



50 MHz to 750 MHz CASCADEABLE AMPLIFIER

Check for Samples: [THS9000](#)

FEATURES

- **High Dynamic Range**
 - $OIP_3 = 36 \text{ dBm}$
 - $NF < 4.5 \text{ dB}$
- **Single-Supply Voltage**
- **High Speed**
 - $V_S = 3 \text{ V to } 5 \text{ V}$
 - $I_S = \text{Adjustable}$
- **Input/Output Impedance**
 - 50Ω

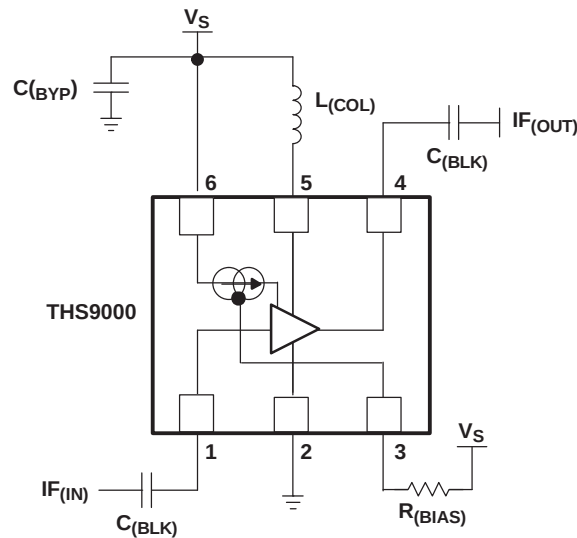
APPLICATIONS

- **IF Amplifiers**
 - TDMA: GSM, IS-136, EDGE/UWE-136
 - CDMA: IS-95, UMTS, CDMA2000
 - Wireless Local Loops
 - Wireless LAN: IEEE802.11

DESCRIPTION

The THS9000 is a medium power, cascadeable, gain block optimized for high IF frequencies. The amplifier incorporates internal impedance matching to 50Ω . The part mounted on the standard EVM achieves greater than 15-dB input and output return loss from 50 MHz to 325 MHz with $V_S = 5 \text{ V}$, $R_{(BIAS)} = 237 \Omega$, $L_{(COL)} = 470 \text{ nH}$. Design requires only two dc-blocking capacitors, one power-supply bypass capacitor, one RF choke, and one bias resistor.

Figure 1. FUNCTIONAL BLOCK DIAGRAM



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments Incorporated.
All other trademarks are the property of their respective owners.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

AVAILABLE OPTIONS

PACKAGED DEVICE ⁽¹⁾	PACKAGE TYPE	TRANSPORT MEDIA, QUANTITY
THS9000DRWT	2 × 2 QFN ⁽²⁾	Tape and Reel, 250
THS9000DRWR		Tape and Reel, 3000

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at www.ti.com.
 (2) The PowerPAD™ is electrically isolated from all other pins.

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature (unless otherwise noted)⁽¹⁾

	THS9000	UNIT
Supply voltage, GND to V _S	5.5	V
Input voltage	GND to V _S	
Continuous power dissipation	See Dissipation Rating table	
Maximum junction temperature, T _J	+150	°C
Maximum junction temperature, continuous operation, long term reliability, T _J ⁽²⁾	+125	°C
Storage temperature, T _{stg}	–65 to +150	°C
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds	+300	°C
ESD Ratings:	HBM	2000
	CDM	1500
	MM	100

- (1) The absolute maximum ratings under any condition is limited by the constraints of the silicon process. Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
 (2) The maximum junction temperature for continuous operation is limited by package constraints. Operation above this temperature may result in reduced reliability and/or lifetime of the device.

DISSIPATION RATING TABLE

PACKAGE	θ_{JA} (°C/W)	POWER RATING ⁽¹⁾	
		T _A ≤ +25°C	T _A = +85°C
DRW ^{(2) (3)}	91	1.1 W	440 mW

- (1) Power rating is determined with a junction temperature of +125°C. Thermal management of the final PCB should strive to keep the junction temperature at or below +125°C for best performance.
 (2) This data was taken using the JEDEC standard High-K test PCB.
 (3) The THS9000 incorporates a PowerPAD on the underside of the chip. This acts as a heatsink and must be connected to a thermally dissipating plane for proper power dissipation. Failure to do so may result in exceeding the maximum junction temperature, which could permanently damage the device. See TI Technical Brief [SLMA002](#) for more information about utilizing the PowerPAD thermally-enhanced package.

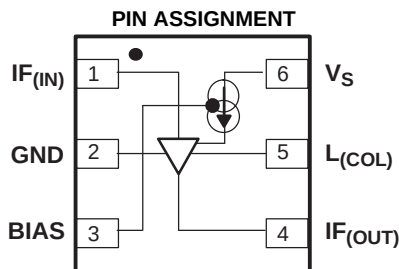
RECOMMENDED OPERATING CONDITIONS

	MIN	NOM	MAX	UNIT
Supply voltage	2.7		5	V
Operating free-air temperature, T _A	–40		+85	°C
Supply current		100		mA

ELECTRICAL CHARACTERISTICS

Typical Performance ($V_S = 5\text{ V}$, $R_{\text{BIAS}} = 237\ \Omega$, $L_{\text{(COL)}} = 470\text{ nH}$) (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Gain	$f = 50\text{ MHz}$		15.9		dB
	$f = 350\text{ MHz}$		15.6		
OIP ₃	$f = 50\text{ MHz}$		36		dBm
	$f = 350\text{ MHz}$		35		
1-dB compression	$f = 50\text{ MHz}$		20.8		dBm
	$f = 350\text{ MHz}$		20.6		
Input return loss	$f = 50\text{ MHz}$		15		dB
	$f = 350\text{ MHz}$		19.7		
Output return loss	$f = 50\text{ MHz}$		17.2		dB
	$f = 350\text{ MHz}$		15.1		
Reverse isolation	$f = 50\text{ MHz}$		21		dB
	$f = 350\text{ MHz}$		20		
Noise figure	$f = 50\text{ MHz}$		3.6		dB
	$f = 350\text{ MHz}$		4		



Terminal Functions

PIN NUMBERS	NAME	DESCRIPTION
1	IF _(IN)	Signal input
2	GND	Negative power-supply input
3	BIAS	Bias current adjustment input
4	IF _(OUT)	Signal output
5	L _(COL)	Output transistor load inductor
6	V _S	Positive power-supply input

SIMPLIFIED SCHEMATIC

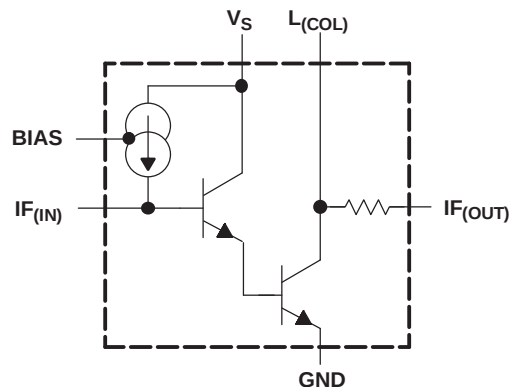


TABLE OF GRAPHS

	FIGURE
S21 Frequency response	1
S22 Frequency response	2
S11 Frequency response	3
S12 Frequency response	4
S21 vs $R_{(Bias)}$	5
Output power vs Input power	6
OIP ₂ vs Frequency	7
Noise figure vs Frequency	8
OIP ₃ vs Frequency	9
I_S Supply current vs $R_{(Bias)}$	10
S21 Frequency response	11
S22 Frequency response	12
S11 Frequency response	13
S12 Frequency response	14
Noise figure vs Frequency	15
OIP ₂ vs Frequency	16
Output power vs Input power	17
OIP ₃ vs Frequency	18

TYPICAL CHARACTERISTICS

S-Parameters of THS9000 as mounted on the EVM with $V_S = 5\text{ V}$, $R_{(BIAS)} = 237\ \Omega$, and $L_{(COL)} = 68\text{ nH}$ to 470 nH at room temperature.

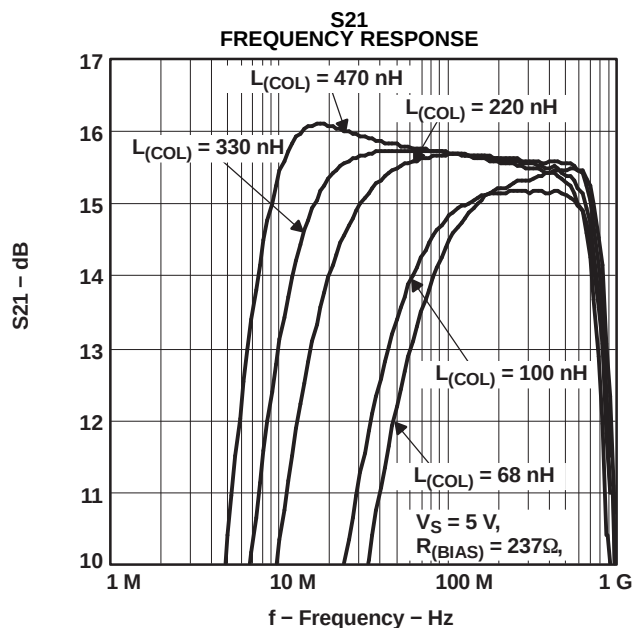


Figure 2.

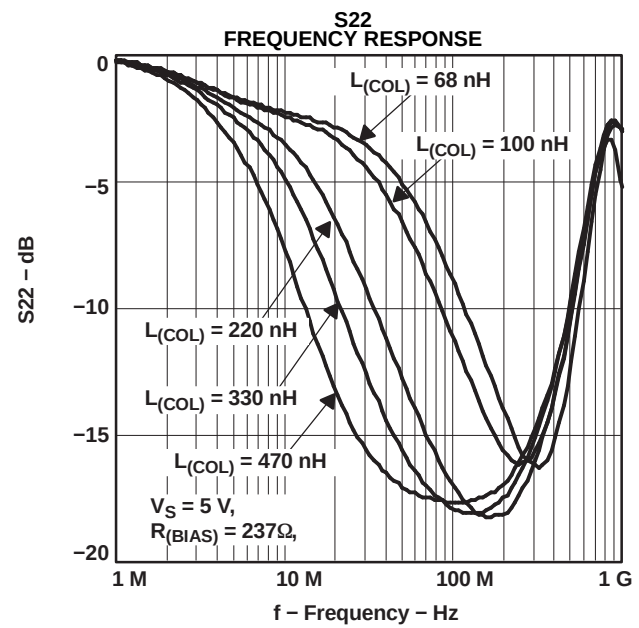


Figure 3.

TYPICAL CHARACTERISTICS (continued)

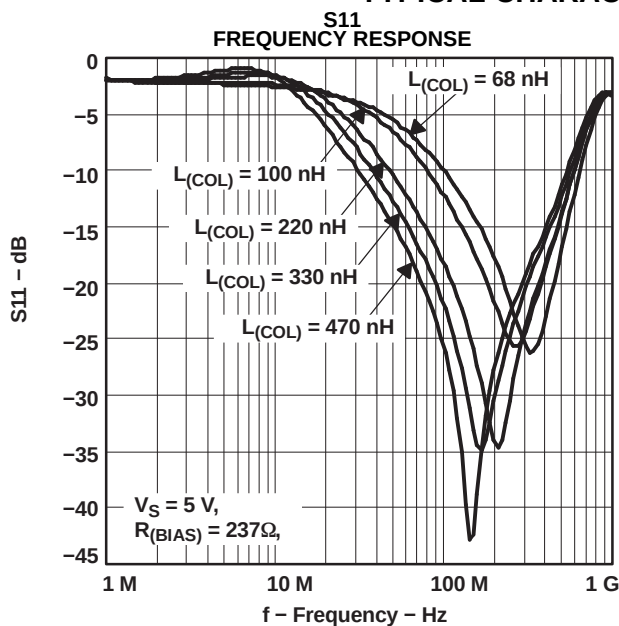


Figure 4.

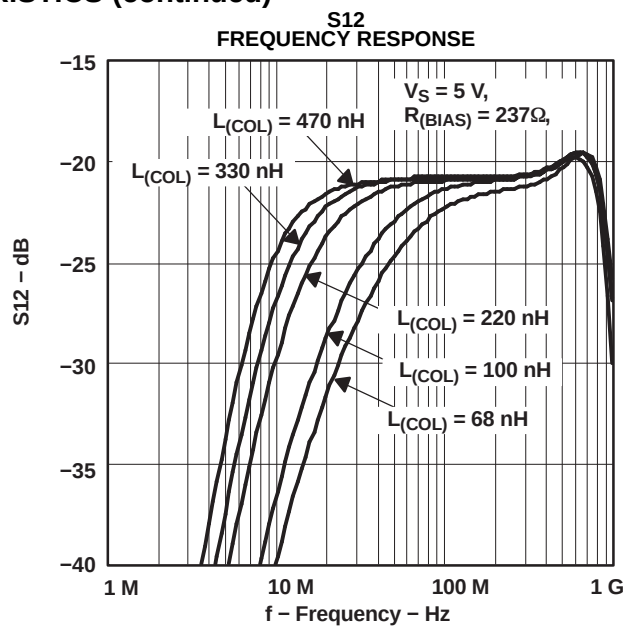


Figure 5.

S-Parameters of THS9000 as mounted on the EVM with $V_S = 3\text{ V}$ and 5 V , $R_{(BIAS)}$ = various, and $L_{(COL)} = 470\text{ nH}$ at room temp.

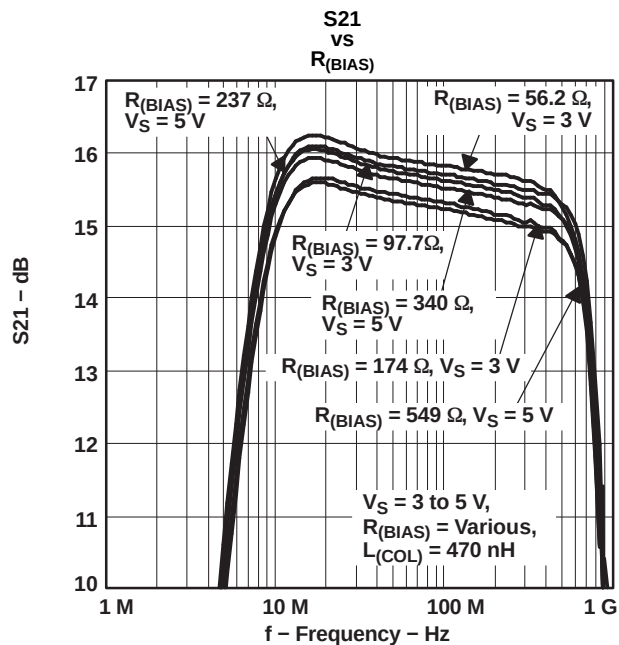


Figure 6.

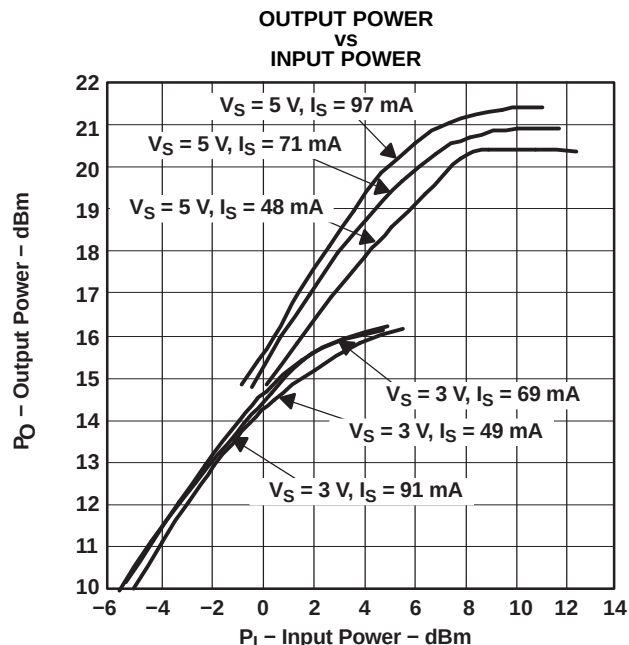


Figure 7.

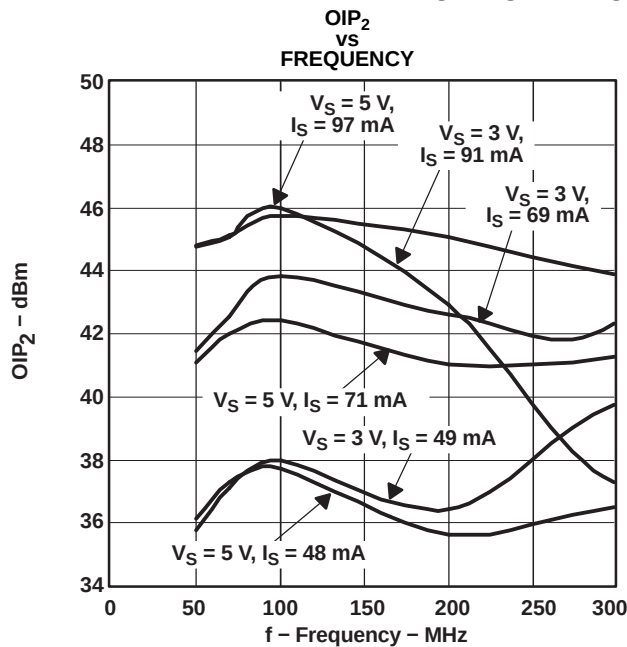
TYPICAL CHARACTERISTICS (continued)

Figure 8.

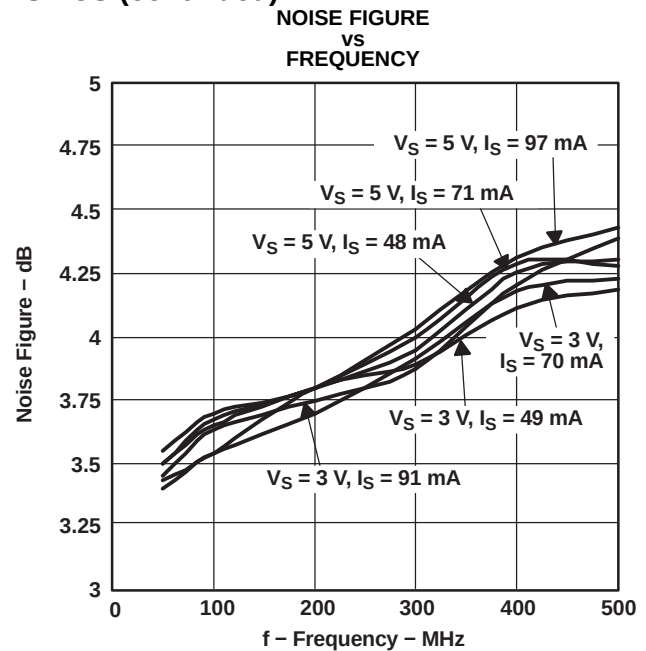


Figure 9.

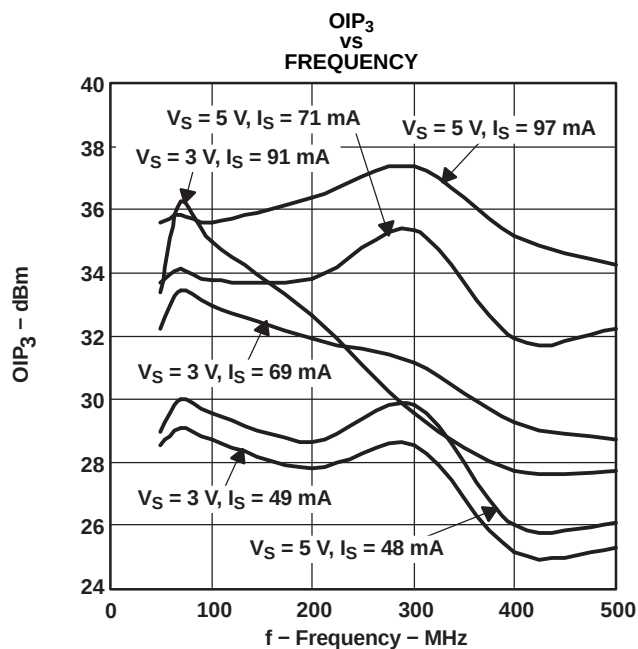


Figure 10.

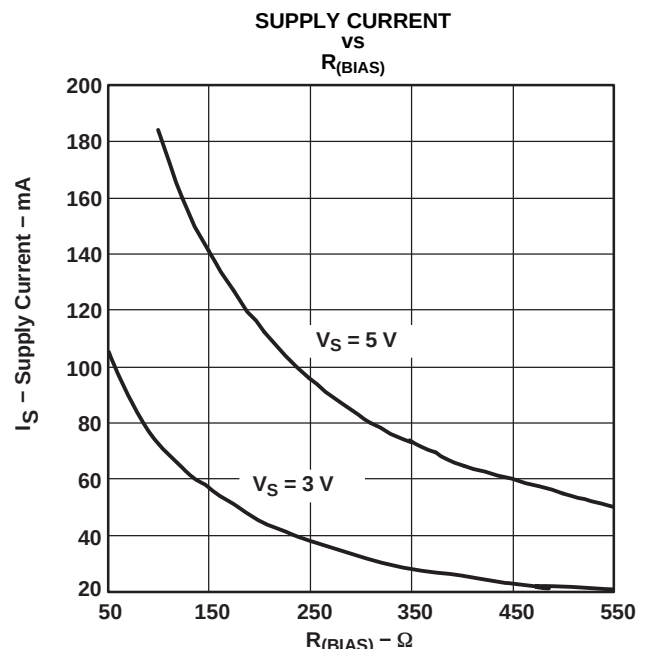


Figure 11.

TYPICAL CHARACTERISTICS (continued)

THS9000 as mounted on the EVM with $V_S = 5\text{ V}$, $R_{(\text{BIAS})} = 237\ \Omega$, and $L_{(\text{COL})} = 470\text{ nH}$ at $+40^\circ\text{C}$, $+25^\circ\text{C}$, and $+85^\circ\text{C}$.

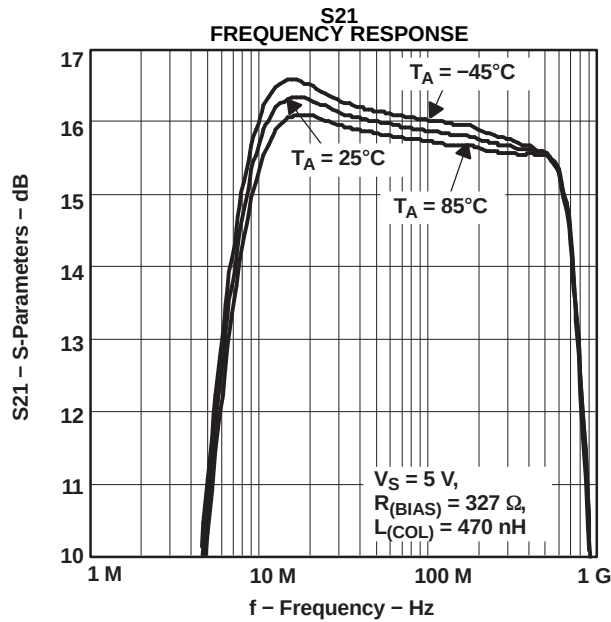


Figure 12.

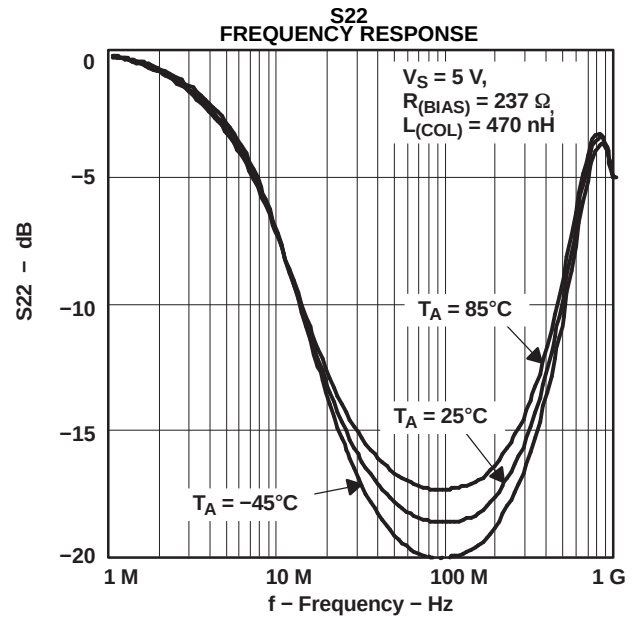


Figure 13.

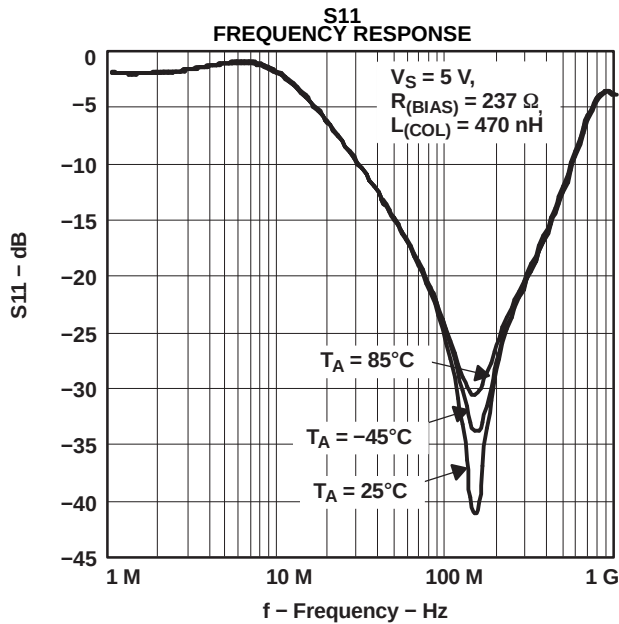


Figure 14.

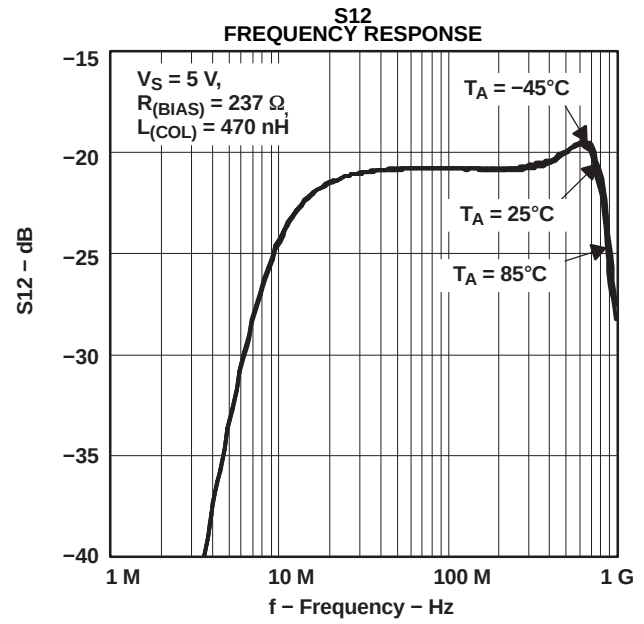


Figure 15.

TYPICAL CHARACTERISTICS (continued)

NOISE FIGURE
VS
FREQUENCY

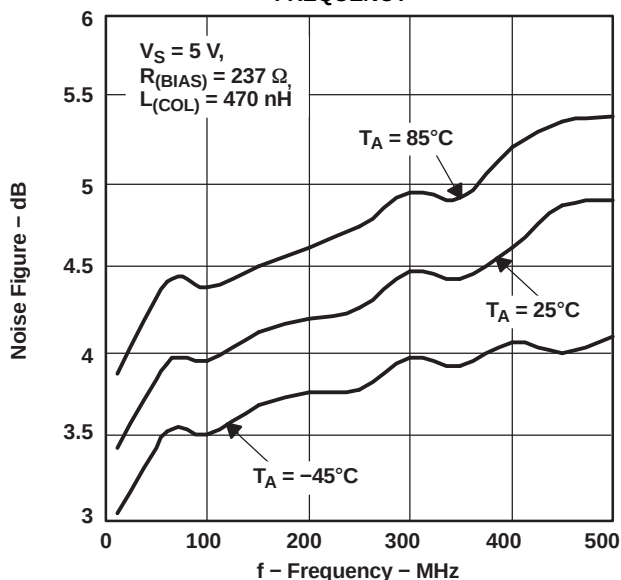


Figure 16.

OIP₂
VS
FREQUENCY

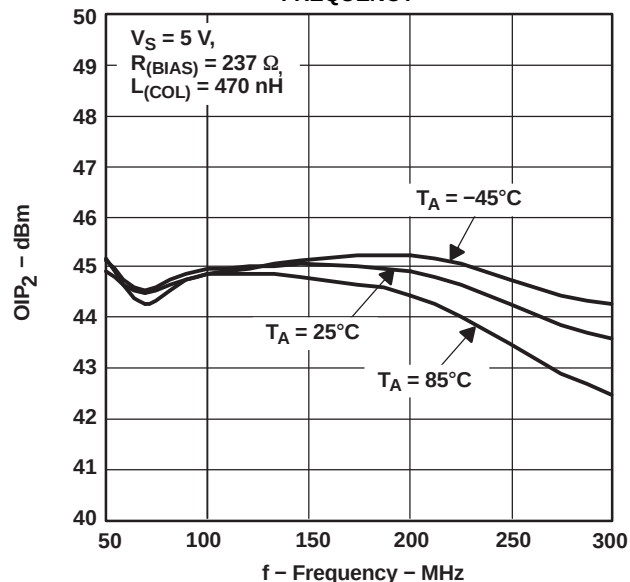


Figure 17.

OUTPUT POWER
VS
INPUT POWER

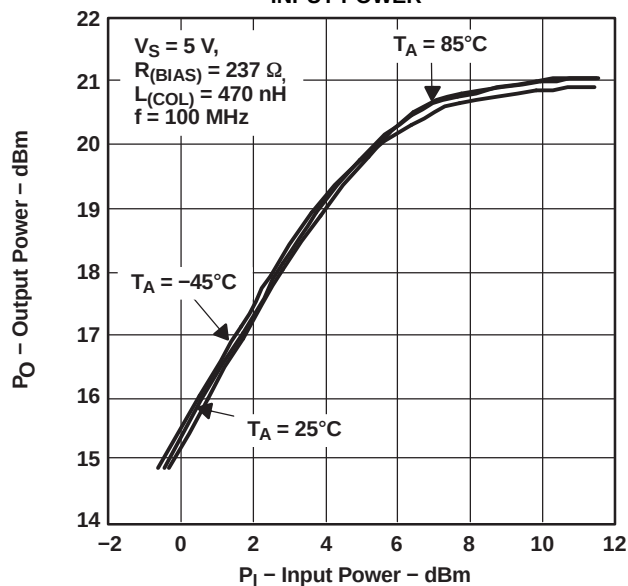


Figure 18.

OIP₃
VS
FREQUENCY

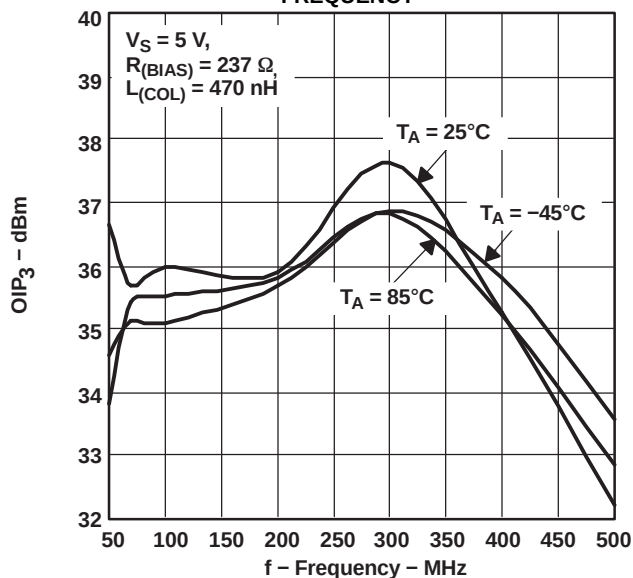


Figure 19.

TYPICAL CHARACTERISTICS

Table 1. S-Parameters Tables of THS9000 with EVM De-Embedded

$V_S = 5\text{ V}$, $R_{(\text{BIAS})} = 237\ \Omega$, $L_{(\text{COL})} = 470\text{ nH}$								
	S21		S11		S22		S12	
FREQUENCY (MHz)	GAIN (dB)	PHASE (°)	GAIN (dB)	PHASE (°)	GAIN (dB)	PHASE (°)	GAIN (dB)	PHASE (°)
1.0	−4.2	−169.5	−2.4	−0.9	−1.9	158.1	−63.1	167.0
5.0	11.3	−124.5	−1.5	−14.5	−2.6	138.0	−32.9	122.4
10.2	15.8	−147.8	−2.2	−42.3	−5.0	101.0	−24.0	80.4
19.7	16.4	−169.4	−6.5	−69.7	−10.5	66.6	−21.3	41.6
50.1	16.0	177.2	−15.6	−91.4	−16.7	30.1	−20.7	14.4
69.7	15.9	173.5	−19.8	−97.7	−17.8	17.7	−20.7	9.1
102.4	15.9	168.4	−26.9	−102.6	−18.2	4.3	−20.7	4.4
150.5	15.8	162.0	−39.0	14.1	−18.1	−8.6	−20.7	−0.7
198.1	15.7	155.8	−27.6	50.8	−17.4	−19.6	−20.7	−1.7
246.9	15.7	149.6	−23.7	40.6	−16.4	−26.7	−20.7	−3.5
307.6	15.6	141.9	−19.8	33.1	−14.9	−37.2	−20.6	−5.7
362.8	15.6	134.7	−17.3	24.7	−13.3	−44.3	−20.4	−7.7
405.0	15.6	129.2	−15.5	20.3	−12.1	−51.0	−20.2	−10.0
452.2	15.6	122.3	−13.8	14.7	−10.6	−58.1	−19.9	−12.5
504.7	15.5	114.9	−11.8	6.3	−9.0	−66.5	−19.7	−16.2
563.4	15.4	105.8	−9.7	−2.9	−7.2	−77.5	−19.4	−22.4
595.3	15.3	100.5	−8.6	−9.1	−6.3	−83.6	−19.3	−26.2
664.5	14.9	88.7	−6.3	−24.2	−4.4	−99.7	−19.3	−36.7
702.1	14.6	81.0	−5.3	−33.2	−3.7	−109.2	−19.6	−43.4
741.8	14.1	76.3	−4.4	−42.9	−3.0	−118.8	−19.9	−50.2
828.1	12.7	60.2	−2.9	−65.5	−2.3	−142.8	−21.7	−69.2
874.9	11.2	51.0	−2.5	−77.9	−2.5	−155.0	−23.6	−75.0
924.4	10.1	50.2	−2.4	−90.4	−3.1	−166.0	−25.8	−85.2
976.7	8.8	51.8	−2.5	−100.7	−4.3	−173.7	−28.4	−78.9
1031.9	9.2	58.2	−2.6	−108.7	−4.7	−175.2	−29.7	−68.7
1090.3	8.9	48.0	−2.5	−115.2	−4.4	−164.7	−31.4	−69.1
1151.9	8.8	39.9	−2.3	−123.3	−3.5	−175.4	−33.6	−83.4
1217.1	8.0	27.7	−2.1	−132.0	−3.0	175.3	−38.2	−81.4
1285.9	7.0	30.5	−2.0	−140.7	−2.8	168.7	−42.3	−25.5
1358.6	5.6	20.6	−1.9	−149.4	−2.9	159.1	−42.2	41.6
1435.5	4.3	19.5	−1.8	−159.4	−3.0	151.3	−38.7	63.3
1516.6	3.4	17.7	−1.9	−168.3	−3.2	144.7	−33.6	62.4
1602.4	2.8	16.5	−2.0	−177.2	−3.5	138.2	−30.5	59.6
1693.0	2.2	8.6	−2.1	174.0	−3.8	131.4	−28.1	56.2
1788.8	1.4	−0.7	−2.2	165.4	−4.1	124.6	−26.2	50.4
1889.9	0.5	−4.1	−2.3	157.0	−4.5	118.2	−24.7	42.4
1996.8	−0.6	−4.5	−2.6	150.0	−4.9	111.2	−24.2	39.5

APPLICATION INFORMATION

The THS9000 is a medium power, cascadeable, amplifier optimized for high intermediate frequencies in radios. The amplifier is unconditionally stable and the design requires only two dc-blocking capacitors, one power-supply bypass capacitor, one RF choke, and one bias resistor. Refer to [Figure 26](#) for the circuit diagram.

The THS9000 operates with a power-supply voltage ranging from 2.5 V to 5.5 V.

The value of $R_{(BIAS)}$ sets the bias current to the amplifier. Refer to [Figure 11](#). This allows the designer to trade-off linearity versus power consumption. $R_{(BIAS)}$ can be removed without damage to the device.

Component selection of $C_{(BYP)}$, C_{IN} , and C_{OUT} is not critical. The values shown in [Figure 26](#) were used for all the data shown in this data sheet.

The amplifier incorporates internal impedance matching to 50 Ω that can be adjusted for various frequencies of operation by proper selection of $L_{(COL)}$.

[Figure 20](#) shows the s-parameters of the part mounted on the standard EVM with $V_S = 5$ V, $R_{(BIAS)} = 237$ Ω , and $L_{(COL)} = 470$ nH. With this configuration, the part is very broadband, and achieves greater than 15-dB input and output return loss from 50 MHz to 325 MHz.

[Figure 21](#) shows the S-parameters of the part mounted on the standard EVM with $V_S = 5$ V, $R_{(BIAS)} = 237$ Ω , and $L_{(COL)} = 68$ nH. With this configuration, the part achieves greater than 15-dB input and output return loss from 250 MHz to 400 MHz.

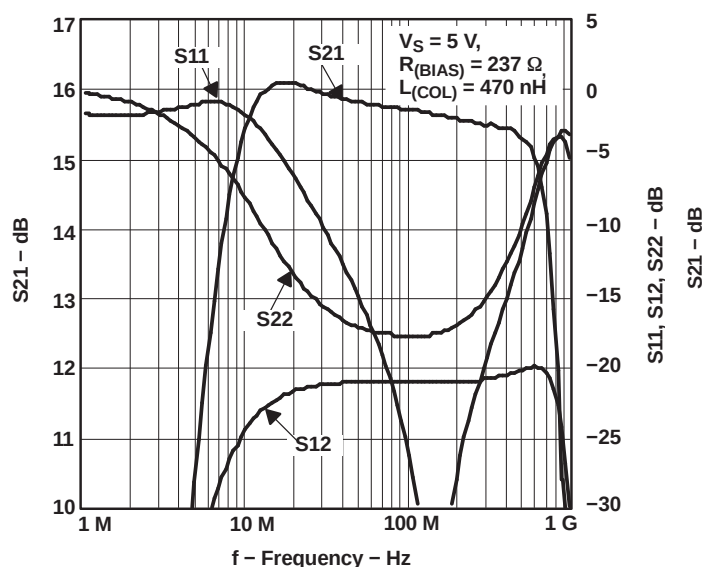


Figure 20. S-Parameters of THS9000 mounted on the standard EVM with $V_S = 5$ V, $R_{(BIAS)} = 237$ Ω , and $L_{(COL)} = 470$ nH

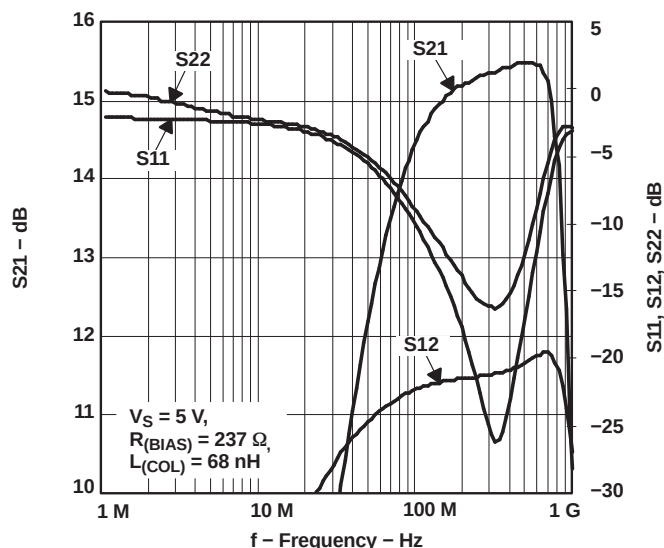


Figure 21. S-Parameters of THS9000 mounted on the standard EVM with $V_S = 5$ V, $R_{(BIAS)} = 237$ Ω , and $L_{(COL)} = 68$ nH

Figure 22 shows an example of a single conversion receiver architecture and where the THS9000 would typically be used.

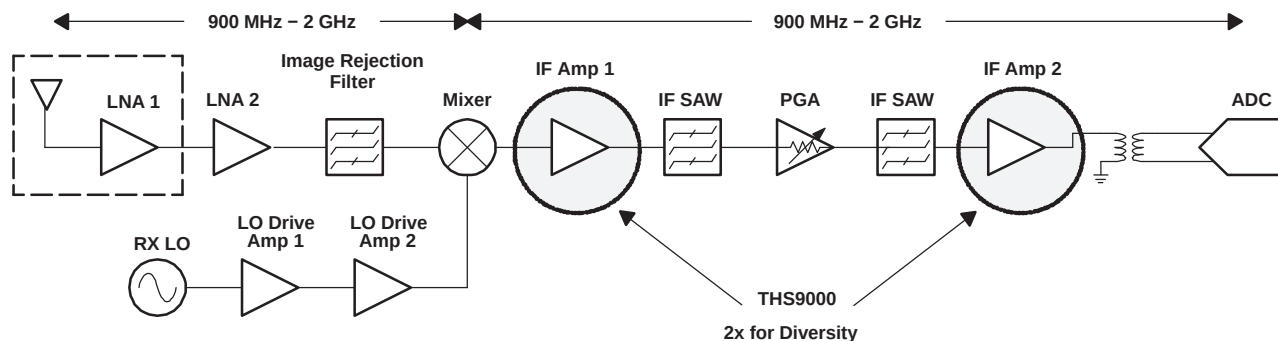


Figure 22. Example Single Conversion Receiver Architecture

Figure 23 shows an example of a dual conversion receiver architecture and where the THS9000 would typically be used.

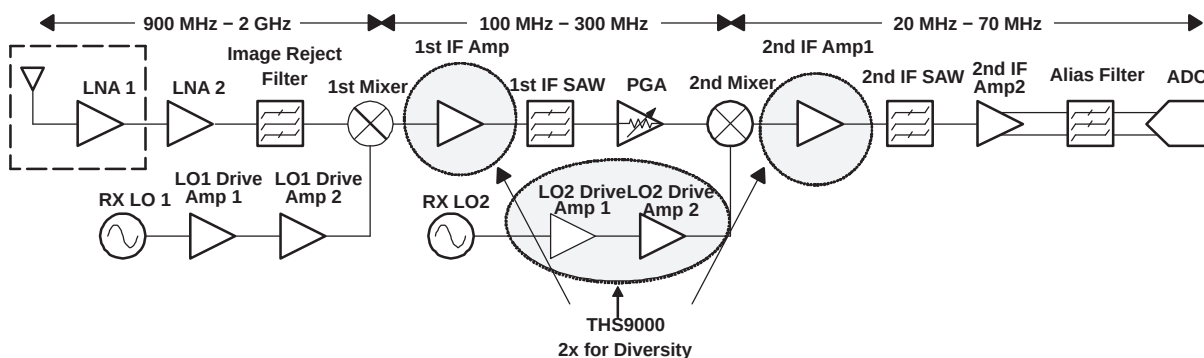


Figure 23. Example Dual Conversion Receiver Architecture

Figure 24 shows an example of a dual conversion transmitter architecture and where the THS9000 would typically be used.

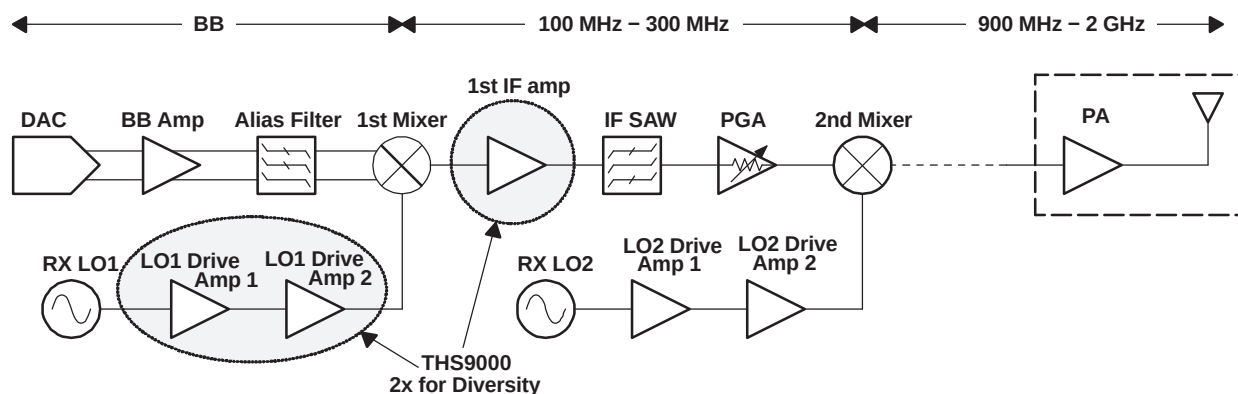


Figure 24. Example Dual Conversion Transmitter Architecture

Figure 25 shows the THS9000 and Sawtek #854916 SAW filter frequency response along with the frequency response of the SAW filter alone. The SAW filter has a center frequency of 140 MHz with 10-MHz bandwidth and 8-dB insertion loss. It can be seen that the frequency response with the THS9000 is the same as with the SAW except for a 15-dB gain. The THS9000 is mounted on the standard EVM with $V_S = 5\text{ V}$, $R_{(\text{BIAS})} = 237\ \Omega$, and $L_{(\text{COL})} = 470\text{ nH}$. Note the amplifier does not add artifacts to the signal.

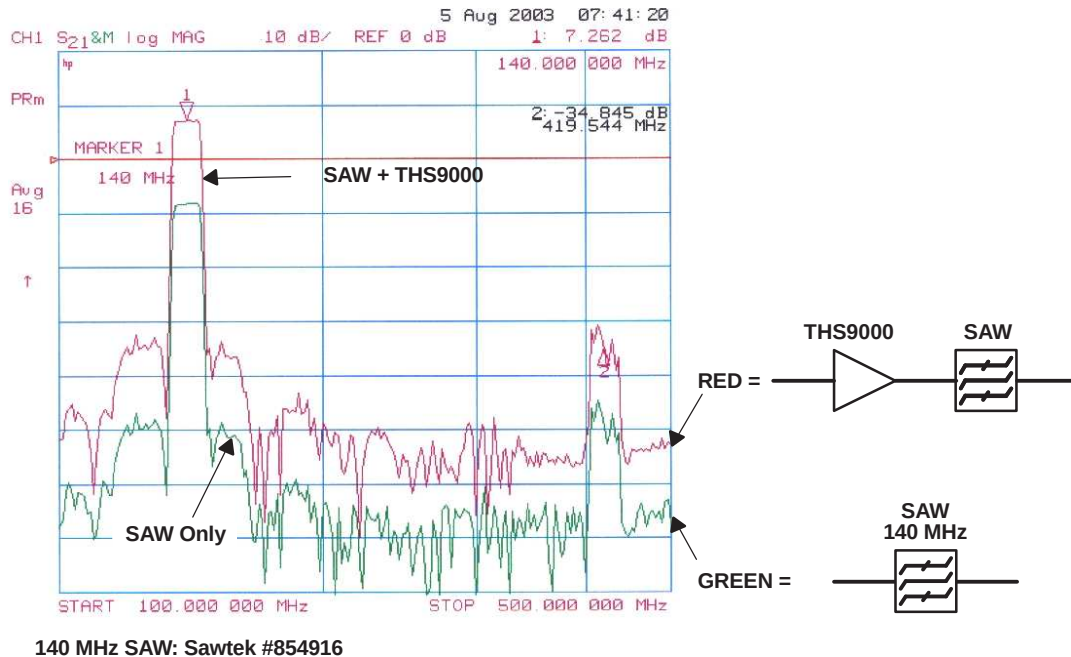


Figure 25. Frequency Response of the THS9000 and SAW Filter, and SAW Filter Only

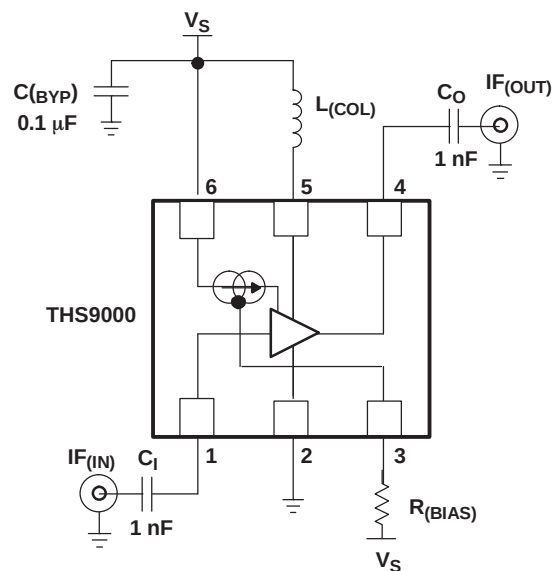


Figure 26. THS9000 Recommended Circuit (used for all tests)

Evaluation Module

Table 1 is the bill of materials, and [Figure 27](#) and [Figure 28](#) show the EVM layout.

Bill Of Materials

ITEM	DESCRIPTION	REF DES	QTY	PART NUMBER ⁽¹⁾
1	Cap, 0.1 μ F, ceramic, X7R, 50 V	C1	1	(AVX) 08055C104KAT2A
2	Cap, 1000 pF, ceramic, NPO, 100 V	C2, C3	2	(AVX) 08051A102JAT2A
3	Inductor, 470 nH, 5%	L1	1	(Coilcraft) 0805CS-471XJBC
4	Resistor, 237 Ω , 1/8 W, 1%	R1	1	(Phycomp) 9C08052A2370FKHFT
5	Open	TR1	1	
6	Jack, banana receptance, 0.25" dia.	J3, J4	2	(SPC) 813
7	Connector, edge, SMA PCB jack	J1, J2	2	(Johnson) 142-0701-801
8	Standoff, 4-40 Hex, 0.625" Length		4	(KEYSTONE) 1808
9	Screw, Phillips, 4-40, .250"		4	SHR-0440-016-SN
10	IC, THS9000	U1	1	(TI) THS9000DRD
11	Board, printed-circuit		1	(TI) EDGE # 6453521 Rev.A

(1) The manufacturer's part numbers are used for test purposes only.

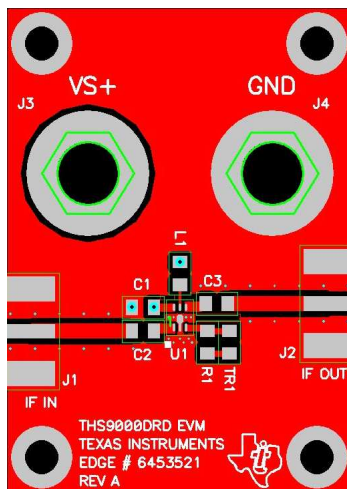


Figure 27. EVM Top Layout

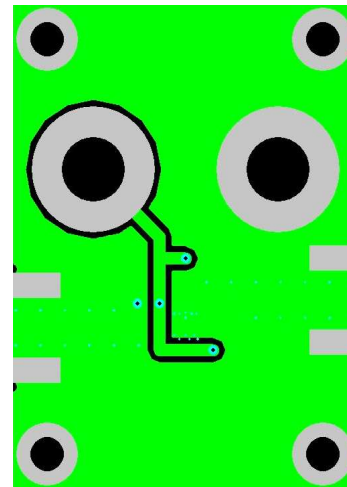
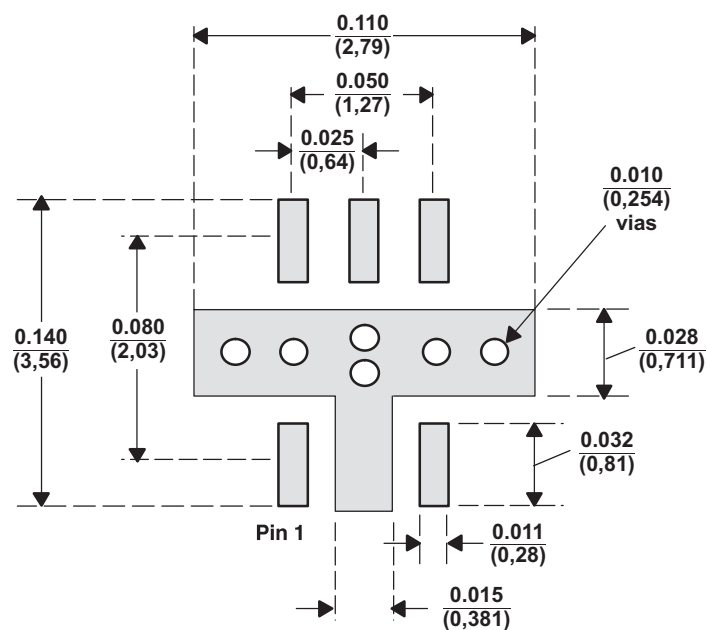


Figure 28. EVM Bottom Layout



TOP VIEW

Figure 29. THS9000 Recommended Footprint dimensions are in inches (millimeters)

REVISION HISTORY

Changes from Revision D (October 2008) to Revision E Page

- Changed the data sheet title From: 50 MHz to 400 MHz CASCADEABLE AMPLIFIER To: 50 MHz to 750 MHz
CASCADEABLE AMPLIFIER [1](#)

Changes from Revision C (February 2007) to Revision D Page

- Removed the DRD ordering options from the *Available Options* table [2](#)
- Formatted the Absolute Maximum Ratings table to current standards [2](#)
- Deleted DRD row from the *Dissipation Rating* table [2](#)

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
THS9000DRWR	Active	Production	VSON (DRW) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	BQX
THS9000DRWR.B	Active	Production	VSON (DRW) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	BQX
THS9000DRWT	Active	Production	VSON (DRW) 6	250 SMALL T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	BQX
THS9000DRWT.B	Active	Production	VSON (DRW) 6	250 SMALL T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	BQX

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

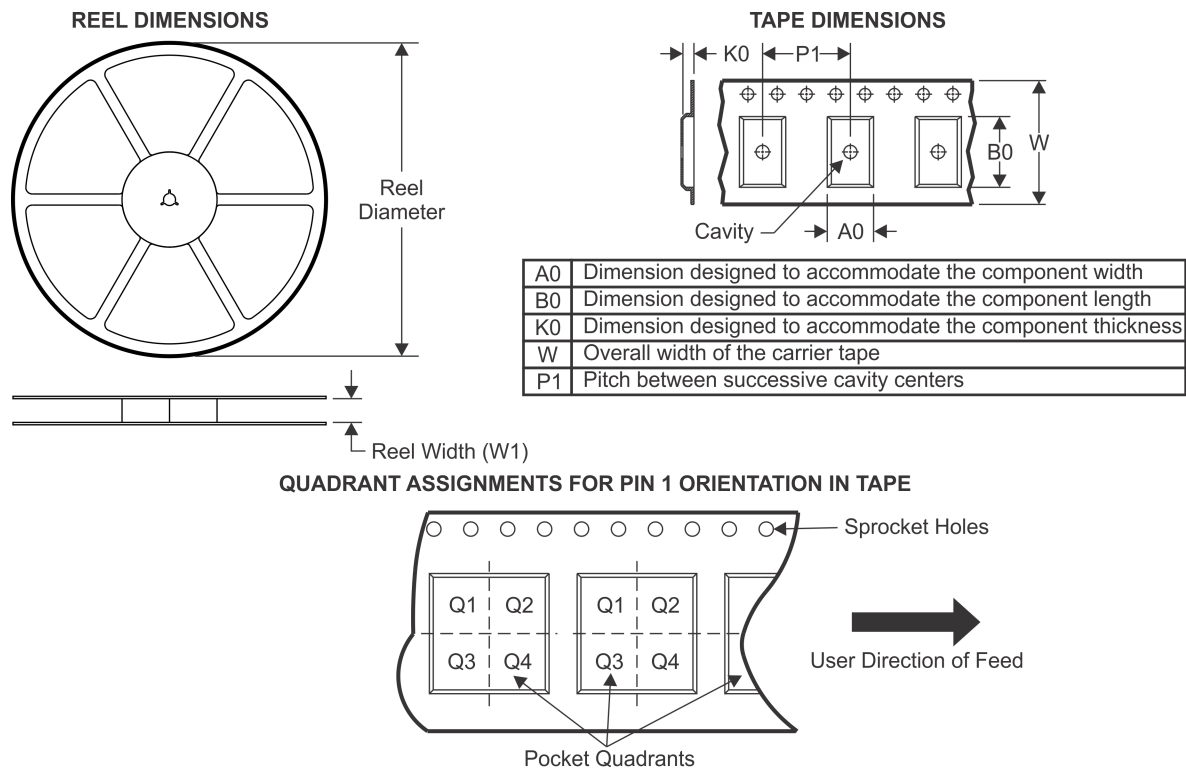
⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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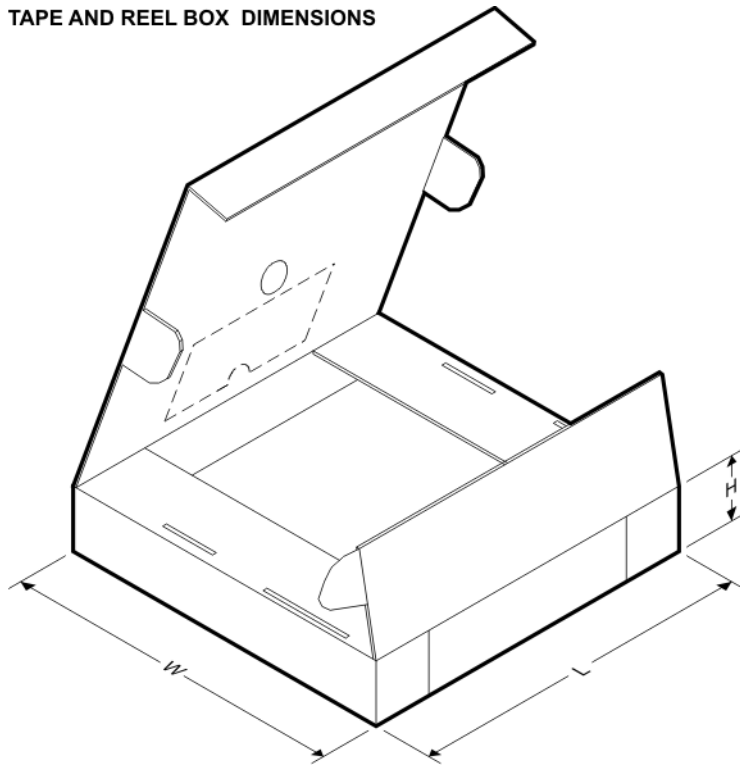
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TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
THS9000DRWR	VSON	DRW	6	3000	179.0	8.4	2.2	2.2	1.2	4.0	8.0	Q2
THS9000DRWT	VSON	DRW	6	250	179.0	8.4	2.2	2.2	1.2	4.0	8.0	Q2

TAPE AND REEL BOX DIMENSIONS

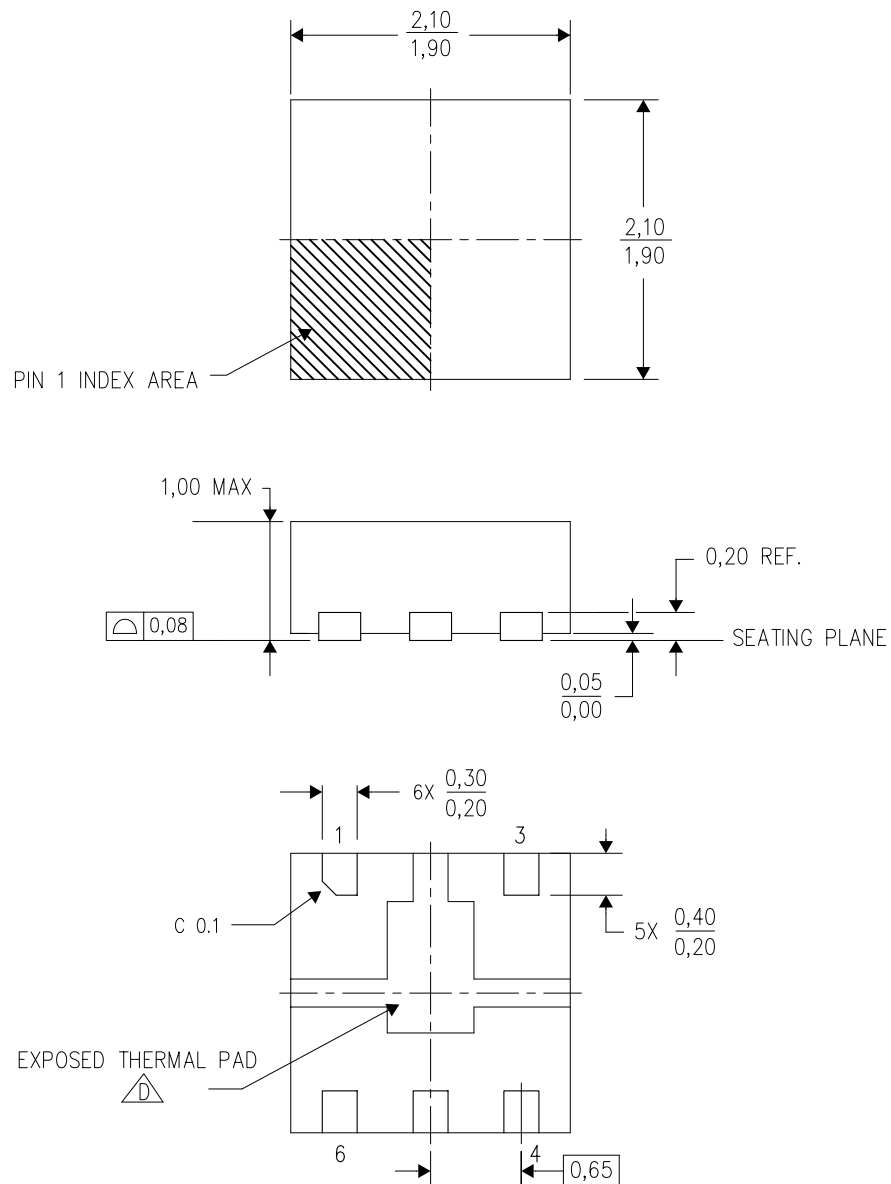


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
THS9000DRWR	VSON	DRW	6	3000	213.0	191.0	35.0
THS9000DRWT	VSON	DRW	6	250	213.0	191.0	35.0

DRW (S-PVSON-N6)

PLASTIC SMALL OUTLINE NO-LEAD



4207179/D 12/10

- NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5-1994.
B. This drawing is subject to change without notice.
C. Small Outline No-Lead (SON) package configuration.

-  The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.

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