Connectivity for a Smarter, Better World

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Both wired and wireless technologies are helping to create new connectivity possibilities with simplicity, scalability and security in mind, aiming to make our world more efficient.

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From driver assistance to in-vehicle networking, the cars of today and tomorrow rely on fast and secure data communication.

Introduction

In a world where billions of data points need to be shared across systems, we need technology to transfer that data securely and without interference. Yet **connectivity** is about more than just sharing data between two points. Connectivity enables systems to evolve as innovations are discovered and implemented. The possibilities are endless, particularly across four key sectors that impact our everyday lives: factories, homes and buildings, grids, and vehicles.

For example, a factory can adjust in real time when product demand shifts. A doorbell camera can be accessed through a smartphone for peace of mind. Grids can re-allocate excess energy from home solar panels and electric cars, known as bidirectional charging. Sensors, cameras and networks in our vehicles can help avoid accidents. Cities can create autonomous systems to ease traffic congestion and pollution.

Connectivity works best for everyone when it is not complex or expensive. Additionally, open standards leverage the knowledge and experience of many experts, helping everyone achieve greater success with fewer delays. In wired connectivity, we at Texas Instruments (TI) participate in the development of PROFINET, **Ethernet**, EtherCAT, CAN, and LIN standards, to name just a few. We also provide solutions to address widely used **interfaces** such as RS-232, RS-485, UART and SPI. For **wireless**, we participate in the development of technologies such as Wi-Fi® 6, *Bluetooth®* Low Energy (LE) and Wi-SUN™. To help manage complex device-to-device interactions, we support the **Matter protocol** and the Ethernet extension of time-sensitive networking (TSN). On a large scale, we pledge our commitment to a more connected world as active members of the Wi-Fi

Alliance, Bluetooth SIG and the Connectivity Standards Alliance.

Ultimately, how well we connect determines how well we can move our world toward a safer, more efficient future.

Connected factories

Industrial environments were among the first in the world to be digitized and connected in a data-driven effort to automate production, provide safer conditions and reduce unexpected outages.

Factory environments can be very noisy and present a variety of signaling challenges due to electromagnetic interference. These challenges typically require wired interfaces that can be used to reliably transmit data over long distances. TI offers a broad portfolio of interface devices to address protocols commonly used in factories to overcome these challenging environments, such as **Ethernet**, **RS-232** and **RS-485** to ensure that data integrity is maintained.

High-voltages that exist in connected factories can present a risk to expensive automated equipment or even people who are operating or maintaining such equipment. Because of the presence of these high voltages, many systems require isolation to ensure that there is no potential for human harm or damage to equipment. Digital isolators for general purpose, UART, and SPI signaling, as well as **isolated interface ICs**, **isolated RS-485** interfaces and **isolated CAN** are able to support isolation in established industrial protocols. To support even higher-speed data transmission, TI also has integrated circuits (ICs) to support Ethernet and Ethernet-derived protocols. In situations where higher bandwidth is required, TI offers products such as **M-LVDS** to overcome bandwidth limitations while able to accurately send and receive data over long distances.

An increase in automation requires a multi-fold increase in the number of sensors to continuously monitor and adjust in real time. For example, high-speed V3Link SerDes aggregate and synchronize multiple sensors for faster processing and decision making. TI has single-chip solutions among its processors and microcontrollers to support high-speed networking hardware for industrial environments. These new solutions can speak multiple serial protocols required by a variety of both mature and novel industrial equipment. For example, PROFIBUS is a protocol widely employed by mature factory and process automation systems. In newer industrial equipment, **Ethernet** has become the primary network protocol. supporting industrial Ethernet protocols such as EtherCAT, PROFINET, Ethernet Industrial Protocol (Ethernet/IP), and Sercos. These are easily employed using TI's microcontrollers and processors, simply through software-selectable images. Selecting low- and deterministic- latency **Ethernet PHYs**, able to withstand harsh environments, provides a TCP/IP enabled, robust communication channel.

Partially and fully automated factory floors rely on industrial communication in order to operate properly with little or no human intervention. By observing and learning patterns and then experimenting with improvements, factory floors can become even more intelligent and productive with robust solutions that provide increased data throughput. Additionally, immediate access to data that feeds from sensors to processors can help identify unsafe conditions, highlight out-of-tolerance tools or recommend scheduled maintenance.

Connected homes and buildings

While our lives in the home, school and workplace are modernizing through connectivity technology, gaps remain due to proprietary systems that aren't always interoperable. We have collaborated in the development of Matter, a common language for smart homes and associated devices. By closing the connectivity gaps that kept many smart home devices from different ecosystems far apart, the open Matter standard is a way to bring smarter products to market faster, and make it easier and more effective for consumers to integrate them into their existing smart home — no matter what other vendors' products are already installed.

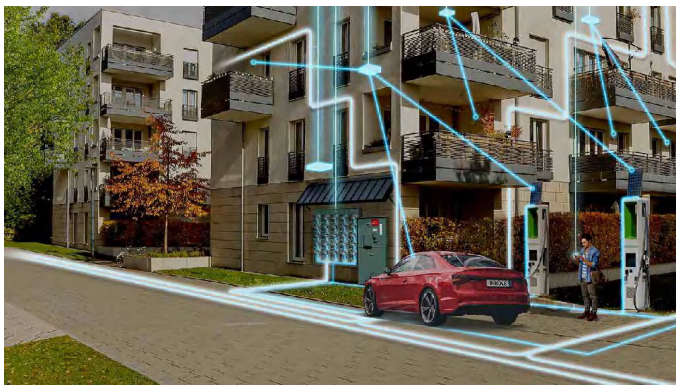
TI brings extensive experience with foundational Wi-Fi and Thread technologies to Matter, and we expect more potent smart home solutions with lower power requirements than today's closed ecosystems. We also expect growing demand from consumers to extend the smart home's reach and capability well beyond their front door. This is one of the reasons we support the Amazon Sidewalk protocol, which extends courtesy wireless networking along Wi-Fi, Sub-1 GHz, and Bluetooth to nearby devices. Amazon Sidewalk could make everything from keeping an outdoor camera connected to finding a lost dog easier to manage.

TI's **SimpleLink™ Low Power Software Development Kits** work across a number of wireless network protocols including Bluetooth, Mesh, Zigbee®, Matter, Amazon Sidewalk, Wi-SUN, MITOY, Wireless M-BUS and Thread. Our hardware networking chips that can speak multiple communication protocols in a software-defined, field-upgradeable way over a single antenna. This design helps product designers bring the products that matter most to market, without multiplying development costs.

The low-power and congestion-reducing potentials of the newly available multi-frequency band **Wi-Fi 6** (2.4Ghz, 5Ghz and 6Ghz) are just as exciting as Wi-Fi 6's maximum theoretical speed. While others may be more focused on delivering more media content to more devices, we are looking to expand network coverage to new products now that more devices can connect without impacting stability and performance. **Learn more** about the capabilities of Wi-Fi 6.

Data harvested from home and building energy management systems can not only lead to convenience but also lower utility usage, costs and waste. This reduces the burden on grid connectivity and other utility supplies while addressing a long-standing frustration: it's easy to spot wasteful lighting and HVAC spending in an office building, particularly after hours. With sensors and management consoles speaking with one another, power usage can be reduced remotely or disabled entirely based on need.

Connected grids



Power generation has evolved quickly from a one-way transfer of energy to a bidirectional flow—connectivity that has to endure extreme environmental conditions and long hauls, with little room for error. Car batteries and solar panels on homes are able to not just power themselves but send energy back to the grid. As the

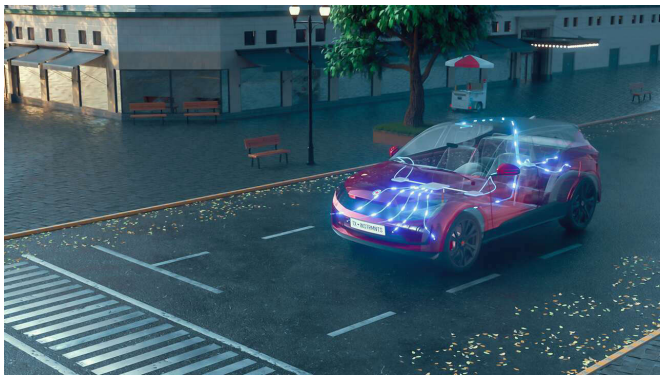
population grows and expands, delivery is a constantly moving target. There is an estimate of needing 20 million public EV charging stations by 2030, for example. And as more alternative power generation sources, including solar and wind, dot the landscape, the grid itself is becoming more decentralized.

To improve generation and distribution, technology helps connected grid operators link up through industrial Ethernet protocols as well as open standards such as RS-485, Controller Area Network (CAN), and Wi-SUN. These channels are essential to help maintain the health and smooth operation of intricate and often invisible components between these vital utility links. Wi-SUN for example, has the advantage of being comprised of mesh networks, meaning that no single point of failure can take down the entire network. The RS-485 wired interface is beginning its fifth decade of service as a robust choice for industrial equipment communications, and wired connectivity remains a valid option even for battery-powered devices such as flow meters. Bluetooth LE also allows for smart meter optical probe replacement, enabling the maintenance team easy access to reading meter data.

When grid operators have a clear understanding of the health of their own assets as well as that of demand and alternative supply sources, they have better chances of avoiding significant faults and recovering quickly from those that occur. Grid communications also make it easier to encourage bidirectional power. EVs and solar panels as well as home storage can be viable sources of power back to the grid during times of peak demand. Making these bidirectional connections work in a safe and trustworthy manner is essential.

As part of our continued investment in the future of the grid, we are advancing the components required to enable EV charging, both on the charger connected to the grid as well as the battery-management system within EVs. With the potential for high voltage from the grid and from EV batteries, isolated devices are essential for any EV charging or battery-management system design. These devices include communication and protection circuitry such as isolated and non-isolated amplifiers, isolated and non-isolated interface ICs, and power for signal isolators. To learn more about key trends for grid infrastructure, please refer to our white paper ***Modernizing the Grid to Make it More Connected, Reliable, and Secure***.

Connected vehicles



Today's vehicles have driving features and infotainment options to propel a safer, more convenient experience, all fueled by wired and wireless communications. Vehicle systems are constantly processing and passing sensor data for maintenance, weather, and traffic, sometimes making autonomous decisions or notifying drivers of present conditions. It is expected that communication technologies in our vehicles must be ready to work reliably anywhere and at any time. Unlike many consumer electronics which can be optimized for room temperature operation, vehicle connectivity cannot degrade in bad weather or shut down temporarily on a hot day, and that's why we design with harsh environments and longevity in mind.

FPD-Link serializers and deserializers, which carry high-resolution uncompressed video for a variety of video interfaces across automotive systems, support advanced driver assistance systems (ADAS) and infotainment displays. High-speed connectivity is important so that data from cameras can remain uncompressed and then processed immediately upon arrival. Decoding delays

of even a fraction of a second could lead self-driving systems to miss a hazard and create a dangerous situation.

Automotive 100/1000BASE-T1 single-pair Ethernet (SPE) is also driving the evolution of communication in vehicles, supporting faster, and more precise data transfer, enabling the next generation of ADAS computing, and enhancing the driving experience. The introduction of multidrop SPE (10BASE-T1S) will further enhance connectivity and efficiency. From corner radar synchronization to the digital instrument cluster, automotive SPE enables applications that bring safety, security and quality of life to every vehicle. TI participates in the advancement of standard protocols such as **LIN and CAN** which carry a variety of data between dozens of vehicle components, including the current CAN XL generation that offer much higher speeds.

Electric vehicle (EV) battery management systems must communicate to ensure proper charge balance across cells while avoiding overheating or other battery damage during the charging process. The growing EV charging station infrastructure is an area to keep watching, relying heavily on both vehicle-to-charger and charger-to-grid communication (bidirectional charging). Because charging stations are deployed in such a wide range of locations ranging from sub-basement parking garages where cellular networks struggle to penetrate, to remote outposts that may lack public LTE/5G coverage at all, their connectivity needs are not cookie-cutter.

Chargers designed with flexible connectivity will make stronger investments and be more resilient to changes in the fast-evolving EV market. Additionally, the high voltages present in EVs themselves and EV charging require further protection. In order to ensure that any individuals or subsystems are protected from such high voltages, **digital isolator** devices and **isolated interface** devices are key products that are used in key applications such as battery management systems, on-board chargers and traction inverters.

Addition by subtraction is also key to EV growth and improvement. Reducing weight is one of the surest ways to improve overall EV efficiency and value. As connectivity needs grow, however, so too does the amount of cabling and wireless connectivity hardware inside the EV. Reducing the size and complexity of internal network cabling directly cuts weight, and by simplifying the rest of the vehicle's design can help other subsystems be smaller and lighter as well.

Expanding the use of open connectivity standards such as PCIe, a bidirectional high-speed serial buses that meet high-bandwidth, ultralow latency performance requirements, can improve links between systems while also reducing the number of discrete processor chips in the design. Because PCIe supports one root complex or central processing unit (CPU) to many end points or receivers, having a centralized and modular design with PCIe can significantly reduce the overall ECUs and cables needed in a car. **WMBS** can also improve communication between battery modules. The cleaner and more integrated the connections between components, the better and safer vehicles can be.

Convenience and infotainment features are also demanding new solutions to enable information sharing, media playback, and consumer mobile device charging inside the vehicle. The ubiquitous interface USB is being adopted more widely in response to this demand, used widely for playing back music, uploading and displaying GPS maps to in-car display, working with Apple Carplay or Android Auto applications, and uploading contacts for in-vehicle calling. The faster, more capable USB Type-C solutions can allow passengers to watch movies, surf the web and social media, even play video games over the internet all while riding in their car or waiting for a charge. Automotive SPE with integrated AVB (Audio Video Bridge) technology provides highly synchronous audio playback. For many convenience features, Bluetooth LE allows for remote start and stop as well as open and lock from a smartphone, and even **maintenance alerts**

such as tire pressure monitoring for communication to the diagnostics system.

Conclusion

There is not a single right or wrong approach to **connectivity**, nor is there a one-size-fits-all approach for industrial and automotive designs. There is a strong role for both wired and wireless technologies—which is why we make significant R&D investments in both fields.

What matters is that data and insights go from where they are to where they need to be, processed to where they need to be understood and turned into action. And it is on those connective arteries that we expect a wealth of smarter and better decisions to be made—decisions about how we live and work and marshal the finite resources of our world.

By supporting advances in wired and wireless technology and resources, we are proudly participating in this next-generation of intelligent infrastructure. By ensuring breadth of choice as well as soundness in quality, reliability, flexibility and innovation, we work toward the day we can all take for granted that the connectivity our world needs is always available, and always suited to the challenges and opportunities at hand.

Additional Resources

- Watch the video **Creating new possibilities with connectivity**
- Learn more about factory communication in **our company blog**
- Discover how TI is advancing **ADAS communications protocols**
- Explore ways to **modernize the grid** through connectivity

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