2.4-GHz RF Front End

FEATURES

- **Seamless Interface to 2.4-GHz Low Power RF Devices from Texas Instruments**
- **Up to 22-dBm Output Power**
- **6-dB Typical Improved Sensitivity on CC24xx and CC2500, CC2510, and CC2511**
- **Few External Components**
  - **Integrated Switches**
  - **Integrated Matching Network**
  - **Integrated Balun**
  - **Integrated Inductors**
  - **Integrated PA**
  - **Integrated LNA**
- **Digital Control of LNA Gain by HGM Pin**
- **100-nA in Power Down (EN = PAEN = 0)**
- **Low Transmit Current Consumption (100-mA at 3-V for 20-dBm Out, PAE = 33%)**
- **Low Receive Current Consumption**
  - **3.4-mA for High Gain Mode**
  - **1.7-mA for Low Gain Mode**
- **4.8-dB LNA Noise Figure, including T/R Switch and external antenna match**
- **RoHS Compliant 4×4-mm QFN-16 Package**
- **2-V to 3.6-V Operation**

APPLICATIONS

- **All 2.4-GHz ISM Band Systems**
- **Wireless Sensor Networks**
- **Wireless Industrial Systems**
- **IEEE 802.15.4 and ZigBee Systems**
- **Wireless Consumer Systems**
- **Wireless Audio Systems**

DESCRIPTION

CC2591 is a cost-effective and high performance RF Front End for low-power and low-voltage 2.4-GHz wireless applications.

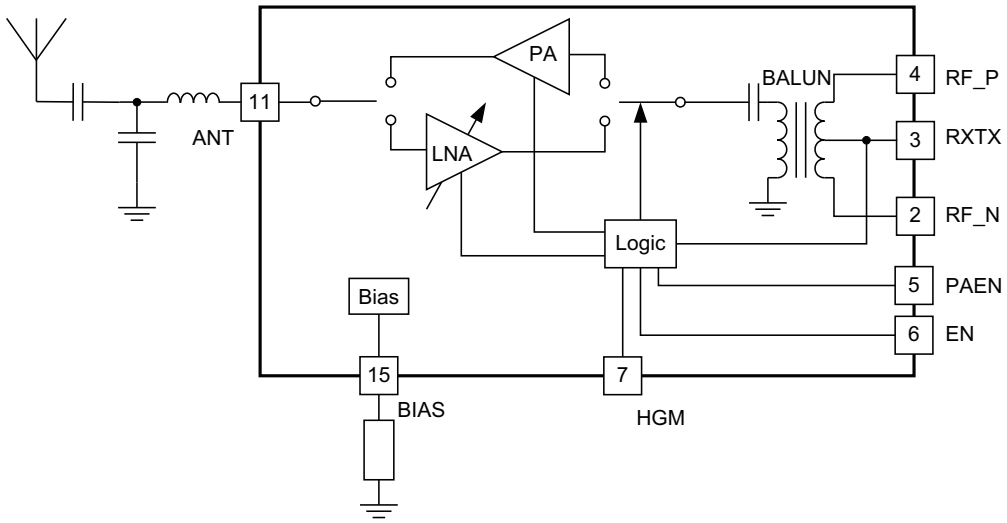
CC2591 is a range extender for all existing and future 2.4-GHz low-power RF transceivers, transmitters and System-on-Chip products from Texas Instruments.

CC2591 increases the link budget by providing a power amplifier for increased output power, and an LNA with low noise figure for improved receiver sensitivity.

CC2591 provides a small size, high output power RF design with its 4x4-mm QFN-16 package.

CC2591 contains PA, LNA, switches, RF-matching, and balun for simple design of high performance wireless applications.

CC2591 BLOCK DIAGRAM



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.

ABSOLUTE MAXIMUM RATINGS

Under no circumstances must the absolute maximum ratings be violated. Stress exceeding one or more of the limiting values may cause permanent damage to the device.

PARAMETER		VALUE	UNIT
Supply voltage	All supply pins must have the same voltage	–0.3 to 3.6	V
Voltage on any digital pin		–0.3 to V_{DD} + 0.3, max 3.6	
Input RF level		10	dBm
Storage temperature range		–50 to 150	°C

RECOMMENDED OPERATING CONDITIONS

The operating conditions for CC2591 are listed below.

PARAMETER		MIN	MAX	UNIT
Ambient temperature range		–40	85	°C
Operating supply voltage		2	3.6	V
Operating frequency range		2400	2483.5	MHz

ELECTRICAL CHARACTERISTICS

T_C = 25°C, V_{DD} = 3 V , f_{RF}= 2440MHz (unless otherwise noted). Measured on CC2591EM reference design including external matching components.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receive current, High Gain Mode	HGM = 1		3.4	4	mA
Receive current, Low Gain Mode	HGM = 0		1.7	2	
Transmit current	P_{IN} = 0.5 dBm		112		
Transmit current	No input signal		40	50	
Power down current	EN = PAEN = 0		0.1	0.3	µA
High input level (control pins)	EN, PAEN, HGM, RXTX	1.3		V_{DD}	V
Low input level (control pins)	EN, PAEN, HGM, RXTX			0.3	
Power down - Receive mode switching time			12		µs
Power down - Transmit mode switching time			1		µs
RF Receive					
Gain, High Gain Mode	HGM = 1		11		dB
Gain, Low Gain Mode	HGM = 0		1		dB
Gain variation, 2400 – 2483.5 MHz, High Gain Mode	HGM = 1		1.3		dB
Gain variation, 2.0V – 3.6V, High Gain Mode	HGM = 1		1.5		dB
Gain variation, -40°C – 85°C, High Gain Mode	HGM = 1		3		dB
Noise figure, High Gain Mode	HGM = 1, including internal T/R switch and external antenna match		4.8		dB
Input 1 dB compression, High Gain Mode	HGM = 1		–17		dBm
Input IP3, High Gain Mode	HGM = 1		–2		dBm
Input reflection coefficient, S11	HGM = 1, measured at antenna port		–11		dB

ELECTRICAL CHARACTERISTICS (continued)

T_C = 25°C, V_{DD} = 3 V , f_{RF}= 2440MHz (unless otherwise noted). Measured on CC2591EM reference design including external matching components.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
RF Transmit					
Gain			22		dB
Output power, P_{OUT}	P_{IN} = 0.5 dBm		20.6		dBm
Maximum output power	P_{IN} = 5 dBm		22		dBm
Power Added Efficiency, PAE	P_{IN} = 0.5 dBm		34%		
Output 1 dB compression			19		dBm
Output IP3			32		dBm
Output power variation over frequency	2400 – 2483.5 MHz, P_{IN} = 0.5 dBm		0.5		dB
Output power variation over power supply	2V – 3.6V , P_{IN} = 0.5 dBm		3.5		dB
Output power variation over temperature	-40°C – 85°C, P_{IN} = 0.5 dBm		1.5		dB
2nd harmonic power	P_{IN} = 0.5 dBm. The 2nd harmonic can be reduced to below regulatory limits by using an external LC filter and antenna.		–15		dBm
3rd harmonic power	P_{IN} = 0.5 dBm. The 3rd harmonic can be reduced to below regulatory limits by using an external LC filter and antenna.		–30		dBm

DEVICE INFORMATION

The CC2591 pinout and description are shown in Figure 1 and Table 1, respectively.

PIN AND I/O CONFIGURATION
(TOP VIEW)

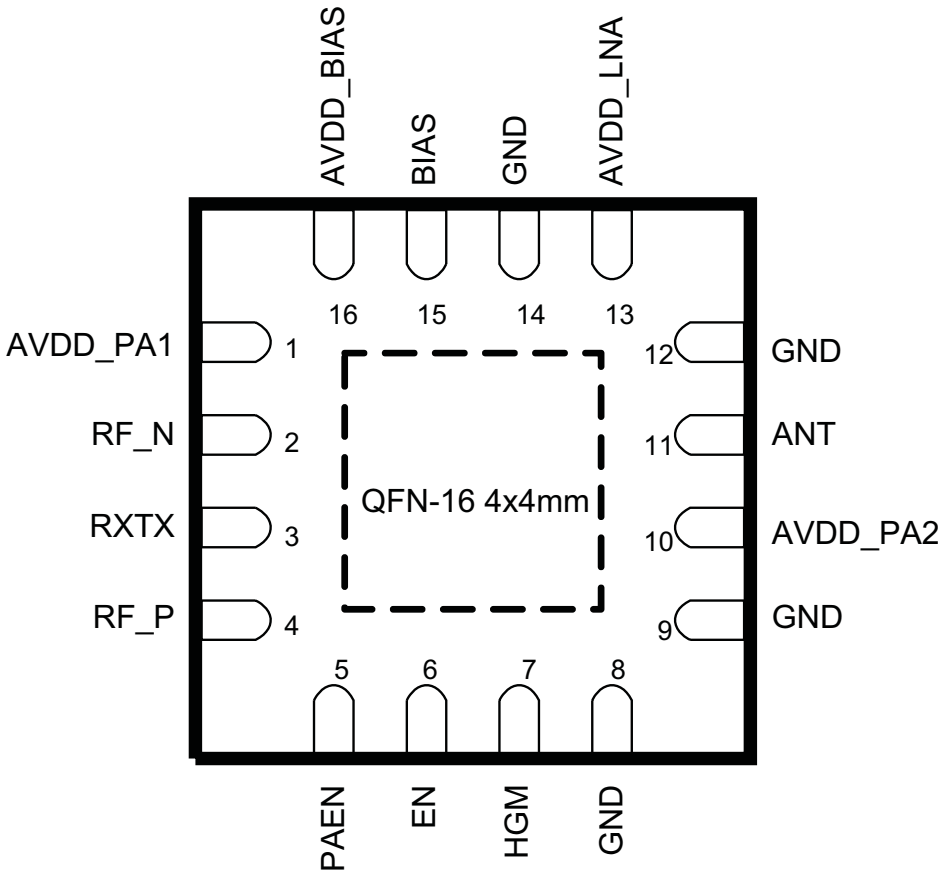


Figure 1.

NOTE:

The exposed die attach pad **must** be connected to a solid ground plane as this is the primary ground connection for the chip. Inductance in vias to the pad should be minimized. It is highly recommended to follow the reference layout. Changes will alter the performance. Also see the PCB landpattern information in this data sheet.

For best performance, minimize the length of the ground vias, by using a 4-layer PCB with ground plane as layer 2 when CC2591 is mounted onto layer 1.

Table 1. TERMINAL FUNCTIONS

TERMINAL		TYPE	DESCRIPTION
NO.	NAME		
—	GND	Ground	The exposed die attach pad must be connected to a solid ground plane. See CC2591EM reference design for recommended layout.
1	AVDD_PA1	Power	2.0 V – 3.6 V Power. PCB trace to this pin serves as inductive load to PA . See CC2591EM reference design for recommended layout.
2	RF_N	RF	RF interface towards CC24xx or CC25xx device.
3	RXTX	Analog/Control	RXTX switching voltage when connected to CC24xx devices. See Table 3 and Table 4 for details.
4	RF_P	RF	RF interface towards CC24xx or CC25xx device
5	PAEN	Digital Input	Digital control pin. See Table 3 and Table 4 for details.
6	EN	Digital Input	Digital control pin. See Table 3 and Table 4 for details.
7	HGM	Digital Input	Digital control pin. HGM=1 → Device in High Gain Mode HGM=0 → Device in Low Gain Mode (RX only)
8, 9, 12, 14	GND	Ground	Secondary ground connections. Should be shorted to the die attach pad on the top PCB layer.
10	AVDD_PA2	Power	2.0 V – 3.6 V Power. PCB trace to this pin serves as inductive load to PA. See CC2591EM reference design for recommended layout.
11	ANT	RF	Antenna interface.
13	AVDD_LNA	Power	2 V – 3.6 V Power. PCB trace to this pin serves as inductive load to LNA. See CC2591EM reference design for recommended layout.
15	BIAS	Analog	Biasing input. Resistor between this node and ground sets bias current to PAs.
16	AVDD_BIAS	Power	2 V – 3.6 V Power.

CC2591EM Evaluation Module

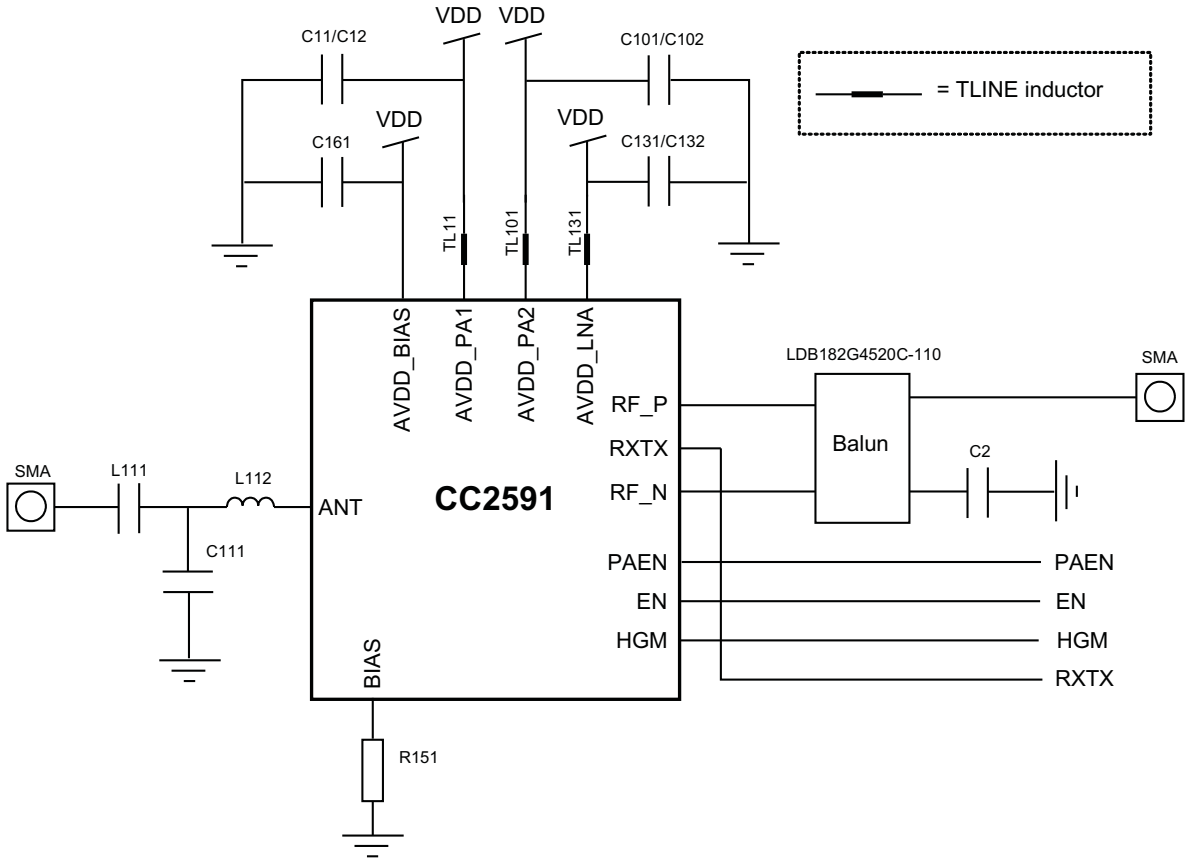


Figure 2. CC2591EM Evaluation Module

Table 2. List of Materials (See CC2591EM Reference Design)

DEVICE	FUNCTION	VALUE
L112	Part of antenna match.	1.5 nH: LQW15AN1N5B00 from Murata
L111	DC block.	1 nF: GRM1555C1H102JA01 from Murata
C111	Part of antenna match.	1 pF: GRM1555C1H1R0BZ01 from Murata
C161	Decoupling capacitor.	1 nF: GRM1555C1H102JA01 from Murata
C11/C12	Decoupling. Will affect PA resonance.	10 pF || 1 nF. The smallest cap closest. See CC2591EM reference design for placement. 10 pF: GRM1555C1H100JZ01 from Murata 1 nF: GRM1555C1H102JA01 from Murata
C101/C102	Decoupling. Will affect PA resonance.	18 pF || 1 nF. The smallest cap closest. See for CC2591EM reference design placement. 18 pF: GRM1555C1H180JZ01 from Murata 1 nF: GRM1555C1H102JA01 from Murata
C131/C132	Decoupling. Will affect PA resonance.	10 pF || 1 nF. The smallest cap closest. See CC2591EM reference design for placement. 10 pF: GRM1555C1H100JZ01 from Murata 1 nF: GRM1555C1H102JA01 from Murata
C2	Decoupling of external balun	1 nF: GRM1555C1H102JA01 from Murata
TL11	Transmission line. Will affect PA resonance.	See CC2591EM reference design.
TL101	Transmission line. Will affect PA resonance.	See CC2591EM reference design.
TL131	Transmission line. Will affect LNA resonance.	See CC2591EM reference design.
R151	Bias resistor	4.3 kΩ: RK73H1ETTP4301F from Koa

TYPICAL CHARACTERISTICS

LNA GAIN AND NOISE FIGURE
vs
FREQUENCY

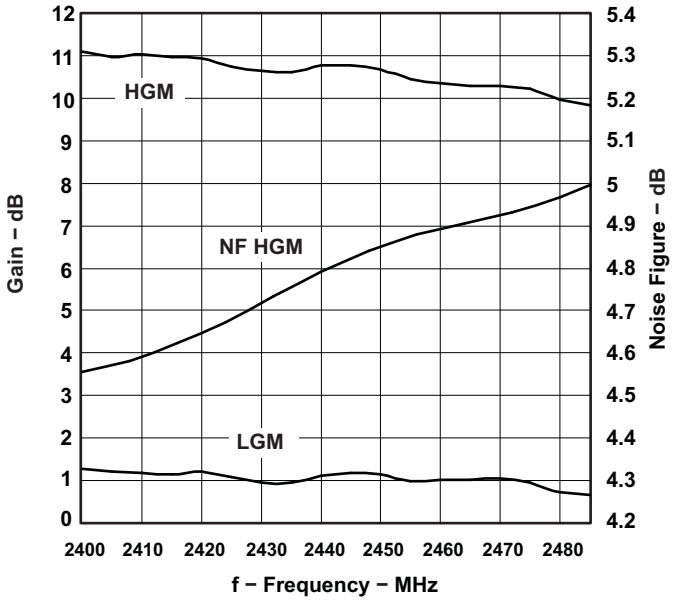


Figure 3.

LNA GAIN
vs
TEMPERATURE

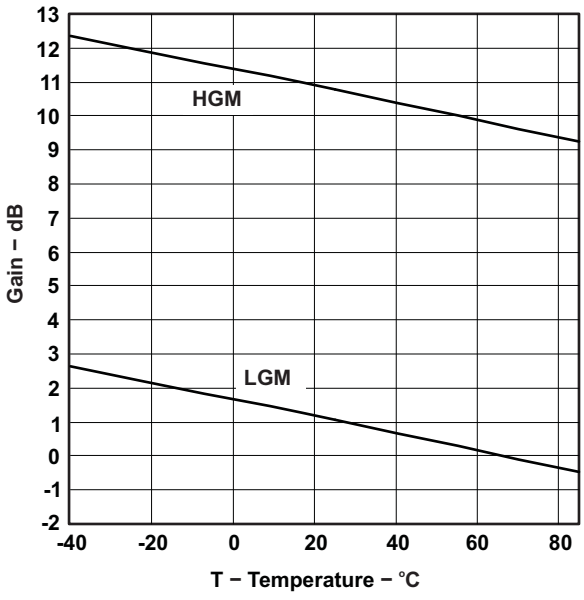


Figure 4.

LNA GAIN
vs
POWER SUPPLY

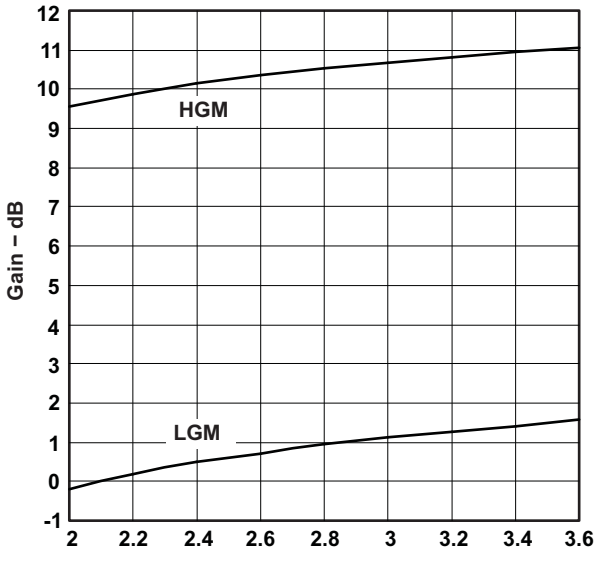


Figure 5.

TYPICAL CHARACTERISTICS (continued)

OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs INPUT POWER

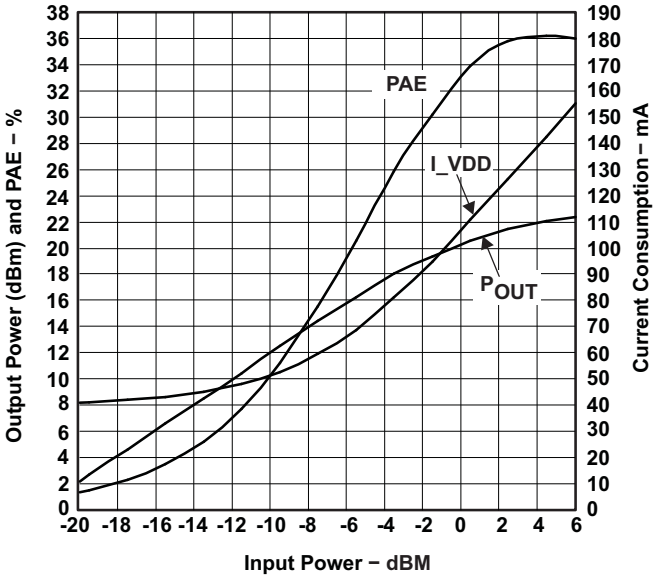


Figure 6.

OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs FREQUENCY

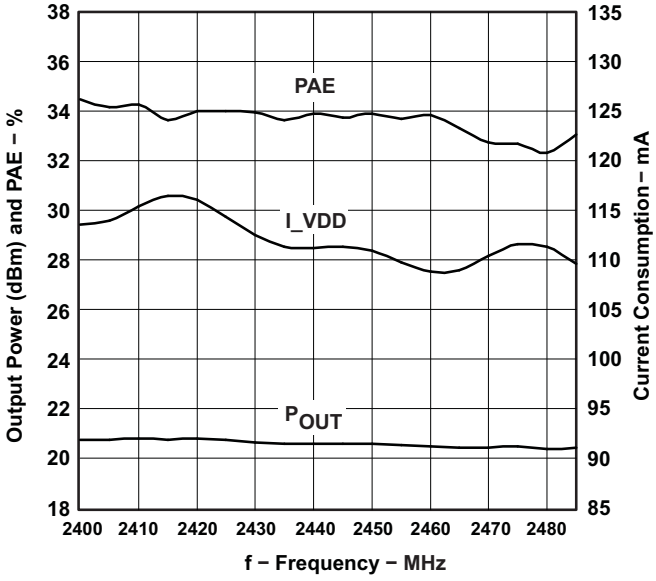


Figure 7.

OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs TEMPERATURE

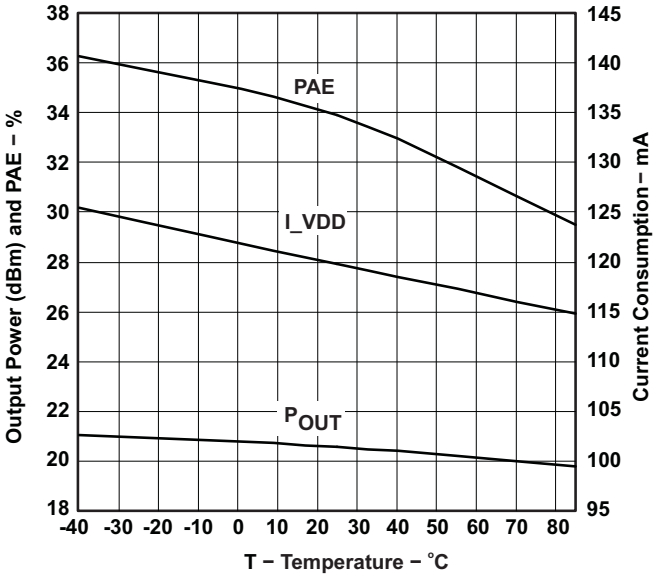


Figure 8.

OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs POWER SUPPLY

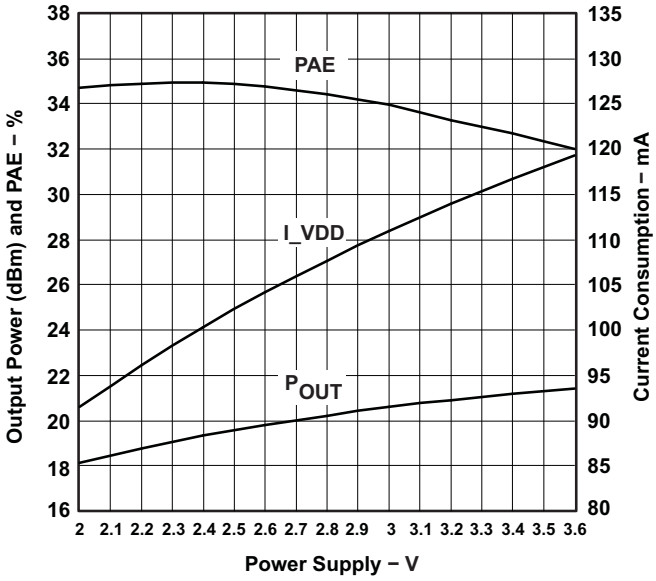


Figure 9.

Controlling the Output Power from CC2591

The output power of CC2591 is controlled by controlling the input power. The CC2591 PA is designed to work in compression (class AB), and the best efficiency is reached when a strong input signal is applied.

Input Levels on Control Pins

The four digital control pins (PAEN, EN, HGM, RXTX) have built-in level-shifting functionality, meaning that if the CC2591 is operating from a 3.6-V supply voltage, the control pins will still sense 1.6-V - 1.8-V signals as logical '1'.

An example of the above would be that RXTX is connected directly to the RXTX pin on CC24xx, but the global supply voltage is 3.6 V. The RXTX pin on CC24xx will switch between 0 V (RX) and 1.8 V(TX), which is still a high enough voltage to control the mode of CC2591.

The input voltages should however not have logical '1' level that is higher than the supply.

Connecting CC2591 to a CC24xx Device

Table 3. Control Logic for Connecting CC2591 to a CC24xx Device

PAEN = EN	RXTX	HGM	MODE OF OPERATION
0	X	X	Power Down
1	0	0	RX Low Gain Mode
1	0	1	RX High Gain Mode
1	1	X	TX

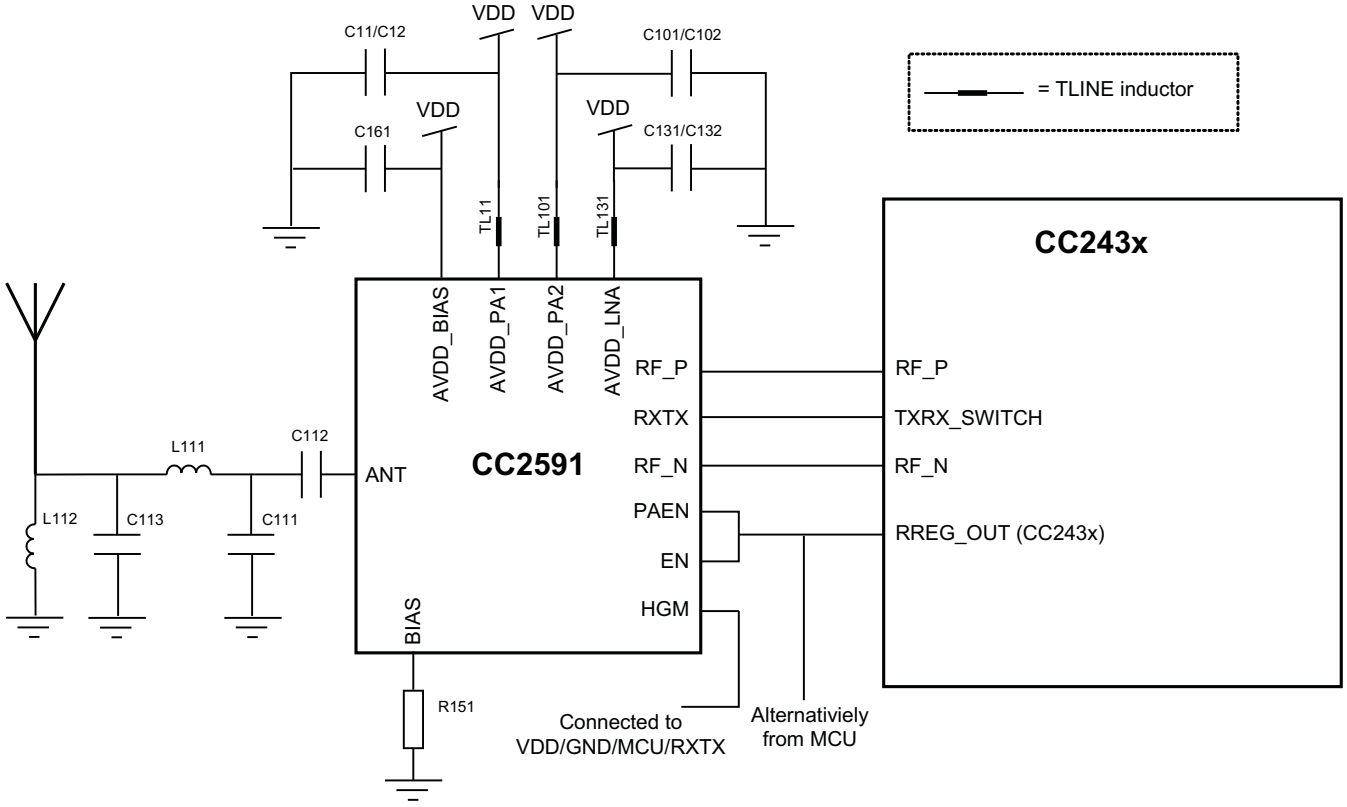


Figure 10. CC2591 + CC24xx Application Circuit

Connecting CC2591 to the CC2500, CC2510, or CC2511 Device

Table 4. Control Logic for Connecting CC2591 to a CC2500/10/11 Devices

PAEN	EN	RXTX	HGM	MODE OF OPERATION
0	0	NC	X	Power Down
0	1	NC	0	RX LGM
0	1	NC	1	RX HGM
1	0	NC	X	TX
1	1	NC	X	Not allowed

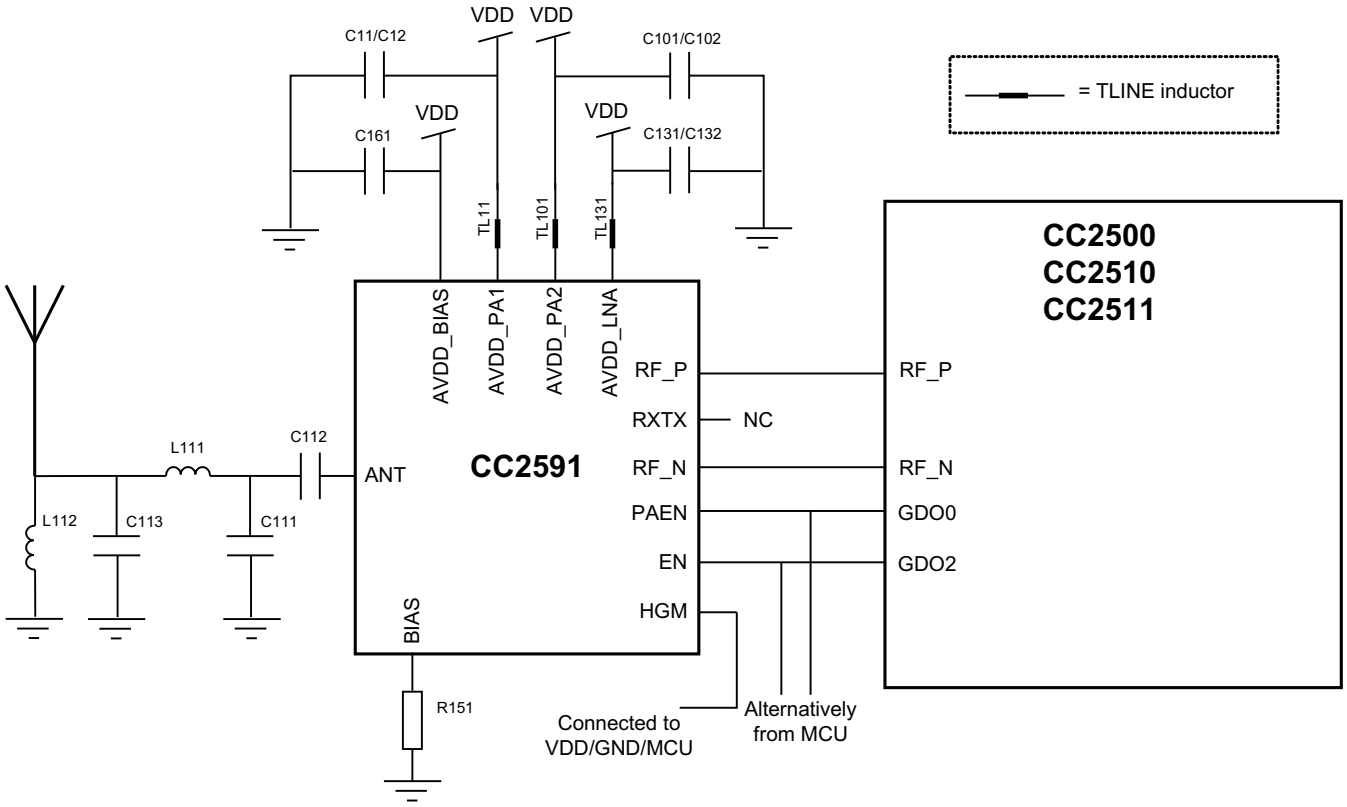


Figure 11. CC2591 + CC2500/10/11 Device Application Circuit

Connecting CC2591 to a CC2520 Device

Control Logic for Connecting CC2591 to a CC2520 Device

PAEN	EN	RXTX	HGM	MODE OF OPERATION
0	0	NC	X	Power Down
0	1	NC	0	RX LGM
0	1	NC	1	RX HGM
1	0	NC	X	TX
1	1	NC	X	Not allowed

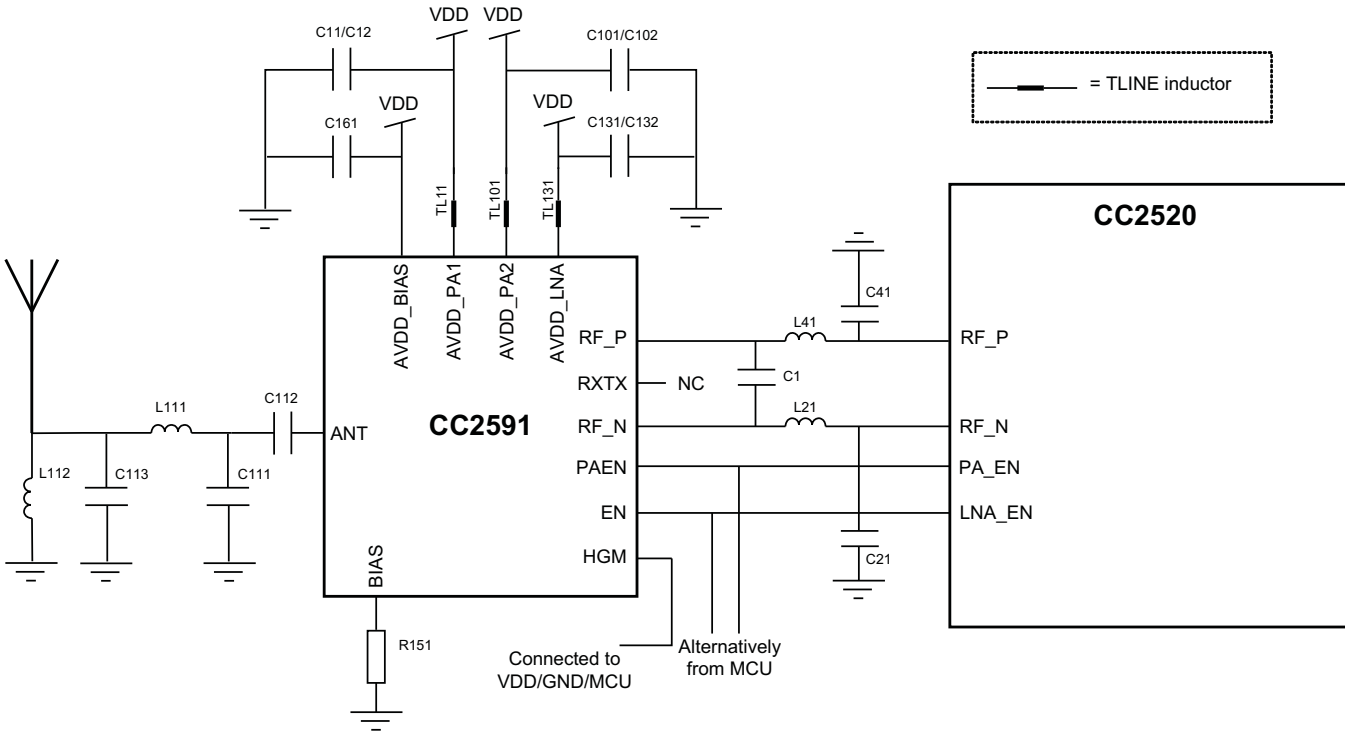


Figure 12. CC2591 + CC2520 Application Circuit

Revision History

Changes from Original (March 2008) to Revision A **Page**

- Changed the data sheet From: Product Preview To: Production Data. Multiple changes throughout. 1

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
CC2591RGVR	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
CC2591RGVRG4	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
CC2591RGVT	ACTIVE	VQFN	RGV	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
CC2591RGVTG4	ACTIVE	VQFN	RGV	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
HPA00420RGVR	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

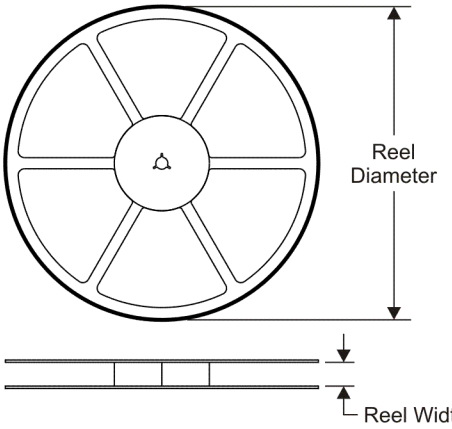
(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, 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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

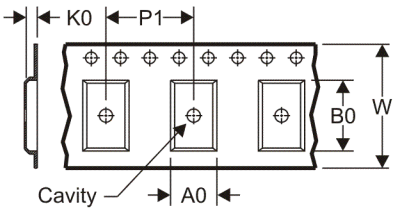
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

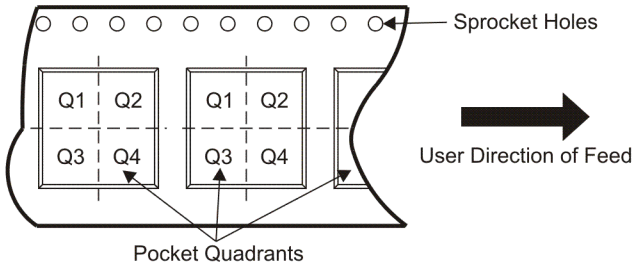


TAPE DIMENSIONS



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

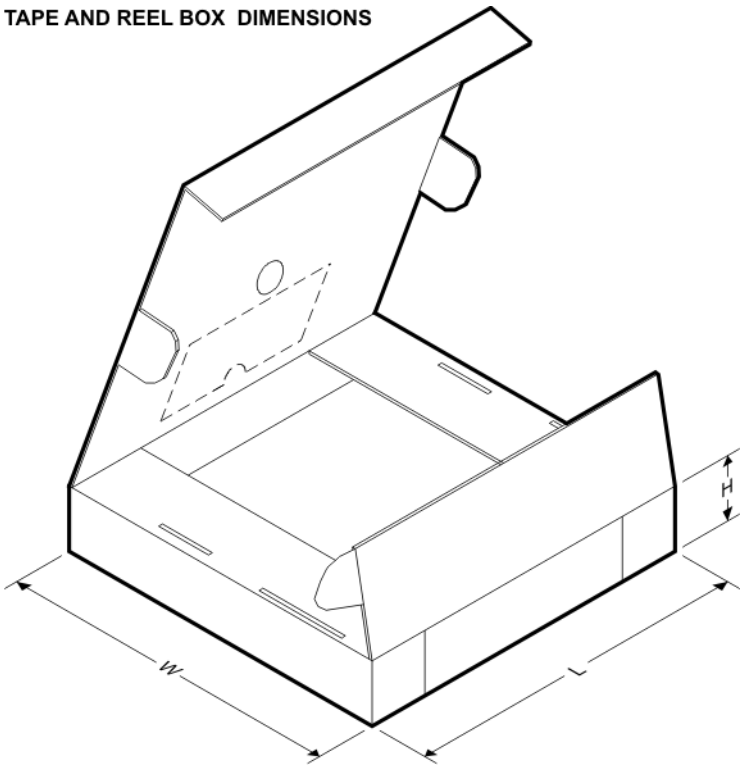
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
CC2591RGVR	VQFN	RGV	16	2500	330.0	12.4	4.3	4.3	1.5	8.0	12.0	Q2
CC2591RGVT	VQFN	RGV	16	250	330.0	12.4	4.3	4.3	1.5	8.0	12.0	Q2

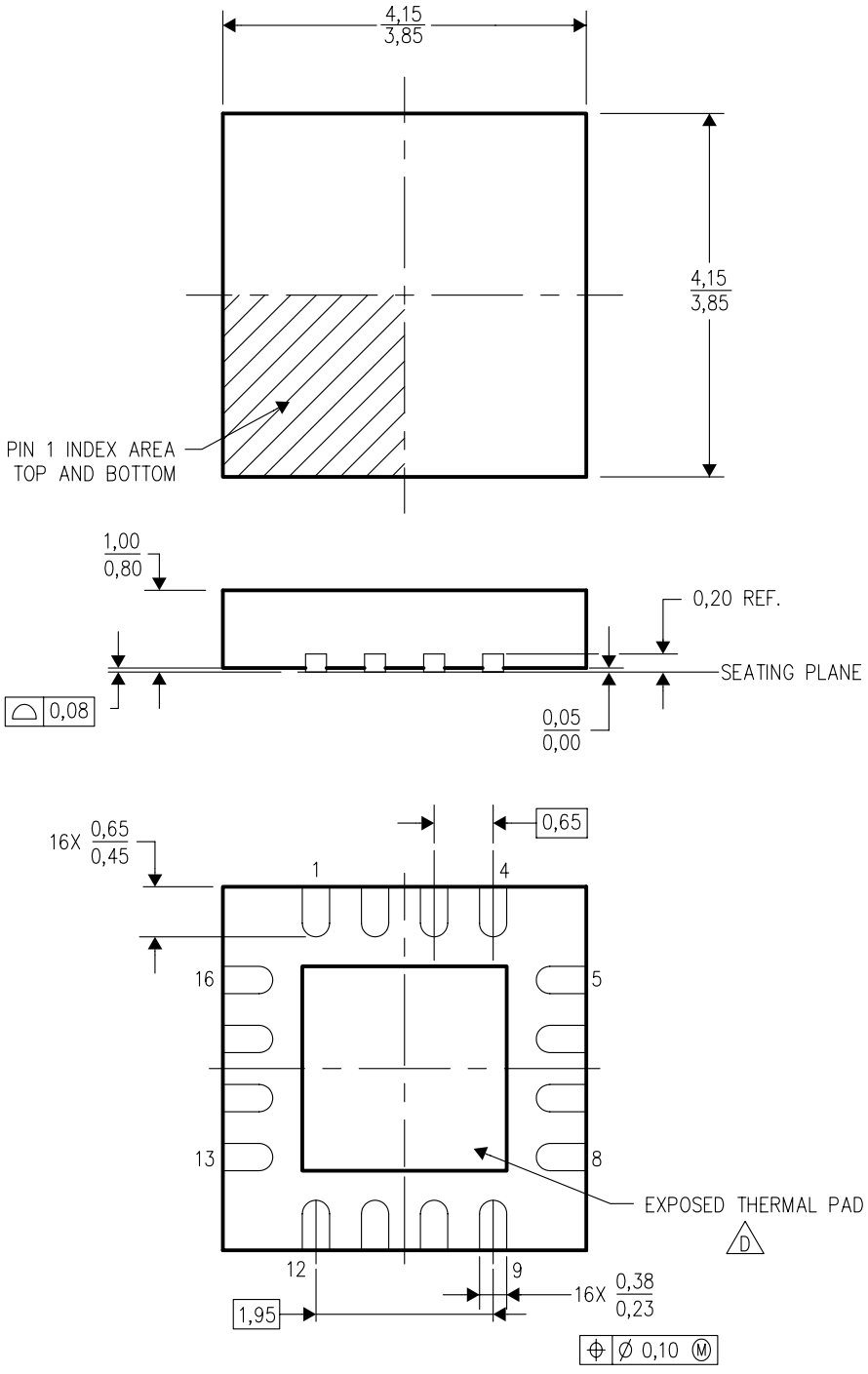
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CC2591RGVR	VQFN	RGV	16	2500	340.5	333.0	20.6
CC2591RGVT	VQFN	RGV	16	250	340.5	333.0	20.6

RGV (S–PQFP–N16) PLASTIC QUAD FLATPACK



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Quad Flatpack, No–leads (QFN) package configuration.
D. 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.
E. Falls within JEDEC MO–220.

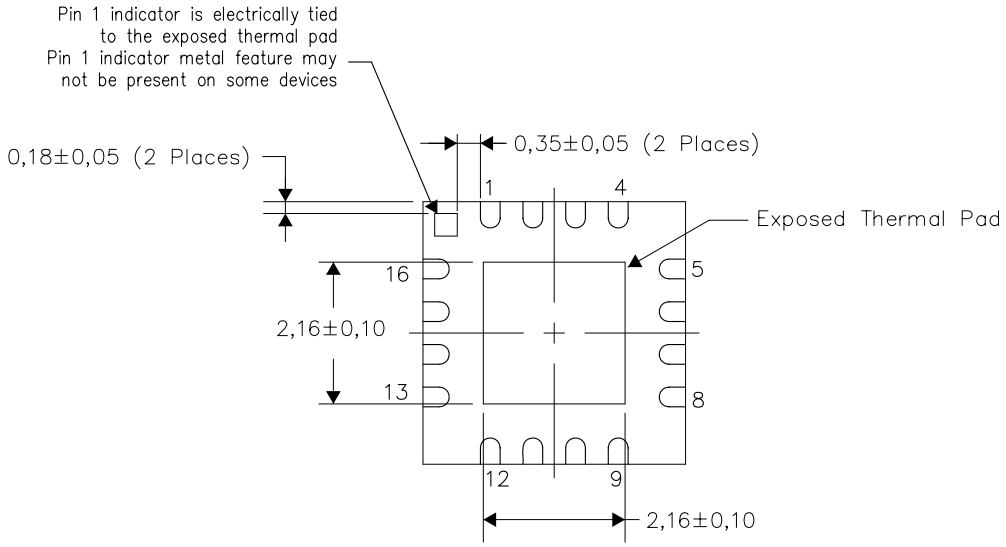
RGV (S–PVQFN–N16) PLASTIC QUAD FLATPACK NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.

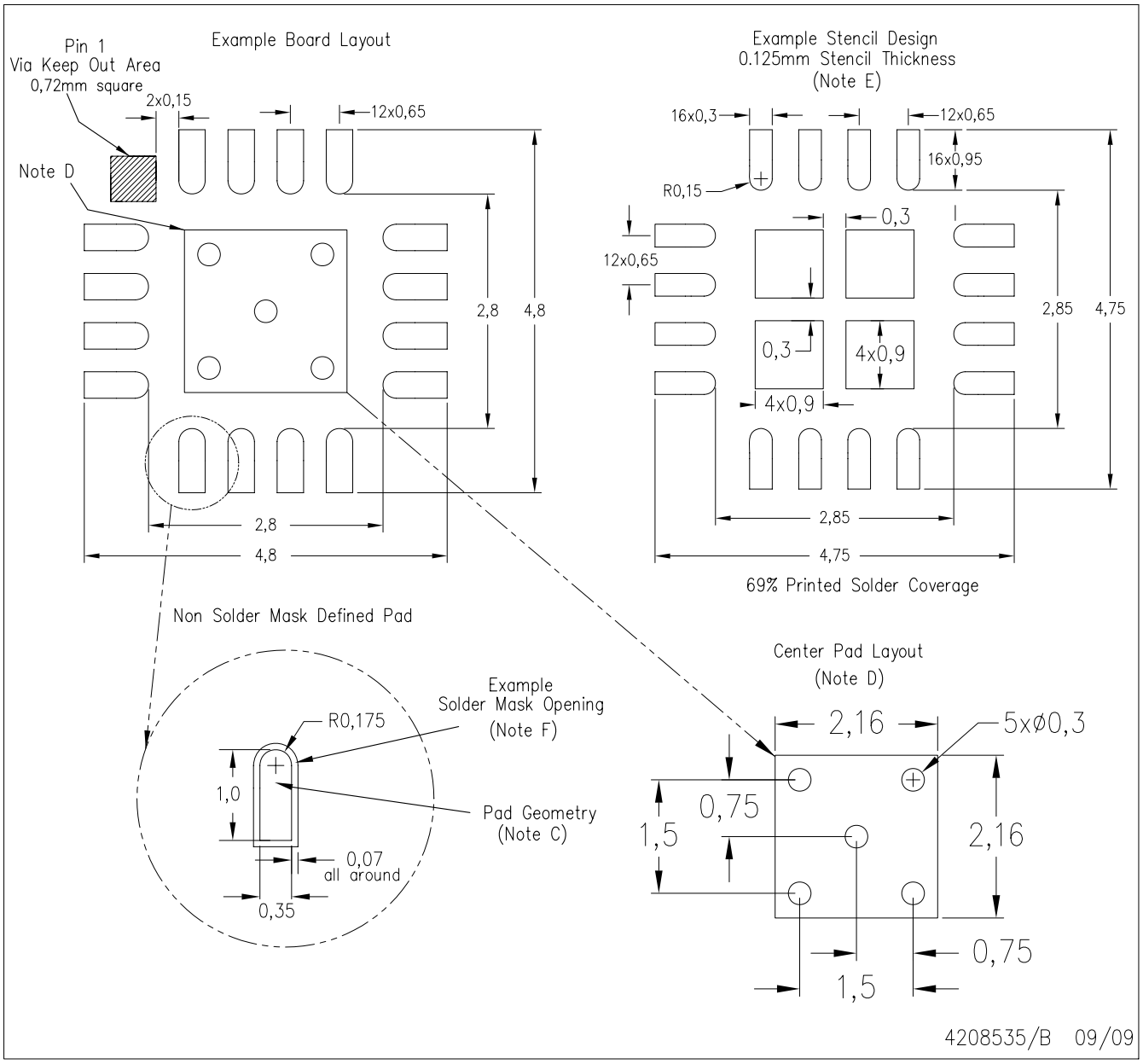


Bottom View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

RGV (S–PVQFN–N16)



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, QFN Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for solder mask tolerances.

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