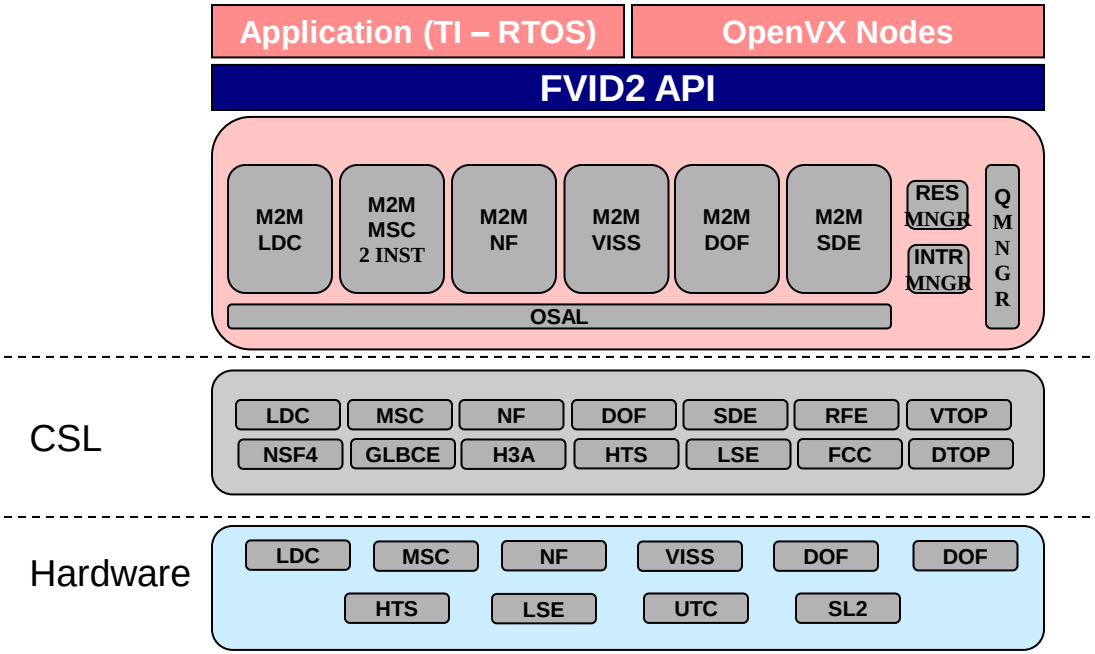
VHWA (Vision Hardware Accelerator)

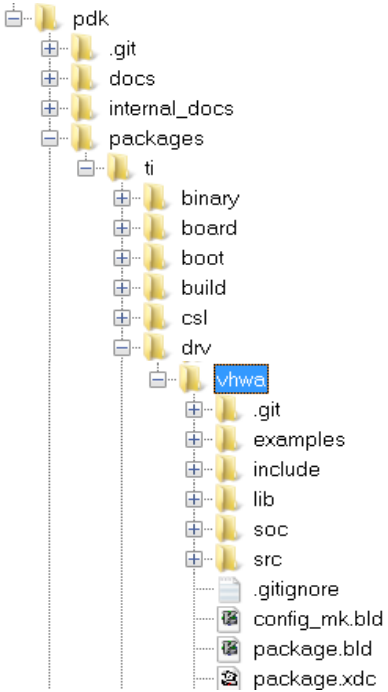
Agenda

- VHWA Drivers in PDK
  - Driver Architecture
  - FVID2 Interface
  - Application Flow
- VPAC Overview
  - Multi-Scalar
  - NF
  - LDC
  - VISS
- DMPAC Overview
  - DOF
  - SDE

VHWA Drivers in PDK

VHWA Driver Architecture

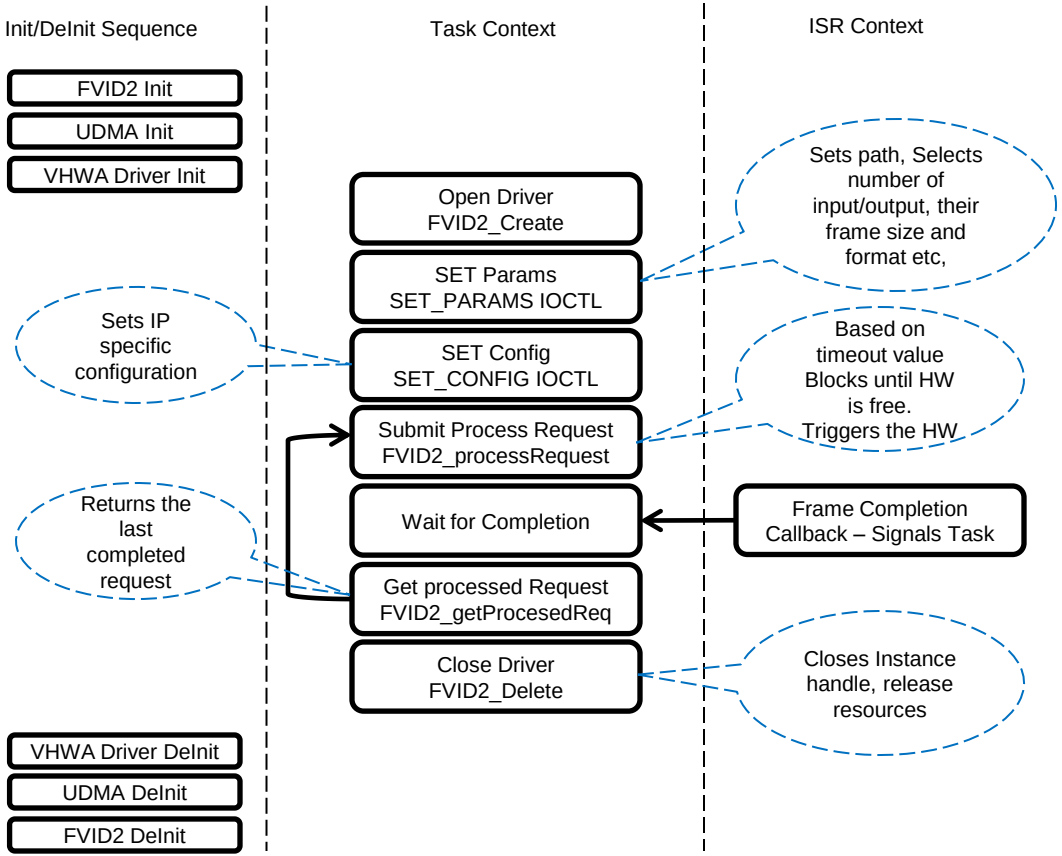




VHWA FVID2 Driver: Understanding FVID2 Interface

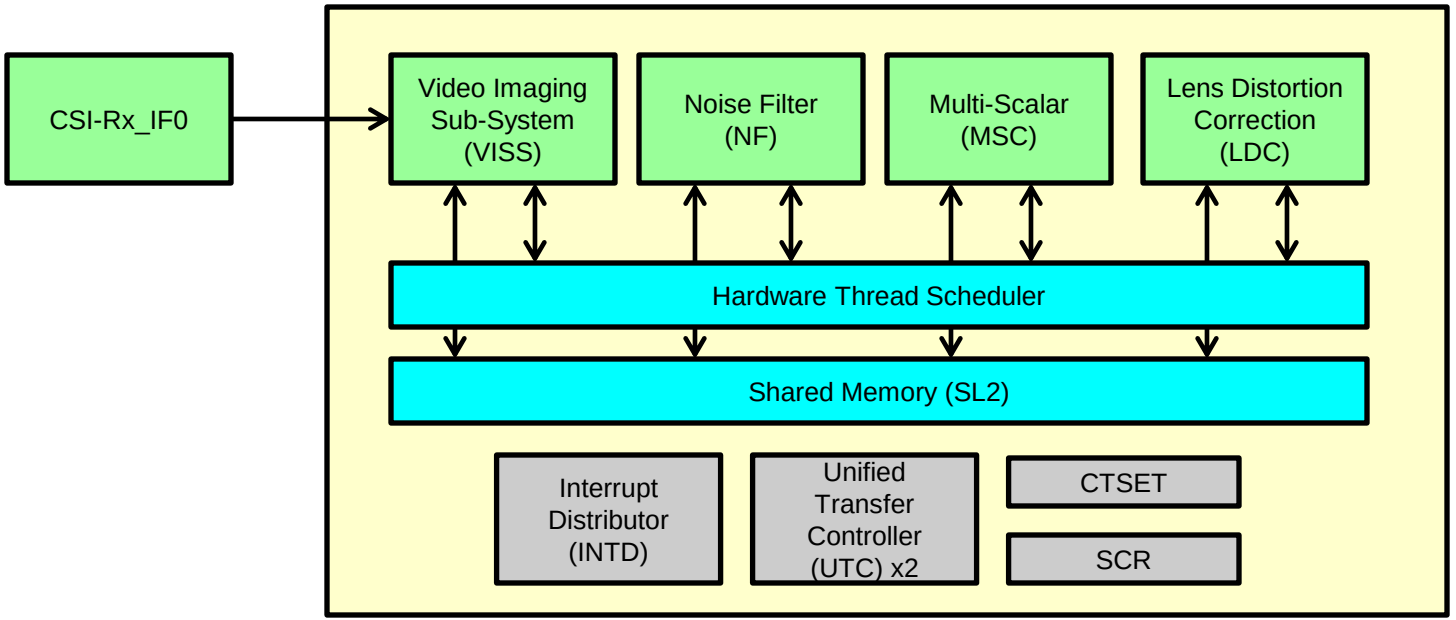
- FVID2 APIs:
  - *FVID2_init*
    - Initializes the drivers and the hardware. Should be called before calling any of the FVID2 functions
  - *FVID2_deInit*
    - Un-initializes the drivers and the hardware
  - *FVID2_create*
    - Opens a instance/channel video driver
  - *FVID2_delete*
    - Closes a instance/channel of a video driver
  - *FVID2_control*
    - To send standard (set/get format, alloc/free buffers etc..) or device/driver specific control commands to video driver
  - *FVID2_processRequest*
    - Submit a pixel processing request to the driver. Used in memory to memory drivers
  - *FVID2_getProcessRequest*
    - Get back the completed pixel processing request from the driver

VHWA FVID2 Driver: Application Flow



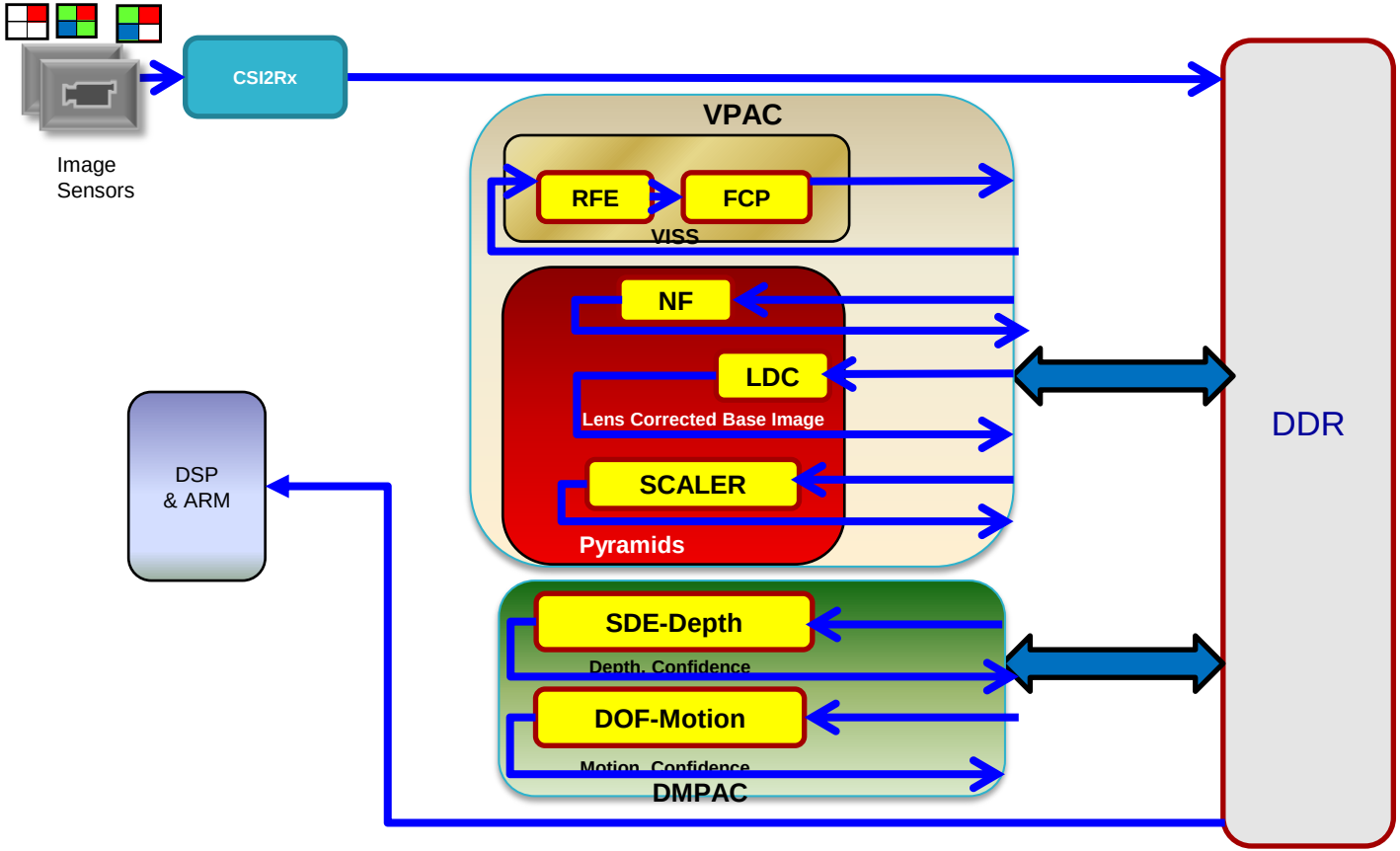
VPAC (Vision Pre-Processing Accelerator)

VPAC Block Diagram



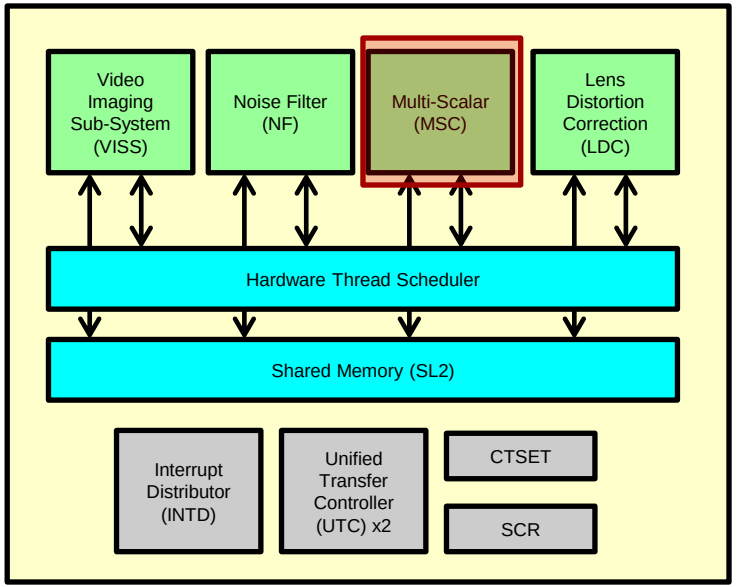
- HTS: Hardware Thread Scheduler
- UTC: Universal Transfer Controller
- NF: Noise Filter
- LDC: Lens Distortion Correction
- VISS: Vision Image signal Processing
- SL2: Level-2 Memory

Typical Functional Flow in VPAC



Scalar: Introduction

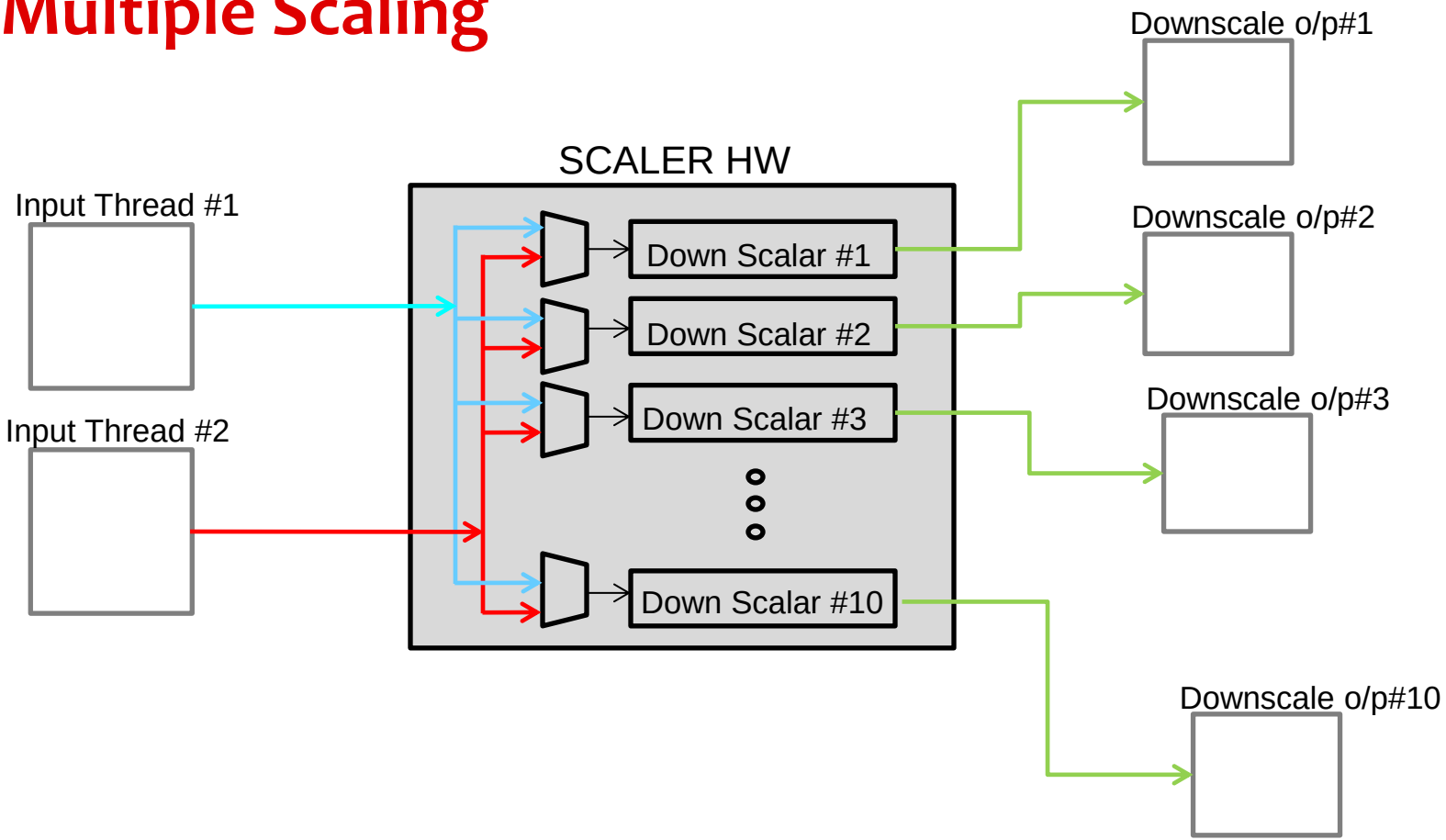
- Downscaling ratio is between 1x and 0.25x
- Programmable kernel sizes for vertical/horizontal filter (3,4, or 5)
- 4 sets of 5 tap-32 phase coefficients
  - Two set can be combined to support 5-tapx64-phase filters
- 2 additional sets of 5-tap Gaussian filter coefficients (single-phase) dedicated for Pyramid (Octave) generation
- 12 bit input & output
- Programmable ROI for input and output for each scalar
- Performance: 1pixel/cycle



Supported DataFormats

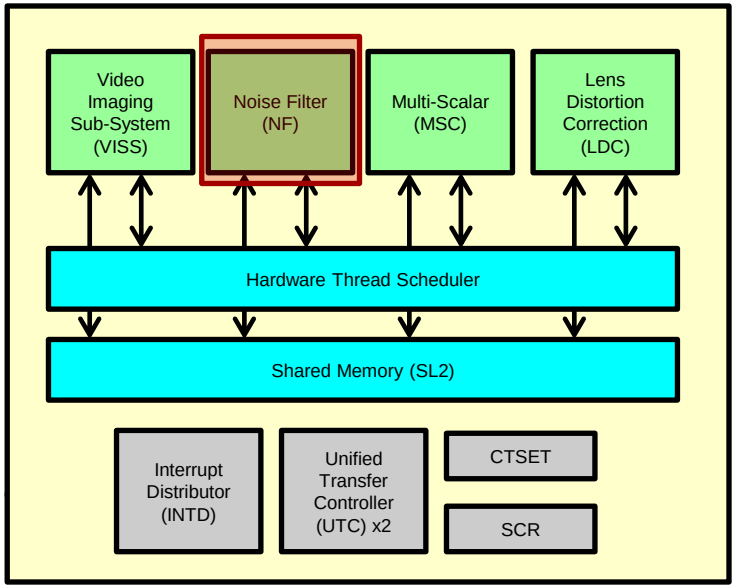
Data Format	Input Bit Depth	Output Bit Depth	Data Format	Input Bit Depth	Output Bit Depth
Luma	8Bit	8Bit	Chroma	8Bit	8Bit
		12Bit			12Bit
	12bit	8Bit		12bit	8Bit
		12Bit			12Bit

MSC: Multiple Scaling



Bilateral Noise Filter

- Support for bilateral and general filtering
- Supports filter size upto 5x5
- LUT based Bilateral weights generation
  - 8 bits for weight
  - 5 zones x 256 coefficients
- Performance : 1 pixel/cycle
- Supported formats: one plane (interleaved plane non-interleaved) YUV 420, 12-bit

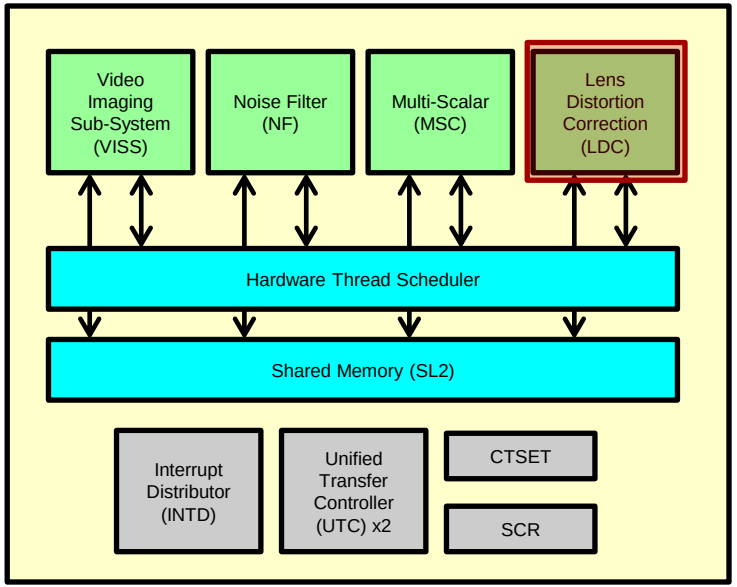


Supported DataFormats

Data Format	Input Bit Depth	Output Bit Depth	Data Format	Input Bit Depth	Output Bit Depth
Luma	8Bit	8Bit	Chroma	8Bit	8Bit
		12Bit			12Bit
	12bit	8Bit		12bit	8Bit
		12Bit			12Bit

Mesh LDC

- Purpose
  - Remap pixels from a distorted input space to an undistorted output space.
  - Apply perspective transform/homography operations.
- Mechanism
  - Perspective transform applied to output coordinates.
  - Remap function described by a 2D offset table (Δx/Δy).
  - Offsets are added to perspective output coordinates to locate input pixels.
  - Interpolation applied to input data to compute output pixels.



- **Supported Formats**
  - YUV 420 & YUV422
  - Up to 12 bits/component
- **Interpolation Type**
  - Bicubic (2 cyc/Pixel)
  - Bilinear (1 cyc/Pixel)

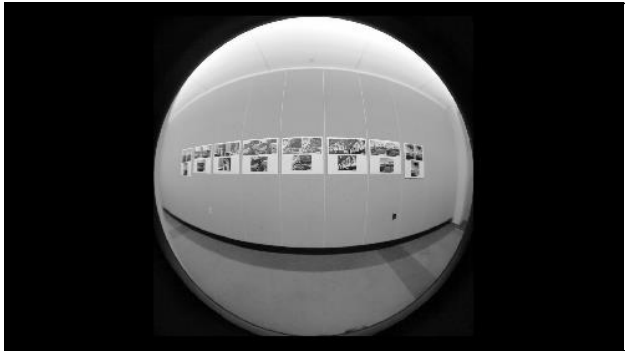
Mesh Warp (LDC)

LDC & Perspective Warp HW

FISHEYE LENS
Supports fisheye lenses upto 180/360^0

PERSPECTIVE TRANFORM
Changing user view point

PERSPECTIVE TRANFORM
Stereo Rectification

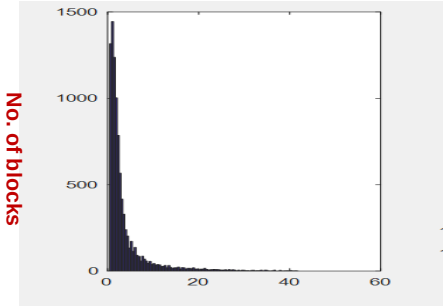


Mesh LDC: Data Formats

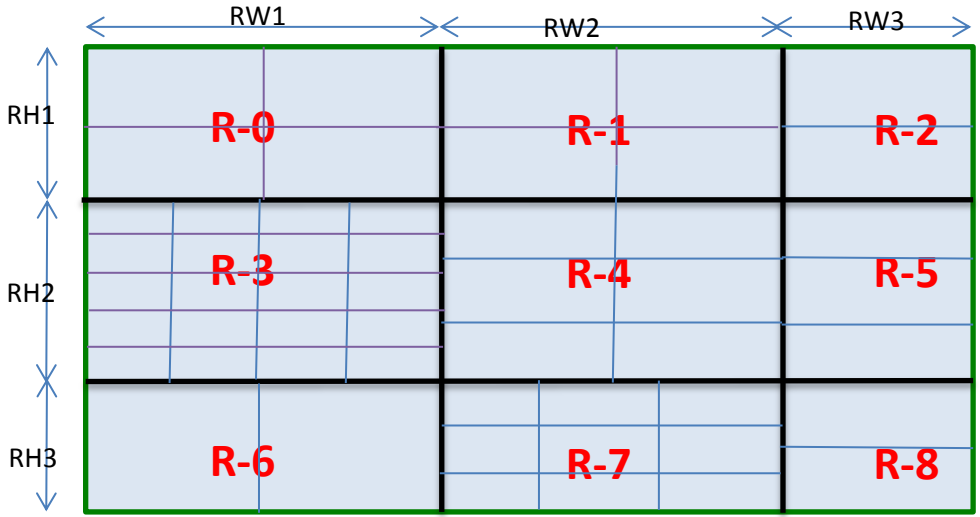
Input		Output	
Data Mode	Data format	Data Mode	Data format
YUV420 (NV12)	8bit	YUV420(NV12)	8bit
			12bit - packed
	12bit - packed		12bit - packed
	12bit - unpacked		12bit - unpacked
Luma Only	8bit	Luma Only	8-bit
			12bit - packed
	12bit - packed		12bit - packed
	12bit - unpacked		12bit - unpacked
YUV420(NV12) Chroma Ony	8bit	YUV420(NV12) Chroma Only	8bit
			12bit packed
	12bit - packed		12bit - packed
	12bit - unpacked		12bit - unpacked
YUV422 (UYVY)	8bit	YUV420(NV12)	8bit
			12bit - packed

Mesh LDC: Multi-Region

- Ideally the output block width (OBW) and output block height (OBH) should be sufficiently large but with the constraint that input block must fit into available internal memory.
- Distortion in wide angle lenses causes block size to be very small due to extreme scaling in particular regions of the image in some cases specially the surround-view cases. This affects the performance of the LDC hardware and overall memory bandwidth.



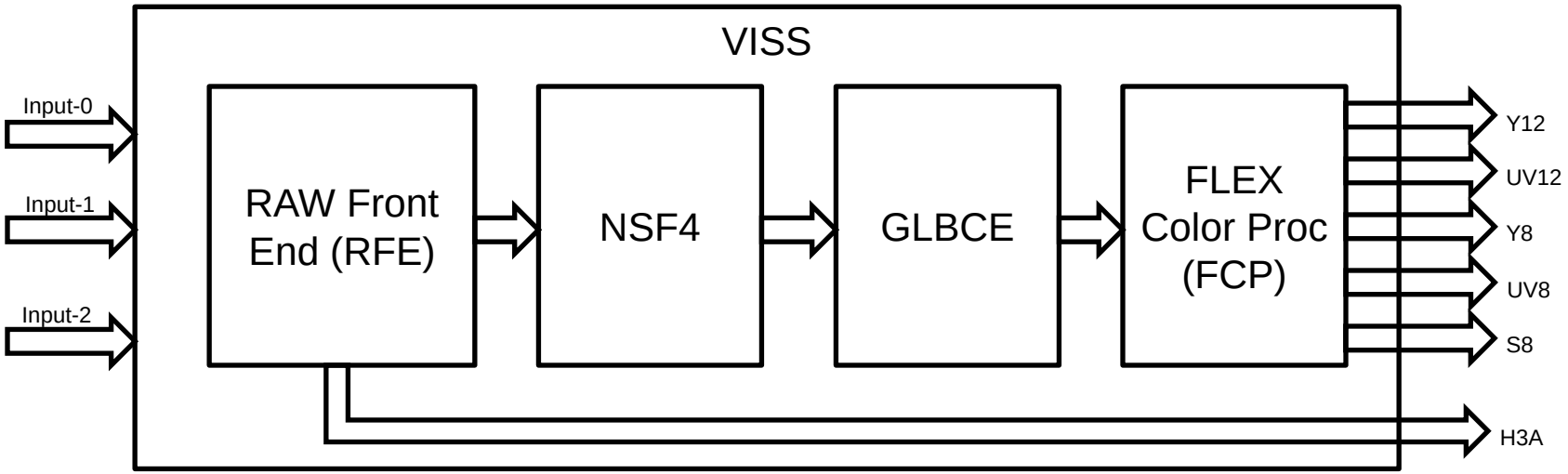
Distribution of fetched block sizes compared to output block size in ratio



Solution in New LDC: Multi-Region LDC

- Divide the frame into multiple slicing regions based on pattern of the transformation.
- Frame will be divided into up to 3 horizontal slices and 3 vertical slices-Total of 9 regions
- Each region can be programmed with independent output block size and optimal pixel pad.
- LDC can be programmed with bigger block size for region with less spatial variation (i.e. scaling factor) and smaller block size for region with high spatial variation
- This improves the band width as well as performance as portion of the image with bigger block size increases

VISS Block Diagram

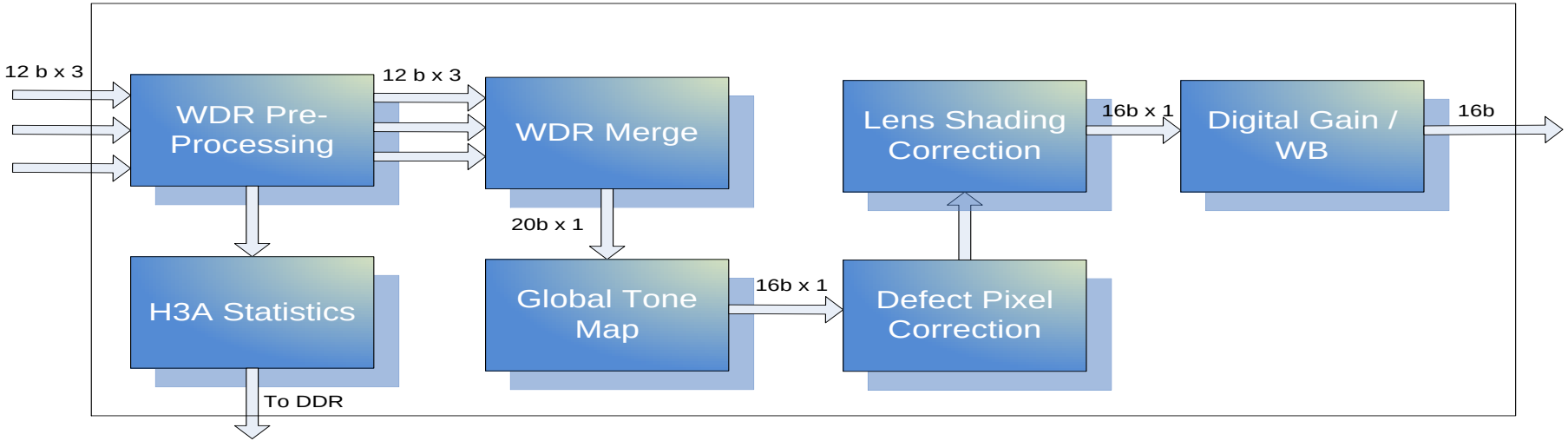


- Input format : 16b unpacked (RAW10/12/14/16) , 12b packed
- Output format : 12b yuv420, 8b yuv420, 8b RGB, 8b S8
- Supports On-the-fly processing ➔ Low latency DDR path (QoS through NavSS and MSMC)
- Supports M2M processing

VISS Features

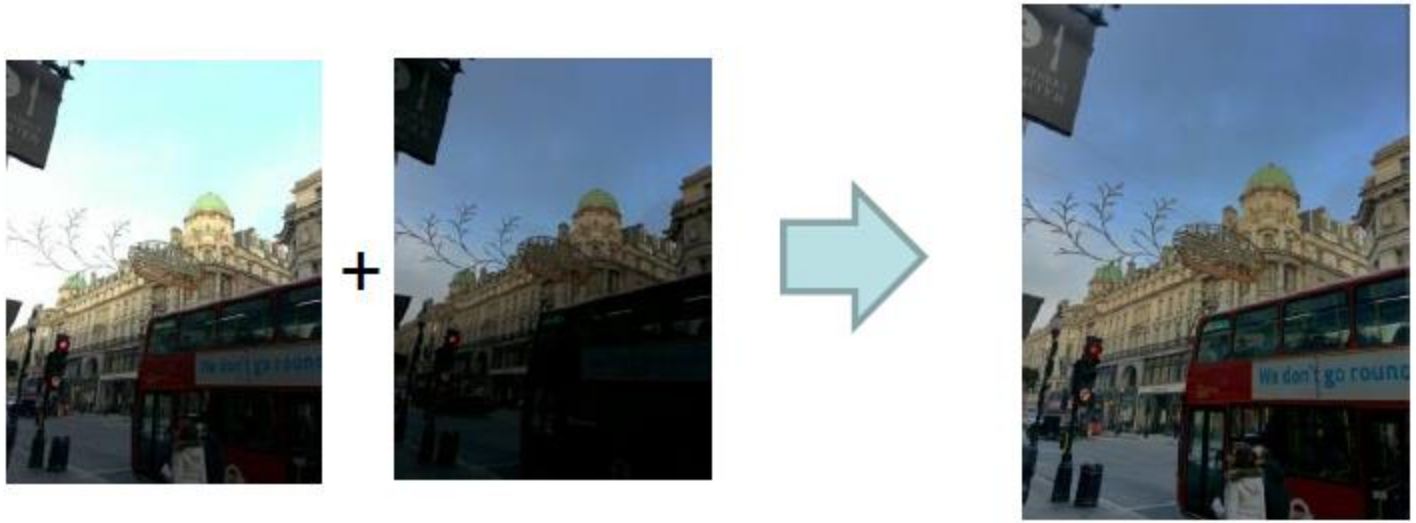
- Performance : 1 pixel/cycles
- Support for 12/16 bit input RAW format
- Support for 8/12 bit YUV output
- Support for multiple RAW formats (e.g. Bayer, RCCC)
  - Flexible to handle any 2x2 RAW format
- Enables Support for other color spaces
  - Support other color spaces e.g. Support for Color saturation and Gray scale for HSV/HSL etc (Hue is not supported)
  - Enables RGB output
- Support for Multiple WDR /HDR Formats and Up-to 3 Exposures
  - Compounded format (12 & 14 bit formats)
  - Stagger format of WDR
  - Rest of WDR Format
- Support of statistics for 3A (Auto-Exposure, Auto-white-balance and Auto-Focus)
- Dual Output (Vision and Visual)
- TI's proven Visual Processing with proven Noise filter and GLBCE (Local Tone Mapping)

RAW Front End (Processing in RAW Domain)



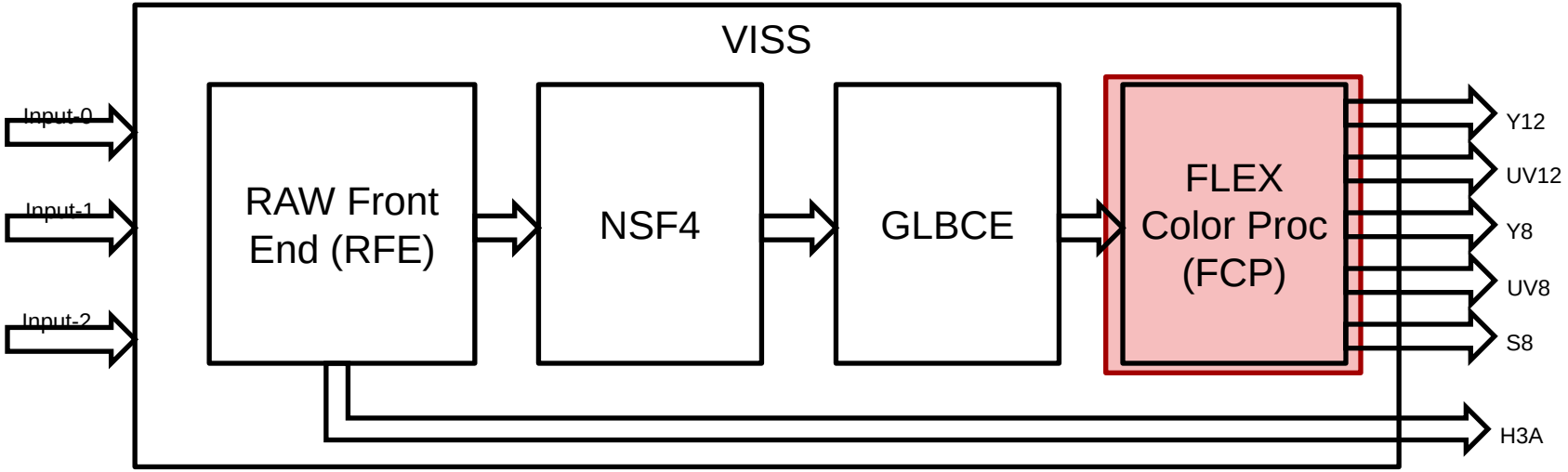
- **WDR Pre-processing**, : To decompress sensor's companded data
- **WDR Merge** : Merge up to 3 RAW images into a WDR image
- **LSC** : Lens Shading Correction using a pre-computed LUT read from memory
- **Digital WB Gain** : Applies WB gains computed by AWB algorithm
- **H3A** : Statistics generator for 3A (AWB, AE, AF) Algos.
- **GTM** : Global Tone Map – Maps output of WDR merge block from 20->16 bpp
- **DPC** : Defect Pixel Correction – OTF & LUT (256 entries) based

Wide Dynamic Range



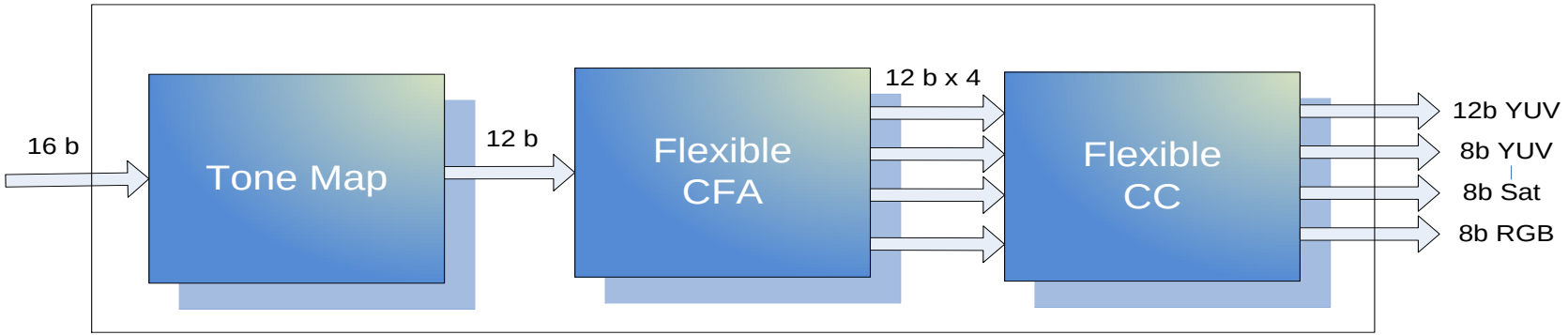
- Consumer cameras have limited Dynamic Range (60 dB)
  - Leads to clipped highlights or/and underexposed shadows
  - Human visual system has a much higher dynamic range
- WDR Sensor
  - Capture Multiple exposures using time multiplexing and/or sensor architecture
  - Combine multiple exposures or transmit them separately

Flexible Color Processing



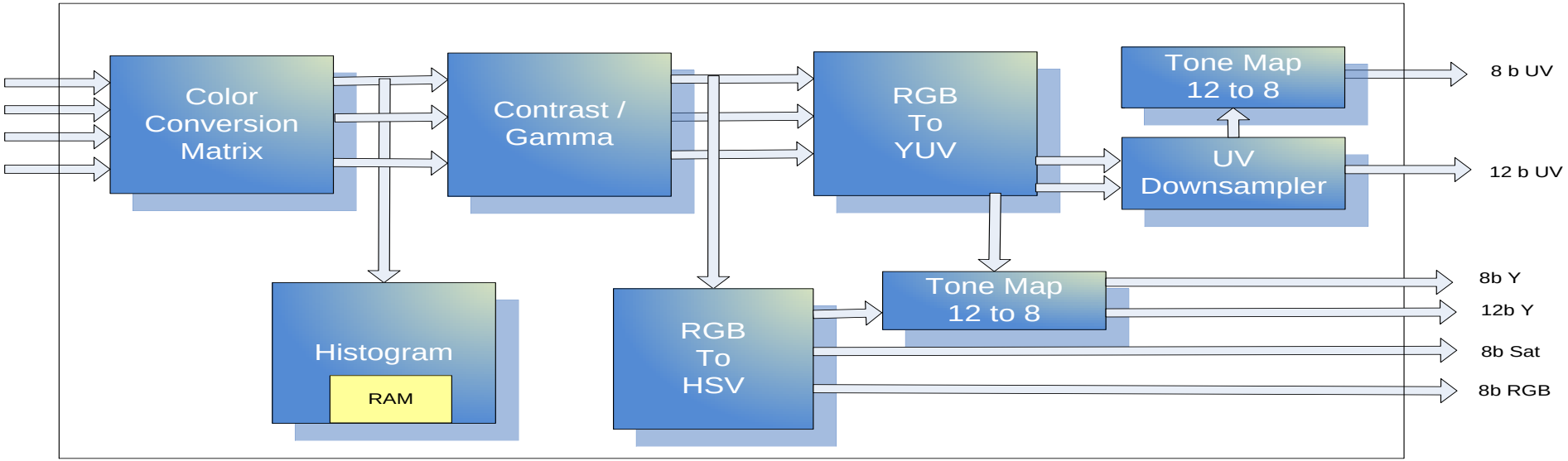
- State-of-the-art TI's 5th Generation Flexible CFA
  - Can support any 2x2 RAW Sensor Pattern
- Flexible Color Conversion Scheme
  - Color Correction Matrix
  - Flexible HSV color plane generation (S &V) only to support different standards
  - 12 bit/Component YUV 420 output generation
  - Full color RGB (24 bits/pixel) output

Flexible Color Processing



- Low latency, On-The-Fly (OTF) operation of 3 key blocks
- Global Tone Map (16 to 12)
  - Used when locally adaptive Tone Map is disabled
- Flexible CFA
  - Generates 12 bit up to 4 color planes output (Eg Full Resolution RGBC or RGB IR)
- Flexible Color Conversion
  - Implements multiple color conversion schemes for both analytics / visual use cases

Flexible Color Conversion

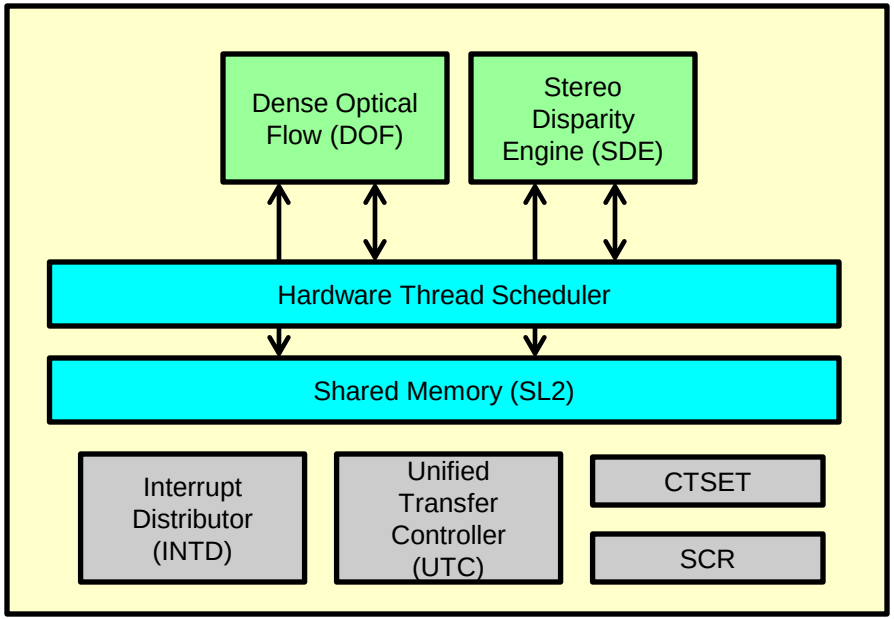


- Flexible architecture for supporting multiple data flows
- Color Correction Matrix (CCM) for supporting accurate color reproduction
- LUT Based Gamma correction / Contrast Stretch Module
- Flexible RGB-HSV Color generation (No Hue)
- RGB-YUV with programmable coefficients
- 12 bit native output with option 8 bit using LUT based tone map.

- Supports RGB output / Supports Saturation outputs
- Supports Grayscale/Luma/IR/Clear Output
- Single cycle/pixel performance
- Support for flexible output format generation including YUV as well as custom

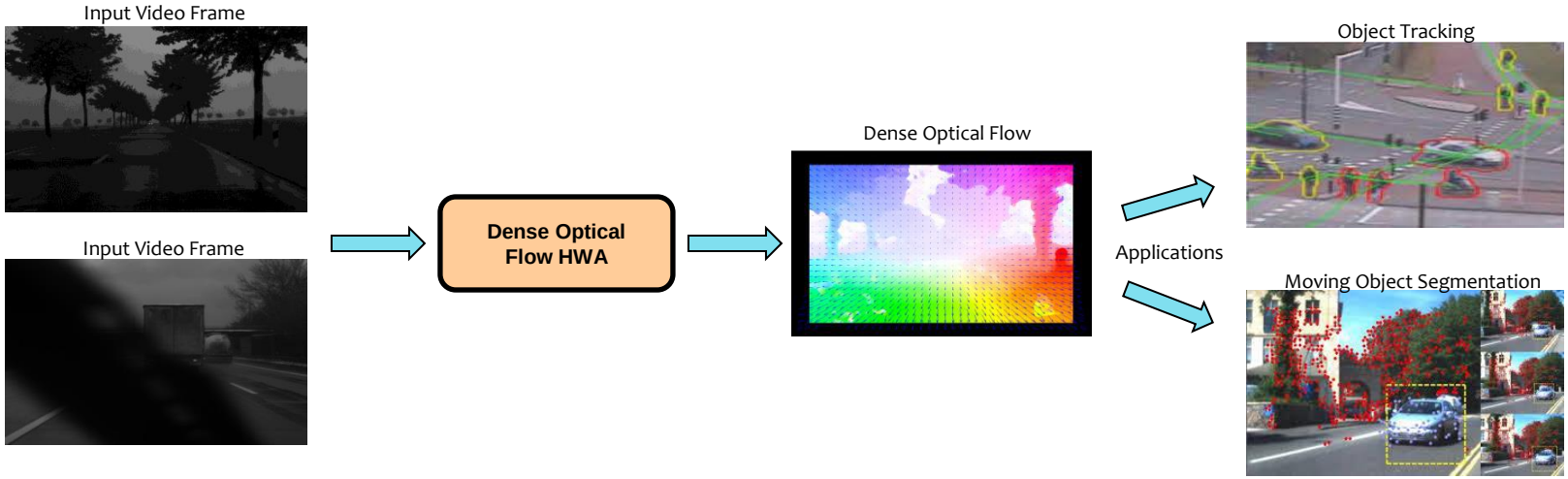
DMPAC (Depth and Motion Perception Accelerator)

DMPAC Block Diagram



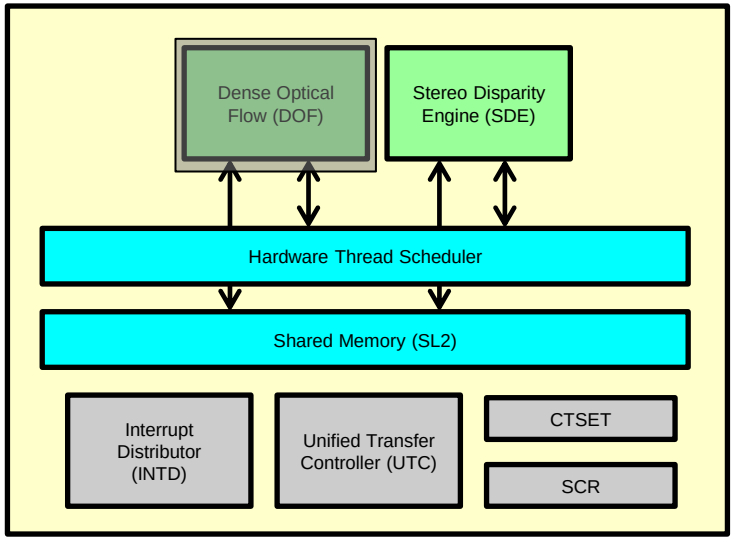
- DOF: Dense Optical Flow
- SDE: Stereo Disparity Engine
- UTC: Universal Transfer Controller
- HTS: Hardware Thread Scheduler
- SL2: Level-2 Memory

Dense Optical Flow (DOF)



DOF: Feature Set

- **Overview**
  - Optical Flow estimates 2D motion vector field given two images
  - Pyramidal approach based coarse-to-fine search strategy
  - Can estimate Large motions with fractional pixel precision
- **Features**
  - Input Image resolution: upto 2MPix (max)
  - Max resolution 2048H x 1024V
  - Input Image Frame Rate: upto 60fps
  - Allows Scalability of input image resolution vs frame rate
    - eg. higher fps at lower resolution
  - 12bit/pixel input and output format
  - Other bit depths can be supported using Format Conversion Module
  - Large Motion search range
  - Dense flow vector map generated for each input pixel
  - Confidence score generated for each flow vector output
  - Supports Sparse optical flow



Stereo Disparity Engine (SDE)

Input Video Frame: Left Camera

Input Video Frame: Right Camera

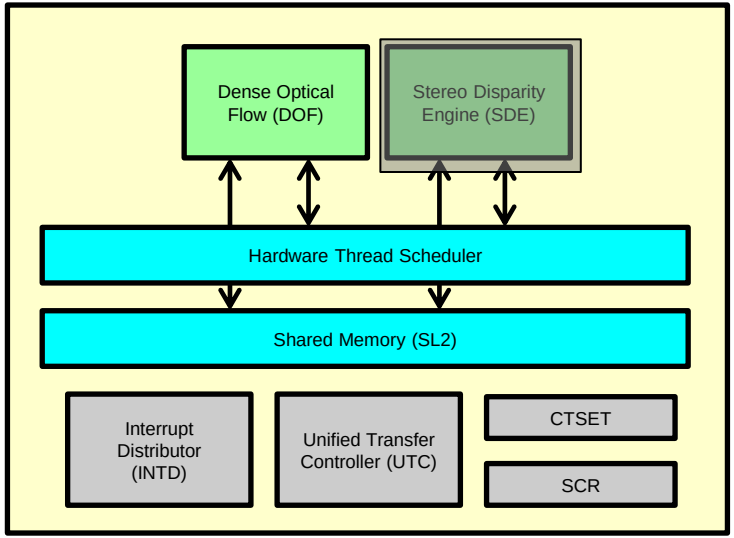
Depth Map

Applications

Object Distance Measurement
Large range applications
Collision Warning
Path Plannng

SDE: Features Set

- **Overview**
  - Stereo estimates depth by measuring disparity from 2 different views
  - Can run in parallel with Optical Flow
- **Feature set**
  - Input Image resolution: 2MPix (max)
  - Max resolution 2048H x 1024V
  - Input Image Frame Rate: 60fps (max with 2MPix)
  - Allows Scalability of input image resolution vs frame rate
    - eg. higher fps at lower resolution
  - 12bit/pixel input and output format
  - Other bit depth can be supported using Format Conversion Module
  - Disparity Search range of -3/+188 (far object)
  - Dense disparity map for each input pixel
  - Confidence score assigned for each disparity output



Questions?
Thank You