# Open-source FPGA Framework for the MicroTCA Ecosystem by DESY



13<sup>th</sup> MicroTCA Workshop

Cagil Gumus Hamburg, 11.12.2024







### What is the goal?

Goals:

• Reduce the time and complexity of developing FPGA firmware

- Increase collaboration
- Reduce reinventing the wheels  $\rightarrow$  Save tax payer's money





# **Visit our repository today!**

FPGA firmware	umentation (public)	
Group ID: 45 👸 Leave group	FPGA Firmware Documentation	♣ FPGA Firmware Documentation / Start Page
The MSK FPGA firmware framework with projects and their components. Go to MSK Firmware documentation site for more details. Subgroups and projects Shared projects Archived projects > Shared projects Of High level software applications and scripts used to operate firmware	Start Page > Git Repository > VHDL code Firmware Framework (fwk) Yocto (FwkLinux) > Firmware Documentation Tools	FPGA firmware documentation site Welcome to the DESY FPGA firmware PUBLIC documentation site. It is part of the internal documentation which has been put into public and is available outsite the DESY. For internal documentation accessible withing DESY network place visit: fwdocu msktools.desy.de/ The firmware documentation follows the documentation-as-code approach. Documentation sources are kept in the git repositories and next the static site is generated with the Antora tool.
Libraries		Navigation
<ul> <li>Se M Modules A RTL modules (IPs) sources</li> <li>Se P Projects D Master projects</li> </ul>		Each project documentation and its version can be selected using left bottom menu. For easier navigation Main documentation This documentation page and project. You can navigate using current Navigation sidebar. Firmware Framework (fwk) The documentation of the FPGA firmware framework. The main tool to develop the firmware. It gives all the information about the projects structure and build process.
<ul> <li>Software Software that runs on FPGA. Bare metal or OS applications.</li> </ul>		Yocto (FwkLinux) All the topics related to Yocto and embedded Linux distro - FwkLinux
> %• T Tools ⊕		Firmware Projects List of all the firmware super projects documentation pages. Firmware Modules
> Se Y Yocto D		List of all the firmware modules/IPs documentation pages.
Documentation     Decumentation     The main firmware documentation module. Default on Antora generated site.      Firmware Framework     The main firmware framework project		Firmware Libraries List of all the desy libraries documentation pages. Firmware Tools List of all the tools used within the FPGA
		Next Git Repository →

### gitlab.desy.de/fpgafw

## fpgafw.pages.desy.de/docs-pub

# **Our open-source arsenal**

# **Starter Designs for AMC**

**Quickly get started with your project!** 

### **Available Today**







DAMC-FMC2ZUP Example Design



Motion Controller Project for PE TRA IV using DAMC-MOTCTRL







DAMC-FMC1Z7IO Example Design



RFSoC 4x2 Test Project



DRTM-AD84

# SIS8372 Example Design

**Companies contributing to the repository** 

Highlight:

Christian Ther provided the example design for their new FMC Carrier AMC Board.

For more information please visit here.





# What is FWK

The Swiss Army Knife of FPGA development

- TCL library for bringing IPs together and interact with the EDA tools
  - Creation of FPGA projects on FPGA vendor tools
  - Implementation of those FPGAs Projects (bit-stream creation)
  - Handle versioning per each IP
  - Combine multiple IPs and create address mapping for each register
  - Create documentation of the IPs
  - Package an IP

٠

. . . .

- Create an IP using Higher-Level-Synthesis (eg. Xilinx HLS)
- Embedded Linux Creation with Yocto



## What is FWK

**Supported FPGA Vendor Tools and Simulation Environments** 













Model Sim.

TODO:

# What is FWK

#### The biggest picture





# **Typical Projects with FWK**

#### **The Power of Abstraction**

- Most of the projects build with FWK has only 2 IPs on the top: BSP(Board Support Package) and APP(Application).
- BSP holds the FPGA logic that is not application related:
  - PCle
  - MPSoC
  - DDR
  - I2C
  - SPI
- Application part has logic that is not board related
  - Controllers
  - DSP Algorithms
  - Data Analysis etc.
- Payload makes sure BSP and Application fits together by defining universal interfaces



# **Other tools**

# **DesyRDL**

### Take SystemRDL to a whole new level

Once you have the register model, you can even create Synthesizable HDL code!

Hence **DesyRDL** is born:

Create all the necessary register access logic automatically using templates (**Jinja2**)

Register interface can be anything (AXI4 / IBUS / Wishbone / Avalon)

Significantly reduces the IP development stage duration.

Templating engine brings extensible interface:





# **Yocto Integration on FWK**

#### **The Power of Abstraction**

- Xilinx MPSoC  $\rightarrow$  ARM comes first, FPGA second.
- For basic projects  $\rightarrow$  Baremetal Application is enough
- For complicated projects  $\rightarrow$  Embedded Linux is (almost) a must.
- FWK takes .xsa file, along with Yocto Layers and produces a embedded Linux image
- We have package feeds setup on Jenkins to speed up the compilation time.
- Supported Boards: DAMC-FMC2ZUP, DAMC-MOTCTRL, ZCU102, ZCU111, RFSoC 4x2, DAMC-UNIZUP, DAMC-FMC1Z7IO, ZCU208 and many more..

Application Processing Unit	Memory	Graphics Processing Unit ARM Mali™-400 MP2		High-Speed Connectivity
CortexTM-A53 Floating Point Unit 32KB 32KB Memory Embedded 1-Cache D-Cache Management Trace	DDR4/3/3L, LPDDR4/3 32/64 bit w/ECC	Geometry Processor	Pixel Processor 1 2	USB 3.0
WPanty WECC Unit Macrocoll I 2 3 4 GIC-400 SCU CCI/SMMU 1MB L2 w/ECC	256KB OCM with ECC	Memory Management Unit		PCIe® 1.0 / 2.0
		64KB L2 Cache		PS-GTR
Real-Time Processing Unit       ARM Cortex**-R5     Vector Floating Memory Protection Unit       128KB     32KB / Cadree     WECC       128KB     32KB / Cadree     WECC       128KB     32KB / Cadree     WECC       128KB     GIC	Platform Management Unit System Management Power Management Functional Safety	Configuration and Security Unit Config AES Decryption, Authentication, Secure Boot Voltage/Temp Monitor TrustZone	System Functions Multichannel DMA Timers, WDT, Resets, Clocking & Debug	General Connectivi GigE USB 2.0 CAN UART SPI Quad SPI NOR NAND SD/eMMC
Programmable Logic	System Monitor	High-Speed Connectivity Interlaken		
Storage & Signal Processing	eneral-Purpose I/O	GTH		
UltraRAM	h-Performance HP I/O	GTY		
	igh-Density HD VO		EMAC	



# Looking ahead

# **Future work for FWK**

### Ideas to improve:

- Honeymoon phase is over.
- Lesson learned:
  - Maintenance of a software abstraction takes WAY more time and effort than initially thought
  - TCL language might not be the best way to move forward
  - There alternative frameworks that does somethings better than us.
- Planning of overhauling the FWK has started.
  - Some ideas:
    - Do the overhaul without disturbing the on-going projects
    - Use Python
    - Evaluate tools like FuseSoC + edalize etc.
    - · Better documentation and tutorials



Prompt: "show me an image of an FPGA developer on top of a mountain. She is looking ahead Created by Gemini.

# Thank you!