

MGS Series Monolithic GaAs Switches

Application Note G007

Introduction

Monolithic GaAs switches provide a popular alternative to PIN diode or mechanical switches. They offer comparable performance, with the added advantages of smaller size and lower cost. Four monolithic switches offered by Hewlett-Packard, the MGS-70018 and MGS-70008 reflective switches and the MGS-71018 and MGS-71008 absorptive switches are discussed in this application note.

Reflective and Absorptive Versions

The Hewlett-Packard MGS-70018, MGS-71018, MGS-70008, and MGS-71008 are all SPDT (Single Pole Double Throw) GaAs MMIC (Monolithic Microwave Integrated Circuit) FET switches. Each has three RF input/output ports, and two DC control ports.

The MGS-70018 and MGS-70008 have I/O ports that are reflective when "off". This means that the port that is not connected to the others is terminated with an RF short circuit. Reflective switches provide the designer with the lowest possible insertion loss.

For applications where the "off" RF port is load sensitive, or where port-to-port isolation is critical, the MGS-71018 and MGS-71008 absorptive switches are suggested. These switches terminate the unconnected RF port with an internal $50\ \Omega$ load. The absorption, by this load, of any high frequency signals appearing at the "off" port, minimizes reflected signals in the system, improving isolation and ensuring that the switch always presents a stable environment at all RF I/O ports.

The MGS-70018 and MGS-71018 switches are functional up to 6 GHz. They are packaged in a standard, 180 mil, 8 lead, glass-metal, surface-mount case. Rugged construction and a hermetic solder seal allow operation over full defense temperature ranges with little change in switch performance. Pin-outs are shown in Figures 1 and 3.

The MGS-70008 and MGS-71008 are functional up to 3 GHz. They come in standard SO-8 surface-mount, plastic packages. Pin-outs are shown in Figures 2 and 4.

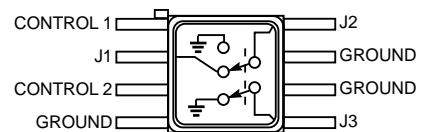


Figure 1. AC Equivalent Circuit of the MGS-70018 Reflective Switch

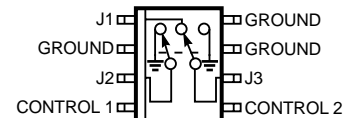


Figure 2. AC Equivalent Circuit of the MGS-70008 Reflective Switch

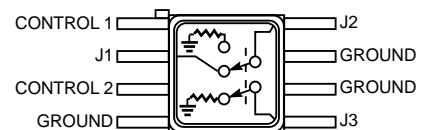


Figure 3. AC Equivalent Circuit of the MGS-71018 Absorptive Switch

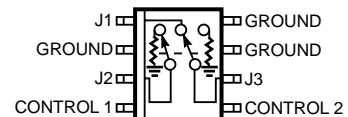


Figure 4. AC Equivalent Circuit of the MGS-71008 Absorptive Switch

Table 1. Comparison of MMIC and PIN Switches

Characteristic	MMIC	PIN
Insertion Loss Typical @ 1 GHz	Low 0.7 dB	Very Low 0.6 dB
Isolation Typical @ 1 GHz	Excellent 45 dB	Excellent 50 dB
Current Consumption Typical	Very Low 12 μ A	Medium 20 mA
Operation to DC	Yes	No
Switching Speed Typical 10% to 90%	Excellent 3 ns	Good 100 ns
Power Handling Typical P _{1DB} @ 1 GHz	Good +25 dBm	Very Good +33 dBm
Third Order Intercept Typical @ 1 GHz	Very Good +45 dBm	Excellent +55 dBm

MMIC Benefits

When compared to PIN diode switches the MGS series monolithic GaAs switches offer several advantages. They require little current, typically less than 12 μ A in the "on" state. This compares favorably to the 20 mA draw typical with many PIN switches. MMIC switches operate with low control voltages, -3.3 V minimum to -8 V maximum. MGS MMIC switches also have inherently fast switching speeds. A 3 ns typical speed (10% to 90%) compares very favorably with the 100 ns achievable with most PIN switches.

Because DC blocking capacitors are not required with the FET switch, it is possible to operate them at DC. The upper frequency of operation, set primarily by the package parasitics, is typically 6 GHz for metal packaged parts and 3 GHz for plastic packaged parts. While PIN diode switches will typically operate to higher frequencies, they are not capable of operation down to DC due to the required blocking capacitor.

Another advantage offered by the monolithic GaAs switches is low video breakthrough from the control ports to the RF ports. Without filtering, the typical spectral noise contribution of the GaAs switch is only -60 dBm (control voltage 50% duty cycle, 10 MHz pulse repetition rate). This allows the system designer to separate control and RF signals with greater ease.

The MGS MMIC switch also offers low distortion. A two tone measurement at 1000 MHz and +5 dBm input power results in third order intermodulation products

below -60 dBc. Coupled with a +27 dBm (0.5 watt) maximum input power handling capability, these switches have an excellent dynamic range. A summary of the advantages and disadvantages of MMIC FETs versus PIN diode switches appears in Table 1.

Applications

The low cost, small size, and high performance of the MGS series MMIC switches make them ideal for a broad array of applications in the HF, VHF, UHF, and Microwave frequencies. Their availability in either hermetic glass-metal or plastic packages makes them an appropriate choice for either commercial or defense product use (Table 2).

The MGS series switches are particularly well suited for use in cellular and cordless telephones. These systems typically require low cost, small size, low power (battery operated), high performance circuits. Availability of plastic, surface-mount, SO-8 packaged switches minimizes cost and size. Ultra-low current draw and operation from control voltages as low as -3.3 V is compatible with battery operation. The typical 1 dB compression point in the 0.25 to 0.5 watt range is compatible with

Table 2. Comparison of Switch Driver Circuits

	Direct Drive	Dual Supply	Single Plus Supply
Voltages	0/-5.2	+5/-5	0/+5
Complexity	Very Simple	Simple	Complex
Speed	Varies	20 ns	100 ns
Current Draw	<0.1 mA	<10 mA	1 - 2 mA
Operation to DC	Yes	Yes	No

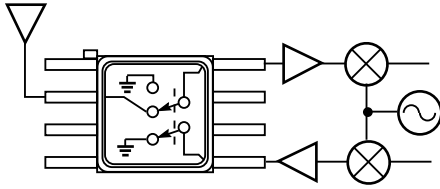


Figure 5. Transmit/Receive Module Using MMIC Switches

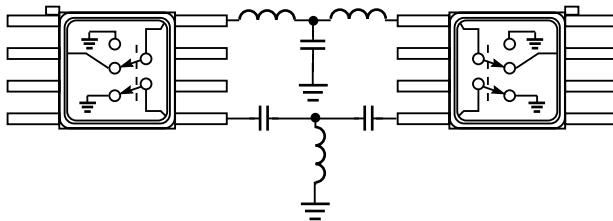


Figure 6. Switched-in Filters for RF Processors

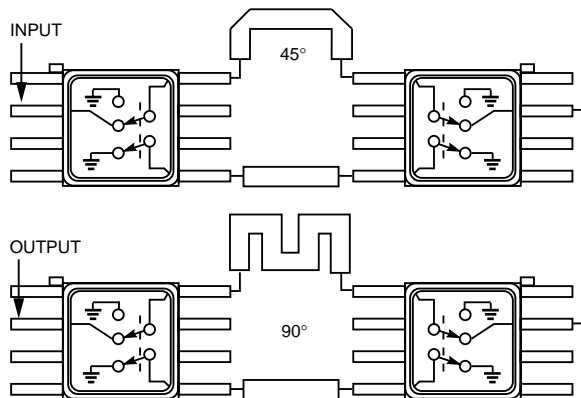


Figure 7. Narrow Band Constant Delay Filter and Phase Control Using MMIC Switches

the transmit power of most hand-held telephones. Thus the MGS switches are excellent choices for transmit/receive antenna switching in these systems.

The same features that make the switches attractive for cellular phone use also make them appropriate for use in the recently deregulated 0.9 GHz, 2.4 GHz, and 5.7 GHz spread spectrum bands. Applications include wireless enhancements to existing hard wired voice and data links such as alarm systems, LANs, PABX,

home control systems, and point-of-sale terminal links to computers, all of which require microwave frequency switches.

Outdoor uses include packet radio networks, access radios, LAN links between buildings, and radio meter readers.

The MGS switches have low loss in the DC - 3 GHz frequency band, making them appropriate for L- and S-band active array radar transmit/receive applications. Another application is in RF and

microwave receivers and direction finders. Here, the switches can be used in RF processor circuits to apply filtering, phase delay, or gain attenuation. Figures 6 and 7 show some simple examples.

Operating Principle

The principle behind FET switches is simple. An array of depletion mode FETs is arranged in such a manner that an externally applied control voltage determines the conduction path in the array. Negative control voltage biases off the FETs in the undesired conduction path.

The normal operating mode for the switches is to always have C1 and C2 in opposite states.

Applying -5 V to Control 1 with 0 V to Control 2, creates a conduction path between J1 and J2. Applying 0 V to Control 1 and -5 V to Control 2 creates a conduction path between J1 and J3 (Figure 8).

The other two states, with both control inputs either at 0 or -5 V, are not normally used. Table 3 is a complete truth table showing the effects of all possible input states. Similar results can be expected for the MGS-71018 and MGS-70018.

Driver Circuits and Usage

To integrate the MGS series switch into a signal processing system, a driving circuit must be provided. The driver circuit and associated components allow the MGS series switch to be controlled by popular logic families such as ECL, TTL or CMOS. The driver circuit must supply bias voltages of 0 to -0.2 V and -3.3 to -8 V to the MGS switch. It should also introduce little switching delay and consume little DC current. The low current draw

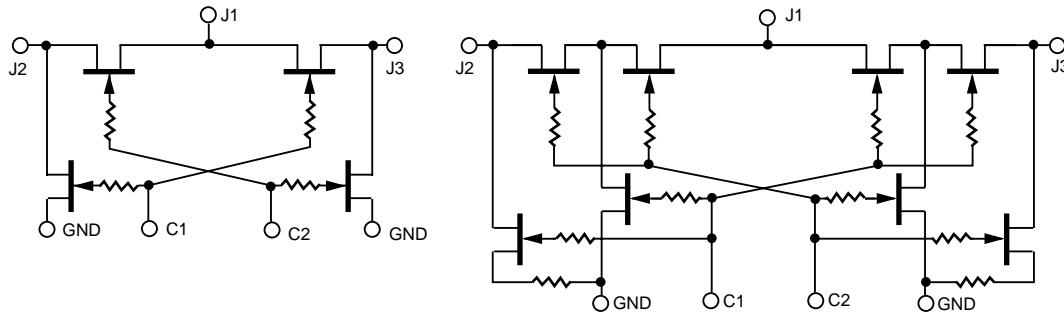


Figure 8. Reflective and Absorptive Switch Schematic Diagrams

Table 3. MGS-70008 / MGS-71008 Truth Table (Typical Performance at 1 GHz)

Control Input		Insertion Loss				Return Loss					
C1	C2	MGS-70008		MGS-71008		MGS-70008			MGS-71008		
		J1-J2	J1-J3	J1-J2	J1-J3	J1	J2	J3	J1	J2	J3
0 V	0 V	16 dB	16 dB	16 dB	16 dB	1 dB	1 dB	1 dB	1 dB	1 dB	1 dB
0 V	-5 V	33 dB	0.8 dB	37 dB	1.2 dB	22 dB	1 dB	22 dB	22 dB	22 dB	22 dB
-5 V	0 V	0.8 dB	33 dB	1.2 dB	37 dB	22 dB	22 dB	1 dB	22 dB	22 dB	22 dB
-5V	-5 V	19 dB	19 dB	26 dB	26 dB	1 dB	1 dB	1 dB	1 dB	1 dB	1 dB

and standard control voltage requirements of the MGS series switches permit several driver topologies.

Direct Drive From -5.2 Volts

When negative voltages are available to the designer, the simplest approach is to drive an MGS series switch directly from -5.2 V. The drive must be complementary, that is when one control line is at -5.2 V, the other must be at 0 V. With this configuration shown in Figure 9, additional external circuitry is not required.

Since the RF signals are coupled directly into the switch without the need for blocking capacitors, operation to DC is possible. The switching speed will depend on the rate at which the complementary logic toggles.

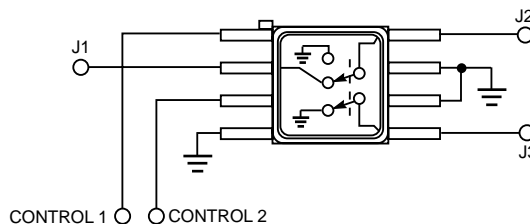


Figure 9. MGS Series Switch Driven Directly from Complementary 0/-5.2 V

Because a driver IC is not required, current consumption will be low – typically less than 0.1 mA. This approach is the recommended mode of operation when negative voltages are available.

Dual Supply Driver

If a $-5.2/0$ V drive signal is not available, the next best approach uses ± 5 V power supply rails to create the drive. Figure 10 shows how a high speed CMOS analog multiplier can be used to drive the control ports of the MGS series switches. The advantages of such a driver are operation to DC, simplicity, low current draw and low cost. The disadvantages are the requirement for a dual voltage power supply and reduction in switching speed (typically 100 to 150 nanoseconds, although faster speeds are possible at higher levels of current consumption).

Appropriate quad analog multiplexers are made by several manufacturers. Examples include the Motorola MC74HC4053 and the Harris CD74HCT4053.

A board layout for the plastic packaged switches, using this circuit configuration, appears on the following page of this application note.

Single Supply Driver

An alternative drive technique requiring only a single positive DC voltage supply is also possible. This technique uses DC blocking and bypass capacitors to “float” the RF ports of the MMIC switch above ground potential. Pull-up resistors are then used to level shift the -5 V control voltage to 0 V and the 0 V control voltage to $+5$ V. The MGS series switch can then be actuated from a single $+5$ V power supply.

Figure 11 shows a schematic of an MGS-70018 driven by a QMOS CD54HCT04 hex inverter. This LSTTL compatible driver has low DC power requirements and high switching speed to the correct voltage levels. As shown in the

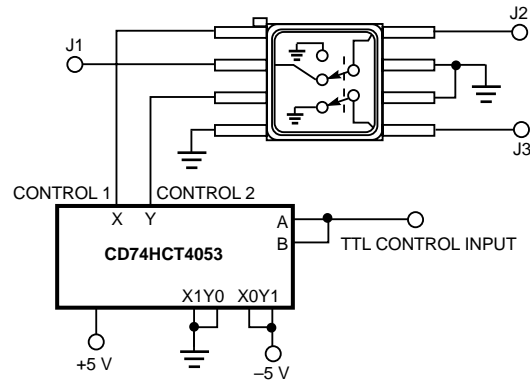


Figure 10. MGS Series Switch with High-Speed CMOS Driver and Separate $+5$ V and -5 V Power Supplies

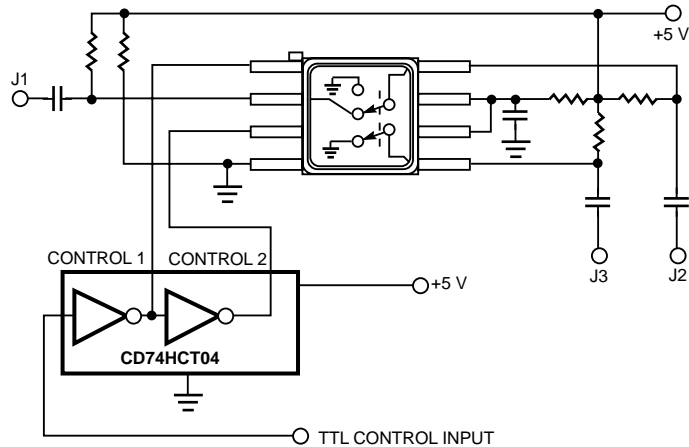


Figure 11. MGS Series Switch with QMOS Driver and Single $+5$ V Power Supply

figure, the switch’s ground, input and output ports must be DC isolated by capacitors. The resistors provide pull-up to $+5$ V and are large in value, typically 1 to 10 K Ω . The capacitor values must be selected to provide a low impedance (less than 10 Ω) at the lowest frequency of operation. The bypass capacitors are usually in the 120 pF range while the blocking capacitors at the RF ports are typically in the 30 to 50 pF range. Other hex inverters such as the CMOS CD4041UB may be used, but will usually result in slower switching speeds and more current draw.

There are some drawbacks to a single supply system. It is complicated to build, does not allow operation to DC because of the blocking capacitors, and typically is more costly than the dual supply driver. For these reasons it is the least-preferred method of the three discussed.

Demonstration Board

This board is designed for either the MGS-71008 or the MGS-70008 switch IC. The driver IC is a Philips 74HCT4053D or equivalent. A bipolar 5 V supply is required. The switches can be driven by a TTL level logic signal.

The microstrip lines are designed to have 50 Ω characteristic impedance when the board is made from 0.063", double sided FR-4 glass-epoxy board material. The bottom side of the board will remain unetched. The pads on the board edges have been designed to fit E. F. Johnson-type 142 SMA connectors. The small + marks indicate the location of holes. The four corner holes can be sized and positioned to fit any enclosure you care to use. The rest of the holes should be 0.030" vias (plated-thru holes) to the bottom side ground plane. For best results, bypass the supply leads with 0.015 μ F chip capacitors using the provided pads.

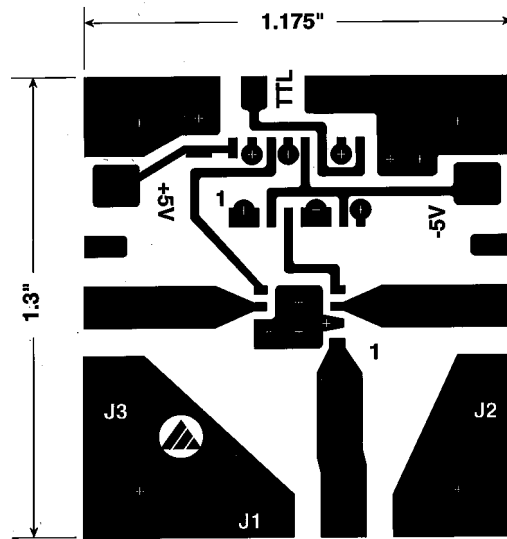


Figure 12. MGS-70008/MGS-71008 Circuit Board Layout (Not to Scale)

DC connections to the board can be made by soldering wires to the pads which are provided, or you can use alligator clips with one jaw (the one on the bottom side of the board) covered with shrink tubing to prevent shorting the power supplies.

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