ML605 Getting Started Guide

1 Hardware Prerequisites

This section describes the hardware prerequisites required for an operational Xilinx Virtex-6 ML605 platform using OpenCPI. Note that the slot configurations in Table 1 are limited by what FPGA bitstreams are currently built by OpenCPI and not by what hardware configurations are theoretically possible using OpenCPI.

Hardware prerequisites are as follows.

- An ML605 board, which has undergone an OpenCPI-specific initial one-time hardware setup [1] and is plugged into a PCIE slot of an x86 computer.
- Optionally, one of the following FMC card configurations in Table 1 may exist

Table 1: OpenCPI-supported ML605 hardware FMC slot configurations

	FMC LPC slot	FMC HPC slot
Zipper LPC setup[1]	Modified[4] Zipper/MyriadRF transceiver card	(empty)
Zipper HPC setup[1]	(empty)	Modified[4] Zipper/MyriadRF transceiver card
FMCOMMS2 LPC setup	FMCOMMS2 transceiver card	(empty)
FMCOMMS2 HPC setup (RX data flow only)	(empty)	FMCOMMS2 transceiver card
FMCOMMS3 LPC setup	FMCOMMS3 transceiver card	(empty)
FMCOMMS3 HPC setup (RX data flow only)	(empty)	FMCOMMS3 transceiver card

2 Software Prerequisites

- A CentOS 6 or CentOS 7 operating system installed on the x86 computer.
- Xilinx ISE installed on the x86 computer, including the necessary Xilinx cable driver modifications necessary for CentOS. For information on supported ISE versions and cable driver modifications, refer to [2].
- OpenCPI RPMs installed on the x86 computer. For more information refer to [3].
- OpenCPI core project compiled for ml605.
- OpenCPI assets project compiled for ml605.

3 Reserve Memory for Driver

When OpenCPI communicates to cards via PCI, it uses a loadable Linux kernel device driver for discovery and DMA-based communication, which requires local (reserved) DMA memory resources. DMA memory resources must be allocated or reserved on the CPU-side memory, that is accessible to both the CPU (via the local mmap system call), as well as, OpenCPI's PCI DMA engine with the board is issuing PCI READ or WRITE TLPs. By default, Linux allocates 128 KB of memory for the OpenCPI driver. However, OpenCPI applications may have buffering requirements that necessitate additional memory resources.

[1] Deprecated Support as of OpenCPI 1.5

In the example provided below, special measures (memmap=) are used to allocate 128 MB of memory. The memmap parameter is used to reserved more block memory from the Linux kernel. While this variable supports many formats, the following usage has proven to be sufficient:

memmap=SIZE$START

Where SIZE is the number of bytes to reserve in either hexadecimal or decimal, and START is the physical address in hexadecimal bytes. It is required that the pages for all addresses and sizes are on even boundaries (0x1000 or 4096 bytes).

3.1 Calculate Values in Preparation for Memory Reservation

At this time, the OpenCPI PCI DMA engine requires that the user-mode DMA memory pool be in a 32 or 64-bit memory range and due to the manner with which Linux manages memory, it is recommended that the address be higher than the first 24 bits. With these requirements, the first step is to find a usable contiguous memory range by examining the BIOS physical RAM map as reported by dmesg.

Run dmesg and filter on BIOS to review the physical RAM map:

```
dmesg | grep BIOS
```

The output will look something like:

```
BIOS-provided physical RAM map:
 BIOS-e820: 0000000000000000 - 000000000009f800 (usable)
 BIOS-e820: 000000000009f800 - 00000000000a0000 (reserved)
 BIOS-e820: 00000000000ca000 - 00000000000cc000 (reserved)
 BIOS-e820: 00000000000dc000 - 00000000000e4000 (reserved)
 BIOS-e820: 00000000000e8000 - 0000000000100000 (reserved)
 BIOS-e820: 0000000000100000 - 000000005fef0000 (usable)
 BIOS-e820: 000000005fef0000 - 000000005feff000 (ACPI data)
 BIOS-e820: 000000005feff000 - 000000005ff00000 (ACPI NVS)
 BIOS-e820: 000000005ff00000 - 0000000060000000 (usable)
 BIOS-e820: 00000000e0000000 - 00000000f0000000 (reserved)
 BIOS-e820: 00000000fec00000 - 00000000fec10000 (reserved)
 BIOS-e820: 00000000fee00000 - 00000000fee01000 (reserved)
 BIOS-e820: 00000000fffe0000 - 0000000100000000 (reserved)
```

Select a "(usable)" section of memory and reserve a subsection of that memory. Once the memory is reserved, the Linux kernel will ignore it. In this example, there are three usable sections:

```
 BIOS-e820: 0000000000000000 - 000000000009f800 (usable)
 BIOS-e820: 0000000000100000 - 000000005fef0000 (usable)
 BIOS-e820: 000000005ff00000 - 0000000060000000 (usable)
```

Upon close review of the usable regions, the first range is too small and below the first 24 bits, while the third ranges is simply too small. Fortunately the second address space meets the address range requirement (between 24 and 32 bits) and it is large enough for to reserve several hundred megabytes of memory.

The starting memory address for the user-mode DMA region is calculated by subtracting 0x08000000 (128 MB) from the largest memory region available, as long as it is greater than 0x08000000 (128MB) and inside the 32-bit address range (address is less than 4GB). In this example, the 2nd region is the largest: 0x5FEF0000 - 0x100000 = 0x5FDF0000 = 1,608,450,048 (1.6GB) and it is inside of the 32-bit address space. The starting memory address (0x5FEF0000 - 0x08000000) is 0x57EF0000. And this is the value that used to construct the memmap parameter, as shown below:

memmap=128M$0x57EF0000

When calculating the starting address, the user must ensure that address occurs on an even page boundary of 4 KB. This may necessitate an additional adjustment to the starting address.

In some cases, the `$dmesg | grep BIOS` returns a value like 0x5FEFFFFF. It is recommended that the user simply change this address, such that, its low word is all zeros, ex. 0x5FEF0000, prior to calculating the starting address.

3.2 Configure Memory Reservation

Critical Note: If other memmap parameters are implemented, e.g. for non-OpenCPI PCI cards, then grubby usage will be different. The OpenCPI driver will use the first memmap parameter on the command line OR the parameter "opencpi_memmap" if it is explicitly given. If this parameter is given, the standard memmap command with the same parameters must ALSO be passed to the kernel.

Once the memmap parameter as been calculated, it will need to be added to the kernel command line in the boot loader.

For CentOS, the utility "grubby" can be used to add the parameter to all kernels in the start-up menu. The single quotes are REQUIRED or the shell will interpret the $0:

CentOS6:

```
sudo grubby --update-kernel=ALL --args=memmap='128M\$0x57EF0000'
```

CentOS 7 uses *grub2*, which **requires a DOUBLE** backslash:

```
sudo grubby --update-kernel=ALL --args=memmap='128M\\$0x57EF0000'
```

To verify the current kernel has the argument set:

```
sudo -v
sudo grubby --info $(sudo grubby --default-kernel)
```

CentOS 7 displays a **SINGLE** backslash before the $, for example:

```
args="ro rdblacklist=nouveau crashkernel=auto rd.lvm.lv=vg.0/root quiet audit=1 boot=UUID=96933\
    cb5-f478-4933-a0d4-16953cf47f5c memmap=128M\$0x57EF0000 LANG=en_US.UTF-8"
```

If no longer desired, the parameter can also be removed:

```
sudo grubby --update-kernel=ALL --remove-args=memmap
```

More information concerning grubby can be found at:
`https://access.redhat.com/documentation/en-US/Red_Hat_Enterprise_Linux/7/html/System_Administrators_Guide/sec-Making_Persistent_Changes_to_a_GRUB_2_Menu_Using_the_grubby_Tool.html`

For the memmap parameter:
`https://www.kernel.org/doc/html/latest/admin-guide/kernel-parameters.html`

3.3 Apply Memory Reservation

Reboot the system, making certain to boot from the new configuration.

3.4 Verify Memory Reservation

Once the system has finished booting, examine the state of the physical RAM map to confirm that the desired memory has been reserved:

```
dmesg | more
Linux version 2.6.18-128.el5 (mockbuild@hs20-bc1-7.build.redhat.com) (gcc version 4.1.2 \
    20080704 (Red Hat 4.1.2-44)) #1 SMP Wed Dec 17 11:41:38 EST 2008
Command line: ro root=/dev/VolGroup00/LogVol00 rhgb quiet memmap=128M$0x57EF0000
BIOS-provided physical RAM map:
 BIOS-e820: 0000000000000000 - 000000000009f800 (usable)
 BIOS-e820: 000000000009f800 - 00000000000a0000 (reserved)
 BIOS-e820: 00000000000ca000 - 00000000000cc000 (reserved)
 BIOS-e820: 00000000000dc000 - 00000000000e4000 (reserved)
 BIOS-e820: 00000000000e8000 - 0000000000100000 (reserved)
 BIOS-e820: 0000000000100000 - 000000005fef0000 (usable)
 BIOS-e820: 000000005fef0000 - 000000005feff000 (ACPI data)
 BIOS-e820: 000000005feff000 - 000000005ff00000 (ACPI NVS)
 BIOS-e820: 000000005ff00000 - 0000000060000000 (usable)
 BIOS-e820: 00000000e0000000 - 00000000f0000000 (reserved)
 BIOS-e820: 00000000fec00000 - 00000000fec10000 (reserved)
 BIOS-e820: 00000000fee00000 - 00000000fee01000 (reserved)
 BIOS-e820: 00000000fffe0000 - 0000000100000000 (reserved)
user-defined physical RAM map:
 user: 0000000000000000 - 000000000009f800 (usable)
 user: 000000000009f800 - 00000000000a0000 (reserved)
 user: 00000000000ca000 - 00000000000cc000 (reserved)
 user: 00000000000dc000 - 00000000000e4000 (reserved)
 user: 00000000000e8000 - 0000000000100000 (reserved)
 user: 0000000000100000 - 0000000057ef0000 (usable)
 user: 0000000057ef0000 - 000000005fef0000 (reserved) <== New
 user: 000000005fef0000 - 000000005feff000 (ACPI data)
 user: 000000005feff000 - 000000005ff00000 (ACPI NVS)
 user: 000000005ff00000 - 0000000060000000 (usable)
 user: 00000000e0000000 - 00000000f0000000 (reserved)
 user: 00000000fec00000 - 00000000fec10000 (reserved)
 user: 00000000fee00000 - 00000000fee01000 (reserved)
 user: 00000000fffe0000 - 0000000100000000 (reserved)
DMI present.
```

A new "(reserved)" area is shown between the second "(useable)" section and the (ACPI data) section. Now, when the "ocpidriver load" is ran, it will detect the new reserved area, and pass that data to the OpenCPI kernel module.

4 Driver Notes

When available, the driver will attempt to make use of the CMA region for direct memory access. In use cases where many memory allocations are made, the user may receive the following kernel message:

```
alloc_contig_range test_pages_isolated([memory start], [memory end]) failed
```

This is a kernel warning, but does not indicate that a memory allocation failure occurred, only that the CMA engine could not allocate memory in the first pass. Its default behavior is to make a second pass, and if that succeeded, the end user should not see any more error messages. This message cannot be suppressed, but can be safely ignored. An actual allocation failure will generate unambiguous error messages.

5 Loading the OpenCPI driver

When OpenCPI is installed via RPMs, the OpenCPI driver should have been installed. However, when developing with source OpenCPI, the user is required to manage the loading of the OpenCPI driver.
The following terminal outputs are intended to provide the user with expected behavior of when the driver is not

and is loaded. The user should note that only when the driver is installed can the ml605 be discovered as a valid OpenCPI container.

```
ocpidriver unload
The driver module was successfully unloaded.

ocpidriver load
Found generic reserved DMA memory on the linux boot command line and assuming it is for OpenCPI\
    : [memmap=128M$0x1000000]
Driver loaded successfully.

ocpidriver unload
The driver module was successfully unloaded.

ocpirun -C
OCPI( 2:816.0497): When searching for PCI device '0000:03:00.0': Can't open /dev/mem, forgot to\
     load the driver? sudo?
OCPI( 2:816.0499): When searching for PCI device '0000:08:00.0': Can't open /dev/mem, forgot to\
     load the driver? sudo?
OCPI( 2:816.0544): In HDL Container driver, got PCI search error: Can't open /dev/mem, forgot \
    to load the driver? sudo?
Available containers:
 #  Model Platform     OS     OS-Version Arch    Name
 0  rcc   centos7      linux  c7         x86_64  rcc0

ocpidriver load
Found generic reserved DMA memory on the linux boot command line and assuming it is for OpenCPI\
    : [memmap=128M$0x1000000]
Driver loaded successfully.

ocpirun -C
Available containers:
 #  Model Platform     OS     OS-Version Arch    Name
 0  hdl   ml605                                  PCI:0000:08:00.0
 1  hdl   alst4                                  PCI:0000:03:00.0
 2  rcc   centos7      linux  c7         x86_64  rcc0
```

6 Proof of Operation

The following commands may be run in order to verify correct OpenCPI operation on the x86/ML605 system.

Existence of ML605 RCC/HDL containers may be verified by running the following command and verifying that similar output is produced.

```
ocpirun -C
Available containers:
 #  Model Platform     OS     OS-Version Arch    Name
 0  hdl   ml605                                  PCI:0000:02:00.0
 1  rcc   centos7      linux  c7         x86_64  rcc0
```

Operation of the RCC container can be verified by running the hello application via the following command and verifying that identical output is produced. Note that the OCPI_LIBRARY_PATH environment variable must be setup to include the hello_world.rcc built shared object file prior to running this command.

```
ocpirun -t 1 assets/applications/hello.xml
```

```
Hello, world
```

Simultaneous RCC/HDL container operation can be verified by running the testbias application via the following command and verifying that identical output is produced. Note that the OCPI_LIBRARY_PATH environment variable must be setup correctly for your system prior to running this command.

```
ocpirun -d -m bias=hdl assets/applications/testbias.xml
Property 0: file_read.fileName = "test.input" (cached)
Property 1: file_read.messagesInFile = "false" (cached)
Property 2: file_read.opcode = "0" (cached)
Property 3: file_read.messageSize = "16"
Property 4: file_read.granularity = "4" (cached)
Property 5: file_read.repeat = "<unreadable>"
Property 6: file_read.bytesRead = "0"
Property 7: file_read.messagesWritten = "0"
Property 8: file_read.suppressEOF = "false"
Property 9: file_read.badMessage = "false"
Property 10: file_read.ocpi_debug = "false" (parameter)
Property 11: file_read.ocpi_endian = "little" (parameter)
Property 12: bias.biasValue = "16909060" (cached)
Property 13: bias.ocpi_debug = "false" (parameter)
Property 14: bias.ocpi_endian = "little" (parameter)
Property 15: bias.test64 = "0"
Property 16: file_write.fileName = "test.output" (cached)
Property 17: file_write.messagesInFile = "false" (cached)
Property 18: file_write.bytesWritten = "0"
Property 19: file_write.messagesWritten = "0"
Property 20: file_write.stopOnEOF = "true" (cached)
Property 21: file_write.ocpi_debug = "false" (parameter)
Property 22: file_write.ocpi_endian = "little" (parameter)
Property 3: file_read.messageSize = "16"
Property 5: file_read.repeat = "<unreadable>"
Property 6: file_read.bytesRead = "4000"
Property 7: file_read.messagesWritten = "251"
Property 8: file_read.suppressEOF = "false"
Property 9: file_read.badMessage = "false"
Property 15: bias.test64 = "0"
Property 18: file_write.bytesWritten = "4000"
Property 19: file_write.messagesWritten = "250"
```

7 Known Issues

7.1 Single Port of Data from CPU to FPGA

The current implementations of the PCI-e specification on this platform correctly implements data flow from the CPU to the FPGA, only under certain configurations (assembly/container) and is limited to only a single port of data from CPU to FPGA. Fundamentally, OpenCPI only supports a single port connection from the CPU to the FPGA.

To ensure the proper configurations are met, assembly and container XML files must be designed based on the following rules:

1. When a single worker exists in an assembly and it ports are connected to the assembly (Externals='true'), then the container must be built for the "base" container. (i.e. the assembly's Makefile must contain "DefaultContainer=").
2. When an assembly's external connections are explicitly defined (i.e. not using Externals='true'), then the first

external assembly connection that is defined in the assembly XML must be that of the CPU to FPGA, and the "base" container used (i.e. the assembly's Makefile must contain "DefaultContainer="), or

3. When defining external connections in a container XML, then the first interconnect container connection defined must be that of the CPU to FPGA and the "base" container used (i.e. the assembly's Makefile must contain "DefaultContainer=").

Note that this applies to the TX/DAC data path connections for bitstreams with transceiver transmit data flow from a CPU (e.g. RCC worker to FPGA TX/DAC data path). See `projects/assets/hdl/assemblies/empty/cnt_1rx_1tx_bypassasm_fmcomms_2_3_lpc_LVDS_ml605.xml` as an example.

References

[1] ML605 Hardware Setup
`https://opencpi.github.io/assets/ML605_Hardware_Setup.pdf`

[2] FPGA Vendor Tools Guide
`https://opencpi.github.io/FPGA_Vendor_Tools_Installation_Guide.pdf`

[3] RPM Installation Guide
`https://opencpi.github.io/RPM_Installation_Guide.pdf`

[4] Required Modifications for Myriad-RF 1 and Zipper Daughtercards
`https://opencpi.github.io/assets/Required_Modifications_for_Myriad-RF_1_Zipper_Daughtercards.pdf`