

SOMs (Systems-On-Modules) are changing the Embedded Landscape

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SOM

SOM (System On Module)

- Generic term
- Comparable to silicon vendors SOC (System on Chip)

SOM is not the name of any one embedded computer specification ... it is a generic term.

SOM integrates all computer functionality into a single module, including ...

- high performance processor(s)
- low power-consumption
- small form factor

SOM aka COM

- COM (Computer On Module)

Every embedded computer concept includes the SOM idea

- SOM concept accommodates a wide variety of footprints
- SOM concept accommodates a wide variety of processor types and electrical interfaces

Overview of SOMs (Systems-On-Modules)

Practical overview of the myriad of proprietary and standard SOMs (Systems-On-Modules) on the market today.

Compare specifications of some the most prominent SOMs.

Review the similarities and differences between today's SOMs.

Objective: Enable you to decide which SOM(s) to consider for your next project.

Many Specifications / Few Standards

Many proprietary specifications.

Many open specifications.

Not many ANSI (VITA) standard SOMs.

Not many IEEE standard SOMs.

For most engineers the functionality and the company behind the specification is more important than the state of standardization.

For example:

PCI and CompactPCI are NOT standards.

SOM Specifications

*PPMC, PIM, PTMC,
PMCx, XMC, AMC*

*Curtiss-Wright, Motorola, SBS, Artesyn, CES, Pentek, Interface Concept, NAT, Technobox,
Transtech...*

*PC/104, PCI-104,
PC/104-Plus*

*Kontron, SBS, Microsys, Arcom, Diamond Systems, Adlink, Arbor, Lippert, Advantech, MPL,
Digital Logic, Hilscher, Erim, Eurotech, Ampro*

EBX

Kontron, MPL, Motorola, Ampro, I-Base, Aurora, Digital Logic

DIMM-PC

Kontron (Jumpotec-Adastra), Diamond Point, Gesytec, Embedded Solutions

ETX

Kontron, Advantech, Lippert, I-Base, Arbor, Blue Chip Technology

COM Express

Kontron (ETXexpress), RadiSys, Trenton, SBS...

DIL/NetPC

SSV

E2Brain

Kontron

Embedded DIMM

RBW Elektronik GmbH

ESM

MEN Micro, Inc.

HICO.nect

Hitex

Max-PC

Sorcus

Miriac

MicroSys

PD series

PFU (Fujitsu)

SCM

Ultimodule

smartModule

Digital Logic

SOM-144

Advantech, BCM

STX

IBSmm, Delta Components

Theseus

Exor

UTX

TQ Components

X-Board

Kontron

XTX

Congatec, Advantech

PrPMC ⁽¹⁾

PrPMC: Processor PMC

VITA standard:

ANSI/VITA 32-2003

Supported by several well-known companies with high-end embedded solutions

Mechanics

- ◆ 74x149mm
- ◆ PrPMC mechanics is tailored to 6U form factor
- ◆ SBC and PrPMC together needing 1-2 slots in the system
- ◆ Not stackable



Suitable for all common processor platforms

On-board functions

- ◆ Memory on board (also can use SO-DIMM, CompactFlash)
- ◆ Typically Ethernet, other serial lines on board
- ◆ Up to 66MHz PCI
- ◆ Front connectors available

No stand-alone capability

No complete system slot functionality

Host and slave functionality (monarch and non-monarch)

Harsh environments

- ◆ In general yes - depending on the supplier

Long-term availability

- ◆ In general yes - depending on the supplier

PrPMC does not compete against the other - more low-cost - SOM solutions

PrPMC is a typical extension for cPCI and VME SBCs

Other PMC Derivates

PIM: PMC Interface Module

- ◆ Uses rear I/O and does not utilize a front bezel

PMCx: PCI-X on PMC

- ◆ Uses the same pin out as the PMC module but increases the maximum component height

PTMC: PCI Telecom Mezzanine Card

- ◆ Based on the four connector standard PCI Mezzanine Card (PMC)
- ◆ Provides all of the traditional PMC 32-bit PCI signals on the Pn1 and Pn2 connectors
- ◆ Supports specialized telecom interfaces on Pn3 and Pn4
- ◆ Pin locations on Pn3/Jn3 and Pn4/Jn4 for signals of the RMII, Ethernet PHY Management Interface, UTOPIA Level 1, UTOPIA Level 2, POS-PHY Level 2, and ECTF H.110 interfaces

AMC and PrAMC – Advanced Mezzanine Card

Based on the AdvancedTCA [ATCA] carrier cards

AMC/PrAMC is not based on the Common Mezzanine Card [CMC]

AMC/PrAMC is not compatible with CompactPCI or VME standards

Dimensions

- ◆ 72.9mm x 183.5mm



PC/104 ⁽¹⁾

*PC/104: Embedded PC based on
104-pin DIN connector*

*A “de facto” standard (specification)
maintained by the
PC/104 Embedded Consortium
<http://www.pc104.org>*

*Supported by the major international
players in the industrial embedded
market place.*

Mechanics

- ◆ 3.6“ x 3.8“ (90x96mm)
- ◆ Difficult to mount on a 3U Eurocard
- ◆ Carrier card with PC/104 takes 2 slots in a VME/CPCI system
- ◆ Self-stacking



PC/104 ⁽²⁾

Used mainly with x86 processors

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE...
- ◆ 8-bit and 16-bit ISA bus
- ◆ Front connectors available

Stand-alone capability

System slot function

Harsh environments

- ◆ Depending on the supplier
- ◆ Stackability limits shock and vibration demands

Long-term availability

- ◆ Depending on the supplier, but not usual (Advantech claims to give up to 10 years)

PC/104 is the most successful embedded PC concept

PC/104's ISA bus is now obsolete

PC/104-Plus and PCI-104 not well supported ... yet.

PC/104-Plus and PCI-104

PC/104-Plus :

PC/104 plus PCI bus

- ◆ 120-pin connector instead of 104 pins

PCI-104: PCI bus only

- ◆ No ISA bus

A new specification

Supported by only a few manufacturers

Not many products on the market

Features similar to PC/104



EBX (1)

EBX:

Embedded Board, eXpandable

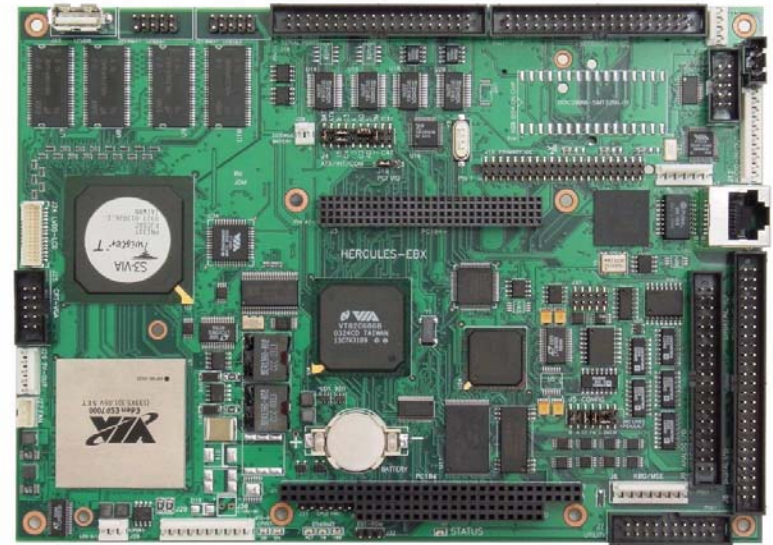
*Open specification introduced by
Motorola and Ampro in 1997*

*Widely supported by large
international players*

Mechanics

- ◆ 5.75" x 8" (146 x 203mm)
- ◆ Stackable PC/104-Plus

*Usable with PowerPC and x86
processors*



On-board functions

- ◆ All kinds of memory on board are possible
- ◆ All kinds of PC I/O on board are possible
- ◆ PCI 33MHz/32-bit signaling
- ◆ No front connectors on board
- ◆ Complete PC functionality on board
- ◆ Optional PC card slot

Stand-alone capability

System slot function

Harsh environments

- ◆ No priority

Long-term availability

- ◆ No priority

Aimed to compete against PC/104(-Plus) and standard motherboard form factors

Claims to include benefits of PC/104 and PCMCIA in a better, more complete solution

EBX is not a CPU mezzanine, but a classical all-in-one SBC

EBX does not compete against the newer CPU mezzanine concepts because it lacks flexibility

DIMM-PC ⁽¹⁾

DIMM-PC is a PC which uses the connector and PCB sizing of SO-DIMM

Open standard introduced by Adastra - bought by JumpTech - bought by Kontron

Doesn't seem to be heavily supported by other suppliers

Mechanics

- ◆ 68 x 40 x 6mm
- ◆ Fits on Eurocard
- ◆ Not stackable



DIMM-PC (2)

*Usable with x86 and Risc
(especially XScale) processors*

On-board functions

- ◆ RAM memory on board, but no SO-DIMM
- ◆ Very limited serial and parallel lines, IDE, FDD, flash disk, BIOS
- ◆ DIMM-144 connector with ISA bus only
- ◆ No front connectors

No stand-alone capability

No system slot function

Harsh environments

- ◆ 0...+60°C
- ◆ Connector not suitable for shock and vibration

Long-term availability

- ◆ No priority - looking at the selection of x86 processors

*Claims to be a complete,
miniature PC*

*Competition to ETX, X-Board etc.,
but on the low-end processor
performance*

*ETX and X-Board are also from
Kontron.*

ETX ⁽¹⁾

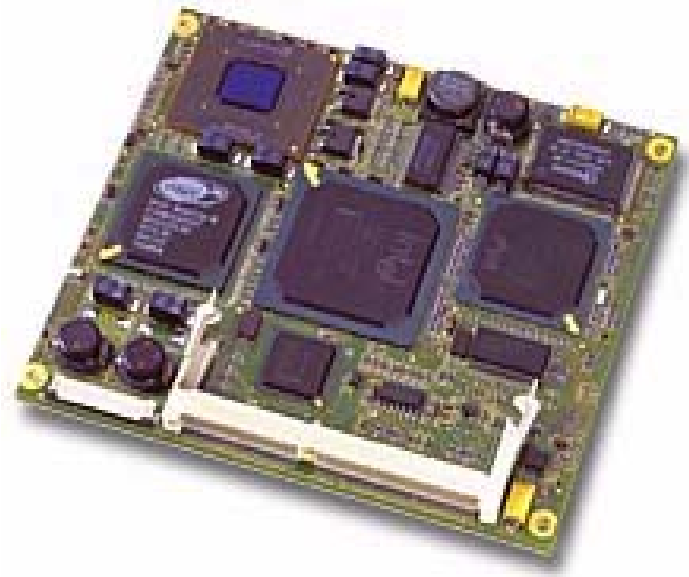
*ETX = Embedded Technology
eXtended*

*Open standard introduced by
JumpTech and Advantech two
years ago*

*Well supported by a wide range of
international players in the
industrial embedded market place*

Mechanics

- ◆ 100mm square, 12mm thick
- ◆ Alternatively 95 x 114mm
- ◆ Does not fit on Eurocard
- ◆ Not stackable



Usable with x86 processors only

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE...
- ◆ 1x 99-pin connector for PCI, USB, audio
- ◆ 1x 99-pin connector for ISA
- ◆ 2 more 99-pin connectors for on-board I/O
- ◆ No front connectors

No stand-alone capability

System slot function

Harsh environments

- ◆ Spec. defines heat sink 2mm thick
- ◆ Depending on the supplier

Long-term availability

- ◆ Depending on the supplier

Competition

- ◆ STX, UTX, X-Board, smartModule
- ◆ ESM

COM Express (1)

COM Express is the new PICMG 1.3 specification for Computer-On-Module (COM)

Based on several new serial differential signaling technologies (i.e. PCI Express, SATA, SDVO...)

Expected to be supported by many of the ETX manufacturers

Mechanics

- ◆ 95x125mm and 110x155mm
- ◆ 2 rows of 220-pin high-speed connectors

Suitable for Pentium M processors with 915GM Express chipset.



COM Express (2)

On-board functions

- ◆ Up to 32 PCI-E lanes 8x1, 3x8, 1x16...
- ◆ Optional 32-bit PCI, PCI-X and LPC
- ◆ Serial ATA (max.4)
Gigabit Ethernet (max.3)
USB (max.8)
SDVO (max.2)
LVDS (max.2)
- ◆ On-board memory

No stand-alone capability – no front connectors

Not compatible with ETX....



DIL/NetPC ⁽¹⁾

*DIL/NetPC is a socket-based
32-bit embedded networking PC*

*Proprietary specification from
SSV Embedded Systems*

Other suppliers not known

Mechanics

- ◆ 82x28mm (DIL-64) or
82x33/66mm (QIL-128) or
45x45mm (PGA-169)
- ◆ Could fit on 6U and 3U
Eurocard
- ◆ One slot in the system
- ◆ Not stackable



Suitable for all low-end 32-bit processor platforms

On-board functions

- ◆ Soldered memory; no slots for CompactFlash, SO-DIMM
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE, fieldbuses...
- ◆ Extension bus with interrupts and chip selects
- ◆ No front connectors

No stand-alone capability

System slot function

Harsh environments

- ◆ In general yes

Long-term availability

- ◆ In general yes

Competition

- ◆ Low-end embedded SOMs
- ◆ For example DIMM-PC, ETX, PC/104, smartModule, phyCORE

E²Brain ⁽¹⁾

E²Brain

“A highly application oriented new platform for advanced computer modules.”

Proprietary specification from Kontron

Not supported by any other supplier ... yet.

Mechanics

- ◆ 125 x 75mm
- ◆ Would fit on 6U and 3U Eurocard
- ◆ One slot in the system
- ◆ Not stackable



Suitable for all common processor platforms

On-board functions

- ◆ Soldered memory, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE, fieldbuses...
- ◆ 33MHz PCI bus and LPC bus (Low Pin Count - replacing ISA)
- ◆ No front connectors

No stand-alone capability

System slot function

Concept with flexible I/O via FPGAs

Harsh environments

- ◆ In general yes

Long-term availability

- ◆ In general yes

Competition

- ◆ All other embedded CPU mezzanines on the market
- ◆ X-Board from Jumptech versus E²Brain from Kontron?

Embedded DIMM

Proprietary specification from
RBW Elektronik GmbH

Square SO-DIMM (67.6mm X 67.6mm)

Complete, processor plus ...

- ◆ Memory - SDRAM, Flash, SRAM, EEPROM
- ◆ I/O - COM, USB, CODEC, CAN, Ethernet
- ◆ Altera FPGA

Available processors:

- ◆ Intel XScale
- ◆ Intel StrongARM
- ◆ Freescale MPC5200
- ◆ Altera NIOS



ESM ⁽¹⁾

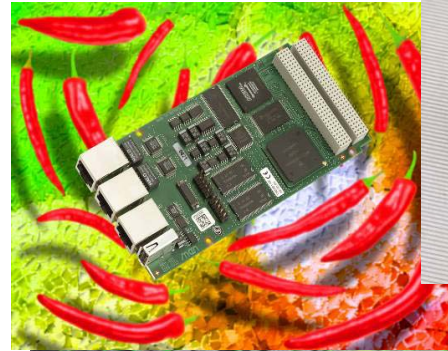
ESM: Embedded System Module

*Proprietary specification,
introduced by MEN Mikro
Elektronik GmbH in 2003*

Specification is open

Mechanics

- ◆ 71x149mm (close to PPMC)
- ◆ Fits with 6U and 3U Eurocards
- ◆ Fits with any size of carrier for deeply embedded systems
- ◆ CPU and ESM take one system slot
- ◆ Stackable with PCI-104



Suitable for all common processor platforms

On-board functions

- ◆ Soldered memory, SO-DIMM and CompactFlash on board
- ◆ Additional serial lines on board like Ethernet, UARTs, IDE, fieldbuses
- ◆ 64-bit PCI up to PCI-X with two 120-pin connectors
- ◆ Front connectors for serial I/O on board

The only SOM with flexible FPGA configuration possibility besides E²Brain and HICO.nect

Harsh environments

- ◆ For all standard ESM - 40...+85°C, shock, vibration, humidity specs., designed for conformal coating

Long-term availability

- ◆ Minimum 5 years

Competes with all embedded CPU mezzanines on the market.

HICO.nect ⁽¹⁾

*HICO.nect: Hi Speed Connection
(faster than PC/104...)*

*Company specification, recently
introduced by Hitex*

*Not yet supported by any other
supplier*

Mechanics

- ◆ 90 x 72mm size
- ◆ Would fit on 6U and 3U Eurocard
- ◆ One slot in the system
- ◆ Stackable with PC/104



*Optimized for RISC architectures
(especially Hitachi processors)*

On-board functions

- ◆ Soldered memory, SRAM, CompactFlash possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE, fieldbuses...
- ◆ Private bus with three connectors to base board (no PCI!)
- ◆ No front connectors

*Concept with flexible I/O via
FPGAs*

No stand-alone capability

System slot function

Harsh environments

- ◆ In general yes

Long-term availability

- ◆ In general yes

Competition

- ◆ Low-end embedded CPU mezzanines like DIMM-PC, X-Board

MAX-PC

“World’s Smallest PC”

Company specification, from Sorbus

Not yet supported by any other supplier

Mechanics:

29 x 58 x 10, size of a matchbox.

Onboard RAM and Flash.

Interface for 2 PCMCIA cards



Miriac Power Module ⁽¹⁾

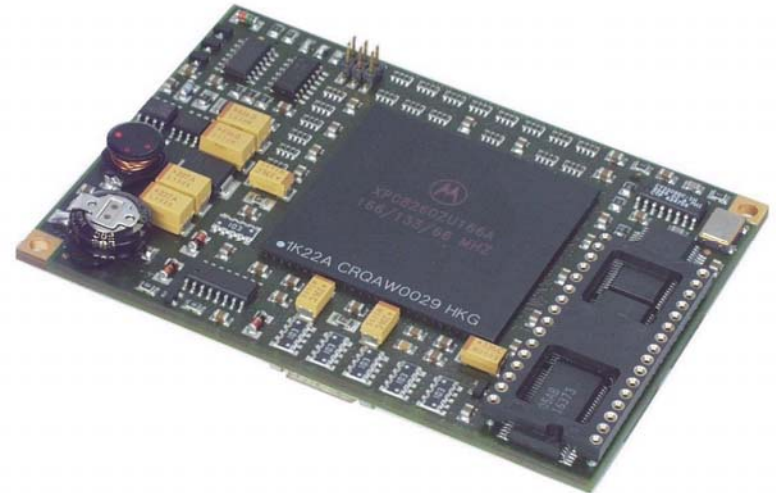
Miriac: "It's not a miracle - it's miriac."

Company specification, recently introduced by MicroSys

Not yet supported by any other supplier

Mechanics

- ◆ 60 x 90mm credit card size (also 55x55 versions)
- ◆ Would fit on 6U and 3U Eurocard
- ◆ One slot in the system
- ◆ Not stackable



Miriac Power Module ⁽²⁾

*Optimized for RISC architectures
(PowerPC, XScale)*

On-board functions

- ◆ Soldered memory, SRAM, CompactFlash possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE, fieldbuses...
- ◆ 33MHz PCI bus with two 140pin connectors to base board
- ◆ No front connectors
- ◆ No FPGA

No stand-alone capability

System slot function

Harsh environments

- ◆ In general yes

Long-term availability

- ◆ In general yes

Competition

- ◆ All other embedded CPU mezzanines on the market

PD2200/2500/2800 Series

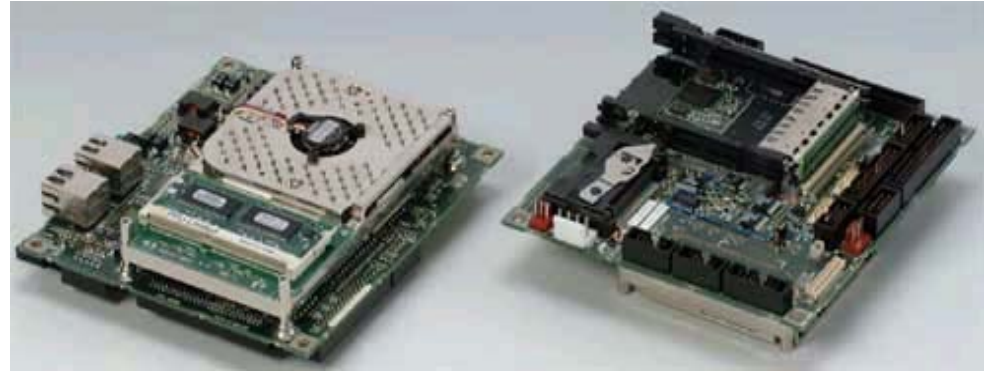
*Pentium PC motherboard
functionality on credit-card size*

*Company specification by PFU
(Fujitsu)*

Other suppliers not known

Mechanics

- ◆ 76.2x127/144.9mm,
85.6x66.3mm
- ◆ No front connectors
- ◆ Not stackable



On-board functions:

- ◆ Memory on SO-DIMM
- ◆ PCI or ISA bus
- ◆ I/O on board like Ethernet,
serial lines, floppy, IDE,...

No stand-alone capability

SCM - Smart Controller Module

Low-end 32/64-bit MIPS CPUs from NEC

Company standard by Ultimodule

Other suppliers not known

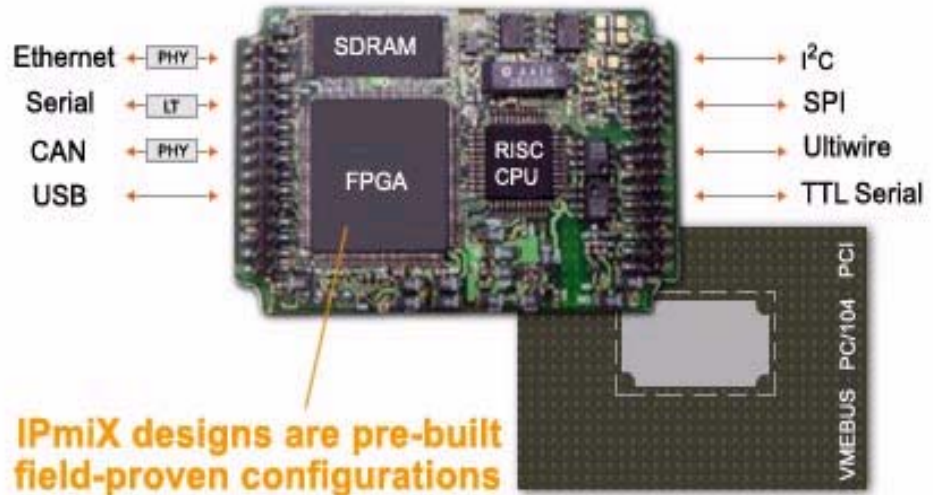
Mechanics

- ◆ 65x40mm
- ◆ No front connectors
- ◆ Not stackable

On-board functions

- ◆ No memory
- ◆ Bus ???
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE, fieldbuses...
- ◆ FPGA for user-defined I/O

No stand-alone capability



smartModule and smartCore ⁽¹⁾

smartModule:

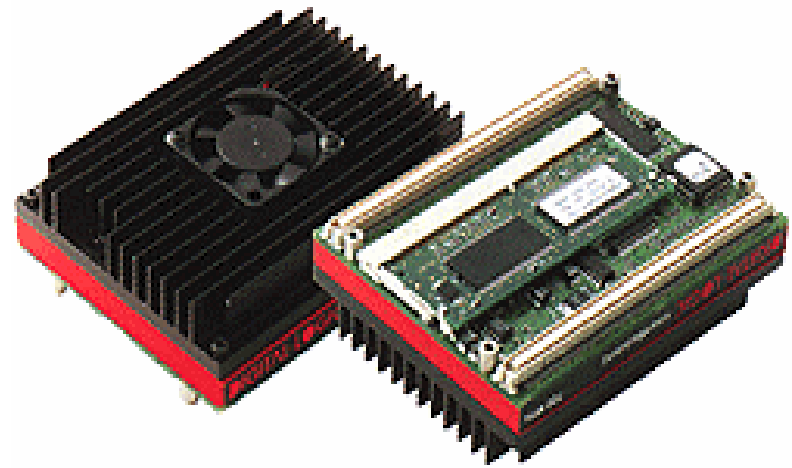
smart embedded PC solution

*Company specification introduced
by Digital Logic*

*Supported only by Digital Logic,
an important player in the
European market*

Mechanics

- ◆ smartModule 66 x 85 x 14 mm
- ◆ smartCore 51 x 68 x 14 mm
- ◆ Fits theoretically on Eurocard,
but not in height
- ◆ Not stackable



smartModule and smartCore (2)

Usable with x86 processors only

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board on smartModule
- ◆ No I/O on smartCore
- ◆ Private smartBus480 connectors with ISA and PCI
- ◆ No front connectors

No stand-alone capability

No system slot function

Harsh environments

- ◆ -40...+70°C with heat sink and fan
- ◆ Long-term availability
- ◆ No priority - looking at the selection of x86 processors

Competition for ETX and the latest STX, UTX, X-Board products

SOM-144 ⁽¹⁾

SOM-144:

System On Module, 144 pins

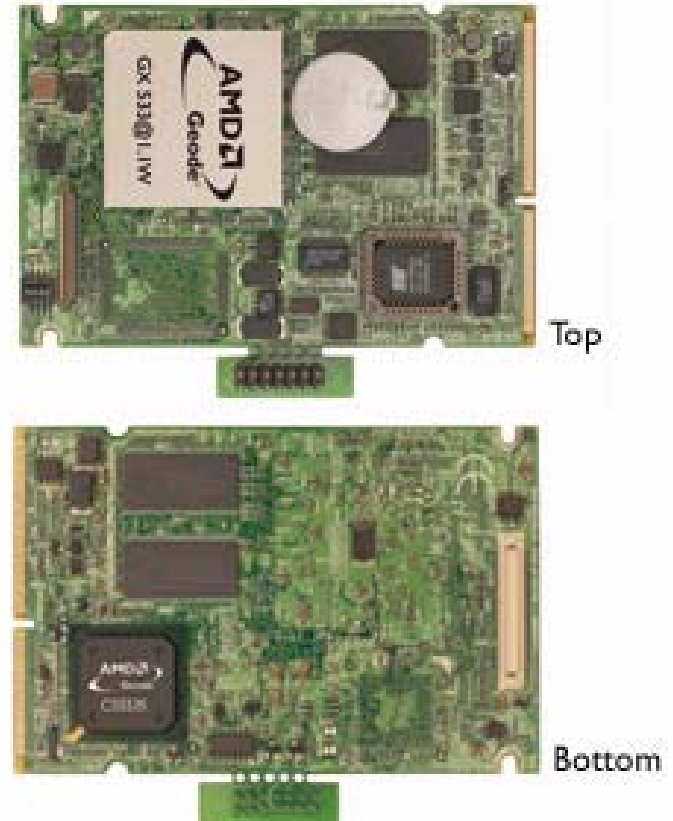
*Open specification introduced by
Advantech*

*Advantech has also introduced
ETX together with Jumptech*

Only supported by Advantech

Mechanics

- ◆ 68 x 100mm
- ◆ not stackable



SOM-144 ⁽²⁾

Usable with x86 and Risc (ARM, X-Scale) processors

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE...
- ◆ 144-pin (x86) and 200-pin (Risc) connectors with PCI bus (“Unified System Bus Interface”)
- ◆ No front connectors

No stand-alone capability

No system slot function

Harsh environments

- ◆ Theoretically yes

Long-term availability

- ◆ Theoretically yes

*Claims to be the low-power and low-cost alternative to ETX
no competition*

STX ⁽¹⁾

STX:
Smarter Technology eXtension

Open specification
www.stx.info

Supported by only a few unknown companies

Mechanics

- ◆ 90x96mm - complies with PC/104
- ◆ Mountings holes as well
- ◆ Difficult to mount on a 3U Eurocard
- ◆ Stackable with PC/104



Used with x86 processors only

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE...
- ◆ PCI and ISA I/O signaling
- ◆ No front connectors

No stand-alone capability

System slot function

Harsh environments

- ◆ Heat sink solutions for ext. temp.
- ◆ Shock and vibration in general yes

Long-term availability

- ◆ No priority - looking at the selection of x86 processors

Aimed to compete against ETX

Claims to be more industrial than ETX

Theseus

Theseus: “A comprehensive embedded automation standard”

ICU: Integrated Control Unit

*Proprietary specification (not a standard)
from EXOR International*

Mechanics: 65 x 40 mm

*Targeted for MIPS or ARM
32-processors*

Includes SDRAM and FPGA

*Designed for integration into legacy
systems.*



UTX ⁽¹⁾

UTX:

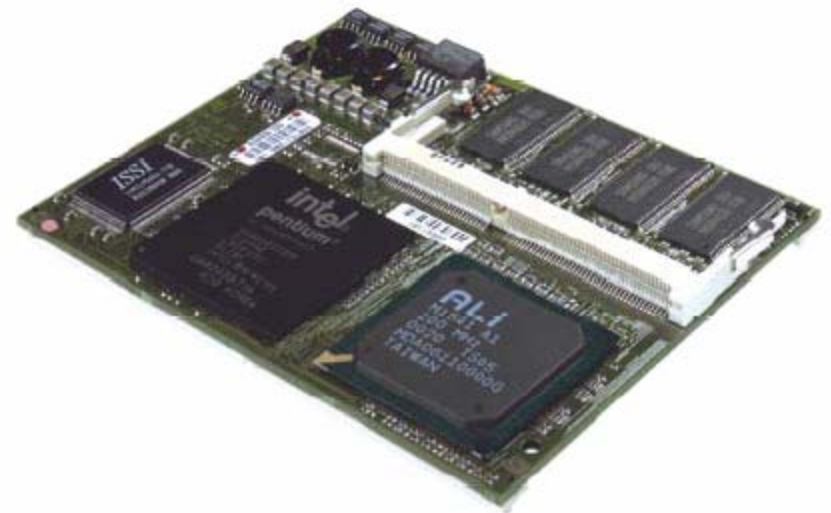
Universal Technology eXtended

*Proprietary specification from
TQ Components*

*Supported only by a few
companies*

Mechanics

- ◆ 108x88mm, smaller than ETX
- ◆ Does not fit on Eurocard
- ◆ Not stackable



Usable with x86 processors only

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash, SO-DIMM possible
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE...
- ◆ PCI 33MHz and ISA I/O signaling
- ◆ No front connectors

No stand-alone capability

System slot function

Harsh environments

- ◆ No priority

Long-term availability

- ◆ No priority

Aimed to compete against ETX

X-Board ⁽¹⁾

*X-Board:
Board which is “reduced to the maX”*

*Open specification, recently
introduced by Kontron*

*Not yet supported by any other
supplier*

Mechanics

- ◆ 8 x 49mm business card size
- ◆ Would theoretically fit on a Eurocard
- ◆ Not stackable



X-Board ⁽²⁾

Kontron claims that it usable with x86 and RISC processors (theoretically)

On-board functions

- ◆ On-board DRAM, SRAM, CompactFlash possible, but no SO-DIMM
- ◆ I/O on board like Ethernet, serial lines, floppy, IDE... (more than DIMM-PC - less than ETX)
- ◆ PCI bus and LPC bus (Low Pin Count - replacing ISA)
- ◆ No front connectors

No stand-alone capability

No system slot function

Harsh environments

- ◆ Extended temperature in general, yes
- ◆ SO-DIMM like connector difficult under shock and vibration

Long-term availability

- ◆ In general yes

X-Board claims to fill the gap between DIMM-PC and ETX

Competition

- ◆ DIMM-PC

XTX – ETX without ISA ⁽¹⁾

XTX: enhancement for ETX
“extended lifecycle for ETX”

Open specification
www.xtx-standard.org

Supported by multiple companies

Mechanics

- ◆ 95x114mm
- ◆ 4 Hirose FX8 connectors (PCI-E)

Used with x86 processors only



XTX – ETX without ISA ⁽¹⁾

On-board functions

- ◆ On-board DRAM, CompactFlash, SO-DIMM
- ◆ I/O on board like Ethernet, serial lines via LPC, USB, IDE...
- ◆ PCI, PCI-E, Serial ATA

*No stand-alone capability
no front connectors*

*Almost backward-compatible to
ETX, but faster*

*Not upward-compatible to COM
Express (as ETX, UTX, STX)*



XMC – Express Mezzanine Card

VITA 42, compatible with CompactPCI or VME standards

- ◆ Also called:
Switched Fabric Mezzanine Card

Board dimensions

- ◆ 74mm x 144mm single-width
- ◆ 149mm x 144mm double-width

Extends PMC specification by using switched fabric interconnects to the existing PCI bus interface

- ◆ An XMC module adds one, optionally two, new connectors to the connectors already on a PMC
- ◆ The new connectors support high-speed differential signals for fabric communications



	VITA 42.1 Parallel RapidIO	VITA 42.2 Serial RapidIO	VITA 42.3 PCI Express
Clock Rate	Up to 500 MHz DDR	2.5 or 3.125 Gbits/s per lane	2.5 Gbits/s per lane
Signals	8-bit parallel	1, 4 or 8 lanes	1, 2, 4 or 8 lanes
Throughput (each direction)	500-1000 Mbytes/s	Up to 2.5 Gbytes/s	Up to 2.0 Gbytes/s

Table 1

Compared here are the current set of protocol standards under the VITA 42 XMC spec.

phyCORE ⁽¹⁾

phyCORE = microcontroller-based rapid development kits

Company specification from Phytec Technology

Other suppliers not known

Mechanics

- ◆ Not known
- ◆ Would fit on 6U and 3U Eurocard
- ◆ One slot in the system
- ◆ Stackable with PC/104(-Plus) (on carrier board)



Suitable for all low-end microcontroller platforms

On-board functions

- ◆ Soldered memory, CompactFlash; no slot for SO-DIMM
- ◆ I/O on board like Ethernet, graphics serial lines, floppy, IDE...
- ◆ 32-bit PCI (?)
- ◆ No front connectors

No stand-alone capability

System slot function

Harsh environments

- ◆ In general yes

Long-term availability

- ◆ In general yes

Competition

- ◆ Low-end embedded SOMs
- ◆ For example DIMM-PC, ETX, PC/104, smartModule, DIL/NetPC

Summary

There are a wide variety of embedded CPU mezzanine specifications to choose from, and the number continues to increase.

No one specification can claim to have a dominant market share.

No one specification can claim to be the “standard.”

Most SOMs are optimized for or used only for x86 processors.

Most SOMs include processor, chipset and memory.

Only a few have front connectors.

Only a few are stackable.

Only a few are able to run in harsh environments.

Only a few take care of long-term availability.

Bottom Line: Choose Wisely

Endnote:

This presentation was originally prepared in 2005 for the CMP



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