# The Ideal Switch®: Glass-based Device With Demonstrated Reliability

Aric Shorey, Chris Keimel, John Mookken, Mark Walker
Menlo Microsystems, Inc.
49 Discovery, Suite 100
Irvine, CA 92618
Ph: (949) 771-0277
Email: aric.shorey@menlomicro.com

## Abstract

Menlo Microsystems Inc. (Menlo Micro) has introduced a MEMS switch that utilizes both a glass substrate and a glass cap with through glass via (TGV) technology to provide an all-glass packaging solution. The MEMS switch technology combined with an all-glass packaging solution, has resulted in the Ideal Switch®. It is the world's smallest, most reliable, and efficient micro-mechanical switch that can be used for numerous RF and power applications. The Ideal Switch® gains superior performance as well as mechanical, electrical and thermal reliability from several aspects of the MEMS and glass packaging design including robust electrical contacts, low electrical loss of glass, and hermetic TGVs which provide a well-controlled environment. This controlled environment is crucial for attaining reliable performance over billions of cycles. In addition to long lifetimes, parasitics are reduced by >75% vs. Si based RF devices enabling the devices to have a wide operational bandwidth from DC to > 50 GHz and high signal integrity.

To enable the volume manufacture of this device, Menlo Micro has driven advancements in the glass supply chain over the past several years, leveraging mostly standard semiconductor manufacturing processes, on glass substrates (with and without TGV). In addition to hermetic TGV, the device contains multi-layer plated and deposited structures, hermetic wafer level glass to glass bonding, post-bond die singulation and device packaging in multiple formats. These devices pass standard JEDEC reliability testing and have operational lifetime in excess of 3 billion cycles. In this presentation we will discuss a number of advanced packaging processes employed by Menlo Micro in the manufacturing process in a volume manufacturing environment as well as key performance metrics of the Ideal Switch®. We will also discuss some early failure modes seen from this glass-based device in both device and packaged form, and how Menlo Micro has established solutions and demonstrated reliable performance relative to JEDEC standards.

## Key words

Menlo Micro, Ideal Switch, MEMS, Glass

## I. Introduction

There has been a lot of progress in establishing glass-based microelectronics solutions over the past several years. [1-5] The advantages include high effiency, ability to provide thin and large format (panel-based) solutions by leveraging capabilities enabled by the Display industry, as well as ability to tailor material properties by adjusting the glass composition. Furthermore, there have been numerous demonstrators and prototype devices that have been fabricated showing the advantages provided by glass-based devices. However, there have been some hurdles to overcome in the transition of proof-of-concept devices into reliable volume manufacturing environments. Over the past few years, the supply chain gaps have started to close or have closed, making volume manufacture of glass-based devices a reality. This has facilitated the advancement of the ability to handle glass thus, allowing for process demonstration and product reliability to be tested. Menlo Micro has demonstrated the ability to process glass through assembly, test, final package and industry standard reliability testing. [6-7]

The combination of glass, an excellent electrical insulator, and metal, an excellent electrical conductor, in a MEMS device platform enables next generation DC to RF switching technology. This electrostatically actuated cantilever-based MEMS device represents an important advancement in MEMS switching technology, providing state-of-the-art contact/electrical reliability, robust package reliability and

stable RF performance across a range of temperatures. [7]

## II. The Ideal Switch® - Glass-based MEMS Device

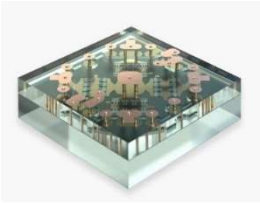
*A. Device Overview*

Menlo Micro has introduced a glass-based MEMS switch that utilizes through glass via technology to provide an all-glass packaging solution. These MEMS solutions combined with the utilization of glass packaging have enabled the creation of the highly reliable Ideal Switch®. It is the world's smallest, most reliable, and efficient micro-mechanical switch that can be used for numerous RF and power applications. [6-8]

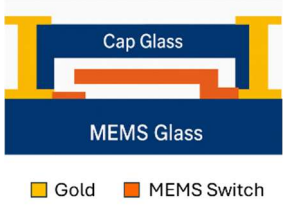
As described above, leveraging the insulating properties of glass along with the highly conductive metal beams provides performance characteristics not available in other relay switch technology. An example of the 2-layer glass-device is shown in Fig. 1. An image of one die is shown in Fig. 1a and the cross-section shown in Fig. 1b. The top glass layer contains TGVs that allow for electrical connection to actuate the beams, which are enclosed in a cavity between the two glass layers. The TGV and the metallic bonds between the glass layers provide a hermetically sealed structure that leads to stable performance and long lifetimes. Devices have tens to hundreds of switches in a small chip scale form factor that control electrical signal or power and provide reliable performance up to billions of cycles.

The TGV technology utilized in Menlo Micro's design provides further advantages in conjunction with the glass packaging solution. [6-8] Namely:

- >60% smaller package size relative to wire bond
- >75% reduction in parasitic
- Devices with a wide operational bandwidth - from DC to > 50 GHz.



1a.




1b.

**Fig. 1:** All glass 2-layer design of Menlo Micro's Ideal Switch®. A. Image of the device and B. schematic of the cross-section showing the MEMS beam and TGV arrangement.

The above considerations are very important for RF applications. The Ideal Switch® also has a great deal of advantages in applications for power distribution and control. The electrical isolation from the glass packaging continues to play an important role in these applications. Substantial additional benefits are provided by the metal-to-metal contacts relative to *semi*conductor-based switches for power distribution and control. While glass is known to be a poor thermal conductor, the fact that the current is carried through metal beams and metal contacts, means that the circuit does not generate as much heat as a semiconductor device, which leads to less heat generation even in high power applications. In semiconductor-based switches, there is heat generation due to the relatively lower conductivity of the semiconductor compared with the metal-beam conductors in the Ideal Switch case. This means that far less hardware is needed to cool the devices and results in much lower resistance, higher efficiency and much less need for cooling hardware relative to semiconductor-based switches.

The Ideal Switch properties discussed above provide numerous technical advantages in both RF and Power distribution applications. Below we highlight these in a number of applications.

## II. Applications

*A. High Performance GPU Testing*

The rapid advancement of artificial intelligence (AI) and machine learning (ML) is driving unprecedented demand for computing power, with GPUs (Graphics Processing Units) now serving as the backbone of modern high-performance computing. From accelerating large language models to powering scientific simulations and autonomous systems, GPUs deliver the extraordinary parallel processing performance today's workloads demand. In tandem with the rise of AI, high-speed interconnect technologies such as PCI Express (PCIe) are evolving at a rapid pace. Each new generation—Gen4, Gen5, Gen6 and now Gen7—has doubled bandwidth, dramatically increasing the complexity of both system design and production validation. As GPUs transition from PCIe Gen5 to Gen6 and beyond, the demand for robust, scalable, and cost-effective production test strategies has become more critical than ever. [9]

Testing high-performance GPUs presents a unique set of challenges, particularly as interface speeds, power demands, and system complexity increase. These challenges span electrical, thermal, and system-level domains:

- **Signal Integrity** – With data rates pushing to 64 gigaTransfers/second and higher, switches and controls must minimize impedance mismatch and crosstalk.
- **Power Input** – Test setups must be able to provide high current with minimal voltage droop, ripple or ground bounce and avoid excessive thermal buildup.

- **Test Speed and Throughput** – Test time must be minimized to reduce cost and must be optimized using parallel testing, reduced pattern depth, and built-in diagnostics to maintain throughput targets.
- **Thermal Stability**- GPUs generate significant heat even under test and traditional must provide stable performance under varying temperature
- **Scalability and Cost -** As AI adoption accelerates, GPU production volumes continue to rise. Scaling test capacity without escalating cost requires new approaches, such as loopback testing, test-on-board (ToB) strategies, and modular test architectures.
- **Versatility** - Test solutions must support a variety of SKUs, interfaces (PCIe, NVLink, HBM), and form factors (PCIe cards, SXM modules) while minimizing changeover complexity and downtime.

To meet these critical challenges, three distinct signal paths must be supported:

- At-speed loopback test in PCIe Gen6
- PCIe Gen5 based scan tests
- DC measurements, including drive strength and sensitivity

Menlo Micro has developed a Dual DP3T switch topology with integrated high speed loopback to enable these three test paths while maximizing coverage and minimizing complexity. By collapsing multiple test modes into a single signal path, advanced switches simplify test hardware design and directly reduce cost of test. Figure 2 illustrates how a single MM5620 device supports these test modes.

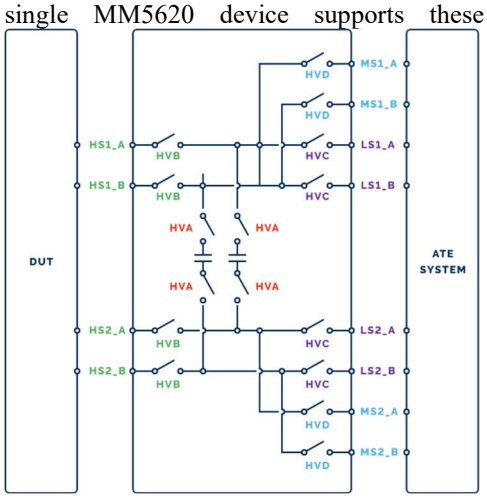



**Fig. 2**: (a) High-level automatic test equipment (ATE) configuration using a single MM5620 device.

The MM5620 loopback switch is based on the glass-based Ideal Switch®. At PCIe Gen6 speeds, where preserving signal integrity becomes critical, the MM5620 provides the low-loss, high-linearity performance necessary to ensure reliable loopback validation. In addition, its versatility allows a single device to support multiple GPU SKUs and platform interfaces, reducing the need for SKU-specific test hardware and accelerating time-to-market.

The versatility of this approach allows the same switch topology to support multiple GPU SKUs and platform interfaces, enabling OEMs and test providers to scale without re-engineering their hardware base. The result is a test strategy that not only accelerates development and production ramps but also lowers total cost of test while maintaining confidence in performance at the highest data rates.

An actual PCIe Gen 6 external loopback test passed on a production GPU load board with the switches with a 20% frequency margin (see Fig. 3). The maximum data rate is close to 80 Gbps (PAM4). The real time scope showed clean eye openings when equalization was applied. Electrical performance of Menlo Micro's MM5627 switch is robust, and it has been selected and successfully used to test multiple GPU load boards.

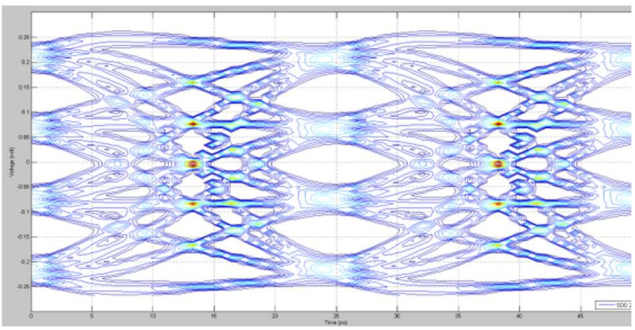


**Fig. 3**: Example of 80 Gbps, PAM4 eye-diagram performance on MM5627 loopback lane.

As AI continues to push the boundaries of computing performance, GPU test methodologies must evolve to stay ahead of escalating interface speeds, thermal loads, and packaging complexity. The industry is entering a new era of chiplet-based architectures, CXL interconnects, and co-packaged optics, all of which will demand new test paradigms that are both scalable and efficient.

While this section has focused on AI accelerators and high-speed GPU testing, the same RF performance characteristics that enable PCIe Gen6 and future Gen7 validation are also applicable to emerging quantum computing systems. Quantum processors require ultra-low-loss, highly linear, and exceptionally reliable switching for signal routing, multiplexing, and test and measurement, often in cryogenic environments where device stability is paramount. The Ideal Switch® technology has been incorporated into Menlo

Micro's cryogenic RF switch, leveraging its low insertion loss, hermetic glass packaging, and proven reliability to deliver stable broadband, highly linear RF performance at cryogenic temperatures. The switch's near-zero power dissipation minimizes thermal loading on dilution refrigerators, helping maintain stable operating temperatures while enabling longer test sequences and increasing experimental throughput for quantum computing research and development.

*B. MEMS for Power Control and Distribution*

The design of power-switching and protection devices has been defined by a trade-off between electromechanical relays (EMRs) and solid-state semiconductor switches, e.g., SiC MOSFETs and SiC JFETs. The requirements for power density, efficiency, and reliability, particularly in high-current and high-voltage (400V-1000V) applications, impose physical limitations on both technologies. This creates a performance gap in circuit-protection applications where the switch is in a normally-on state and conduction efficiency is the primary concern. [10]

From a switching theory perspective, the best switch would combine the benefits of all existing switching technologies while avoiding their drawbacks. Such a switch should have zero on-state resistance ($R_{DS(on)}$), resulting in perfectly efficient, lossless conduction when closed, and infinite off-state resistance, providing galvanic isolation with zero leakage current when open. This perfect switch has remained, so far, unachievable because its requirements place contradictory demands on materials science and physics. It forces a compromise between two imperfect solutions. Electromechanical relays approximate two of the ideal characteristics of metallic contacts: a very low-resistance conduction path and a physical air gap when open for electrical isolation. Solid-state switches, on the other hand, avoid mechanical wear and can support high switching-cycle counts, but the on-state resistance is relatively high and typically increases with temperature.

The Ideal Switch® provides a solution that is neither a scaled-down traditional relay nor a conventional solid-state transistor. It is a micro-electro-mechanical system (MEMS) that combines the physical principles of a mechanical switch with the manufacturing precision and scale of semiconductor fabrication. The architecture is built around an electrostatically actuated cantilever beam that creates a physical metal-to-metal contact.

The core element of the Ideal Switch architecture is the contact structure (see Fig. 1b). On a single die, hundreds or thousands of microscopic switch cells are fabricated in parallel. Each cell has a small, flexible metal cantilever beam suspended over a stationary contact. To actuate the switch, a DC voltage is applied to generate an electrostatic field that pulls the cantilever down, establishing a direct (metal to metal) connection. This actuation is power-efficient and requires very low holding to maintain the closed state.

As described above, the architecture also uses a glass substrate. Unlike silicon, which is conductive, glass is an electrical insulator. This provides superior isolation performance for high-frequency signals and possesses favorable thermal and mechanical properties. The use of glass and Through Glass Vias (TGVs), which provide vertical interconnects through the substrate and reduce device size. The proprietary metal alloy used for the MEMS beam improves both conductivity and contact reliability under repeated switching. Furthermore, the metal-to-metal contact gives a low on-resistance that does not change with temperature, which means heat generation is minimized.

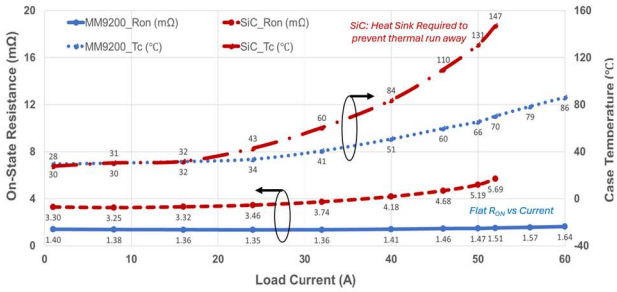



Fig. 4: Resistance/Temperature as a function of load for Ideal Switch (blue) and SiC-based switch. The ohmic metal contacts of the MEMS switch result in near constant resistance across its operating temperature range while the SiC switches increase in temperature and begin to exhibit thermal runaway.

A good demonstration of the above is highlighted in Fig. 4. The test summarized by this data in Fig. 4 is from two identically sized boards subjected to the same load. The first board, using JFETs, reached an operating temperature of >80°C at 40 A. The second board, using Menlo Micro's MEMS switches, operated at ~50°C with the same 40A. This difference under the same electrical load highlights the potential thermal impact of a lower, more stable $R_{DS(on)}$. Furthermore, the additional near 50 °C increase in temperature of the SiC-based device at 50A (10 additional amps) highlights the impact of temperature dependent resistance of a semiconductor-based device relative to a device based on metal-to-metal contact.

Leveraging advantages of the metal-to-metal contact and the excellent isolation properties in this glass-based Ideal Switch device will have significant impact on numerous power control applications. The primary application areas for this technology are resettable smart electronic fuses

(eFuses) and advanced circuit breakers (ACBs). These applications align with the core strength of high current-carrying capability, low conduction loss, and reliable actuation.

Menlo Micro has been working on programs to apply this technology for high-power distribution and control. One such program progressed through two hardware milestones. The first was a 500-V, 100-A board designed to prove that MEMS could switch at that power level. The second, was a 0.5 MW prototype: 1000V, 500A (Fig. 5) that demonstrated active load control and the ability to scale hundreds of MEMS switch elements in a single unit. These program milestones were met and demonstrated the ability to utilize glass-based MEMS in high-power control applications.



**Fig. 5**: 1000V, 500A (0.5MW) prototype advanced circuit breaker.

Menlo Micro continues work on the miniaturization into smaller form factor solutions. Applications are numerous across defense and commercial applications. One of the most important applications is for data centers. The move towards higher-voltage power architectures in AI data centers is creating a new requirement for compact and efficient protection devices. Menlo Micro positions its MEMS switch for this front-end protection role, where it can function as a surface-mountable eFuse or circuit breaker.

Menlo Micro is developing power modules based on its MEMS switch platform for circuit breakers and switchgear to enable the next generation of 800V AI data centers, providing high-performance power distribution, control, and protection across the entire data center infrastructure. There is a lack of a standard solution for this application. The Ideal Switch has performance characteristics to address this important industry need. These advantages will provide similar advantages for industrial automation and building management.

## III. Conclusion

Menlo Micro has demonstrated the ability to manufacture MEMS devices with all glass packaging utilizing the advances in through glass via technology and scalable volume manufacturing processes. The device has been shown to operate reliably over billions of cycles. The unique metallurgy and glass packaging gives the switch unique advantages in both RF and Power distribution and control applications. The metal-to-metal contact gives very low on-resistance and the glass packaging gives excellent electrical isolation. The TGV technology provides the ability to miniaturize the device.

Here, we highlight two applications that underscore the importance of this technology. The efficient, highly linear and reliable performance makes it crucial in the application of the test and measurement of AI chips. This is directly applicable to memory and other devices as well. Furthermore, given the low resistance and hermetic packaging, the technology is well suited for test and measurement applications of Quantum Computing devices at cryogenic temperatures, making this another important emerging application.

The second rapidly emerging application is for high-power distribution and control. The metal-to-metal contact used in the Ideal Switch MEMS devices has very low resistance in the ‘On’ state which significantly reduces operating temperature and reduces the need for expensive and bulky cooling hardware. This has positive implications for size reductions in e-fuse and advanced circuit breaker applications and will address the growing need for 800V solutions in data centers.

The advanced materials science employed in the Ideal Switch provided by both the metallurgy and glass packaging are proving to be extremely valuable in growing applications. The Ideal Switch demonstrates that MEMS technology can move beyond traditional sensing and RF applications to become a foundational building block for next-generation power distribution, control and protection infrastructure. By combining the efficiency of metal contacts, the isolation of glass packaging, and the scalability of semiconductor manufacturing, Menlo Micro is enabling a new era of compact, reliable, and intelligent power control for applications ranging from AI data centers to advanced industrial systems.

## References

[1] Shorey, AB, Kuramochi, S. and C. H. Yun, “Through Glass Via (TGV) Technology for RF Applications” International Symposium on Microelectronics; 2015; 2015. p. 386-9.

[2] M. Lueck, A. Huffman, A. Shorey, “Through Glass Via (TGV) and Aspects of Reliability”, Electronic Components and Technology Conference (ECTC), IEEE 65th (2015).

[3] J. Iannotti, D. Legare, T. Budka, D. Hummel, “ESA Architecture for Low SWaP-C Applications Enabled by Multilayer Glass Substrate Technology”, GOMAC Tech Conference, March 2020.

[4] S. Hwangbo, A.B. Shorey, Y.K. Yoon, “Millimeter-Wave Wireless Intra-/Inter- Chip Communications in 3D Integrated Circuits using Through Glass Via (TGV) disc-loaded Patch Antennas”, 66th

Electronics Components and Technology Conference (ECTC), pp. 2507-2512 (2016).

[5] Shorey, Nelson, Levy, Ballentine, “Thin Glass Handling Solutions for Microelectronic Packaging”, 53rd International Symposium on Microelectronics, IMAPS 2020.

[6] A. Shorey, J. Baloun, M. Walker, “The Ideal Switch® with Advanced Glass Packaging”, 57th International Symposium on Microelectronics, IMAPS 2024.

[7] A. Shorey, J. Brewer, C. Nassar, M. Strohmayer, “The Ideal Switch®: Glass-Based Device with Demonstrated Reliability”, 58th International Symposium on Microelectronics, IMAPS 2025.

[8] T. Moran, C. Keimel, T. Miller, “Advances in MEMS Switches for RF Test Applications”, EuMW 2016.

[9] Xu Zhu, Nicholas Yost and Stewart Yang, Menlo Micro “Edge Coupled DC to 60 GHz Differential SPDT RF MEMS Switch for High Speed Digital Applications,” IEEE/MTT-S International Microwave Symposium (IMS 2025), San Franscisco, CA, USA: https://www.researchgate.net/publication/394633368_Edge_Coupled_DC-60GHz_Differential_SPDT_MEMS_Switch_for_High-Speed_Digital_ Applications

[10] A. Shaukat, A. Jadhav, “The Normally-On Problem: MEMS Aim to Displace JFETS in Power Production”, Power Electronics News, April, 28, 2026.