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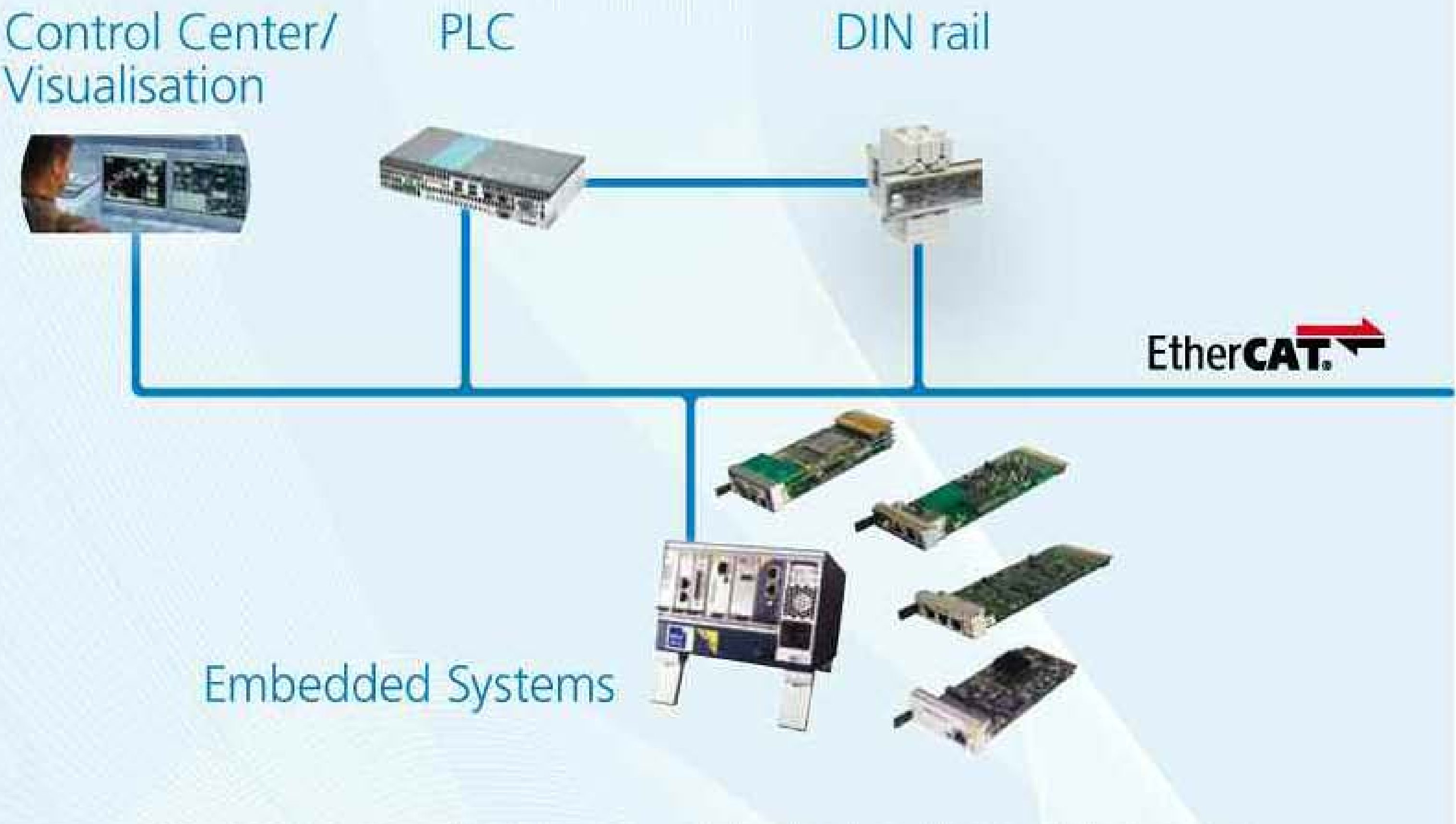
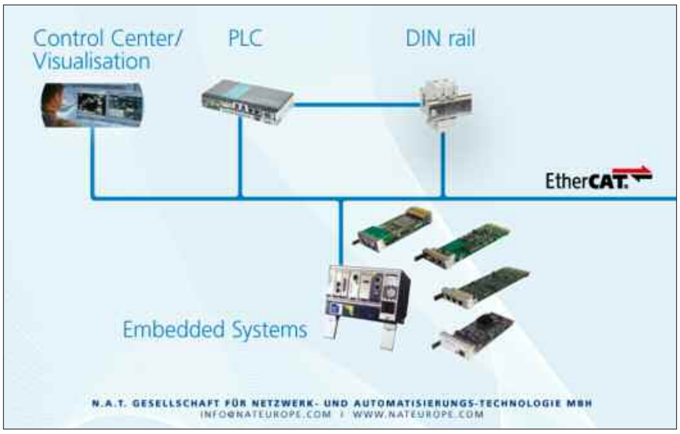


Cover Story:
EtherCat and MicroTCA: the new standard for industrial automation

EtherCAT and MicroTCA: the new standard for industrial automation

By Vollrath Dirksen, N.A.T.

Combining the field bus EtherCAT with the computing architecture MicroTCA enables new ideas for improving existing industrial automation solutions applications and will even pave the way to a completely new range of applications.



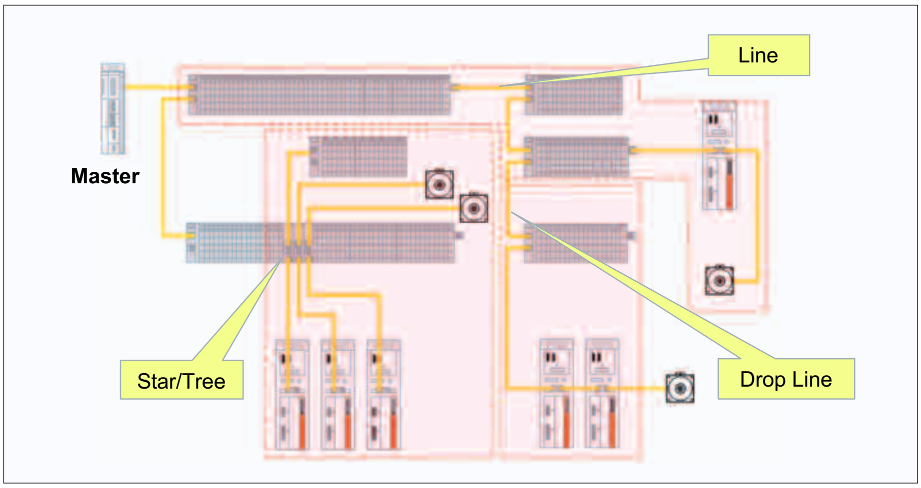
The range of solutions for industrial automation is very wide, because the requirements for performance, size, environment, availability, communication, kind of input/output devices differ so much. Very often proprietary hardware is used as it meets exactly the needs and price expectations. Disadvantageous are the restrictions in flexibility and the impossibility to reuse them in different applications and of course the lifetime costs. For more flexibility any kind of PC, box-PCs up to industrial PCs can be used. The good price to performance to flexibility ratio is paid by higher service costs exchanging IO, fans, ineffective cooling environment and shorter life cycle. Proprietary hardware is needed for fault detection and IPC defined setup.

The solutions for interconnection additionally differ significantly because of the different requirements. Field busses are one option to solve this. Settled field busses have different connectors and configuration profiles and require separate intelligent hardware, which often has to be tuned to address the continuous increasing performance expectations. The architecture for the network interconnection in the industrial automation market may be bus, line or tree oriented and sometimes all these combinations together. Therefore older field bus standards have been refreshed to meet some of the new requirements and newer field busses based on Ethernet having been introduced. To find the best solution for industrial applications for today and the future, one should have a look to early days of Ethernet and VMEbus. More than 25 years ago, the VMEbus (Versa bus Module Europe) standard was created. It used the at that time latest technologies and built an architecture that scales with the requirements of the application and had space for later extensions. A high volume market (telecom) accepted this standard with a lot of companies having committed themselves to it what was the main reason for success. As this market has a very limited amount of different IO compared to the automation market, all needed IO was very quick available. Because of the high volume the costs of VMEbus system came down to a level, that the applications in the automation and other markets saw the better flexibility of IO, scalability and benefits of second source compared to proprietary solutions. Over the years faster standards like cPCI were created with better performance, but they could not eliminate the VMEbus. The main reason for long time success is not the performance, but also the complete IO range and the expected price.

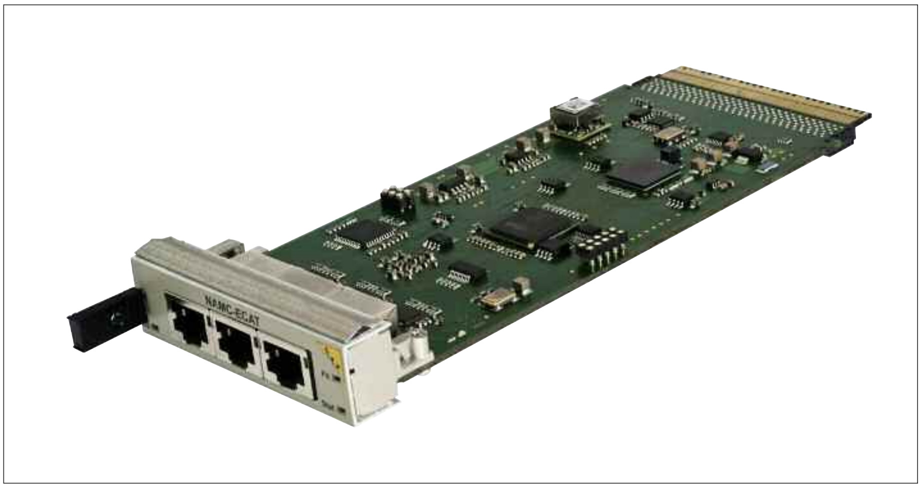
A very similar story is Ethernet. The prices of this standard also dropped because of its adoption by the computer industry (PC) market and Ethernet growing with the demands of the applications from 10 Mb/s, 100 Mb/s, 1 Gb/s, 10 Gb/s, ….As Ethernet still meets the performance requirements and the interconnection of completely different architectures, the success story continues. Because of the common RJ45 connector, also field busses are adapted to this connector to overcome the problem of different connectors for each field bus (CAN to CANopen, Profibus to ProfiNet). Comparing these success stories with new established standards like MicroTCA, and EtherCAT shows similarities and the way forward.

The new computing architecture is called MicroTCA – Micro Telecom Computing Architecture. The open standard was released in 2006 by PICMG and the first adopting market was the telecom market. The boards plugged into a MicroTCA system are based on the open PICMG standard AMC(Advanced Mezzanine Card).The reason for the success in the telecom market was not only the right price and the high bandwidth, but also that the key AMC boards were available from multiple sources.

Because of the high volume the system prices decreases to the price expectations of other markets e.g. the industrial automation market. Therefore the "T" in MicroTCA should not be seen anymore as abbreviation for "Telecom" but for "Technology" instead. MicroTCA as Micro Technology Computing Architecture better



EtherCAT topology



NAMC-ECAT EtherCAT slave in AMC form factor

reflects the usage of this standard. Beside the price for sure the technical advantages are the key drivers to consider MicroTCA for new applications, which need higher bandwidth and/or management functions and which search for replacement of older standards or proprietary solutions to reduce life cycle and maintenance/service costs.

The backplane of MicroTCA systems offers differential lanes for the intercommunication and separate lanes for clock signals, management bus and user specific implementations. The topology is defined by the combination of the switch board and the AMC boards. The interconnection can be Gigabit Ethernet or PCIexpress or SATA or SAS or 10 Gigabit-Ethernet or Serial Rapid IO or user defined.

The charming aspect of this standard is the mixture of mentioned data pathes. For example an industrial automation system could have PCIexpress combined with SATA and Gigabit Ethernet. A high performance security application may have Serial Rapid IO as low latency (100 ns) multiprocessor interconnection. A MicroTCA system can be as small as 2 boards and as big as 12 boards. The same AMC boards can also be reused in an ATCA (Advanced Telecom Computing Architecture Boards) with up to 14 *4 or 14 *8 boards. The first adopters in the industrial automation market take advantage of the higher bandwidth and the management functions. With more IO becoming available and further price cut also lower demanding applications will benefit from the scalability and the reusage of the components. Compared to small size module standards, card based systems have a well established defined architecture and form factor for a very long time.

Ethernet for Control Automation Technology – EtherCAT – is used since 2003 in a growing number of automation applications as high speed, real time field bus. It is an open standard supported by the world's largest industrial Ethernet Organisation, the EtherCAT Technology group. EtherCAT is the fastest system available (update of 100 servo axis all 100µs, update of 1000 digital IO all 30 µs) with outstanding synchronisation features (<1µs accuracy) and very simple parameterisation. No underlying sub-system is required. Standard Ethernet cable and Ethernet interfaces are used to build all topologies: line, tree, star and ring. EtherCAT is an IEC, ISO and Semi standard.

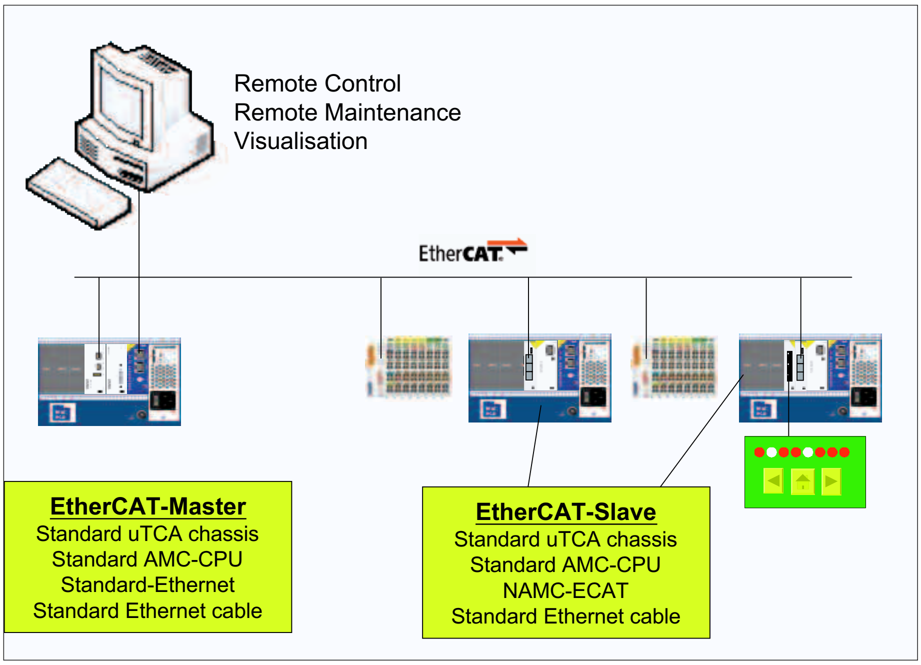
EtherCAT is an optimised protocol using Ethernet as the base structure and transporting data direct in the Ethernet frame. Each EtherCAT slave device knows the exact position of their data in the frame. For a line and tree architectures no switches or hubs are needed. Up to 65.535 nodes per segment can be addressed and with optical Ethernet the network can be more than 500 km long.

The EtherCAT slave is easy to implement by using highly integrated Slave Controllers for low interface costs. The Real-time protocol is handled in hardware. Simple IO slaves do not require a µC at all. Otherwise the device application determines the µC performance, not the field bus protocol.

MicroTCA and EtherCAT have a lot of similarities namely flexible topologies, easy scalability and high performance. In addition both offer redundancy and hot swap. A new approach is to combine these two successful standards for industrial automation applications. To use a MicroTCA system as an EtherCAT Master only a standard Ethernet port and Ethernet cable are needed. On the CPU (8, 16 or 32 bit) the EtherCAT master stack software has to be installed. One can develop an own master solution, adapt the master sample code (available for a nominal fee and in source code) or purchase a commercially available master solution.

As EtherCAT master the MicroTCA system allows to build control applications with a very scalable architecture. The smallest solution is a system with only one CPU collecting data and doing the control of all EtherCAT devices. A midsize system would be a CPU, a SATA hard disk as storage device, a graphic card for visualisation and some additional IO cards for proprietary functions. If more processing power is needed, additional CPU boards or FPGA and DSP boards can be plugged into the system. As redundancy is defined in the MicroTCA standard, it is also very easy to build a redundant system with no single point of failure.

Even more impressive is to use a MicroTCA system as a slave device in an EtherCAT network to get an intelligent node at the target machines that can be adapted to the different requirements on-site. Special hardware is needed to integrate MicroTCA systems in an EtherCAT network with an EtherCAT Slave



MicroTCA as EtherCAT master and slave

Controller (ESC). N.A.T. offers such an AMC board with the NAMC-ECAT. It uses the ET1100 ASIC as low cost EtherCAT Slave Controller and offers three RJ45 connectors at the front panel. This allows building all topologies of EtherCAT as there are line, bus and tree topology. The CPUs inside the MicroTCA access the NAMC-ECAT via PCIexpress and for remote control the management bus IPMI is available. The range of AMCs based on Single or Dual Core PowerPC and Core2Duo or Atom and high performance FPGA or DSP offer a wide range of processing power directly at the machine i.e. robot or inspection system. IO can be integrated into the MicroTCA system by AMC-IO cards or via one or more EtherCAT networks connecting to the CPUs.

N.A.T. realised a small EtherCAT master system with a 5 slot MicroTCA chassis, an AMC with PowerPC MPC8560 running EtherCAT master software based on the real-time operating system OS9. The NAMC-8560-IO board controls through its Ethernet port at the front panel an EtherCAT network.

A second system with 5 slots is based on a Core2Duo AMC board plus an AMC with SATA hard disk and an AMC graphic card for visualisation with transparent windows and multiple language support. This system controls more than 100s of IO, i.e. analogue inputs, digital inputs and digital outputs. By adding two additional graphic cards, this MicroTCA EtherCAT Master system can be extended to visualise the data and in addition video data on 6 DVI or VGA high resolution monitors. The size of such a compact system is 13x20x25 (in cm). With a bigger chassis the amount of processing power for pre-processing and the number of graphic cards can further be increased. Into this MicroTCA system additional AMC-IO boards and by using N.A.T.'s adapter boards (AMC to PCI, AMC to cPCI) also settled form factors can be used. To demonstrate the integration of a MicroTCA system as slave device inside an existing EtherCAT network, a MicroTCA system is plugged in a raw with other EtherCAT devices. The MicroTCA system is built with a small MicroTCA chassis, a PowerPC AMC module and an AMC-EtherCAT-slave module NAMC-ECAT from N.A.T. and an AMC-Digital-IO card. The application running on the PowerPC writes and reads the data in the memory space of the NAMC-ECAT. No protocol stack software for EtherCAT is needed, why nearly the complete performance of the MPC8560 processor is available for the application. The EtherCAT Slave Controller (ESC) on the NAMC-ECAT takes care to get the receive data from the right position from the Ethernet frames and to insert the transmit data in the allocated slot in the Ethernet frames in Real-time.

This EtherCAT network is controlled by an EtherCAT Master realised on a separate MicroTCA System with an AMC-Core2Duo card and a second AMC with a SATA hard disk and graphic chip. On this Linux system the EtherCAT Master software runs and the software XiBase9 from Xisys that visualises the data processed by the MicroTCA EtherCAT slave system and several non intelligent Beckhoff IO devices. The Xibase9-Software uses the advantages of the data centric model of Gamma from RST Automation. Gamma realises a hardware abstraction layer, so that tools like CodeSys, Labview. Matlab, XiBase9, Python etc can be plugged in, without caring about the hardware technology underneath. At the SPS/IPC/DRIVES on the joint stand of Embedded4You e.V., where N.A.T is member of, the MicroTCA-EtherCAT demos were part of example implementations for EmbeddedSPS4You. EmbeddedSPS4You enables more powerful and new pioneering applications for the industrial automation market using flexible architectures based on open standards.

As MicroTCA allows the power consumption to be up to 80 Watts per slot, very high performance CPU, DSP and FPGA can be used to realise performance intensive applications with low latency demand and high data throughput. For world wide distributed systems the standardised remote management and control functions of MicroTCA systems will make the health status and inventory information easy accessible and will reduce the service costs and reaction time. In Industrial PCs extra hardware (proprietary solution) is integrated to set the PC in a defined status. In the MicroTCA standard this is all defined, so that different AMC modules can be easily integrated and firmware release conflicts can be detected before the system restarts.

Also very small systems can be used with the same technology, so that a lot of components can be used from small up to the high end systems. EtherCAT connects via a single RJ45 connection up to several ten thousands of IO devices to a control system, whereby the data can also include precise time stamps of the data creation. Therefore EtherCAT preserves a lot IO slots needed in the Control System. EtherCAT can be scaled up and down like a MicroTCA system can be scaled up and down without any extra costs.

The MicroTCA standard can be seen as the successor of the VMEbus/CPCI because it defines the scalability, flexibility, availability, extension and the variety of topology combinations needed for all the different automation applications of today and of the future. The operating system and topology agnostic management functions allow detecting the configuration, inventory and the health status of a MicroTCA at start-up and during runtime. Therefore conflict detection of hardware and/or software or even firmware release mismatches is made easy. EtherCAT uses the advantages and the popularity of Ethernet without taking the disadvantages of high CPU load and latency. It connects a lot of low cost and high performance IO in real-time to the needed control and processing units. EtherCAT allows a smooth migration path from legacy field busses i.e. CANopen, PROFIbus, PROFInet, ControNet, Modbus-IDA, DeviceNET, IO-Link, Interbus etc by low cost field bus gateways. ■