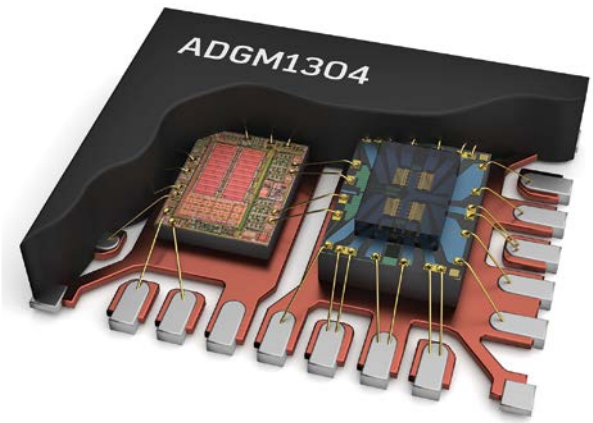
JACK BROWNE | Technical Contributor

Tiny MEMS Switches Route DC to 14 GHz

This pair of MEMS switches offers SP4T functionality in miniature components that feature companion low-voltage switch drivers for ease of installation and application.

Electromechanical switches and relays have been a part of RF/microwave circuits and systems design for some time. They can handle reasonable input power levels for their small sizes, but are typically slower and larger than solid-state switches.

Edging closer in speed to solid-state devices, a line of microelectromechanical-systems (MEMS) switches from Analog Devices (www.analog.com) targets RF/microwave signal switching in a fraction of the size and power consumption of electromechanical relays while promising considerably faster switching speeds and much greater reliability. The first two switches in the MEMS product line—single-pole, four-throw (SP4T) models ADGM1304 and ADGM1004—offer similar wideband performance from dc to 14 GHz, with the latter also incorporating electrostatic-discharge (ESD) protection.

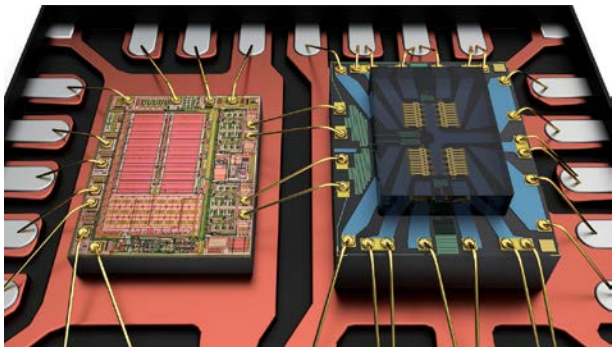


1. This cutaway view of the ADGM1304 SP4T MEMS switch shows the driver and switch circuitry side by side inside an LFCP measuring 5 × 4 × 0.95 mm.

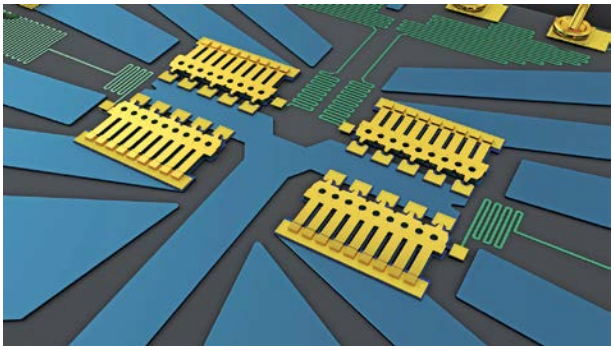
Analog Devices is no stranger to designing and fabricating MEMS devices, supplying MEMS accelerometers for airbags in motor vehicles since 1991.The two new RF/microwave switches, manufactured in the company's own MEMS foundry, come in compact packages with silicon caps that provide hermeticity *(Fig. 1)*. Each package includes an electrostatically activated MEMS switch die and a low-current, low-voltage driver IC *(Fig. 2)*. The integrated driver is TTL/CMOS compatible for parallel interfaces; having the driver within the same miniature package as the MEMS chip simplifies circuit design and saves space on printed circuit boards (PCBs).

The two switches meet MIL-STD-883 requirements. Thus, they are well-suited for automatic-test-equipment (ATE) applications with high circuit density and in portable circuits and test applications where power is limited power (such as from a rechargeable battery).

The MEMS switches are not capacitive, but rather dc-coupled for a wide range of broadband applications. They are designed for use with nominal supply voltages of +3.1 to



2. Each of the packaged MEMS switches also contains a low-voltage TTL/CMOS switch driver for ease of use.



3. This close-up of the MEMS switch illustrates how different switch states are achieved through spring force on the cantilever structure.

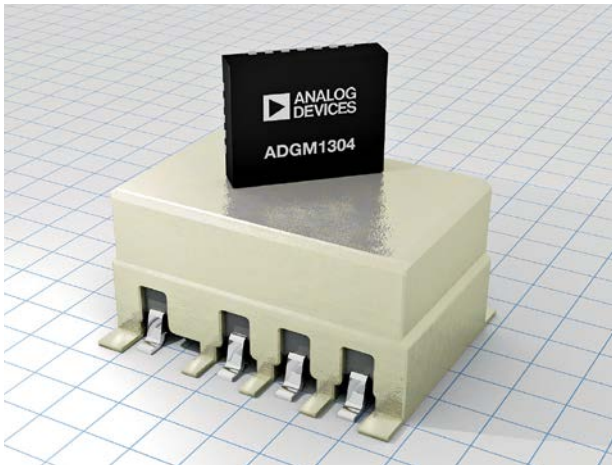
+3.3 V dc. The devices use spring force for actuation and de-actuation *(Fig. 3)*, with very little wear on the contacts after an almost inconceivable number of switching cycles. In fact, both switches are rated for operating lifetimes of billions of switching cycles. They are evaluated with the same reliability testing used by Analog Devices for its semiconductor devices to ensure consistency in lifetime testing. The two MEMS switches are capable of operating lifetimes 10× longer than electromechanical relays.

SWITCH SPECS

In terms of performance, the model ADGM1004 SP4T MEMS switch has a 2.5-kV ESD rating per the human-body model (HBM); the ADGM3004 doesn't include ESD protection. These miniature switches feature extremely low on-resistance of 1.8 Ω. Both are usable from dc to 14 GHz, with typical insertion loss of 0.45 dB at 2.5 GHz and 0.63 dB at 6.0 GHz. The return loss is at least 14 dB at typically 17 dB from dc to 6 GHz. Isolation is customarily 24 dB at 2.5 GHz and 19 dB at 6.0 GHz, from the control to an RF output port. Crosstalk is typically 30 dB measured at 2.4 GHz.

Although these are mechanical devices, they provide impressive switching speed, with 30 μs typical on switching time and 5 μs typical off switching time. The settling time for the rising edge of a switched signal is generally 40 μs and typically 8 μs for the falling edge. Both switches offer excellent linearity, with typical input third-order-intercept point (IIP3) of +69 dBm. The non-ESD-protected model ADGM1304, even with its compact size *(Fig. 4)*, is rated for maximum input power to +36 dBm. It is quite capable of maintaining high signal integrity throughout its frequency range, with second harmonics of typically –90 dBc and third harmonics of typically –85 dBc.

Model ADGM1004 and its ESD protection come in a 24-lead lead-frame chip-scale package (LFCP) measuring 5 × 4 ×1.45 mm, complete with TTL/CMOS driver. Model ADGM1304 is housed in a LFCP measuring 5 × 4 × 0.95 mm.



4. The ADGM1304 SP4T MEMS switch (top) occupies a fraction of the board space as a conventional drop-in high-frequency relay (bottom).

Both switches are frugal on power consumption, requiring only 1 μA current during sleep mode.

These two switches are the first in what promises to be an extensive line of miniature high-speed MEMS switches for commercial and industrial applications, as well as in ruggedized versions for the harsh environments encountered in defense and aerospace applications. With their performance levels and operating lifetimes, they should provide service to those applications without need of replacements.

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