Groundbreaking 5 kV ESD MEMS Switch Technology

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Introduction

Groundbreaking technology is needed to solve big problems. Electromechanical relays' origins date to the earliest days of the electric telegraph, with no replacement switching technology being available to meet all market needs—in particular, the need for smarter, more connected applications in test and measurement, communications, defense, healthcare, and consumer markets. As an example of growing market needs, test and measurement end users are demanding multistandard test solutions in the smallest form factor possible, with a need to maximize parallelism in testing while spanning 0 Hz/dc to 100s of GHz in frequency range. Electromechanical relays are increasingly limiting to system designers due to their narrow bandwidths, limited actuation lifetimes, limited number of channels, and large package sizes.

Microelectromechanical system (MEMS) switches can deliver the innovation needed to overtake relays and drive industry to the next level. With an internal state-of-the-art MEMS switch fabrication facility, Analog Devices is now delivering mass produced, high performance, fast, mechanically durable, low power, electrostatic discharge (ESD) protected, small form factor MEMS switches.

MEMS Switch Technology

Central to ADI MEMS switch technology is the concept of an electrostatically actuated, micromachined, gold cantilever beam switching element. The MEMS switch can be thought of as a micrometer scale mechanical relay with metal-to-metal contacts that are actuated via high dc voltage driven electrostatics. Figure 1 shows a close up graphic of a single MEMS switch cantilever. Clearly visible are the five contacts that are in parallel and the hinge structure with air gaps to the rear of the graphic. This switch design is used in the ADGM1304 SP4T MEMS switch and the enhanced ESD protected ADGM1004 SP4T switch.

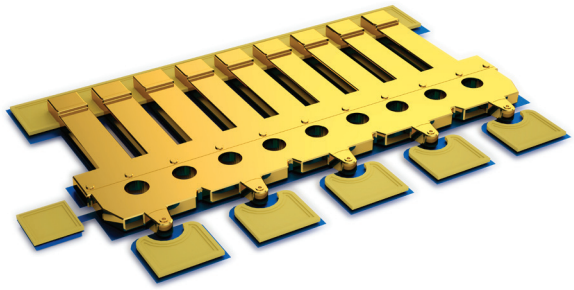

Figure 1. Close up graphic showing one MEMS cantilever switch beam.

A companion driver integrated circuit (IC) has been designed by ADI to generate the high dc voltage required to actuate the switch, which guarantees fast, reliable actuation and long cycle lifetimes, and makes the device easy to use. Figure 2 shows the MEMS die and driver IC in an ultrasmall, SMD QFN package. The copackaged driver is very low power—typically 10 mW, which is 10× lower than typical driver requirements for RF relays.

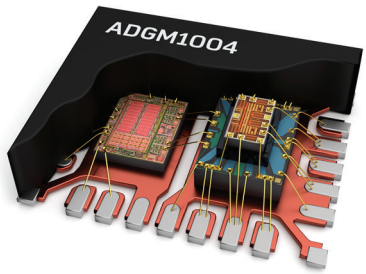

Figure 2. ADGM1004 enhanced ESD protected MEMS switch.

Integrating ESD Protection

Leveraging off the ADGM1304 MEMS switch product, ADI developed the ADGM1004 MEMS switch to enhance RF port ESD performance by integration of solid-state ESD protection technology. The RF port human body model (HBM) ESD rating for the ADGM1004 switch has increased to 5 kV. This level of ESD protection is a MEMS switch industry first.

The integrated, solid-state ESD protection is a proprietary ADI technology that enables very high ESD protection with minimal effect on the MEMS switch RF performance. Figure 3 shows the ESD protection element in the package. It shows a die mounted on the MEMS die and the wire bonds to the RF pins of the package. These are optimized for RF and ESD performance.

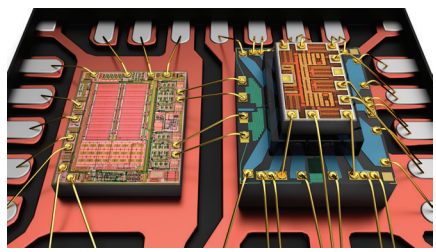

Figure 3. ADGM1004 drive IC (left), MEMS switch die (right), with RF port ESD protection die mounted on top with wire bonds to the metal lead frame.

To realize the ADGM1004 product, ADI has combined three proprietary lithographic technologies with assembly and a MEMS capping technology to enable this breakthrough in performance.

RF and 0 Hz/DC Performance

The strength of the MEMS switch is that it brings together 0 Hz/dc precision and wideband RF performance in a tiny, surface-mountable form factor. Figure 4 shows measured insertion loss and off isolation for the ADGM1004 single-pole, four-throw (SP4T) MEMS switch. Insertion loss is only 0.45 dB at 2.5 GHz, and – 3 dB bandwidth at up to 13 GHz. The RF power handling is rated to 32 dBm with no compression and the third-order intercept point (IP3) linearity is a constant 67 dBm typical over frequency with no degradation at very low frequencies.

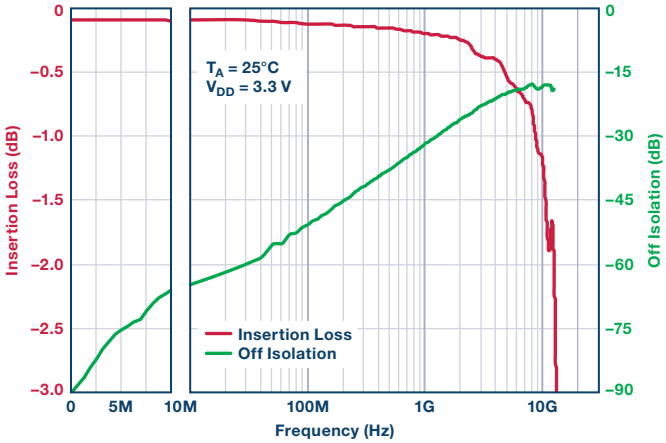

Figure 4. ADGM1004 MEMS switch RF performance. Linear scale < 10 MHz.

The ADGM1004 MEMS switch design delivers very high performance for 0 Hz/dc precision applications. Table 1 is a summary of these important specifications.

Table 1. ADGM1004 Precision Specifications I

ESD (HBM)	ESD (FICDM)	On Resistance	Off Leakage	0 Hz/DC V, I Ratings
5 kV RF ports 2.5 kV non-RF ports	1.25 kV All ports	1.8 Ω typical	0.5 nA max	±6 V, 220 mA

The HBM ESD rating in Table 1 of 5 kV HBM for the RF ports is a significant increase compared to the ADGM1304 part, which was rated at 100 V HBM. This improves ease of use in human handling, ESD sensitive applications.

Table 2. ADGM1004 Precision Specifications II

Switching Speed	Supply Voltage, Power	Package Size	Cycle Lifetime
30 µs	3.1 V to 3.3 V, 10 mW typical	5 mm × 4 mm × 1.45 mm	1 billion min

Having a small size solution is a critical requirement across all markets. Figure 5 shows a to-scale comparison of the packaged ADGM1004 SP4T MEMS switch design compared to a typical DPDT electromechanical relay with up to 95% volume savings being achieved.

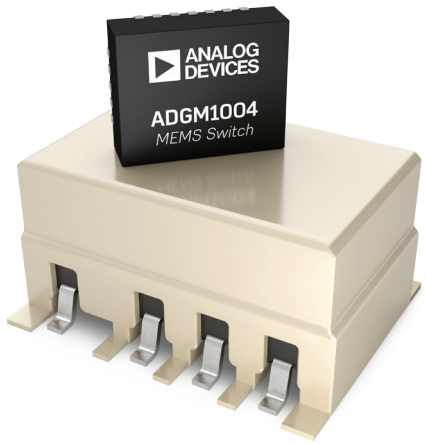

Figure 5. ADGM1004 MEMS switch (four switches) compared to a typical electromechanical RF relay (four switches).

Finally, to aid system designers, the ADGM1004 switch has been characterized for cycle lifetimes when toggling with RF power passing through the switch (hot switching). Figure 6 shows the lifetime probability when hot switching a 2 GHz, 10 dBm RF signal. The mean cycle number before failure (T50) point from this sample testing is in the order of 3.4 billion cycles. Higher power testing results are available in the ADGM1004 data sheet.

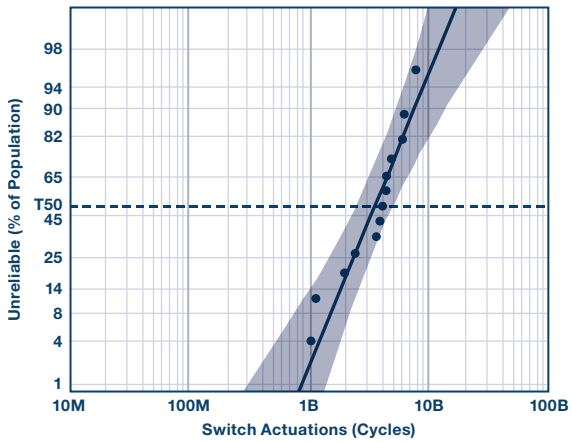

Figure 6. Log normal failure probability with 95% confidence interval (CI) indicated for hot switching a 10 dBm RF signal.

Conclusion

The groundbreaking, enhanced ESD protected ADGM1004 MEMS switch enables a large increase in ease of use while preserving excellent switch performance both in RF and 0 Hz/dc applications. ADI's MEMS switch technology brings best-in-class performance from 0 Hz/dc with switches that are up to 95% smaller, 10× more reliable, 30× faster, and that use 10× less power vs. RF relays. The new ADGM1004 MEMS switch is an exciting new addition to Analog Devices' overall switch offerings.

About the Authors

Eric Carty received his master's degree in experimental physics from the National University Maynooth, Ireland, in 1998. Before joining Analog Devices, he spent 10 years working as an RF passive component design engineer. Since 2009 he has been a senior applications engineer in Analog Devices focusing on RF switches and MEMS technology research and development. He currently manages the Switch and Multiplexor Applications Department at Analog Devices. He can be reached at *eric.carty@analog.com*.

Padraig McDaid received his bachelor's degree in electronic engineering from University of Limerick, Ireland, in 1998. Padraig manages the Switch and Multiplexer Marketing Department at Analog Devices, with a primary focus on MEMS technology research and development. Prior to joining Analog Devices in 2009, Padraig worked in various RF design, applications, and marketing roles within multinational companies and small-to-medium size businesses. He can be reached at *padraig.mcdaid@analog.com*.

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