Highlight 1

TDK's Technological Innovations: Creating Solutions for Global Issues

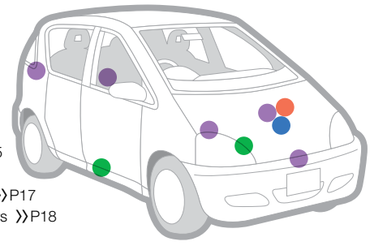
In the world of automobiles, the shift to hybrid electric vehicles (HEVs) and electric vehicles (EVs) and similar forms of transport is well under way, with the aim of solving global environment issues. Electronic components used in such cars must be compact, lightweight, as well as highly efficient and reliable. This special report deals with the field of car electronics which is a major focus of TDK's operations. We talked with developers of key components and introduce the opinions of people who are involved in contributing to society through their work.

What makes TDK automotive components special?

Development at TDK does not mean simply shuffling around existing ingredients. We start from scratch, i.e. the raw materials and use our expertise to meet the wide and varied needs of our customers. We also define our own, highly demanding quality standards, so that TDK can provide products with full confidence.

Market needs
- ☐ Compliance with stricter fuel economy regulations
- ☐ Move away from fossil fuels
- ☐ Improved safety
- ☐ Improved comfort

Technology based solutions
- ☐ Smaller dimensions and lighter weight
- ☐ High efficiency
- ☐ High reliability
- ☐ Move away from rare metals



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"Three core technologies" from TDK

TDK products are solidly based on three core technologies. Materials technology is the starting point and the source of our product power. Process technology brings out the potential of each material to the fullest. Evaluation & simulation technology allows us to utilize our accumulated know-how for pushing the envelope and blazing new trails. These three aspects are closely interwoven and enable us to create innovative, outstanding products that help solve important issues facing today's society.

Develop and refine materials through in-depth knowledge

Utilize nanotechnology to realize designs that meet advanced and specialized needs

Use advanced analysis and simulation techniques, noise measurements, etc. to sustain the creation of new products

Grasping the true needs of customers to build a win-win relationship

I belong to the Automotive Marketing Group. I present products to customers both in Japan and overseas, visit plants to assess requirements, and provide follow-up. If I want customers to see the advantages of our products, I of course first have to thoroughly know and understand them ourselves. I therefore work closely together with the technical departments and communicate not only by email and telephone but also often face-to-face.

One of the main tenets that I stick to when dealing with customers is to always keep a promise. Often this also means that, when asked to provide such and such a product, I will not simply accept the customer's description and say "can do." I first have to explore the background for the request and get a firm grip of what is actually required, and what TDK can do towards meeting the requirement. In order to enable a fuller assessment, design engineers sometimes will come along on our customer visits.

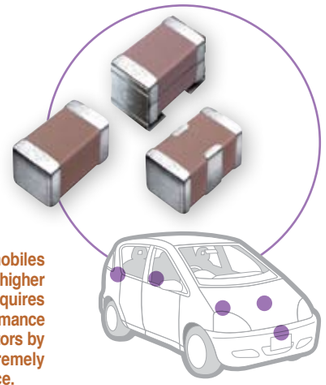
In building a relationship with a customer, I aim for a scenario that comes out as win-win, that is beneficial to them and to us. And I am most proud and happy when the customer recognizes our efforts by selecting our product, or when I get calls assuring us that "TDK is a company we depend on." This puts our day-to-day work in a larger context involving a connection among numerous people.

TDK-EPC Corporation
Electronic Components Sales & Marketing Group
Automotive Sales Strategy Group 2

Takahiro Chihara

Capacitors

Materials Technology | Process Technology



Quickly responding to market needs with quality products providing high capacitance and stable performance in high-temperature environments

Capacitors are important components that serve to store an electrical charge. Primarily used in automobiles are multilayer ceramic chip capacitors which are becoming increasingly smaller while providing higher capacitance. For example, the harsh environment inside the engine compartment of a car requires components that can resist strong shocks and vibrations, while also maintaining their rated performance over an extremely wide temperature range—from bitter cold to searing heat. TDK outpaced competitors by introducing the X8R class of multilayer ceramic chip capacitors which are guaranteed to withstand extremely high temperatures, and the company continues to develop capacitors with even greater performance.

TDK-EPC Corporation
Ceramic Capacitors Business Group
Applied Products Department, Design Section

Atsushi Takeda (left),
Takeru Yoshida (right)

Down-to-earth research and development

The basic parameters of a capacitor are its capacitance rating, i.e. how much electricity it can store, and its temperature characteristics, which refers to how stable the capacitance remains at various temperatures. Multilayer ceramic chip capacitors achieve high capacitance by integrating numerous dielectric and electrode layers in a sandwich-like configuration. The X8R type from TDK features characteristics that change only by a maximum of 15 percent over a range from -55 to +150 degrees centigrade. Based on the technology developed for this existing product line introduced in 2001, development of capacitors with higher capacity through increasing the number of layers is under way.

Severe restrictions exist regarding the thickness of a product, since this is part of its specifications. Making improvements therefore demands highly advanced technology. For example, having to fit some 600 plus layers into a 2.5 mm space presents the question of how to shave off some tenths of a micron per layer. At the same voltage rating, the thinner the dielectric the shorter the life of the capacitor. To reduce thickness by half, life of material must be extended by a factor of 10. Such difficult and sometimes conflicting goals are approached through extended test runs in close collaboration with the Materials & Process Development Center. Even if the material on its own tests fine, results may differ when it is tightly packed in hundreds of layers. These complexities make multilayer ceramic chip capacitors a highly challenging field.

Towards an even wider temperature range

Products that will be used in the automotive environment where high temperatures are to be expected must maintain their reliability for many years after installation. Even seemingly minor aspects, such as the terminals that link the capacitor to the circuit board, must be developed with great care. Many dozens of test samples are produced and evaluated according to some 10 to 20 performance parameters. This process can frequently take as long as a year.

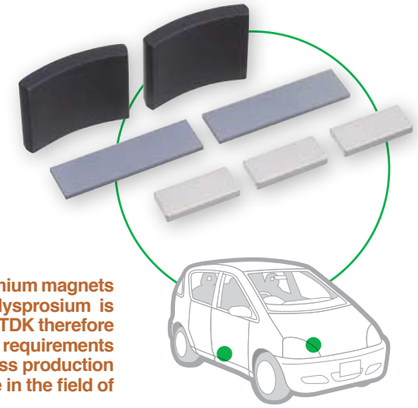
An increasingly frequent request from customers these days is for multilayer ceramic capacitors that can withstand even higher temperatures than current products. This has to do with the fact that components in DC-DC converters, namely power supply equipment found not only in automobiles but also in various household appliances and other products, increasingly use silicon carbide*, a material offering performance characteristics that do not deteriorate even at 150 degrees centigrade and higher. Multilayer ceramic chip capacitors used in the peripheral circuitry of DC-DC converters therefore also need to maintain their performance into this temperature range. TDK is determined to rise to the challenge again. A spirit of boldly entering new realms is essential. The occasional failure comes with the territory and should not be feared. However, the important thing is to learn from failures and build momentum towards the next step.

The components that we create are almost never actually seen by the consumer. But without these components, many of the end products being used in society simply would not function. This inspires us to do our best each and every time.

* Silicon carbide: A compound of carbon and silicon that is renowned for its hardness, heat resistance, and chemical stability.

Magnets

Materials Technology | Process Technology



New processes reduce reliance on rare earth materials and open up new possibilities for magnets and motors

Dysprosium, a rare earth material, is indispensable for manufacturing neodymium magnets which are the strongest permanent magnets. However, since nearly all dysprosium is sourced from China, a stable supply may not always be assured. Since 2006, TDK therefore has been working on a new manufacturing process which reduces dysprosium requirements to about 20 to 50 percent as compared to conventional methods. In 2010, mass production using the new process has started. This development is relevant for example in the field of motors for electric vehicles, where neodymium magnets play a crucial role.

TDK Corporation
Ferrite & Magnet Products Business Group
Product Development Department, Product Development Section 1

Makoto Iwasaki

Bringing a new process to mass production

I was involved with development of the process from the beginning and have now overseen its move into mass production. Neodymium magnets require doping with dysprosium to achieve heat resistance, but there is also a negative effect, because the more dysprosium is used, the less magnet performs. Because dysprosium is very rare and therefore costly, a method that would allow reducing dysprosium use has long been a theme in the industry.

Normally, a neodymium magnet is formed by pulverizing an alloy containing dysprosium and then applying heat treatment. By contrast, with TDK's new method called HAL (High-Anisotropic field Layer), the magnet is first shaped to the required size, and only then is the dysprosium dispersed on the surface. This allows us to achieve the same high heat resistance and coercivity while using significantly less dysprosium.

The major hurdle that had to be overcome on the way to applying this process to mass production was finding a method for reliable quality management. So far, the quality of magnet material used to be evaluated in lot units. However, with the HAL process the characteristics of the neodymium magnets can differ, depending on the size and shape of the magnet. Therefore, quality management needs to be more granular, looking at the individual magnet. This idea paved the way for the breakthrough to mass production.

Once we got to this point, all of our team members strongly felt that the new method would change the way we think about neodymium magnets, that it would bring about a sea change in the magnet industry. The realization of mass production capability became a major project that involved almost all sections within the Ferrite & Magnet Products Business Group dealing with metallic magnets. Marketing and materials procurement, production technology, and various other sections

contributed valuable information and advice. For this I feel truly thankful.

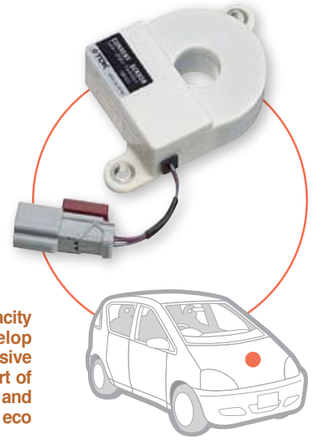
Mass production outlook for other products

Currently, mass production using the HAL process has started for products used in industrial equipment and home appliances, but intensive efforts to laterally expand it to other products are ongoing. In particular, neodymium magnets are indispensable for low-pollution vehicles such as electric cars and hybrids. In the automotive environment where high temperatures, strong vibrations and other severe conditions are the norm, high reliability is a key aspect. We are aiming to establish a mass production framework for the new technology, taking these special demands into account.

Neodymium magnets which are mainly used in motors of various kinds should be designed from the outset with the desired characteristics of the motor for the respective application in mind. Rather than simply fulfilling a list of required specs, this will allow us to propose optimal solutions. The problem should not be tackled in isolation, looking only at magnets or only at motors. We need to find common ground, also with the motor designers at the customer. The HAL process which allows individual management of magnetic characteristics for each magnet has enormous practical application potential in this regard.

Current Sensors

Process Technology | Evaluation & Simulation Technology

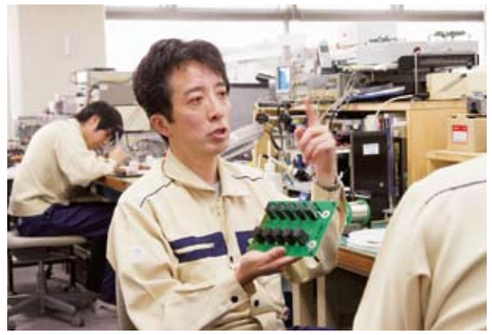


Increased accuracy of current measurement boosts performance and makes energy use notably more efficient

In hybrids and electric vehicles, correctly assessing and controlling remaining battery capacity is crucial for improved fuel economy. With this in mind, TDK set out in 2002 to develop current sensors that would help to protect the battery bank from overcharging and excessive discharging, thereby extending battery life. 2005 saw the successful mass production start of a current sensor for hybrid vehicles, featuring a maximum measurement tolerance of 1% and a measurement range of ±200 amperes. With the aim of extending the technology to other eco cars, a wide range of products is currently under development.

TDK-EPC Corporation
Sensors Business Group
Sensor Department

Teiichiro Oka



Realizing higher product reliability

I am in charge of design verification and customer follow-up. It was in 2007 that TDK was selected as a supplier of current sensors for a new model hybrid electric vehicle from a major manufacturer. Right from the outset, the customer presented us with strict demands in terms of the reliability and performance required for automotive use. Thanks to our accumulated technological know-how, we were able to meet the lead-free stipulation for soldering and circuit components. We also were able to greatly reduce power consumption by adopting a single power supply design using 5 V.

The magnetic balancing method used by TDK for current detection by principle provides high precision, but there is still the risk of tolerances due to the various circuit parts used in the sensor. It is also possible that a component selected to fulfill a certain purpose at one point may interfere with another part or section, leading to unforeseen consequences. To achieve performance that is 100 % assured, aspects such as circuit design and parts selection were often worked on and reworked carefully by all members of our team in a long, laborious process. At times likes these, it is fortunate that we have a constructive work environment and like to help each other out. In the end, this made it possible for us to overcome the various difficulties.

Because the various auto manufacturers implement latest proprietary technology in their eco cars, standardizing a sensor for current measurements is a difficult task. By applying TDK's broad know-how that takes manufacturing aspects into consideration already from the design stage, we are working on a viable solution. Detailed customization to meet the respective demands of customers is of course possible and necessary, but in the medium to long term, standardization to cover the greatest common factor is a requirement of sound product policy. The resulting cost reduction then flows back as an advantage to the entire automotive industry.

Developing the next-generation current sensor

At the moment, we are working on the next generation of sensors that may use different current detection elements. Most current sensors at the moment have a Hall element and make use of the Hall effect (electromotive force generated when a magnetic field is applied to a conductor or semiconductor through which an electric current flows), but in future these may be replaced by sensors with an MR element using the magnetoresistive effect. Their higher sensitivity to the magnetic field should enable the construction of new sensor types that have cost advantages over current products. TDK is applying MR element know-how acquired through the development of magnetic heads for hard disk drives to develop and market current sensors for a wide range of applications.

The most talked about application at the moment of course is eco cars, but current sensors can be used to achieve efficient energy use also in other areas. In future, Smart Grid and eco house related applications are on the horizon, and we are also preparing to meet latent demand for sensors to be used in various other electric products. Through these efforts, I hope to contribute more and more to improving the environment.

DC-DC Converters

Materials Technology | Process Technology | Evaluation & Simulation Technology

Products with smaller size and lower weight will contribute to improved fuel economy and longer battery life in eco cars

Hybrid electric and electric vehicles must convert the 100 - 400 V of the main battery bank to 14 V for operating various other electrical equipment in the car such as lights and windshield wipers. As the first company in the industry, TDK started working on DC-DC converters for this purpose in 1995. In 2009, the latest models of the GEN4.5 series went into mass production. Featuring thoroughly redesigned parts and a new form factor, these are 45% lighter and 1% more efficient than their predecessors.

TDK Corporation
Technology Group
Device Development Center
EV Development Group

Masahiro Gamo

Collaboration with other departments is the key

I began to work in this sector by joining the Generation 4.5 (GEN4.5) development team. TDK is classifying the basic circuitry of DC-DC converters into generations, starting with Generation 3 (GEN3) which went into mass production in the year 2001. Subsequent to Generation 4, development of Generation 4.5 began in 2005 with a formidable goal, namely to halve both weight and cost of the units. This seemed almost impossible at the outset, but for people working in research and development, comments such as "no way" or "not doable" merely pose a challenge to think about how to begin approaching such a goal.

As a result of various attempts and intensive deliberations, a way to make significant progress was finally discovered: we decided to unify the power components and control board which formerly had used a two-stage configuration. In concrete terms, this meant a re-evaluation of more than 500 parts, looking at them one by one and thinking about how to make them smaller or even eliminate them. At the same time, transformers were also integrated on the control board. The ferrite type PC95 transformer from TDK was selected as main transformer because of its wide temperature range extending from 25 to 120 degrees centigrade and its low-loss characteristics. This product was developed by the TDK Magnetics Business Group upon special request, using a ferrite material that is about 16 % lighter than the material in Generation 4 products. Because TDK is not only a developer of DC-DC converters, but also a transformer manufacturer and a ferrite manufacturer, we have a distinct advantage when it comes to creating products with a special combination of features.

Getting the most out of proprietary technology

After building more than ten prototypes, Generation 4.5 was finally completed. In recognition of the contribution to fuel economy and battery life afforded by its compact dimensions and light weight, the series won the "Conference for the Promotion of Monodzukuri*1 Co-Chair's Award" in the Sixth 'Cho' Monodzukuri Innovative Parts and Components division, a program sponsored by Nikkan Kogyo Shimbun Ltd.*2 As developers, we are proud of the simple elegance of GEN4.5 which does away with all superfluous elements, and our customers seem to agree. That the products also received a third-party prize is an additional source of pride for all those who were involved in the project.

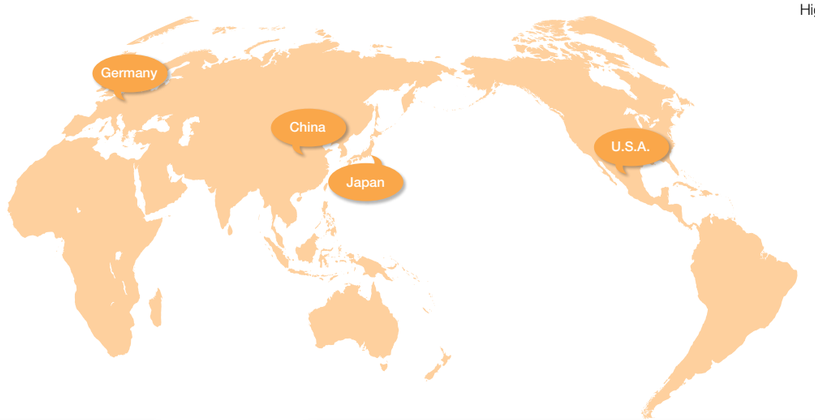
Currently, the implementation of GEN4.5 in a wide range of car models is under preparation, and as developers we have started looking towards Generation 5. For products to be widely accepted in the marketplace, low cost is another crucial factor in addition to compact size. With regard to both of these aspects, TDK is in the fortunate position of being able to utilize its own materials technology. We should leverage this advantage to devise unique products. Close cooperation with other departments is essential while we pursue the central task of electronic components and materials development, to create not only advanced DC-DC converters but many other kinds of products that make a difference and contribute something to the world at large.

*1: "Monodzukuri" is craftsmanship in manufacturing with special emphasis on continual improvement.
*2: Daily Newspaper, specialized in business and industry (Japanese language only)

The People Behind the Products

The Role of Technological Innovation in Society

Before TDK products reach our customers, many people around the world have already been involved in myriad ways.
We asked some of these people to comment on how they see their daily work within the larger context of creating products that contribute to society through technological innovation.



Design & Development

Germany
EPCOS AG
Product Development
Pressure-Transmitters (SEN PD PS T)

Bert Hundertmark

My work: Developing new fuel sensors for the pressure transmitter department

Most sensor development is done according to customer specifications, and one needs to be fully aware of new challenges and their applications. This also relates to the development of a range of sensors designed to maintain high accuracy of the fuel system over time when adopting new fuels. Through the development of fuel sensors that are also found in HEVs etc., enabling the use of fuels that are kind to the environment, I hope to contribute to the preservation of the fossil fuel resources of our planet.

Procurement

Japan
TDK Corporation
Ferrite & Magnetic Products Business Group
Planning Management Department, Procurement Strategy Section

Kazuya Sakamoto

My work: Magnet materials procurement, and procurement strategy planning

When procuring raw materials, it is of course necessary to obtain and analyze a vast amount of information. I also try to actually visit source locations and ascertain the reliability of information through various means. In the field of HEVs and EVs, Japan is playing a leading role and has the potential to contribute to society through many beneficial products.

Production

Germany
EPCOS AG
Front End Production Pressure Sensors (SEN O PS P ST)

Birgit Nowak

My work: Front-end process supervisor for the pressure sensor

The pressure sensors which are my specialty already are shaped to facilitate application by the customer, but I am currently proposing innovations regarding materials and processes. Our goal is not only to reduce material and energy consumption during the manufacturing process but also to enable customers to realize more compact and efficient designs by making our sensors even smaller and more capable.

Production

Japan
TDK Corporation
Ferrite & Magnetic Products Business Group
Production Technology Department, Production Technology Section 1

Hiroshi Miyasaka

My work: Introduction and improvement of metallic magnet processing equipment

My aim is to realize facilities that excel in terms of machining precision, production capacity, and cost. Magnets play an important role in motors, generators, and many other power source devices. By introducing better manufacturing equipment and supplying large quantities of high-performance magnets, I believe TDK can contribute to more efficient use of energy and the realization of an energy-saving society.

Marketing

Germany
EPCOS AG
Product Marketing Sensors (SEN PM)

Holger Hegner

My work: Marketing of temperature and pressure sensors for automobiles

My mission is to enable customers to design their products making optimum use of the performance specs and know-how that we can provide. This is indispensable for combining comfortable drive performance with environment-friendliness. Automotive sensors are used in a wide range of applications. We not only aim to reduce energy consumption by optimizing sensor control, we also pay close attention to weight reduction, ease of recycling and other aspects. By improving the fuel economy of HEVs and EVs, we do our part in helping to solve automobile related problems.

Marketing

Japan
TDK-EPC Corporation
Electronic Components Sales & Marketing Group
Chubu Region Marketing Strategy Section

Kuniyoshi Tsukijima

My work: Marketing of magnet products to car manufacturers and car electric equipment manufacturers

Neodymium magnets for HEVs are custom-produced according to customer specifications. Right from the beginning, we must therefore be clear about customer's requirements and propose the best technical solutions through TDK technology. Communication between the business groups is essential, so that manufacturing and marketing go hand in hand. Through the sale of high-performance neodymium magnets, we contribute to the spread of HEVs and hope to help build a better global environment.

Procurement

Japan
TDK-EPC Corporation
Ceramic Capacitors Business Group
Procurement Section

Atsushi Kudo

My work: Materials procurement for chip capacitor products

As society at large keeps evolving, the environment for materials procurement also has undergone a major change in the past few years. To achieve the most important goals of cost reduction and stable supply, team work is the key, with all members working towards the same objective. I take pride in working to ensure stable materials procurement, so that customers can continue to use our products in full confidence.

Design & Development

Japan
TDK-EPC Corporation
Ceramic Capacitors Business Group
Capacitor Products Group, Large Capacity Product Section

Yoshitomo Matsushita

My work: Ceramic capacitor product design

Ceramic capacitors are often thought of as general-purpose products, leading to a tendency to look towards existing lineups. However, when we develop products, we always keep customers' expectations with regard to specs, quality, and cost in mind. While we do not directly deliver to end users, our work is guided and inspired by the thought of having people use products that incorporate TDK components.

Procurement

Japan
TDK Corporation
Power Systems Business Group
Management Group, Development Purchasing Team

Hisanori Yatomi

My work: Parts supply activities for EVs power supplies

I participate in the design review process from the initial product development stage and make proposals related to cost reduction and green procurement. The age of HEVs and EVs dominance is just about to begin. Parts and materials that I helped to procure are used in the production of high-performance and cost-effective power supplies for EVs. This in turn should contribute towards countering global warming and preserving precious resources.

Quality Assurance

Japan
TDK-EPC Corporation
Ceramic Capacitors Business Group
Quality Assurance Strategy Department, Quality Assurance Section 1

Yukinori Takaki

My work: Development follow-up for new ceramic capacitor

Passive components supplied by TDK are indispensable in automobiles, household appliances, and many other products surrounding our daily lives. By improving the reliability of these parts, we help to reduce breakdowns and contribute to ensuring consumer safety and trust. Preventive measures and risk assessment already during the development stage, along with cooperation among developers, are the tools which I apply to enhance the reliability of product development.

Quality Assurance

Japan
TDK Corporation
Power Systems Business Group
EV Power Supply Business Unit, Quality Management Group

Fumitomo Ueno

My work: Quality assurance of DC-DC converters and chargers for HEVs and EVs applications

Because our department is involved with quality assurance for parts that are crucial for eco cars carrying precious human cargo, we are pursuing a policy of zero defects, which we try to ensure through a completely reliable quality system. By doing so, we want to protect the safety of eco car drivers and passengers, and also contribute to reducing the environmental load and moving towards a low-carbon society by promoting increased HEVs and EVs acceptance.

Marketing

China
TDK (Shanghai) International Trading Co., Ltd.
SCM Dept. IS Group

Kumi Zhu

My work: Automotive marketing IS (Inside Sales)

Operating as an information center, we must be able to swiftly provide to-the-point proposals, which requires us to have a clear image of our work. The team members' mission is to tackle a task however difficult it may seem, and work towards achieving customer satisfaction. Information sharing and team work are therefore essential for providing good services to the customer.

Marketing

U.S.A.
TDK Corporation of America
Sales Mid East Region

Jeremy Jungman

My work: Marketing of chargers and DC-DC converters for EVs

The U.S. has taken a strong initiative to significantly reduce automotive emissions and greenhouse gases. TDK technology has enabled us to bring low-cost, high-performance DC-DC converters as well as chargers and other products for electric vehicles to the market. As an industry leader, we contribute to the reduction of CO_2 emissions through our activities in the EVs sector.