LMH9235 3.3 GHz – 4.2 GHz Single-Ended to Differential Amplifier with Integrated Balun

1 Features

- Single-channel, single-ended input to differential output RF gain block amplifier
- Supports 3.3 GHz – 3.8 GHz band directly or 3.7 GHz – 4.2 GHz band with external matching components
- 17.5 dB typical gain across the band
- Less than 3 dB noise figure
- 34.5 dBm OIP3
- 18 dBm output P1 dB
- 270 mW power consumption on 3.3 V single supply
- Up to 105°C T_C operating temperature

2 Applications

- Differential driver for high GSPS ADCs
- Single-ended to differential conversions
- Balun alternatives
- RF gain blocks
- Small cell or m-MIMO base stations
- 5G active antenna systems (AAS)
- Wireless cellular base station
- Low-cost radios

3 Description

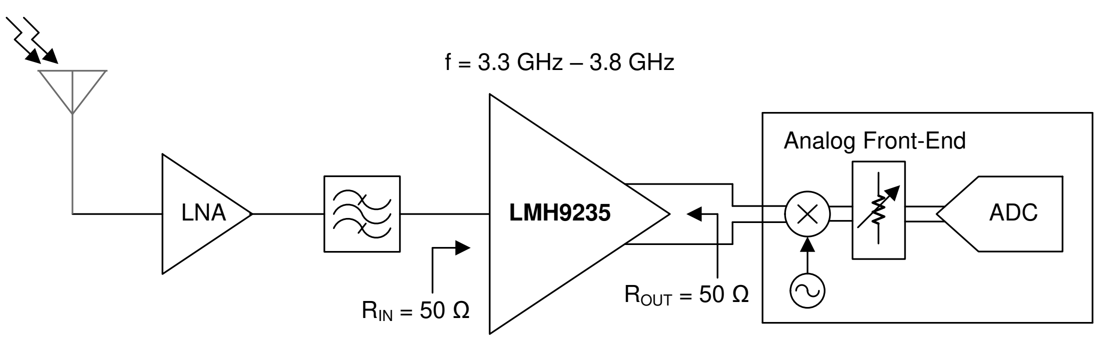
The LMH9235 device is a high-performance, single-channel, single-ended input to differential output receive RF gain block amplifier supporting 3.6 GHz center frequency band. The device is well suited to support requirements for the next generation 5G AAS or small cell applications where LNA gain is not sufficient to drive full-scale of an analog front-end (AFE). The RF amplifier provides 17 dB typical gain with good linearity performance of 34 dBm Output IP3, while maintaining about 3 dB noise figure across the whole 1 dB bandwidth. The device is internally matched for 50 Ω impedance at both the single-ended input as well as the differential output providing easy interface with an RF-sampling or Zero-IF analog front-end (AFE).

Operating on a single 3.3 V supply, the device consumes about 270 mW of active power making it suitable for high-density 5G massive MIMO applications. Also, the device is available in a space saving 2 mm x 2 mm, 12-pin QFN package. The device is rated for an operating temperature of up to 105°C to provide a robust system design. There is a 1.8 V JEDEC compliant power down pin available for fast power down and power up of the device suitable for time division duplex (TDD) systems.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LMH9235	WQFN (12)	2.00 mm × 2.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.



LMH9235: Single-Ended to Differential Amplifier

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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (June 2020) to Revision C (May 2021) — **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document ... 1

Changes from Revision A (May 2020) to Revision B (June 2020) — **Page**

- Added *3.7 GHz – 4.2 GHz Band with External Matching Components* to the Features section ... 1
- Changed the P_{OUT}/TONE measurements of Figure 6, Figure 7 and Figure 8 From: *1-MHz tone spacing* To: *10-MHz tone spacing* ... 6
- Added *Shifting the Operating Band* section ... 12
- Added *Design Requirements and Procedure* section ... 12

Changes from Revision * (May 2020) to Revision A (June 2020) — **Page**

- Changed status From: *Product Preview* To: *Production Data* ... 1

5 Pin Configuration and Functions

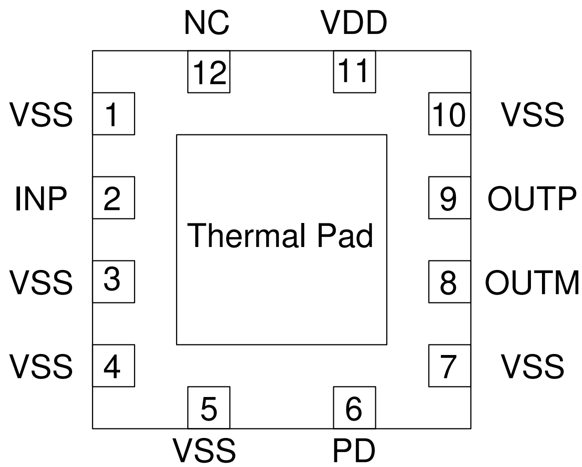


Figure 5-1. RRL Package 12-Pin WQFN Top View

Table 5-1. Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	VSS	Power	Ground
2	INP	Input	RF single-ended input into amplifier
3	VSS	Power	Ground
4	VSS	Power	Ground
5	VSS	Power	Ground
6	PD	Input	Power down connection. PD = 0 V = normal operation; PD = 1.8 V = power off mode.
7	VSS	Power	Ground
8	OUTM	Output	RF differential output negative
9	OUTP	Output	RF differential output positive
10	VSS	Power	Ground
11	VDD	Power	Positive supply voltage (3.3 V)
12	NC	—	Do not connect this pin
Thermal Pad		—	Connect the thermal pad to Ground

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[(1)]

		MIN	MAX	UNIT
Supply voltage	VDD	–0.3	3.6	V
RF Pins	INP, OUTP, OUTM	–0.3	VDD	V
Continuous wave (CW) input	f_{IN} = 3.55 GHz at INP		25	dBm
Digital Input PIN	PD	–0.3	VDD	V
T_J	Junction temperature		150	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Rating* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, allpins[(1)]	±1000	V
		Charged device model (CDM), per JEDEC specificationJESD22-C101, all pins[(2)]	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
VDD	Supply voltage	3.15	3.3	3.45	V
T_C	Case (bottom) temperature	–40		105	°C
T_J	Junction temperature	–40		125	°C

6.4 Thermal Information

THERMAL METRIC[(1)]		LMH9235	UNIT
		RRL PKG	
		12-PIN WQFN	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	74.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	72.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	37.1	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	3.2	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	37.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	14.2	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.

6.5 Electrical Characteristics

T_A = 25°C, VDD = 3.3V, frequency = 3.55 GHz, single-ended input impedance (R_{IN}) = 50 Ω, differential output load (R_{LOAD}) = 50 Ω unless otherwise noted

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
RF PERFORMANCE - LMH9235						
F_{RF}	RF frequency range		3300		3800	MHz
BW_{1dB}	1-dB Bandwidth			700		MHz
S_{21}	Gain			17.5		dB
NF	Noise Figure	R_S = 50 Ω		3		dB
OP1dB	Output P1dB	R_{LOAD} = 50 Ω differential		18		dBm
OIP3	Output IP3	f_{in} = 3.55 GHz ± 5 MHz spacing, P_{OUT}/TONE = 2 dBm		34.5		dBm
	Differential output gain Imbalance			±0.5		dB
	Differential output phase Imbalance			±3		degree
S_{11}	Input return loss (1)	f = 3.3 - 3.8 GHz		–9		dB
S_{22}	Output return loss (1)	f = 3.3 - 3.8 GHz		–10		dB
S_{12}	Reverse isolation	f = 3.3 - 3.8 GHz		–40		dB
CMRR	Common Mode Rejection Ratio (2)			30		dB
Switching and Digital input characteristics						
t_{ON}	Turn-ON time	50% V_{PD} to 90% RF		0.5		µs
t_{OFF}	Turn-OFF time	50% V_{PD} to 10% RF		0.2		µs
V_{IH}	High-Level Input Voltage	PD pin	1.4			V
V_{IL}	Low-Level Input Voltage	PD pin			0.5	V
DC current and Power Consumption						
I_{VDD_ON}	Supply Current - active	V_{PD} = 0 V		80		mA
I_{VDD_PD}	Supply Current - power down	V_{PD} = 1.8 V		10		mA
P_{dis}	Power Dissipation - active			270		mW

(1) Reference impedance: Input = 50 Ω single-ended, Output = 50 Ω differential
(2) CMRR is calculated using (S_{21}-S_{31})/(S_{21}+S_{31}) for Receive (1 is input port, 2 & 3 are differential output ports)

6.6 Typical Characteristics

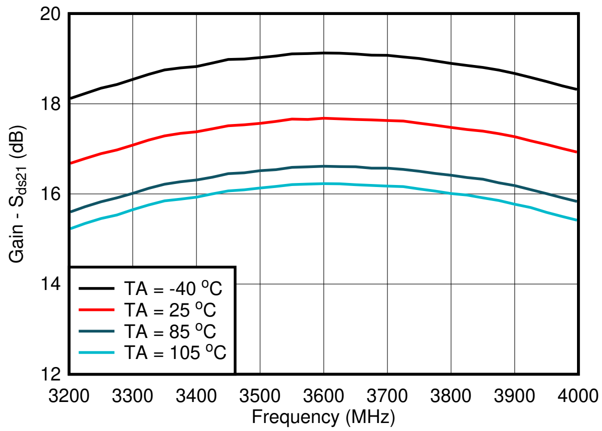


Figure 6-1. Gain vs Frequency and Temperature

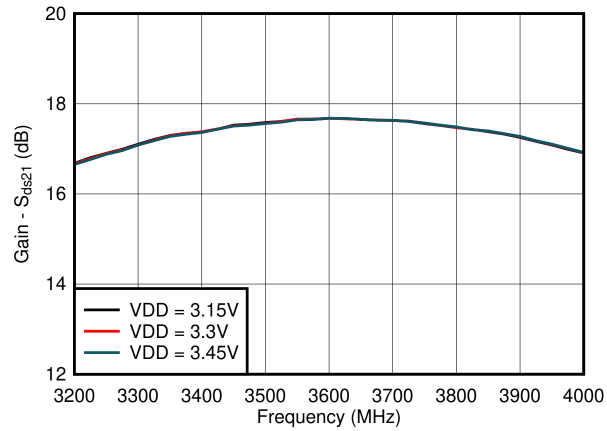


Figure 6-2. Gain vs Frequency and Supply Voltage

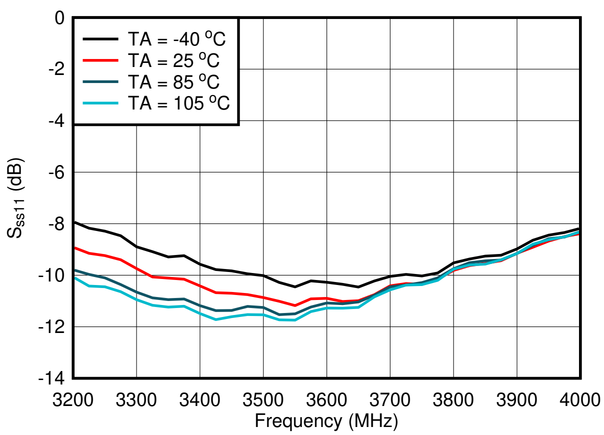


Figure 6-3. Input Return Loss vs Frequency

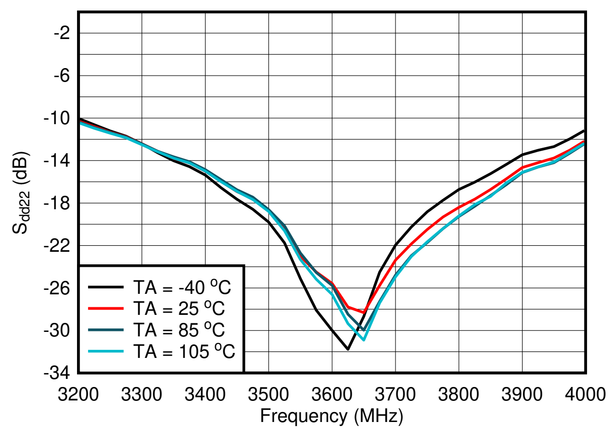


Figure 6-4. Output Return Loss vs Frequency

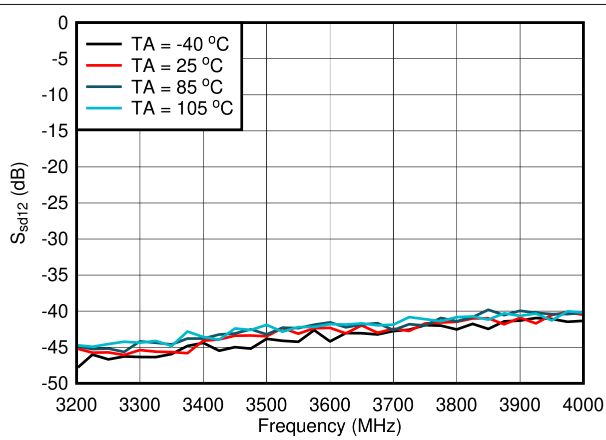
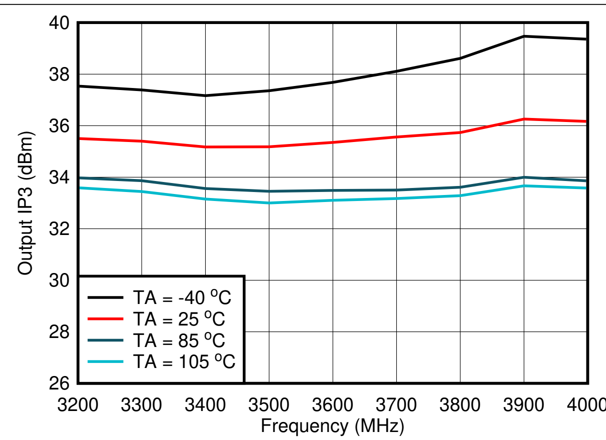


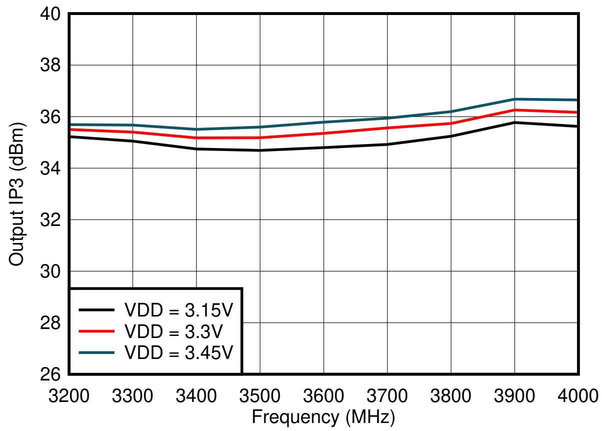
Figure 6-5. Reverse Isolation vs Frequency



P_{OUT}/TONE = 2 dBm, 10-MHz tone spacing

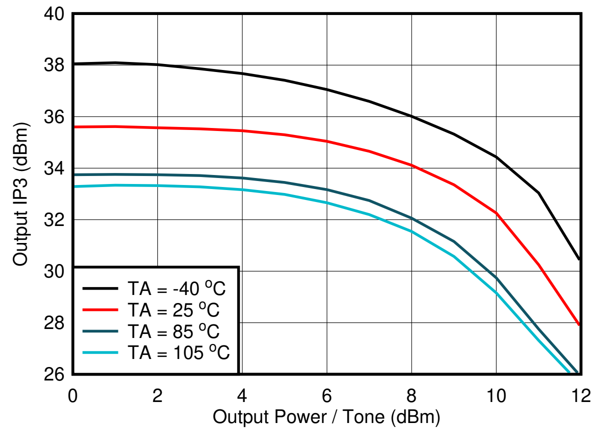
Figure 6-6. Output IP3 vs Frequency and Temperature

6.6 Typical Characteristics (continued)



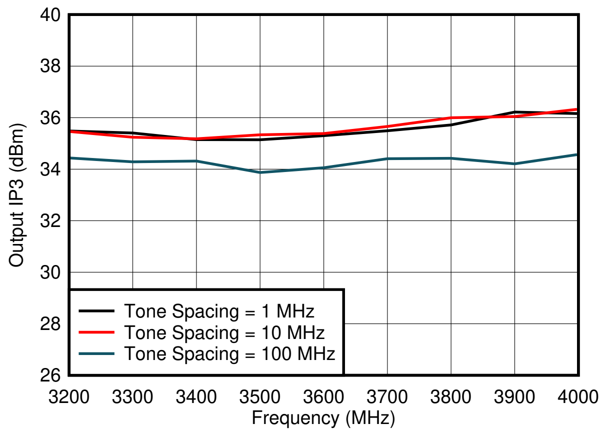
P_{OUT}/TONE = 2 dBm, 10-MHz tone spacing

Figure 6-7. Output IP3 vs Frequency and Supply Voltage



f = 3550 MHz, 10-MHz tone spacing

Figure 6-8. Output IP3 vs Output Power per Tone



P_{OUT}/TONE = 2 dBm

Figure 6-9. Output IP3 vs Frequency and Tone Spacing

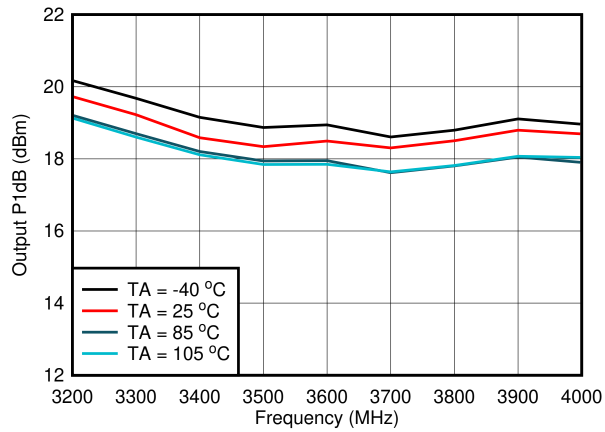


Figure 6-10. Output P1dB vs Frequency and Temperature

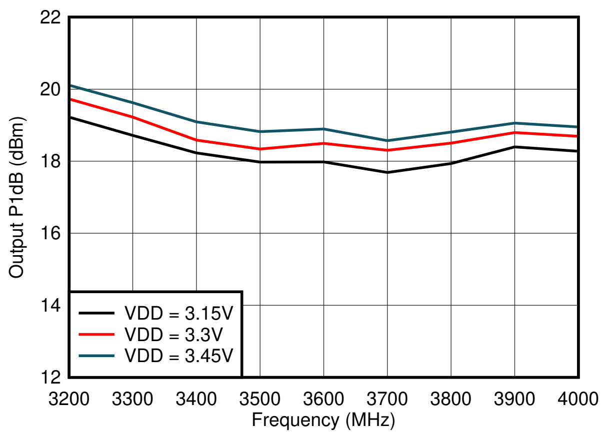
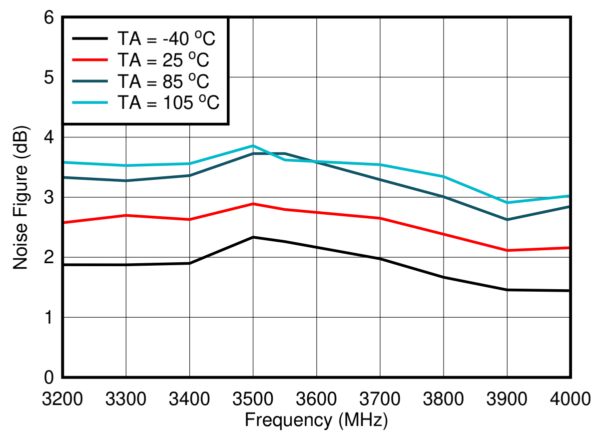


Figure 6-11. Output P1dB vs Frequency and Supply Voltage



Z_{SOURCE} = 50 Ω

Figure 6-12. Noise Figure vs Frequency and Temperature

6.6 Typical Characteristics (continued)

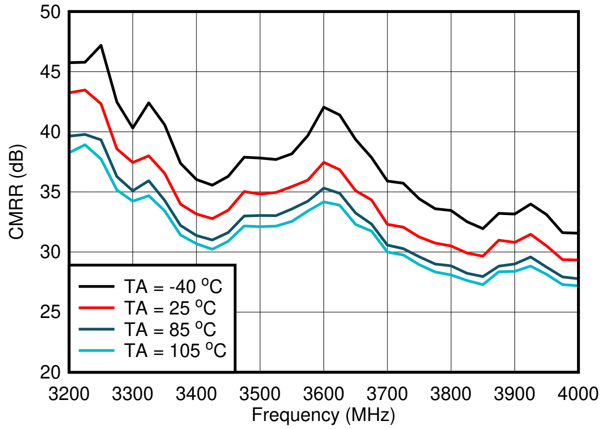


Figure 6-13. CMRR vs Frequency

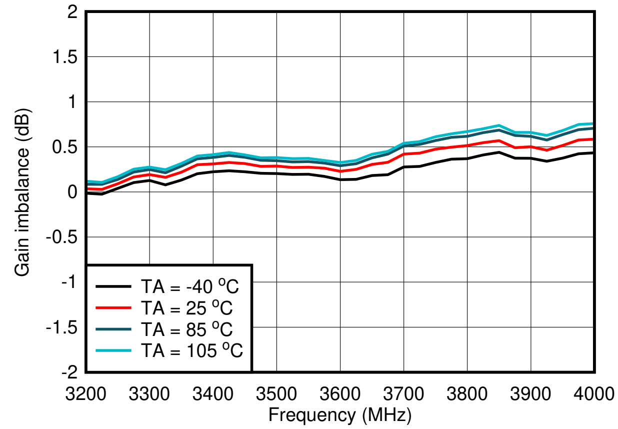


Figure 6-14. Gain Imbalance vs Frequency and Temperature

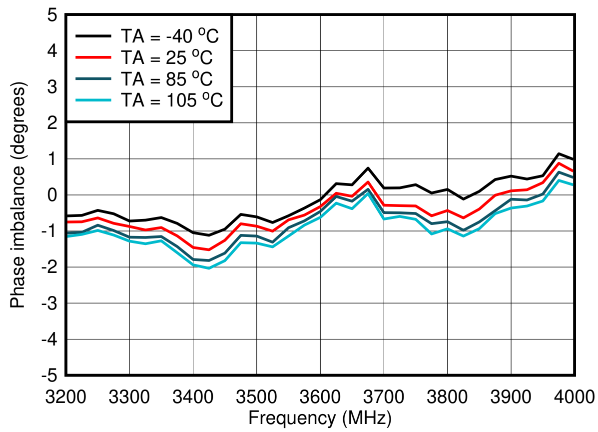


Figure 6-15. Phase Imbalance vs Frequency and Temperature

7 Detailed Description

7.1 Overview

The LMH9235 device is a single-ended input to differential output narrow-band RF amplifier that is used in receiver applications. The LMH9235 provides ≈ 17 dB fixed power gain with excellent linearity and noise performance across 1 dB bandwidth of the 3.55 GHz center frequency. The device is internally matched for 50 Ω impedance at both the single-ended input as well as the differential output, as shown in Section 8.

The LMH9235 has on-chip active bias circuitry to maintain device performance over a wide temperature and supply voltage range. The included power down function allows the amplifier to shut down saving power when the amplifier is not needed. Fast shut down and start up enable the amplifier to be used in a host of TDD applications.

Operating on a single 3.3 V supply and consuming ≈ 80 mA of typical supply current, the device is available in a 2 mm x 2 mm 12-pin QFN package.

7.2 Functional Block Diagram

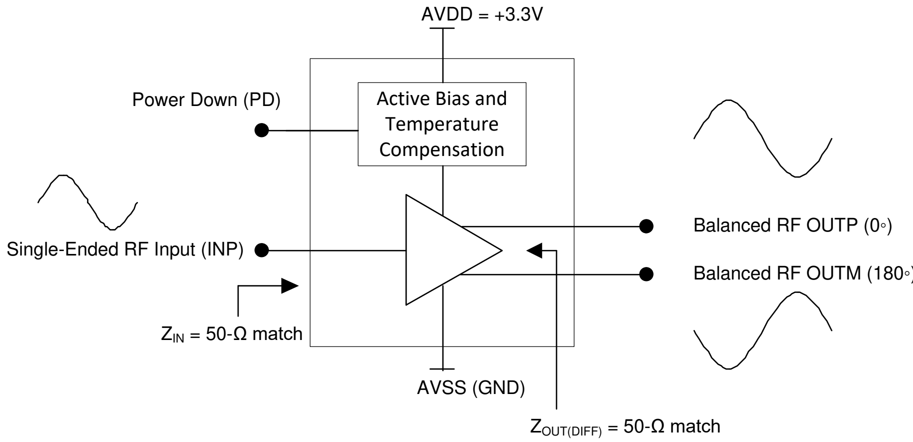


Figure 7-1. Functional Block Diagram

7.3 Feature Description

The LMH9235 device is single-ended to differential RF amplifier for narrow band active balun implementation. The device integrates the functionality of a single-ended RF amplifier and passive balun in traditional receive applications achieving small form factor with comparable linearity and noise performance, as shown in Figure 7-2.

The active balun implementation coupled with higher operating temperature of 105°C allows for more robust receiver system implementation compared to passive balun that is prone to reliability failures at high temperatures. The high temperature operation is achieved by the on-chip active bias circuitry which maintains device performance over a wide temperature and supply voltage range.

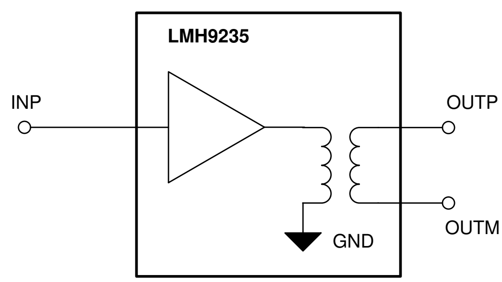


Figure 7-2. Single-Ended Input to Differential Output, Active Balun Implementation

7.4 Device Functional Modes

The LMH9235 features a PD pin which should be connected to GND for normal operation. To power down the device, connect the PD pin to a logic high voltage of 1.8 V.

8 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

8.1 Application Information

The LMH9235 device is a single-ended, 50 Ω input to differential 50 Ω output RF gain block amplifier, used in the receive path of a 3.55 GHz center frequency, 5G, TDD m-MIMO or small cell base station. The device replaces the traditional single-ended RF amplifier and passive balun offering a smaller footprint solution to the customer. TI recommends following good RF layout and grounding techniques to maximize the device performance.

8.2 Typical Application

8.2.1 Matching to a 100 Ω AFE

A typical application of the LMH9235 device driving an AFE is shown in Figure 8-1.

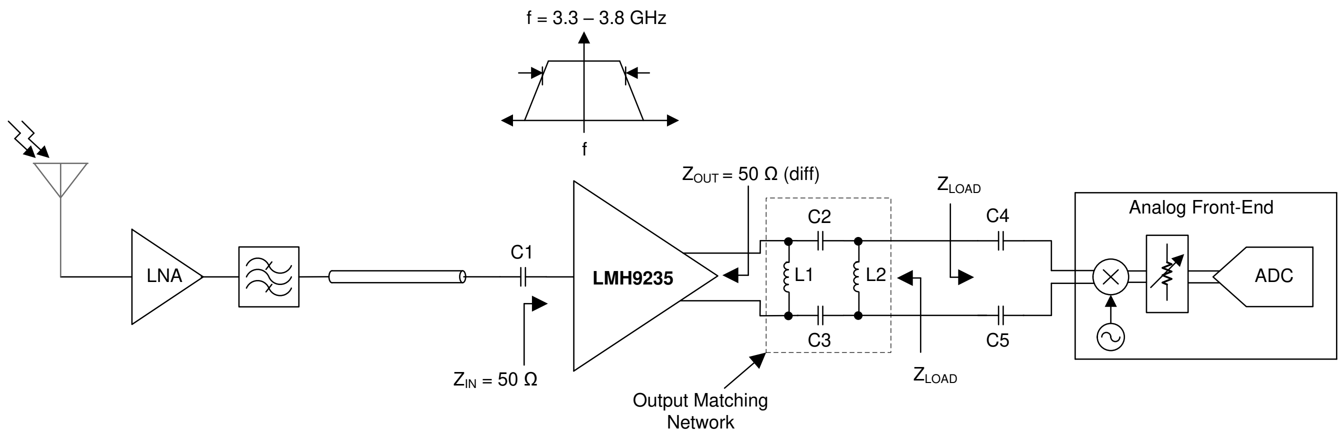


Figure 8-1. LMH9235 in Receive Chain Driving an Analog Front-End

8.2.1.1 Design Requirements

Z_{LOAD} represents the impedance of the AFE. With a matching network comprising of L1, L2, C2, and C3 as shown, the LMH9235 is matched to the impedance of AFE. The capacitors C1, C4, and C5 are for dc-blocking purpose.

8.2.1.2 Detailed Design Procedure

The table shows the matching network components for 50 Ω (differential) and 100 Ω (differential) AFE impedances.

Table 8-1. Matching Network Component Values

Component	Value for $Z_{LOA\ D}$ = 50 Ω (differential)	Value for Z_{LOAD} = 100 Ω (differential)
C1	22 pF	22 pF
C2, C3	SHORT	1.5 pF
L1	OPEN	OPEN
L2	OPEN	4.3 nH
C4, C5	22 pF	22 pF

8.2.1.3 Application Curves

The graphs given below show the gain, input return loss and output return loss of the design with different AFE terminations.

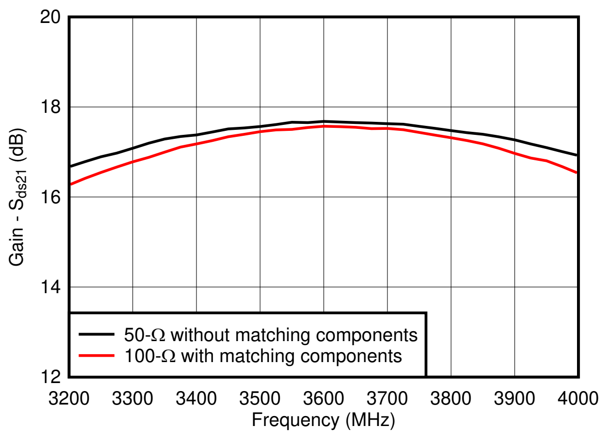


Figure 8-2. Gain vs Frequency for Different Terminations

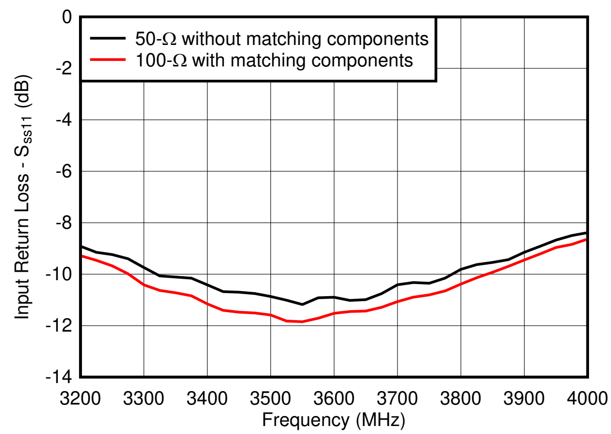


Figure 8-3. Input Return Loss vs Frequency for Different Terminations

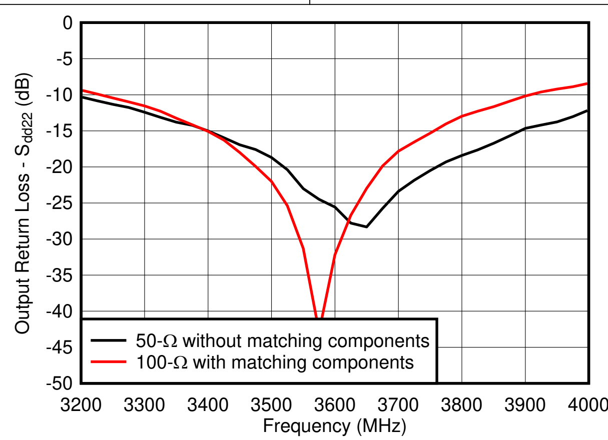


Figure 8-4. Output Return Loss vs Frequency for Different Terminations

8.2.2 Shifting the Operating Band

It is possible to tune the frequency band of operation of this chip by a simple external network at the input as shown in Figure 8-1. In this example, with the help of 2 components at the input, the frequency band is shifted to 3.7 - 4.2 GHz.

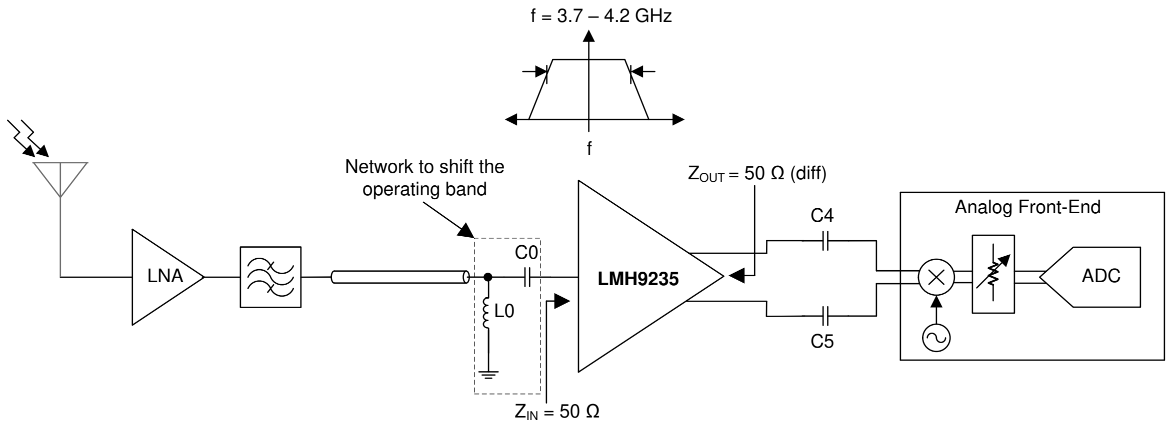


Figure 8-5. Shifting the Operating Band

8.2.2.1 Design Requirements and Procedure

The components C0 and L0 are meant to shift the operating band from 3.3 - 3.8 GHz to 3.7 - 4.2 GHz. The capacitors C4, and C5 are for dc-blocking purpose. The values of these components are given in the table below.

Table 8-2. Matching Network Component Values

Component	Value
C0	2 pF
L0	2 nH
C4	22 pF
LC5	22 pF

8.2.2.2 Application Curves

The graphs given below show the gain, input and output return loss and OIP3 of the design shown in Figure 8-1.

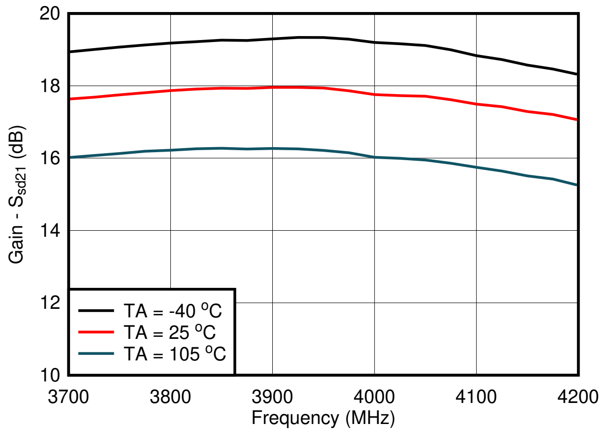


Figure 8-6. Gain vs Frequency

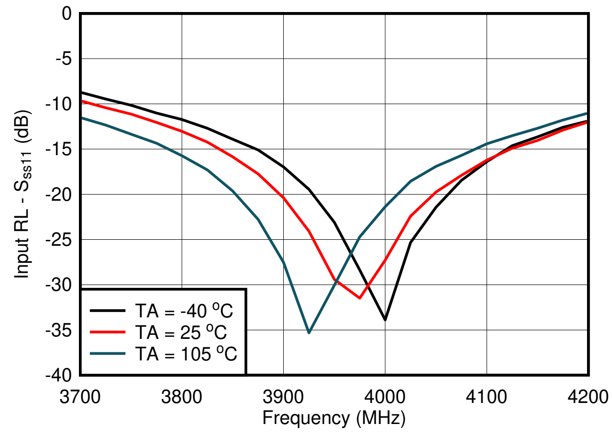


Figure 8-7. Input Return Loss vs Frequency

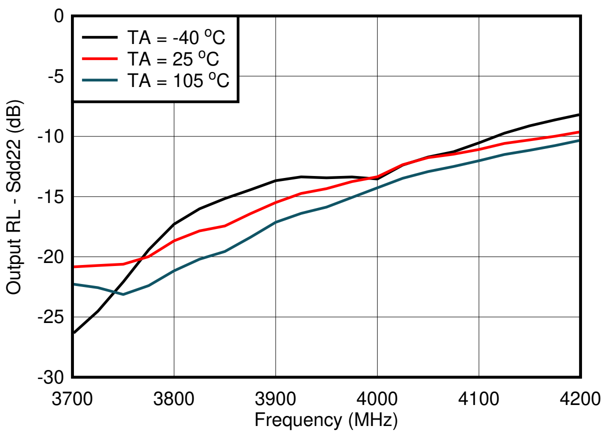


Figure 8-8. Output Return Loss vs Frequency

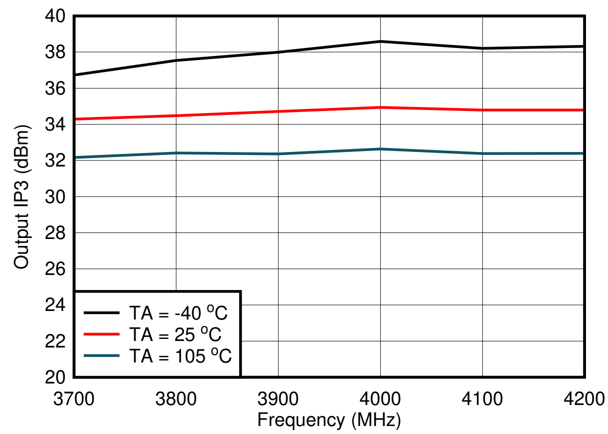


Figure 8-9. Output IP3 vs Frequency and Temperature

9 Power Supply Recommendations

The LMH9235 device operates on a common nominal 3.3-V supply voltage. It is recommended to isolate the supply voltage through decoupling capacitors placed close to the device. Select capacitors with self-resonant frequency above the application frequency. When multiple capacitors are used in parallel to create a broadband decoupling network, place the capacitor with the higher self-resonant frequency closer to the device.

10 Layout

10.1 Layout Guidelines

When designing with an RF amplifier operating in the frequency range 3.3 GHz to 3.8 GHz with relatively high gain, certain board layout precautions must be taken to ensure stability and optimum performance. TI recommends that the LMH9235 board be multi-layered to improve thermal performance, grounding, and power-supply decoupling. Figure 10-1 shows a good layout example. In this figure, only the top signal layer is shown.

- Excellent electrical connection from the thermal pad to the board ground is essential. Use the recommended footprint, solder the pad to the board, and do not include a solder mask under the pad.
- Connect the pad ground to the device terminal ground on the top board layer.
- Ensure that ground planes on the top and any internal layers are well stitched with vias.
- Design the input and output RF traces for appropriate impedance. TI recommends grounded coplanar waveguide (GCPW) type transmission lines for the RF traces. Use a PCB trace width calculator tool to design the transmission lines.
- Avoid routing clocks and digital control lines near RF signal lines.
- Do not route RF or DC signal lines over noisy power planes.
- Place supply decoupling caps close to the device.
- The differential output traces must be symmetrical in order to achieve the best differential balance and linearity performance.

See the *LMH9235 Evaluation Module* user's guide for more details on board layout and design.

10.2 Layout Example

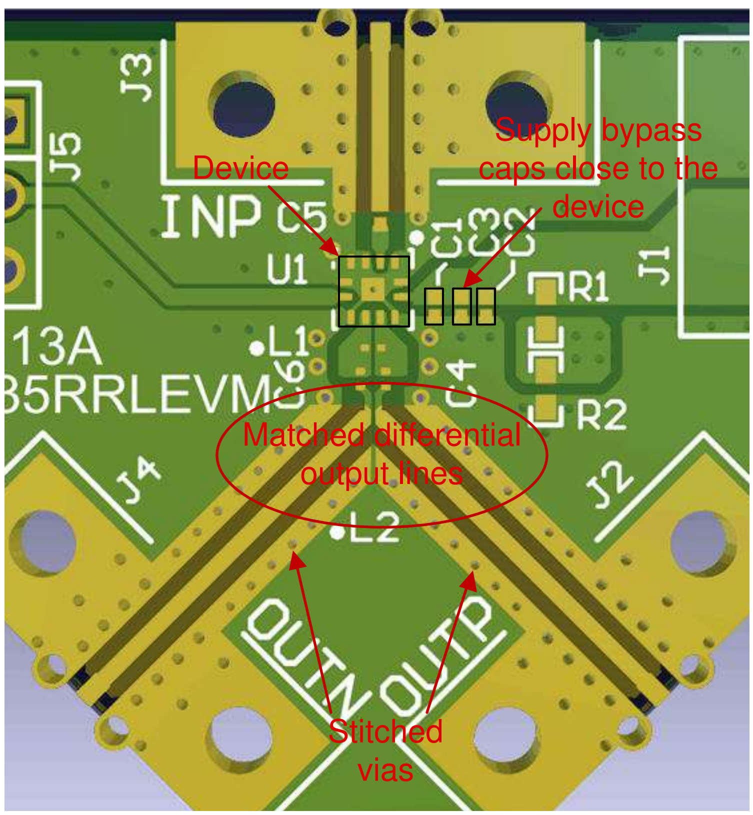


Figure 10-1. Layout Showing Matched Differential Traces and Supply Decoupling

11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, LMH9235RRLEVM EU Declaration of Conformity (DoC).
- Texas Instruments, LMH9235 Evaluation Module User's Guide.

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

11.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.
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11.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.6 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LMH9235IRRLR	ACTIVE	WQFN	RRL	12	3000	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 105	35BO	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

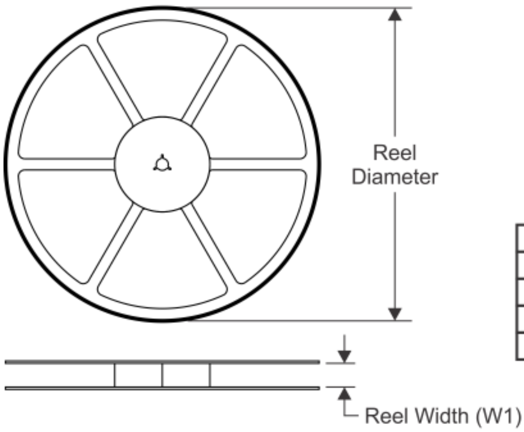
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

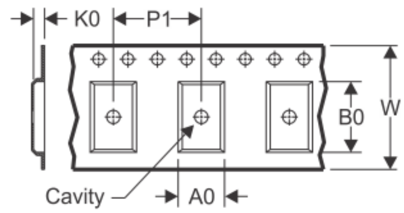
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

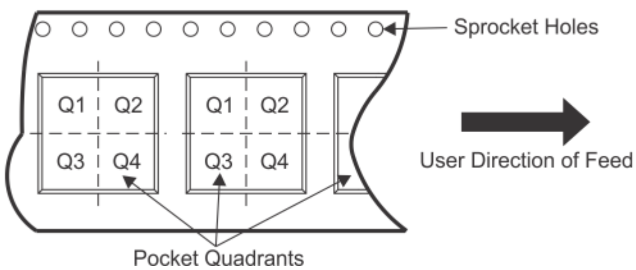


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

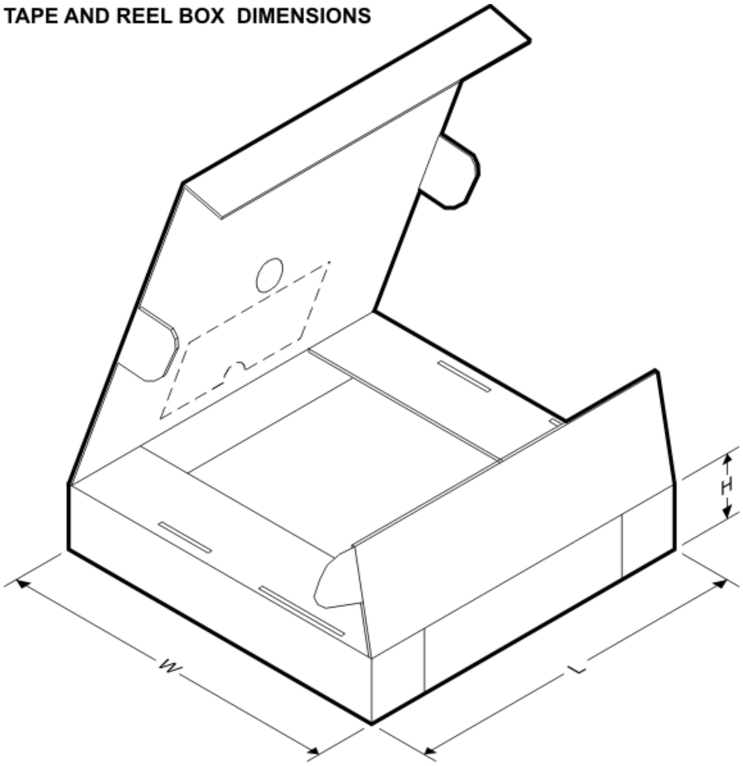
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

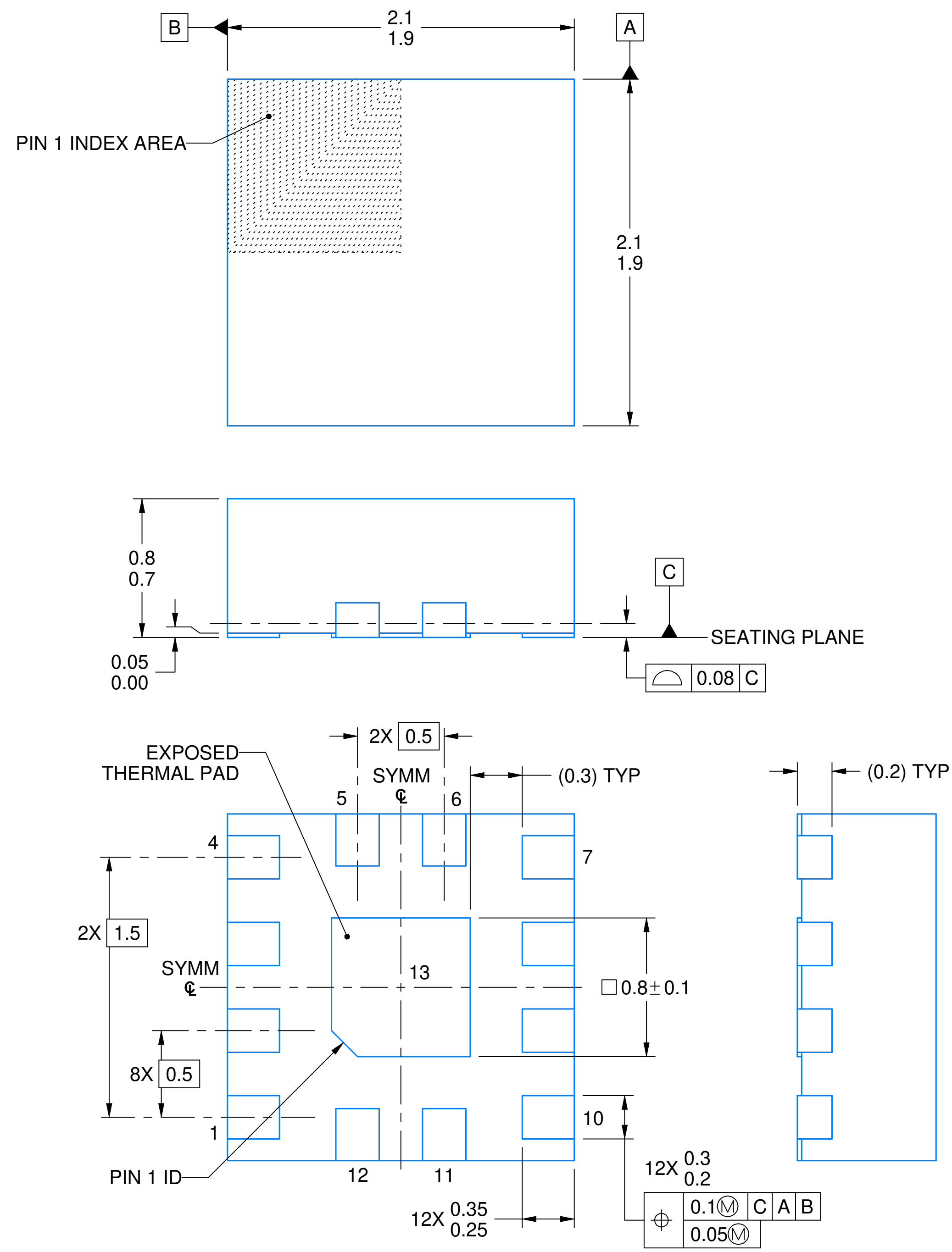
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMH9235IRRLR	WQFN	RRL	12	3000	180.0	8.4	2.2	2.2	1.2	4.0	8.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMH9235IRRLR	WQFN	RRL	12	3000	213.0	191.0	35.0



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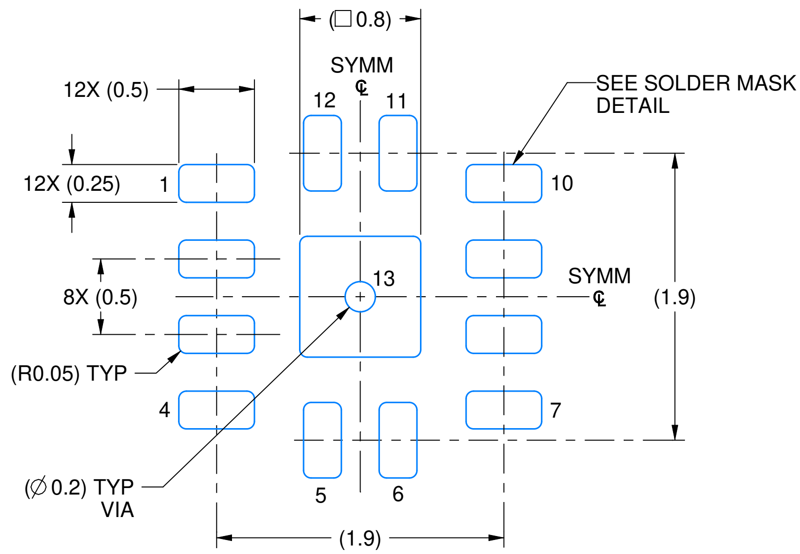
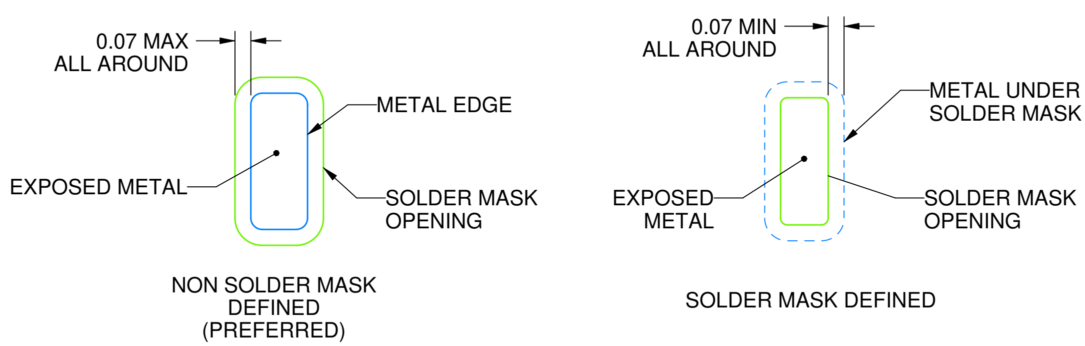
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X



SOLDER MASK DETAILS

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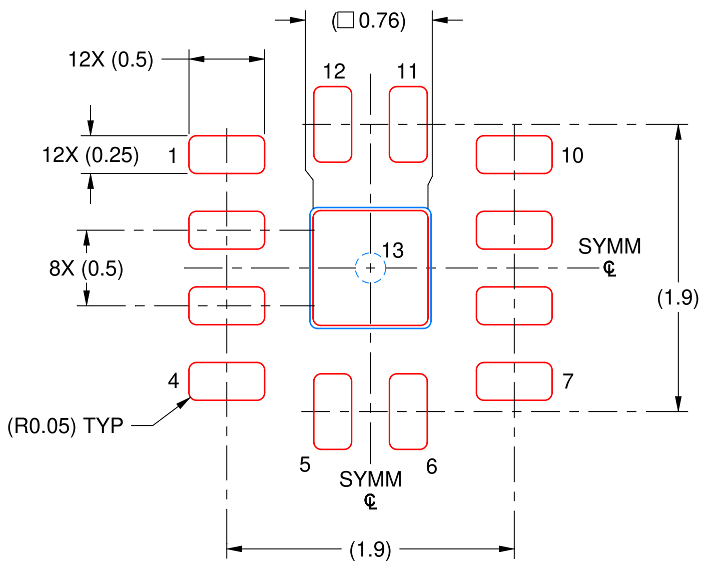
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 20X

EXPOSED PAD 13
90% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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