EBOOK

POWER AND THE POTENTIAL OF TOMORROW

Perspectives on the State of Power

JULY 2023

molex

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INTRODUCTION

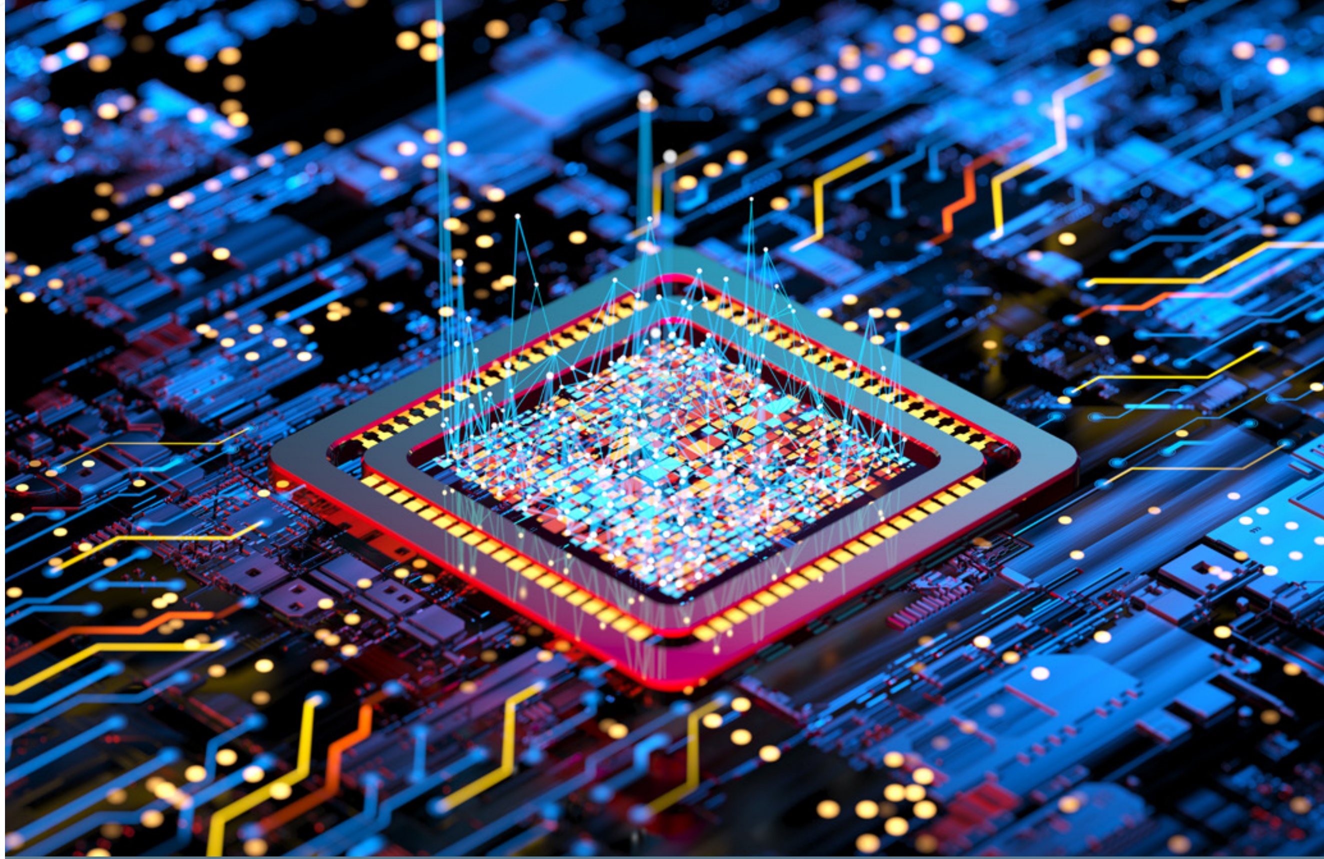
Underneath the explosive growth of data, devices and connectivity lies the infrastructure of power. Will systems have the quantity — and quality — of power needed to keep up with demand?

To answer this question, Molex commissioned Dimensional Research* to survey over 800 qualified engineers with experience in power design about the challenges and opportunities in their field.

The results, published in the **Molex 2023 State of Power**, reveal the current obstacles and future drivers of power system design. But what do these results mean in practice?

Technological transformations are underway in several sectors: data centers and the resource-intensive processing of new artificial intelligence (AI) models, device connectivity inside the automobile and along the roadway and the rapid rise of automation in the factory and warehouse.

In this eBook, we explore how major industries are utilizing advancements in power design to realize their connected futures, informed by the survey respondents and our experience working with today's technology leaders. We hope these observations will inspire your journey into a challenging new era of automation, data and — underlying it all — power.



At Molex, we believe in the transformative power of creating connections. With more than 80 years' experience delivering connectivity at scale, we help power the innovation necessary for the next generation of data centers, medical devices, factories, vehicles and more. Our global, multi-disciplinary team of engineering experts continuously collaborates with our customers to drive power solutions forward and provide the framework for tomorrow's technologies.

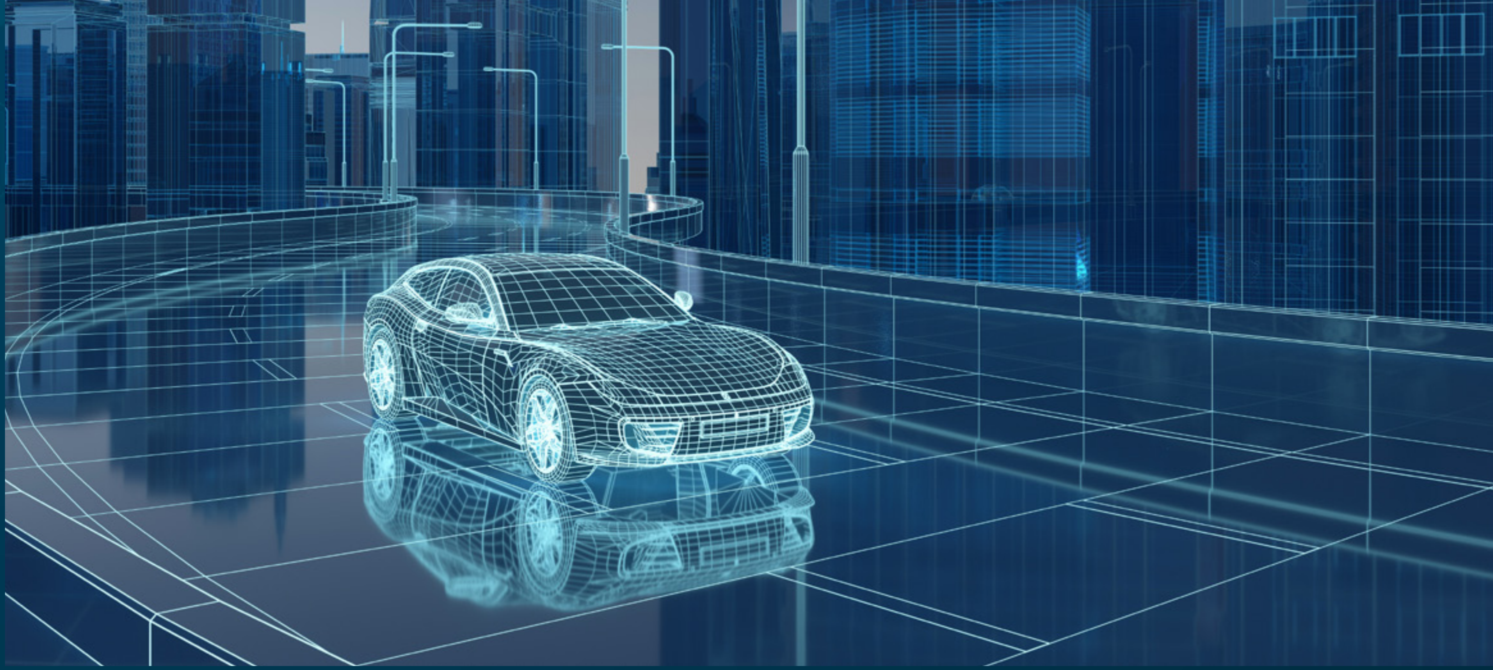
* Dimensional Research provides practical market research for technology and manufacturing companies, delivering actionable information that reduces risk, increases customer satisfaction and grows the business.

DIGITAL UNIFICATION IS DEPENDENT ON POWER

At a certain point of its assembly, an electric vehicle (EV) in the factory of the future will be capable of driving itself from station to station.

Acting as its own conveyor with the knowledge of where it is in the assembly process, the autonomous guided vehicle (AGV) drives to one robot to get a windshield, then to the next to get bumpers. If that station is backed up with delays, it can decide to move over to seatbelts instead. The car will know what parts it has, what it still needs, and where to get them — in real time. It will know the shortest lines in the factory and queue up there.

Once it completes all the steps, it can drive out the door, stopping briefly to honk at the general manager's office for a thumbs-up before taking off for the highway. The brain of the car now fills with instantaneous information about the distance from guardrail sensors and adjacent semis. The product performs new tasks in a completely different electronic context.



Finally, it reaches its destination: your driveway. It will alert you to let you know the car you ordered has arrived. In the weeks that follow, it makes yet another transformation, becoming a member of the family.

The EV's rules of operation are now devised by collecting data on all the household routines and individual preferences. It will remember you want the seat warmed up on weekday mornings when temperatures dip below 50°F (10°C). On long trips, it can offer your child an array of their favorite entertainment options (perhaps when the volume of their complaining gets too loud). Knowing your schedule, the EV can head to the shop for a tire rotation while you're at the dentist.

EXPANDING DIGITAL UNIFICATION

To contemplate the factory or the roadway or the household of the future is an exercise in extrapolating a process that is already happening: digital unification. Digital unification is the current evolutionary trajectory of computerized processes. And it is the long-range goal of Industry 4.0, toward which many product developers are now striving.

How ever you extrapolate it, we'll soon find products being made, delivered and used in very different ways — perhaps not exactly like the scenario above, but something close to it.

Both the objects and the environment will collect and share information to make decisions. The object can disengage from one environment and ensconce itself in another while adopting a new set of rules and functions.

Because we've already witnessed some progress in digital unification, it may be tempting to think the engineering challenge is simply to provide more signal bandwidth for the multitude of products, sensors and robots to come.

But this neglects the more fundamental engineering obstacle on the path to this industrial internet of things (IIoT) future.

The big limitation between today and tomorrow is power.

THE GRADUAL ENHANCEMENT OF SUPPLY

At the root of today's digital unification challenge is the convoluted infrastructure that supplies power in industrial settings. Power capabilities grow in facilities gradually over time, so capacity is applied incrementally. The problem is that a sprawling industrial facility with this legacy arrangement will have a hard time making the jump to Industry 4.0.

Water and electricity are close analogues. Let's say for instance your house used up all the capacity from the water main on your street. To get additional supply, rather than putting in one larger-gauge pipe to the street which would disrupt service and require retrofitting, a second identical supply line is added. When water needs go up even more, you use up your street's excess capacity and elect to add a pipe from the adjacent street. A year later that is maxed out, so extensions are installed to mainlines three or four streets away.

Each gradual increase in capacity results in another duplicated layer of infrastructure, which takes up more space in the walls of your house. The source gets farther and farther away, so the pipe needs more pressure. Additionally, and most importantly, when you want to rearrange your fixtures, you may get confused about what source a faucet is drawing from, and whether that line is filled up or not.

Instead of just one stem from the water department to the house, it is served by several branches, each flowing at a different level of capacity.

HOW TO PAINT A FACTORY (OR A CAR) INTO A CORNER

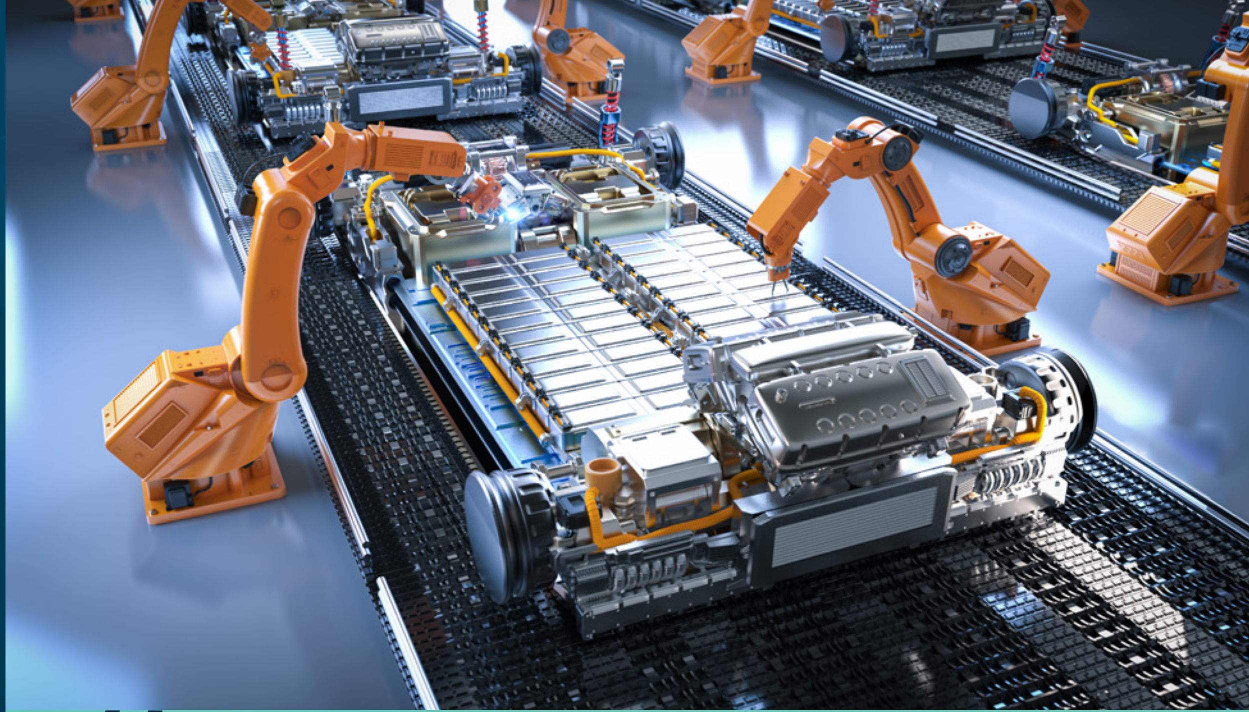
Like the plumbing analogy, factories in operation over decades often paint themselves into the same corner with power cabling.

The accrual of new supply lines can result in crowded spaces, particularly at connection points. Cables can run up to a mile or more, which requires more voltage to maintain the same flow. And as equipment, tools, robots, sensors and other applications multiply, they might find themselves in outlets to a number of different branch lines. These challenges are illustrated in the Molex State of Power survey, where issues of cost, thermal limits, safety, and power quality are among the most reported.

The electrical infrastructure inside today's automobile, despite (and because of) all its advanced electronic features, suffers from the same kind of cabling congestion. Surprisingly, even in a recent model, each electrical mechanism has its own dedicated power cable.

To combat these challenges, some EV automakers are looking to replace heavy cabling with **busbars** to route power from batteries to inverters and motors, and to converters within the vehicle, which allows for ease of insulation and weight savings. Cables are a key contributor to the overall weight of the vehicle. In an EV, an increase in weight leads to a decrease in range.

The legacy architecture of the automobile could be considered a microcosm of the automotive factory, as it too faces the same steep growth curve in the number of discrete devices that will need power in the next phase of digital unification (**automated driving**, **RADAR and LIDAR sensors**, **cockpit controls** and so on).



> **97%** of design engineers surveyed expressed facing at least one significant challenge related to designing power systems.

In fact, the need to monitor and gain more agile control of power, as well as increase the size of the power pipeline to make Industry 4.0 processes work, is occurring at many levels: throughout the facilities, the roadway, the vehicle, and its onboard systems.

THE AMPLIFIED NEED TO MONITOR POWER

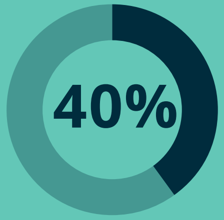
The limits of gradual enhanced power supply in dynamic environments, where objects are adding and subtracting themselves to networks, have serious and hardline consequences.

Case in point: if the devices and equipment that draw on a power source go beyond capacity, the result is thermal energy. Overheating can cause downtime, as well as permanent damage to equipment and injury to workers.

Naturally, in a large factory it is someone's job to monitor and prevent operations from surpassing this hard limit of power consumption. On the other hand, there is growing pressure to put more and more IIoT equipment, sensors and smart devices to use in the factory setting.

With a convoluted, multi-branched electrical network, it is difficult to monitor, predict and respond to changes.

Before the promise of IIoT flexibility can come to fruition, systems need to know what processes are drawing on power at any given moment. And they need the ability to shift supply from one sector of a network to another.



"Almost 40% of respondents agree that power management poses the greatest challenge in industrial applications."

POWERING TOWARD DYNAMIC ALLOCATION

Molex is on the engineering forefront of delivering power when and where it needs to be. In the future, power monitoring and control needs to be as smart as the car it is building.

Molex is working with major automakers and device manufacturers to develop **more intelligent architectures** where devices will be served from different power distribution hubs with greater capacity to meet the increasing demands for power and data. Our communication and control solutions are at the heart of the monitoring and logic functionality that ensures the functional integrity and safety of the system.

Products like our innovative **Brad M-12 Power L-Code Connectors** allow machine builders and integrators to meet increasing capacity requirements for control power and motor power with a plug-and-play wiring solution that delivers nearly three times the power of its predecessor, the 7/8” mini-change. Additionally, M12 power solutions are rapidly emerging as the choice for 24VDC device power infrastructure, supporting up to 60% more power than the solutions commonly used just a few years ago.

Molex is **unveiling** another vital solution supporting the IIoT infrastructure: the next generation Power-over-Data-Line (PoDL) cable called Single Pair Ethernet (SPE), designed specifically to address increasing demands for data and power at the field level.

At all levels of system design, power requirements must be understood in real time so that capacity can respond to the spontaneous expansions of networks. Molex brings unprecedented expertise and capability to the power infrastructure challenges of tomorrow.

POWERING THE FUTURE OF AI

New breakthroughs in artificial intelligence (AI) performance are setting up the race to deliver the most powerful data centers for the future. As AI applications continue to grow in complexity and demand exponentially more computation, power resources may govern which data centers can update to the next tier of processing and maintain their premium status.

In recent years, AI has emerged as a game changer in industries ranging from healthcare and finance to transportation. Machine learning algorithms and deep neural networks have become powerful tools for data analysis, pattern recognition and decision making. However, these AI applications require massive amounts of computing power and energy to operate effectively.

Training large AI models can consume a significant amount of power. Graphics Processing Units (GPUs) or Tensor Processing Units (TPUs) are often employed to perform the complex matrix calculations required for deep learning algorithms much faster than traditional CPUs. These specialized hardware units are designed to handle large volumes of data and optimize the processing required for machine learning.

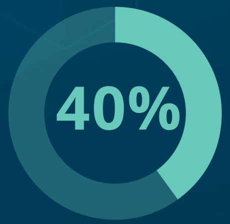
WHEN LARGE MODELS SCALE UP

Recent examples have shown that training models can require as much as several hundred kilowatts of power. For example, OpenAI's Large Language Model (LLM) GPT-3 was trained on 175 billion parameters and 570GB of internet-sourced data, which **reportedly** required 355 megawatts of power.

OpenAI's next version, GPT-4, is hundreds of times more capable than GPT-3, with a training set of 170 trillion parameters, which makes it the most powerful AI engine ever seen, at least for the time being.

OpenAI utilized Microsoft Azure data centers for the GPT project. Companies will continue to build and maintain data centers in their own facilities to support breakaway success in popularity or rapid expansion of their user base. But they will likely need to rely on cloud-based services as well — such as Microsoft Azure, Amazon Web Services and Google Cloud Platform — to provide the additional computing power needed to meet sudden spikes in demand.

These large-scale cloud platforms have been leading the development of hyperscale data center best practices and boast the most advanced data center performance in terms of compute speed and bandwidth.



listed power management as the top challenge in the data center.

said their top challenge was power distribution.

In this highly competitive landscape, the most promising AI projects will vie for the most reliable data centers that can provide the heaviest loads in computational processing. The outlook for the next phase of AI growth and data center upgrades becomes clear: there may not be enough premium data center services for everybody.

The bottleneck may be largely imposed by the limitation of electric power. Our Molex survey of more than 800 design engineers and their managers shows that 40% of respondents list power management as the top challenge when implementing power systems in a data center. Power distribution came in a distant second place at 20%.

DOUBLING DATA CAPABILITIES

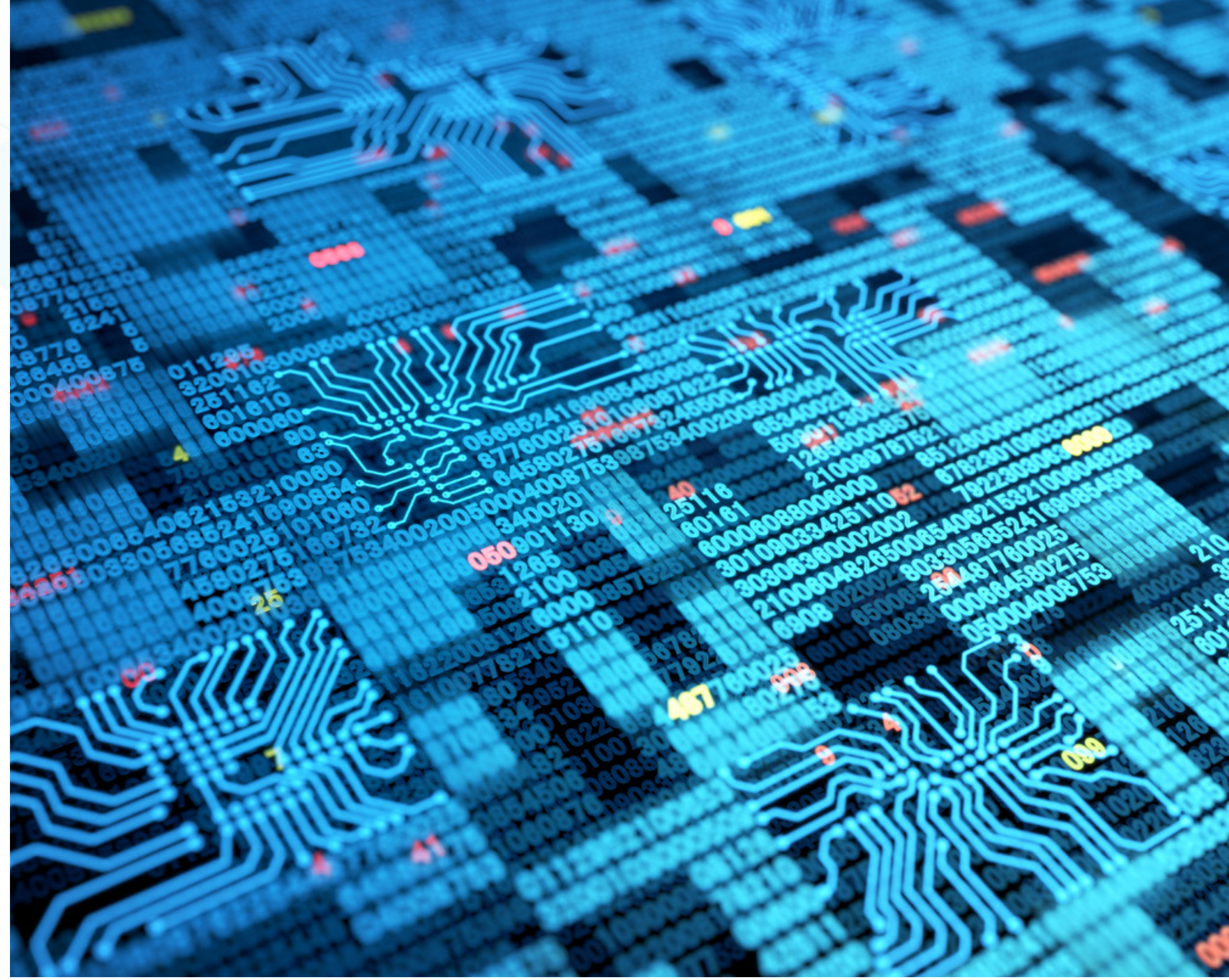
State-of-the-art data centers today deliver data rates of up to 112 Gbps. Many data centers are in the process of upgrading hardware and connectors to reach this level of speed and performance.

The drive to create a **224 Gbps-PAM4** data center is already on the horizon to meet the growing demand for AI processing. However, the **infrastructure components** for 224G are only in the early stages of being released to market, which means it will be several years before a fully 224G facility becomes commonplace.

Doubling the data rate capability of the world's data centers in aggregate will be a mammoth undertaking because it requires a significant boost in electrical power generation. Given that AI consumes two percent of energy resources today, tomorrow's upgrade may be the equivalent of adding a few new major cities to the world map, each needing power plants of their own.

In fact, the power requirements for a typical GPU module have grown from 450W per module in 2018 to 1000W in 2022, or from 3600W to 8000W per box for an OCP OAM, driven by the use of more computing power.

This power increase correlates to more heat generation than ever before, and a need for heat sinks and components that can handle the higher temperatures. Molex **Mirror Mezz Connectors** are built for both the increased power requirements and the associated heat management. The same connector can be used for 450W and 1000W GPU models and performs well in air and liquid cooling.



ADAPTING TO WHAT'S NEXT

The collision between exponentially increasing power requirements for an AI-enabled data center and the limitations of current facilities spawns creative solutions. Some current hyperscale data centers might not be able to make the next generation leap, simply because of unfortunate geography. Certain localities may not elect to mete out another slice of their limited power generation to cloud-server companies. Or an aged grid — even one in transition to renewable resources — could experience intermittent outages, which might prove problematic for data services.

The bottleneck might also reside inside the facility as it transitions from Technology A to Technology B and maxes out its internal power distribution architecture. In addition to investing in hardware, data centers must also focus on new ways of optimizing their power consumption as the industry approaches building out AI-driven data centers. This could include the use of advanced cooling systems, energy-efficient hardware and innovative power management strategies. An AI-driven management tool might even be a future solution for data centers as they wrestle with optimizing their current resources.

As AI continues to reshape the world of computing, data centers must adapt to meet the growing demands of these applications. The competition for the most computational and powerful resources will continue to intensify as the AI landscape expands and more companies seek to deploy AI applications in their operations. Data center operators must invest in the latest technologies and strategies to stay ahead of the curve and remain competitive in this dynamic landscape.

That's why Molex is investing in the technologies of tomorrow, including **224 Gbps-PAM4 capabilities** and a full host of solutions for data center power management.

POWERING THE DATA CENTER OF THE FUTURE

Data centers are one of the most critical components of modern business infrastructure, but they're also one of the most energy-intensive. A single data center can **require up to 50 times the energy per floor space** when compared to a standard commercial office building. As a whole, these installations account for approximately 2% of the total electricity use in the United States and that number is only expected to climb.

This upswell of demand is coming from three drivers of change in the data center market. Data center operators are now preparing in the short term to meet long-term challenges.

A DEMAND-DRIVEN CHALLENGE

The growing demand for energy is driven by an increasing need for more processing power as emerging technologies gain traction with businesses and the general public. In fact, the Molex State of Power survey found that 53% of data center design engineers believe the need for higher functionality is a key trend forcing innovation in power design.

High-Speed Bandwidth

The development of high-speed Internet has been a game-changer in the way we communicate, work and live. In the early days of the Internet, dial-up connections were slow and clunky, limiting what we could do online. But with the advent of broadband Internet in the late 1990s, faster connections became possible, allowing us to browse the web, download files and video chat without buffering or delays. As technology improved, the speeds of these connections skyrocketed, making it possible to stream high-quality video, experience AR and VR, and run complex applications in the cloud. Today, high-speed Internet service is a necessity for many people, and it continues to evolve, with developments like 5G and fiber optics promising faster speeds and greater reliability.

The Internet of Things (IoT)

IoT encompasses the interconnected network of everyday devices, appliances and systems that can transmit and receive data via the Internet. It enables us to control every aspect of our environment like temperature, lighting and appliances. IoT connects everything from our smartphones to our cars, thermostats and even home security systems. IoT can automate processes to make life more convenient, such as smart home devices that can control, monitor and optimize our energy usage or remind us when we need to restock groceries. The IoT market is on a rapid growth trajectory and is projected to reach an **estimated $621 billion by 2030**, with technological advances allowing for even greater capabilities and possibilities.

Machine Learning & Artificial intelligence

As discussed previously, training a large-language model (LLM) like GPT-3 just once takes megawatts of power. Looking at all the different ways in which AI is being used today and will be used in the future, it’s easy to imagine that as AI chatbots like ChatGPT replace the typical search engine, which would likely result in an exponential increase in the amount of computing power required to support processing the world’s volume of AI queries. In preparing for this future, it is critical for data centers to conserve current energy supplies while finding new ways of delivering more processing power.

HOW DATA CENTERS ARE EVOLVING

To meet the needs of users in the ever-growing digital landscape, modern data centers are adapting on a few different fronts.

Better Hardware

Designing a data center capable of meeting tomorrow's challenges starts with the smallest components. Each piece of hardware must be optimized for reliability and efficiency. Shielded connectors, busbars and cables can be configured to minimize interference and maximize space. The latest generation of microprocessors provide both high performance and energy efficiency. **Advances in modularity** now allow servers to be more easily reconfigured and upgraded to accommodate future growth. And 224 Gbps-PAM4 system architecture will become a necessity for the demands of generative AI.

Power Standardization

A data center is only as good as its uptime, so ensuring servers are online when and where they are needed is mission critical. Making certain that the energy supply remains uninterrupted requires a series of redundant backup systems. Today's data centers use generators and capacitive banks to guarantee a consistent supply of power. Increasingly, the industry is also seeing a shift toward renewables generated on site through the installation of solar panels and wind turbines. On a smaller scale, **edge, far-edge and microdata centers** are going so far as to include lithium-ion battery backups on every shelf.

Thermal Management

More processing means more heat generation, so maintaining growing data center systems at scale requires innovative and unique approaches to thermal management. Liquid immersion cooling in particular is a technique that's recently been receiving attention in the data center power environment. In 2020, Microsoft's Project Natick demonstrated that a sealed container on the ocean floor could safely and **reliably house 864 servers and 27.6 petabytes of storage** for two years with the cooling effect of the seawater contributing to a demonstrable increase in energy efficiency. Now, system designers are taking things one step further by immersing servers directly in baths of non-conductive liquid, creating a passive heat-sink configuration that has the potential to support the cost and energy requirements of the data centers of the future at scale.

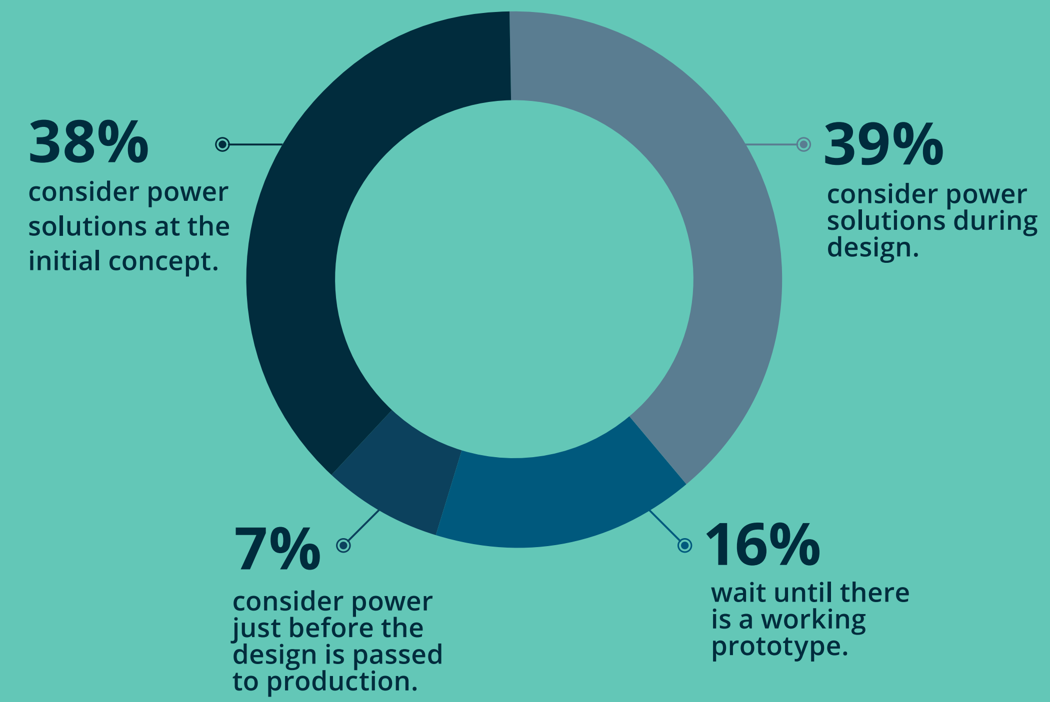
In addition, data center operators across the globe are seizing the opportunity to put the heat potential of their equipment to practical use. Amazon, Apple, Facebook and other tech giants have instituted heat recycling programs that **utilize the thermal energy generated by their data centers** to heat homes and even entire city districts. These programs, though costly to institute, show real-world promise, especially in the colder climates favored for large-scale data infrastructure.

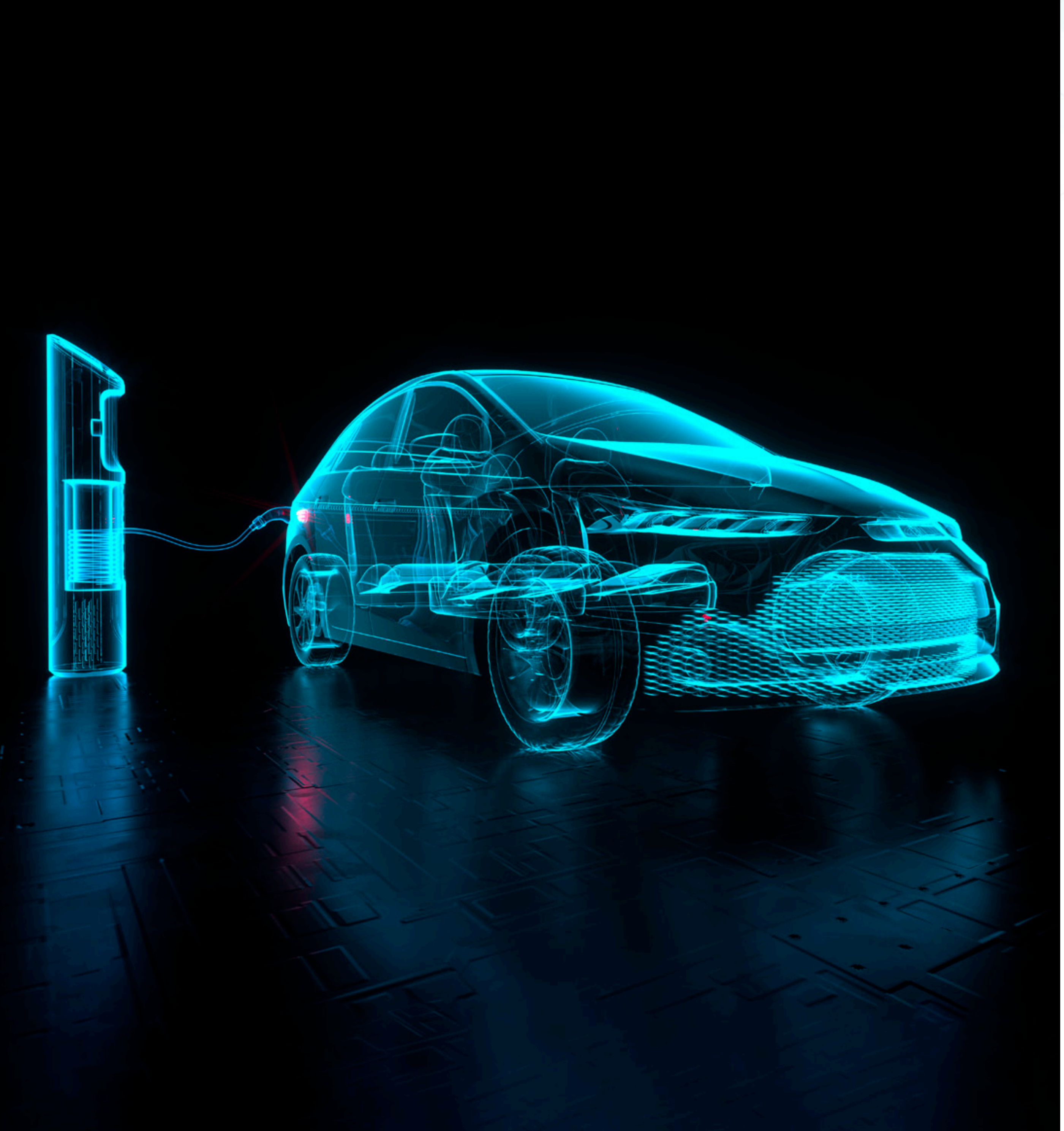
THE FUTURE OF DATA IS EFFICIENCY

New technologies continue to push data center designers towards greater efficiency and capability. Custodial responsibility extends to operators to find creative solutions in energy usage. Among several approaches, they need to select the methods that best balance the demands of efficiency with power quality and reliability.

In this tech-driven age, the demands on power infrastructure will increase year by year. Consequently, those designing and maintaining the centers of our digital future must think ahead and devise a network that can quickly adapt to new developments.

Engineers recognize the significance of power solutions — and they consider them early in the product development process.





INNOVATIONS IN EV BATTERY TECHNOLOGY

The 12V power model has been standard in the automotive industry since the 1950s, making it the default in automobile design and components. This standard has enabled automakers to keep costs low and maintain a simple electrical architecture even as features and **electrification** have expanded over time.

12V has had a good run, but as modern consumers increase their expectations of performance and in-vehicle experience, the 12V standard must evolve. The emergence of the **software-defined vehicle** and the move to mild hybrid architecture, as well as more stringent emissions laws, are making 48V design increasingly necessary to meet consumer demands and regulatory requirements.

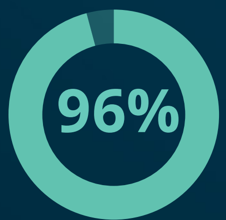
Though adoption of 48V faces some challenges, electrical innovators are now readying the path to higher-efficiency systems based on this new standard. Several key factors should be well understood and considered as automotive design ushers us into the electrified future. These include drivers of the 48V standard, advantages for automakers and consumers, and challenges associated with the move to 48V.

FACTORS DRIVING THE MOVE TO 48V POWER

The move to more robust power standards won't happen overnight, but some key electrical and consumer factors will influence automaker adoption of 48V as the standard for mild hybrid and fully electric vehicles.

Legislative Action for Reduced Emissions

Recent legislation has called for drastic emissions reduction in newly built vehicles, particularly in the U.S. and Europe. These changes fuel the shift to mild hybrid architectures such as integrated starter generators and 48V power networks, as well as an increase in engine design efficiency. Design engineers are feeling the pressure. In the Molex survey, 57% of respondents say it requires significant effort to comply with power-related regulations.

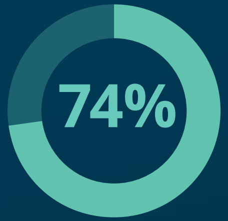


of design engineers surveyed said it takes effort to understand and comply with power-related regulatory requirements.

More stringent fuel economy regulations are similarly pushing the development of advanced technologies such as stop-start systems, advanced driver assistance systems (ADAS) and alternative propulsion solutions like electric vehicles (EVs). These new technologies require higher voltage from power sources, prompting the move to a 48V standard.

Consumer Preference

Carbon-conscious buyers show a strong preference for hybrid, plug-in hybrid electric vehicles (PHEV) and electrically-enhanced cars. OEMs and component providers keen to meet these consumer demands are now building the next generation of components and vehicles in response. It's no surprise that the Molex survey found that 74% of design engineers who work on power list energy efficiency as a main priority.



of those surveyed cited energy efficiency as top-of-mind when designing or implementing power systems.

Electric Turbocharging

E-turbo features enhanced engine performance by using an electric motor to spin a turbine and boost air intake into the engine. This kind of turbocharging requires greater power than traditional turbocharging systems powered by either 12V or 24V systems. As more efficient and powerful electric turbocharging systems become standard, 48V power sources will take center stage.

Space Efficiency

The shift to 48V architectures is more than just an increase in the system voltage. The shift also requires a change in the electrical architecture of today's vehicles. Feature-rich, higher-performance vehicles rely on lighter and smaller components that deliver the same electrical efficiency in a higher-density architecture. 48V standards are vital to delivering consumer-friendly possibilities such as better infotainment and vehicle integration features.

ADVANTAGES OF 48V POWER

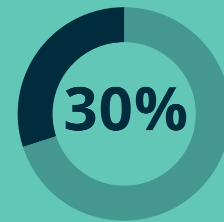
Increased power and efficiency open the door to opportunities for both producers and consumers. The additional efficiency and features made possible by 48V will help producers meet increasing consumer interest in higher-tech, lower-footprint vehicles.

On the engineering side, the new platform introduces new advantages:

Smaller Package Size
48V power allows smaller component production that can deliver the same level of electrical efficiency in a higher-density architecture. This makes it easier to create feature-rich, high-performance vehicles without sacrificing space. Automotive designers can reduce the size of the electrical system while retaining the same features, resulting in improved overall vehicle performance.

Production Cost Savings
Smaller components require fewer materials, reducing production and retail costs while still meeting consumer demand. The improved efficiency of 48V systems can help reduce total energy usage by up to 30%.

Better Feature Offerings
Smaller component footprints allow automotive designers to pack more features into a given space. Cars can include more advanced technology such as wireless charging, robust infotainment systems and advanced driver-assistance systems despite their smaller size. These enhancements improve the overall driving experience for customers and also boost a car's value and perceived quality.

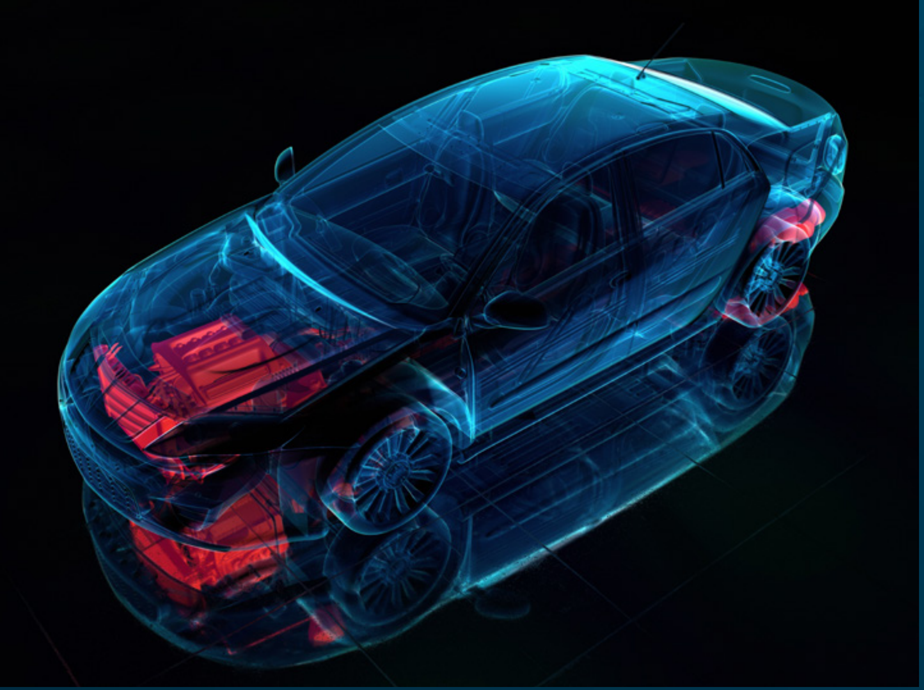


> Among the several unique challenges posed by EVs, 30% of design engineers named in-vehicle power electronics as the most challenging application.

Additionally, the reduced physical size of these components enables automakers to design sleeker and more aerodynamic vehicles with improved handling and stability.

Lower Emissions
The increased efficiency of 48V systems decreases fuel consumption, carbon dioxide (CO2) and other pollutants that internal combustion vehicles emit. Smaller components lead to lighter vehicles with less drag, further reducing emissions.

Better Fuel Economy
Reducing engine load through electric enhancements helps automakers reduce the energy needed to propel the vehicle. The result is lower fuel consumption and better fuel economy. The greater efficiency of 48V systems also allows vehicles to maintain their performance at higher speeds, allowing them to travel farther on a single tank or charge.



Consumers, too, find a host of benefits with the change to 48V, such as:

Improved Vehicle Performance
Next-generation power solutions enhance existing engine performance, providing more power and torque for improved acceleration. Electric motors deliver smoother torque at lower speeds to increase stability and comfort when cornering or driving on uneven surfaces.

48V systems also help reduce the load on the internal combustion engine, allowing it to work more efficiently and reducing fuel consumption while still delivering high performance. These lighter vehicles enjoy an increased power-to-weight ratio, improving overall performance.

Lower Vehicle Costs
With smaller and fewer components, 48V architecture allows a more efficient production process. Manufacturers reduce the materials and labor needed to build a vehicle, reducing their overall costs. For consumers, lighter and more energy-efficient vehicles require less fuel to power and maintain over their lifetime, reducing cost of ownership for drivers.

Improved Handling
Electrically enhanced vehicles respond to inputs with speed and precision, making them more maneuverable than other vehicles. The reduced weight allows vehicles to accelerate faster while maintaining steering stability, giving drivers increased control over their cars.

Lighter vehicles also make it easier for manufacturers to fit in advanced active safety systems, like lane-keeping assist, without sacrificing overall performance. This increases the overall safety of the vehicle and gives drivers improved confidence when navigating challenging roads and terrains.

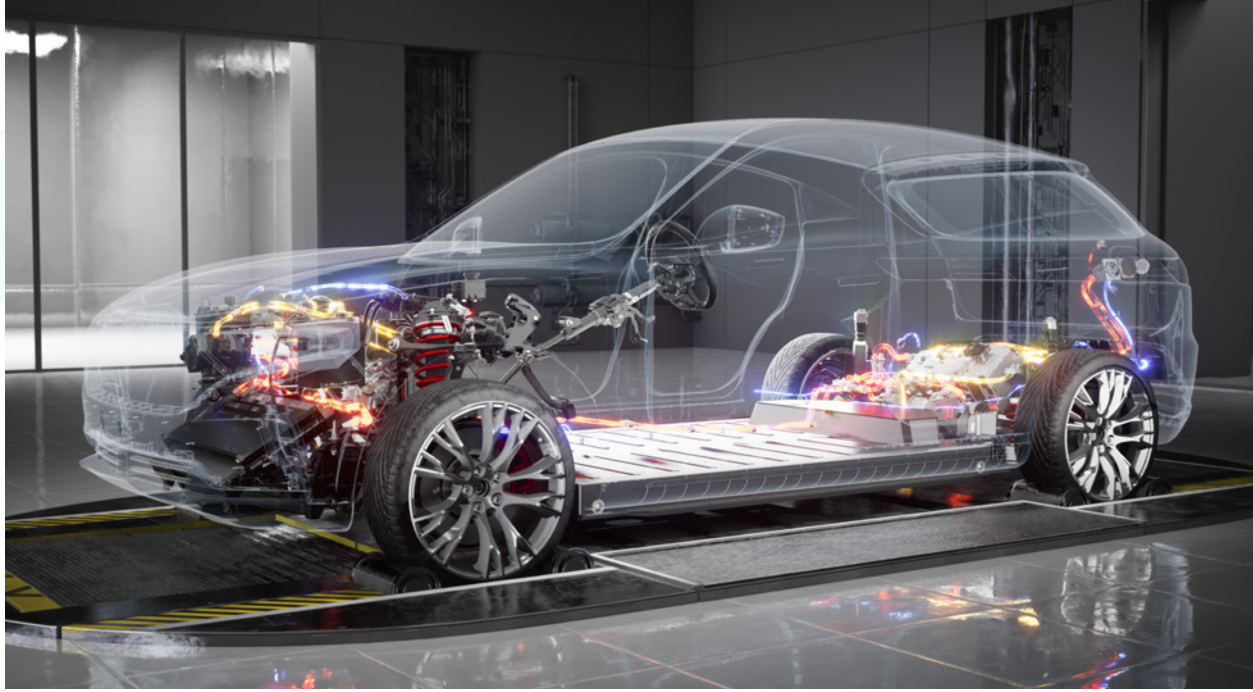
CHALLENGES IN THE PATH FROM 12V TO 48V

Where 12V design is deeply embedded into auto production, transitioning to 48V will be slower than desired. The transition speed will in part rely on changes in componentry design required to meet the technical requirements of 48V systems, taking into account their own production methods and existing infrastructure.

Considerations such as cost and the relative novelty of 48V technology can further slow adoption since strong business cases are required to drive large-scale technology changes.

Better battery management is integral to the success of 48V architecture. Without the right design, automakers risk inefficient power storage, increased costs and potential safety risks due to system instability. To ensure that they are making the most of their available power storage and battery capacity, automakers must invest in better hardware and software. This can include using predictive algorithms to adjust charging cycles based on usage needs and developing better ways to track battery health over time.

Advanced energy control systems will be needed to manage the voltage levels within each cell to prevent overcharging or undercharging the battery stack. These measures require a significant investment in research and development, but are necessary for creating reliable 48V systems capable of meeting the demands of modern driving conditions and potentially extreme environments.



MOLEX 48V COMPONENTRY

As demand for EVs has grown over the past 30 years, Molex has played a critical role in serving the automotive industry. Molex was an early developer of solutions that support 48V applications, including connectors and power distribution systems that provide robust power management. Our components facilitate consistent connection and communication across a 48V system to ensure reliable performance in any environment.

SMART FACTORY DEVELOPMENTS CREATE NEW DEMANDS ON POWER

When a product defect is discovered in a traditional assembly line, an inspector hits a red emergency stop button. Engineers and managers rush in to find the problem in the line and then troubleshoot a solution. This brings the entire operation to a halt for an indeterminate amount of time. Each delay has the potential to derail cost estimates and lengthen production schedules.

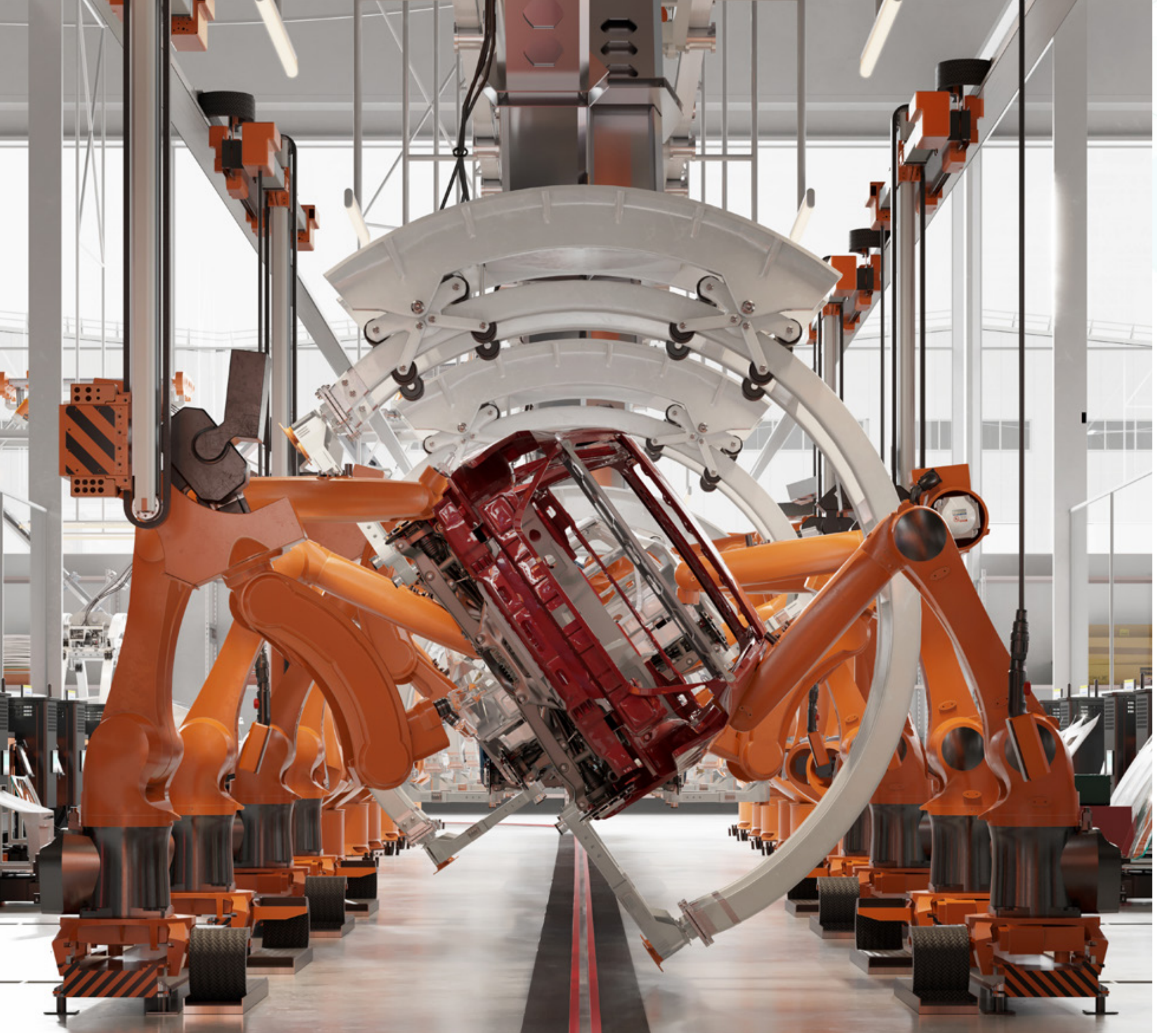
A key goal of Industry 4.0 is the realization of self-monitoring assembly lines, where inspection and correction occur automatically, without costly production delays.

In this scenario, vision systems can identify quality issues without direct human involvement. Machine learning (ML) modules analyze the visual data in real time, calculate machine adjustments and correct the course for the next product on the line.

This industrial 'auto-correct' capability may have many guises in the future. The same sophisticated ML that infers facial recognition can be trained to spot flaws in the layers of **3D printed parts**. Laser scanning and measurement can detect parts that are out of alignment. Self-correction could evolve incrementally as additional hardware attachments to existing robots or cobots, autonomous factory vehicles (AFVs) or Industrial Internet of Things (IIoT) devices are introduced.

The prospect of no longer having to press pause on the conveyor is an attractive business objective. In the fully automated factory, production time becomes much more predictable, with less risk of cost and schedule overruns. The risk for human error is diminished, too. AI may soon become capable of optimizing quality based on its own rules, far surpassing the limits of manual inspection.

All efforts toward enabling a truly smart factory have a common denominator: the need for new power infrastructure.



POWER DISTRIBUTION

Smart factories introduce a higher demand for electrical power for both the larger machinery performing production tasks and the new extensive **information network**.

This layer of communication and control includes wiring and devices, like cameras, sensors, actuators and control units. A self-correcting assembly line might also require a range of electrical upgrades, such as transformers, switchgear power supplies and power distribution panels, to accommodate the additional load.

Ideal smart factory **signal-and-power components** would combine a ruggedness to survive on the floor with the speed and reliability attributes of data center infrastructure.

Industry standard organizations like Underwriters Laboratory (UL) and National Fire Prevention Association (NFPA) are already anticipating these requirements and other emergent issues. For example, more powered devices on the floor introduce more frequencies that can interfere with machine performance. This means sensitive electronics such as those found in servo motors are particularly susceptible to disruption from nearby devices in the environment.

Connector and cabling standards, in conjunction with design accommodation from major manufacturers like Molex, aim for better **shielding** from electromagnetic interference (EMI) and increased efficiency. For instance, next-generation cabling can be consolidated into smaller spaces while using fewer **busbars**.

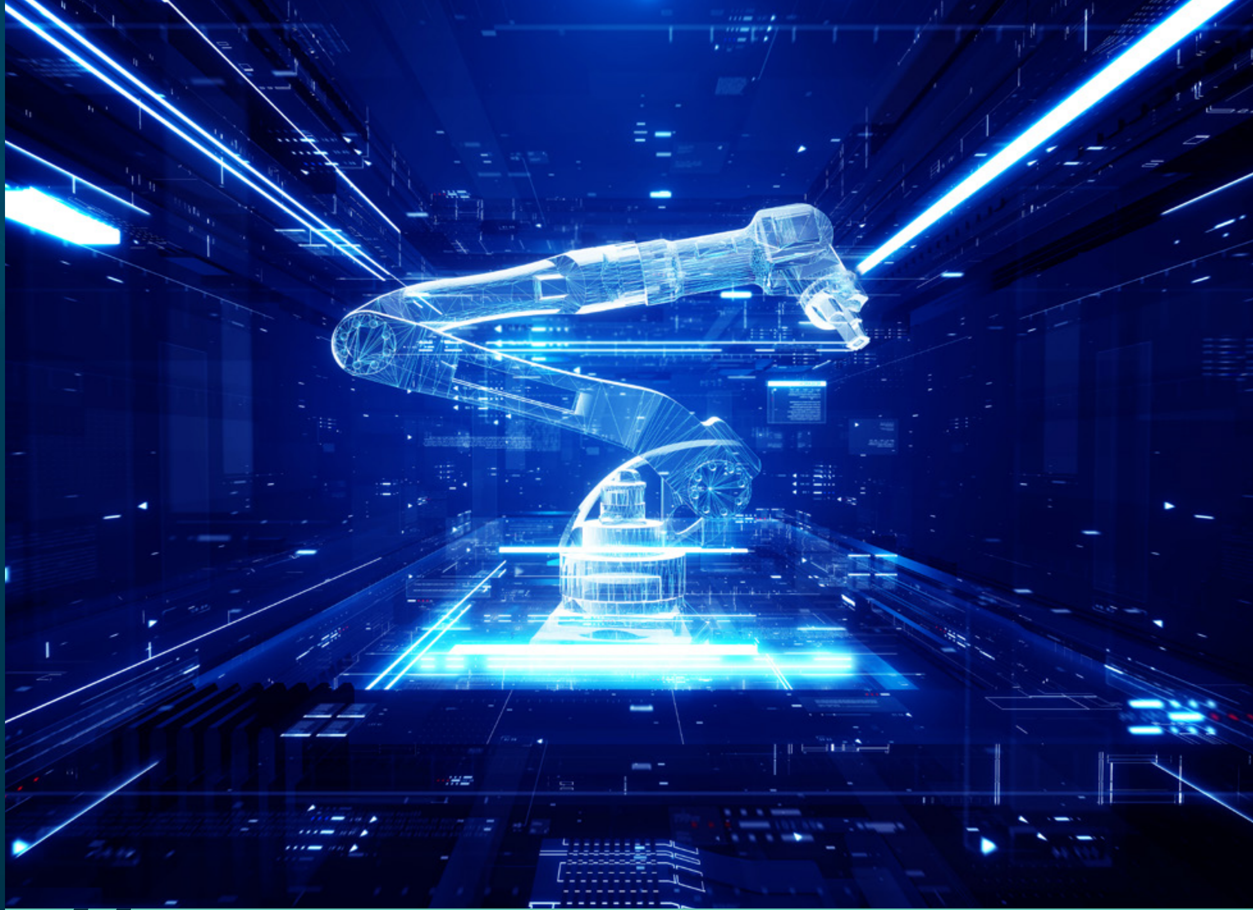
POWER QUALITY

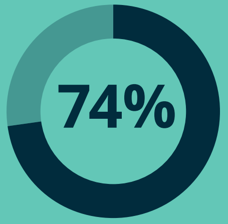
Data centers often take extra measures to ensure power quality. Forward-looking industrial facilities are following suit, generating current that is smoother and more reliable.

A smart factory with a greater emphasis on power quality might feature new types of components. Capacitive banks, for example, are employed to eliminate fluctuations in supply lines. On the demand side, variable frequency drives give robotic motors a softer start. Rather than an intense drag on power as they come up to speed, these motor drives consume power evenly over a few seconds.

If an assembly line without interruption is the goal, then it is imperative that the communication, control lines and data processing keep running. As is frequently the case with data centers, critical computing units may each have their own dedicated battery backup. In addition to batteries, both factories and data centers are also protecting against the effects of dropped power by incorporating on-site sources of energy.

As AI-driven self-correction gains hold, factory power managers will have more decisions to make. When to switch power supply will merely be one of them. Fortunately, AI-driven data analysis provides factories with something else: an enhanced ability to monitor and manage power.





"Increasing energy efficiency is the top priority when designing or implementing power systems, according to 74% of engineers surveyed."

POWER MONITORING

Real-time AI-driven diagnostics works for more than correcting product flaws. A smart factory of the future would benefit from control systems that can track voltage and current levels throughout the operation.

By monitoring each production activity consuming power, managers can prevent total usage from exceeding physical or compliance limits and predict the power requirements of activities based on previous data.

Power diagnostic tools would enable managers to maximize uptime and schedule preventative maintenance during predictable transitions. A higher-resolution view of power consumption shows operations managers how to add more production activities given the limits of available power.

Real-time power monitoring also enables better load balancing, reduces transmission losses and improves the resilience and flexibility of the power distribution system.

MORE DATA MEANS MORE POWER

The convergence of automation, data analytics and advanced technologies in the factory of the future presents a unique set of challenges for power management as well as opportunities for new levels of autonomy and control.

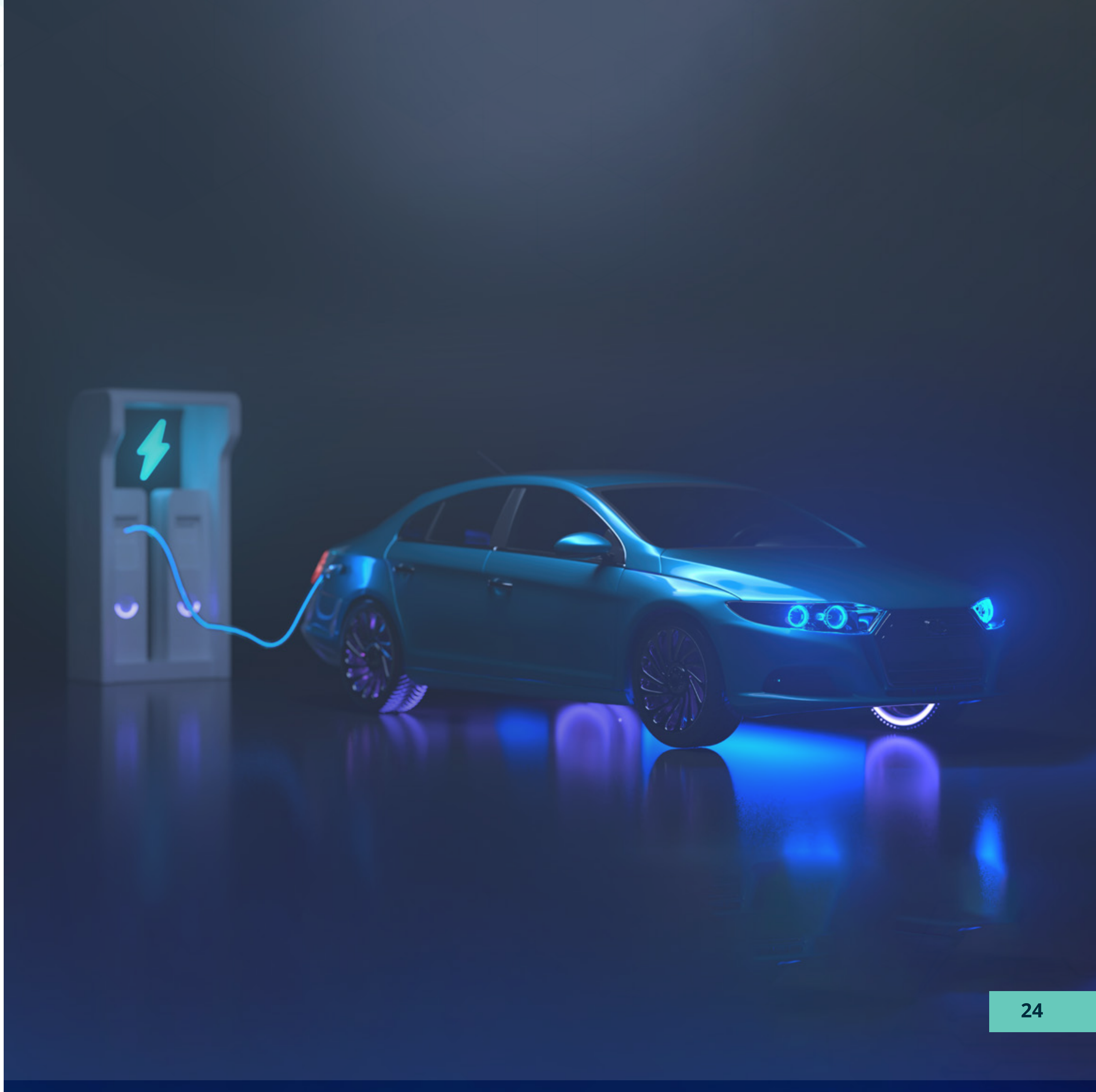
Manufacturers must navigate the risks associated with EMI, especially with the increasing reliance on smart tools. Embracing self-adjusting assembly lines powered by vision systems offers higher precision, quality and productivity. And real-time AI-driven diagnostics for power infrastructure empower factories to optimize their operations and ensure compliance while minimizing downtime.

As the factory of the future continues to take shape, harnessing the power of data becomes essential for unlocking new levels of efficiency, productivity and innovation in manufacturing processes.

START YOUR ENGINES: EVs ARE BECOMING MORE EFFICIENT

Electric vehicles (EVs) are rapidly gaining market share in the automotive industry. In 2020, EVs accounted for less than 5% of all new auto sales; that **number rose to 14% in 2022**. Will the EV market plateau or continue to make gains?

We're facing a once-in-a-lifetime industry paradigm shift in vehicle architecture. If manufacturers can design and implement EVs with higher levels of efficiency while consolidating the footprint of electronic assemblies — and do all of this cheaper than the current model requires — the market will continue its ascent. In this article, we'll explore an EV industry on the precipice of achieving these goals on multiple levels.



MORE EFFICIENT CHARGING SOOTHES MAJOR EV PAIN POINT

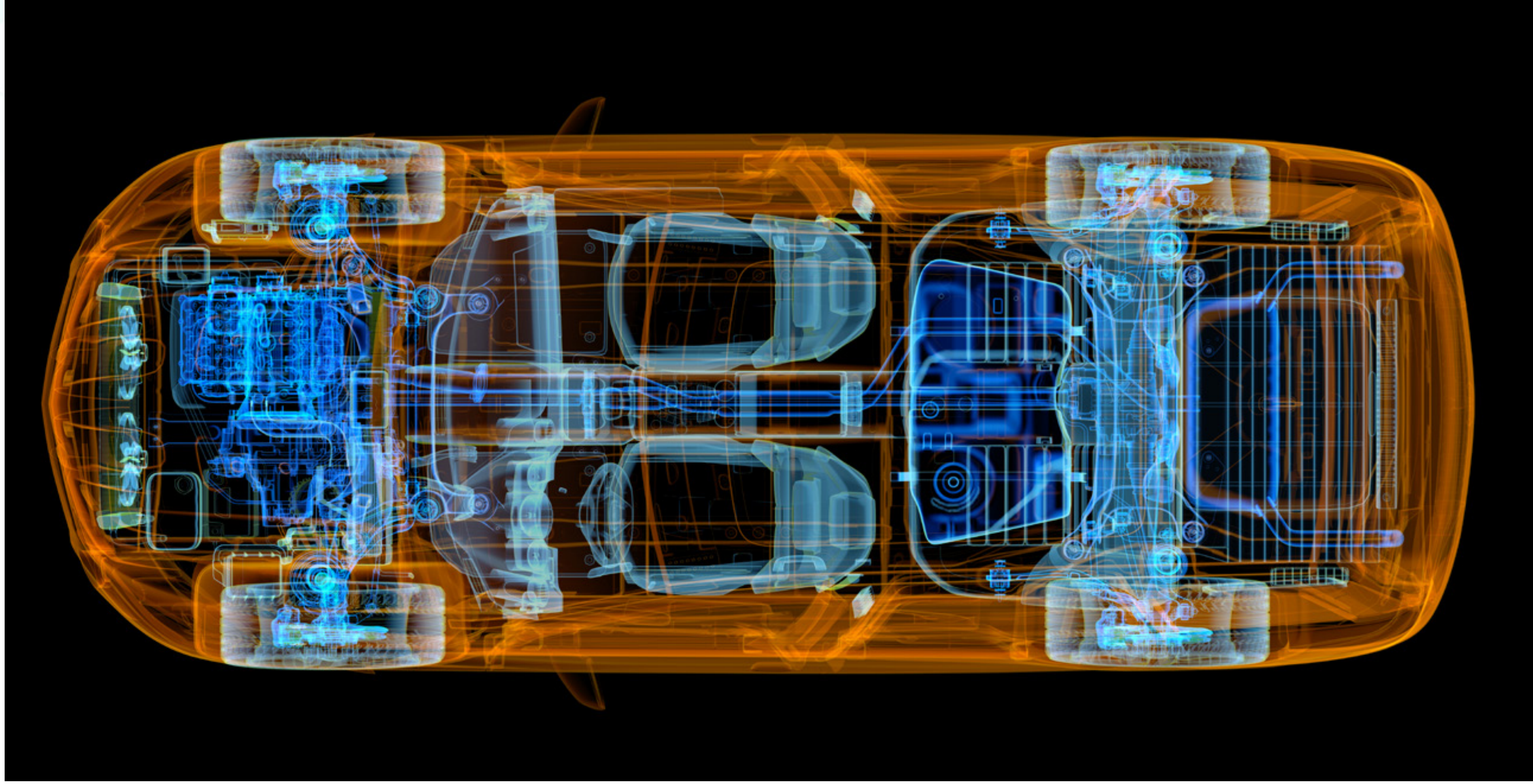
A gas-powered car and its owner spend around five minutes at the gas pump, and drivers have been conditioned to expect this experience when refueling. Can similar times be achieved at public EV charging stations?

By the beginning of 2023, there were **130,000 charging points across the United States** and **2.7 million worldwide**. Public charging stations are seeing advances that allow for faster-charging power and speed. Progress in charging technology has facilitated enhanced power delivery to EVs, with higher power outputs that can furnish more electricity to the vehicle, decreasing charging times.

EV charging infrastructure has improved in terms of power capacity. Fast chargers with higher power outputs, such as DC fast chargers, are now more widespread. These chargers can deliver more electrical power to the vehicle, resulting in more efficient charging for time-crunched motorists.

A growing number of charging stations now also feature dynamic charging capabilities, allowing power adjustment based on the battery's state of charge. This dynamic charging ensures that the battery receives the optimum charging rate at all times, maximizing charging efficiency and minimizing charging time.

SMALLER, LIGHTER COMPONENTS FOR ACROSS-THE-BOARD SAVINGS



Smaller component footprints and weight reduction throughout electronics systems play a critical role in making EVs more efficient and cost-effective.

Smaller Package Size

Miniaturization can help maximize performance when space is at a premium. Fitting all the electronic components into an EV is complex, but design engineers are finding ways to make them more compact. Wire harness packages are driven by wire size and voltage; a vehicle's overall weight can be reduced by making these harnesses smaller and more efficient.

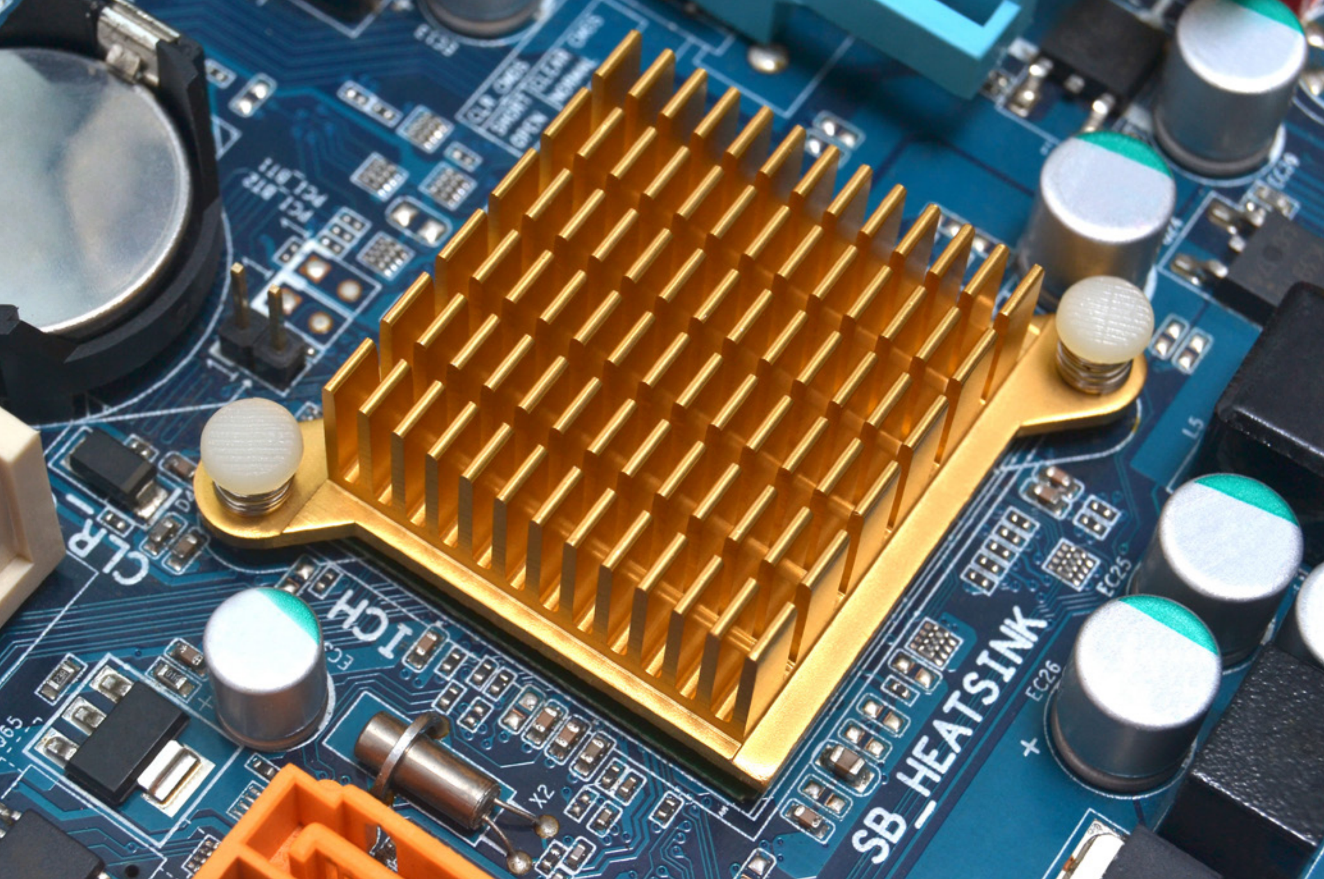
Reduced Weight

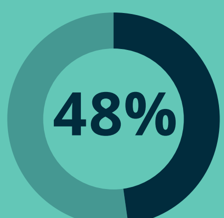
Although thicker than traditional copper wire, opting for aluminum cable contributes to weight and cost savings. And, despite the need for larger gauge wire to conduct the same amount of energy, aluminum wire weighs only 30 percent of the weight of copper. Additionally, aluminum wire costs up to half as much as copper wire.

Manufacturers have begun using metal alloys, composites and polymers to decrease the weight of internal electronic systems further. Using these materials strategically reduces weight without compromising functionality and durability.

Combined Effects

By reducing weight and package size and opting for more cost-effective materials where appropriate, EVs can be more efficient without sacrificing performance. The value of optimizing each component across the entire vehicle assembly adds up to real efficiency gains.





Thermal management is top-of-mind for many design engineers. 48% say it is the biggest challenge when designing or implementing power systems.

LOWER SYSTEM TEMPERATURES ARE CRITICAL TO SAFE AND EFFICIENT EVs

Design engineers are working diligently toward achieving lower temperatures in their electrical systems. For instance, connectors used in EVs are being optimized for lower temperatures, allowing for the use of lower-cost resins without compromising performance. This optimization eliminates the over-engineering of connectors, reducing costs while maintaining reliability and functionality.

Electronic components with smaller footprints reduce heat generation, allowing for better heat dissipation. Heat sinks, using materials with high thermal conductivity, absorb and dissipate the heat created by electrical components. Insulation techniques also help to minimize the heat transfer between hot and cold areas inside the EV. This prevents thermal degradation, allowing each system to perform as designed. Combining these thermal techniques allows internal EV components to withstand high operating temperatures without compromising performance.

SOPHISTICATED BATTERY MANAGEMENT SYSTEMS IMPROVE OVERALL EV EFFICIENCY

An EV's battery management system (BMS) plays a crucial role in overseeing battery storage systems by employing various control techniques like charge-discharge control, temperature regulation and monitoring cell potential, current and voltage. These measures effectively enhance the safety and longevity of the Energy Management System (EMS) by ensuring proper supervision and continuous monitoring.

By combining battery state of charge accuracy, cell balancing, thermal management and protection against overcharge and discharge, an advanced BMS helps the entire vehicle efficiently distribute and optimize energy levels. In a recent **Molex survey** of over 800 design engineers, 22% of respondents reported that battery packs pose the biggest challenge when designing and implementing EV power systems. The battery pack was ranked as the second biggest challenge behind in-vehicle power electronics.

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Designers are adopting higher-voltage power, using 48 volts instead of 12 to engage sensors, motors, ECUs and other components. Higher voltages deliver the same amount of energy with less current, enabling thinner and lighter cables. Similarly, EV power trains are moving to higher-voltage architectures and adopting more efficient controller and wiring setups.

DRIVING THE FUTURE OF EVs

Using all the advancements discussed above, EVs can have more compact, lighter-weight electronic components that enhance vehicle efficiencies. This is the next chapter the EV industry has been waiting for.

When EV manufacturers need smaller, more efficient and lighter-weight systems, Molex provides them with a comprehensive lineup of **miniaturized solutions** to help enable dependable functionality. As the demand for more sophisticated electronic systems within EVs continues, Molex's proven expertise will help drive the EV market forward.

RISE TO THE CHALLENGE

It's undeniable that the world is growing increasingly connected and more dependent on data. But whether it's the road to digital unification, the evolution of AI or more efficient EVs, technological progress is dependent on reliable power solutions. Today's design engineers must now balance simultaneous data and power connectivity requirements from a space, functionality, performance and cost standpoint. Is compromise unavoidable?

Power design doesn't need to be a paradox. Explore how other design engineers are tackling today's challenges and preparing for the future.

EXPLORE THE MOLEX STATE OF POWER 2023 REPORT

Ready to overcome your power design challenge? Visit us at **Molex.com**.

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