

Keysight Technologies

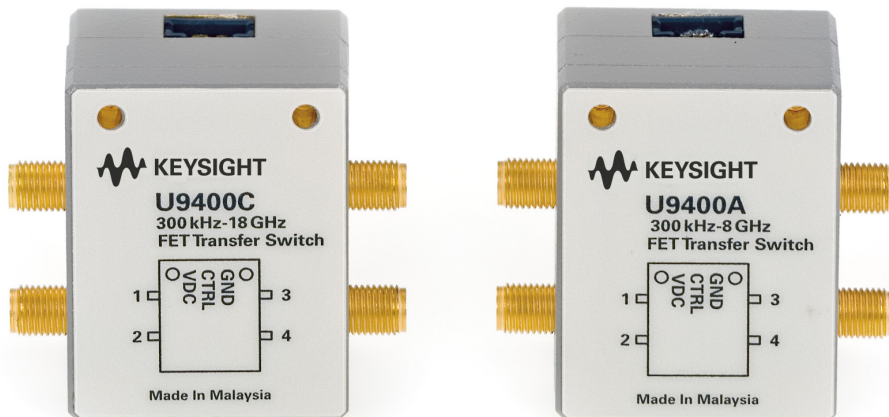
U9400A/C

Solid State FET Transfer Switches

U9400A 300 kHz to 8 GHz FET Transfer Switch

U9400C 300 kHz to 18 GHz FET Transfer Switch

Technical Overview



Description

Keysight Technologies, Inc. U9400A/C solid state FET transfer switches offer superior performance in terms of isolation and video leakage across a broad operating frequency range. The U9400A/C enable high-performance testing from frequencies as low as 300 KHz up to 8 GHz with the U9400A and 18 GHz with the U9400C. These transfer switches are used to increase system flexibility and simplicity, and are easily controlled with an integrated TTL-compatible driver.

The U9400A/C switches offer unmatched isolation performance between ports, as high as 100 dB at 8 GHz and 90 dB at 18 GHz. In addition, Keysight U9400A/C FET switches provide low video leakage of 90 mVpp which ensures safe testing of sensitive components. High video leakage can degrade measurement accuracy and possibly damage sensitive components or equipment. Low video leakage makes these switches particularly suited for measuring sensitive devices and components such as mixers and amplifiers. To learn more about video leakage and how it can affect measurements and devices, see Keysight's "*Video Leakage Effects on Devices in Component Test Application Note*."

The U9400A/C also feature an industry-leading settling time of 0.35 ms, measured to 0.01 dB of the final value (the typical settling time of FET switches is > 50 ms). This equates to a 500 ns switching speed making the U9400A/C ideal for RF and microwave switching applications in instrumentation, communication, radar, switch matrices and various other test systems where speed and lifetime of a switch are critical.

Key Features

- Minimize crosstalk with port-to-port isolation of > 100 dB at 8 GHz
- Increase test setup flexibility with a broad operating frequency range
- Prevent damage to sensitive components with low video leakage of 90 mVpp
- Maintain fast throughput with an industry-leading settling time for FET switches of 350 μ s
- Eliminate the need for external drivers with integrated TTL-compatible driver

An Overview of GaAs FET Switches: Benefits and Disadvantages

Gallium Arsenide (GaAs) FET switches have inherently low video leakage which make them more suitable for measuring devices that have low maximum input power ratings. Sensitive components such as receivers, traveling wave tubes (TWT) and handset power amplifiers typically have maximum input power ratings of < 13 dBm and can be easily damaged or over-driven by the high video leakage. Keysight U9400A/C switches have 90 mV_{pp} video leakage compared to common PIN switches in the market which typically have ≥ 1 V video leakage.

The ON and OFF switching of PIN diode switches use the same path as the RF which make them perform poorly below 10 MHz.

Historically, the main drawback of GaAs FET switches has been a long settling time. The settling time of a switch is defined as 50% of TTL drive to 0.01 dB (99.88% of V_{final}) of the final RF value as shown in Figure 1.

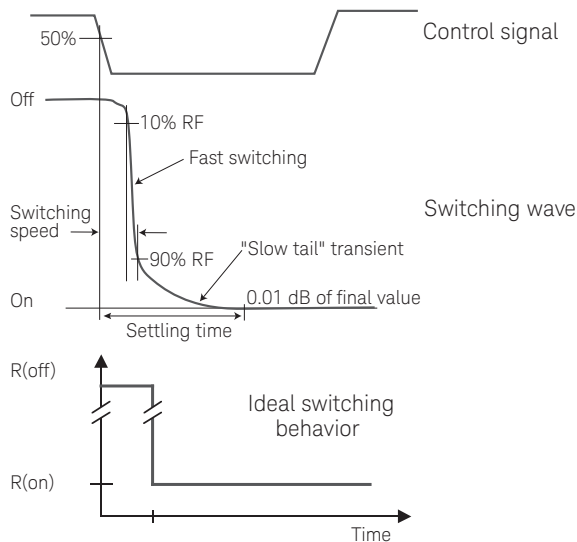


Figure 1. Typical transient behavior of FET switches from OFF state to ON state

Settling time includes:

- The time delay of the switch driver
- Switching speed
- The time it takes to settle within 0.01 dB of its final value.

Typical GaAs FET switches have settling time in the order of tens of milliseconds largely due to the slow transients or the “gate lag” effect. Gate lag occurs when electrons become trapped at the surface of the GaAs device. The conventional method of reducing gate lag in GaAs devices is usually achieved by controlling the gate trough geometry so that the gates fit “tightly” in the bottom of the trough. However, this approach reduces the breakdown voltage and power handling of the device. As shown in Figure 1, the typical transient behavior of FET switches from OFF state to ON state has a slow tail effect that increases the settling time.

Keysight has managed to counteract this drawback with a patented design that eliminates the gate lag effect resulting in a much faster settling time of 350 μ s. You can now have the benefits of FET switches without a reduction in switching speed.

Applications

A 0.01 dB settling time of 350 μ s makes U9400A/C switches suitable for signal routing in EGSM/GSM power amplifier testing since each slot of a GSM signal is 577 μ s. Figure 2 shows a timing diagram for a GSM/EDGE signal, and as you can see one slot equals 577 μ s. Switches used in the test system must switch and settle within 577 μ s so that the system itself can start to capture data within the time frame of the slot 1 signal to ensure accurate measurements.

Video leakage also plays a vital role in switch selection for this specific application. High video leakage can potentially cause permanent damage to power amplifiers because their maximum input power is typically < 13 dBm. The alternative is to use electro-mechanical switches with low or no video leakage, but the switching speed (typically in ms) is usually too slow for this application.

Keysight U9400A/C have a very fast settling time and negligible video leakage making them particularly well suited for routing signals in this test system.

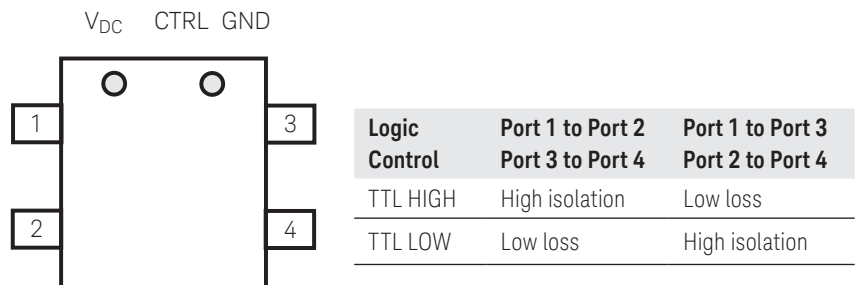


Figure 2. Driving the switch

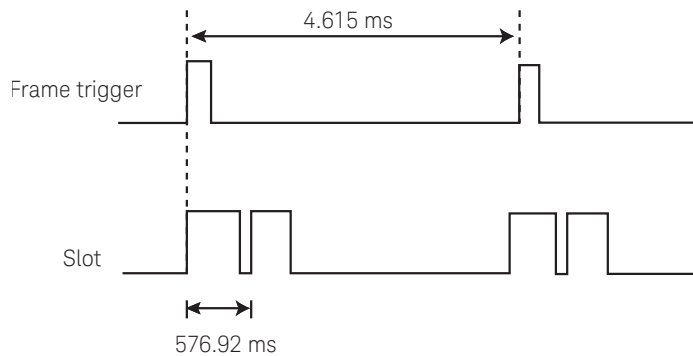


Figure 3. Timing diagram for a GSM/EDGE signal

Keysight U9400A/C solid state transfer switches can be used in numerous ways to enhance system flexibility and simplicity. The following five examples show how U9400A/C can be used to route the signals: as a drop-out switch, as an SPDT switch, for signal reversal, to bypass an active device, and to switch between multiple instruments and DUTs.

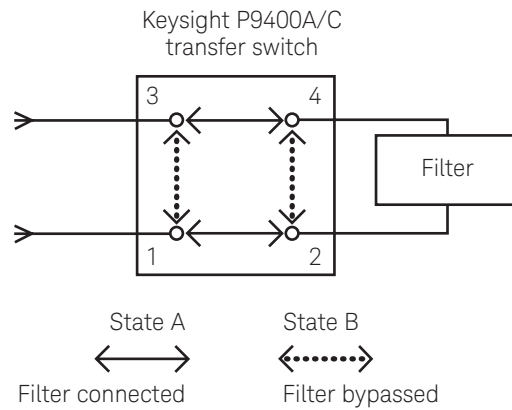


Figure 4. Keysight U9400A/C as a drop-out switch

The U9400A/C can be used as a simple drop-out switch where a signal is either run through the device or straight through the switch thus bypassing the device.

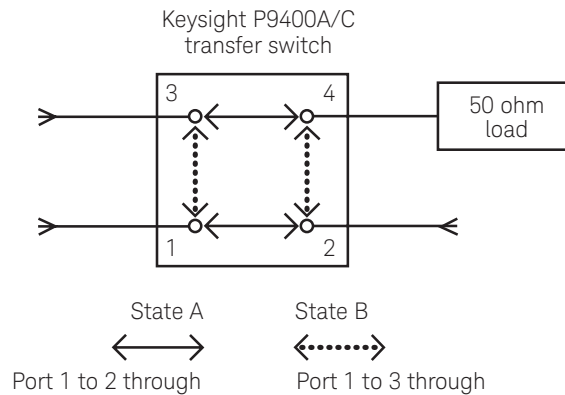


Figure 5. Keysight U9400A/C configured as an SPDT switch

By attaching an external termination, a design engineer can use the U9400A/C in an SPDT terminated switch configuration.

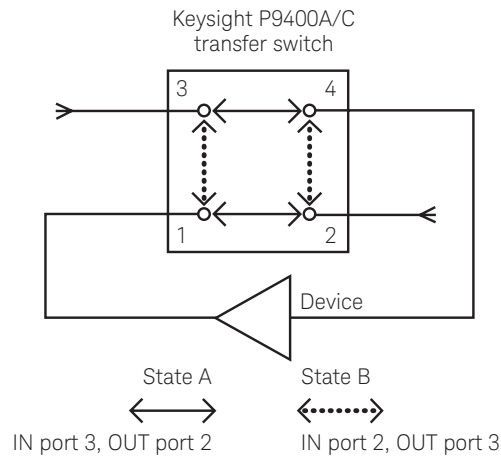


Figure 6. Keysight U9400A/C used in signal reversal application

In the signal reversal configuration, a device can be connected across two diagonal ports of the U9400A/C transfer switch. This will allow the signal direction through the device to be reversed.

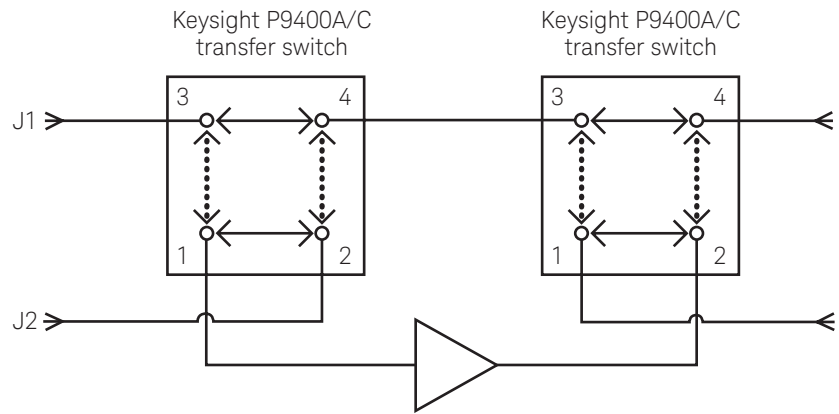


Figure 7. Keysight U9400A/C used to bypass an active device

In Figure 7, an active device, such as an amplifier, is inserted into a signal path presenting a unique problem. A single transfer switch has the undesirable characteristic of shorting the output of the amplifier to its input when the signal is bypassing the amplifier. Two transfer switches are used in this example. Two SPDT switches can serve the similar purpose. However when two transfer switches are used, an additional signal path is always simultaneously available.

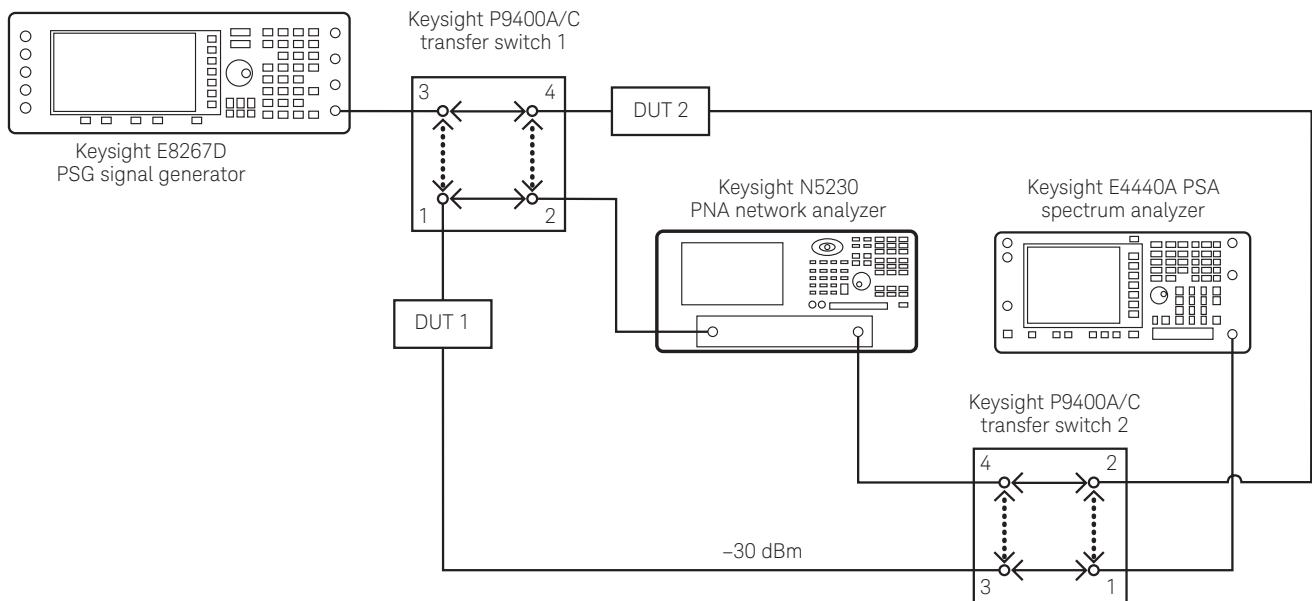


Figure 8. Switching and testing two DUTs between two different test sets simultaneously

Control Input	State	DUT 1 connected to	DUT 2 connected to	Tests
High	<--->	Network analyzer	Network analyzer	S-parameter
Low	<--->	Spectrum analyzer and signal generator	Spectrum analyzer and signal generator	Spurious signal, harmonics

Figure 8 shows an example of a versatile configuration of transfer switches that tests two DUTs simultaneously, each through different sets of equipment targeting distinctive measurement parameters.

DUT 1 is tested for S-parameters using a network analyzer, while DUT 2 is tested on harmonics and spurious signals using a signal generator and a spectrum analyzer. Examples of devices that can be conveniently tested include amplifiers, mixers and receivers. With only one TTL control input that controls both switches' control pins, both tests can be run simultaneously and efficiently on both DUTs. This increases throughput and simplifies your test system.

The U9400A/C switch's outstanding isolation of 100 dB is showcased in this application example. Assume that the transmitted power coming out from DUT 1 is -20 dBm. At the same time, DUT 2 is tested on spurious signal, which might be measured to a value as low as -100 dBm or more. This requires switch #2 to have an isolation of more than $-100 \text{ dBm} - (-20 \text{ dBm}) = -80 \text{ dB}$.

This is only one of the countless measurement uncertainties that require careful attention. Switches with low or moderate isolation performance can impair system accuracy and time is wasted calculating for the uncertainties and dealing with complexities that result from the precise timing requirements of ultra fast switching and testing systems.

Specifications

The specifications refer to the performance standards or limits against which the solid state FET transfer switches are tested. Typical and nominal characteristic are included for additional information only and are not specifications.

Typical (typ.): Expected performance of an average unit which does not include guardbands.

Nominal (nom.): A general, descriptive term that does not imply a level of performance.

All specifications and characteristics are tested at 25 °C (unless otherwise stated).

RF Specifications

Model	U9400A	U9400C
Frequency range	300 kHz to 8 GHz	300 kHz to 18 GHz
Insertion loss	< 3.0 dB (300 kHz to 4 GHz) < 3.5 dB (4 to 8 GHz)	< 5.0 dB (300 kHz to 8 GHz) < 6.5 dB (8 to 18 GHz)
Isolation	> 100 dB	> 90 dB
Return loss (ON Ports)	> 15 dB	> 10 dB
Switching speed ¹ (typical)	4/0.5 μ s	5/1 μ s
Settling time (typical)	350 μ s	350 μ s
Video leakage (typical)	90 mVpp	90 mVpp
Characteristic impedance (nominal)	50 Ω	50 Ω
Connectors	SMA (f)	SMA (f)

Absolute Maximum Ratings²

Parameters	U9400A/C	
	Min	Max
RF input power (Average)	-	+ 29 dBm (U9400A) + 27 dBm (U9400C)
VDC	+ 11 V	+ 26 V
Control Input High Voltage	+ 2.4 V	+ 5 V
Control Input Low Voltage	0 V	+ 0.8 V
Current sourcing at RF1 or RF2 ³	-	60 mA

1. Switching speed is based on 50% TTL to 90% RF (ON time) or 50% TTL to 10% RF (OFF time).
2. Operation in excess of any one of these may result in permanent damage to the products.
3. Sinking not allowed.

Environmental Specifications

U9400A/C solid state switches are designed to fully comply with Keysight product operating environment specifications. The following summarizes the environmental specifications for these products.

Temperature:

Operating	-40 °C to +85 °C
Storage	-65 °C to +125 °C
Cycling	-65 °C to +150 °C, 10 cycles @ 20 °C per minute ramp rate, 20 minutes dwell time per MIL-STD-833F, Method 1010.8, Condition C (modified)

Humidity:

Operating	50% to 95% RH @ 40 °C, one 24 hour cycle, repeated 5 times
Storage	< 90% RH @ 65 °C, 24 hours

Shock:

Half-sine, smoothed 1000 G @ 0.5 ms, 3 shock pulses per orientation, 18 total per MIL-STD-833F, Method 2002.4, Condition B (modified)

Vibration:

Broadband random 50 to 2000 Hz, 7.0 G rms, 15 minutes, per MIL-STD-833F, Method 2026-1 (modified)

Altitude:

Storage < 15,300 meters (50,000 feet)

ESD Immunity:

Direct discharge	1.5 kV per IEC 61000-4-2
Air discharge	2.5 kV per IEC 61000-4-2

U9400A/C Mechanical Dimensions

Dimensions are in mm (inches) nominal, unless otherwise specified.

	U9400A	U9400C
Length, mm (inches)	48.75 (1.919)	48.75 (1.919)
Width, mm (inches)	46.7 (1.839)	46.7 (1.839)
Net weight, kg (lb)	0.095 (0.209)	0.095 (0.209)

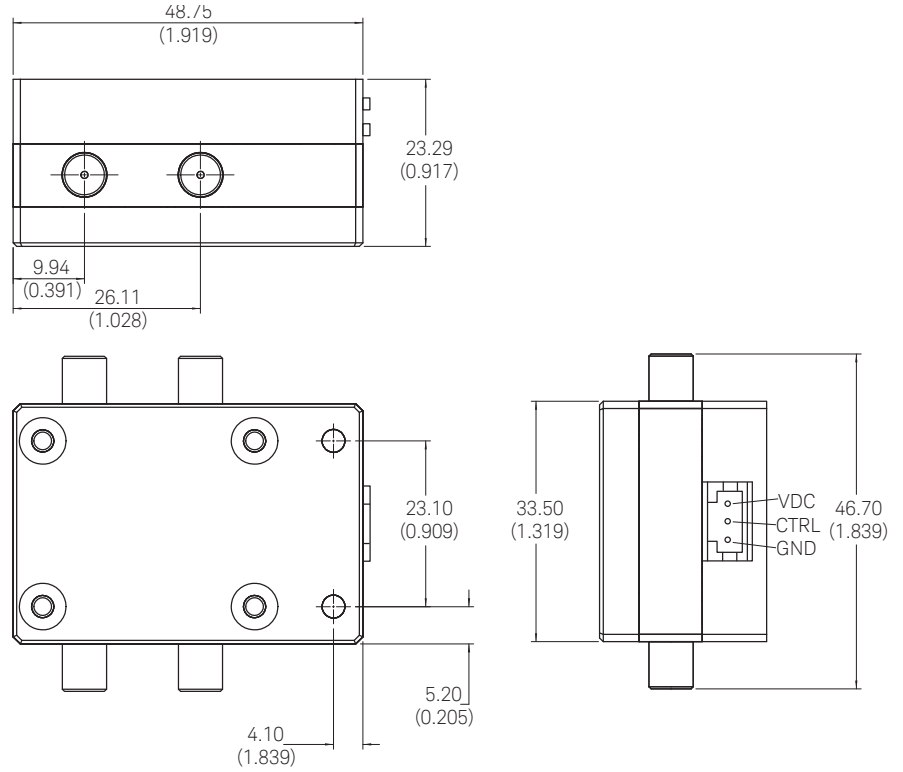


Figure 10. U9400A/C DC cable mechanical dimensions

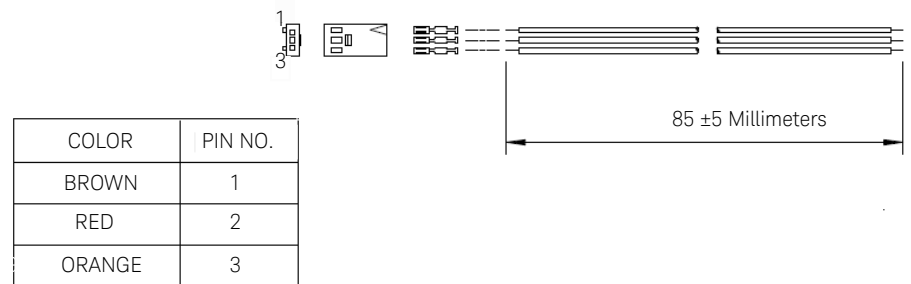


Figure 9. U9400A/C Mechanical dimensions

Typical Performance

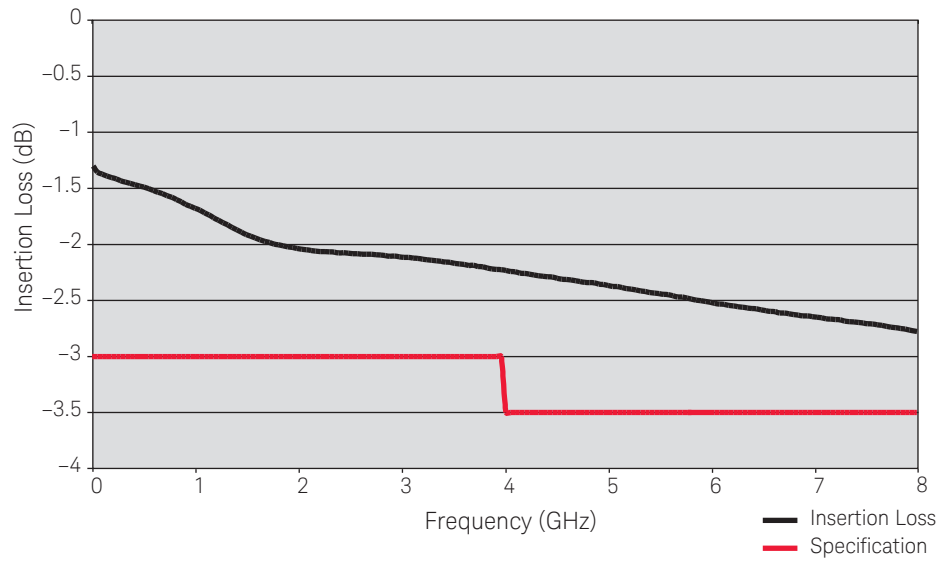


Figure 11. U9400A insertion loss versus frequency (typical)

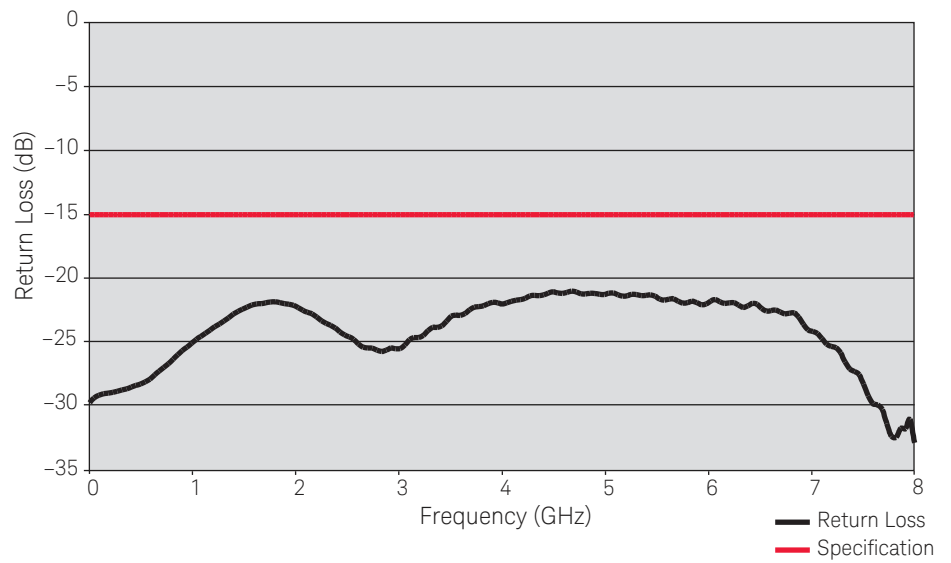


Figure 12. U9400A return loss versus frequency (typical)

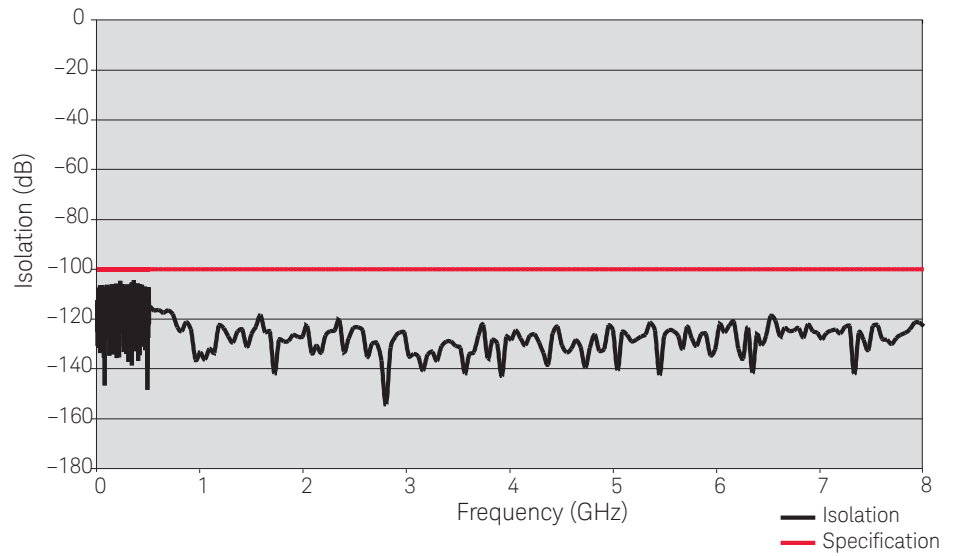


Figure 13. U9400A isolation versus frequency (typical)

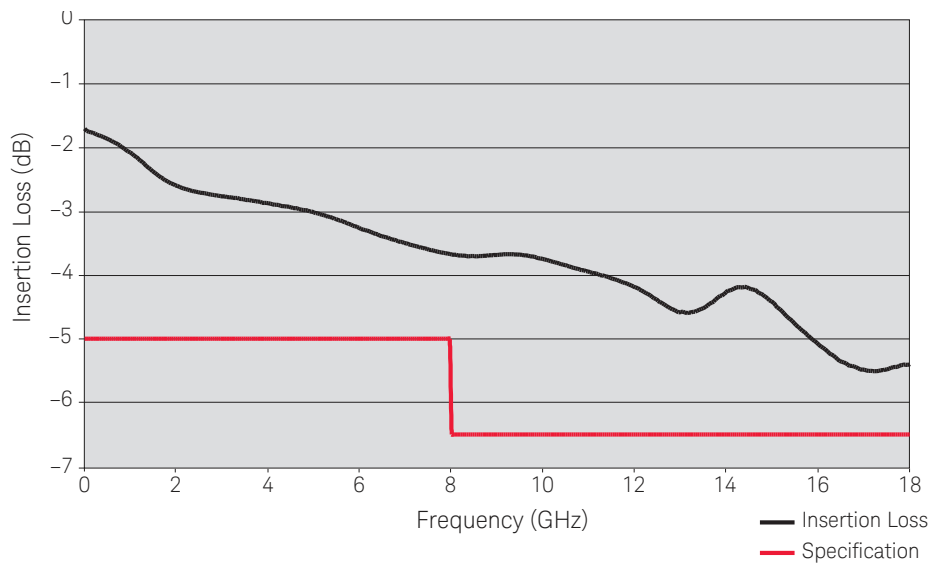


Figure 14. U9400C insertion loss versus frequency (typical)

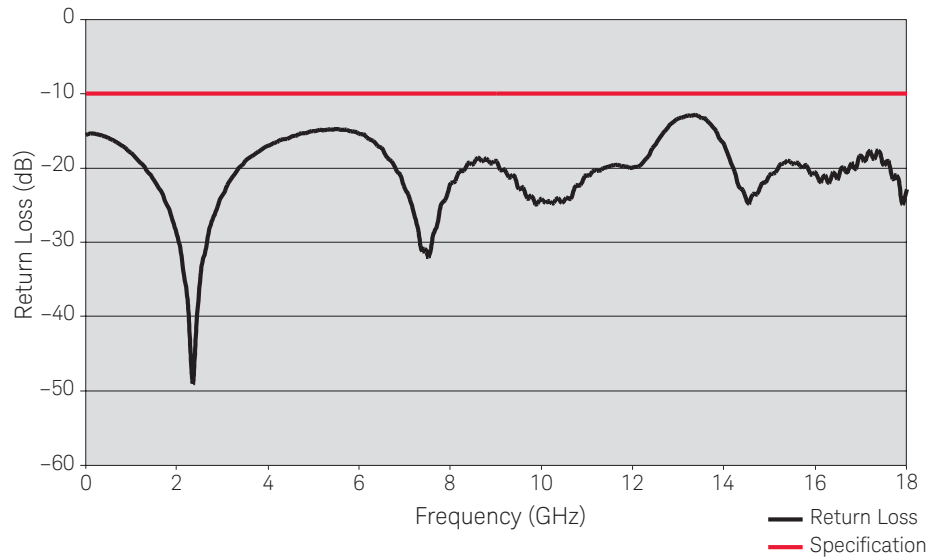


Figure 15. U9400C return loss versus frequency (typical)

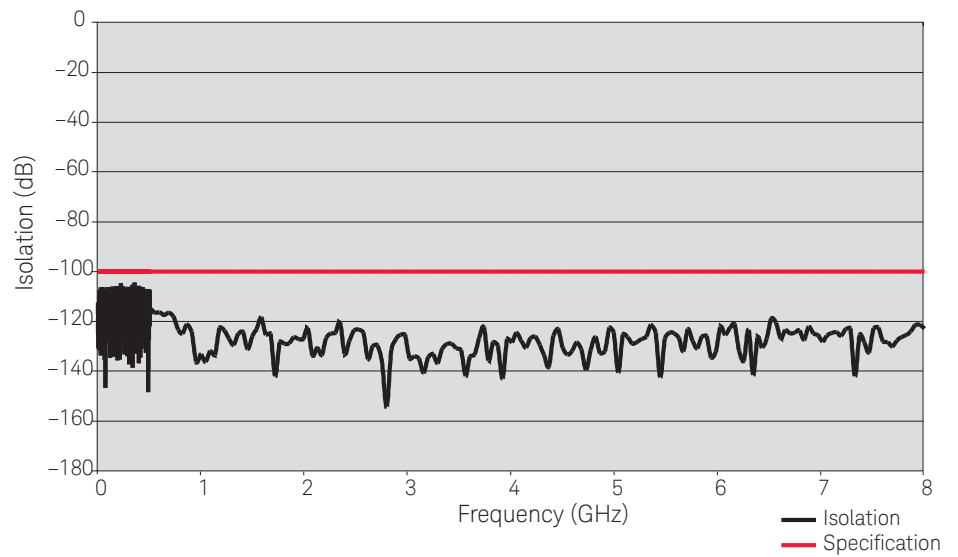


Figure 16. U9400C isolation versus frequency (typical)

Ordering Information

U9400A 8 GHz solid state FET transfer switch

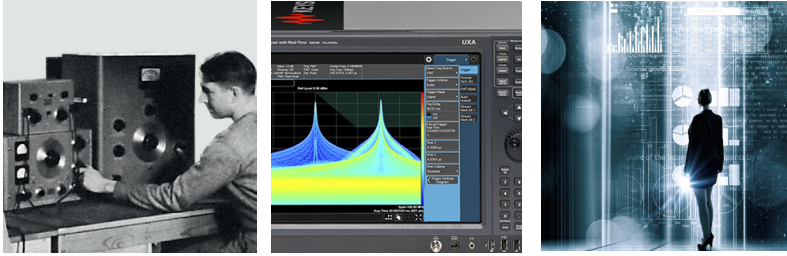
U9400C 18 GHz solid state FET transfer switch

Related Literature

Video Leakage Effects on Devices in Component Test, Application Note, 5989-6086EN
Selecting the Right Switch Technology for Your Application, 5989-5189EN

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