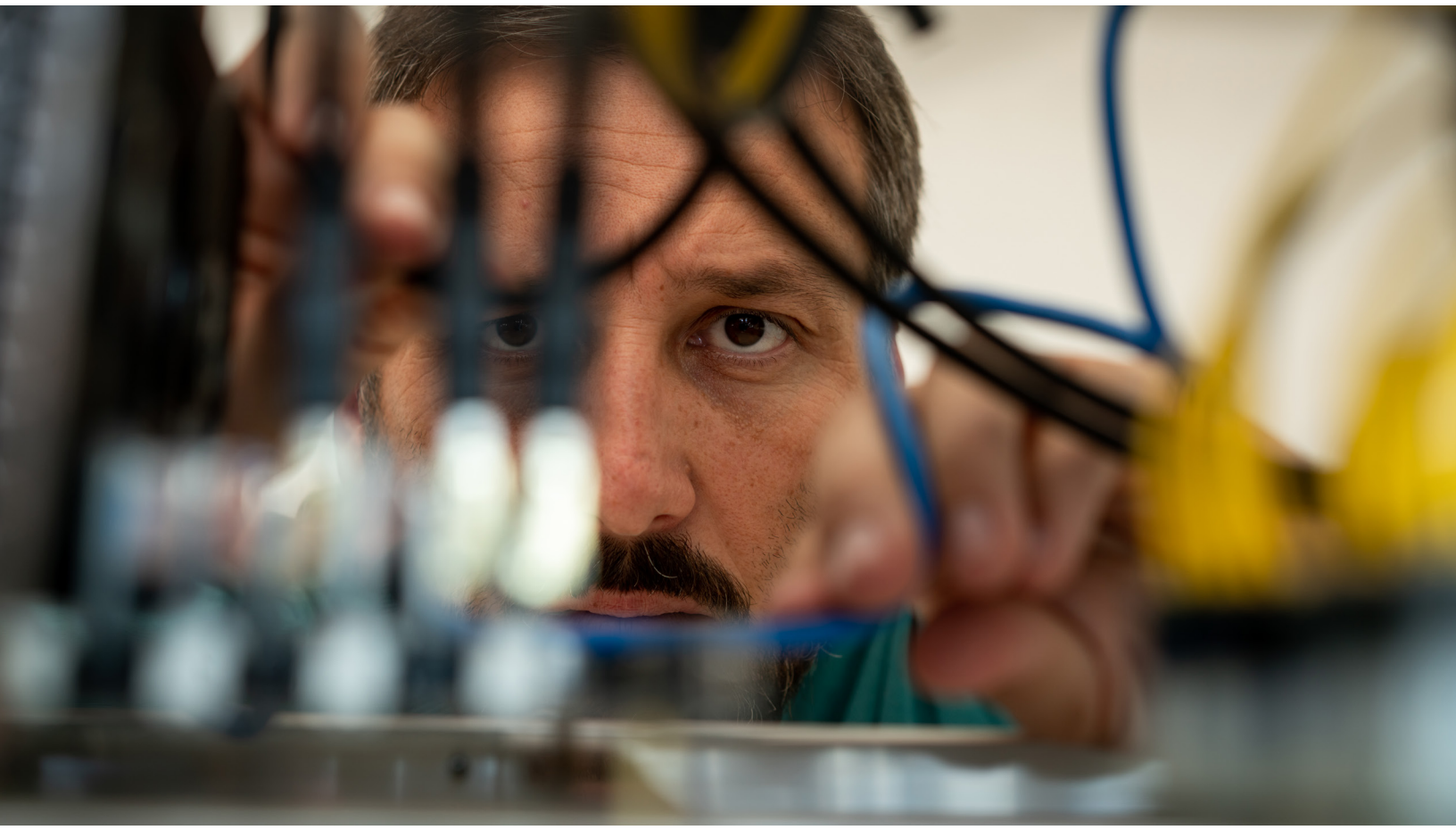
WHITE PAPER

ERGONOMIC CONSIDERATIONS WITHIN **ELECTRONIC CONNECTOR DESIGN**



molex

creating connections for life

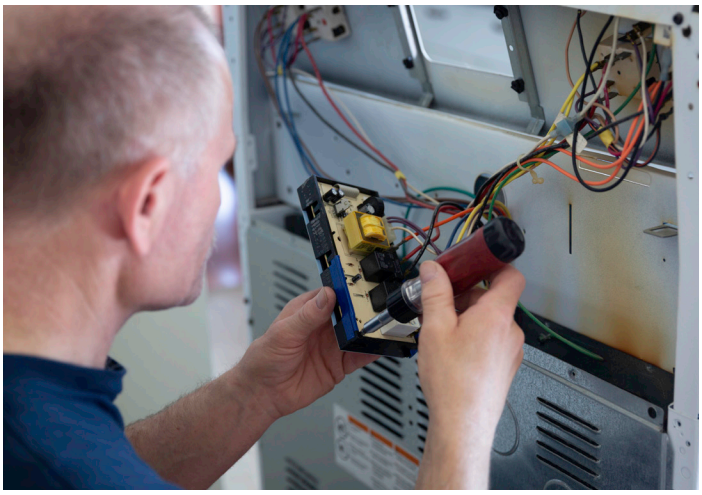
Consumers today expect their home appliances to have more features than ever. More features involve more connections, smart sensor capabilities and the means to accommodate future enhancements. With these expectations and design demands comes a growing focus on operator assembly safety and improved ergonomics. Specific areas of connector design for original equipment manufacturers, harness manufacturers and appliance assembly/component factories must be addressed to support ongoing ergonomic improvement.

The Growing Importance of Ergonomics

Ergonomics is the science and practice of designing jobs and workplaces to match the capabilities and limitations of the human body. Simply put, ergonomics optimizes design factors to help maximize productivity by minimizing operator fatigue and discomfort. The most common workplace injury related to poor ergonomics is carpal tunnel syndrome — a repetitive motion injury in which a pinched nerve in the wrist causes numbness and tingling in the hand.

Carpal tunnel syndrome impacts more than eight million Americans each year. About 120,000 of those carpal tunnel cases are severe enough to warrant surgery to relieve symptoms. Research shows that repetitive motion injuries and musculoskeletal disorders cost U.S. employers an estimated $80 billion per year. They also require about 23 days of recovery per employee.

To help reduce the number of repetitive motion injuries and musculoskeletal disorders suffered by their workforces, some employers are prioritizing ergonomics to identify improvements that can help reduce injuries related to repetitive tasks. Making ergonomic changes within the work environment may help reduce the chances of carpal tunnel or a similar repetitive motion injury.



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Connector Design and Ergonomics

Design features that enable easier assembly of core terminals and connectors in home appliances can often measurably improve ergonomics without sacrificing application-related functionality. These features include:

Reduced contact/connector mating forces

Reducing the force required to mate connections can help reduce strain on operators, lowering fatigue and risk of injury. This, in turn, can often enhance quality, safety and efficiency. Improvements in connector mating are driven by contact design and include base material, plating, lubricant selection and housing design.

Connector housing design and contact lead-in

This important design factor ensures that housings are pre-aligned ahead of contact mating and the lead-in is supported for contacts. These considerations help reduce any potential interference or stubbing at the point of contact driving higher mating forces. Specifically, chamfers on connector housings, good radii on male connector pins and mating receptacle lead-in features are used to improve overall ergonomics related to the connector mating process.

Safe push points

Well-positioned and designed operator push points are a key consideration in ergonomics and safety in high-volume assembly environments. Connector housings must also be rounded and free of sharp points on edges, allowing for optimal leverage and comfort.

Audible and tactile feedback

By providing audible and tactile feedback within the connector latching, connector manufacturers can help reduce unnecessary operator strain during assembly and eliminate time spent checking potentially faulty connections. When the connector is fully engaged, the operator can hear and/or feel that the connection is secure and move to the next task — rather than exerting unnecessary force to ensure the connection has been made.

Other features that can help ease connector assembly while improving overall operator efficiency include the following:

Polarization and keying of mating connector plugs and receptacles

Polarization helps prevent connector mis-mating with improper orientation. Including mechanical keying features ensures that multiple connectors of the same position are assembled to the proper mating connector. Color-coding is often supported with keying to aid in operator assembly efficiency. See Figure 1.

Contact float within housings

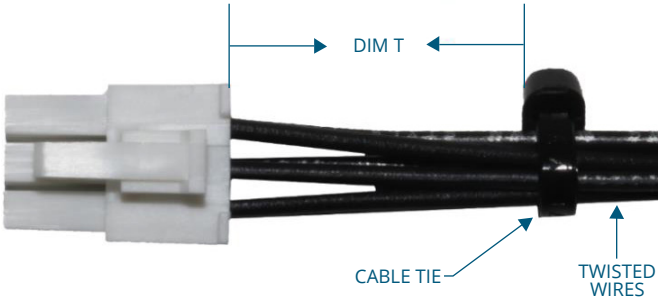
This feature allows movement within contacts for improved mating and reduced stubbing. It also creates adequate distance between contact and wire restriction point. See Figure 2.

- The “T” dimension defines a “free” length of wire, or a length of wire that is not subject to significant bias by external factors such as wire tie, wire twisting or other means of bending or deforming of the wires that repositions them from their natural relaxed state or location where they enter the housing. This dimension is a general recommendation and may need to be adjusted for different wire gauges, wire type, insulation thickness and insulation material.
- Wires are to be dressed in such a manner to allow the terminals to float freely in the housing pocket.

Figure 1: *Polarization and Keying of Connectors – Molex Nano-Fit Power Connectors*

TIE AND/OR WIRE TWIST LOCATION

Circuit Size	Dim T Min.
2 to 6	.50” (12.7 mm)
8	.75” (19.1 mm)
10 to 12	1.00” (25.4 mm)
14 to 16	1.34” (34.0 mm)
18 to 20	1.45” (37.0 mm)
22 to 24	1.57” (40.0 mm)



Note: Pictorial view shown for illustration purposes.

Figure 2: *Contact float within housings allows adequate distance from contact to wire restriction. Featured here is the Molex Mini-Fit Sigma Connector System.*

Housing locking/retention mechanism design

This type of design provides tactile feedback and alerts the operator with an audible click upon successful connector mating, thereby lowering overall insertion force. See Figure 3.

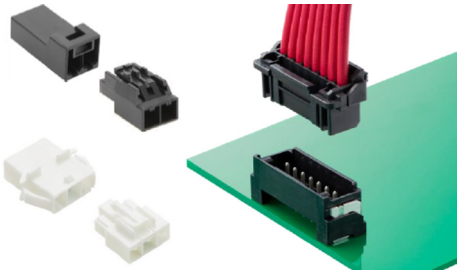


Figure 3: *Housing locking/latching within Molex VersaBlade Connector System (left) and Molex Micro-One Wire-to-Board Connection System (right)*

Terminal Position Assurance (TPA)

TPA helps ensure that the terminal is fully seated and retained in the housing to eliminate contact back-outs. It also enhances contact retention and alignment. See Figure 4.

Figure 4: *Terminal Position Assurance Examples*

Color and mating orientation cues

Adding these types of visual cues enables fast, easy operator identification that can improve assembly ergonomics and overall productivity. See Figure 5.

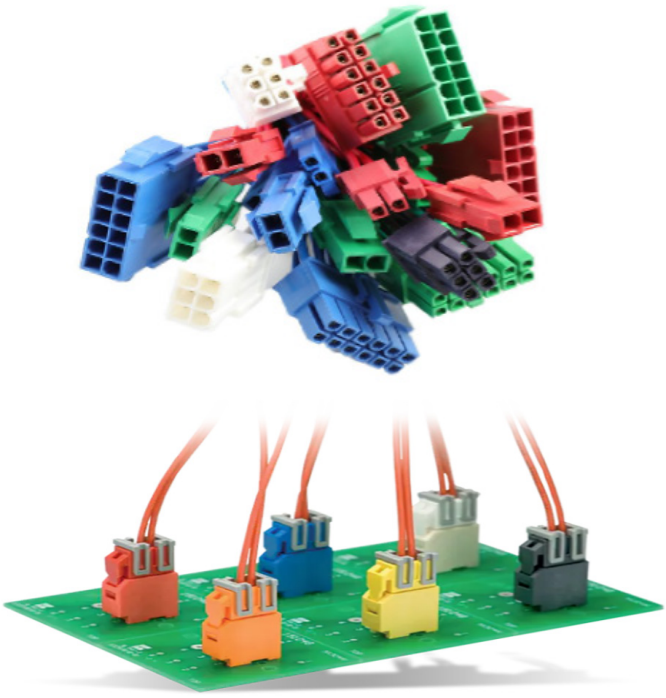


Figure 5: *Color coding of connectors. Molex Mini-Fit Versa Color Power Connectors (top) and Molex CP-6.5 Series Wire to Board Connectors (bottom)*

Lever actuation

Compared to conventional connector plug and receptacle mating approaches, this feature can reduce overall mating force. A built-in lever offers mechanical assistance that can often enable connector mating with 1/6 of the typical mating force required. This approach is often used in select automotive applications where simultaneous mating of 40 to 80+ circuits within electronic modules is common. See Figure 6.

Figure 6: *Lever Actuated Connector – Molex MX123 Sealed Connector System*

Use of proper extraction tooling

Extraction tooling is used when needed to aid in repair operator safety. See Figure 7.

Figure 7: *Extraction Tool Examples*

Real-World Examples: Ergonomic Connectors for Home Appliances

A few examples of connectors for use in home appliances within the Molex portfolio include these signal and low-to-mid power connector offerings, including a targeted lower mating force offering.

Connector Family	Nano-Fit Power Connectors	Micro-Fit+ Connector System	Ultra-Fit Power Connectors
Pitch	2.50mm	3.00mm	3.50mm
Tin Maximum Mating Force	0.7 lbs.	0.5 lbs.	0.95 lbs.
Gold Maximum Mating Force	0.25 lbs.	0.26 lbs.	0.5 lbs.

Connector Family	Micro-One Connection System	Micro-Lock Plus Connector System	Mini-Lock Connector System	KK Plus Connector System
Pitch	2.00mm	1.25mm	2.50mm	2.50mm
Tin Maximum Mating Force	0.55 lbs.	0.25 lbs.	0.8 lbs.	0.7 lbs.

Ergonomic Risk Factors During Connector Assembly

By combining optimized connector designs with best practices in the workplace, assembly personnel can perform tasks more efficiently and effectively. This can improve worker safety and morale, reduce employee turnover and lead to fewer errors. Examples of risk factors associated with the assembly of connectors include the following:

Factor	Risk
Static posture	Specific assembly postures that a worker maintains over long periods of time can reduce blood flow and impact muscles.
Quick motions	Quick movements can increase the amount of impact force applied to the body.
Finger/hand compression	Grasping sharp pinch points on small components can result in potential tendon and/or muscle damage.
Recovery between tasks	Inadequate recovery time can exacerbate operator fatigue and increase assembly times overall.
Mating force	High mating force can cause a variety of injuries, including carpal tunnel syndrome.
Repetition of similar movements	Continued repetition of similar movements can cause tendon issues and increased nerve pressure.
Posture	Positions that stretch physical limits can compress nerves and irritate tendons.

Harness Maker Challenges

Wire harness manufacturing for home appliances poses many ergonomic challenges due to the high number of contact insertions into housings and repetitive motions required. Ergonomics within harness assembly is based on addressing four primary biomechanical risk factors: the amount of force applied, how awkward the working postures are, how much time is spent in these postures and how often the forces and postures repeat. Carpal tunnel and tendonitis are two of the more common repetitive motion injuries associated with wire processing. “Wire harness assembly is very hand intensive,” says Julia Abate, executive director of the Ergonomic Center of North Carolina. “Anytime you’re doing any manual tasks that are repetitive, such as wire cutting, stripping, crimping or wrapping, there is a greater risk for injury. Holding wires or fitting wires into connectors requires numerous two-finger and lateral pinches, which can cause problems.”

Wire harness assembly is very hand intensive

Understanding Industry Specifications and Software

For design engineers aiming to improve ergonomics in home appliance assembly, it is important to review industry specifications and consider software designed to tackle this challenge. The United States Council for Automotive Research (USCAR) and HandPak software are two important starting points.

USCAR

USCAR provides electrical connector assembly ergonomic design criteria recommendations under its USCAR25 specification. This document describes the overall design, assembly force, testing, evaluation and packaging guidelines for conventional hand-mated connectors, mechanical assist connectors and twist lock connectors. It also provides details on connector positions assurance design and use. Although focused within automotive markets, many of the criteria and performance requirements can be addressed where needed for connectors designed for other industries.

USCAR25: Electrical Connector Assembly Ergonomic Design Criteria - SAE International

HandPak Software

HandPak software, developed by Potvin Biomechanics, is used to quantify acceptable forces and torques for occupational tasks placing demands on the forearm, wrist and hand. The software is appropriate for analysis of acceptable mating forces of connectors within various applications, especially those with high volume repetitive motions for connector mating assembly.

Modules include the analysis of:

- Forearm pronation and supination torques
- Wrist flexion, extension, radial deviation and ulnar deviation torques
- Various pinch and hand grips
- Pushes and pulls with the fingers/thumbs and hand grips

HandPak is used by many companies in vehicle assembly, parts manufacturing, rehabilitation, laboratory technology, consulting, health sciences, government work and more. Tasks can be assessed for single effort strength, or to account for duty cycle (combination of effort durations and frequencies).

HandPak – Potvin Biomechanics

CONCLUSIONS

Optimizing connector design to reflect current best practices in workplace ergonomics helps assemblers perform tasks more efficiently and effectively. This, in turn, can drive improvements in safety and morale with reduced employee turnover and fewer errors — which benefits appliance manufacturers, their specialized teams and their customers.

Molex: Designing with Ergonomics in Mind

As interest in worker health and safety continues to grow alongside consumer demands for more features in home appliances, it is essential to consider ergonomics at every point of the manufacturing process. Molex brings over 80 years of innovation and engineering excellence to every design challenge. This knowledge and expertise underscores the Molex approach in all that we do, including creating connectors with easy and secure assembly in mind, and helping operators stay healthy while keeping assembly plants running smoothly. Molex can provide the critical expertise and product selection needed for the entire home appliance design process, from concept to final assembly.

WORKER HEALTH & SAFETY

TECHNICAL EXPERTISE

HOME APPLIANCE EXPERIENCE

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