Windshield Heat Control: an Evolving Technology

By Astronics Advanced Electronic Systems

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Windshield heat control (WHC) is a critical part of an aircraft, playing a vital role in maintaining flight safety. Astronics AES has become increasingly involved in windshield heat control technical advancements over the past 30 years, applying our expertise in aircraft electrical systems, and expanding upon our Electronic Power Distribution System (EPDS) with Electronic Circuit Breaker (ECB) and arc-fault detection technology. There is a trend in the industry demanding higher performance technologies in the business jet segment, and as technology improves, more options emerge for WHC functions. The Astronics WHC lineup comprises four different system options that are flying in the Boeing 717, 727 and 737; McDonnell Douglas DC-9, MD-11, MD-80 and MD-85; the Gulfstream GIII, GIV, and GV; and our latest WHC product on the Hondajet. For those aircraft implementing solid-state electrical power distribution, Astronics WHC functions can be integrated into our electronic power distribution system (EPDS), offering reduced installation complexity and weight, while increasing safety. The newest generation of WHCs come equipped with the ability to detect and interrupt electrical arcs that can cause windshield damage, as well as a host of other safety features. Combined, over 16,000 WHC units have been delivered to the aviation industry.

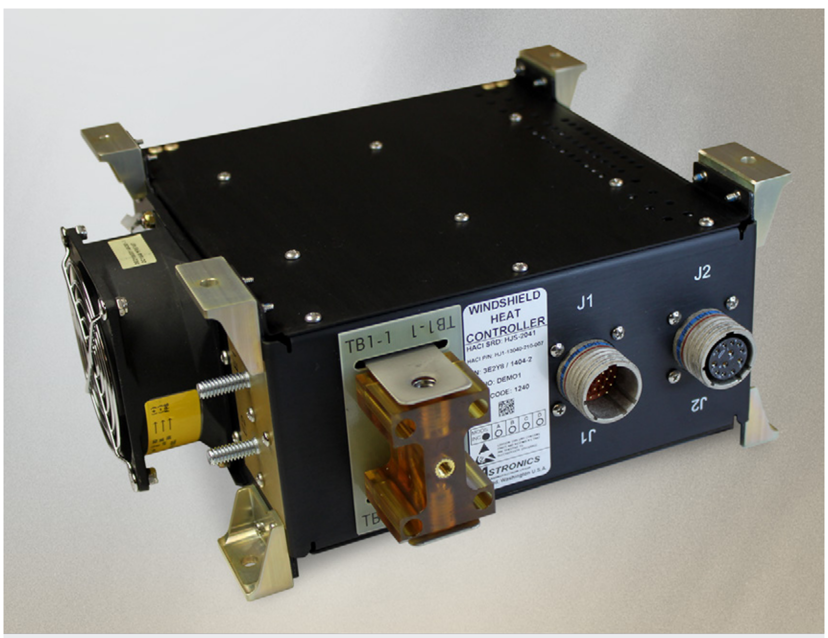
Windshield heat controllers generally must be capable of handling two primary functions: defog and deice. Defogging is used to prevent (or eliminate) condensation build-up on the inside of the windshield, while deice prevents (or eliminates) ice from forming on the outside of the window. Defogging and deicing functions, however, have significantly different power requirements, and the windshield heat controller must be able to regulate the two.

Defogging functions typically require 1 to 2.5 watts per square inch of window, whereas deice typically requires approximately 5 watts per square inch. In different temperature and environmental conditions, using too much or too little power yields drastic consequences—on a hot day, for example, applying deice power levels while on the ground will over-heat, damage, and possibly melt the windshield. In contrast, a windshield that fogs up or freezes reduces pilot visibility and puts the safety of the entire aircraft at risk. Proper windshield temperature is also important to maintain structural properties of the transparency in the case of bird strike events. Thus, a windshield heat controller is necessary to regulate the range of power to be distributed over the window.

Over the years, the technology to control windshield temperature has changed dramatically. From first flights that had no windshield heat at all, to some of the highly intelligent systems today, windshield heat control is an evolving technology. Using bleed air to heat the windshield is the most recent windshield heating technique that is seeing a decline in use. The process involves taking hot, compressed air from inside the engine of the aircraft while in flight, and re-routing it to blow across the windshield. The use of bleed air requires significant power and is largely inefficient—excessive tubing to channel bleed air increases aircraft weight, air intakes in the wings decrease aerodynamic performance, and various mechanical parts used to monitor the system require additional energy and more maintenance overall.

More recently, some DC aircraft have been outfitted with small, resistive wires embedded in their windshield. These wires are often arranged in a back-and-forth zigzag pattern, causing them to be dubbed "wiggle wires." Once powered, the wiggle wires warm up, and in turn heat up the windshield. Unfortunately, this method of heating creates not only the obvious problem of reduced visibility due to the physical presence of the wires, but can also cause optical distortion through the windshield as uneven heating occurs caused by the placement of the wires. Aircraft that utilize this method of heating often have much smaller areas capable of being defogged, which further reduces pilot visibility under certain conditions.

A more preferred method of windshield heating is to apply a thin, transparent, conductive film over the surface of the window. A voltage is applied to the film, which evenly distributes heat over the entire window. A window with this film, typically Indium Tin Oxide (ITO) or gold, is much more visually appealing than a window with wiggle wires; visibility is not impaired, and heating is uniform over the entire surface. Our latest generation WHC (P/N 1404-2), used on the Hondajet, offers this capability.



Astronics 1404-2 WHC for conductive film windshields

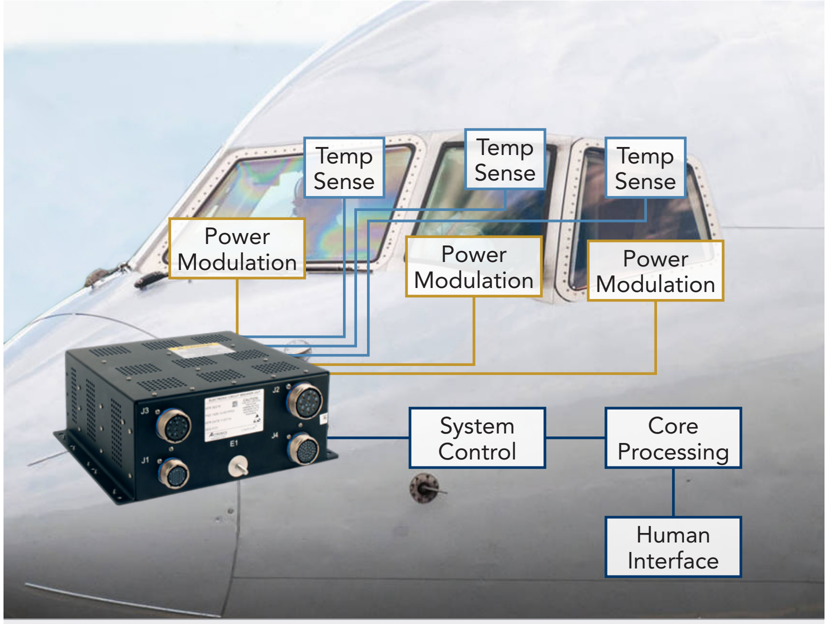
There is a common trend among various business jet manufacturers, based on feedback from the pilot community, toward using more aesthetically pleasing methods of WHC. Thin film window heat has become the expected level of quality and performance in even the entry-level business aircraft. A technology that was once reserved for high performance aircraft is now expected on entry-level jets and even some turboprops.

In an effort to give aircraft manufacturers a greater opportunity to provide the best product to their customer, Astronics has developed various WHC models which successfully allow a low voltage (28VDC) aircraft to utilize the thin-film method of windshield heating. For both AC and DC aircraft, two options are available: a stand-alone system or a WHC system integrated into the aircraft Electrical Power Distribution System (EPDS).

A stand-alone system is typically packaged into one or two individual Line Replaceable Units (LRUs). For a DC aircraft, Pulse Width Modulation or an on/off scheme is used to modulate the DC current, which heats the windshield. Thus, a constant windshield temperature is maintained, which an otherwise unmodulated DC current is unable to accomplish. For AC aircraft, a WHC is built using FETs or SRCs. These components control the AC power and provide the level of power necessary to evenly heat the windshield.

Another option available for 28VDC aircraft, typical for most turboprops and small-midsized business jets, is to create high voltage DC for the window heat by boosting voltage from the 28VDC bus. This stand-alone system benefits from 95% conversion efficiency, and successfully provides enough voltage to power thin film heating elements. Despite some concerns regarding ITO thin film heaters combined with DC current and possible metal migration, 30+ years of field experience has refuted these doubts. DC ITO thin film heaters are often used to heat liquid crystal displays, and no such ill effects have been discovered. Thus, this system (as implemented in our 1404-2 WHC) offers a unique solution for a DC aircraft to power a thin film windshield heater.

As a final note, the aviation industry is clearly moving toward solid-state electrical power distribution, where integration of various utility functions (WHC, De-Icing, Landing Gear, Thrust reversers, etc.) can be easily accommodated, using these solid-state switching devices as active elements. A WHC function entirely integrated into the aircraft's Electrical Power Distribution System (EPDS) offers significant value, given high efficiencies and substantial weight savings by elimination of one or more WHC LRUs. This option is available for both DC and AC aircraft. The EPDS, utilizing Electronic Circuit Breakers (ECBs), distributes power throughout the entire aircraft for use by all its loads and systems; it is these ECBs, which double as power control switches for the WHC. Analog sensors incorporated into the EPDS are used to monitor temperature measurement devices, which are embedded into the windshield. Thus, the entire system watches over and controls the windshield heat as needed—without introducing any additional components. This approach provides an elegant solution, integrating seamlessly with the aircraft power system.



Fully integrated WHC function

Astronics has many years of experience, providing highly robust and safe WHCs. The degree of sophistication is worth noting. Each system typically includes two WHCs, with the system level architecture isolating the two—each WHC independently controls two zones within each main windshield and, in some applications, a side window zone as well. The WHC system architecture is generally arranged so that a failure in one zone controller does not propagate to the second, and does not impact the operation and control of the opposite windshield. Multiple Built-In-Test (BIT) functions are integrated into the WHC as well, including both power-up and continuous BIT, which assure that the WHC is functioning properly at all times. Furthermore, the WHC provides back-up over-temperature sensing and offers protection in the case of a failed sensor. All these safety features, and more, contribute to a superior line of WHCs.

In summary, there are numerous options available today to perform aircraft windshield deice and defog functions. The small-midsize class of aircraft now has expectations of quality and functionality that demand newer technology, namely thin film heating elements. Advances in power conversion and control technology have made it feasible to have "high voltage" thin film windshields designed into the smaller 28 VDC class of aircraft. Furthermore, it is now possible to integrate the window heat control function into the power distribution of either AC or DC aircraft, which can provide the most elegant, reliable, and weight effective solution for the aircraft.

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