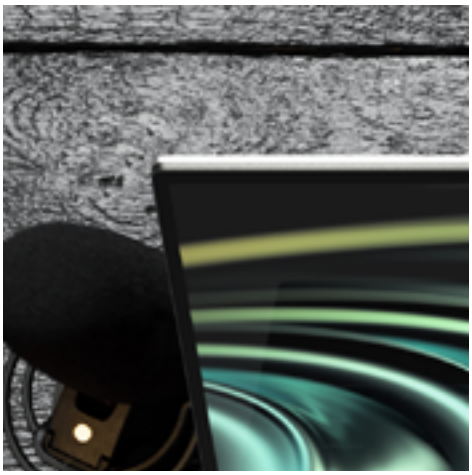
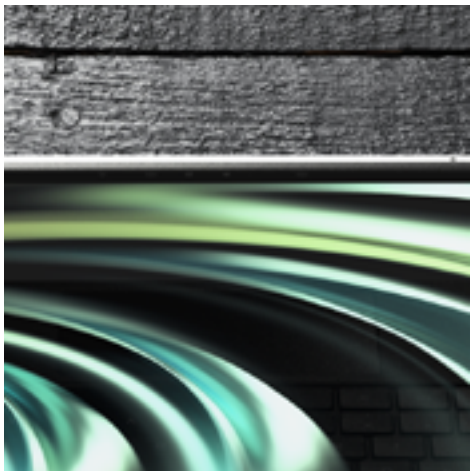
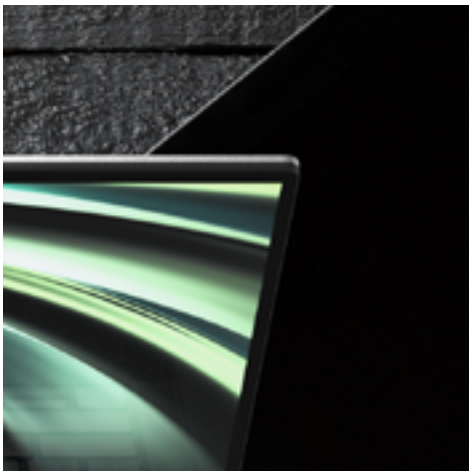
DELL Technologies

Rethinking the Evolution of the PC industry

Setting the new standard of memory performance



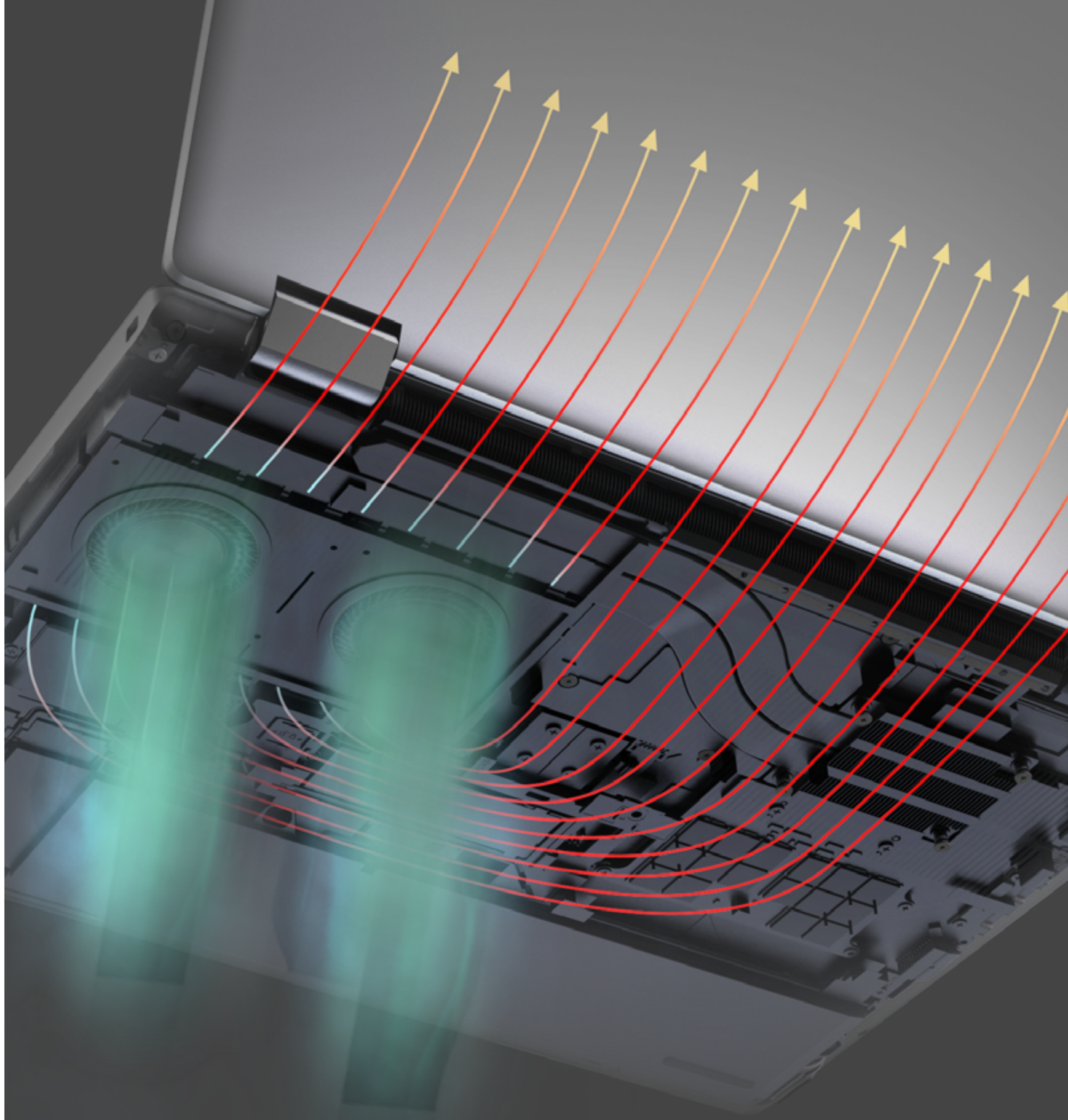


Introduction

The computer industry is one of continual innovation and development, pushing the boundaries of possibility with constantly evolving products. As user needs and demands constantly change and increase, the industry must ensure products meet not just current demands, but also future requirements - resulting in faster, higher performing PCs and hardware.

The foundation that this culture of innovation is built on is standards. Widely accepted and utilized standards are necessary to ensure a level playing field throughout any industry, and serve as the building blocks that future innovations can be built on. Standardization of technology is necessary to ensure products not only meet user needs consistently and reliably, but also ensures a level of guaranteed functionality and stability for industry innovators to improve upon.

In turn, these advances can offer industry-wide improvements and user benefits that then set the new industry standard, becoming the recognized baseline of efficiency and effectiveness that the next generation of innovation is built on.



CAMM – Developed to meet present and future industry challenges

Compression Attached Memory Module (CAMM), the latest innovation in Double Data Rate (DDR) memory from Dell Technologies, has been developed to meet the increasing demands on computer memory from users across a range of high-intensity roles and workloads.

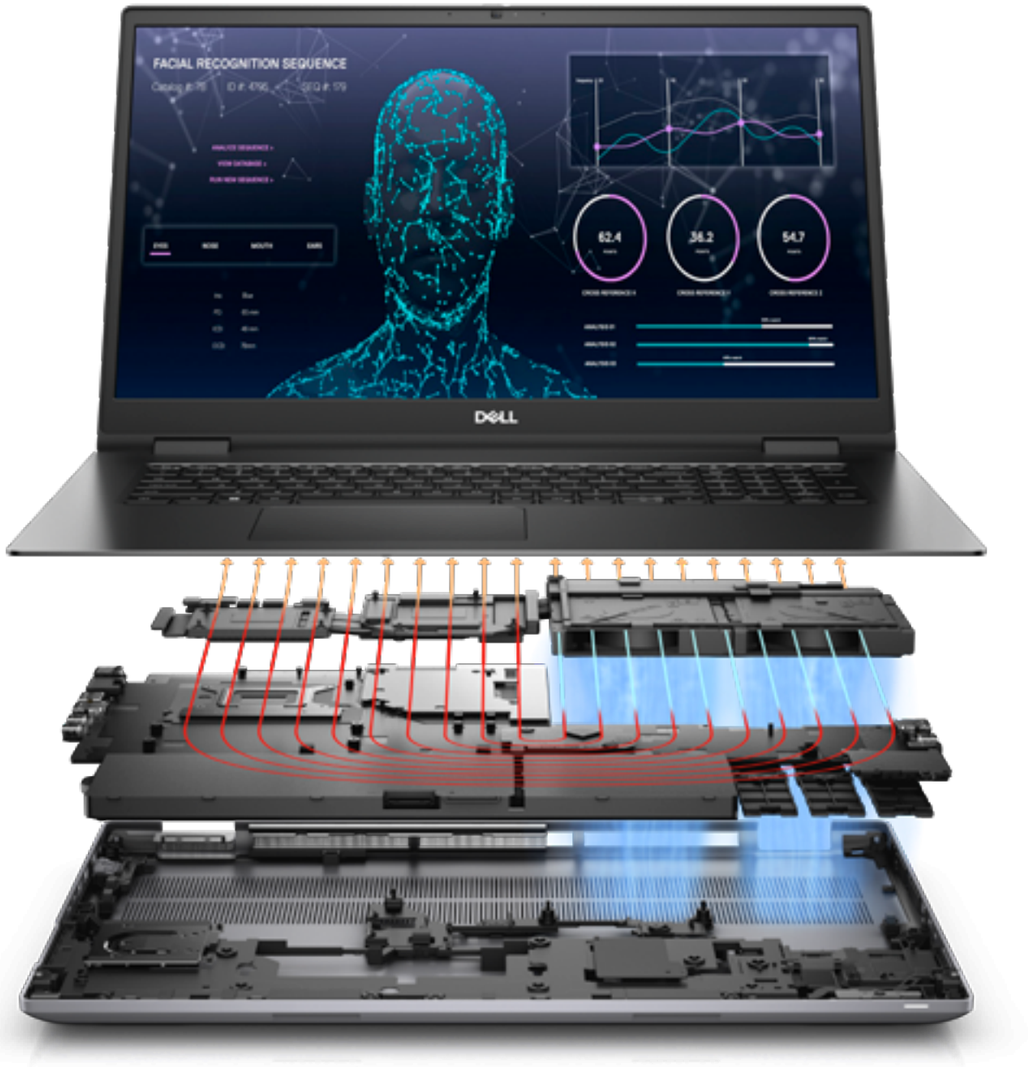
Within the high-compute, memory intensive workstation environment, users are demanding faster interactions between processor and memory, graphics cards and other components. For tasks such as high level rendering and similarly intensive workloads, large scale data transfers require a considerable amount of compute and memory resource to ensure consistently fast throughput.

Job roles across a wide range of verticals are demanding more from their compute and memory infrastructure. From media and entertainment roles including animation and video editing, to Computer Aided Design (CAD) and 3D design, scientific research and data analysis, AI and Machine Learning, VR and AR development, medical imaging, oil and gas exploration and across the financial sector, there are a growing number of applications requiring faster data processing speeds and increased reliability to perform at the highest levels. These job profiles are also in need of hardware solutions that match shifts to working patterns that see them operating outside of traditional office environments, such as reduced form factors without compromising on performance. Expectations are beginning to grow around the need for 'next generation' of DDR memory - especially as the currently accepted industry standard has been established for some time.

Small Outline Dual In-Line Memory Module (SODIMM) technology was pioneered with the development of DDR in 1996 before being finalized by the Joint Electron Device Engineering Council (JEDEC) in 2001, and has been meeting the needs of users and the industry ever since, becoming the recognized standard for memory form factors in PC client products. However, while technologies are optimized and refined throughout their lifecycles to meet changing user needs, exceeding their original capabilities, eventually those technologies will hit a performance ceiling.

With SODIMM, that ceiling is fast approaching, perhaps arriving within the next year, and has come in the form of bus speeds. It has become apparent that, even with advancements made to the original SODIMM technology, it may not be possible to improve SODIMM bus speeds past the practical limit of 6400 megatransfers per second (MT/s). While this will initially be felt by those using workstations to handle intensive workflows, eventually the impact of this limitation will be felt across the wider PC industry.

Clearly the industry has a need for the next generation of DDR memory, but one that retains the widely respected SODIMM tenets of modularity and simplicity while improving on signal integrity, the key to faster bus speeds. CAMM has been developed specifically to address this need for increased performance, while maintaining the industry wide expectations around SODIMM.



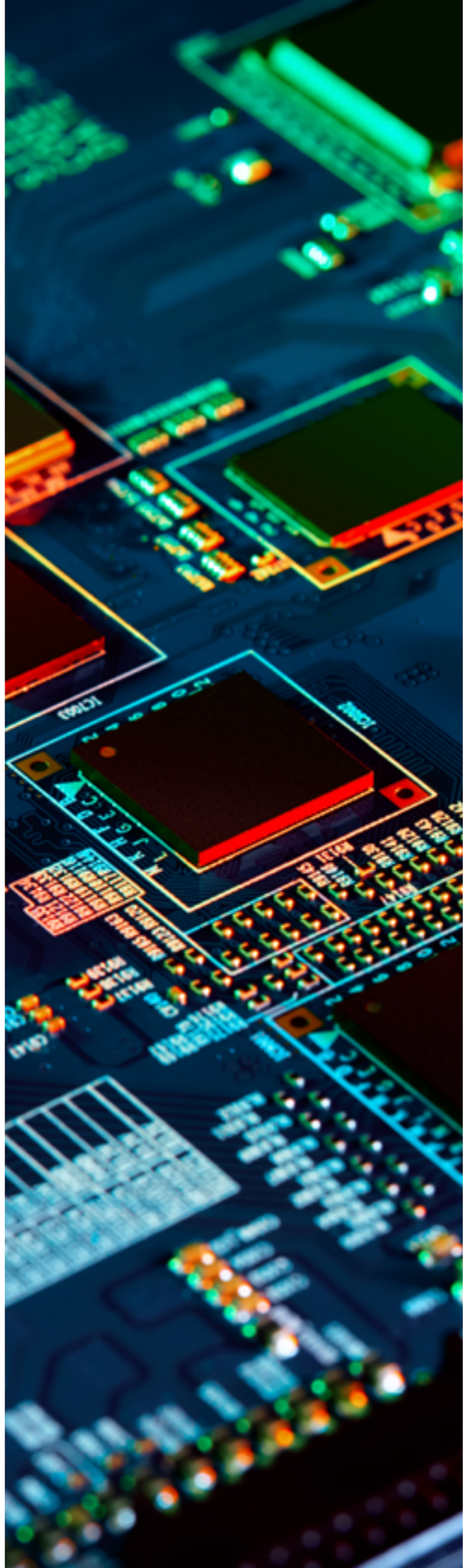
Progressive, not proprietary

Every major technology shift will naturally include a period where the new solution exists as proprietary technology while the concept is being proved. However, one of the key tenets of the PC industry is open development and common standards that place users clearly at the center of new technology development.

Part of the core Dell Technologies ethos in solution development is that all products are engineered to adhere to open standards and to give users freedom of choice, and that innovation should drive the entire industry forward rather than exist as a locked, proprietary technology. This has been integral in the development of CAMM, and while its aim is to become the next industry standard for DDR memory, this will not solely benefit Dell Technologies, but will provide users with benefits in data processing speed, reduced form factor, simplified system architecture and increased thermal efficiency, and will establish a new industry-wide baseline for the next generation of innovators to work from.

The initial steps in the development of CAMM begin in 2019. The proposal was to benchmark the development of a new memory module connector and form factor, eventually leading to the development of CAMM. By comparing and analyzing the new concept against existing SODIMM PC standards for modular DDR, examining the benefits across a wide spectrum of PC systems and design parameters, including SODIMM system scaling and form factor.

CAMM has been invented and developed by Dell Technologies independently, with guidance and support from partners including Intel (CPU and memory) and Amphenol (connectors). Developing and manufacturing a computer system is an inherently collaborative undertaking, with systems built using components sourced from a variety of manufacturers and suppliers. Once the industry standard completes in around one year's time, a user with a CAMM equipped laptop will be able to purchase RAM modules from any third-party supplier, and be able to install these themselves, giving users free choice of components and upgrades. At present, CAMM is a project that is being spearheaded by Dell Technologies and its partners.



Building a computer system is an inherently collaborative effort, and this is something Dell Technologies respects and actively engages in. Components within a system are cross-licensed for use by numerous different manufacturers, and although these components are under patent (as CAMM is by Dell Technologies), these components cannot be truly proprietary as they must integrate and cooperate seamlessly, for the benefit of users and manufacturers. Recognizing the necessity and value of this is why Dell Technologies is engaging with the required frameworks to establish the new standard of memory.

https://en.wikipedia.org/wiki/DDR_SDRAM#:~:text=The%20development%20of%20DDR%20began,in%20June%202000%20(JESD79)

Establishing the new DDR memory standard

As part of the Dell Technologies commitment to non-proprietary, standardized technology that benefits the wider ecosystem, work with the JEDEC has begun on standardizing CAMM technology.

From June 2022, a dedicated task group has been assembled to review CAMM and progress its standardization under JEDECs Reasonable and Non-Discretionary (RAND) terms. These terms ensure that technologies reviewed must not be anti-competitive, must be reasonably priced and be non-discriminatory against any other companies.

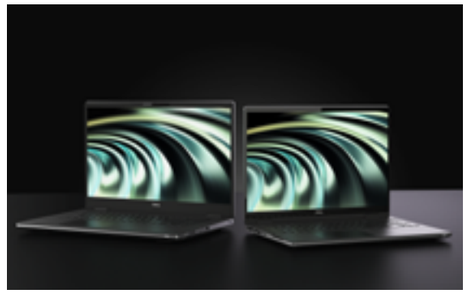
As part of this ongoing process, which will progress over a six to eighteen month period, Dell Technologies will work with JEDEC and a task group of 45 members from 22 other companies during the discussion and standardization process, reviewing CAMM's design and benefits and working in parallel to develop systems so that, once standards are ratified, CAMM is ready to be integrated across the industry.

Continued Consumer Choice

A key consideration when introducing new technology must always be maintaining consumer choice. There are many reasons why users would want to adopt or adapt to new technologies at their own pace, and it is vital that customers have freedom of choice during this period. This paradigm has been witnessed countless times, with an example being the transition from spinning hard drives to SSDs.

Enabling backwards compatibility for customers has been a consideration throughout the development of CAMM, allowing customers to migrate at their own pace. This commitment extends to designing CAMM equipped workstation products that allow users to choose between CAMM and SODIMM options. Selected early generation CAMM enabled systems will use an interposer to connect SODIMM to the system, so users can select SODIMM as their preferred memory option, connecting to the same mount as the CAMM module. This gives users freedom of choice during the initial transition period as the wider industry adapts to the shift in standards.

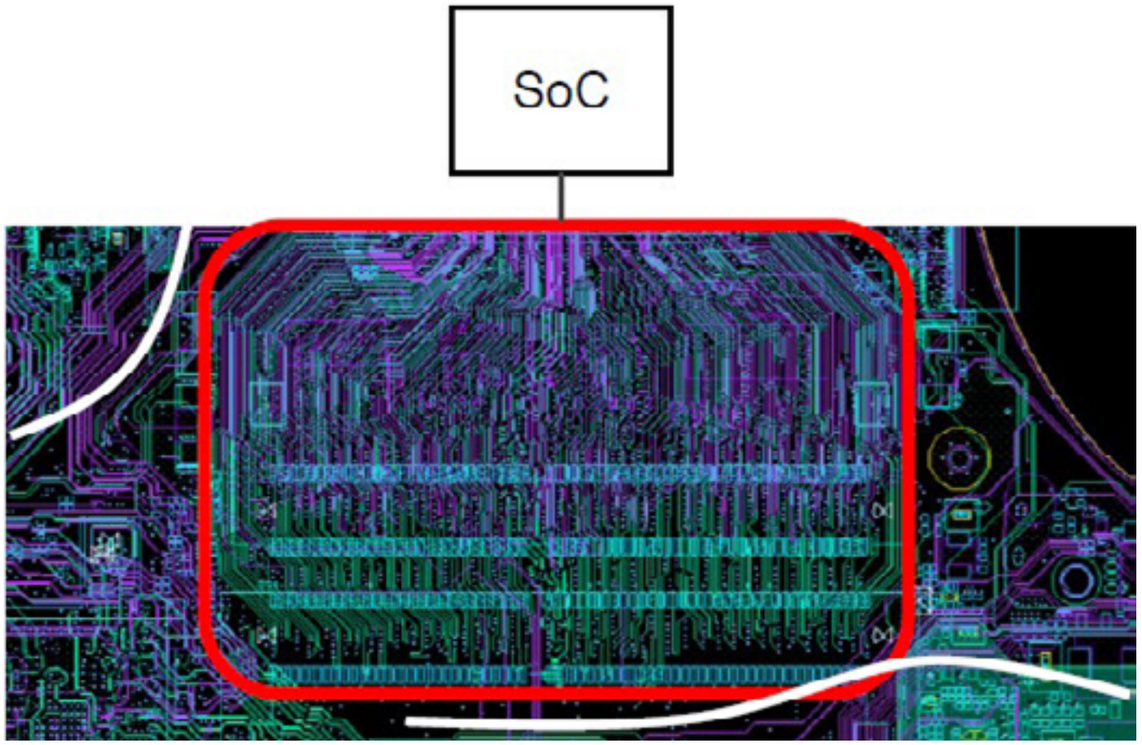
This commitment to choice is also integral to the design of our CAMM enabled workstation range, which has been developed to give users access to modular, highly configurable systems with architecture that makes maintenance or upgrades easier to perform. With these considerations and improvements, users can choose system configurations and make modular upgrades to optimize their systems to meet their specific requirements, and to increase the longevity of their preferred products.

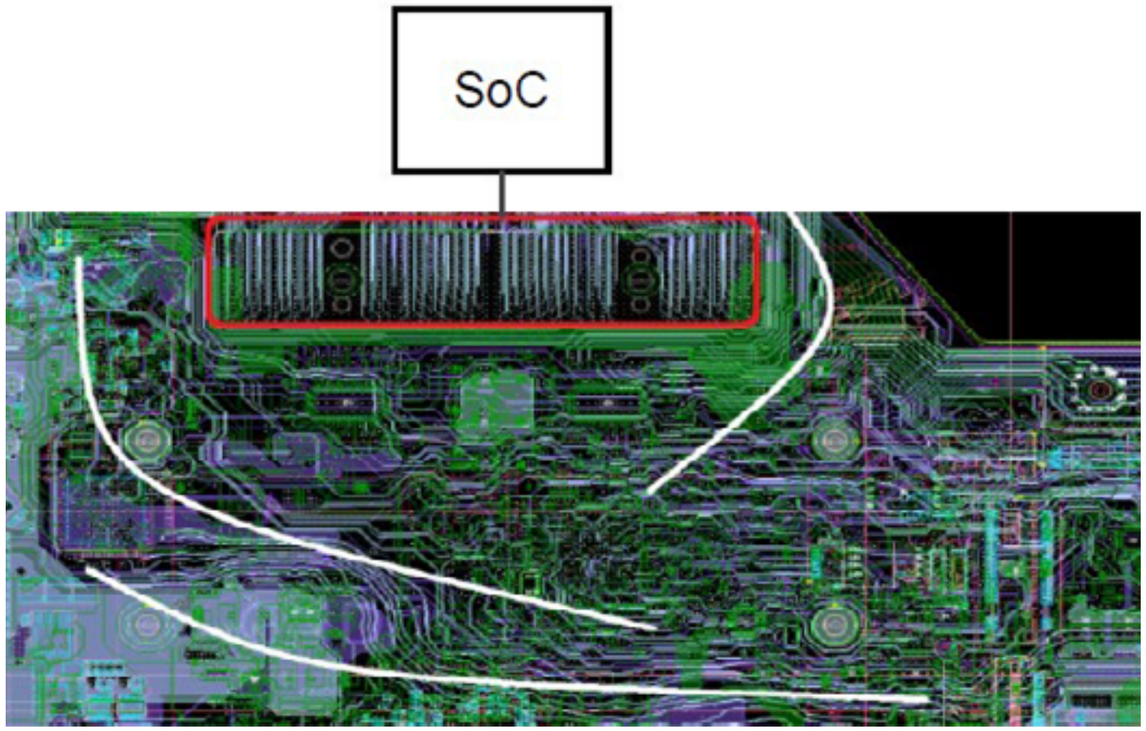


Solving 25 years of system level challenges

Although designed to supersede SODIMM primarily to address bus speed limitations and drive memory-intensive computing forward, CAMM has also been developed to address other system challenges presented by SODIMM form factors that have been felt across the industry for a quarter of a century. By innovating solutions to challenges including DDR routing, system form factor, reliability and thermal performance, CAMM has delivered system-wide benefits for users and established a firm baseline for the industry to develop further innovations from.

With a traditional SODIMM based system architecture, a considerable amount of space on the PCB board is occupied by routing traces, as illustrated in the above image by the area outlined in red. The large routing footprint occupied creates a twofold challenge. Firstly, it means that other elements of the system must be routed to connect around the SODIMM footprint (illustrated above by the white lines), which can result in reduced performance as signals will inevitably take longer to travel through longer connections. It also reduces the space available to include other system features.

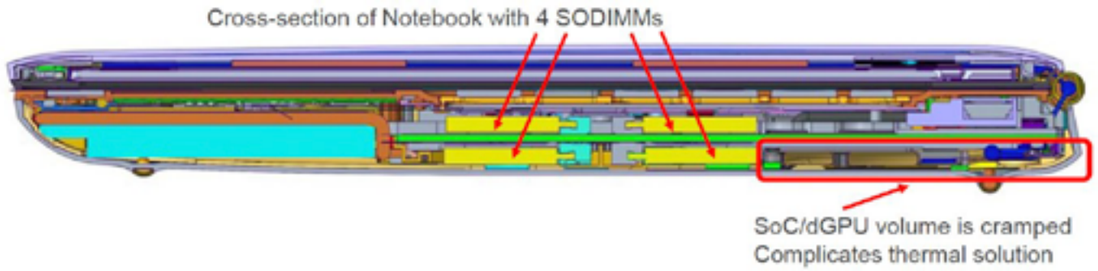


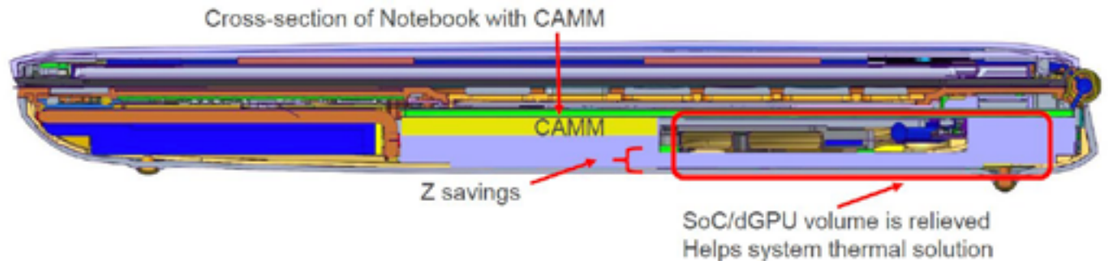


Solving 25 years of system level challenges - cont

CAMM has addressed this issue by implementing a smaller overall form factor and an inherently modular design. Reducing the number of connectors and their overall footprint considerably, as illustrated by the area outlined in red above, CAMM modules are able to fit closely to the SoC and remove areas of congestion. By reducing the length of signal pathways, as demonstrated by the white lines in the image, CAMM organically improves performance and frees up space across the motherboard. This will naturally allow more components to be added into the newly freed space, such as the inclusion of another SSD, giving users and manufacturers a greater range of potential options. This advancement will be felt from the very first iterations of CAMM enabled systems, and has laid the groundwork for future developers to capitalize on these space savings and performance increases.

By reducing overall memory footprint and introducing smaller modules, CAMM allows manufacturers to make considerable Z axis space savings, resulting in thinner laptop and workstation form factors. When compared to a 4-SODIMM system, the smaller space occupied by CAMM allows other components to relocate within the architecture to permit further form factor reductions. By allowing the memory modules to move, this has also solved a secondary issue with SODIMM memory form factors.





This internal space saving in CAMM enabled systems also allows for external form factor reduction. Workstation customer demand has long been focused on higher performance in smaller form factors. Reductions in Z axis size were previously made challenging by systems that included a 4x SODIMM module set up, where modules were placed both on top of and underneath the motherboard.

By occupying considerable space across a PCB, SODIMM comes into contact with the CPU/GPU area. This area can frequently generate temperatures that, without a sufficient cooling solution in place, interfere with the operations of the memory module, as DRAM components are particularly sensitive to thermals and operate within a strict limit of thermal tolerance. CAMM, in allowing memory modules to be moved away from the CPU/GPU, boosts performance by ensuring the DRAM does not suffer from performance issues and system throttling due to overheating.

Solving 25 years of system level challenges - cont

CAMM is also addressing longstanding issues with reliability and system performance over lifespan. Due to the position of components and connectors, SODIMM memory modules provided an inadequate environmental seal. This has resulted in recurrent issues where environmental contaminants, including particle infiltration and oxidation, have disrupted connections and led to ongoing memory failure. These contaminants cause weak interconnect between SODIMM connectors and card contacts, which is solved by unseating SODIMMs and reseating them again. CAMM has solved this common and recurrent issue by ensuring contacts are not exposed to air, and are contained in a chamber within the connector housing. Once the PCB is located on the top and bottom of the chamber, it is sealed, greatly minimizing environmental and contaminant impact on the contacts.

Indeed, this challenge has become so expected across the industry that the first step many engineers will take when looking to resolve memory issues will be to disassemble a system, from the top and the bottom of the housing, in order to remove debris that is obstructing connections. With SODIMM enabled systems like workstations, notebooks and laptops, this can prove challenging, as a lot of infrastructure, such as a majority of the keyboard, must be removed in order to troubleshoot memory issues, resulting in a lengthy and complex repair process, which is also necessary to fully diagnose and troubleshoot memory unseating. Opening a system in this way also risks other components being damaged during the repair or replacement process.

CAMM has counteracted these issues in two ways. Firstly, the way that CAMM connects to the PCB ensures a more comprehensive environmental seal, helping to reduce the amount of particulate infiltration or pin oxidation that might lead to memory failure, reducing the need for troubleshooting and repair work over the lifespan of the product. Secondly, the reduced footprint CAMM occupies within the internal system architecture allows it to be placed in locations that are more accessible to engineers and users, without the need for extensive removal of other infrastructure to access the memory modules. This means servicing, repairing and upgrading CAMM enabled systems is less time consuming and challenging than with SODIMM based systems.

CAMM's modularity and overall space saving, as well as it presenting easier access to users looking to conduct repairs, replacements or upgrades to their system, also presents advantages when it comes to what is rapidly becoming a key consideration across the technology space – sustainability. As we reflect on our environmental impact and seek to make products and solutions that prioritize sustainability, CAMM's advancements in ease of repair, replacement and upgradability, as well as its reductions in thermal load and environmental contaminant risk will allow users to rely on their systems for longer. Longer life cycles, and easier upgradability that will keep products in step with future advancements, is a key part of reducing environmental impact and ensuring that the future of computer system development is more sustainable.

Memory, innovated

CAMM is SODIMM reimagined, both in its design changes and in its continuation of the key SODIMM tenets of modularity and simplicity. The notion of placing a connector in the middle of a memory interface is, however, a radical one, and it has taken considerable development and testing to prove that disrupting the previously adhered to design constraints between CPU and memory is viable.

To where CAMM innovates on the SODIMM design, it is worth comparing them directly. Both work by extending the system memory interface from the host CPU to a connector. From a profile view, a four-SODIMM memory subsystem looks like the diagram below (Fig. 1), with two SODIMMs on the top side of the motherboard and two on the bottom. The blue line represents one memory channel, while the red line represents the second memory channel.

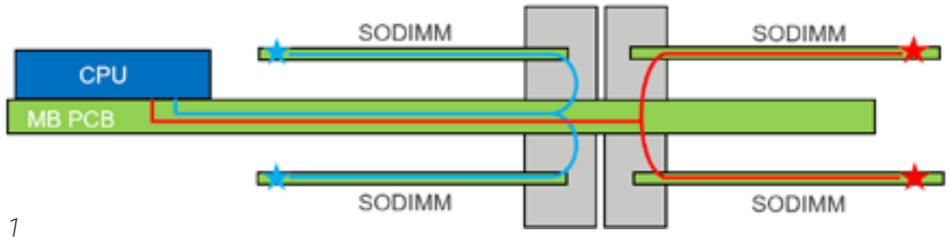


Fig. 1

SODIMM's symmetrical design means that the distance from CPU to DRAM is the same for each path across each of the four SODIMM modules. While this simplifies signal integrity tuning and assures memory access timings are similar across each SODIMM, it does mean that bus speed is limited by total channel length, trace stubs and connector style – leading to the bus speed ceiling previously discussed.

CAMM overcomes this by straightening the signal channel, routing left to right with no U-turns. Channel length is now determined by the size of the memory module needed to deliver a given memory capacity. The compression connector is placed between the motherboard and CAMM module, with compression contacts on both sides, and nothing is soldered to the motherboard, which helps increase repairability and reusability.

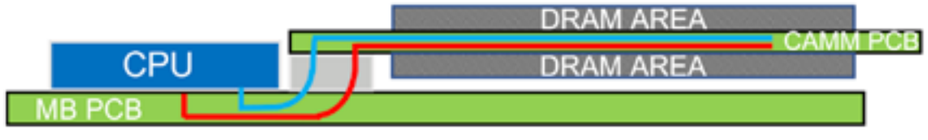


Fig. 2

With its intentionally modular design, CAMM is optimized to give users and manufacturers a wider range of options. Connectors can be varied in functionality and height as needed by a particular design, allowing motherboard designs to be simplified. As Fig. 2 illustrates, in this particular instance a connector height of 1.8mm does not allow enough clearance for motherboard components. A connector height of 2.8mm is required, and CAMM allows this to be implemented so that more components can be added to the board.

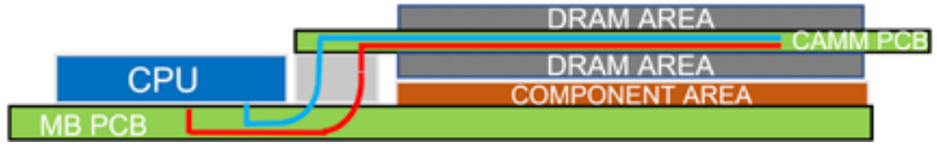


Fig. 3

Reclaimed motherboard area is a key advantaged of CAMM's implementation, and a scaled approach to memory module size is a further advantage. Scalability is a new approach for the memory industry, and allows system designs to allocate only the footprint needed based on maximum memory capacity. The total length of each CAMM module is determined by the number of DRAM chips required to meet the total memory capacity size.

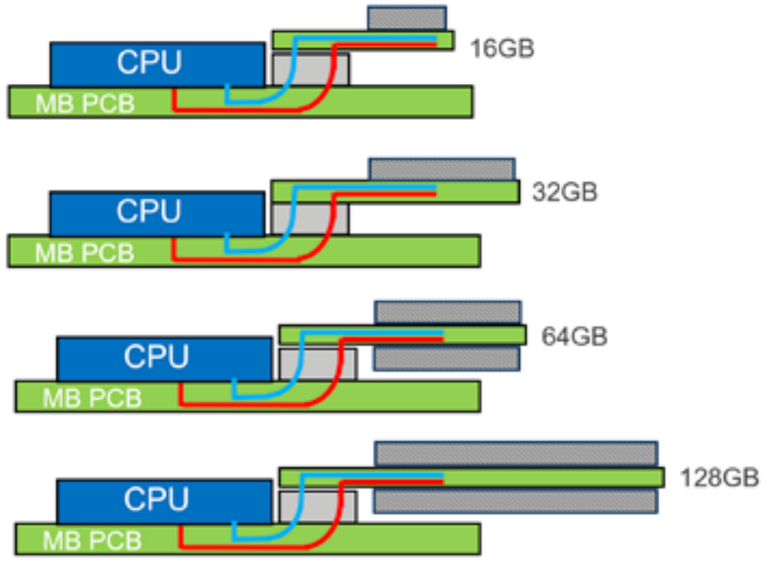


Fig. 4

Conclusion

The development of CAMM is both evolutionary and revolutionary for computer memory, intended as the next stage for modular memory and a revolutionary form factor to empower future innovation. While many elements of CAMM technology are mold-breaking and innovative, designed specifically to address longstanding industry challenges posed by SODIMM, the technology has nevertheless been developed under the same principles of modularity, simplicity, and a non-proprietary approach that maintains the clear need for standardization.

While designed to set the new industry standard, CAMM is also ready to evolve, both as a result of continual refinement by Dell Technologies and by being well placed to be expanded on by the wider industry. It will act not only as a springboard for future memory innovations, but also drive wider component design and redesign. By asking questions of the existing standards and approaches and then disrupting these standards through innovation, CAMM will encourage innovators to develop technologies that not only address legacy challenges, but also position the industry to anticipate future challenges and user requirements. But, as with the development process of CAMM, this evolution and innovation is only possible amid a spirit of knowledge sharing, community, collaboration and standardization.

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