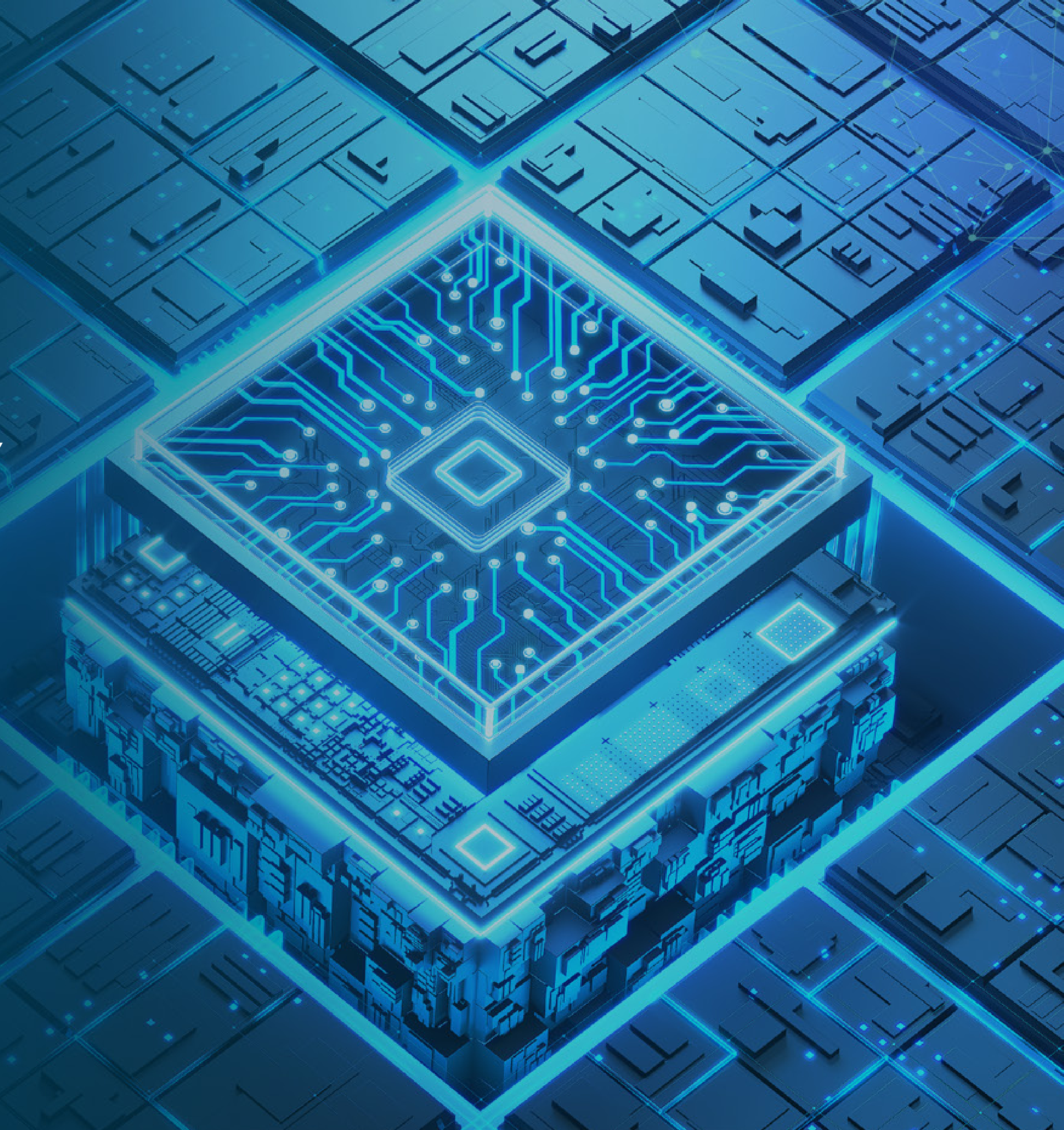
molex

EBOOK

THE RELIABILITY RUN-DOWN

How can design engineers meet business and customer requirements without sacrificing reliability?



DECEMBER 2023

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INTRODUCTION

Electronic devices and systems are simultaneously becoming smaller, faster and more powerful — not to mention more connected than ever before.

But as customer expectations grow, delivering reliable performance becomes more complex. Engineers and system architects are forced to balance product performance with business requirements and market expectations — a scenario that often leads to compromises.

In this ebook, we'll break down insights gained from our ***Reliability and Hardware Design Survey*** and explore the ways design engineers in multiple major industries across the globe are taking on the challenges of growing product complexity without sacrificing reliability.

As engineers face increasingly complex challenges to reliability, suppliers play an increasingly important role. 91% of respondents to our ***Reliability and Hardware Design Survey*** agree: you cannot build reliable products without trusted and proven suppliers.

Molex is up to the challenge — and our history proves it. We have spent over 80 years building engineering expertise into every stage of the product lifecycle. We specialize in navigating complex design tradeoffs and delivering cutting-edge interconnect solutions that will stand the test of time.

TIPS TO AVOID RELIABILITY RISKS: FIVE CONSIDERATIONS IN ELECTRONIC DESIGN

Across industries, product reliability has become unequivocally linked to brand reputation, and failures in reliability can be devastating to a company's brand, product success and even the adoption of new technologies.

Yet the recent ***Molex Reliability and Hardware Design Survey*** of more than 750 design engineers and system architects found only 3% of respondents cite reliability as the top priority when evaluating design tradeoffs.

Here are five design considerations that engineers are unwilling to sacrifice and the innovations that are driving reliability assurance.

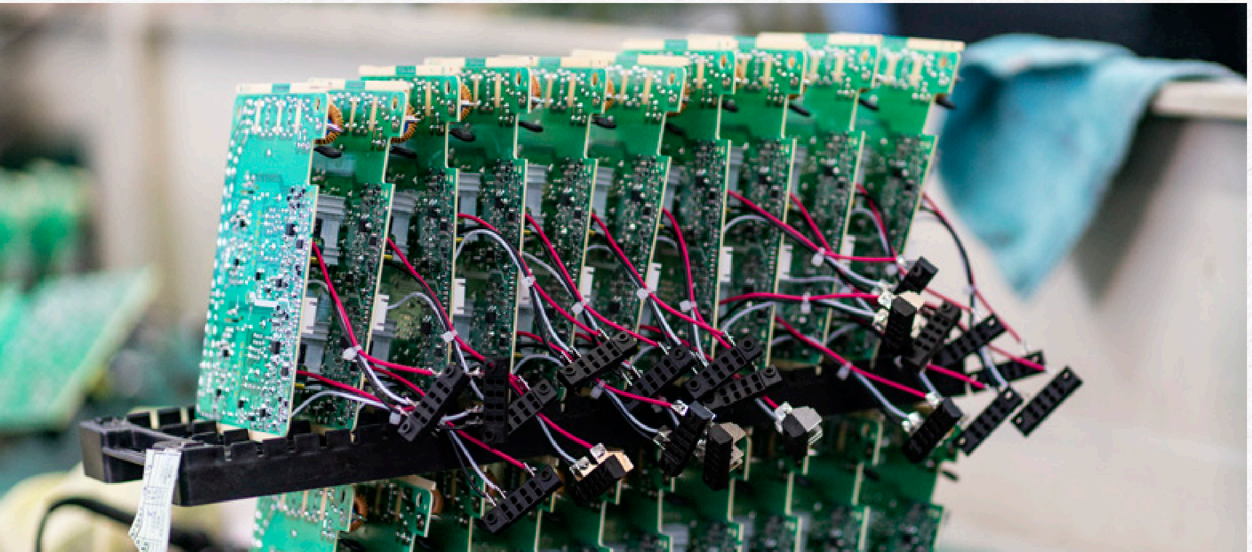
TECHNOLOGY CAN PREDICT THE BALANCE OF COST, MANUFACTURABILITY AND RELIABILITY

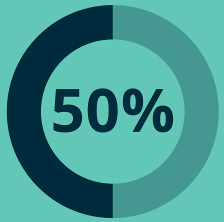
Although technically two different criteria, a product’s cost and manufacturability often go hand-in-hand — and the data supports the correlation.

50% of survey respondents cited cost and 46% listed manufacturability as the most likely design tradeoffs to be prioritized over a product’s reliability. But are tradeoffs necessary and can business requirements still be met without sacrificing reliability?

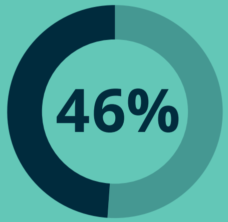
Innovations driven by the transportation industry in **predictive engineering and digital twins** are challenging preconceptions. Software has long existed to support PCB design, highlight thermal hotspots and identify EMI issues.

But advancements in predictive and digital twin technologies are beginning to pull the full picture together and predetermine product performance in real-world environments before physical prototyping.





of design engineers cite cost as the design tradeoff most likely to be prioritized over a product’s reliability.



listed manufacturability.

How does this help balance cost, manufacturability and reliability? A couple of ways include:

Material Selection

The choice of the metals, plastics and other materials used within the design of a product can greatly influence product cost, means of manufacturing and assembly and long-term reliability under typical and extreme uses.

Thermal management — which has a particularly significant impact on reliability — is heavily influenced by materials. This choice can also influence manufacturing method, such as enabling the use of 3D printing.

Predictive engineering can not only predict how well materials will perform, but also how well they can withstand environmental exposures and the rigors of everyday use.

Component Selection

Predictive modeling can help determine whether an off-the-shelf or custom component is necessary in order to meet performance criteria — large influencers to cost — and how reliable the component will be over the product lifecycle.

Molex is even using predictive engineering in the design of its own high reliability connectors and recently developed a high-fidelity digital twin that can predict a connector's current rating with 95% accuracy and measure the effects of temporary current spikes.

For an industry like transportation where reliability can affect user safety, this technology can help reduce recalls and warranty claims.

What's next for predictive engineering and digital twins? Companies are already beginning to pair this technology with AR/VR devices, enabling engineers to directly interact with the virtual world and environment.

As this technology grows in popularity, we can expect engineers to visualize the reliability characteristics of systems, subsystems and components within — such as on the factory floor of an Industry 4.0 facility — data that will prove invaluable to controlling costs, manufacturability and reliability of future devices.

Engineers are excited for this future, with almost half of respondents believing that innovations in data-driven technologies like artificial intelligence (AI), machine learning (ML), simulations and data analytics offer the best opportunity to improve electronic product reliability over the next five years.

USER EXPERIENCES BRIDGE SOFTWARE AND HARDWARE RELIABILITY

It's no surprise that trends in how consumers interact with everyday devices such as smartphones are extending into professional applications and a poor user experience (UX) may quickly doom a product's launch.

Over 1/3 of survey respondents placed the user experience as a must, even at the expense of a product's reliability. But the UX is a complex representation of both software and hardware design, and what may be perceived as a hardware reliability issue by the user may actually be the product of coding.

Further, UX errors are also subject to external influences that may also be perceived as a reliability issue of the device. Connectivity concerns, such as data center downtime, network congestion or even interference from nearby devices can significantly disrupt the UX. How else can UX affect reliability?

Touchscreen Interactivity

The success of touchscreens on smartphones has led to their integration into devices across almost every industry. From car entertainment systems to medical devices, capacitive touch switches have reinvented what it means to control a device.

For a user experience to be considered reliable, though, touch screens must be responsive, resistant to constant physical pressure and legible. Polystyrene sulfonate or poly (3,4-ethylenedioxythiophene) — also known as PEDOT — is a groundbreaking organic polymer that's ideal for the touch human-machine interfaces (HMI) of devices like home appliances.

Although not as ultra-clear as traditional indium tin oxide (ITO) touch switches, PEDOT provides several performance benefits that directly support reliability, including resistance to high-temperature applications like kitchen range cooktops and greater durability when applied to curved and untraditional surfaces.

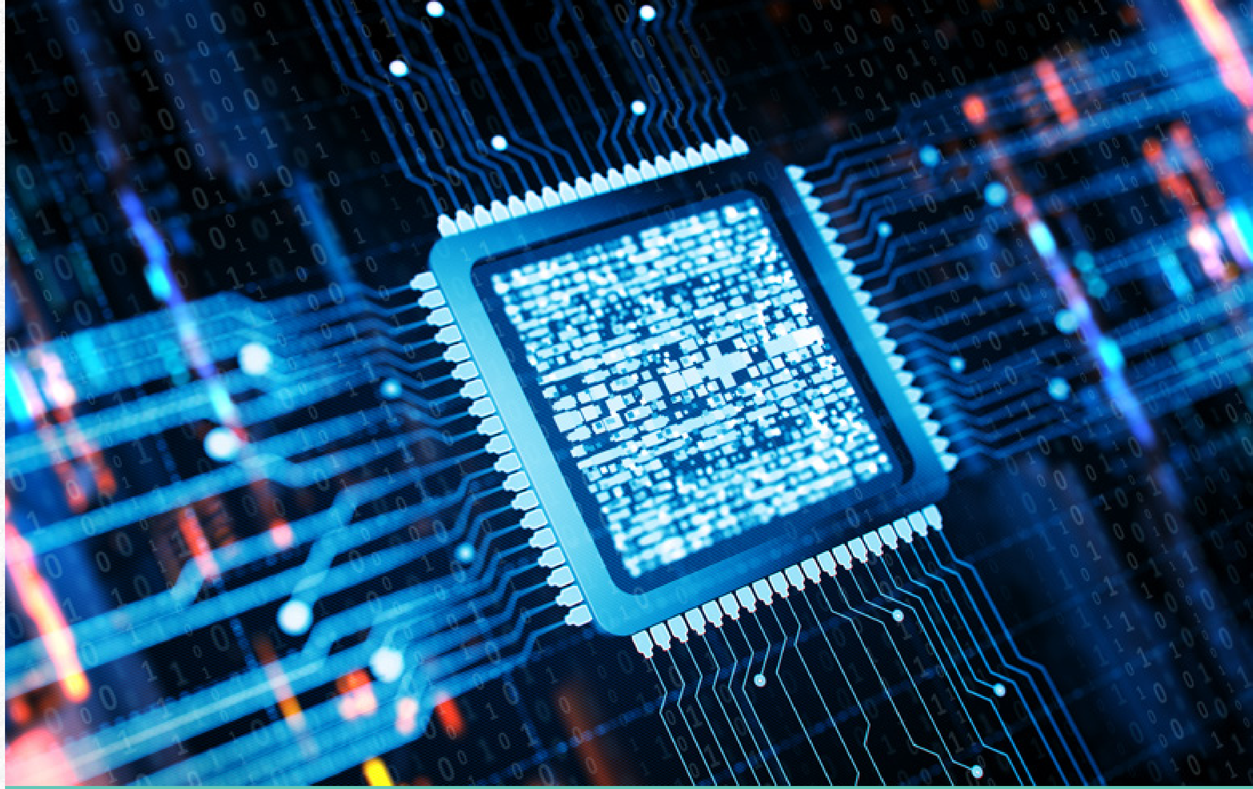
Contactless Connectivity

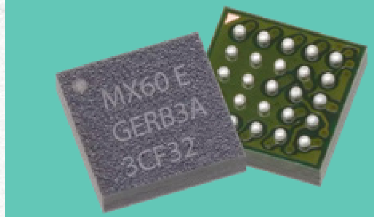
Emerging contactless connectivity devices, such as **Molex's MX60 series of solutions**, provide several benefits to user experience while improving long term reliability when compared to traditional mechanical connectors.

Contactless connectors utilize miniaturized radio frequency (RF) receivers and transceivers to wirelessly exchange data over close proximity, and can communicate in protocols such as DisplayPort, Gigabit Ethernet and USB SuperSpeed.

Suddenly, two monitors can be placed alongside each other and immediately transfer their screens from one to another without a physical cable, simplifying user setup and removing the risk of damaging the connection point from misalignment or misuse.

Additionally, the use of contactless connectivity can eliminate debug ports — improving the user experience of the engineer or technician involved while removing a common entry port of water and dust.





Contactless connectivity is paving the way for sleeker, more flexible and more durable technologies. Molex's **MX60 DisplayPort, MX60 Gigabit Ethernet** and **MX60 USB SuperSpeed Contactless Devices** offer high-speed, solid-state wireless connections with excellent reliability and robustness for harsh environments.

POWER CONSUMPTION PUTS RELIABILITY TO THE TEST

From transportation to data centers, power consumption is on the rise as users demand faster, more feature-rich and more capable systems and devices. The survey respondents reflected this shift with 25% of respondents placing power consumption near the top of their list of priorities.

But this trend has an interesting relationship with reliability as it not only poses design challenges — especially around thermal management — but it stresses the reliability of the power grid itself as it adapts to heightened use.

How can engineers design for higher power without putting reliability at risk?

High Reliability Connectors

Although quality is always important to delivering reliable performance, this importance is amplified in high power applications where low-quality connectors can cause damage to both the system and its surroundings.

For instance, poor quality charging of EV batteries can lead to shortened lifespans, reduced driving distances and even thermal runaway. Similar risks apply in home energy storage systems where the low-quality transfer of power from renewable sources may reduce the likelihood that the battery system kicks on when it is needed most.

For power, heat is one of the greatest threats to reliability. When evaluating **connectors for high power applications**, it's important to not only consider the current but also specialized design characteristics such as large contact surfaces and low contact resistance to minimize heat generation.

RELIABILITY REQUIRES WITHSTANDING REAL-WORLD USE

The growing prevalence of IoT devices and increasing sophistication of systems throughout every industry are placing complex electronics into a wider array of environmental conditions and use cases.

This hasn't gone unnoticed by product designers. 23% of engineers consider a product's ability to withstand environmental and use conditions as one of their primary design criteria.

The use of predictive analytics engineering is one way to ensure durability without sacrificing other aspects of reliability, but what else can be done? Let's again look to transportation.

Learning from Vehicles

Few applications expose electronic systems to a wider range of harsh conditions than the transportation industry. The components used within a car or truck must be capable of withstanding water, dust, extreme temperatures and persistent vibrations.

In a sense, vehicles can be seen as an enormous real-world test of component reliability, and those that have met the rigors of the road can survive almost anything. The same connectors that may be traditionally classified as designed for transportation are also **ideal for industrial robotics, outdoor lighting, agricultural equipment and watercraft.**

A washing machine creates exposure to liquids, heat, cold and vibration. A drone may fly through high winds and moisture-saturated air. A solar farm can be exposed to summer heat and winter weather. Vehicles and the components within have proven resistant to it all.

When considering connector reliability for environmental conditions and everyday use, seek:

- Rugged housings with high ingress protection (IP) ratings such as IP67, IP68 and IP69k protect from fluid and debris
- Locking and alignment mechanisms such as connector position assurance (CPA), terminal position assurance (TPA), primary lock reinforcement (PLR), independent secondary lock (ISL) and inertia lock minimize accidental disconnection
- Wide operating temperature ranges protect from both freezing and high heat conditions

The trajectory of device complexity and market demands likely won't ease up any time soon. But with the right tools, components and collaborative partners, achieving design goals and ensuring reliability are well within reach.

PUSHED TO THE LIMIT: ACCELERATED LIFE TESTING IS KEY TO DATA CENTER RELIABILITY

Data centers are critical infrastructure for our increasingly connected world. However, the environments in which they operate can be difficult for the equipment inside them. Factors like heat, humidity and dust can lead to system failures, downtime and data loss. And this reinforces the need for thorough environmental testing.

Since data centers operate around the clock, the components that keep them running need to be tested for reliability over a long period of time — a difficult scenario for continuous duty devices with multi-year lifespans.

By exposing components to extreme conditions beyond what they would experience under typical operations, engineers can perform Accelerated Life Testing (ALT) to more quickly determine when a part will fail and better optimize them for their intended environment.

But even ALT has its challenges. In data centers, the traditional operating environment has been air cooling. However, liquid immersion is emerging as a preferred cooling technique, and current standards and test methods do not address the unique variables involved in this cooling scenario.

How can today's system architects and design engineers optimize their devices for long-term reliability? ALT is a great place to start.

WHAT IS ACCELERATED LIFE TESTING?

Accelerated Life Testing (ALT) is the process in which products or components are subject to extreme conditions outside of standard operational parameters to artificially age the item under test, identify faults and predict performance under normal operation.

Typical factors include thermal cycling, humidity, shock and vibration along with other criteria. For a data center where systems and devices often operate continuously and for extended periods of time, traditional testing may take years.

ALT expedites the process and allows a manufacturer to significantly reduce testing times, accelerate product development and determine the overall product lifespan.

TYPES OF ALT

Although sometimes considered different classifications of tests, ALT can generally be broken into two categories — quantitative and qualitative — each containing a multitude of test types.

QUANTITATIVE ALT METHODS

In quantitative ALT, the goal is to determine the predicted lifespan of a device by speeding up the time-to-failure and produce data to measure the reliability under a specific influencer. Typically, this is done using one of two general types:

Overstress Acceleration

This is the preferred method for continuously-operating or very high usage products that are exposed to stresses exceeding normal use.

For instance, a product or component may be exposed to very high temperatures under the notion that extreme temperature exposure over shortened periods of time accurately simulates normal temperature exposure over the expected lifespan.

Similar tests can be done for factors like humidity and vibration. Because of the continuous nature of data centers, overstress acceleration tests are critical.

Usage Rate Acceleration

For products that do not operate continuously, these tests are used to more quickly simulate failure by performing a function at a faster or more frequent rate. For instance, connectors are tested to determine their mating cycles, or the number of times a connector can be connected and disconnected without failing to meet performance specifications.

To expedite the test, the connect and disconnect process can be performed more rapidly when the mechanical forces involved remain the same as under normal operating conditions, and it is only the frequency that changes.

QUALITATIVE ALT METHODS

Where quantitative ALT produces data to measure how long a product can perform under specific stresses, qualitative ALT identifies the cause of failure and is often performed on a smaller sample size. Qualitative ALT tests vary but may include:

Highly Accelerated Life Testing (HALT)

Within HALT, a product is subject to a variety of simultaneous and independent stresses, such as temperature and vibration, to identify where and why a failure occurs. Although the stresses may be the same or similar to quantitative ALT, the goal of HALT is not to measure how long a product performs but rather to identify how it fails.

Highly Accelerated Stress Screen (HASS)

After HALT is finalized and design is complete, HASS can act as a final test to ensure reliability at the start of manufacturing. Although HASS exposes a product under test to the same stresses as HALT, HASS is specifically used as part of the production screening process.

Variations of qualitative ALT tests include shake and bake testing, torture tests and elephant tests.

ALT AT A GLANCE

1. **Quantitative ALT:** Determines predicted lifespan of a device by speeding up the time-to-failure. Methods include:
    - Overstress Acceleration, which tests devices for durability against extreme temperatures, vibration, humidity, etc
    - Usage Rate Acceleration, which tests continued function of rapid, frequent mechanical processes such as mating cycles and connecting/disconnecting.
2. **Qualitative ALT:** Identifies specific causes of failures. Methods include:
    - Highly Accelerated Life Testing (HALT), which exposes product to simultaneous and independent stresses to determine which elements cause a failure and at time periods.
    - Highly Accelerated Stress Screen (HASS), which ensures the same stresses identified in HALT no longer cause failure at production.

ALT TESTING OF CONNECTORS: EIA-364

The EIA-364 *Electrical Connector/Socket Test Procedures Including Environmental Classifications* standard establishes recommended minimum test sequences and procedures for electrical connectors and sockets, including ALT.

Each EIA-364 standard assesses specific criteria, such as mating and un-mating force (EIA-364-13), humidity (EIA-364-31), durability (EIA-364-09) or thermal cycling (EIA-364-110) and serves as a baseline for connector performance based on the environments in which they will be deployed.

For data center equipment, the EIA-364-1000 *Environmental Test Methodology for Assessing the Performance of Electrical Connectors* and *Sockets Used in Controlled Environment Applications* is uniquely applicable.

Originally designed for business office applications, ECIA-364-1000 covers relatively mild, controlled environment use, such as devices within data centers.

Although EIA-364 tests are recommendations and not requirements, they have become industry standard and serve as the ALT guidelines for many manufacturers.

CHALLENGES OF ALT IN LIQUID ENVIRONMENTS

While EIA-364 and other ALT standards provide clear reliability guidelines for traditional air environments, ALT for components used within liquid immersion cooling applications is much less defined.

Challenging this is the fact that there are already more than a dozen proprietary dielectric liquids on the market, all performing differently.

Does that mean a manufacturer needs to perform ALT for 12+ liquids in addition to air? Will different products need to be manufactured per medium?

The Open Compute Project (OCP) Immersion Project aims to answer these questions and more using input and insights from industry experts to form a working group devoted to **liquid immersion cooling.**

While air cooling has been the traditional method to lower server temperatures in data centers, immersion cooling has proven **more energy efficient and cost effective** while requiring less space.

Through the Immersion Project, OCP is working to establish standardized definitions, specifications, compatibility requirements and best practices for both immersion solutions and immersion-ready equipment.

Ideally, through the guidance of organizations like OCP, manufacturers will be able to design one product that performs reliably across all liquid and air-cooled environments. For system architects and design engineers, this will simplify the BOM and minimize the risk of confusion and error.

And engineers are excited to get ahead of the game. In fact, a recent ***Molex Reliability and Hardware Design Survey*** found that 51% of the 756 respondents already strive to meet possible future industry reliability certifications and standards, in addition to current requirements.

HOW GRID RELIABILITY CHALLENGES ARE ACCELERATING INNOVATION IN ENERGY MANAGEMENT

The demand for power is growing at an exponential rate. Driven heavily by Asia, world energy consumption **will increase by almost 50%** between 2018 and 2050, as predicted by U.S. Energy Information Administration.

This rising demand will occur while a large portion of the global power grid infrastructure is at a critical point in its lifecycle. In Europe alone, 40% of the grid infrastructure is over 40 years old.

The challenges to the traditional grid establish a theme throughout energy management applications — in order to have efficient, reliable power, the grid must be modernized using smarter equipment with a focus on data and dependability.

CHALLENGES TO GRID RELIABILITY

While aging infrastructures and growing demand contribute to power grid instability, other factors also play a role. Unexpected events can cause widespread outages — not just locally, but for entire regions.

Extreme Weather

Significant changes in temperatures, as well as long stretches of hot or cold weather, put a strain not only on power demand, but on grid equipment as well.

Weather events like tornados, hurricanes, flooding and severe thunderstorms can knock out power to the surrounding areas they affect. Recently, a typhoon struck Okinawa, Japan, **leaving 200,000 households without power**.

Geopolitical Disruption

Geopolitical relations and conflicts can have significant ripple effects, including disruption to grid reliability. For instance, a military strike on grid infrastructure in one country can lead to a major power outage in a neighboring region.

Trade embargoes and tariffs can trigger fuel shortages and force governments and citizens alike to seek cheaper or more accessible alternatives.

As a result of these types of global scenarios, the EU is diversifying its energy sources to limit its dependence on foreign oil resources.

Wildlife

Animals also wreak havoc on power grids. In Japan, one snake was responsible for **knocking out power to nearly 10,000 homes**. In the US, **squirrels alone cause nearly half of all wildlife-related power outages.**

While these examples may conjure amusing visuals, wildlife causes considerable damage to transformers, substations and power lines, leading to costly large-scale outages.

Cybersecurity Threats

In recent years, cyber attacks have targeted critical energy infrastructure facilities across the globe, bringing to light a new threat to the grid.

Hackers can gain access to power grids digitally — through ransomware and internet of things (IoT) system vulnerabilities — and remotely disable equipment.

Although these incidents are generally underreported, they are **steadily increasing**, a situation that will likely continue as global grids begin integrating more connected technologies and become more exposed.

Communities, institutions, companies and entire countries are experimenting with innovative energy initiatives as a result of these disruptive environmental, geopolitical and cyber events.

GLOBAL TRENDS TOWARD GRID MODERNIZATION

Faced with the reality of increasingly unreliable centralized power grids, both public and private sector entities have implemented an array of modern energy approaches that differ significantly around the world.

In Europe, for instance, countries like Germany have embraced the concept of the "all-electric society" with the intent to phase out traditional power sources and implement fully renewable energy systems. But the European approach toward a renewable energy future poses unique challenges to infrastructure.

For example, in the summer of 2023, electricity prices in many European countries **fell into negative territory** due to a high amount of solar power being fed back into the grid while traditional sources were unable to significantly reduce their output, resulting in a power surplus.

Moving forward, the challenge and opportunity will be to store this energy for use in the darker winter months.

In the United States to date, renewable energy has been identified as an approach to supplement and support the traditional power grid during periods of high use or critical failure.

This helps alleviate the strain of spikes in demand, protect critical infrastructure during downtime and simply minimize potential disruptions. Through **energy independence**, the U.S. hopes to diversify its energy sources and integrate more reliable backup solutions.

And in Asia, grid modernization is highly varied. In China, government initiatives have accelerated efforts to update and replace aging grid infrastructure — **relying heavily on traditional power sources like coal** while installing large solar and wind farms. The Philippines is **emphasizing national energy security** while Thailand's focus **centers around renewable energy** and carbon capture mechanisms.

These global examples illustrate that while motivations and methodologies may differ, there is universal consensus on the importance of grid modernization.

SMART GRID TECHNOLOGY OFFERS A RELIABLE PATH FORWARD

Smart grid technology, which encompasses a broad category of products and systems that work in tandem to modernize power infrastructure, aims to make the power grid more reliable and resilient.

Along with replacing aging infrastructure, deploying emerging smart grid technology can provide efficiencies through greater awareness of energy use and allocation and more protection from downtime. Here's how:

Smart meters replace traditional gas and electricity meters outside homes and provide greater visibility to usage. Many smart meters can send data to an in-home display, offering consumers the opportunity to save money by minimizing use at peak hours.

The same data is securely sent to the energy company, enabling providers to better anticipate usage and both prevent and detect power outages.

In the Asia-Pacific region, the number of installed smart metering devices is projected to **reach one billion in 2026** which will deliver benefits to consumers and the power grid.

Distributed energy resources (DERs) are like miniature power plants in your backyard. A DER is any small-scale, decentralized energy source that can generate or store electricity.

Examples include photovoltaic (or solar power) systems, wind turbines, heat pumps and **battery energy storage systems (BESSs)**.

DERs help reduce energy waste by generating electricity near the location where it will be used. They subsequently improve power grid reliability by acting as backup power sources during outages and relieving the grid during peak operation.

Microgrids are localized electric grids that operate independently of a centralized grid. A series of DERs can make up a microgrid, allowing an area to maintain electricity during an outage of the larger, centralized grid.

Microgrids aim to keep critical infrastructure like hospitals and communication networks running during periods of disruption or even to replace traditional energy sources altogether.

A good example of a microgrid community is **Borrego Springs, California**, USA. This remote town has one 60-mile power line connecting it to the centralized power grid.

When severe weather occurs, residents are easily cut off from the main grid; but with its localized smart grid, Borrego Springs can keep the lights on.

Other success cases for community microgrids can be found in places like **Olst, Netherlands**, and in **Shuanghu, the Tibet Autonomous Region of China.**

ON THE ROAD TO RELIABILITY: HOW TEST-TO-FAILURE IS ENSURING LONG-TERM PERFORMANCE

For automotive design engineers, every emerging feature, functionality and architecture introduces a variety of unique challenges, especially when these advancements are often occurring simultaneously.

For instance, EVs and vehicles equipped with advanced driver assistance systems (ADAS) have significantly more complex electrical systems and sensors than conventional internal combustion engine (ICE) vehicles, and they often require new approaches to thermal management, a greater focus on battery safety and consideration of functional safety for features like wire steering and electric braking.

Challenges such as these will only increase with emerging functionality, including in EVs, the incorporation of more interactive infotainment systems, the continual evolution of ADAS and the eventual evolution of full self-driving (FSD).

As the complexity of vehicle electrical systems increases, the performance requirements are placing added stress on the components used. For example, some connectors within EVs may experience near continuous operation not only when the vehicle is driving but also when charging and must be designed to support these additional operational conditions.

The vehicles of today and tomorrow demand component manufacturers like Molex to be more cognizant than ever in ensuring parts perform to standards and regulatory requirements as well as operate reliably in the field over the life of the vehicle.

Designing for Reliability (DFR) requires a fundamental shift that calls for reevaluating traditional test methods and incorporating innovative reliability prediction models that can be leveraged by AI and ML to better optimize designs for performance in real-world conditions — down to the component level.

MOVING FROM TEST-TO-PASS TO TEST-TO-FAILURE

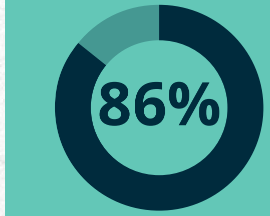
Although vehicle functionality is becoming increasingly complicated, many automakers are working to simplify the components within and seeking single solutions that can be applied in a variety of locations with different stress conditions or duty cycles.

For Molex, that means designing our connectors to withstand greater ranges of heat, vibration, ingress, corrosion and other variables. But to do so, we need to identify the design strength for reliable operation and switch the traditional test-to-pass model to test-to-failure.

While test-to-pass is the historical norm, it only tells us if we pass or fail test criteria — it doesn't measure how far off we are when failing, nor the safety factor if passing. By contrast, test-to-failure determines the safety margins, or the difference between the design's limit, such as product strength and the specification acceptance criteria for performance.

This approach isn't unique to the transportation industry and reflects the challenge engineers face when accounting for more complex, feature-rich expectations. In the recent **Molex Reliability and Hardware Design Survey** of more than 750 design engineers and system architects, 86% of respondents revealed that they design new products to either surpass current requirements or aim to meet possible future requirements in addition to current requirements.

How is Molex driving this transition to real-world reliability testing?



of design engineers surveyed said they aim to either surpass current requirements or meet possible future requirements when designing new products.

PUSHING THE LIMITS WITH TEST-TO-FAIL

Accelerated Life Testing (ALT) is a widely used **method across industries** to simulate the field life of a product. This is achieved by exposing the product to extreme environmental and use conditions over a shortened period, and then determining whether it still meets specifications.

These exposures could be to stresses that exceed everyday use cases, such as very high vibration level or temperatures, or accelerated usage rates such as repeatedly connecting and disconnecting a connector. However, it is important to note that ALT is not a perfect test strategy and can lead to under or overdesign if not used appropriately.

Test-to-failure generates a more accurate understanding of product strength relative to field stress by straining the item to its point of failure. The test-to-failure data can also be used to develop the acceleration factor for the ALT. By leveraging test-to-failure methodologies, designers can optimize a product without overdesign while still ensuring performance and reliability requirements are met.

Molex uses the test-to-failure method to better understand how well our products will withstand real-world environments, improve current and future product designs and provide confidence to our customers. But we're not just measuring the performance of a physical product or prototype — we're predicting the reliability throughout the product design cycle.

TRAINING PREDICTIVE MODELS WITH TEST-TO-FAILURE DATA

Predictive engineering and digital twins have long had a place in automotive design, but Molex is now applying these **same methodologies to the component-level** using data captured through extensive product testing, such as test-to-failure, and informed by POF models.

Fundamentally, this provides customers and Molex alike with several major benefits, including:

1. Products are proven to be capable of withstanding the demanding conditions — with the supporting data as evidence.
2. The prototyping and testing stage can be simpler, more cost-effective, collaborative and even more experimental, enabling improvement to virtual prototypes prior to physical prototyping.

Better yet, the AI and ML models supporting these methodologies are continuously trained on the latest product test results, making them increasingly more capable and accurate over time. Modeling such as this enables more that can be used across a broader range of transportation requirements.

THE KEY TO ACHIEVING A RELIABLE FUTURE

As engineers face increasingly complex challenges to reliability, suppliers play an increasingly important role.

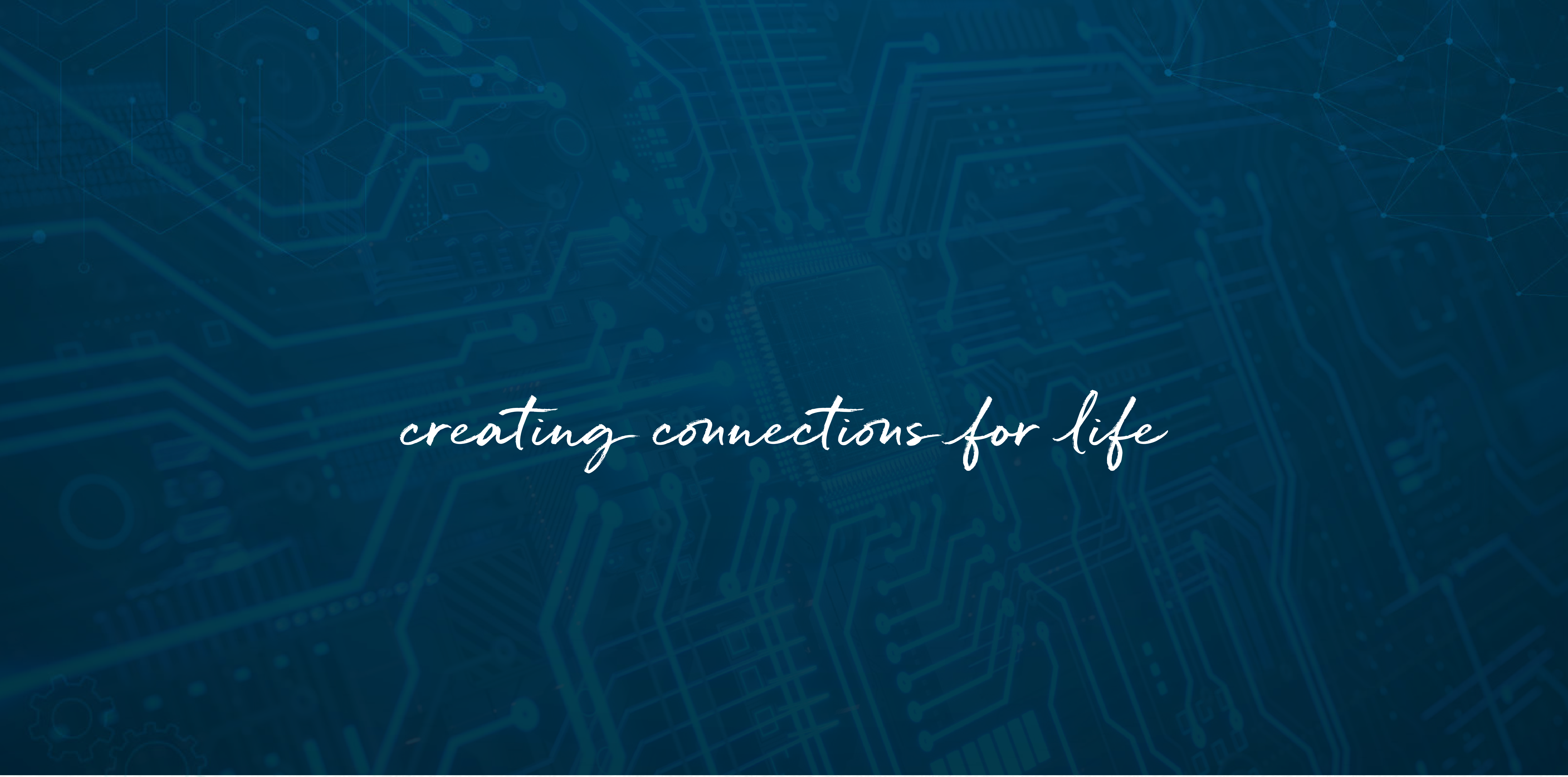
At Molex, we take our reputation as a trusted supplier and industry leader very seriously. We combine a comprehensive product portfolio with a broad range of interdisciplinary engineering expertise, from design through to prototyping and testing.

Our extensive history in design for reliability methodologies has laid the groundwork for our innovative, predictive approach and provides our customers with the data needed for more informed decision making and greater confidence in the long-term reliability of our products.

Our global engineering and supply chain resources are ready to help supplement your team and navigate the challenges, opportunities and solutions of new technology design.

Interested in learning more about reliability at Molex? Explore **reliability trends and solutions**, and view the complete Reliability and Hardware Design Survey Report **here**.

DOWNLOAD SURVEY REPORT



creating connections for life

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