

# DRA76x/77x Performance

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## ABSTRACT

This application report looks into the System-on-Chip (SoC) level performance characteristics of key usecases targeted for DRA76x/77x. This document discusses the data path infrastructure and parameters that manage the system level throughput. Different optimization techniques for optimum system performance are also described.

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## Trademarks

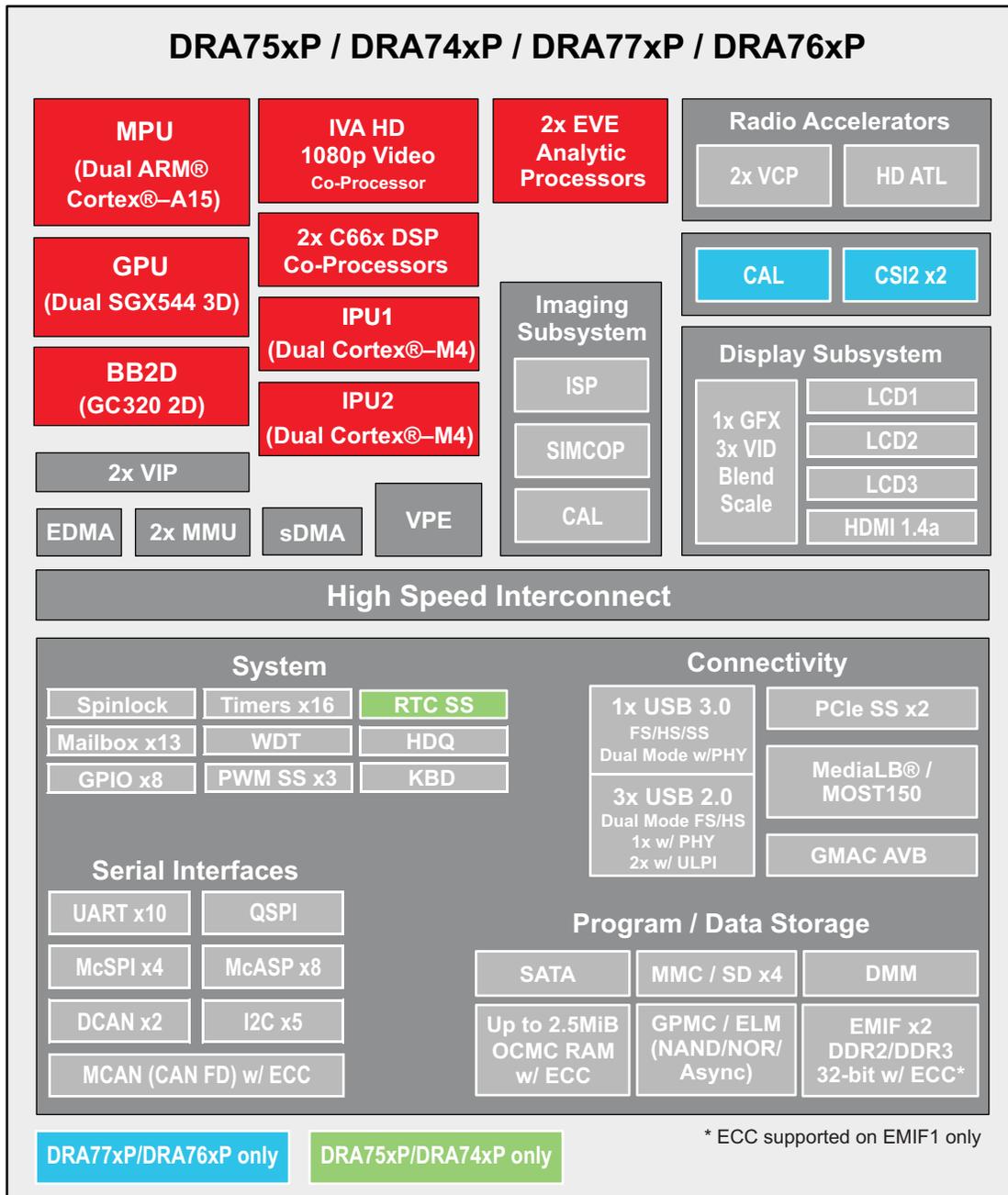
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## 1 SoC Overview

DRA76x/77x is a high-performance, automotive vision application device based on enhanced OMAP™ architecture integrated on a 28-nm technology.

The device block diagram is shown in [Figure 1](#).



intro\_001

Figure 1. DRA75xP, DRA74xP, DRA77xP, DRA76xP Block Diagram

For more information regarding the DRA76x/77x device, see the [DRA75xP, DRA74xP, DRA77xP, DRA76xP SoC for Automotive Infotainment Silicon Revision 1.0 Technical Reference Guide](#).

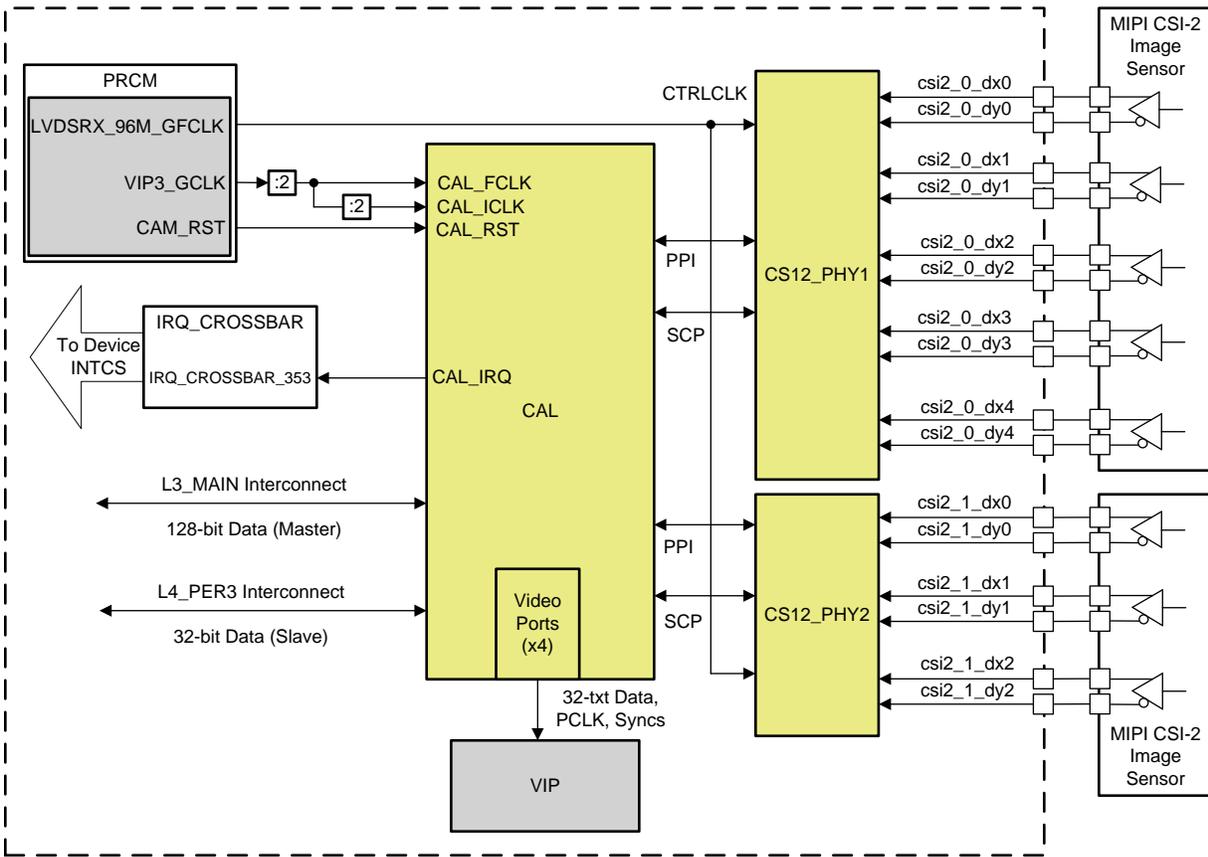
The following sections discuss the performance aspects of various new IP features added in the DRA76x/77x device versus DRA76x/77x and critical usecase performance entitlement that the device achieves.

## 2 Camera Interface Subsystem (CAL)

This section looks performance aspects of the Camera Interface subsystem comprising of:

- Camera Adapter Layer (CAL)
- CAL interfaces:
  - Two PPI interfaces to CSI-2 PHY

Figure 2 shows the Camera subsystem block diagram.



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**Figure 2. Camera Subsystem Overview**

The following enhancements are present in the CAL subsystem in DRA76x/77x:

- Video Port
  - Extend VP1 to replicate as VP2, VP3 and VP4 (16 Bits per Cycle mode on VPORTs)
  - Extend the programming model of VP1 to map to the 3 new VPs without any new register addition
  - Automatically map VP1 -> CPORT1, VP2 -> CPORT2, VP3 -> CPORT3, VP4 -> CPORT4
  - Same Programming parameters applied on all 4 VP
  - New Input: EN\_BASELINE\_MODE 1bit: Baseline compatibility mode. Driven via Control Module MMR
  - Baseline\_mode = 1 -> CAL in baseline Mode ( 0 = 4 New VP mode )
- DMA
  - Support of a new mode that bifurcates YUV422 (16b format) input to 2 DMA output planes for Y and UV each (termed as YUV422 Bi-Planar mode).
  - The DMA needs to allocate 2x numbers for channels of x number of input streams.

## 2.1 CAL Standalone Performance

In the following subsections, performance aspects of different modes of operation of the CAL IP in DRA76x/77x are discussed. In all the experiments the following IP frequencies are applied:

- CAL: 266 MHz
- CSI PHY Control Clock: 96 MHz
- L3 Interconnect : 266 MHz
- EMIF Controller: 266 MHz
- DDR3 Clock : 666 MHz

### 2.1.1 CAL PPI0 (4L) Capture

In this mode, the CAL IP is configured for capture of a single channel of 1920x1080 frame @ 30 FPS. Pixels are configured to be 16 bits per pixel. The CAL Write DMA is configured for constant addressing mode and linear write pattern.

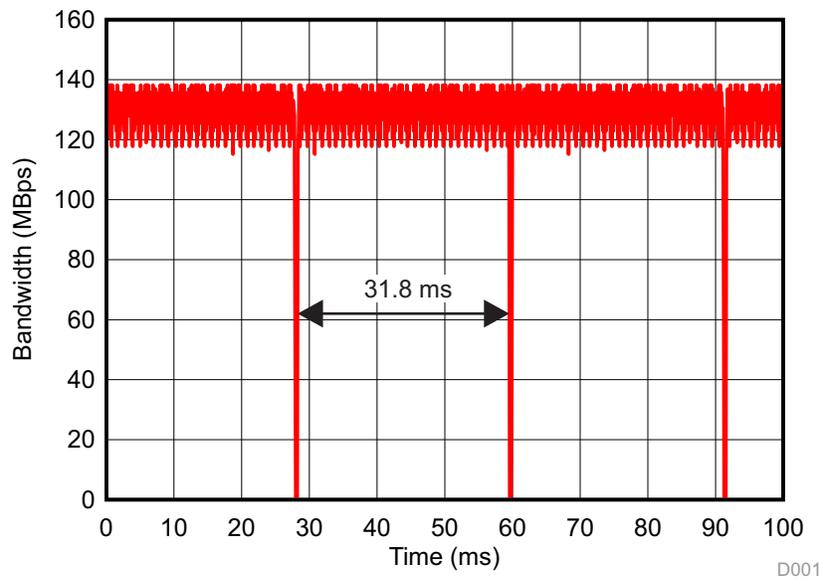
The CAL test is configured with the parameters shown in [Table 1](#).

**Table 1. CAL PPI0 (4L) Capture Test Parameters**

Test Parameter	Value
Capture Width (in Pixels)	1920
Capture Height (in Pixels)	1080
Bits per pixel	16
Horizontal Blanking	10
Vertical Blanking	15
Data format	0x2A (Raw 8)
Number of Lanes	4 Lanes

Expected Bandwidth = 1920 x 1080 x 30 FPS x 2 Bytes per pixel = 124.416 MBps

Measured Average Bandwidth = 128.439 MBps



**Figure 3. CAL Initiator Bandwidth Statcoll Measurement**

### 2.1.2 Channel CAL PPI0 (4L) Capture With YUV422 to YUV422BP

In this mode, the CAL IP is configured for capture of a 4 channels of 1920x1080 frame @ 30 FPS. Pixels are configured to be 16 bits per pixel. The CAL Write DMA is configured for constant addressing mode and linear write pattern. Write DMA Bi-planar mode is enabled to split the Y and UV planes.

**Table 2. CAL PPI0 (4L) 4 Channel Capture Test Parameters**

Test Parameter	Value
Capture Width (in Pixels)	1920
Capture Height (in Pixels)	1080
Bits per pixel	8
Horizontal Blanking	10
Vertical Blanking	15
Data format	0x2A (Raw 8)
Number of Lanes	4 Lanes
Number of Virtual Channels	4

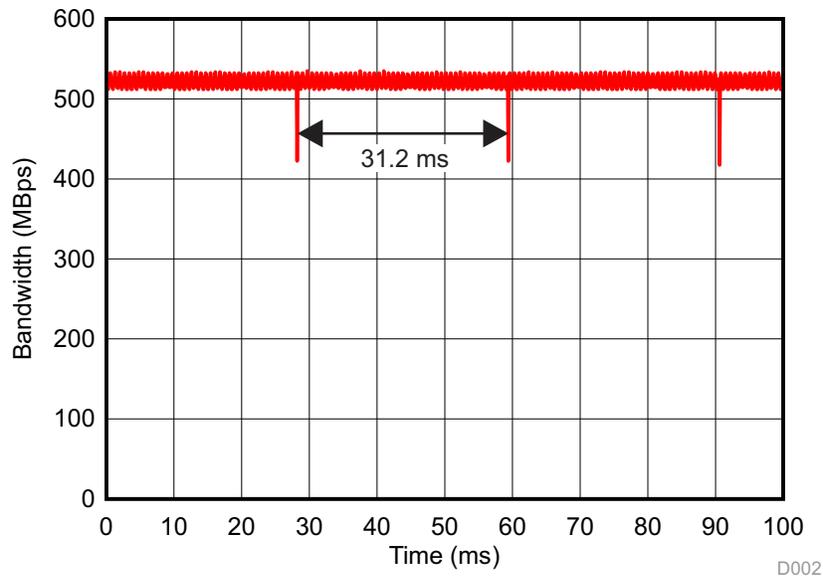
The pixel processing extraction is configured to 8 bits and the pixel packing is configured to 16 bits.

All the pixel processing contexts are utilized and all the write DMA contexts are utilized to generate 8 streams (4 channels each having Y and UV data).

Expected Bandwidth = 1920 x 1080 x 30 FPS x 2 Bytes per pixel x 4 channels = 497.664 MBps

Measured Average Bandwidth = 520.976 MBps

Without the YUV422 to YUV422 BP conversion 4 WR\_DMA contexts are utilized with similar bandwidth profile.



**Figure 4. CAL Initiator 4 Channel YUV422 BP Bandwidth Statcoll Measurement**

### 2.1.3 CAL to VIP 1 Channel Baseline Mode

When baseline mode is enabled, only one VPORT between CAL and VIP is enabled.

In this mode, VIP 1A has been configured to capture the input frames using active video signaling and convert the incoming YUV422 frames to YUV420. CAL upon capturing the frames from PPI0 will forward the frames to the first VPORT. In order for VIP to capture correctly, it is important to set the CAL\_CSI2\_CTXx.LINES to the exact number of lines one wants to capture via VIP.

In case of erroneous frames received due to CSI packets being dropped due to errors in the transmission, the CAL to VIP behavior for capturing or dropping the received frames is as below:

- Small Frame Reception Case: If the expected frame size is 65x65 (set CAL\_CSI2\_CTXx .LINES = 65) and the received input frame is 64x64, no data written out by VIP.
- Correct Frame Reception Case: If the expected frame size is 64x64 (set CAL\_CSI2\_CTXx .LINES = 64) and the received input frame is 64x64, 64 lines written out. This corresponds to a normal working case.
- Large Frame Reception Case: If the expected frame size is 48x48 (set CAL\_CSI2\_CTXx .LINES = 48) and the received input frame is 64x64, only 48 of 64 lines each is written out. Extra data not written out.

The CAL + VIP is able to receive frames normally after short and long frames are received.

The CAL + VIP can operate at a maximum VP\_CLK frequency of 90% of VIP functional clock frequency. In DRA76x/77x, the VIP clock frequency is 266 MHz. Thus, 239 MHz is the maximum VPORT pixel clock frequency.

The expected bandwidth is this test is  $1920 \times 1080 \times 1.5 \text{ Bytes per pixel} \times 30 \text{ fps} = 93.312 \text{ MBps}$ .

The observed bandwidth was  $\text{VIP1\_P1} + \text{VIP1\_P2} = 32.36 + 64.75 = 97.12 \text{ MBps}$ .

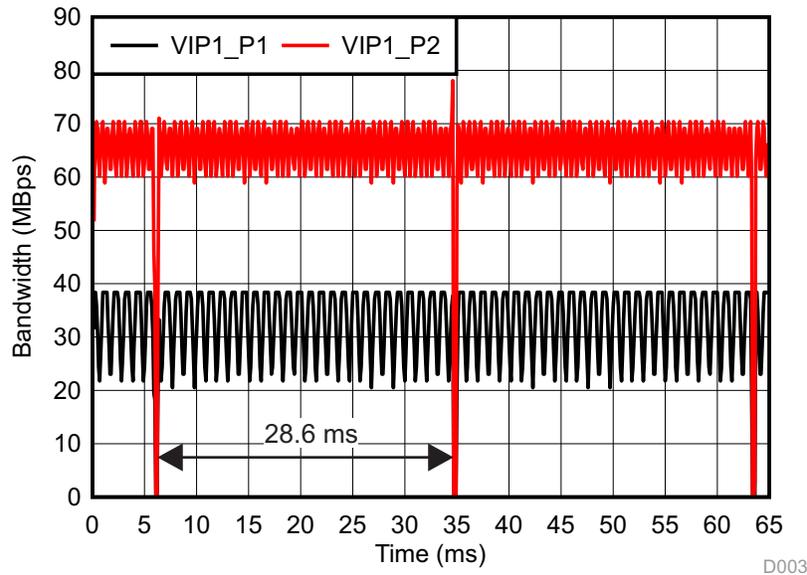
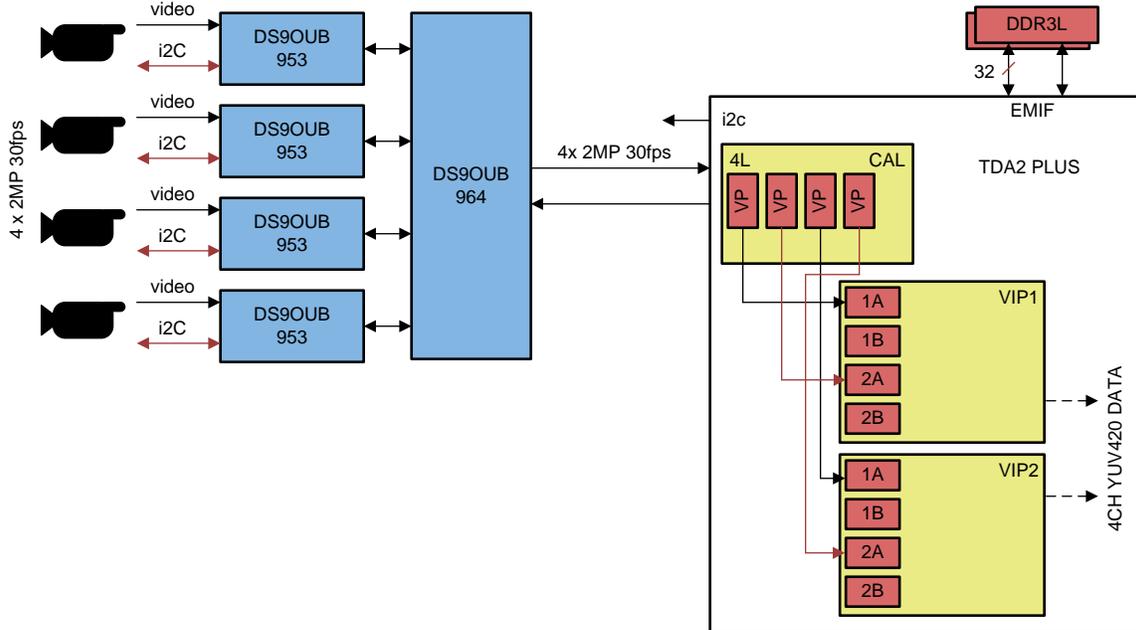


Figure 5. VIP Initiator 1 Channel YUV420 Bandwidth Statcoll Measurement @ 239 MHz VP\_CLK

### 2.1.4 CAL to VIP 4 channel Capture

In this configuration, the EN\_BASELINE\_MODE is set to 0 (default). This enables using all of the four VPORTs available in DRA76x/77x. CAL PPI0 (4L) is configured to capture four channels of 1920x1080 frames @ 30 FPS, 2 bytes per pixel. The CAL captured data is then sent to VIP 1A, 2A, 3A, 4A. VIP performs conversion from YUV422 to YUV420 for all 4 channels.

This configuration is useful in surround view applications that are targeted for DRA76x/77x with an external ISP as shown in Figure 6.



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Figure 6. Channel CAL + VIP Configuration for Surround View Applications

The expected bandwidth is  $1920 \times 1080 \times 1.5 \text{ Bytes per pixel} \times 30 \text{ fps} \times 4 \text{ Channels} = 373.25 \text{ MBps}$ .

The observed average bandwidth was  $VIP1\_P1 + VIP1\_P2 + VIP2\_P1 + VIP2\_P2 = 72.34 + 143.32 + 72.44 + 143.35 = 431.45 \text{ MBps}$ .

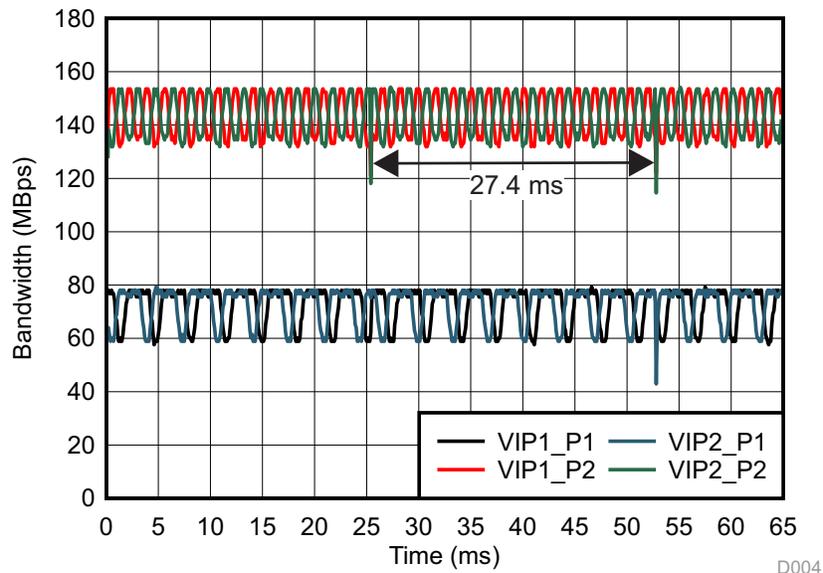


Figure 7. VIP Initiator 4 Channel YUV420 Bandwidth Statcoll Measurement @ 133 MHz VP\_CLK

## 2.2 CAL Performance With Multiple Initiators

In this section, the CAL MFLAG behavior is analyzed when multiple initiators are executed in parallel with CAL, which causes the CAL FIFO to overflow and not be able to meet its real-time performance.

The CAL performance is further discussed in the context of planned automotive usecases for the DRA76x/77x device in [Section 6](#).

Hard real time traffic can't be stalled for long periods of time. Indeed, the camera sends data at constant speed and it can only be stalled until FIFOs on the path are filled up. When FIFOs become full, data is discarded and the frame is therefore corrupted. To minimize the risk of real time data corruption, CAL IP supports the MFLAG based Quality of Service Mechanism.

Dynamic MFLAG generation is used when the write DMA operates on real time data. In that case, the MFLAG value depends on the number of slots ready to generate transactions in the write DMA (n):

- 00: SAFE ( $n < \text{CAL\_CTRL.MFLAGL}$ )
- 01: VULNERABLE ( $\text{CAL\_CTRL.MFLAGL} \leq n < \text{CAL\_CTRL.MFLAGH}$ )
- 11: ENDANGERED ( $\text{CAL\_CTRL.MFLAGH} \leq n$ )

Software should ensure that:

- $\text{CAL\_CTRL.MFLAGL} \leq \text{CAL\_CTRL.MFLAGH}$  (only 0x00 or 0x11 generated when  $\text{CAL\_CTRL.MFLAGL} = \text{CAL\_CTRL.MFLAGH}$ )
- $\text{CAL\_CTRL.MFLAGL} = 0x00, 0xFF$  or less or equal to  $2^{(\text{WFIFO}-3)}$
- $\text{CAL\_CTRL.MFLAGH} = 0x00, 0xFF$  or less or equal to  $2^{(\text{WFIFO}-3)}$

In this experiment, the following initiators were enabled along with the CAL capture of 4 channels of 1920x1080 Raw 12 bit @ 30 FPS.

DSS: 1 video pipe traffic of 1920x826 ARGB8888 @ 60 FPS.

DSP1 EDMA and DSP2 EDMA

The DDR frequency was set to 532 MHz.

Table 3 shows the measured bandwidth from the different initiators that causes the CAL overflows.

**Table 3. Initiator Average Bandwidth at Which CAL Overflows With DDR @ 532 MHz**

Initiators	Average Bandwidth (MBps)
CAL	747.31
DSP1_EDMA	2840.98
DSP2_EDMA	1850.67
DSS	377.81
IPU1	49.48
IPU2	17.31
EMIF1_SYS	2891.95
EMIF2_SYS	2891.59
Total EMIF	5783.54 (67.9 % efficiency)

With this initiator bandwidth profile, the CAL MFLAG behavior is as shown in Table 4.

**Table 4. CAL MFLAG Setting Behaviors**

CAL MFLAG Setting	CAL Overflow Behavior
No CAL MFLAG	CAL Overflows
Always on CAL MFLAG	No CAL Overflows
Adaptive MFLAG (50% - 75% of 8KB WFIFO)	CAL Overflows
Adaptive MFLAG (25% - 75% of 8KB WFIFO)	No CAL overflows

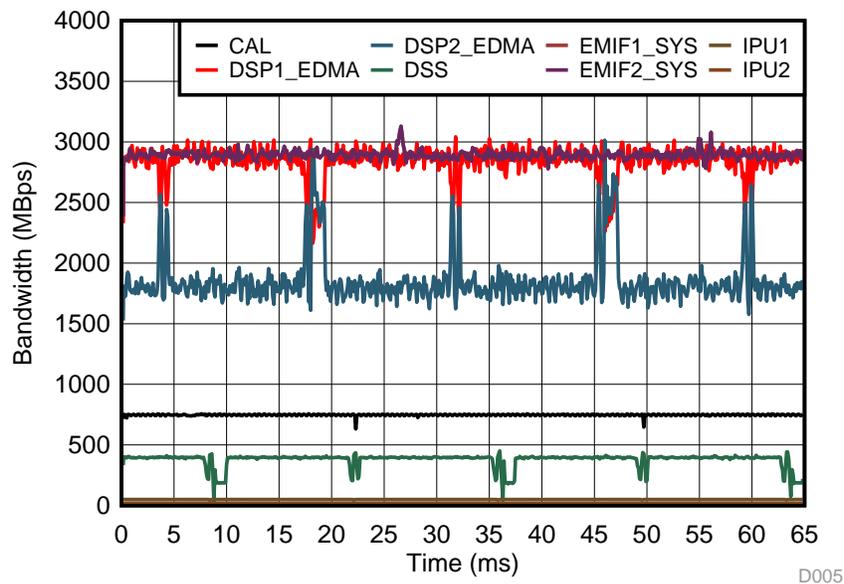
The following adaptive MFLAG setting is recommended for CAL overflow:

```

/* Set adaptive MFLAG for 25% to 75% of the WFIFO size (64 x 16 bytes).
 * WFIFO = 9 for DRA76x/77x.
 */
WR_FIELD_32(CAL_INST, CAL_CAL_CTRL, CAL_CAL_CTRL_MFLAGH, 0x30);
WR_FIELD_32(CAL_INST, CAL_CAL_CTRL, CAL_CAL_CTRL_MFLAGL, 0x10);

```

A snapshot of the bandwidth profile with this CAL MFLAG setting is as shown in Figure 8.



**Figure 8. CAL Bandwidth Along With Other Initiators With Adaptive MFLAG Setting**

### 3 Imaging Subsystem (ISS)

The imaging subsystem (ISS) (see Figure 9) deals with the processing of the pixel data coming from memory (image format encoding and decoding can be done to and from memory). With its subparts, such as interfaces and interconnects, image signal processor (ISP), and still image coprocessor (SIMCOP), the ISS is a key component for the following applications:

- Rear View Camera
- Front View Stereo Camera
- Surround View Camera

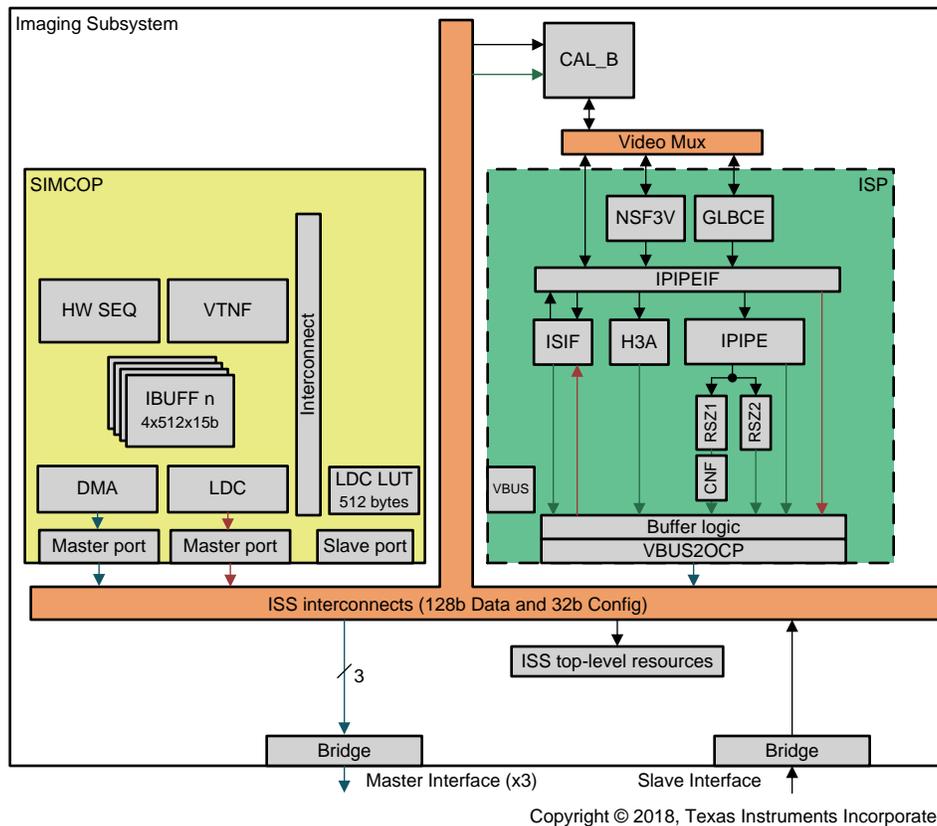


Figure 9. ISS Overview

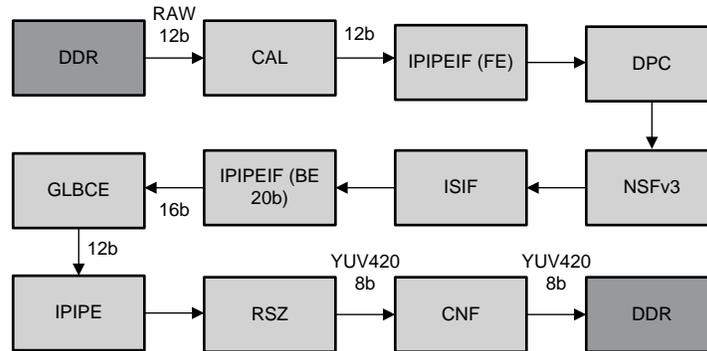
#### 3.1 ISS Standalone Performance

This section reviews the ISS standalone performance for different modes of operation planned for the ISS based usecases in DRA76x/77x. In all the experiments the following IP frequencies are applied:

- ISS : 354 MHz (OPP\_NOM), 425 MHz (OPP\_OD), 532 MHz (OPP\_HIGH)
- L3 Interconnect : 266 MHz
- EMIF Controller: 266 MHz
- DDR3 Clock : 666 MHz

### 3.1.1 ISP Memory to Memory Single Pass WDR

The ISP processing in memory-to-memory mode for a single pass wide dynamic range is shown [Figure 10](#).

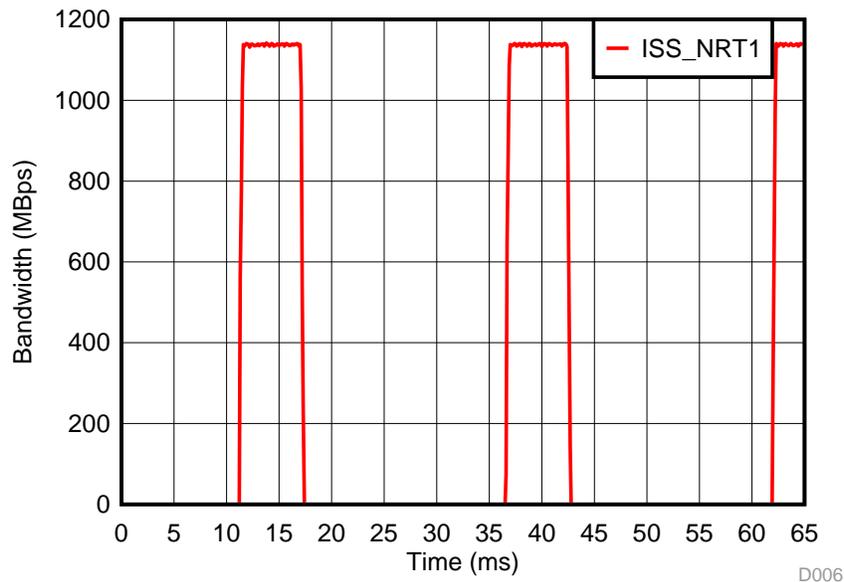


**Figure 10. Single Pass ISP Sub Block Data Processing Flow**

The expected bandwidth in this configuration is calculated as shown below:

- Input = 1920 x 1080 x 30 FPS x 12 bits per pixel / 8 = 93.312 MBps
- Output = 1920 x 1080 x 30 FPS x 1.5 Bytes per pixel = 93.312 MBps

In measurements with a FPS of 39.5, the average bandwidth was found to be 255.88 MBps. The bandwidth profile is shown in [Figure 11](#).



**Figure 11. ISS 1 Channel ISP Single Pass WDR Bandwidth**

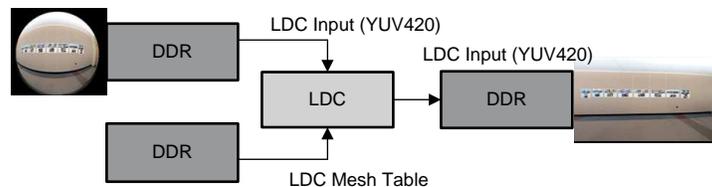
In order to further understand the impact of the frequency and maximum performance achieved by the ISP, multiple experiments were conducted for OPP\_NOM, OPP\_OD, OPP\_HIGH frequencies. The results were compared with the TDA3x ISP performance at 212.8 MHz operation. The ISP efficiency for single pass WDR was found to be approximately 94%.

**Table 5. ISS ISP Performance and Efficiency at Different Operating Frequencies**

ISS frequency (MHz)	Freq Ratio	Single Pass WDR Time (ms)	Single Pass WDR Mpix/s	ISP Efficiency	Max Number of 1080p30 channels	Headroom (ms) in 33 ms
212.8	0%	10.4	199.38	94%	3	1.8
354	66%	6.2	334.45	94%	5	2
425.6	100%	5.2	398.77	94%	6	1.8
532	150%	4.15	499.66	94%	7	3.95

**3.1.2 Simcop Memory-to-Memory Lens Distortion Correction**

The lens distortion correction operation involves reading the input distorted frame based on a mesh table input that maps the input block to output blocks. The LDC read interface is used to read the input image and mesh table. The SIMCOP DMA is used to write out the output blocks to DDR. The data flow is shown in Figure 12.



**Figure 12. Single Channel SIMCOP LDC Operation**

The block size of the output frame determines the bandwidth degradation for the input LDC bandwidth. The calculation of the degradation factor can be understood with the example in Table 6.

**Table 6. Calculating the LDC Bandwidth Degradation Factor**

<p><b>Example 1:</b></p> <ul style="list-style-type: none"> <li>• 64x8 out block will need input block of 74x18 with pix_pad of 5.</li> <li>• After OCP alignment Luma block will be 96x18 Bytes and Chroma block will be 96x9 Bytes.</li> <li>• With this Degradation factor is 3.375 (96*27/(64*8*1.5)).</li> </ul>	
<p><b>Example 2:</b></p> <ul style="list-style-type: none"> <li>• 64x32 out block will need input block of 70x38 with pix_pad of 3.</li> <li>• After OCP alignment Luma block will be 96x38 Bytes and Chroma block will be 96x19 Bytes.</li> <li>• With this Degradation factor is 1.78 (96*57/(64*32*1.5)).</li> </ul>	

The following SIMCOP settings provide the best performance. In all of the SIMCOP based measurements, these settings have been applied. Application developers and ISS driver developers are recommended to set:

- SIMCOP DMA Burst Size = 8 x 128 Bit Burst
- SIMCOP DMA Tags = 0xF
- LDC Read Tags = 0xF

With these settings, the SIMCOP LDC performance was analyzed with a unity mesh table. The parameters shown in [Table 7](#) were used for the analysis:

**Table 7. LDC Parameters for Unity Mesh Table Based Performance Analysis**

LDC Parameter	LDC Parameter Value
Input Width	1920
Input Height	1088
Output Width	1920
Output Height	1088
Output Block Width	64
Output Block Height	32
Pixel Pad	3
Interpolation	Bi-Cubic / Bi-Linear
LDC LUT Downscale factor	4

The SIMCOP performance was analyzed for the different OPPs planned in DRA76x/77x for both Bi-Linear and Bi-cubic interpolation. As expected the Bi-cubic interpolation leads to approximately 50% SIMCOP utilization. [Table 8](#) shows the detailed analysis for Bilinear Interpolation and [Table 9](#) shows the Bicubic interpolation. These provide the best case SIMCOP LDC efficiency.

**Table 8. SIMCOP LDC Bi-Linear Interpolation Performance for Unity Mesh**

ISS Frequency (MHz)	Frequency Ratio	LDC Time (ms) (Bi-linear)	Standalone LDC (Unity Mesh) Mpix/s (BiLinear)	Efficiency	Max Number of 1080p30 Channels	Headroom (ms) in 33 ms
212.8	0%	10.00	207.36	97%	3	3
354	66%	6.02	344.22	97%	5	2.88
425.6	100%	5.03	412.66	97%	6	2.85
532	150%	4.02	516.33	97%	8	0.872

**Table 9. SIMCOP LDC Bi-Cubic Interpolation Performance for Unity Mesh**

ISS frequency (MHz)	Freq Ratio	LDC Time (ms) (Bicubic)	LDC Mpix/s (Bicubic)	Efficiency	Max Number of 1080p30 Channels	Headroom (ms) in 33 ms
212.8	0%	19.82	104.62	49%	1	13.18
354	66%	11.9	174.25	49%	2	9.2
425.6	100%	10	207.36	49%	3	3
532	150%	8.85	234.31	44%	3	6.45

Analysis was also performed with a valid mesh table. For the Valid mesh table analysis the output block width, block height and pixel pad were set to 32, 36 and 2 respectively. The impact in [Table 10](#) is visible with Bi-linear interpolation where the efficiency drops from 97% to 93%.

**Table 10. SIMCOP LDC Performance With a Valid Mesh Table**

Condition	ISS Frequency (MHz)	LDC Time (ms)	LDC Mpix/s	Efficiency	Max Number of 1080p30 Channels	Headroom (ms) in 33 ms	Average Bandwidth (MBps)
LDC Bi-linear Interpolation	532	4.20	493.71	93%	7	3.6	1917.45
LDC Bi-cubic Interpolation	532	7.94	261.16	49%	4	1.24	1049.98

The bandwidth profile for a valid mesh table bi-linear interpolation is shown in Figure 13 and Figure 14.

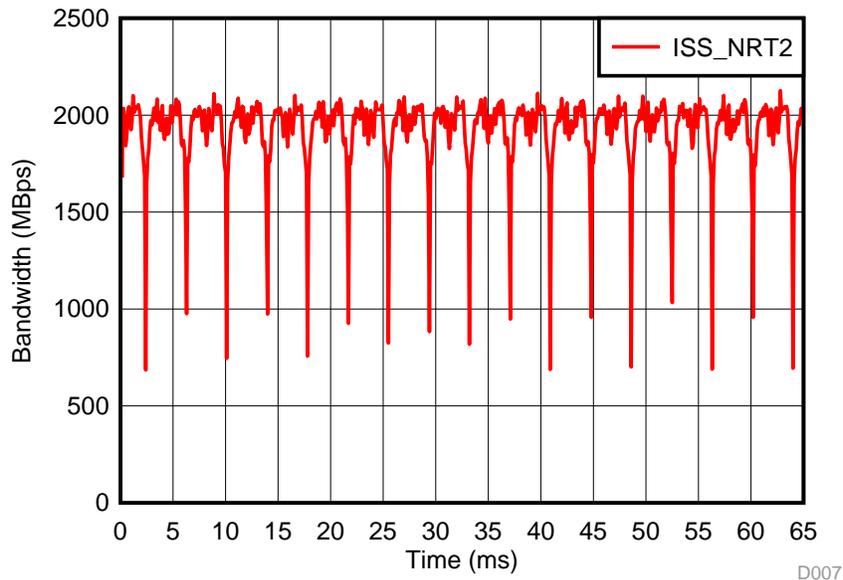


Figure 13. Bilinear Interpolation Bandwidth Profile With a Valid Mesh Table at 532 MHz ISS Operation

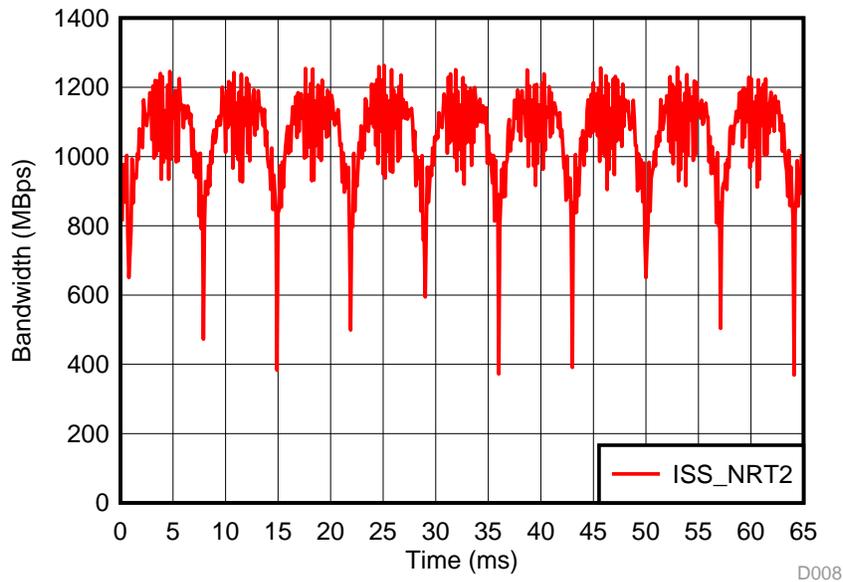


Figure 14. Bi-Cubic Interpolation Bandwidth Profile With a Valid Mesh Table at 532 MHz ISS Operation

### 3.1.3 ISS Performance With Multiple Initiators

In this section, the impact of other initiator traffic on the ISS performance is discussed when they are running simultaneously. The following additional initiators were enabled, as shown in [Table 11](#).

**Table 11. ISS Multi-Initiator Bandwidth Analysis**

Initiator	Initiator Bandwidth (Mbps)	Remarks
ISP	1488.47	RAW to YUV420
BB2D	1959.07	SGX 3D Synthesis (Output RGB24)
DSS	360.63	
EDMAs	449.25	Loading EDMA traffic
MPU	1088.25	A15 mem copy loading traffic.
Total	5345.67	

The impact of the other initiators on the ISP Single Pass WDR performance was measured in terms of increase in the frame processing time, decrease in the efficiency and overall Mpix/second processing. The results are as shown in [Table 12](#).

**Table 12. Impact of System Traffic on ISP Single Pass WDR Performance**

Condition	ISS Frequency (MHz)	Single Pass WDR Time (ms)	Single Pass WDR Mpix/s	Efficiency	Max Number of 1080p30 Channels	Headroom (ms) in 33 ms
Standalone ISP	532	4.15	499.66	94%	7	3.95
With System Traffic	532	4.45	465.98	88%	7	1.85

Lens distortion correction with Bi-linear interpolation was further added to this multi-initiator traffic to analyze the impact of system traffic on the LDC performance. It was found due to the 2D block access nature of the LDC read and Simcop DMA writes, there is significant impact of system traffic on LDC performance. Typical measures that can be used to mitigate these are:

- Place a Bandwidth regulator on the NRT2 port to give required priority to the LDC traffic.
- Place the mesh table data on the OCMC RAM of the device to reduce LDC traffic contention at the DDR.

---

**NOTE:** In the DRA76x/77x integration, the NRT1 and NRT2 ports have the same number of L3 switch hops. Thus unlike TDA3xx the swapping of NRT1 and NRT2 does not give any noticeable benefit in terms of bandwidth performance.

---

**Table 13. Impact of System Traffic on LDC Performance**

Condition	LDC Time (ms) (Bi-linear)	LDC Mpix/s (Bi-Linear)	Efficiency	Max Number of 1080p30 Channels	Headroom (ms) in 33 ms
LDC Only <sup>(1)</sup>	4.20	493.71	93%	7	3.6
LDC + Single Pass WDR <sup>(2)</sup>	4.36	475.60	89%	7	2.48
With Other System Traffic <sup>(3)</sup>	5.80	357.52	67%	5	4
With Other System Traffic (BR on NRT2 = 1600 MBps) <sup>(4)</sup>	5.40	384.00	72%	6	0.6

(1) Standalone, no other initiators

(2) SIMCOP + ISP Traffic

(3) Just by adding LDC to SRV traffic. Overall DDR traffic = 5.217 GBps

(4) Bandwidth regulator enabled on NRT2 port. Overall DDR traffic = 5.15 GBps. Swapping NRT1 and NRT2 does not make any difference (expected as the L3 switch levels are the same).

#### 4 EMIF EDMA Performance

The DRA76x/77x EMIF controller and DDR PHY have the following enhancements with respect to the TDA2xx EMIF controller and PHY:

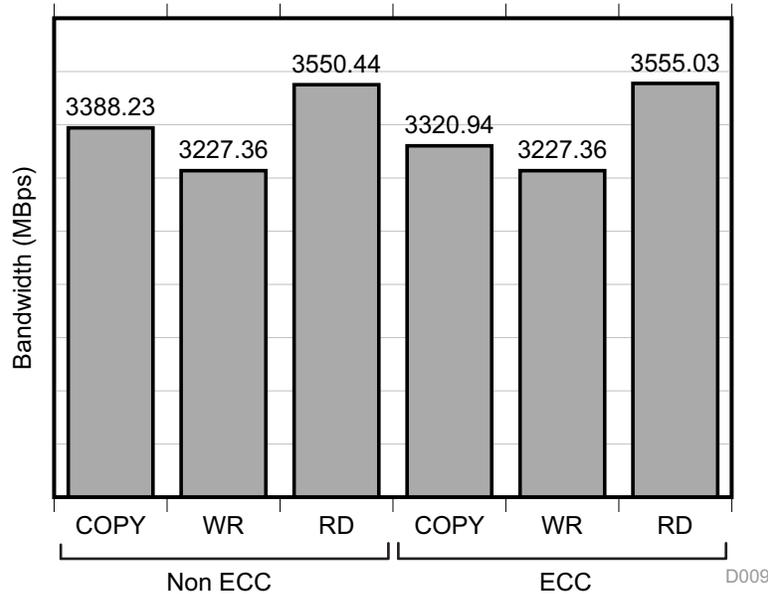
- Support for 666 MHz DDR3 clock
- Optimized Command and Write Data FIFO sizing (see [Table 14](#))
- ECC Read Modify write support

**Table 14. EMIF FIFO Sizing Differences Between DRA76x/77x**

Parameter	TDA2xx		DRA76x/77x	
	System Local Interface Entries	MPU Local Interface Entries	System Local Interface Entries	MPU Local Interface Entries
Pre Command FIFO	6	4	6	4
Command FIFO	Up to 10	Up to 10	Up to 16	Up to 16
Pre Write FIFO	6	8	10	12
RMW FIFO	NA	NA	Up to 16	Up to 16
Write Data FIFO	(256-bit) Up to (19 × 256 bits) + 6	Up to 19 + 8	Up to (16 × 256 bits)	Up to 16
Return Command FIFO	22	24	22	24
SDRAM Read Data FIFO	22	24	22	24
Register Read Data FIFO	2	0	2	0
RMW Read Data FIFO	NA	NA	Up to 16	Up to 16

To understand the impact of the difference between DRA76x/77x EMIF performance, a 2 TC EDMA transfer was performed.

The effect of ECC transfers versus non ECC transfers was analyzed and the results show that the performance between ECC and non ECC transfers is comparable.



**Figure 15. EDMA 2 TC ECC vs Non ECC Performance @ 532 MHz**

In another experiment to understand the impact of the frequency upgrade from 532 MHz to 666 MHz along with the FIFO sizing changes, the partial IVI usecase was run and additional EDMA load was run in parallel to keep the EMIF FIFOs fully occupied to analyze the EMIF behavior. More details regarding the IVI traffic are discussed in [Section 5](#). As can be seen in [Table 15](#), with a frequency scaling of 532 MHz to 666 MHz (approximately 25%), an equivalent performance gain 5486.26 MBps to 6863.22 MBps (approximately 25%) is achieved.

**Table 15. DRA76x/77x EMIF Performance Analysis @ 532 MHz and @ 666 MHz**

Expt Name	TDA2Px-DDR3 @ 532 MHz	TDA2Px-DDR3 @ 666 MHz
EMIF1_SYS (MBps)	2045.97	2799.14
EMIF2_SYS (MBps)	2046.54	2790.17
MA_MPU_P1 (MBps)	696.62	634.85
MA_MPU_P2 (MBps)	697.13	639.06
Total DDR BW	5486.26	6863.22
Efficiency	64.5%	64.4%

To stretch the DRA76x/77x device to its limit, the EDMA transfers were increased until DSS started underflowing. Since the IVI real time DSS traffic requirement is high, in this experiment the DSS would underflow due to L3 limits. This analysis gave insight into the maximum EMIF performance available by maximizing the EMIF FIFO usage. In this configuration, [Table 16](#) gives the relative performance between DRA76x/77x EMIF and TDA2XX EMIF both operating at 532 MHz.

**Table 16. DRA76x/77x EMIF Performance vs TDA2xx @ 532 MHz**

Expt Name	TDA2Px-EMIF @ 532 MHz	TDA2xx EMIF @ 532 MHz
EMIF1_SYS (MBps)	2496.503864	2002.71136
EMIF2_SYS (MBps)	2493.411011	1985.6016
MA_MPU_P1 (MBps)	396.9076276	720.65952
MA_MPU_P2 (MBps)	395.2099299	719.42016
Total DDR BW	5782.032432	5428.39264
Efficiency	67.9%	63.8%

## 5 IVI Usecase Performance

In an automotive infotainment system, DRA76x/77x can be used as either the main processor in the head-unit (Integrated Head Unit) or co-processor (either the applications (HMI)-processor or a co-processor (for radio, audio)). Infotainment system requires a rich set-of high-level OS, high-resolution multi-display, camera input, navigation, speech, radio, multimedia, and connectivity support.

DRA76x/77x extends the target use cases for TDA2x. The list of planned usecases for IVI is given in [Table 17](#).

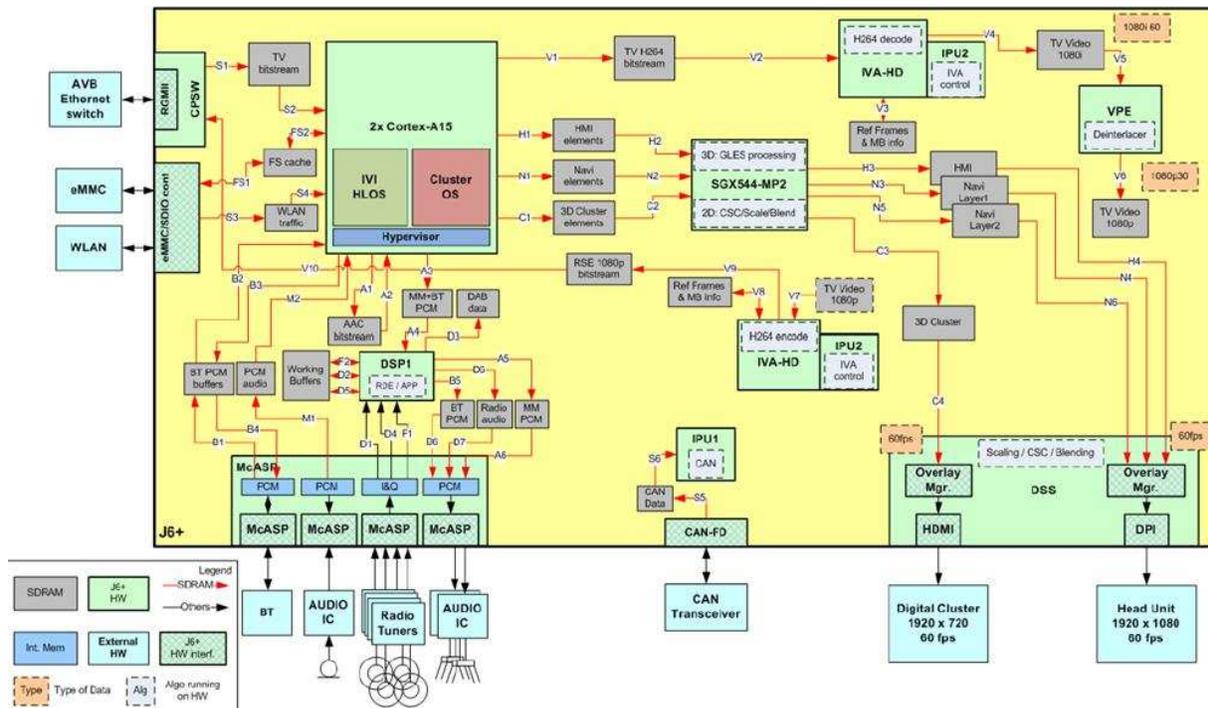
**Table 17. IVI Usecases and Different Initiator Roles**

	2xA15	GPU	IPU2 + IVA-HD + VPE Decode	IPU2 + IVA-HD Encode	C66x DSPs / EVEs	IPU1
UC1 (Highway Driving + Dual-Navi + Media): Infotainment + Cluster Info	HLOS, HMI, Nav (main disp.) + Nav (info disp.), Connectivity, and so forth.	HMI, Nav (maps on both displays)	1080i-60 decode DTV w/external decoder De-Interlace 1x 1080i60 (for RSE display)	1080p30 encode (for remote eAVB display)	Audio mixing & routing	CAN stack
UC2 (Highway Driving + Projection + Navi + Media): Infotainment + Cluster Info + Multi- DAB Radio	HLOS, Projection mode, HMI, Nav (info disp.), Connectivity, etc.	HMI, Nav	Phone projection mode: 1080p30 decode	1080p30 encode (for remote CE device over WiFi)	Multi DAB Radio + Audio mixing & routing	CAN stack
UC3 (Street Driving + Navi + 2D Surround-view, or LDW/TSR/OD): Infotainment + Cluster Info + Multi- DAB Radio + Info ADAS or Driver Monitoring	HLOS, HMI, Nav, Connectivity, and so forth.	HMI, Nav	1080i-60 decode DTV w/external decoder De-Interlace 1x 1080i60 (for CE device, or RSE display)	1080p30 encode (for remote CE device over WiFi), OR Car black-box encoding (recording at least 2 cameras – front/back: 720p resolution)	InfoADAS (2D SRV + OD/PD) (or LDW + TSR + OD/PD, or Driver monitor.) + Multi DAB Radio + Audio mixing & routing	CAN stack
UC4 (3D SRV w/ Park Assist): Infotainment + Cluster Info + Dual DAB Radio	HLOS, HMI, 3D SRV (main disp.) + Cluster Info (info disp.), Connectivity, and so forth.	HMI, 3D SRV processing			3D SRV + Park Assist + Multi-DAB Radio + Audio mixing & routing	

Table 17. IVI Usecases and Different Initiator Roles (continued)

	2xA15	GPU	IPU2 + IVA-HD + VPE Decode	IPU2 + IVA-HD Encode	C66x DSPs / EVEs	IPU1
UC5 (Street Driving w/ 3D SRV + Navi + Media): Infotainment + Cluster Info + Multi- DAB Radio	HLOS, HMI, 3D SRV (main disp.) + Nav (info disp.), Connectivity, and so forth.	HMI, 3D SRV processing, Nav	1080i-60 decode DTV w/external decoder De-Interlace 1x 1080i60 (for RSE display)	1080p30 encode (for remote eAVB display) OR Car black-box encoding (recording at least 2 cameras – front/back: 720p resolution)	3D SRV + Multi-DAB Radio + Audio mixing & routing	CAN stack
UC6 (Integrated Cockpit + Navi + Media): Infotainment + Digital Cluster	Hypervisor, IVI HLOS, Cluster OS, Nav, Connectivity	HMI, Nav, & Digital Cluster	1080i-60 decode DTV w/external decoder De-Interlace 1x 1080i60 (for RSE display)	1080p30 encode (for remote eAVB display)	Audio mixing & routing	CAN stack
UC7 (Integrated Cockpit + Navi + Media + Radio): Infotainment + Digital Cluster + Dual DAB Radio	Hypervisor, IVI HLOS, Cluster OS, Nav, Connectivity	HMI, Nav, & Digital Cluster	1080i-60 decode DTV w/external decoder De-Interlace 1x 1080i60 (for RSE display)	1080p30 encode (for remote eAVB display)	Dual DAB Radio + Audio mixing & routing	CAN stack

The UC7 IVI usecase is the heaviest with respect to bandwidth requirements. A summary of the data flow as a part of UC7 is as shown in Figure 16.



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Figure 16. UC7 (Integrated Cockpit + Navi + Media + Radio)

A summary of the top three worst case bandwidth IVI usecase requirements are listed in [Table 18](#)

**Table 18. Top Three Worst Case Bandwidth Requirements for IVI**

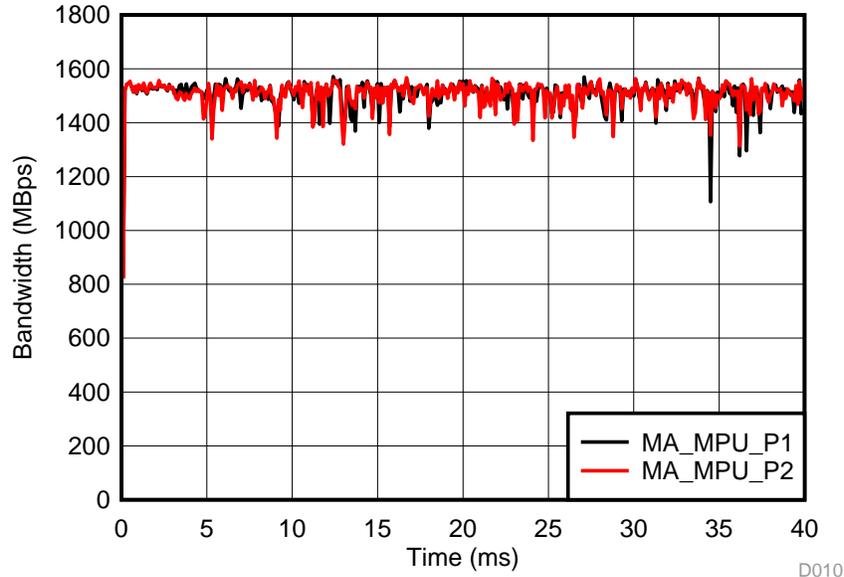
Initiator	IVI UC Traffic Requirement		
	UC5	UC6	UC7
MPU	678.8	1280.8	1280.8
GPU	2217.31	2103.72	2103.72
DSP	227.56	2.54	61.67
IVA	1348.43	1348.43	1348.43
CAL	165.69	0	0
DSS	1168.13	1426.64	1426.64
VPE	466.56	466.56	466.56
Misc	33.90858	32.03222	33.03422
Total	6306.389	6660.722	6720.854

The following subsections discuss the different configurations used for each initiator to generate the overall IVI UC7.

### 5.1 MPU CPU Traffic

The Cortex A15 is responsible for generating OS traffic, TV Bit stream Out, Modem/WiFi data Out, TV AAC stream In, BT SCO Audio, Microphone Audio, Filesystem transfers in the UC7. In order to mimic this, A15 was configured to perform memory copy transfers with MPU I-Cache and D-Cache enabled. Hardware default A15 configurations were used to get optimal performance.

In the standalone mode, the MPU was found to generate a total average bandwidth of 3011.5 MBps.

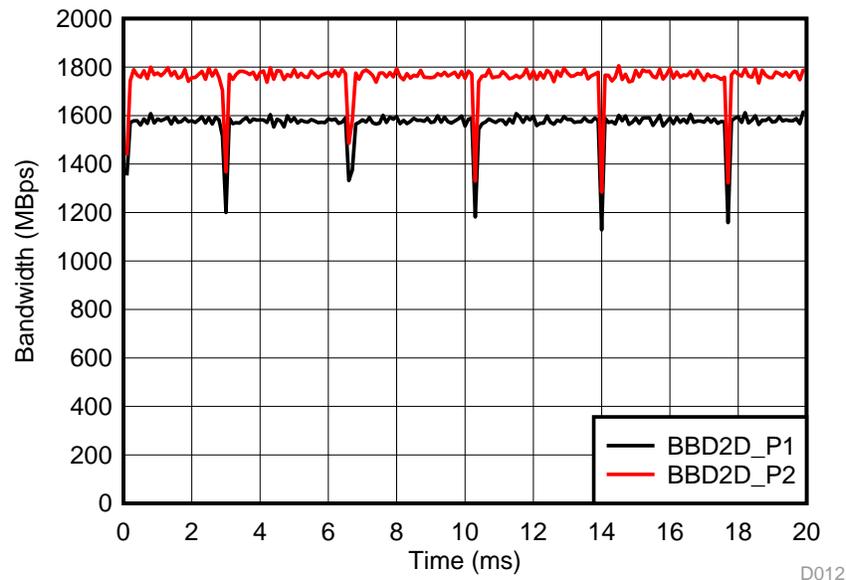


**Figure 17. MPU (Standalone) OS Mimic Memory Copy Performance Bandwidth Plot**

## 5.2 Graphics Processing Traffic

The GPU is responsible for generating the HMI, Navigation and the 3D cluster graphics as a part of IIVI UC7. GPU programming is tightly coupled with Linux OS. In the non-OS based test, the GPU traffic was mimicked by the BB2D 2D graphics engine which has a relatively similar access pattern compared to other initiators and also connects to the same L3 switch fabric as the GPU. The BB2D was configured to perform a 4 layer 1080p YUV420 overlay.

With the BB2D processing such frames back to back the total average bandwidth was measured to be 3306 MBps in the standalone mode.



D012

**Figure 18. BB2D (Standalone) Graphics Mimic Performance Bandwidth Plot**

## 5.3 Display Traffic

The display traffic as a part of UC7 is listed below:

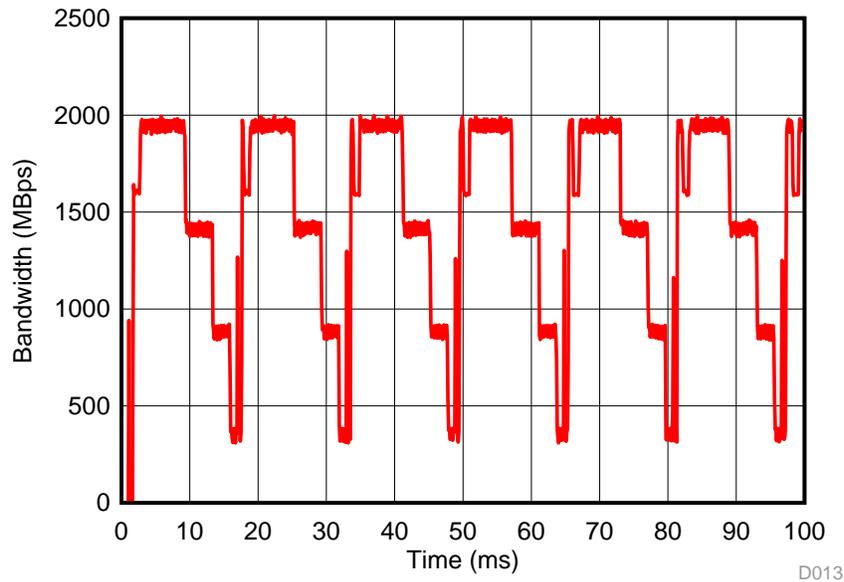
- One Video output (1920x1080 @ 60 FPS) with the blend of the following three:
  - DSS read of HMI (Keyboard layer) Buf (Display1) @ 60fps (1920x826) - 4 BPP
  - DSS read of Navi Layer1 Buf (Display1) @ 60fps (1920x543) - 4 BPP
  - DSS read of Navi Layer2 Buf (Display1) @ 60fps (1920x1007) - 4 BPP
- Second Video output (1920x720 @ 60 FPS) with following:
  - DSS read of 3DCluster (1920x720) for Display2 @ 60 fps- 4 BPP

In order for such high real-time display traffic to be supported without sync losses and underflows, the following settings are recommended:

- BURSTSIZE = 8 x 128-bit bursts
- BUFPRELOAD = 1 (Hardware pre-fetches pixels up to high threshold value)

With the above settings in place the DSS was able to achieve an average bandwidth of 1445.56 MBps without any underflows and sync losses.

The DSS bandwidth profile for this configuration is shown in [Figure 19](#).



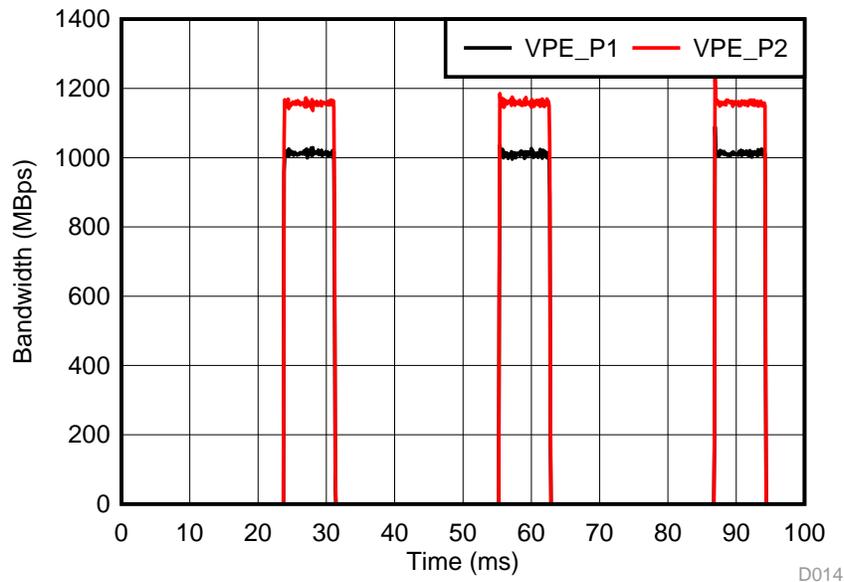
**Figure 19. DSS Standalone Bandwidth Profile for IVI Usecase Traffic**

#### 5.4 VPE Processing Traffic

The Video Processing engine is responsible for de-interlacing 1080i decoded streams of YUV420 to generate progressive 1080p YUV420 stream at 30 FPS.

In this operation the VPE traffic in standalone mode was found to be on an average 485.69 MBps with peak traffic of 2194 MBps. In the sequent sections we will see how placing a BW limiter on the VPE ports will enable the DSS traffic to not underflow when all the initiators are executed together.

The VPE standalone BW profile is as shown in [Figure 20](#).

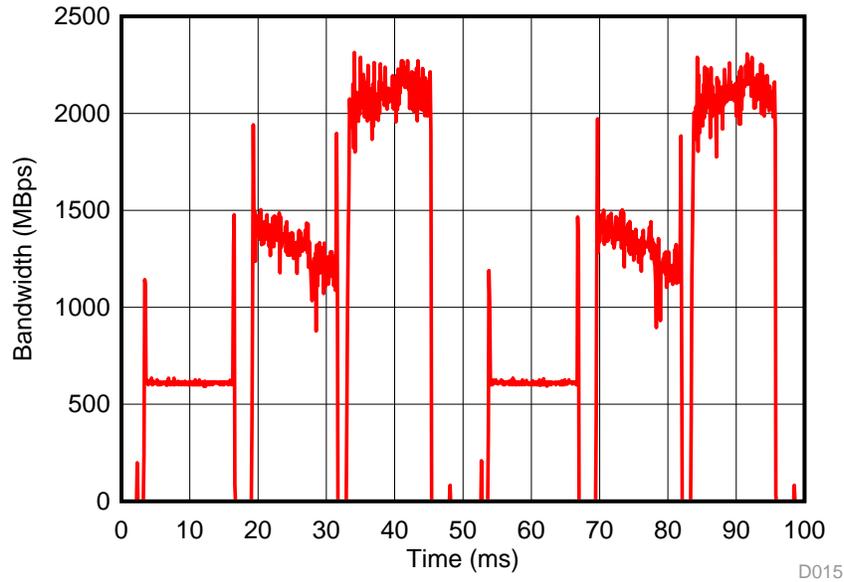


**Figure 20. VPE Standalone Bandwidth Profile for IVI Usecase**

### 5.5 IVAHD Decode Traffic

The IVI UC7 requires decoding 2 1080i60 TV streams and encoding one 1080p30 encode. In order to mimic this traffic a standalone codec decoder client application was run to decode a continuously looping I, P, B and B frames. The choice of the decoded sequence was such that the IVA bandwidth requirement was close to requirement.

With the stream HD\_CR\_KyuRyu.264, the IVA average bandwidth for decode was found to be 1008.2 MBps. The bandwidth profile is as shown in [Figure 21](#).



**Figure 21. IVA Standalone 1080p60 Decode Bandwidth Profile for IVI Usecase**

## 5.6 IVI Usecase Integrated Bandwidth

Once the different initiators from the different sub-experiments were run together with DDR set at 666 MHz, multiple bandwidth knobs had to be employed to ensure the IVI usecase requirements are met with no DSS underflows and in time processing of the video frames. The step-by-step application of bandwidth knobs enable understanding where the system level bottlenecks reside.

**Table 19. BW Knobs to Make IVI UC7 Work on DRA76x/77x**

Expt Name	DDR3 - 666 MHz (DSS Adaptive MFLAG + BB2D BR + No Extra EDMA + max sys = 12 + A15 lower priority)
OCP_CONFIG	0x0C500000
EMIF1_SYS (MBps)	2799.14
EMIF2_SYS (MBps)	2790.17
MA_MPU_P1 (MBps)	634.85
MA_MPU_P2 (MBps)	639.06
Total Avg. DDR BW	6863.21
Avg. Efficiency	64.4%
Remarks	<ol style="list-style-type: none"> <li>1. No DSS Underflows.</li> <li>2. IVA 1080p60, no drops.</li> <li>3. BB2D higher BW (2.6GBps versus 2.1 GBps requirement)</li> <li>4. MPU bandwidth meeting requirement.</li> </ol>
BW Knobs Used	<ol style="list-style-type: none"> <li>1. VPE BW Limiter to both ports (700 MBps).</li> <li>2. DSS Adaptive MFLAG (50%-75% thresholds) + DSS Priority Highest</li> <li>3. BB2D BW Regulator 1000 MBps.</li> <li>4. Sys Threshold kept to 12.</li> <li>5. MPU_MA_PRIORITY = 6</li> </ol>

With respect to the requirement the initiator wise traffic is as given in [Table 20](#).

**Table 20. Initiator Wise Break Down of IVI UC7 Validation**

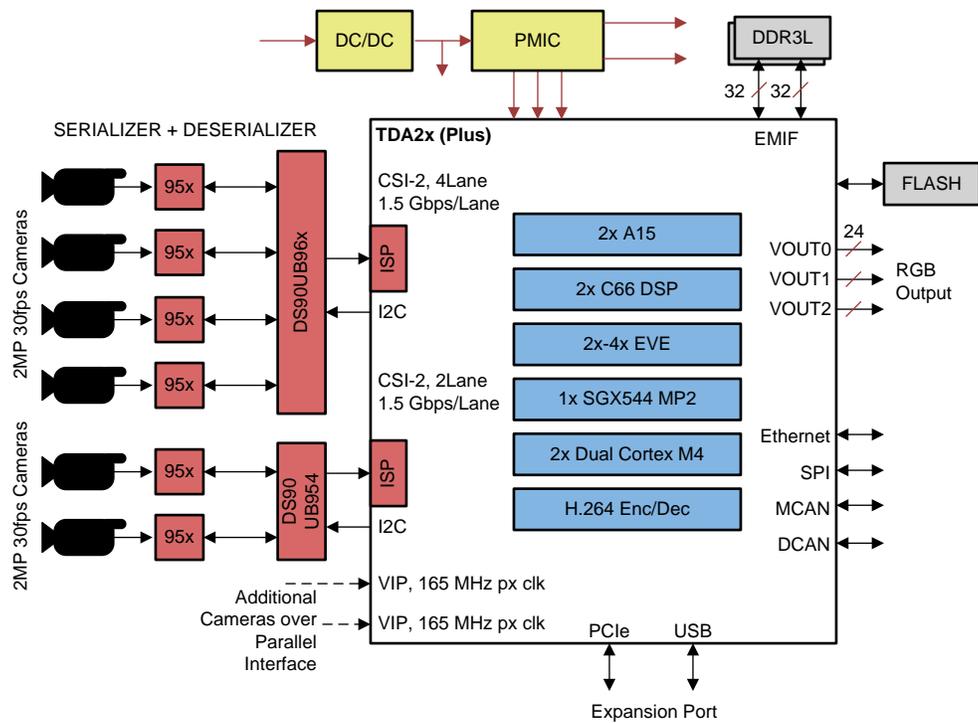
Initiator	UC7 Requirement From UCAD (MBPS)	Test Traffic (MBPS)	Remarks
MPU	1280.8	1273.9	Just short, with realistic GPU traffic, should adjust.
GPU	2103.72	2612.94	Mimic via BB2D 1080p 4 layer overlay. Higher BW likely to absorb DSP and IVA difference.
DSP	61.67	–	
IVA	1348.43	962.08	Mimic via IPBB 1080p60 decode. (Stream: HD_CR_KyuRyu.264)
CAL	0	–	
DSS	1426.64	1477.33	Matched VID/GFX display dimensions, format and pixel clock rate.
VPE	466.56	510.19	
Miscellaneous	33.03422	57.94	IPU CPU traffic
<b>Total</b>	<b>6720.854</b>	<b>6863.218</b>	<b>Approximately 140 MBps higher traffic than requirement</b>

## 6 ADAS Usecase Performance

DRA76x/77x extends the following target use cases:

- ADAS 6-8 Ch smart surround view + CMS – Capture: 6-8 Ch, 2-3ch HD display (2 x 2MP@30/60fps), SRV processing: GPU @665 MHz, Analytics, A15 @500 MHz, IPU1 @ 212 MHz, 2x DSPs, and 2x EVEs. Function: N-view, 3D stitch view for rendering, CMS, Rear View.
- Front Camera Analytics – Analytics: 2x DSP@800(-1000) MHz, and 4x EVE@650(-900) MHz
- Wide Angle or Satellite RADAR Fusion – Analytics: 2xDSP@800 MHz, and 4x EVE@650 MHz

The ADAS 6 Channel Surround view + ISP based system description is as shown in Figure 22. This is primary usecase targeted for ADAS.



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Figure 22. DRA76x/77x Surround View System

The expected bandwidth analysis of the usecase corresponding to 6 channel input and processing is shown in [Table 21](#).

**Table 21. ADAS 6 Channel Surround View + CMS With ISP**

Operation	Type	IP	H	V	BPP	FPS	CH	BW (MB/S)
4x2 MP@30fps capture for SV (WR) RAW	WR	CAL	1920	1080	2	30	4	497.66
ISP read of all SV Channels	RD	ISP	1920	1080	2	30	4	497.66
4x 2MP 30fps capture for SV (WR)	WR	ISP	1920	1080	1.5	30	4	373.25
2x1 MP@60fps capture for CMS (WR) RAW	WR	VIP	1280	720	2	60	2	221.18
ISP read of all SV Channels	RD	ISP	1280	720	2	60	2	221.18
4x 2MP 30fps capture for SV (WR)	WR	ISP	1280	720	1.5	60	2	165.89
SGX 3D Synthesis (Output RGB24)	RD/WR	SGX	1920	1080	3	30	1	1740.00
Display RGB24	RD	DSS	1920	1080	3	30	1	186.62
CMS O/P ( 2 displays)	RD	DSS	1280	720	1.5	60	2	165.89
Deflicker for 2x1MP@60 CMS cameras	RD/WR	IVA+DSP						1000.00
Analytics for 2MP, 3 camera@10fps	RD/WR							1800.00
<b>Total</b>								<b>6869.34</b>

Other variations of the ADAS usecases include:

- ADAS\_4CH\_SRV + ISS: Concurrent execution of the following initiators:
  - CAL\_4\_CHANNEL\_RADAR\_CAPTURE
  - DSS\_3VID\_3VENC
  - GC320 traffic to mimic SGX traffic
  - ISS\_4CH\_ISP\_PROCESSING
  - DSP1 and DSP2 EDMA, EVE EDMA
- ADAS\_7CH\_SRV\_CMS\_UC: Concurrent execution of the following initiators:
  - CAL\_VIP\_7\_CHANNEL\_CAPTURE
  - DSS\_3VID\_3VENC
  - GC320 traffic to mimic SGX traffic
  - DSP1 and DSP2 EDMA, EVE EDMA
- ADAS\_8CH\_SRV\_CMS\_UC: Concurrent execution of the following initiators:
  - CAL\_VIP\_8\_CHANNEL\_CAPTURE
  - DSS\_3VID\_3VENC
  - GC320 traffic to mimic SGX traffic
  - DSP1 and DSP2 EDMA, EVE EDMA

### 6.1 Display Traffic

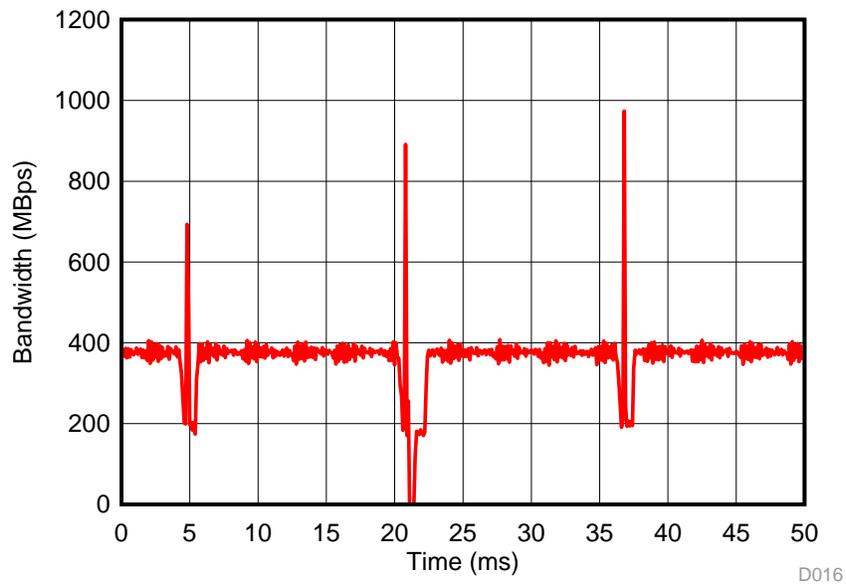
The display traffic as a part of the ADAS usecase is as listed below:

- One display with SV Output RGB888: 1920x1080 @ 3 bpp @ 30 FPS
- Second display CMS Output - 2 Channels: 1280x720 @ 1.5 bpp @ 60 FPS

With YUV420, the DISPC Scaler is enabled automatically (the Scaler is used to convert YUV420 to YUV444 before YUV2RGB conversion). Scaler will request multiple lines at the start from the DMA (to pre-fill the Scaler line buffers), even when the display is in blanking state. This can cause DMA to underflow without any Display sync-lost. This is a harmless condition. To avoid it you can force the DMA to pre-fetch up to the high threshold value (set DISPC\_VID3\_ATTRIBUTES.BUFPRELOAD to '1').

With the above settings in place the DSS was able to achieve an average bandwidth of 363.87 MBps without any underflows and sync losses.

The DSS bandwidth profile for this configuration is shown in [Figure 23](#).



**Figure 23. DSS Standalone Bandwidth Profile for IVI Usecase Traffic**

## 6.2 ADAS 6 Channel + ISP Integrated Bandwidth

Once the different initiators from the different sub-experiments were run together with DDR set at 666 MHz, multiple bandwidth knobs had to be employed to ensure the ADAS usecase requirements are met with no DSS underflows and in time processing of the frames. The step-by-step application of bandwidth knobs enable understanding where the system level bottlenecks reside.

**Table 22. BW Knobs to Make ADAS 6Ch SRV + ISP Work on DRA76x/77x**

Expt Name	DDR3 - 666 MHz (ISP + DSP1 + EVE + BL & BR on BB2D + MPU Lower)
OCP_CONFIG	0xC500000
Avg. EMIF1_SYS (MBps)	3587.231926
Avg. EMIF2_SYS (MBps)	3589.380462
Avg. MA_MPU_P1 (MBps)	208.1853929
Avg. MA_MPU_P2 (MBps)	207.546379
Total Average DDR BW	7592.34
Avg. Efficiency	71.2%
Peak. Total DDR BW (MBps)	7907.84
Peak Efficiency	74.2%
Remarks	<ol style="list-style-type: none"> <li>1. DSS not underflowing (YUV420)</li> <li>2. CAL no overflows.</li> <li>3. DMA traffic block based (128x128) - 3 GBps.</li> <li>4. ISP 6 Channel Single Pass WDR completes in time.</li> <li>5. BB2D Traffic just meeting requirement. (1.67 GBps)</li> </ol>
BW Knobs Used	<ol style="list-style-type: none"> <li>1. DSS Adaptive MFLAG (50%-75% thresholds) + High Priority + BUFPRELOAD = 1</li> <li>2. BB2D BW Limiter 1100 MBps and BB2D BW Regulator 900 MBps</li> <li>3. MPU_MA_PRIORITY = 6</li> <li>4. CAL Adaptive MFLAG (25%-75% thresholds)</li> <li>5. Sys Threshold = 12</li> </ol>

The DMA traffic was tuned further to be block based and further ISP traffic was added. With further settings of DSS BufPreload = 1, DSS dynamic MFLAG and priority, EMIF OCP\_CONFIG, and appropriate MPU priority the ADAS usecase goals were met.

With respect to the requirement, the initiator wise traffic is given in [Table 23](#).

**Table 23. Initiator Wise Break Down of ADAS 6Ch SRV + ISP Validation**

Initiator	Expected BW (MB/S)	Test Case BW	Remarks
CAL	718.85	749.15	6x2 MP@30fps capture for SV (WR) RAW
ISP	1257.98	1279.47	RAW to YUV420
GPU	1740.00	1666.27	SGX 3D Synthesis (Output RGB24) - Slightly lower bandwidth can be traded off with EDMA traffic in real system.
DSS	352.51	371.20	YUV 420 BUFPRELOAD = 1
EDMAs	2800	3010.56	Approximately 200 MBps higher than required
MPU	-	415.73	Extra traffic in the system
<b>Total</b>	<b>6869.34</b>	<b>7492.38</b>	<b>Approximately 623.03 MB higher traffic than requirement</b>

### 6.3 ADAS 4 Channel SRV + ISP Integrated Bandwidth

With the settings found during the 6 Channel ADAS SRV + ISP bandwidth analysis the 4 Channel ADAS SRV + ISP was analyzed. The expected bandwidth in this configuration is given in [Table 24](#).

**Table 24. ADAS 4 Channel SRV + ISP Expected Bandwidth Analysis**

Operation	Type	IP	H	V	BPP	FPS	CH	BW (MB/S)
4x2 MP@30fps capture for SV (WR) RAW	WR	CAL	1920	1080	2	30	4	497.66
ISP read of all SV Channels	RD	ISP	1920	1080	2	30	4	497.66
4x 2MP 30fps capture for SV (WR)	WR	ISP	1920	1080	1.5	30	4	373.25
SGX 3D Synthesis (Output RGB24)	RD/WR	SGX	1920	1080	3	30	1	1740.00
Display RGB24	RD	DSS	1920	1080	3	30	1	186.62
Analytics for 2MP, 3 camera@10fps	RD/WR							1800.00
<b>Total</b>								<b>5095.20</b>

With no CAL or VIP overflows and no DSS underflows the initiator wise break down of bandwidth is as shown in [Table 25](#).

**Table 25. Initiator Wise Break Down of ADAS 4Ch SRV + ISP Validation**

Initiator	Expected BW (MB/S)	Test Case BW (MB/s)	Remarks
Capture	497.66	436.33	4x2 MP@30fps capture for SV (WR) 12 bit packed data captured at higher FPS.
ISP	870.91	874.72	RAW to YUV420
GPU	1740.00	1762.65	SGX 3D synthesis (Output RGB24)
DSS	186.62	371.20	6 channel DSS configuration used. Higher than required bandwidth
EDMAs	1800.00	3316.82	Approximately 1.5 GBps higher than required
MPU	-	510.19	Extra traffic in the system
Total	5095.20	7271.91	Approximately 2.17 GBps higher traffic than requirement

## 7 References

- [DRA75xP, DRA74xP, DRA77xP, DRA76xP SoC for Automotive Infotainment Silicon Revision 1.0 Technical Reference Guide](#)

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