EBOOK

# Preparing for the Next Chapter of Connectivity

WHAT'S ON THE HORIZON FOR CONNECTIVITY AT HOME, ON THE ROAD AND BEYOND?



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molex

# TABLE OF CONTENTS


Introduction ..... 01

Redefining “Everything” in V2X: The New Era of Connected Vehicles ..... 02

6G on the Horizon: Redefining Wireless Possibilities ..... 07

Trends in Connector Development for 2030 and Beyond ..... 12

Contactless Connectivity: A Rival of Mechanical Connectors? ..... 18

Staying on the Connectivity Course ..... 22

# INTRODUCTION

We're on the brink of a technological revolution driven by innovations in connectivity. Mechanical connectors are facing competition from contactless counterparts, vehicle-to-everything (V2X) is extending to power and the framework for a 6G world is in the early stages of development.

Meanwhile, we are only just beginning to unlock the potential of artificial intelligence (AI) and machine learning. In just a few short months, generative AI is showing early signs of making long-standing impacts on product design, functionality and supporting infrastructure — features and demands that will continue to rapidly evolve.

In the years ahead, we'll see new, game-changing applications across nearly every industry as design engineers and manufacturers continue to harness the growing power of connectivity. But what's coming down the road? What challenges will stand in the way? And how is Molex innovating connectivity solutions as well as the process for designing them? This eBook addresses those questions and more.



Connectivity is the cornerstone of products and solutions across every industry. But meeting the growing demands of higher power, faster data rates and smaller form factors poses significant design challenges.

Molex has been at the forefront of developing innovative interconnect solutions for over 80 years. Our commitments to superior quality and unmatched customer relationships are supported by our global engineering expertise and supply chain resources. Together with our clients, we navigate complex requirements to minimize performance trade-offs and develop cost-effective solutions.

# REDEFINING “EVERYTHING” IN V2X: THE NEW ERA OF CONNECTED VEHICLES

Although not quite a flying car from *The Jetsons*, KITT from the 1980s TV series *Knight Rider* was a vehicle ahead of its time.

The modified Pontiac Trans Am was an AI supercomputer on wheels: autonomous driving, intelligent voice communication, remote access to data and the ability to control external electronic devices. And that’s just a sampling of the extensive list of features that wowed audiences just four decades ago.

KITT may have been a work of Hollywood fiction, but many of its features are now an automotive reality thanks to vehicle-to-everything (V2X) communication. Recent years have introduced the first generation of V2X-capable vehicles, **starting with the VW Golf 8 in 2019**.

Vehicles like the Golf 8 and others since are equipped with an array of sensors and antennas to better communicate with the world around them — laying the groundwork for eventual autonomy.

But even more recently, a new type of V2-connectivity has emerged, founded on electric vehicle (EV) bidirectional charging. Signal connectivity via V2X is now accompanied by power connectivity through vehicle-to-grid (V2G), vehicle-to-home (V2H) and vehicle-to-load (V2L) capabilities.

How do these new technologies combine to shape the EV of the future?



## SIGNAL CONNECTIVITY ENHANCES THE DRIVING EXPERIENCE

**V2X** is often referred to as "the IoT on wheels" and is a broad classification made up of an abundance of communication subcategories such as vehicle-to-device (V2D), vehicle-to-network (V2N), vehicle-to-pedestrian (V2P) and vehicle-to-vehicle (V2V).

The wireless infrastructure to support V2X, which exists both inside and outside the vehicle, has enabled new safety and convenience features like collision warning systems, adaptive cruise control and parking assistance while providing a framework for autonomous driving. But what makes this infrastructure possible?

The Molex report — ***Predicting the Connectivity of Tomorrow: The Innovations Driving the Connected World*** — explores the past, present and future of vehicle antennas. In it, Florian Scherbel, Global Product Manager at Molex, explains how vehicles have transitioned from having one AM/FM rod antenna to what is the next generation of connected vehicles with almost 30 antennas — each serving unique purposes from 4G/5G network connectivity and V2X functionality to Bluetooth compatibility and eventually communication with Non-Terrestrial Networks (NTN) and 5G/6G mmWave elements.

Many of these antennas are designed to support and enable connectivity for V2X applications, such as satellites, cell towers, sensors, smartphones and even other vehicles.

But the abundance of antennas poses both aesthetic and performance challenges to engineers, ultimately leading to the following foundational question: *How do I incorporate more antennas in a way that neither disrupts the vehicle's appearance nor performance of the antenna?*

To maintain and improve appearance and performance, innovative non-conductive materials and design approaches are enabling antennas to be hidden throughout the vehicle and used in conjunction with shark fin antennas, enhancing signal reliability while ensuring the cabin and body of the vehicle can be streamlined.

While V2X technologies enable signal connectivity, a new era of V2 functionality for EVs is made possible with bidirectional charging.

### What's in that Acronym?

V2X is an all-encompassing acronym for vehicle-to-everything, but it does get more specific. Within V2X is V2:

- B – Building
- C – Cloud
- D – Device
- G – Grid
- H – Home
- I – Infrastructure
- L – Load
- N – Network
- P – Pedestrian
- V – Vehicle



## POWER CONNECTIVITY RETHINKS THE DEFINITION OF VEHICLE CHARGING

Traditional EV charging is considered unidirectional in that an EV draws power from the charger — it's a one-way connection.

The future of EV power connectivity, though, may be in bidirectional charging where a vehicle can take from and feed power to a connected system.

While the process may sound simple, bidirectional charging places significant emphasis on power quality and integrity to ensure the transmitted energy meets requirements.

Although there are slight variations in name, three technologies are driving bidirectional charging forward: vehicle-to-grid (V2G), vehicle-to-home (V2H) and vehicle-to-load (V2L).

## WHAT IS VEHICLE-TO-GRID (V2G)?

V2G is a technology that enables EVs to send energy back to the power grid and to utility providers from their batteries — transforming a vehicle into a mobile battery energy storage system (BESS).

This helps to save money for the vehicle owner and establishes a new means of resiliency for the grid.

### V2G Reduces Charging Costs

Allowing EVs to feed energy back to the grid opens an interesting door to potential cost savings — or even profit — for the vehicle owner. The costs associated with charging a vehicle vary depending on demand on the grid, but they are often cheaper in the early hours of the morning. With V2G technology, an EV could charge during less expensive times and sell back to the grid during peak demand.

### V2G Adds Grid Resiliency

Although experts believe V2G is years away from being **fully realized**, tests are underway to determine the viability of V2G technology as a means of adding redundancy to the grid.

In fact, a recent test is being undertaken in **a New York school district** where electric school buses are sending energy back to the grid during off-periods, such as over the weekend and during summer months when demand may be up but school is not in session.

Some locations are eying V2G even more intently. A bill in California has recently been introduced, **requiring new EVs to offer V2G options by 2027** in order to help mitigate California's power grid shortcomings.

## WHAT IS VEHICLE-TO-HOME (V2H)?

V2H technologies enable the energy stored in an EV **to serve as a home power source**, such as in cases where a blackout takes down the power. When used more broadly than just residential structures, for example in a small office building, the technology is referred to as vehicle-to-building (V2B).

### V2H Provides Homeowners with Energy Flexibility

V2H offers significant benefits for EV owners, both as an emergency source of energy and as part of an overall home energy management approach. During power outages caused by storms, grid failures or any other incident resulting in power loss, an EV battery can serve as an emergency battery backup system.

In addition, V2H could provide EV owners the option to shift energy consumption from the grid to receiving power from a vehicle's battery, such as during peak grid demand hours when prices are at a premium.

### V2H is Still a Developing Application

V2H is still in its infancy but is beginning to see more rapid adoption from automakers. Although **GM has announced a V2H initiative**, questions still surround pricing for the equipment associated with making V2H possible with its vehicles.

Automakers will have to decide if they want to sell these systems themselves or rely on a third-party OEM partner (as is the case with the **Ford F-150 Lightning and Sunrun**).

## WHAT IS VEHICLE-TO-LOAD (V2L)?

While V2G and V2H technologies focus on vehicles powering larger systems, V2L enables an EV to power a specific device, such as an outdoor light at a worksite.

### V2L Gives EV Users Power on the Go

Charging a smartphone with a vehicle is now an everyday activity, but V2L enables significantly greater flexibility in powering external devices. For emergency use, V2L can be an excellent option in disaster relief efforts, allowing a vehicle to act similarly as a gasoline-powered generator.

For recreational use, V2L EVs can power electric grills and televisions at outdoor events like picnics, camping trips and tailgating events. For professional use, construction workers can charge their tools using V2L technology. The possibilities are endless.

### V2L Faces Several Hurdles to Adoption

Although the concept of V2L is simple, it has some limitations in its current form. For instance, using an EV battery for V2L applications can **contribute to increased battery wear and degradation**, which can diminish range potential and shorten the lifespan of the battery.

Additionally, V2L standards for connectors, power levels and communication protocols have yet to be established. As a result, different EV models can have interoperability challenges.





# 6G ON THE HORIZON: REDEFINING WIRELESS POSSIBILITIES

6G network technology is the next generation of wireless technology, promising to deliver even faster speeds, lower latency and greater capacity than 5G. Whereas 5G's potential has been most realized for consumers, 6G will be more focused on supporting long-awaited industry applications. 6G is still in its early stages of development. But it could revolutionize how we live and work.

## TRANSITIONING FROM 5G TO 6G: HOW DO WE GET FROM HERE TO THERE?

To power their on-the-go and connected lifestyles, today's consumers are searching for faster, more reliable experiences — from their smartphones to their wearable devices and in-vehicle infotainment system.

Network providers recognize this need and continue to develop and invest in 5G infrastructure — the premier wireless technology available today. But as industry applications, such as those within factories and warehouses continue to grow and stretch the limits of 5G, 6G development is becoming more of a focus for network providers. In fact, **6G testing and rollout should kick off in 2030**.

The move to 6G networks is not as simple as flipping a switch and will require significant investments in infrastructure. New towers will be needed to provide the broader coverage and higher bandwidth that 6G requires. Fiber optic cables will be needed to carry the massive amounts of data that 6G will generate. And new software will be required to manage the complex network of 6G devices.

In addition to infrastructure, the transition to 6G will also require new devices. 5G devices will not be compatible with 6G networks, so new smartphones, vehicles and IoT devices will have to be developed.

6G is still in its early stages of development, and there is not yet a single standard for the technology. While this could slow down the deployment of 6G networks because different vendors will have to develop their own solutions, ongoing efforts to develop 6G standards are underway which could accelerate 6G network deployment.

## MILLIMETER WAVE FREQUENCIES: THE KEYS TO UNLOCKING TRUE 6G

Millimeter wave frequencies (mmWave) are radio frequencies with a wavelength of 1 millimeter to 10 millimeters, and **offer several advantages** over other frequencies. They have high bandwidth to support a large amount of data. They also have low latency to transmit data quickly.

These advantages make mmWave frequencies ideal for resource-intensive applications where speed and reliability are critical.

However, mmWave frequencies also **pose some challenges**. They have a limited range so they can only travel short distances. They are also easily blocked by objects, such as buildings, walls and trees. These factors require mmWave networks to be densely deployed with many base stations to provide solid coverage.

In addition, because they are much more **prone to signal attenuation than lower frequency bands**, mmWave frequencies require massive MIMO antennas and precision, high-frequency connectors to achieve optimal performance.

## LONG-AWAITED CAPABILITIES: 6G APPLICATIONS

The development of 6G networking technology has generated excitement and anticipation as it has the potential to unlock a new era of transformative applications once only imagined. Recent advancements in AI have only heightened the possibilities.

### Self-Driving (Autonomous) Vehicles

6G technology will enable self-driving vehicles to achieve a higher level of autonomy than is currently possible with 5G — making possible a future of highways populated with autonomous vehicles.

6G's ultra-low latency and high bandwidth enable real-time communication between the vehicle and its surroundings, helping vehicles to avoid accidents and make better decisions.

### Remote Healthcare, Including Robotic Surgery

Geographic location may cease to be a limiting factor for medical procedures. 6G is expected to advance remote healthcare by enabling it to be performed more effectively and efficiently than is currently possible, such as 6G-enabled remote surgery for patients in rural areas or requiring specialized care unavailable locally.

### Virtual Reality (VR) and Augmented Reality (AR)

Immersive tech like VR gaming could see a new era with 6G networking technology. With next-level VR gaming, users may transport themselves into realistic virtual worlds.

Similarly, 6G could broaden the possibility for **AR training**, where users interact with virtual objects in the real world, allowing trainees to learn new skills in a more immersive and realistic way. 6G could even bring the advent of **tactile internet and holographic communications**.

### Smart Cities

We've heard a lot about smart cities but will only be able to fully experience them once 6G is a reality. Supporting infrastructure, including wireless networks and **224G data centers**, will enable self-driving vehicles to communicate with traffic lights and road sensors.

Additionally, fully realized 6G will allow real-time communication between first responders and the public, improving coordination and communication during emergencies.



### Industrial Automation

6G will enable Industry 4.0 to embrace the possibilities of artificial intelligence, machine learning and digital twin technology — where large amounts of data must be processed, analyzed and acted upon instantaneously.

This technology can be used to **monitor, control and automate** industrial processes in real time. This enables improved efficiency and productivity, such as adjusting manufacturing lines when a fault is detected and better raising awareness of a potential issue before the fault occurs.




### Internet of Things (IoT)

The greater bandwidth and connectivity offered by 6G will provide increased functionality for IoT devices. From smart home appliances to wearables and medical devices, 6G technology will facilitate greater interactivity and data sharing among IoT-enabled hardware.

### Stronger, Faster, Safer

6G has the potential to unlock some of the most highly anticipated applications of our time, including:

- Fully autonomous vehicles
- Remote healthcare and robotic surgery
- New immersive heights for VR and IR
- True smart cities
- Improved Industry 4.0 automation
- Increased IoT functionality

At the same time, 6G is expected to enable great strides in key areas of data security:

- Stronger encryption
- Robust authentication and authorization mechanisms
- Ultra-low latency and real-time communication

## SECURITY CONCERNS: WILL 6G CLOUD DATA BE SAFE?

6G is expected to bring **several advancements in data security** but it is essential to remember that no system is entirely secure. Each IoT device is a potential gateway for attack, and the security of the entire network depends on the security of its embedded software.

High-profile instances of data breaches, data loss and data privacy have occurred over the past few years, raising questions about the safety of cloud data — especially in applications like robotic surgery and autonomous vehicles where human lives are on the line.

Despite these concerns, 6G is expected to take several steps forward in the arena of data security, including:

**Stronger Encryption**

6G is expected to employ more robust encryption protocols, making it more difficult for unauthorized parties to access and decipher data transmitted over the network. This will protect data stored in the cloud and during transmission.

**Robust Authentication and Authorization Mechanisms**

6G will likely incorporate multi-factor authentication, biometric recognition and AI-driven behavior analysis to verify user identities and ensure that only authorized personnel can access sensitive information stored in the cloud.

**Ultra-Low Latency and Real-Time Communication**

6G's potential for ultra-low latency and real-time communication could enable rapid threat detection and response. This means that security systems could quickly identify and mitigate potential breaches before they escalate.

## WILL 6G BE LIMITED OUT OF THE GATE?

Starting with 1G in 1979, each generational “leap” of wireless technology has occurred **about every decade**. 6G will become the sixth-generation technology standard, but it won't be fully realized on day one.

As infrastructure is built out, broadband providers will no doubt be racing to have the best network. This means that like 5G, 6G will need to evolve and iterate along the way to allow for the full potential of the network technology to be realized.

Just as 4G LTE was a big step forward to 5G, 6G will need additional development over multiple years. Each generation in wireless tech has provided iterative enhancements along the way, and 6G will be no exception.



# TRENDS IN CONNECTOR DEVELOPMENT FOR 2030 AND BEYOND

Seven years in the future doesn't seem that futuristic. Yet in that span, the world is likely to witness several game-changers in the datacom, transportation, energy and consumer connectivity industries.

A recent Molex report, **Predicting the Connectivity of Tomorrow**, shares an in-depth look at the inspiring developments in electronics through the remainder of this decade.

The report showcases emerging applications like **contactless connectivity** and data transmission at twice the speeds we see today, as well as slim devices that cross new frontiers in miniaturization.

Here, we'll offer a glimpse into Molex's innovative approach to connector design — squarely aimed at enabling the connectivity of the future.

What will drive major trends in the development of interconnect solutions from now until the end of the decade? And how will Molex keep up with the rapidly evolving landscape of data, devices and infrastructure?

## THE ART OF INTERCONNECTIVITY

Making a connector that can move more power or data might seem like a simple feat. But like any other design problem, interconnect technology must make trade-offs between variables that are often at odds with each other.

For any connector, the main variables are:

- Signal integrity and power quality
- Rate of data transfer and/or power rating
- Thermal management
- Form factor, size and weight

Amplifying one variable often generates deficiencies in others. Higher power applications, for example, force engineers to consider the extra thermal energy generated. Faster speeds through a cable or wireless device might result in more noise and less signal.

A glimpse into the future of connector design can already be seen in Molex's miniaturization efforts, where engineers are balancing heat, weight, power and data in an ever-smaller form factor.

## PREDICTING ELECTRICAL PERFORMANCE

What will the development of new hardware components look like in 2030? Recently, the Molex predictive engineering simulation team collaborated on a pilot project to help develop **MX-DaSH Connectors**.

This approach provides a preview of the enormous changes to come in product development. The team is helping current transportation clients find the right balance of variables in their custom components.



Molex's MX-DaSH Hybrid Inline and Wire-to-Board Connectors combine 14 connector signals into one for compact connectivity to an ECU domain controller/computer. This allows engineers to meet multiple connectivity needs while saving precious real-estate.

The **predictive engineering approach** originates in transportation applications, where assemblies of vehicle subsystems come together in a virtual space. These 3D parts, referred to as digital twins, are embedded with all the simulated physics of the physical object.

The software simulation can provide insights into the electrical, mechanical and thermal performance of a product well before the fabrication of a physical prototype.

Predictive analysis can introduce various stressors from environmental conditions or replicate a lifetime of wear and tear. The Molex team has made progress in simulating a single connector that can demonstrate the effects of these stimuli on power and signal quality.

Likewise, engineers can make a dimensional change to a connector design and measure how it impacts the product's thermal profile or mechanical longevity.



## WHAT'S NEXT FOR DIGITAL TWINS

As digital twins continue to advance, they will provide performance validation on a wider range of factors, including structural integrity, weight, package size optimization, current rating, electromagnetic interference (EMI), high-voltage safety, ergonomic assembly and serviceability.

Though still in the early stages of its technological maturity, predictive engineering has the potential in a more advanced form to upend all current notions of product development. To cutting-edge interconnect designers, full-function predictive engineering is the ultimate achievement.

Looking into the near future, digital twins will likely grow to encompass an entire assembly of a client's product, so engineers can follow the interactions occurring throughout the application. Engineers can pinpoint performance capabilities, identify and fix problems before production, and receive valuable feedback about usage over the lifetime of an electronic product.

Artificial intelligence (AI) can devise novel strategies and locate a precision balance of thermal management, performance, weight and form factor.

Digital twins may accompany troubleshooting technicians in the field, who will be able to view an 'x-ray' of complex machinery through augmented reality (AR) smart glasses. Likewise, virtual reality (VR) will let designers understand local infrastructure and perform failure analysis by stepping into a virtual site remotely. Will we see this in the future design of connectors? Only time will tell.

Over time, digital twins might also prove their fidelity to the extent that the simulations replace physical prototypes for the purposes of product compliance. Imagine a 15-minute demonstration of a connector in simulation replacing a 6-week process of mechanical testing and prototyping.

The net result could be significantly shortened design cycles. By knowing how the different variables of a connector interact, product developers will be able to unlock new breakthroughs in miniaturization, power quality and cost efficiency.

## TRENDS DRIVING THE CONNECTOR OF THE FUTURE

How will connectors change over the remainder of the decade? Here are some of the market drivers placing pressure on the variables of connector design, along with examples of Molex innovations already in the pipeline:

1. **Faster Data Rates**
   The appetite for more and more data will be driven by the rising expectations of consumers along with the expansion of AI and Internet of Things (IoT) applications.

   Pressure to innovate around data rates will be ongoing and will come to bear wherever the bottleneck is tightest — whether at the data center, at the edge or at points of transmission.

   Increasing the speed of connections and cabling introduces increased risks to signal integrity. A **hybrid cable** made up of both fiber optics and copper wire is one Molex solution to address this conflict.

   By utilizing optical fibers to transmit data signals, while using the copper wires to transmit power, hybrid cables can transmit power over long distances while ensuring high-speed data transmission.

   In seven years, much of the **datacom infrastructure** will no longer operate at 112 Gbps, but at twice that rate. Molex has been on the cutting-edge of next-generation data center architectures by introducing the first-to-market comprehensive portfolio of **224 Gbps-PAM4** products.

2. **Higher, Faster Power Throughput**
   The decade ahead will look for ways to transfer energy from storage stations to portable devices. As batteries for EVs, homes and renewable installations proliferate, the demand grows for reliable ways to put this energy into action — preferably faster.

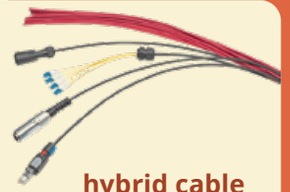
   Higher power is the answer to quick EV charging, but upgrades in voltages require an overhaul of connectivity in both vehicles and charge points. New designs also need to take into account safety risks and thermal effects.

   Molex is responding with high-performance **busbar, connector and cable assembly solutions** designed especially for high voltages. Innovations like embedded sensors inside busbars may be commonplace in EV charging stations by 2030.

3. **Smaller Components**

The trend of miniaturization continues across many industries, most prominently in RF/wireless devices, automotive, consumer electronics, data centers and edge computing.

Designers must face the challenge of creating smaller assemblies with greater feature density, driven by evolving user expectations for high performance in slimmer, more compact and even **more rugged packages**.



hybrid cable



high-power busbars



micro-connectors

As data and power demands continue to increase with the expansion of AI, IoT, renewables and more, designers will need interconnect solutions that can handle high data speeds, high power and harsh environments – without adding bulk.

Molex has responded to these demands with innovations like **hybrid cable** made up of fiber optics and copper wire, **high-power busbars** designed for high voltages and rugged **micro-connectors**.

Molex's commitment to solving new miniaturization problems has resulted in **innovative interconnect solutions** that increase functionality while driving down component footprints.

4. **Contactless Connectivity**

What is the best connector for a 360-degree-pivoting industrial robotic arm? Eventually, the answer may be “one that isn’t there.”

Contactless connectivity offers untethered freedom of movement as well as the elimination of tasks involving repeated manual mating and de-mating. Transferring both power and signal a short distance through magnetic inductive coupling has hundreds of potential applications in industries like automotive, industrial and consumer electronics.

Although still an emerging technology, contactless connectivity solutions offer the possibility of improved reliability, increased ruggedness and lower cost compared to conventional mechanical connectors.



## CROSS-OVER INNOVATIONS

The definition of innovation is creating or capturing value in new and different ways. Molex finds value through close collaboration with its customers — joining our own engineering teams with those of our customers to meet the requirements of today and prepare for the needs of the future.

This provides us with unique insight across industries and the ability to educate our customers on connectivity solutions, technical breakthroughs and successful manufacturing techniques that can be adapted from other applications.




After all, many of today's trends were inspired or adapted from elsewhere. Here are just a few cases in point:

- Vehicle infotainment is a confluence of popular features from consumer electronics and datacom infrastructure.
- Medical technology companies refined miniaturized diagnostics, which now inform the future of consumer wearables.
- And the consumerization of devices implies that user experiences from popular products like smartphones can be applied to other environments.

Regardless of the source of inspiration, clients benefit from Molex's deep investments in next-generation predictive engineering, prototyping and manufacturing methodologies.

These approaches allow for faster development cycles, improved product quality and greater production flexibility — capabilities that are only growing over time.

# CONTACTLESS CONNECTIVITY: A RIVAL OF MECHANICAL CONNECTORS?

Traditional mechanical connectors are now facing a rival in both form and function. Contactless connectivity solutions are cable-free, solid-state devices that enable the wireless transfer of data between devices in close proximity. Rather than using cables and mechanical connectors to bridge the gap, contactless solutions utilize high-speed mmWave RF transceivers and antennas to send and receive signals.

**Contactless connectivity solutions** are just beginning to hit the market but are already proving to be viable alternatives to mechanical connectors in a wide range of applications. What's causing their growing popularity among design engineers?



## UNDERSTANDING THE THREE MODES OF CONTACTLESS CONNECTIVITY

Not all contactless connectivity is created equal. Like their mechanical counterparts, contactless connectors can operate in three transmission modes — each with their own unique purpose and benefit.

**Simplex connectivity** only transmits data in one direction. Data can flow from one device to another, but not vice versa. Simplex connectors are often utilized for unidirectional applications where input is one way, such as a keyboard sending a signal to a computer.

**Half-duplex connectivity** transmits data in both directions, but not at the same time. Some example applications include wireless docks for laptops and peripheral devices or the connection of individual monitors on video walls.

**Full-duplex connectivity** enables simultaneous data transmission between two devices, improving efficiency and reducing latency. Today, full-duplex functionality can be achieved using two pairs of certain half-duplex devices, such as Molex's **MX60 USB SuperSpeed Contactless Connectivity Solutions**. Future full-duplex solutions will house the RF transceiver and antennas in a single package, allowing the use of only one pair of devices.

## ADVANTAGES OF CONTACTLESS CONNECTORS TO MECHANICAL CONNECTORS

Contactless connectivity is emerging to support many of today's most popular communication protocols, such as USB SuperSpeed, **Gigabit Ethernet** and **DisplayPort**. Here are a few reasons designers should be considering contactless alternatives to mechanical connectors.

### Similar Speeds

It isn't enough to simply communicate at a specific protocol, contactless connectivity solutions must perform similarly to their traditional counterparts. For instance, Molex's MX60 SuperSpeed solution can transmit at 5 Gbps when operating in full-duplex mode with two pairs and 10 Gbps when operating with four pairs, which is ideal for applications like docking stations, ruggedized laptops, AR/VR devices and factory automation. Between 2025 and 2028, we predict that the available speeds of contactless connectivity will more than double, significantly expanding the types of suitable applications.

### Sleeker Designs

Contactless connectivity eliminates the need to make space for mechanical connectors, enabling sleeker and more aesthetically pleasing designs. For instance, foldable displays can eliminate the hinge or border used to hide the cable and connector. Designers can minimize the wiring necessary to support audio and video processing within AR/VR devices, reducing headset bulkiness and weight. And docking stations can take up less space on the desk by allowing laptops and peripheral devices to easily connect.

### Superior Ruggedization

Contactless connectivity solutions are ideal for harsh environments as they enable completely sealed product designs, minimizing potential damage caused by dust, dirt and moisture. Furthermore, the lack of cables and mechanical connectors eliminates wear caused by vibration, repetitive motion and repeated connections. Devices will no longer require diagnostic ports which are particularly vulnerable to environmental conditions that can impact durability.

### Improved Manufacturability, Configurability and Testability

Removing diagnostic ports not only protects from ingress but also reduces the time to manufacture, configure and test products. Factory automation systems can immediately connect with, evaluate, diagnose and patch devices without the need for manual intervention or mechanical connection.

### Increased Convenience and User Experience

For both the design engineer and the end user, contactless solutions can simply be more convenient than other interconnect solutions. Designers can use contactless connectivity to replace other high-speed I/O or flex-to-board solutions. End users can more quickly set up systems and devices and avoid the need to connect or hide cables.

### But Power is a Requirement

Although the advantages are numerous, contactless connectivity does have a downside. Unlike traditional connectors, contactless solutions do consume power. As a result, solutions like the MX60 series are being designed to consume only milliwatts.




## IMPROVING UPON THE APPLICATIONS OF TODAY AND TOMORROW

Contactless connectivity is primed to play a dominant role in both current and emerging applications, especially those involving harsh environments. Here are a few examples:

**Video displays** can be easily arranged by simply placing screens alongside each other, allowing signals to be sent and received between displays. The added durability is ideal for outdoor applications.




**Ruggedized networking equipment** such as waterproof networking adapters will be capable of withstanding the elements due to minimal risk of ingress, also ensuring system uptime with reduced risk of failure from extended exposure to rain and snow.

**Industrial robots** will minimize wear by replacing mechanical connectors with contactless solutions, especially in areas exposed to motion and ingress, such as rotating arms. Cables and connectors will not be subject to repetitive bending motions that eventually cause breakage.

**Consumer electronics** such as smartwatches and smartphones can grow lighter, smaller and sleeker while improving durability and resistance to environmental conditions.

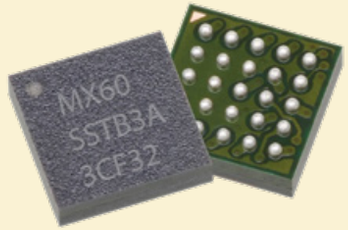
**Medical technology** such as sterilization devices can reduce the risk of exposing sensitive electronic systems to harsh chemicals, heat and vibration.

**Self-driving vehicles** can utilize contactless solutions to communicate between systems, reducing weight and simplifying the wire harness.

## MOLEX: CONNECTING THE FUTURE

Molex is a leader in mmWave antenna design, signal integrity and volume manufacturing, proven by its recent release of the **MX60 series of contactless connectivity solutions**. The first models in the MX60 series replace traditional USB SuperSpeed, DisplayPort and Gigabit Ethernet connectors, and a solution for USB2 and other low-speed interfaces is currently in development. What will the future of contactless connectivity bring? The potential for contactless connectivity is endless and will enable product designs and functionality not yet envisioned.

MX60 USB SuperSpeed Contactless Devices offer high-speed solid-state wireless connections by replacing mechanical connectors, resulting in a convenient and cost-effective connectivity solution that can withstand extreme vibration and harsh environments.



# STAYING ON THE CONNECTIVITY COURSE

The next decade is sure to be filled with ground-breaking product innovations we previously could have scarcely imagined. It's exciting, but it will also be challenging; staying on top of developments and preparing for the next big change will be critical for product designers moving forward. Explore these concepts and more in the Molex report, ***Predicting the Connectivity of Tomorrow: Innovations Driving the Connected World***.

Join us as we launch into the future of connectivity.

**EXPLORE THE FUTURE OF CONNECTIVITY**





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