TECHNOLOGY BRIEF

Maximum environmental protection and effective cooling for reliable deployment anywhere

mercury

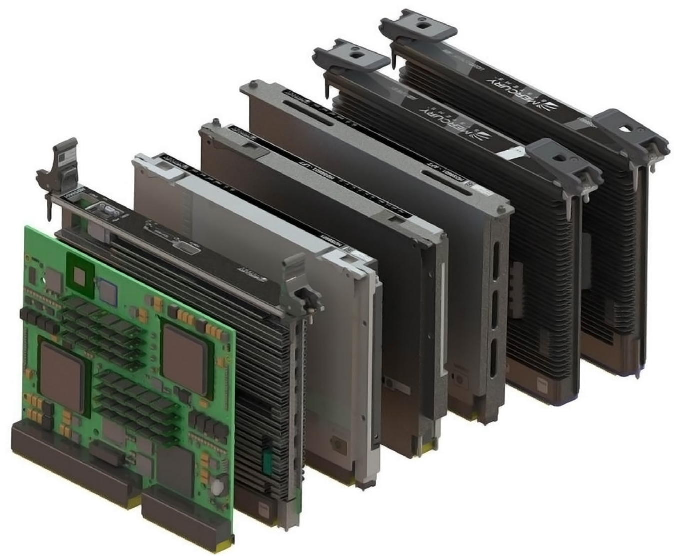
Environmental Protections for Operation at the Tactical Edge

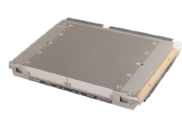
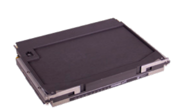
Even the best commercial components cannot survive hostile environments without protection. To intensify extreme temperature resilience and mechanical durability without increasing pre-integration risk, cost and schedule, Mercury takes a modular open systems architecture (MOSA) approach to design subsystems for operation at the tactical edge.

Applying MOTS+ rugged packaging and effective cooling technologies across a portfolio of OpenVPX™ building blocks creates scalable, interoperable processing subsystems that easily move from the lab to the tactical edge. Mercury's agnostic cooling approach applies the air, conduction, Liquid Flow-Through, Air Flow-Through, Air Flow-By™ and Liquid Flow-By™ architectures to a single OpenVPX board design.

OpenVPX (ANSI/VITA 46), championed by Mercury and introduced in 2009, is the standard for packaging high-performance commercial processing technology into rugged, SWaP- optimized subsystems capable of operation in a wide range of environments—from industrial to defense and aerospace applications. OpenVPX is the foundational standard for many other defense open systems architectures, including Sensor Open Systems Architecture (SOSA), Future Airborne Capability Environment (FACE) and Common/C4ISR/EW Modular Open Suite of Standards (CMOSS).

As processing capabilities and their thermal signatures increase, the OpenVPX standard working groups within the VME International Trade Association (VITA) Standards Organization continue to add greater capability and performance to the VITA portfolio of cooling architectures. The environmental protection, cooling effectiveness and SWaP performance of these architectures are summarized in the table below.



	AIR COOLED	CONDUCTION COOLED	AIR FLOW-BY	AIR FLOW-THROUGH*	LIQUID FLOW-THROUGH	LIQUID FLOW-BY
						
VITA Standard	48.1	48.2 REDI**	48.7 REDI**	48.8 REDI**	48.4 REDI**	REDI***
Cooling Efficiency	Low	Low	Med	Med	High	High
Weight	Low	High	Med	Med	Med	Med
Environmental Protection	Low	Med	High	Med	High	High
Ruggedness Level	L0 - L2	L3	L4	L5	L6	L7

* 48.8 REDI covers 1.0" 1.2" 1.4" pitch

** VPX-REDI compliant: OpenVPX paired with the ruggedized enhanced design implementation standard (REDI) VITA 48. VPX-REDI supports higher functional ruggedness and two-level maintenance (2LM).

*** VPX-REDI aligned

ENVIRONMENTAL QUALIFICATION LEVELS — OPENVPX — MULTIFUNCTION PROCESSING

		AIR COOLED			CONDUCTION COOLED	AIR FLOW-BY	AIR FLOW-THROUGH	LIQUID FLOW-THROUGH	LIQUID FLOW-BY
		COMMERCIAL RL0	RUGGED RL1	RUGGED RL2	RUGGED RL3	RUGGED RL4	RUGGED RL5	RUGGED RL6	RUGGED RL7
3U cooling typical power		~100W*			~40W / ~100W**	~150W*		Contact factory	
6U cooling typical power		~150W*	~130W*	~100W*	~140W**	~200W*		300W***	
Temperature	Operating	0 °C to +40 °C	-25 °C to +50 °C	-40 °C to +55 °C	-40 °C to +70 °C	-40 °C to +55 °C		-40 °C up to +71 °C air temp -40 °C to +50 °C fluid Inlet (PAO) -40 °C to +60 °C fluid Inlet (EGW)	
	Extended[1]	0 °C to +50 °C	N/A	40 °C to +70 °C	40 °C to +85 °C	40 °C to +71 °C			
	Storage[3]	-40 °C to +85 °C	-55 °C to +85 °C	-55 °C to +105 °C					
	Max rate of change	N/A	5 °C/min	10 °C/min					
COTS/COTS+	Durability: temperature range	N/A	250 cycles, -50 °C to +100 °C						
MOTS/MOTS+		N/A	500 cycles, -50 °C to +100 °C						
MOTS+ Ultra		N/A	625 cycles, -50 °C to +100 °C						
COTS/COTS+ MOTS/MOTS+ MOTS+ Ultra	Durability: dwell @ extremes	N/A	30 min. after stabilization						
COTS/COTS+ MOTS/MOTS+ MOTS+ Ultra	Durability: max rate of change	N/A	4 °C/min ± 2 °C/min						
Humidity	Operating[2]	10-90%, non-condensing	5-95% ± 4%, non-condensing						
	Storage								
Altitude	Operating[2]	0-10,000 ft	0-30,000 ft		0-60,000 ft	0-30,000 ft		0-70,000 ft	
	Storage	0-30,000 ft	0-50,000 ft	0-70,000 ft					
Vibration	Random	0.04 g2/Hz peak; 5-100 Hz, 1 hr/axis	0.04 g2/Hz peak; 20-2000 Hz, 1 hr/axis		0.005 to 0.100 g2/Hz incline from 5 to 100 Hz, 0.100 g2/Hz constant from 100 to 1000 Hz, 0.100 to 0.025 g2/Hz decline from 1000 to 2000 Hz; 1 hr/axis				
	Sine	N/A			.75" displacement 5 to 15 Hz; 10G peak from 15 to 2000 Hz; 1 hr/axis				
	Shock	z-axis: 20g; X, Y-axes: 32g; 11 ms 1/2-sine pulse, (3 pos., 3 neg.)	z-axis: 50g; X, Y-axes: 80g; 11 ms 1/2-sine pulse, (3 positive, 3 negative)						
Salt/Fog		N/A	Contact factory		5% NaCl				
VITA 47		EAC1: low op temp EAC1: AC1C2C1V1OS1	EAC4: AC1C2C2V2OS1 EAC5: AC2C2C2V2OS1	EAC3: AC3C3C4V2OS1	ECC3: CC3C3C4V3OS2 ECC4: CC4C4C4V3OS2	EFC2: FC2C2C4V3OS2 EFC3: FC3C2C4V3OS2		ELC2: LC2C2C4V3OS2 (PAO) ELC3: LC3C2C4V3OS2 (EGW)	

[1] Product performance may be diminished to achieve extended operating temperatures. Examples include processor throttling, reduced core counts, reduced FPGA functionality and/or other limitations.

[2] The test is a non-operational test with operational testing occurring during the last 2 hours of each full cycle (2 cycles total) per MIL-STD-810.

[3] Storage temperature is a non-operational test defined per MIL-STD-810, where the product is brought to the high storage temperature for a minimum of two hours, returned to ambient temperature and functionally tested. The product is then brought to the low storage temperature for a minimum of 2 hours and returned to slightly above ambient for functional testing. All temperature transition rates are less than of 10°C/min. One cold/hot cycle constitutes the complete non-operational storage temperature test.

* For forced convection cooled product, the end user must maintain required volumetric flow rate (CFM). Contact Mercury for application specific guidance.

** Module conduction cold-plate edge is maintained at or below 71°C.

*** Performance varies with coolant type, fluid temperature and flow rate. Contact Mercury for application specific guidance.

Cooling Architectures

AIR COOLING

(ANSI/VITA 48.1) — Conventional

Air cooling may be subdivided into CFM and air management approaches. A CFM, or "cubic feet per minute" approach, is the "traditional" approach to cooling (ANSI/VITA 48.1) and is in widespread use within many commercial, development and other applications that are deployed within relatively benign environments. This approach relies upon fans to push cooling air across the OpenVPX modules to remove their generated heat. Although the lowest cost, this type of cooling is the least efficient of the VITA cooling architectures as the air tends to take the path of least resistance, often not adequately cooling the hottest module regions.

CONDUCTION COOLING

(ANSI/VITA 48.2) — Rugged

To maximize heat dissipation and increase processing density, modern conduction-cooled architectures feature efficient heat spreaders, advanced thermally conductive materials and enhanced thermal interfaces. However, processing solutions powered by many contemporary processors produce more heat than venerable, rugged and reliable conduction-cooled solutions can handle. These applications are being designed/upgraded with more effective air-management, liquid and hybrid cooling approaches that are similarly rugged, but offer greater cooling capability.

LIQUID FLOW-THROUGH

(ANSI/VITA 48.4) — High Performance

Liquid is a more effective coolant than air, delivering significant thermal performance over even the best air-cooled management approaches. The cooling liquid, often the platform's own fuel, is connected via dripless quick-disconnects and circulated within each module's cooling jacket. This approach is similar to a car engine cooling system. The ability to expel so much heat enables full-throttle, deterministic (no CPU thermal throttling) and reliable processing. Keeping processing elements well within their maximum operating temperature increases a module's mean time between failure (MTBF) by an order of magnitude.

AIR FLOW-BY

(ANSI/VITA 48.7) — Managed

Air Flow-By™ uses an air management approach of cooling instead of a CFM method. Rather than pointing an unmanaged air stream across each OpenVPX module, Air Flow-By uses a plenum (reservoir) of pressured cooling air, which is directed (managed) across each module. Air Flow-By modules are sealed units (EMC and environmentally) that fit snugly within their chassis and without further consideration would block any airflow altogether. The effectiveness of Air Flow-By is achieved by introducing module-specific air passageways across their surfaces directing air to their hot spots; these channels regulate where the cooling occurs and how much cooling is applied. In effect, the cooling air is efficiently applied to where the heat is generated and has no opportunity to take the path of lesser resistance.

The Air Flow-By architecture cools both sides of each module. The cooler PCB side of the module (few, if any active devices) contributes additional cooling to the hot component-side of the module it abuts, maximizing its effectiveness.

Full Air Flow-By design packages are available from VITA's website for members under the Fair, Reasonable, and Non-Discriminatory, zero-cost (FRAND-Z) licensing terms.

Figure 1: 6U OpenVPX Liquid Flow Through (ANSI/VITA 48.4) module

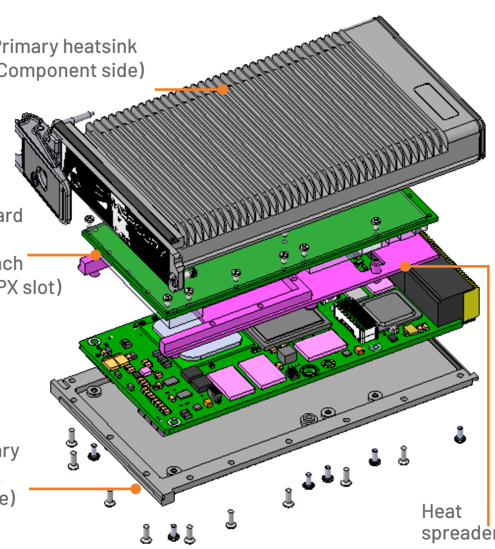


Figure 2: 3U OpenVPX Air Flow-By (ANSI/VITA 48.7) module

AIR FLOW-THROUGH

(ANSI/VITA 48.8) — High Performance

Air Flow-Through similarly uses an air management cooling approach. Instead of defining the airflow at the component level, Air Flow-Through channels the air over fabricated fins that are placed within a cavity in the middle of the module. Although lacking the precision of Air Flow-By, this approach is efficient and well suited to cooling mezzanine cards that reside close to the center of the module (Figure 3). Mezzanines, when used within the Air Flow-Through architecture, necessitate an increase in the standard 1-inch OpenVPX module width to 1.2 or 1.4-inches, giving room to both the fins and mezzanines. As such, Air Flow-By has a SWaP advantage if mezzanines are used, as the architecture does not require an increase in module width.

Mercury has conducted various performance tests between VITA air-cooling architectures (tech brief entitled "Comparison of high performance OpenVPX forced air-cooling architectures") and concluded that Air Flow-Through is generally marginally more efficient for 3U and that Air Flow-By is generally more efficient for 6U and larger systems.

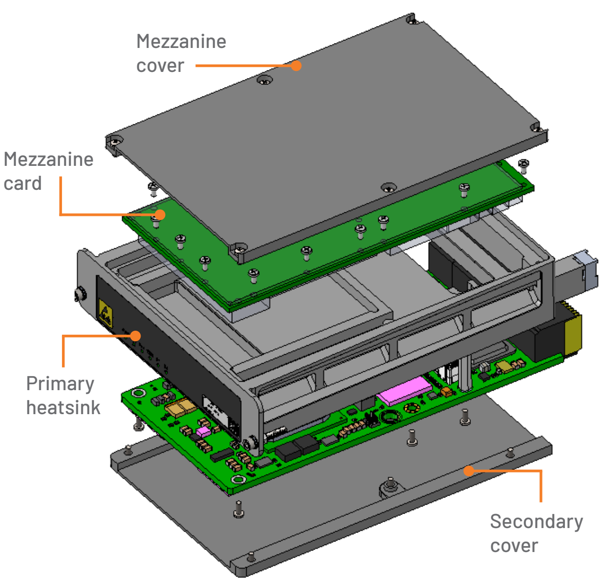


Figure 3: 3U OpenVPX Air Flow-Through (ANSI/VITA 48.8) module construction

LIQUID FLOW-BY

Dual/Redundant Liquid/Air-Cooling

Although not a current VITA standard, Liquid Flow-By™ is interoperable with the overarching VITA 46 standard and exceeds REDI requirements. Liquid Flow-By is the logical next step to a truly agnostic approach to OpenVPX cooling as it combines the best attributes of Air Flow-By (VITA 48.7) and Liquid Flow-Through (VITA 48.4) into a single entity enabling dual/redundant cooling. Mission-critical and large payloads that are subject to wide variations in environmental conditions benefit greatly from this approach. An airborne payload, for example, may be air cooled during ground-level pre-flight preparation and liquid cooled (fuel) during a high-altitude (limited air) mission.

Figure 4: 6U OpenVPX Liquid Flow-By module

CONFORMAL COATINGS

Conformal coats protect circuits from moisture and abrasion and act as a barrier to tin whisker growth. Mercury protects electronics with specialty coating, including acrylic or parylene, that supplements our baseline Mil-I-46058C and IPC-CC-830-compliant urethane coating. Mercury complies with the Government Electronics and Information Technology Association (GEIA) GEIA-STD-0005-2, Level 2B: standard for mitigating the effects of tin whiskers in aerospace and high-performance electronic systems.

Figure 5: Agnostic Air Flow-By extreme air-cooling technology applied to rugged 3U and 6U OpenVPX and ATCA server blades – all may be conformal coated.

OPTIONAL SERVICES

Environmental Screening and Analysis Services		Standard Module Services	
Cold Start Testing	Safety Margin Analysis	Engineering Change Order (ECO) Notification	Alternate Mean Time Between Failure (MTBF) Calculations
Cold Soak Testing	Temperature Cycling	ECO Control	Hazmat Analysis
Custom Vibration	Power Cycling	Custom Certificate of Conformity (CofC)	Diminished Manufacturing Sources (DMS) Management
CFD Thermal Analysis	Environmental Stress Screening	Custom UID Labeling	Longevity of Supply (LOS)
Finite Element Analysis			Longevity of Repair (LOR)

Contact factory for additional information

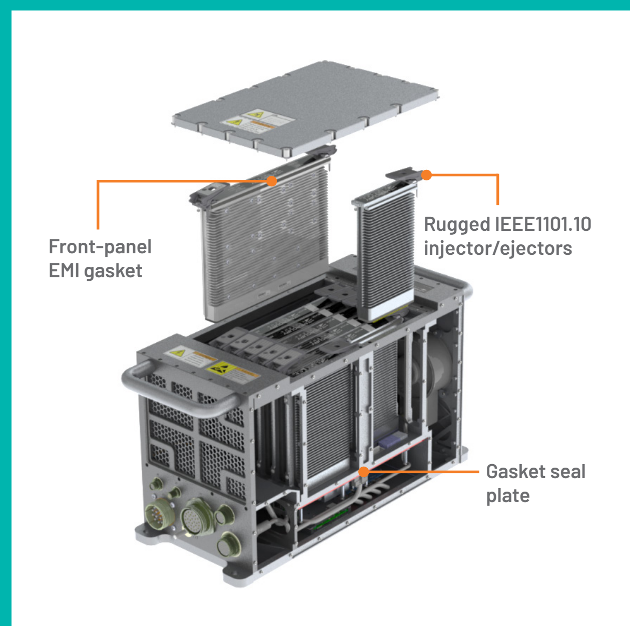
Holistic Subsystem Pre-Integration

Maximum environmental protection and effective cooling

Mercury is the only commercial company with domain experience across the whole sensor processing chain.

From RF acquisition, digitization and processing, to information exploitation and dissemination, we have the engineering domain expertise to pre-integrate your processing solution.

The level of cooling and environmental protection in our compute and RF modules/subsystems is configurable to meet the requirements of your processing application. This enables not only your but also other third-party content to be fully integrated, including software, reducing your program risk.



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