RTM RF Backplane Extensions for MicroTCA.4 Crates – Concept and Performance Measurements

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RF Signal Distribution in Multichannel Control Systems

- RF front end require distribution of tens precise LO / CLK / REF signals to RTM and/or AMC cards

- Impedance controlled lines and coax connectors

- Tens of cables hanging in front of the crate very difficult cable management!
The First Idea – RTM RF Backplane in the MTCA.4 Crate

CRATE FRONT

AMC

RTM

REAR

Zone 3

Zone 2
ADF Connector

Zone 1
Multipin RF Coaxial Connector

AMC Backplane

RTM Backplane

ERMET ZD, 3x10 diff. pairs

Radiall Coaxipack 2
6-pin, 6GHz RF connectors
First RF Backplane Version – Assumptions and Problems

- Custom design for E-XFEL LLRF
- Single input with adapter board
- RF signals distributed to 8 slots
- LO and MO signal power splitting on board (careful RF design) (no flexibility)
- 50Ω matching of not used RF signals:
  - manually by putting loads on connectors (dummy load boards)
- EMI protection from the “digital world” (AMC Backplane)
- Improve system reliability
- Easier maintenance: no need to disconnect multiple cables during service
Further Development of RF Backplane Concept

- Empty areas behind front Power Module and MCH used for further extensions of MTCA.4 standard
  - eRTM concept
  - Rear Power Modules for eRTMs and µRTMs
  - Allows for significant reduction of control system size (removal of external LO and CLK signal sources)

- RF signal distribution from slot #15 to all µRTM slots

- Automatic matching of unused RF signals
  - RF hot-plug (probably world’s first)

- Necessary to introduce management over the Backplane
RTM Backplane – Final Concept Highlights

- **Fully compatible to the standard.** No mechanical collision with standard RTM boards. Supported by crate manufacturers.

- **Hot swap functionality for RF signals.** IPMI extension for RTM Backplane worked out with N.A.T.

- RTM Backplane is passive. All intelligence in modules -> great flexibility for users.

- Developed a concept of extended RTM (eRTM) boards.

- **Redundant high performance rear power supply** for analog applications and additional power for digital RTMs.
### Slots, eRTMs and Rear Power Supply Modules

#### Crate Top View

<table>
<thead>
<tr>
<th></th>
<th>RPM</th>
<th>RPM</th>
<th>MCH-RTM</th>
<th>µRTM</th>
<th>µRTM</th>
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<td>ZONE 3 Connectors</td>
<td>RTM Backplane</td>
<td>AMC Backplane</td>
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#### Crate Rear View

- **RTM Backplane Manager (MCH-RTM)**
- **1 or 2 Rear Power Modules**
- **Up to 3 extended RTMs (eRTM)**
- **Redundant MCH-RTM or eRTM**

*open for redundant MCH-RTM architecture*
eRTMs

- Offer system designers additional space (note that eRTMs are wider (6HE) than uRTMs (4HE))
- Designers can use 2 or 3 slots for one module
  - eRTMs are intended for applications requiring significant space for components like filters or precise temperature stabilization
- Backplane provides management, power supply and data links for eRTMs
- Slot 15 was designated for RF signal entry

eRTM #15 example. LO and CLK generator
Courtesy: T. Rohlev, U. Mavric. See poster on Tuesday

Universal slot #15 test adaptor
Connector Zones on the RTM Backplane

- 3 x eRTM (3 x 6HP) in Zones 1, 2, and 3
- 12 x μRTM (12 x 4HP)
- 2 x RPM (6HP) in Zones 2 and 3

Up to 6 coax lines 50Ω, DC-6GHz
uRFB Management and Rear Power Supply

- Management by MCH-RTM in slot #1-1 and (option) #13
- Standard (AMC) management extended to the RTM side
- MCH-RTM can also provide fast CPU with direct links to AMC backplane
- FRUs with information about connectivity and power
- Rear PM can supply **4 x +12V to eRTMs and 12x +/-VV to μRTMs**
- μRTM can use +/-VV from RTM Backplane or standard +12V from AMC
- **Economic use case**: power supply for eRTM in slot #15 from MCH-RTM (no Rear PM) but limited to max 25W
- Optional high voltage (~100 V, not on the RTM Backplane for safety reasons!) Rear PM for e.g. piezo driver application
- 27 RF signals (optimized for 1.3 GHz but can work up to 6 GHz)
- 22 CLK signals
- „Analog” power supply: +/-7 V for RTMs and +12 V for eRTMs
- Management and communication
RF and CLK Performance Optimization

> **Required:**

- min. 80 dB isolation of RF-to-RF and CLK-to-RF signals
- „as low as reasonably achievable” RF loss and phase drifts
- Reflections lower than -15 dB

> **Careful RF PCB design performed**

- 16 layer PCB
- Hybrid design: RF substrate for RF and CLK lines, standard substrate for power supply
- Large effort put in grounding (to minimize reflections, crosstalk, loss)
- Optimization of power supply network (4 x 12V, 7A; 12 x 2 x +/- VV 2A) including control of return currents
- 3D EM simulations of coaxial connectors to PCB interface
Automated Test Stand

- Time consuming RF measurements of RF and CLK performance

- Automated test stand and adapter boards were designed to allow fully automatic measurements and report generation

- ~400 VNA measurements needed for full test
  - manually 1-2 days + 1 day for report generation assuming no human mistake is done…
  - **with test stand ~25 min. including report**
Test Boards

VNA calibration board

Adapter board for precise S-parameter measurements

eRTM15 test board

uRTM test board
Performance Measurement Results (Example)

Table I: Measured Attenuation and Reflections of the Backplane @1.3GHz for LO, REF and CAL Lines

| Slot | $A_{\text{REF}}$ [dB] | $|\Gamma_{\text{REF}}|$ [dB] | $A_{\text{LO}}$ [dB] | $|\Gamma_{\text{LO}}|$ [dB] | $A_{\text{CAL}}$ [dB] | $|\Gamma_{\text{CAL}}|$ [dB] |
|------|-----------------------|-----------------|-------------------|-----------------|-------------------|-----------------|
| 4    | 2.4                   | -24.3           | 2.9               | -40.0           | 2.5               | -26.1           |
| 5    | 2.1                   | -23.4           | 2.7               | -20.5           | 2.4               | -17.9           |
| 6    | 2.0                   | -20.4           | 2.3               | -25.7           | 2.3               | -22.4           |
| 7    | 2.0                   | -15.9           | 2.2               | -18.7           | 2.1               | -22.3           |
| 8    | 1.6                   | -22.5           | 2.2               | -21.0           | 2.0               | -19.0           |
| 9    | 1.6                   | -24.5           | 2.0               | -23.0           | 1.7               | -26.8           |
| 10   | 1.5                   | -16.0           | 1.9               | -18.6           | 1.6               | -18.8           |
| 11   | 1.4                   | -19.4           | 1.5               | -22.4           | 1.5               | -19.6           |
| 12   | 1.1                   | -16.2           | 1.4               | -19.1           | 1.4               | -30.0           |

Table I: Measured crosstalk between REF and LO lines @ 1.3 GHz, [dB]

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Phase Drifs

- Critical for LLRF applications
- PCB traces are sensitive to temperature and humidity variations on level important for LLRF
- Test board was designed and a method developed to calibrate out test cable drifts
- Measured phase drifts
  - by temperature are in range of 40 – 70 fs/°C p-p
    (~0.035 °C @1.3 GHz) for the longest line
  - by humidity ~2 \( \frac{fs}{%RH} \)
  - usually humidity changes by few tens %/day
  - Expected drifts 10 – 20 \( \frac{fs}{%RH} \) p-p during day
PICMG Standardization Process

- All ideas and developments were base for PICMG standardization

- PICMG Hardware Group did a great job to collect it all, improve and significantly extend before putting into PICMG document

- PICMG document covers general RTM Backplane with MCH-RTM, eRTMs and Rear PMs, mechanics, protective covers and more

- Very impressive document: ~170 pages, 45 figures, 55 tables

- Close to release
Summary

- Compact solution integrated with the crate
- No collision with standard MTCA cards
- Reduces number of cable connections and improves reliability and maintainability
- Hot-swap for high-performance RF signals up to 6 GHz
- High-performance +/-V managed power supplies for RTMs
- eRTMs to increase number and size of modules
- Developed and tested successfully
- Still plan to do extensive performance tests with Rear PMs
- PICMG standard to be available soon
Thank you for attention!