Silicon SPDT Switch, Nonreflective, 9 kHz to 44 GHz

Data Sheet

ADRF5027

FEATURES

- Ultrawideband frequency range: 9 kHz to 44 GHz
- Nonreflective design
- Low insertion loss
  - 1.1 dB to 18 GHz
  - 1.5 dB to 26 GHz
  - 2.2 dB to 40 GHz
  - 3.8 dB to 44 GHz
- High isolation
  - 53 dB to 18 GHz
  - 48 dB to 26 GHz
  - 48 dB to 40 GHz
  - 43 dB to 44 GHz
- High input linearity
  - P1dB: 26 dBm typical
  - IP3: 54 dBm typical
- High power handling
  - 24 dBm insertion loss path
  - 24 dBm isolation path
- All off state control
- No low frequency spurious signals
- 0.1 dB RF settling time: 6.0 µs typical
- 20-terminal, 3 mm × 3 mm LGA package
- Pin compatible with ADRF5026, fast switching version

APPLICATIONS

- Industrial scanners
- Test and instrumentation
- Cellular infrastructure: 5G mmWave
- Military radios, radars, electronic counter measures (ECMs)
- Microwave radios and very small aperture terminals (VSATs)

FUNCTIONAL BLOCK DIAGRAM

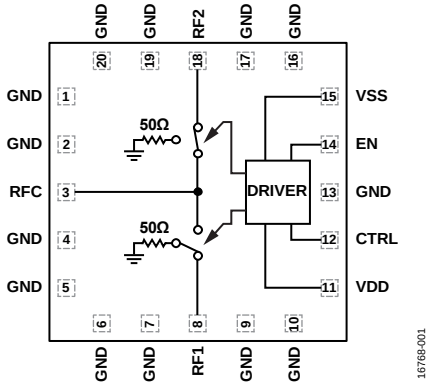


Figure 1.

GENERAL DESCRIPTION

The ADRF5027 is a nonreflective, single-pole, double-throw (SPDT) radio frequency (RF) switch manufactured in a silicon process.

The ADRF5027 operates from 9 kHz to 44 GHz with better than 3.8 dB of insertion loss and 43 dB of isolation. The ADRF5027 features an all off control, where both RF ports are in an isolation state. The ADRF5027 has a nonreflective design and both of the RF ports are internally terminated to 50 Ω.

The ADRF5027 requires a dual-supply voltage of +3.3 V and −3.3 V. The device employs complimentary metal-oxide semiconductor/low-voltage transistor-transistor logic (CMOS/LVTTL) logic-compatible controls.

The ADRF5027 is pin compatible with the ADRF5026 fast switching version, which operates from 100 MHz to 44 GHz.

The ADRF5027 RF ports are designed to match a characteristic impedance of 50 Ω. For ultrawideband products, impedance matching on the RF transmission lines can further optimize high frequency insertion loss and return loss characteristics. Refer to the Narrow-Band Impedance Matching section for an example of a matched circuit that achieves a low insertion loss response of 2.2 dB from 28 GHz to 43 GHz.

The ADRF5027 comes in a 20-terminal, 3 mm × 3 mm, RoHS-compliant, land grid array (LGA) package and can operate from −40°C to +105°C.

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REVISION HISTORY

7/2018—Revision 0: Initial Version

SPECIFICATIONS

ELECTRICAL SPECIFICATIONS

VDD = 3.3 V, VSS = −3.3 V, V_{CTRL}/V_{EN} = 0 V or VDD, and T_{CASE} = 25°C in a 50 Ω system, unless otherwise noted.

Table 1.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
FREQUENCY RANGE			0.009		44,000	MHz
INSERTION LOSS	IL					
Between RFC and RF1/RF2		9 kHz to 18 GHz		1.1		dB
		18 GHz to 26 GHz		1.5		dB
		26 GHz to 35 GHz		1.9		dB
		35 GHz to 40 GHz		2.2		dB
		40 GHz to 44 GHz[1]		3.8		dB
RETURN LOSS	RL					
RFC and RF1/RF2 (On)		9 kHz to 18 GHz		18		dB
		18 GHz to 26 GHz		14		dB
		26 GHz to 35 GHz		14		dB
		35 GHz to 40 GHz		12		dB
		40 GHz to 44 GHz[1]		7		dB
RF1/RF2 (Off)		9 kHz to 18 GHz		28		dB
		18 GHz to 26 GHz		28		dB
		26 GHz to 35 GHz		17		dB
		35 GHz to 40 GHz		13		dB
		40 GHz to 44 GHz[1]		10		dB
ISOLATION						
Between RFC and RF1/RF2		9 kHz to 18 GHz		53		dB
		18 GHz to 26 GHz		48		dB
		26 GHz to 35 GHz		48		dB
		35 GHz to 40 GHz		48		dB
		40 GHz to 44 GHz		43		dB
Between RF1 and RF2		9 kHz to 18 GHz		60		dB
		18 GHz to 26 GHz		60		dB
		26 GHz to 35 GHz		60		dB
		35 GHz to 40 GHz		60		dB
		40 GHz to 44 GHz		50		dB
SWITCHING CHARACTERISTICS						
Rise and Fall Time	t_{RISE}, t_{FALL}	10% to 90% of RF output		1.3		µs
On and Off Time	t_{ON}, t_{OFF}	50% of triggered V_{CTRL} to 90% of RF output		3.6		µs
RF Settling Time						
0.1 dB		50% of triggered V_{CTRL} to 0.1 dB of final RF output		6.0		µs
0.05 dB		50% of triggered V_{CTRL} to 0.05 dB of final RF output		7.5		µs
INPUT LINEARITY[2]		200 kHz to 40 GHz				
1 dB Compression	P1dB			26		dBm
Third-Order Intercept	IP3	Two-tone input power = 12 dBm each tone, Δf = 1 MHz		54		dBm
SUPPLY CURRENT		VDD and VSS pins				
Positive	I_{DD}			2		µA
Negative	I_{SS}			100		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 and High Current	I_{INL}, I_{INH}			<1		µA

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
RECOMMENDED OPERATING CONDITONS						
Supply Voltage						
Positive	V_{DD}		3.15		3.45	V
Negative	V_{SS}		−3.45		−3.15	V
Digital Control Voltage	V_{CTRL}, V_{EN}		0		V_{DD}	V
RF Input Power[3]	P_{IN}	f = 200 kHz to 40 GHz, T_{CASE} = 85°C[4]				
Insertion Loss Path		RF signal is applied to the RFC or through connected RF1/RF2			24	dBm
Isolation Path		RF signal is applied to terminated RF1/RF2			24	dBm
Hot Switching		RF signal is present at the RFC while switching between RF1 and RF2			24	dBm
Case Temperature	T_{CASE}		−40		+105	°C

[1] Impendence matching on RF transmission lines improves high frequency performance. Refer to the Applications Information section for more information.
[2] For input linearity performance vs. frequency, see Figure 11 and Figure 13.
[3] For power derating vs. frequency, see Figure 2 and Figure 3. This power derating is applicable for insertion loss path, isolation path, and hot switching power specifications.
[4] For 105°C operation, the power handling degrades from the T_{CASE} = 85°C specification by 3 dB.

ABSOLUTE MAXIMUM RATINGS

For recommended operating conditions, see Table 1.

Table 2.

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 Voltage	−0.3 V to VDD +0.3 V
RF Input Power[1] (200 kHz to 40 GHz at T_{CASE} = 85°C[2])	
Insertion Loss Path	26 dBm
Isolation Path	25 dBm
Hot Switching	25 dBm
Temperature	
Junction, T_J	135°C
Storage Range	−65°C to +150°C
Reflow	260°C
Electrostatic Discharge (ESD) Sensitivity	
Human Body Model (HBM)	
RFC, RF1, RF2 Pins	1500 V
Digital Pins	2000 V
Charged Device Model (CDM)	1250 V

[1] For power derating vs. frequency, see Figure 2 and Figure 3. This power derating is applicable for insertion loss path, isolation path, and hot switching power specifications.
[2] For 105°C operation, the power handling degrades from the T_{CASE} = 85°C specification by 3 dB.

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.

θ_{JC} is the junction to case bottom (channel to package bottom) thermal resistance.

Table 3. Thermal Resistance

Package Type	θ_{JC}	Unit
CC-20-3		
Through Path	423	°C/W
Terminated Path	241	°C/W

POWER DERATING CURVES

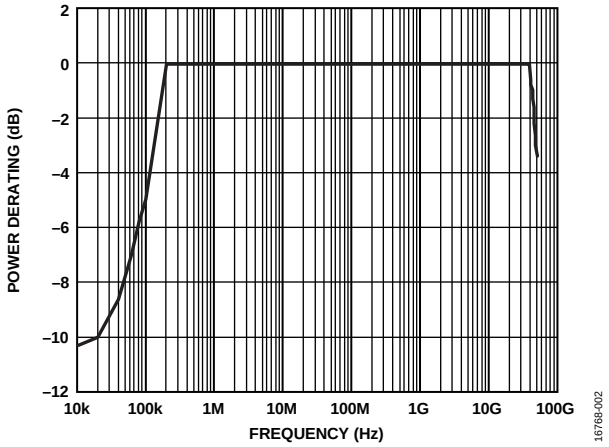


Figure 2. Power Derating vs. Frequency, Low Frequency Detail, T_{CASE} = 85°C

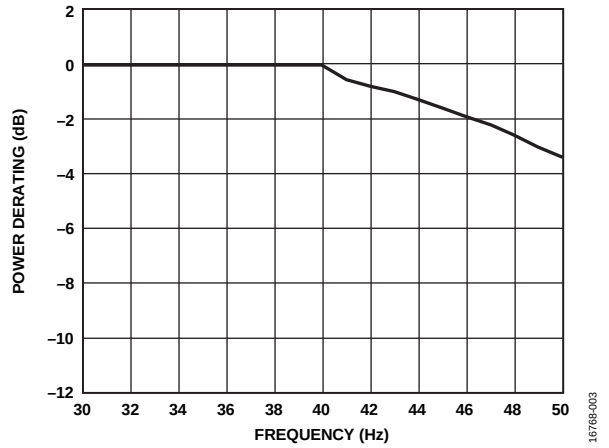


Figure 3. Power Derating vs. Frequency, High Frequency Detail, T_{CASE} = 85°C

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

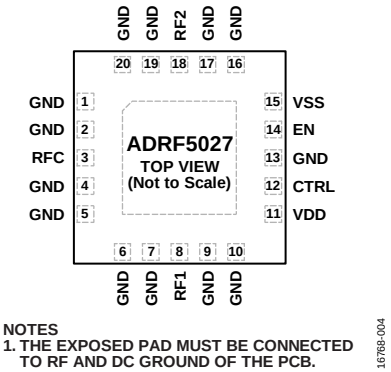


Figure 4. Pin Configuration

Table 4. Pin Function Descriptions

Pin No.	Mnemonic	Description
1, 2, 4, 5, 6, 7, 9, 10, 13, 16, 17, 19, 20	GND	Ground. These pins must be connected to the RF and dc ground of the PCB.
3	RFC	RF Common Port. This pin is dc-coupled to 0 V and ac matched to 50 Ω. No dc blocking capacitor is necessary when the RF line potential is equal to 0 V dc. See Figure 5 for the interface schematic.
8	RF1	RF1 Port. This pin is dc-coupled to 0 V and ac matched to 50 Ω. No dc blocking capacitor is necessary when the RF line potential is equal to 0 V dc. See Figure 5 for the interface schematic.
11	VDD	Positive Supply Voltage.
12	CTRL	Control Input Voltage. See Table 5 for the truth table. See Figure 6 for the interface schematic.
14	EN	Enable Input Voltage. See Table 5 for the truth table. See Figure 6 for the interface schematic.
15	VSS	Negative Supply Voltage.
18	RF2	RF2 Port. This pin is dc-coupled to 0 V and ac matched to 50 Ω. No dc blocking capacitor is necessary when the RF line potential is equal to 0 V dc. See Figure 5 for the interface schematic.
	EPAD	Exposed Pad. The exposed pad must be connected to the RF and dc ground of the PCB.

INTERFACE SCHEMATICS

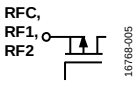


Figure 5. RFC, RF1, RF2 Interface Schematic

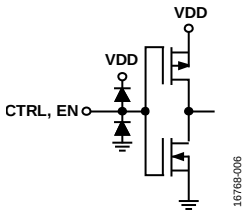


Figure 6. CTRL, EN Interface Schematic

TYPICAL PERFORMANCE CHARACTERISTICS

INSERTION LOSS, RETURN LOSS, AND ISOLATION

VDD = 3.3 V, VSS = −3.3 V, V_{CTRL}/V_{EN} = 0 V or VDD, and T_{CASE} = 25°C in a 50 Ω system, unless otherwise noted.

Insertion loss and return loss are measured on the probe matrix board using ground-signal-ground (GSG) probes close to the RFx pins. Signal coupling between the probes limits the isolation performance of ADRF5027. Isolation is measured on the ADRF5027-EVALZ evaluation board. See the Applications Information section for details on the ADRF5027-EVALZ evaluation board and probe matrix board.

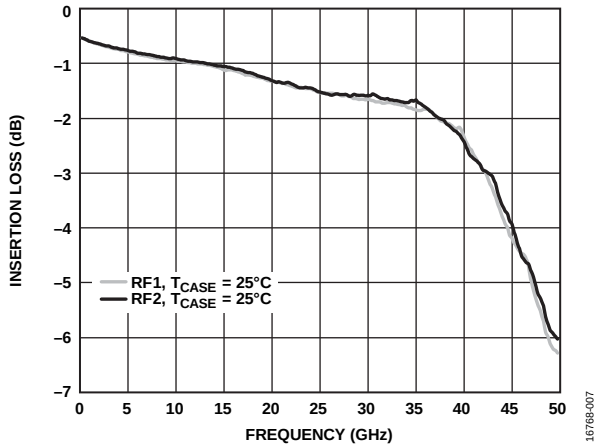


Figure 7. Insertion Loss vs. Frequency at Room Temperature for RF1 and RF2

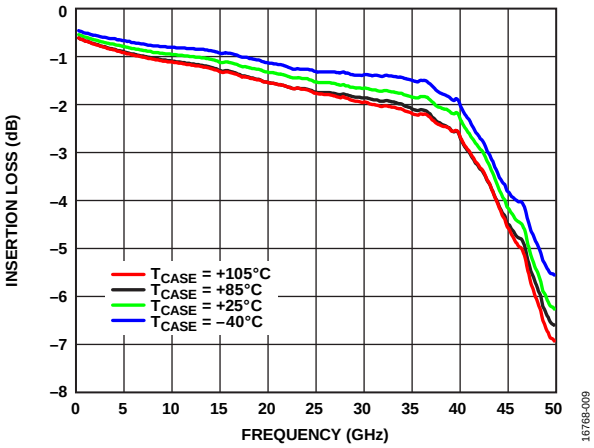


Figure 9. Insertion Loss vs. Frequency over Temperature

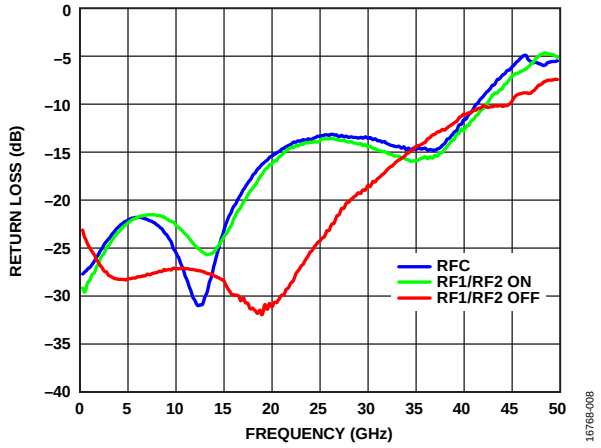


Figure 8. Return Loss vs. Frequency

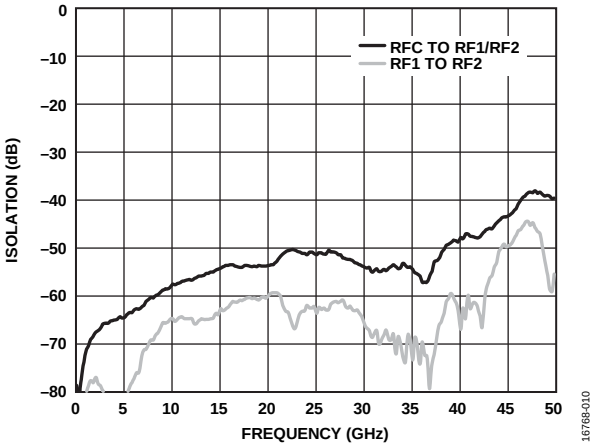


Figure 10. Isolation vs. Frequency

INPUT POWER COMPRESSIONS AND THIRD-ORDER INTERCEPT

VDD = 3.3 V, VSS = −3.3 V, V_{CTRL}/V_{EN} = 0 V or VDD, and T_{CASE} = 25°C in a 50 Ω system, unless otherwise noted. All of the large signal performance parameters are measured on the ADRF5027-EVALZ evaluation board.

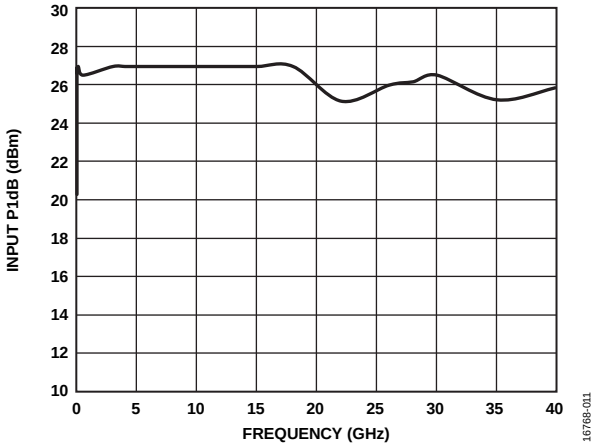


Figure 11. Input P1dB vs. Frequency

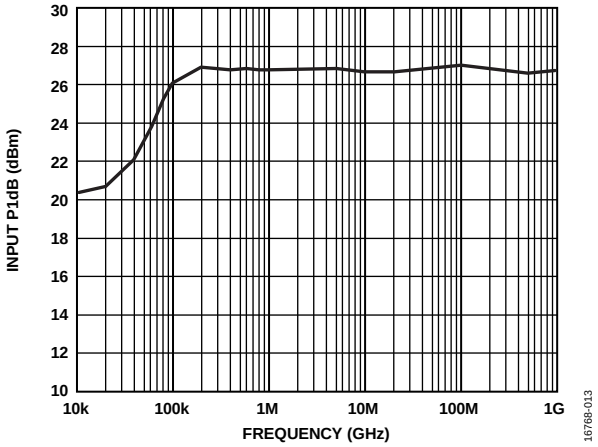


Figure 13. Input P1dB vs. Frequency (Low Frequency Detail)

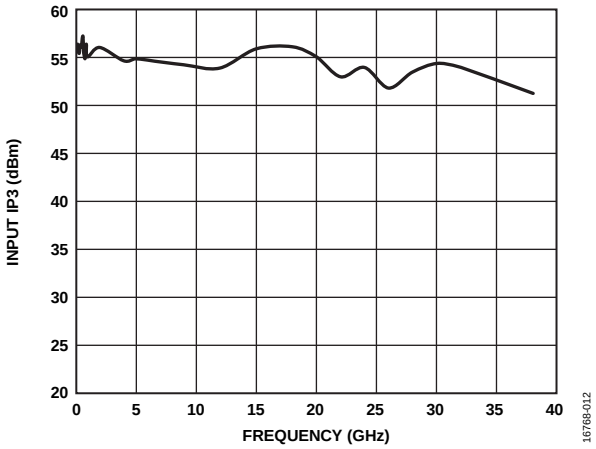


Figure 12. Input IP3 vs. Frequency

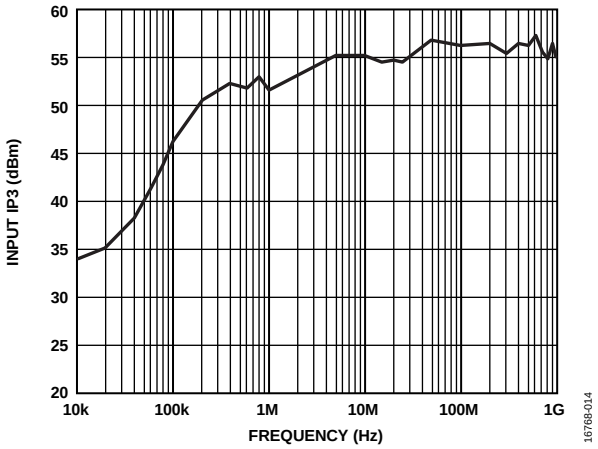


Figure 14. Input IP3 vs. Frequency (Low Frequency Detail)

THEORY OF OPERATION

The ADRF5027 requires a positive supply voltage applied to the VDD pin and a negative supply voltage applied to the VSS pin. Bypassing capacitors are recommended on the supply lines to filter high frequency noise.

All of the RF ports (RFC, RF1, and RF2) are dc-coupled to 0 V, and no dc blocking capacitors are required at the RF ports when the RF potential is equal to 0 V.

The RF ports are internally matched to 50 Ω. Therefore, external matching networks are not required. Impedance matching on the RF transmission lines can improve insertion loss and return loss performance at high frequencies.

The ADRF5027 integrates a driver to perform logic function internally and to provide the advantage of a simplified control interface. The driver features two digital control input pins, CTRL and EN. When the EN pin is logic low, the logic level applied to the CTRL pin determines which RF port is in insertion loss state and which RF port is in isolation state.

The ADRF5027 supports an all off state control. When the EN pin is logic high, both the RF1 to RFC path and the RF2 to RFC path are in an isolation state, regardless of the logic state of the CTRL pin. The RF1 and RF2 ports are terminated to internal 50 Ω resistors, and the RFC port becomes open reflective (see Table 5).

The ADRF5027 design is bidirectional with equal power handling capabilities. An RF input signal (RF_{IN}) can be applied to the RFC port or the RF1 or RF2 port. The isolation path provides high loss between the unselected RFx port and the insertion loss path.

The power-up sequence is as follows:

1. Power up GND.
2. Power up VDD.
3. Power up VSS.
4. Power up the digital control inputs. The relative order of the logic control inputs is not important. Powering up the digital control inputs before the VDD supply can inadvertently forward bias and damage the internal ESD protection structures.
5. Apply an RF input signal.

The power-down sequence is the reverse order of the power-up sequence.

Table 5. Control Voltage Truth Table

Digital Control Input		RF 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	Isolation (off)	Isolation (off)
High	High	Isolation (off)	Isolation (off)

APPLICATIONS INFORMATION

EVALUATION BOARD

The ADRF5027-EVALZ evaluation board is a 4-layer evaluation board. The outer copper (Cu) layers are 0.5 oz (0.7 mil) plated to 1.5 oz (2.2 mil) and are separated by dielectric materials. Figure 15 shows the ADRF5027-EVALZ evaluation board stack up.

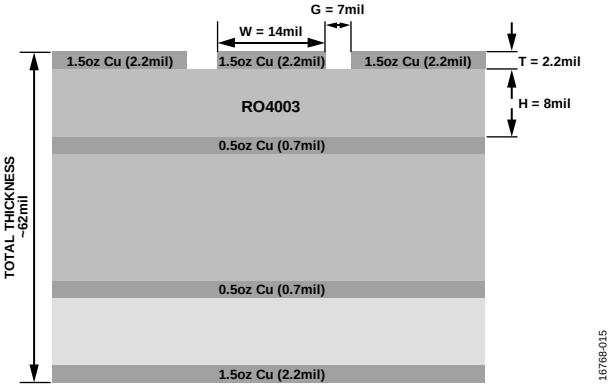


Figure 15. Evaluation Board Stack Up

All RF and dc traces are routed on the top copper layer, whereas the inner and bottom layers are ground planes that provide a solid ground for the RF transmission lines. The top dielectric material is 8 mil Rogers RO4003, which offers optimal high frequency performance. The middle and bottom dielectric materials provide mechanical strength. The overall board thickness is 62 mil, which allows 2.4 mm RF launchers to be connected at the board edges.



Figure 16. Evaluation Board Layout

The RF transmission lines are designed using a coplanar waveguide (CPWG) model with a width of 14 mil and a ground spacing of 7 mil, and have a characteristic impedance of 50 Ω. For optimal RF and thermal grounding, as many plated through vias as possible are arranged around transmission lines and under the exposed pad of the package.

The RF input and output ports (RFC, RF1, and RF2) are connected through 50 Ω transmission lines to the 2.4 mm launchers (J1, J2, and J3, respectively). These high frequency RF launchers are connected by contact and are not soldered to the board.

The thru calibration line, THRU CAL, can calibrate out the board loss effects from the ADRF5027-EVALZ evaluation board measurements to determine the device performance at the pins of the IC. Figure 17 shows the typical board loss for the ADRF5027-EVALZ evaluation board at room temperature, the embedded insertion loss, and the de-embedded insertion loss for the ADRF5027.

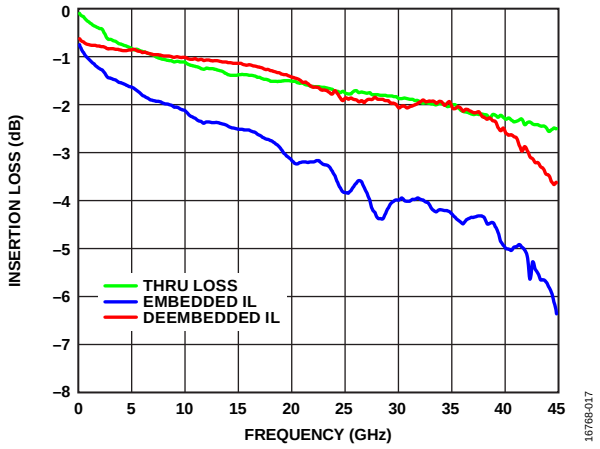


Figure 17. Insertion Loss vs. Frequency

Two power supply ports are connected to the VDD and VSS test points, and the ground reference is connected to the GND test point. On the supply traces, VDD and VSS, a 100 pF bypass capacitor filters high frequency noise. Additionally, unpopulated component positions are available for applying extra bypass capacitors.

Two control ports are connected to the EN and CTRL test points. There are provisions for the resistor capacitor (RC) filter to eliminate dc-coupled noise, if needed by the application.

The ADRF5027-EVALZ evaluation board schematic is shown in Figure 18.

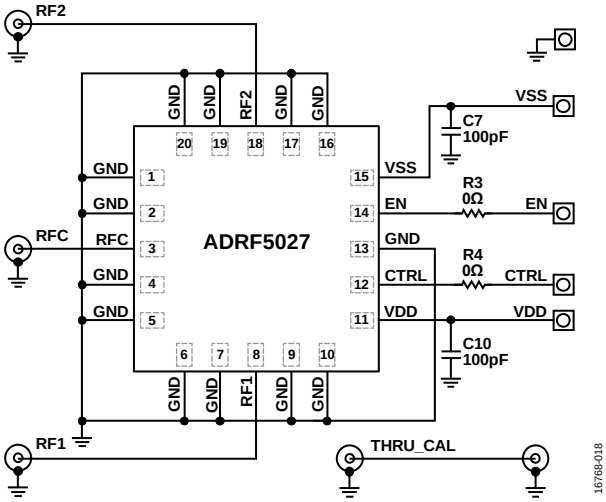


Figure 18. Simplified Evaluation Board Schematic

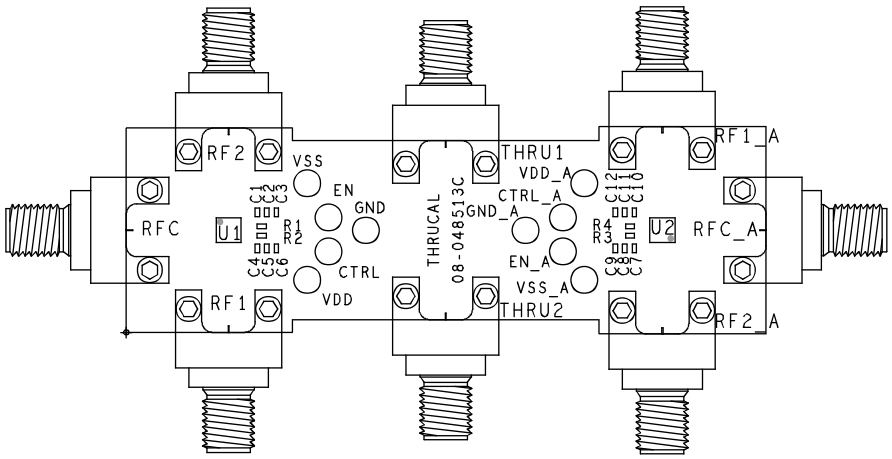


Figure 19. Evaluation Board Component Placement

Table 6. Evaluation Board Components

Component	Description
RF1_A, RFC_A, RF2_A	End launch connectors, 2.4 mm
VDD_A, VSS_A, CTRL_A, EN_A, GND_A	Through-hole mount test points
C7, C10	100 pF capacitors, 0402 package
R3, R4	0 Ω resistors, 0402 package
U2	ADRF5027 SPDT switch

PROBE MATRIX BOARD

The probe matrix board is a 4-layer board. This board also uses an 8 mil Rogers RO4003 dielectric. The outer copper layers are 0.5 oz (0.7 mil) plated to 1.5 oz (2.2 mil). The RF transmission lines were designed using a CPWG model with a width of 14 mil and a ground spacing of 7 mil to have a characteristic impedance of 50 Ω.

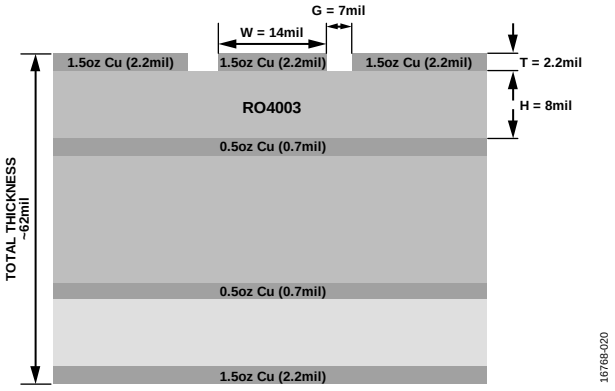


Figure 20. Probe Matrix Board Stack Up

Figure 20 and Figure 21 show the stack up and the layout, respectively, of the probe matrix board. Measurements are made using GSG probes at close proximity to the RF pins. Probing reduces the reflections caused by mismatch arising from connectors, cables, and board layout, resulting in a more accurate measurement of insertion loss and return loss. Signal coupling between the RF probes limits the isolation measurement.

The ADRF5027-EVALZ evaluation board is used for making isolation measurements.

RF traces for a through-reflect-line (TRL) calibration are designed on the probe matrix board. Board loss is compensated for by using a nonzero line length at calibration. The actual board duplicates the same layout in matrix form, which allows multiple devices to assemble at once. Insertion loss and return loss measurements are made on this board, while isolation measurements are made on the ADRF5027-EVALZ evaluation board.

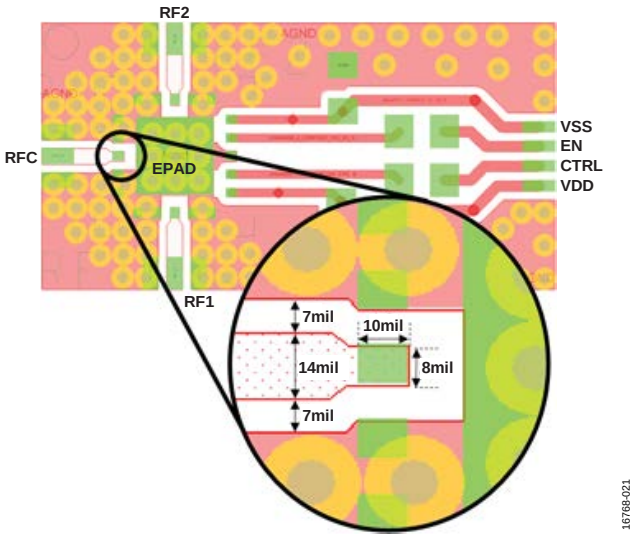


Figure 21. Probe Matrix Board Layout

Narrow-Band Impedance Matching

5G mmWave Frequencies

Narrow-band impedance matching on the RF transmission lines can improve return loss and insertion loss for a targeted frequency range. The impedance matched circuit, highlighted in Figure 22, achieves a low insertion loss response of 2.2 dB from 28 GHz to 43 GHz (see Figure 23). The dimensions of the 50 Ω lines are 14 mil trace width and a 7 mil gap. To implement this impedance matched circuit, an 8 mil trace with a width of 5 mil is inserted between the pin pad and the 50 Ω trace.

Table 7, Figure 23, Figure 24, and Figure 25 show the measured performance of ADRF5027 on the impedance matched circuit on the probe matrix board.

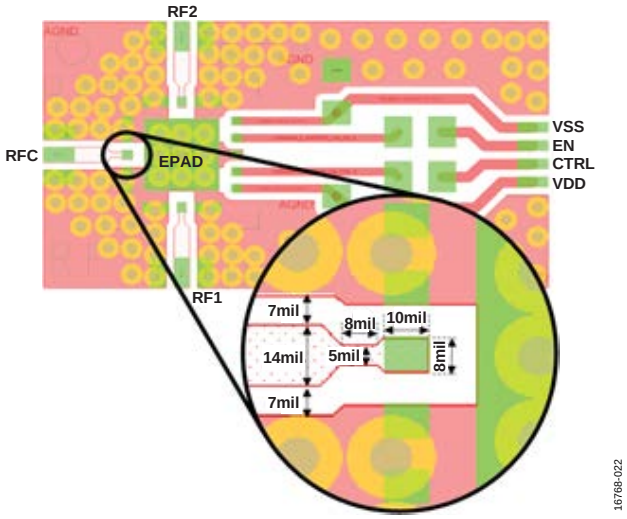


Figure 22. Impedance Matched Circuit

Table 7. Impedance Matched Parameters

Parameter	Test Condition	Typ	Unit
Insertion Loss	See Figure 23		
Between RFC and RF1/RF2	9 kHz to 18 GHz	1.1	dB
	18 GHz to 26 GHz	1.8	dB
	26 GHz to 35 GHz	2.3	dB
	35 GHz to 40 GHz	2.2	dB
	40 GHz to 44 GHz	2.7	dB
Return Loss	See Figure 24		
RFC and RF1/RF2 (On)	9 kHz to 18 GHz	20	dB
	18 GHz to 26 GHz	8	dB
	26 GHz to 35 GHz	7	dB
	35 GHz to 40 GHz	10	dB
	40 GHz to 44 GHz	14	dB
RF1/RF2 (Off)	See Figure 24		
	9 kHz to 18 GHz	25	dB
	18 GHz to 26 GHz	23	dB
	26 GHz to 35 GHz	17	dB
	35 GHz to 40 GHz	11	dB
	40 GHz to 44 GHz	7	dB

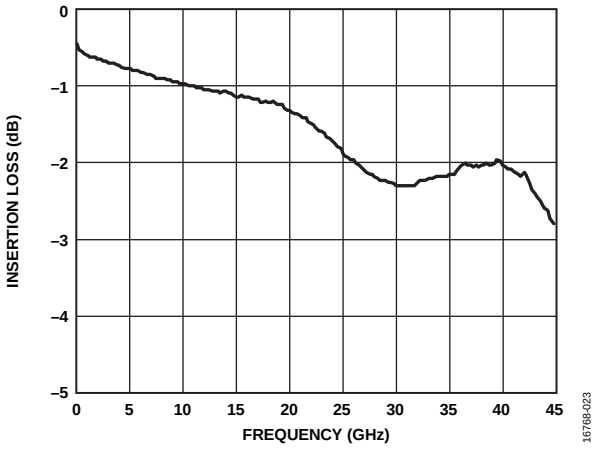


Figure 23. Insertion Loss vs. Frequency, with Impedance Matching

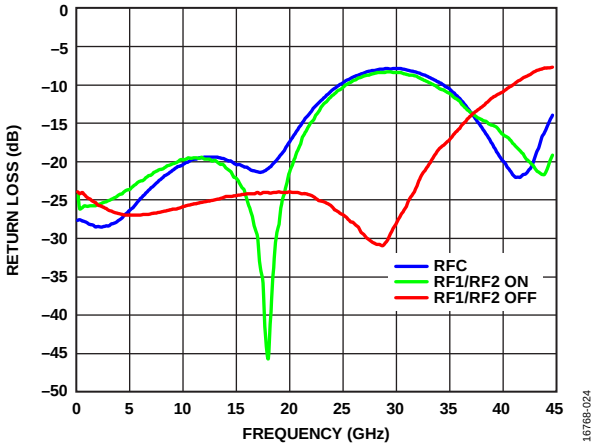


Figure 24. Return Loss vs. Frequency, with Impedance Matching

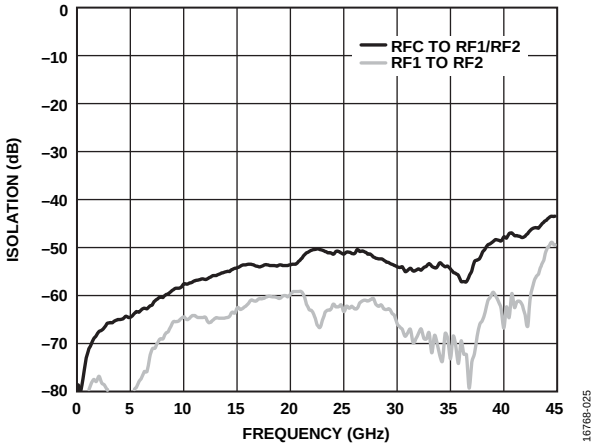


Figure 25. Isolation vs. Frequency, with Impedance Matching

OUTLINE DIMENSIONS

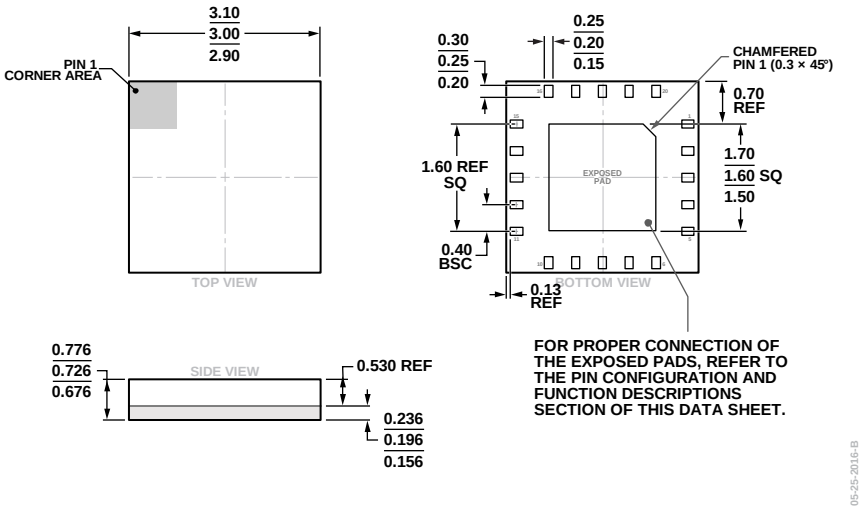


Figure 26. 20-Terminal Land Grid Array [LGA]
3 mm × 3 mm Body and 0.726 mm Package Height
(CC-20-3)
Dimensions shown in millimeters

ORDERING GUIDE

Model[1]	Temperature Range	Package Description	Package Option	Marking Code
ADRF5027BCCZN	−40°C to +105°C	20-Terminal Land Grid Array [LGA]	CC-20-3	027
ADRF5027BCCZN-R7	−40°C to +105°C	20-Terminal Land Grid Array [LGA]	CC-20-3	027
ADRF5027-EVALZ		Evaluation Board		

[1] Z = RoHS Compliant Part.

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