TEXAS INSTRUMENTS
LMH9235
JAJSJ46C – MAY 2020 – REVISED MAY 2021

LMH9235 バラン内蔵、3.3GHz～4.2GHz、シングルエンド入力 / 差動出力アンプ

1 特長

- シングル・チャネル、シングルエンド入力から差動出力への RF ゲイン・ブロック・アンプ
- 3.3GHz～3.8GHz 帯を直接、または 3.7GHz～4.2GHz 帯を外付け整合部品を使ってサポート
- 17.5dB (標準値) のゲイン (帯域内)
- 3dB 未満のノイズ指数
- 34.5dBm の OIP3
- 18dBm の出力 P1dB
- 270mW の消費電力 (+3.3V 単電源)
- 最高 T_A = 105℃の動作温度

2 アプリケーション

- 高 GSPS ADC の差動ドライバ
- シングルエンドから差動への変換
- バランの代替品
- RF ゲイン・ブロック
- スモール・セルまたは m-MIMO 基地局
- 5G アクティブ・アンテナ・システム (AAS)
- 無線セルラー基地局
- 低コスト無線

3 概要

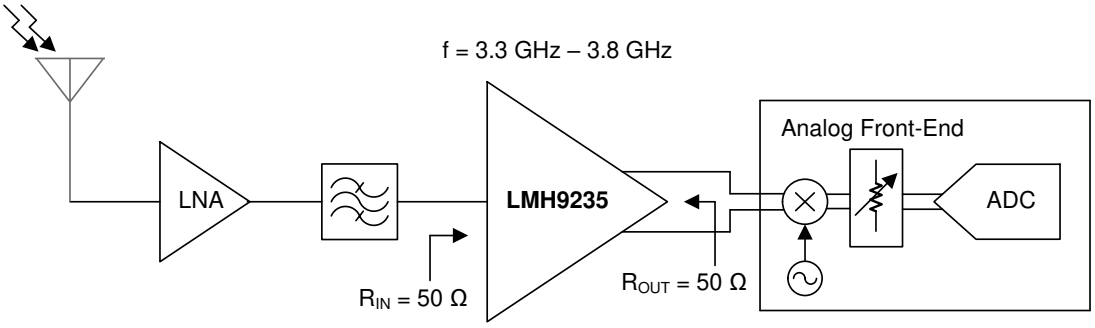
LMH9235 デバイスは、3.6GHz の中心周波数帯域をサポートするシングルエンド入力 / 差動出力の高性能シングル・チャネル受信 RF ゲイン・ブロック・アンプです。本デバイスは、LNA ゲインが不足してアナログ・フロント・エンド (AFE) のフルスケールを駆動できない場合に次世代 5G AAS またはスモール・セル・アプリケーションの要件をサポートするのに適しています。この RF アンプは、17dB (標準値) のゲインと 34dBm の出力 IP3 という優れた直線性を備えている一方、1dB 帯域幅全体にわたって約 3dB のノイズ指数を維持します。本デバイスは、シングルエンド入力と差動出力の両方で 50Ω のインピーダンスに内部的に整合しているため、RF サンプリングまたはゼロ IF アナログ・フロントエンド (AFE) と容易に接続できます。

3.3V の単電源で動作するこのデバイスは、アクティブ消費電力が約 270mW であるため、高密度 5G Massive MIMO アプリケーションに適しています。また、このデバイスは省スペースの 2mm × 2mm、12 ピン QFN パッケージで供給されます。このデバイスは最高 105℃の動作温度で定格が規定されているため、堅牢なシステム設計が可能です。時分割複信 (TDD) システムに適した、デバイスの高速な電源オン / オフに利用できる 1.8V JEDEC 準拠のパワー・ダウン・ピンを備えています。

製品情報(1)

部品番号	パッケージ	本体サイズ (公称)
LMH9235	WQFN (12)	2.00mm × 2.00mm

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。



LMH9235：シングルエンド入力 / 差動出力アンプ

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4 Revision History

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Changes from Revision B (June 2020) to Revision C (May 2021)	Page
• 文書全体にわたって表、図、相互参照の採番方法を更新	1

Changes from Revision A (May 2020) to Revision B (June 2020)	Page
• 「特長」セクションに「3.7GHz～4.2GHz 帯を外付け整合部品を使って」を追加	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
• ステータスを製品プレビューから*量産データに変更*	1

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5 Pin Configuration and Functions

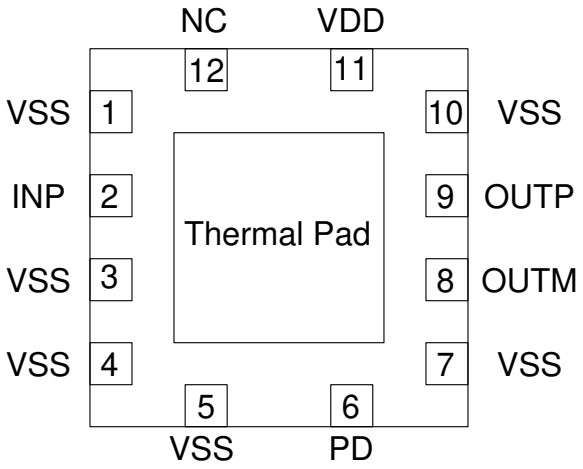

図 5-1. RRL Package 12-Pin WQFN Top View

表 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

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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 RRL PKG 12-PIN WQFN	UNIT
$R_{\theta JA}$	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.

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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)

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6.6 Typical Characteristics

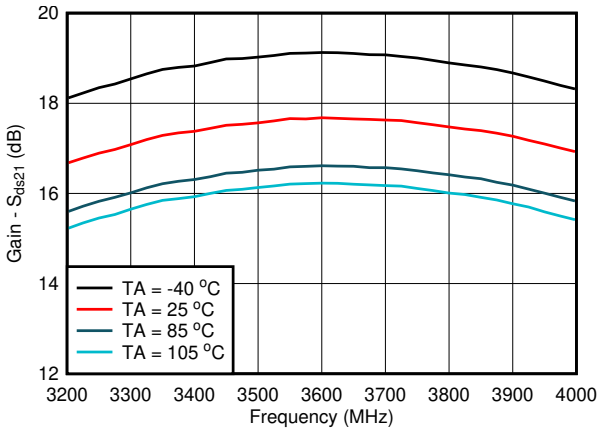


図 6-1. Gain vs Frequency and Temperature

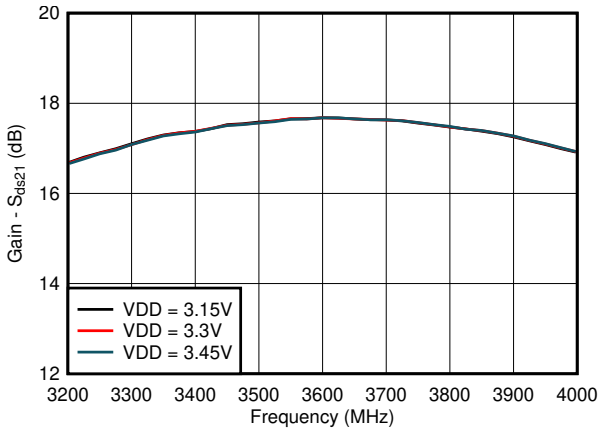


図 6-2. Gain vs Frequency and Supply Voltage

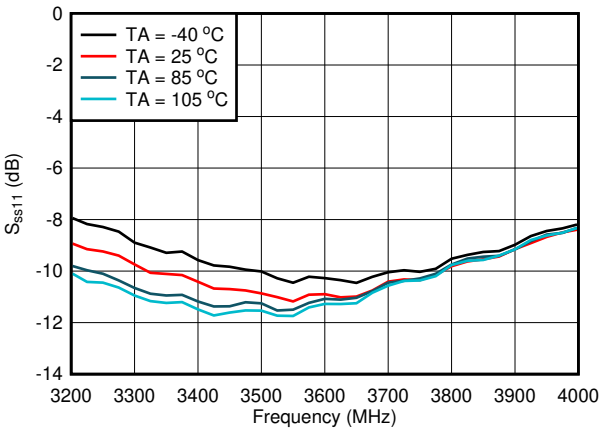


図 6-3. Input Return Loss vs Frequency

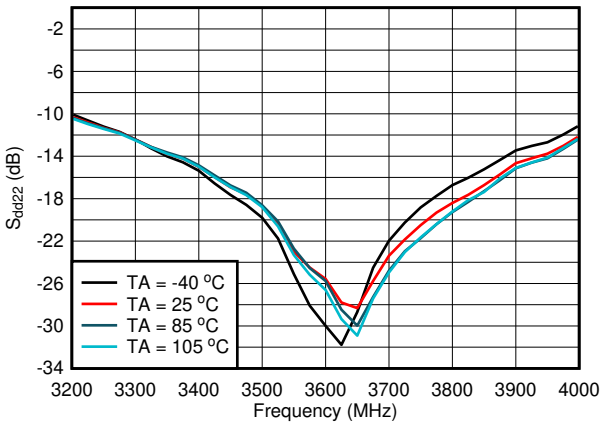


図 6-4. Output Return Loss vs Frequency

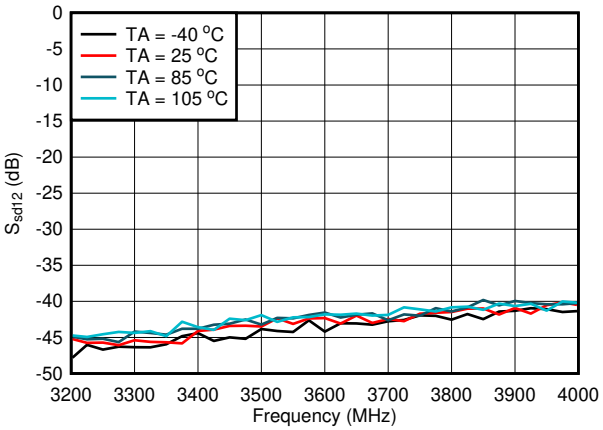
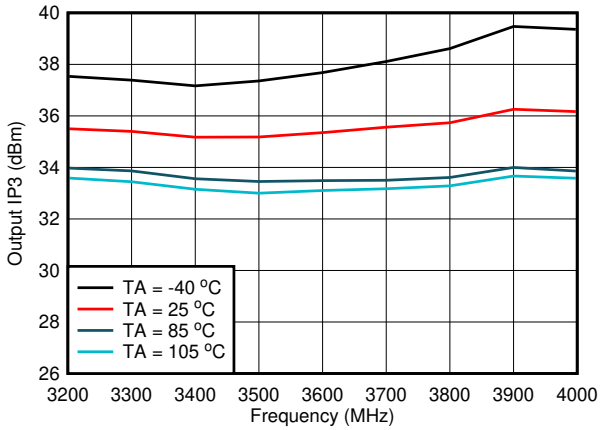


図 6-5. Reverse Isolation vs Frequency



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

図 6-6. Output IP3 vs Frequency and Temperature

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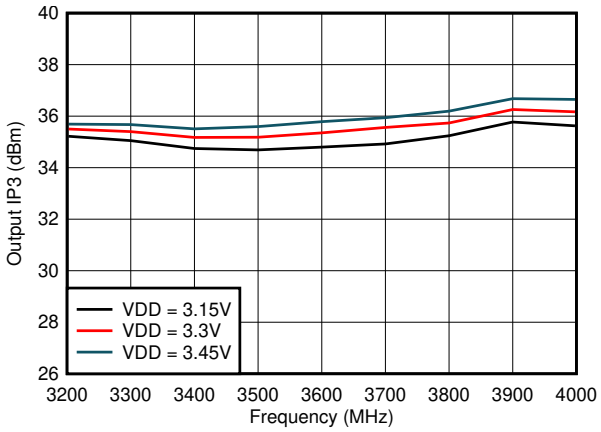
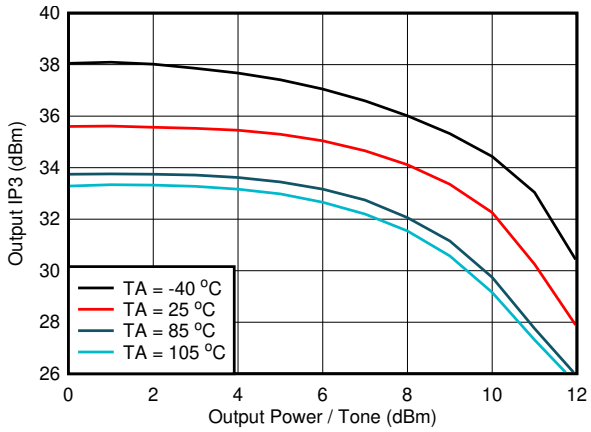
6.6 Typical Characteristics (continued)



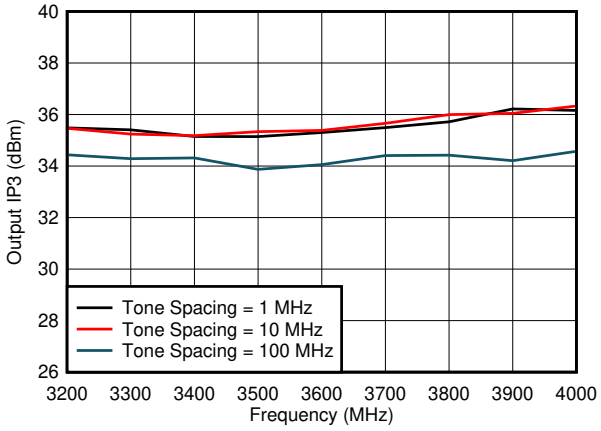
P_{OUT}/TONE = 2 dBm, 10-MHz tone spacing

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



f = 3550 MHz, 10-MHz tone spacing

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



P_{OUT}/TONE = 2 dBm

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

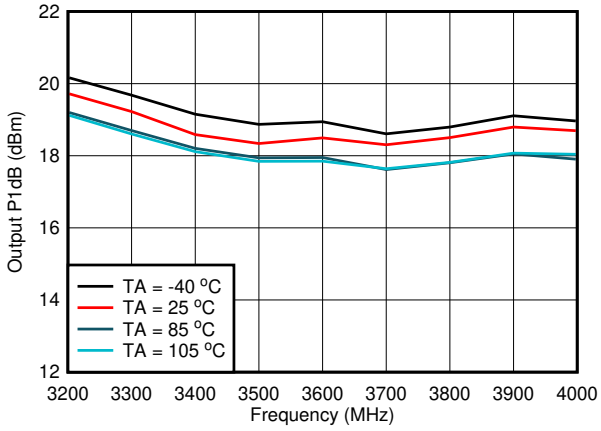


図 6-10. Output P1dB vs Frequency and Temperature

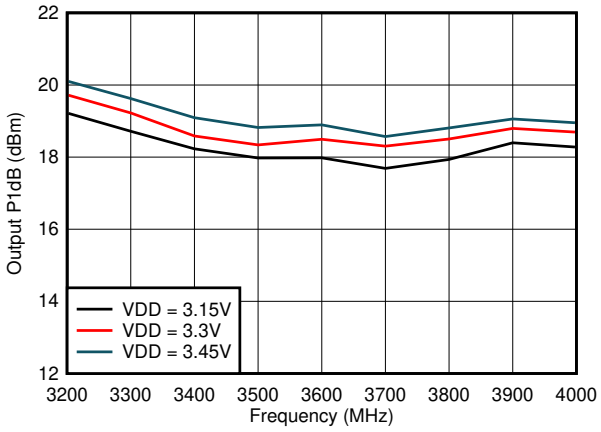
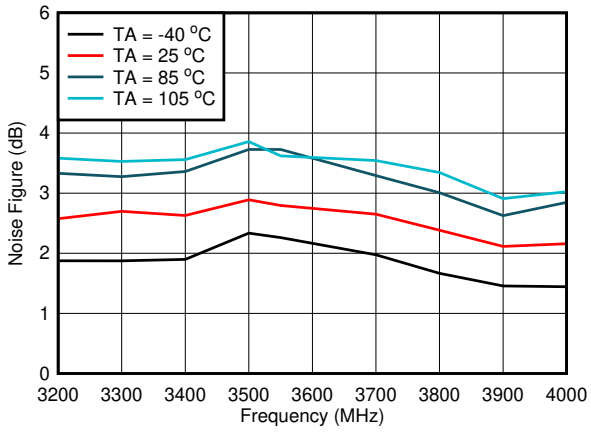


図 6-11. Output P1dB vs Frequency and Supply Voltage



Z_{SOURCE} = 50 Ω

図 6-12. Noise Figure vs Frequency and Temperature

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6.6 Typical Characteristics (continued)

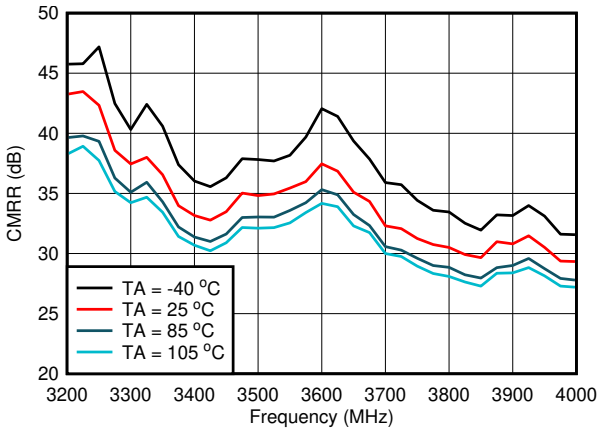

図 6-13. CMRR vs Frequency

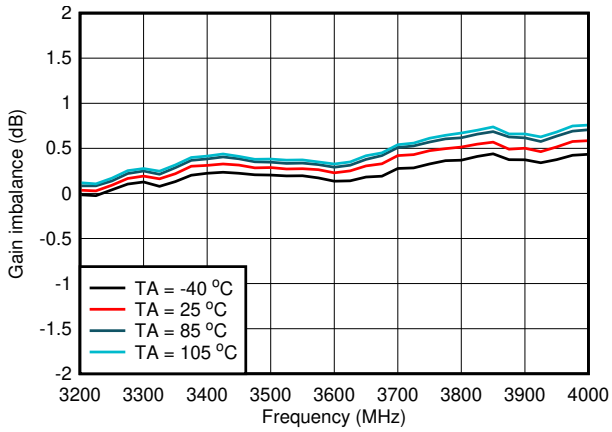

図 6-14. Gain Imbalance vs Frequency and Temperature

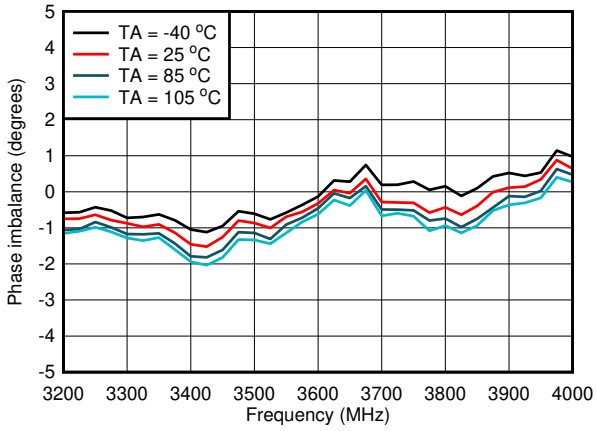

図 6-15. Phase Imbalance vs Frequency and Temperature

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 セクション 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.

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7.2 Functional Block Diagram

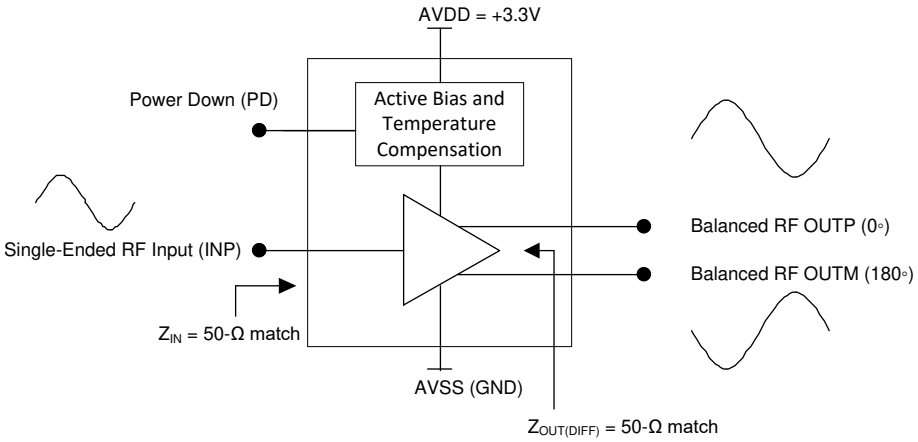

図 7-1. Functional Block Diagram

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 図 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.

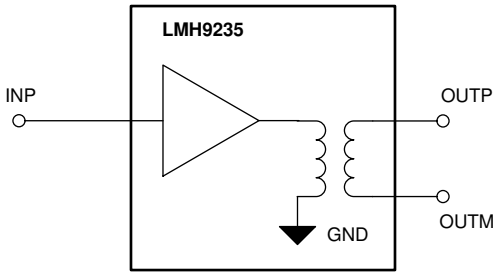

図 7-2. Single-Ended Input to Differential Output, Active Balun Implementation

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

以下のアプリケーション情報は、TI の製品仕様に含まれるものではなく、TI ではその正確性または完全性を保証いたしません。個々の目的に対する製品の適合性については、お客様の責任で判断していただくことになります。お客様は自身の設計実装を検証しテストすることで、システムの機能を確認する必要があります。

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

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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 図 8-1.

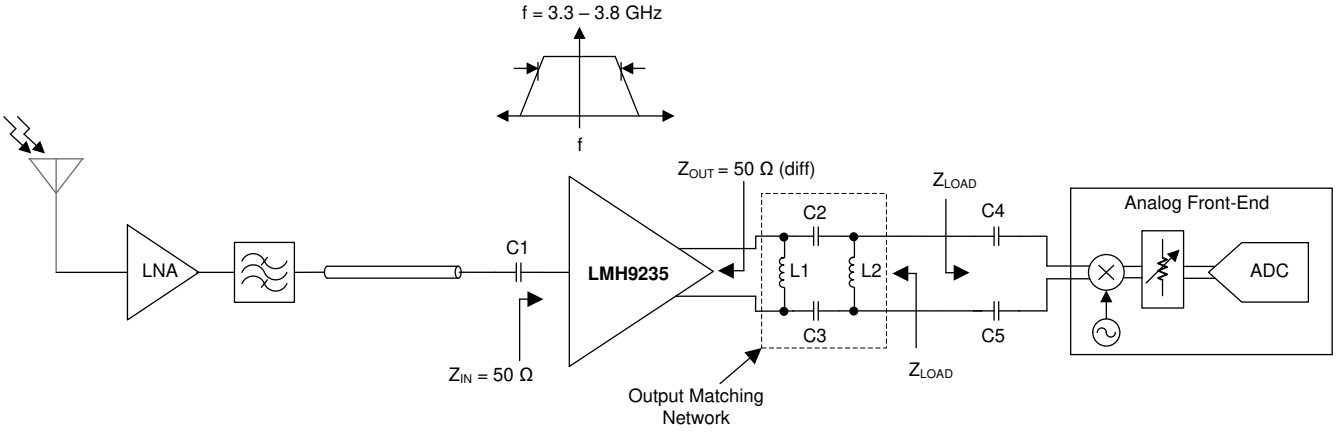

図 8-1. LMH9235 in Receive Chain Driving an Analog Front-End

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.

表 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

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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.

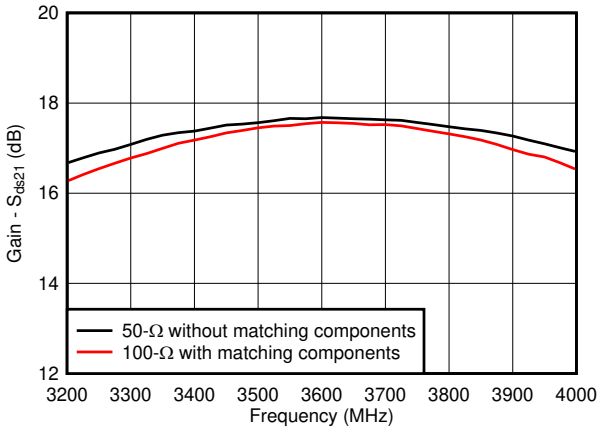

図 8-2. Gain vs Frequency for Different Terminations

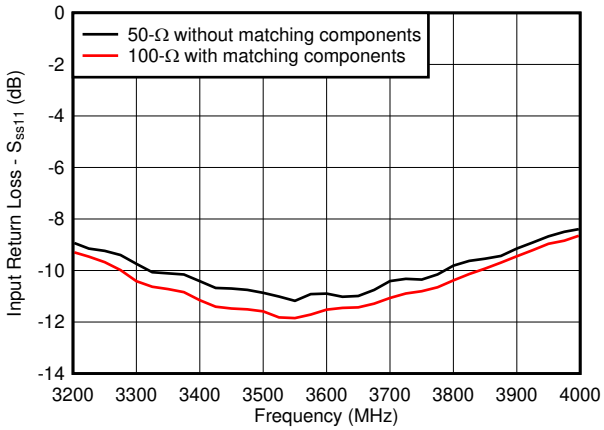

図 8-3. Input Return Loss vs Frequency for Different Terminations

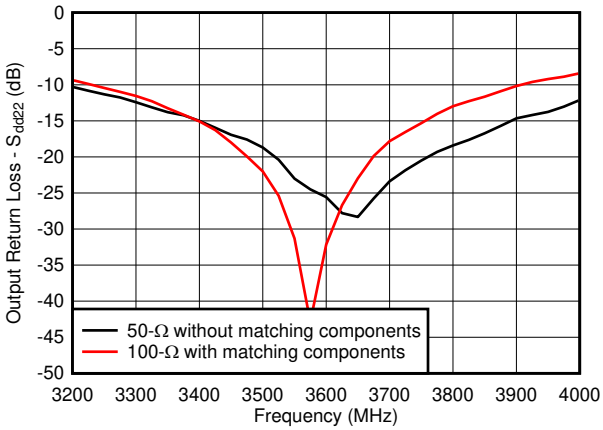

図 8-4. Output Return Loss vs Frequency for Different Terminations

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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 図 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.

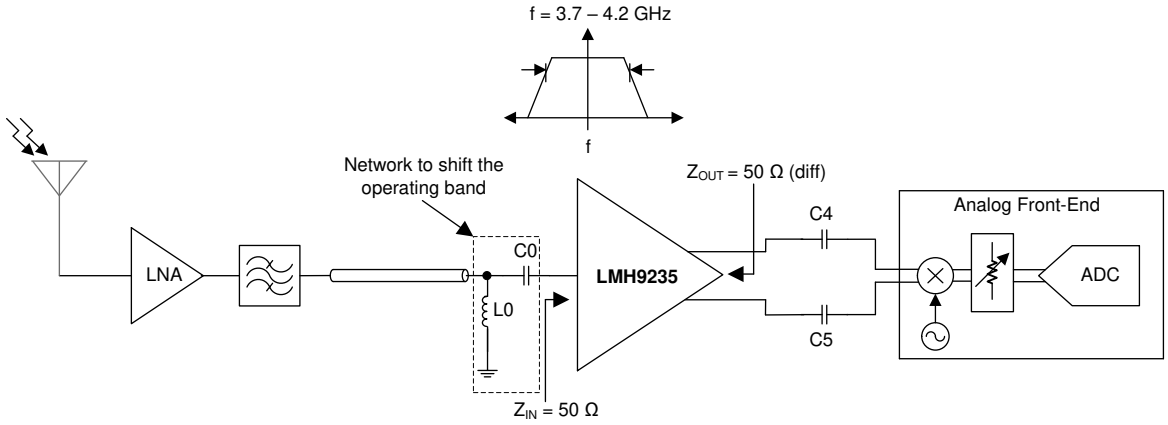

図 8-5. Shifting the Operating Band

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.

表 8-2. Matching Network Component Values

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

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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 図 8-1.

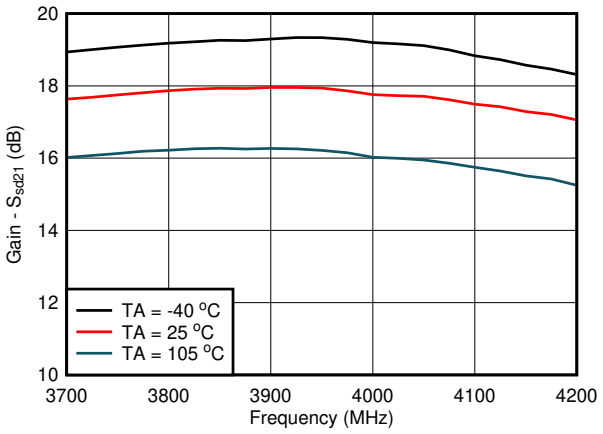

図 8-6. Gain vs Frequency

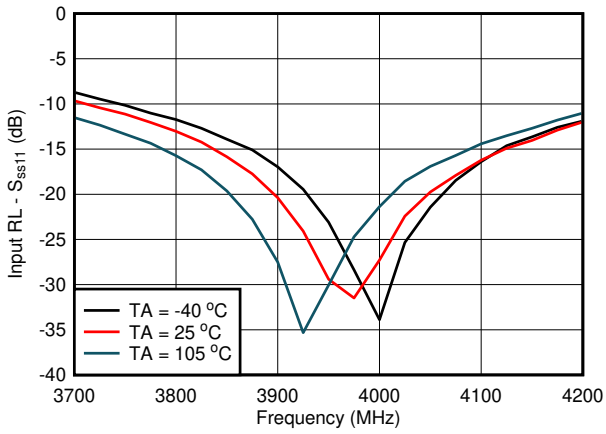

図 8-7. Input Return Loss vs Frequency

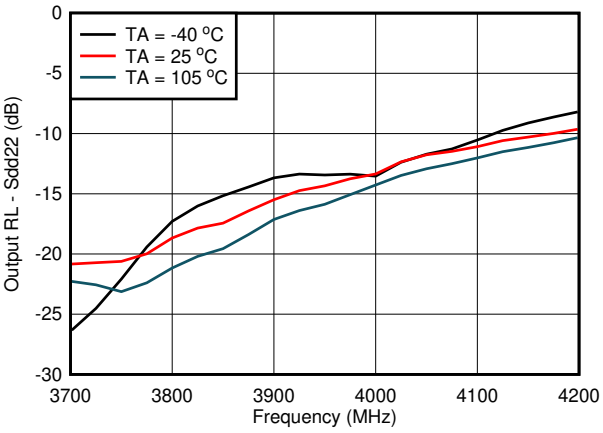

図 8-8. Output Return Loss vs Frequency

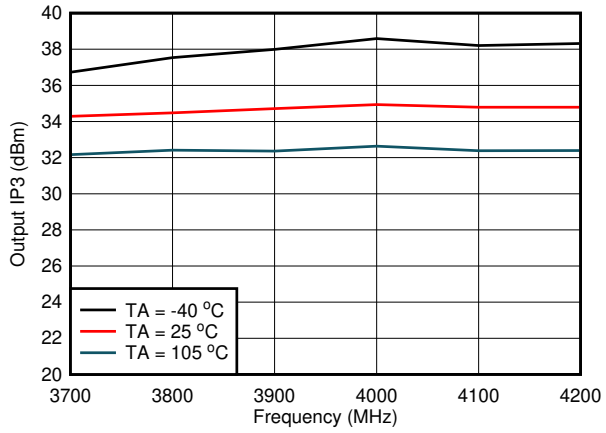

図 8-9. Output IP3 vs Frequency and Temperature

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.

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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. 図 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

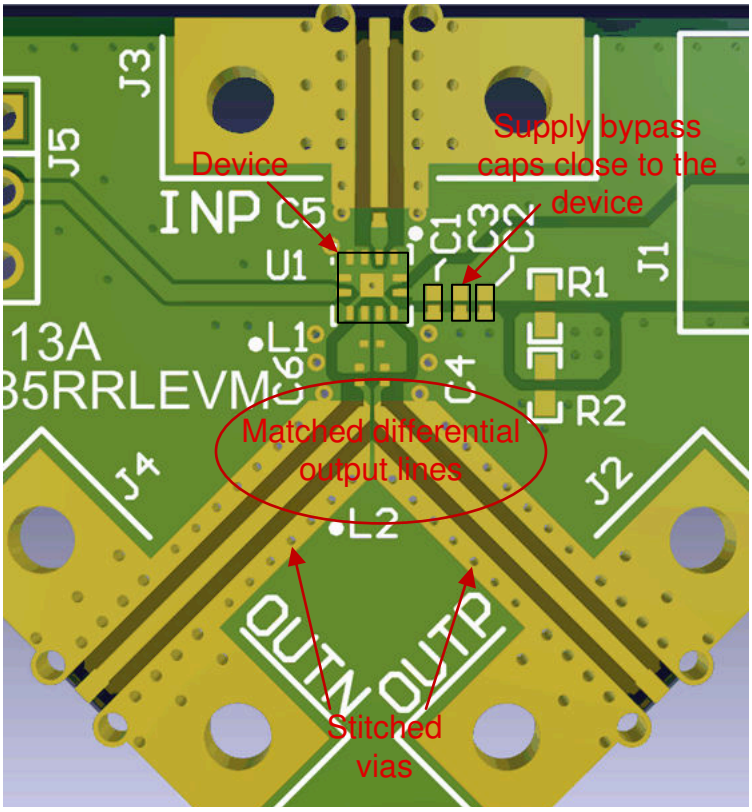

図 10-1. Layout Showing Matched Differential Traces and Supply Decoupling

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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 サポート・リソース

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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.

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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)
LMH9235IRRLR	Active	Production	WQFN (RRL) | 12	3000 | LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 105	35BO
LMH9235IRRLR.B	Active	Production	WQFN (RRL) | 12	3000 | LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 105	35BO

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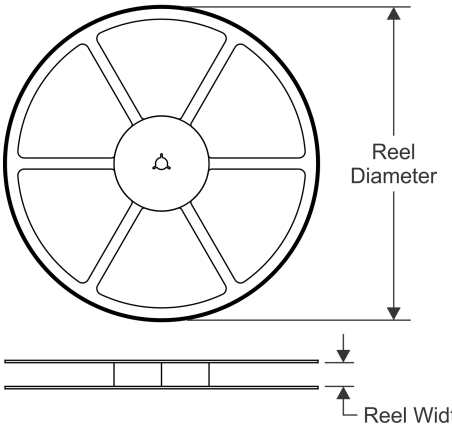
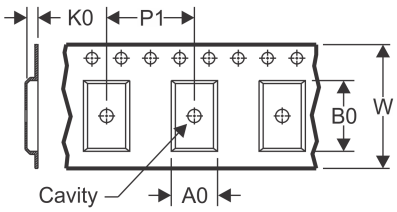
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

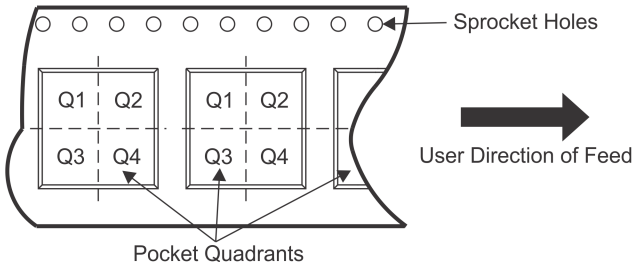


TAPE DIMENSIONS



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

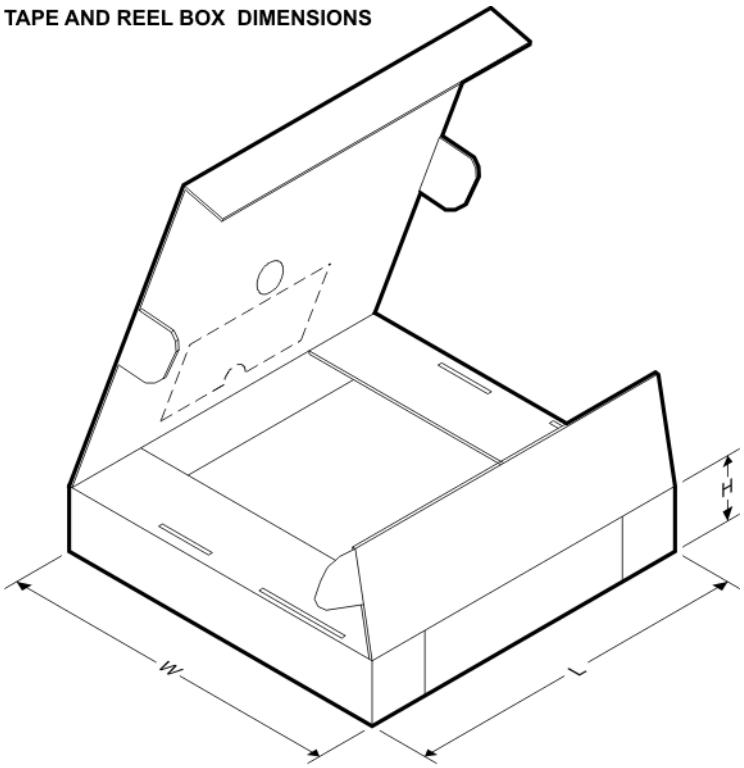
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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

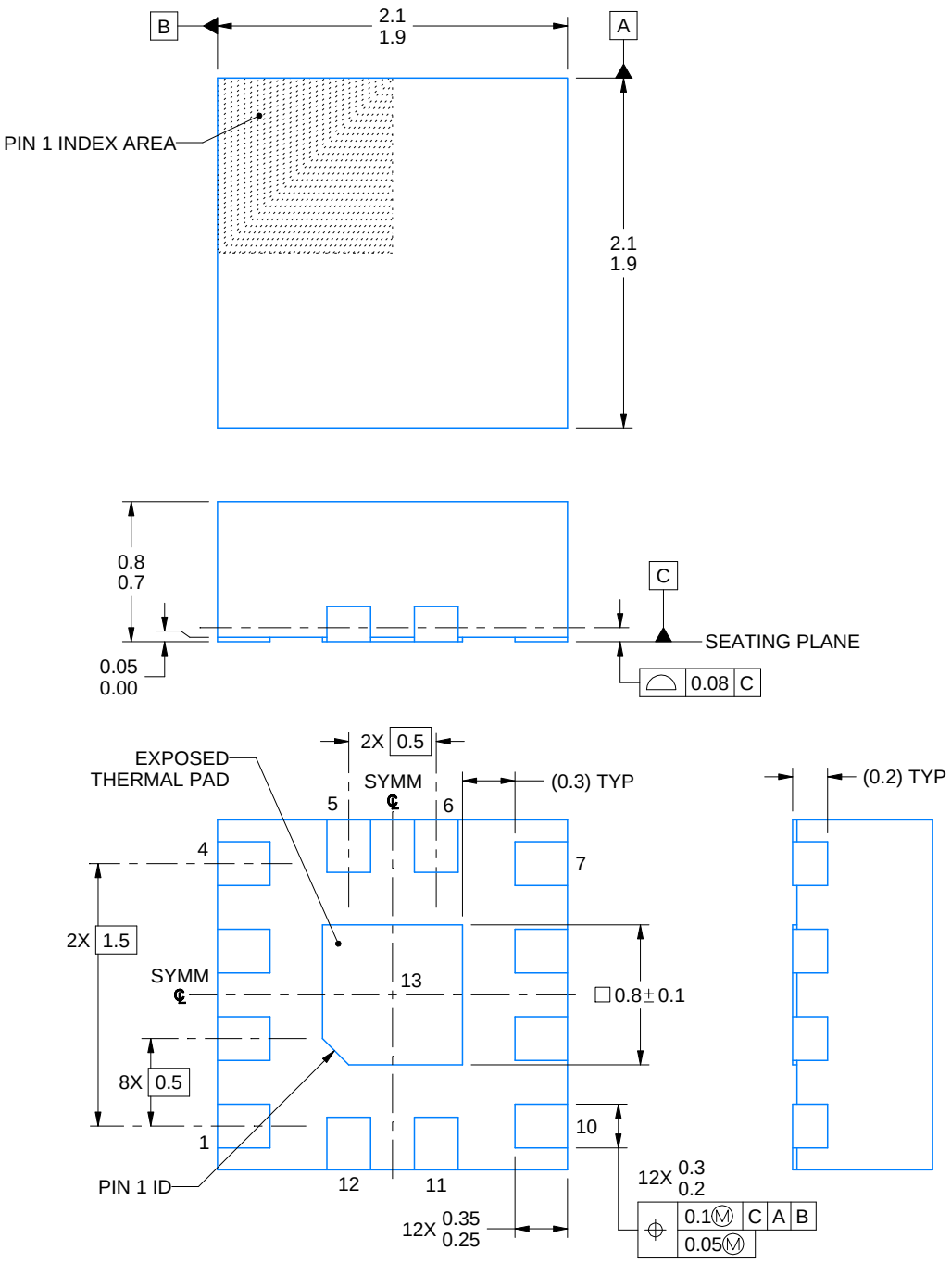
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMH9235IRRLR	WQFN	RRL	12	3000	213.0	191.0	35.0

RRL0012A

PACKAGE OUTLINE

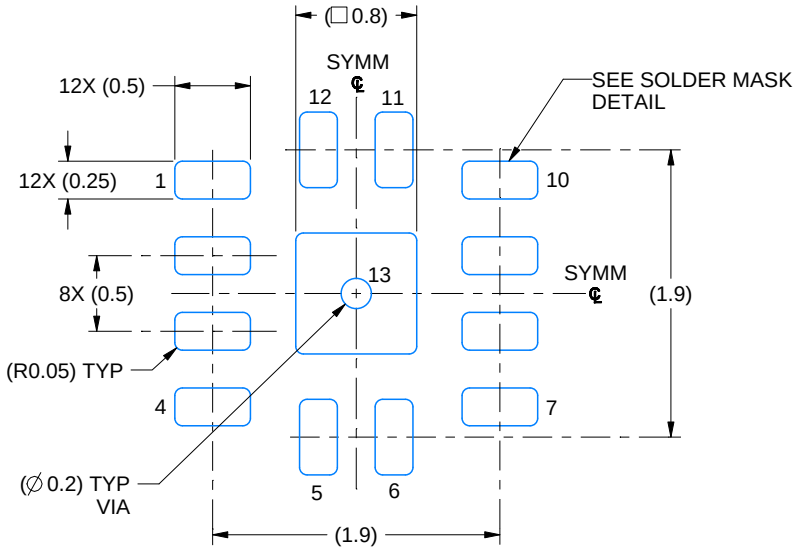
WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

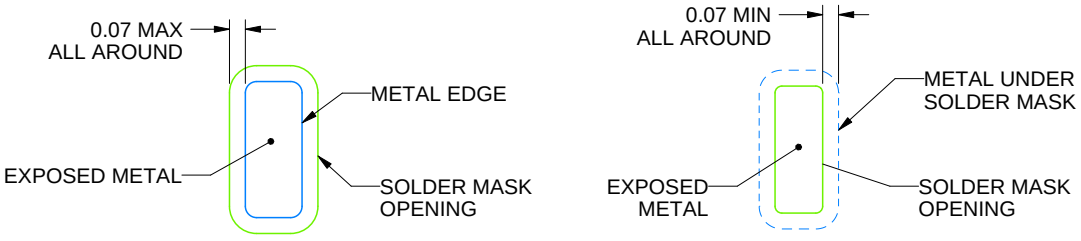


NOTES:

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



NON SOLDER MASK DEFINED (PREFERRED)

SOLDER MASK DEFINED

SOLDER MASK DETAILS

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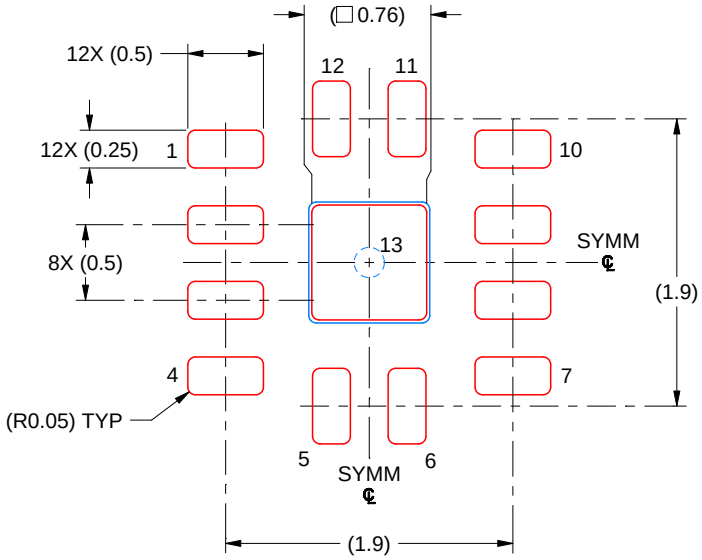
NOTES: (continued)

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

4224942/A 04/2019

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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