# Wideband, 37 dB Isolation at 1 GHz, CMOS 1.65 V to 2.75 V, 4:1 Mux/SP4T

## ADG904/ADG904-R

### FEATURES

**Wideband switch: –3 dB @ 2.5 GHz**
**ADG904: Absorptive 4:1 Mux/SP4T**
**ADG904-R: Reflective 4:1 Mux/SP4T**
**High off isolation (37 dB @ 1 GHz)**
**Low insertion loss (1.1 dB dc to 1 GHz)**
**Single 1.65 V to 2.75 V power supply**
**CMOS/LVTTL contol logic**
**20-lead TSSOP**
**Low power consumption (1 μA max)**

### APPLICATIONS

**Wireless communications**
**General-purpose RF switching**
**Dual-band applications**
**High speed filter selection**
**Digital transceiver front end switch**
**IF switching**
**Tuner modules**
**Antenna diversity switching**

### FUNCTIONAL BLOCK DIAGRAMS

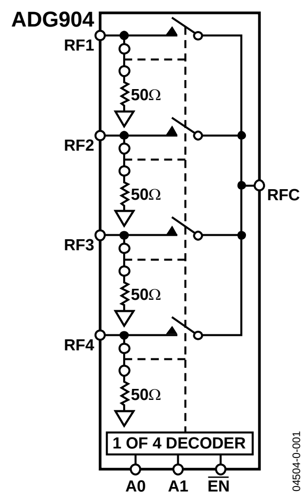


*Figure 1*

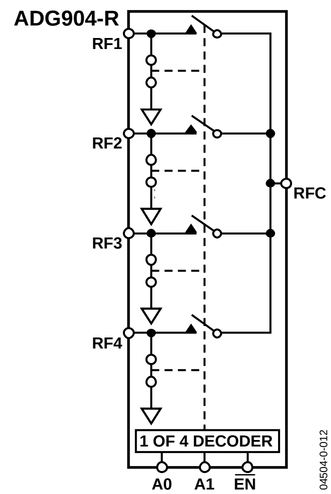


*Figure 2*

### GENERAL DESCRIPTION

The ADG904/ADG904-R are wideband analog 4:1multiplexers that use a CMOS process to provide high isolation and low insertion loss to 1 GHz. The ADG904 is an absorptive/matched mux with 50 Ω terminated shunt legs; the ADG904-R is a reflective mux. These devices are designed such that the isolation is high over the dc to 1 GHz frequency range.

The ADG904/ADG904-R switches one of four inputs to a common output, RFC, as determined by the 3-bit binary address lines A0, A1, and $\overline{EN}$. A Logic 1 on the $\overline{EN}$ pin disables the device.

The parts have on-board CMOS control logic, thus eliminating the need for external control circuitry. The control inputs are both CMOS and LVTTL compatible. The ADG904/ADG904-R's low power consumption makes them ideally suited for wireless applications and general-purpose high frequency switching.

### PRODUCT HIGHLIGHTS

1. –37 dB off isolation @ 1 GHz
2. 1.1 dB insertion loss @ 1 GHz
3. 20-lead TSSOP packages

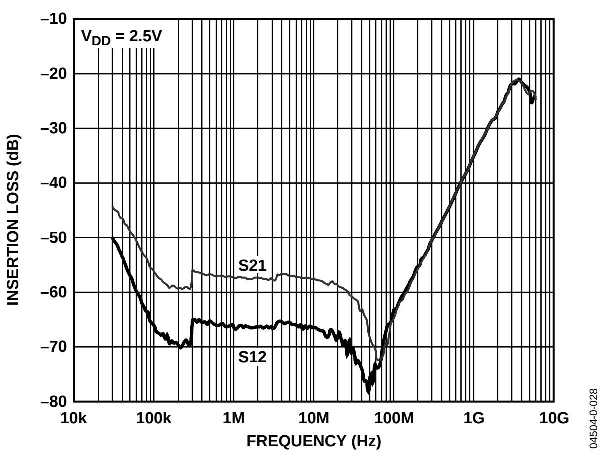


*Figure 3. Off Isolation vs. Frequency*

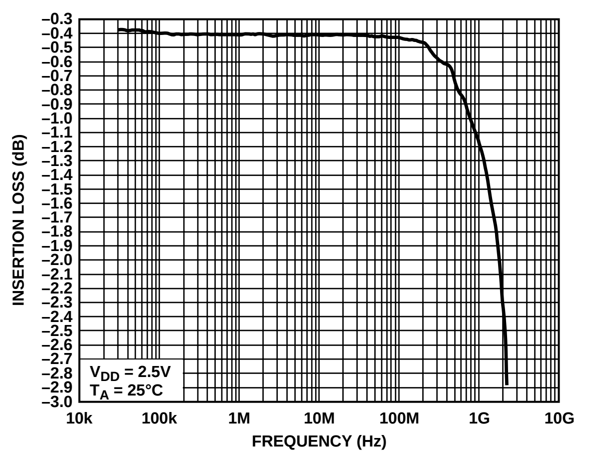


*Figure 4. Insertion Loss vs. Frequency*

**Rev. 0**



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## REVISION HISTORY

Revision 0: Initial Version

# SPECIFICATIONS

Table 1. $V_{DD}$ = 1.65 V to 2.75 V, GND = 0 V, Input Power = 0 dBm, all specifications $T_{MIN}$ to $T_{MAX}$, unless otherwise noted[1]

| Parameter | Symbol | Conditions | B Version Min | Typ[2] | Max | Unit |
|---|---|---|---|---|---|---|
| AC ELECTRICAL CHARACTERISTICS | | | | | | |
| Operating Frequency[3] | | | DC | | 2 | GHz |
| 3 dB Frequency[4] | | | | | 2.5 | GHz |
| Input Power[4] | | 0 V dc bias | | | 7 | dBm |
| | | 0.5 V dc bias | | | 16 | dBm |
| Insertion Loss | $S_{21}$, $S_{12}$ | DC to 100 MHz; $V_{DD}$ = 2.5 V ± 10% | | 0.4 | 0.8 | dB |
| | | 500 MHz; $V_{DD}$ = 2.5 V ± 10% | | 0.6 | 0.9 | dB |
| | | 1000 MHz; $V_{DD}$ = 2.5 V ± 10% | | 1.1 | 1.5 | dB |
| Isolation—RFC to RF1–RF4 | $S_{21}$, $S_{12}$ | 100 MHz | 69 | 70 | | dB |
| | | 500 MHz | 60 | 65 | | dB |
| | | 1000 MHz | 30 | 37 | | dB |
| Crosstalk | $S_{21}$, $S_{12}$ | 100 MHz | 64 | 70 | | dB |
| | | 500 MHz | 60 | 65 | | dB |
| | | 1000 MHz | 30 | 35 | | dB |
| Return Loss (On Channel)[4] | $S_{11}$, $S_{22}$ | DC to 100 MHz | 21 | 27 | | dB |
| | | 500 MHz | 18 | 26 | | dB |
| | | 1000 MHz | 15 | 30 | | dB |
| Return Loss (Off Channel)[4] | $S_{11}$, $S_{22}$ | DC to 100 MHz | 18 | 22 | | dB |
| | | 500 MHz | 16 | 23 | | dB |
| | | 1000 MHz | 18 | 22 | | dB |
| On Switching Time[4] | $t_{ON}$ ($\overline{EN}$) | 50% $\overline{EN}$ to 90% RF | | 8.5 | 10 | ns |
| Off Switching Time[4] | $t_{OFF}$ ($\overline{EN}$) | 50% $\overline{EN}$ to 10% RF | | 13 | 16 | ns |
| Transition Time | $t_{TRANS}$ | 50% Ax to 10% RF | | 12 | 15 | ns |
| Rise Time[4] | $t_{RISE}$ | 10% to 90% RF | | 3 | 5 | ns |
| Fall Time[4] | $t_{FALL}$ | 90% to 10% RF | | 7.5 | 9 | ns |
| 1 dB Compression[4] | $P_{-1 dB}$ | 1000 MHz | | 16 | | dBm |
| Third Order Intermodulation Intercept | $IP_3$ | 900 MHz/901 MHz, 4 dBm | 28 | 31 | | dBm |
| Video Feedthrough[5] | | | | 3 | | mV p-p |
| DC ELECTRICAL CHARACTERISTICS | | | | | | |
| Input High Voltage | $V_{INH}$ | $V_{DD}$ = 2.25 V to 2.75 V | 1.7 | | | V |
| | $V_{INH}$ | $V_{DD}$ = 1.65 V to 1.95 V | 0.65 $V_{CC}$ | | | V |
| Input Low Voltage | $V_{INL}$ | $V_{DD}$ = 2.25 V to 2.75 V | | | 0.7 | V |
| | $V_{INL}$ | $V_{DD}$ = 1.65 V to 1.95 V | | | 0.35 $V_{CC}$ | V |
| Input Leakage Current | $I_I$ | 0 ≤ $V_{IN}$ ≤ 2.75 V | | ± 0.1 | ± 1 | µA |
| CAPACITANCE[4] | | | | | | |
| RF Port On Capacitance | $C_{RF}$ ON | f = 1 MHz | | 3 | | pF |
| Digital Input Capacitance | C | f = 1 MHz | | 2 | | pF |
| POWER REQUIREMENTS | | | | | | |
| $V_{DD}$ | | | 1.65 | | 2.75 | V |
| Quiescent Power Supply Current | $I_{DD}$ | Digital inputs = 0 V or $V_{DD}$ | | 0.1 | 1 | µA |

[1] Temperature range B Version: −40°C to +85°C.
[2] Typical values are at $V_{DD}$ = 2.5 V and 25°C, unless otherwise stated.
[3] Operating frequency is the point at which insertion loss degrades by 1.5 dB.
[4] Guaranteed by design, not subject to production test.
[5] Video feedthrough is the dc transience at the output of any port of the switch when the control voltage is switched from high to low or low to high in a 50 Ω test setup, measured with 1 ns rise time pulses and 500 MHz bandwidth.

# ABSOLUTE MAXIMUM RATINGS

**Table 2. $T_A$ = 25°C, unless otherwise noted**

| Parameter | Rating |
|---|---|
| $V_{DD}$ to GND | –0.5 V to +4 V |
| Inputs to GND | –0.5 V to $V_{DD}$ + 0.3 V[1] |
| Continuous Current | 30 mA |
| Input Power | 18 dBm |
| Operating Temperature Range | |
| Industrial (B Version) | –40°C to +85°C |
| Storage Temperature Range | –65°C to +150°C |
| Junction Temperature | 150°C |
| TSSOP Package | |
| $\theta_{JA}$ Thermal Impedance | 143°C/W |
| Lead Temperature, Soldering (10 sec) | 300°C |
| IR Reflow, Peak Temperature (<20 sec) | 235°C |
| ESD | 1 kV |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Only one absolute maximum rating may be applied at any one time.

**Table 3. Truth Table**

| A1 | A0 | $\overline{EN}$ | ON Switch[2] |
|---|---|---|---|
| X | X | 1 | None |
| 0 | 0 | 0 | RF1 |
| 0 | 1 | 0 | RF2 |
| 1 | 0 | 0 | RF3 |
| 1 | 1 | 0 | RF4 |

[1] RFx Off Port Inputs to Ground = –0.5 V to $V_{DD}$ – 0.5 V.
[2] OFF Switches have:
50 Ω termination to GND (ADG904).
Shunt to GND (ADG904-R).

## ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

# PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

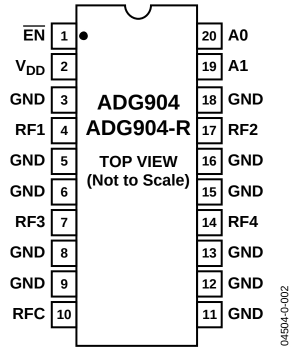


*Figure 5. 20-Lead TSSOP (RU-20)*

**Table 4. Pin Function Descriptions**

| Pin No. | Mnemonic | Function |
|---|---|---|
| 1 | $\overline{EN}$ | Active Low Digital Input. When high, the device is disabled and all switches are off. When low, Ax logic inputs determine on switches. |
| 2 | $V_{DD}$ | Power Supply Input. These parts can be operated from 1.65 V to 2.75 V. $V_{DD}$ should be decoupled to GND. |
| 3, 5, 6, 8, 9, 11, 12, 13, 15, 16, 18 | GND | Ground Reference Point for All Circuitry on the Part. |
| 4 | RF1 | RF1 Port. |
| 7 | RF3 | RF3 Port. |
| 10 | RFC | Common RF Port for Switch. |
| 14 | RF4 | RF4 Port. |
| 17 | RF2 | RF2 Port. |
| 19 | A1 | Logic Control Input. |
| 20 | A0 | Logic Control Input. |

# TERMINOLOGY

**Table 5.**

| Parameter | Description |
|---|---|
| $V_{DD}$ | Most Positive Power Supply Potential. |
| $I_{DD}$ | Positive Supply Current. |
| GND | Ground (0 V) Reference. |
| Ax | Logic Control Input. |
| $V_{INL}$ | Maximum Input Voltage for Logic 0. |
| $V_{INH}$ | Minimum Input Voltage for Logic 1. |
| $I_{INL}$ ($I_{INH}$) | Input Current of the Digital Input. |
| $C_{IN}$ | Digital Input Capacitance. |
| $t_{ON\ (\overline{EN})}$ | Delay between Applying the $\overline{EN}$ Control Input and the Output Switching On. |
| $t_{OFF\ (\overline{EN})}$ | Delay between Applying the $\overline{EN}$ Control Input and the Output Switching Off. |
| $t_{RISE}$ | Rise Time. Time for the RF signal to rise from 10% of the On level to 90% of the On level. |
| $t_{FALL}$ | Fall Time. Time for the RF signal to fall from 90% of the On level to 10% of the On level. |
| $t_{TRANS}$ | Transition Time. Delay between applying the digital control input and the output switching on. |
| Off Isolation | The Attenuation between Input and Output Ports of the Switch when the Switch Control Voltage is in the Off Condition. |
| Insertion Loss | The Attenuation between Input and Output Ports of the Switch when the Switch Control Voltage is in the On Condition. |
| Crosstalk | Measure of Unwanted Signal Coupled through from One Channel to Another as a Result of Parasitic Capacitance. |
| $P_{-1\ dB}$ | 1 dB Compression Point. The RF input power level at which the switch insertion loss increases by 1 dB over its low level value. $P_{-1\ dB}$ is a measure of how much power the On switch can handle before the insertion loss increases by 1 dB. |
| $IP_3$ | Third Order Intermodulation Intercept. This is a measure of the power in false tones that occur when closely spaced tones are passed through a switch, whereby the nonlinearity of the switch causes these false tones to be generated. |
| Return Loss | The Amount of Reflected Power Relative to the Incident Power at a Port. Large return loss indicates good matching. By measuring return loss, the VSWR can be calculated from conversion charts. VSWR (voltage standing wave ratio) indicates the degree of matching present at a switch RF port. |
| Video Feedthrough | Spurious Signals Present at the RF ports of the Switch when the Control Voltage is Switched from High to Low or Low to High without an RF Signal Present. |

# TYPICAL PERFORMANCE CHARACTERISTICS

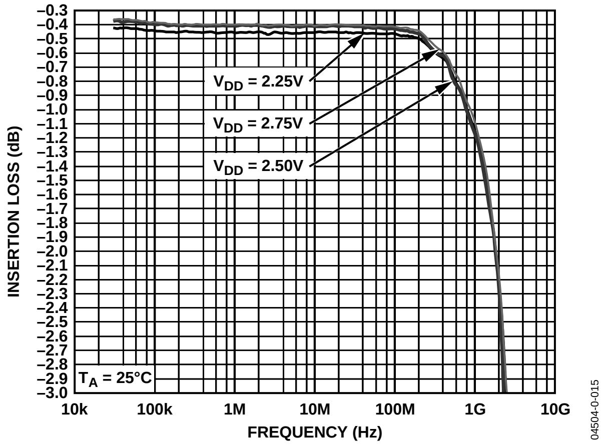


*Figure 6. Insertion Loss vs. Frequency over Supplies (RF1–RF4, S12, and S21)*

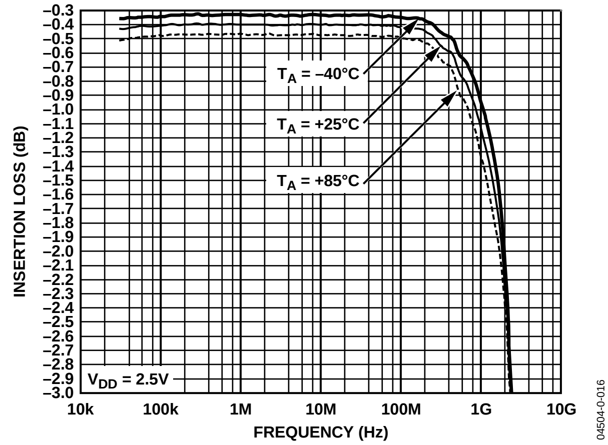


*Figure 9. Insertion Loss vs. Frequency over Temperature (RF1-RF4, S12, and S21)*

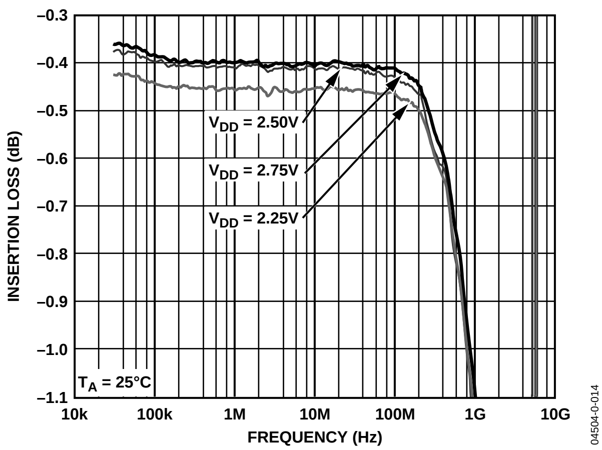


*Figure 7. Insertion Loss vs. Frequency over Supplies (RF1-RF4, S12, and S21) Zoomed Figure 6 Plot)*

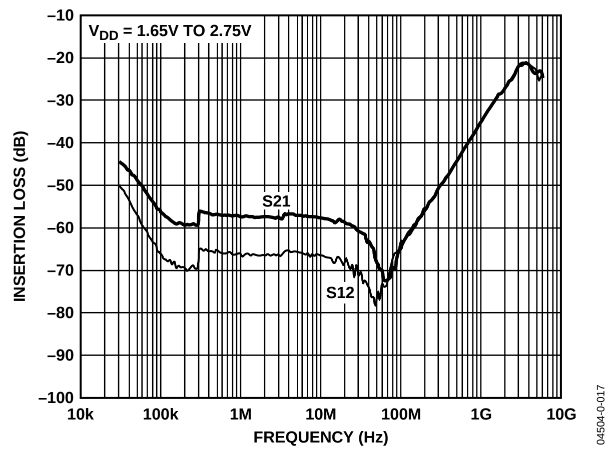


*Figure 10. Isolation vs. Frequency over Supplies (RF1-RF4, S12, and S21)*

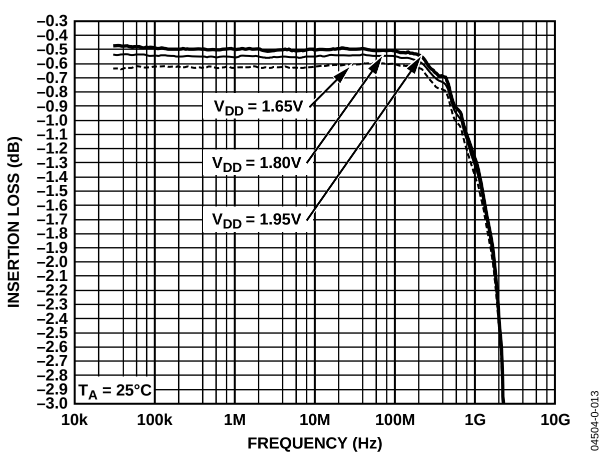


*Figure 8. Insertion Loss vs. Frequency over Supplies (RF1–RF4, S12, and S21)*

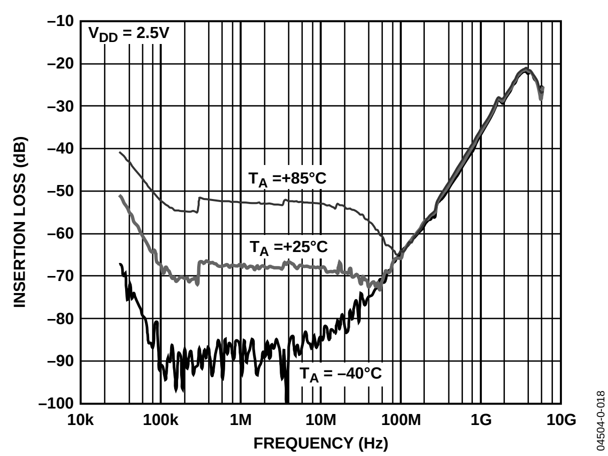


*Figure 11. Isolation vs. Frequency over Temperature (RF1-RF4, S12, and S21)*

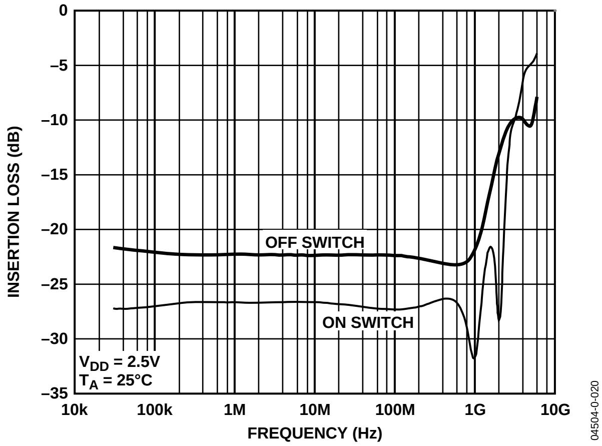


Figure 12. Return Loss vs. Frequency (RF1-RF4, S11)

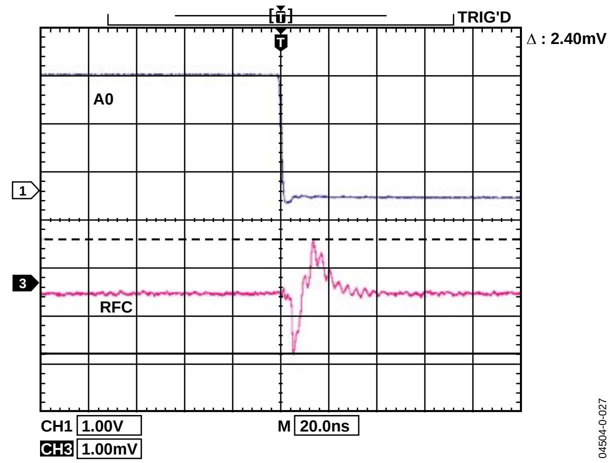


Figure 15. Video Feedthrough

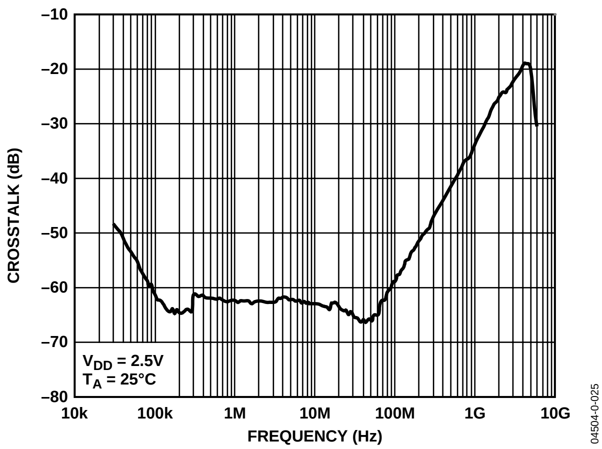


Figure 13. Crosstalk vs. Frequency

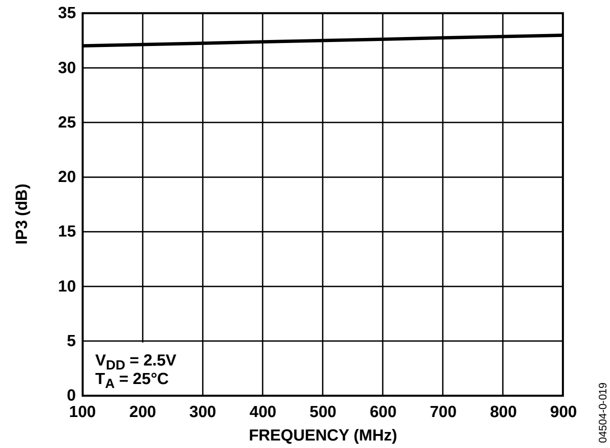


Figure 16. IP3 vs. Frequency

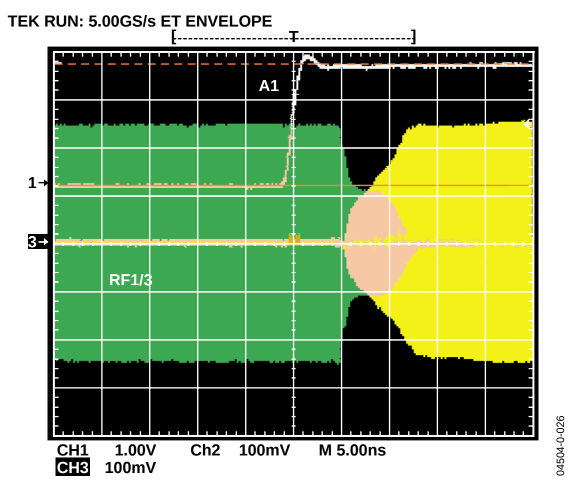


Figure 14. Switch Timing

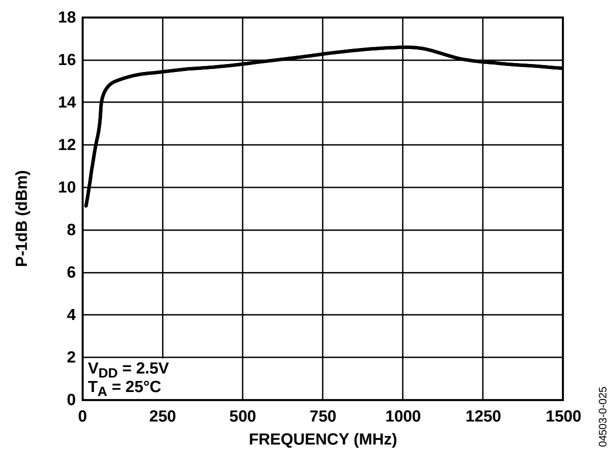


Figure 17. P-1dB vs. Frequency

# TEST CIRCUITS

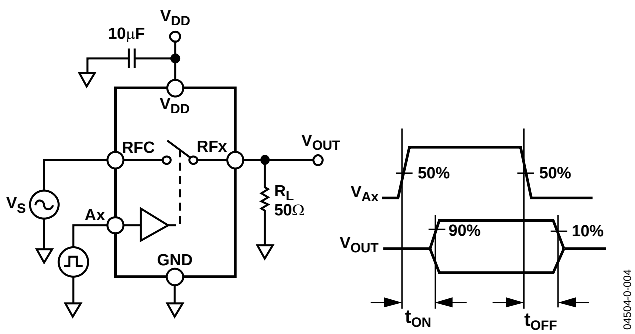


Figure 18. Switch Timing: $t_{ON}$, $t_{OFF}$

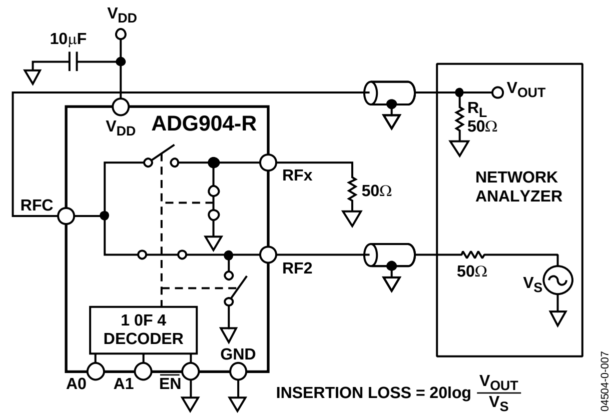


Figure 21. Insertion Loss

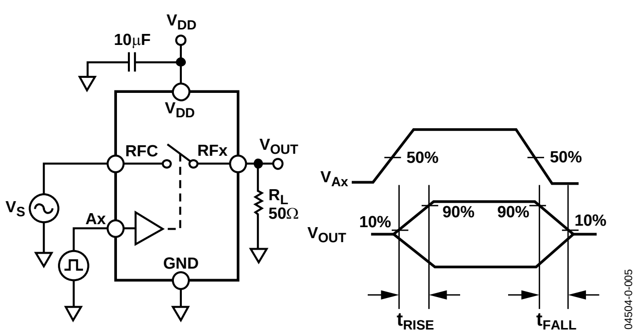


Figure 19. Switch Timing: $t_{RISE}$, $t_{FALL}$

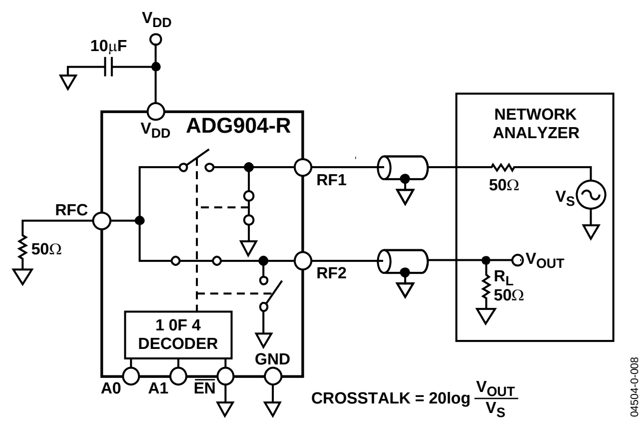


Figure 22. Crosstalk

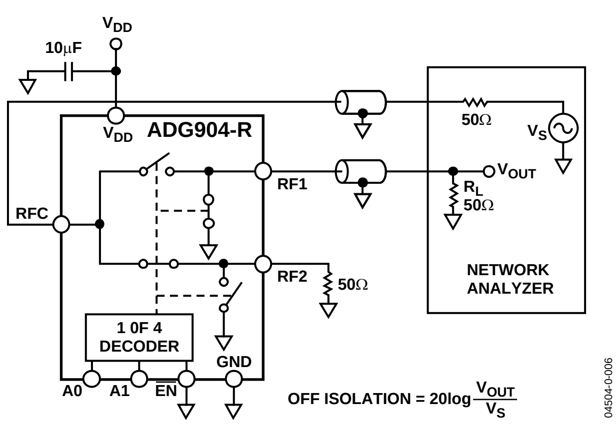


Figure 20. Off Isolation

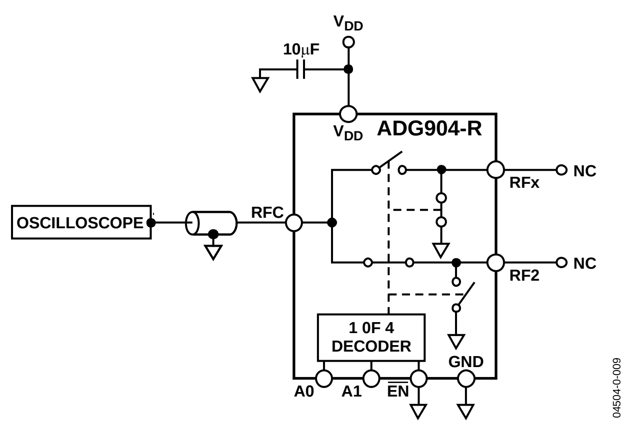


Figure 23. Video Feedthrough

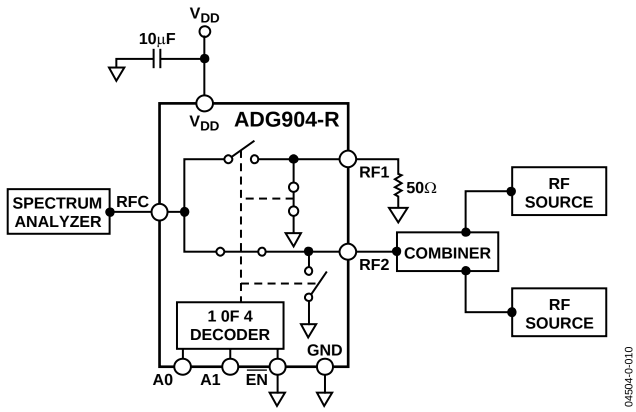


Figure 24. $IP_3$

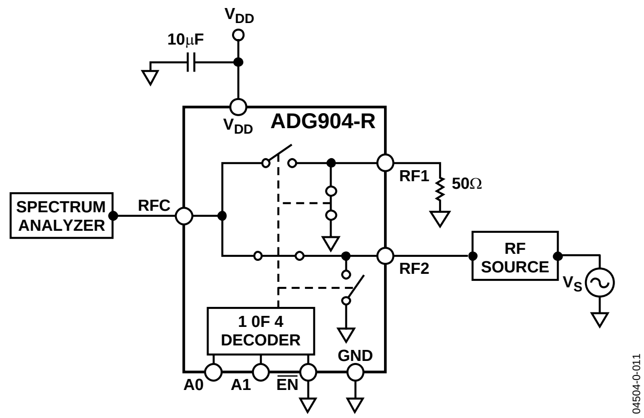


Figure 25. P-1 dB

# APPLICATIONS

The ADG904/ADG904-R are ideal solutions for low power, high frequency applications. The low insertion loss, high isolation between ports, low distortion, and low current consumption of these parts make them excellent solutions for many high frequency switching applications. They may be used in applications such as switchable filters, transmitters and receivers for radar systems, and communication systems from base stations to cell phones.

The ADG9xx wideband switches are designed to meet the demands of devices transmitting at ISM band frequencies to 1 GHz and higher. The low insertion loss, high isolation between ports, single pin control interface, no requirement for dc blocking capacitors, and TTL interface compatibility make them cost effective and easy to integrate switching solutions for many high frequency switching applications and low power applications where the parts can handle up to 16 dBm of power.

## ABSORPTIVE VS. REFLECTIVE

The ADG904 is an absorptive (matched) switch with 50 Ω terminated shunt legs; the ADG904-R is a reflective switch with 0 Ω terminated shunts to ground. The ADG904 absorptive switch has a good VSWR on each port, regardless of the switch mode. An absorptive switch should be used when there is a need for a good VSWR that is looking into the port but not passing the through signal to the common port. The ADG904 is therefore ideal for applications that require minimum reflections back to the RF source. It also ensures that the maximum power is transferred to the load.

The ADG904-R reflective switch is suitable for applications where high off port VSWR does not matter and the switch has some other desired performance feature. It can be used in many applications, including high speed filter selection. In most cases, an absorptive switch can be used instead of a reflective switch, but not vice versa.

## ANTENNA DIVERSITY SWITCH

The ADG904 is ideal for use as an antenna diversity switch, switching in different antennas to the tuner. The low insertion loss ensures minimum signal loss and high isolation between channels, making these SP4T switches suitable for switching applications in tuner modules and set-top boxes.

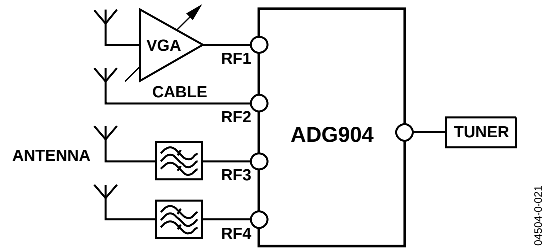


*Figure 26. Tuner Modules*

## FILTER SELECTION

The ADG904 can be used to switch high frequency signals between different filters, and to multiplex the signal to the output. These SP4T switches are also ideal for high speed signal routing.

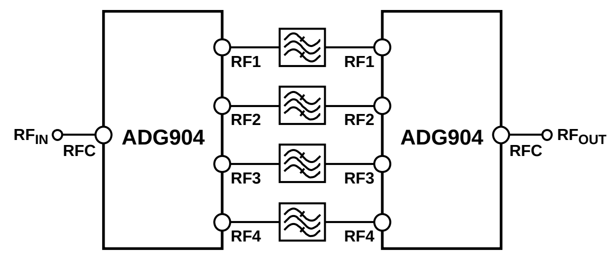


*Figure 27. Filter Selection*

## Tx/Rx SWITCHING

The low insertion loss and high isolation between ports ensures that the ADG904/ADG904-R is a suitable transmit/receive switch for all ISM band and WirelessLAN, providing the required isolation between the transmit and receive signals.

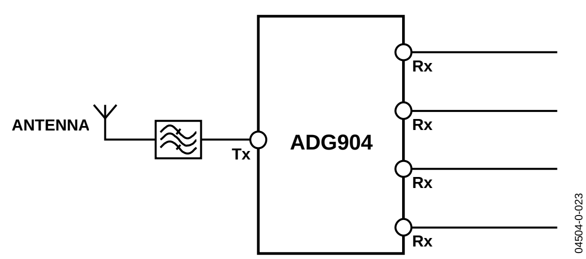


*Figure 28. Tx/Rx Switching*

# EVALUATION BOARD

The ADG904/ADG904-R evaluation board allows designers to evaluate the high performance, wideband switches with minimal effort.

To prove that these devices meet the user's requirements, only a power supply and a network analyzer, along with the evaluation board, are required. An application note available with the evaluation board gives complete information on operating the evaluation board.

The RFC port (see Figure 29) is connected through a 50 Ω transmission line to the bottom left SMA connector, J4. RF1, RF2, RF3, and RF4 are connected through 50 Ω transmission lines to SMA connectors J5, J6, J7, and J8, respectively. A through transmission line connects J9 and J10; this transmission line is used to estimate the loss of the PCB over the environmental conditions being evaluated.

The board is constructed of 4-layer, FR4 material with a dielectric constant of 4.3 and an overall thickness of 0.062 inches. Two ground layers with grounded planes provide ground for the RF transmission lines. The transmission lines were designed using a coplanar waveguide with a ground plane model using a trace width of 0.024 inches, clearance to ground plane of 0.008 inches, dielectric thickness of 0.02 inches, and a metal thickness of 0.0021 inches.

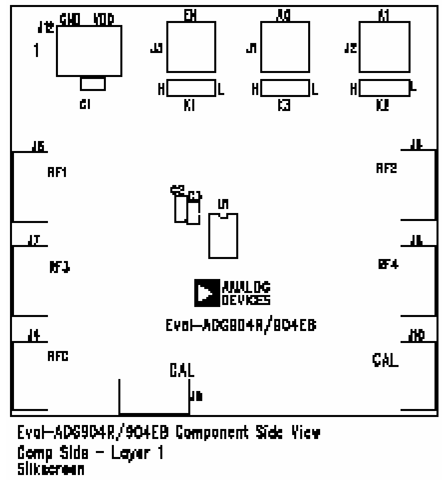


*Figure 29. ADG904/ADG904-R Evaluation Board Top View*

# OUTLINE DIMENSIONS

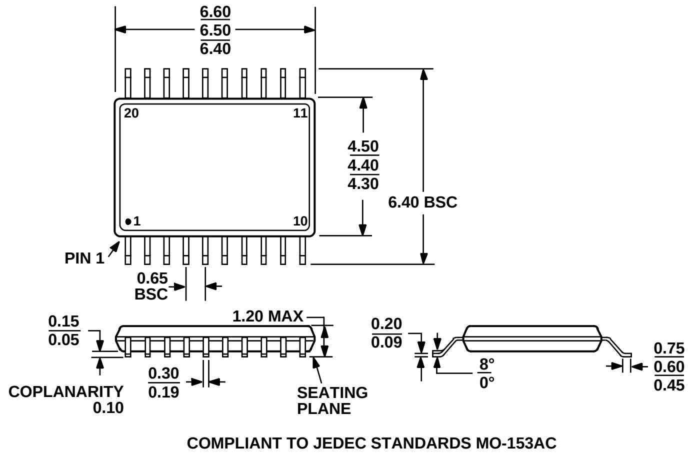


*Figure 30. 20-Thin Shrink Small Outline Package [TSSOP]*
*(RU-20)*
*Dimensions shown in millimeters*

## ORDERING GUIDE

| Model | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| ADG904BRU | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-500RL7 | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-REEL | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-REEL7 | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-R | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-R-500RL7 | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-R-REEL | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| ADG904BRU-R-REEL7 | –40°C to +85°C | Thin Shrink Small Outline Package (TSSOP) | RU-20 |
| EVAL-ADG904EB | | Evaluation Board | |
| EVAL-ADG904REB | | Evaluation Board | |

## NOTES

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