OpenCPI - Open Component Portability Infrastructure

An Open Source Infrastructure for Heterogeneous/Embedded Component-Based Systems and Applications

Advanced OpenCPI Platform Development

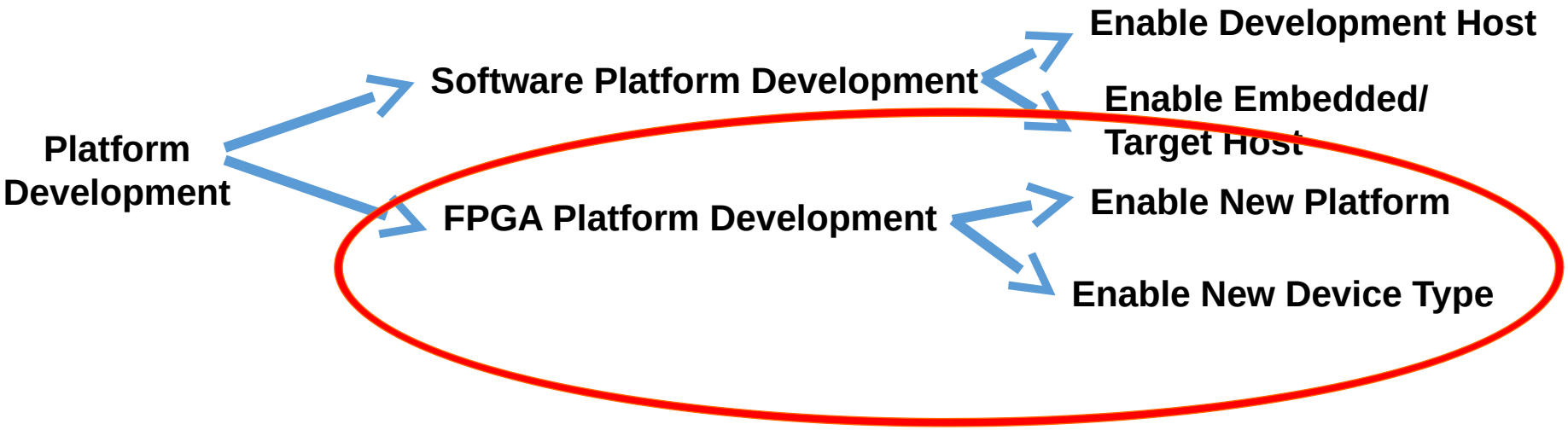
Summary of OpenCPI Development Roles

Three types of development with common XML-driven workflow

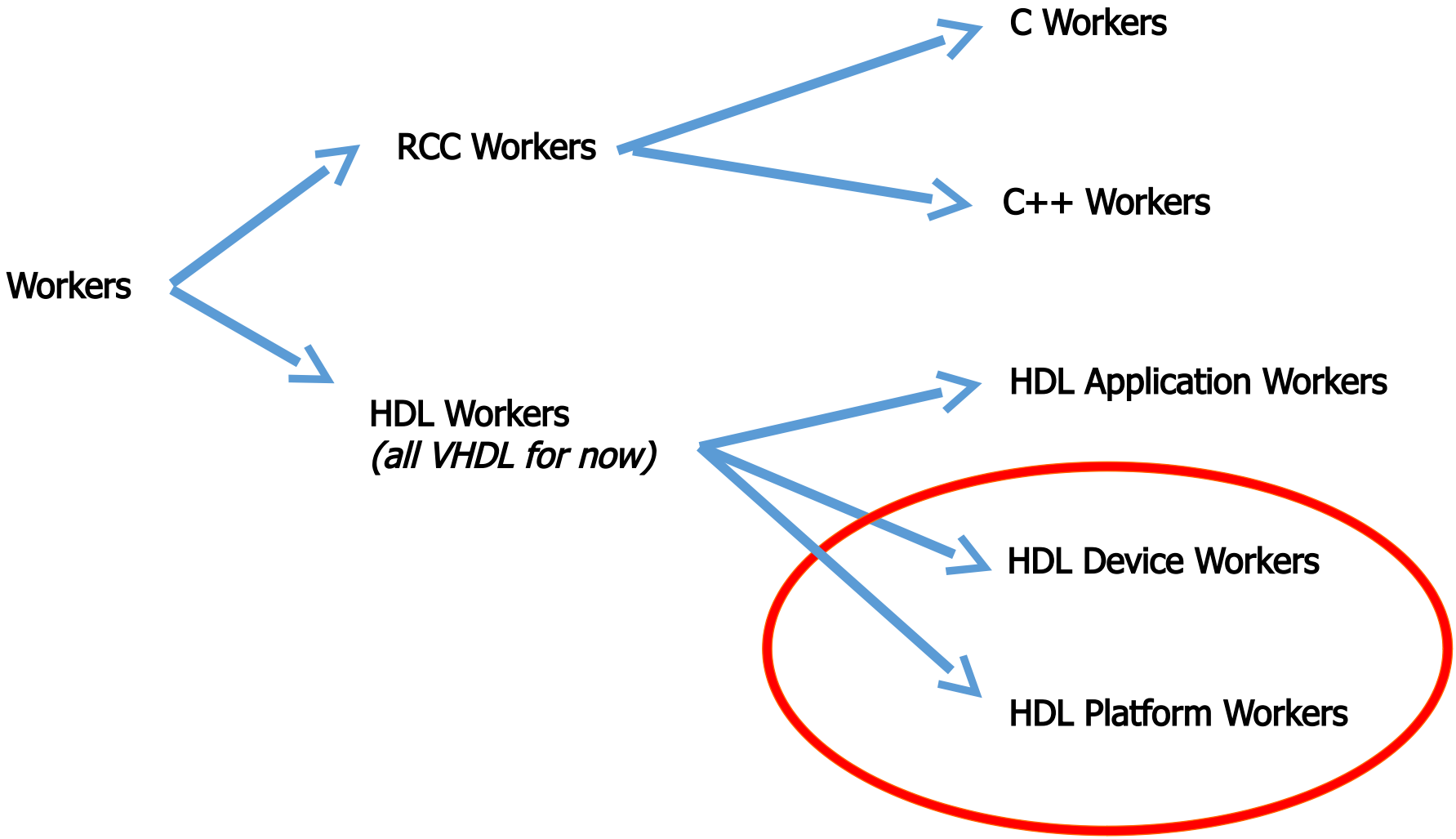
	Application Development	Component Development	Platform Development
Objective	• Create applications using components	• Create building blocks for applications	• Create infrastructure for running applications
Examples	• Tb_bias • FSK app	• Bias • FIR filter	• Zedboard • Transceivers
Key functions	• Declare components and their connections and properties	• Process data and interface between other components • Vendor agnostic (ideally)	• Provide interface to software and FPGA peripheral (devices workers)
Skills Required	• Familiarity with component library	• S/W: C, C++ • H/W: VHDL	• H/W: VHDL • Strong knowledge of platform architecture and interfaces
	Knowledge of OpenCPI build flow		

Types of OpenCPI Platform Development

Enabling new platforms and devices for OpenCPI apps



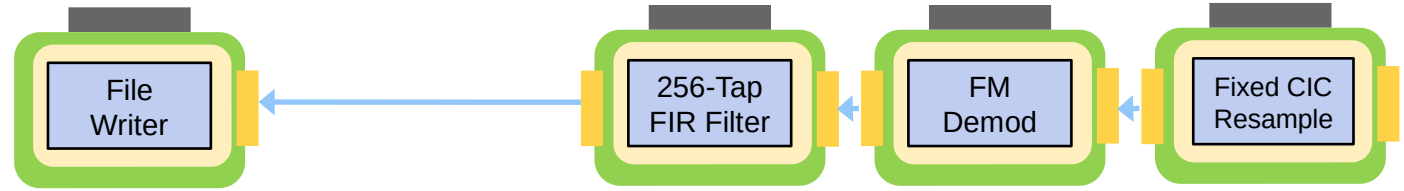
Types of OpenCPI Workers



What is an OpenCPI FPGA Platform?

- An **OpenCPI FPGA Platform** is the FPGA, its surrounding infrastructure and attached devices.
- *Enabling the platform* allows it to be used for an OpenCPI application.
- Put another way…

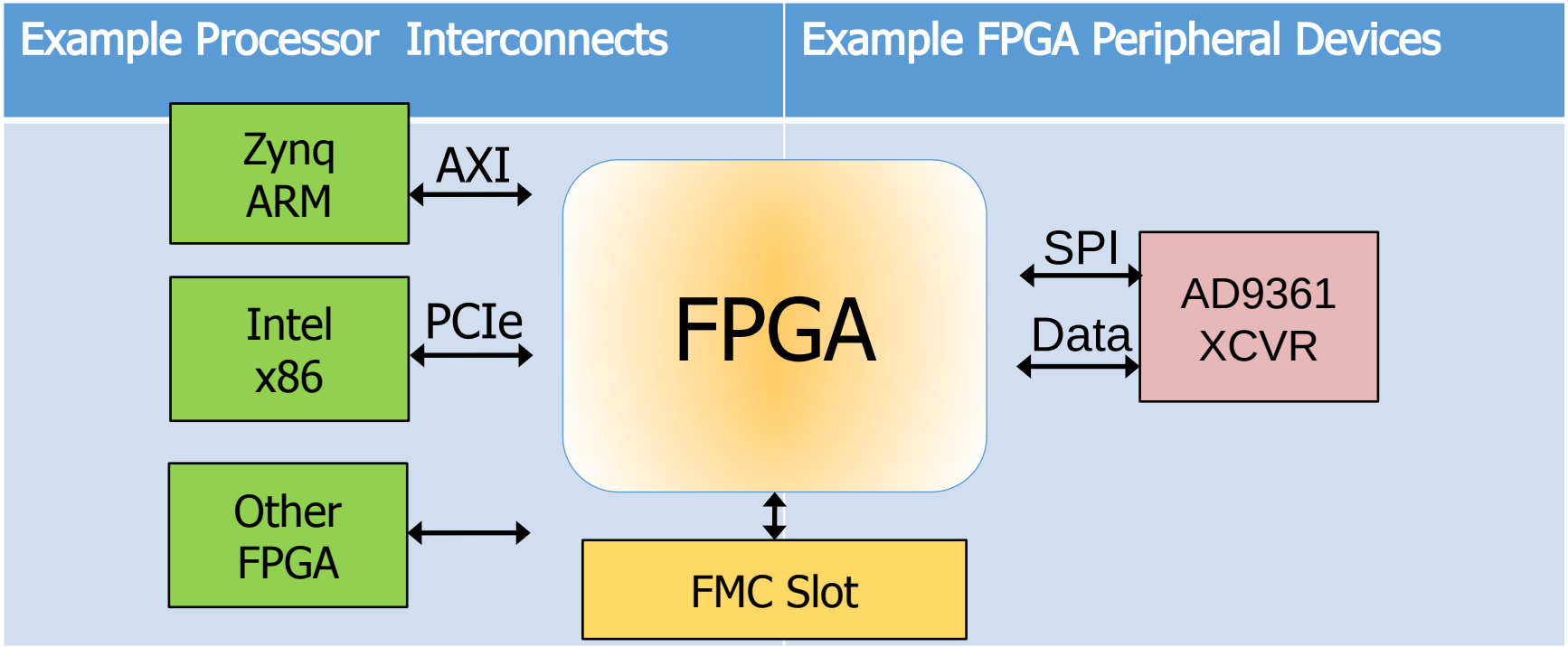
What do I need to run an OpenCPI app?



on *my* hardware?

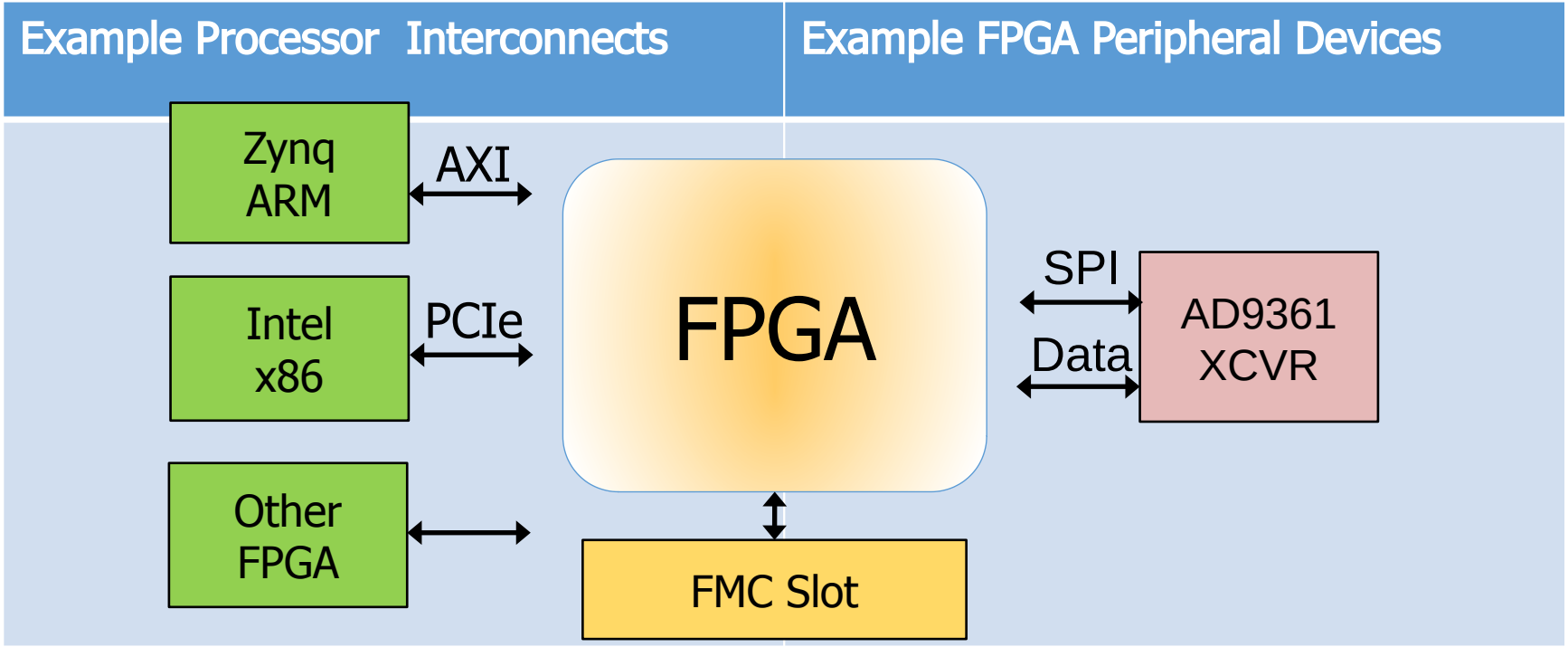
What Does an OpenCPI FPGA Platform Consist of?

1. ***The FPGA:*** a place where HDL application workers may execute
2. ***Interconnects:*** off-chip connections to processor(s) or other FPGA platforms
3. ***Devices:*** peripherals attached to the FPGA, useful to applications
4. ***Slots:*** hardware physical interfaces where ***cards*** (with devices) are plugged in



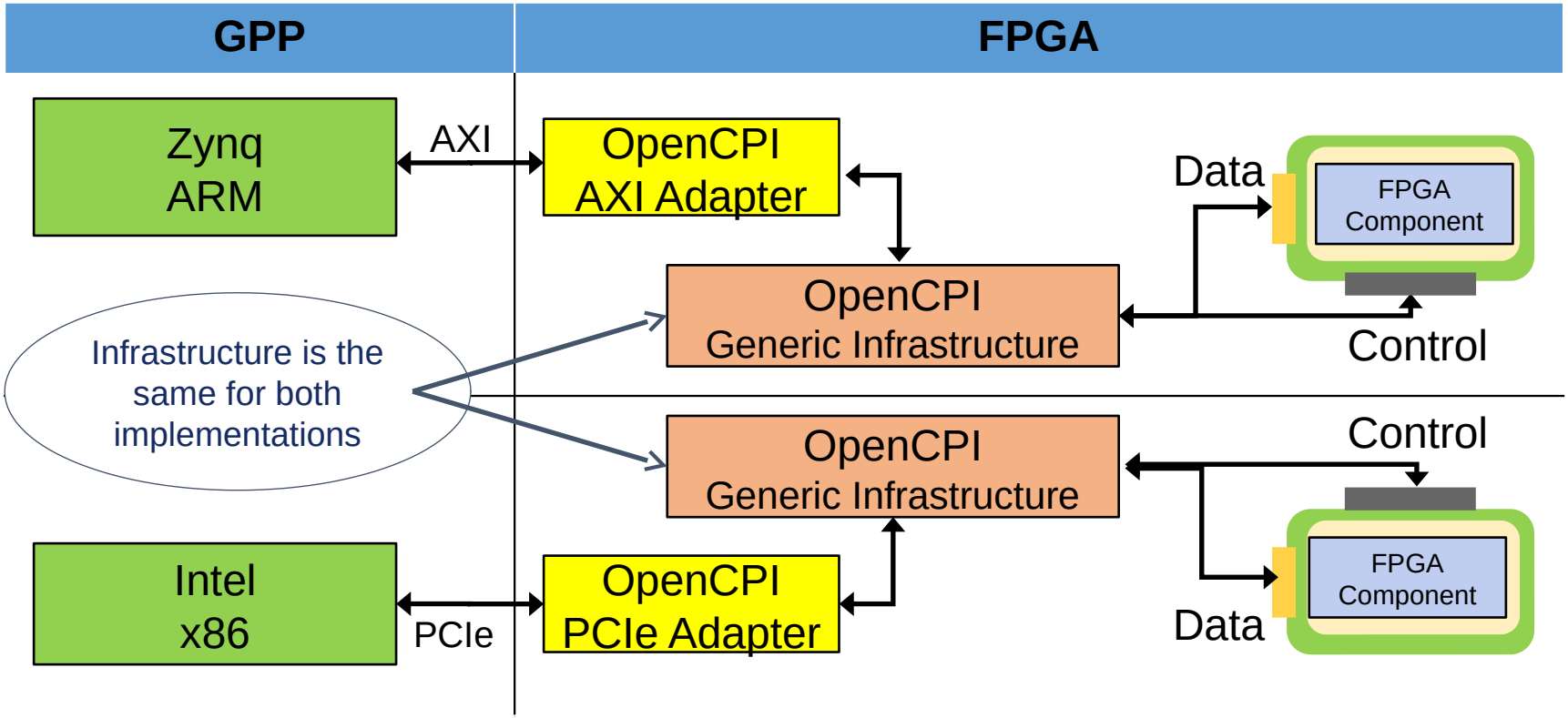
What is Needed to Enable an OpenCPI FPGA Platform?

1. The OCPI on-chip ***clocks***, ***control*** and ***data planes*** must be adapted to the external (off-FPGA) resources available in the platform: create the ***HDL platform worker***.
   - ***Control Plane:*** mechanisms to allow the processor to control and configure FPGA workers
   - ***Data Plane:*** mechanisms to allow messages to flow between on-chip workers and workers elsewhere
   - ***Clocks:*** the mechanisms to provide clocking and time-of-day to FPGA workers
2. The attached devices must be supported by specialized workers acting as device drivers: create or reuse ***HDL device workers***.



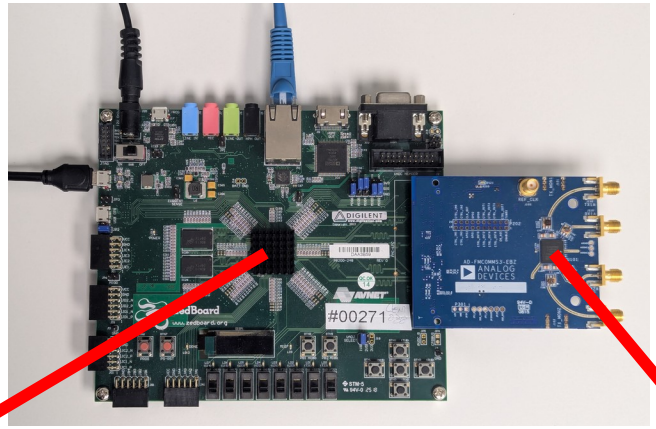
Generic, Platform-agnostic FPGA Infrastructure

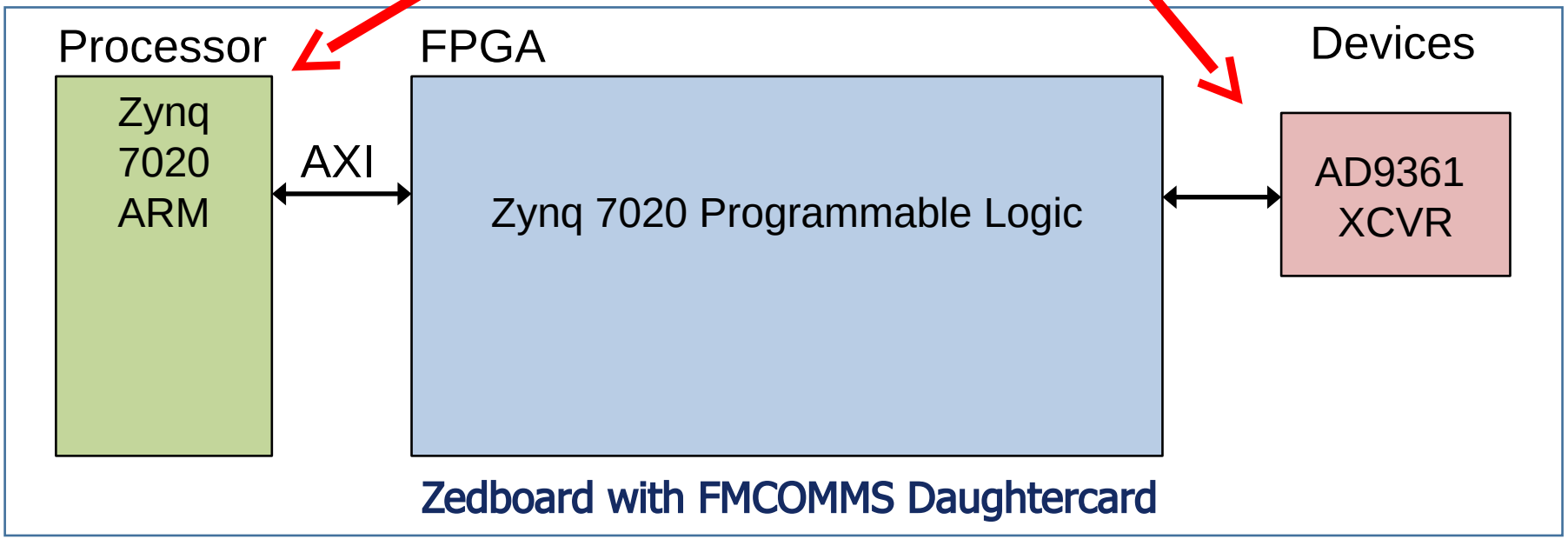
- Generic Infrastructure Modules
  - For controlling FPGA worker registers/properties from software (control plane)
  - For data transfer from FPGA workers to/from other platforms and software (data plane)
    - These modules are instanced automatically as needed
- Some existing ***HDL device workers***/drivers for controlling certain devices (on any platform).
- Adapter logic for different processor/FPGA interconnects



Case Study: Zedboard with FMCOMMS

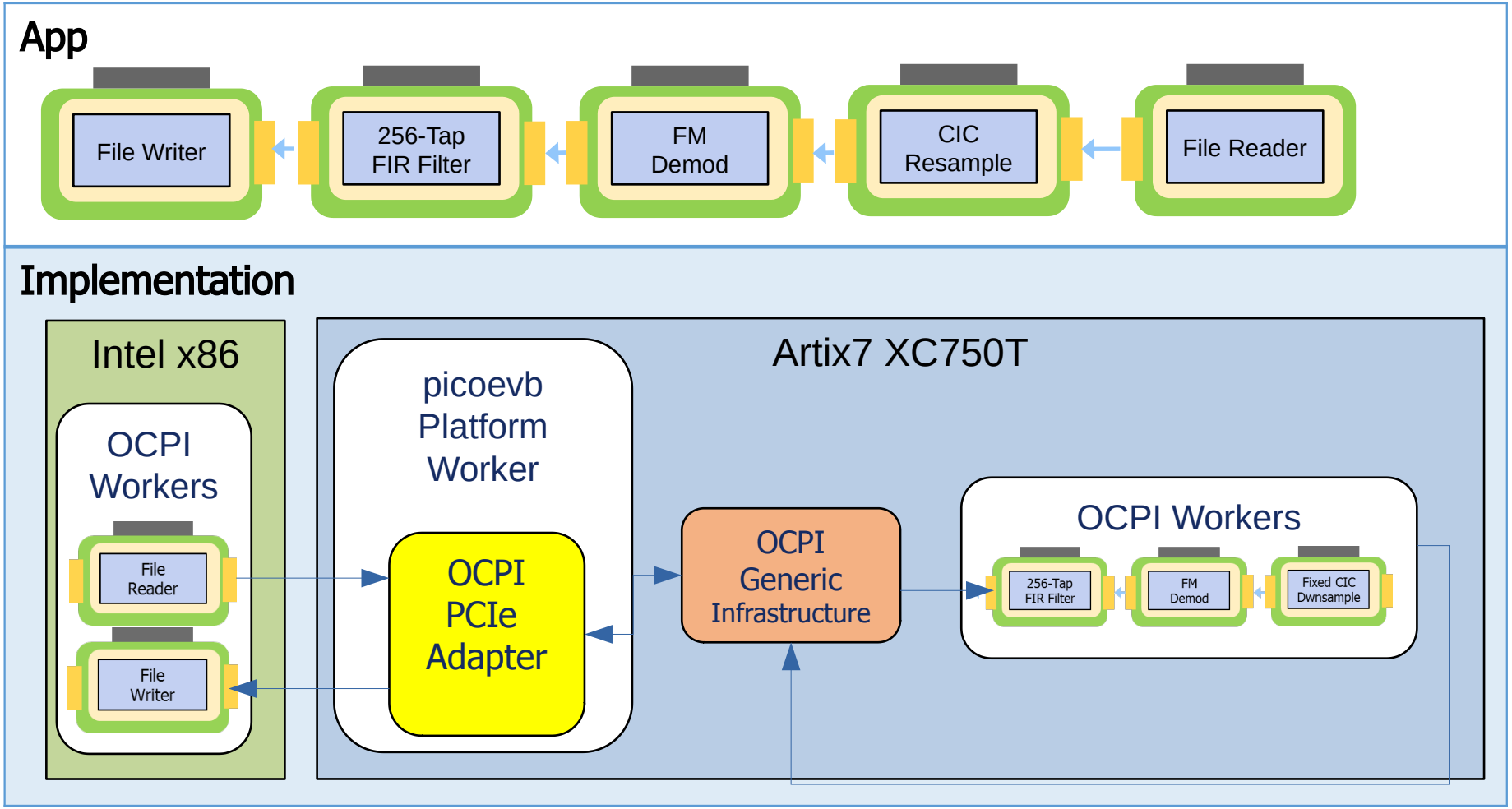
Treated as one board, ignoring the card/slot aspect for now





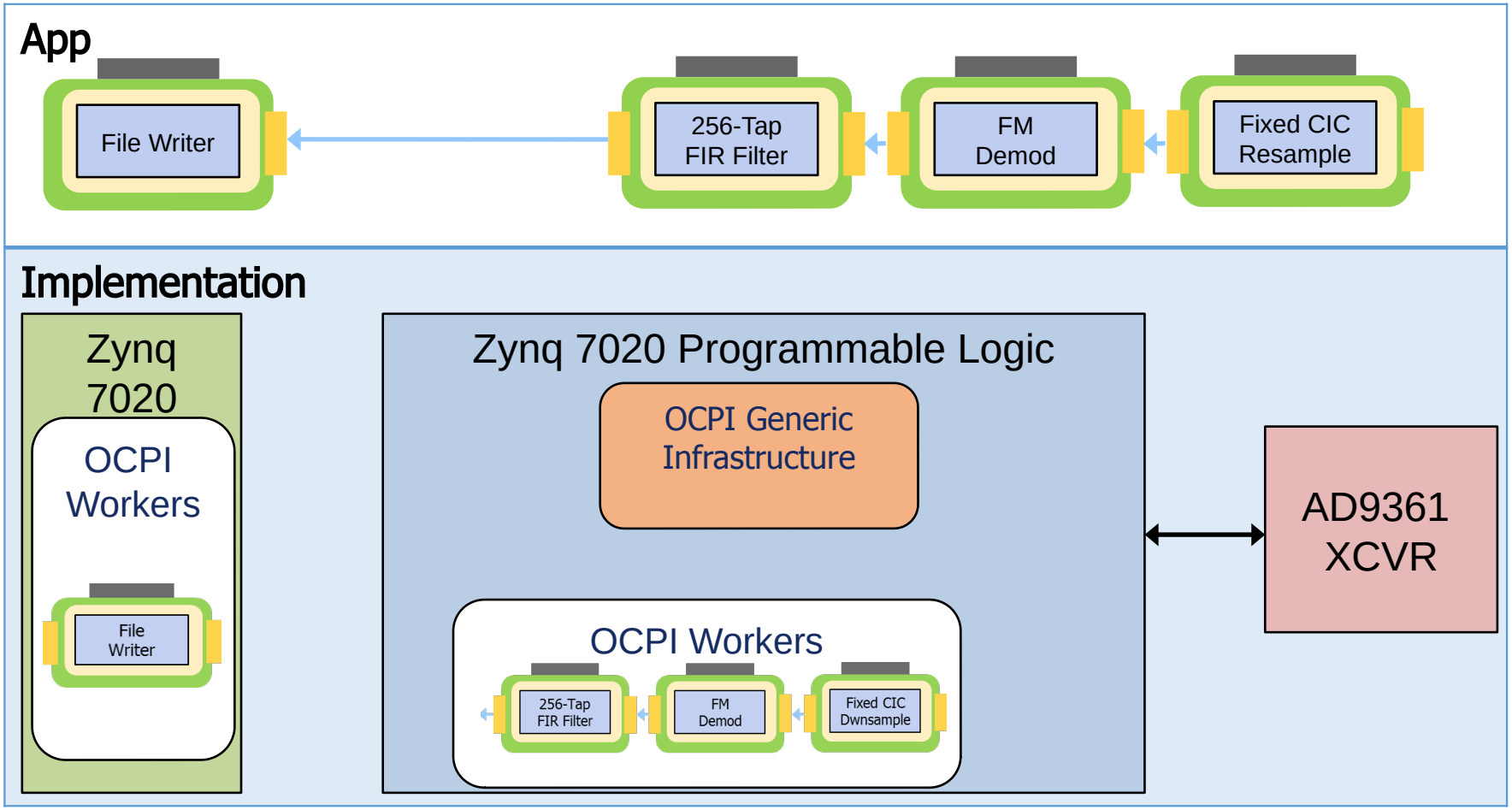
Case Study: What We Started With

- Artix7 PCIe development kit: picoevb
- OpenCPI adapter logic for Artix 7 PCIe
- Existing application using file based input and output
- *No devices used*



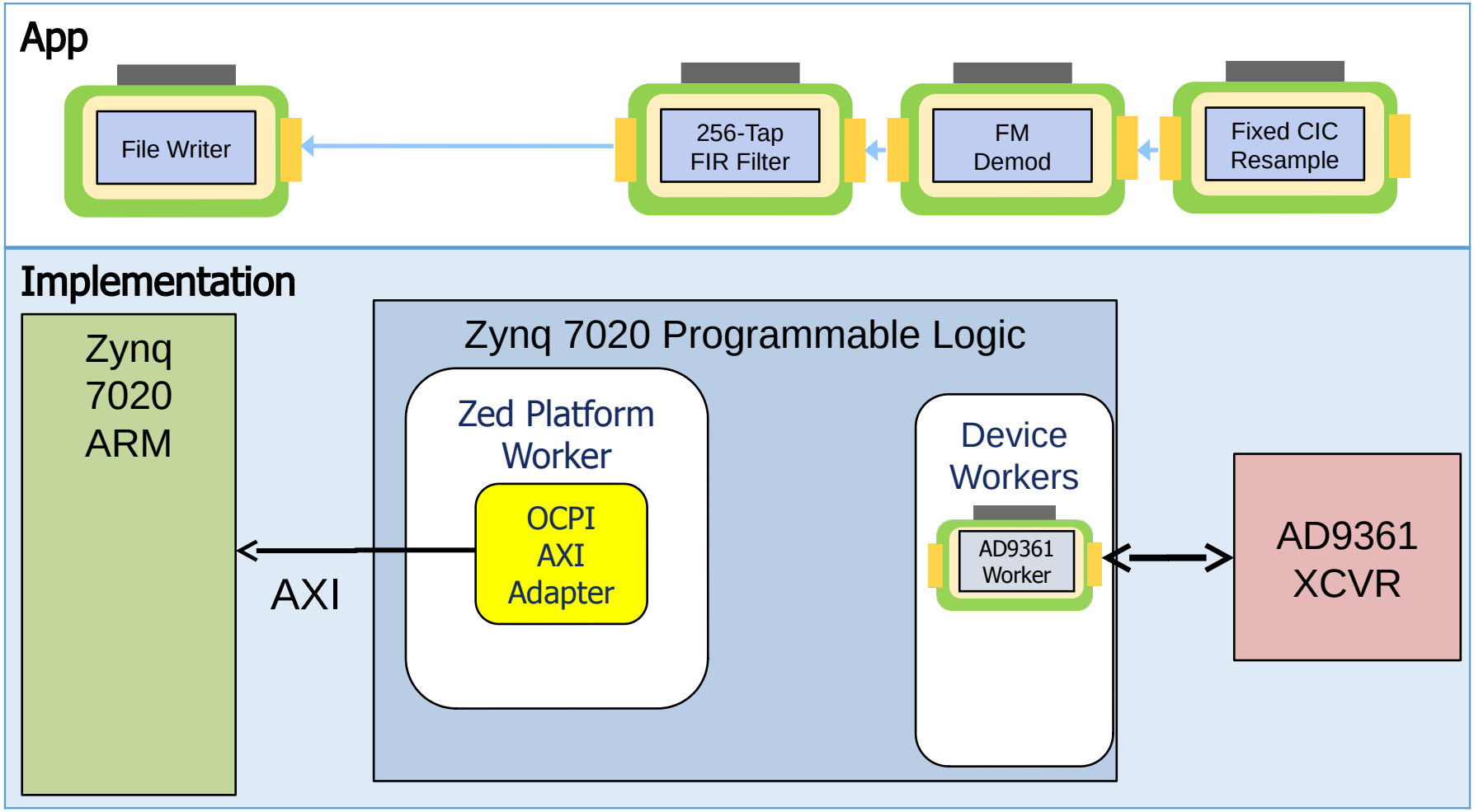
Case Study: What Could Be Re-used?

- What could be reused?
  - Generic infrastructure
  - HDL and software workers
    - Workers must be recompiled for Zynq/ARM. No code changes needed

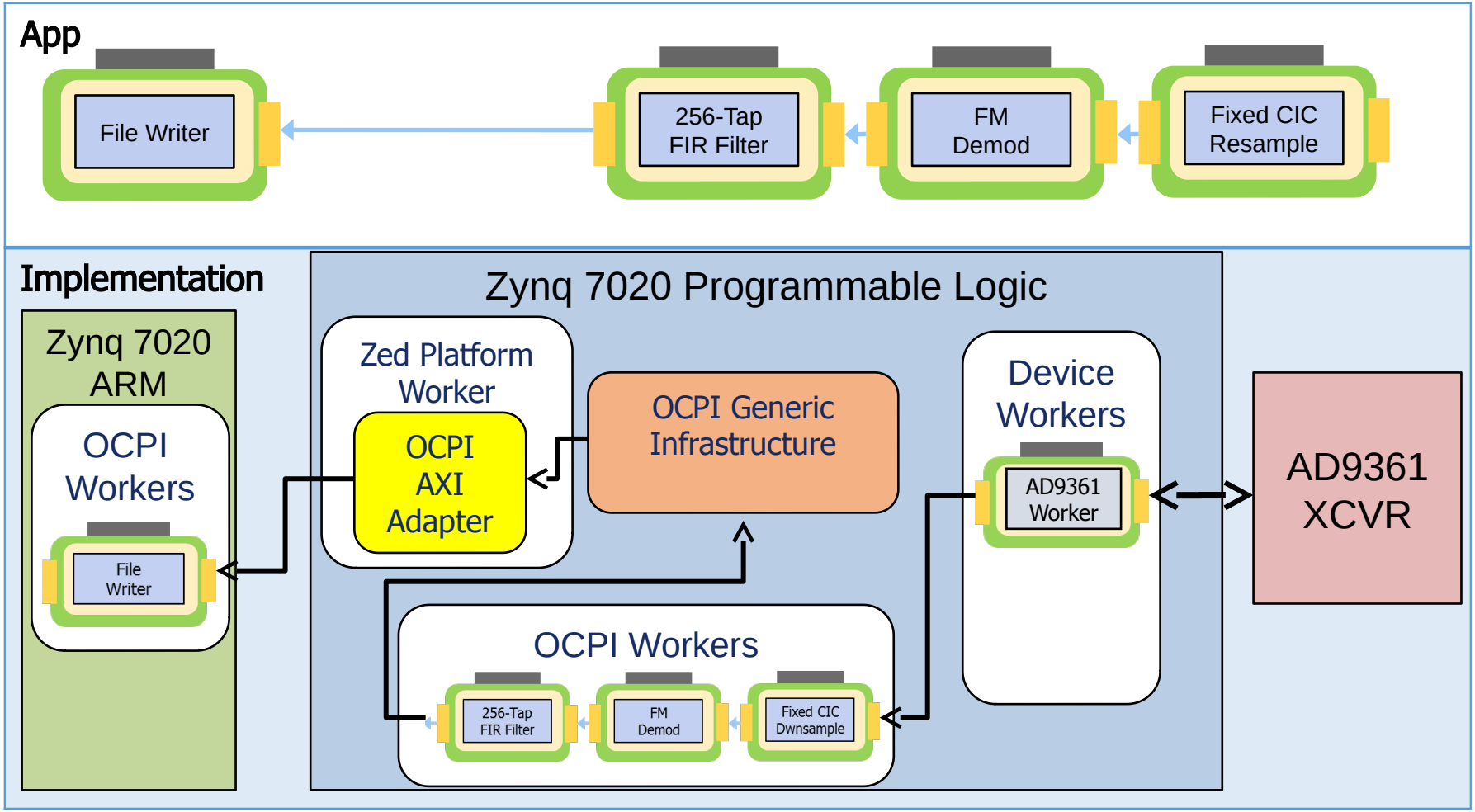


Case Study: What was Needed?

- What was needed?
  - Zed platform worker with OCPI adapter
  - Device workers to ingest data and control devices

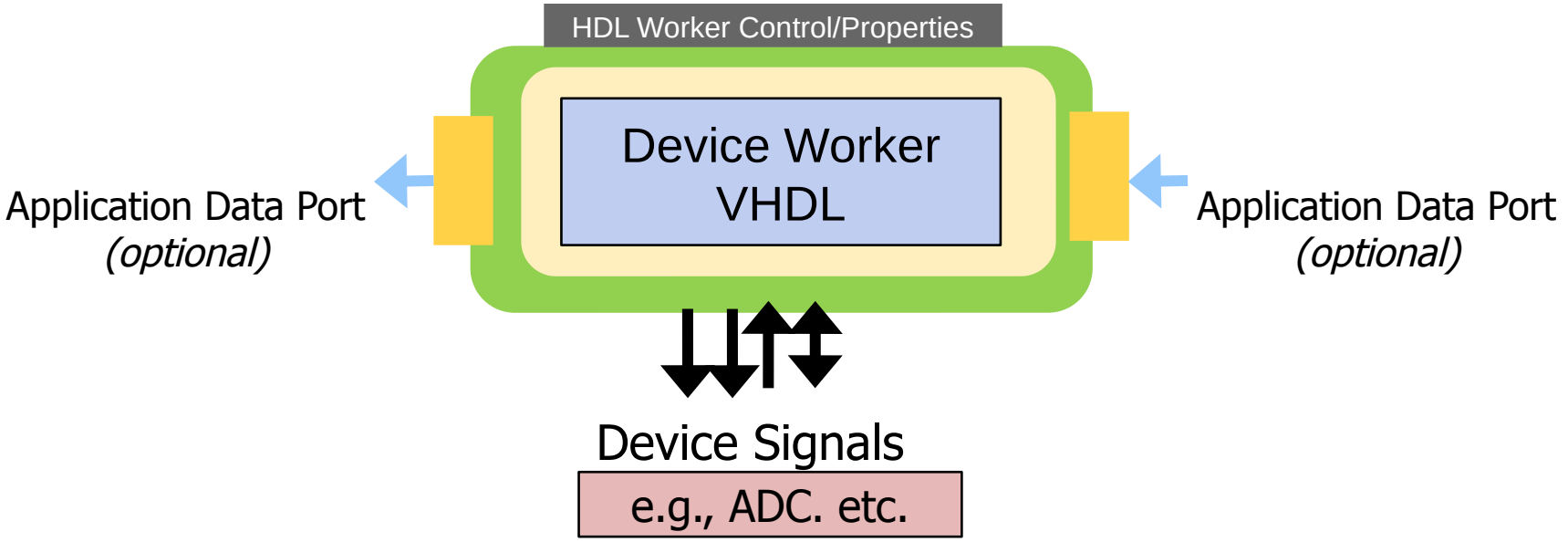


Case Study: Final Implementation



FPGA (HDL) Device Worker

- Acts as the controlling logic for an attached device: the *device driver*
- A superset of an application worker, with normal properties and ports
- Connects directly to the I/O pins for signals between FPGA and device
- HDL Device Worker OWD/XML has element: **`<Signal>`**
  - Declares signals to/from the device, with their direction, width, I/O attributes
  - These signals are made directly available in the VHDL architecture worker code

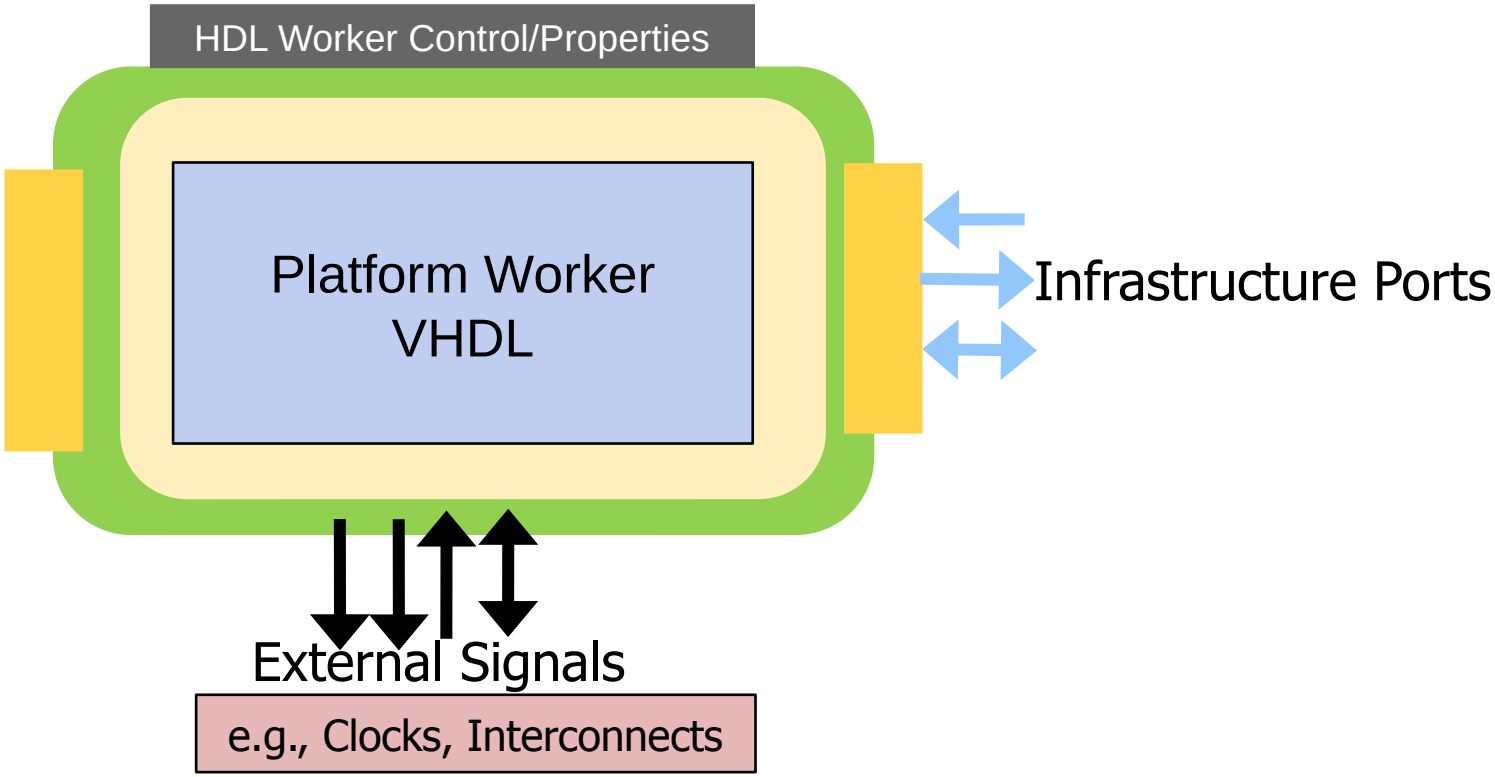


FPGA Device Worker OWD XML Example

```
<!-- Example ADC worker -->
<HdlDevice language="vhdl" firstrawproperty='dc_regval' spec='qadc-spec'>
  <ControlInterface Timeout="1024"/> <!-- timeout long enough for the SPI
access -->
  <Property name='USE_CTL_CLK_p' type='bool' default='1'/>
  <Property name='source' type='enum' enums='adc,count,loopback' initial='1'/>
  <!-- Properties in registers -->
  <property name='dc_regval'    type='uchar' volatile='true'/>
  <property name='rccal_lpfcal' type='uchar' volatile='true'/>
  <property name='dc_cntval'    type='uchar' writable='true' volatile='true'/>
  <!-- Ports -->
  <StreamInterface Name="OUT" producer='true' DataWidth="32"/>
  <!-- Signals to/from the device -->
  <Signal Output="RX_CLK"/>
  <Signal Input="RX_IQ_SEL"/>
  <Signal Input="RXD" width="12"/>
  <Signal Input="RX_CLK_IN"/>
  <Signal Output="SEN"/>
  <Signal  Input="SDO"/>
  <Signal Output="SDIO"/>
  <Signal Output="SCLK"/>
  <Signal Output="RESET"/>
</HdlDevice>
```

FPGA (HDL) Platform Worker

- A special type of HDL device worker
- Based on the "platform-spec" OCS, has properties
- As a device worker, has external hardware/pin signals via <signal>
- Has "infrastructure" ports to connect to generic infrastructure



FPGA Platform Worker Must Provide:

1. A suitable clock for the control plane
   - Currently this is widely used as the "default clock" for many purposes
2. A suitable clock for timekeeping
   - Typically the highest quality/stability
3. A path for an external processor to perform control access ops
   - Typically allow processor to perform memory mapped load/store access
   - Adapt this path to the OpenCPI "control plane master" interface.
4. A bus-mastering/DMA path for the system interconnect(s)
   - Typically allow OCPI generic infrastructure to be bus master.
   - Adapt this path to the OCPI generic "data plane" interface

FPGA (HDL) Platform Worker OPHD

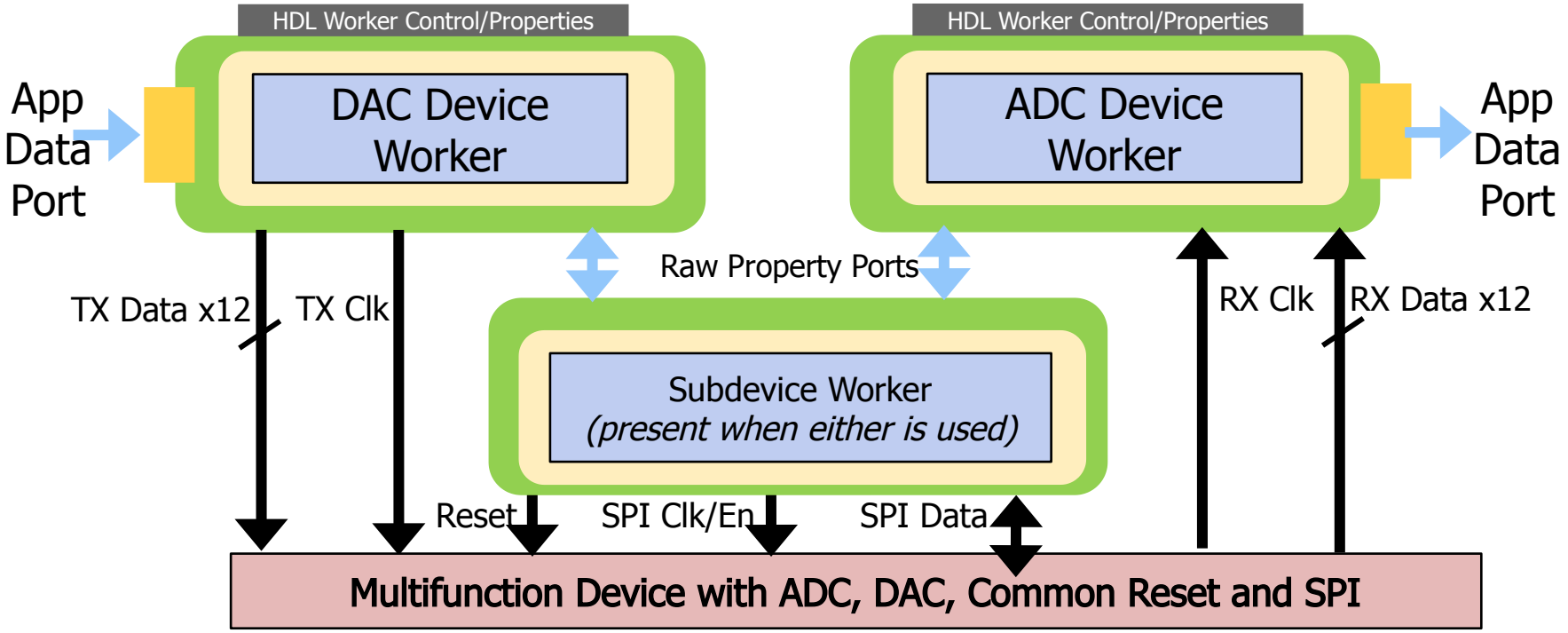
- Top level element is <HdlPlatform>
- Spec is "platform-spec"
- Declare infrastructure ports using these elements:
  - <Timebase> for timekeeping clock
  - <Metadata> for access to in-bit-stream compressed artifact metadata
  - <CpMaster> for access to generic control plane infrastructure
  - <unoc> or <sdp> for access to generic data plane infrastructure
- Declare attached devices using <device> elements
  - including any build parameters and settings required for this platform
- Declare available slots using <slot> elements.
  - including any non-standard slot pin signal names

Complications for Device Workers

- Multiple devices may share some external signals
  - SPI and I2C configuration busses
  - Clocks, resets
- Complex multifunction devices should act as separate simple devices
  - Don't want to waste logic for unused functions
  - Want functional modularity of device workers to be consistent
- Solution is "subdevices", which are special device workers for:
  - Encapsulating signal sharing among device workers
  - Instantiated automatically when any of its supported devices are used.
  - May or may not have their own properties

Subdevice Worker Example

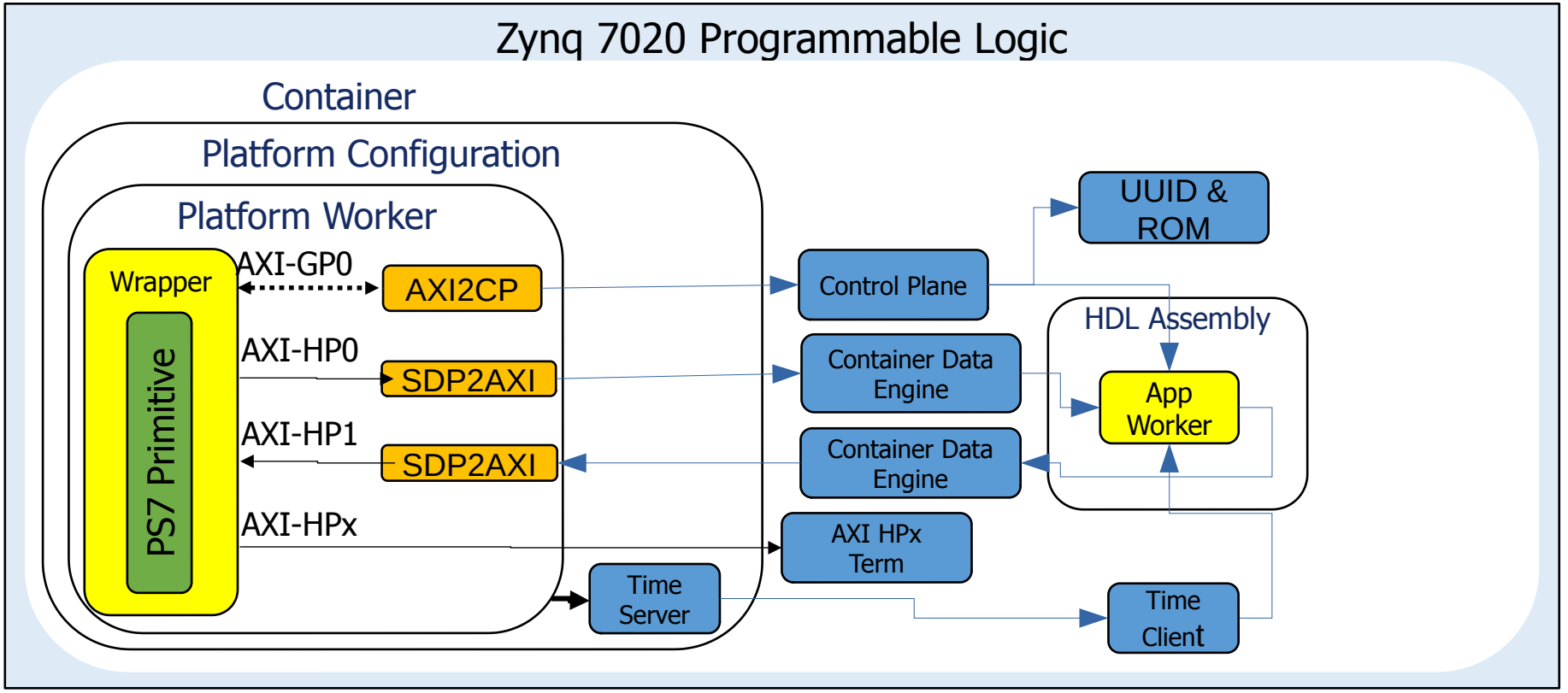
- ADC and DAC have separate data paths and clocks
- They share an SPI and master reset



Detailed Platform Diagrams

- Platform modules can be found in the hdl/platforms directory
- They have implementation XML and source code
  - Just like other workers
- Responsible for instancing OpenCPI adapter logic and some generic infrastructure

Zed Build Example: Single Worker App with File/Read File/Write Outputs



Generic Infrastructure included with OpenCPI – instanced by platform developer
Generic Infrastructure included with OpenCPI – automatically instanced and connected, as needed, by the code-generation tool
Vendor supplied hard IP block
Custom code required for platform enablement

Where Can I Find More Information?

- *OpenCPI Platform Development Guide*
  - https://opencpi.gitlab.io/releases/develop/docs/OpenCPI_Platform_Development_Guide.pdf
- *Matchstiq BSP Case Study*
  - https://opencpi.gitlab.io/releases/develop/docs/assets/Matchstiq_BSP_Case_Study.pdf
- *Matchstiq Platform Worker* Data Sheet
  - https://opencpi.gitlab.io/releases/develop/docs/assets/Matchstiq_Z1_Platform_Worker.pdf