Table of Contents

OpenSFF Management Module Specification 26.0.0DRAFT2

1. Introduction

1.1 Purpose and Scope

This document defines the requirements for design, implementation, and interoperability of Management Modules (MM) in supported OpenSFF enclosures. The Management Module provides out-of-band management and enables consistent KVM redirection, power control, and remote administration across different vendor systems.

The specification defines mechanical, electrical, software, and interoperability requirements with the goal of consistent functionality across vendor implementations. It applies to both Enterprise Enclosures, which MUST provide a Management Module slot, and Core Enclosures, which MAY include a Management Module slot as an optional feature.

1.2 Relationship to Other Specifications

The Management Module Specification complements the following documents:

- OpenSFF Compute Node Specification
- OpenSFF Enclosure Specification

Module designers MUST reference these documents for mechanical dimensions, power budgets, and signal routing definitions to ensure seamless integration.

1.3 Terminology and Abbreviations

This section defines terms used throughout this specification and aligns with concepts used in the OpenSFF Compute Node and Enclosure documents.

- Anchor Linux: A minimal, secure Linux distribution builder purpose-built for OpenSFF Management Modules with CPUs. It provides the runtime environment for IP-KVM, configuration management, telemetry, and inter-node communication.
- Core Compute Node: A compute node variant using the Core connector (SFF-TA-1002 4C+), supporting CPU, memory, and I/O.
- Enterprise Compute Node: A compute node variant using both the Core and Enterprise connector (SFF-TA-1002 4C), enabling additional I/O such as additional Ethernet and USB-C
- Full-featured MM: MM variant with an embedded CPU, memory, and storage, capable of running Anchor Linux to provide advanced management.
- GPIO: General-Purpose Input/Output lines used by the MM to drive multiplexer select signals or read status inputs.
- Management Connector: SFF-TA-1002 4C+ connector with a unique pinout dedicated to the MM slot.
- MM: Management Module, the removable module providing KVM redirection and out-of-band management functionality.
- Out-of-Band Management: Management network separate from primary data paths, used for firmware updates, power control, and console access.
- Pass-through MM: MM variant without a CPU or OS, routing signals directly to external ports.

1.4 Document Conventions

- All measurements and numeric values shall include their associated units.
- Requirements: The words "SHALL," "MUST," "SHOULD," and similar terms are used to indicate the

relative degree of obligation in accordance with accepted standards practices as described in RFC 2119. See examples:
  - "SHALL" or "MUST" indicate a mandatory requirement.
  - "SHOULD" indicates a recommendation.
  - "MAY" indicates that something is permissible.

1.5 Versioning Guidelines

The full version of any OpenSFF standard MUST follow the format “Year.Major.Minor.STAGE#”. This consists of:

- Year: The two-digit year in which the specification cycle began (e.g., 26 indicates the 2026 revision cycle). The Year field reflects a new generation of the standard that introduces substantial design or performance changes across the ecosystem.
- Major: Incremented when a change or clarification may affect product implementation.
- Minor: Incremented for editorial or non-technical changes that do not affect product implementation, including non-breaking corrections or clarifications made after an official version is released.
- STAGE#: An optional field that indicates the document’s development status, along with a number denoting revisions within the stage. These stages are:
  - DRAFT#: An internal working draft for development and early review
  - RC#: Release candidate, with completed content and published for public or partner review
  - (no suffix): Final release of a version

2. Module Variants

The Management Module (MM) standard defines a range of possible implementations to accommodate different enclosure designs, vendor capabilities, and market requirements. While this specification describes two primary reference designs, Pass-through and Full-featured, vendors MAY create intermediate or alternative solutions that meet the electrical, mechanical, and interoperability requirements outlined here.

2.1 Pass-through Management Module

A Pass-through MM contains no CPU or operating system and simply routes signals from the management connector to its external ports. It enables local KVM access via DisplayPort and USB Type-A ports exposed on the I/O shield, and provides a direct Ethernet uplink to the internal management network.

Typical Characteristics:

- One RJ45 port directly connected to the internal management network.
- Two USB Type-A ports for keyboard and mouse input.
- One DisplayPort output for video.
- Hardware-based slot selection logic (e.g., push button or rotary selector)
- Visual slot identification reflecting the currently selected slot / compute node.

2.2 Full-featured Management Module

A Full-featured MM includes an embedded CPU, memory, and storage sufficient to run Anchor Linux, providing IP-KVM, telemetry collection, configuration management, and advanced out-of-band services.

Full-featured MMs MUST support KVM redirection, with the ability to select one node at a time and provide IP-KVM functionality to remote users.

Typical Characteristics:

- Embedded CPU equivalent to Intel N100 class
- At least 8GB system memory
- Persistent local storage for Anchor Linux and management services
- One RJ45 port connected to the MM’s own NIC
- Two USB Type-A ports for local keyboard and mouse input
- One DisplayPort output for local video output.
- Support for chassis SD card synchronization, including:
  - Validation and import of chassis data on boot
  - Backup of MM configuration data on major changes
  - Restore of configuration
- Optional future eDP output dedicated to enclosure status displays

2.3 Intermediate and Alternative Designs

The MM standard allows for other implementations that fall between the two reference designs, or are purpose-built for niche requirements. These alternative designs MUST adhere to the physical, electrical, and interface requirements in this specification to ensure interoperability.

3. Physical Characteristics

The physical design of the Management Module (MM) ensures interoperability with all OpenSFF-compatible enclosures featuring a dedicated MM slot. All MMs, regardless of variant or capability, MUST conform to the specified dimensions, connector placement, and retention methods to guarantee interoperability across compatible enclosures.

3.1 Form Factor and Overall Dimensions

The Management Module shares the same overall length as an OpenSFF Compute Node (see Compute Node Specification, Section 3.1) to simplify backplane layout.

Accordingly, the MM MUST conform to the following overall dimensions:

Parameter	Value	Notes
Length	215 mm	Measured from the inside mating surface of the I/O shield to the end of the connector plug
Width	110 mm	Full width of the I/O shield
Height (Total)	30 mm	Includes PCB and all components on the top and bottom
PCB Thickness	1.6 mm	Standard PCB Thickness

The internal mechanical envelope allows the following clearances for components, heatsinks, and other structural elements:

- 22.4 mm clearance above the PCB
- 6 mm clearance below the PCB

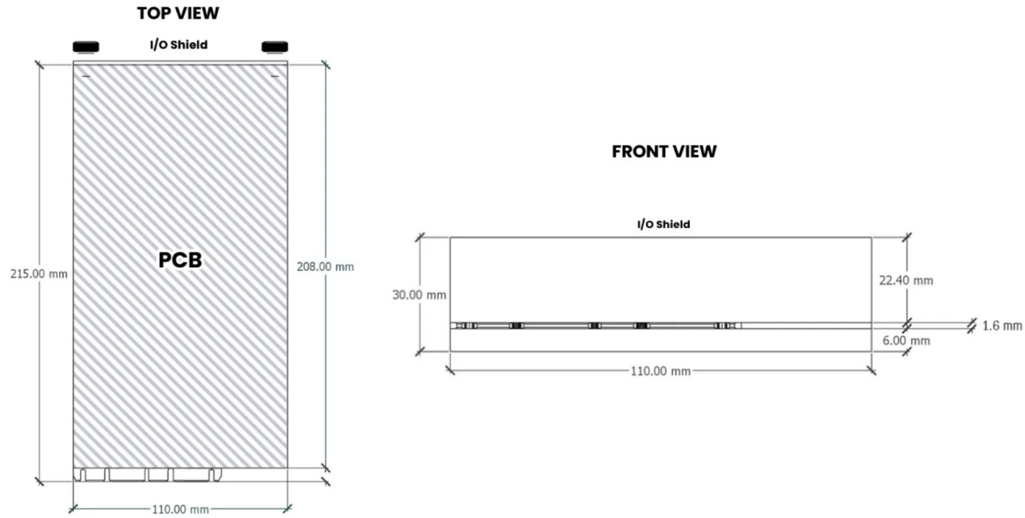

FIGURE 3.1. Management module dimensions

3.2 Component Placement and Keep-Out Zones

3.2.1 Top Components

The top side of the MM PCB is typically populated with the following components:

- CPU or SoC, memory, and storage (for Full-featured MMs)
- Power delivery circuits, VRMs, passive cooling (such as heatsinks)

Maximum Dimensions for Components on the Top Side of the PCB:

- Length: 202 mm (centered): Maximum usable length, excluding the physical Management connector plug, and accounting for keep-out zones along the PCB edges facing the edge plug and the I/O shield. Exceptions are permitted for ports that exit through the I/O shield.
- Width: 102 mm (centered): Maximum usable width, allowing clearance for the air shroud (see Section 6.3) and a buffer zone for optional support structures such as PCB card guides.
- Height: 22.4 mm: Maximum top-side height, considering PCB thickness and internal shroud height (see Section 6.3).

The maximum height of 22.4 mm for top-side components SHALL be defined by the MM air shroud (see Section 6.3). For MMs with a CPU or other components exceeding a TDP of 5W, the shroud is required, and all components MUST fit entirely beneath it.

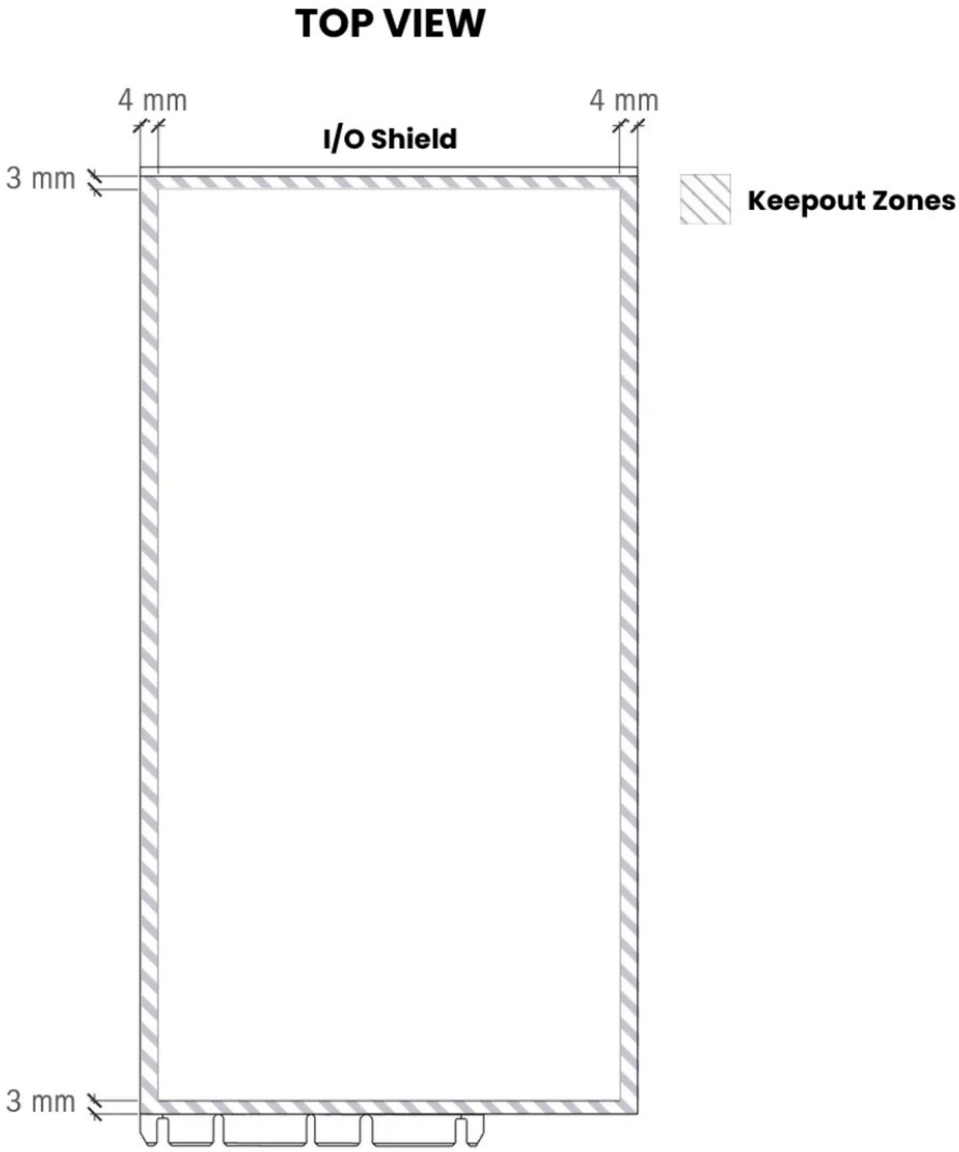

FIGURE 3.2.1 Keepout zones for top side components

3.2.2 Bottom Components

The bottom side of the MM PCB may contain low-profile components not exceeding 6 mm

- Connectors and small ICs
- Low-profile heat spreaders
- Storage (such as M.2 NVME)

Maximum Dimensions for Components on the Bottom Side of the PCB:

- Length: 202 mm (centered): Maximum usable length, excluding the physical Management connector plug, and accounting for keep-out zones along the PCB edges facing the edge plug and the I/O shield. Exceptions are permitted only for through-hole solder tails, leads, or mechanical reinforcements associated with ports that exit through the I/O shield.
- Width: 102 mm (centered): Maximum usable width, allowing a buffer zone for optional support structures such as PCB card guides.
- Height: 6 mm: Maximum height, considering PCB thickness and clearance required for backplane mating and slot insertion.

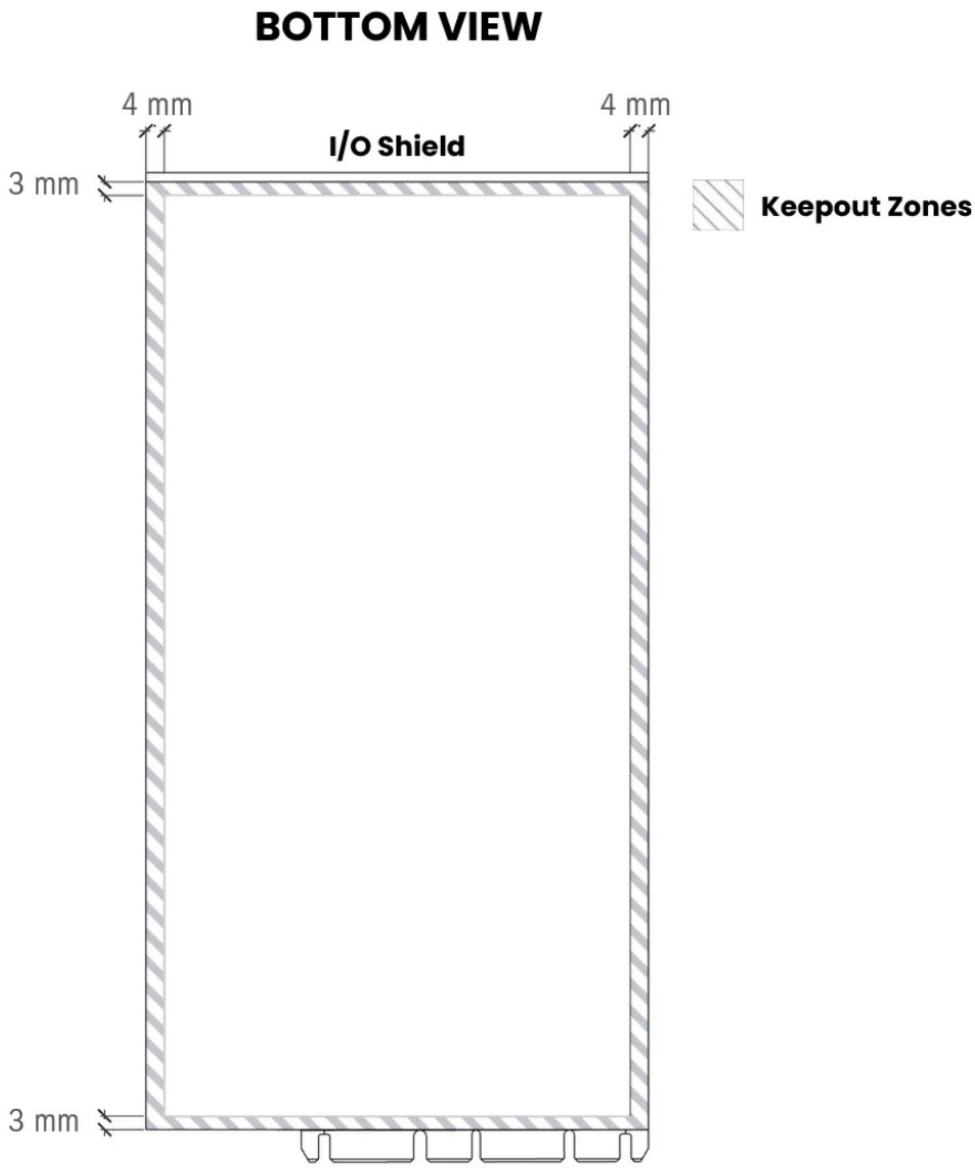

FIGURE 3.2.2 Keepout zones for components under the PCB

3.2.3 General Component Placement Restrictions

Component placement on both the top and bottom of the PCB MUST be restricted in the following areas:

- Length: To accommodate keep-out zones from the I/O shield and the Enterprise connector edge plug.
- Width: To allow space for optional PCB guides and clearance for the MM’s air shroud (see Section 6.2).
- Height: To allow easy insertion and removal, and to avoid interference with the MM’s air shroud or adjacent modules.

Note: Exceptions are permitted for ports exiting through the I/O shield (top side) and for associated through-hole leads or mechanical reinforcements (bottom side).

3.3 I/O Shield

The Management Module MUST provide a metal I/O shield to function as physical protection, airflow egress, and a structural mounting surface. The I/O shield MUST also have cutouts to accommodate the external ports defined in this specification.

Required Ports:

- One RJ45 port for management networking
- Two USB Type-A ports for keyboard and mouse
- One DisplayPort output for video

The I/O shield MUST have the following dimensions:

- Width: 110 mm
- Height: 30 mm
- Thickness: 1.2 mm (minimum)

The I/O shield MUST be perforated, to act as an exhaust for the enclosure's cooling system.

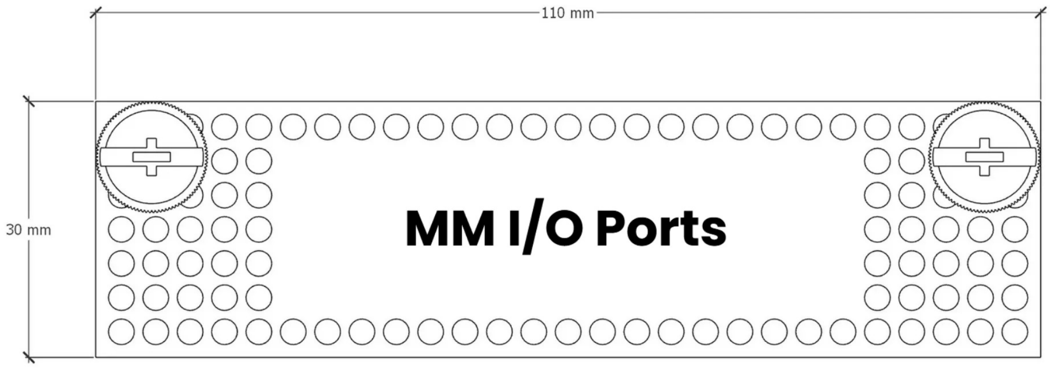

FIGURE 3.3.1. I/O shield dimensions

The I/O shield MUST be mounted using two captive M4 thumbscrews and matching screw holes, with the following specifications:

- Mounting: Two captive M4 thumbscrews.
- Hole Center Location: 6.5 mm from top and side edges of the I/O shield.
- Screw Hole Clearance: Minimum 2.5 mm clearance around the screw hole (measured at the inside mating surface of the I/O shield).

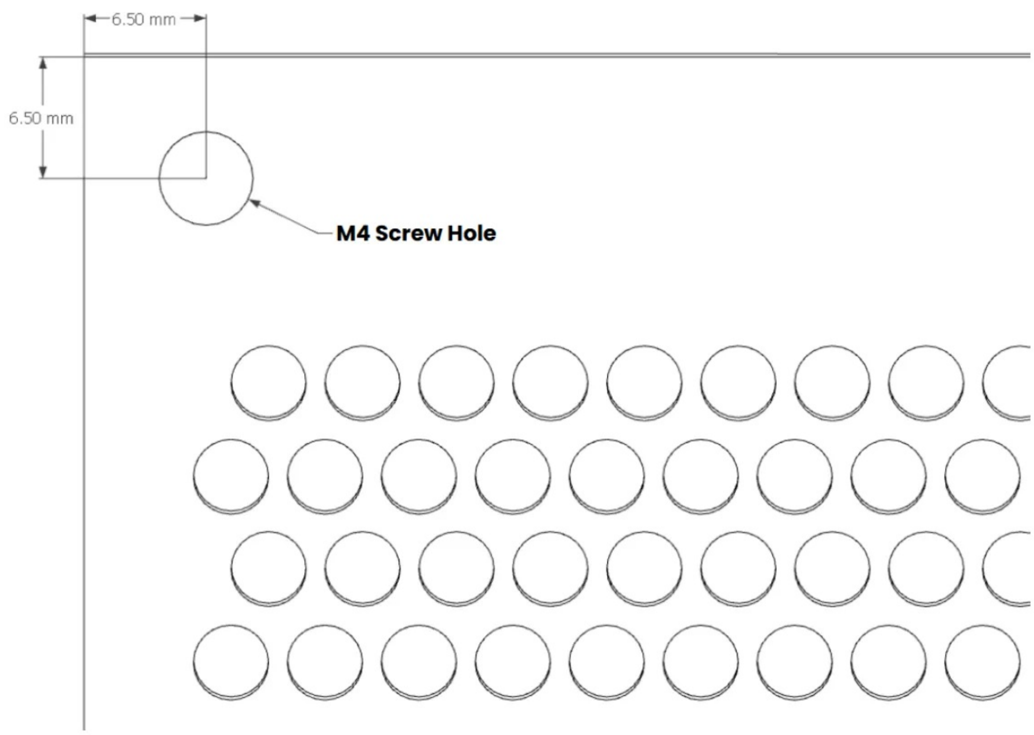

FIGURE 3.3.2. M4 screw hole position (only left side shown)

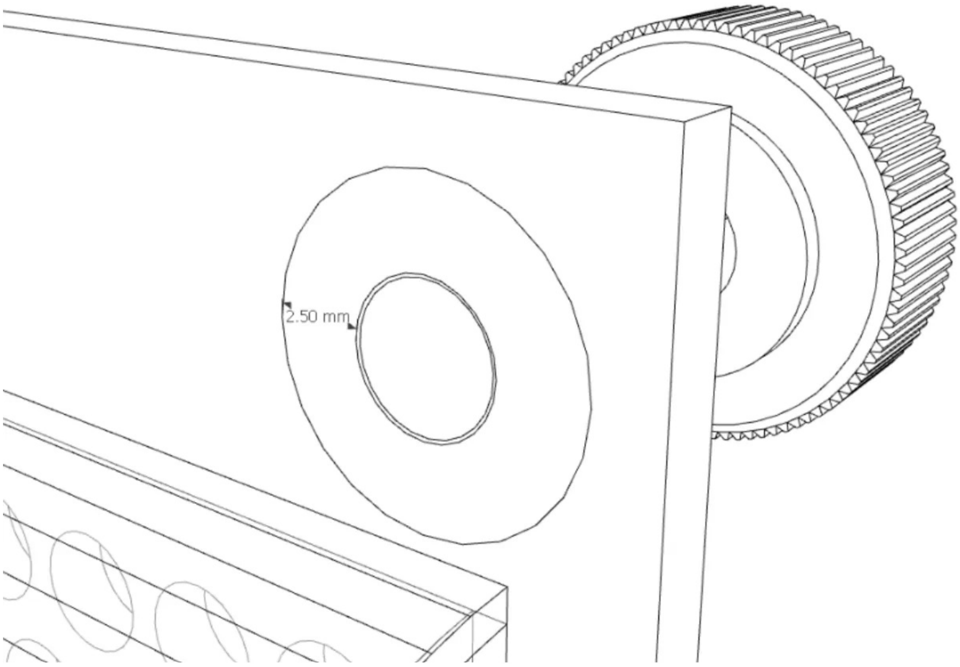

FIGURE 3.3.3. Screw hole clearance from inside mating surface of I/O shield

Additional connectors on the I/O shield may be connected at the manufacturer's discretion.

3.4 Mechanical Envelope and Retention Interface

The OpenSFF management module is designed for blind-mate insertion into a compatible enclosure slot. This section defines the required mechanical envelope, rear connector alignment, and retention mechanism to ensure consistent fit and serviceability across OpenSFF enclosures.

3.4.1 Connector Alignment and Layout

The MM’s connector plug is designed for blind-mate insertion into an enclosure-defined bay envelope, which establishes the physical reference for connector positioning.

The connector MUST meet the following requirements:

- Alignment
  - The outermost guide notch shall align with the right edge of the PCB and I/O shield envelope (as viewed from the rear)
  - The connector plug MUST support blind-mate insertion without interference when following the defined bay envelope
- Layout
  - Connector position: 0mm from the left side of the PCB, including guide notch (as viewed from the connector plug side)
  - Guide notches: Provided on each side of the connector plug
  - Spacing: 34 mm between the right edge of the guide notch and the end of the PCB width (as viewed from the connector plug side)

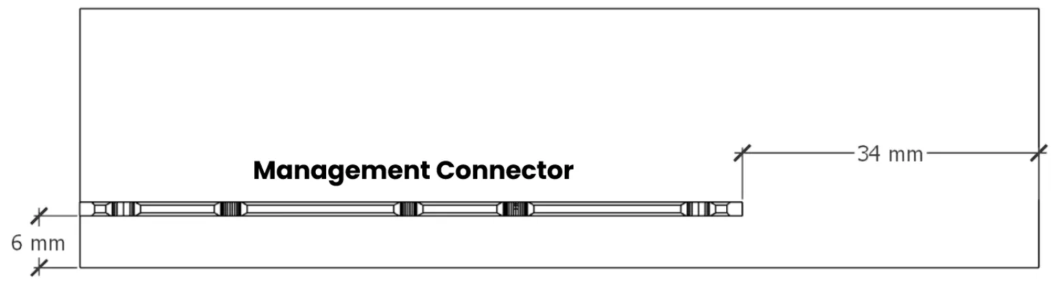

FIGURE 3.4.1a Management Connector Plug Layout (Front View)

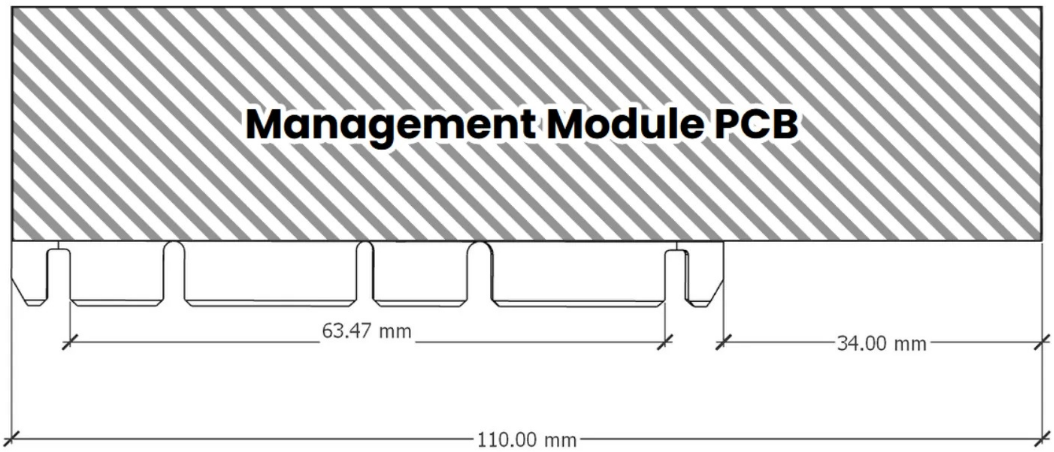

FIGURE 3.4.1b Management Connector Plug Layout (Top View)

3.4.2 Enclosure Retention Interface

The management module is secured within the enclosure using two captive M4 thumbscrews integrated into its rear I/O shield, as specified in Section 3.3. The enclosure MUST provide compatible threaded mounting points that align with the screw hole positions and support tool-less installation.

Specifically, the enclosure MUST:

- Position threaded retention points to match the MM’s 6.5 mm offset from the top and side edges of the I/O shield
- Provide a rigid backing structure to prevent flex during tightening or vibration during operation
- Maintain a 2.5 mm clearance radius around each mounting point to avoid interference with the cooling shroud
- Recess the screw mating surface by 1.2 mm from the enclosure's interior panel face to accommodate the I/O shield thickness and ensure flush contact during retention

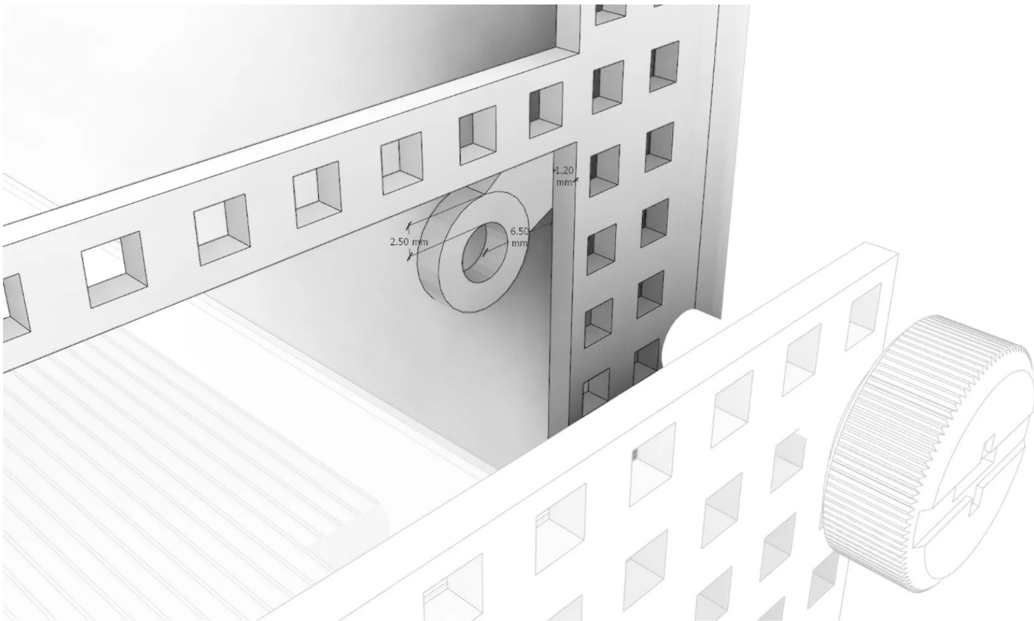

FIGURE 3.4.2 MM Retention Mechanism Layout and Measurements

3.5 Temperature and Humidity Requirements

The MM MUST be designed to operate within the following temperature and humidity ranges:

- Operating temperature: 10 °C to 35 °C
- Storage temperature: –40 °C to 65 °C
- Relative humidity: 8% to 80% (non-condensing)

3.6 Vibration Resistance

The MM MUST be designed to withstand vibration levels encountered in typical operating environments. See section 9.3.1 for testing specifications.

3.7 Environmental Tolerance

The Management Module MUST operate reliably in environments with typical indoor air quality, including the presence of fine dust or particulate matter (PM5 or smaller), consistent with ISO 14644-1 Class 9 cleanliness levels. The MM is NOT required to meet a formal Ingress Protection (IP) dust rating; however, they must exhibit baseline environmental resilience by withstanding standardized particulate exposure and durability validation tests. Designs SHALL NOT rely on user-replaceable air filters within the MM itself to maintain operational integrity under these conditions.

Design considerations for dust resilience:

- All components critical to system operation (including CPU sockets, memory modules, VRMs, and the like) must be positioned to limit direct accumulation of non-conductive dust
- The shroud and its airflow pathways should be designed to reduce turbulence and stagnation zones where debris can accumulate
- Where feasible, PCB coatings MAY be used to mitigate the effects of inductive or corrosive dust ingress

Serviceability Guidelines:

- The Management Module MUST be field-serviceable using non-specialized tools, with no requirement for internal cleaning during the expected lifecycle or warranty period (defined by vendor/manufacturing partner, not less than 3 years).
- Accessible areas (e.g. DIMM slots, M.2 storage slots) must remain free of obstructive debris that

could impact upgrade or maintenance operations.

See section 9.2.7 for the testing requirements for dust/debris ingress.

4. Electrical Specifications

4.1 Power Requirements

- The MM MUST be powered by 12 VDC through the Management connector.
- The MM MUST support a maximum power consumption of 50 Watts.

4.2 Ethernet

The MM MUST support Ethernet connectivity as follows:

- Number of ports: One port
- Speed: 2.5 Gbps or better
- Connector type: RJ-45

4.3 USB

The MM MUST support USB connectivity as follows:

- Number of USB 2.0 ports: Two, via Type A connectors

4.4 DisplayPort

- The MM MUST support DisplayPort connectivity with a minimum version of 1.4.

5. Management Connector Specifications

The 4C+ connector, referred to in this specification as the Management connector, is a card edge interface based on the SFF-TA-1002 specification. It features 168 contacts and supports up to 52 differential pairs of high-speed signals.

5.1 Pin Assignment

The 4C+ connector used in the OpenSFF Management Module follows a standardized pin configuration optimized for signal integrity, interoperability, and power distribution. The layout includes:

- Predefined ground pins distributed throughout the connector to minimize impedance and improve return path quality
- Dedicated power and management pins, which MUST NOT be reassigned for signaling purposes
- High-speed signal lanes arranged in a GSSGSSG pattern to support clean differential pair routing and minimize crosstalk

The MM MUST use the 4C+ pinouts as specified in Figure 5.1.

Management Connector (4C+)					
Side A			Side B		
Pin #	Signal	Description	Pin #	Signal	Description
OA1	+12V	+12 volt power	OB1	+12V	+12 volt power
OA2	+12V	+12 volt power	OB2	+12V	+12 volt power
OA3	+12V	+12 volt power	OB3	+12V	+12 volt power
OA4	res	Reserved	OB4	res	Reserved
OA5	res	Reserved	OB5	res	Reserved
OA6	GND	Ground	OB6	GND	Ground
OA7	res	Reserved	OB7	res	Reserved
OA8	res	Reserved	OB8	res	Reserved
OA9	GND	Ground	OB9	GND	Ground
OA10	res	Reserved	OB10	res	Reserved
OA11	res	Reserved	OB11	res	Reserved
OA12	GND	Ground	OB12	GND	Ground
OA13	res	Reserved	OB13	res	Reserved

OA13	res	Reserved	OB13	res	Reserved
OA14	res	Reserved	OB14	res	Reserved
KEY					
A1	KVM_NEXT	KVM Steps to Next Host (Pass-through MM)	B1	POWER_BTN	Power button
A2	KVM_RESET	KVM Resets to Slot 1 (Pass-through MM)	B2	RESET	Reset signal
A3	I2C_SCL	Serial Clock Line for KVM GPIO Expander (CPU MM)	B3	LED_STATUS	Front Panel Power LED
A4	I2C_SDA	Serial Data Line for KVM GPIO Expander (CPU MM)	B4	GND	Ground
A5	res	Reserved	B5	res	Reserved
A6	res	Reserved	B6	res	Reserved
A7	GND	Ground	B7	GND	Ground
A8	res	Reserved	B8	res	Reserved
A9	res	Reserved	B9	res	Reserved
A10	GND	Ground	B10	GND	Ground
A11	ETH0_BI+_D3	Ethernet Port 0 Bi-directional+ (Pair 1)	B11	ETH0_TX+_D1	Ethernet Port 0 Transmit Data+ (Pair 2)
A12	ETH0_BI-_D3	Ethernet Port 0 Bi-directional- (Pair 1)	B12	ETH0_TX-_D1	Ethernet Port 0 Transmit Data- (Pair 2)
A13	GND	Ground	B13	GND	Ground
A14	ETH0_RX+_D2	Ethernet Port 0 Receive Data+ (Pair 3)	B14	ETH0_BI+_D4	Ethernet Port 0 Bi-directional+ (Pair 4)
A15	ETH0_RX-_D2	Ethernet Port 0 Receive Data- (Pair 3)	B15	ETH0_BI-_D4	Ethernet Port 0 Bi-directional- (Pair 4)
A16	GND	Ground	B16	GND	Ground
A17	DP_IN_ML_Lane_p0	Displayport In Main Link Lane+ (Pair 1)	B17	DP_IN_ML_Lane_p1	Displayport In Main Link Lane+ (Pair 2)
A18	DP_IN_ML_Lane_n0	Displayport In Main Link Lane- (Pair 1)	B18	DP_IN_ML_Lane_n1	Displayport In Main Link Lane- (Pair 2)
A19	GND	Ground	B19	GND	Ground
A20	DP_IN_ML_Lane_p2	Displayport In Main Link Lane+ (Pair 3)	B20	DP_IN_ML_Lane_p3	Displayport In Main Link Lane+ (Pair 4)
A21	DP_IN_ML_Lane_n2	Displayport In Main Link Lane- (Pair 3)	B21	DP_IN_ML_Lane_n3	Displayport In Main Link Lane- (Pair 4)
A22	GND	Ground	B22	GND	Ground
A23	DP_IN_AUXCH_p	Displayport In Auxiliary Channel+	B27	DP_IN_HOTPLUG	Displayport In Hot Plug Detect
A24	DP_IN_AUXCH_n	Displayport In Auxiliary Channel-	B28	SD_CD	SPI SD Card Detect
A25	GND	Ground	B29	GND	Ground
A26	SD_MOSI	SPI SD - Master Out Slave In	B20	SD_SCK	SPI SD Serial Clock
A27	SD_MISO	SPI SD - Master In Slave Out	B21	SD_CS	SPI SD Chip Select
A28	GND	Ground	B28	GND	Ground
KEY					
A29	GND	Ground	B29	GND	Ground
A30	DP_OUT_ML_Lane_p0	Displayport Out Main Link Lane+ (Pair 1)	B30	DP_OUT_ML_Lane_p1	Displayport Out Main Link Lane+ (Pair 2)
A31	DP_OUT_ML_Lane_n0	Displayport Out Main Link Lane- (Pair 1)	B31	DP_OUT_ML_Lane_n1	Displayport Out Main Link Lane- (Pair 2)
A32	GND	Ground	B32	GND	Ground
A33	DP_OUT_ML_Lane_p2	Displayport Out Main Link Lane+ (Pair 3)	B33	DP_OUT_ML_Lane_p3	Displayport Out Main Link Lane+ (Pair 4)
A34	DP_OUT_ML_Lane_n2	Displayport Out Main Link Lane- (Pair 3)	B34	DP_OUT_ML_Lane_n3	Displayport Out Main Link Lane- (Pair 4)
A35	GND	Ground	B35	GND	Ground
A36	DP_OUT_AUXCH_p	Displayport Out Auxiliary Channel+	B36	DP_OUT_HOTPLUG	Displayport Out Hot Plug Detect
A37	DP_OUT_AUXCH_n	Displayport Out Auxiliary Channel-	B37	res	Reserved
A38	GND	Ground	B38	GND	Ground
A39	USB0_D+	USB 2.0 Port 1 Data+	B39	res	Reserved
A40	USB0_D-	USB 2.0 Port 1 Data-	B40	res	Reserved
A41	GND	Ground	B41	GND	Ground
A42	MM_PRESENT	Management Module Presence Detect	B42	MM_CPU	GND if MM has a CPU, pull up if none
KEY					
A43	GND	Ground	B43	GND	Ground
A44	res	Reserved	B44	res	Reserved
A45	res	Reserved	B45	res	Reserved
A46	GND	Ground	B46	GND	Ground
A47	res	Reserved	B47	res	Reserved
A48	res	Reserved	B48	res	Reserved
A49	GND	Ground	B49	GND	Ground
A50	res	Reserved	B50	res	Reserved
A51	res	Reserved	B51	res	Reserved
A52	GND	Ground	B52	GND	Ground
A53	res	Reserved	B53	res	Reserved
A54	res	Reserved	B54	res	Reserved
A55	GND	Ground	B55	GND	Ground
A56	res	Reserved	B56	res	Reserved
A57	res	Reserved	B57	res	Reserved
A58	GND	Ground	B58	GND	Ground
A59	res	Reserved	B59	res	Reserved
A60	res	Reserved	B60	res	Reserved
A61	GND	Ground	B61	GND	Ground
A62	res	Reserved	B62	res	Reserved
A63	res	Reserved	B63	res	Reserved
A64	GND	Ground	B64	GND	Ground
A65	res	Reserved	B65	res	Reserved
A66	res	Reserved	B66	res	Reserved
A67	GND	Ground	B67	GND	Ground
A68	res	Reserved	B68	res	Reserved
A69	+12V	+12 volt power	B69	+12V	+12 volt power
A70	+12V	+12 volt power	B70	+12V	+12 volt power

(red)	Power
(dark grey)	Ground
(yellow)	System Control
(blue)	USB
(orange)	Ethernet
(purple)	DisplayPort
(brown)	KVM Control
(light green)	Metadata Storage Access
(light grey)	Reserved

FIGURE 3.1. 5.1 Management Connector Pinout

5.2 Supported Protocols

See OpenSFF Compute Node section 5.1.2.

5.3 Electrical Characteristics

See OpenSFF Compute Node section 5.1.3.

5.4 Mechanical Characteristics

See OpenSFF Compute Node section 5.1.4.

6. Airflow and Cooling

The Management Module (MM) relies on enclosure-provided front-to-back airflow for thermal management. A plastic shroud directs this airflow across the module's thermal solution and out through perforations in the I/O shield. All major heat-generating components are passively cooled by the module's thermal assembly, which MUST operate as part of the active cooling system supplied by the enclosure.

6.1 Requirements

The cooling system must manage thermal output across an inlet air temperature range of 10 °C to 35 °C. Junction or case temperatures of all critical components must remain within specified limits to prevent throttling or damage:

- Maximum Ambient / Intake Temperature:** **35 °C
- Maximum Junction Temperature (CPU): 85 °C
- Maximum Junction Temperature (Memory Modules): 85 °C
- Maximum VRM MOSFET Case Temperature: 120 °C

To ensure reliable operation, the cooling system must deliver sufficient airflow across the MM's thermal interfaces:

- Minimum airflow requirement: 18.4 m³/h at the shroud inlet.
- Required static pressure: 1.06 mmH_2O at 18.4 m³/h, to overcome losses through heatsink fins, ducting, filters, and other chassis restrictions.

These figures are based on theoretical airflow calculations, adjusted upward (by about 200%) to align with empirical data from comparable systems and provide adequate margin.

The MM MUST integrate a thermal solution capable of maintaining all components within the limits defined above. Designs with very low power dissipation (e.g., components below 5W TDP) MAY omit a dedicated thermal assembly, including the shroud, if enclosure airflow alone maintains compliance.

6.2 Design Guidelines

- The MM's thermal solution MUST support a maximum TDP of 50W, consistent with the overall power budget defined in Section 4.1.
- Thermal solutions SHOULD be optimized for the enclosure's airflow path and pressure characteristics.
- Acceptable methods include heatsinks, vapor chambers, heatpipes, or equivalent thermal transfer assemblies.
- Where conduction to a cooling assembly is required, high-quality Thermal Interface Material (TIM) or equivalent MUST be used. The thermal solution MUST function in conjunction with enclosure airflow as specified above.
- Cutouts, pedestals, or similar features MAY be used to minimize TIM bond-line thickness.

6.3 The Shroud

A plastic shroud MUST be used to direct airflow across the MM's thermal solution whenever the module includes a CPU or other components exceeding a thermal design power (TDP) of 5W per component. For modules below this threshold, including most Pass-through MMs, the shroud MAY be omitted provided that all temperature limits defined in Section 6.1 are satisfied.

- Maximum External Dimensions: 215 mm (L) × 104 mm (W) × 22.4 mm (H)
- The inlet section MUST extend 7 mm beyond PCB length (equal to connector plug length) to seal against the enclosure intake fan array.
- Shroud width and height MUST taper at the top corners to clear I/O shield mounting features (see Figure 3.4.2).
- Shroud Inlet: Minimum area of 22 mm (H) × 88 mm (W).
- Shroud Outlet:** **I/O shield perforations SHALL meet exhaust requirements while preserving I/O functionality and structural integrity.
- Design Features: Baffles or channels MAY be included to direct airflow over memory or VRMs. Curves and fillets MUST be incorporated where possible to reduce turbulence and flow separation.

7. KVM Signal Routing

The Management Module (MM) is responsible for selecting and controlling console access (keyboard, video, and mouse) across all installed compute nodes in an enclosure.

Enclosures provide passive routing infrastructure: one USB 2.0 uplink and one DisplayPort output from each node are multiplexed to the MM slot. The enclosure does not interpret or emulate signals; it only forwards the active path selected by the MM.

7.1 Signal Multiplexing Interface

The MM interfaces with the enclosure's multiplexer subsystem, which accepts one USB 2.0 and one DisplayPort signal from each node.

The MM MUST:

- Drive the multiplexer select lines to determine which node's console is active.
- Ensure that only one node is selected at a time.
- Prevent invalid or conflicting signal states.
- Maintain full compatibility with USB 2.0 and DisplayPort 1.4 electrical standards.

The MM SHALL assume that the enclosure preserves full signal integrity and prevents interference from non-selected nodes.

7.2 Slot Selection Control

Slot selection is always under MM control. Enclosures SHALL NOT implement independent slot selection or override mechanisms.

The MM MUST provide a reliable method for users to select or change the active slot, through either:

- Hardware interface: Local buttons or switches driving the multiplexer directly.
- Software interface: Anchor Linux services exposing slot selection via the Rust backend and Flutter frontend.

Regardless of implementation, the MM drives the multiplexer select lines and owns slot selection logic.

7.3 Visual Slot Identification

The Management Module (MM) MUST provide a means of indicating the currently selected compute node for KVM redirection.

- Pass-through MMs:
    - MUST provide a physical visual indicator on the module itself.
    - Acceptable display methods include:
        - A numeric 7-segment display (e.g., Slot 1–9 or hexadecimal 0–F).
        - A segmented alphanumeric or OLED display.
        - A user-configurable LED matrix.
    - The physical indicator MUST directly reflect the slot index selected by the multiplexer control signals. \
- Full-featured MMs:
    - MUST provide this indication in software, as part of the Anchor Linux IP-KVM user interface.
    - If a physical indicator is provided, it MUST also accurately reflect the multiplexer selection state.

Note: In configurations where the MM performs blind slot selection (i.e., without reading slot presence data), the indication, whether physical or software, reflects only the current selection state. It does not guarantee that a node is present or operational in the selected slot.

7.4 Implementation Notes

The Management Module specification recognizes two implementation classes:

- Pass-through MM
    - Relies on a hardware control element (e.g., momentary push-button switch, stepped rotary switch)
    - Directly forwards the active USB 2.0 and DisplayPort signals after multiplexing
    - No interpretation, buffering, or format conversion is performed
- Full-featured MM
    - Includes a CPU and software stack (Anchor Linux) for remote KVM functionality.
    - Video signals must be made available to the CPU as a standard USB video device (UVC).
    - Conversion of DisplayPort signals into a format consumable by UVC capture is REQUIRED, but the method is left to vendor implementation.
    - USB 2.0 signals are forwarded and managed through software.

General requirements:

- The specification does not mandate a specific conversion architecture for video capture. Vendors MAY use any standards-compliant method (e.g., bridging or protocol translation) that results in a valid UVC stream.
- Multiplexer control MUST remain deterministic and synchronized across both USB and DisplayPort paths.
- Enclosures and MMs MUST preserve full compliance with DisplayPort 1.4 and USB 2.0 electrical specifications, regardless of implementation details.

8. Configuration and Metadata Management

This section defines how configuration data and enclosure metadata are stored, validated, and backed up using the chassis-mounted SD Card. It also specifies the role of the Management Module in maintaining configuration continuity, as well as the use of software-defined parameters to optimize KVM control behavior.

8.1 Enclosure-Level Metadata Store

Enterprise Enclosures that support a Management Module (MM) SHALL provide an SD Card in SPI mode on the backplane. The SD Card contains:

- Chassis description and layout, including slot definitions and enclosure-level settings.
- Also serves as a backup target for MM configuration data

8.2 Validity by Module Type

- Full-featured MMs: MUST mount and use the SD Card as described.
- Pass-through MMs: SHALL ignore the SD Card and provide no configuration persistence. In this mode, the enclosure operates solely with its hardware defaults.

8.3 Boot Behavior (Full-featured MM only)

On boot, the MM SHALL attempt to validate the SD Card contents (e.g., by verifying SHA-256 checksums or equivalent integrity mechanisms).

- If the SD Card data is valid, the MM imports the chassis description into its runtime environment.
- If the SD Card is absent or the data is invalid, the MM continues operation using its internal configuration store.

8.4 Backup Behavior (Full-featured MM only)

The MM SHALL back up configuration data to the SD card only when major configuration changes occur.

8.5 Restore Behavior (Full-featured MM only)

The MM SHALL NOT automatically restore configuration from the SD Card.

- Restoration occurs only when explicitly requested through the management interface.
- By default, the MM prioritizes its internal storage to preserve continuity of operation.

8.6 Fallback Behavior (All MM types)

If the MM cannot access or parse the SD Card storage, of if a Pass-through MM is installed, the following functions remain fully operational at the hardware level:

- Physical KVM signal routing
- Internal management network pass-through

8.7 Software-defined Control Parameters (Full-featured MM only)

Certain aspects of KVM control behavior MAY be parameterized and stored on the SD Card, allowing them to be tuned in software for the specific enclosure hardware implementation. These parameters include, but are not limited to:

- Reset timing: Duration of reset assertions, timing between successive reset pulses, and pause intervals between reset sequences.
- Slot selection timing: Debounce periods, switching delays, and pause intervals needed to ensure

reliable multiplexer settling when changing active nodes.
- Combined switch/reset sequences: Timing relationships between slot switching and node reset events.

By externalizing these values to the SD Card, Full-featured MMs can adjust their control behavior to match the characteristics of the enclosure's multiplexer subsystem and related hardware components, while preserving interoperability across all OpenSFF-compatible systems.

9. Testing Requirements

To ensure interoperability, reliability, and performance across a wide range of deployments, all Management Modules conforming to this specification MUST undergo testing aligned with industry-recognized standards for modular computing hardware, with additional functional validation unique to MM roles.

9.1 Electrical Testing

Management Modules SHALL be subjected to the following electrical tests to ensure user safety and insulation integrity:

9.1.1 Safety and Insulation Testing

- Dielectric Withstand Test (Hi-Pot Test)
    - Purpose: To verify the insulation strength of the MM's components and PCB to prevent electrical breakdown and ensure safety.
    - Procedure: Applying a high voltage (AC or DC) between isolated parts for a specified duration and checking for current leakage or breakdown.
- Insulation Resistance Test
    - Purpose: To measure the resistance between isolated circuits to ensure effective insulation.
    - Procedure: Applying a DC voltage across insulation barriers and measuring the insulation resistance.
- Ground Continuity Test
    - Purpose: To verify the proper connection of all exposed metal parts to the ground terminal.
    - Procedure: Measuring the resistance between the ground pin and accessible metal parts (should be $<0.1\Omega$).
- Standards Reference: IEC 60950 / IEC 62368-1.

9.1.2 Functional Electrical Testing

- Power-Up and Basic Functionality Test
    - Purpose: To ensure the management module powers up correctly and basic I/O is operational.
    - Procedure: Apply 12VDC and verify power-on, power button function, and basic USB power.
- Voltage Rail Verification
    - Purpose: To confirm VRMs generate correct voltage levels within tolerance under various loads.
    - Procedure: Measure voltage at test points on the PCB.
- Ethernet Port Testing
    - Purpose: To ensure functionality and speed (2.5 Gbps or faster) of Ethernet port.
    - Procedure: Verify link establishment, perform data transfer, and run benchmarks.
    - Tools: Network testers, iperf.
- USB Port Testing (USB 2.0 Type A)
    - Purpose: To verify functionality and data transfer speeds of USB ports.

    - Procedure: Test detection and data transfer with various USB devices.
    - Tools: USB testers, data transfer benchmarks.
- DisplayPort Output Testing
    - Purpose: To ensure the DisplayPort output functions correctly.
    - Procedure: Verify signal output and resolution support with a compatible display.
- Signal Integrity Testing (High-Speed Interfaces)
    - Purpose: To ensure signal quality on Management connector for reliable data transfer.
    - Procedure: Measure signal parameters at the connector interface.
    - Tools: Oscilloscope, signal integrity tools
    - Considerations: May require custom test fixtures mimicking enclosure backplane.
- Power Integrity Testing
    - Purpose: To assess the stability and noise levels of power delivery.
    - Procedure: Measure voltage ripple, noise, and transient response.
    - Tools: Oscilloscope, power analyzer

9.1.3 Electromagnetic Compatibility (EMC) Pre-compliance Testing

- Conducted Emissions: Measure RF noise emitted through connectors or traces.
- Radiated Emissions: Measure RF noise radiated by the MM.
- Electrostatic Discharge (ESD) Immunity: Test resistance to ESD events.
- Electromagnetic Interference (EMI) Susceptibility: Test operation in external electromagnetic fields.

9.2 Thermal and Environmental Testing

All management modules must undergo thermal validation under representative operating conditions to ensure reliable function and safety. Thermal tests are designed to evaluate the system's ability to maintain safe operating temperatures, prevent thermal throttling, and operate within acoustic boundaries. Tests must be performed using defined workloads and thermal conditions that simulate real-world deployment scenarios, including those with unfiltered airflow and exposure to airborne particulate matter.

Note: Some tests in this section (e.g., those requiring sustained CPU load or thermal throttling checks) apply only to Full-featured Management Modules. Pass-through MMs, which lack CPUs and DRAM, SHALL be exempt from such tests but MUST still demonstrate safe thermal behavior under representative multiplexer load conditions.

The following mandatory thermal and environmental tests MUST be performed:

9.2.1 Thermal Testing Under Specified Ambient Inlet Temperatures

- Purpose: To ensure the MM can operate reliably without thermal throttling or component damage within the specified ambient inlet temperature range and under specific fan failure scenarios.
- Procedure: Run the MM at its maximum representative load (50 W) within a controlled environment with the following conditions:
    - Condition 1: All Fans Operational: Ambient inlet temperature maintained at ≤35 °C with all enclosure cooling fans functioning correctly. Monitor processor/package temperature, onboard DRAM temperature, and power regulation components until steady state is reached.
    - Condition 2: Single Fan Failure: Ambient inlet temperature maintained at ≤35 °C with one non-operational enclosure cooling fan not directly cooling the MM's active thermal zone. Monitor the same components until steady state is reached.
- Pass/Fail Criteria:
    - Processor/Core Maximum Junction Temperature (Tj): ≤85 °C
    - Memory Maximum Junction Temperature: ≤85 °C (if present)
    - Power Regulation (VRM/PMIC) Casing Temperature: ≤120 °C
    - No thermal throttling of the MM processor or memory should occur during the test.

9.2.2 Thermal Performance Under Varying Ambient Temperatures

- Purpose: To evaluate the effectiveness of the MM cooling solution across the specified operating range (10 °C to 35 °C).
- Procedure: Perform thermal testing (as in 9.2.1, Condition 1) at multiple controlled ambient temperatures.
- Analysis: Ensure cooling remains adequate at the upper limit (35 °C).

9.2.3 Transient Thermal Response Testing

- Purpose: To assess how quickly the MM thermal solution can dissipate heat when the workload changes rapidly.
- Procedure: Apply a step load change (e.g., idle ↔ full representative load) and monitor temperature response of critical components.
- Metrics: Rate of temperature change (°C/s), overshoot, and settling time.

9.2.4 Hot Spot Identification

- Purpose: To identify localized areas of excessive heat on the MM PCB or components.
- Procedure: Use infrared cameras to create thermal images of the MM under load, highlighting hot spots.

9.2.5 Acoustic Testing Under Thermal Load

- Purpose: To measure noise levels generated by enclosure fans when the MM contributes thermal load.
- Procedure: Measure sound pressure at a specified distance from the enclosure while the MM is under sustained representative load.
- Metrics: Noise levels in dBA.

9.2.6 Long-Duration Thermal Soak Test

- Purpose: To assess the long-term reliability of the MM under continuous thermal stress.
- Procedure: Run the MM at sustained representative maximum load (50 W) within the maximum ambient temperature (35 °C) for an extended period (24-72 h). Monitor for thermal degradation or failure.

9.2.7 Debris Exposure Validation

- Purpose: To validate thermal and mechanical resilience when unfiltered airflow introduces particulate accumulation.
- Procedure: See details below.
  - Setup: MM installed in a standard operational chassis with airflow paths unobstructed, and placed inside a test chamber to simulate an ISO 14644-1 Class 9 cleanroom. Airflow is directed through natural intake zones using an external fan array integrated into the chassis.
  - Debris: ISO 12103-1 A2 Fine Test Dust introduced at intervals over a 72-hour simulated uptime.
  - Load: MM operated under representative maximum thermal load during exposure.
  - Monitoring: Record inlet/outlet temps, fan RPMs, and onboard sensor telemetry (processor, DRAM, regulators, if applicable).
- Validation Criteria:
  - No thermal throttling during or after the test (Full-featured MMs only).
  - No increase in maximum fan RPM exceeding 10% over baseline
  - Acoustic measurements must remain within 3 dBA of pre-test levels
  - Post-test visual inspection must show no critical obstructions that may impair serviceability or

airflow.

Note: OpenSFF-compatible systems are not required to meet formal ingress protection (IP) ratings; however, systems using open or semi-open airflow paths must demonstrate thermal resilience under controlled debris exposure conditions as defined in this document.

9.3 Mechanical Testing

9.3.1 Vibration and Shock

Management modules must satisfy all applicable shock and vibration standards as outlined in IEC 60068-2-57:2013 and EC 60068-2-81:2003. During operational shock and vibration testing, the MM MUST maintain continuous electrical performance with no interruptions. For non-operational testing, physical damage or limitation of functional capabilities MUST NOT occur.

	Operating	Non-Operating
Vibration	0.5 G RMS, 5–500–5 Hz Random Vibe, 1 sweep, 20 min along three axes (+/–) 5–20 Hz – 6 dB/Oct 20–250 Hz – 0.0007 G^2/Hz 250–500 Hz – 6 dB/Oct	1.2 G, 5–500–5 Hz per sweep 1 sweep at 0.5 Octave/min, 3 axes 5–10 Hz – 0.5 G 10–350 Hz – 1.2 G 350–500 Hz – 0.5 G

TABLE 9.3.1 Vibration and shock requirements

9.3.2 Mechanical Compliance of SFF-TA-1002 Interface

The management module’s plug, based on the SFF-TA-1002 connector specifications, SHALL meet the mechanical performance requirements defined in this section to ensure interoperability and reliable engagement with the corresponding backplane connector.

Mechanical testing SHALL be conducted using an axial tension/compression system (e.g., Instron Tensile Tester) in accordance with EIA-364 procedures. All force measurements SHALL be executed at a constant rate of 25.4 mm/min. Testing SHALL be performed using management modules manufactured to this document’s upper limits, as specified below, to represent worst-case tolerance conditions.

Mechanical Test	**Procedure**	**Test Description**
Insertion Force (Management Module to Backplane Connector)	EIA-364-13	Measure axial insertion force required to fully engage the MM into the backplane connector.
Unmating Force (Management Module from Backplane Connector)	EIA-364-13	Measure axial force required to disengage the MM from the backplane connector.
Durability (Mating/Unmating Cycles)	EIA-364-09 (Modified)	Plug and unplug the MM at a controlled rate of 25.4 mm/min. Perform required cycles for connector grade per the table below. Replace the backplane connector after every 25 cycles.

TABLE 9.3.2a Mechanical testing requirements

Connector Grade	Number of Cycles
A	200
B	100
C	50

TABLE 9.3.2b Mating cycles by connector grade

9.4 Compliance Testing

Final verification SHALL be conducted by accredited laboratories to confirm conformity with all requirements specified in Section 10, including:

- EMC emissions and immunity
- Electrical safety and insulation
- Environmental directive compliance

10. Compliance and Certification

10.1 Electromagnetic Compatibility (EMC)

- **FCC CFR47 Part 15, Subpart B, Class A criteria:** U.S. regulation for controlling electromagnetic interference from digital devices.

- **EU EMC Directive (2004/108/EC):** Establishes uniform EMC requirements across EU member states, ensuring mutual acceptance of compliant equipment.

10.2 Safety Standards

- **UL 62368-1, IEC 62368-1, EN 62368-1:** Hazard-based safety standards for audio/video, information, and communication technology equipment.

10.3 Environmental Standards

- **RoHS Directive (2015/863/EU):** Restricts use of specific hazardous substances in electrical and electronic equipment to protect human health and the environment.

- **REACH Regulation (EC) No 1907/2006:** Requires registration, evaluation, authorization, and restriction of chemicals within the EU.

- **WEEE Directive (2012/19/EU):** Aims to reduce the environmental impact of electrical and electronic equipment through proper waste handling and recycling.