



OMNETICS
CONNECTOR CORPORATION

THE EVOLUTION

Of Miniature Quick Release Connectors In Defense Electronics

In the ever-evolving landscape of defense electronics, the drive towards miniaturization and enhanced performance has never been more critical.

The integration of sophisticated technologies in military operations demands connectors that are not only smaller and lighter but also rugged and reliable. This article explores the evolution of miniature quick release connectors, their impact on defense systems, and the technological advancements that have enabled their development.

The Miniature Connector Revolution

The modern battlefield is increasingly dominated by centralized data management systems that connect various facets of military operations. From battlefield coordination via satellites to troop monitoring through soldier-worn electronics, the need for advanced embedded electronics that operate at higher signal speeds and offer more data processing, transmission, and storage capabilities has never been greater. Solid-state circuitry has evolved to meet these needs, with new materials and technologies playing a pivotal role.

One of the most significant advancements is the use of materials like Gallium Arsenide (GaAs) and Gallium Nitride

(GaN) in microwave circuitry. These materials facilitate higher speed signal processing and are integral to the latest military technologies. Complementary Metal-Oxide-Semiconductor (CMOS) technology also offers improved circuitry for memory storage and digital processing, essential for military computers and remote-control systems.

The electrified defense industry today is rapidly expanding the use of centralized data management systems that penetrate all sectors of military operations. Satellite-based battlefield coordination systems collect and process data, transmitting signals to and from central control centers in the field. These systems direct operations on the battlefield and actively monitor troop activities through sensors, detectors, and surveillance devices mounted on equipment and soldier-worn electronics.

To support these advanced technologies, embedded electronics must operate at higher signal speeds, offer more data processing, and provide enhanced transmission and storage capabilities.



LATCHING MICRO-D
POWER PLUS SIGNALS

The solid-state circuitry industry has evolved extensively to support this new wave of technology, competing with new military devices from near-peer competitors. New chip materials, such as GaAs, are employed in much of the latest military technology for higher speed signal processing in microwave circuitry. Silicon chip technologies using CMOS offer improved baseline portable circuitry for memory storage and digital processing in military computers, observation devices, and remote-control circuitry for drones and autonomous weapons. These field-effect transistors and integrated circuits function rapidly on very low energy systems. Newer GaN circuits are improving surveillance and high-end ultraviolet signal management (EUV).

Laser pulsed plasma circuits generate high-power laser beams for very short wavelength light, significantly increasing the resolution of scanned images from satellites with LIDAR scanning equipment on board. New defense-based solid-state circuits operate on lower currents and voltages, extending battery life in the field. Portable radar systems can be carried in backpacks, and multimode surveillance devices can be mounted on helmets, allowing soldiers to be individually monitored and report their position via GPS systems. These new defense instruments operate at high signal speeds while being increasingly more portable, necessitating smaller, rugged, and lightweight electronics.

As technical and data collection capabilities expand, the need for transporting additional data storage and transmission modules grows. Quick and easy yet rugged and reliable electronic cable and connector exchanges are critical within the battlefield environment. Micro-wave and coaxial cabling are also becoming smaller and more miniaturized, with trends indicating more applications for higher speed switching and multiple frequencies in both transmit and receive modes. The shorter wavelengths of RF frequencies will ensure the miniaturization of more portable antennas, and more densely packed modules will result from this miniaturization process, adding to potential EMI and ESD sensitivity.

Electromagnetic Interference and Signal Integrity

Electromagnetic interference (EMI) issues necessitate improved shielding and RF leakage protection within instrumentation, as well as cable shielding and metal connector back-shells for portable equipment. Interconnects must ensure low noise and crosstalk (NEXT) specifications are met. As signal speeds and multi-signal level transmissions, such as pulse amplitude modulation (PAM) methods, increase, noise and crosstalk will emerge as key specifications for cables and connectors.

As PAM techniques are adapted to voltage level modulation methods, coaxial cables will carry multiple signals on one line. More portable and rugged Nano and Micro Coax are emerging through a process of adaptation on PCB modules and evolving out to EOU (end of unit) to reduce size and weight. Specially designed Nano-coax and connectors are adapted for board-to-cable routing in instruments requiring high mobility.



UAV HELICOPTER

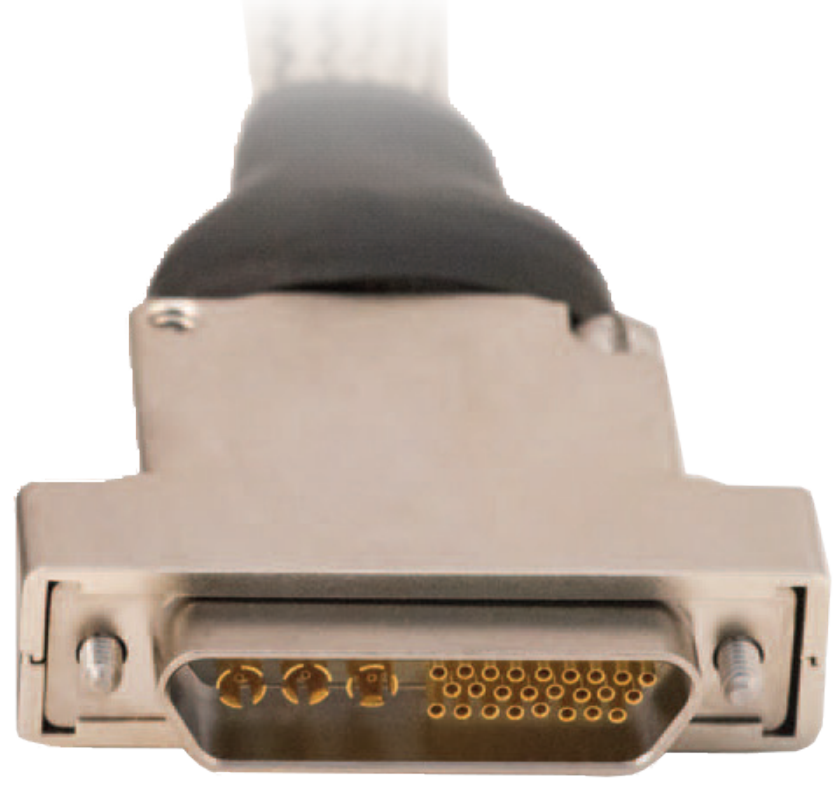
As signal speeds increase and voltages decrease, signal integrity design and management become critical to the functions needed in mobile military and aerospace systems. Connector-to-cable design requires a perfect match to the electrical application of the circuit. Digital signal quality is more often assured by using differential cable design that matches the impedance of the output and/or input system of the processor boards and detectors. Proper shield and drain wire interconnections increase system accuracy and help ensure appropriate eye pattern quality. Eye patterns are used to evaluate the combined effects of channel noise and interference in pulsed-transmission systems inside the cable. Shielding also improves the transmitted signal through the connector and cable assembly, reducing jitter and crosstalk. Reduced size, lower weight, and ruggedness immediately follow in the list of important specifications to serve the needs of portable ground troop electronics, airborne equipment such as UAVs, and military satellite systems. Military connector designers must seriously plan and implement the use of military pin-to-socket elements that exceed the minimum requirements of wear during insertion and retraction force.

The Importance of Quick and Easy Connections

On the battlefield, the ability to quickly replace modules within systems is essential. Connectors designed for rapid and reliable exchange play a crucial role in maintaining operational efficiency. Connectors must be designed to offer quick and easy replacement of modules from within the systems while on missions in the field. Military quality specialists such as Omnetics and other suppliers offer a variety of down-sized designs from circular and rectangular designs to strip and PZN formatted connectors.

Circular Micro and Nano-Connectors serve USB 3.0 speeds and higher in many signal formats, from digital circuitry to sensor and detector information. Circular connectors by design are a natural shape for handling smaller and more flexible round cabling used for higher speed in tight environments, including power systems. A portion of the industry still uses rectangular connectors for cable-to-board interface systems and panel-to-device equipment.

Circular-shaped Micro and Nano Breakaway connectors provide a "Quick Release" function and have proven reliability and service. They are often designed with all-metal back shells and match



braided shielded cable. Variations occur in both cable designs and pin arrangements, designed to application-specific needs.

A notable example is the high-speed USB circular connector that carries both power and digital signals on a mixed signal cable with differential signal wiring. By including mixed signals such as power and signals inside the same cable, the total size and weight, as well as cost of two parallel cables and connectors, are reduced. This “quick release” system has proven to offer easy plug-and-remove functions while retaining signal integrity for high shock and vibrations, such as those experienced in helicopter and UAV functions.

Ruggedness and Reliability

Defense electronics are often exposed to extreme environmental conditions, including wide temperature ranges, constant vibration, and high shock. Connectors must be designed to withstand these conditions while maintaining reliability over long periods of non-use. Key specifications include the materials used, the design for rugged sustainability, and the ability to handle high electrical currents and remote signal control integrity amid high electrical noise or cyber-interruptive environments.

Metal Micro-D rectangular connectors continue to fit well and reliably in many applications. Micro-Ds with reference to MIL-DTL-83513, offering wire-to-wire spacing at .050”, handle wiring sizes up to 26 AWG and carry up to 3 amperes per line. The flex-pin mating elements are made in a one-piece design stamped from Beryllium Copper per ASTM B488 and ASTM B194 BeCu, respectively. The spring characteristics of BeCu are ideal for withstanding high shock and vibration situations and are plated with 50 micro inches (1.27 μm) of gold over 50 micro inches (1.27 μm) of nickel. All pins are plated post-forming to ensure a non-porous surface.

Quick Connection Latching Micro-D connectors have extended the old standard designs with rapid field change-over and installation formats. The squeeze-latches are made of stainless steel springs and handles. The new latching connectors have been proven to work from -55°C to +125°C

while maintaining signal integrity in shock up to 50gs and vibration to over 20gs, as specified in long-standing military specs. Metal back shells and braided shielding help protect the system from EMI and potential cyber intrusion.

Board mount latching Micro-Ds are designed for military specification PCB layouts in both through-hole and SMT configurations. Shells can include shear control brackets when specified.

Metal Nano-D rectangular connectors are being employed at a rapid pace as they have achieved performance per MIL-DTL-32139, ensuring rugged reliability while being significantly smaller for HDMI-type signaling. Omnetics Nano-D connectors accept up to 30 AWG wiring that can handle up to 1 ampere per line. Mixed signaling is accomplished by allocating sections of the connector for high speed and other areas to carry power.

Technological Advancements in Connector Design

The evolution of connector design has led to the development of latching Micro-D and Nano-D connectors, which offer quick and easy mating and de-mating. These connectors are designed to meet military specifications, withstanding temperatures from -55°C to +125°C while maintaining signal integrity under high shock and vibration. Latching Nano-D connectors have become popular in defense satellite systems, hand-launched drones, and soldier-borne autonomous weapons due to their low weight and mass, which helps when facing the physics of mass effects in shock and vibration during use.

Latching Nano-D mechanisms are also made of stainless steel and are frequently used for reduced space and quick replacement of memory and control circuitry in autonomous defense systems. Their lower weight compared to larger connectors and cables is advantageous for UAV re-use, as drone landings often experience higher shock than during flight.

Testing and Certification

To ensure connectors meet stringent military standards, independent testing labs evaluate their performance under extreme conditions. Key tests include mechanical shock, low-level circuit resistance (LLCR), and sinusoidal vibrations. These tests confirm the connectors' ability to maintain signal integrity and mechanical stability, even in the harshest environments.

Mechanical shock tests evaluate the latching mechanism holding the plug to the receptacle in its mated position. The receptacle is clamped into position, and the plug is not restrained, with testing conducted according to MIL-DTL-83513 or MIL-DTL-32139 specifications. LLCR tests are run at 100 milliamps and 20 millivolts, ensuring resistance remains well within circuit specifications. Sinusoidal vibration tests are conducted at 10 to 2000 Hz to 20 Gs for 4 hours over three axes.

Choosing the Right Connector

Selecting the appropriate connector involves reviewing the system's design requirements and considering factors such as size and shape, cable type, mate/de-mate method, and environmental conditions. Online solid modeling and 3D samples facilitate the customization of connectors to meet specific needs, ensuring a perfect fit and reliable performance.

System designers should start by analyzing the size and shape requirements to ensure the connector fits and allows for easy mating and de-mating. The diameter of the cable entering the back of the connector and the type of circuit—whether analog or digital—must be considered to match the signal impedance and power requirements. Power considerations include sharing power with two or more pins, while shielding and EMI protection are crucial to minimize noise or crosstalk within the circuits. The ruggedness and reliability of the connector in various environments, the need for mixed signal technologies, and concerns about cyber intrusion must also be addressed.

Quick and easy mating and de-mating for device replacement are vital in ensuring operational efficiency. Designers should also consider the available space for latching mechanisms within their designs. Choosing the right connector begins with analyzing these requirements and selecting a standard device from a proven supplier. If customization is needed, working with a connector supplier to develop application specific adjustments using online solid modeling and 3D samples can expedite the process.

Future Trends and Innovations

As defense technology continues to advance, the role of miniature quick release connectors will become even more critical. Future trends may include further miniaturization, increased integration of mixed signal technologies, and enhanced EMI and ESD protection. Innovations in materials and manufacturing processes will likely lead to connectors that are even more robust and reliable, capable of operating in the most challenging environments.

The ongoing development of autonomous systems, UAVs, and soldierworn electronics will drive the demand for connectors that offer higher performance, greater durability, and more efficient data transmission. As these systems become more sophisticated, the need for connectors that can handle higher data rates, increased power loads, and more complex signal processing will grow.

In conclusion, the evolution of miniature quick release connectors has significantly enhanced the capabilities of defense electronics. These connectors are crucial for ensuring the reliability and performance of sophisticated military systems, enabling rapid data transmission, improved signal integrity, and robust performance in extreme conditions. As technology continues to advance, the role of these connectors will become even more critical, supporting the next generation of military operations.