CONNECT AND PROTECT

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

nVent
SCHROFF

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

CONTENT

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

1. INTRODUCTION

A number of technology trends have emerged over the last years in the defense market that have impacted electronics hardware requirements. Fleet modernizations across land, air, and sea require next generation C5ISR developments such as artificial intelligence for ISR applications, interoperability and SATCOM implementation resulting in more powerful electronics that require enhanced cooling.

Military electronics have increasingly become decentralized, smaller, and more powerful with one such example of the arrival of mobile command posts that are lightweight, quick to setup, and creatively powered. Unmanned vehicle investments have continued requiring increasing distance and payload capabilities resulting in the need for lighter yet more powerful electronic systems.

A key requirement that is fundamental throughout these trends is meeting SWaP, or Size, Weight, and Power requirements without compromising performance in extreme environments.

Thermal performance continues to be one of the most challenging aspects of meeting increasing SWaP requirements. Today's engineers must have access to key hardware components' thermal data to make the best data driven design decisions possible.

Examples of these hardware components include printed circuit board assemblies, Wedge-Loks and the VITA conduction-cooled assemblies to which they are assembled.

This white paper will explore how nVent SCHROFF has approached thermal testing methods at the module level, resulting data, and how this data can be leveraged to make more informed design decisions based on how Card-Lok selection impacts thermal performance. There are also new high thermal product options that can significantly impact thermal performance of a module.

The following sections include:

- Thermal testing methodology and fixtures
- Impact of Card-Loks on overall thermal performance on VITA conduction cooled module configurations including VITA 48.2 and VITA 46
- Card-Lok thermal resistance
- New high thermal conduction cooled modules and Card-Lok designs

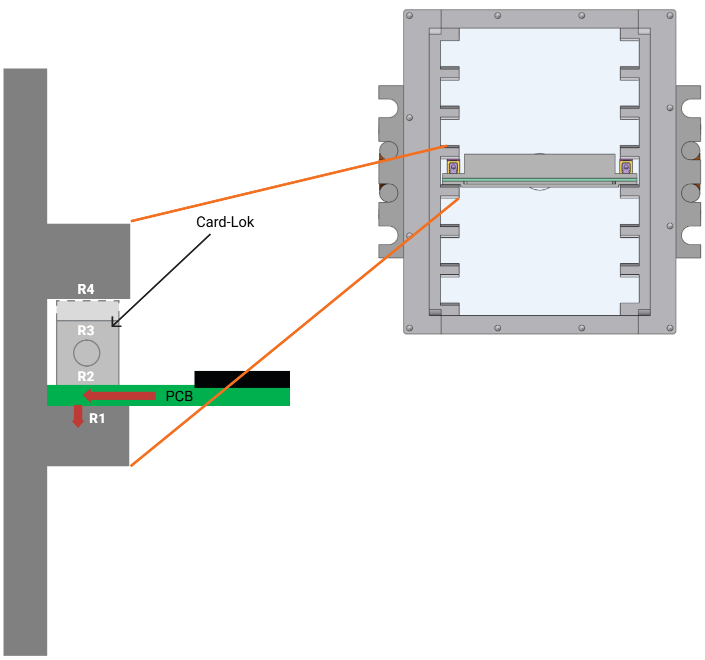
Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

2. COMMON CONDUCTION COOLED MODULE CONFIGURATIONS

To better understand the impact of Card-Loks on thermal performance of VITA modules, it's first helpful to understand the differences between the common setups and the likely resulting thermal paths. This in turn will inform the design decisions that will make the most impact in improving thermal performance of the module.

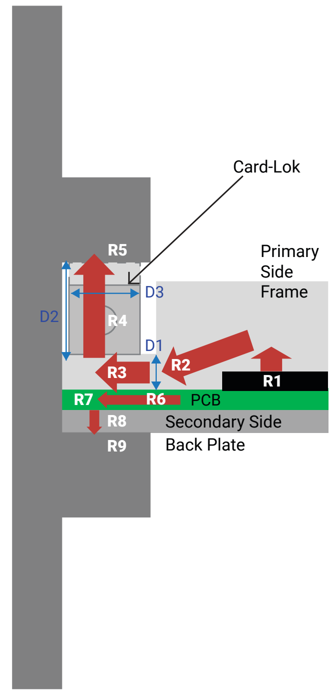
Module configuration and thermal path:
PCB with Card-Lok and no frame

In the following cross-section diagrams, the dark grey represents the chassis. R3 represents the Card-Lok, the PCB is noted in green and the black rectangle represents the hot component on the PCB on the primary side of the PCB.



In this setup, we can assume that R1 and R2 are comparable. Most of the heat goes directly from the PCB to the chassis, and the overall thermal resistance of the Card-Lok (R2+R3+R4) has a low impact. Given this, to achieve the best thermal performance R1 needs to be minimized. The Card-Lok must provide a high and uniform clamp force resulting in the best contact between the PCB and chassis. In this case, the higher the clamp force of the Card-Lok, the better the thermal contact.

Module configuration and thermal path:
Typical VITA 46 module configuration with Card-Lok on primary side of frame



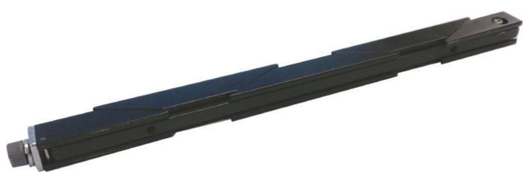
In this VITA 46 example, both a frame and secondary side back plate must be accounted for in the thermal analysis. The hot component is located on the primary side of the frame and the Card-Lok is also mounted on the primary side of the frame.

Most of the heat is assumed to go through the frame and the Card-Lok (vs the PCB and the secondary side back plate). In this case, the resistance of the Card-Lok itself greatly impacts the overall thermal performance of the module. Card-Lok resistance is discussed in Section 4 of this paper.

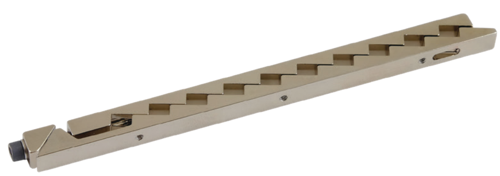
Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

Considerations to improve thermal performance of this setup include:

- High clamp force or high high thermal / low resistance Card-Loks to reduce R3, R4, R5, R7, and R9. Suggested series include nVent SCHROFF's Calmark 260HC High Clamp Force or 260HTS High Thermal Sawtooth series.



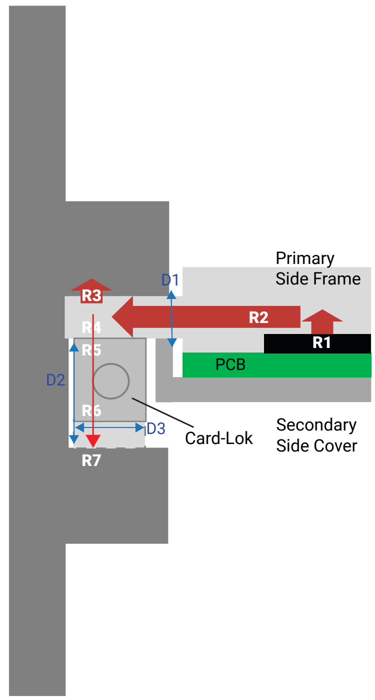
260HC High Clamp Card-Lok, improves clamp force up to 3X over similarly sized Card-Loks. Drop-in replacement for similarly sized Card-Loks to avoid major re-designs.



260HTS High Thermal Sawtooth series, low resistance Card-Lok that improves thermal performance up to 15% over similarly sized Card-Loks. Serves as drop-in replacement for similarly sized Card-Loks.

- Increase D1 to flow more heat through the frame (would require a smaller Card-Lok height, D2, to keep same chassis gap width)
- Increase the retainer width, D3, to increase the heat transfer area
- Eliminate R4 by integrating the retainer with the frame. This concept is explored in more detail in Section 3 of this paper.

Module configuration and thermal path: Typical VITA 48.2 module configuration with Card-Lok on secondary cover of the frame



In this VITA 48.2 module configuration, the hot component is located on the primary side of the frame while the Card-Lok is mounted to the secondary side cover.

In this configuration most of the heat will flow directly from the primary side frame to the chassis (R1 + R2 + R3). This is the most thermally efficient setup as it reduces the number of thermal interfaces and removes the retainer from the main thermal path. Also, removing the secondary side flange reduces a thermal interface and increases D1 which enables more heat transfer. In this case, the thermal resistance of the Card-Lok itself is not critical. Clamp force of the Card-Lok is more important as it helps to improve contact for the R3 heat path.

Module Configuration Conclusions

Selecting the best Card-Lok for high thermal performance does not automatically mean picking a low thermal resistance Card-Lok. Depending on the module configuration, the best design choice might be a high clamp force Card-Lok. Understanding the module configuration used in an application is key to selecting the best Card-Lok.

The following sections of the paper explore the testing apparatus and resulting data confirming the above recommendations for the most common VITA module configurations and the associated thermal performance results with a variety of Card-Loks.

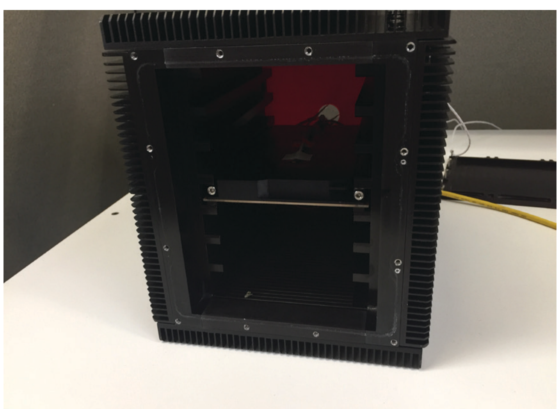
Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

3. TESTING THE CARD-LOK IMPACT ON OVERALL MODULE PERFORMANCE

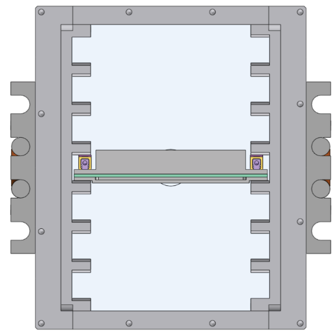
Chassis Level Thermal Test Fixture and Setup

There are a number of thermal performance variables at play in the different conduction cooled VITA module configurations, including the thermal resistance of the Card-Lok, the interface resistance between the frame and the Card-Lok, the interface resistance between the PCB and the Card-Lok, the interface resistance between the Card-Lok and the chassis, and the impact of the clamp force and its uniformity on the thermal resistance between the frame and the chassis. Given the complexity of evaluating each thermal performance variable, and given their various impacts on each module configuration, it was decided to evaluate the end result of the stabilized board temperature with a given power input. This test fixture allowed the evaluation of multiple module configurations and an understanding of the true impact of a Card-Lok design on the application.

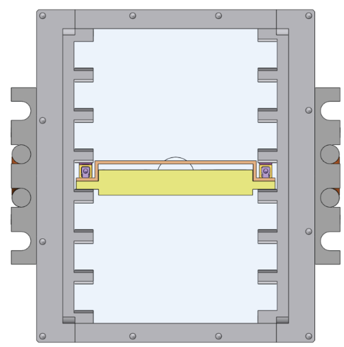
The fixture was comprised of a rugged liquid-cooled conduction cooled chassis where different VITA module configurations could be installed. The liquid-cooled chiller was set to 20°C for the test. The chassis was also insulated to reduce environmental impacts on the tests.



Three VITA 48.2 module configurations varying the primary and secondary side mounting of the Card-Lok were tested and results are presented in the following section.



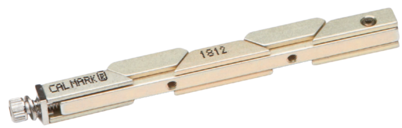
260 Card-Lok mounted to the primary side of the module frame installed in the test fixture



260 Card-Lok mounted to the secondary side of the module frame installed in the test fixture

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

The module configurations tested included three of nVent SCHROFF’s Calmark Card-Lok designs:



260 series
Historically one of the most-used Card-Lok sizes and profiles used in the aerospace and defense industry

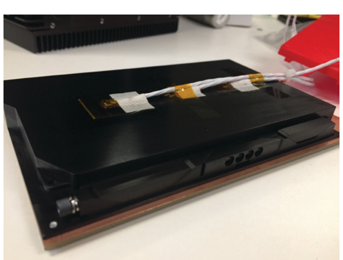
260HTS High Thermal Sawtooth series, low resistance Card-Lok

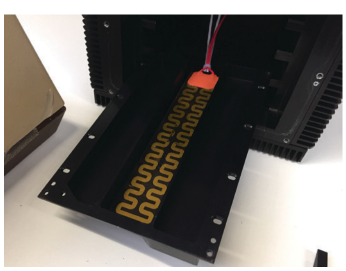
New high thermal design that features a sawtooth designed profile along the length of the Card-Lok that provides a continuous and uniform surface along the PCB/heat frame and along the cold wall for superior cooling performance. The 260HTS is the same size and profile as the 260 and is a drop-in replacement.

260HTS High Thermal Sawtooth series integrated into the module frame.

New design concept where the Card-Lok is machined into the frame itself to eliminate a thermal interface. For best thermal performance, the 260HTS design is integrated into the frame.

The module itself included temperature measurements along the module as shown below. The power applied to the frame was 50W MAX. Card-Loks were torqued to the recommended 6 in-lbs.





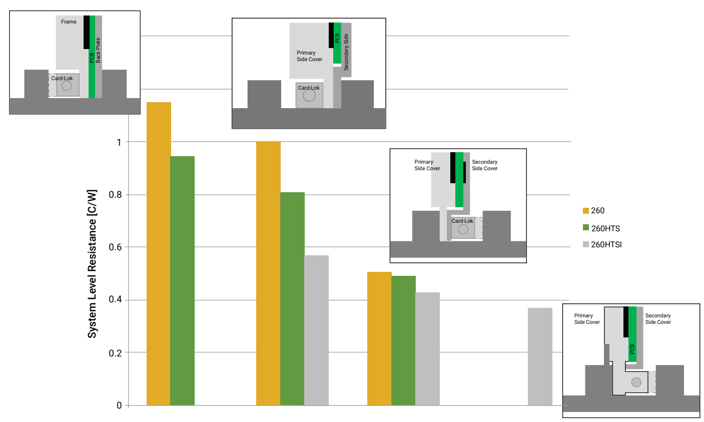
Testing Results

The following are the results for the conditions and fixture outlined in the previous section.

Note, this setup provided comparative data between module configurations and does not provide the resistance of the Card-Lok itself, that topic is covered later in Section 4 of this paper. System level resistance is depicted on the Y-axis. The X-axis shows different VITA module configurations where "PS" represents the

Card-Lok mounted to the primary side of the frame and "SS" represents the Card-Lok mounted to the secondary side of the frame.

The 260 series is represented by the yellow bar, the 260HTS high thermal sawtooth series is depicted by the green bar, and finally, the design with the 260HTS integrated into the frame of the module is represented by the gray bar.



In the VITA 46 and VITA 48.2 primary side setups, it was shown that the lower resistance Card-Lok, the 260 HTS, provided significantly improved thermal performance. As noted in Section 2 of this paper, more heat flows directly through the Card-Lok in these module configurations, so by using a lower resistance / high thermal performance Card-Lok, a greater impact on the overall thermal performance of the module is attained. When the 260HTS is machined into the frame, eliminating a thermal interface, thermal performance is improved further.

Whereas in the VITA 48.2 secondary side setup, where less heat flows through the Card-Lok, it was noted that using a low resistance/high thermal Card-Lok does not have a large impact on the overall thermal performance. A higher clamp-force Card-Lok could be a better design decision.

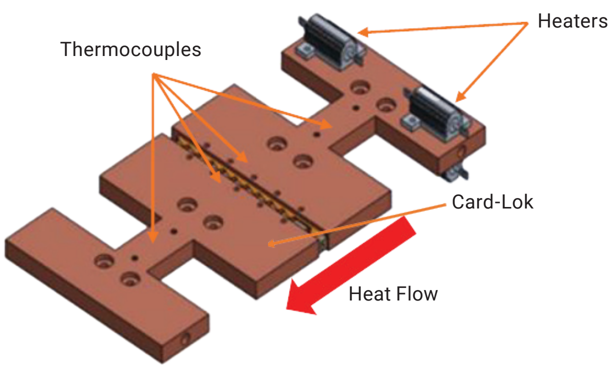
The last test result shown on the far right of the graph is a variation of the 48.2 secondary side mounting where the rear cover is not placed between the Card-Lok and the chassis primary frame which also eliminates an interface in addition to the interface eliminated by the 260HTS being machined into the frame. This also allows the size of the flange on the frame to be increased to conduct more heat for the best thermal performance of the modules tested.

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

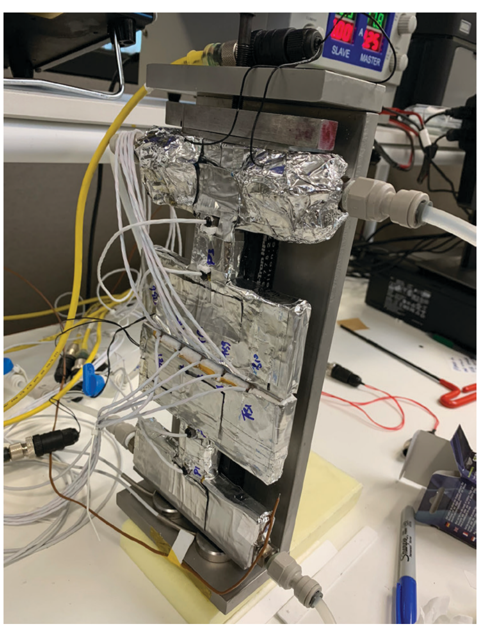
4. CARD-LOK RESISTANCE TEST FIXTURE AND METHOD

This fixture was developed to measure resistance of the Card-Lok itself. The resistance value can then be leveraged in detailed thermal models of modules and overall system performance.

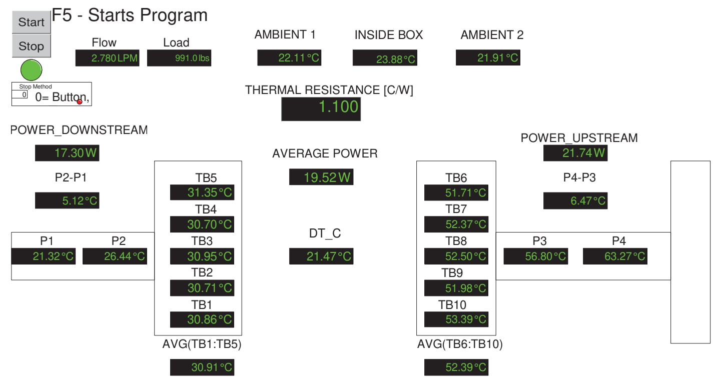
Heaters are located on one side of the fixture which moves heat in one direction across the Card-Lok through aluminum blocks. Thermocouples are placed on each side of the Card-Lok measuring the heat flowing through the Card-Lok which enables the resistance of the Card-Lok to ultimately be calculated. Clamp force can be simultaneously measured in this fixture.



To minimize environmental impacts the fixture is insulated. A chiller is used to cool one end of the fixture to remove residual heat from the system. Below the setup used for testing is depicted, below is the insulated fixture with chillers and not pictured is the test program on the desktop computer that reads the inputs and temperatures throughout the fixture.



Below is a screenshot from the testing program where the heaters are located on right hand side, thus heat flows right to left. Temperature readings are shown by "P1-4" in the aluminum blocks and "TB1-10" directly before and after the Card-Lok. The chillers were maintained at 15°C and 30-40 Watts of constant power were applied to the heaters in the fixture.



Temperature readings P1-4 are used to calculate the heat flow through sample under test. Ideally the heat flow would have been exactly the power input through the heaters, but due to heat losses across the system, the heat flow is calculated using Fourier's law of thermal heat conduction using the thermal conductivity, cross-sectional area and temperature difference of the resistance thermal devices (RTD). The thermal resistance is then calculated using the average temperature difference between TB1-5 and TB6-10 divided by the calculated average heat through the sample under test.

To calculate thermal resistance,

$$R\_th = \frac{\text{Average Temperature Difference}}{\text{Average Heat Flow}}$$

Average Temperature Difference =

$$\frac{TB6+TB7+TB8+TB9+TB10}{5} - \frac{TB1+TB2+TB3+TB4+TB5}{5}$$

$$\text{Average Heat Flow } P_{average} = \frac{\text{Heat Flow}_{upstream} + \text{Heat Flow\_downstream}}{2}$$

Heat flow is calculated using Fourier's Law of Thermal Conduction :

$$q=-k\nabla T$$

q = Power input
k = material conductivity
∇T = temperature gradient (dT/dx) or the change in temperature over the distance between thermocouples. In this fixture heat flow is calculated as such:

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

$$\text{Heat Flow}_{upstream} = K_{upstream} A_{upstream} \frac{P4 - P3}{X_{P3P4}}$$

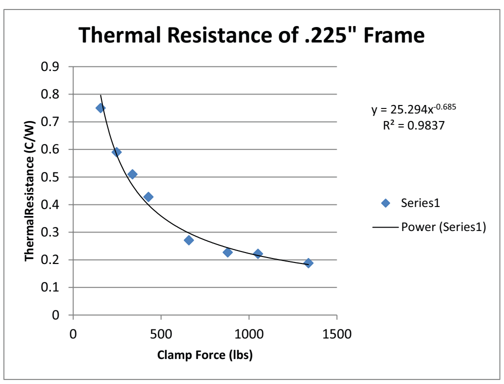
$$\text{Heat Flow}_{downstream} = K_{downtream} A_{downstream} \frac{P2 - P2}{X_{P1P2}}$$

Where X is the distance between the RTDs P1, P2 , P3 and P4. To find the thermal contact resistance of a conduction cooled frame and the cold plate, a bare 6061-T6 aluminum test sample of surface finish of 32µin Ra is tested on the fixture without the Card-Loks.

Using Fourier's law of heat conduction, as shown above, the contact resistance of one side of the cold wall and the frame can be determined as follows:

$$R_{contact} = \frac{R_{measured} - R_{Frame}}{2}$$

The clamp force is varied and the thermal resistance recorded at steady state as shown in the plot below.



This R_contact value can be used for calculating the contact resistance based on the Card-Lok clamp force exerted. In the case of a junction where there is frame and Card-Lok between the cold wall, the junction resistance can be estimated by using the Card-Lok resistance and the contact resistance as such:

$$R_{Junction} \approx \frac{R_{cardlok} R_{Contact}}{R_{cardlok} + R_{Contact}}$$

The frame thermal resistance is ignored since it much smaller than the thermal resistance of the cardlok and the contact resistance. In order to validate the accuracy of the above test method, a high performance thermal grease Gelid GC-Extreme was used between the thermal bars at a load of about 40 lbs and the thermal resistance of the frame was measured at .016 C/W. Afterwards, a sample coupon of .240" Thick x 5"x .405" Aluminum 6061 having a typical thermal conductivity of 170 W/m-K was used along with the Gelid GC-Extreme between the thermal bars and the sample coupon.

The measured resistance of the aluminum coupon was then compared with the calculated thermal resistance using the thermal conductivity of Aluminum and twice the resistance of the thermal grease that was measured. The difference between measured and calculated values was 4%, which is quite good at such low resistance values.

Card-Lok Resistance Results for Thermal Models

Below are examples of the Card-Lok resistance testing completed. The Card-Lok resistance value can then be used in system thermal models.

Sample Part Number	Clamp force (lbs)	Thermal Resistance [C/W]
A260-4.80	380	3.89
A260HTS-4.80	731	1.92
260HTS Integrated in Frame*	731	1.64

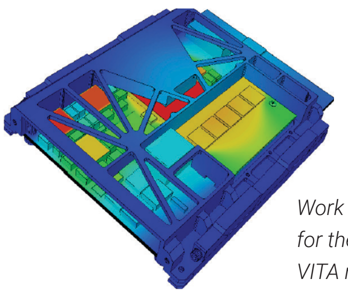
*Calculated based on 260HTS and aluminum block interface resistances

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

5. CONCLUSION AND ADDITIONAL TECHNICAL SUPPORT AVAILABLE

The thermal methods described in this paper provide enhanced thermal information for design engineers, ultimately enabling more data driven design decisions when it comes to Card-Lok selection. Card-Lok resistance and clamp force have a varying impact on the overall system thermal performance depending on the VITA module configuration used. Accurate resistance values for Card-Loks to be used in system level thermal models are available.

nVent SCHROFF's experienced engineering team can support consulting on Card-Lok selection or completing thermal testing for application specific Card-Lok and module configurations. The engineering team can also design thermally efficient modules based on board layout. All products are manufactured in an AS9100 compliant facility, from prototypes to production.



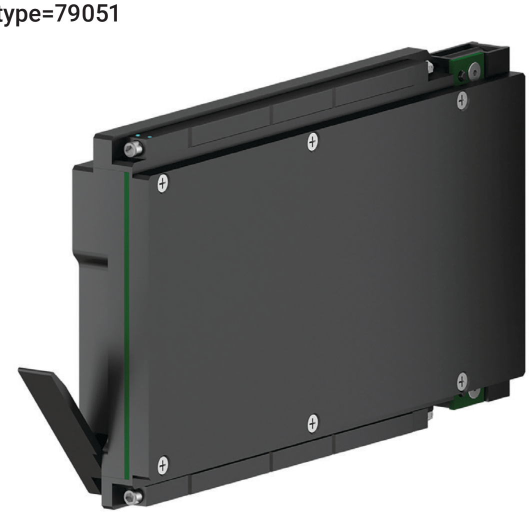
Work with experienced engineering team for thermally efficient conduction cooled VITA module designs

Standards compliant CAD models are available for VITA 48.2, 46, 30.1, and IEEE 1101.2 to save design engineers time on the front-end of the design cycle.

Engineers can download the templates, make necessary modifications in their CAD environment based on board layout or cooling needs and return the updated CAD file to the nVent SCHROFF team to quote and manufacture.

The templates include 3U and 6U configurations as well as standard or high performance versions and are available at on nVent SCHROFF's website under the resources tab:

https://schroff.nvent.com/en-us/resources/resource-library/new#type=79051



nVent SCHROFF continues to offer a broad Card-Lok and extractor offering including high performance designs for the most rugged environments. In addition to the Card-Lok thermal testing expertise outlined in this paper, nVent SCHROFF's engineering team can leverage in-house testing fixtures to provide R&D support for unique application requirements such as a specific extraction forces.

Applications served by this offering range from VITA conduction-cooled modules, MIL systems with second level maintenance requirements to sheet metal aviation applications.

MIL extractors for VITA applications

Tolerance compensating for second level maintenance

Broad extractor offering to meet application requirements

Impact of Card-Lok Selection on VITA Conduction Cooled Module Thermal Performance

In addition to design support and thermal analysis, nVent SCHROFF VITA conduction cooled module kits include the Card-Loks, extractors, frame/covers, thermal pads, assembly hardware, EMC gaskets, part marking and special packaging requirements such as ESD all based on application requirements. Components included in the kit are managed by a single part number, simplifying the supply chain.

1 Hardware

- Meeting the latest VITA standards
- High performance options
- 2nd level maintenance ready designs

2 Extractors

- Broad selection of extractors to application requirements

3 Card & Wedge LOKs

- Standard COTS or modified to meet application needs
- High performance, industry leading designs from nVent SCHROFF's Calmark and Birtcher lines
  - Best in class thermal designs
  - Increased resistance to shock and vibration

4 Conduction Cooled Assembly

- Milled clamshell or assembly
- Follows VITA standards
- Downloadable CAD files available
- Assembly and kitting

5 Other Components

- EMC Gaskets
- Thermal pads
- ESD Packaging

Please visit us at Schroff.com or Contact Us to review your next design's requirements with an expert.

Schroff.com: https://schroff.nvent.com/en-us/

Contact Us: https://schroff.nvent.com/en-us/solutions/schroff/applications/contact-us

Aerospace and Defense Applications: https://schroff.nvent.com/en-us/solutions/schroff/applications/aerospace-and-defense-overview

6. AUTHORS CREDIT

- Sebastien Buzit, Manager of Engineering and Customer Projects
- Gawtam Jhoty, Senior Mechanical Engineer
- Katie Hausman, Global Product Manager
- Danielle Henne, Global Marketing Specialist

nVent SCHROFF, Inc.,
7328 Trade Street, San Diego,
CA 92121 USA
+1 800-525-4682

Our powerful portfolio of brands:

CADDY ERICO HOFFMAN RAYCHEM SCHROFF TRACER

nVent

nVent.com/SCHROFF

SCHROFF-WPCS-H86793-IntegratedCCAWP-EN-2105