Application Development on the MicroTCA.4 Platform: Challenges and Solutions.

MicroTCA Workshop in China

Cagil Gumus (CJ)
Hefei, 18 September 2024

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Motivation

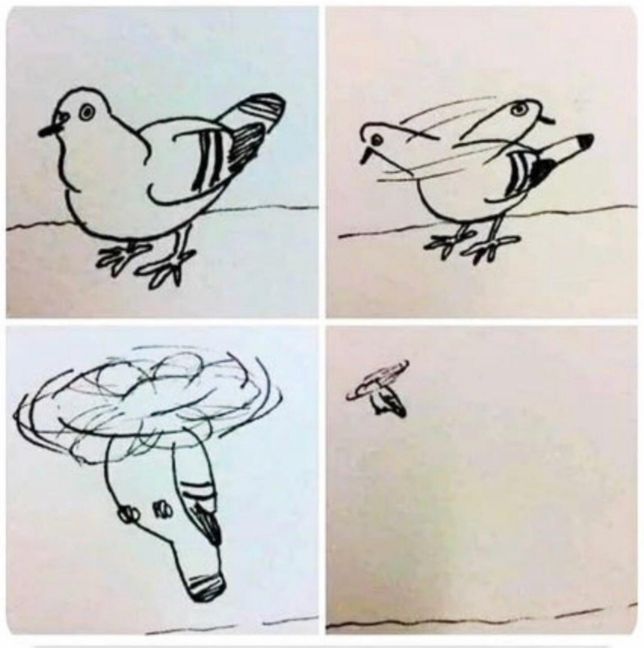
MicroTCA can get very simple and very complicated.

Your application requirements can change the MicroTCA system significantly.

- Many different applications using the same standard →
  - The standard is quite flexible →
    - System engineering becomes less straight forward
- For the newcomers, the task of assembling a new system from scratch can be daunting.

This tutorial will show some of the critical elements of MicroTCA systems that effect design decisions.

Credit: r/birdsarentreal



It works != Best solution

Choose the right MTCA Crate

Choose the right MTCA Crate

The trade off between functionality – redundancy – reliability

Questions to ask:

- How many AMC cards do you need?
- How about redundancy? (Power Module, MCH …)
- What kind of AMC cards?
- RTM cards necessary?
- RF Backplane Necessary?
- How should be the AMC Backplane configuration?
  - Fat Pipe Configuration (PCIe, 10/40 GigE, SRIO ..)
  - Point-to-Point Links
  - SATA
  - JTAG on Backplane?

RackPak/M2-40 MTCA.4 system

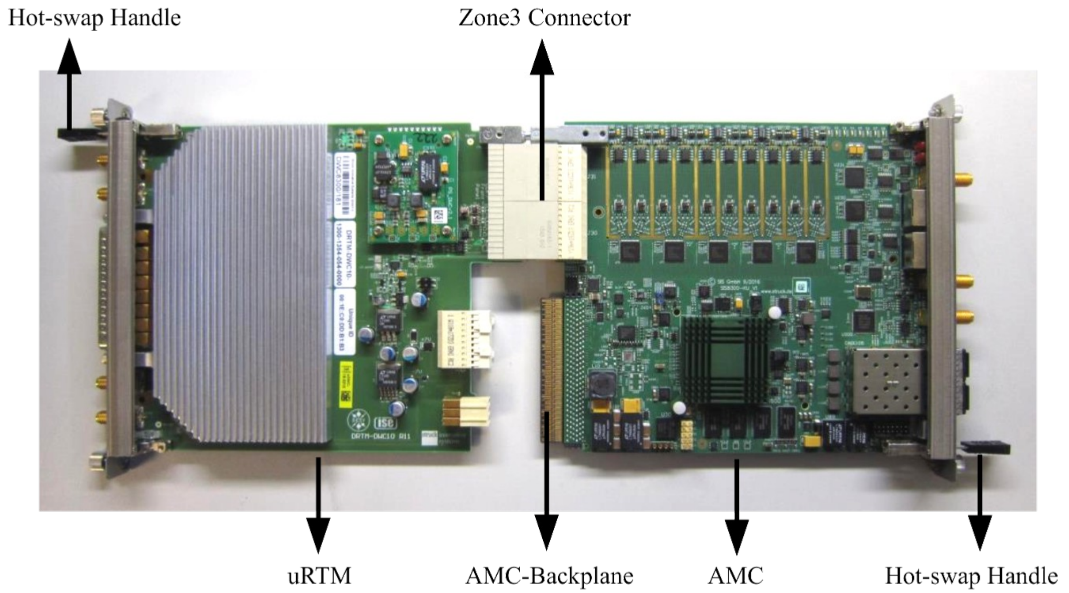
RackPak/M4-2 MTCA.4 system

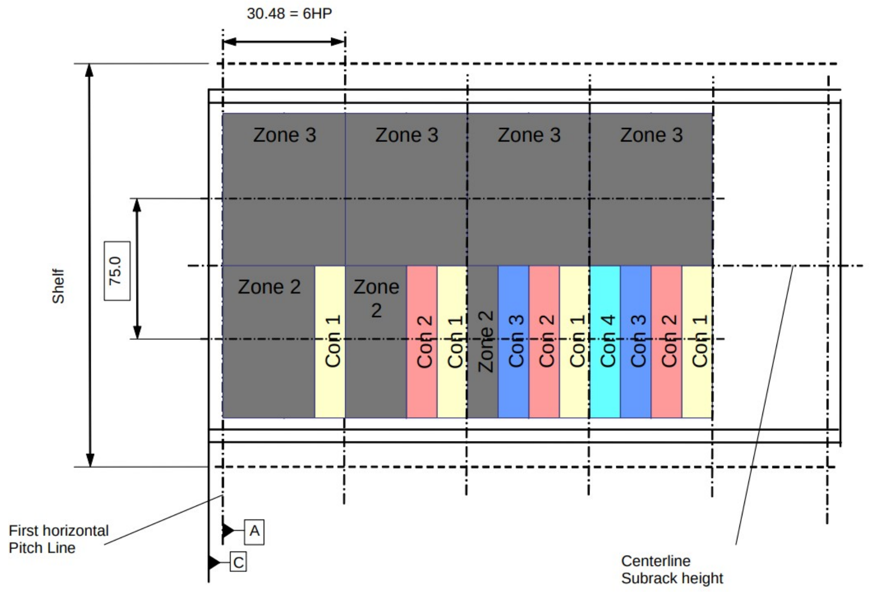
Choose the right AMC+RTM Pair

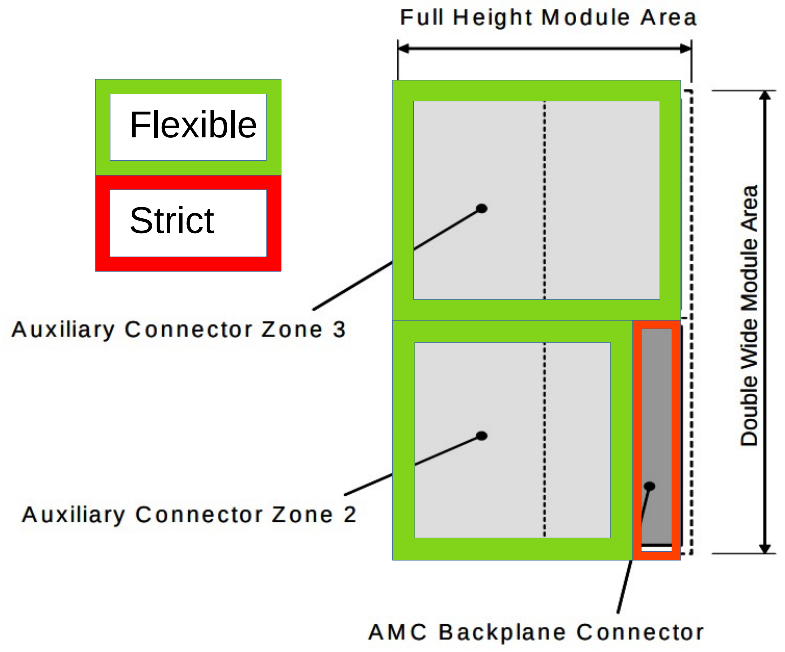
Choosing the right AMC + RTM

Importance of Zone2/3 Connectivity

- Mostly : AMC → COTS
- RTM → In-house development or COTS
- The MicroTCA.4 Standard does **not** dictates how Zone2 and Zone3 connector should be.
- There are recommondations done by companies/facilities.
- The interoperability might be an issue.





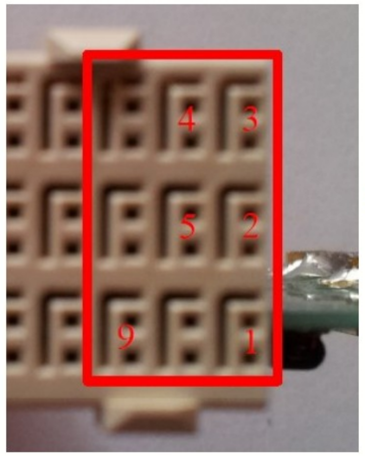


Choosing the right AMC + RTM

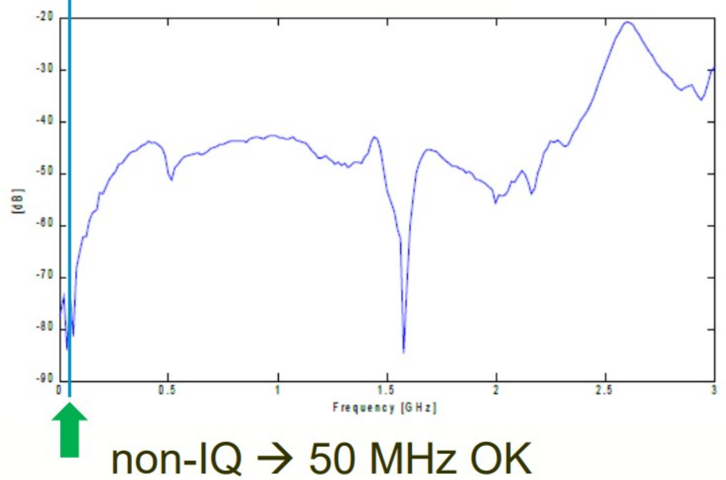
Analog signal performance of Zone3

- Critical Question: How do I transfer analog signals inside the MicroTCA environment?
  - Direct injection from front panel of AMC
  - Over Zone3
- Analog signal transfer over Zone3 can be limited in terms of maximum frequency >200MHz is problematic for LLRF applications
- Solution: New connector: COAXIPACK 2 from Radiall
  - Upto 3GHz
-

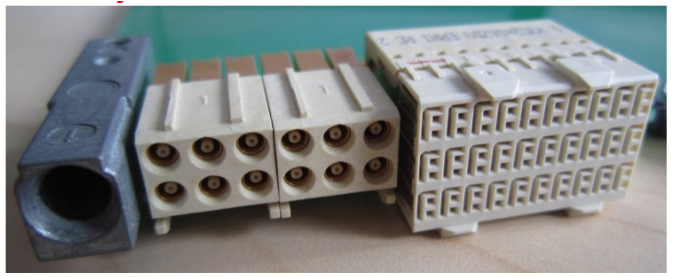
A new Zone 3 Class for RF Signals up to 3 GHz in MicroTCA.4 Johannes Zink, MTCA Workshop 2019

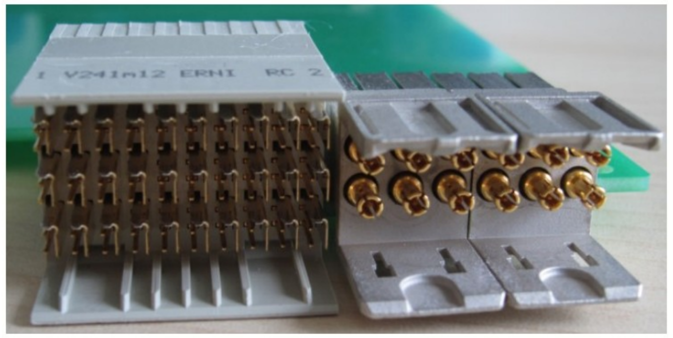


x-talk 4 → 5



non-IQ → 50 MHz OK

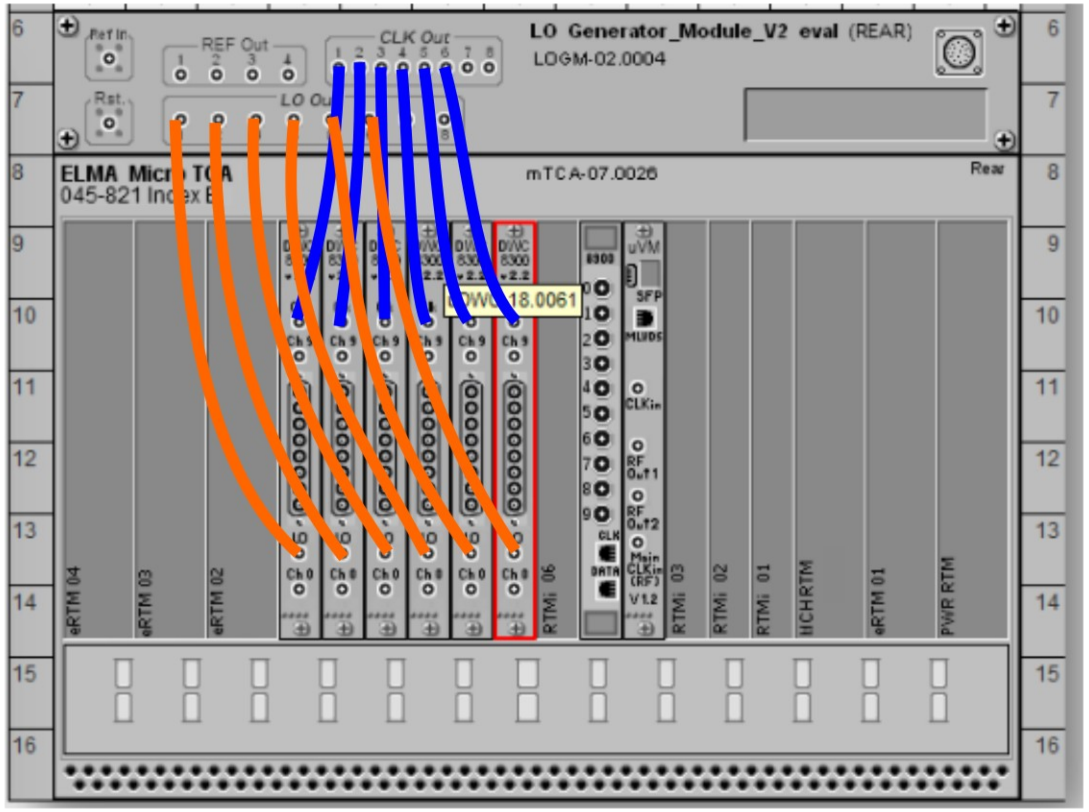




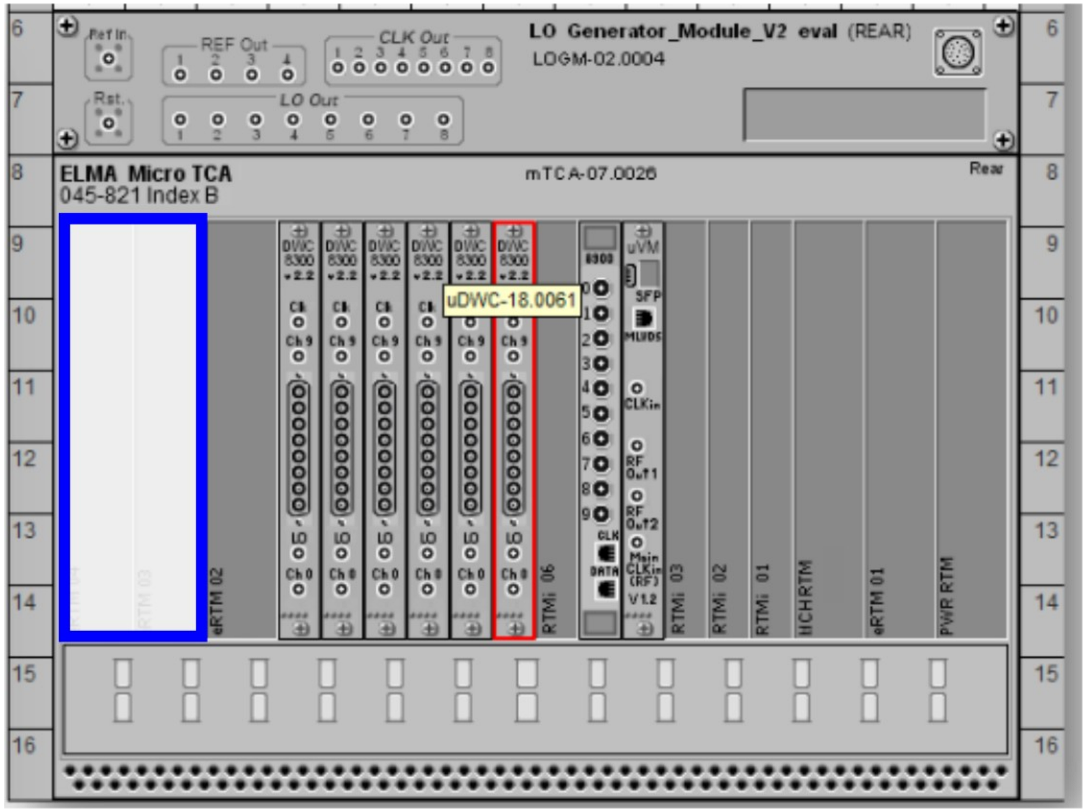
RF Backplane (MicroTCA.4.1)

Motivation: Getting rid of spaghetti, better management for analog signal distribution

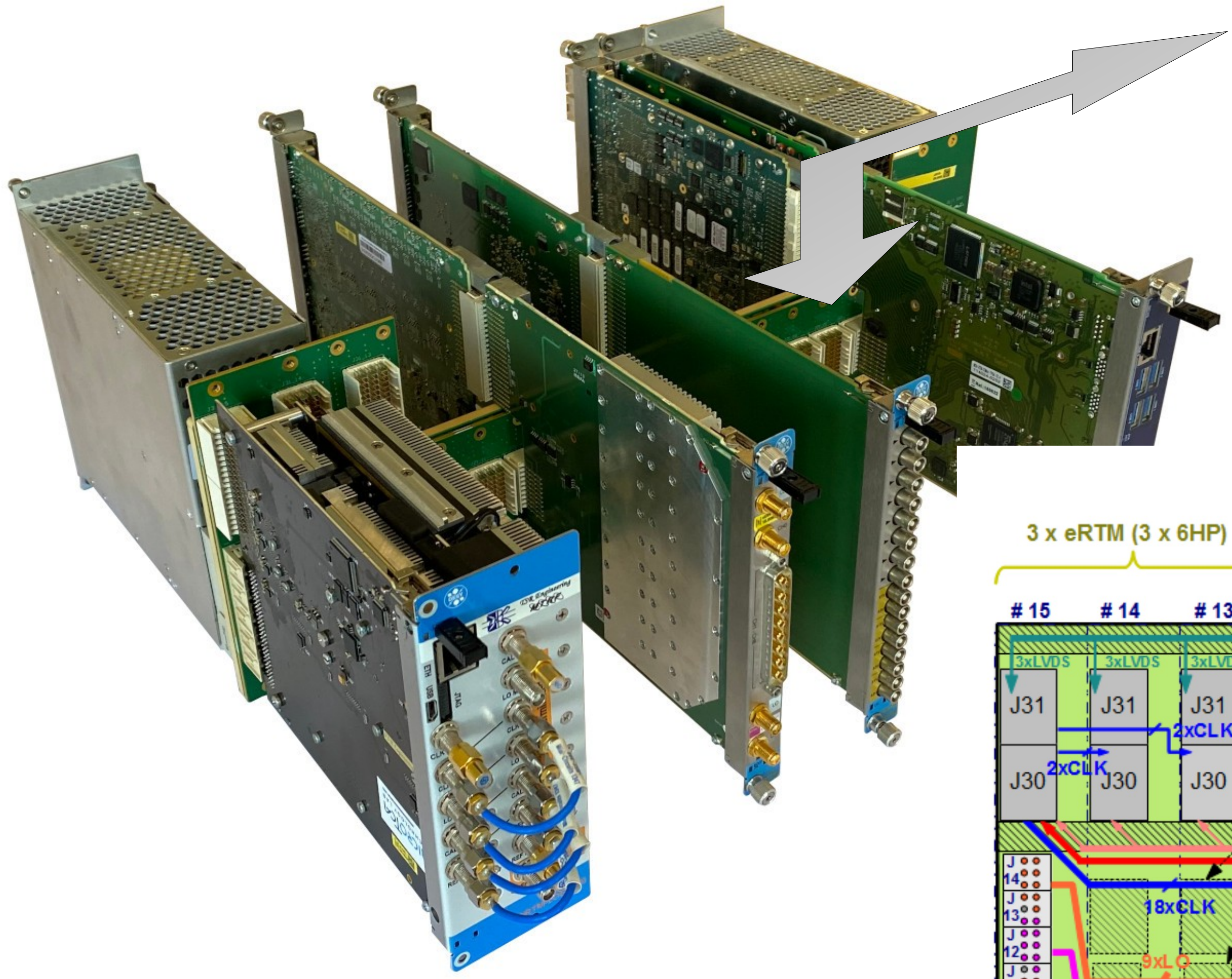
Before

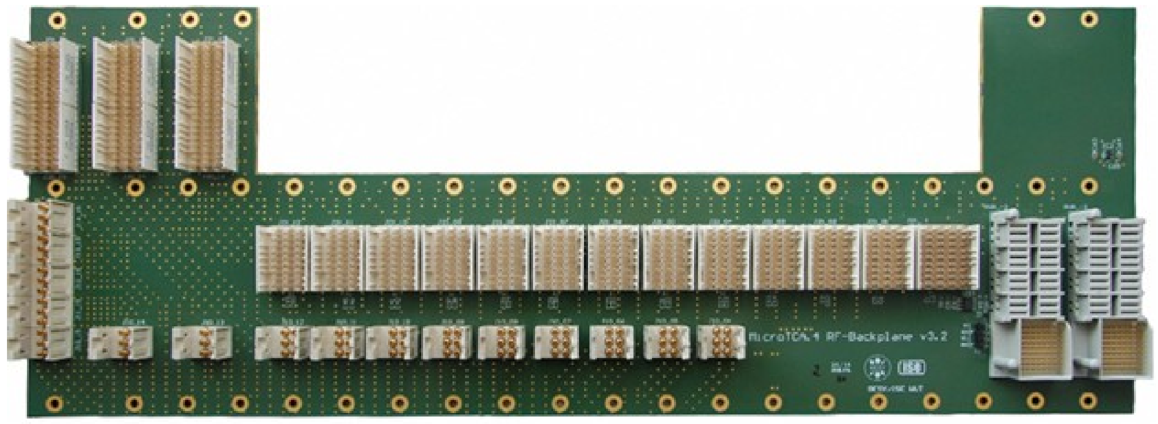


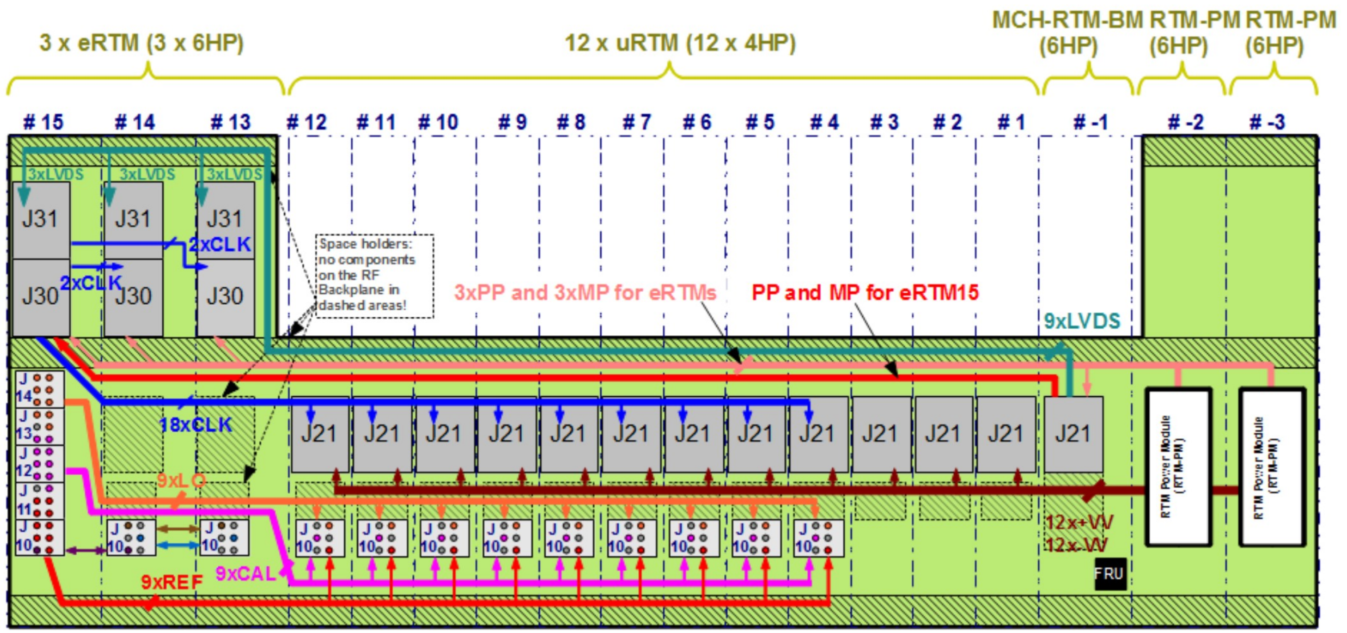
After



RF Backplane







Know your AMC-Backplane

Know your AMC Backplane

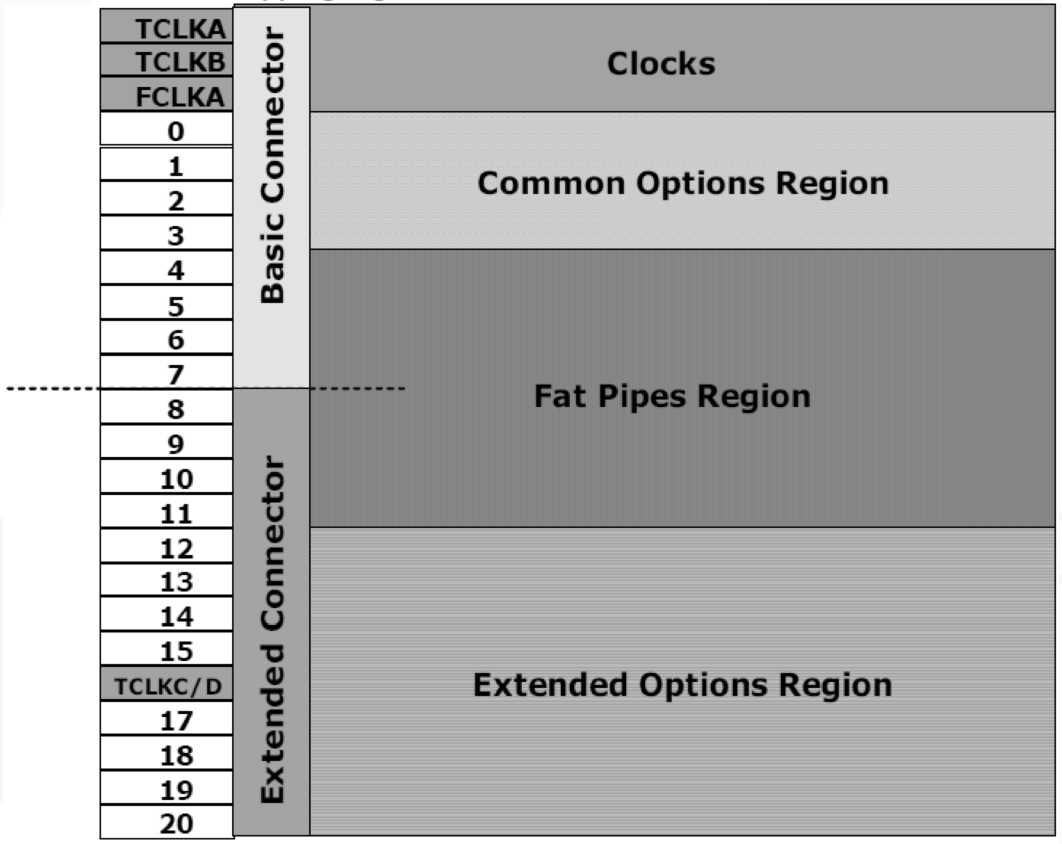
Which ports to use on your application?

Protocols on the AMC backplane

- IPMI (Management)
- Gigabit Ethernet (Ports 0-1)
- SATA* (Ports 2-3)
- Fat Pipe + Extended Fat Pipe* (Ports 4-11)
  - PCIe
  - SRIO
  - 10/40 GbE
- Point-to-Point Links* (Ports 12-15)
- MVLDS* (Ports 17-20)
- Clocks* (TCLKA,TCLKB TCLKC,FCLK)
- JTAG*

- * → Changes depending on the crate/application

Figure 6-11 AMC Port mapping regions



Pro Tip:

Don’t know how your crate backplane looks like?

Backplane configuration is stored on the Carrier FRU EEPROM (FRU ID: 253)

NAT MCH: ‘show_fruinfo 253’

Know your AMC Backplane

Eg: PCIe

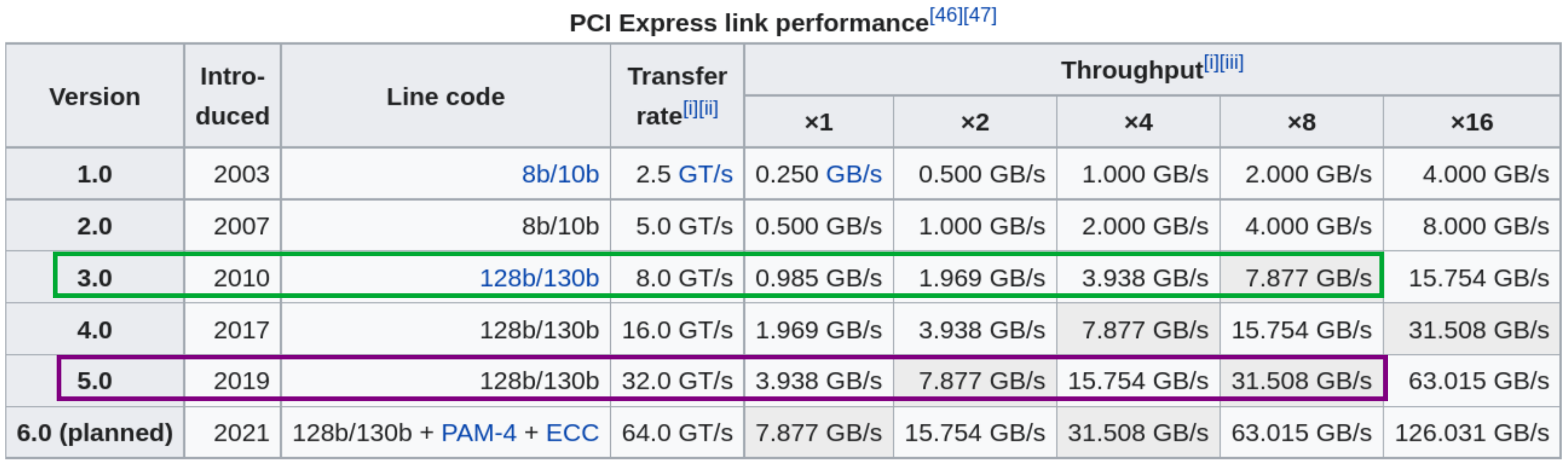
MicroTCA Crate can offer PCIe lanes in different ways:

Ports 4-7 (x4) → MCH #1
Ports 8-11(x4) → MCH #2

Ports 4-11(x8) → MCH #1

Critical Question #1:
How much bandwidth/latency does your application require?

Critical Question #2:
Does my MicroTCA crate satisfy the answer to Critical Question #1?

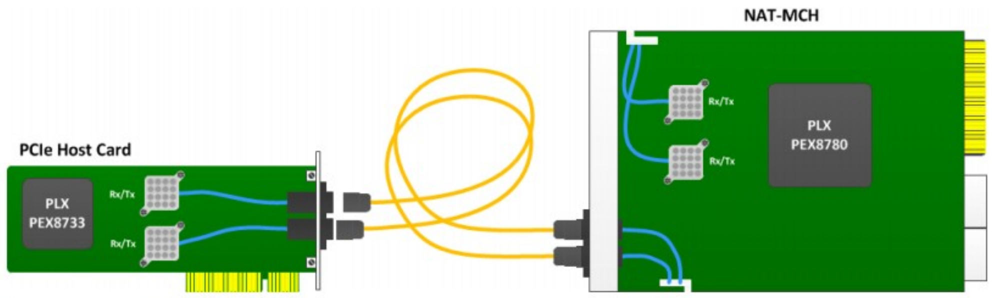


PCI Express link performance[46][47]

	Version	Intro-duced	Line code	Transfer rate[i][ii]	Throughput[i][iii]				
					×1	×2	×4	×8	×16
	1.0	2003	8b/10b	2.5 GT/s	0.250 GB/s	0.500 GB/s	1.000 GB/s	2.000 GB/s	4.000 GB/s
	2.0	2007	8b/10b	5.0 GT/s	0.500 GB/s	1.000 GB/s	2.000 GB/s	4.000 GB/s	8.000 GB/s
Now	3.0	2010	128b/130b	8.0 GT/s	0.985 GB/s	1.969 GB/s	3.938 GB/s	7.877 GB/s	15.754 GB/s
	4.0	2017	128b/130b	16.0 GT/s	1.969 GB/s	3.938 GB/s	7.877 GB/s	15.754 GB/s	31.508 GB/s
Future	5.0	2019	128b/130b	32.0 GT/s	3.938 GB/s	7.877 GB/s	15.754 GB/s	31.508 GB/s	63.015 GB/s
	6.0 (planned)	2021	128b/130b + PAM-4 + ECC	64.0 GT/s	7.877 GB/s	15.754 GB/s	31.508 GB/s	63.015 GB/s	126.031 GB/s

PCIe Root Complex outside of the crate

Suffering from weak CPU-AMC? Here is your solution



Needed Parts:

- 4 x Finisar BOA
- 4 x Pig Tail
- 4 x Face Plate Adapter
- 2 x Patch Cord 5m
- Resulting Costs for a PCIe

GenIII x16 Uplink Connection:

Effects MCH selection!

Pros:

- Cheaper & Powerful PC outside of 80W limitation
- Many choices in the industry for parts
- Many more PCIe slots available on the motherboard for more cards

Cons:

- CPU is not managed by MCH
- Boot sequence of crate and PC has to be done properly

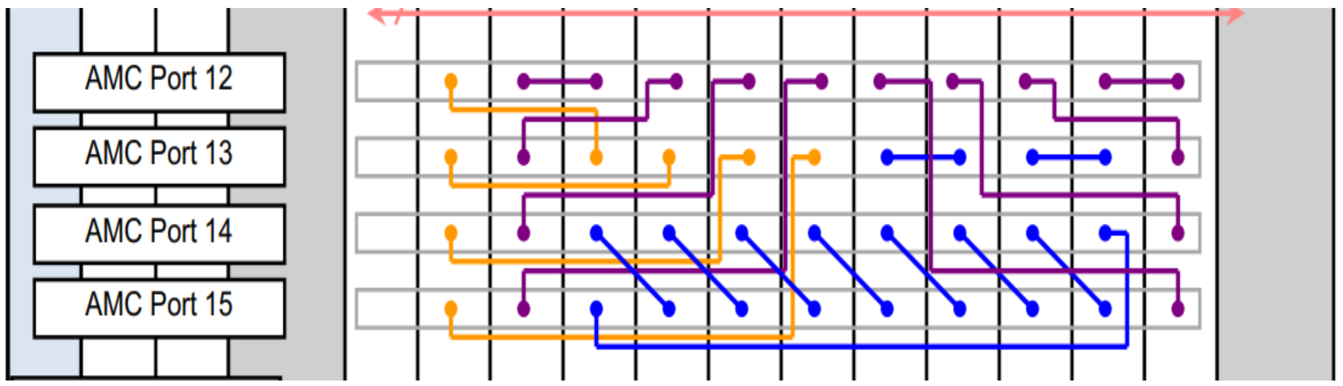
Know your AMC Backplane

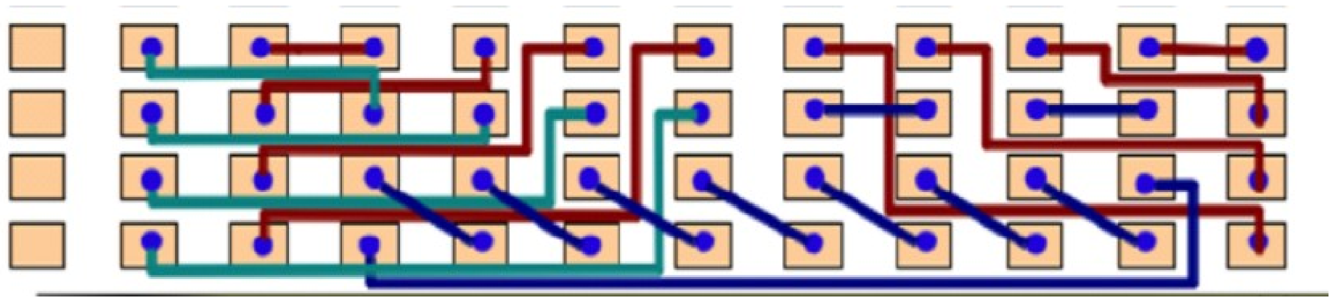
Point to Point Links

Point to Point links offer direct communication from FPGA to FPGA.

Used for data aggregation / fast feedback between boards

These lines are ‘hard wired’. Double check the connectivity before ordering.





Know your AMC Backplane

Examples of P2P Links

Use Case Example:

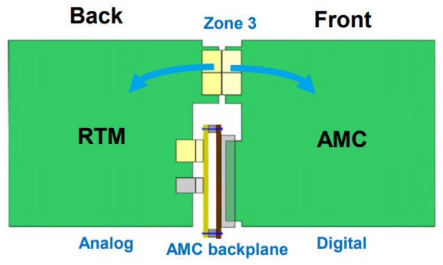
Data aggregation on point-to-point links on Europan-XFEL LLRF Crates:

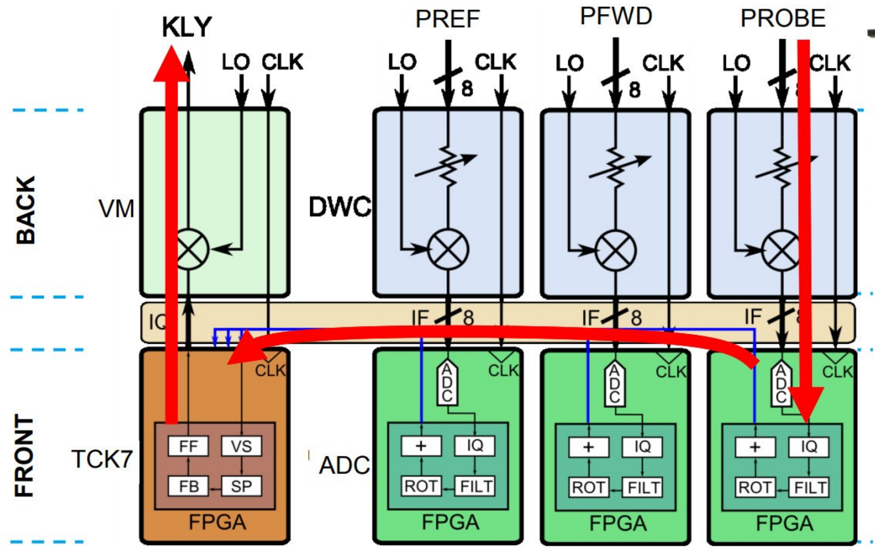
Probe + Forward + Reflected signals of 16 cavities gets send to main controller board.

Some numbers:
6.25Gbps link rate
Sending 11x32 bits payload packet
End to End latency: ~344ns

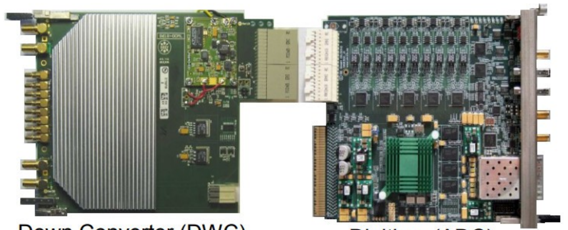
Higher data rates with fully occupied crates harder to achieve because of big EMI issue

- AMC: Advanced Mezzanine Card
- RTM: Rear Transition Module
- 12 slots, hot swap
- Redundant power supply





Vector Modulator (VM) LLRF Controller (TCK7)

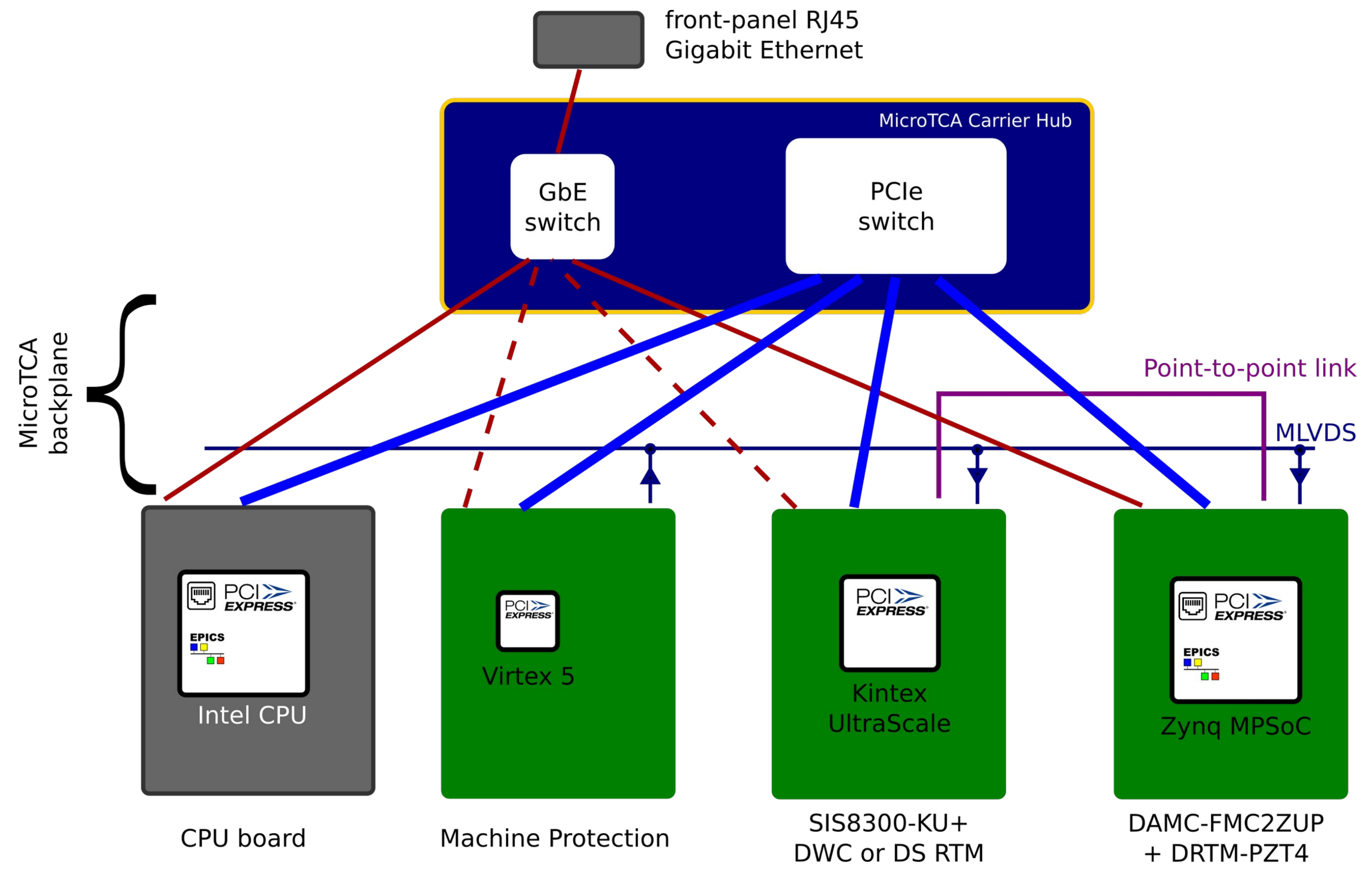


Down Converter (DWC) Digitizer (ADC)

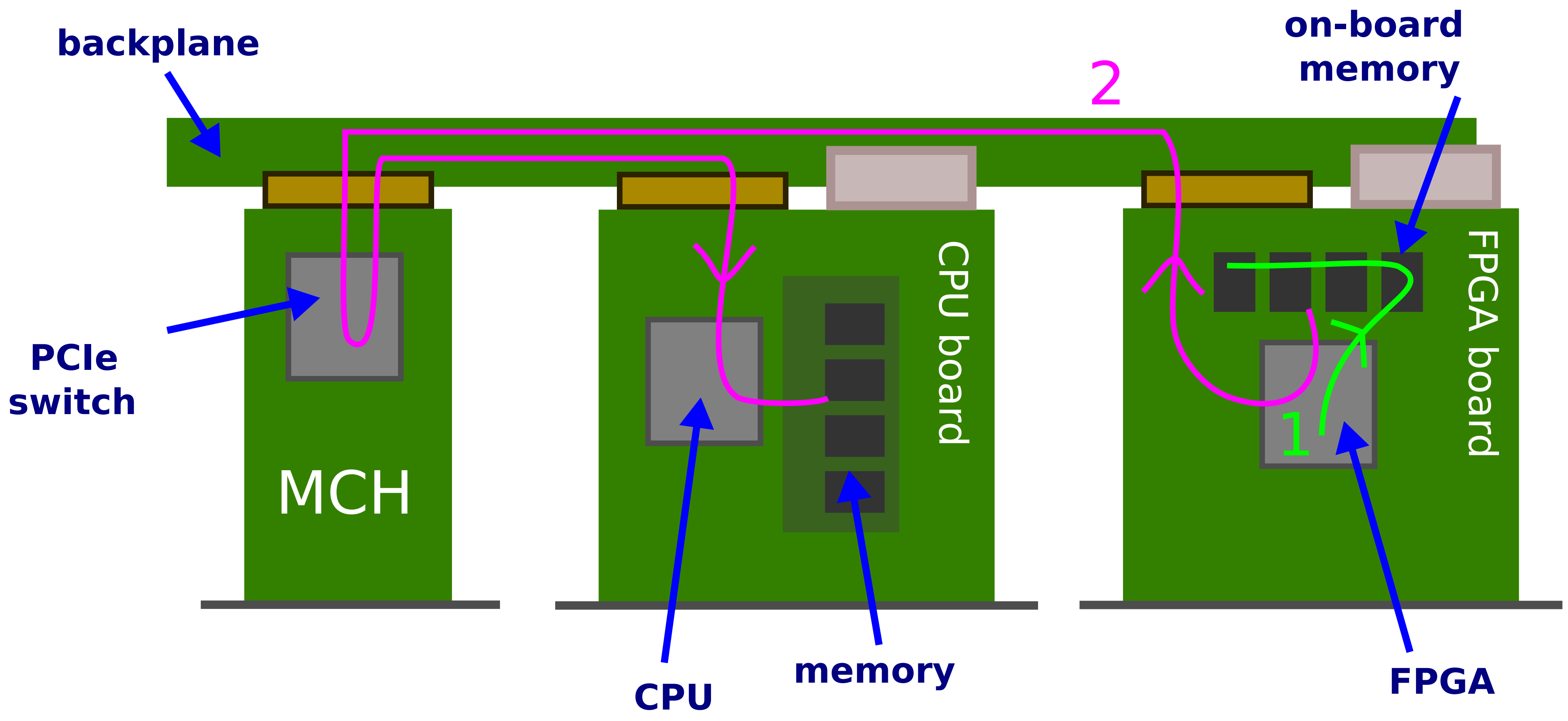
Julien Branlard | LLRF installation for the European XFEL | 7.12.2016 | Page 6

Visualize how the data moves inside the MTCA Crate

Document the Data Transfer inside Crate



Tracing the Data Transfer inside the MTCA Crate



Know your clocking options

MLVDS

- Multipoint LVDS is used in MicroTCA for communication between cards.
- Ports 17-20 Can be used to forward **clocks, triggers and interlocks** to all other cards on the crate.
- Mesh Topology
  - One AMC acts as a driver
  - other cards can be configured as receivers.
- Wired OR is also possible in MLVDS
  - more than one card can drive the same line (with the same polarity)

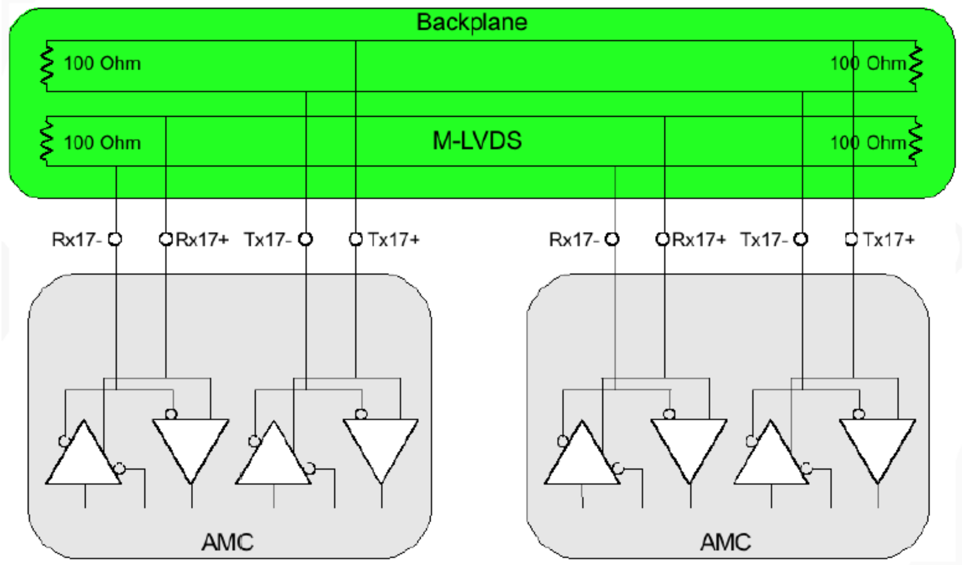


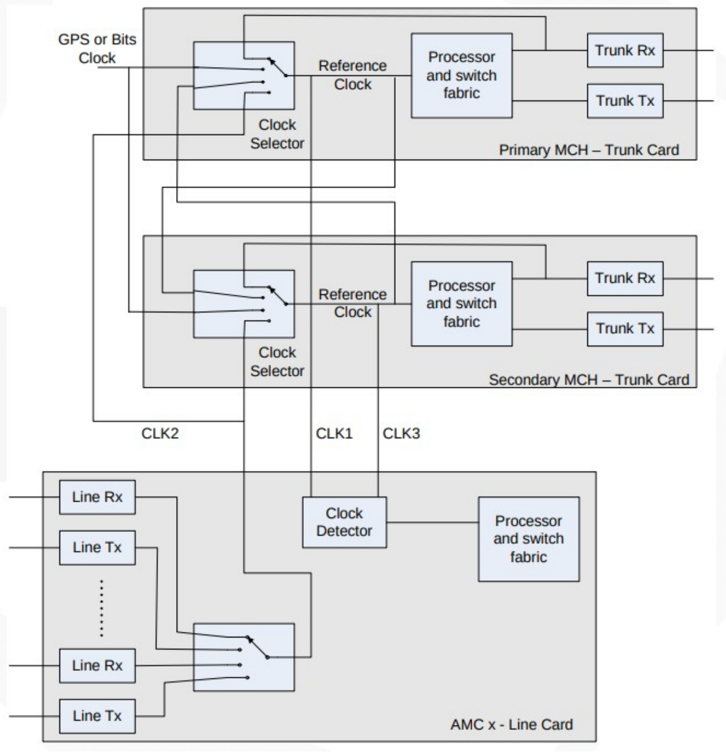
Figure 6-4: M-LVDS transceiver shown for port 17

Table 6-1: Example usage of the 8 bus lines for triggers, interlocks and clocks

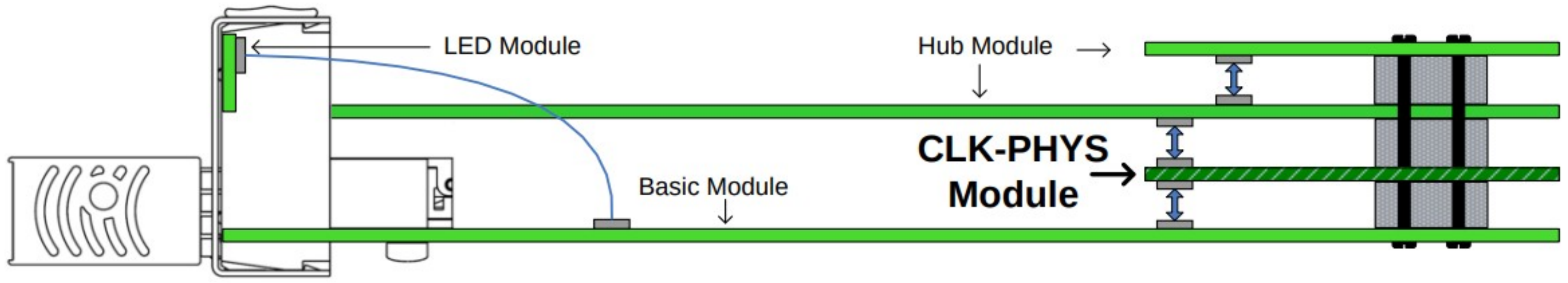
AMC Port	Name	Description	Usage
Rx17	TrigStart	Start sampling data	Triggers
Tx17	TrigEnd	Stop sampling data	
Rx18	TrigReadOut	Start data transfer to CPU	
Tx18	ClkAux	Low performance clock	
Rx19	Reset	Reset of counter, dividers	
Tx19	Interlock 0	Interlock line 0	3 interlocks to provide 2 out of 3 redundancy
Rx20	Interlock 1	Interlock line 1	
Tx20	Interlock 2	Interlock line 2	

Clock Distribution inside MicroTCA

- MCH can be used to distribute clocks inside the MicroTCA crate
- TCLKA/B/C/D and FCLK can be generated
- Specially useful for synchronizing multiple AMCs



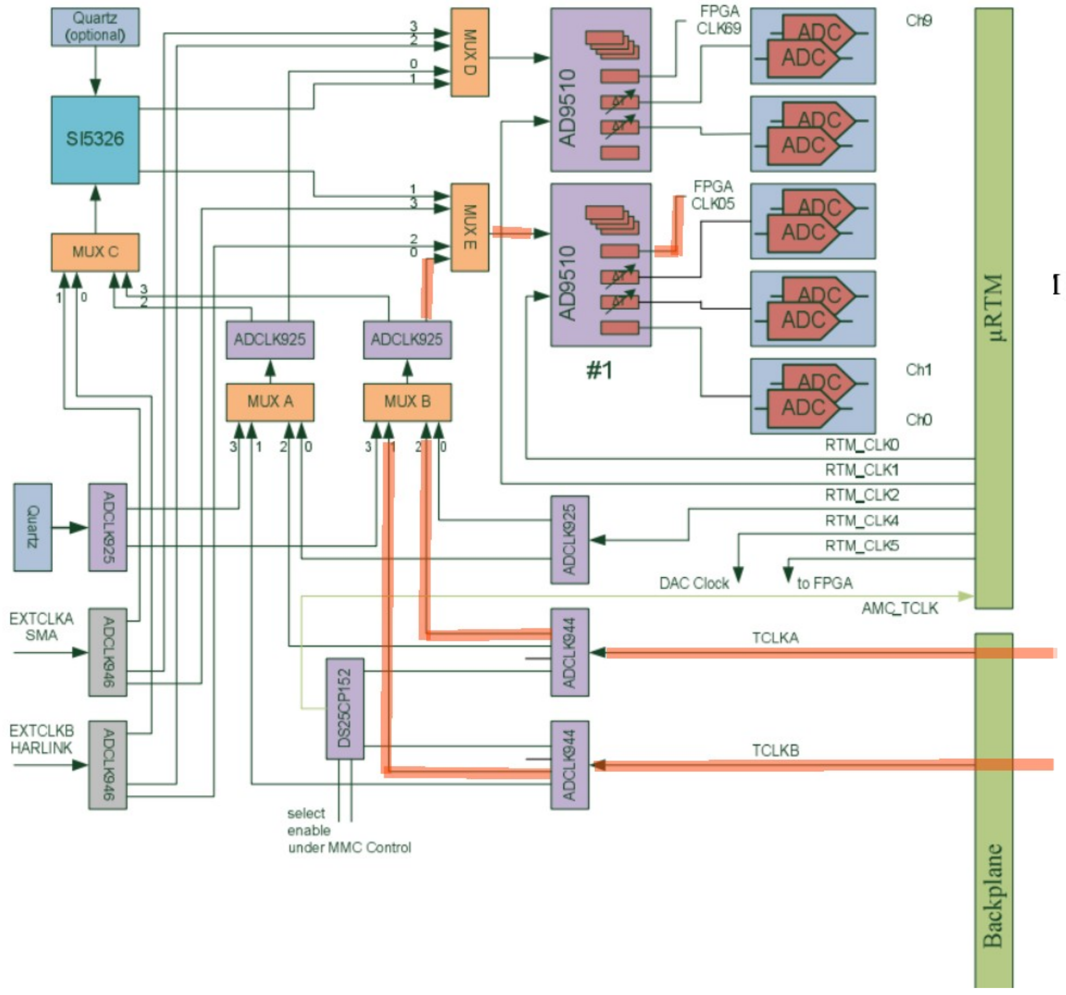
PICMG AMC.0 Specification

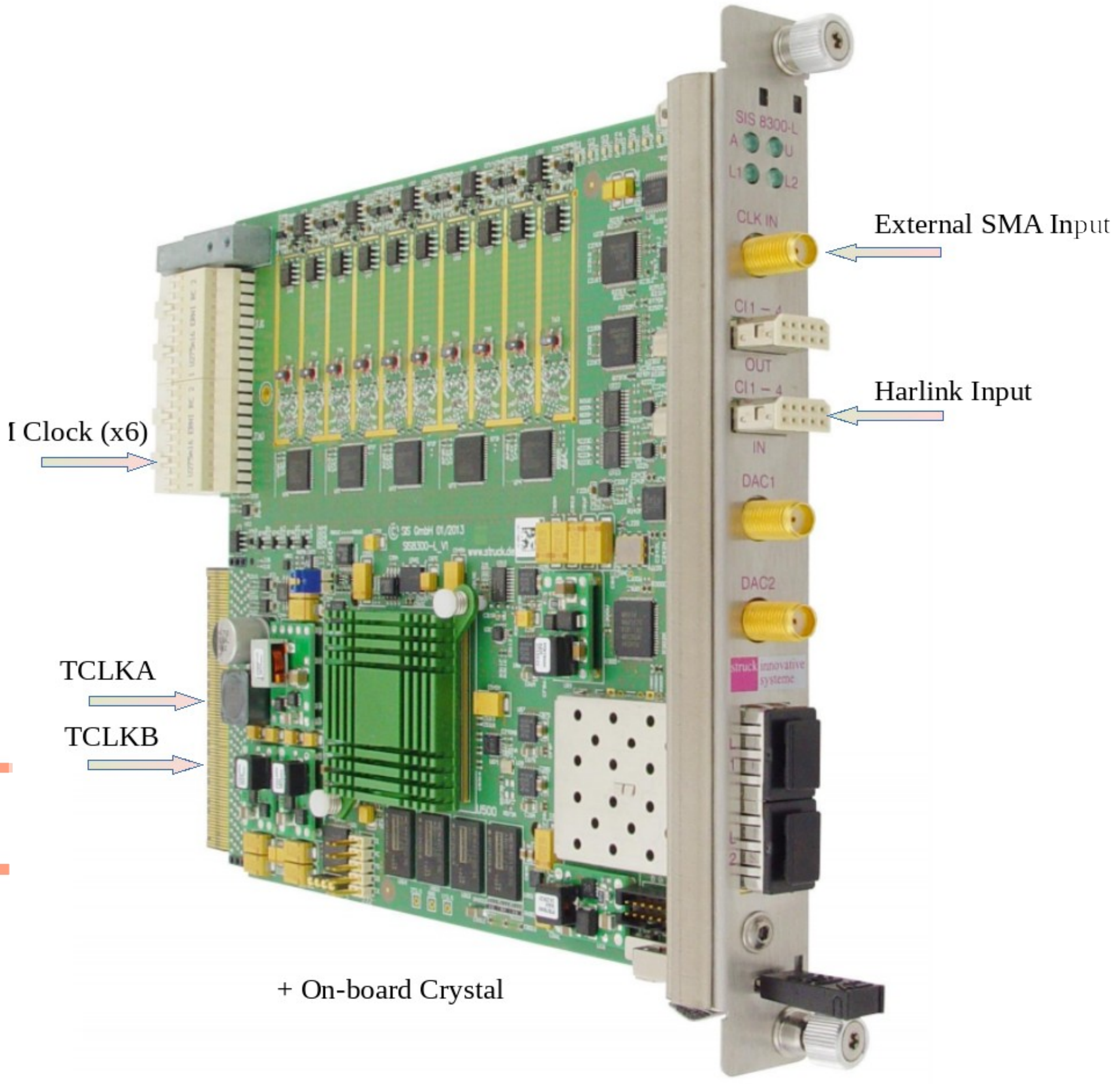


NAT-MCH CLK-PHYS-Module – Technical Reference Manual

Clocking Options for an AMC

Case in point: SIS8300-L2 from Struck GmbH

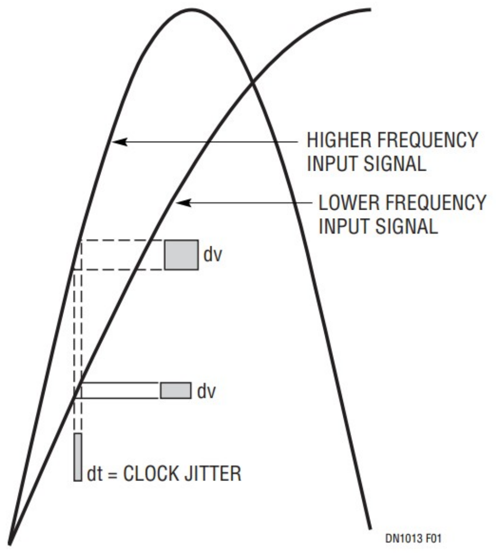




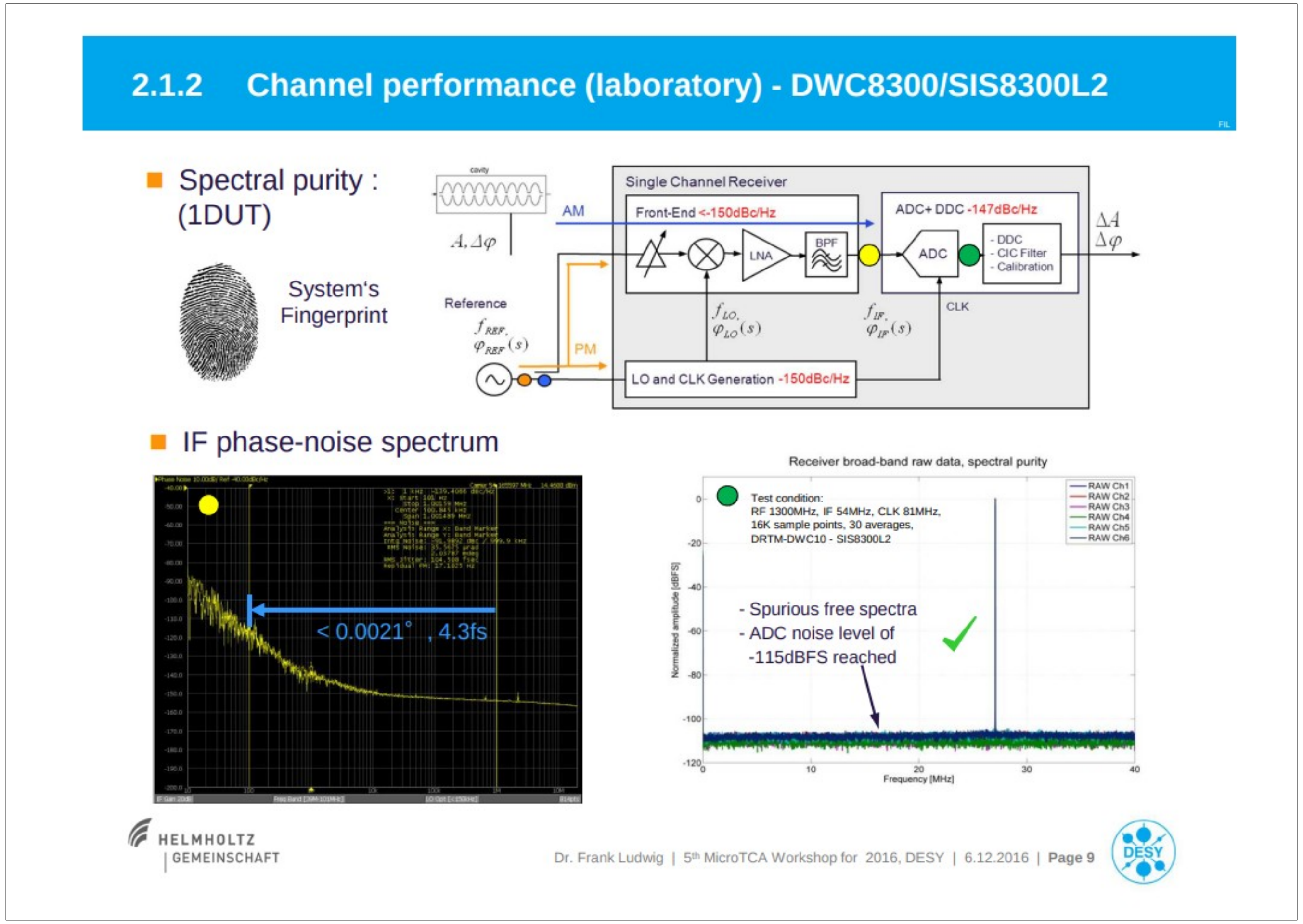
Clock Jitter effects on ADCs

For digitizers with high input frequencies, jitter of the ADC clock becomes important.

The amount of clock jitter will set the maximum SNR that you can achieve for a given input frequency



Linear Technology | Understanding the Effect of Clock Jitter on High Speed ADCs Design Note 1013



2.1.2 Channel performance (laboratory) - DWC8300/SIS8300L2

- Spectral purity : (1DUT)

System's Fingerprint

- IF phase-noise spectrum

Test condition:
RF 1300MHz, IF 54MHz, CLK 81MHz,
16K sample points, 30 averages,
DRTM-DWC10 - SIS8300L2

- Spurious free spectra
- ADC noise level of -115dBFS reached

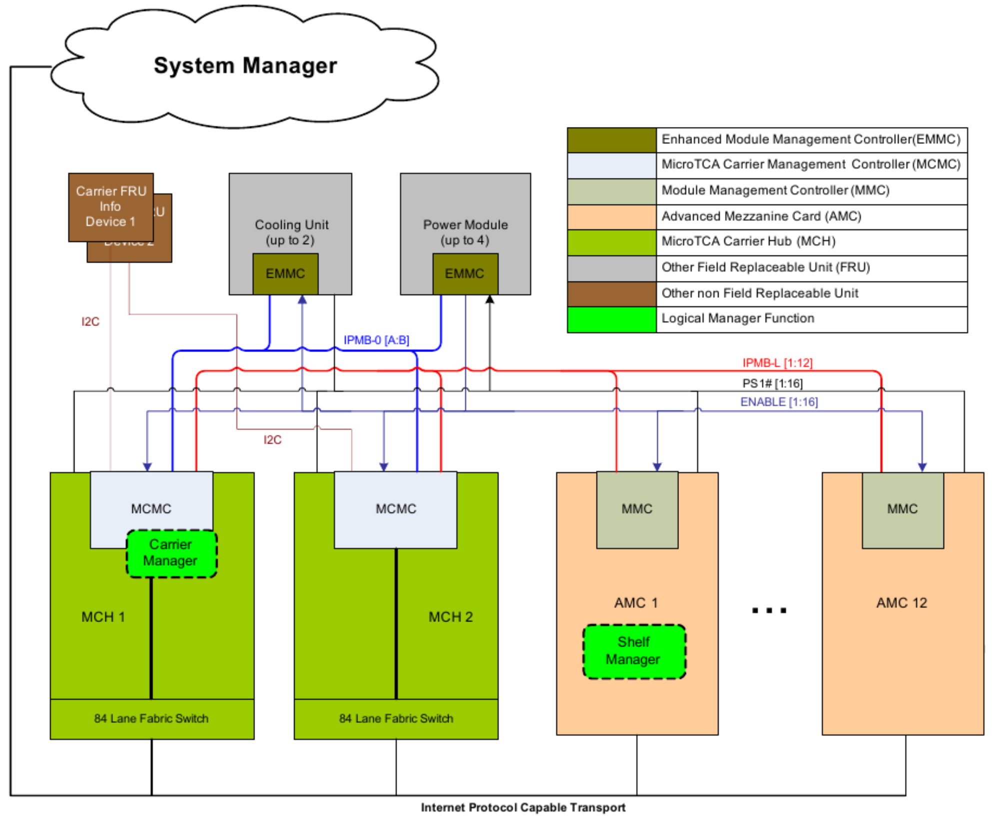
Dr. Frank Ludwig | 5th MicroTCA Workshop for 2016, DESY | 6.12.2016 | Page 9

Dr. Frank Ludwig | 5th MicroTCA Workshop | High Performance Measurement Applications in MicroTCA.4

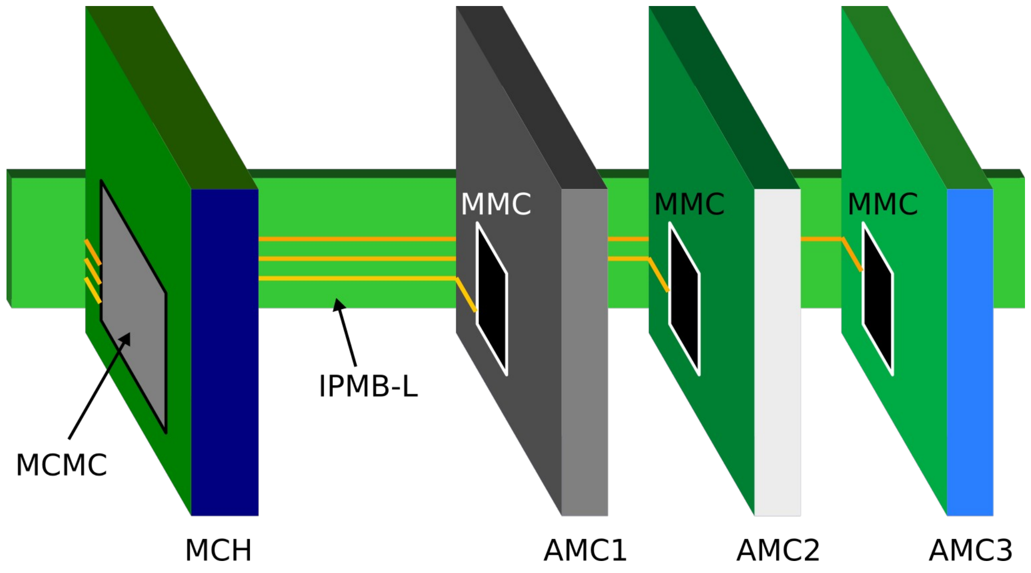
Learn how to use IPMI

What is IPMI?

- MicroTCA Standard uses: IPMI (Intelligent Platform Management Interface) for management.
- Specification is led by Intel. Widely used in computer system vendors.
- I2C based protocol that is message-based interface

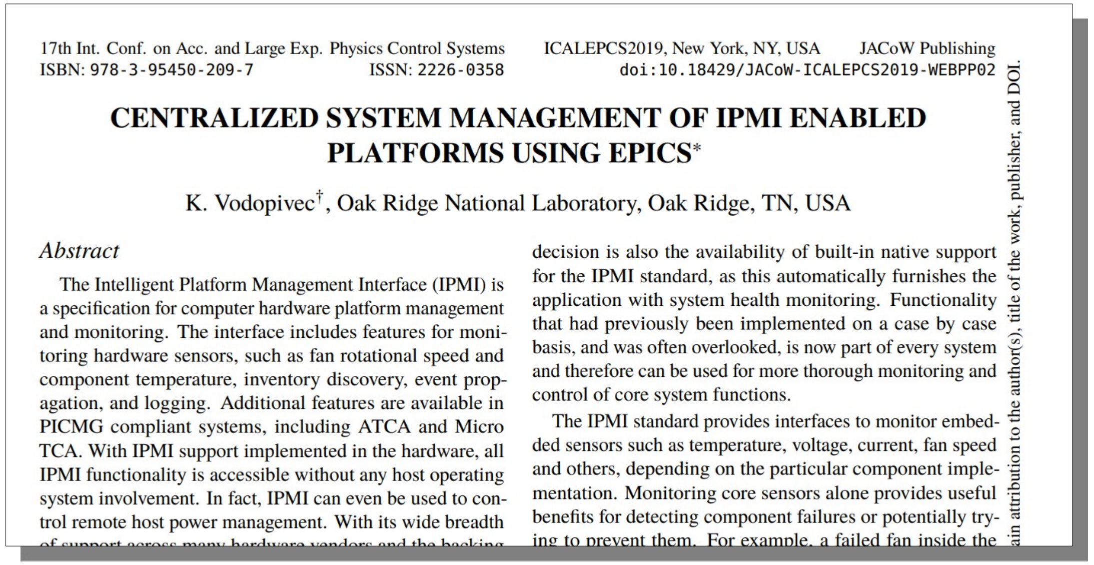


System Manager
Carrier FRU Info Device 1
Device 2
Cooling Unit (up to 2)
EMMC
Power Module (up to 4)
EMMC
I2C
IPMB-0 [A:B]
IPMB-L [1:12]
PS1# [1:16]
ENABLE [1:16]
I2C
MCMC
Carrier Manager
MCH 1
84 Lane Fabric Switch
MCMC
MCH 2
84 Lane Fabric Switch
MMC
AMC 1
Shelf Manager
...
MMC
AMC 12
Internet Protocol Capable Transport
🟫 Enhanced Module Management Controller(EMMC)
⬜ MicroTCA Carrier Management Controller (MCMC)
🟩 Module Management Controller (MMC)
🟧 Advanced Mezzanine Card (AMC)
🟩 MicroTCA Carrier Hub (MCH)
⬜ Other Field Replaceable Unit (FRU)
🟫 Other non Field Replaceable Unit
🟩 Logical Manager Function



Use Open Source tools for IPMI

- 3 main projects for open-source tool (Windows/Linux) for controlling IPMI-enabled systems:
  - ipmitool
  - OpenIPMI
  - FreeIPMI
- By-pass MCH and gain full control of the crate
- Abstraction layer between System Manager and System



17th Int. Conf. on Acc. and Large Exp. Physics Control Systems ICALEPCS2019, New York, NY, USA JACoW Publishing
ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-WEBPP02

CENTRALIZED SYSTEM MANAGEMENT OF IPMI ENABLED PLATFORMS USING EPICS*

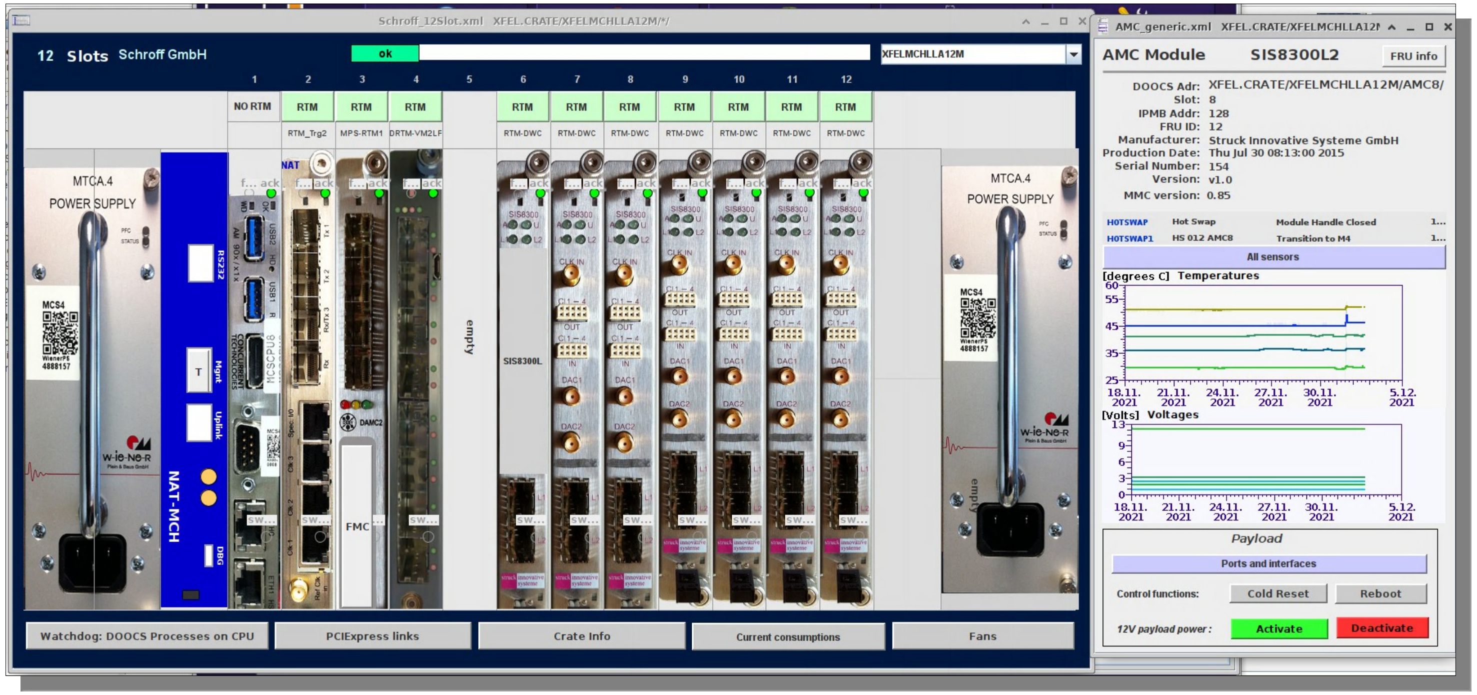
K. Vodopivec†, Oak Ridge National Laboratory, Oak Ridge, TN, USA

Abstract

The Intelligent Platform Management Interface (IPMI) is a specification for computer hardware platform management and monitoring. The interface includes features for monitoring hardware sensors, such as fan rotational speed and component temperature, inventory discovery, event propagation, and logging. Additional features are available in PICMG compliant systems, including ATCA and Micro TCA. With IPMI support implemented in the hardware, all IPMI functionality is accessible without any host operating system involvement. In fact, IPMI can even be used to control remote host power management. With its wide breadth of support across many hardware vendors and the backing

decision is also the availability of built-in native support for the IPMI standard, as this automatically furnishes the application with system health monitoring. Functionality that had previously been implemented on a case by case basis, and was often overlooked, is now part of every system and therefore can be used for more thorough monitoring and control of core system functions.

The IPMI standard provides interfaces to monitor embedded sensors such as temperature, voltage, current, fan speed and others, depending on the particular component implementation. Monitoring core sensors alone provides useful benefits for detecting component failures or potentially trying to prevent them. For example, a failed fan inside the



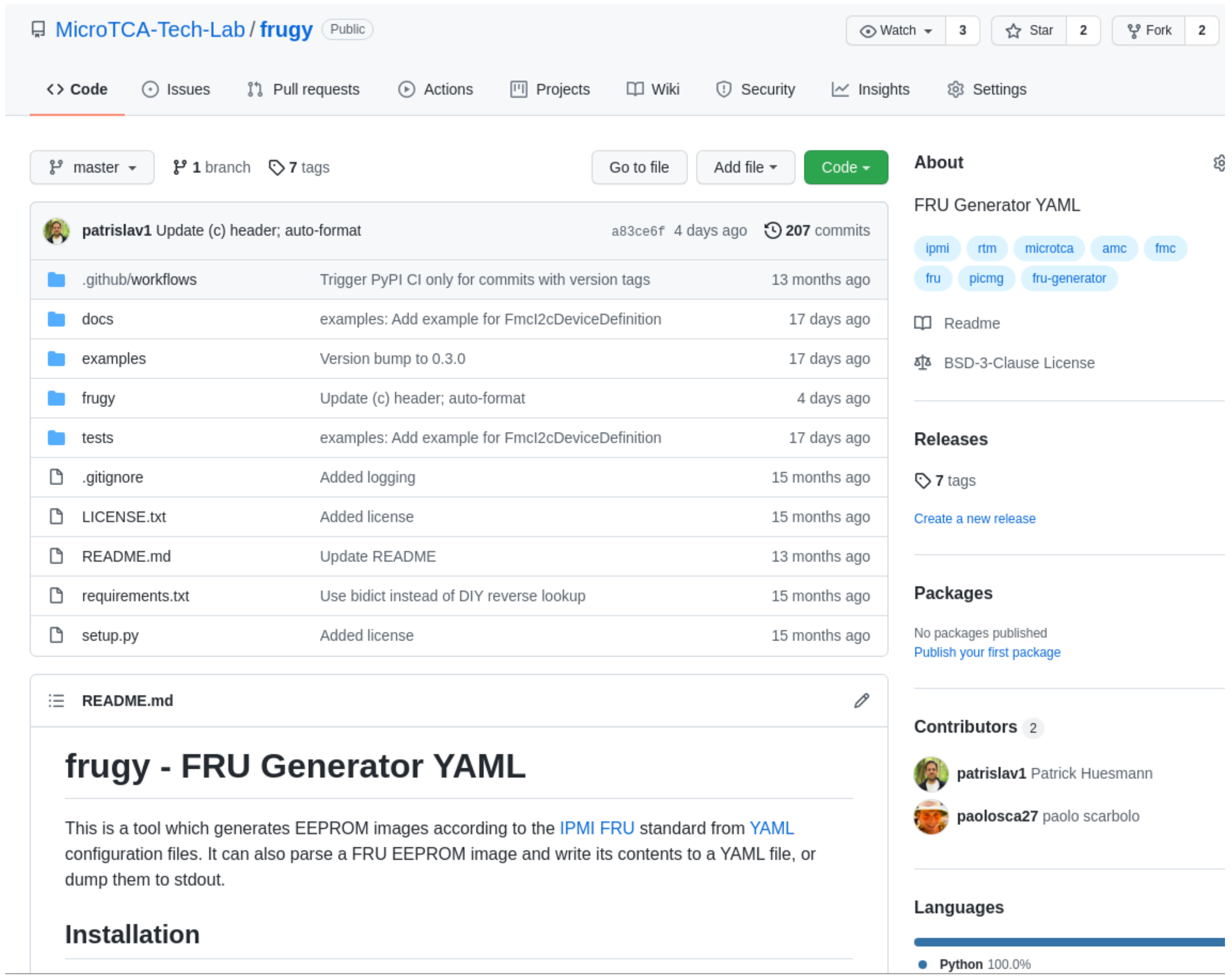
AMC Module SIS8300L2

DOOCS Adr:	XFEL.CRATE/XFELMCHLLA12M/AMC8/
Slot:	8
IPMB Addr:	128
FRU ID:	12
Manufacturer:	Struck Innovative Systeme GmbH
Production Date:	Thu Jul 30 08:13:00 2015
Serial Number:	154
Version:	v1.0
MMC version:	0.85

HOTSWAP	Hot Swap	Module Handle Closed	1...
HOTSWAP1	HS 012 AMC8	Transition to M4	1...

Edit FRU with frugy

- frugy is a **open-souce** tool from MicroTCA-Technology Lab.
- Generated EEPROM images according to the IPMI FRU Standard from **YAML configuration files**.
- Especially useful for people developing a custom AMC board.
- Can be used to ‘edit’ existing FRUs
  - eg. lowering required current for specific AMC on a heavily occupied MTCA crate
  - Edit Inventory information with custom ID for your own company


MicroTCA-Tech-Lab / **frugy** Public

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Code | Issues | Pull requests | Actions | Projects | Wiki | Security | Insights | Settings

master | 1 branch | 7 tags | Go to file | Add file | Code

patrislav1 Update (c) header; auto-format — a83ce6f 4 days ago — 207 commits

.github/workflows	Trigger PyPI CI only for commits with version tags	13 months ago
docs	examples: Add example for FmcI2cDeviceDefinition	17 days ago
examples	Version bump to 0.3.0	17 days ago
frugy	Update (c) header; auto-format	4 days ago
tests	examples: Add example for FmcI2cDeviceDefinition	17 days ago
.gitignore	Added logging	15 months ago
LICENSE.txt	Added license	15 months ago
README.md	Update README	13 months ago
requirements.txt	Use bidict instead of DIY reverse lookup	15 months ago
setup.py	Added license	15 months ago

README.md

frugy - FRU Generator YAML

This is a tool which generates EEPROM images according to the IPMI FRU standard from YAML configuration files. It can also parse a FRU EEPROM image and write its contents to a YAML file, or dump them to stdout.

Installation

About

FRU Generator YAML

ipmi, rtm, microtca, amc, fmc, fru, picmg, fru-generator

Readme

BSD-3-Clause License

Releases

7 tags

Create a new release

Packages

No packages published
Publish your first package

Contributors 2

patrislav1 Patrick Huesmann

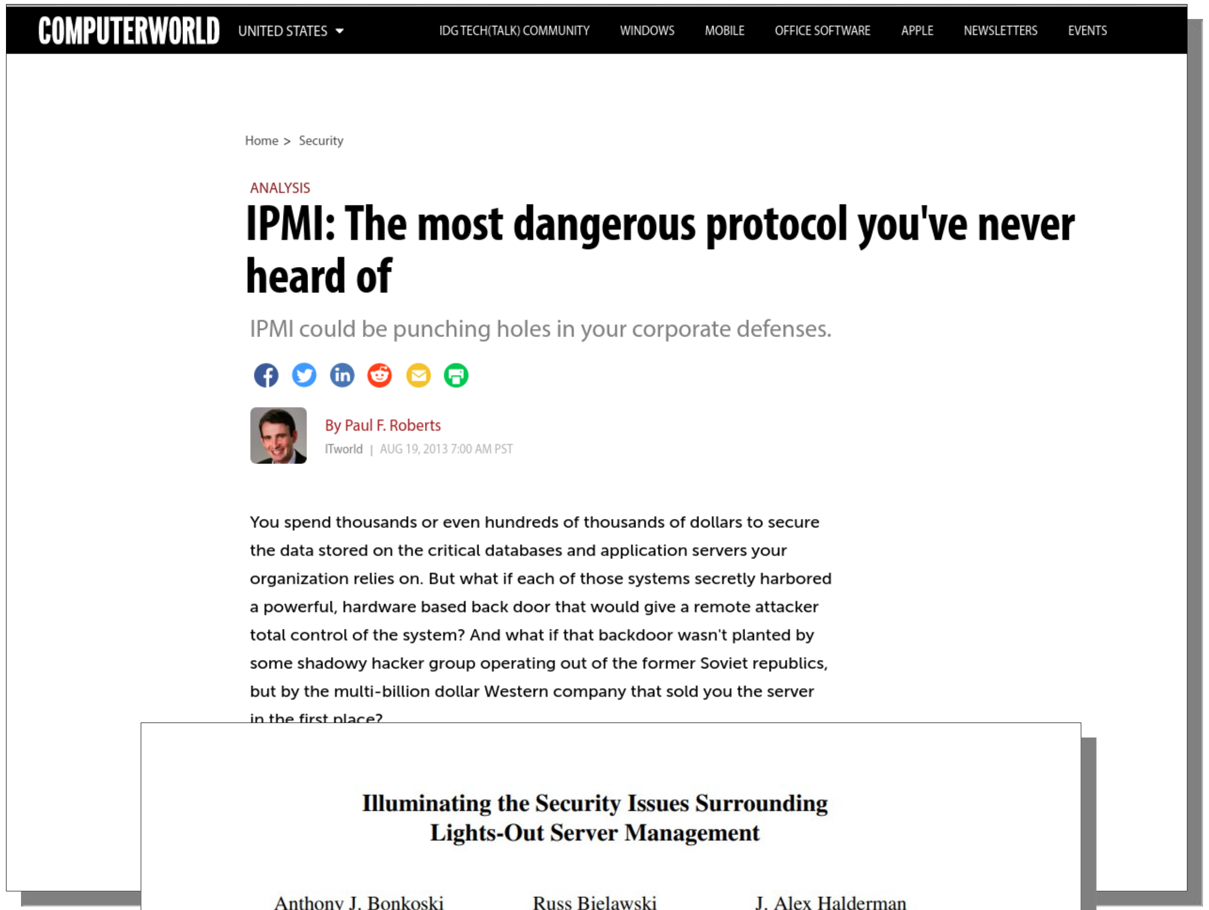
paolosca27 paolo scarbolo

Languages

● Python 100.0%

IPMI Security

- In today's standards IPMI can be considered 'not secure enough'
- **Several vulnerabilities:**
  - **Insecure input validation**
    - **Bad Privilage Checking**
  - **Shell Injection Vulnerabilities**
  - **Buffer Overflow Vulnerabilities**
- Things to do:
  - Keep IPMI firmware up to date (Even though it is EOL)
  - Change default passwords
  - NEVER **configure IPMI devices on public IP addresses.**
    - Isolate them on a physically separated network.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Home > Security

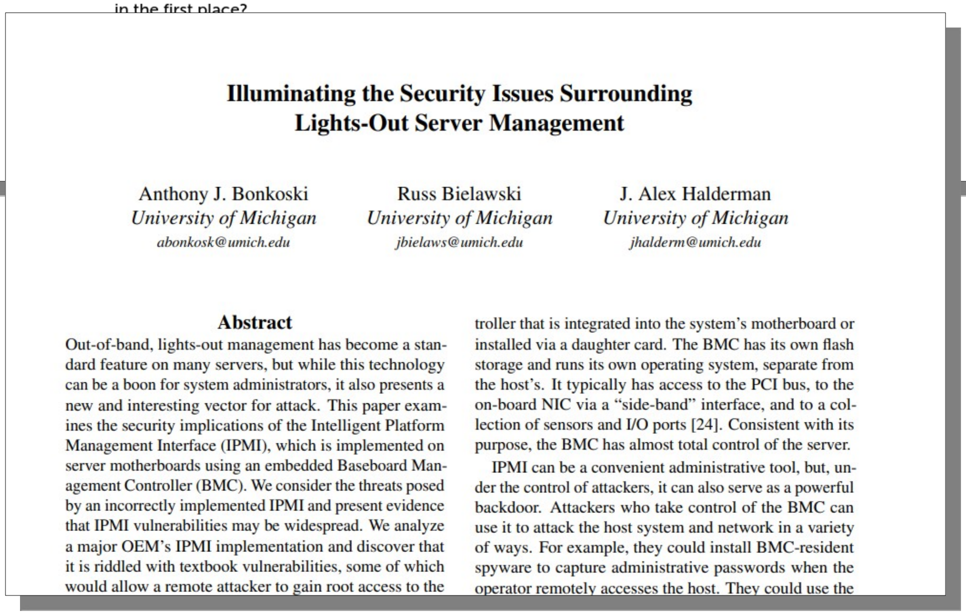
ANALYSIS

IPMI: The most dangerous protocol you've never heard of

IPMI could be punching holes in your corporate defenses.

By Paul F. Roberts
ITworld | AUG 19, 2013 7:00 AM PST

You spend thousands or even hundreds of thousands of dollars to secure the data stored on the critical databases and application servers your organization relies on. But what if each of those systems secretly harbored a powerful, hardware based back door that would give a remote attacker total control of the system? And what if that backdoor wasn't planted by some shadowy hacker group operating out of the former Soviet republics, but by the multi-billion dollar Western company that sold you the server in the first place?


Illuminating the Security Issues Surrounding Lights-Out Server Management

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Abstract

Out-of-band, lights-out management has become a standard feature on many servers, but while this technology can be a boon for system administrators, it also presents a new and interesting vector for attack. This paper examines the security implications of the Intelligent Platform Management Interface (IPMI), which is implemented on server motherboards using an embedded Baseboard Management Controller (BMC). We consider the threats posed by an incorrectly implemented IPMI and present evidence that IPMI vulnerabilities may be widespread. We analyze a major OEM's IPMI implementation and discover that it is riddled with textbook vulnerabilities, some of which would allow a remote attacker to gain root access to the

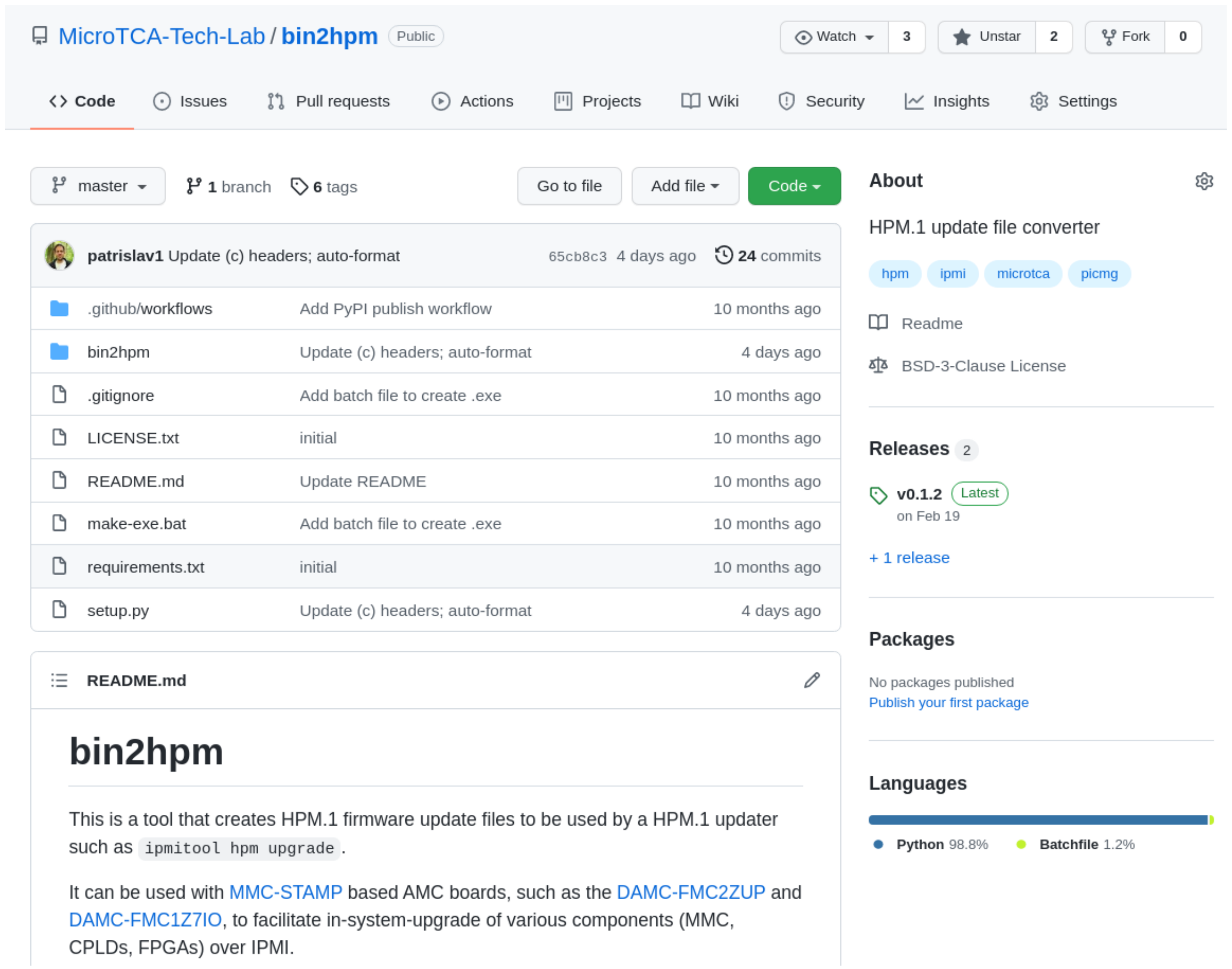
troller that is integrated into the system's motherboard or installed via a daughter card. The BMC has its own flash storage and runs its own operating system, separate from the host's. It typically has access to the PCI bus, to the on-board NIC via a "side-band" interface, and to a collection of sensors and I/O ports [24]. Consistent with its purpose, the BMC has almost total control of the server.

IPMI can be a convenient administrative tool, but, under the control of attackers, it can also serve as a powerful backdoor. Attackers who take control of the BMC can use it to attack the host system and network in a variety of ways. For example, they could install BMC-resident spyware to capture administrative passwords when the operator remotely accesses the host. They could use the

Exploit all Firmware Upgrade Options

Firmware Upgrade of AMCs

- Use PCIe/Ethernet to send the bit file to FPGA and trigger reconfiguration. (Xilinx: ICAP)
  - Fast! (~ seconds)
  - If you lose PCIe/Ethernet this method is useless.
- Use HPM (Hardware Platform Management)
  - Created by PICMG
  - Uses IPMI bus to send the firmware data
  - Extremely slow (Ultrascale ~ 1 hr)
  - Can update MMC firmware
- Use JTAG
  - From AMC backplane
  - From JTAG Connector on the PCB



patrislav1 Update (c) headers; auto-format 65cb8c3 4 days ago 24 commits

.github/workflows	Add PyPI publish workflow	10 months ago
bin2hpm	Update (c) headers; auto-format	4 days ago
.gitignore	Add batch file to create .exe	10 months ago
LICENSE.txt	initial	10 months ago
README.md	Update README	10 months ago
make-exe.bat	Add batch file to create .exe	10 months ago
requirements.txt	initial	10 months ago
setup.py	Update (c) headers; auto-format	4 days ago

README.md

bin2hpm

This is a tool that creates HPM.1 firmware update files to be used by a HPM.1 updater such as `ipmitool hpm upgrade`.

It can be used with MMC-STAMP based AMC boards, such as the DAMC-FMC2ZUP and DAMC-FMC1Z7IO, to facilitate in-system-upgrade of various components (MMC, CPLDs, FPGAs) over IPMI.

About

HPM.1 update file converter

hpm ipmi microtca picmg

Readme

BSD-3-Clause License

Releases 2

v0.1.2 Latest on Feb 19

+ 1 release

Packages

No packages published
Publish your first package

Languages

Python 98.8% Batchfile 1.2%

Use

MSK-DESY FPGA Framework:

FWK

Use Open Source libraries for Quick Start

- MSK-Group of DESY has **open-sourced** its FPGA framework called FWK. `gitlab.desy.de/fpgafw`

  → Talk by Michael Buechler tomorrow

- Many BSP’s available for modern AMC’s
- Petra IV: Motion Control Project (Open-Source based on DAMC-MOTCTRL) →
  → Talk by Michael Randall tomorrow.
- Tools: Yocto, Scripts, Example Python Applications etc.

Board Support Packages

SIS8300KU

Available with Example Design

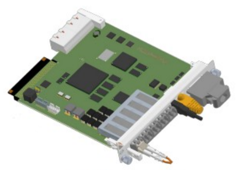
DAMC-FMC2ZUP

Available with Example Design

DAMC-Z7IO

Coming soon!

DAMC-MOTCTRL



Coming soon!

DRTM-DS8VM1

Available as a Module

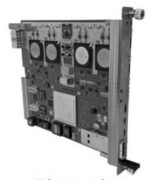
DRTM-DWC8VM1

Available as a Module

DAMC-DS812ZUP

Planned

DAMC-DS5014DR



Planned

Thank you

Contact

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