# 9 kHz to 20 GHz, Nonreflective, Silicon SPDT Switch

## FEATURES

- Wideband frequency range, 9 kHz to 20 GHz
- Nonreflective 50 Ω design
- Low insertion loss
  - 0.6 dB typical between 9 kHz to 6 GHz
  - 0.8 dB typical between 6 GHz to 12 GHz
  - 1.05 dB typical between 12 GHz to 20 GHz
- High isolation
  - 55 dB typical between 9 kHz to 6 GHz
  - 50 dB typical between 6 GHz to 12 GHz
  - 45 dB typical between 12 GHz to 20 GHz
- High input linearity
  - P0.1dB: 35 dBm typical
  - IP3: 62 dBm typical
- High RF power handling
  - Through path: 35 dBm peak and 33 dBm average
  - Terminated path: 32 dBm peak and 30 dBm average
  - Hot switching (RFC): 35 dBm peak and 33 dBm average
  - Hot switching (RFx): 32 dBm peak and 30 dBm average
- CMOS/LVTTL compatible
- No low-frequency spur; no negative voltage generator
- RF on and off time: 5.0 µs
- RF settling time (0.1 dB): 5.3 µs
- Single-supply operation ($V_{DD}$ = 3.3 V, $V_{SS}$ = 0 V)
- 20-terminal, 3 mm × 3 mm, LGA package
- Pin compatible with ADRF5023 and ADRF5027

## APPLICATIONS

- Test instrumentation
- Military radios, radars, electronic counter measures (ECMs)
- Microwave radios and very small aperture terminals (VSATs)

## FUNCTIONAL BLOCK DIAGRAM

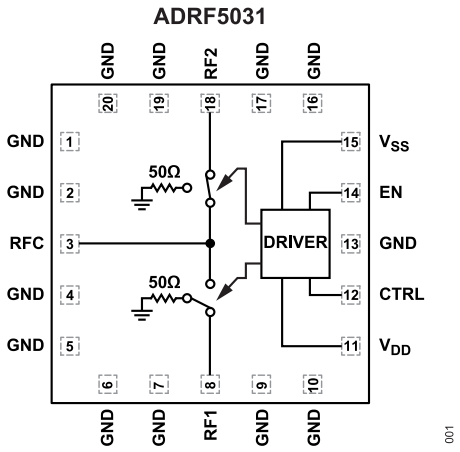


*Figure 1. Functional Block Diagram*

## GENERAL DESCRIPTION

The ADRF5031 is a nonreflective, SPDT switch manufactured using the silicon on insulator (SOI) process. The ADRF5031 operates from 9 kHz to 20 GHz with an insertion loss of lower than 1.05 dB and isolation of higher than 45 dB. The device has an RF input power handling capability of 33 dBm average and 35 dBm peak for forward and reverse through paths, hot switching through the RFC port, and 30 dBm average and 32 dBm peak for terminated paths and hot switching through RFx ports. The ADRF5031 operates with dual-supply voltages of ±3.3 V. The ADRF5031 employs complementary metal-oxide semiconductor (CMOS) and low-voltage transistor to transistor logic (LVTTL)-compatible control.

The ADRF5031 can also operate with a single positive supply voltage ($V_{DD}$) applied while the negative supply voltage ($V_{SS}$) is tied to ground. In this operating condition, the small signal performance is maintained while the switching characteristics, linearity, and power handling performance are derated. See Table 2 for more details.

The ADRF5031 is pin compatible with the ADRF5023 and ADRF5027 and also pin compatible with ADRF5030, a fast switching version, which operates between 100 MHz to 20 GHz.

The ADRF5031 is packaged in a 20-terminal, 3 mm × 3 mm, RoHS-compliant, land grid array (LGA) and operates from −40°C to +105°C.

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## REVISION HISTORY

**11/2024—Rev. 0 to Rev. A**

Changes to Ordering Guide ..... 12

**9/2024—Revision 0: Initial Version**

## SPECIFICATIONS

$V_{DD}$ = 3.3 V, $V_{SS}$ = −3.3 V, CTRL voltage ($V_{CTRL}$) = 0 V or $V_{DD}$, and $T_{CASE}$ = 25°C for a 50 Ω system, unless otherwise noted. RFx refers to RF1 or RF2.

***Table 1. Electrical Characteristics***

| Parameter | Symbol | Test Conditions/Comments | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| FREQUENCY RANGE | f | | 0.009 | | 20000 | MHz |
| INSERTION LOSS | | | | | | |
| Between RFC and RFx (On) | | 9 kHz to 6 GHz | | 0.6 | | dB |
| | | 6 GHz to 12 GHz | | 0.8 | | dB |
| | | 12 GHz to 20 GHz | | 1.05 | | dB |
| RETURN LOSS | | 9 kHz to 20 GHz | | | | |
| RFC | | | | 22 | | dB |
| RFx (On) | | | | 20 | | dB |
| RFx (Off) | | | | 17 | | dB |
| ISOLATION | | | | | | |
| Between RFC to RFx and RFx to RFx | | 9 kHz to 6 GHz | | 55 | | dB |
| | | 6 GHz to 12 GHz | | 50 | | dB |
| | | 12 GHz to 20 GHz | | 45 | | dB |
| SWITCHING | | | | | | |
| Rise and Fall Time | $t_{RISE}$, $t_{FALL}$ | 10% to 90% of RF output | | 3.0 | | µs |
| On and Off Time | $t_{ON}$, $t_{OFF}$ | 50% $V_{CTRL}$ to 90% of RF output | | 5.0 | | µs |
| Settling Time (0.1 dB) | | 50% $V_{CTRL}$ to 0.1 dB of final RF output | | 5.3 | | µs |
| INPUT LINEARITY[1] | | f = 1 MHz to 20 GHz | | | | |
| Input Compression | P0.1dB | | | 35 | | dBm |
| Third-Order Intercept | IP3 | Two-tone input power = 14 dBm each tone, f = 1 MHz to 20 GHz, Δf = 1 MHz | | 62 | | dBm |
| Second-Order Intercept | IP2 | Two-tone input power = 14 dBm each tone, f = 8 GHz, Δf = 1 MHz | | 116 | | dBm |
| VIDEO FEEDTHROUGH | | | | 4.5 | | mV p-p |
| SUPPLY CURRENT | | $V_{DD}$ and $V_{SS}$ pins | | | | |
| Positive Supply Current | $I_{DD}$ | | | 150 | | µA |
| Negative Supply Current | $I_{SS}$ | | | 520 | | µA |
| DIGITAL CONTROL INPUTS | | CTRL and EN pins | | | | |
| Voltage | | | | | | |
| Low | $V_{INL}$ | | 0 | | 0.8 | V |
| High | $V_{INH}$ | | 1.2 | | 3.3 | V |
| Current | | | | | | |
| Low | $I_{INL}$ | | | <1 | | µA |
| High | $I_{INH}$ | | | 33 | | µA |
| RECOMMENDED OPERATING CONDITIONS | | | | | | |
| Supply Voltage | | | | | | |
| Positive | $V_{DD}$ | | 3.15 | | 3.45 | V |
| Negative | $V_{SS}$ | | −3.45 | | −3.15 | V |
| Digital Control Inputs Voltage | $V_{CTRL}$ | | 0 | | $V_{DD}$ | V |
| RF Input Power[2, 3] | $P_{IN}$ | f = 1 MHz to 20 GHz, $T_{CASE}$ = 85°C | | | | |
| Through Path | | RF signal is applied to RFC or through connected RFx (RF1 or RF2) | | | | |
| Average | | | | | 33 | dBm |
| Peak, Pulse[4, 5] | | | | | 35 | dBm |
| Terminated Path | | RF signal is applied to unselected RFx (terminated within internal resistor) | | | | |
| Average | | | | | 30 | dBm |
| Peak, Pulse | | | | | 32 | dBm |

## SPECIFICATIONS

*Table 1. Electrical Characteristics (Continued)*

| Parameter | Symbol | Test Conditions/Comments | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Hot Switching (RFC) | | RF signal is applied to RFC while switching in between RF1 or RF2 | | | | |
| Average | | | | | 33 | dBm |
| Peak, Pulse | | | | | 35 | dBm |
| Hot Switching (RFx) | | RF signal is applied to RFx while switching in between RF1 or RF2 | | | | |
| Average | | | | | 30 | dBm |
| Peak, Pulse | | | | | 32 | dBm |
| Case Temperature | $T_{CASE}$ | | −40 | | +105 | °C |

[1] For input linearity performance over frequency, see Figure 12 to Figure 15.

[2] For power derating over frequency, see the Power Derating Curve section.

[3] For 105°C operation, the power handling degrades from the $T_{CASE}$ = 85°C specification by 3 dB.

[4] Peak: ( ≤100 ns pulse duration, 5% duty cycle).

[5] Pulse: (>100 ns pulse duration, 15% duty cycle).

## SINGLE-SUPPLY OPERATION

$V_{DD}$ = 3.3 V, $V_{SS}$ = 0 V, $V_{CTRL}$ = 0 V or $V_{DD}$, and $T_{CASE}$ = 25°C for a 50 Ω system, unless otherwise noted.

*Table 2. Single-Supply Operational Specifications*

| Parameter | Symbol | Test Conditions/Comments | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| FREQUENCY RANGE | f | | 0.009 | | 20.000 | MHz |
| SWITCHING CHARACTERISTICS | | | | | | |
| Rise and Fall Time | $t_{RISE}$, $t_{FALL}$ | 10% to 90% of RF output | | 9.2 | | µs |
| On and Off Time | $t_{ON}$, $t_{OFF}$ | 50% $V_{CTRL}$ to 90% of RF output | | 14 | | µs |
| 0.1 dB RF Settling Time | | 50% $V_{CTRL}$ to 0.1 dB of final RF output | | 16 | | µs |
| INPUT LINEARITY | | f = 1 MHz to 20 GHz | | | | |
| Power Compression | P0.1dB | | | 24 | | dBm |
| Third-Order Intercept | IP3 | Two-tone input power = 0 dBm each tone, Δf = 1 MHz | | 48 | | dBm |
| RECOMMENDED OPERATING CONDITONS | | | | | | |
| RF Input Power | $P_{IN}$ | f = 1 MHz to 20 GHz, $T_{CASE}$ = 85°C | | | | |
| Through Path | | RF signal is applied to the RFC or through connected RFx | | | 24 | dBm |
| Terminated Path | | RF signal is applied to unselected RFx (terminated within internal resistor) | | | 24 | dBm |
| Hot Switching | | RF signal is applied to the RFC while switching between RFx | | | 24 | dBm |

## ABSOLUTE MAXIMUM RATINGS

For the recommended operating conditions, see Table 1.

*Table 3. Absolute Maximum Ratings*

| Parameter | Rating |
|---|---|
| Positive Supply Voltage | −0.3 V to +3.6 V |
| Negative Supply Voltage | −3.6 V to +0.3 V |
| Digital Control Input[1] | |
| Voltage | −0.3 V to $V_{DD}$ + 0.3 V |
| Current | 3 mA |
| RF Input Power, Dual Supply[2] ($V_{DD}$ = 3.3 V, $V_{SS}$ = −3.3 V, f = 1 MHz to 20 GHz, $T_{CASE}$ = 85°C[3]) | |
| Through Path | |
| Average | 34 dBm |
| Peak | 36 dBm |
| Terminated Path | |
| Average | 30.5 dBm |
| Peak | 32.5 dBm |
| Hot Switching (RFC) | |
| Average | 33.5 dBm |
| Peak | 35.5 dBm |
| Hot Switching (RFx) | |
| Average | 30.5 dBm |
| Peak | 32.5 dBm |
| RF Input Power, Single Supply ($V_{DD}$ = 3.3 V, $V_{SS}$ = 0 V, f = 1 MHz to 20 GHz, $T_{CASE}$ = 85°C) | |
| Through Path | 25 dBm |
| Terminated Path | 25 dBm |
| Hot Switching (RFC) | 25 dBm |
| RF Input Power, Unbiased ($V_{DD}$, $V_{SS}$ = 0 V) | |
| Average | 31 dBm |
| Peak[4] | 36 dBm |
| Temperature | |
| Junction, $T_J$ | 135°C |
| Storage Range | −65°C to +150°C |
| Reflow | 260°C |

1 Overvoltages at the digital control input are clamped by internal diodes. Current must be limited to the maximum rating given.

2 For power derating over frequency, see Figure 2.

3 For 105°C operation, the power handling degrades from the $T_{CASE}$ = 85°C specification by 3 dB for dual supply.

4 Peak: (≤100 ns pulse duration, 5% duty cycle).

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

Only one absolute maximum rating can be applied at any one time.

## THERMAL RESISTANCE

Thermal performance is directly linked to printed circuit board (PCB) design and operating environment. Careful attention to PCB thermal design is required.

$\theta_{JC}$ is the junction-to-case bottom (channel-to-package bottom) thermal resistance.

*Table 4. Thermal Resistance*

| Package Type | $\theta_{JC}$[1] | Unit |
|---|---|---|
| CC-20-21 | | |
| Through Path | 110 | °C/W |
| Terminated Path | 50 | °C/W |

1 $\theta_{JC}$ was determined by simulation under the following conditions: the heat transfer is due solely to the thermal conduction from the channel through the ground pad to the PCB, and the ground pad is held constant at the operating temperature of 85°C.

## POWER DERATING CURVE

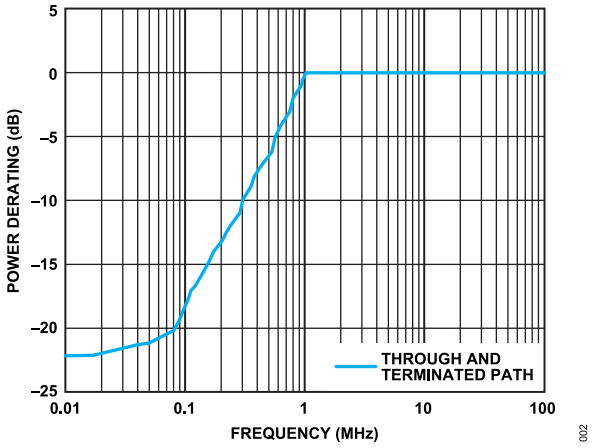


*Figure 2. Power Derating vs. Frequency, Low-Frequency Detail, $T_{CASE}$ = 85°C*

## ABSOLUTE MAXIMUM RATINGS

## ELECTROSTATIC DISCHARGE (ESD) RATINGS

The following ESD information is provided for handling of ESD-sensitive devices in an ESD-protected area only.

Human body model (HBM) per ANSI/ESDA/JEDEC JS-001.

Charged device model (CDM) ratings are per ANSI/ESDA/JEDEC JS-002.

### ESD Ratings for the ADRF5031

*Table 5. ADRF5031, 20-Terminal LGA*

| ESD Model | Withstand Threshold (V) | Class |
|---|---|---|
| HBM | 4 kV for the RFx and RFC pins | 3A |
| | 4 kV for the supply and digital control pins | 3A |
| CDM | 500 V for all pins | C2A |

## ESD CAUTION

**ESD (electrostatic discharge) sensitive device**. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

## PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

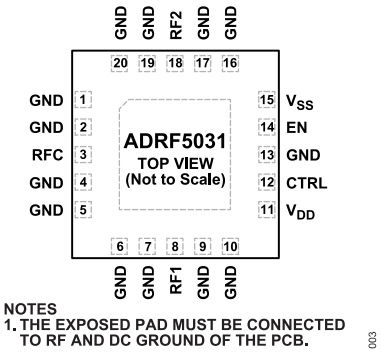


*Figure 3. Pin Configuration (Top View)*

*Table 6. Pin Function Descriptions*

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1, 2, 4, 5, 6, 7, 9, 10, 13, 16, 17, 19, 20 | GND | Ground. The GND pins must be connected to the RF and /DC ground of the PCB. |
| 3 | RFC | RF Common Port. The RFC pin is DC-coupled to 0 V. No DC-blocking capacitor is necessary when the RF line potential is equal to 0 V DC. See Figure 4 for the interface schematic. |
| 8 | RF1 | RF Port 1. The RF1 pin is DC-coupled to 0 V. No DC-blocking capacitor is necessary when the RF line potential is equal to 0 V DC. See Figure 4 for the interface schematic. |
| 11 | $V_{DD}$ | Positive Supply Voltage. See Figure 6 for the interface schematic. |
| 12 | CTRL | Control Input Voltage. See Figure 5 for the interface schematic. |
| 14 | EN | Enable Input Voltage. See Table 7 for the truth table. See Figure 5 for the interface schematic. |
| 15 | $V_{SS}$ | Negative Supply Voltage. See Figure 7 for the interface schematic. |
| 18 | RF2 | RF Port 2. The RF2 pin is DC-coupled to 0 V. No DC-blocking capacitor is necessary when the RF line potential is equal to 0 V DC. See Figure 4 for the interface schematic |
| | EPAD | Exposed Pad. The exposed pad must be connected to the RF and DC ground of the PCB. |

## INTERFACE SCHEMATICS

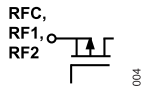


*Figure 4. RFC, RF1, and RF2 Interface Schematic*

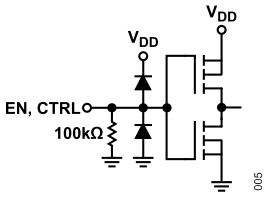


*Figure 5. EN and CTRL Interface Schematic*

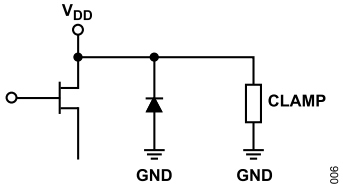


*Figure 6. $V_{DD}$ Interface Schematic*

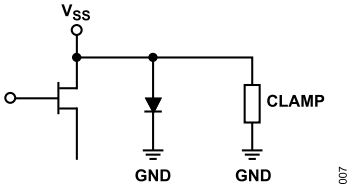


*Figure 7. $V_{SS}$ Interface Schematic*

## TYPICAL PERFORMANCE CHARACTERISTICS

### INSERTION LOSS, RETURN LOSS, AND ISOLATION

$V_{DD}$ = 3.3 V, $V_{SS}$ = –3.3 V, $V_{CTRL}$ = 0 V or $V_{DD}$, and $T_{CASE}$ = 25°C for a 50 Ω system, unless otherwise noted. RFx refers to RF1 to RF2.

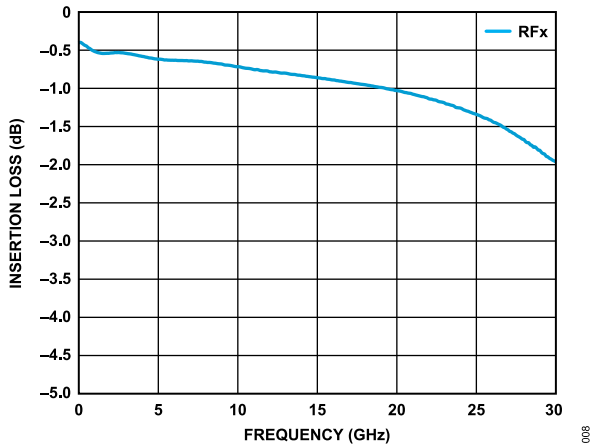


*Figure 8. Insertion Loss vs. Frequency for the RFx Pins*

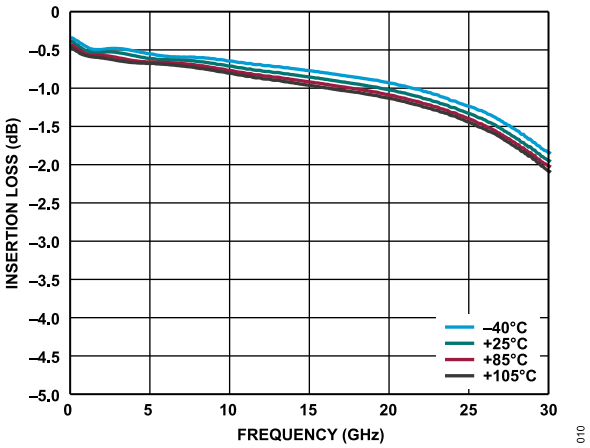


*Figure 10. Insertion Loss vs. Frequency over Various Temperatures*

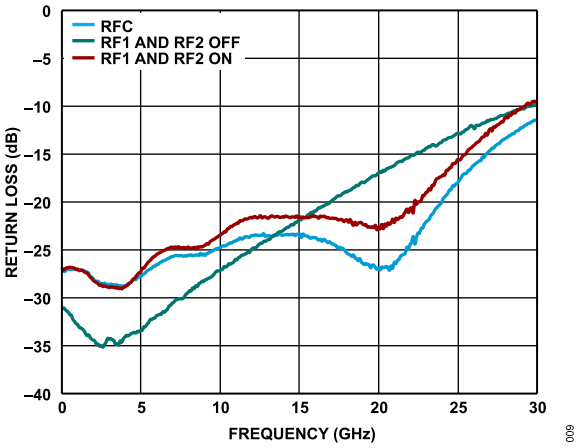


*Figure 9. Return Loss vs. Frequency for RFC and RFx (On and Off)*

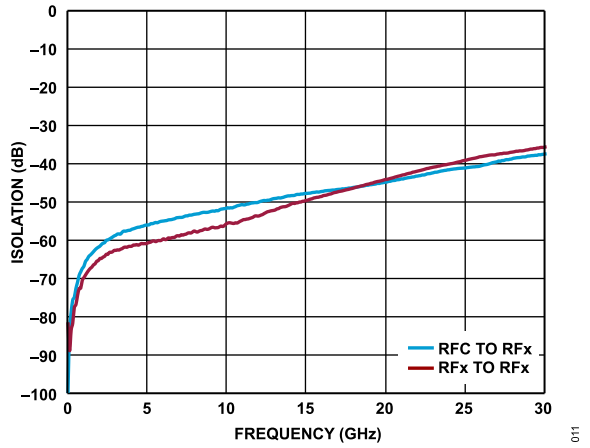


*Figure 11. Isolation vs. Frequency for RFC to RFx and RFx to RFx*

## TYPICAL PERFORMANCE CHARACTERISTICS

### INPUT POWER COMPRESSION AND THIRD-ORDER INTERCEPT

$V_{DD}$ = 3.3 V, $V_{SS}$ = −3.3 V, $V_{CTRL}$ = 0 V or $V_{DD}$, and $T_{CASE}$ = 25°C for a 50 Ω system, unless otherwise noted.

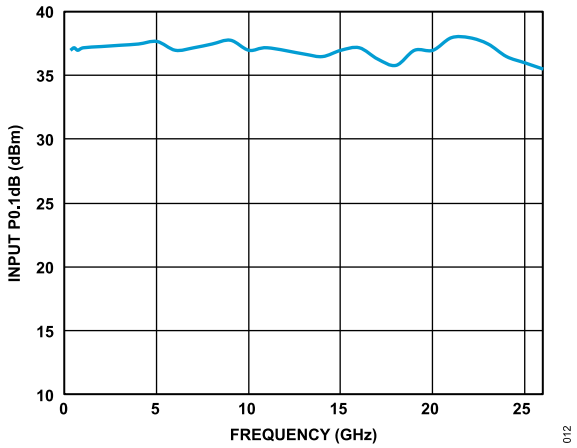


Figure 12. Input P0.1dB vs. Frequency

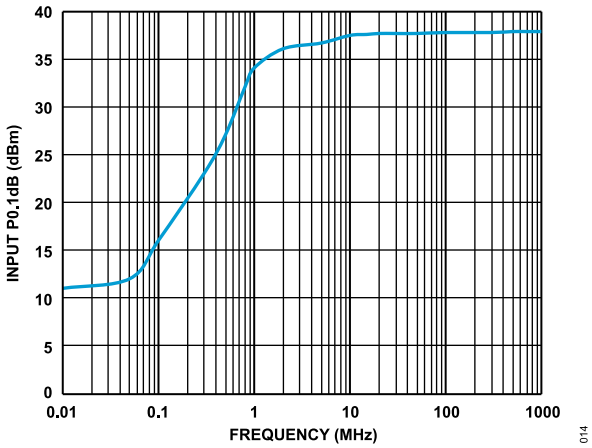


Figure 14. Input P0.1dB vs. Frequency (Low-Frequency Detail)

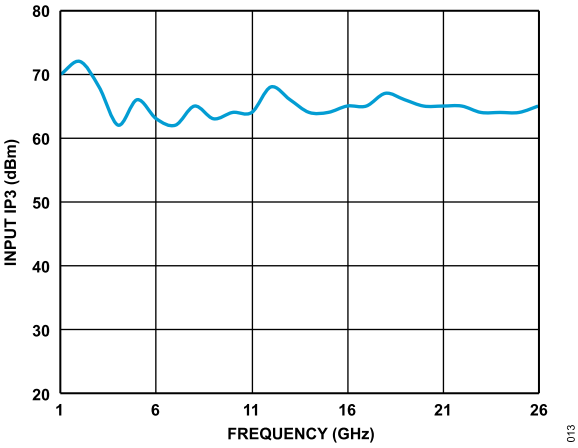


Figure 13. Input IP3 vs. Frequency

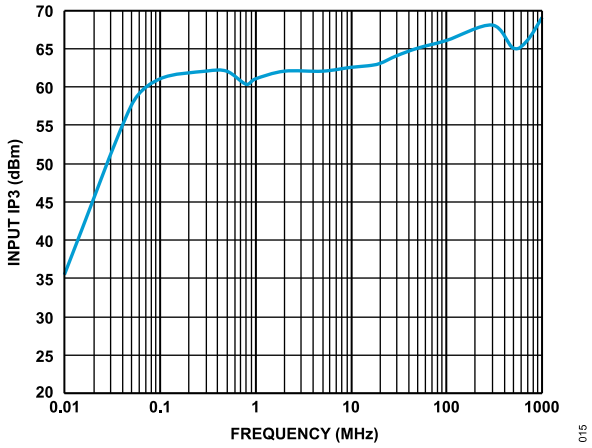


Figure 15. Input IP3 vs. Frequency (Low-Frequency Detail)

## THEORY OF OPERATION

The ADRF5031 integrates a driver to perform logic functions internally and to provide the user with the advantage of a simplified CMOS-/LVTTL-compatible control interface. There are two digital control input pins (EN and CTRL) that determine which RF port is in the insertion loss state and in the isolation state. See Table 7 for the control voltage truth table.

When the EN pin is logic high, all RF paths are in isolation state regardless of the logic state of other pin. The RFx ports are terminated to internal 50 Ω resistors, and RFC becomes reflective.

### RF INPUT AND OUTPUT

The RF ports (RFC, RF1, and RF2) are DC-coupled to 0 V, and no DC blocking is required at the RF ports when the RF line potential is equal to 0 V. The RF ports are internally matched to 50 Ω.

The ADRF5031 is bidirectional with equal power handling capabilities. The RF input signal can be applied to the RFC port or the selected RFx throw port.

The insertion loss path conducts the RF signal between the selected RFx throw port and the RFC (common) port. The isolation paths provide high loss between the insertion loss path and the unselected RFx throw port. The unselected RFx port of the ADRF5031 is nonreflective.

The power handling of the ADRF5031 derates with frequencies less than 1 MHz. See Figure 2 for derating of the RF power towards lower frequencies.

### POWER SUPPLY

The ADRF5031 requires that a positive supply voltage is applied to the $V_{DD}$ pin and a negative supply voltage to the $V_{SS}$ pin. Bypassing capacitors are recommended on the supply lines to minimize RF coupling.

The ideal power-up sequence is as follows:

1. Connect GND.
2. Power up $V_{DD}$ and $V_{SS}$. Power up $V_{SS}$ after $V_{DD}$ to avoid current transients on $V_{DD}$ during ramp up.
3. Apply digital control inputs. The relative order of the control inputs is not important. However, powering the digital control inputs before the $V_{DD}$ supply can inadvertently forward bias and damage the internal ESD protection structures. To avoid this damage, use a series 1 kΩ resistor to limit the current flowing into the control pin. Use pull-up or pull-down resistors if the controller is in a high impedance state after $V_{DD}$ is powered up, and the control pins are not driven to a valid logic state.
4. Apply RF input signal.

***Table 7. Control Voltage Truth Table***

| Digital Control Input | | RFx Paths | |
|---|---|---|---|
| **EN** | **CTRL** | **RF1 to RFC** | **RF2 to RFC** |
| Low | Low | Isolation (off) | Insertion loss (on) |
| Low | High | Insertion loss (on) | Isolation (off) |
| High | Low or high | Isolation (off) | Isolation (off) |

## APPLICATIONS INFORMATION

The ADRF5031 has two power supply pins ($V_{DD}$ and $V_{SS}$) and two control pins (EN and CTRL). Figure 16 shows the external components and connections for the supply pins. The VDD and VSS pins are decoupled with a 100 pF capacitor. The pinout of the ADRF5031 allows the placement of the decoupling capacitors close to the device. No other external components are needed for bias and operation, except for DC-blocking capacitors on the RFx and RFC pins when the RF lines are biased at a voltage other than 0 V. See Table 6 for further details.

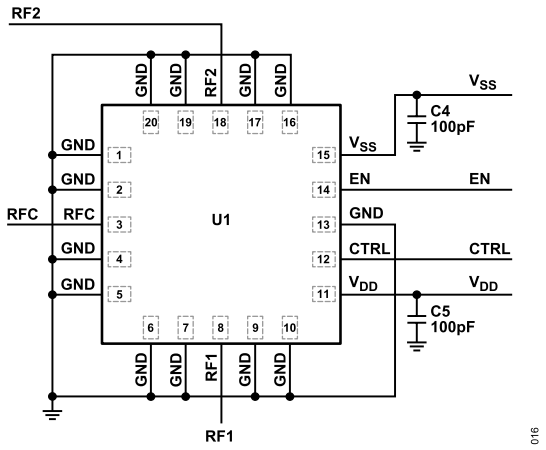


*Figure 16. Recommended Schematic*

## RECOMMENDATIONS FOR PCB DESIGN

The RF ports are matched to 50 Ω internally, and the pinout is designed to mate a coplanar waveguide (CPWG) with a 50 Ω characteristic impedance on the PCB. Figure 17 shows the referenced CPWG RF trace design for an RF substrate with 8 mil thick Rogers RO4003C dielectric material. A RF trace with a 14 mil width and 7 mil clearance is recommended for 1.5 mil finished copper thickness.

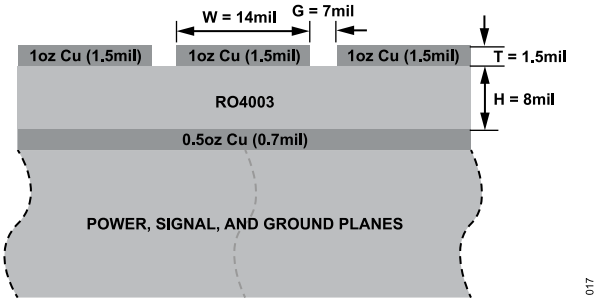


*Figure 17. Example PCB Stack-Up*

Figure 18 shows the routing of the RF traces, supply, and control signals from the ADRF5031. The ground planes are connected with densely filled through vias for optimal RF and thermal performance. The primary thermal path for the ADRF5031 is the bottom side.

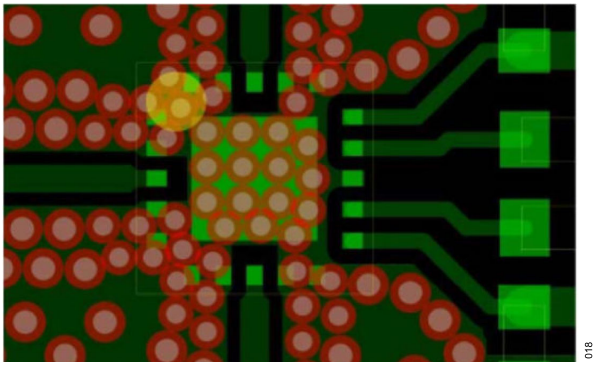


*Figure 18. PCB Layout*

Figure 19 shows the recommended layout from the RF pins of the ADRF5031 to the 50 Ω CPWG on the referenced stack-up. PCB pads are drawn 1:1 to the pads of the ADRF5031. The ground pads are drawn solder mask defined, and the signal pads are drawn as pad defined. The RF trace from the PCB pad is extended with the same width to the package edge and tapered to RF trace. The paste mask is designed to match the pads of the ADRF5031 without any aperture reduction. The paste mask is divided into multiple openings for the paddle.

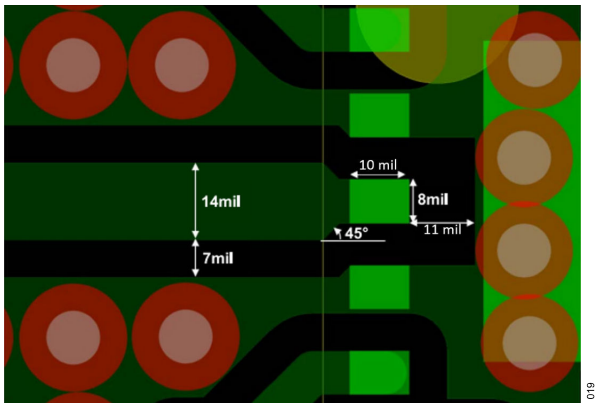


*Figure 19. Recommended RF Pin Transition*

For alternate PCB stack-ups with different dielectric thickness and RF trace design, contact Analog Devices Technical Support for further recommendations.

## OUTLINE DIMENSIONS

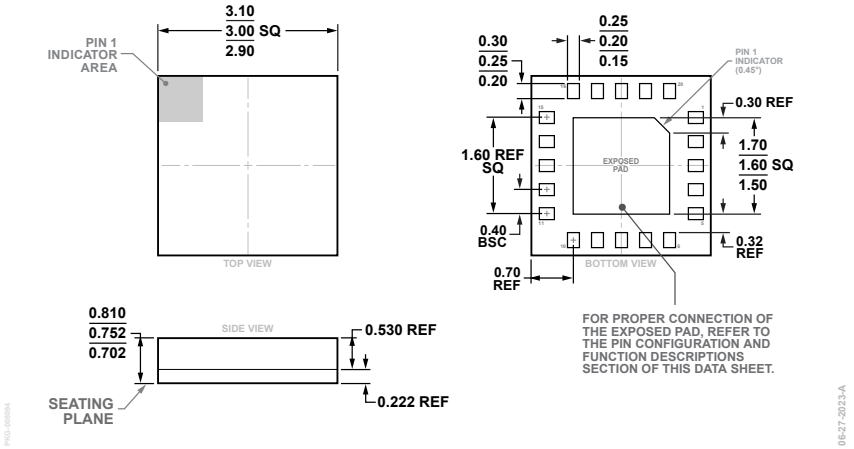


*Figure 20. 20-Terminal Land Grid Array [LGA]*
*(CC-20-21)*
*Dimensions shown in millimeters*

## ORDERING GUIDE

| Model[1] | Temperature Range | Package Description | Package Quantity | Package Option |
|---|---|---|---|---|
| ADRF5031BCCZN | −40°C to +105°C | 20-Terminal Land Grid Array [LGA] | Reel, 500 | CC-20-21 |
| ADRF5031BCCZN-R7 | −40°C to +105°C | 20-Terminal Land Grid Array [LGA] | Reel, 500 | CC-20-21 |

[1] Z = RoHS-Compliant Part.

## EVALUATION BOARDS

*Table 8. Evaluation Boards*

| Model[1] | Description |
|---|---|
| ADRF5031-EVALZ | Evaluation Board |

[1] Z = RoHS-Compliant Part.