Thermal Management Techniques in Avionics Cooling

Modern electronic thermal output and the evolving face of cooling technologies

Modern unmanned aerial vehicles (UAVs) and military aircraft carry advanced electronics and equipment critical to their successful operation. Innovation is carrying airborne technologies farther and higher than ever before, and avionic cooling practices are evolving to keep up.

Cooling options

To accommodate the immense heat generated by modern UAV electronics, design engineers have several cooling options at their disposal. While the method implemented often depends on design restrictions such as space and thermal load, each method has its own inherent advantages and disadvantages that must be considered.

Natural & Forced Air Convection

Natural and forced air convection systems were the original cooling method for early UAV's and are often the least costly option available.

Air provides thermal relief simply by flowing through the system either freely through vents in a natural convection design or propelled via fans in forced convection systems. To facilitate heat transfer, heat sinks are often integrated with the heat producing device.

Figure 1 Air Cooled Biplane Engine

Despite the benefits of simple design and the abundance of coolant available in the Earth's atmosphere, air-cooled systems are limited in their thermal management capabilities. Air can only remove so much heat, therefore these systems' cooling capabilities typically cannot compensate for the amount of heat generated by modern UAV electronics. In addition, using unfiltered air may pose additional complications in applications where maintaining isolation from the external environment is required.

Cold Plate

Cold plates use a metal plate to remove heat from power electronics. Electronic devices are mounted onto the metal, facilitating heat transfer to a cooling fluid that runs through the cold plate. While typically a simple and compact cooling method, cold plates must also be paired with an additional cooling method to remove heat from the cooling fluid.

This reliance on a secondary cooling method may complicate designs and severely limit the cold plate's thermal management capabilities in complex or enclosed systems.

Heat Sink

Heat sinks, which are essentially cold plates with cooling fins, are more efficient at removing heat due to their increased surface area exposed to the secondary cooling system, typically forced air.

Due to heat sink size demands to accommodate both fins and a forced air system, designs implementing this cooling method must often be larger in scale.

Figure 2 Heat Sink Example

Liquid

To accommodate the increasing thermal relief demands of modern electronics, design engineers have turned to liquid-cooled cold plates. In these designs, coolant runs through the cold plate, removing heat and releasing it through a heat exchanger.

Using this method, the cold plates are kept at a fairly even temperature, avoiding temperature spikes and allowing for effective thermal transfer.

Compact and efficient, liquid cooling is ideal for designs with space constrains and high thermal output, making them a good fit for many aircraft applications. The downfall of this perfect match, however, comes in the form of increased cost, design complexity and the demand for more engineering hours.

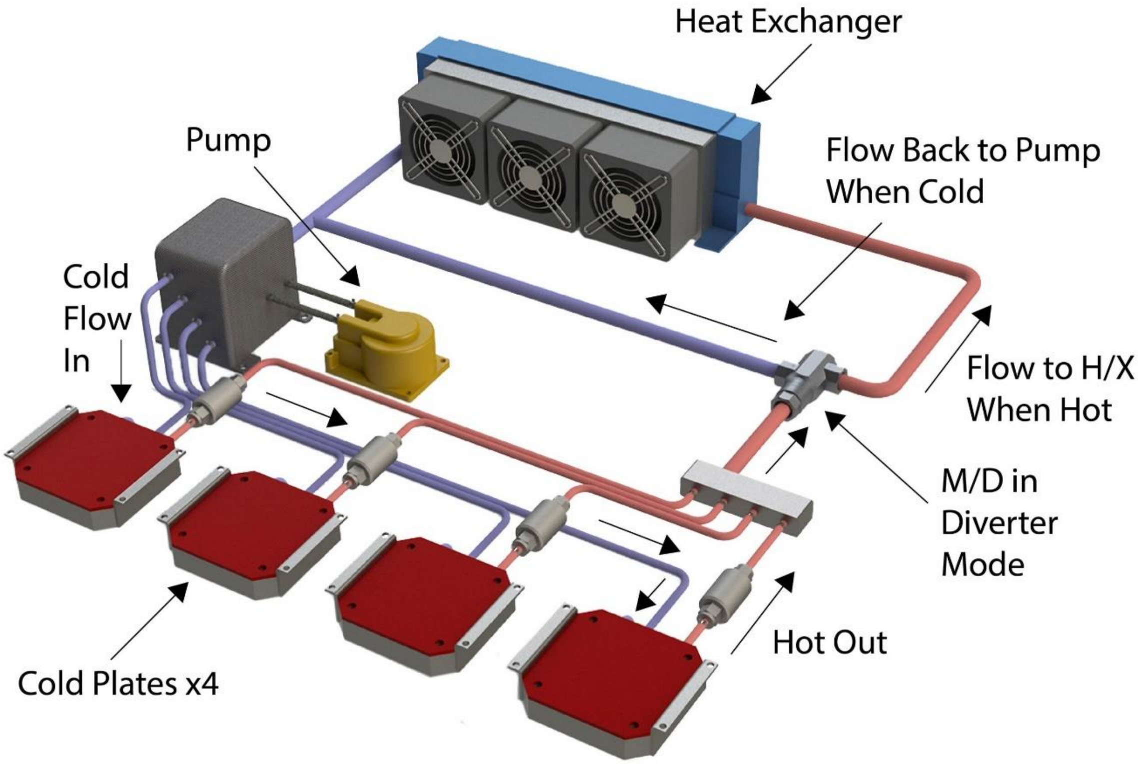

Figure 3 Liquid Cooling System Example

Fixed vs. Thermostatic Liquid Control

In liquid-cooled cold plate designs, coolant is circulated in one of two ways – fixed flow or thermostatic flow. With traditional fixed flow through a liquid cooling design, coolant continuously moves between the cold plate and the heat exchanger, regardless of the coolant's actual temperature. This decreases cooling efficiency and increases coolant usage.

To remedy this design limitation, thermostatic valves are used to direct coolant flow either to the heat exchanger or back through the system, solely based on coolant temperature. This ensures efficient usage of coolant, facilitates stable and uniform electronic device temperatures, and reduces overall system wear, extending the life of system components.

Which Cooling Technique Is Best?

Selecting which cooling method to implement into a project will depend heavily on thermal load, space restrictions, and cost sensitivity.

For less complex systems, forced air and cold plates may satisfy meager thermal management needs. However, as UAV designs become more complex, design engineers are likely to continue turning to liquid cooling to keep up.