IoT and Industry 4.0 front-ends based on an Open Standard I/O-Bus

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This article introduces emBRICK, an open, modular-plug-in I/O-hardware for direct sensor/actor adoption for professional control and measuring applications. Hardware and software development can run in parallel, saving cost and time and substantially accelerating time to market.

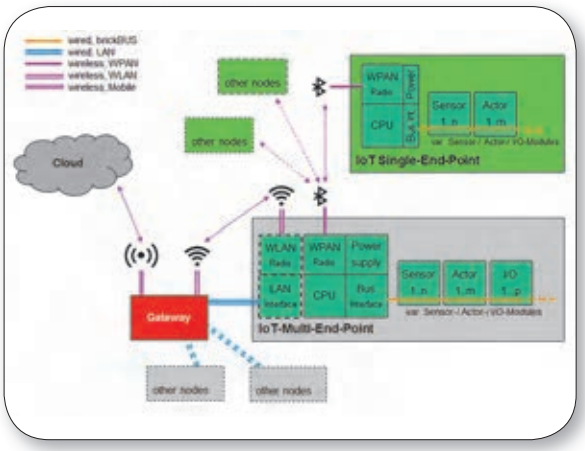

Figure 1. Standardization, the prior challenge of IoT

■ Some main driving factors against the background of Internet of Things and Industry 4.0 innovations nowadays are, in addition to connectivity, the continuing miniaturization and higher integration of mechanical, electromechanical and electronic components. This leads to increasing functionality at smaller scale devices, but growing complexity down to sensor and actuator level of control systems. The related I/O infrastructure is radically changed by that. The software and hardware complexity within the functionality chain of control devices from the CPU to I/O components down to sensor/actuator level becomes more and more application- and vendor-specific.

Product maintenance, lifecycle management and/or functional replacement at I/O infrastructure level can become a challenge in terms of cost, compatibility and long-time availability of products. Approaches that might improve this situation are open source solutions emerging potentially into standards. Standards are a perfect means for interoperability between products offered by different vendors. Open source solutions on the other hand allow vendor-independent access to technology, know-how and resources by community driven innovations. As displayed in figure 1, a typical IoT infrastructure in an industrial environment may consist of end points integrated and connected to the cloud via manifold interfaces and communication channels. End point functionality may vary from simple switches to complex, multi-point infrastructures integrating power I/Os, power amplifiers and intelligent sensor-actor combinations.

The biggest challenges to move IoT and Industry 4.0 visions into real products in this environment are missing or partly implemented standards. Standards are the key ingredient to support a seamless integration of technologies, solutions, and products from sensor level to the cloud. Industry-wide standardization efforts are mainly driven by the big worldwide industrial and political players via standardization bodies. Within the IoT and Industry 4.0 context, they focus on themes like communication infrastructure, safety and security norms or on more sector-oriented approaches like AUTOSAR for the automotive industry or OPC-UA for industrial M2M communication.

On the sensor-actor and I/O level there are mainly existing company proprietary solutions, hence standards are missing and more complex to establish. The reason for that is legacy and grown infrastructures serving a huge variety of diverse requirements. Because of that there are currently no major activities seen by the standardization bodies to address this issue. Some consequences of missing standards to interface CPUs and sensor/actors are: isolated solutions, proprietary technologies within the nodes, incompatible sensor/actor-CPU interfaces amongst vendors, missing interchangeability options of vendor independent solutions, longevity of technology and higher risk of investment. Thus, from project design to serial production including lifecycle management, the overall project and product cost will stay high. Additionally, the project management will stay more complex and more inefficient.

To address this limitation, IMACS GmbH decided in 2013 to introduce an open, modular-plug-in I/O-hardware for direct sensor/actor adoption for professional control and measuring applications. This new combination of technology, products, and I/O infrastructure is known as emBRICK and offered under an open source license model. To ensure a high market acceptance the emBRICK technology basis is available free of cost under an open source license. That covers for example circuit diagrams, protocol stack software and reference design information. It is a single master, multiple slave I/O-system. The different modules, called bricks, can be easily plugged together to get the required amount of I/Os. They are initiated by a generic boot process without any manual configuration. This combines in a perfect way the cost-ef-

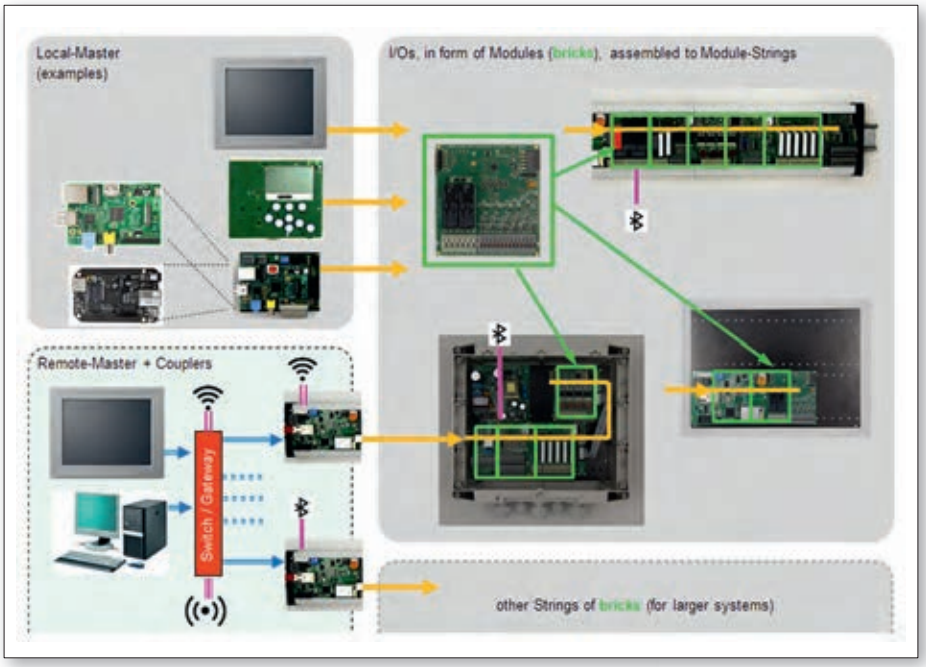

Figure 2. emBRICK components and topology examples

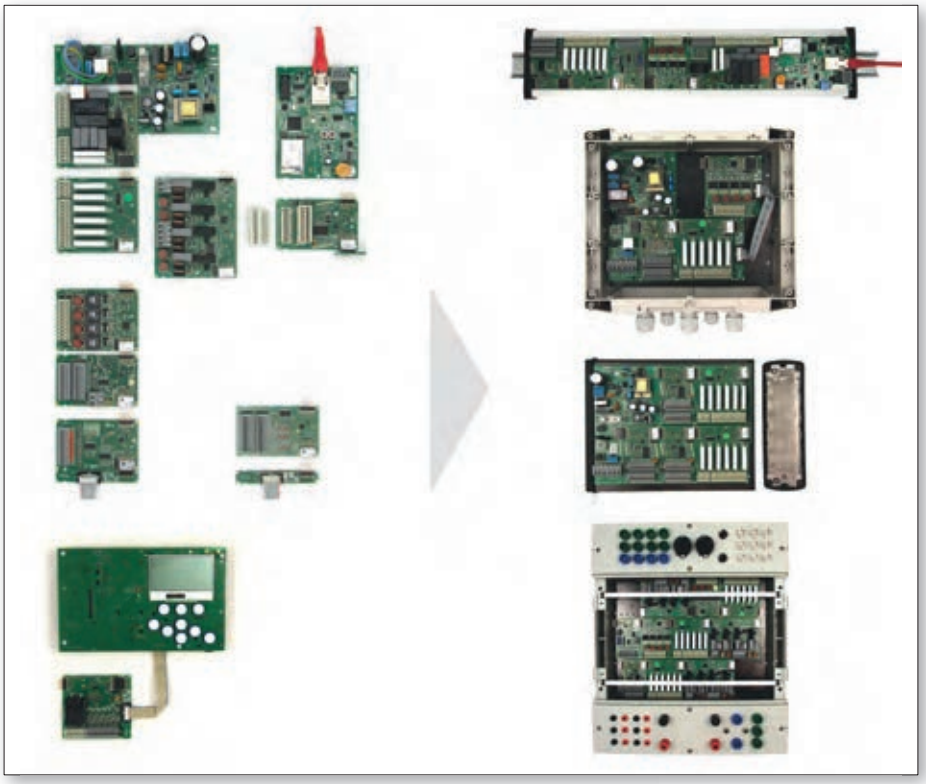

Figure 3. Examples of available emBRICK components

ficient and tailored characteristics of a dedicated embedded system with the readiness to use and flexibility of a PLC system. The communication between control masters and the I/O slaves is performed by a specifically designed, open source, robust and simple serial bus system the brickBUS. This I/O concept combines the advantages of a PLC with embedded design approaches, e.g. flexibility and minimal development cost with favourably priced, more compact and sector-specific I/O hardware. brickBUS allows single master multiple slave system designs just by stacking from 1 to more than 1000 I/O modules to realize powerful and flexible embedded PLC solutions. The extremely simple low cost connection is based on SPI or GPIO and can be driven by literally every µController, industry PC or other embedded control device. It supports slave power management, auto configuration, is industrial grade and as mentioned already available under a modified open source BSD license. The bus protocol code and documentation is freely available by example targets. It is targeted for custom applications and can be applied by the use of off-the-shelf low cost controllers. Furthermore, by available couplers the architecture is open for LAN, WLAN, CAN, Fieldbus or serial line communication. For a fast jump start, as of today there are more than 50 I/O bricks for different industries (e.g. building and industrial automation), various autarkic host systems and coupling boards, starter kits, enclosures and mounting kits available.

The programming environment is based on standards like C, C++, IEC61131 conform programming (e.g. CODESYS) or UML modelling tools (e.g. eTrice, SiSy, radCASE, Enterprice Architect). Supported are various RTOSs, Windows, Linux or middleware solutions like GAMMA. The initial intention of the emBRICK technology was to enable control systems by: connecting small existing I/O modules, the bricks, in a plug and play fashion (auto detection and configuration), linking to any available master controller independent of CPU architecture, allowing flexible scalability and application-specific topologies, and addressing a wide range of performance and energy requirements. Furthermore it should have an I/O bus that is flexible and combines various I/O capabilities without complex and time-consuming engineering and development cycles, interconnects to any existing industrial and IoT communication infrastructure, shows PLC functionality out of the box with the flexibility of an embedded system, saves project cost and development time with no need to re-invent the wheel, offers the concept in an open source license model to allow community-driven technology development and vendor independence, achieves project cost reductions and guarantees investment protection.

Combining these characteristics, embedded control systems and/or PLCs based on the emBRICK technology can be a suitable means to reach out from sensor/actuator levels into IoT and Industry 4.0 infrastructures. The ready-to-use construction kit works right out of the box and can be extended or upgraded without any configuration or reinstallation processes. It is freely programmable, robust and reliable, highly performant and is therefore especially suitable for applications in industrial and building automation, mechanical and plant engineering industries, control and measurement markets or process technology. emBRICK is a perfect fit for prototyping projects which can rapidly move into production. Hard and software development can run in parallel, saving cost and time and substantially accelerating time to market. ■