

A Broadband High-Isolation Electronic Switch Covers 30 kHz to 22 GHz

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This design case history shows how FET MMIC switches can be used in a module that combines fast switching with wide bandwidth and high isolation

Switches are common components, used extensively in microwave systems to direct the signal flow between components [1]. For this project, our particular interest was in a

SPDT input device for a microwave instrument that required high isolation over a wide frequency range. This is just one of a variety of applications where fast switching is required in addition to appropriate RF performance, such as insertion loss, frequency response, distortion, and maximum signal level.

Relay-based electromechanical switches traditionally provide superior performance in the areas of broadband frequency coverage and low insertion loss, which is why they are widely utilized in test and measurement instruments. Nevertheless, their slow switching speed, short lifetime, and high cost often results in a preference for switches based on solid-state devices such as PIN diodes and FETs [2, 3]. PIN diodes behave as current-controlled resistors and are widely used as switches because they exhibit excellent insertion loss, switching speed, and power handling characteristics [4, 5]. However, their operating bandwidth is limited by the bias circuitry, which is usually constructed from lumped elements that are prone to parasitic effects.

In contrast, FET switches demonstrate very wide frequency coverage, starting from nearly DC through millimeter waves and are readily available as integrated MMIC devices [6]. Also, the gate drive circuitry is separate from the signal path and does not require special RF isolation. One of the disadvantages of

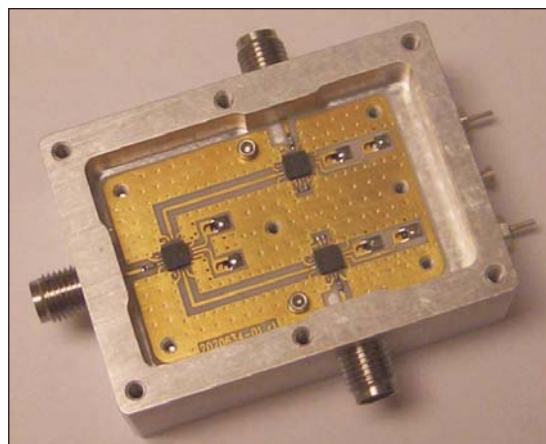


Figure 1 · Photo of the RF board.

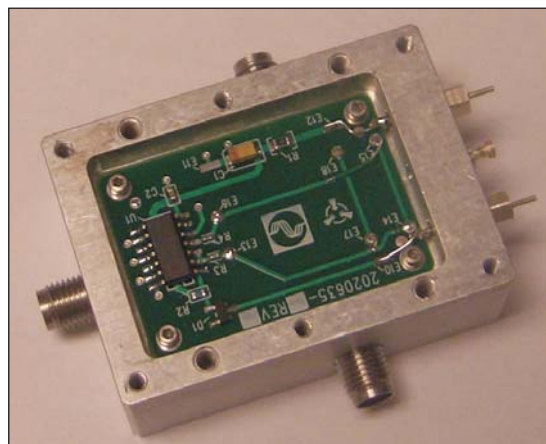


Figure 2 · Control board mounting on the opposite side of the module.

the FET switches, however, is that they exhibit relatively low isolation, which can be overcome by cascading individual devices, as shown in this paper.

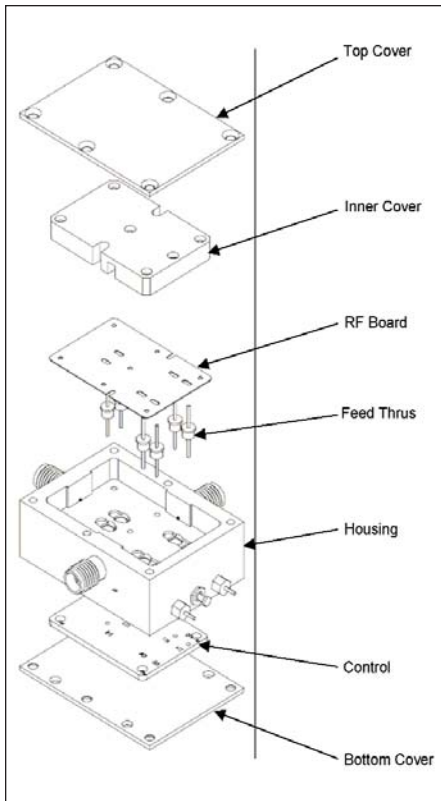


Figure 3 · Detail drawing showing switch construction.

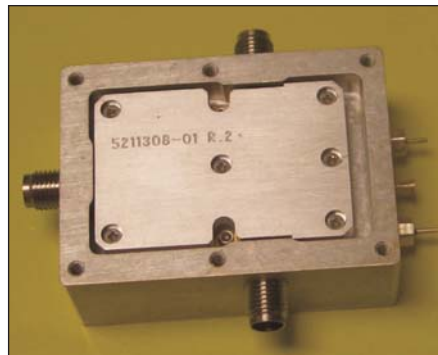


Figure 4 · Inner cover installation.

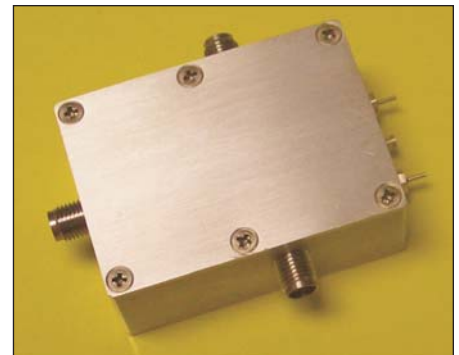


Figure 5 · Completed assembly.

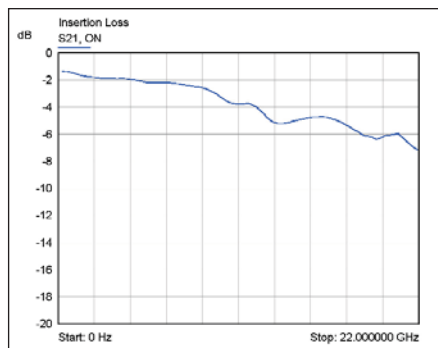


Figure 6 · Insertion loss plot from 0 to 22 GHz.

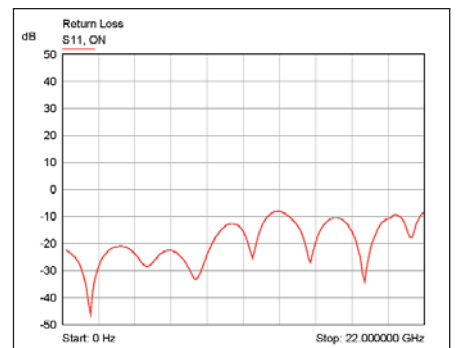


Figure 7 · Return loss plot, showing only small ranges less than 10 dB.

Module Design

The switch design is based on a SPDT, non-reflective, surface-mount IC available from Hittite. The device features low insertion loss and extremely wide frequency coverage, ranging from DC to about 25 GHz. Unfortunately, the measured isolation was only 35 to 37 dB at high frequencies; therefore, cascading was required. The ICs were put on an RF printed circuit board (shown in Figure 1) made from Rogers R4003C, 8-mil thick material. The utilized devices required negative control signals, which were generated on a separate board, as shown in Figure 2.

The boards were placed into the top and bottom cavities of a metal housing as depicted in Figure 3. The connection between the boards was provided with EMI filter feed-thrus. The feed-thru capacitance was chosen to minimize signal leakages between the boards while keeping switching

speed characteristics within desirable limits for the intended application.

In the design of the enclosure, special attention was paid to optimize isolation characteristics. The RF board was pressed down to the housing floor with an inner cover (Figure 4), which evenly distributed the pressure through the board surface to reduce ground leakages. Also, two rectangular channels were machined out on the cover's bottom side (not shown) along with the RF signal paths in order to prevent direct crosstalk between the paths. In addition, a microwave absorber was inserted into the channels to remove undesired signal reflections. Finally, the assembly was shielded with top and bottom covers as shown in Figure 5.

Test Data

The developed module exhibited fairly wide frequency coverage from

30 kHz to 22 GHz. The lowest operating frequency was limited by DC blocking capacitors that were placed in front of the switch ICs. The measured insertion loss between the input and one of the outputs is shown in Figure 6. The module demonstrated an insertion loss ranging from less than 2 dB at low frequencies up to about 7 dB at 22 GHz. The input return loss measured at the main input was about -10 dB across the entire band as indicated in Figure 7.

The switch on-off isolation between the input and either of the outputs was found to be in the 70 dB range as indicated in Figure 8. The harmonic distortion was tested at 5 GHz with +16 dBm input signal. The generated harmonics did not exceed the -55 dBc level as shown in Figure 9. No significant compression was detected at the indicated input power level. The input IP3 at the same frequency and +5 dBm input power

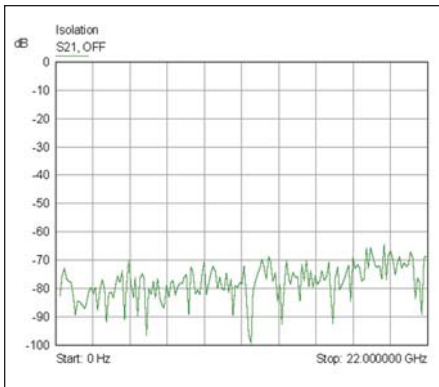


Figure 8 · Isolation performance of 70 dB or more over most of the 22 GHz frequency span.

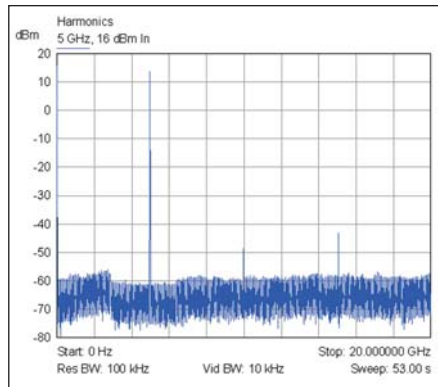


Figure 9 · Harmonics were measured at -55 dBc worst case, relative to a +16 dBm input signal.

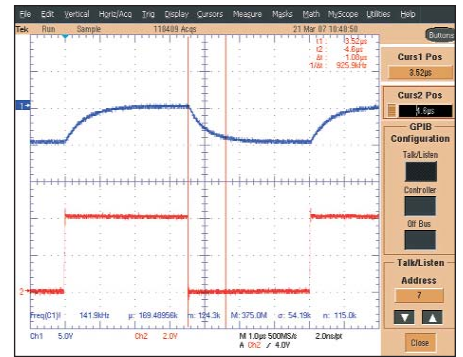


Figure 10 · Switching speed measurement shows the 1 μ sec delay due to R-C time constant of the driver circuitry.

(each tone) was better than +42 dBm.

The switching speed performance was tested by applying a square-wave control signal as indicated in the test results shown in Figure 10. The switch exhibited about a 1 μ sec delay due to a low-pass filter formed by driver output resistors and the capacitive feed-thrus. Switching speed mainly depends on the driver circuit and can be easily brought to the nsec range by reducing feed-thru capacitance. However, the lower capacitance slightly degrades isolation characteristics.

Conclusion

A broadband, high isolation, electronic switch based on commercially available surface-mount ICs has been developed and characterized. The switch has demonstrated excellent isolation, insertion loss, and linearity characteristics between 30 kHz and 22 GHz. The switching time has been limited to 1 μ sec by the driver circuit and can be further reduced if desired.

The developed module can be an attractive low-cost alternative to mechanical switches in a variety of applications where fast switching and high reliability of solid-state devices are required.

References

1. D. Pozar, *Microwave Engineering*, Addison-Wesley, 1990.

2. I. Bahl and P. Bhartia, *Microwave Solid State Circuit Design*, Second Edition, John Wiley & Sons, 2003.

3. R. Garver, *Microwave Control Devices*, Artech House, 1976.

4. L. Devlin, A. Dearn, and G. Pearson, "Low Loss MM-Wave Monolithic SP4Ts," in *Workshop on Design for Broadband Wireless Access Proc.*, May 2001.

5. R. Caverly and G. Hiller, "Distortion in p-i-n Diode Control Circuits," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 35, May 1987, pp. 492-501.

6. S. Nam, D. Raynes, and I. Robertson, "A Programmable High-Isolation Monolithic Millimeter-Wave SPST Switch," in *2000 MTT-S International Microwave Symp. Dig.*, pp. 501-504.

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