ADDRESSING THE TIME TO CHARGE INDUSTRIAL AND COMMERCIAL TRANSPORTATION VEHICLES

The Future of E-mobility, Expertly Engineered

For a business operation, meeting the needs of customers is a given. When that business is in the transportation sector, those needs can usually be summarized as providing on-time delivery at the lowest cost to the customer. Businesses want to minimize total cost of ownership (TCO) while still meeting customer demands to drive their profitability and operational efficiency.

Each one of the concerns illustrated below in Figure 1 is directly related to the challenges that the industrial and commercial transportation (ICT) industry is currently addressing. Each one affects TCO in some way, and each one will eventually be solved. One of these key challenges facing the industry today is the time to charge a battery electric vehicle (BEV).

There are many commercial applications where time to charge is not the biggest concern. City buses, for example, can adopt full electric propulsion architectures very quickly. Cities across the US and Europe are introducing electric buses for municipal applications. China has focused on bus fleet electrification and 72% of China's public buses are expected to be electric by 2025. These buses run well-defined routes and have dedicated recharging stations in their parking garages.

School buses are another candidate for BEV quick adoption. They are used a small percentage of the day and travel well-defined routes. Local (last mile) deliveries from postal services or package services are also in a position to quickly adopt BEVs.

For other commercial applications, the move to BEV propulsion is not so straightforward. For a long-haul transportation business moving products, people, or produce, a delay of hours to recharge a truck or bus is simply unacceptable. Goods need to arrive at their intended location quickly and on-time. Travelers booking passage on a cross-country motor coach cannot be expected to stop every few hours and then wait a few more hours to charge the bus. Time to charge must at least be on par with diesel refueling.

As US statesman and scientist Benjamin Franklin once said, time is money. Long charging delays lead to fewer customers, less throughput, and lower revenues.

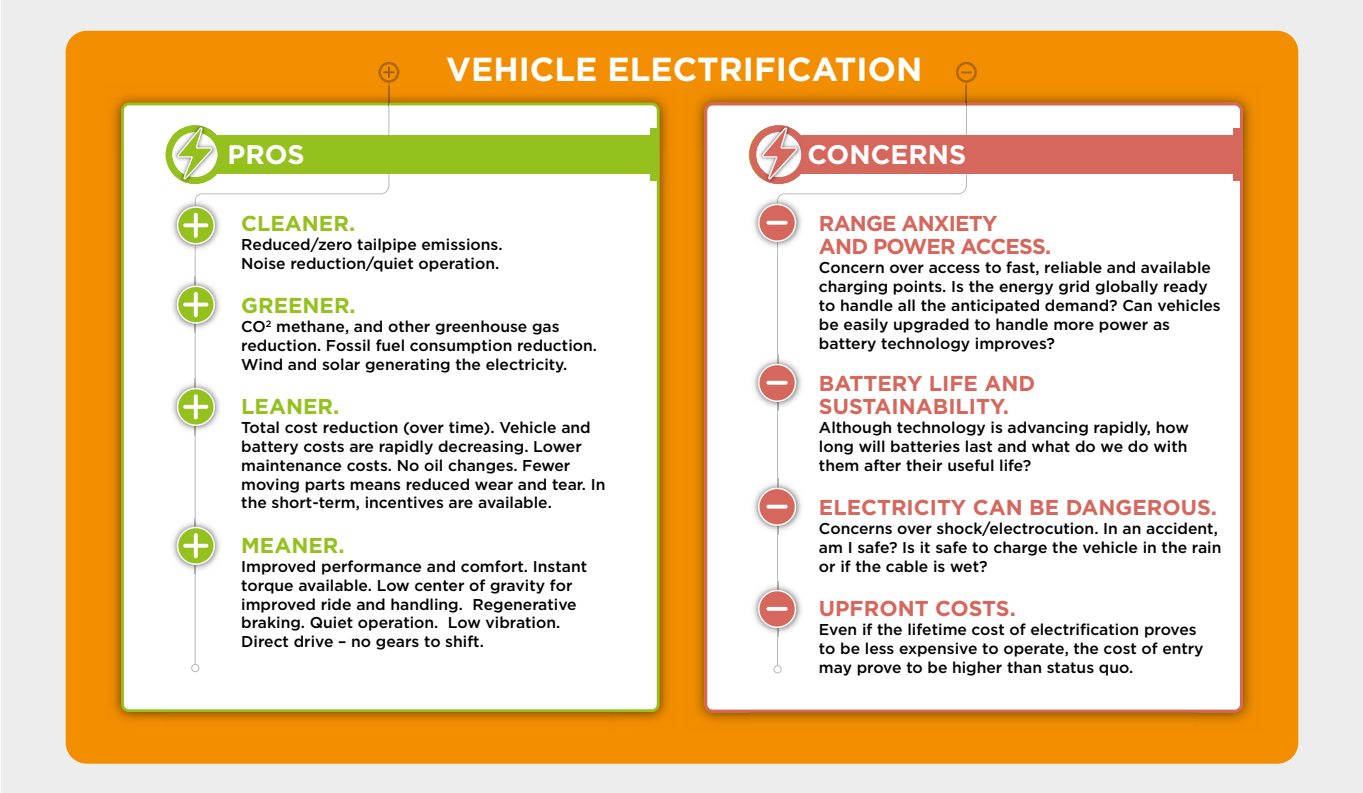

Figure 1: Vehicle Electrification – Pros and Concerns

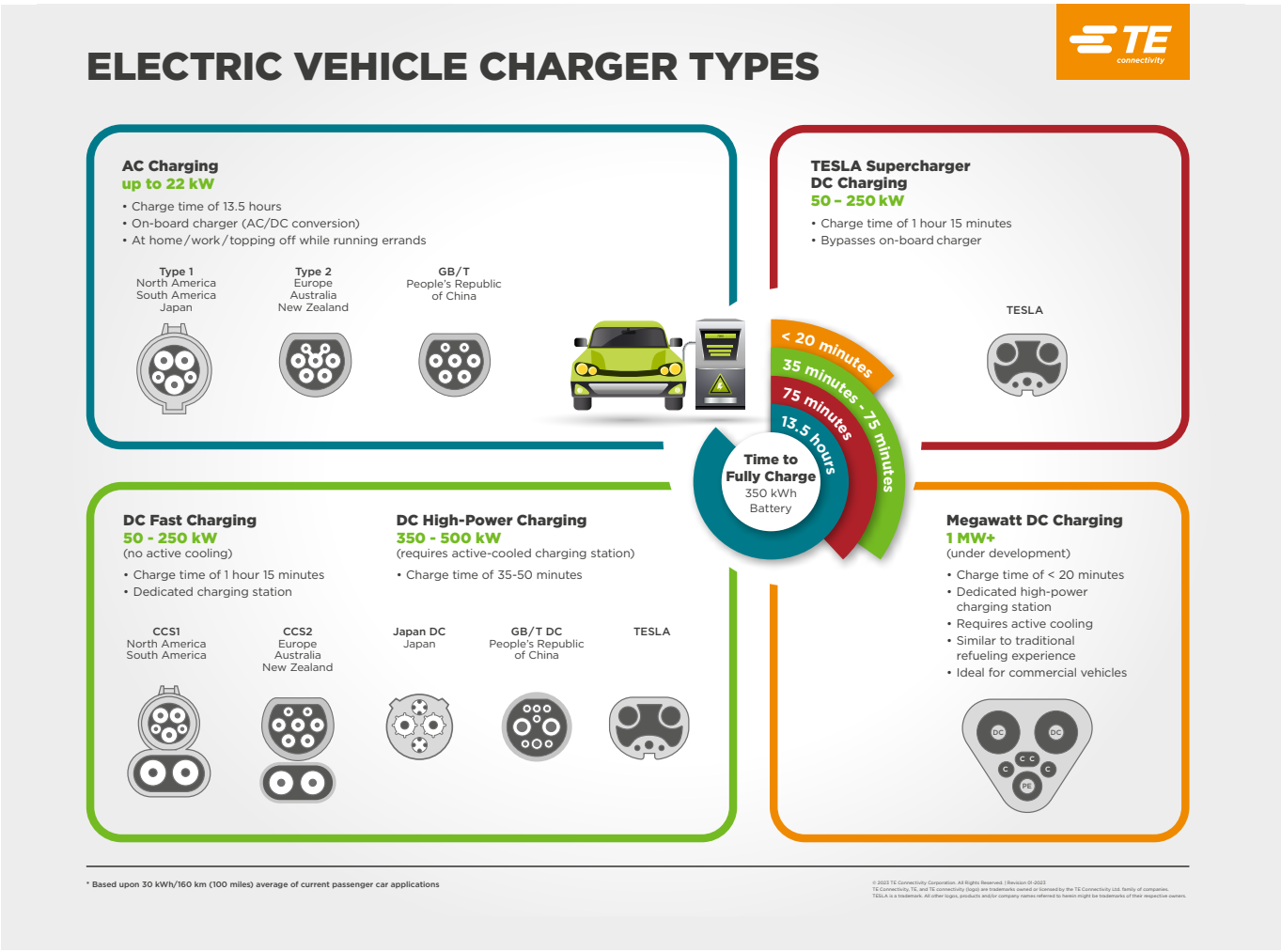

Figure 2: Charger Types Overview

The Industry is Focusing on Providing a Faster Charging Infrastructure

Electric vehicle charging stations seem to be popping up everywhere. But in reality, the ability to quickly and conveniently charge one's car (let alone a heavy-duty long-haul truck) pales in comparison to the availability to do so at a diesel or petrol station. The transportation and power utility industries are hard at work addressing this critical industry need, as demonstrated in figure 2 on the previous page..

Today's available fast chargers, providing between 50 to 250 kW, typically can add just under 200 miles of driving range in one hour for a typical electric car. Currently, the industry is developing high-power charging (HPC) to provide the same amount of charge (200 miles of range) in 10 minutes or less, producing an experience similar to filling up your gas tank in an internal combustion engine (ICE) vehicle. The commercial vehicle segment, with larger batteries and longer journeys, has a strong need for even higher power charging capability, given the large battery capacities for their applications.

Several groups, including the Society of Automotive Engineers (SAE), CharIN E.V., and the CHAdeMO association are working to develop charging standards for electric vehicles worldwide.

Several protocols and physical interfaces have been developed along the way by these industry-wide bodies. Work is underway to establish and accelerate ultrafast DC charging. While the exact implementation of a standard is still under debate and discussion, it is certain that at some point in the not-too-distant future an ultrafast DC charging capability will exist. Whether via plug-in charging stations as outlined in Figure 2, or via pantograph, ensuring that vehicles are ready to take advantage of ultrafast charging cannot wait until the standard interface is defined.

Vehicles face Technical Challenges related to Fast-Charging Connectivity

Will vehicles be ready to effectively handle 500 KW charging? 1MW and beyond charging? Although the need to be able to charge a vehicle in minutes rather than hours is apparent, the way to safely and effectively address this requirement is not as obvious.

These demands are driving the industry to focus on a broad range of solutions to solve never-before-seen challenges. Charging inlets must be able to handle 10 to 20 times the power of the current generation of electric cars. Trying to

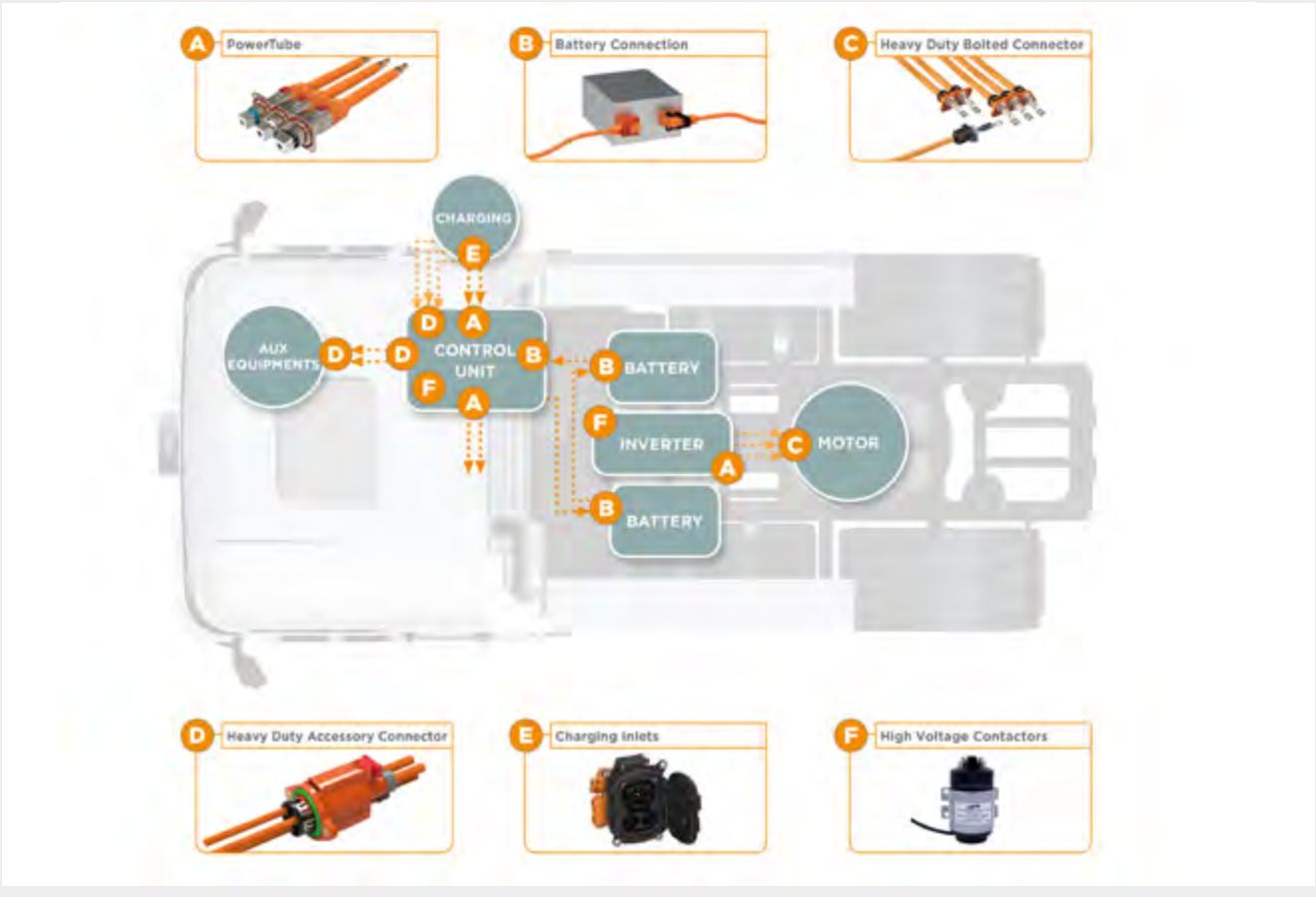

Figure 3. Solutions for Industrial and Commercial Transportation Electrification Architectures

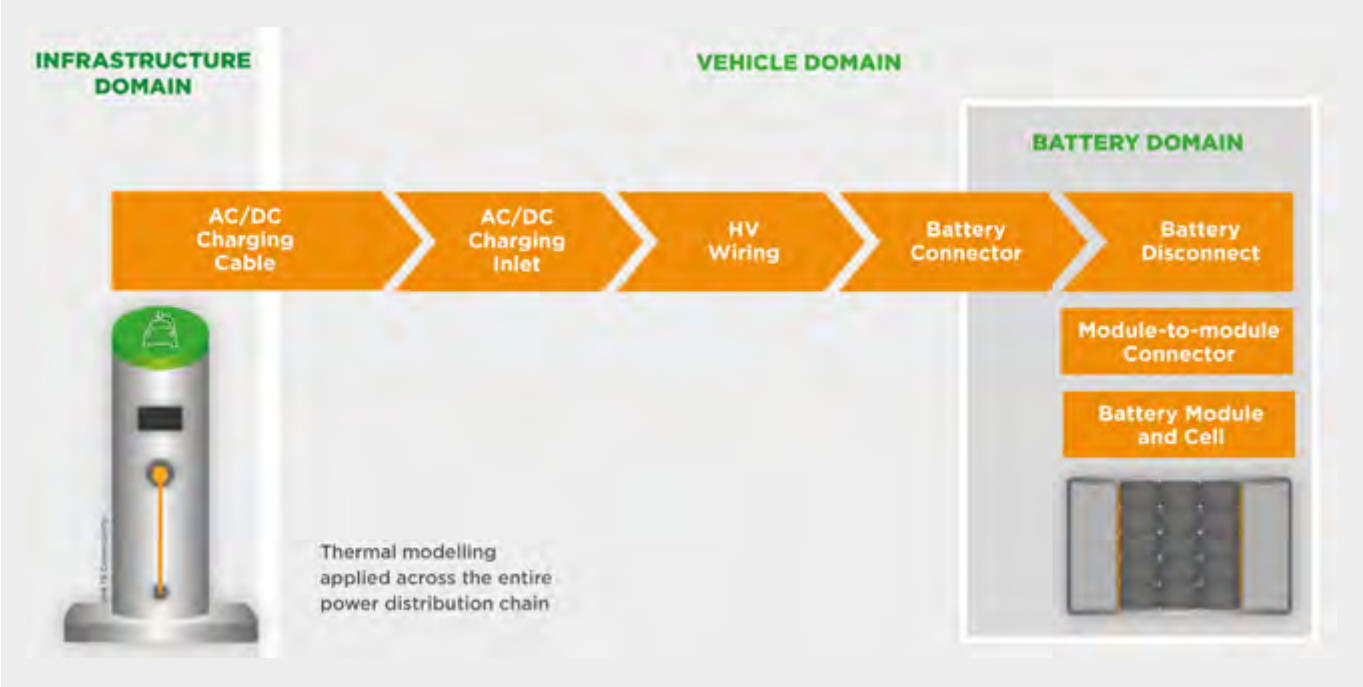

Figure 4: High Power Connectivity Path: Thermal Modelling

push up to 1 (or more) Megawatts of power through an inlet sized to handle 50 kilowatts is akin to someone trying to drink from a firehose. Connections, cables, and switches/ contactors must all be able to intelligently manage this power transfer, dealing with heat, arcing, and safety issues. New thermal modeling and simulations techniques need to be developed, allowing for optimized design of components and subsystems that can be stressed by the high charging voltage and current needs.

Accurate sensing, both contacting and non-contacting, needs to provide real-time information for intelligent power management.

Figure 3 shows a simplified representation of a connectivity architecture that each vehicle manufacturer develops and customizes to its needs. As a connectivity supplier, TE works closely with customers to support their success by providing robust solutions tailored to their specific needs and vehicle architectures. Specifically, for fast charging, TE supports customers by breaking down application requirements from the charging inlet through the battery by answering a series of smaller, more focused questions. When we work with our customers, we help them evaluate:

- How do vehicles best address varying global standards? Referencing Figure 2, there are many competing worldwide standards for the charging plug interface, each with their own advantages and disadvantages. TE, working with global customers and across multiple transportation segments, has tailored solutions to match the market needs. TE Connectivity, working with global customers and across multiple transportation segments, has tailored solutions to match the market needs. Utilizing our HIVONEX product portfolio, we provide a modular, platform building block approach which enables TE to quickly and cost-effectively deliver the right solutions at the right time for all ICT applications.
- Does more power mean more heat? Thermal management for charging is the biggest challenge for the inlet, plug, and cable. Simple physics dictates that P=V*I; Heat = I2R (where P = Power; V = Voltage; I = Current; R = Resistance). Typical battery packs are currently at 800 V. Moving from 50 kW (480 Vx100A) to 350 kW (800 Vx437.5A) is ~7X increase in power for 25X increase in heat. TE has an in-house electro-thermal modeling and simulation capability, allowing for optimized design of components and subsystems that can be stressed by the high charging voltage and current needs.
- Does the higher power required to do fast charging drive technology advances in the vehicle charging inlet? TE has developed charging inlets, as part of our HIVONEX product portfolio with integrated sensing and actuation capability, to allow for intelligent charging control while providing touch-safe operation and charging state feedback safely and reliably. These inlets can be scaled to accommodate varying customer electrical/electronic architectures inside the vehicle, from discrete point-to-point operation or via distributed intelligent control. TE's architecture and electronics teams delivers solutions to fit varying charging station approaches and protocols.
- Does higher power mean bigger wires and bigger connections? Currents exceeding 200A require cooling to keep cable and connector sizes manageable from the charging station to the vehicle. The ergonomics of such a large connector would not be physically possible to connect without mechanical assistance. While the

connection from the inlet need not be physically handled like a charging cable, it still needs to be as small, light, and cost-efficient as possible. TE works with customers to proactively address these complex problems, leveraging material science and contacts physics expertise as well as employing active cooling and advanced power management techniques in creating innovative new solutions. Figure 4 illustrates some of the cooling opportunities along the high power connectivity path.

- What is the safety impact of the higher power requirement for fast charging? The higher the power and voltage, the higher the safety risk. Charging interfaces are limited to 1000 V due to voltage safety concerns. It is critical to manage temperatures, so people don't burn themselves touching the charging handle. TE Connectivity works with customers to provide connectivity solutions to address these challenges. Our HIVONEX charging inlet products are specifically designed to meet the high voltage and temperature requirements of the ICT market. By integrating sensing (temperature, voltage, current) all along the current path, as well as providing controllable elements (contactors, relays, smart inlets, smart actuators), TE's customers have different levers they can use to intelligently manage and safely control the power path from beginning to end.
- Can in-vehicle battery connections handle the increased power? Battery technology development is a prime area of industry investment. Increasing the driving distance on a single charge means batteries are needed with increased power density. The challenge is how to maximize power per Cm^3 while minimizing the package size and keeping costs under control. TE Connectivity is developing high-voltage, physically compliant, battery module contacts and connection interfaces enabling battery pack scalability for our customers. They are robust, harsh environment interconnects with integrated current, voltage, and temperature sensing, enabling smart control of battery management (state-of-charge and state-of-health). This enables customers to balance the active chemical mass versus the mechanical overhead of the battery system.

TE Connectivity as the Supplier of Choice

In summary, there is a strong industry need to deliver more power to the battery in a shorter amount of time (from hours to minutes) to refuel vehicles for long-haul commercial applications. More power means more heat and more component stress within the vehicle from the charging inlet to the battery. This phenomenon must be intelligently managed. Contacting and non-contacting sensing techniques are needed to provide accurate, real-time temperature, voltage, and current information. To address these challenges, TE Connectivity's team of engineers and scientists engage closely with customers and help support their success by developing robust solutions tailored to their specific needs and vehicle architectures for the harshest of environments today and well into the future.

We are a system-knowledgeable connectivity solutions supplier with electronics architecture and physical integration expertise, enabling us to speak our customers' technical language. We support our customers with a comprehensive product portfolio, technical design expertise and know-how, manufacturing and application tooling

prowess, and leveraging the power of TE - our depth and breadth of industries and markets served by our engineers, scientists, and global presence.

Product Portfolio

As a global leader in connectivity solutions, we collaborate with our customers and other industry technology leaders to create engineered solutions that address the diverse architectural needs for high power connectivity solutions. We have a strong HIVONEX product portfolio of terminals and connectors tailored to meet increasing power and vibration requirements.

We can now provide fast charging interconnects with our HIVONEX Powertube series. Both high current charging for DC and HV circuits. Available in different orientations to cater to the customers' needs in their HV applications. Extensively tested for robustness and validated to the harshest
conditions, and shielding to protect against EMI/EMC.

We can provide robust, harsh environment interconnects with integrated current, voltage, and temperature sensing enabling smart control of battery management (state-of-charge and state-of-health). To round out the HIVONEX product portfolio, we offer high-voltage contactors (electronically controllable switches) and high voltage connectors such as PowerTube enabling safe and efficient power switching and distribution for intelligent and optimized charging.

Technical design expertise and know-how

Drawing upon more than 75 years of physical connection systems expertise, TE's team of engineers, contact physicists, and material scientists work closely with customers to develop optimized solutions to ever-increasing connectivity demands and challenges.

With design centers around the world, all the simulation, modeling, prototyping, and testing can be done close to where our customers are located. Additional technical capability includes: RF design and EMC expertise; design, manufacturing, and application tooling expertise in miniaturized and compliant interconnect technology enabling small, robust packaging; seamless electronics integration; environmental test and development laboratories at design locations to support both ends of the product development cycle; tools and equipment to optimize designs to customers' ever-evolving operating environment needs.

Depth and breadth of industries served and global presence

TE serves a vast array of customers representing diverse industries and markets including consumer electronics, aerospace and defense, industrial, appliances, transportation, to name a few. By linking and leveraging across our company, our industrial and commercial transportation-focused engineers can draw upon the knowledge and experience of colleagues across the globe to solve ICT industry challenges.

We participate in various standards committees and industry consortia, enabling us to address problem solutions early in the process. We invest extensively in upfront R&D, seeking to collaborate on solving tough industry challenges before they become problems for our customers.

Manufacturing and application tooling

As a global manufacturer of connectivity solutions with an in-house application tooling business unit, we not only practice world-class manufacturing process for our products, but also confirm that our product designs align with specific customers' manufacturing methods and practices. TE's active partnerships with groundbreaking manufacturing technology allows us to widen the scope of capabilities for our customers. We work with the complete supply chain, from harness makers to module makers to system suppliers, to provide optimized system-level performance for high power connectivity. We provide the right power connectivity solution for the specific application and need.

To connect with us click here

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ABOUT TE CONNECTIVITY

TE Connectivity is a global industrial technology leader creating a safer, sustainable, productive, and connected future. Our broad range of connectivity and sensor solutions, proven in the harshest environments, enable advancements in transportation, industrial applications, medical technology, energy, data communications, and the home. With more than 85,000 employees, including over 8,000 engineers, working alongside customers in approximately 140 countries, TE ensures that EVERY CONNECTION COUNTS. Learn more at **www.te.com** and on LinkedIn, Facebook, WeChat and Twitter.

LET'S CONNECT

We make it easy to connect with our experts and are ready to provide all the support you need. For additional information or product assistance, please contact your field representative or our customer service department. Additional information is also available on the website **te.com/ict.**

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