TDA3x ISP and Vision SDK

Agenda

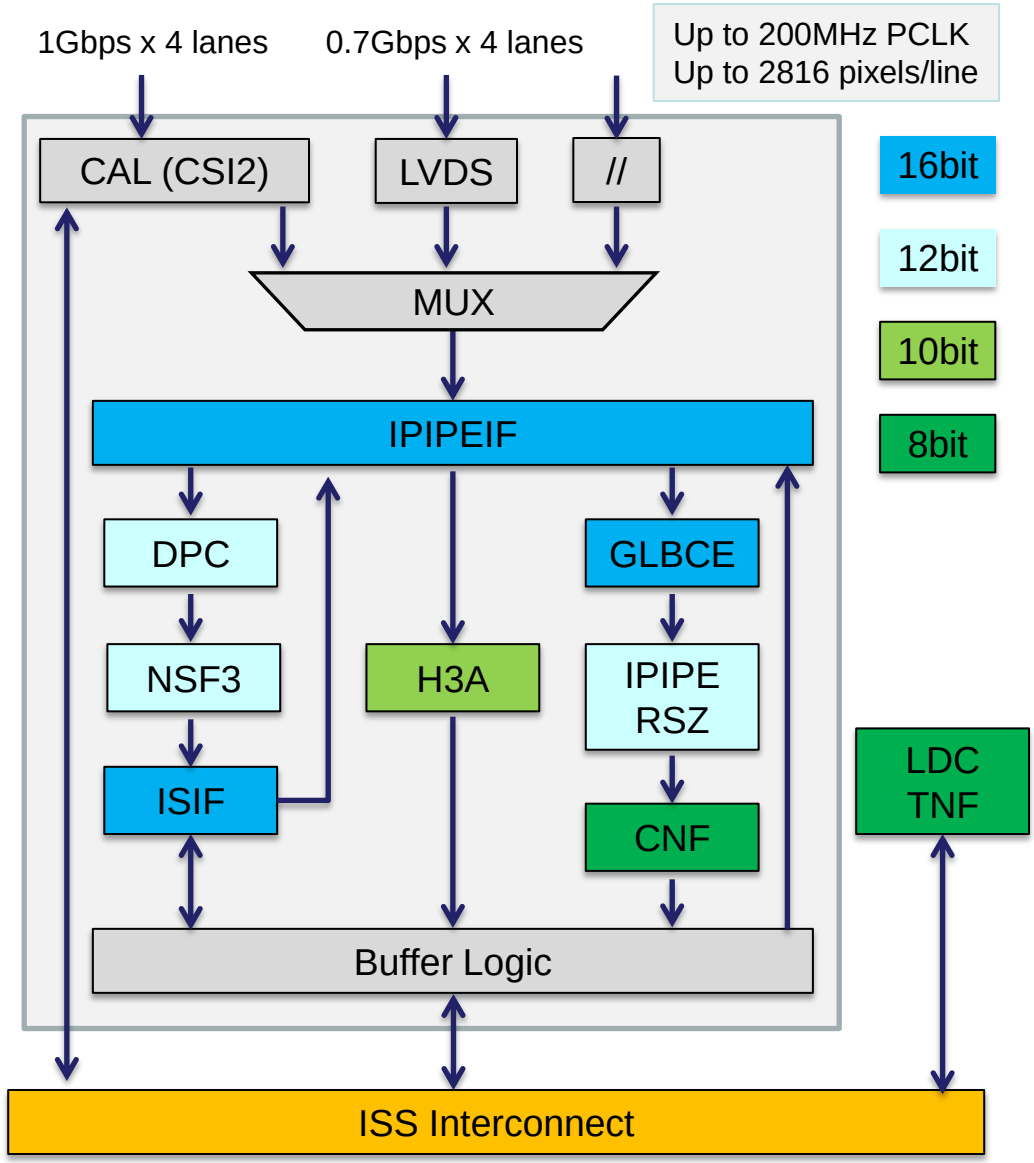
- ISP Overview
- Vision SDK Links
- Usecases in Vision SDK

TDA3x ISP Overview

Focus on top level architecture and data flow as ISP6.5 gets more complex with HDR sensor input and in-pipeline noise filtering and GLBCE

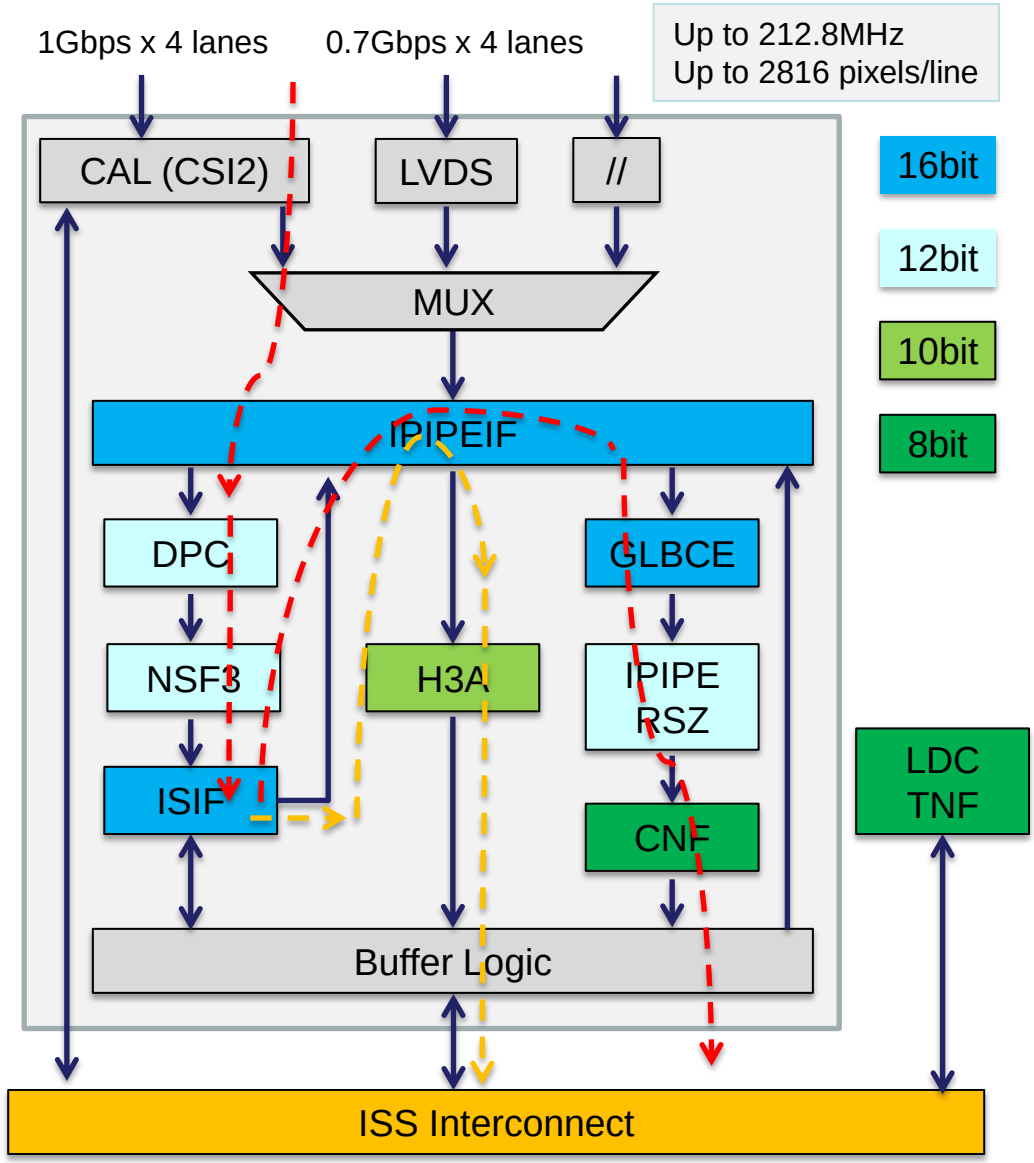
ISP6.5 Top Level Overview (TDA3x)

- ISS: imaging sub-system
- CAL: camera adaptation layer
- IPIPEIF: IPIPE interface
- DPC: defective pixel correction
- NSF3: high ISO noise filter
- ISIF: image sensor interface
- H3A: hardware 3A statistics
- GLBCE: HDR tone mapping
- IPIPE: image processing pipeline
- RSZ: bi-cubic image resizer
- CNF: chroma noise filter
- LDC: lens distortion correction
- TNF: temporal noise filter



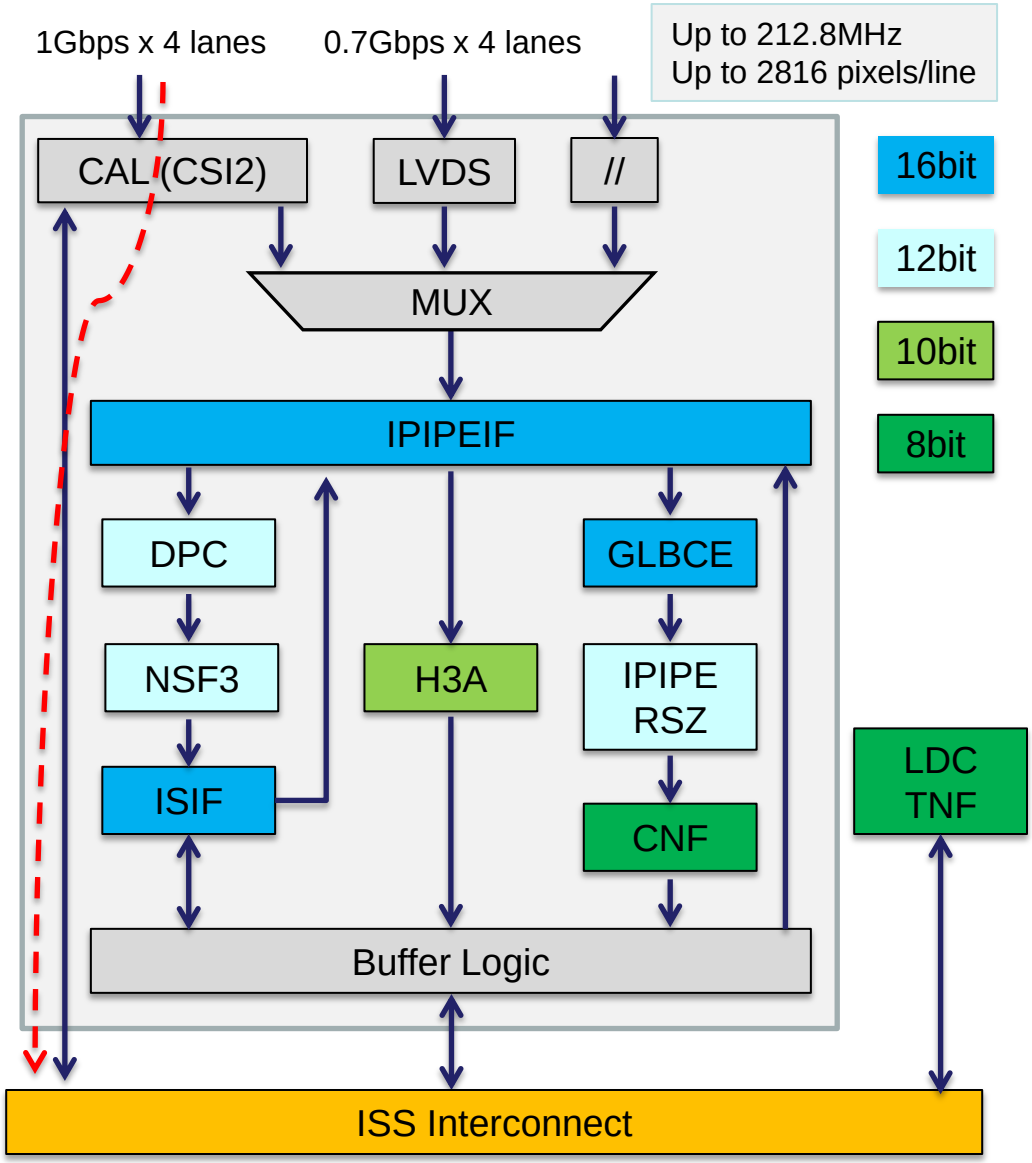
On-The-Fly Data Flow

- On-the-fly
  - Sensor input images go through ISS pipeline without storage in DDR
  - Minimum delay
  - Minimum DDR traffic overhead
  - Up to 212.8M pixels/second
- Main use case
  - 12-bit linear Bayer pattern sensor
- Possible use case (unverified)
  - 16-bit linear Bayer pattern input
  - Companded Bayer pattern input
  - IPIPEIF → GLBCE → DPC/NSF3
    - Decompand in IPIPEIF or GLBCE
  - Inferior image quality
    - Noise is harder to tune
    - H3A is after GLBCE
    - Same WB on long/short frames
  - In general, NOT recommended



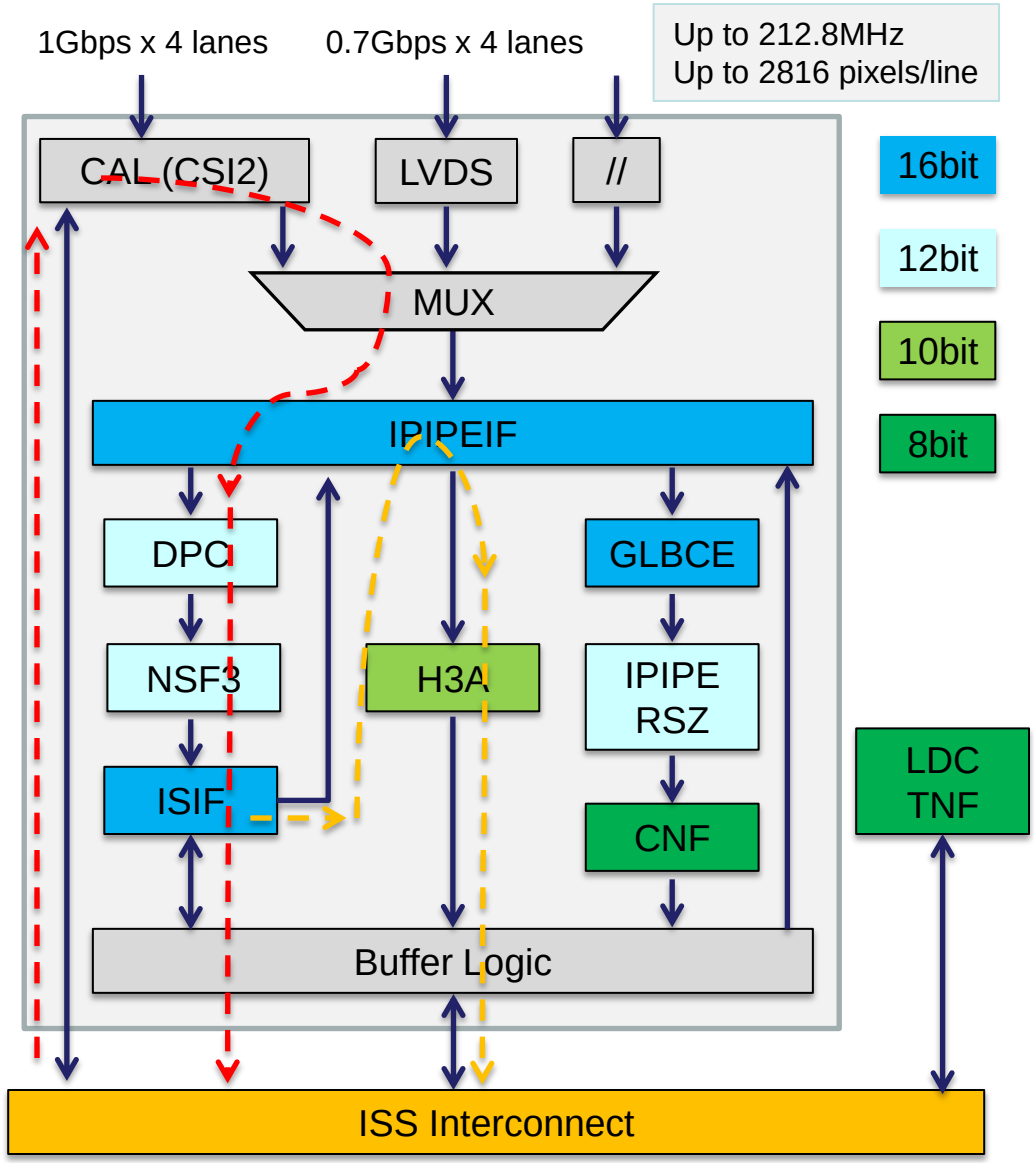
Companded HDR Data Flow: Path A

- Main use cases
  - 16-bit linear HDR Bayer pattern input
  - Companded HDR Bayer pattern input
  - DDR traffic overhead
    - Extra 2 write and 2 read per pixel
  - Up to 106.4M pixels/second
  - 2 frames/slices of latency (3 with LDC)
- Similar use case
  - Dual exposure frames from sensor
    - Frame deinterleaving has been done
    - No decompanding
- Path A
  - Move sensor input to DDR
  - 16-bit linear input
  - Companded 14 or 16 bits (20 linearly)



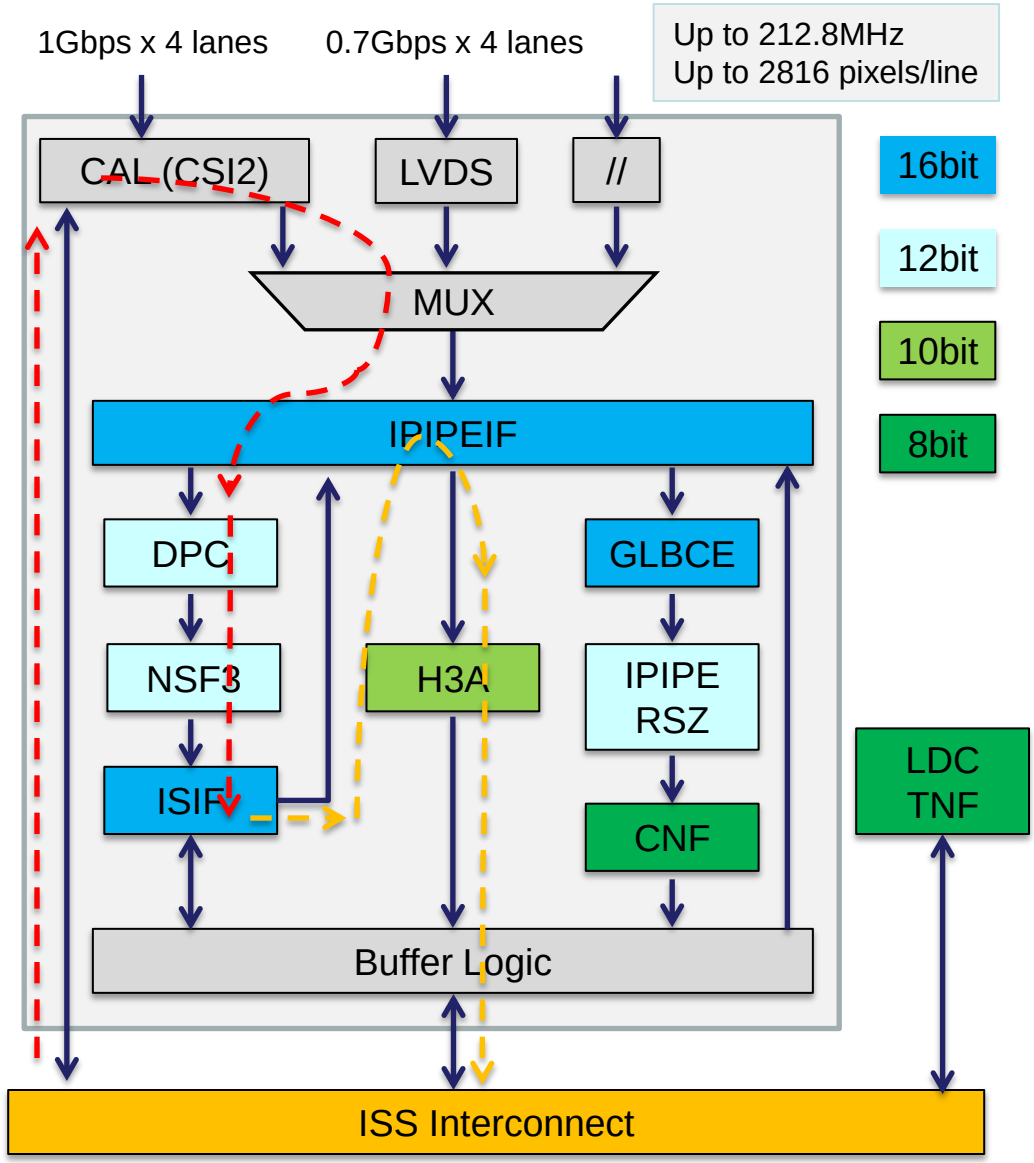
Companded HDR Data Flow: Path B1

- Preprocess short exposure frame
  - Top 12 linear bits
- IPIPEIF
  - Decompand if necessary
  - Saturation to top 12 bits
- DPC
- NSF3
- ISIF
  - Black level
  - LSC
- H3A



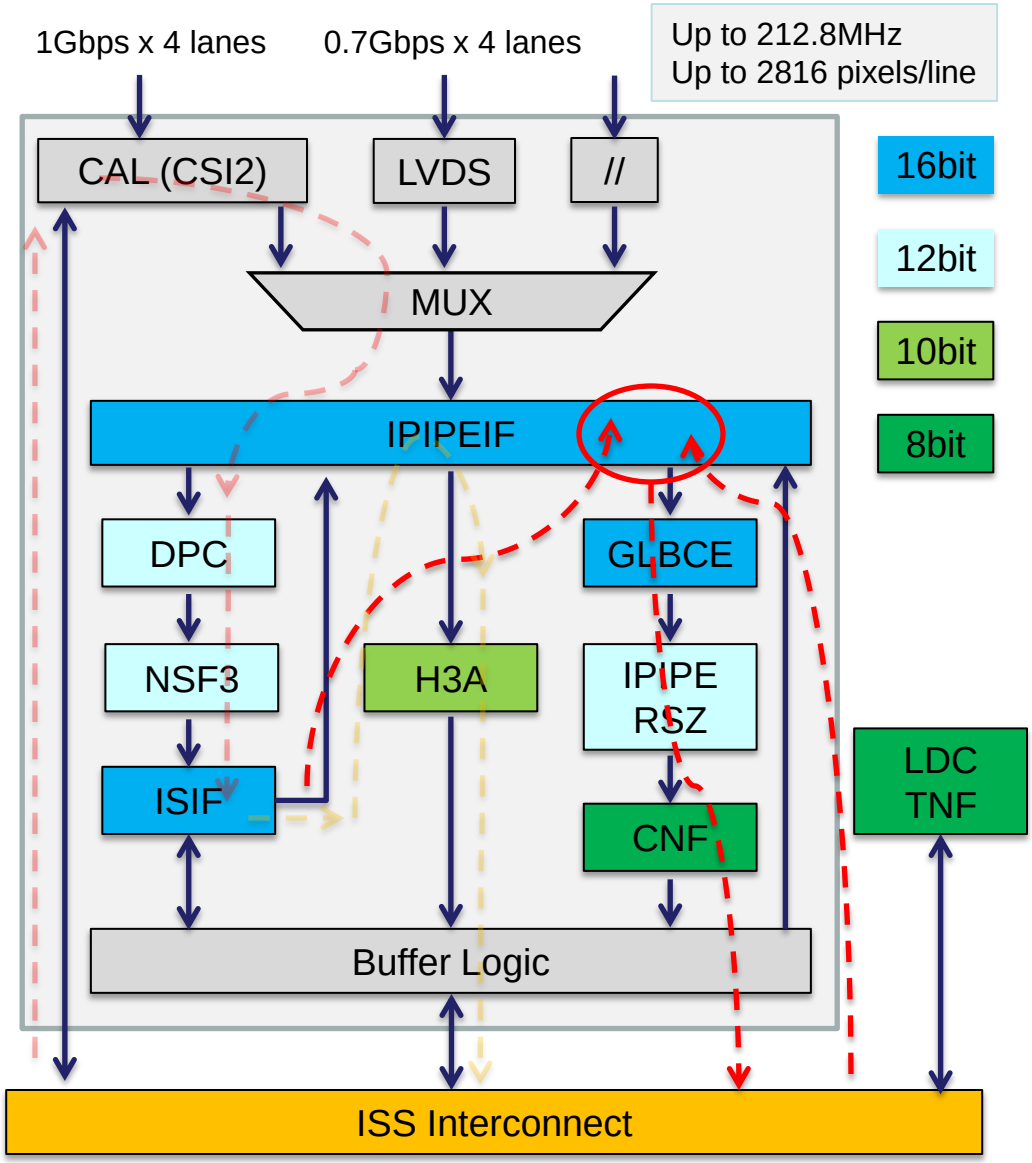
Companded HDR Data Flow: Path B2

- Preprocess long exposure frame
  - Bottom 12 linear bits
- IPIPEIF
  - Decompand if necessary
  - Saturation to bottom 12 bits
- DPC
- NSF3
- ISIF
  - Black level
  - LSC
- H3A

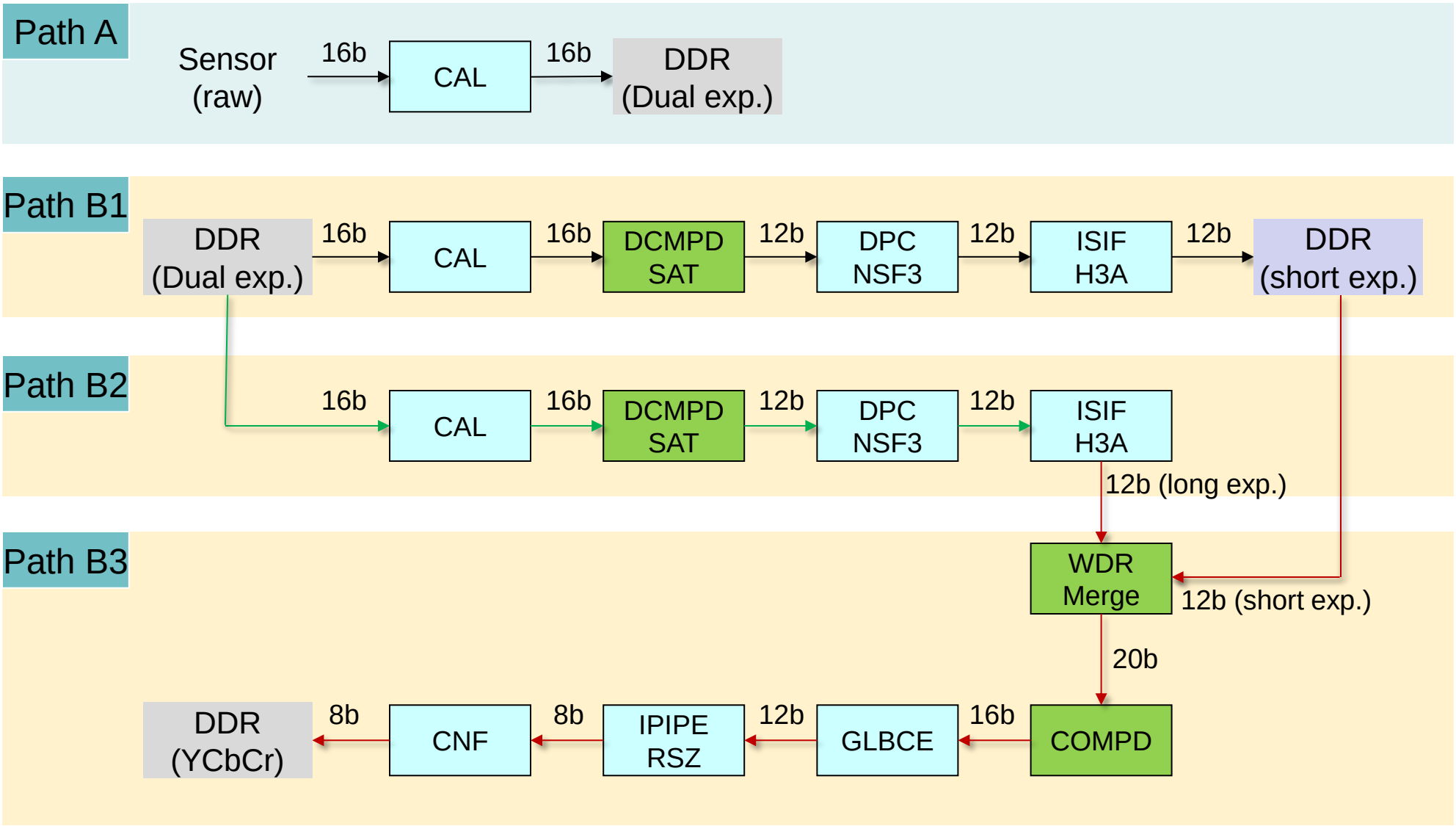


Companded HDR Data Flow: Path B3

- Merge and post process 2 frames
- IPIPEIF
  - 2-frame gain adjustment
  - White balance
  - Merge long and short frames
  - 20-bit to 16-bit compression
- GLBCE
  - 16-bit to 12-bit HDR tone mapping
- IPIPE/RSZ/CNF
  - Raw conversion (Bayer to YCbCr)



Companded HDR Data Flow: Summary



Sensor Interface

- Camera PHY (2 modes)
  - MIPI D-PHY with 4 lanes: 1.0 Gbps/lane
- Camera Adaptation Layer (CAL)
  - Protocol stack for MIPI CSI2
  - Supports all MIPI supported formats
    - RAW/DPCM/YUV
    - RAW 8, 10, 12, 14, 16 bits (companded or linear)
    - Concurrent read of pixel stream from SDRAM
  - Supports 16b parallel interface
  - Real-time priority on I/F port traffic
  - Detection and correction of 1 Bit ECC errors
  - Detection of > 1b ECC errors
  - CRC on long packets
- Dedicated instances to interface with sensor & read from memory

Image Pipe Interface (IPIPEIF)

- Data and synchronization interface of ISP
- Decompand (CMPD), Saturation (SAT), and Compand (CMPD)
- DFS: Dark Frame Subtraction (fixed pattern noise)
- WDR: gain adjustment, WB, and 2-frame merge

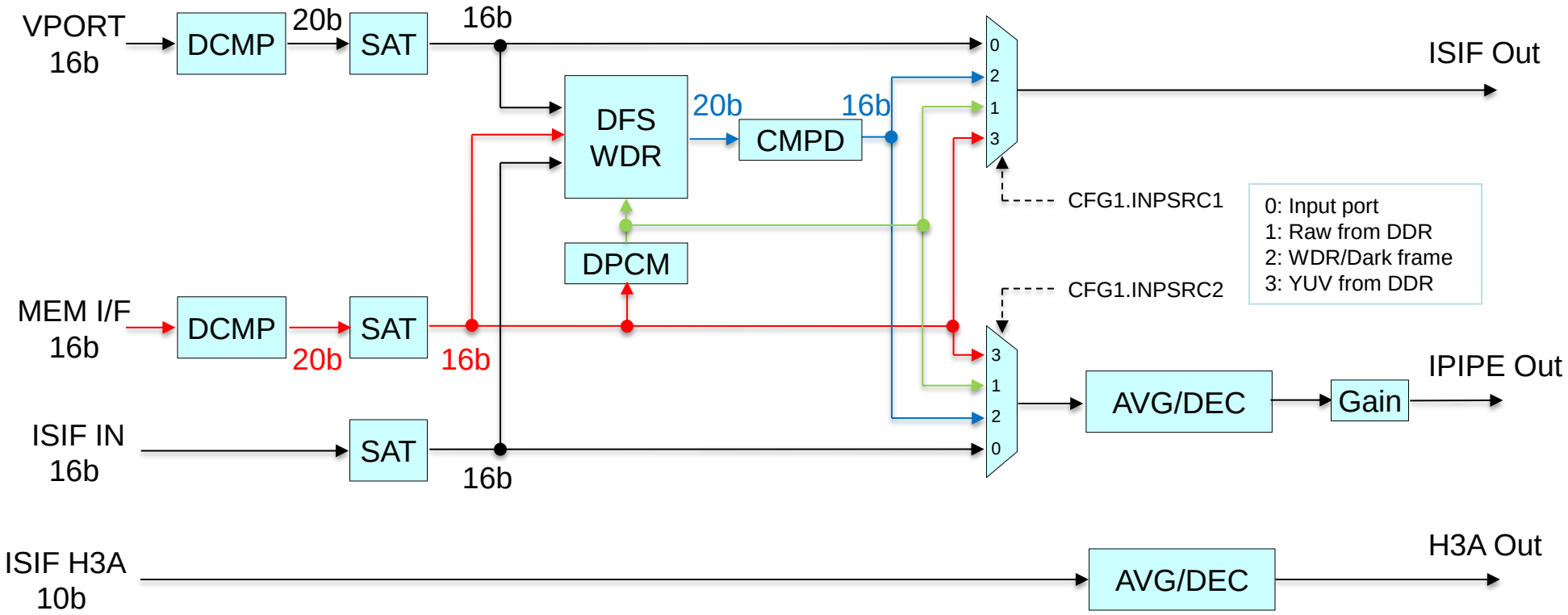
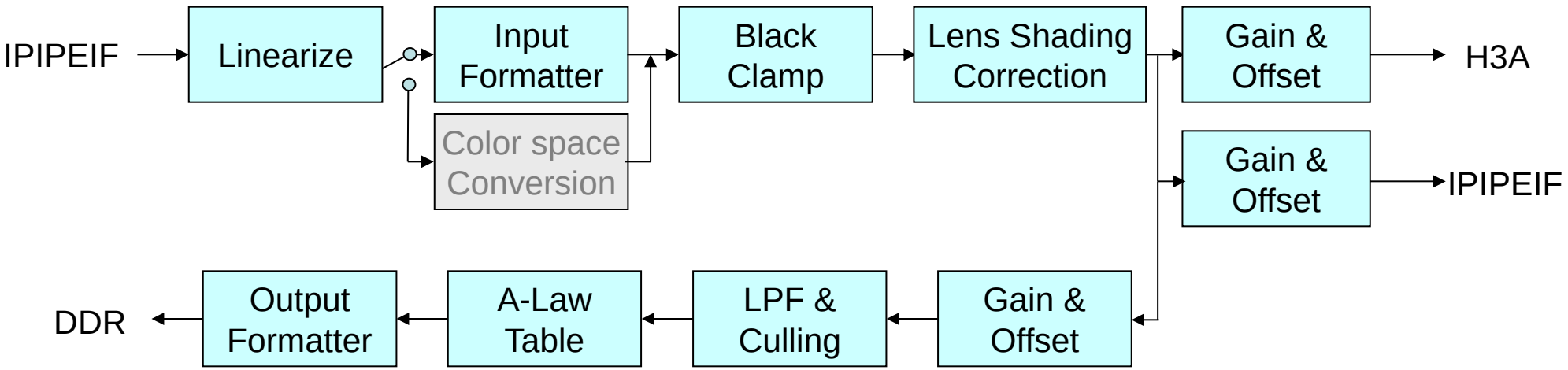


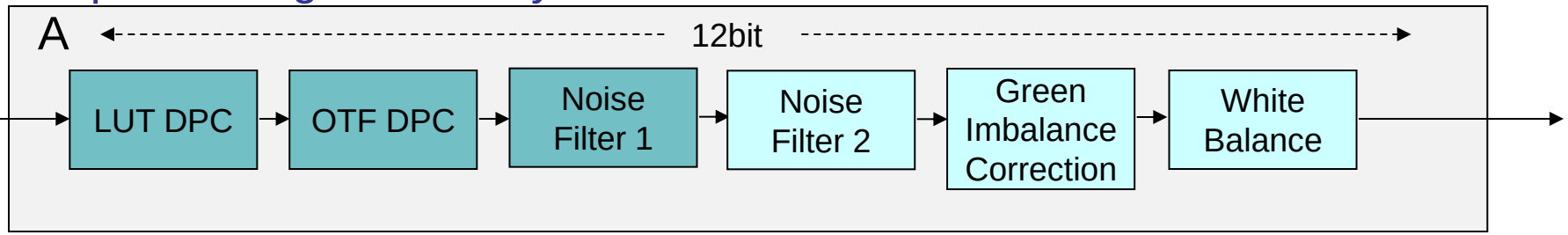
Image Sensor Interface (ISIF)

- Sensor raw input → linear Bayer pattern format (supported by IPIPE)
  - Sensor linearization
  - Sensor pixel format conversion (non-Bayer → Bayer)
    - Max input image width: 4736 pixels (DM36x), 5376 pixels (DM38x/812x), or 2816 (TDA3x)
  - Adaptive black clamp (black level)
  - 2D Lens Shading Correction (LSC)
  - Digital gain control

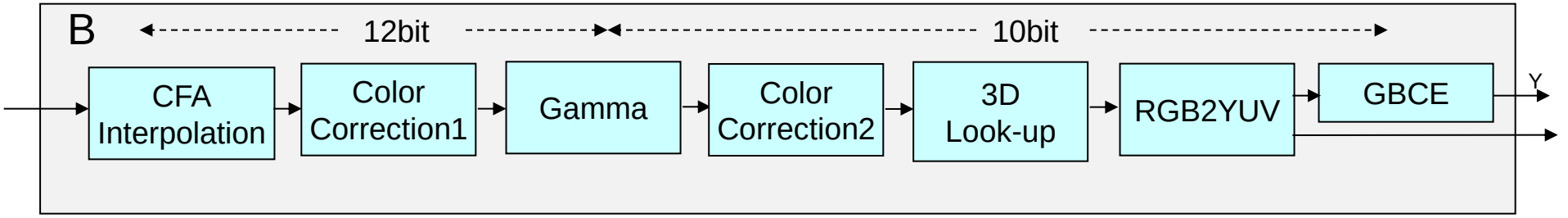


IPIPE: Pipeline Stages

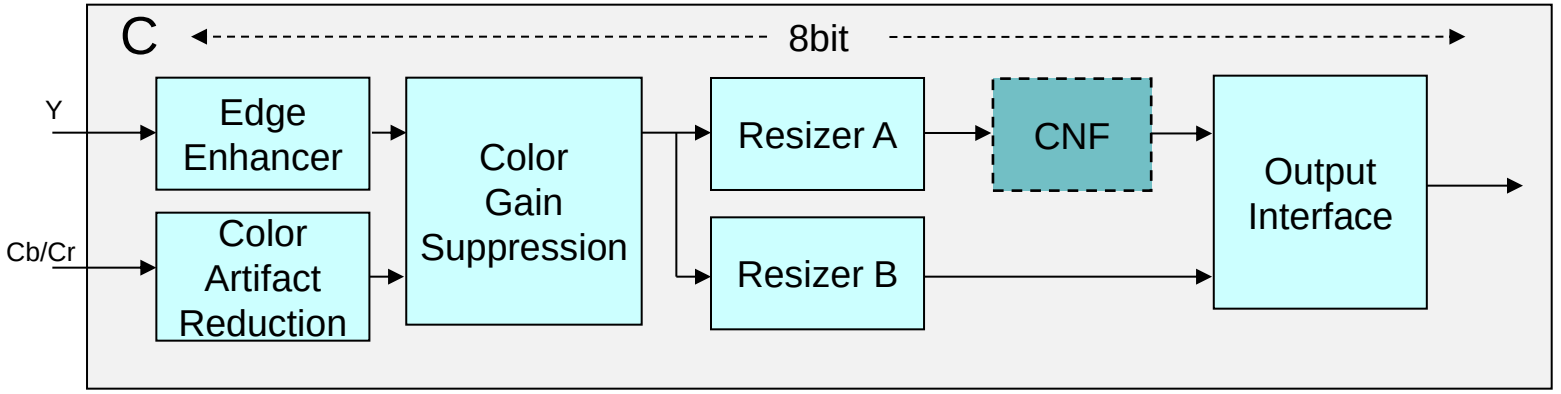
- Raw processing: 12-bit Bayer



- Color processing: 12-bit Bayer → 12-bit RGB → 10-bit RGB → YCbCb

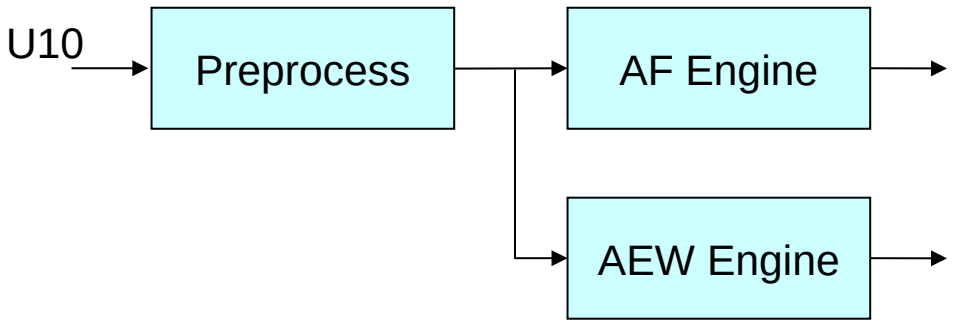


- YCbCr processing: 8-bit YCbCr



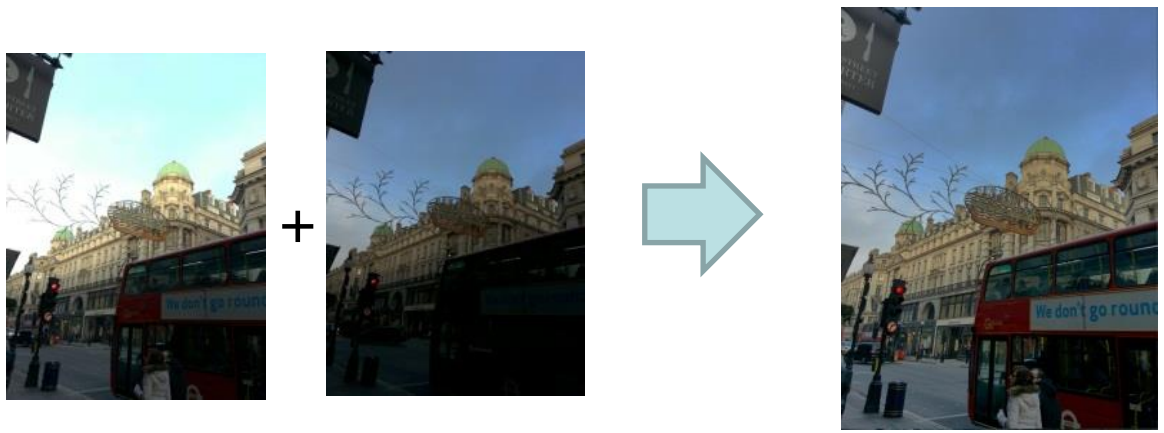
H3A

- Preprocessing (optional)
  - ISIF (10-bit) → horizontal median filter → A-law compression
- AF engine: Horizontal AF and Vertical AF
  - FV filters: two 10-tap IIRs (HAF) and two 5-tap FIRs (VAF)
  - Accumulate FV and FV^2 (every pixel or row peaks) for R/G/B pixels per paxel
    - VAF off: HFV for R/G/B (up to 36H x 128V paxels)
    - VAF on: HFV, HFV^2, VFV, VFV^2 for G only (up to 12H x 12V paxels)
- AEW engine
  - Window partitioning and down-sampling
  - Saturation check
  - Accumulate SUM, SQ_SUM, or collect Min/Max per window



WDR (GLBCE): Adaptive Local Tone Mapping

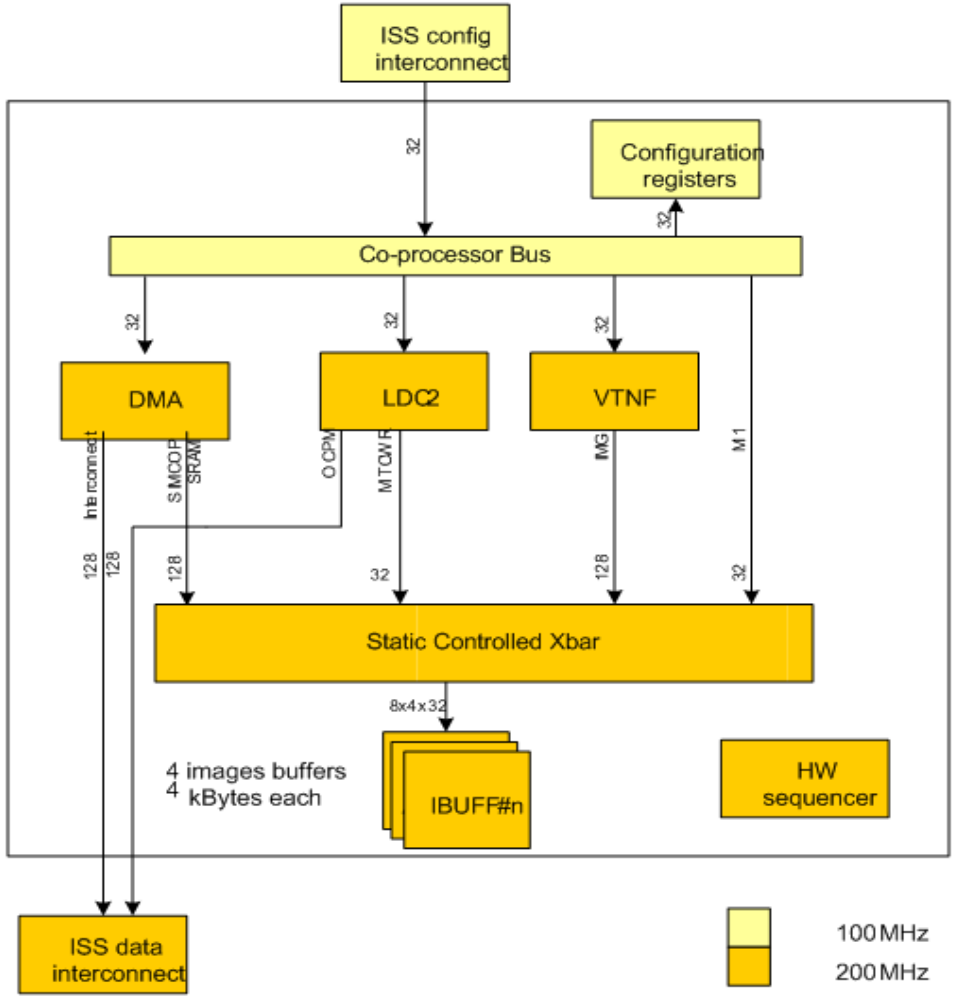
- State-of-the-art locally adaptive brightness and contrast enhancement
- Natural feeling images
  - Brighter shadows
  - No clipping of highlights
  - Improved local contrast
- Supports HDR and LDR sensors (WDR input port is only 16-bit wide)
  - Use a global curve to convert 20-bit input to 16-bit first (e.g., square root)
  - Shift 12-bit LDR input into the 12 MSBs of the 16-bit input port



Resizer

- Two simultaneous output images
- Down-scaler: 1/2x, 1/4x, ~ 1/128x
- Normal-scaler: 1/16x ~ 16x
- Interpolation: 1/256 pixel resolution
  - 4-tap cubic interpolation
  - 3-tap linear filtering + linear interpolation
- Y and UV clipping
- Supported color formats
  - UYVY422 → UYVY422
  - UYVY422 → 420SP (NV12)
  - 420SP →420SP (Y first, then C)
- Output Interface
  - RGB converter, Image flipping (H/V)

SIMCOP Block Diagram



Mesh LDC Features

- Autonomous memory-to-memory operation
  - Tile based processing
- Lens distortion correction (YCbCr input)
  - Support 8-bit YCbCr 422 (UYVY) and 420 (NV12/NV21) formats
  - Up to 8192x8192 image size
  - 2D perspective transform for image warping
  - Mesh LUT based distortion correction (i.e., arbitrary geometric transforms)
  - Pixel interpolation (1/8 pixel precision)
    - Bi-cubic Y and bi-linear Cb/Cr: 2 cycles/pixel
    - Bi-linear Y and bi-linear Cb/Cr: 1 cycle/pixel

Image Quality Tuning Overview

Image Quality Factors

- Tone reproduction: light / dark (lightness perception)
  - Contrast, dynamic range, and ISP tonal adjustment
  - Tuning: GLBCE, IPIPE Gamma, GBCE
- Color reproduction: vivid / dull (color perception)
  - Lighting, lens/IR-cut-filter/sensor (CA, CRA), display characteristics
  - Tuning: ISIF black level, IPIPE AWB, RGB2RGB, 3DLUT
- Sharpness: sharp / blurred
  - Lens MTF, anti-aliasing low pass filter
  - Tuning: IPIPE EE; NSF2 EE,
- Noise
  - Shot noise (photo current and dark current), readout noise, FPN, bad/hot pixels
  - Tuning: IPIPE DPC, CNF, NSF3, TNF, IPIPEIF dark frame subtraction
- Lens related
  - Barrel/pin-cushion/fisheye distortion, shading (vignetting), lateral chromatic aberration
  - Tuning: LDC, LSC
- Image/video compression
  - Loss of details, coding artifacts

Color Reproduction

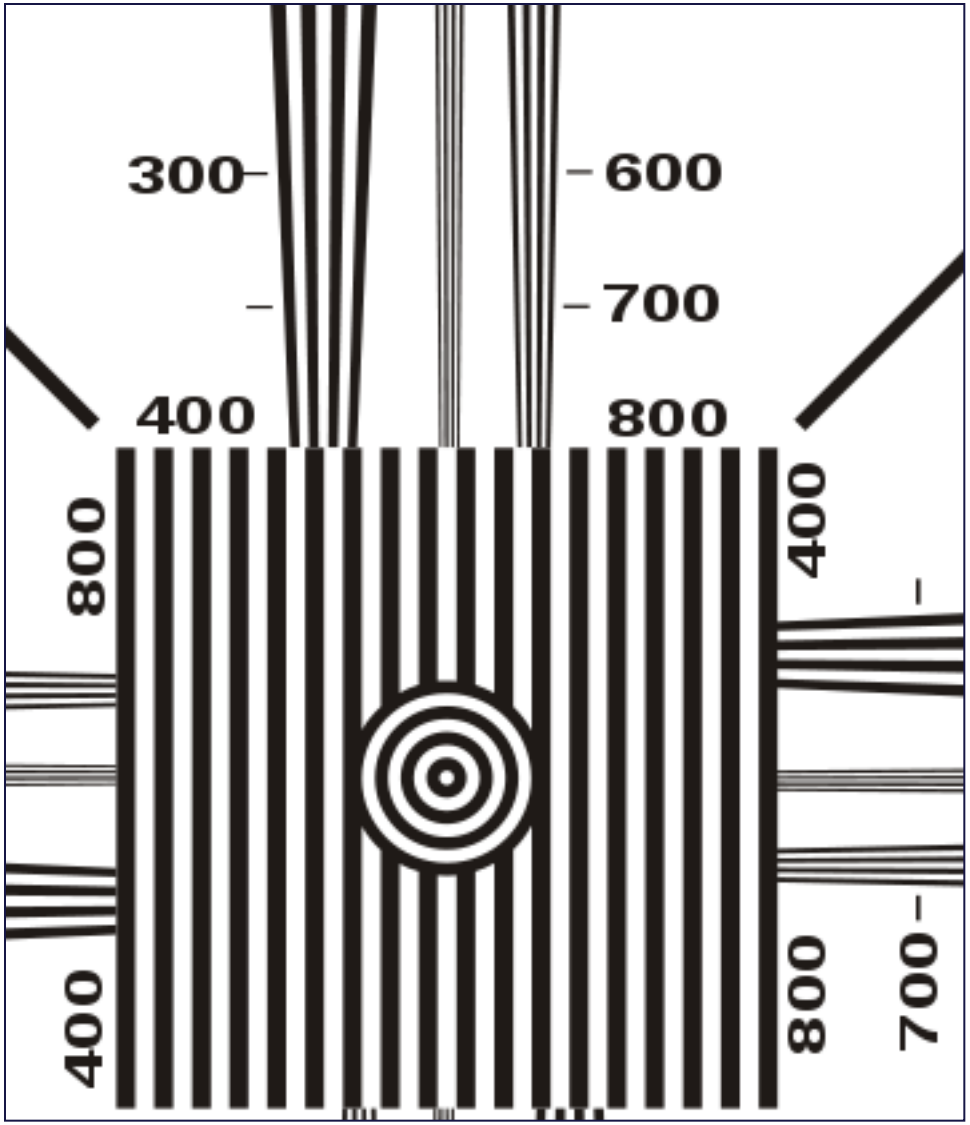
Sensor color

Reference color

Color before tuning

Color after tuning

Sharpness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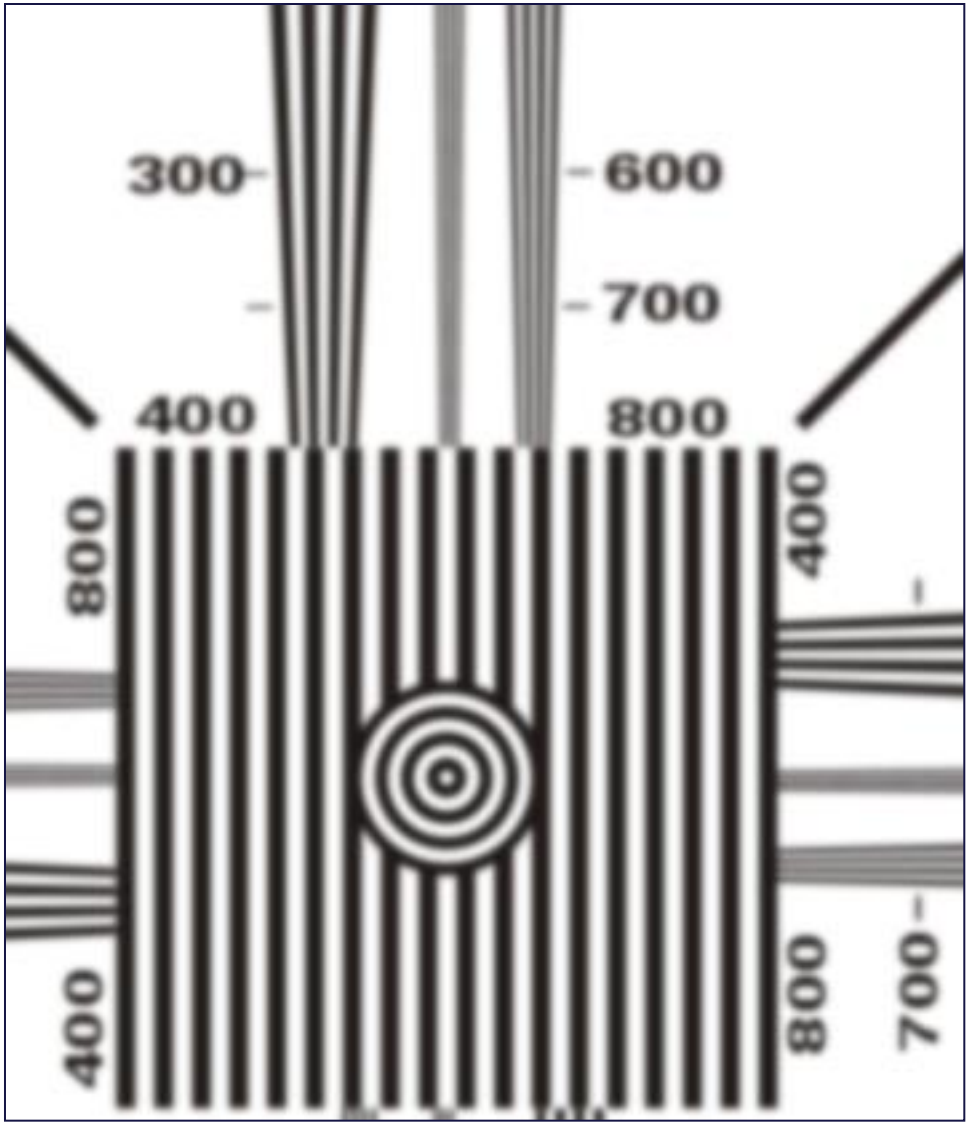
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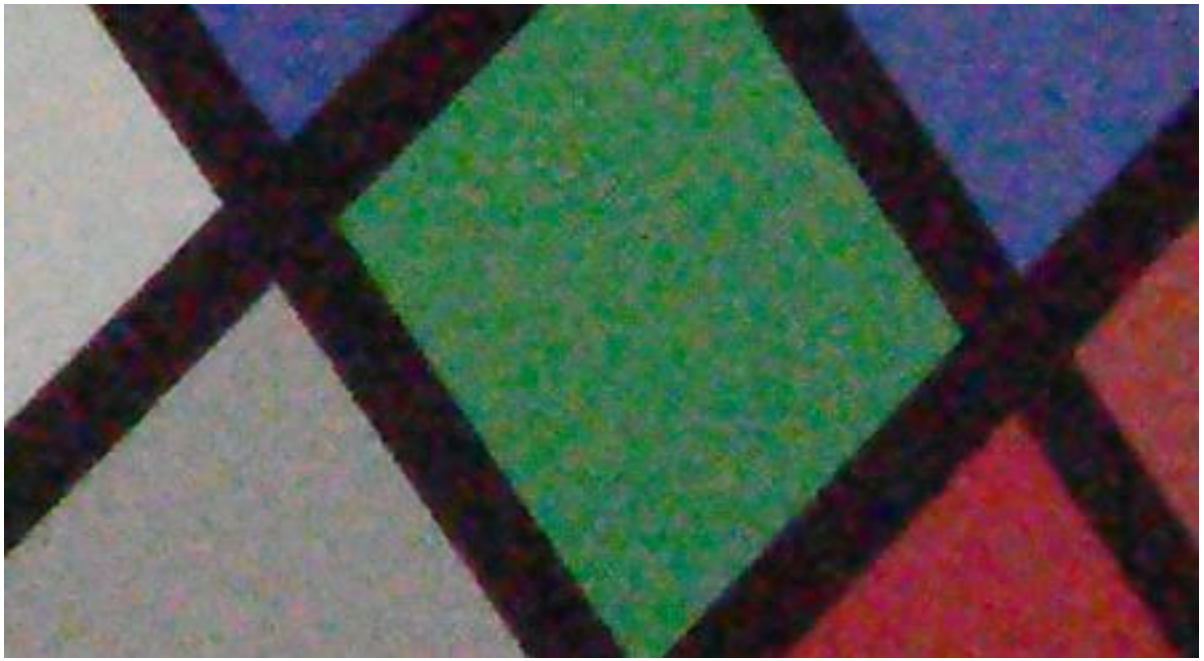
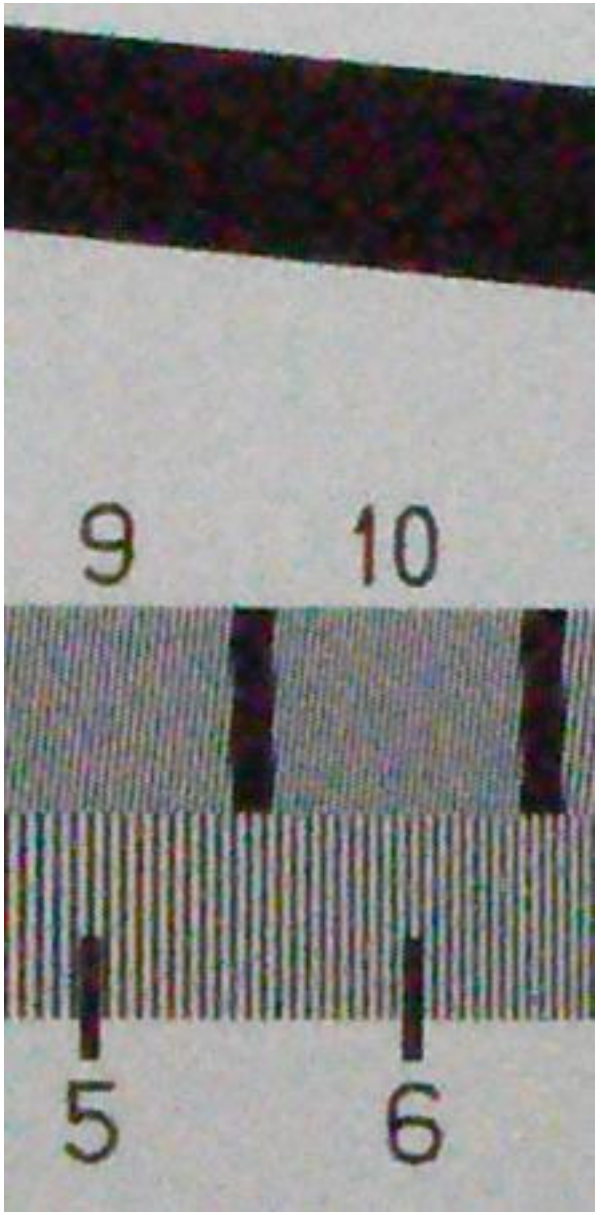
Noise





Dynamic Range & Tone Reproduction

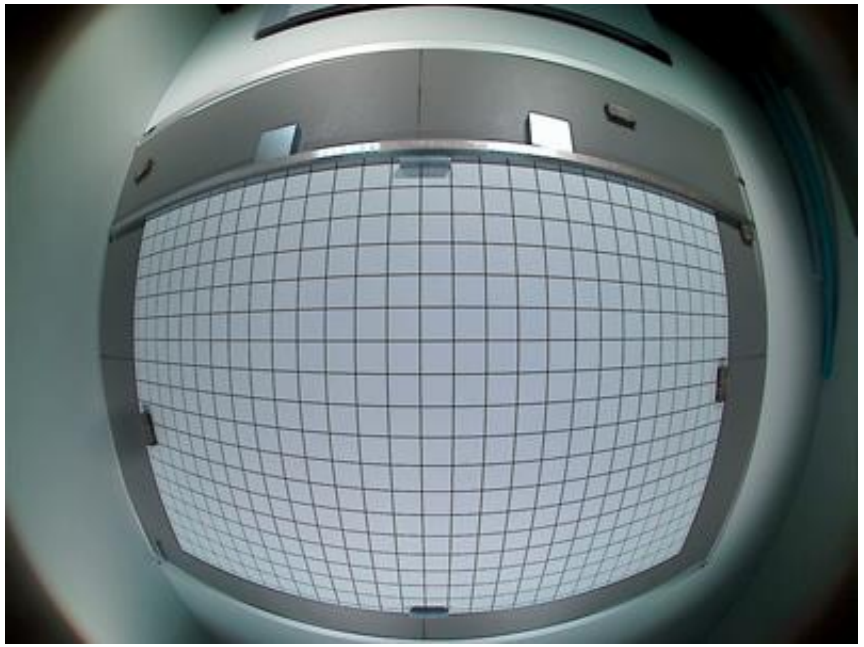
- Global and local brightness and contrast enhancement

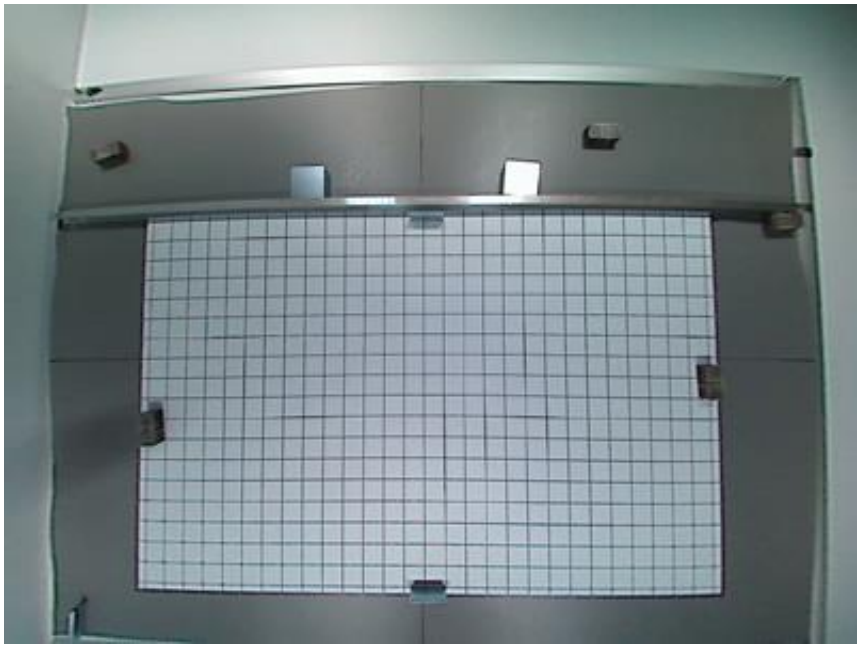
Low dynamic range

High dynamic range

Lens Distortion and Shading

- Barrel/pin-cushion distortion
  - Radial distortion model
- Lens shading (dark corners)
  - Natural (light falloff)
  - Mechanical

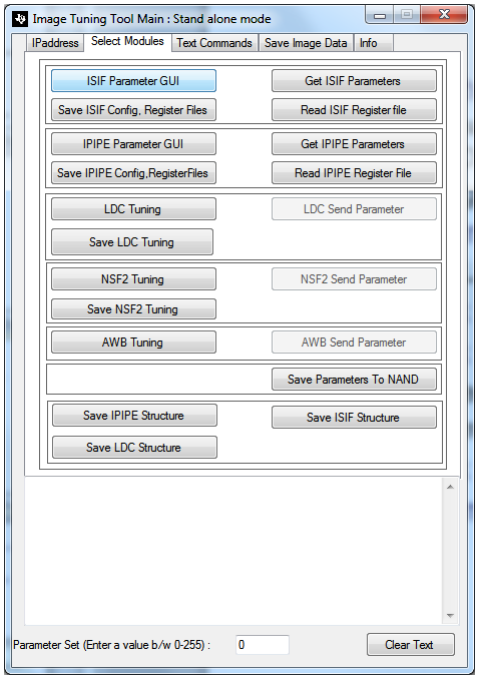


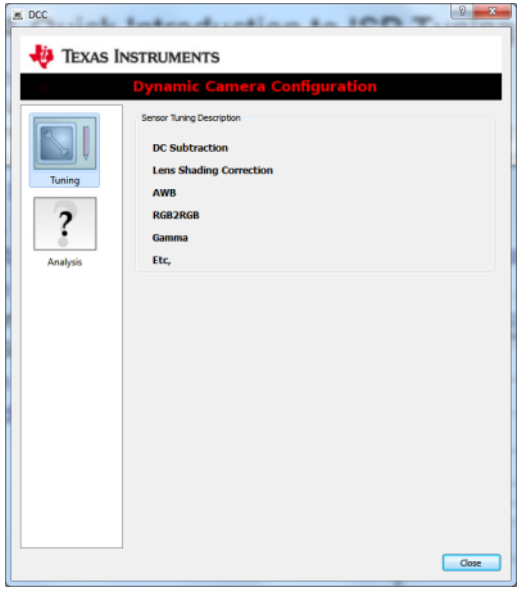


Introduction to ISP Tuning Tool

A Quick Introduction to ISP Tuning Tool

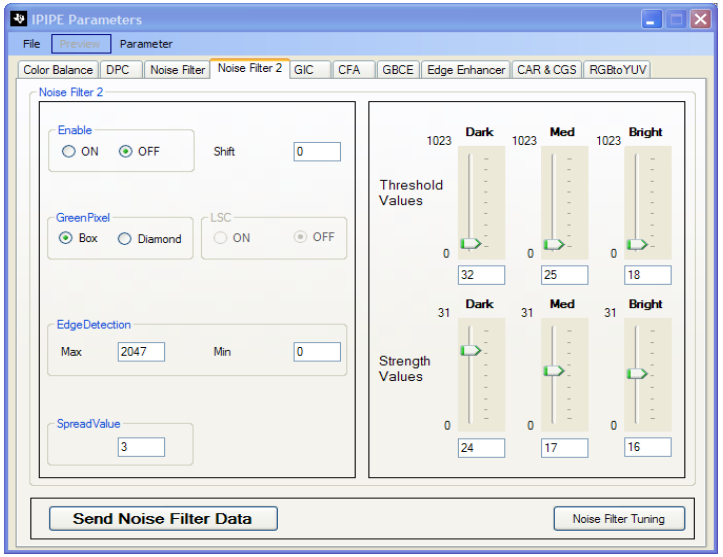
- Tuning tools are PC software
  - ITT (Image Tuning Tool) for DM365 ISP (built on .net framework)
  - DCC (Dynamic Camera Configuration) for DM8127/385 ISP (built on Qt framework)
- Tuning for specific sensor, lens, aperture, zoom, lighting condition, noise, …
  - Support most ISP modules: ISIF (LSC), IPIPE, LDC, NSF2, TI-AWB
- Can work in standalone mode with captured RAW/YUV data files
- Can work with TI-IPNC H/W through Ethernet
  - Require a S/W tuning server running on IPNC
  - Can read and write ISP parameters in real-time
  - Can work with any sensor (need sensor driver)
  - Can command IPNC to capture RAW/YUV data



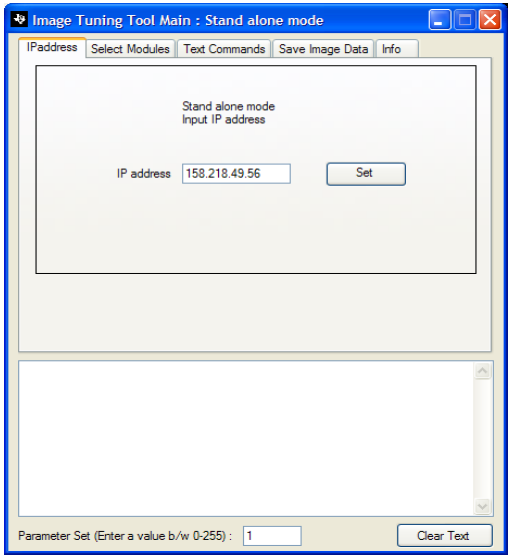


Screenshots

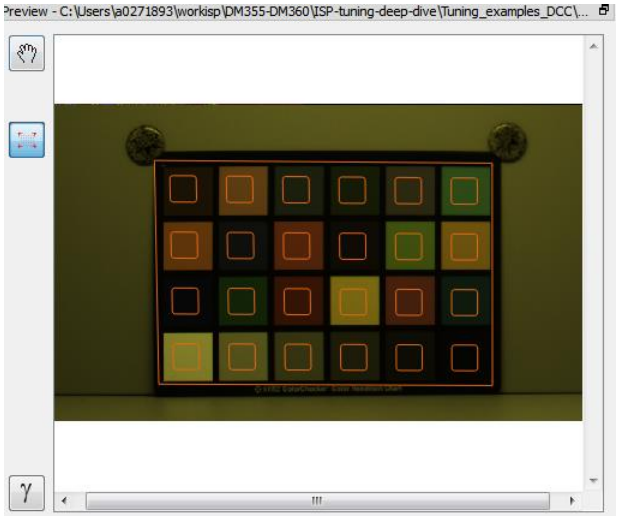
Semi-automatic tuning

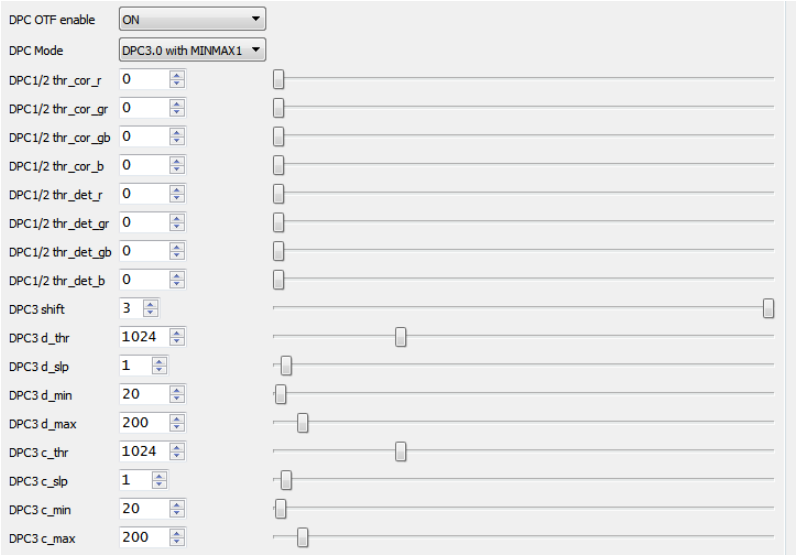


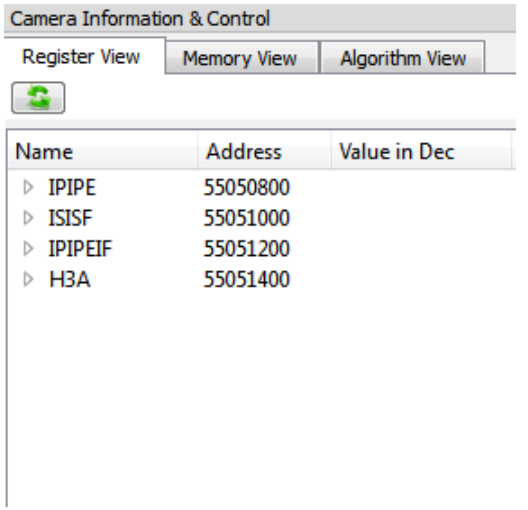
GUI-based tuning



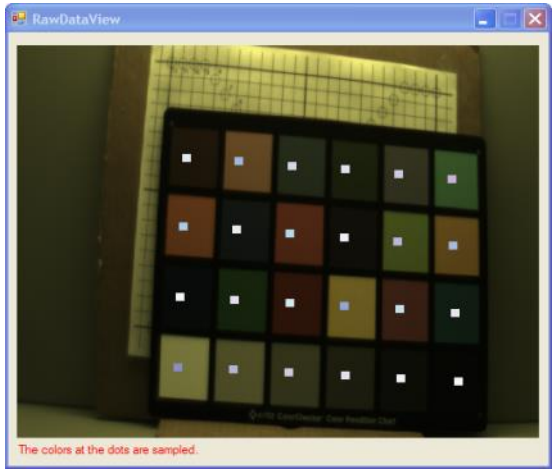
Hardware connection



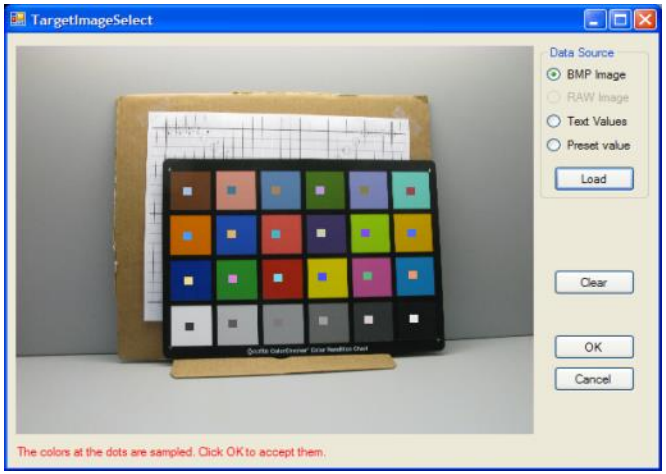




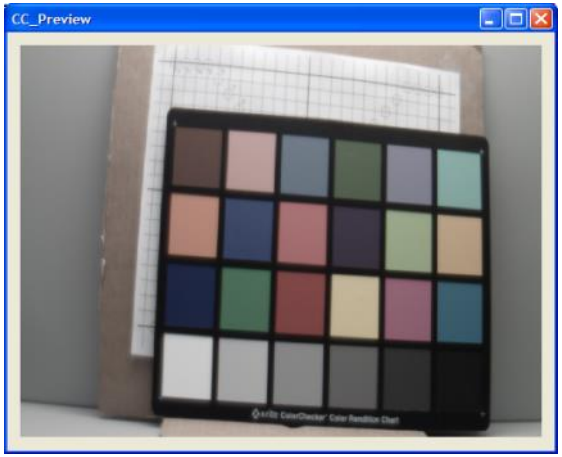
IPIPE White Balance and Color Correction



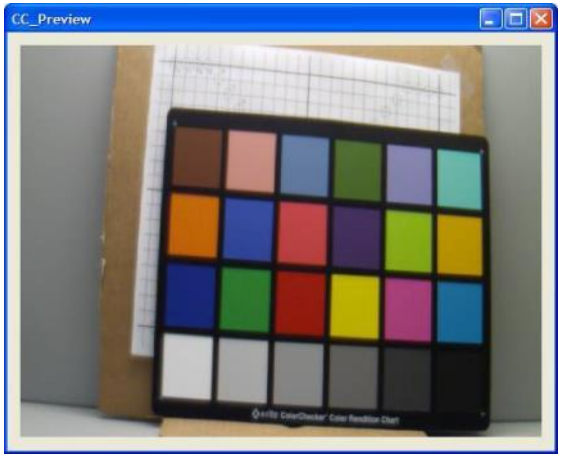
Sample RAW data



Sample reference

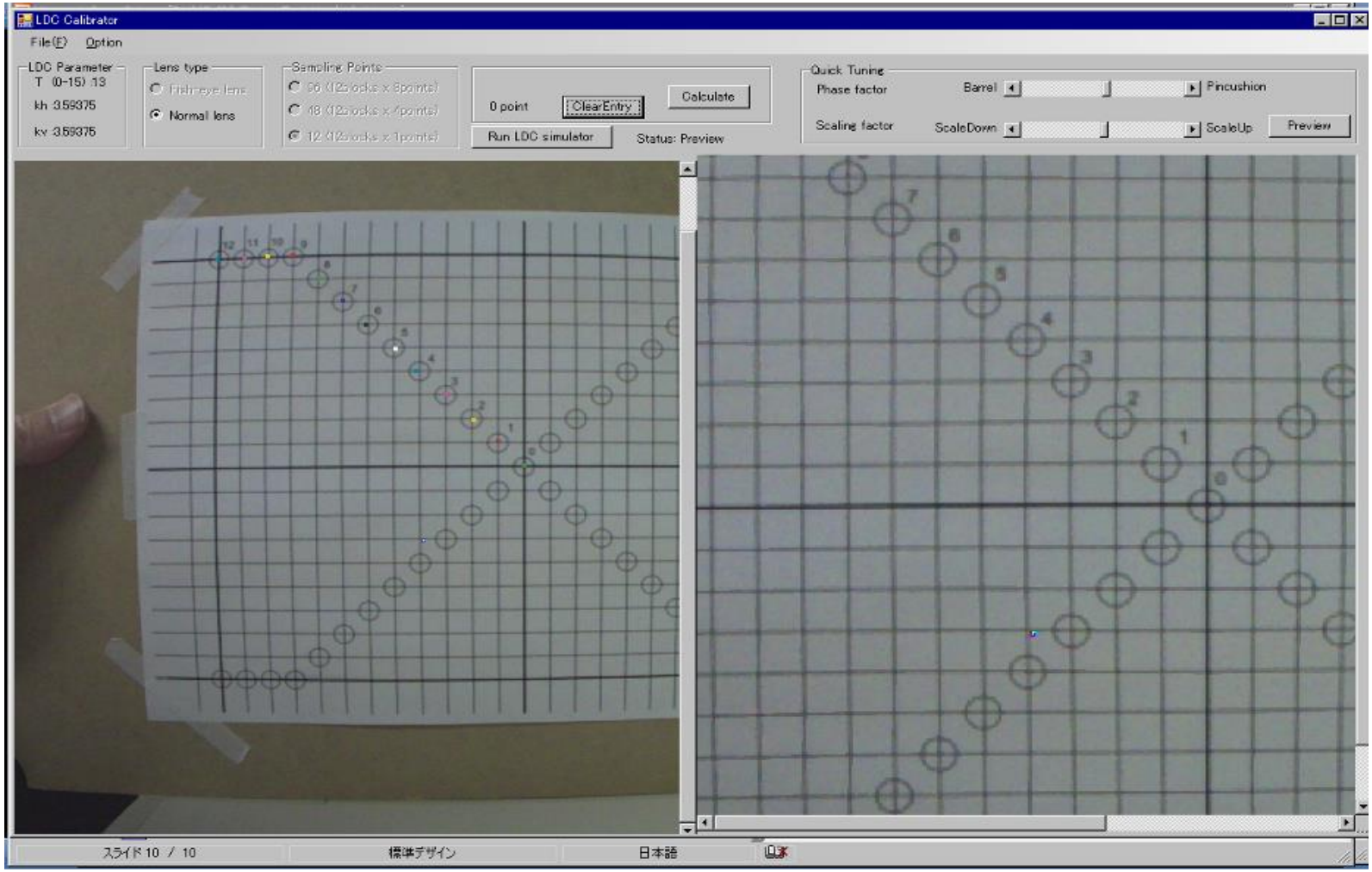


Before tuning



After tuning

Lens Distortion Correction



Vision SDK Links

Capture

- Capture multiple channels from CSI2 interface
  - Supports all standard CSI2 data formats
  - Multichannel support via virtual channel
- Capture single channel from parallel port
  - 16b interface in discrete sync mode
- Lane Position & Polarity configurable
- Ability to detect 1 bit ECC errors (which was corrected)
- Ability to detect / notify on un-correctable ECC errors
- Ability to detect CRC errors
- Following are some of the key features supported
  - Crop
  - Ability to save/dump frame

ISP

- Supports following modes of processing
  - Linear 12b
  - 1 Pass WDR
  - 2 Pass WDR
  - 2 Pass WDR with line interleaved
  - 12b Mono chrome
- Supports multiple channels
- Supports BAYER input format and outputs YUV420 SP or YUV422
- 2 Independent output resolutions, for an input
- H3A statistics output
- Ability to configure complete ISP parameters
- Ability to configure AEWB parameters

- Ability to dump frames at different stages with in ISP
- As a simple resizer, takes in YUV420/YUV422, resizes and outputs YUV420/YUV422

SIMCOP

- Supports following modes of processing
  - LDC Only
  - VTNF Only
  - LDC & VTNF mode
- Supports YUV420 SP/YUV422 input format and outputs YUV420 SP or YUV422
- Supports multiple channels
- Per Channel Configuration of LDC & VTNF
- Ability to dump processed frames
- Ability to pad output frames

Use cases

- Single channel capture, ISP, SIMCOP, AEWB and Display
- 4 channel 2D SRV
  - 4 channel capture (CSI2), ISP, SIMCOP, AEWB, Geometric Alignment, Photometric Alignment, synthesis and Display
- 4 channel 3D SRV
  - 4 channel capture (CSI2), ISP, DeWarp, AEWB, synthesis and Display
- Supported Sensors
  - AR0140, OV10640, IMX224 for single channel usecase
  - TIDA00262 with UB960, IMI (OV10640) with UB960 for SRV usecase

Thank You

TDA3x & TDA2x 3D SRV
https://www.youtube.com/watch?v=WrqmGBVykxk
TDA3x EUNCAP 2018 Front Camera
https://www.youtube.com/watch?v=lBXmCEYdqio&list=PLISmVLHAZbTSKSkrJfOTZ3RnlccL9RH4o&index=48
TDA3x CMS Solution
https://www.youtube.com/watch?v=gJmuqWMOlGo&list=PLISmVLHAZbTSKSkrJfOTZ3RnlccL9RH4o&index=55