MicroTCA™

PICMG® MTCA.0 R1.0

Micro Telecommunications Computing Architecture Short Form Specification

September 21st, 2006

This short form specification is derived from the PICMG® MTCA.0 Micro Telecommunications Computing Architecture (MicroTCA.0) specification.

For guidelines on the design of the MicroTCA™ compliant modules and systems, refer to the full specification. Do not use this short form specification for any design decisions.

Not Intended for Design - Do not Claim Compliance

Short Form created by Stuart Jamieson of Emerson Network Power, Embedded Computing

Not Intended for Design - Do not Claim Compliance

Overview

This short form PICMG® Micro Telecommunications Computing Architecture (MicroTCA™) specification outlines the requirements for a system that uses PICMG Advanced Mezzanine Cards (AdvancedMCs) directly on a Backplane. The specification defines the general mechanical, electrical, thermal, and management properties of a MicroTCA Shelf necessary to support AMC.0-compliant Modules.

This short form specification is for introductory purposes only. For the full details, or for normative requirements, please refer to the full length MicroTCA specification.

Introduction and Objectives

MicroTCA has a primary purpose of serving as a platform for telecommunications and enterprise computer network equipment. Its secondary goal is to function as a platform for other demanding marketplaces, such as Customer Premises Equipment (CPE).

MicroTCA is complementary to the PICMG3.0 Advanced Telecommunications Computing Architecture (AdvancedTCA, or PICMG3). Where AdvancedTCA is optimized for very high capacity, high performance applications, MicroTCA is designed to address cost sensitive and physically smaller applications with lower capacity, performance, and perhaps less stringent availability requirements. MicroTCA preserves many of the important philosophies of AdvancedTCA, including basic interconnect topologies and management structure.

MicroTCA is a modular standard. By configuring highly diverse collections of AdvancedMCs in a MicroTCA Shelf, many different application architectures can be easily realized. The common elements defined by MicroTCA are capable of interconnecting these AdvancedMCs in many interesting ways—powering and managing them, all at high efficiency and low cost.

This PICMG MicroTCA specification was written with the following design goals in mind:

- Complementary to AdvancedTCA
- Full conformance with the AMC.0 Module definition
- Favorable cost, size, and modularity
- Target low start-up costs
- Scalable Backplane bandwidth
- Modular and serviceable
- Standardized Shelf management implementation compatible with AdvancedTCA
- Support 300 mm nominal equipment depth and 19 in. nominal equipment width
- Cooling: 20–80 W/AdvancedMC
- Support for extended temperatures (–40 to +65 degrees Centigrade)
- Power: 12 V to AdvancedMCs, in conformance with AMC.0
- Life span: at least eight years
- Backplane bandwidth: SerDes @ 1–12+ Gb/s
- Backplane topologies: Star, Dual Star, Mesh
- Scalable system reliability: from .999 to .99999
- Support any/all AdvancedMC-defined form factors

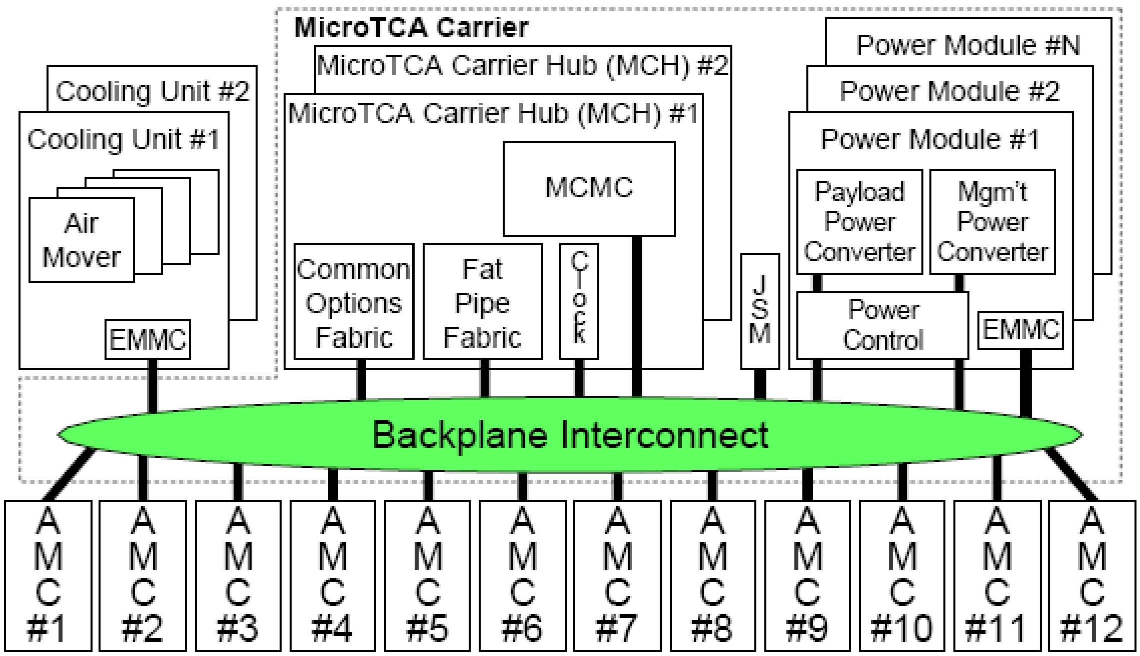
- Hot Swap/plug-and-play support, in conformance with AMC.0 and consistent with AdvancedTCA

System Elements of MicroTCA

For the purposes of this specification, a minimum MicroTCA system is defined as a collection of interconnected elements consisting of at least one AdvancedMC, at least one MicroTCA Carrier Hub (MCH), and the interconnect, power, cooling, and mechanical resources needed to support them. As an example, a typical MicroTCA system consists of up to twelve AdvancedMCs, one (and optionally two for redundancy) MCHs, Power Modules (PMs) with optional redundancy and load sharing, a cooling subsystem (again, optionally redundant), an interconnect (typically a Backplane), and the mechanical elements comprising a Subrack and Shelf.

Please refer to Figure 1 during the following discussion of MicroTCA Shelf elements:

Figure 1 MicroTCA block diagram



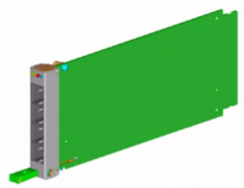
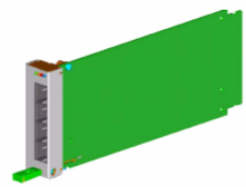
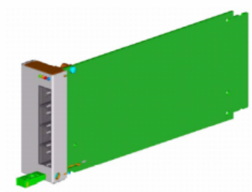
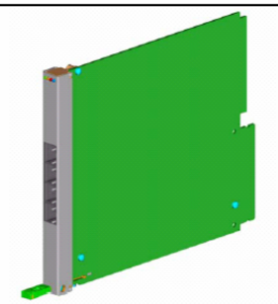
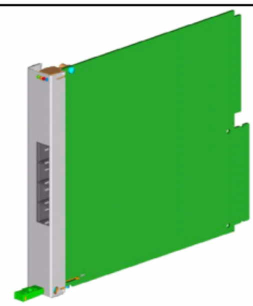
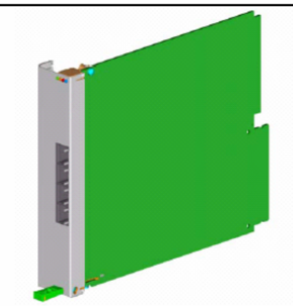
AdvancedMCs

AdvancedMCs are the primary component of MicroTCA. The ability to use any AdvancedMCs that conform to the AdvancedMC standard without modification in MicroTCA is an over arching goal of this standard. They provide the functional elements needed to implement useful system functions. Examples of AdvancedMCs that could be installed into a MicroTCA Shelf include CPUs, Digital Signal Processing devices, packet processors, storage, and various sorts of I/O AdvancedMCs (including metallic and optical line units, RF devices, and interfaces to other boxes). MicroTCA offers a significant advantage because the same AdvancedMCs that connect directly to the MicroTCA Backplane can also be equipped on an AdvancedTCA Carrier Board.

MicroTCA supports six different mechanical sizes of AdvancedMCs. The largest is the Double Full-Size (formerly Full-Height, Double-Width) AdvancedMC, which occupies a mechanical volume of 150 x 187.3 x 30.48 mm. This volume can be subdivided into some number of smaller AdvancedMCs, which permits functions to be better partitioned onto Modules. The volume of two adjacent Full-Size Modules can be occupied by three Mid-Size or four Compact AdvancedMCs. Each double AdvancedMC can be replaced by two AdvancedMC of the same Form Factor.

Figure 2 describes the four AdvancedMC form factors that MicroTCA supports, as well as their properties and some potential applications.

Figure 2 AdvancedMC Module configuration examples

	Compact-Size (3HP)	Mid-Size (4HP)	Full-Size (6HP)
Single modules	 73.8x13.88x181.5mm	 73.8x18.96x181.5mm	 73.8x28.95x181.5mm
Double modules	 148.8x13.88x181.5mm	 148. 8x18.96x181.5mm	 148. 8x28.95x181.5mm

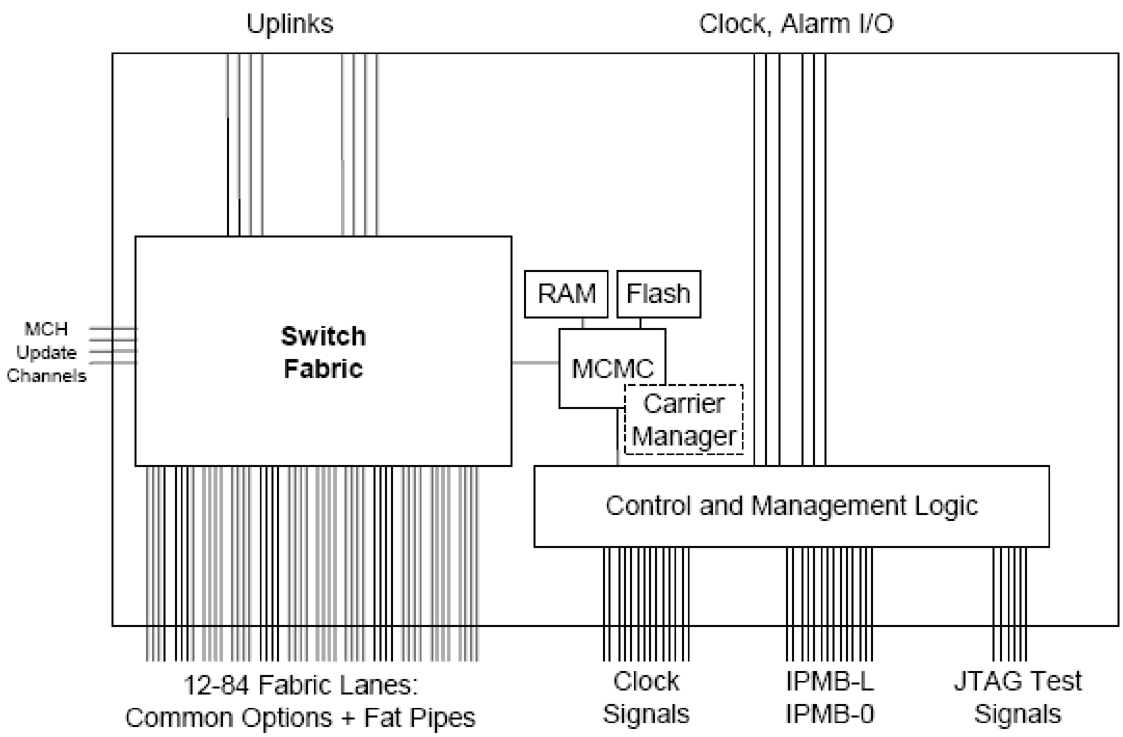
MicroTCA Carrier

The MicroTCA Carrier concept is the basis for the MicroTCA specification. Elements of a MicroTCA Shelf act as a MicroTCA Carrier, which emulates the requirements of the Carrier Board defined in AMC.0 to properly host AdvancedMC Modules. Carrier functional requirements include power delivery, interconnects, and Intelligent Peripheral Management Interface (IPMI) management, among others as defined in the AMC.0 base specification.

These Carrier functions are implemented on AdvancedTCA Carrier Boards that accept up to eight AdvancedMCs. The term “MicroTCA Carrier” used in MicroTCA refers to Carrier functions needed to provide an infrastructure that supports nominally twelve AdvancedMCs. The elements inside the dotted line in Figure 1 represent the MicroTCA Carrier functions.

A MicroTCA Carrier Hub (MCH) combines the control and management infrastructure and the interconnect fabric resources needed to support up to twelve AdvancedMCs into a single Module, which is the same size as an AdvancedMC. MCHs are the infrastructure elements that are shared by all AdvancedMCs. Since MCHs represent a single point of failure in a MicroTCA solution (where any fault could bring down the entire system), it is possible to include a pair of MCHs to make the solution suitable for High Availability (HA) applications. Figure 3 shows a block diagram of an MCH.

Figure 3 MicroTCA Carrier Hub block diagram (12 AdvancedMCs/48 Lanes)



Backplane and Connectors

MicroTCA requires a Backplane into which the AdvancedMCs and other elements are plugged. High performance connectors of several types are specified by MicroTCA. MicroTCA Carrier elements typically occupy one or more Slots on the Backplane. AdvancedMC Backplane Connectors at each AdvancedMC position bring the signals from the AdvancedMC's card edge connector into the Backplane.

Another connector type, called the MicroTCA Carrier Hub Connector, is used to connect an MCH to the backplane to carry the signals to multiple AdvancedMCs. These connectors are optimized to carry high speed serial signals (supporting bit rates over 10 Gb/s). Power Module Input Connectors are used to bring the input power to the Power Modules. Power Module Output Connectors carry high current power supply connections and various control and management signals from the Power Modules to the Backplane.

Mechanical infrastructure/Subrack

A mechanical support structure is required to hold the AdvancedMCs, MicroTCA Carrier elements and Backplane in correct alignment and secure it to the supporting chassis or Frame. This structure, including mounting holes, Card Guides, EMC/ESD control structures, and the means to direct the cooling airflow, is called the Subrack. Various additional mechanical elements, including a means to mount the cooling and power elements, cable guides, and brackets, are added to the Subrack to form the entire mechanical infrastructure (Shelf, Cube, or Pico) of a MicroTCA Shelf.

Cooling and thermal subsystem

MicroTCA Shelves can have high power density. A cooling infrastructure is necessary to remove this heat from the electronics. Typically, this will consist of fans or blowers, filters, and air plenums which direct a large flow of forced air through the air paths between the AdvancedMCs and MicroTCA Carrier elements. MicroTCA Shelves may use different cooling approaches, such as conductive cooling or natural convection.

Control and management infrastructure

The first element of an MCH is the MicroTCA Carrier Management Controller (MCMC) with its Carrier Manager function as the central authority in a MicroTCA Carrier to monitor and control the constituent AdvancedMCs. The Carrier Manager function makes use of IPMB-L Links to each AdvancedMC, as well as presence detect, enable, and Geographic Address signals. IPMB-L and IPMB-0 are located on the MCH(s), while presence detect and enable control are implemented in the Power Modules, under Carrier Manager control.

The MicroTCA Shelf, consisting of one or more MicroTCA Carriers, is managed by the Shelf Manager. The MicroTCA Shelf Manager also monitors events and controls the Cooling Units.

The control and management subsystem of the MicroTCA Carrier also includes the common overhead functions of clock generation and distribution. Several clock signals are distributed to each AdvancedMC position in order to provide network grade synchronization.

Interconnect fabric infrastructure

An interconnect fabric provides the main connectivity among the AdvancedMCs in a MicroTCA Shelf. This interconnect consists of a central switch and a number of high speed serial Lanes to each AdvancedMC position. Lanes on MicroTCA are differential high speed Serializer / Deserializer interconnects (SerDes), with bandwidth capability of at least 3.125 Gb/s in each direction. Although some MicroTCA implementations using inexpensive connectors and backplanes will run these Lanes at slower rates such as 1 Gb/s, many MicroTCA Shelves will permit these bit rates to increase to beyond 10 Gb/s per Lane.

The interconnect protocol used in MicroTCA depends upon the specific format expected by the AdvancedMCs and implemented on the MCHs fabric. All AdvancedMC subsidiary specification formats are supported in MicroTCA, including PCI Express/Advanced Switching (AMC. 1), Ethernet (AMC.2), Storage Interfaces (AMC.3), and RapidIO (AMC.4). Future subsidiary specifications of AdvancedMCs, as well as proprietary Backplane protocols, are also possible.

The fabric component of an MCH is the hub of a star network. Two MCHs are required to implement a dual-star network. In some MicroTCA Shelves, there are supplementary paths directly from each AdvancedMC position to other AdvancedMC positions, permitting the construction of supplemental mesh interconnects and special I/O structures, in addition to the dual star supported by the MCH fabrics.

Power infrastructure

One important function of the MicroTCA Carrier is to supply and control the power to the AdvancedMCs. The AdvancedMC standard specifies a 12 V main Payload Power feed to each AdvancedMC. The MicroTCA Power Module(s) take the input supply and convert it to 12 V to provide radial Payload Power to each AdvancedMC. 3.3 V Management Power for AdvancedMCs is also supplied by the Power Subsystem. The power control logic on the Power Module performs sequencing, protection, and isolation functions. The Power Subsystem is controlled via the Carrier Manager which performs power budgeting to ensure adequate power is available prior to enabling Power Channels.

The Power Subsystem consists of one or more Power Modules. Each Power Module is responsible for converting the input supply that arrives at an Input Power Connector on its Face Plate (either AC or DC) to the individual branches of 12 V Payload Power and 3.3 V Management Power needed to run the AdvancedMCs, MCHs, and CUs. If extra capacity or redundancy is required, up to four Power Modules can be managed in a MicroTCA Shelf.

Power Modules also include the supervisory functions necessary to manage the Power Subsystem. They have circuitry to detect the presence of AdvancedMCs, MCHs, and CUs, and to energize individual power branches. Power Modules also monitor the power quality of each branch and protect against overload. If a Redundant Power Module is configured, it will automatically take over the Power Channel responsibilities of a failed Primary Power Module.

Test Infrastructure

An optional JTAG Switch Module (JSM) supports serial scan testing of complete MicroTCA Shelves, as well as their individual elements. This testing is most often carried out during manufacturing tests in a factory setting, but MicroTCA can also supports the use of these JTAG test capabilities in active systems in the field. JSM functions may be located in special slots on the backplane, or integrated into other Modules.

Theory of operation

MicroTCA works by providing the necessary infrastructure and interconnections to permit the AdvancedMC elements in a system to perform their intended functions. The MCH provides the management, clock, and fabric hub signals required by the AdvancedMC specification to each AdvancedMC position over the Backplane. Please refer back to Figure 1 during the following discussion of MicroTCA Shelf operation.

The primary function of this MicroTCA system is to support the various types of AdvancedMCs that perform the system's processing, storage, and I/O functions. The twelve AdvancedMC positions shown in Figure 1 can be populated with a diverse mix of AdvancedMC types. Conversely, it is possible to configure a MicroTCA system with only a single type of AdvancedMC. AdvancedMCs can include functionality that employs CPUs for control and feature processing, network processing units for packet processing and I/O, DSP AdvancedMCs for signal processing, storage AdvancedMCs, including built-in disk or flash storage, or interfaces to external storage arrays, and various I/O AdvancedMCs, such as subscriber lines, Ethernet, or optical networking.

A set of common functions is needed to manage the AdvancedMCs, as shown in Figure 3. These functions are included in the MCH Module. They include a primary interconnect fabric to interconnect the high speed serial interfaces on AdvancedMCs, MicroTCA Carrier Management Controller (MCMC) and Carrier Manager functions to configure and control the elements, synchronization clocks, and JTAG test circuits. MCHs are optionally duplicated, permitting the creation of highly reliable systems.

The switch fabric may support any of several protocols, as defined by the AdvancedMC subsidiary specifications that govern the complement of AdvancedMCs in a given MicroTCA Shelf. A PCI Express/Advanced Switching fabric supports AMC. 1, an Ethernet fabric supports AMC.2, a storage fabric switch supports AMC.3, and a serial RapidIO switch supports AMC.4. Other protocols for the switch fabric are possible.

In addition to the MCH, a power infrastructure is required for a MicroTCA Carrier. Power is delivered to a MicroTCA Shelf through either connections to AC mains voltage or to the +24, -48, or -60 V DC supplies typical of telecommunication installations. The Power Module produces the +12 V DC Payload Power required to operate the AdvancedMCs from the input voltage. The power control block splits, switches, distributes, and protects this +12 V source for the AdvancedMCs. The Power Module also produces, controls, and monitors multiple branches of +3.3 V Management Power for radial distribution to the AdvancedMCs, MCHs, PMs, and Cooling Units.

Hot Swap support is another important function of the MicroTCA Carrier. Individual AdvancedMCs must be installed and removed from a MicroTCA Shelf without disrupting the operation of the other AdvancedMCs. Hot Swap functions on the PMs and Carrier Manager ensure that no damaging power transients occur as AdvancedMCs are inserted and withdrawn, and no disruptions hamper the operations of other AdvancedMCs that may share the same power infrastructure.

A set of Cooling Units ensures that enough air is forced through the AdvancedMC, PM, and MCH air pathways to keep their temperature within a safe thermal envelope. These Cooling Units typically consist of several individual fans or blowers working in parallel to move an appropriate amount of air at the required pressure. Control systems in the Shelf Manager and Cooling Unit can dynamically adjust the fan speeds in order to provide enough cooling for the given environmental condition, minimizing component wear and acoustic noise.

Fault tolerance and several redundancy options are supported in MicroTCA. Simple, inexpensive systems with less stringent availability requirements are often implemented as simplex Shelves with single MCHs and PMs. As more reliability is required, the common elements of a MicroTCA Shelf can be duplicated optionally, including a pair of

MCHs, duplex or N+1 spared PMs, and redundant CUs. Availability levels up to 99.999% are supported in fully redundant MicroTCA Shelves.

Glossary

The following glossary contains definitions of terms and acronyms that appear in this document:

Table 1 Glossary

Term or acronym	Description
Backplane	An interconnecting device with connectors, allowing Modules to plug into it
Board	An electronic assembly usually consisting of components mounted on a printed circuit
Card Guide	A mechanical component that provides AdvancedMC guidance in a Slot
Component Side 1	The side of the AdvancedMC which supports the greater Component Envelope Height
Component Side 2	The side of the AdvancedMC which supports the lower Component Envelope Height. This side can be used for the solder connections of the components on Component Side 1 and for low-height electronic components.
Contact List	Defines the use of each contact. Directed signals appear in the lists differently, as applicable to the respective viewpoint of the Module and the MicroTCA Backplane.
Cooling Unit (CU)	A subassembly including fans or blowers to move air to cool a MicroTCA Shelf and related support electronics
CPE	Customer Premise(s) Equipment
Cube	A MicroTCA packaging option where AdvancedMCs, MCHs, PMs, cooling, and mechanical elements are all packaged in a small, roughly cubic enclosure that is approximately 200 mm or 8 in. on a side
Double-Width Slot	Mounting location on a MicroTCA Shelf for a Full-Height or Half-Height Double-Width Module. Double-Width Slots may be created by removing a Strut and Card Guide between two Single-Width Slots.
Double-Width Module	A Module that is roughly twice the width of a Single-Width AdvancedMC Module. Double-Width AdvancedMCs measure approximately 150 mm wide.
Electronic Keying or E-Keying	Abbreviation for Electronic Keying. Electronic Keying defines the process in which a MicroTCA Carrier determines if the Control and Fabric interfaces on a Module are compatible with the MicroTCA Carrier interconnects and the other Modules they reach.
Fabric Interface	The set of MCH Fabric Channel interfaces that provides up to seven Fabric Channels to the Advanced MCs
Frame	An enclosure used for mounting one or more MicroTCA Shelves
FRU	Field Replaceable Unit, any entity that can be replaced by a user in the field
Half-Height Module	The component height on Component Side 1 of Half-Height Modules is optimized to allow for two stacked Modules to equally split the maximum height (AdvancedTCA pitch) available. The term Half-Height should not be taken literally as being half of a Full-Height Module. Face Plate height is 13.88 mm.
Intelligent FRU	A FRU containing a management controller. Intelligent FRUs include the AdvancedMCs, MCHs, CUs, PMs, and OEM Modules, etc.

Table 1 Glossary (continued)

Term or acronym	Description
JTAG	Formally, Joint Test Action Group, an organization that proposed adoption of a specification for a test access port and boundary-scan architecture. Informally, but commonly, the standard, namely IEEE Std 1149.1, that arose from the efforts of the Joint Test Action Group.
Management Power (MP)	The 3.3 V power for a Module's management function, individually provided to each Slot by the MicroTCA Shelf
Shelf	An electronic assembly consisting of the Subrack, Backplane, Modules, cooling devices, power subsystems, etc. for one or more MicroTCA Carriers. Also historically known as a chassis. Shelves are usually mounted in Frames.
Shelf Manager	The entity responsible for managing the cooling in a MicroTCA Shelf. It also routes messages between the System Manager Interface and the Shelf-Carrier Manager Interface, provides interfaces to system repositories, and responds to event messages.
Single-Width Module	AdvancedMC Module with a width around 74 mm which fits in a Single-Width AdvancedMC Slot
Slot	The union of a Connector and a Card Guide that defines the position of one AdvancedMC, MCH, Power Module, OEM Module or CU. Slots are similar in concept to the Bays used in the AMC.0 specification. A MicroTCA Subrack typically contains multiple Slots.
Subrack	A mechanical assembly that provides the interface to Modules, including AdvancedMCs, and consists of the Card Guides, ESD discharge, alignment/keying, Handle interface, Face Plate mounting hardware, EMC Gasketing, and Backplane interface
Zone 2	A region used for I/O expansion typically to the left of an AdvancedMC Connector within a Slot (standard vertical orientation, viewed from the front)
Zone 3	A region used for I/O expansion typically above an AdvancedMC Connector within a Slot (standard vertical orientation, viewed from the front)

Mechanical

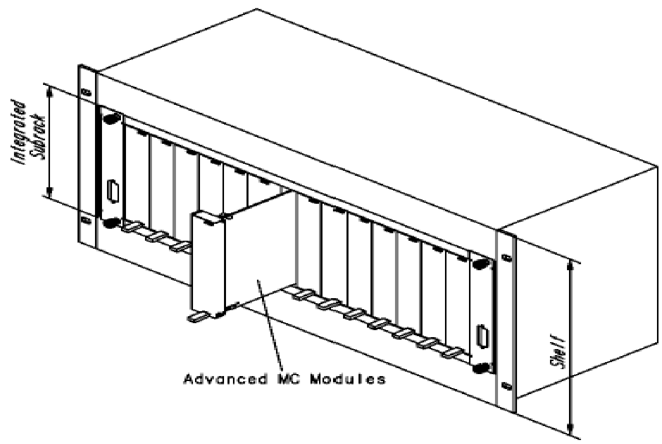
The mechanical MicroTCA structure holds the AdvancedMC Modules, MCH Modules, Power Modules, JTAG Switch Modules, FRU ROMs, and the Backplane into the correct alignment. The architecture defines a rack-mountable Shelf, which **may** be divided by Cubes, or free-standing Cubes, or Pico subassemblies to be populated with AdvancedMC Modules.

Shelf

There are basically two types of Shelves:

- The 19 in. Shelf, as defined in IEC 60297
- The Metric Shelf, as defined in IEC 60917 and ETS 300 119-4

Figure 4 Example of a Shelf



Shelf dimensions

Figure 5 Shelf dimensions—top view

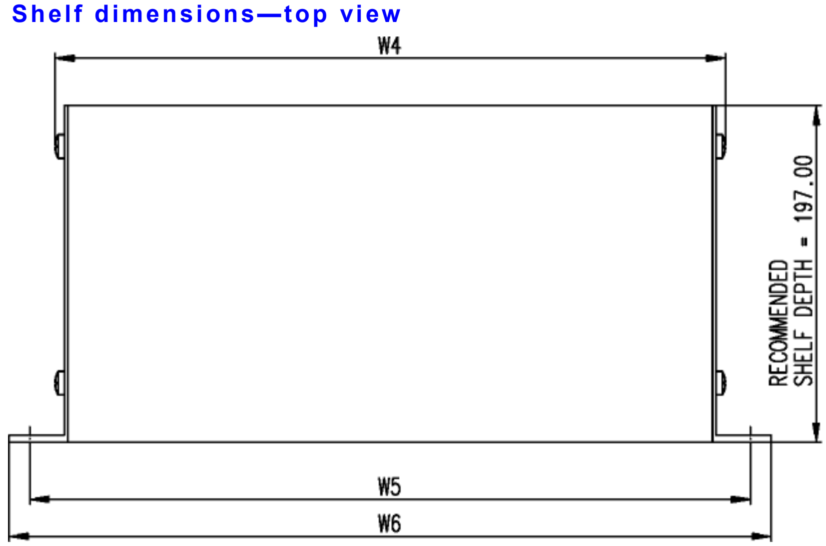


Table 2 Shelf dimension

	W6 Shelf Width	W4 Shelf Body Width	Frame Width Aperture	W5 Frame Mounting Points	Height
IEC 60297 19 in.	482.60	<= 449.0	>= 450	465.10	U= 44.45mm n x U
IEC 60917 Metric (ETSI)	535.00	<=499.0	>= 500	515.00	SU= 25.0mm n x SU
IEC 60917 Metric (ETSI)	482.60	<=449.0	>= 450	465.10	SU= 25.0mm n x SU

Optional Subrack attachment plane

The optional attachment plane provides for the following additional features:

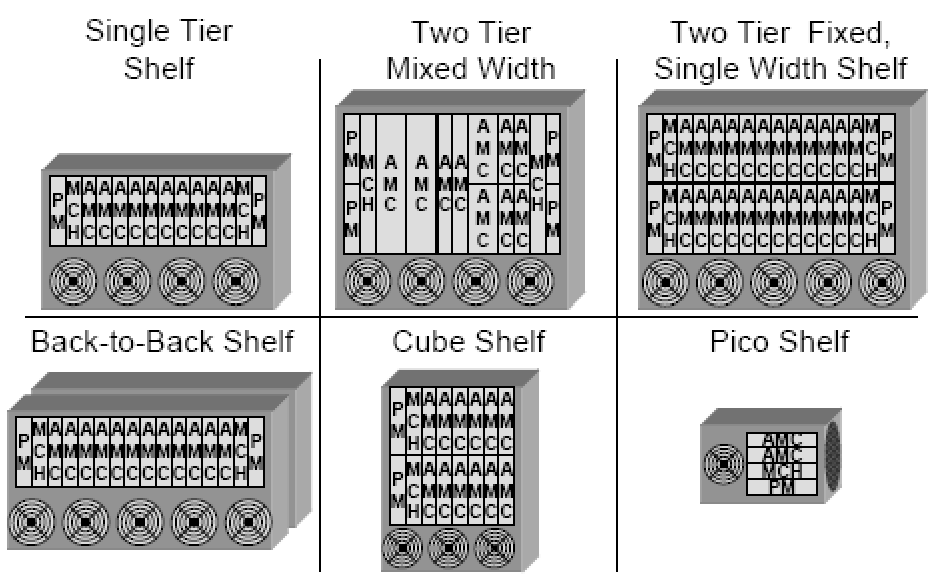
- The attachment of filler panels (low cost)
- The attachment of filler/airflow management devices (low cost)
- The attachment of front access conversion devices (field-replaceable)
- The attachment of PMs (weight/size) See Section 2.8, "Power entry/Power Module".
- The attachment of cable management devices See Section 2.7, "Cable management".
- The attachment of additional AdvancedMC Module locking devices

MicroTCA enclosure types

The standard MicroTCA elements described in this document can be assembled into many different types of systems that conform to this specification. Although the variability of these systems is large, it is believed that there will be a few popular implementation types. This section describes a few of these types in order to provide more concrete illustrations of how to assemble the standard elements into actual systems. It should be understood that other arrangements of the standard elements are possible and can still represent full compliance with the MicroTCA specification.

Figure 6 illustrates six different packaging possibilities for MicroTCA. Different complements of AdvancedMCs will fit, depending upon AdvancedMC size, MCH capacity, Shelf width, and Shelf height. This section (and the rest of this specification) emphasizes vertical placement of boards; however horizontal board orientation is also permitted, and has mechanical and thermal implications. MicroTCA also permits variations in airflow paths, location of cooling units, and cable management capabilities.

Figure 6 MicroTCA packaging illustration



Typical arrangement examples

The following figures show examples of typical mechanical arrangements for MicroTCA systems:

Figure 7 Overview example

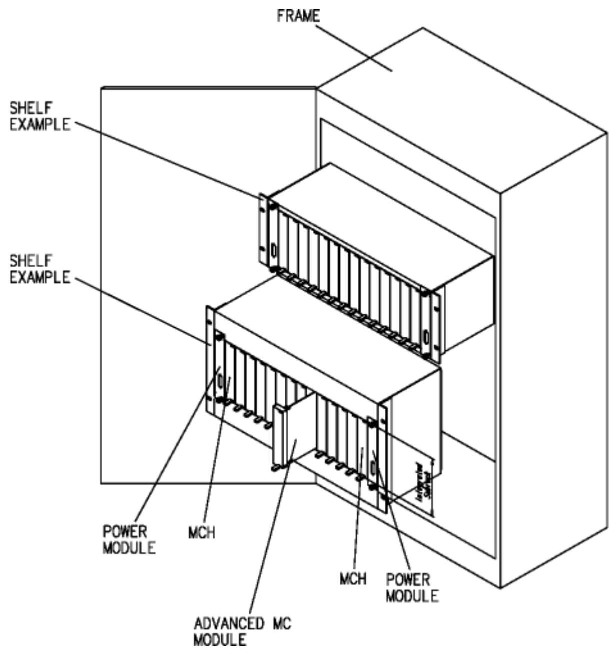
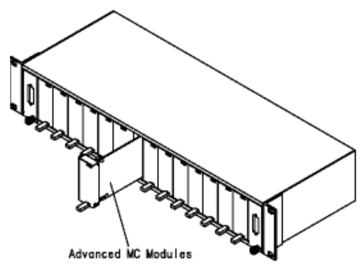


Figure 8 Shelf examples for Single-Width (75 mm) and Double-Width (150 mm) AdvancedMC Modules



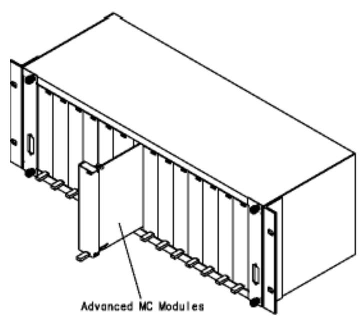


Figure 9 Shelf detail example

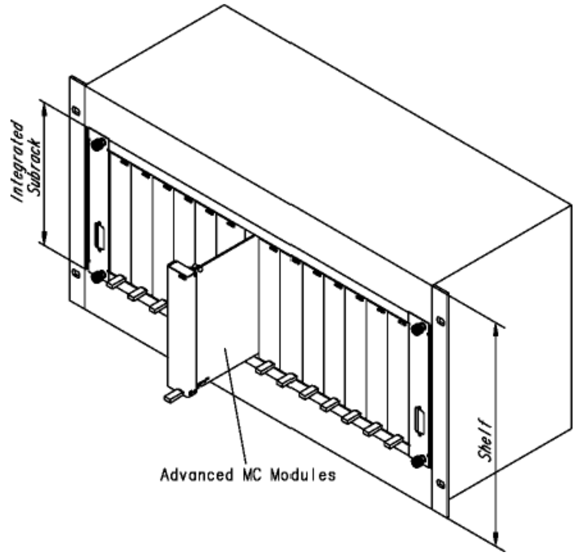


Figure 10 Multiple Shelves in a Frame example

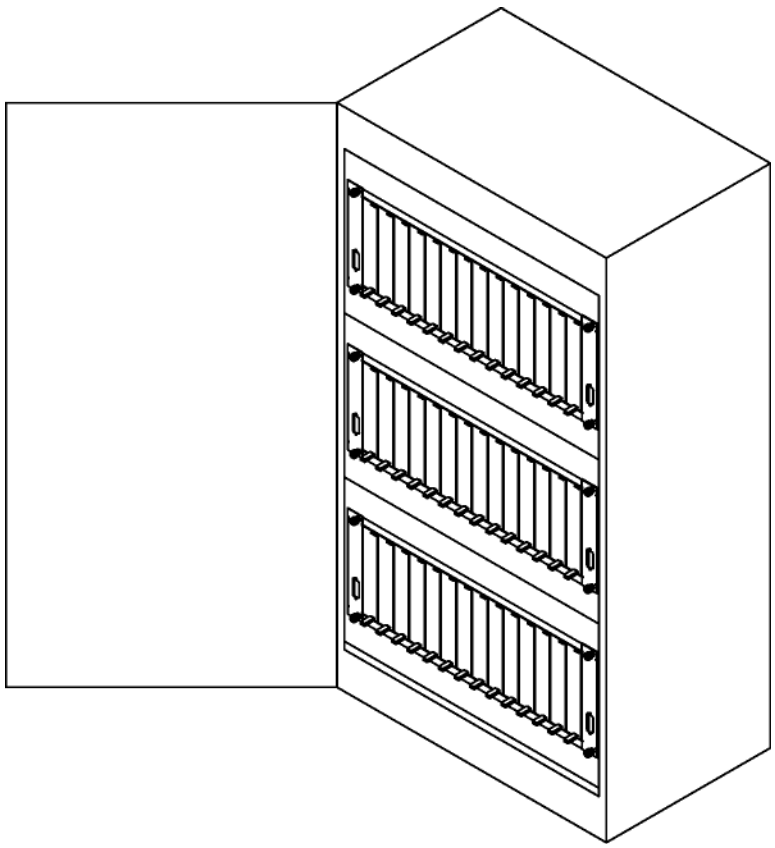


Figure 11 Single Cube on a mounting plate example

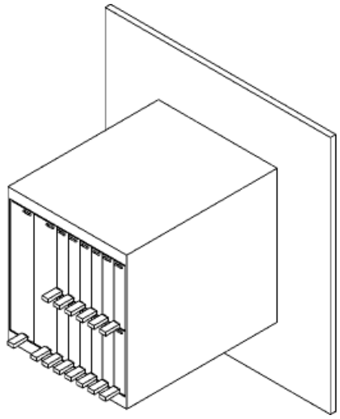


Figure 12 Multiple Carriers in a Shelf example

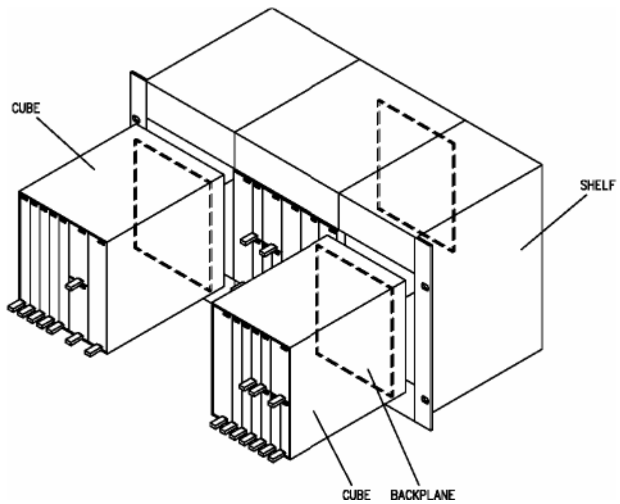


Figure 13 Pico on a panel example

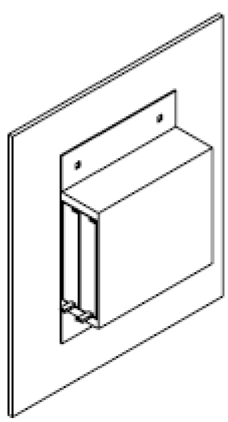
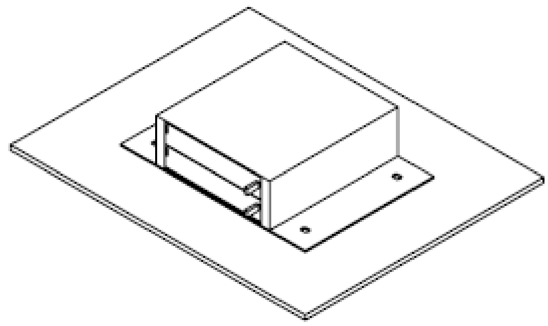


Figure 14 Pico on a motherboard host example



Other implementation options

It is important to realize that MicroTCA Shelves can be constructed using alternative physical arrangements not shown here. MicroTCA Shelves are not limited to cabinet-mounted applications. The compact size of AdvancedMCs allows MicroTCA enclosures to fit into a variety of space-constrained applications, where only a few AdvancedMCs are needed to complete a system.

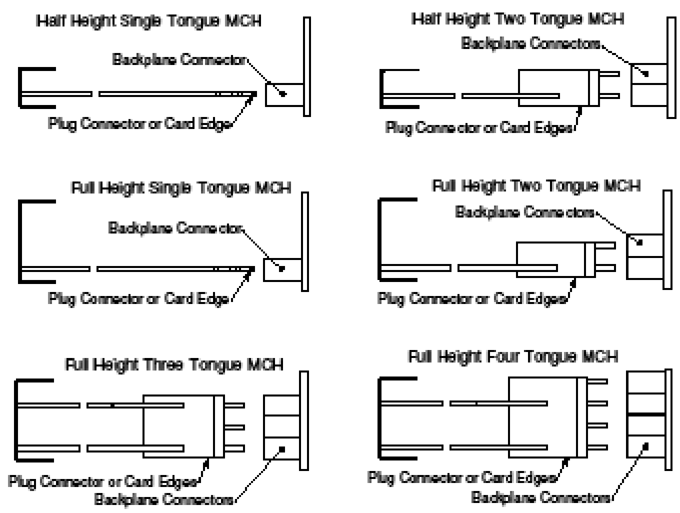
MicroTCA Shelves also can be large capacity systems, perhaps with hundreds of AdvancedMCs making up the complete system. These can combine many communities of AdvancedMCs in multiple Tiers and back-to-back packaging to achieve a very high system density.

In the future special MicroTCA Shelves may be developed for applications where extended temperature, ruggedness, or other environmental factors dictate enclosure design. Additionally Industrial, medical, and military applications of MicroTCA may require special packaging options. Extensions to this MicroTCA specification will be required to accommodate these demanding environmental requirements.

MicroTCA Carrier Hub

The MicroTCA Carrier Hub provides the fabric, clock and management for the MicroTCA Carrier. This functionality can be provided by a modular multi-board form-factor assembly or as functionality implemented on the backplane/motherboard (as in the Pico configuration). The level of functionality provided by the MCH can also flexible and as such the specification provides the scope to have multiple PCBs, as well as multiple connectors to the backplane (see Figure 15).

Figure 15 MCH module types



Auxiliary Connector (Zone 2 and Zone 3) keying

A simple mechanical Auxiliary Connector keying method is used to simplify interoperability between AdvancedMCs and MicroTCA Backplanes that use the Backplane Connector Zones 2 and 3 areas. This framework restricts how AdvancedMCs and MicroTCA Backplanes interact, so that in the future designers can take advantage of Zones 2 and 3 in such a way as to allow forward compatibility and additionally prevent any mechanical or electrical damage to any of these components.

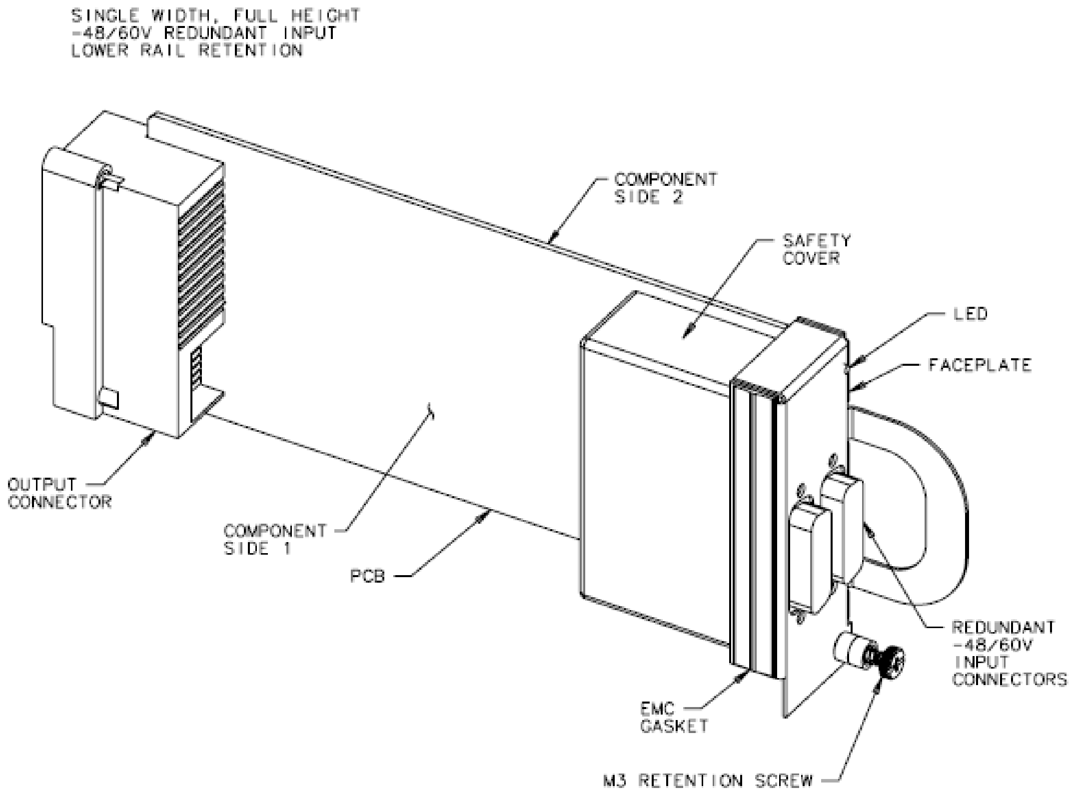
Power entry/Power Module

The power entry into a MicroTCA Shelf, Cube, or Pico may be accomplished via:

- DC or AC power source
- Separate power source
- Integrated power source
- Power Module which fits into a specific Power Module slot in a MicroTCA Subrack.

Power Modules occupy an integral number of Half-Height Slots. The weight of a Power Module must not exceed 1000 g. Power Modules should be located in the outermost Slots of a Shelf.

Figure 16 Power Module Example



Cooling Units (CUs)

CUs may be of different design or configuration.

- CUs can be designed as an integral part of a MicroTCA Shelf, Cube or Pico enclosure or separate unit.
- CUs can be of redundant or non-redundant nature.
- CUs can be designed as a FRU or component of the total MicroTCA supporting installation.
- A CU can contain single or multiple FRUs.

Hardware Platform Management

MicroTCA provides for extensive hardware platform management capabilities, which may be used by an overall System Manager. The management capabilities defined in this specification facilitate:

- Low-level hardware management services, based on the Intelligent Platform Management Interface (IPMI)
- High-speed management services, based on an Internet Protocol (IP) suite

MicroTCA hardware platform management includes Module management, MicroTCA Carrier management, and Shelf management. In this section, the term Module is used to refer to a Module supported in MicroTCA, including the MCH, AdvancedMC, PM, CU and OEM Modules.

The MicroTCA specification leverages the management architecture and requirements defined in the AMC.0 specification to preserve AdvancedMC compatibility in a MicroTCA Shelf. The specification covers MicroTCA management other than AdvancedMC management, which is defined in the AMC.0 specification. Therefore, readers of this short form specification will find being conversant with the platform management aspects described in the IPMI, AdvancedTCA, and AMC.0 specifications helpful.

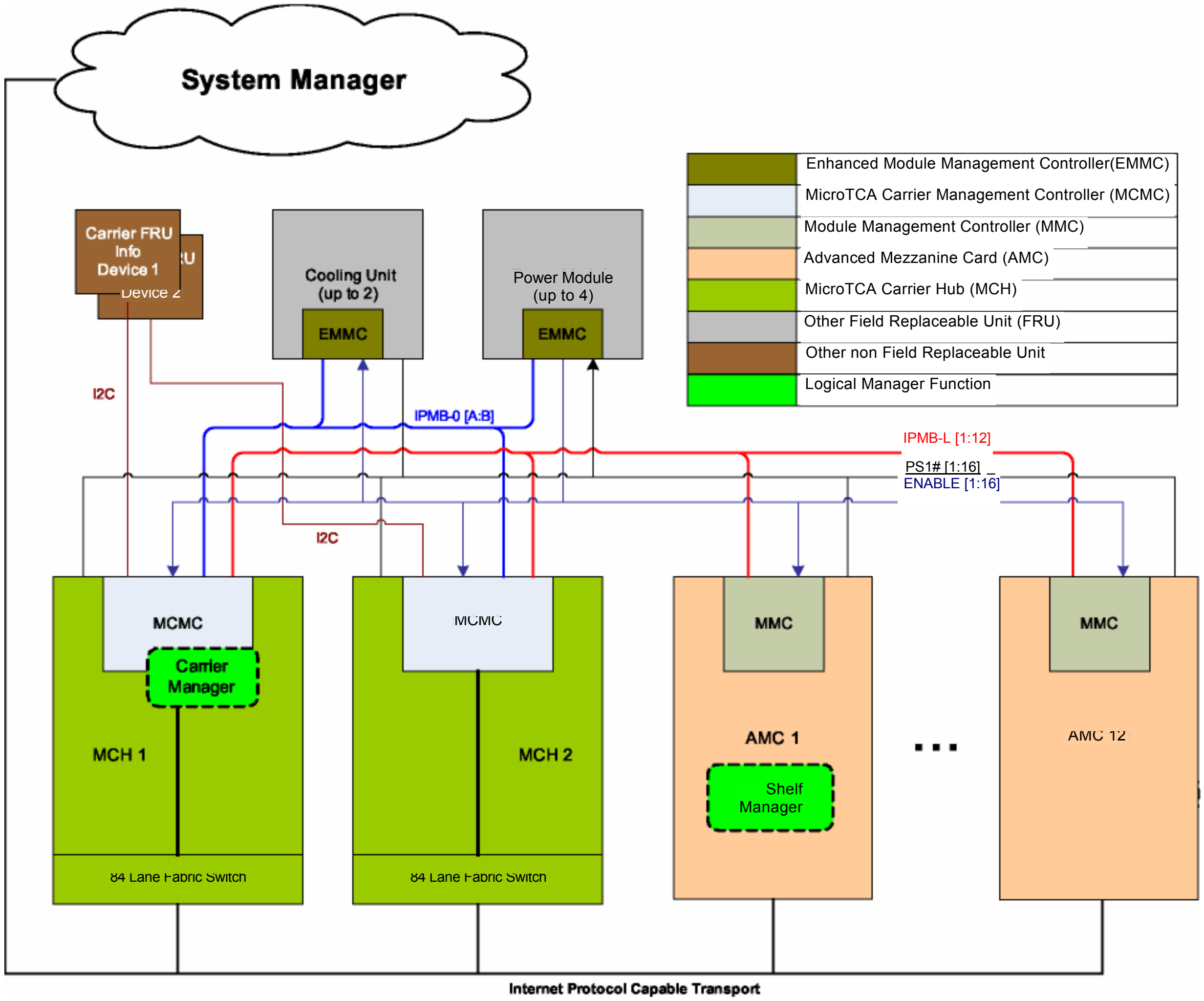
MicroTCA hardware platform management does not cover the implementation of the MicroTCA Shelf for different form factors. Instead, it specifies the following minimum requirements:

- AdvancedMC management, such that AMC.0 Base specification-compliant AdvancedMCs can interoperate with AdvancedTCA Carrier Boards or MicroTCA Carriers.
- MicroTCA Carrier management, which is conceptually similar to the management of an AdvancedTCA Carrier Board.
- Shelf management, which can involve one or more MicroTCA Carriers comprising a MicroTCA Shelf.

MicroTCA management architecture

Figure 17 shows the logical elements of a sample MicroTCA Shelf, with primary emphasis on management.

Figure 17 Management aspects of an example MicroTCA Shelf



The System Manager is the highest-level management entity in MicroTCA. It is responsible for managing one or more MicroTCA Shelves and possibly other Shelf types. It is a logical entity and beyond the scope of the MicroTCA specification. Figure 17 shows a System Manager external to the Shelf. In some systems (such as single Shelf systems), the System Manager can be integrated within the Shelf.

The MicroTCA Shelf Manager manages up to sixteen MicroTCA Carriers that comprise a MicroTCA Shelf. Each Carrier Manager interfaces to the Shelf Manager using a logical Shelf-Carrier Manager Interface, which can be an IP-based interface. The MicroTCA specification preserves the management hierarchy of an AdvancedTCA system through the MicroTCA Carrier model.

The Shelf Manager is a mandatory logical management function and can be implemented on any FRU. In a MicroTCA Shelf, the Shelf Manager functions as the aggregation point for hardware management information from one or more MicroTCA Carriers. The Shelf Manager watches over managed entities such as AdvancedMCs, MCHs, PMs, CUs, and OEM Modules. It reports anomalous conditions to the System Manager and takes corrective actions where appropriate. The Shelf Manager can also provide the collective hardware health status of the MicroTCA Carriers that comprise the MicroTCA Shelf and can communicate with the telco alarms for visual/audible indications of the collective health status of the MicroTCA Shelf that it monitors.

The MicroTCA specification recommends that redundant Shelf Manager instances be provided. The specification does not specify the mechanisms by which an active Shelf Manager communicates with its backup(s). The selection of the backup, coherency of redundant information, and the fail-over process are all beyond the scope of the MicroTCA specification.

MicroTCA Carrier model

The MicroTCA Carrier leverages the AdvancedMC Carrier Board management architecture, which is defined in the AMC.0 specification. A MicroTCA Shelf consists of at least one MicroTCA Carrier. Up to sixteen MicroTCA Carriers can be grouped together to form a single MicroTCA Shelf.

MicroTCA Carrier management functions are fulfilled by the Carrier Manager, a logical function that manages each MicroTCA Carrier, possibly with redundant instances. This document uses Carrier Manager to refer to the MicroTCA Carrier Manager.

The Carrier Manager function resides with a MicroTCA Carrier Management Controller (MCMC), a physical management controller similar to an AdvancedTCA Carrier IPM Controller. The Carrier Manager and MCMC reside with Fabric switches and clock distribution on the MicroTCA Carrier Hub (MCH). A MicroTCA Carrier can be implemented with either single or redundant MCHs.

Additional MicroTCA Carrier architectural elements include Module Management Controllers (MMCs) present in AdvancedMCs, Enhanced Module Management Controllers (EMMCs) present in PMs, CUs and OEM Modules, Carrier FRU Information devices, management hardware interfaces, and a set of management commands.

The Carrier Manager, representing the entire MicroTCA Carrier, exists on only one MCH at a time, even if a redundant MCH is available. The Carrier Manager is at address 20h on IPMB-0 and IPMB-L. The MCMC only represents its MCH local sensors and is at address 1 0h for MCMC 1 and 12h for MCMC 2 on IPMB-0.

The MCMC is a variant of an AdvancedTCA-defined IPM Controller and communicates with the Carrier Manager, a logical management function that provides management interfaces to managed entities within a MicroTCA Carrier. The Carrier Manager manages the AdvancedMCs, MCHs, PMs, CUs and OEM Modules, and represents these entities in a MicroTCA Carrier to the Shelf Manager.

Key differences from PICMG 3.0 and AMC.0 specifications

While the MicroTCA specification attempts to closely follow the management capabilities defined in the PICMG 3.0 AdvancedTCA specification, the unique nature of MicroTCA concepts, scalable reliability, and cost requirements necessitate certain differences in capabilities.

The MicroTCA Shelf Manager functions are not the same as the functions of the AdvancedTCA Shelf Manager. Many of the functions performed by the Shelf Manager in AdvancedTCA are performed by the Carrier Manager in MicroTCA. The following paragraphs describe some areas where specific AdvancedTCA-defined features may be impacted or extended.

Certain FRUs need to be powered-up by the Carrier Manager before the Shelf Manager is operational in the MicroTCA Shelf, for example, when the Shelf Manager is running on an AdvancedMC. For such FRUs, activation is managed by the Carrier Manager, based on the contents of the MicroTCA Carrier Activation and Power Management record in the Carrier FRU Information.

A newly connected Shelf Manager must discover the state of the already activated FRUs. This is similar to the behavior of an AdvancedTCA Shelf Manager when starting in a running AdvancedTCA Shelf.

There is no Shelf-level power budget function in MicroTCA. The Shelf Manager does not participate in MicroTCA Carrier power budgeting.

The Shelf-Carrier Manager Interface between a remote Shelf Manager and a Carrier Manager is an IP-capable interface. This is different from AdvancedTCA, which uses IPMB-0 as the primary in-Shelf management communication interface. An RMCP session is created by the Carrier Manager to the remote Shelf Manager prior to any management commands being issued to the Carrier Manager or events being sent to the Shelf Manager. The implementation is free to choose the level of security for the RMCP session within the constraints of what is specified in the IPMI specification.

When a Shelf Manager is located with a Carrier Manager, the Shelf-Carrier Manager Interface is implementation-defined. The Carrier Manager and the local Shelf Manager establish the Shelf-Carrier Manager Interface during Carrier Manager startup.

The Shelf Manager receives platform event messages from Carrier Managers over the Shelf-Carrier Manager Interface.

The Shelf Manager does not provide E-Keying for the MicroTCA Carrier or for implementation-defined inter-MicroTCA Carrier connections. The Carrier Manager performs the E - Keying functions within a MicroTCA Carrier.

A MicroTCA FRU can be activated by the Carrier Manager without Shelf Manager involvement. When activating a FRU, the Carrier Manager commands a PM to enable Payload Power only if the MicroTCA Carrier Power Subsystem can meet the FRU's power requirements.

The MicroTCA Shelf Manager does not participate in power budgeting or E-Keying. The Carrier Manager handles those responsibilities.

The Carrier Manager performs power budgeting in the M3 state for a given FRU, in contrast to AMC.0 where the Carrier-level power budgeting is done in the M1 state.

After the Carrier Manager has established the Shelf-Carrier Manager Interface with the Shelf Manager, the Shelf Manager discovers the already activated MicroTCA FRUs and synchronizes its internally tracked FRU states with the MicroTCA Carrier FRU states.

The MicroTCA Shelf FRU Information is specified as a logical entity and can be located in the Carrier FRU Information device. In implementations where the Shelf FRU Information is located with the Carrier FRU Information, the Shelf Manager reads the Shelf FRU Information from the Carrier Manager using FRU Device IDs 1 and 2. In a Shelf with multiple MicroTCA Carriers, the Shelf FRU Information is located and validated as part of the Shelf Manager election process. Other Shelf FRU Information location implementations are not precluded by this specification.

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Power

The Power Subsystem is made up of the following elements:

- power source, which provides energy to the system
- power entry elements, which provide an interface between the power source and the rest of the Power Subsystem and implement functions such as power line conditioning
- power conversion elements, which take the source energy and provide the required system voltages in a controlled manner
- distribution elements, including Connectors, Backplane, and power-carrying conductors
- monitoring and telemetry elements
- limiting elements, which protect the loads and distribution system in case of faults
- control elements, managed by the Carrier Manager on a MicroTCA Carrier Hub (MCH)

The Power Subsystem incorporates the following functionality:

- provides energy conversion from input sources to 12 V for Payload Power and 3.3 V for Management Power
- provides independent Payload Power distribution branches for up to twelve AdvancedMCs, up to two MCHs and up to two Cooling Units (note that JSM power is not independent, but typically fed from one of the MCH branches)
- provides independent Management Power distribution branches for up to twelve AdvancedMCs, up to two MCHs, up to two Carrier FRU Information Devices and up to two Cooling Units
- provides an interface to the Carrier Manager to permit monitoring of the Power Module status and operation of the distribution control elements internal to the Power Module

The four most common sources of AC and DC energy are: –48 V DC, –60 V DC, +24 V DC, and Universal AC in the range of 100–240 V AC. While other sources are possible, they are not currently covered by the MicroTCA specification.

The Power Subsystem and the Carrier Manager communicate via IPMB-0. This allows a Carrier Manager to monitor and control the Power Subsystem.

It is expected that many MicroTCA applications will require redundancy in the Power Subsystem, while other applications will not. The intent of the MicroTCA specification is not to require redundancy, but to facilitate implementation when required.

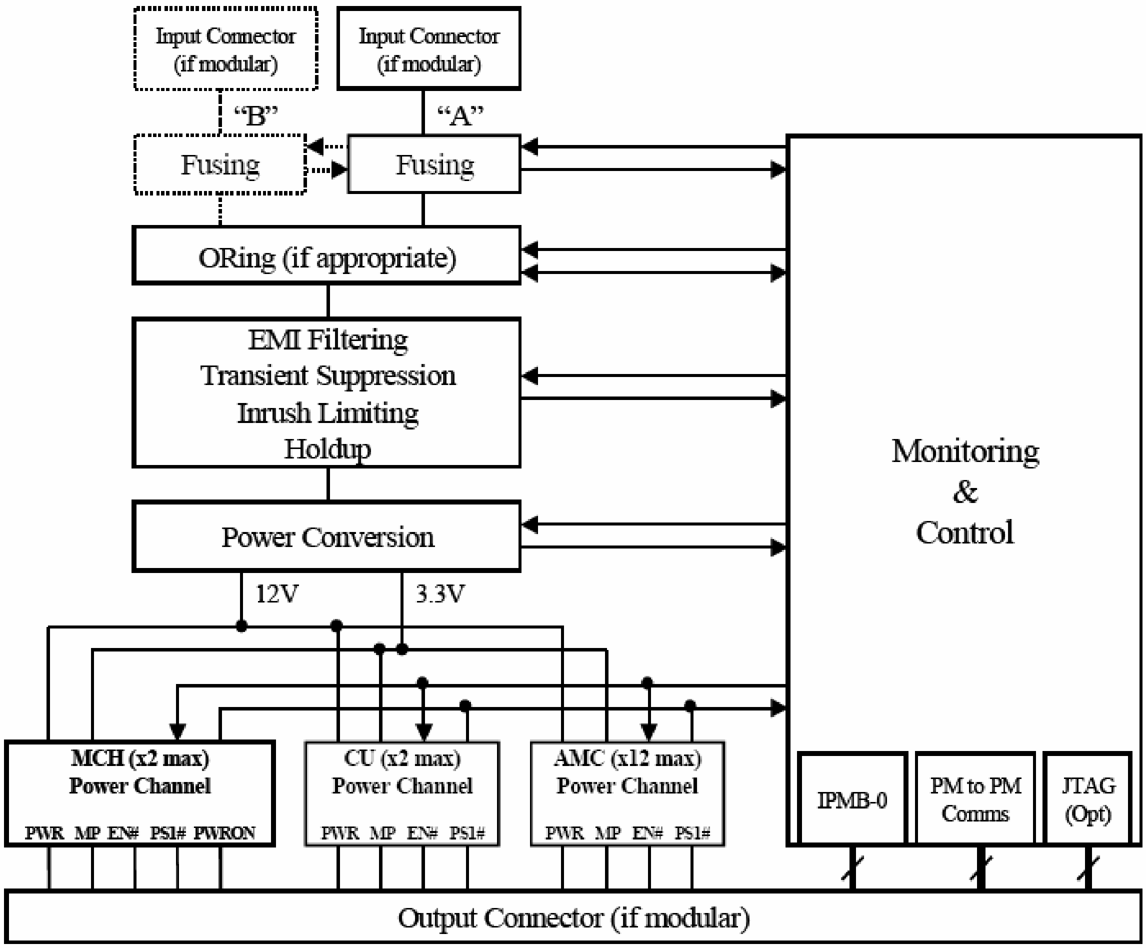
Because MicroTCA is applicable to a broad range of applications and power levels, it is not the intent of this section to cover all possible implementations and partitioning. Instead, it concentrates on the functionality of the various elements and required interfaces.

Detailed discussion of one recommended Power Module implementation is included in the full specification. This covers the case where an “all-in-one” Power Module is intended for inclusion within the same Subrack as AdvancedMCs and MCH Modules. In addition, up to four of these Modules can be included to implement 3+1 redundancy, for example.

Power architecture

The basic functionality of a DC-powered subsystem is illustrated in Figure 18 below:

Figure 18 Power Subsystem functionality



The Power Subsystem takes energy from one or more input sources and then performs the following functions:

- conditions the power to protect against disturbances associated with the sources of energy
- combines the feeds, if necessary and appropriate
- converts and regulates the power to voltage levels required by the loads in a MicroTCA system
- feeds the power radially to the loads so that each load can be managed independently of the others

This is all performed under the supervision of a control and monitoring subsystem.

The functionality of an AC-powered subsystem will be similar in many ways. However, one major difference is in the handling of multiple AC feeds. Most systems will probably constrain a Power Module to operation from a single AC feed, so that multiple AC feeds will require multiple power modules. It is possible to implement multiple feeds on a power module. This requires either relay switching, which is often unacceptable, or the introduction of parallel power conversion circuitry prior to the stage that provides electrical isolation.

Partitioning of the Power Subsystem

There are many methods by which such a system may be implemented, partitioned, and/or modularized.

Figure 18 could represent a Module that comprises the entire Power Subsystem, or it could be one of up to four such Modules used in a redundant configuration. The Module receives its energy from up to two DC feeds and provides power independently to up to twelve AdvancedMCs, up to two MCHs, and up to two Cooling Units. This Module can be used in applications where payload and Management Power are provided with N+1 redundancy, where N=1, 2, or 3. In addition, this Module can be used to provide non-redundant payload and Management Power (i.e. the special case of N+0).

Power sources

MicroTCA systems may be powered from a variety of sources. Development of the specification and the architectures herein, have given consideration to Power Modules with the following sources of power (all voltages levels listed are nominal):

- –48 V battery plants
- –60 V battery plants
- +24 V battery plants
- 100 V AC mains power
- 120 V AC mains power
- 230 V AC mains power

To support these differing power sources and to support modular implementations, a number of different Power Module types are anticipated:

- Negative DC voltage Modules—this type accepts either –48 VDC or –60 VDC feeds to power the system
- Positive DC voltage Modules—this type accepts +24 VDC to power the system
- AC-powered Modules—this type of Module accepts 100 V, 120 V or 230 V AC mains to power the system

And within these Module types, subtypes may emerge, depending on the level of optimization required. For example, further optimization of the negative DC voltage Module may result from limiting its input to only –48 VDC battery plants.

System power-up

Power management of the MicroTCA Carrier has two distinct stages.

- The Early Power stage starts from the moment a source of energy is made available to the PM and ends when the Carrier Manager assumes control of power management tasks.
- The Normal Power stage starts once a Carrier Manager is elected by one or more powered and initialized MCHs.

Autonomous mode may also be used during system maintenance, for example, where all MCHs are removed from a system but the remaining load modules must continue to operate undisturbed.

Thermal

Within the MicroTCA specification this section provides information to designers, manufacturers, integrators, and users of MicroTCA to facilitate interoperability among the many components that must work together for a successful thermal solution. MicroTCA may implement a Shelf, Cube, or Pico solution.

The thermal requirement for AdvancedMC Modules is defined in the PICMG® AMC.0 Advanced Mezzanine Card Base Specification, Section 5 "Thermal". However, MicroTCA solutions act as an alternative Carrier (as defined in AMC.0) for AdvancedMC Modules, yet may be configured into many application-specific design solutions. Their compliance with thermal requirements must meet or exceed that which is defined for AMC.0.

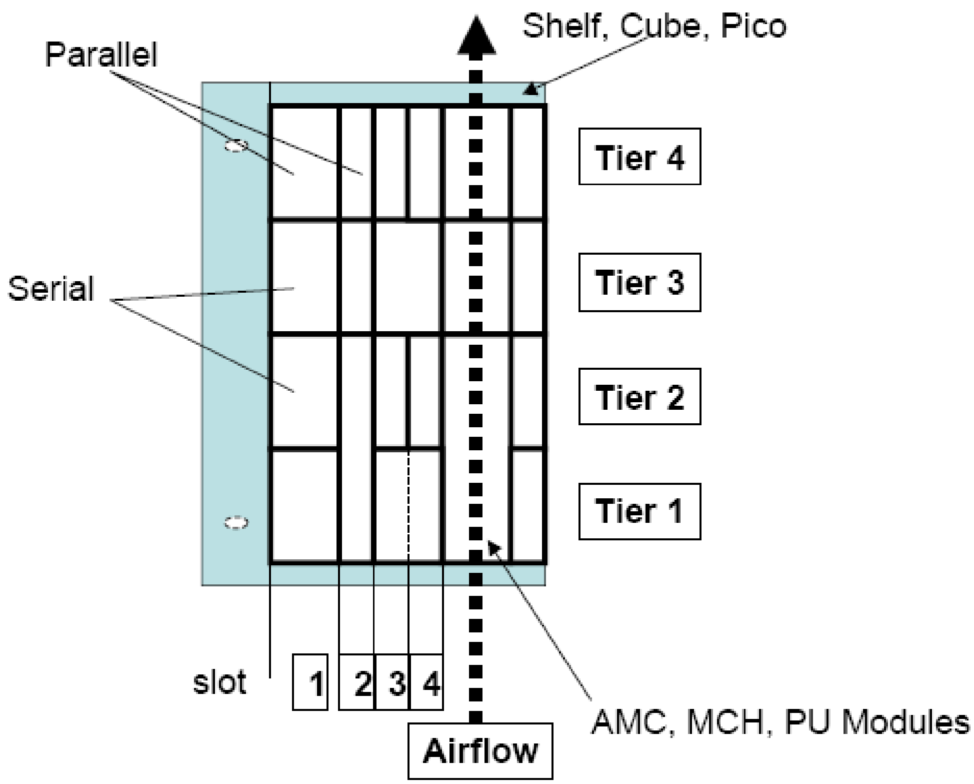
This specification provides simple MicroTCA thermal guidelines. However, the system integrator will have the ultimate responsibility to ensure that all components meet the thermal requirements for MicroTCA.

Note: The thermal guidelines in this specification only apply to (forced) air cooling. Since power consumption can be more or less than power dissipation, depending upon if energy is received or sent out of face plate-connected cables, this section defines power dissipation, not power consumption.

Subrack Slot

The Subrack is divided into Slots. Each Slot is a receptacle for an AMC.0 Module. Over its (19 in.) width, a typical MicroTCA 19-in. based Subrack/Shelf can contain up to 29 Half-Height Slots or 14 Full-Height Slots in a single or multiple Tier. A Cube or Pico system can contain one or more Slots.

Figure 19 Subrack Slot in the MicroTCA grid



Air distribution in a Slot

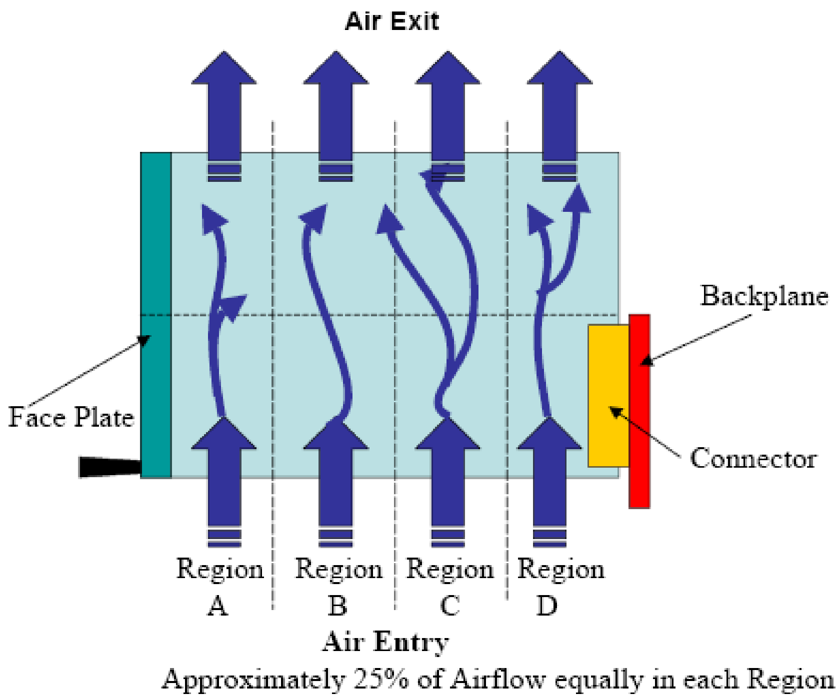
In any Slot within the Subrack, the recommended inlet air distribution is shown in Figure 20.

The Shelf/Cube/Pico should distribute the incoming air equally (25% ±5%), from front-to-back at the bottom of the Slot.

To permit AdvancedMC, MCH, and PM designers to direct air to critical components located anywhere on the Board, the Shelf/Cube/Pico should allow the exhaust air to have the ability to exit from the top of the Slot uniformly through any of the four zones.

Additionally, the Shelf/Cube/Pico should allow the exhaust air to have the ability to exit from the top of the Slot for any distribution of the four regions. The ability to facilitate interoperability is maximized by providing a Slot with equal distribution of incoming air, permitting the flexibility to Channel the air at the Board level and allowing air to exit the Slot with a variety of distribution possibilities.

Figure 20 Inlet airflow distribution for a single Slot



Air inlet and exhaust

The airflow path through a MicroTCA System may vary:

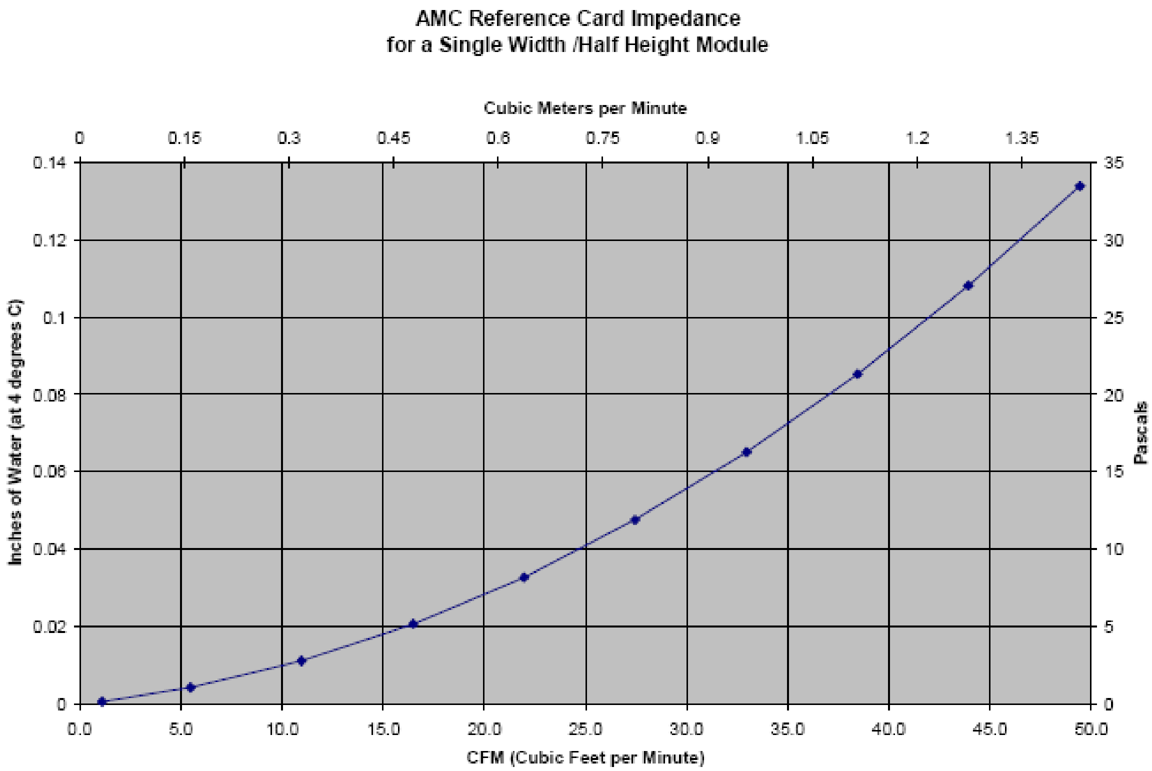
- Front air entry – Rear air exit (preferred for a self-contained Shelf or Cube, installed outside the 300 mm cabinet environment)
- Bottom air entry – Top air exit
- Front air entry – Side/rear air exit
- Side-to-side (right-to-left) is permissible, if acceptable by the end user

It is the system integrator's responsibility to ensure that the airflow through the MicroTCA system and all installed AdvancedMCs, MicroTCA Carrier Hubs, and Power Modules ensures the required operational temperatures of the installed components in the defined environment.

Slot cooling capability

The airflow through the MicroTCA Slot has to work against the resistance incurred by the formations of the AMC.0 Modules. See AMC.0 Section 5.3 Figure 5-2.

Figure 21 Airflow impedance



The Slot cooling capability shall be provided by the system manufacturer, in terms of the Slot impedance curve and the Slot fan flow curve for each Slot.

To ensure consistent cooling performance across all Slots within the system, Slots not populated with Modules shall incorporate an air blocking device that increases the airflow impedance of that Slot. Airflow management filler panels installed in empty Slots satisfy these requirements.

Module cooling requirements

Module cooling requirements shall be specified by the Module manufacturer, in terms of the volumetric airflow rate required to meet maximum allowed temperature rise across the Module at the operating condition of maximum power dissipation and maximum inlet operating temperature.

Interconnect

The AdvancedMC Connector provides up to 21 ports of fabric interconnect connectivity. The MCH Connector provides up to 84 ports of fabric interconnect connectivity to up to twelve AdvancedMCs (normally seven fabrics for twelve AdvancedMCs). This gives the flexibility to support a variety of fabric topologies. The following sections describe two fabric topologies that are expected to cover many of the application requirements and can be supported with MicroTCA applications.

Topology models

There are fundamentally two MicroTCA topology models that can be adopted, these being the centralized MCH switch model and the Module-to-Module direct connectivity model. A mix of these topologies could exist within a given system. For example, a typical system could provide 1000BASE-BX Ethernet and/or PCI-Express as a centralized switched fabric. A storage topology could be routed as either direct Module-to-Module interconnects, or as a switched fabric.

Centralized MCH switch model

The general-purpose MicroTCA system could implement a centralized fabric-specific switch on the MCH. This allows point-to-point connectivity to be achieved from each Module to each and every other Module.

Module-to-Module direct connectivity model

It is allowed and supported to establish direct connection between a Port of one AdvancedMC Slot and a Port of another AdvancedMC Slot. This can help in developing optimized solutions.

If the interconnect between two AdvancedMC Modules is based on LVDS, then it is required to make a cross-over on the Backplane between the transmit and receive pairs for each connected Port. This ensures that the transmit connections of one AdvancedMC are connected to the receive connections of the other AdvancedMC.

JTAG interface

Testing is an important issue in MicroTCA systems. The JTAG port supported in the AMC.0 specification provides a means to test the AdvancedMC Modules. MicroTCA extends this capability to test the entire MicroTCA system, including explicit definition for Power Modules and MCHs, and implicit allowance to extend testing capability to Cooling Units and OEM Modules which are outside the scope of the specification. This testing can occur at the subsystem level, at factory system test, and during field diagnostic operations. The system-wide test infrastructure is also valuable to update various non-volatile memories in a MicroTCA system, including those that hold microprocessor, DSP or NPU firmware, or FPGA configuration data.

The JTAG support is provided via the Extended Side of the AdvancedMC Connector. The separate JTAG interfaces to the AdvancedMCs will allow the JTAG chain to be kept intact in the absence of an AdvancedMC in a Slot. The JTAG sub-system will provide independent access to each AdvancedMC Module, so Module-specific JTAG tests can be applied independently of the population configuration of the other Slots.

The JTAG Star and Multi-drop architectures ideally provide this independent access, but are not directly possible for MicroTCA, given the existing pin-out and resources available in the AdvancedMC, as well as the physical size of the MicroTCA Carrier Hub (MCH) Connector.

To support the user with a flexible interface, a JTAG Switch Module (JSM) is suggested to provide JTAG system-level support from the MCH Test Access Port (TAP) interface or an external tester interface. This interface provides a Star JTAG architecture, allowing the MCH or external tester to connect to each Module individually to perform test and update operations, while the MCH implements a single JTAG TAP interface at its edge. The MCH also is able to perform test and update operations on the redundant MCH.

Connectors

In the MicroTCA Specification this section specifies the family of Connectors for MicroTCA systems which mount on the Backplane and the Modules. It specifies the AdvancedMC Backplane Connectors, the MicroTCA Carrier Hub Connectors, the power input/output Connectors, and any Auxiliary Connectors. The design of the interconnect systems **shall** be RoHS compliant.

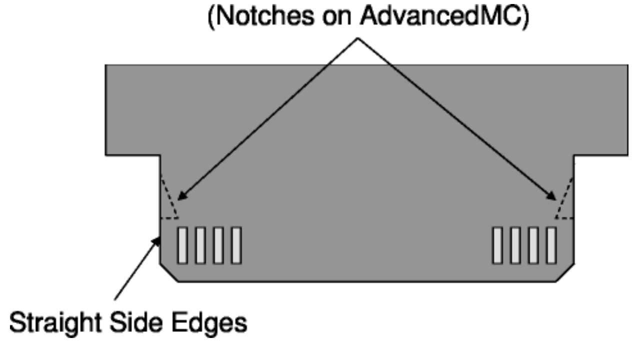
AdvancedMC Backplane Connectors

The AdvancedMC Backplane Connector described in this section is designed to accept the AdvancedMC Modules, as specified in the AMC.0 specification.

The AdvancedMC Backplane Connector described in this section is designed to accept special version of tongue as well which does not have two side notches specified in AMC.0 specification.

AdvancedMC Backplane Connector shall support the AdvancedMC, the special tongue which has straight side edges on AdvancedMC interface as shown in Figure 22 and the MCH plug which has reduced mating forces features.

Figure 22 Straight side edges special mating interface



Connector characteristics

The AdvancedMC Backplane Connector shall be able to perform at a 100 °C temperature condition, which includes a 30 °C temperature rise by current distribution from 70 °C maximum ambient temperature. Additionally the connector shall conform to the following current-carry guidelines:

- The current-carrying capability of each general-purpose conductor inside the AdvancedMC Backplane Connector shall be 0.5 A minimum, which includes a 20% margin on rated current in accordance with IEC 60512-5-2.
- The current-carrying capability of each Ground conductor inside the AdvancedMC Backplane Connector shall be 0.375 A minimum, which includes a 20% margin on rated current in accordance with IEC 60512-5-2.
- The current-carrying capability of each power conductor inside the AdvancedMC Backplane Connector shall be 1.9 A minimum, which includes a 20% margin on rated current in accordance with IEC 60512-5-2.
- The current-carrying capability of each differential pairs conductor inside the AdvancedMC Backplane Connector shall be 0.125A minimum, which includes a 20% margin on rated current in accordance with IEC 60512-5-2.

The connector design shall ensure that no contact exceeds its current rating due to current balancing caused by variations in contact resistance.

The connector high speed signal characteristic requirements on the AdvancedMC Backplane Connector may have future refinements which will be based on the analysis of the allowable connector loss budget for 12.5 Gbps single lane signal transmission on the entire channel.

The AdvancedMC Backplane Connector **will be designed to** withstand 200 mating cycles without damage that would impair normal operation.

Engaging and separating forces

Table 3 Engaging and separating forces

Mating sides	Force
Maximum engaging force	100 N
Maximum separating force	65 N
Maximum bottoming force	200 N

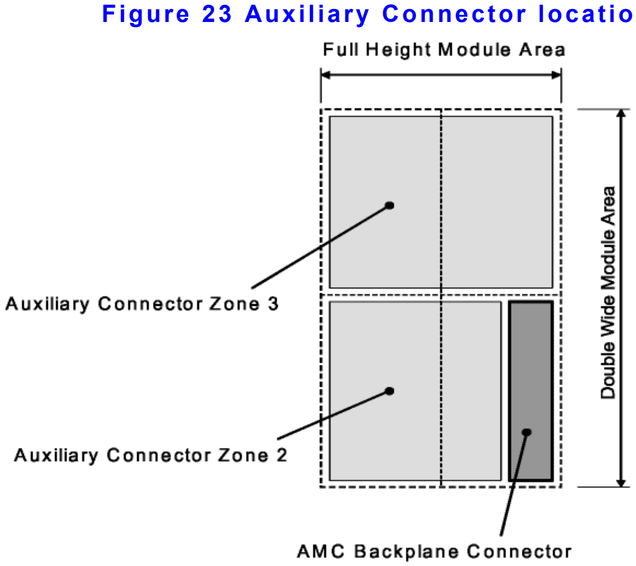
Under the conditions stated above, the force needed to engage and disengage an AdvancedMC Module PCB in the AdvancedMC Backplane Connector shall not exceed the values given in Table 3. Additionally the connector will withstand to 200 N at 1 minute duration of Module insertion-bottoming force, without damage that would impair normal operation.

AdvancedMC Auxiliary Connector

To add connectivity to AdvancedMC Modules, the AdvancedMC Module and the Backplane may use additional Auxiliary Connectors in the location shown Figure 23 in combination with the AdvancedMC Backplane Connector .

Additional design considerations are required when the Auxiliary Connector is used with an AdvancedMC Backplane Connector. The tolerance stack up on these Connectors create misalignment which may cause of damaging the Connector, short-circuit, and contact-off problems.

Figure 23 Auxiliary Connector location



Regulatory

It is highly recommended that the equipment specified and developed based on the MicroTCA specification meet the performance requirements set forth in the regulatory and industry standards for Telecommunications/Information Technology Equipment, based on the targeted market for the equipment.

It is recommended that MicroTCA equipment meet regulatory requirements and industry standard requirements to enhance compatibility and to ease system integration. In the context of this section, the term Equipment refers to a complete functional product. This includes any cooling systems, power supplies, filters, Shelf hardware, and representative circuit pack fills required for system operation.

Details on the applicable standards are provided in the full specification. This section simply highlights the topics that designers should be considering.

All equipment shall meet the most recently adopted versions of the following regulatory compliance requirements. In general, these requirements are harmonized standards with similar requirements applied worldwide; however, countries or regions do declare deviations to these standards to account for conditions not included in the base standard.

Evaluations therefore should be completed for each market where the product will be deployed. A regulatory compliance specialist should determine the appropriate requirements for the regions where the product will be marketed, including:

- Safety
- Electromagnetic compatibility
- Ecology standards