

中国科学院大学
University of Chinese Academy of Sciences



MICROTCA CHASSIS TRAINING

MicroTCA Hands-on Training

Zhang Jin, Liu Fang

The 15th MicroTCA Workshop for Industry and Research (Sep. 14-17, 2026)

CONTENTS

Table of Contents

[01](#) MicroTCA Overview

[02](#) Chassis Architecture & Mechanical Structure

[03](#) Backplane

[04](#) Chassis Management

[05](#) MCH Module

[06](#) AMC Modules & RTM

[Appendix](#) Glossary & Board Buses

01

MicroTCA Overview

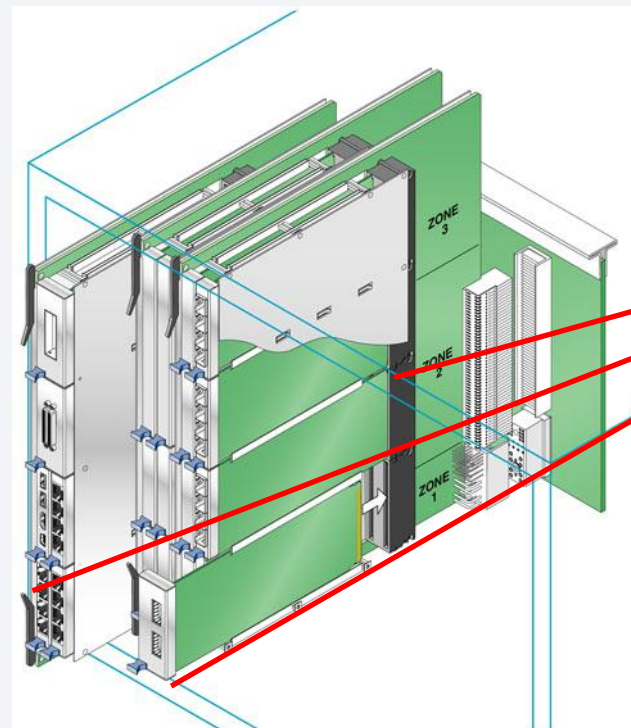
From ATCA to MicroTCA • PICMG Standards Family • MTCA.0 Core Specification

01 • Standards | xTCA Standards & MicroTCA

PICMG xTCA Standards (PCI Industrial Computer Manufacturers Group)

Standard No.	Name	Scope
PICMG 3.0-3.5	ATCA	Advanced Telecom Computing Architecture: shelf / backplane / carrier / power / cooling / management
PICMG AMC.0	AdvancedMC	Advanced Mezzanine Card: module mechanics / electrical / connector / hot swap / IPMI
PICMG MTCA.0	MicroTCA	MicroTCA core specification: chassis / backplane / power / cooling / MCH / system management
MTCA.1	Air-Cooled, Ruggedized	Extra fastening screws; vibration/shock resistant
MTCA.2	Military Ruggedized	Clamshell enclosure for higher reliability
MTCA.3	Conduction-Cooled	Wedge locks conduct heat to the cold plate; fanless design
MTCA.4	Rear I/O Extended	Adds RTM rear transition modules and high-precision clocks on top of MicroTCA; for particle physics and accelerators
MTCA.4.1	Enhancements for MicroTCA.4 R1.0	Auxiliary rear backplane, rear power modules (RPM), etc.

ATCA Architecture



MicroTCA Architecture



	ATCA (PICMG 3.0)	MicroTCA (MTCA.0)
Module Architecture	Carrier board + AMC mezzanine cards	AMCs plug directly into backplane
AMC Compatibility	Supports AMC.0 modules (via carrier)	Supports AMC.0 modules
Management & Switching	Dedicated Shelf Manager and Carrier Manager	MCH integrates management + switching + clocks
Per-Slot Power	Up to 200 W (carrier level)	Up to 80 W (double-width full-size AMC)

MicroTCA.0 R1.0 System Components & Specifications (9U)

Component	Qty	Function Description
AMC Modules	12	Payload: computing / data acquisition / I/O / storage
MCH	2	Carrier hub: system management / Fabric switching / clock distribution
PM (Power)	4	Power modules: AC/DC or DC/DC conversion, N+1 redundancy
CU (Cooling)	2	Cooling units: forced air; fan speed controlled by the MCH closed loop
Backplane	1	Interconnect: Fabric / clocks / management / power distribution
Card Cage	1	Mechanical support: card guides + alignment pins

Specifications (MTCA.0 R3.0, 2023)

- Max. MCH/CU power: 110 W (double-width full-size module)
- Protocols: PCIe Gen4/5; Ethernet Fabric up to 100 GbE



Next generation

Specifications (MTCA.0 R4.0, 2026)

- IPMI record corrections
- Per-slot power limit raised from 110 W in R3.0 to 220 W
- MCH with more fabric ports
- 13 additional 32 Gbps ports

...

02

Chassis Architecture

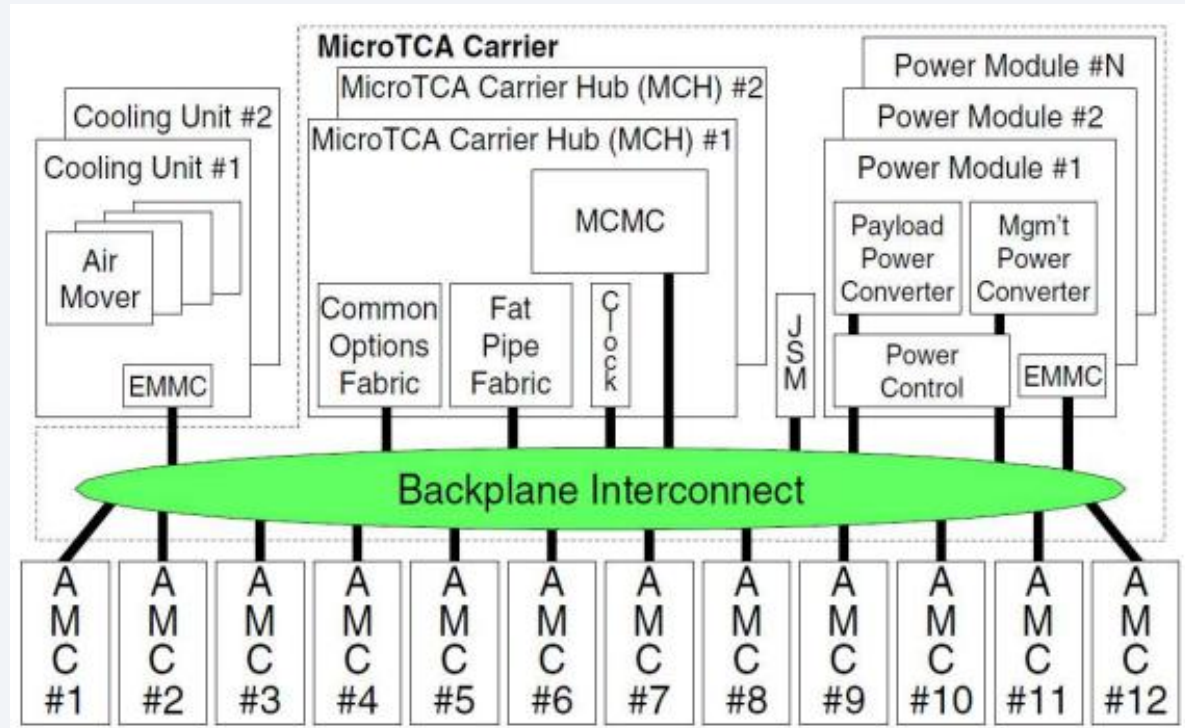
[Chassis Structure](#) • [Photos](#)

Chassis Architecture

Chassis Components & Functions

- 01 Card Cage — Mechanical Support
- 02 Backplane — Signal Interconnect
- 03 Power Module (PM) — Power Supply
- 04 Cooling Unit (CU) — Air Cooling
- 05 MCH Module — Management
- 06 AMC/RTM Modules — User Payload Modules

MicroTCA Architecture Diagram



02 • NAT Mainstream Chassis Portfolio

Source: NAT Europe official product pages

NAT NATIVE Series Chassis



NATIVE-mini • 1U Compact



NATIVE-C1 • 1U • 6 Single-Width Mid-Size AMCs



NATIVE-C3-PTM • 3U



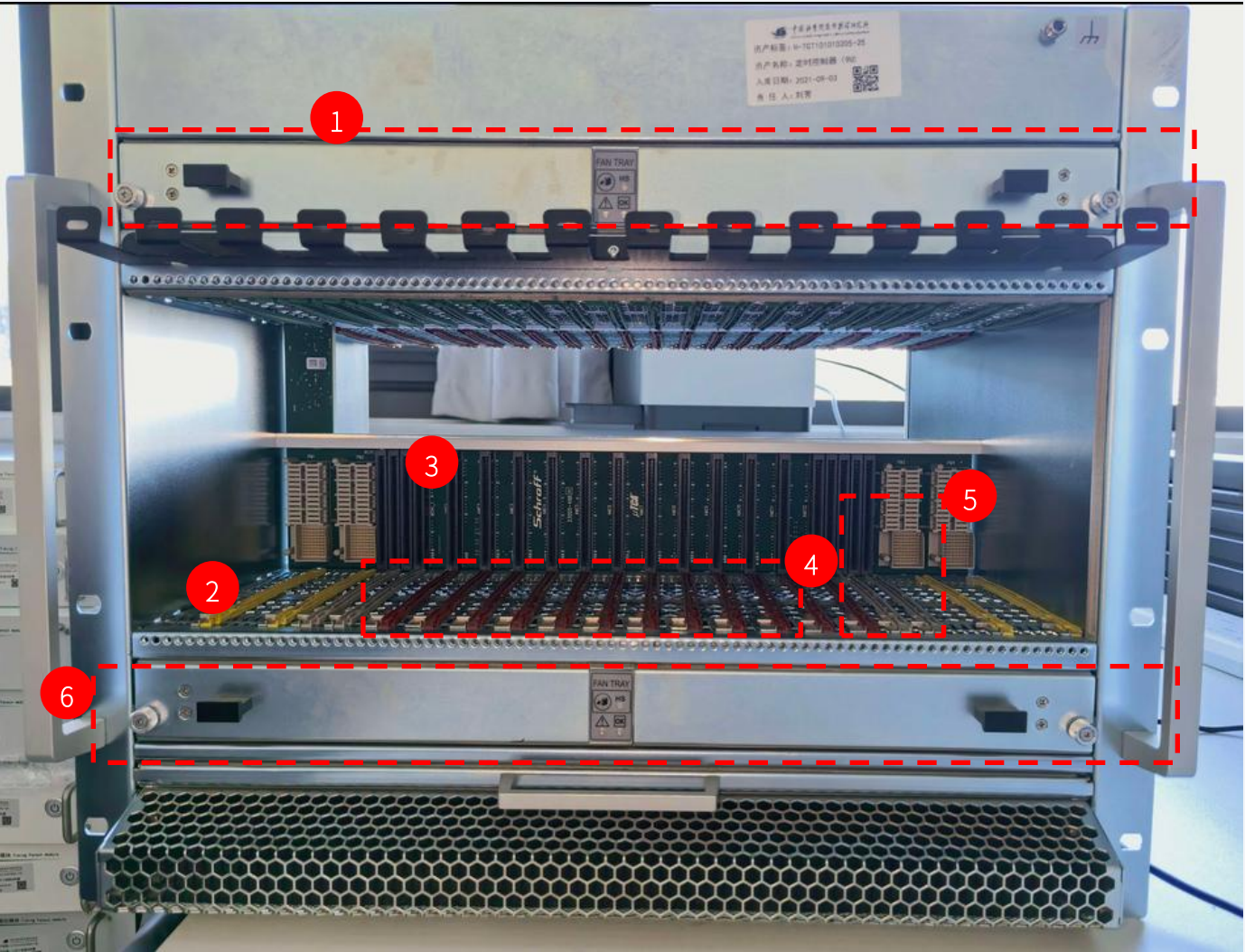
NATIVE-C5 • 5U Half-Width



NATIVE-R9 • 9U MTCA.4

NAT NATIVE Series Technical Comparison

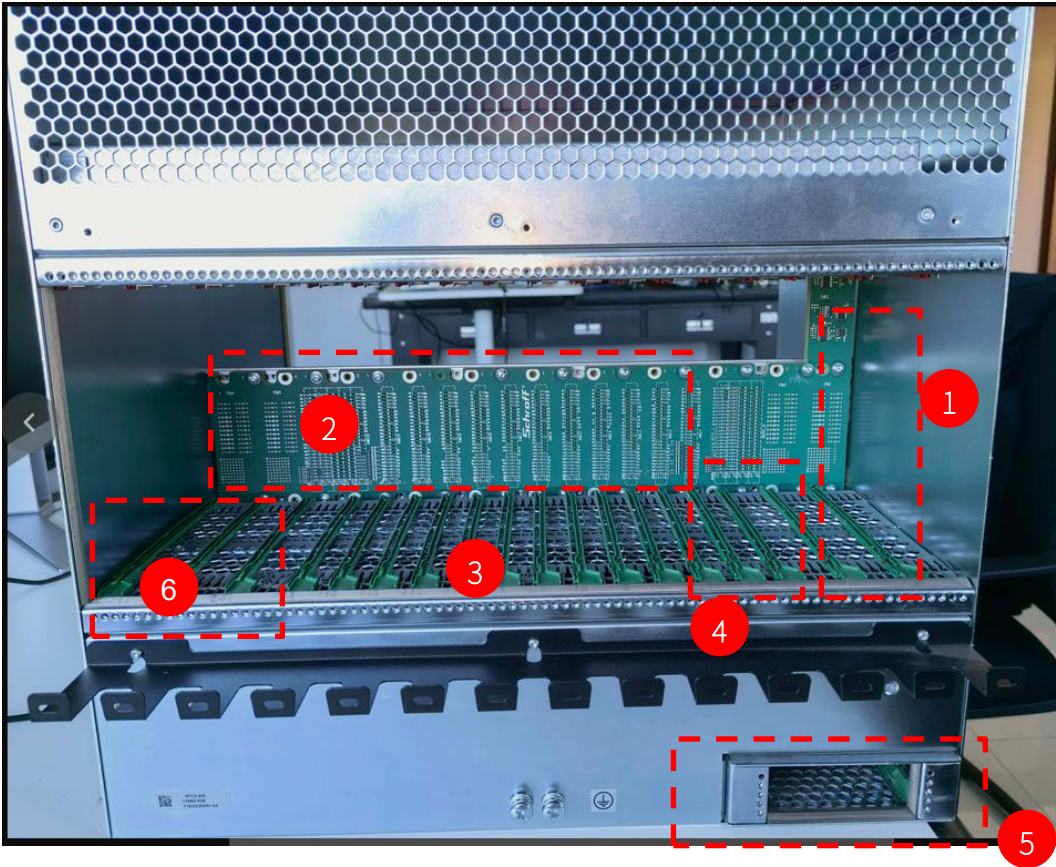
Model	Height	AMC Slots	PM/MCH	Typical Application
mini	1U	2 single-width or 1 double-width	eMCH + 150 W	Portable development, lab validation
C1	1U	6 single-width mid-size	1 MCH 1 PM	1U rack deployment, 40 G backplane, edge computing
C3-PTM	3U	12 single-width or 6 double-width	2 MCH 4 PM	Redundant configuration, high power density, industry/research
C5	5U	6 double-width mid-size + 1 double-width full-size	1 double-width MCH 1 double-width PM	Double-width high-power modules, mid-scale systems
R9	9U	12 double-width mid-size + 12 RTM	2 MCH + RTM 6 PM (2 RPM)	Flagship MTCA.4 for large-scale research facilities
C2/R2	2U	12 single-width or 6 double-width	2 MCH 2 PM	2U rack, MTCA.0/MTCA.4, compact redundant system



Front side

Component Functions

No.	Component	Description
1	Top FAN TRAY (Upper)	Upper push-pull exhaust unit, hot-swappable; the MCH closed-loop controls fan speed from temperature sensors.
2	Power Module (PM)	Converts AC 100-240 V to +12 V Payload /+3.3 V Management; panel: handle, switch, LEDs, AC inlet; N+1 redundancy, hot-swappable.
3	Backplane & Connectors	(Black) 12 AMC slots; (white)2 MCH + 2 PM slots
4	AMC Card Guides (red, 12)	Red guides align AMC modules on insertion for precise mating; 12 slots allow mixed single/double-width, compact/mid/full-size modules.
5	MCH Guides	(white)MCH slots: 1+1 redundancy;
6	Bottom FAN TRAY (Lower)	Lower push-pull unit; draws cool air in at the bottom, across heat sinks, out through the top fans.

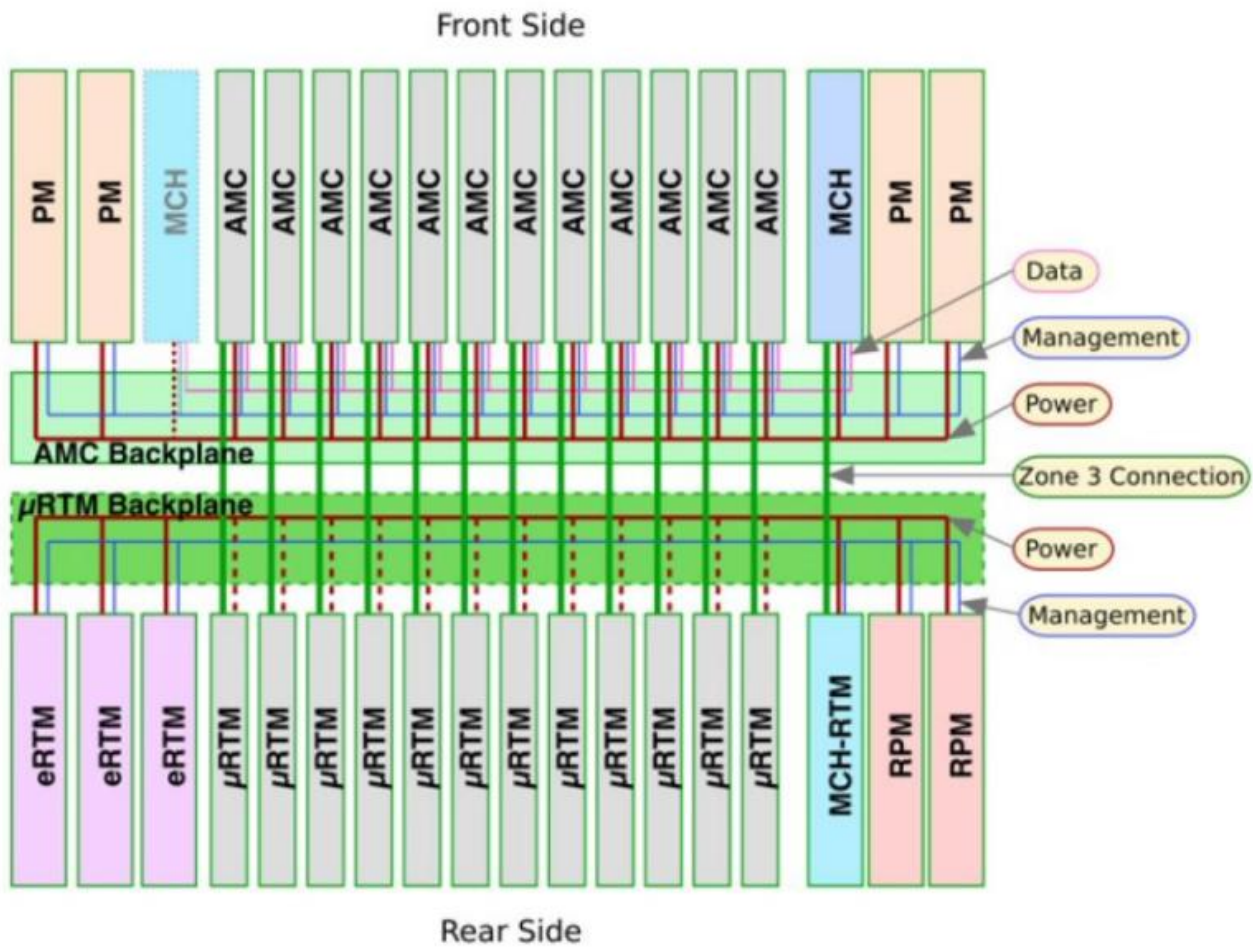


Rear side

Component Functions

No.	Component	Description
1	RPM Slot & Guides	Rear Power Input
2	Rear Backplane	Supplies management and payload power to eRTM slots over the rear backplane.
3	uRTM Guides (green, 12)	Green guides align RTM modules on insertion for precise connector mating.
4	MCH Card Guides (green)	Monitors all rear RTMs over the rear IPMI/I ² C bus: status, hot-swap control, power on/off sequencing.
5	JSM Slot (JTAG Switch Module)	JSM switches and centrally manages the JTAG debug chains of all AMC boards.
6	eRTM Slot	Enhanced RTM; larger power budget, more Zone 3 signal pairs and a wider panel.

Chassis Specification: 9U high (400 mm) x 84HP wide (427 mm) x 373 mm deep, 19-inch rack. MTCA.4 dual backplane, 12 double-width full-size AMCs + 12 RTMs; front-to-rear push-pull airflow.



MTCA.4.1

Slot Types & Numbering

Slot Type	Qty	Function
AMC	1-12	User payload modules
MCH	1-2	Management & switching core
PM	1-4	Power modules in dedicated bays
CU	1-2	Cooling fan trays
RPM	1-2	Rear power input modules
RTM	1-12	Routes AMC user I/O to the rear panel; power ≤ 30 W
eRTM	1-3	Higher power (≤ 80 W) and richer rear I/O
MCH-RTM	1	max 120 W

03

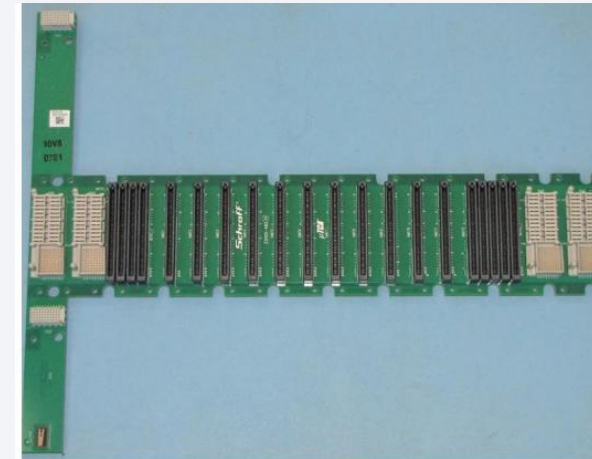
Backplane

Backplane Functions • Signals & Buses

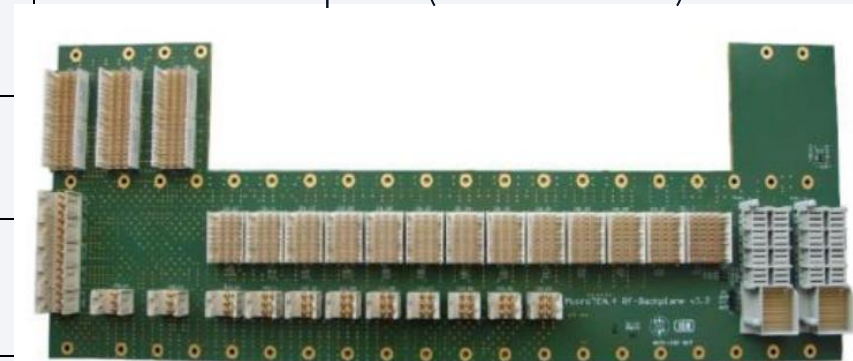
Backplane Functions

	Function	Description
01	High-Speed Signal Interconnect	Fabric data exchange (PCIe/Ethernet/SRIO) between all modules; Ports 0-15 via MCH switching or point-to-point links
02	Power Distribution	Distributes +12 V Payload and +3.3 V Management from the PMs to every slot
03	Management Communication	IPMB-L radially links the MCMC to every MMC; IPMB-0 backplane bus links the MCMC to EMMCs/fans for chassis-wide management
04	Clock Distribution	TCLKA/B/C/D bidirectional system reference clocks; FCLKA dedicated low-jitter PCIe reference clock
05	Trigger	Ports 17-20 multi-point bus, bypassing the MCH switch
06	Mechanical Support & Alignment	Provides physical slots and alignment pins for all pluggable modules, ensuring correct insertion and precise connector mating

MicroTCA Backplane Example

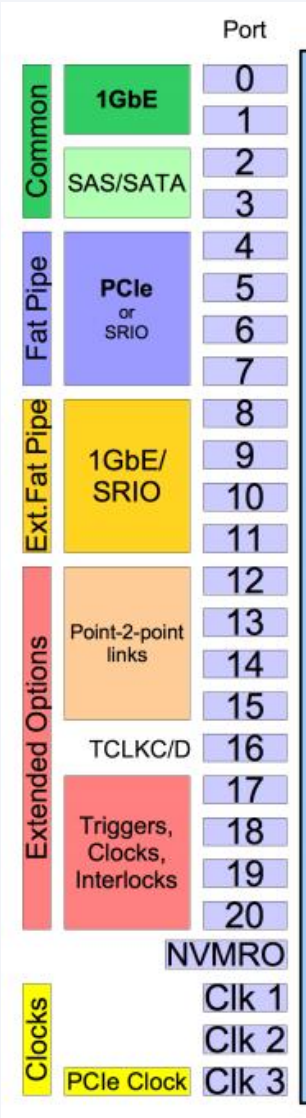


Front Backplane (MTCA.0 Rev1.0)



Rear Backplane (MTCA.4.1)

Backplane Signals



Fabric Port Allocation

Port	Function & Protocol
Port 0-1	Gigabit Ethernet (1000BASE-X)
	Fabric A (to MCH1)
	Fabric B (to MCH2)
Port 2-3	SAS/SATA
Port 4-11	Fat pipe - PCIe \SRIO\Ethernet
Port 12-15	Point-2-Point Links
Port 17-20	Multi-point trigger/clock/interlock signals (MLVDS)
	(MTCA.0 Rev4) Memory protection - prevent firmware modification
TCLKA-D	Low-jitter system reference clock
FCLKA	PCIe, SRIO
JSM	to AMC, MCH, PM

MTCA.0 R1.0

- MCH slots located at both chassis sides (long traces)
- AMCs ordered linearly left to right by physical position



MTCA.0 R3.0

- Max. MCH/CU power: 110 W (double-width full-size module)
- Protocols: PCIe Gen4/5; Ethernet Fabric up to 100 GbE
- MCH slots moved to the chassis center; high-speed traces limited to <= 250 mm



MTCA.0 R4.0

- All components extended to 80 W, 110 W, 220 W
- Adds a second AMC connector and a second power-module connector
- Adds NVMRO (Non-Volatile Memory Read-Only) hardware memory protection, globally controlling firmware write access of all modules

04

Management

Power Management • Power Sequencing • Hot-Swap Management • IPMI

Management Architecture

Management Buses

IPMB-L: point-to-point links from the MCMC on the MCH to the MMC on each AMC; carries module management messages

IPMB-0/1: dual-redundant I2C buses from the MCMC to the EMMCs on PMs and CUs

I2C-bus: management bus connecting the AMC and its uRTM

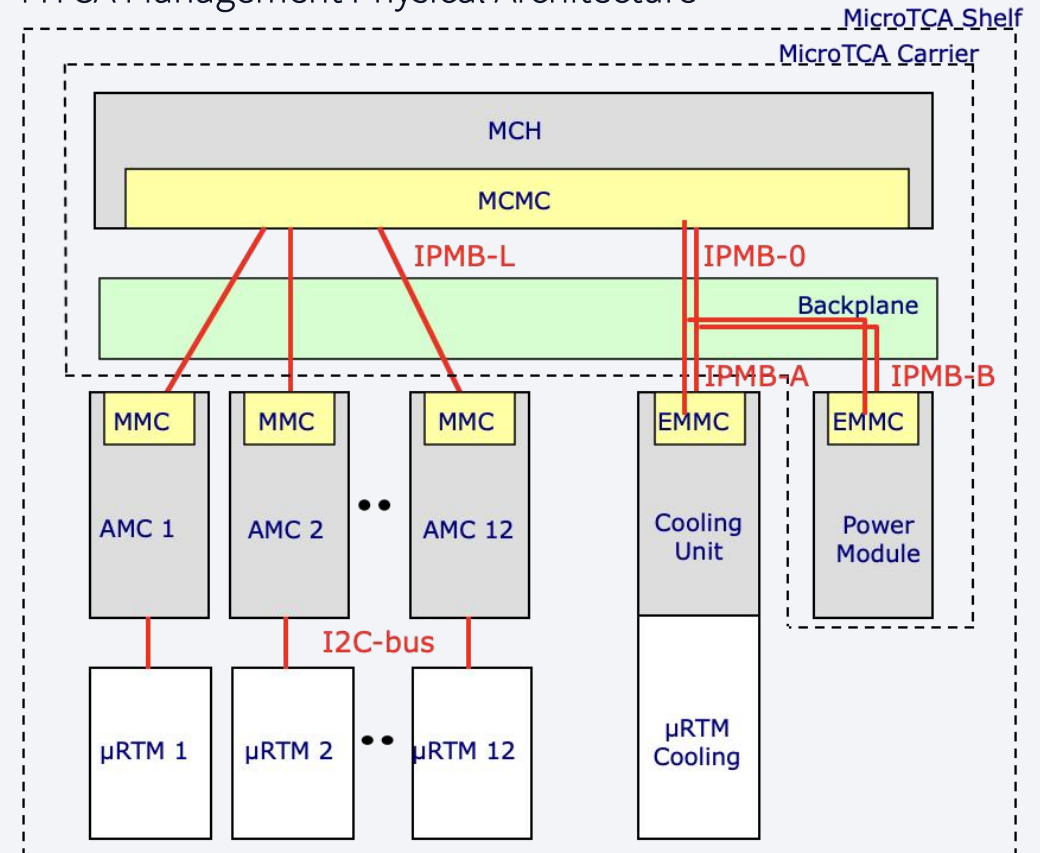
Management Controller Hierarchy

controller	Location	Responsibility
MCMC	On MCH	MicroTCA Carrier Management Controller; core of system management
MMC	On AMC	Module Management Controller; handles AMC power/hot swap/sensors
EMMC	On PM/CU	Enhanced Module Management Controller; manages power/cooling modules

Architecture Highlights

- Layered management: MCMC -> MMC/EMMC -> uRTM
- Dual-bus redundancy: IPMB-0/1 physically isolated; automatic switchover on bus failure
- Mixed point-to-point/bus topology: point-to-point IPMB-L isolates AMCs; multi-point IPMB-0 saves pins for PM/CU
- Management messages: FRU reads, sensor queries, power control, hot-swap events

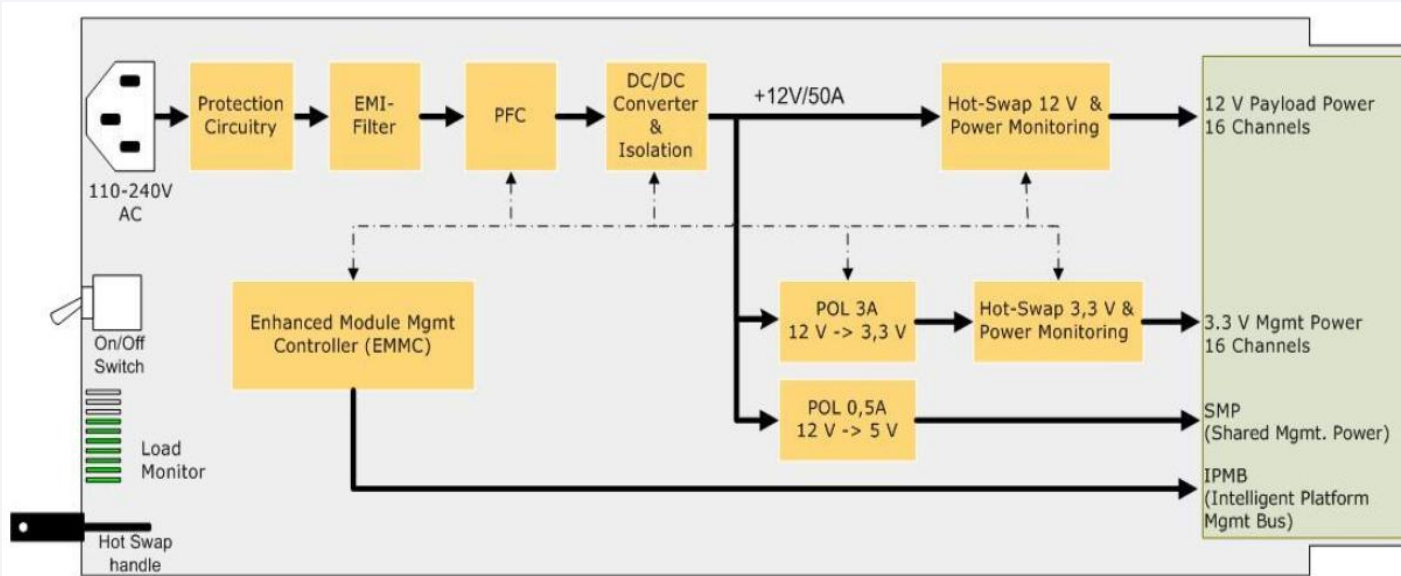
MTCA Management Physical Architecture



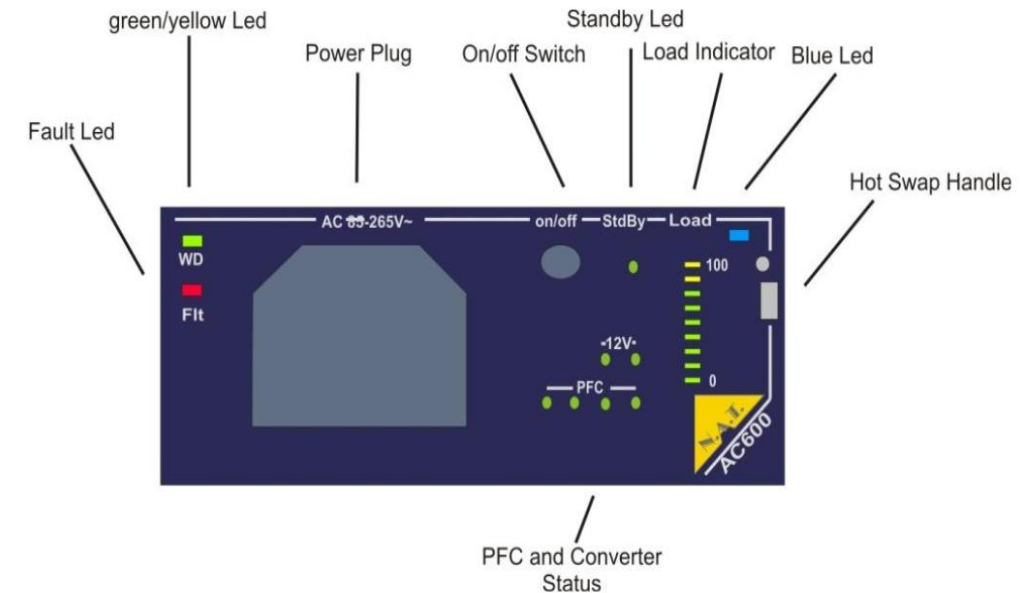
04 • Power System | NAT-PM Power Module

Source: NAT-PM-AC TechRef

Power Module Internal Block Diagram



Front Panel & LED Indicators



Internal Architecture

- DC conversion: external AC input -> +12 V Payload / +3.3 V Management
- EMMC enhanced module management controller -> IPMB interface to the MCH
- 16 independent power channels with programmable per-channel current limiting
- SMP backup power: other PMs can power the EMMC if the input fails

Automatic Failover: a standby module takes over automatically on failure; the failed module is hot-swappable

Model

- AC600: 600 W rated, single-width 6HP
- AC1000: 1000 W rated, double-width 12HP

Front Panel Interfaces

- AC power inlet
- power switch

LED Status Definitions

- Solid green: normal operation
- Blinking green: standby / management power
- Solid yellow: warning (temperature/voltage)
- Solid red: fault (overcurrent/overtemperature)
- Blinking red: critical fault, replacement required

Power Management

+12 V Payload	+3.3 V Management
• Main payload • 6.6 A/slot max (~80 W) • MCH-switched • Auto off on module removal	• Always-on management rail • 1.0 A/slot max (~3.3 W) • Live on insertion • Powers the MMC controller

Power Distribution Architecture

+3.3V: wired directly to management circuits of all slots, always on

+12V: independently routed to each AMC slot via MCH-controlled backplane power switches

This enables independent per-slot power switching and supports hot-swap management.

Channel	Powered Device	Voltage
CH01	MCH1	+12V/ +3.3V
CH02	MCH2	+12V/ +3.3V
CH03	CU1	+12V/ +3.3V
CH04	CU2	+12V/ +3.3V
CH05-16	AMC1-AMC12	+12V/ +3.3V

System Power-On/Off Sequence & Power Management

Power-On Sequence

Step 1: External power applied; PM runs self-test; presence (Pres.) signal asserted

Step 2: +3.3 V /12V powers up

Step 3: MCH/CU asserts Enable; Fan spin up, MCMC/EMMC boot

Step 4: MCH Shelf Manager and MCMC start; IPMB-0 bus initialized;

Step 5: MCH manages the PMs via IPMB-0

Step 6: AMCs activate (M4); blue LED solid on; system ready

Power-Off Sequence

Step 1: Issue power-off command

Step 2: Notify all modules to save data

Step 3: Sequentially disable +12 V Payload slot by slot

Step 4: MCH deasserts Enable; PMs shut down PP/MP

Step 5: Remove external power (for full shutdown only)

Power Sequencing Key Points

Staggered Power-Up: +12 V is enabled slot by slot at 100-500 ms intervals, preventing inrush current from exceeding PM capacity and tripping overcurrent protection.

Per-Slot Independent Control: Any slot +12 V can be switched independently, allowing online reset of a faulty module without affecting other slots.

Do not Cut Power Directly: Cutting external power directly may cause data loss or file-system corruption.

MicroTCA AMC Power-Up Sequence & MMC State Machine

MMC State Machine (M-State)

State	Blue LED	Name	FRU State	Meaning & Power State
M0	Off	Module Absent	FRU Not Installed	Module not installed (or removed)
M1	On	Power-Up Wait	FRU Inactive	Inserted; management power is on, but Payload not activated
M2	Long Blink	Powered	FRU Activation Request	Activation request received; reading FRU data and negotiating power
M3	Off	Green Only	FRU Activation In Progress	Activation in progress; Payload power enabled, E-Keying configured
M4	Off	Enabled	FRU Active	Normal operation; Payload power and Fabric interfaces enabled
M5	Short Blink	Soft Shut Down	FRU Deactivation In Progress	Deactivation request received (handle opened or management command)
M6	Short Blink		FRU Deactivation Request	Deactivation in progress; Payload power off, interfaces disabled
M7		Hard Shut Down		Safe to remove; blue LED fast blink

AMC Power-Up Sequence (Auto-Run After Insertion)

T0 Module Inserted: +3.3 V Management powers up

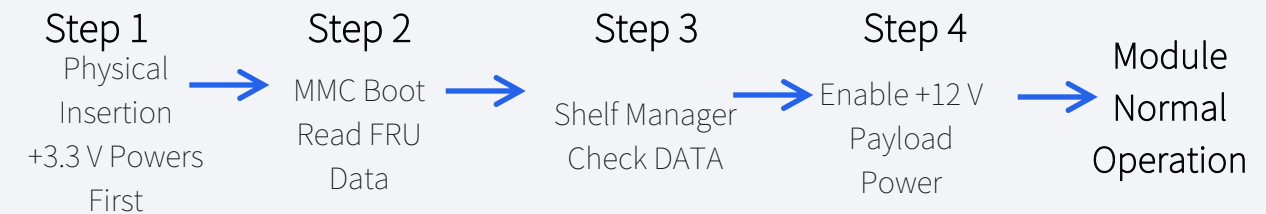
T0+100 ms M1 State: MMC initializes its I2C/IPMB interface and sends a Module Hot Swap Event ("module present") to the Shelf Manager

T0+300 ms FRU Read: Shelf Manager reads the FRU EEPROM via IPMB (model/serial/power/compatibility); blue LED slow blink (1 Hz)

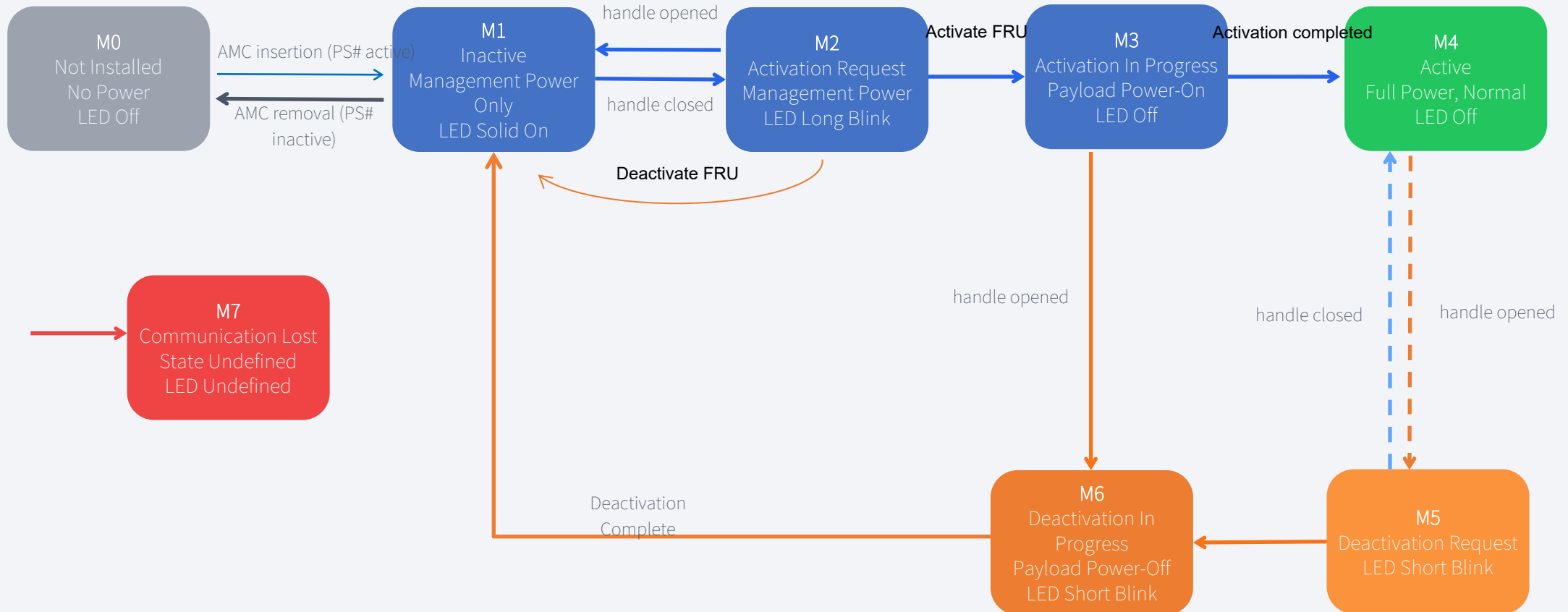
T0+500 ms Power Check: Shelf Manager verifies the power budget and sends Set Power Level

T0+800 ms M2 State: MMC enables local +12 V Payload; DC-DC converters generate all voltage rails; processor reset released

T0+2-10 s M4 State: Module enters normal operation; blue LED solid on



AMC M0-M7 State Transition Diagram (FRU State)



Power-Up Flow (blue arrows): M1 Inactive -> M2 Activation Request (MCMC issues activation command) -> M3 Activation In Progress (+12 V payload power on, wait 100 ms) -> M4 Active (module operating normally)

Power-Down Flow (orange arrows): M4 Active -> M5 Deactivation Request -> M6 Deactivation In Progress (payload power off, PERST# asserted) -> M1 Inactive (safe to remove)

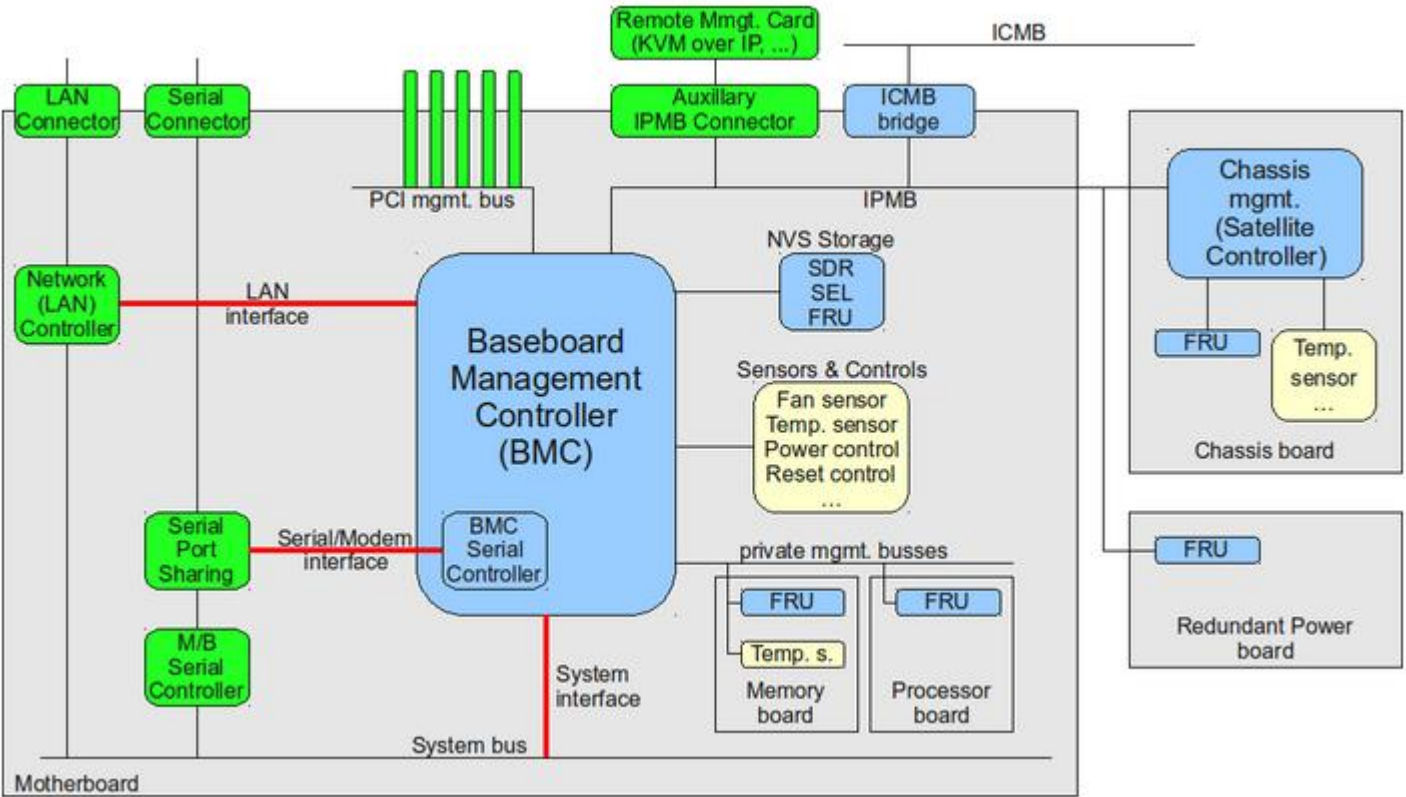
Exception State: M7 (communication lost between MCMC and MMC)

Lab 1

Power Management • Power Sequencing • Hot-Swap Management

08 • Intelligent Platform Management (IPMI)

IPMI Architecture Main Blocks	Actual Location in an MTCA Chassis
BMC	MCMC on the MCH card
IPMB Bus	IPMB-0 on the MTCA backplane (I ² C management bus to all slots)
Satellite Controller	MMC on each AMC <i>and</i> EMMC on power / fan modules
LAN Interface	Ethernet port on the MCH
Serial Connector	Debug serial port on the MCH
SEL / SDR / FRU	SEL on the MCMC; distributed SDR and FRU EEPROM on each AMC
Sensors and Control circuitry	temperature/voltage sensors on each AMC; chassis fans; power monitoring
System Interface	Backplane management channel between MCH and AMCs



IPMI Architecture Diagram

MicroTCA Extensions

In standard IPMI the BMC is soldered onto the mainboard and talks to a single CPU via the System Interface; in **MTCA the MCMC resides on a pluggable MCH card** and manages up to 12 AMCs + 2 MCHs + 2 power modules + multiple fans over IPMB — a multi-node, distributed management architecture, extended with **MTCA-specific features such as AMC hot swap, Fat Pipe configuration and MCH redundancy**

SDR, FRU Information & SEL Log

SDR (Sensor Data Record)

Temperature Sensors: FPGA/CPU/ambient temperature; threshold alarms

Voltage Sensors: monitoring of +12 V/+3.3 V and all rails

Current Sensors: +12 V current per slot for power calculation

Fan Sensors: tachometers for failure detection

Presence Sensors: hot-swap handle switch / module presence / power state

FRU (Field Replaceable Unit)

Common Header: version / area offsets

Internal Use: vendor-private data

Chassis Info: chassis model / serial number

Board Info: board model / serial / version / manufacture date

Product Info: product name / model / part number

Power Record: max. power / power level

Storage: EEPROM, read/write by the MMC

SEL (System Event Log)

Event Type: threshold crossing / state change / hot swap / configuration change

Record Format: 16-byte standard event record

Timestamp: relative or absolute timestamp (UTC)

Storage Capacity: typically 1024 records, circular overwrite

Read Command: Get SEL Entry (0Ah/43h)

PEF (Platform Event Filtering): selected events can trigger alarms / power-off / reset

Use Case: Troubleshooting

IPMI Information Retrieval Procedure

Step 1: Read the SEL to locate event time and type (Get SEL Info + Get SEL Entry)

Step 2: Read module FRU to confirm model/serial/firmware version (Get FRU Inventory Area Info + Read FRU Data)

Step 3: Read related sensor values and thresholds (Get Sensor Reading + Get Sensor Threshold)

Common IPMI Commands & Management Interfaces

Common IPMI Commands

Category	NetFn	Cmd	Description
Device ID	06h	01h	Get Device ID - controller model/version/capabilities
Sensors	04h	2Dh	Get Sensor Reading - current sensor value and status
FRU	0Ah	11h	Read FRU Data - FRU EEPROM contents (model/serial)
SEL	0Ah	43h	Get SEL Entry - system event log records
Power Control	00h	02h	Cold Reset / Warm Reset - reset management controller
PICMG Extensions	2Ch	00h	Get PICMG Properties - PICMG extensions and supported version

Management Interface Types

LAN Interface: RMCP remote management protocol
Serial/Telnet: terminal/basic mode for local debugging

IPMI Management Software Ecosystem

Open-Source CLI Tools: ipmitool (mainstream, raw commands), freeipmi (GNU suite), ipmiutil (lightweight scripting)
OS Drivers: Linux loads ipmi_msghandler/ipmi_devintf/ipmi_si kernel modules and creates /dev/ipmi0; install an IPMI driver on Windows
Vendor-Specific Software: NAT mTCA Shell (NAT MCH dedicated CLI with PICMG extensions, MCH configuration, AMC/RTM management, firmware upgrade), VadaTech UTC, Web GUI

05

MCH

MCH Functions • Architecture • Management Interfaces

MCH Functions

Shelf Manager

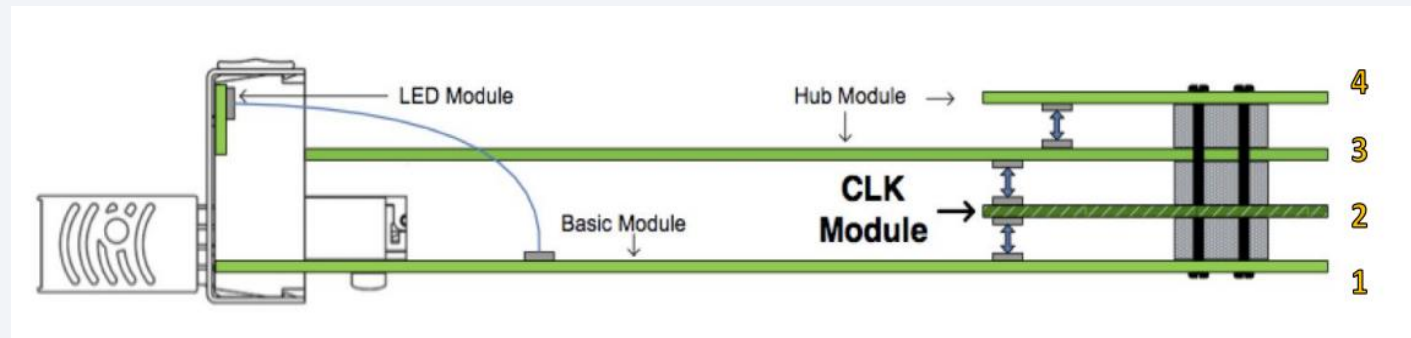
System Management Core
IPMI protocol
Sensor Monitoring
Power/thermal control
Hot-Swap Management

Fabric Switch

Data Switching Core
Basic Fabric
Fat Pipe Fabric

Clock Generator

Clock Distribution Core
Low-jitter LVDS outputs
Trigger signal distribution
Synchronous Ethernet (SyncE)



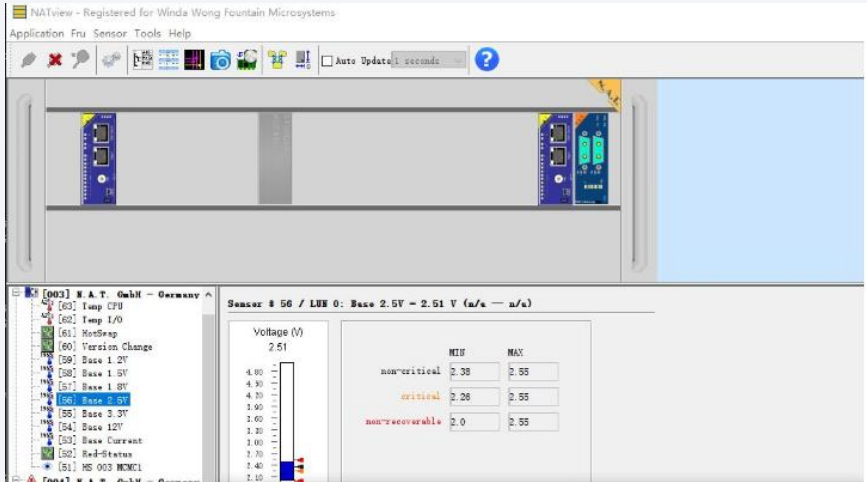
MCH Hardware Architecture

The MCH front panel provides the management Ethernet port, serial port, clock I/O and status LEDs. Internally it integrates a management processor (running Shelf Manager firmware), switch ASICs (Ethernet/PCIe), clock chips (low-jitter PLL + clock buffers) and a local MMC. The MCH connects to all AMC slots through backplane connectors, interconnecting management, data and clock signals.

Three Management Access Methods

Access Method	Interface	Typical Use Case
USB Console	USB-to-Serial	Initial Setup / Disaster Recovery
Telnet	Direct Ethernet	Internal Network Debugging
Web UI	Direct Ethernet	Graphical Configuration

Natview UI



Basic CLI Commands

```
N.A.T. MCH commands:
reboot                - reboot card
printfreq             - print system frequencies
history              - print complete console history
update_firmware       - update firmware in flash
update_fpga           - update FPGA firmware
exit                  - exit from remote login

=== application commands: ===
--- Configuration Support ---
mch                   - print MCH configuration
mchcfg                - modify MCH configuration
upload_cfg            - upload switch/clock configuration via TFTP
cfg_ctrl_cmd          - configuration control command

--- Debugging Support ---
csif_dbg              - configure CM/SHM interface debug
imgb_dbg              - configure IPMI MSG debug
lshm_dbg              - configure local SHM debug
red_dbg               - configure redundancy debug
rmcp_dbg              - configure RMCP interface debug
sdrrep_dbg            - configure SDR repository debug
sel_dbg               - configure SEL debug

--- Print and Show Commands ---
idb_info              - print IPMI data base information
imgb_info             - print IPMI MSG information
lshm_info              - print local SHM information
sdrrep_info           - print SDR repository information
sel_info              - print SEL information
session_info          - print session management information
show_ekey              - show all activated connections
show_fru              - show all FRUs
show_fruinfo <fru_id> - show FRU contents
show_cu               - show Cooling Unit Status
show_pm               - show Power Module Status
show_pwrconf          - show Backplane Power Configuration
show_sensorinfo <fru_id> - show sensors for FRU
show_urtm             - show voltages of URTMS
show_clk <fru_id>     - show clock information
version               - print firmware version information
```

Web UI

NAT-MCH by N.A.T.

Setup

Base Configuration

JSM

Switch: BASE CASE

Age Time

Port on/off

Port VLAN

802.1Q VLAN

802.1X

802.1p

Port Mirroring

Jumbo Frame

Link Aggregation

Rapid Spanning Tree

Serdes/SGMII

Link Status

BCM5396 counters

Switch: SRIO GEN II

Status

Routing Table

Error Rate

Port Statistic

Maintenance

Script Management

Board Information

System Information

Reboot NAT-MCH

Update MCH

Change Password

N.A.T. Webpage

Home

Welcome to the HTML based NAT-MCH configuration tool.

Setup Functions:

Base Configuration: - Changes Base Configuration.

Age Time: - MAC Table setup: set the aging of the MAC Table Entries.

Port VLAN: - Port based VLAN setup and port enable/disable.

802.1Q VLAN: - 802.1Q VLAN setup.

802.1X: - 802.1X security setup.

802.1p: - 802.1p Quality of Service setup.

Port Mirroring: - Mirroring of the inbound and outbound traffic on a port.

Jumbo frames: - Support of the Jumbo frames on a port.

Link Aggregation: - Support of up to four the Link Aggregation groups.

Rapid Spanning: - Support of the Rapid Spanning Tree by IGBE-Switch.

ICMP Snooping: - Support of the ICMP Snooping by IGBE-Switch (FW4000 only).

Link Status: - Show the current status of the Ethernet links.

Counter Statistic: - Show the counter statistic of the Ethernet switch.

Maintenance Functions:

Script Management: - Backup/Restore settings to/from flash memory or file.

Board Information: - Provides hardware information of this NAT-MCH.

System Information: - Collect hardware information of this system.

Reboot NAT-MCH: - Allows rebooting over the Web Interface.

Update MCH: - Allows updating several components over the Web-Interface.

Change/Reset Password: - Allows changing or resetting of the MCH Password over the Web-Interface.

N.A.T. Webpage: - Opens the N.A.T. webpage in a new browser window.

Home: - Shows this page.

Lab 2

SecureCRT-IPMI Commands

Basic CLI Commands

```
welcome to N.A.T. MCH CM/SHM Firmware V2.23.6 Fin

Current open telnet sessions:
  192.168.1.10:60432 (this connection)
```

```
Type <?> to see a list of available commands.
nat> show_fru
```

FRU Information:

FRU	Device	State	Name
0	MCH	M4	NAT-MCH-CM
3	mcmc1	M4	NAT-MCH-MCMC
6	AMC2	M4	CCT AM G64/472
9	AMC5	M4	mTCA-EVM-300
10	AMC6	M4	mTCA-EVR-300
40	CU1	M4	Schroff UTCA CU
51	PM2	M4	NAT-PM-AC600D
60	Clock1	M4	MCH-Clock
61	HubMod1	M4	MCH-PCIE
95	AMC6-RTM	M1	mTCA-EVRTM-300

```
nat> show_link_state
```

FRU	Device	Port	Type	Linkwidth	Speed
6	AMC_2	0	Eth	x1	1.000 Gbps
		1	Eth	x1	1.000 Gbps
		4	PCIE	x4	8.000 GT/s
		5	PCIE	x4	8.000 GT/s
		6	PCIE	x4	8.000 GT/s
		7	PCIE	x4	8.000 GT/s
		8	PCIE	x4	8.000 GT/s
	AMC_2	9	PCIE	x4	8.000 GT/s
		10	PCIE	x4	8.000 GT/s
		11	PCIE	x4	8.000 GT/s
9	AMC_5	4	PCIE	x1	2.500 GT/s
10	AMC_6	4	PCIE	x1	2.500 GT/s

```
nat> sel_info
Enter SEL device (0=CM, 1=SHM) (RET=1/0x1): 1
SEL(1): print modes
print help: 1
print common short information: 2
print common information: 3
print all decoded entries: 4
print all raw entries: 5
print single decoded entry: 6
print single raw entry: 7
print SEL time: 8
Enter info mode (RET=4/0x4): 4
```

timestamp	rec_id	type	I2C/LUN, ch	sensor	num	event	data	CRC
1970/01/01 00:00:10	0x0001	SYS	20/0	0	Version Chg	70	spec	c1 00 00 OK
1970/01/01 00:00:10	0x0002	SYS	20/0	0	UTCA FRU HS	71	spec	a2 01 03 OK
1970/01/01 00:00:10	0x0003	SYS	20/0	0	UTCA FRU HS	71	spec	a3 02 03 OK
1970/01/01 00:00:16	0x0004	SYS	20/0	0	UTCA FRU HS	87	spec	a2 01 28 OK
1970/01/01 00:00:16	0x0005	SYS	20/0	0	UTCA FRU HS	87	spec	a3 02 28 OK
1970/01/01 00:00:16	0x0006	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 03 06 OK
1970/01/01 00:00:16	0x0007	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 03 09 OK
1970/01/01 00:00:16	0x0008	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 03 0a OK
1970/01/01 00:00:16	0x0009	SYS	20/0	0	GEN Red Stat	62	spec	01 00 03 OK
1970/01/01 00:00:16	0x000a	SYS	20/0	0	UTCA FRU HS	71	spec	a4 03 03 OK
1970/01/01 00:00:16	0x000b	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 5b 01 OK
1970/01/01 00:00:17	0x000c	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 1b 03 OK
1970/01/01 00:00:17	0x000d	SYS	20/0	0	UTCA FRU HS	87	spec	a4 03 28 OK
1970/01/01 00:00:18	0x000e	SYS	20/0	0	Temperature	24	thresh	01 ff ff OK
1970/01/01 00:00:19	0x000f	SYS	20/0	0	UTCA FRU HS	89	spec	a2 01 09 OK
1970/01/01 00:00:19	0x0010	SYS	20/0	0	UTCA FRU HS	101	spec	a2 01 09 OK
1970/01/01 00:00:19	0x0011	SYS	20/0	0	UTCA FRU HS	103	spec	a2 01 0a OK
1970/01/01 00:00:19	0x0012	SYS	20/0	0	UTCA FRU HS	115	spec	a2 01 0a OK
1970/01/01 00:00:20	0x0013	SYS	20/0	0	UTCA FRU HS	117	spec	a2 01 06 OK
1970/01/01 00:00:20	0x0014	SYS	20/0	0	UTCA FRU HS	119	spec	a2 01 06 OK
1970/01/01 00:00:20	0x0015	SYS	20/0	0	UTCA FRU HS	117	spec	a3 02 06 OK
1970/01/01 00:00:20	0x0016	SYS	20/0	0	UTCA FRU HS	89	spec	a3 02 09 OK
1970/01/01 00:00:20	0x0017	SYS	20/0	0	UTCA FRU HS	103	spec	a3 02 0a OK
1970/01/01 00:00:20	0x0018	SYS	20/0	0	UTCA FRU HS	119	spec	a3 02 06 OK
1970/01/01 00:00:20	0x0019	SYS	20/0	0	UTCA FRU HS	101	spec	a3 02 09 OK
1970/01/01 00:00:20	0x001a	SYS	20/0	0	UTCA FRU HS	115	spec	a3 02 0a OK
1970/01/01 00:00:20	0x001b	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 1b 09 OK
1970/01/01 00:00:20	0x001c	SYS	20/0	0	UTCA Pwr Chan	28	spec	a1 1b 0a OK
1970/01/01 00:00:21	0x001d	SYS	20/0	0	UTCA FRU HS	89	spec	a4 03 09 OK
1970/01/01 00:00:21	0x001e	SYS	20/0	0	UTCA FRU HS	101	spec	a4 03 09 OK
1970/01/01 00:00:22	0x001f	SYS	20/0	0	UTCA FRU HS	103	spec	a4 03 0a OK
1970/01/01 00:00:22	0x0020	SYS	20/0	0	UTCA FRU HS	115	spec	a4 03 0a OK
1970/01/01 00:00:22	0x0021	SYS	20/0	0	UTCA FRU HS	115	spec	a1 00 01 OK
1970/01/01 00:00:22	0x0022	SYS	20/0	0	UTCA FRU HS	130	spec	a2 01 01 OK

```
nat> show_pwrconf
Backplane power policy: REDUNDANCY
backplane channel assignment:
```

Pchannel:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
PM1(prim)	x	-	x	-	x	x	x	x	x	x	-	-	-	-	-	-
PM2(red)	x	-	x	-	x	x	x	x	x	x	-	-	-	-	-	-
PM3(-)																
PM4(-)																
PM assigned	1/2	0/0	1/2	0/0	1/2	1/2	1/2	1/2	1/2	1/2	0/0	0/0	0/0	0/0	0/0	0/0
BP Amps:	7.6	0.0	7.6	0.0	7.6	7.6	7.6	7.6	7.6	7.6	0.0	0.0	0.0	0.0	0.0	0.0

```
nat> show_pm
```

```
PM1: - unknown
PM2: - online, primary(fru 51) : budget 50.0 A (alloc 23.5 A avail 26.5 A)
PM3: - unknown
PM4: - unknown
```

chan	FRU	FruId	primPM	redPM	PS1	Pon	ENA	MP	PP	Amps
1	MCH1	3	2	-	y	y	y	y	y	4.5
2	MCH2	4	-	-	-	-	-	-	-	-
3	CU1	40	2	-	y	-	y	y	y	7.0
4	CU2	41	-	-	-	-	-	-	-	-
5	AMC1	5	2	-	-	-	-	-	-	-
6	AMC2	6	2	-	y	-	y	y	y	6.0
7	AMC3	7	2	-	-	-	-	-	-	-
8	AMC4	8	2	-	-	-	-	-	-	-
9	AMC5	9	2	-	y	-	y	y	y	4.0
10	AMC6	10	2	-	y	-	y	y	y	2.0
11	AMC7	11	-	-	-	-	-	-	-	-
12	AMC8	12	-	-	-	-	-	-	-	-
13	AMC9	13	-	-	-	-	-	-	-	-
14	AMC10	14	-	-	-	-	-	-	-	-
15	AMC11	15	-	-	-	-	-	-	-	-
16	AMC12	16	-	-	-	-	-	-	-	-

```
> AMC5(9): Handle=0x02 - opened
5(9): disable RTM...
y_DisableAMCPorts(9): disabling all ports
5: channel 0 disabled, Ports[4 LSHM: FRU 9 sensor 87 LUN 0 'Hot Swap' hotswap M4->M5
w: FRU 9 sensor 75 LUN 0 'HS 009 AMC5' hotswap M4->M5
w: FRU 9 sensor 87 LUN 0 'Hot Swap' hotswap M5->M6
```

```
ndle state=0x06 - quiesced
_disableFCLK(60): disabling FCLK-A for AMC11
w: FRU 9 sensor 75 LUN 0 'HS 009 AMC5' hotswap M5->M6
wON: - AMC5/4-7 down
w: FRU 9 sensor 87 LUN 0 'Hot Swap' hotswap M6->M1
SHM: FRU 9 sensor 75 LUN 0 'HS 009 AMC5' hotswap M6->M1
.....
```

```
5(9): Handle=0x01 - closed
_enableFCLK(60): enabling FCLK-A for AMC5 11
w: FRU 9 sensor 75 LUN 0 'HS 009 AMC5' hotswap M1->M2
w: FRU 9 sensor 75 LUN 0 'HS 009 AMC5' hotswap M2->M3
w: FRU 9 sensor 87 LUN 0 'Hot Swap' hotswap M1->M2
w: FRU 9 sensor 87 LUN 0 'Hot Swap' hotswap M2->M3
y(AMC5): channel(0): Port[4 - - -] - used:[4] PCIe downstream Gen 1, no SSC
w: FRU 9 sensor 75 LUN 0 'HS 009 AMC5' hotswap M3->M4
w: FRU 9 sensor 87 LUN 0 'Hot Swap' hotswap M3->M4
LS_MON: - AMC5/4-7 up
```

06

AMC Modules & RTM

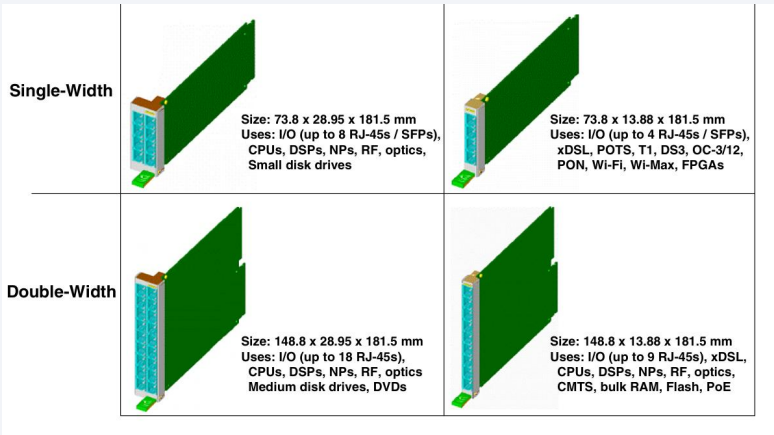
AMC Form Factors • Connectors & Pin Zones • MMC • RTM • Hot Swap

AMC Module Specification

Four Standard AMC Form Factors (defined in AMC.0 R2.0)

Type	Max. Power	Typical Application
Single Compact	20 W	Low-power management, interface conversion
Single Full	40 W	General-purpose computing, data acquisition
Double Compact	60 W	Multiple interfaces, extended storage
Double Full	80 W	High-performance FPGA/CPU, research DAQ

AMC Form Factors (MTCA.0 Figure 1-3)



No.	Spec Name	Core Content	Version
AMC.0	Base Specification	Mechanical/electrical/management/hot-swap framework	R3.0
AMC.1	PCIe Fabric	PCI Express Gen1-5, x1/x4/x8/x16, Fat Pipe	R3.0
AMC.2	Ethernet Fabric	1/10/40 GbE, dual-plane redundancy, auto-negotiation	R2.0
AMC.3	Storage Interface	SAS 3-12 Gb/s / SATA 1.5-6 Gb/s; HDD/SSD modules	R1.0
AMC.4	SRIO Fabric	Serial RapidIO Gen1-2; low-latency packet switching	R1.0

AMC.0 Base Specification - Core Definitions

Power Specification: +3.3 V Management (always on, <= 10 W); +12 V Payload (<= 80 W, MMC controlled)

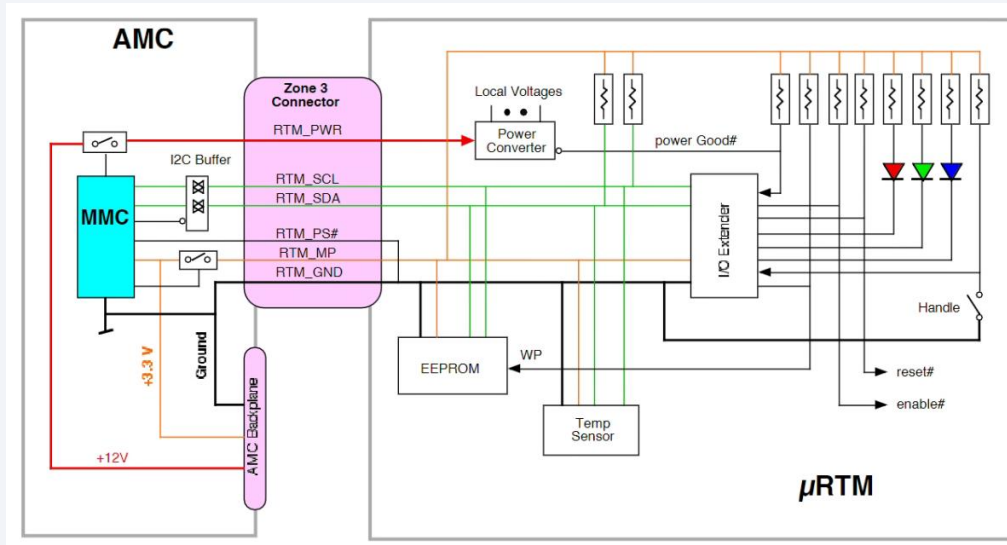
Management Controller: MMC (Module Management Controller); implements the M0-M7 state machine; IPMB-L communication

Hot Swap: triggered by the handle switch;

FRU Data: EEPROM stores manufacturer/model/serial/power level; E-Keying compatibility check

AMC Connectors & MMC

AMC-uRTM Signal Diagram

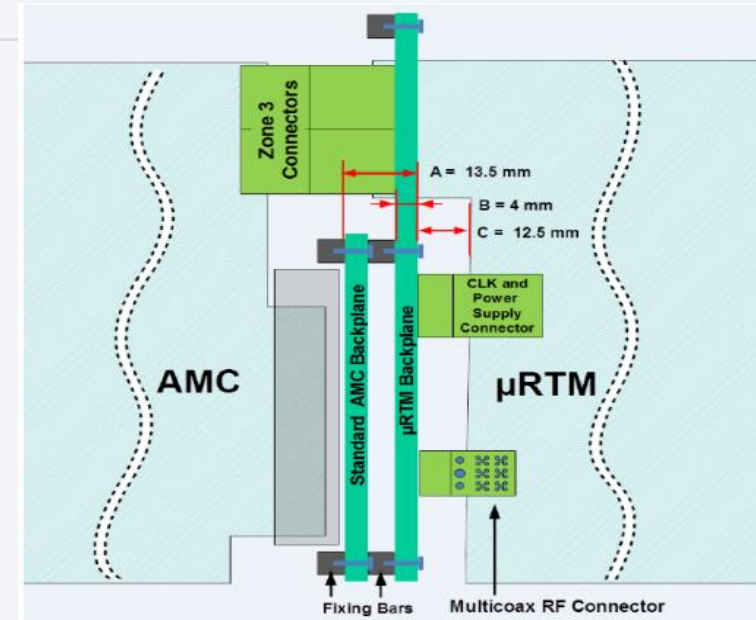


MMC Functions

MMC: management controller on the AMC, always powered from +3.3 V

Hardware: typically an ARM series MCU

Core Functions: insertion/removal detection; local sensor monitoring (temperature/voltage/current); FRU storage (EEPROM); +12 V Payload enable; IPMB communication responding to Shelf Manager commands; firmware upgrade (Update Channel)



Management Architecture

- MMC is always powered from +3.3 V Management
- In MTCA.4 the uRTM communicates with the AMC MMC over an I2C bus, powered on/off by the AMC MMC via RTM_PWR_EN

RTM Hot Swap (Microswitch-Triggered)

RTM Insertion Procedure

- 1. Slide the RTM in along the guides; the Zone 3 connector mates
- 2. Close the handle; the microswitch releases, PS# is pulled low, and the AMC MMC detects RTM presence
- 3. AMC MMC asserts RTM_PWR_EN; the RTM powers up
- 4. AMC MMC reports "RTM activated" to the MCH over IPMB; system ready

RTM Hot-Swap Characteristics

- 1. **No dedicated MMC:** the RTM has no module management controller of its own; it is fully managed by the corresponding AMC MMC via dedicated management signals on the Zone 3 connector.
- 2. **Microswitch Triggered:** the RTM ejector carries a microswitch; actuating it toggles the switch, and the AMC MMC detects the hot-swap event via GPIO.
- 3. **Powered by the AMC:** RTM +12 V/+3.3 V are not supplied directly by a PM but controlled by the AMC via the RTM_PWR_EN backplane signal; the AMC MMC can remove RTM power at any time.

RTM Removal Procedure (Microswitch-Triggered)

- Step 1: Open the handle** - the mechanical action toggles the microswitch.
- Step 2: AMC MMC Detects the Event** - the AMC MMC detects the microswitch change via GPIO, recognizes an RTM removal request, and reports the RTM hot-swap event to the Shelf Manager over IPMB.
- Step 3: Remove RTM Power** - the AMC MMC pulls RTM_PWR_EN low, removing RTM +12 V via the backplane.
- Step 4: Physically Remove the RTM** - after ~1-2 s for full discharge, pull the RTM out; the Zone 3 connector separates, RTM_PS# goes high, and the MMC detects RTM absence.

	AMC Hot Swap	RTM Hot Swap
Management Controller	Dedicated MMC	None; managed by the AMC MMC
Power Source	Directly from PM	Via backplane (controlled by AMC)

Lab 3

PCIe Virtual Switches & RTM Hot Swap

Web UI

			AMC1				AMC2				AMC3	AMC4	AMC5	AMC6	RTM1
			4..7	8..11	12..15	17..20	4..7	8..11	12..15	17..20	4..7	4..7	4..7	4..7	
Link Width			x4	x4	x4	x4	x4	x4	x4	x4	x4	x4	x4	x4	x16
Virtual Switch	Upstream AMC	NT-Upstream AMC													
none			☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	AMC2/4..7	- none -	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
1	- none -		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	- none -		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	- none -		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Max. Link Speed			8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s	8.0 GT/s

PCie Link Status Menu

	AMC1				AMC2				AMC3	AMC4	AMC5	AMC6	RTM
	4..7	8..11	12..15	17..20	4..7	8..11	12..15	17..20	4..7	4..7	4..7	4..7	
	-	-	-	-	x4	x4	-	-	-	-	x1	x1	-
Link Speed	-	-	-	-	8 GT/s	8 GT/s	-	-	-	-	2.5 GT/s	2.5 GT/s	-

PCie Error Counters Menu

	AMC1				AMC2				AMC3	AMC4	AMC5	AMC6	RTM
	4..7	8..11	12..15	17..20	4..7	8..11	12..15	17..20	4..7	4..7	4..7	4..7	
	x4	x4	x4	x4	x4	x4	x4	x4	x4	x4	x4	x4	x16
RCV_CNT	0	0	0	0	223	0	0	0	0	0	0	0	0
Bad TLP	0	0	0	0	0	0	0	0	0	0	0	0	0
Bad DLLP	0	0	0	0	0	0	0	0	0	0	0	0	0

Reset ☐ Refresh

```
Type <?> to see a list of available commands.
nat> RTM6(95): Handle=0xa1 - closed
LSHM: FRU 95 sensor 130 LUN 0 'RTM Hot Swap' hotswap M1->M2
LSHM: FRU 95 sensor 130 LUN 0 'RTM Hot Swap' hotswap M2->M3
LSHM: FRU 95 sensor 130 LUN 0 'RTM Hot Swap' hotswap M3->M4
```

Thank You!

Glossary

Abbr.	Full Name & Description
AMC	Advanced Mezzanine Card - payload module in a MicroTCA system
ATCA	Advanced Telecom Computing Architecture - predecessor standard of MicroTCA
CU	Cooling Unit - fan cooling module
FRU	Field Replaceable Unit - stores module model/serial/power information
IPMB	Intelligent Platform Management Bus - dual-redundant I2C management bus
IPMI	Intelligent Platform Management Interface - standard system management protocol
MCH	MicroTCA Carrier Hub - integrates Shelf Manager/Fabric Switch/Clock Generator
MMC	Module Management Controller - local controller on AMC/PM/CU
MTCA	Micro Telecommunications Computing Architecture - topic of this training
PICMG	PCI Industrial Computer Manufacturers Group - standards organization
PM	Power Module - converts input power to +12 V Payload and +3.3 V Management
RTM	Rear Transition Module - maps to an AMC via Zone 3 in MTCA.4, providing rear-panel I/O
SDR	Sensor Data Record - defines sensor parameters and thresholds
SEL	System Event Log - records all significant events and alarms

Standards List, Vendor Overview & Common Commands

PICMG Standards List

Standard No.	Content
MTCA.0	MicroTCA base specification (core standard)
MTCA.1	Air-cooling enhancements (high power density)
MTCA.3	Ruggedized environments (-40 to +70 C, vibration)
MTCA.4	Rear Transition Modules (dual backplane, research DAQ)
AMC.0	AMC base specification (form factors/connectors/interfaces)

Major Vendors at a Glance

Vendor	Profile & Management Software
NAT	Germany; mainstream mTCA.4 vendor for research; full AMC/RTM/MCH/chassis portfolio; software: NAT mTCA Shell dedicated CLI + Web GUI with PICMG extensions, firmware upgrade, MCH/AMC/RTM configuration
VadaTech	USA; high-performance FPGA/CPU AMCs and full chassis range; software: UTC (Universal Tool for Control) CLI + Web GUI for chassis monitoring and module management
Elma	Switzerland; chassis/backplane specialist, industrial/carrier grade; Elma Bustronic backplane design services; standard IPMI-compatible management
Pentair	Formerly Schroff, Germany; chassis/backplanes/power, carrier grade; software: Schroff Case Controller for power/thermal/environment monitoring
CAEN	Italy; AMC/RTM dedicated to nuclear/particle-physics DAQ; software: CAEN Fast Controller for trigger/clock/DAQ configuration

ipmitool Command Quick Reference

Command	Description
ipmitool -H IP -U user sel list	List all System Event Log (SEL) records
ipmitool -H IP -U user sdr list	List current readings of all sensors (SDR)
ipmitool -H IP -U user fru print	Read all FRU data (model/serial/version)
ipmitool -H IP -U user picmg policy set	Set PICMG power and module activation policies

Shelf Manager System Management Functions

Core Management Functions

Asset Management: auto-discovers all modules and reads FRU data (model/serial/version/power)

Sensor Monitoring: real-time acquisition of temperature/voltage/current/fan speed with threshold alarms

Power Management: power-budget allocation, independent per-slot +12 V control, power on/off sequencing

Thermal Management: automatic fan-speed control by temperature with a three-stage policy

Hot-Swap Management: insertion/removal detection, safe power sequencing, blue LED control

IPMI Protocols & Interfaces

Interface/Protocol	Description
IPMB-0/1	Dual-redundant I2C management bus to all MMCs
RMCP+	Remote Management Control Protocol; out-of-band Ethernet management
SOL	Serial over LAN; serial console redirection
SNMP	Simple Network Management Protocol; integration with NMS
CLI	Command-line interface; local management via serial/SSH

Shelf Manager firmware: typically runs on ARM or PowerPC processors; mainstream solutions include the MMC-1 reference design from Pigeon Point Systems (PPS), the NAT (Networked Access Technologies) Shelf Manager, and the open-source OpenIPMI implementation. The firmware implements all IPMI v2.0 commands: device ID query, sensor reads, FRU read/write, power control, SEL, PEF, etc. Administrators manage the system and troubleshoot via CLI, SNMP or Web UI.

Switching, Clock Distribution & Redundancy

Data Switching Capability

Switch Type	Speed	Description
Base Interface	1 GbE	Mandatory; management + control plane
Fabric GbE	10/25/100 G	Data plane; optional
PCIe	Gen3/4/5	root complex / endpoint switching
SRIO	1x/4x	RapidIO; common in DSP clusters
Uplink Ports	10/40/100 G	Front-panel optical/electrical uplinks

MCH Active/Standby Redundancy Principle

In the dual-star topology, MCH1 connects to Fabric A of every AMC and MCH2 to Fabric B. During normal operation MCH1 is the active Shelf Manager and MCH2 is standby, synchronizing state over IPMB.

If MCH1 fails, MCH2 takes over Shelf Manager functions within 1 s; the data plane switches transparently via link aggregation (LAG) or multipath software.

Clock distribution is also redundant: the standby MCH clock outputs stay high-Z and are enabled automatically on active-MCH failure.

Clock Distribution & Active/Standby Redundancy

Clock Source: local OCXO/TCXO or external 10 MHz input

Clock Output: CLK1/CLK2 dual-star distribution to all AMCs

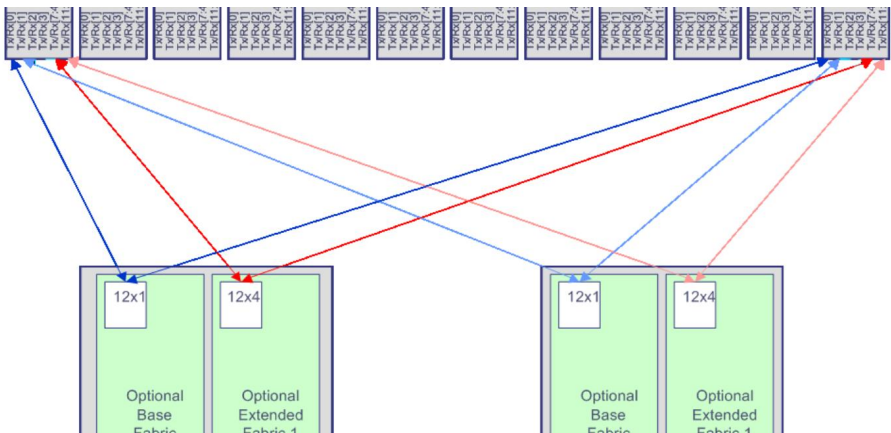
Jitter: ≤ 1 ps RMS (12 kHz-20 MHz)

Trigger Distribution: TCLKA/TCLKB point-to-point or multicast

Active/Standby Switchover: MCH1 active, MCH2 standby, automatic failover

Switchover Time: management plane < 1 s, data plane < 50 ms

Fabric Interconnect Architecture (MTCA.0 Figure 6-2)



12 AMCs x dual MCHs, dual-star Fabric interconnect

Function	NAT-MCH G-3	NAT-MCH G-4 (improvements)
CPU + O/S + memory	Single core NXP Coldfire + OK1 + 64Mb	Dual ARM core (A9, Xilinx Zynq) + FreeRTOS + 1GB
Base Switch	Broadcom 1GbE	Microchip 1/10/40GbE, dual ARM core (A53)
Base Fabric + Uplinks	12x 1GbE + 2x 1GbE (RJ45)	12x 1/2.5/10GbE + 2x 1/10GbE (RJ45/iX/SFP-DD)
Clock Module + ext. Input/output	CLK123, CLK12F, CLK-PHYS + dual input/output	CLK-G4 + dual input/output and GPS
IEEE1588/SyncE + TSN support + OXCO	Not supported+ Not supported + NAMC-PTM	Supported + Supported + OXCO
Fat pipe Ethernet switch	Marvell Amstrong-LP 40GbE	Marvell Amstrong-LP 40GbE
Fat Pipe + Uplinks	12x XAUI + MPO	12x XAUI/10/40G + SFP-DD
Fat pipe PCIe Switch + PCIe Gen	PLX + Gen3	MicroChip + Gen4
Fat Pipe + Uplinks	12x PCIe Gen3 + Finisar BOA (NAT-MCH-PHYS80)	12x PCIe Gen4 + SFP-DD
Fat pipe SRIO Switch + SRIO Gen	IDT + Gen2	?
Fat Pipe + Uplinks	12x SRIO Gen2 + Infiniband	?
User Interfaces	CLI, Web (GoAhead) => Update with 2.22.x	unified CLI, reworked Web (Mongoose) incl. CLI
NATView: HPM update + backplane viewer + FRU-Ed	JRE on external device	Integrated into Web interface (excl. FRU-Editor)

Power Module (PM) Specifications & N+1 Redundancy

Key PM Specifications

Parameter	Specification
Input Voltage	100-240 V AC or -36 to -72 V DC
Output Power	300 W / 600 W / 1000 W classes
Output Voltage	+12 V Payload + +3.3 V Mgmt
Conversion Efficiency	>= 90% (80 PLUS Platinum)
Hot Swap	Supported; live replacement without interruption
Redundancy	1+1 / 2+1 / 3+1 / 2+2

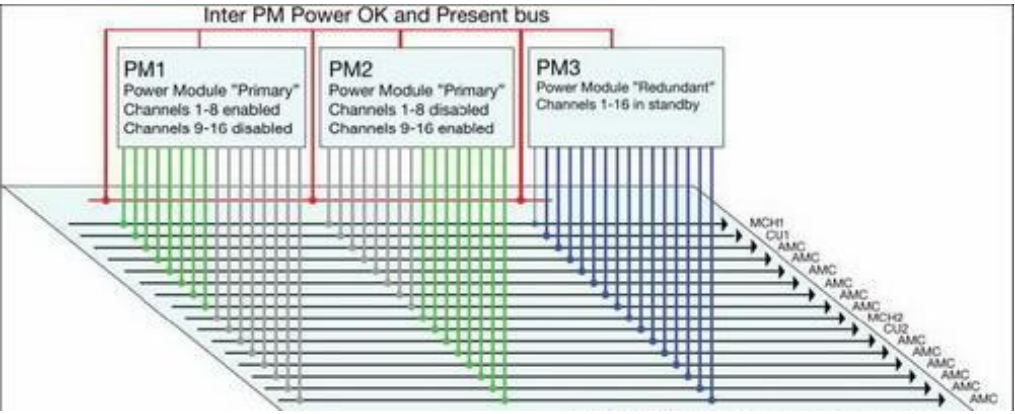
N+1 Redundancy Principle

Up to 4 PMs in parallel: N active, 1 standby; current sharing

Automatic Failover: auto switchover to standby; failed PM is hot-swappable

Power Budget: total power = (N-1) x per-module power

Diagram: 2+1 redundant PM architecture (PM1/PM2 active, PM3 standby)



Power Budget Calculation Example

Total system power = sum of AMC power + MCH power + cooling power + conversion losses
Fully populated 12 double-width full-size AMCs (80 W/slot) = 960 W + ~50 W MCH + ~100 W fans + 10% losses ~ = 1200 W
Required: 3x 600 W PMs (2+1 redundancy, 1200 W available) or 4x 300 W PMs (3+1, only 900 W - insufficient) -> 3x 600 W recommended