_thresh	10, 32, 64
both.wide_edge_detect	1
spatial_filter.specify	2
spatial_filter.fir_strength_iso	109
spatial_filter.fir_strength_dir	20

Table 16: Parameters.

Step C) To tune sharpening_fir.fir_strength_iso/dir

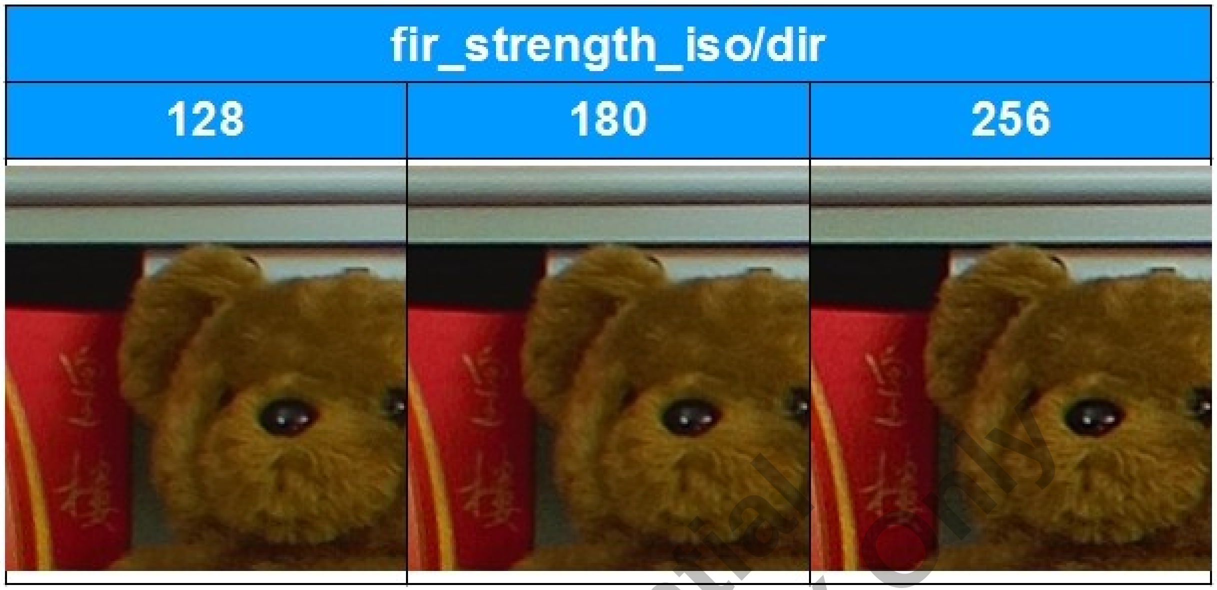
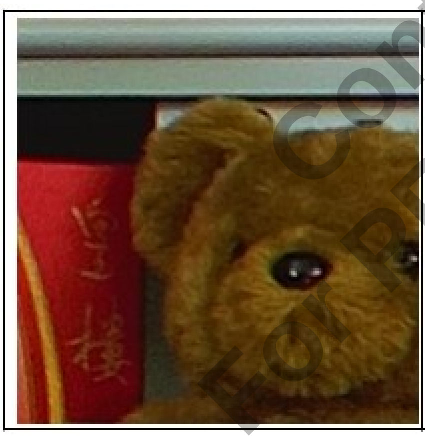


Figure 28: Sample Images at Low ISO.

Remarks

	fir_strength_iso/dir = 256 Sharpness gets better. But some edges are more wider.

both.mode	2
both.edge_thresh	23
both.wide_edge_detect	1
spatial_filter.specify	2
spatial_filter.fir_strength_iso	128, 180, 256
spatial_filter.fir_strength_dir	128, 180, 256

Table 17: Parameters.

Step D) To tune sharpening_coring.coring_table

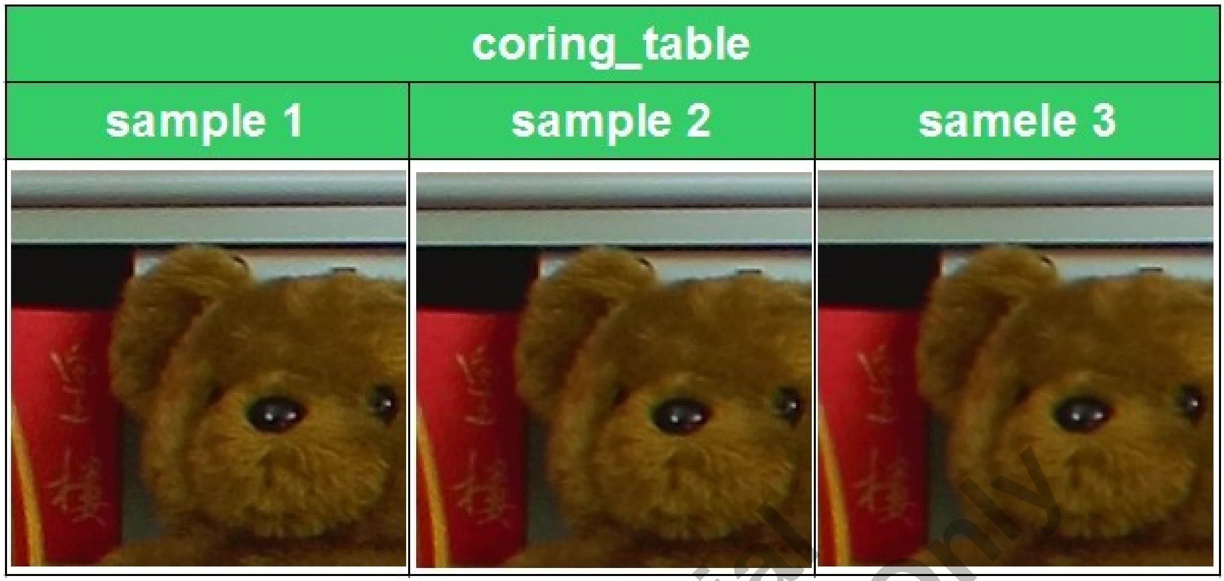
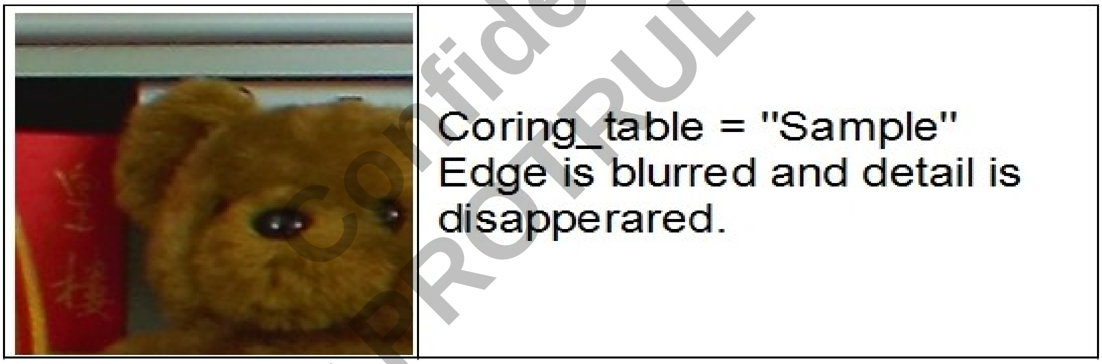
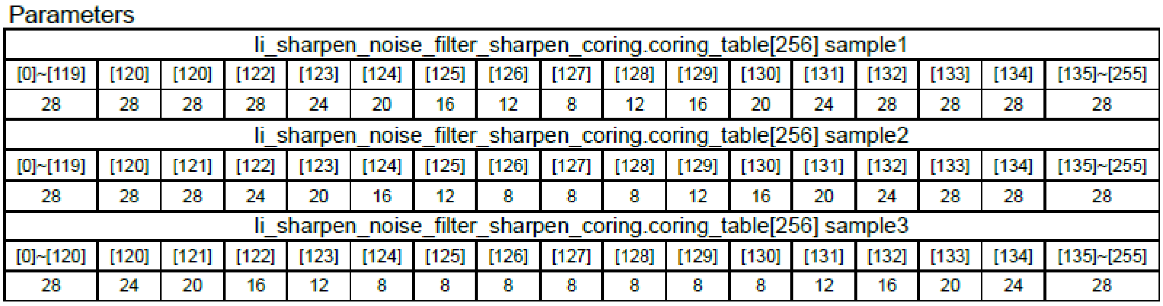


Figure 29: Sample Images at Low ISO.

Remarks



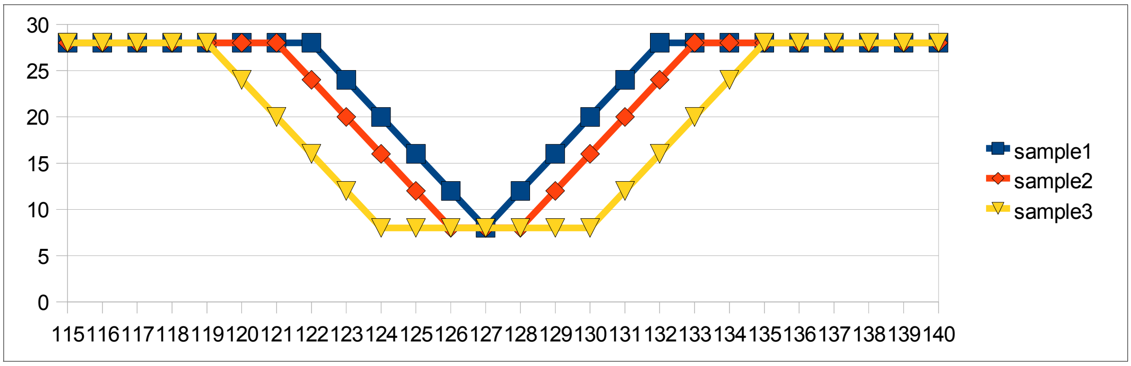
Coring_table = "Sample"
Edge is blurred and detail is disapperared.



Parameters

li_sharpen_noise_filter_sharpen_coring.coring_table[256] sample1																
[0]~[119]	[120]	[120]	[122]	[123]	[124]	[125]	[126]	[127]	[128]	[129]	[130]	[131]	[132]	[133]	[134]	[135]~[255]
28	28	28	28	24	20	16	12	8	12	16	20	24	28	28	28	28
li_sharpen_noise_filter_sharpen_coring.coring_table[256] sample2																
[0]~[119]	[120]	[121]	[122]	[123]	[124]	[125]	[126]	[127]	[128]	[129]	[130]	[131]	[132]	[133]	[134]	[135]~[255]
28	28	28	24	20	16	12	8	8	8	12	16	20	24	28	28	28
li_sharpen_noise_filter_sharpen_coring.coring_table[256] sample3																
[0]~[120]	[120]	[121]	[122]	[123]	[124]	[125]	[126]	[127]	[128]	[129]	[130]	[131]	[132]	[133]	[134]	[135]~[255]
28	24	20	16	12	8	8	8	8	8	8	8	12	16	20	24	28

Figure 30: Parameters.



Optional) Wide Edge Detection

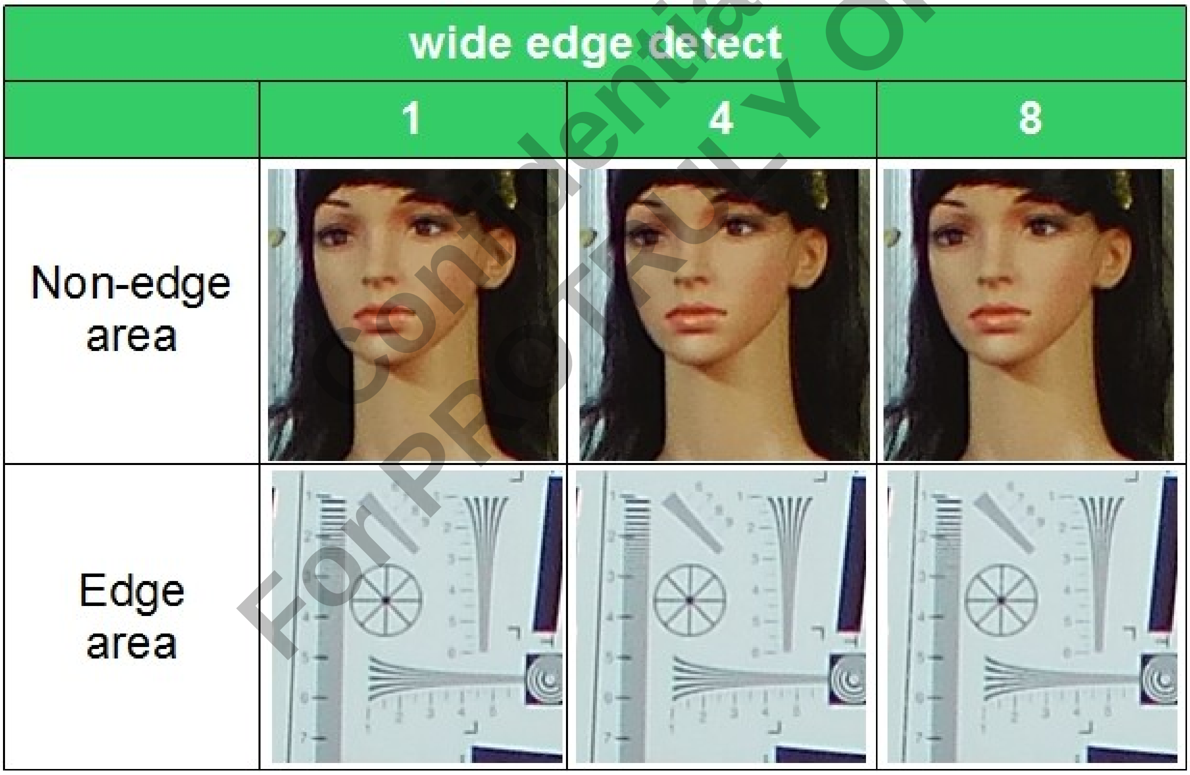


Figure 31: Sample Images of Wide Edge Detect.

A12 edge-detection is controlled by wide_edge_detect. Increasing this parameter enhances sensitivity and increases edge-direction decisions for wide high-contrast edges, regardless of proximity to an edge. Smaller values enhance the sensitivity and increase edge-direction decisions for closely spaced lines and finer details. The effect of this parameter is generally subtle in nature; however, note that the following issues can occur.

When the value of wide_edge_detect is small, there may be an increase in artifacts a few pixels away from high-contrast edges.

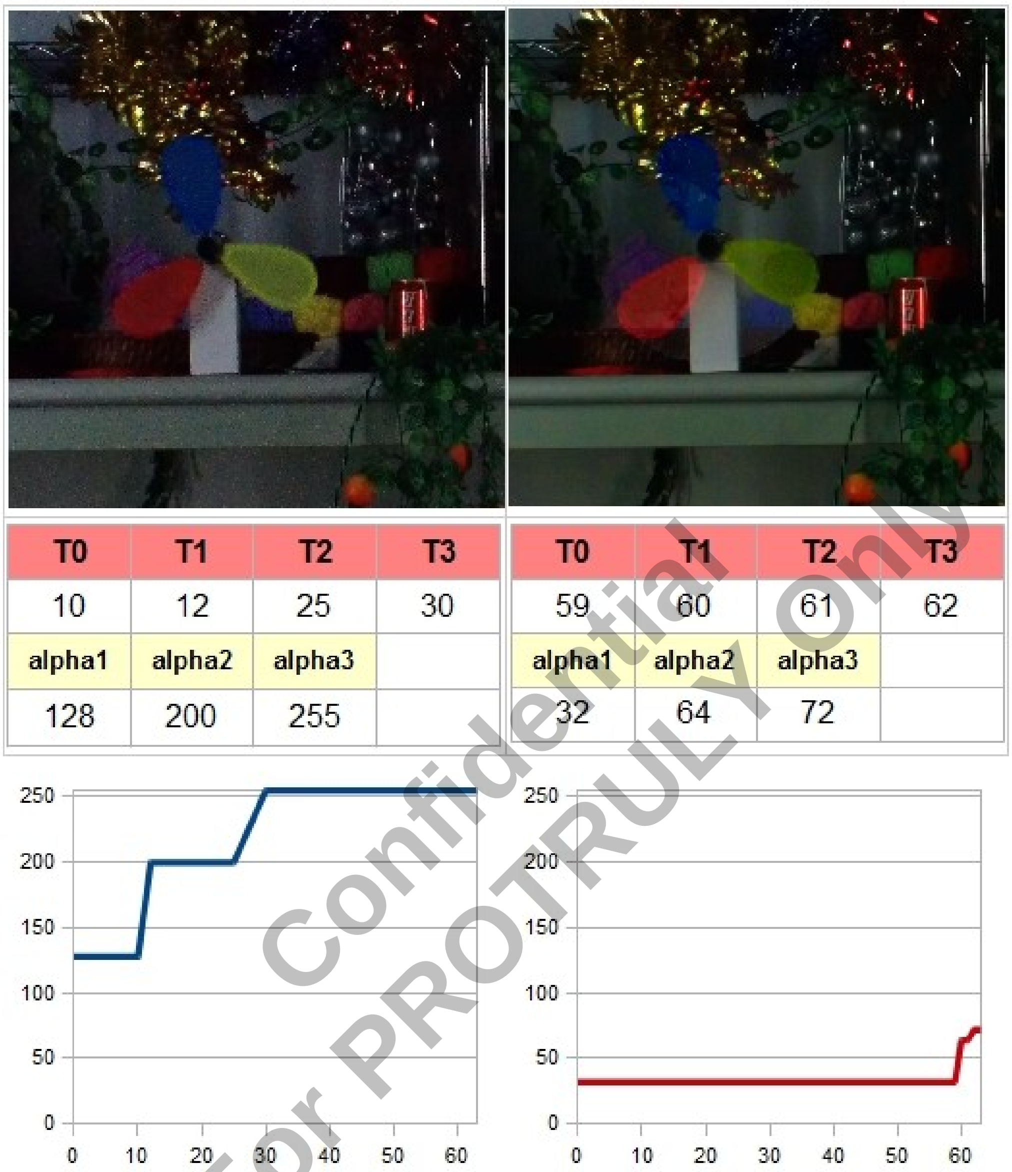
When the value of wide_edge_detect is large, there may be an increase in the blurring of closely spacial lines or a reduction in fine-detail.

3.11. Case Study and Examples: Video MCTF

Motion-compensated temporal filtering (MCTF). 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, alpha1-alpha3. Typically the curve is non-decreasing, so that the weight only increases as temporal differences increase. In Step 2, a preliminary filtered sample is computed as preliminary = ((256-W) * previous + W * current)/256. In Step 3, the final filtered sample is computed as the preliminary filtered sample.

3.11.1 Video MCTF: Tuning Example

The case on the right of Figure 32 is that it keeps too much of the previous. Therefore, it shows ghosts in moving parts, but less noise in still parts. Its the opposite in the left of Figure 32.



T0	T1	T2	T3
10	12	25	30
alpha1	alpha2	alpha3	
128	200	255	

T0	T1	T2	T3
59	60	61	62
alpha1	alpha2	alpha3	
32	64	72	

Figure 32: Sample Images at high ISO.

4. Basic Tuning Flow

4.1. Basic Tuning Flow: Preparation

Before starting the IQ tuning, the following steps need to be performed:

- ➢ Target board, either real camera sets or development boards like BuB are usable if A12 is on board.
- ➢ Windows PC
  - ✧ Teraterm (**http://hp.vector.co.jp/authors/VA002416/teraterm.html**) installed
  - ✧ Has USB port
  - ✧ Has Serial port
- ➢ Firmware (Ambarella SDK + Customer APP)
- ➢ Raw image data if it is necessary to see the result from external raw data
- ➢ iTuner configuration file if it is necessary

Raw image data and iTuner configuration file are produced by “Raw Capture” command while tuning flow. If it is required to use external raw data that is captured from another camera, this is also achievable using ituner.
More details are described in *AMBARELLA_SDK6_UG_iTuner_Still* and *AMBARELLA_SDK6_UG_iTuner_Video*.
Furthermore, IQ tuning supports graphic user interface. Amage is a tool that is used for IQ tuning. It has the following requirements:

- Libusb
- Microsoft.Net Framework 4.0
- Ambarella Amage

More details are provided in A*MBARELLA_SDK6_UG_A12_Amage*.

4.2. Basic Tuning Flow: Tuning Flow

After the above preparation steps are accomplished, the following IQ tuning flow is recommended:

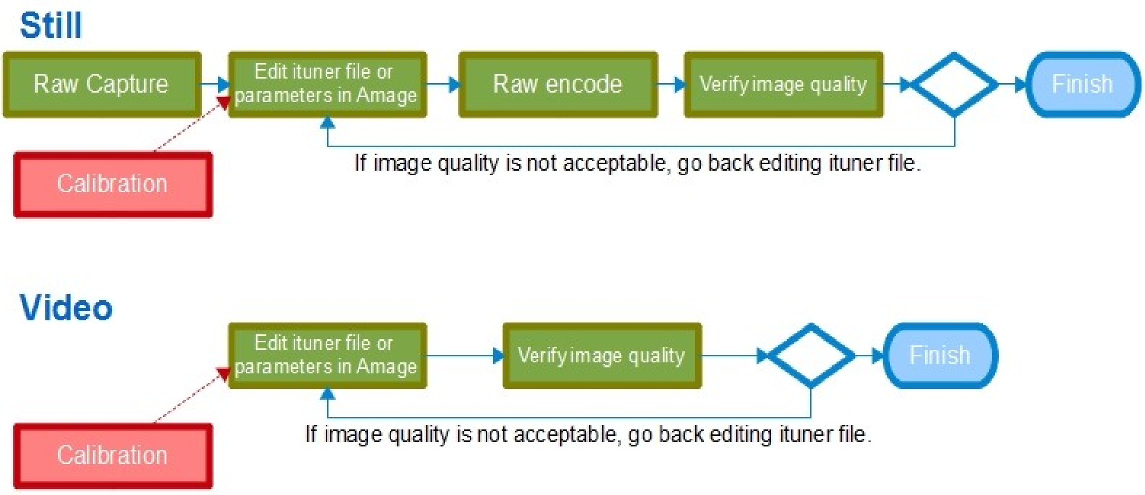

Still
Raw Capture
Edit ituner file or parameters in Amage
Raw encode
Verify image quality
Finish
Calibration
If image quality is not acceptable, go back editing ituner file.
Video
Edit ituner file or parameters in Amage
Verify image quality
Finish
Calibration
If image quality is not acceptable, go back editing ituner file.

Figure 33: IQ Tuning flow.

The above flow shown in Figure 33 is the most basic unit of tuning, and it is likely that this flow is repeated many times along the development phases.

It is important to have calibration data to see the finest image quality expected as a product. iTuner has a flexible functionality to enable/disable to use calibration data and data is easily replaced in it. As development proceeds, calibration process will be more stable and accurate. User can apply the latest calibration data to any raw image captured by the **Raw Capture** command.

More details are provided in *AMBARELLA_SDK6_UG_iTuner_Still* and *AMBARELLA_SDK6_UG_iTuner_Video.*

5. Calibration

There are several calibration processes associated with IQ tuning supported in Ambarella SDK. Note that not every user needs to perform calibration, often, IQ tuning will be spent in the loop around the raw encode of Figure 33.

- Bad pixel calibration – sensor oriented
- Vignette (lens shading) compensation calibration – lens oriented
- Chromatic aberration calibration – lens oriented
- WARP (lens distortion) calibration – lens oriented

Each process produces calibration data to be used. Binary data usable in the ituner raw encode is provided by **Raw Capture** command after the calibration process.

More details on the calibration is provided in *AMBARELLA_SDK6_UG_Calibration*.

6. Reference

The table below shows a list of documents that have more details on IQ tuning. Please refer to them when necessary.

SDK6-UG-003	AMBARELLA_SDK6_UG_iTuner_Still	
SDK6-UG-004	AMBARELLA_SDK6_UG_iTuner_Video	
SDK6-UG-005	AMBARELLA_SDK6_UG_Calibration	
SDK6-UG-008	AMBARELLA_SDK6_UG_A12_Amage	

Table 18: List of IQ Related Documents.