INTEL ARRIA 10 GX DEV KIT
PCIE GEN3x8 DMA
ON NVIDIA XAVIER SYSTEM

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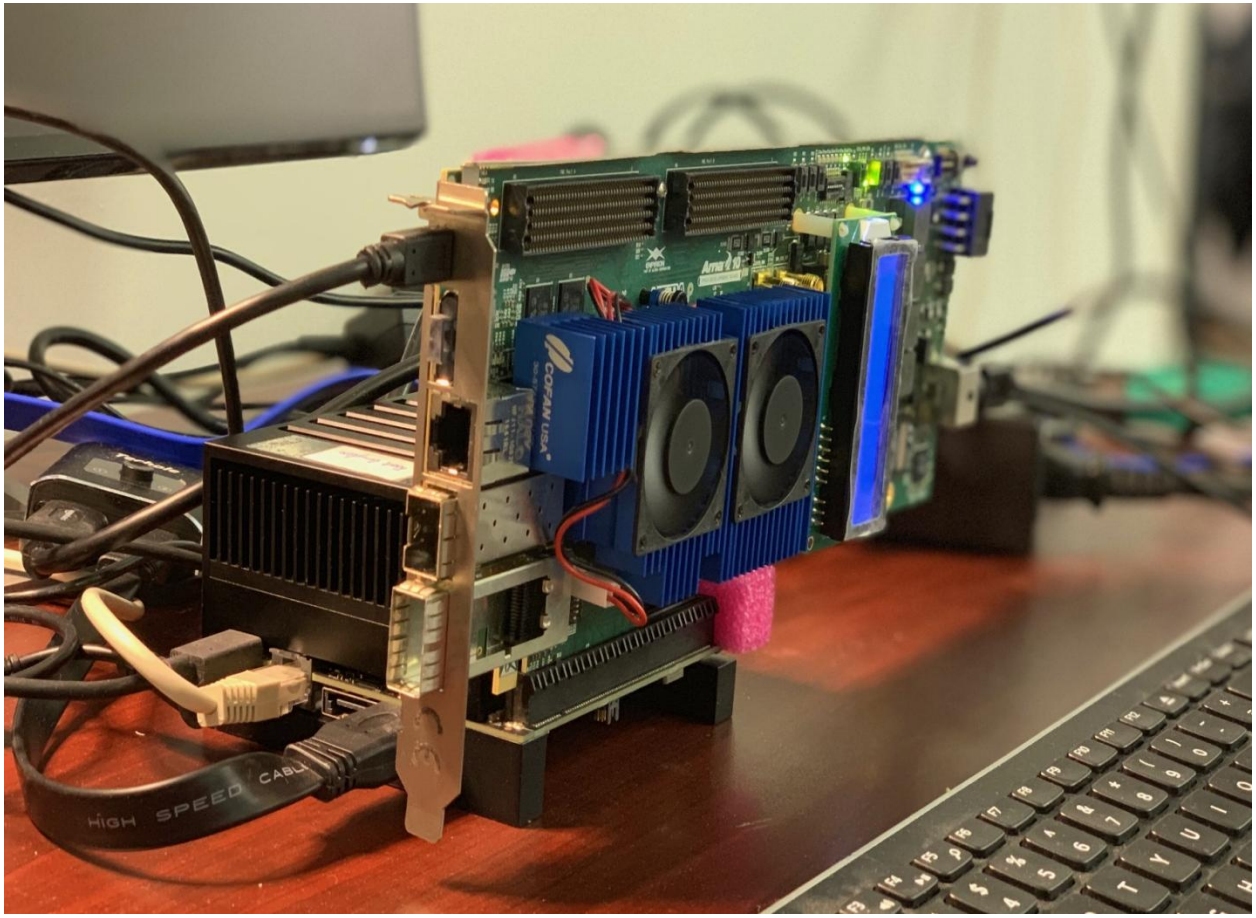
INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **System Set-Up**

1. Nvidia Jetson Xavier PCIe Root Port
2. FPGA ARRIA 10 GX Dev Kit
3. OS: Ubuntu 18.04 Release tegra-l4t-r32.2.0
4. Quartus Prime Pro 19.2



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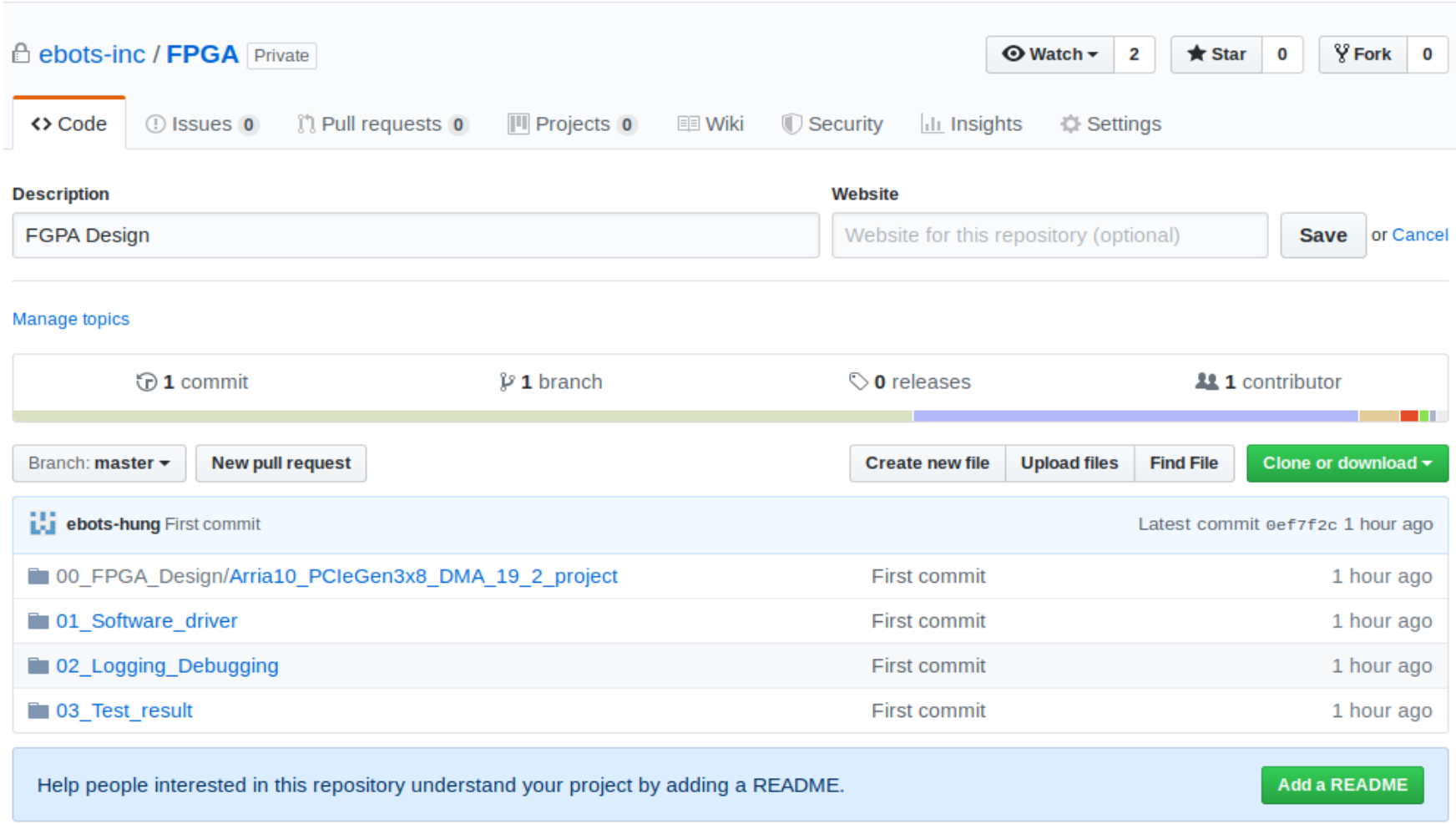
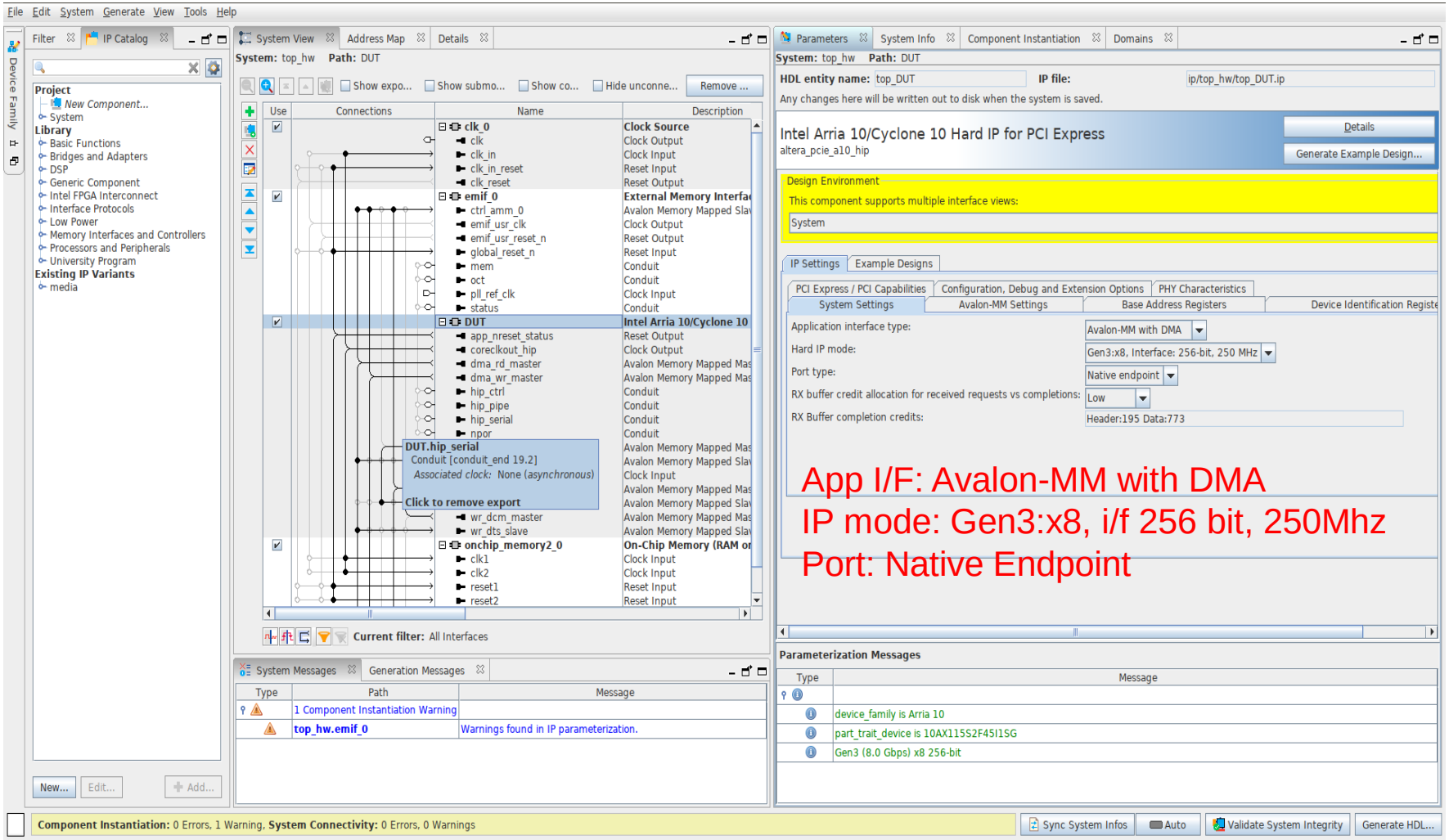
- **GITHUB – Configuration Management**



https://github.com/ebots-inc/FPGA

INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **FPGA – Hard IP PCIE Configuration**



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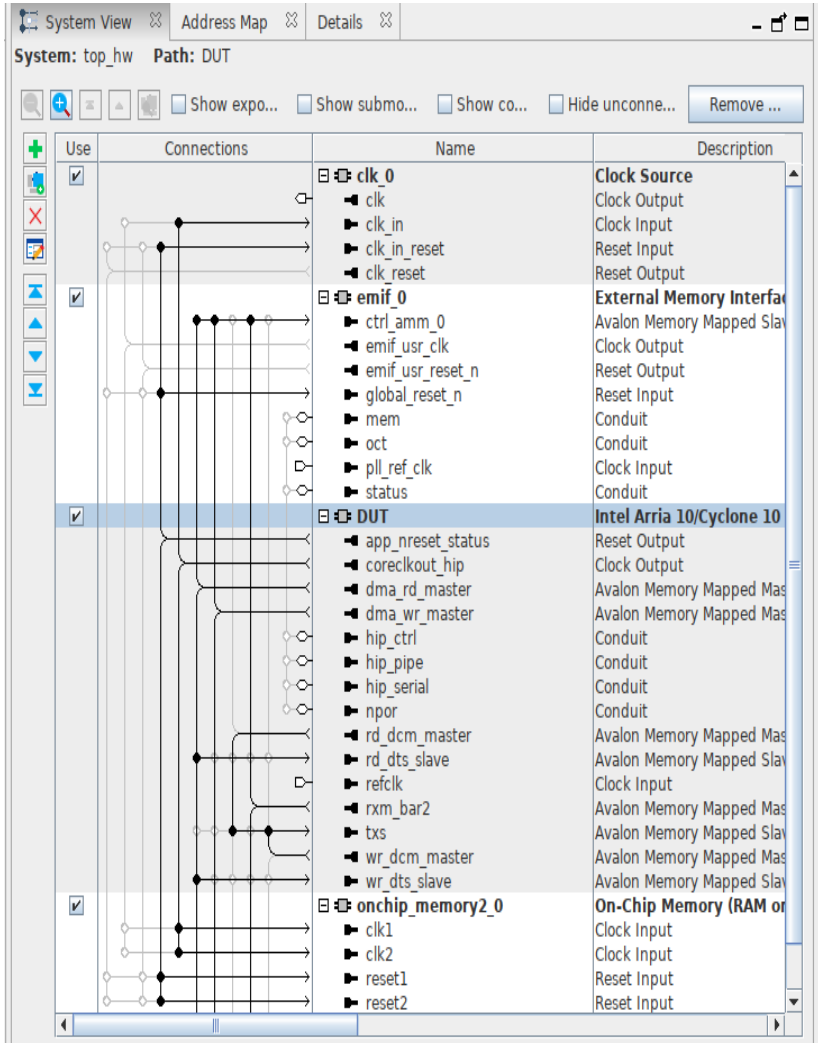
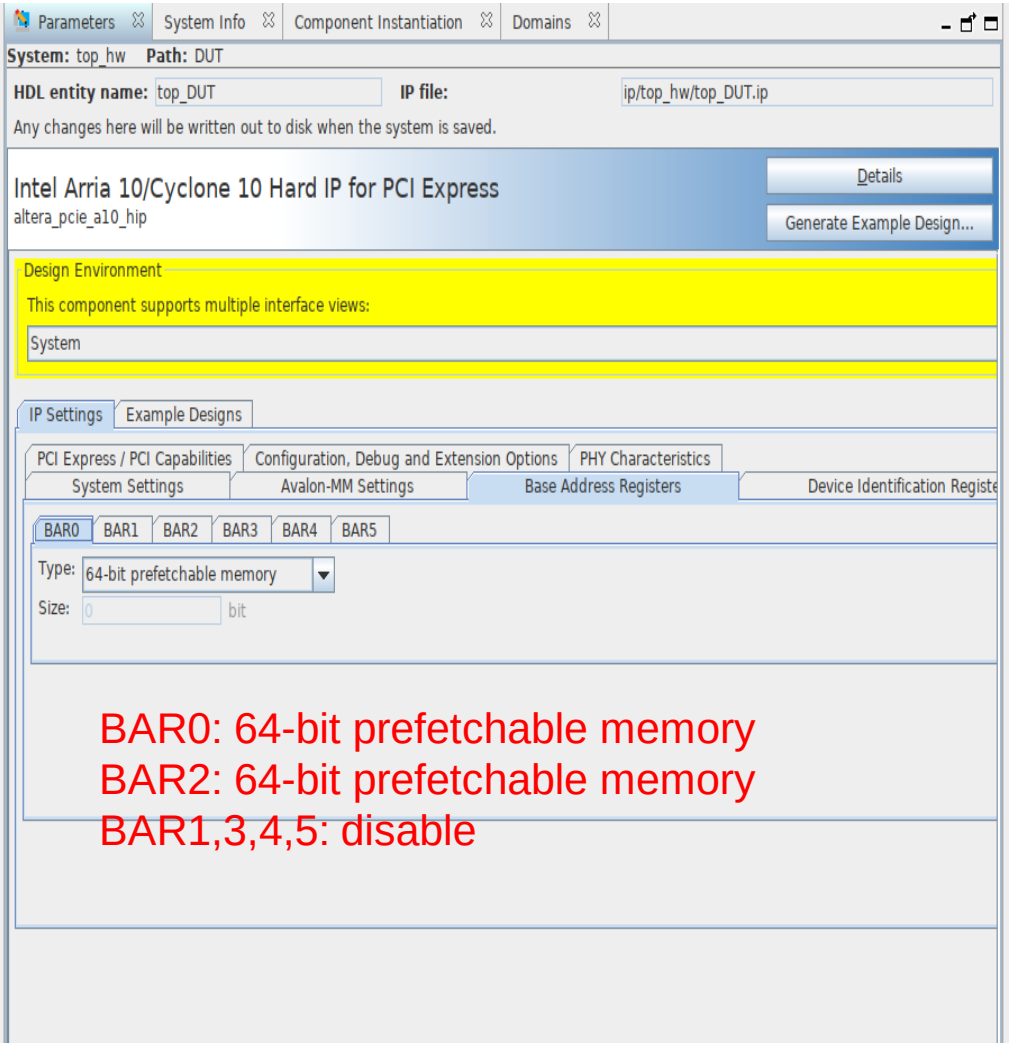
- **FPGA – Hard IP PCIE Configuration (cont.)**





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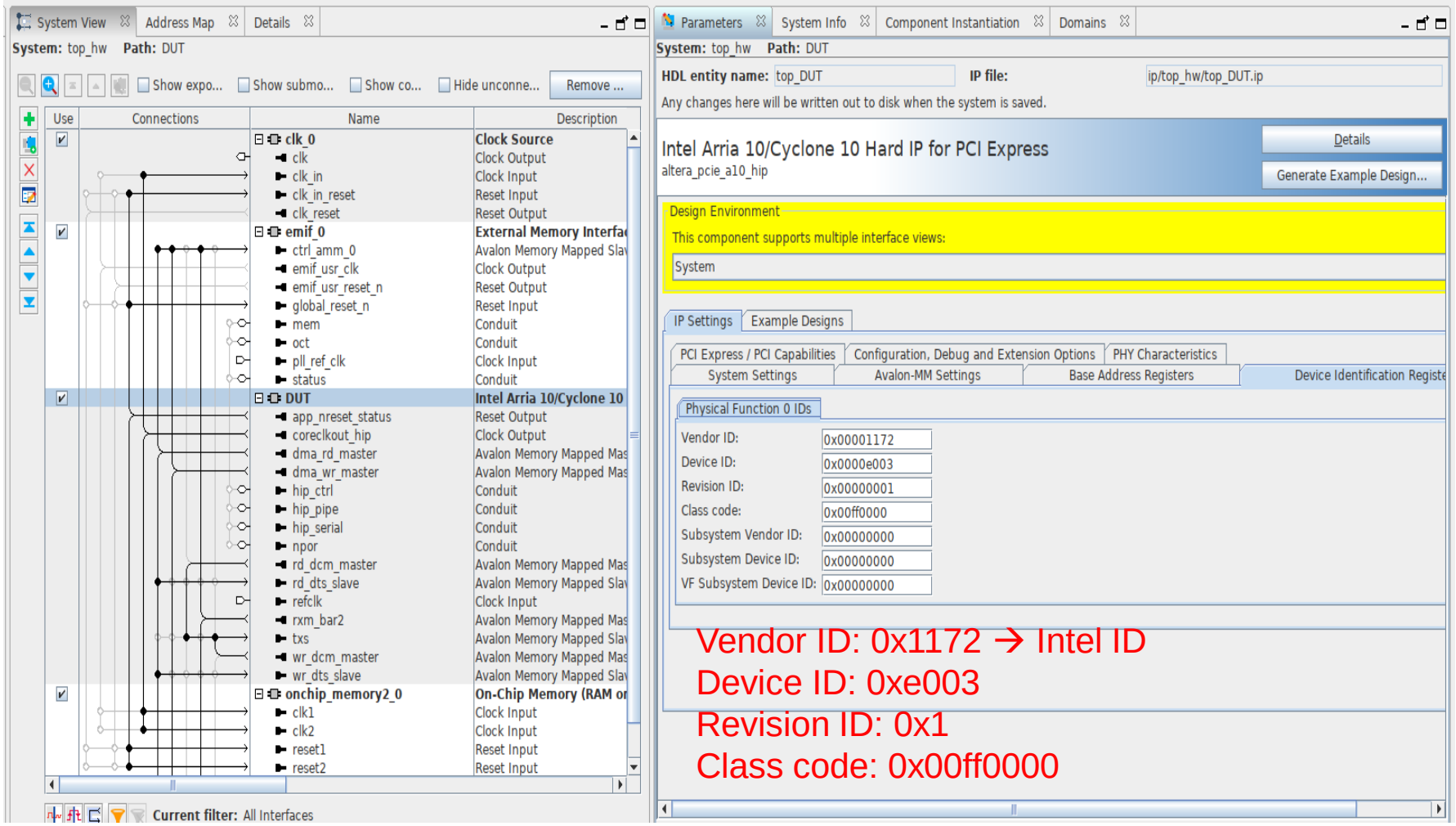
- **FPGA – Hard IP PCIE Configuration (cont.)**



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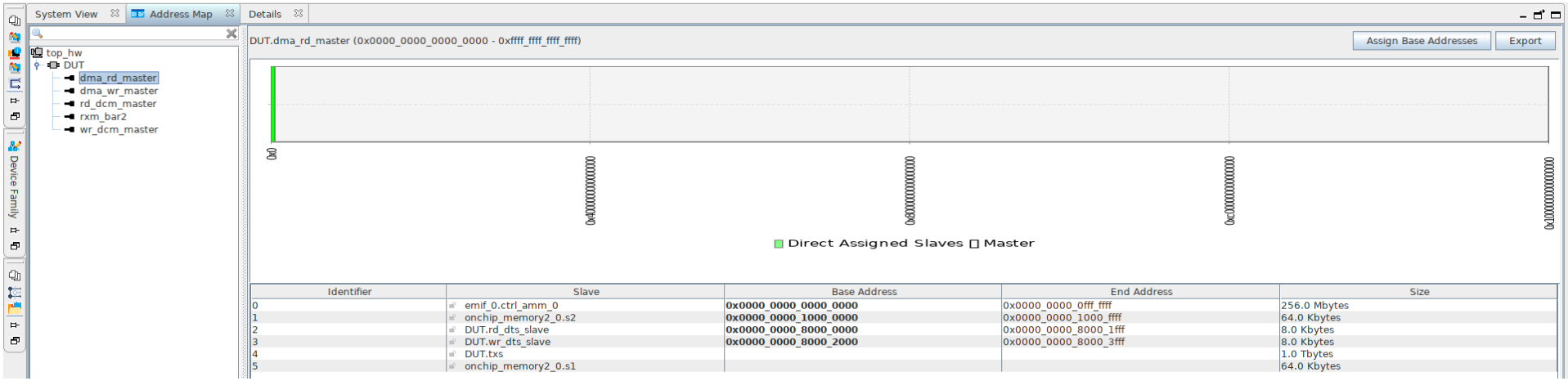
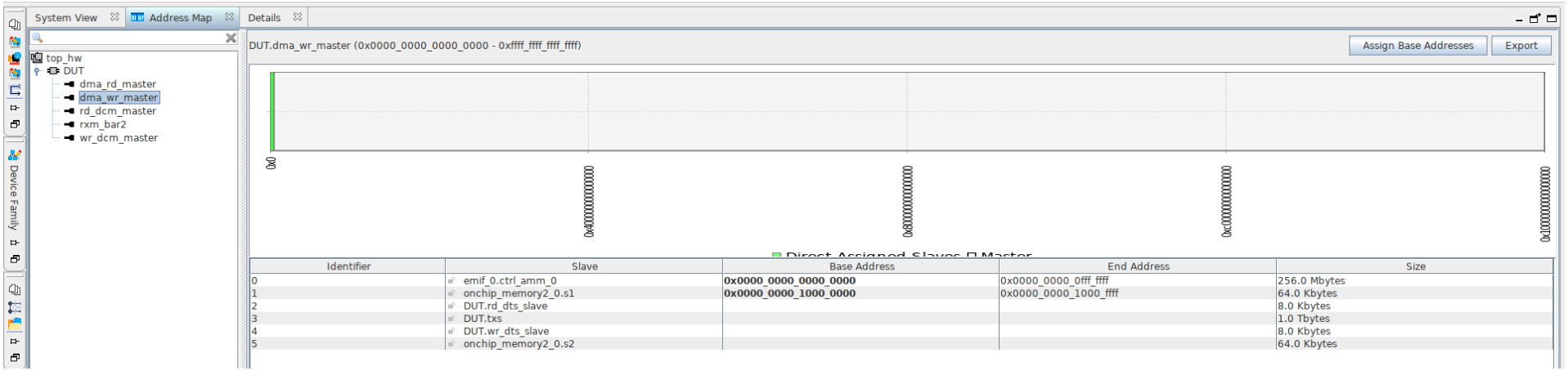
- **FPGA – Memory Map**



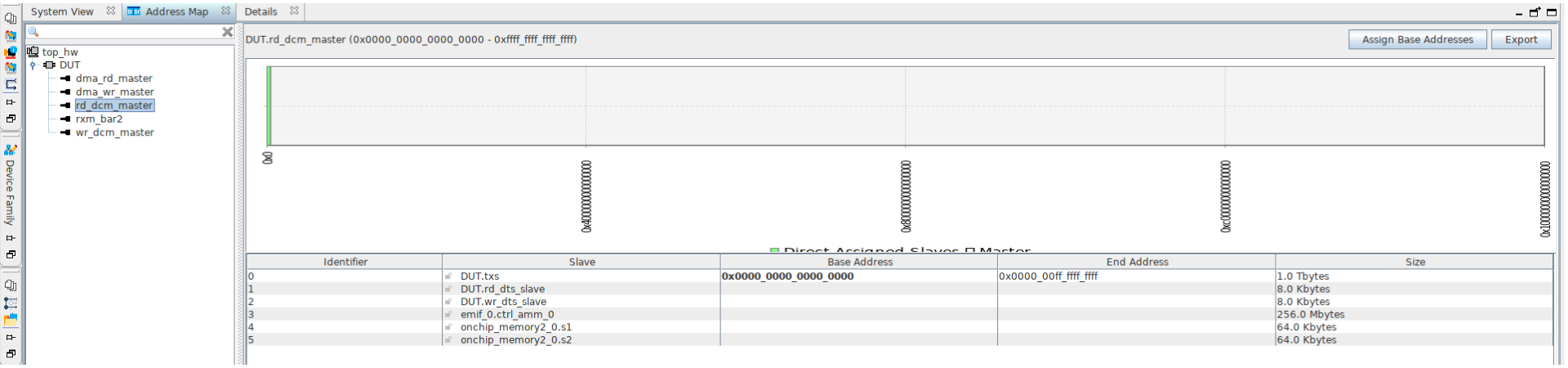
dma_rd_master: 0x0000_0000_0000_0000 → 0xffff_ffff_ffff_ffff



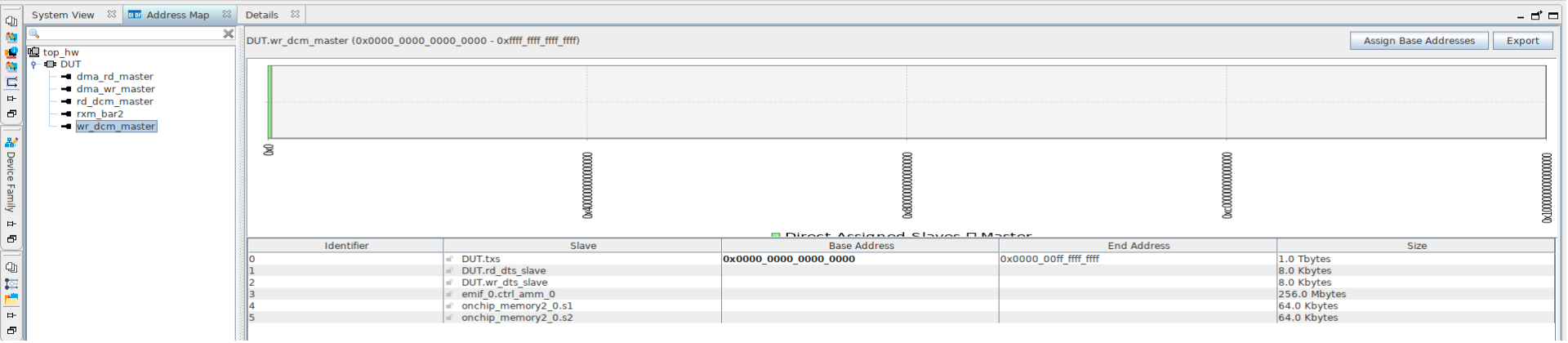
dma_wr_master: 0x0000_0000_0000_0000 → 0xffff_ffff_ffff_ffff

INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **FPGA – Memory Map (cont.)**

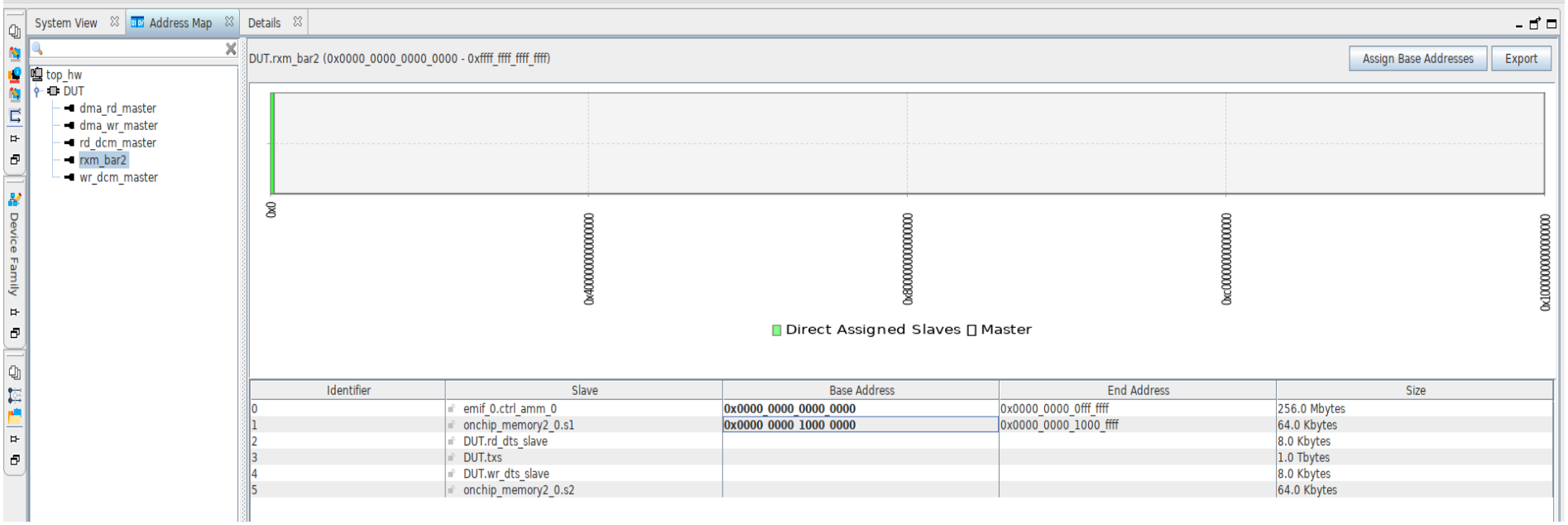


rd_dcm_master: 0x0000_0000_0000_0000 → 0xffff_ffff_ffff_ffff



wr_dcm_master: 0x0000_0000_0000_0000 → 0xffff_ffff_ffff_ffff

- **FPGA – Memory Map (cont.)**

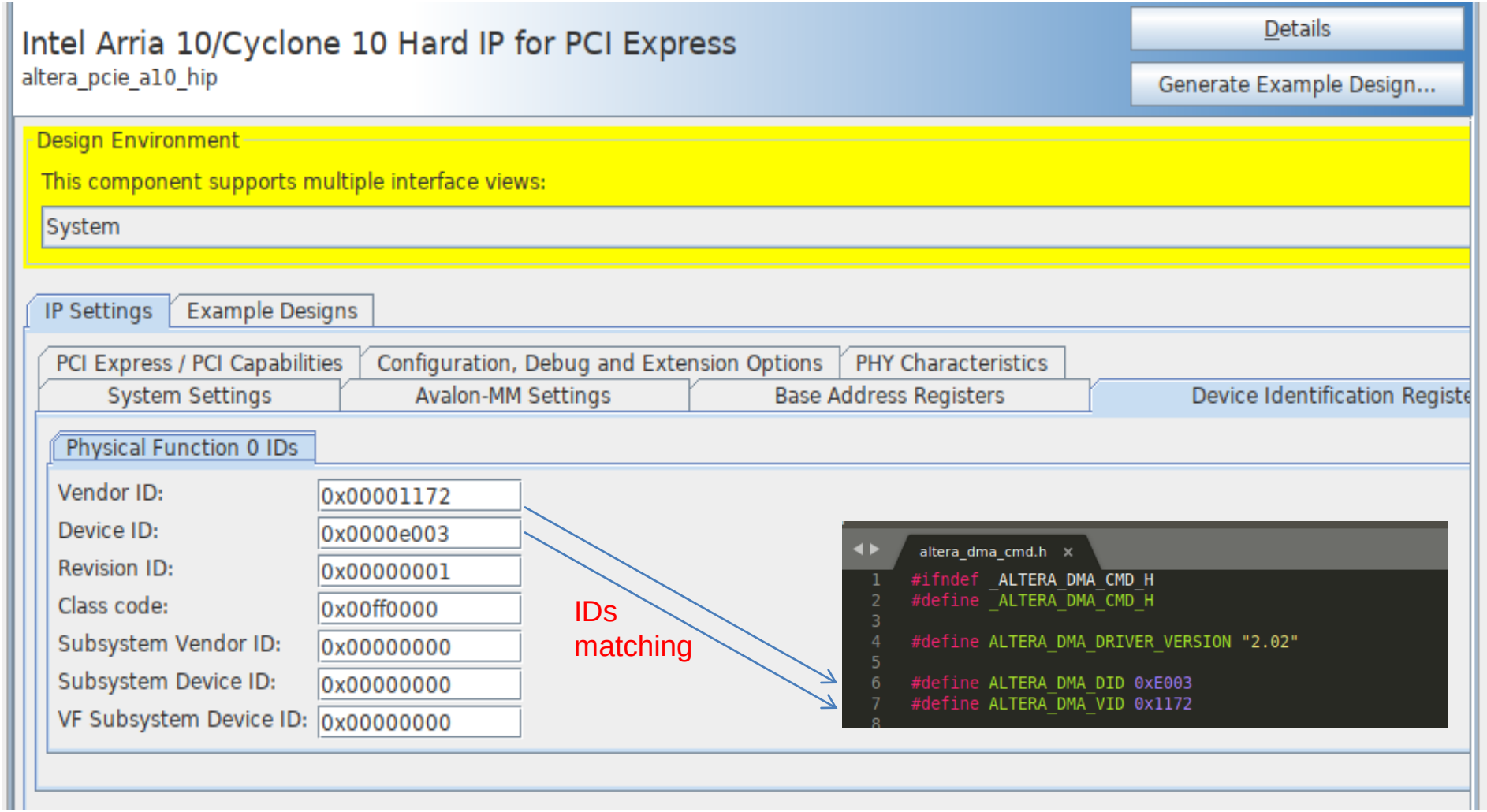


Rxm_bar2: 0x0000_0000_0000_0000 → 0xffff_ffff_ffff_ffff

Slave	Base Addr.	End Addr.	Size
Emif_0.ctrl_amm_0	0x0000_0000_0000_0000	0x0000_0000_0fff_ffff	256MB
Onchip_memory2_0.s1	0x0000_0000_1000_0000	0x0000_0000_1000_ffff	64KB
Rd_dts_slave			8KB
txs			1TB

INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **NVIDA JETSON XAVIER – PCIE device driver**

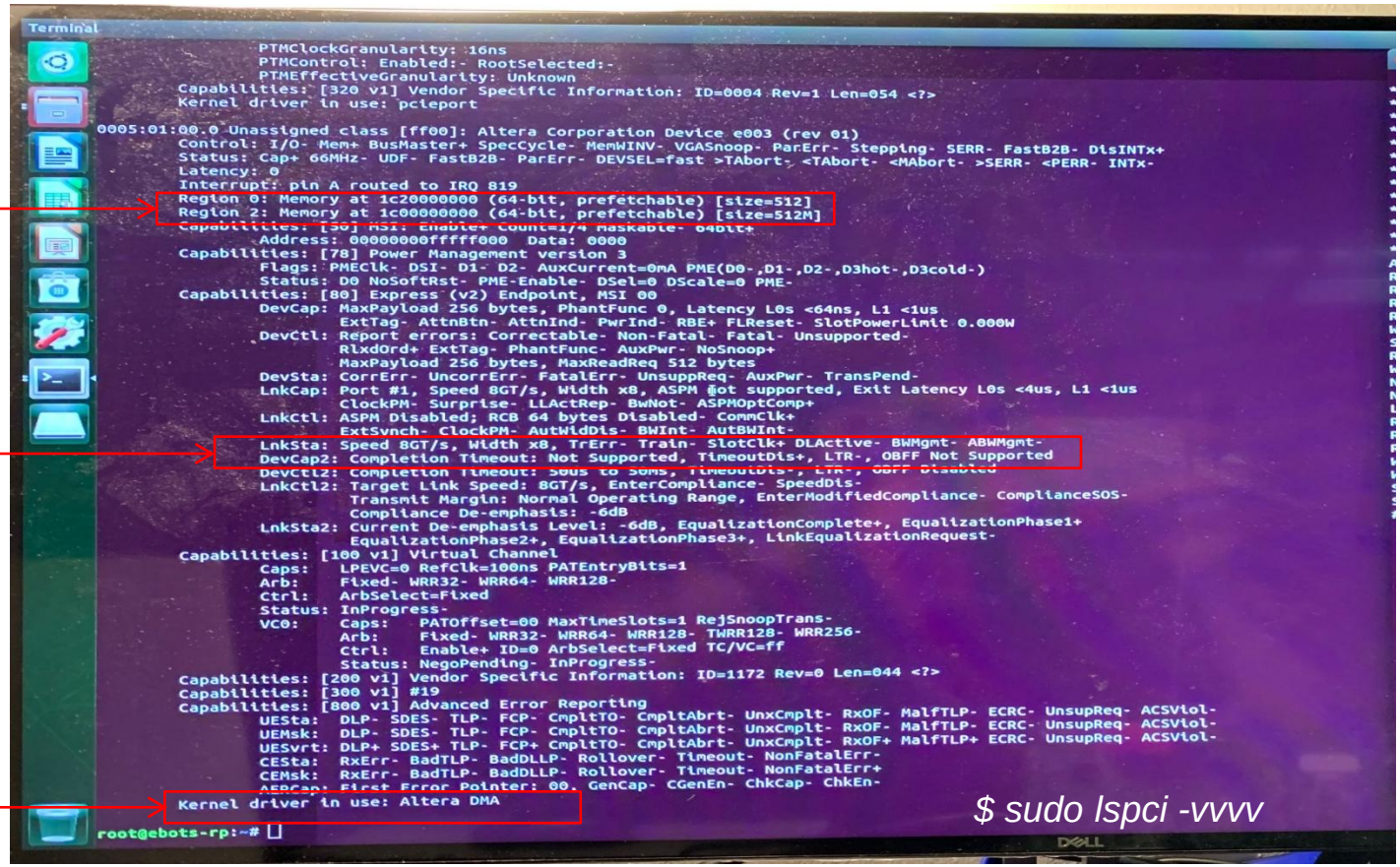


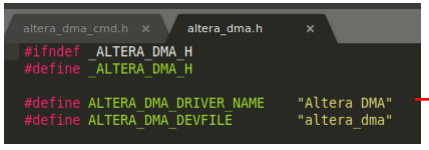
INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **NVIDA JETSON XAVIER – PCIE device list**

BAR0, BAR2 mapped successfully

PCIe max-speed: 8GT/s





- **NVIDA JETSON XAVIER – System Log**

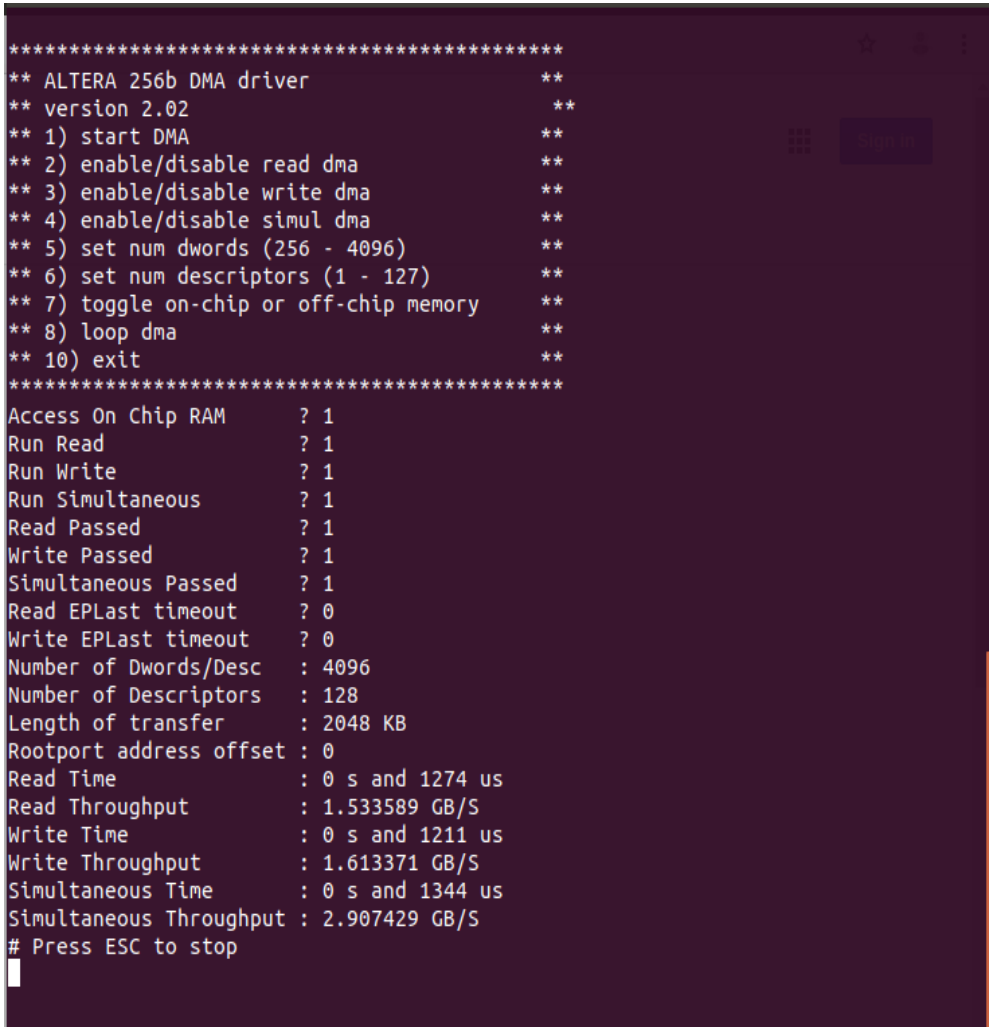
```
[ 9.237954] pcie-tegra.c:nvidia,max-speed is 4 | NOTE: 1: Gen1, 2: Gen2, 3: Gen3, 4: Gen4
[ 9.238134] tegra-pcie-dw 141a0000.pcie: PCIe max-speed check
[ 9.239524] tegra-pcie-dw 141a0000.pcie: Setting init speed to max speed
[ 9.241998] OF: PCI: host bridge /pcie@141a0000 ranges:
[ 9.243436] OF: PCI: IO 0x3a100000..0x3a1fffff -> 0x3a100000
[ 9.244864] OF: PCI: MEM 0x1f40000000..0x1fffffffff -> 0x40000000
[ 9.248309] OF: PCI: MEM 0x1c00000000..0x1f3fffffff -> 0x1c00000000
[ 9.877487] tegra-pcie-dw 141a0000.pcie: link is up
[ 9.879186] tegra-pcie-dw 141a0000.pcie: PCI host bridge to bus 0005:00
[ 9.880634] pci_bus 0005:00: root bus resource [bus 00-ff]
[ 9.882050] pci_bus 0005:00: root bus resource [io 0x300000-0x3fffff] (bus address [0x3a100000-0x3a1fffff])
[ 9.883533] pci_bus 0005:00: root bus resource [mem 0x1f40000000-0x1fffffffff] (bus address [0x40000000-0xffffffff])
[ 9.885015] pci_bus 0005:00: root bus resource [mem 0x1c00000000-0x1f3fffffff pref]
….
[ 9.888533] pci 0005:01:00.0: [1172:e003] type 00 class 0xff0000
[ 9.888645] pci 0005:01:00.0: reg 0x10: [mem 0x00000000-0x000001ff 64bit pref]
[ 9.888717] pci 0005:01:00.0: reg 0x18: [mem 0x00000000-0x1fffffff 64bit pref]
[ 9.889528] iommu: Adding device 0005:01:00.0 to group 64
[ 9.902405] pci 0005:00:00.0: BAR 15: assigned [mem 0x1c00000000-0x1c2fffffff 64bit pref]
[ 9.904273] pci 0005:01:00.0: BAR 2: assigned [mem 0x1c00000000-0x1c1fffffff 64bit pref]
[ 9.906370] pci 0005:01:00.0: BAR 0: assigned [mem 0x1c20000000-0x1c200001ff 64bit pref]
[ 9.907790] pci 0005:00:00.0: PCI bridge to [bus 01-ff]
[ 9.909119] pci 0005:00:00.0: bridge window [mem 0x1c00000000-0x1c2fffffff 64bit pref]
[ 9.910515] pci 0005:00:00.0: Max Payload Size set to 256/ 256 (was 256), Max Read Rq 512
[ 9.911969] pci 0005:01:00.0: Max Payload Size set to 256/ 256 (was 128), Max Read Rq 512
```


- **NVIDA JETSON XAVIER – System Log**

```
[ 317.624493] altera_dma: loading out-of-tree module taints kernel.
[ 317.625486] Altera DMA: altera_dma_init(), Aug 14 2019 10:45:01
[ 317.625831] Altera DMA 0005:01:00.0: enabling device (0000 -> 0002)
[ 317.625867] Altera DMA 0005:01:00.0: pci_enable_device() successful
[ 317.626173] Altera DMA 0005:01:00.0: pci_enable_msi() successful
[ 317.626206] Altera DMA 0005:01:00.0: using a 64-bit irq mask
[ 317.626213] Altera DMA 0005:01:00.0: irq pin: 1
[ 317.626219] Altera DMA 0005:01:00.0: irq line: 0
[ 317.626225] Altera DMA 0005:01:00.0: irq: 819
[ 317.626231] Altera DMA 0005:01:00.0: request irq: 0
[ 317.626240] Altera DMA 0005:01:00.0: BAR[0] 0x1c20000000-0x1c200001ff flags 0x0014220c, length 512
[ 317.626258] Altera DMA 0005:01:00.0: BAR[1] 0x00000000-0x00000000 flags 0x00000000, length 0
[ 317.626272] Altera DMA 0005:01:00.0: BAR[2] 0x1c00000000-0x1c1fffffff flags 0x0014220c, length 536870912
[ 317.626286] Altera DMA 0005:01:00.0: BAR[3] 0x00000000-0x00000000 flags 0x00000000, length 0
[ 317.626295] Altera DMA 0005:01:00.0: BAR[4] 0x00000000-0x00000000 flags 0x00000000, length 0
[ 317.626303] Altera DMA 0005:01:00.0: BAR[5] 0x00000000-0x00000000 flags 0x00000000, length 0
[ 317.627586] Altera DMA 0005:01:00.0: BAR[0] mapped to 0xffffff800dbfc000, length 512
[ 317.627766] Altera DMA 0005:01:00.0: BAR[2] mapped to 0xffffff8060000000, length 536870912
```

INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **DMA Test Result – PCIe Gen1x8**
  - Length of Transfer: **2048KB**
  - Read Throughput: **1.53GB/s**
  - Write Throughput: **1.61GB/s**
  - Simultaneous Throughput: **2.9GB/s**



- **DMA Test Result – PCIe Gen3x8**
  - Length of Transfer: **2048KB**
  - Read Throughput: **4.59GB/s**
  - Write Throughput: **6.30GB/s**
  - Simultaneous Throughput: **7.74GB/s**

```
*****************************************
** ALTERA 256b DMA driver                **
** version 2.02                           **
** 1) start DMA                          **
** 2) enable/disable read dma            **
** 3) enable/disable write dma           **
** 4) enable/disable simul dma           **
** 5) set num dwords (256 - 4096)        **
** 6) set num descriptors (1 - 127)      **
** 7) toggle on-chip or off-chip memory  **
** 8) loop dma                           **
** 10) exit                              **
*****************************************
Access On Chip RAM      ? 1
Run Read                ? 1
Run Write               ? 1
Run Simultaneous        ? 1
Read Passed             ? 1
Write Passed            ? 1
Simultaneous Passed     ? 1
Read EPLast timeout     ? 0
Write EPLast timeout    ? 0
Number of Dwords/Desc   : 4096
Number of Descriptors   : 128
Length of transfer      : 2048 KB
Rootport address offset : 0
Read Time               : 0 s and 426 us
Read Throughput         : 4.586366 GB/S
Write Time              : 0 s and 310 us
Write Throughput        : 6.302555 GB/S
Simultaneous Time       : 0 s and 505 us
Simultaneous Throughput : 7.737790 GB/S
# Press ESC to stop
```

INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **DMA Test Result – PCIe Gen3x8 with External Memory DDR3 (2133Mbps, x64 bus width)**
  - Length of Transfer: **2048KB**
  - Read Throughput: **4.65GB/s**
  - Write Throughput: **3.54GB/s**
  - Simultaneous Throughput: **4.57GB/s**

Throughput Differences for On-Chip and External Memory

This reference design provides a choice between on-chip memory implemented in the FPGA fabric and external memory available on the PCB. The on-chip memory supports separate read and write ports. Consequently, this memory supports simultaneous read and the write DMAs.

The external memory supports a single port. Consequently, the external memory does not support simultaneous read DMA and write DMA accesses. In addition, the latency of external memory is higher than the latency of on-chip memory. These two differences between the on-chip and external memory result in lower throughput for the external memory implementation.

Source @AN 829: PCI Express Avalon®-MM DMA Reference Design*

```
*******************************************
** ALTERA 256b DMA driver                **
** version 2.02                           **
** 1) start DMA                          **
** 2) enable/disable read dma            **
** 3) enable/disable write dma           **
** 4) enable/disable simul dma           **
** 5) set num dwords (256 - 4096)        **
** 6) set num descriptors (1 - 127)      **
** 7) toggle on-chip or off-chip memory  **
** 8) loop dma                           **
** 10) exit                              **
*******************************************
Access On Chip RAM      ? 0
Run Read                ? 1
Run Write               ? 1
Run Simultaneous        ? 1
Read Passed             ? 1
Write Passed            ? 1
Simultaneous Passed     ? 0
Read EPLast timeout     ? 0
Write EPLast timeout    ? 0
Number of Dwords/Desc   : 4096
Number of Descriptors   : 128
Length of transfer      : 2048 KB
Rootport address offset : 0
Read Time               : 0 s and 420 us
Read Throughput         : 4.651886 GB/S
Write Time              : 0 s and 552 us
Write Throughput        : 3.539478 GB/S
Simultaneous Time       : 0 s and 856 us
Simultaneous Throughput : 4.564935 GB/S
#
```

INTEL ARRIA 10 GX DEV KIT – PCIE GEN3x8 DMA

- **Comparison table – PCIe Gen3x8 DMA (RP: x86 vs ARM, DMA: OCM vs DDR3/DDR4)**

	On-Chip-Memory		DDR3		DDR4	
	X86(1)	**ARM**	**x86**	**ARM**	**x86(2)**	**ARM**
Read	6.38GB/s	4.59GB/s	Not tested	4.65GB/s	6.62GB/s	Not tested
	79.75%	57.38%		58.12%	82.75%	
Write	6.34GB/s	6.3GB/s	Not tested	3.54GB/s	6.26GB/s	Not tested
	79.25%	78.75%		44.25%	78.25%	
Simultaneous Read/Write	11.69GB/s	7.74GB/s	Not tested	4.56GB/s	4.05GB/s	Not tested

NOTE

DDR3 Specification: Running at 1066Mhz, BW at 2133Mbps, Bus width x64
DDR4 Specification: Running at 1200Mhz, BW at 2400Mbps, Bus width x64
ARM based System: Nvidia Jetson Xavier

Source @
(1) AN 829: PCI Express Avalon®-MM DMA Reference Design*
(2) AN708: PCI Express DMA Reference Design Using External Memory

THANK YOU