TEXAS INSTRUMENTS

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Bringing on the revolution in manufacturing automation

Summary

Changes in industrial communications today are creating what some call a revolution in manufacturing automation. Key to these changes is Industrial Ethernet, which adds deterministic delivery, time-triggered support, greater distances and safer, more reliable operation to the advantages of traditional Ethernet. Owing to the many proprietary implementations of Industrial Ethernet, as well as legacy serial protocols, silicon and software solutions must provide a basic compatible technology that enables ease of design and promotes across-the-board communications. Through semiconductor innovation, industrial customers can look forward to the advantages of speed, safety, efficiency and flexibility brought by advanced network communications.

TI's innovation for Industrial Ethernet opens new possibilities for enhanced industrial communications

Throughout the world, a major step forward in automated manufacturing is taking place. New sophistication in networking is bringing faster, more flexible communications to the factory floor, helping manufacturers produce more efficiently and enabling them to respond more quickly to changing market conditions. Control networks that were once isolated are now linked to the front office and the field, bringing data that can affect production decisions in real time. This movement is often called the "Smart Factory," and its implications are revolutionary – so much so that an initiative in Germany has dubbed the new era of manufacturing "Industry 4.0" to indicate its equivalent importance to the periods following the three earlier industrial revolutions of steam power, mass production and early automation.

Technology innovation to enable a smarter factory in the future represents an investment in control intelligence and infrastructure, and a company must be convinced of a worthwhile payback before it will invest. New solutions for advanced automation not only must enhance communications, but they must do so affordably. Today such solutions are appearing on the market. Texas Instruments plays a leading role in providing this technology, and continues development to meet tomorrow's needs. TI's long-standing expertise in network communications, working relationships with many leading equipment manufacturers, and participation in standards bodies mean that the company is well-positioned to create circuitry that meets the needs of advanced networks for factory automation. Important solutions are already appearing from TI that will help bring on the revolution in industrial communication and its benefits.

Smart factories bring many advantages

What's driving the current revolution in manufacturing? Among other things, the rest of the world has become networked, and factories are beginning to take greater advantage of the available information. Businesses can tap databases to understand customer preferences, product successes and failures, delivery information, repair and maintenance feedback, changes in material availability, and a host of other factors that affect design and manufacturing. This information traditionally affects

production indirectly, after threading its way through office procedures. Why not send it to the automated factory directly via the network? If sales indicate that 56 percent of customers prefer green items and only 44 percent prefer red, why spend a week changing 50-50 production runs when networked automation can make the change right away?

Advanced communications are indispensable due to the complexity of today's manufacturing: an automobile plant, for example, typically has more than 100,000 nodes requiring electronic communication. These motors, sensors, actuators, cameras, scanners, robots and their varied control equipments need to be coordinated in order to maximize productivity and minimize costs. Sophisticated communications on the factory floor can report problems quickly to help keep machines up and running as much of the time as possible. Smarter factories can turn out a greater variety of products in greater quantities, and can do so using less power for each item. To a large extent, cost efficiencies equate to energy efficiencies, and more sophisticated communications and control among factory equipments help make manufacturing greener as well as less expensive.

Industrial Ethernet for next-generation industrial communications

Manufacturers have been introducing networked control systems to their equipments for decades, but technology and market conditions mean that these proprietary, sometimes incompatible networks will now have to become interconnected and responsive to more centralized control (Figure 1). Ethernet, the overwhelmingly accepted choice for data networks, makes sense for industrial communications as well. Ethernet is well understood and supported, offers a wide address range, and transmits with much higher bit rates than the older serial communications used for many equipments, thus allowing more precise control. Use of Ethernet also simplifies the interface between factories and data networks—a key feature of advanced automation.

However, Industrial Ethernet has to be modified somewhat to meet its application requirements. Deterministic data delivery, support for time-triggered events, connections over factory distances, topologies that ensure safety and reliability: all these factors have been specified for Industrial Ethernet. Until now, equipment manufacturers have found their own ways to support these features, which are essential to manufacturing. The challenge lies in introducing basic hardware and software technology that can simplify development of the many implementations of Ethernet that are already used in industry, as well as communications among them and with legacy serial networks.
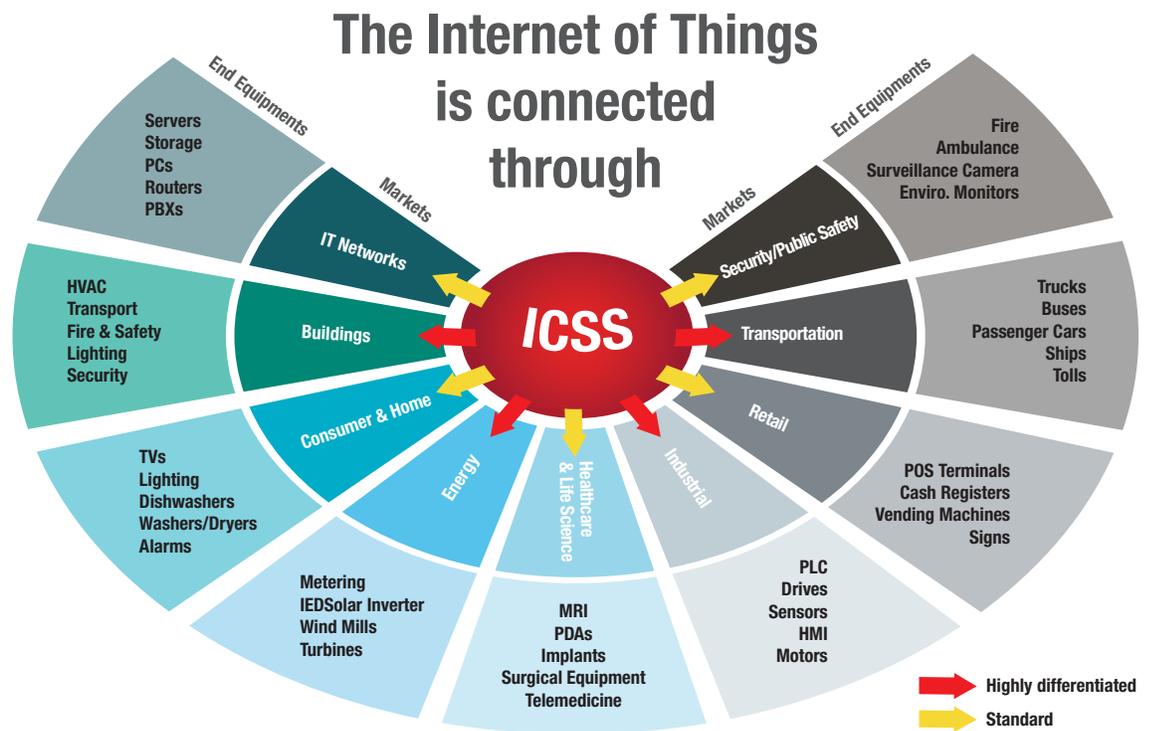
The Internet of Things is connected through

Figure 1. *The Industrial Communications Subsystem built into TI's AM335x microprocessors enables connection to a wide range of application areas beyond manufacturing.*

Deterministic delivery

With packet transmissions dependent on collision detection and retransmission, traditional Ethernet offers a non-deterministic delivery mechanism that is not reliable within a specified timeframe. However, packet communications among industrial equipments must operate deterministically, within narrowly defined time limits. For example, the motors on a belt-driven assembly line must behave synchronously, often with time-driven inputs from sensors along the line, or operation of the entire assembly line may be disrupted. Since Industrial Ethernet requires deterministic delivery, developers must have access to certain parameters in the data link layer to control packet flow and scheduling. Such "hooks" to the data link layer should enable programming timed transmissions to the nanosecond, so that messages can be sent and received without indeterminate delays.

Time-triggered events

In some instances, data handling speeds also need to be specified, since many events in industry are time-triggered. For instance, control may be based on reading in a group of inputs and sending to a group of outputs. Precise specification of the times required for these triggering events means that production process times can be more carefully defined, leading to higher production outputs. Apart from providing deterministic transmission times, as discussed above, solutions for Industrial Ethernet must support the specification of time-triggered events such as, say, reading in data from X number of sensors.

Longer connections

Manufacturing operations have strict requirements for timing and physical interconnections. Ethernet distances can be up to 100 meters between nodes, which is already greater than the widely used Control Area Network (CAN) bus, with its limit on distances between nodes of only 40 meters. Industrial Ethernet increases this distance to 160 meters to support the needs of manufacturing plants, which may be spread over large areas with connections among different buildings or outdoor equipments.

Safe, reliable topologies

Additionally, factory equipment networks require some different arrangements in topology from data networks to ensure safe, reliable operation. For example, motors that drive an assembly line have been traditionally connected in a line topology, all slaves to a master control unit. A connection break between any two motors stops communication to all motors downstream from the control unit, effectively halting the entire line until the break can be repaired. Industrial Ethernet supports a ring topology with two bidirectional ports on each node, eliminating unidirectional packet collisions and enabling redundant data to flow simultaneously in opposite directions around the ring.

In routine ring-based operation, a node responds to packets coming from one direction and ignores redundant packets coming from the other direction. When there is an emergency caused by a ring break between two nodes, the control system can still send the same data in each direction as far as the break. In the assembly line example, motors on one side of the break would still receive data coming from one direction, and motors on the other side of the break would receive data coming from the other direction. Thus, all motors would keep operating and the assembly line would not stop. Industrial Ethernet also supports line topologies where safety and reliability are not critical, star topologies where nodes or subnets need to be in direct contact with a central system, and peer-to-peer configurations when master-slave is inadequate.

The need for compatible technology

Finally, integrated circuit solutions to support Industrial Ethernet must provide certain features for reasons of practical application. There are more than 100 network protocols used in industrial systems, many of them legacy standards based on serial communications. Of this total, 29 protocols are Ethernet-based, with some amount of proprietary engineering built in to address issues such as those discussed above.

In order to serve the industrial communications market today, IC solutions and the supporting software must provide a basic technology that is common to existing protocols, allowing equipment manufacturers to build the devices into systems that uses their own intellectual property. Moreover, multiple protocols may be used in a single factory, especially where older serial communications continue to exist alongside more recently deployed Industrial Ethernet. Therefore, IC solutions must have the capability for multi-protocol support in a single device, providing the means to communicate with legacy equipments and keep them functioning in a more up-to-date control environment. When these features are available in an inexpensive solution, equipment manufacturers can easily build flexible, advanced Industrial Ethernet into their products.

TI innovation delivers cost-effective Industrial Ethernet solutions

Until now, competing proprietary protocols have meant that adding Industrial Ethernet to control electronics requires adding a separate module, or at least an FPGA or ASIC that is separate from the controller, thus increasing the size, cost and power requirements of the system. TI's AM335x "Sitara" microprocessor (Figure 2) resolves this problem by integrating the core, peripherals and flexible hardware support for Industrial Ethernet in a single device. Although classed as a microprocessor because of its high level of performance and integration, the AM335x offers the ease of use familiar with microcontroller units. Featured in the device is an integrated Industrial Communication Subsystem (ICSS), which leverages TI's expertise in high-speed network communications to maintain deterministic delivery and also provides open intellectual property for implementation of different legacy and proprietary protocols.

TI's AM335x for Industrial Communications

AM335x Cortex™-A8 based processors
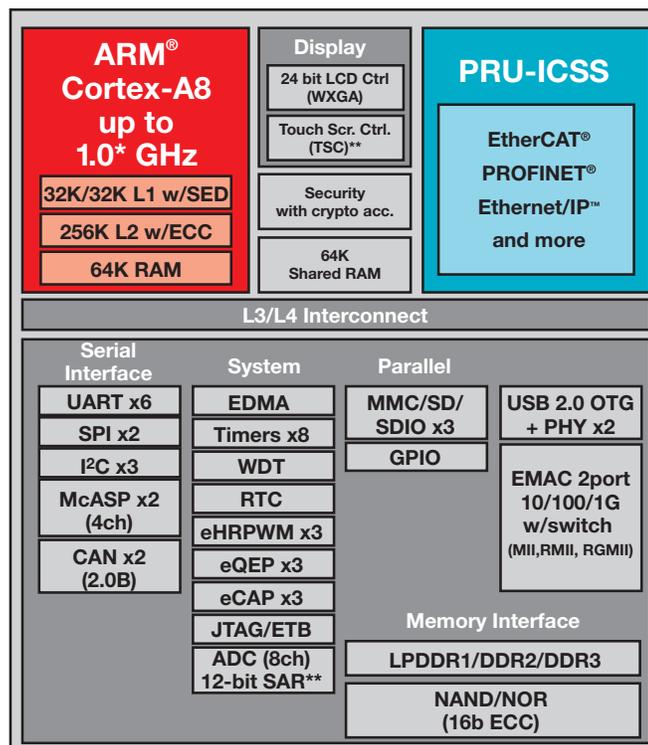
*   800MHz+ only available on 15x15 package. 13x13 supports up to 600 MHz.
** Use of TSC will limit available ADC channels.
SED: single error detection/parity

Figure 2. *TI's AM335x microprocessor combines a high-performance ARM core, an Industrial Communication Subsystem with support for Ethernet and legacy protocols, and a variety of essential interfaces.*

The impact of a single-chip microprocessor-Industrial Ethernet solution for automation equipment is difficult to exaggerate. While previously control electronics often had to be built onto a board, now they can be included in the housing of even small equipments such as sensors and actuators. The device is a fraction of the cost of previously available solutions on multiple chips. The power requirements of the AM335x are low, as little as seven milliwatts, though the real savings in power will come from the additional electromechanical control that the device enables in factory automation.

Smaller, much less expensive control and high-end communications will be available for all machines, including key equipments such as programmable logic controllers (PLCs), human machine interfaces (HMI), industrial drives and sensors, such as flow and vision sensors. Manufacturers will be able to automate more functions than they have been able to do until now, and they will be able to move production faster, with more flexible output and safer, more reliable processes.

Outside of the factory there are many growing applications (Figure 3). Industrial Ethernet is appealing for use in large-scale transportation aboard ships, trains and trucks, where many of the same concerns apply that are present in

Widespread Applications for Industrial Ethernet
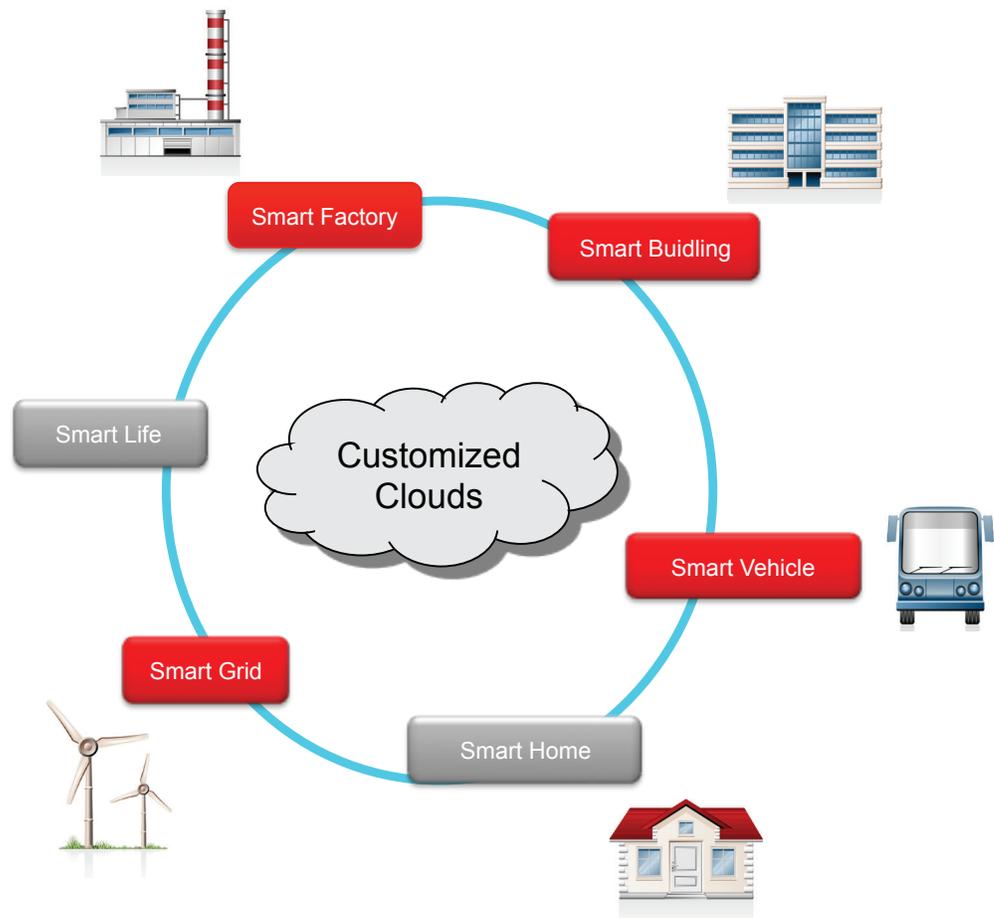
Figure 3. *Industrial Ethernet finds use in many areas of the smart world beyond the factory.*

manufacturing, including speed, reliability, safety and distance. Even in automobiles, where distance is not a factor, Industrial Ethernet is beginning to replace older networks such as CAN because of its speed and reliability. The more monitoring and control information that can be loaded safely onto a car's network, the more wires and mechanical linkages that can be removed, making the vehicle lighter and more fuel-efficient.

Industrial Ethernet is also finding application in certain large-scale installations. A typical theme park, for instance, has nodes requiring electronic communications that number in the tens of thousands, and large hotels with casinos may have similar numbers of connections. Smart Grid communication in substations and industrial supply stations also could move to Industrial Ethernet to prevent power-outages and better balance energy distribution with decentralized installation of renewable energy.

Advanced sensors may also be designed into these equipments to provide sophisticated environmental interaction, as well as communication with TI-enabled wireless sensing nodes to extend functionality over wide areas (though without reliability guarantees of Industrial Ethernet). Smart factories, then, are only the beginning of the list of potential applications for Industrial Ethernet based on TI semiconductor advancements.

Revolutionary advances require revolutionary solutions

Whether the new age of industrial automation is revolutionary, as some say, or simply a significant evolutionary advance, it is nonetheless bringing in an important new stage in equipment communications. Using Industrial Ethernet, factories are increasing the volume and variety of output while operating more safely and energy-efficiently. Other areas such as transportation, automotive systems, power distribution and building installations are also benefiting from the same communications technology. As industrial communications start to move forward at a revolutionary pace, TI technology is significantly adding to the momentum.

For more information on TI solutions for Industrial Automation, visit www.ti.com/industrial. For more on how TI innovation is driving the future of electronics, visit www.ti.com/innovation.

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