HARWiN

ADVANCEMENTS IN EVTOL INTERCONNECTS

INDUSTRY WHITEPAPER

Energy storage systems (ESSs) have led to revolutions in many industries, from data centers and renewable energy to e-mobility with electric vehicles (EVs), electric vertical take-off vehicles (eVTOLs) and smaller e-bikes. Batteries are the main driving force behind most of the mobile systems, due to their energy density compared to alternatives such as flywheels, supercapacitors, or hydrogen fuel cells.

Battery-powered mobile applications, particularly EVs and eVTOLs, come with their fair share of regulatory constraints. Automotive ICs and connectors, for instance, must comply with stringent standards that enforce a high level of reliability in terms of operating temperature (e.g., AEC-Q100). This level of scrutiny for EV subsystems and their components extends to both the civilian and military aircraft with even more design considerations. The inherent volatility of batteries and the potential of different chemistries for thermal runaway requires tighter checks and balances in eVTOLs with the onboard battery management system (BMS) and operating system (OS) monitoring, controlling, and reporting battery utilization and battery events that may require attention.

Critical avionics, flight control, and navigation systems must be able to endure the inherent mechanical shocks and vibration of the environment. At the crux of all aircraft systems are their connections, calling for a myriad of standards for aircraft connectors (e.g., ISO 461-1, MIL-DTL-38999, MIL-DTL-5015, MIL-DTL-12520, MIL-DTL-22992, ARINC standards, etc.). However, not all systems necessarily call for military-grade or aerospace-grade components as they are almost always subject to longer lead times due to buyer imposed restrictions on the seller (e.g., parts tracking, testing, qualification, etc.). In many cases, high reliability commercial off the shelf (COTS) components can meet mission requirements while lowering research and development (R&D) costs, granting companies a more rapid time-to-field.

BMS interconnects in eVTOLs come with all of the design constraints of aircraft in terms of their ability to maintain a high integrity connection despite the inherent mechanical shocks and vibration of their environment. Harwin offers a lineup of high-reliability COTS connectors well-suited towards these applications. These small form factor connectors offer both power and data functionality as well as withstand shock, vibration and temperature extremes making them well-suited towards BMS in stressful aerospace environments. This article dives into the requirements of connectors in eVTOLs and Harwin's eVTOL connector offering.

eVTOL picking up speed for commercial launch

eVTOLs have emerged as an enabling technology that could transform the future of urban mobility systems, granting passengers and other potential payloads (e.g., packages) access to the underutilized airspace above. However, in order for these technologies to be fully realized, major advancements in battery weight, power density, high power semiconductors, motor technologies and fast-charging abilities must be developed, and they must be able to meet the emerging (and changing) standards set out for them. Current development in eVTOLs involve multiple batteries (often Li-ion) supplying power to multiple (up to 36) battery-powered lighting propellers driven by hundred kilowatt electric motors generally carrying up to 4 passengers.

The FAA has been working on standards for Advanced Air Mobility (AAM)—a generic term for aircraft that are highly automated and electric in some capacity. Standards for "airworthiness" such as flight modes, configurations, and speeds are included in the recent FAA standards, as well as subsystem criteria for the electric engine and related propeller are listed. At the moment, a company named Joby Aviation may be the closest to receiving eVTOL certification by using FAA's part 23 requirements (Figure 1). However, the vast majority of eVTOLs efforts are still in the development phase at the moment with a slow progression towards their production phase and eventual commercial launch in the coming decade. Applications for these aircraft are mostly for air taxis and, in some cases, medical air mobility. More recently, UPS has invested in eVTOLs to incorporate into its package delivery system. While there is much focus on the cutting-edge technologies required to truly realize eVTOLs, there is also the need to consider the connections between these critical systems; namely the connectors and cable assemblies used in power distribution system.

Figure 1: The Joby Aviation S-4 all-electric eVTOL, which has six electric motors to carry one pilot and four passengers, was awarded military airworthiness approval in 2020, and recently established a new certification agreement with the FAA for a more rapid commercial entry date of 2024. Image used courtesy of Joby Aviation

The interconnected backbone of the eVTOL-power distribution system

Batteries are a double-edged sword for eVTOLs; they have the benefit of limiting and potentially eliminating the exorbitant fuel consumption of traditional aircraft, but these electrochemical systems come with strong safety concerns that cannot be overlooked. Batteries leverage a delicate Faradaic process that forces the ions at the cathode back to the anode so there may be sufficient electrochemical potential. This charge/discharge process will eventually lead to the cracking of the electrode material and the decomposition of the solvent and salt components of the electrolyte.

All complex electronic systems that siphon their power from a battery require a battery management system (BMS) to precisely monitor and control battery parameters such as temperature, voltage, current, state of charge (SoC), and depth of discharge (DoD) to minimize the cyclic stresses on the battery and optimize battery lifetime. The BMSs themselves must be robust and able to withstand the temperature extremes, mechanical shocks and vibration that come with mobile applications. The connections to and from the BMS (e.g., analog communication buses, incoming sensor data, voltage and current monitoring, ARINC 653 or other OS, etc.) must also be able to withstand the very same stressors without unmating or causing intermittent connections that will ultimately impact system reliability and potentially lead failures down the line (Figure 2).

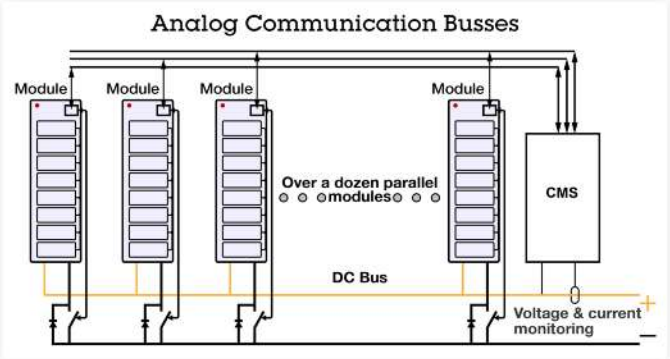

Figure 2: Basic battery architecture for an aircraft.

Requirements of connectors in eVTOLs

Within the cable assembly, the connector heads themselves may be the most critical part as these parts latch onto and maintain the connection. There are generally four important qualities of a high-reliability connector used in an eVTOL power distribution system (i.e., connections to and from the BMS):

- Inclusion of both power and signal connections
- EMI/RFI protection
- Ability to endure shock, vibration and temperature extremes
- Lightweight and small form factor

The connector determines the amount of board estate taken, and the inclusion of both power and signal connections allows designers to save board real estate and minimize the number of mating points to and from the PCB—another technique that will also yield a higher reliability system. It is important for engineers to be able to choose connectors that have a combination of a variety of power and signal connectors to simplify the design process.

Aircraft can house many sources of electromagnetic interference (EMI). Both communications equipment and switched mode power supplies (SMPS) with high switching frequency FETs will have radiated emissions, and while these are kept to a minimum by conforming to EMC standards, they are nonetheless considerations with interconnects that could potentially conduct noise to interfere with sensitive circuitry. They could even function as an antenna, radiating these EM signals to exacerbate interference. It is important that connectors offer a degree of EMI and RFI protection as cables can act as a major “transmitter” and “receiver” of EMI.

In the event of mechanical vibration or shock, these components will undergo the most strain and must maintain the integrity of their connection or the system will fail to operate. The ability to endure shock, vibration and temperature extremes is a prerequisite for eVTOL applications.

A major consideration with any aerospace application is the size and weight of the component itself. Every gram counts when a payload must be lifted in the air and travel from one set location to another, especially when there is a fixed amount of miles that can be traveled per charge. Maximizing the number of miles that an eVTOL can travel is directly affected by the weight of its native systems, so innovations that make any and all components lighter and smaller will optimize eVTOL performance.

Saving space and weight on PCB interconnect

There are major constructional differences between standard connectors and high reliability connectors for PCB signal and power connections. The D-subminiature (D-sub) connector is often the default choice for I/O connections to and from computer systems. This, however, is often impractical for more ruggedized use cases such as military and aerospace applications, so the micro-D variant may be used. It is at most half the length of the D-sub with 9 pins to a little over hundred pins. These pins can be for signal, power, or coax, depending upon the vendor and the military standard for these connectors is MIL-DTL-83513.

Harwin’s Gecko connectors are dual row interconnect solutions for cable-to-board, cable-to-cable and board-to-board connections that come with either signal (2A) connections (Gecko-SL) or power (10A) and signal (2A) connections (Gecko-MT). These connectors are Harwin’s equivalent to the Micro-D connector heads. While the Micro-D connectors save both space and weight when compared to the D-sub connector, the Harwin Gecko connectors enable up to 45% space savings over Micro-D connectors with the same pin count (Figure 3). This is due to a reduction in both profile and overall connector body size with a smartly designed connector head. There is also up to a 75% reduction in weight achieved due to this smaller size and choice in materials. The Gecko-SL also offers an increased pin density compared to Micro-D enabling more connections per unit area.

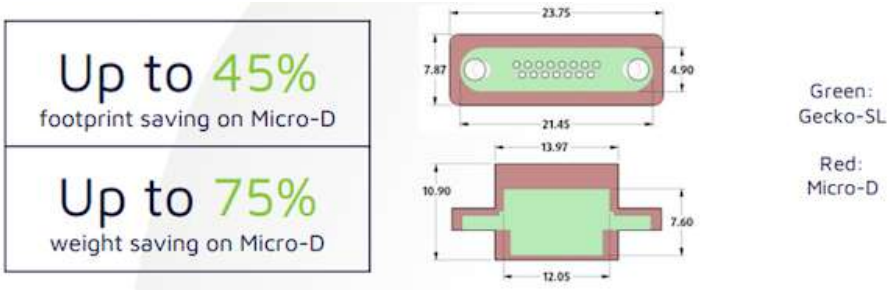

Figure 3: Harwin's Gecko-SL (Screw-Lok) saves up to 45% in connector footprint and up to 75% of connector weight. Image courtesy of Harwin.

For PCB configurations that also include coax for high frequency signal communications, the Harwin Datamate connectors can be used with all-power (40A), all-coax (Up to 6 GHz), or power (20A) and signal (3A) multiport ganged connector heads (Figure 4). The combination of power and coax permits a great deal of flexibility for board designs that require ruggedized power, coax, and signal connections.


2 Power and 2 signal male vertical PCB connector


4 High Power female cable connector with solder cups

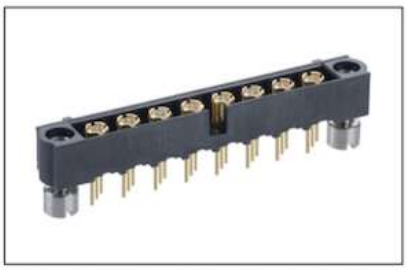
8 coax male vertical PCB connector with board mount

Figure 4: While Gecko connectors are ideal for space-savings in signal and power/signal combinations, a higher power ruggedized connection may be necessary. This is where Datamate connectors offer higher rated current power and signal connections as well as coaxial connections for more design flexibility.
Image courtesy of Harwin.

Preventing “repetitive stress injuries” on your connections

The Harwin Gecko connectors incorporate a patented single piece 4-fingered Beryllium Copper female contact that gives high electrical performance and sustained mechanical durability (Figure 5). The contact withstands high vibration and shock without any interruption in signal continuity. These are precision-machined contacts, plated with a gold finish to resist wear from multiple insertions and offering high levels of conductivity.

ENVIRONMENT

Operating Temperature -65°C to +150°C	**Humidity Classification** 56 days at 93% RH	**Vibration (with latches)** 10-2,000Hz, 1.5mm, 198m/s² (20G), 6 hours total
Shock (with latches) 981m/s² (100G) in Z Axis, 490m/s² (50G) in X & Y Axis	**Outgassing** 0.68% TML, 0.01% CVCM, 0.26 WVR (Water Vapour Recovered)	

MECHANICAL

Durability (contacts) 1,000 mating cycles	**Durability (latches)** 100 mating cycles	**Insertion force (per contact)** 2.8N max
Withdrawal Force (per contact) 0.2N min	**Latch retention force (per mating pair)** 20N min	

Figure 5: The Harwin Gecko six-finger Beryllium copper female contact and its environmental and mechanical specifications. Images courtesy of Harwin.

Outside of the connector pins, there is also generally a mechanism to keep the connector heads in place. This is typically some sort of latching system. However, these can come undone under shock and vibration, so the Gecko-SL and Gecko-MT both have a corrosion-resistant “screw-lok” connection that allows for a strong fixing to the board (Figure 6). The screws are better for extreme vibration cases where multiple matings are required, they are easier to manage than the latch-based alternative, and are generally more robust.

Similar to many MIL-SPEC aviation-grade connectors, Gecko connectors include a backshell to provide additional strain relief at the connector head. The backshells are aluminum to save weight and are designed to accommodate additional metal braiding, a necessary addition to provide additional EMI and RFI protection.

Figure 6: Screw-lok fixing hardware for Gecko connectors and Gecko connector with aluminum backshell. Image courtesy of Harwin.

Meeting the challenge of high integrity connections in eVTOLs

Any complex system is only as good as the parts it is made up of, and this is especially the case with connectors. These components are often considered an afterthought in the circuit and layout design process; however, they are critical for maintaining connections to and from the PCB and can make or break a design. When it comes to eVTOLs, connectors and cable assemblies must be able to withstand the harsh aeronautical environment while saving both space and weight. This requires innovations in materials, construction, and precise machining and assembly practices.

Harwin specializes in providing high reliability, precision-machined interconnect with test reports available. Both the Gecko and Datamate connectors enable signal, power/signal, power, and coax connections in a space-saving, ruggedized package that is well-suited for eVTOLs. These are particularly well-suited for the connections to and from the BMS. Learn more by visiting Harwin.