



## 2.4-GHz RF Front End, 14-dBm output power

### FEATURES

- Seamless Interface to 2.4-GHz Low Power RF Devices from Texas Instruments
- Up to +14-dBm (25mW) 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
  - 22-mA at 3-V for +12-dBm, PAE = 23%
- Low Receive Current Consumption
  - 3.4-mA for High Gain Mode
  - 1.8-mA for Low Gain Mode
- 4.6-dB LNA Noise Figure, including T/R Switch and external antenna match
- RoHS Compliant 4x4-mm QFN-16 Package
- 2.0-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

**CC2590** is a cost-effective and high performance RF Front End for low-power and low-voltage 2.4-GHz wireless applications.

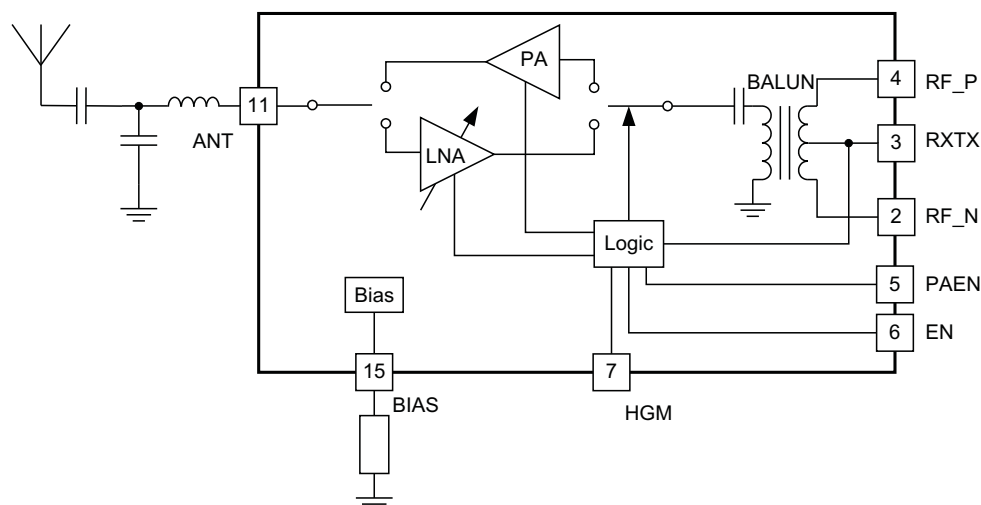
**CC2590** is a range extender for all existing and future 2.4-GHz low-power RF transceivers, transmitters and System-on-Chip products from Texas Instruments.

**CC2590** increases the link budget by providing a power amplifier for increased output power, and an LNA with low noise figure for improved receiver sensitivity.

**CC2590** provides a small size, high output power RF design with its 4x4-mm QFN-16 package.

**CC2590** contains PA, LNA, switches, RF-matching, and balun for simple design of high performance wireless applications.

### CC2590 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.

**CC2590**



SWRS080-SEPTEMBER 2008

www.ti.com



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	V
Input RF level		+10	dBm
Storage temperature range		-50 to 150	°C
Reflow soldering temperature	According to IPC/JEDEC J-STD-020	260	°C
ESD	Human Body Model, all pins except pin 10	2000	V
	Human Body Model, pin 10	1900	V
	Charged Device Model	1000	V

**RECOMMENDED OPERATING CONDITIONS**

The operating conditions for CC2590 are listed below.

PARAMETER	MIN	MAX	UNIT
Ambient temperature range	-40	85	°C
Operating supply voltage	2.0	3.6	V
Operating frequency range	2400	2483.5	MHz

**ELECTRICAL CHARACTERISTICS**

$T_C = 25^\circ\text{C}$ ,  $V_{DD} = 3.0\text{V}$ ,  $f_{RF} = 2440\text{MHz}$  (unless otherwise noted). Measured on CC2590EM reference design including external matching components.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receive current, High Gain Mode	HGM = 1		3.4	4.0	mA
Receive current, Low Gain Mode	HGM = 0		1.8	2.0	mA
Transmit current	$P_{IN} = 0.5\text{ dBm}$ , $P_{OUT} = 12.2\text{ dBm}$		22.1		mA
	$P_{IN} = -3.5\text{ dBm}$ , $P_{OUT} = 10.0\text{ dBm}$		16.8		mA
Transmit current	No input signal		8.0	10.0	mA
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	V
Power down - Receive mode switching time			1.4		µs
Power down - Transmit mode switching time			0.8		µs
<b>RF Receive</b>					
Gain, High Gain Mode	HGM = 1		11.4		dB
Gain, Low Gain Mode	HGM = 0		0		dB
Gain variation, 2400 – 2483.5 MHz, High Gain Mode	HGM = 1		1.2		dB
Gain variation, 2.0V – 3.6V, High Gain Mode	HGM = 1		1.7		dB
Noise figure, High Gain Mode	HGM = 1, including internal T/R switch and external antenna match		4.6		dB
Input 1 dB compression, High Gain Mode	HGM = 1		-21		dBm



**ELECTRICAL CHARACTERISTICS (continued)**

$T_C = 25^\circ\text{C}$ ,  $V_{DD} = 3.0\text{V}$ ,  $f_{RF} = 2440\text{MHz}$  (unless otherwise noted). Measured on CC2590EM reference design including external matching components.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input IP3, High Gain Mode	HGM = 1		-9		dBm
Input reflection coefficient, S11	HGM = 1, measured at antenna port		-19		dB
<b>RF Transmit</b>					
Gain			14.1		dB
Output power, $P_{OUT}$	$P_{IN} = 4.5\text{ dBm}$		13.8		dBm
	$P_{IN} = 0.5\text{ dBm}$		12.2		dBm
	$P_{IN} = -3.5\text{ dBm}$		10.0		dBm
Power Added Efficiency, PAE	$P_{IN} = 0.5\text{ dBm}$		23.5		%
Output 1 dB compression			10.4		dBm
Output IP3			23		dBm
Output power variation over frequency	2400 – 2483.5 MHz, $P_{IN} = 0.5\text{ dBm}$		0.3		dB
Output power variation over power supply	2.0V – 3.6V, $P_{IN} = 0.5\text{ dBm}$		3.2		dB
Output power variation over temperature	-40°C – 85°C, $P_{IN} = 0.5\text{ dBm}$		1.1		dB
2nd harmonic power	The 2nd harmonic can be reduced to below regulatory limits by using an external LC filter and antenna. See application note AN032 for regulatory requirements.		-14		dBm
3rd harmonic power	The 3rd harmonic can be reduced to below regulatory limits by using an external LC filter and antenna. See application note AN032 for regulatory requirements.		-28		dBm

**CC2590**

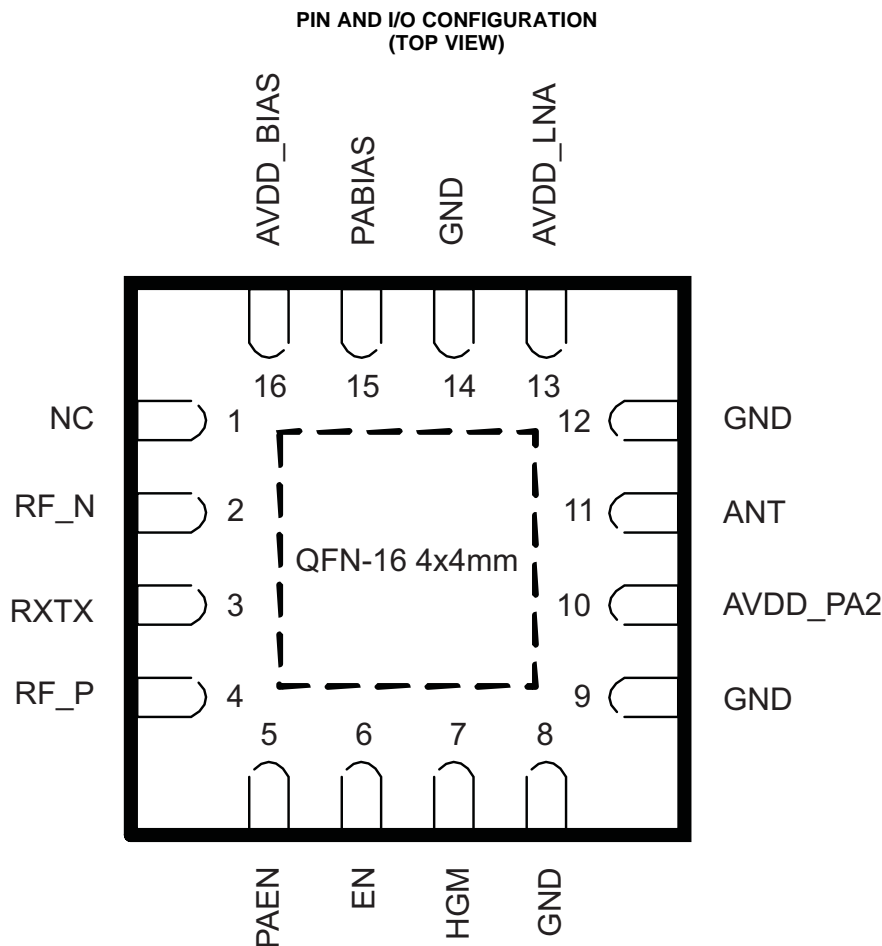


SWRS080-SEPTEMBER 2008

www.ti.com

**DEVICE INFORMATION**

The CC2590 pinout and description are shown in [Figure 1](#) and [Table 1](#), respectively.



**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 CC2590 is mounted onto layer 1.



**Table 1. PIN FUNCTIONS**

PIN		TYPE	DESCRIPTION
NO.	NAME		
—	GND	Ground	The exposed die attach pad must be connected to a solid ground plane. See CC2590EM reference design for recommended layout.
1	NC		Not Connected
2	RF_N	RF	RF interface towards CC24xx or CC25xx device.
3	RXTX	Analog/Control	RXTX switching voltage when connected to CC24xx devices. See <a href="#">Table 3</a> , <a href="#">Table 4</a> , and <a href="#">Table 5</a> for details.
4	RF_P	RF	RF interface towards CC24xx or CC25xx device
5	PAEN	Digital Input	Digital control pin. See <a href="#">Table 3</a> , <a href="#">Table 4</a> , and <a href="#">Table 5</a> for details.
6	EN	Digital Input	Digital control pin. See <a href="#">Table 3</a> , <a href="#">Table 4</a> , and <a href="#">Table 5</a> 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 CC2590EM reference design for recommended layout.
11	ANT	RF	Antenna interface.
13	AVDD_LNA	Power	2.0-V – 3.6-V Power. PCB trace to this pin serves as inductive load to LNA. See CC2590EM 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	2.0-V – 3.6-V Power.

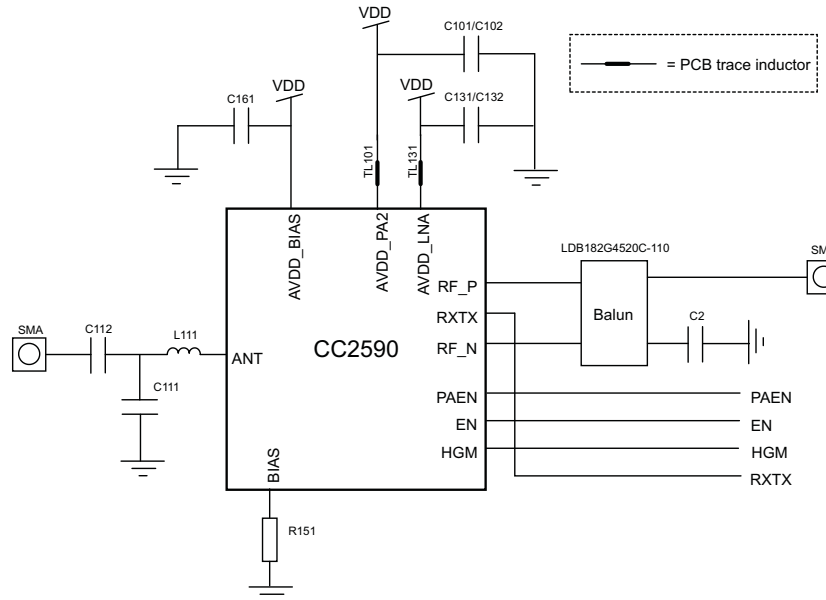
**CC2590**



SWRS080-SEPTEMBER 2008

www.ti.com

**CC2590EM Evaluation Module**



**Figure 2. CC2590EM Evaluation Module**

**Table 2. List of Materials (See CC2590EM Reference Design)**

DEVICE	FUNCTION	VALUE
L112	Part of antenna match.	1.5 nH: LQW15AN1N5B00 from Murata
C111	Part of antenna match.	0.5 pF, GRM1555C1HR50BZ01 from Murata
C112	DC block.	47 pF, GRM1555C1H470JZ01 from Murata
C161	Decoupling capacitor.	1 nF: GRM1555C1H102JA01 from Murata
C101/C102	Decoupling. Will affect PA resonance. See CC2590EM reference design for placement.	27 pF    1 nF. The smallest cap closest to CC2590. 27 pF: GRM1555C1H270JZ01 from Murata 1 nF: GRM1555C1H102JA01 from Murata
C131/C132	Decoupling. Will affect LNA resonance. See CC2590EM reference design for placement.	18 pF    1 nF. The smallest cap closest to CC2590. 18 pF: GRM1555C1H180JZ01 from Murata 1 nF: GRM1555C1H102JA01 from Murata
C2	Decoupling of external balun	1 nF: LWQ15AN1N5B00 from Murata
TL101 <sup>(1)</sup>	Transmission line. Will affect PA resonance. (simulated inductance: 0.87nH)	See CC2590EM reference design. Transmission line: Length ≈ 40 mil, Width = 8 mil
TL131	Transmission line. Will affect LNA resonance. (simulated inductance: 1.64nH)	See CC2590EM reference design. Transmission line: Length ≈ 100 mil, Width = 8 mil
R151	Bias resistor	4.3 kΩ: RK73H1ETTP4301F from Koa

(1) Transmission lines are measured from edge of pad of the CC2590 footprint to edge of pad of DC coupling capacitor. The length of the transmission lines depend on the distance to the ground plane. If another PCB stack up is chosen the length of the transmission lines needs to be adjusted.

PCB description: 4 layer PCB 1.6mm

- Copper 1: 35 μm
- Dielectric 1-2: 0.35 mm (e.g. 2x Prepreg 7628 AT05 47% Resin)
- Copper 2: 18 μm
- Dielectric 2-3: 0.76 mm (4 x 7628M 43% Resin)
- Copper 3: 18 μm
- Dielectric 3-4: 0.35 mm (e.g. 2x Prepreg 7628 AT05 47% Resin)
- Copper 4: 35 μm

DE104iML or equivalent substrate (Resin contents around 45%, which gives Er=4.42 at 2.4GHz, TanD=0.016)

**TYPICAL CHARACTERISTICS**

**LNA GAIN AND NOISE FIGURE  
vs  
FREQUENCY**

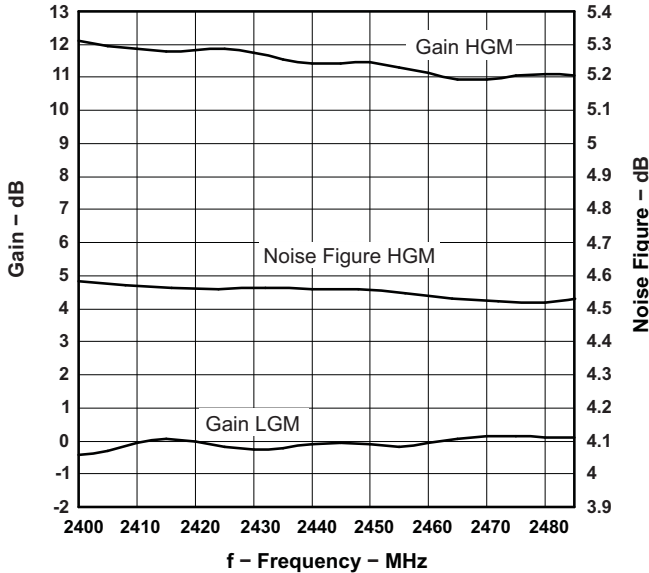


Figure 3.

**LNA GAIN  
vs  
TEMPERATURE**

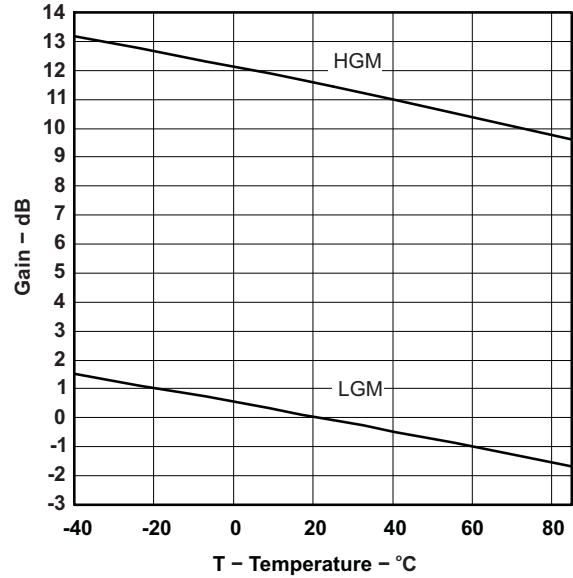


Figure 4.

**LNA GAIN  
vs  
POWER SUPPLY**

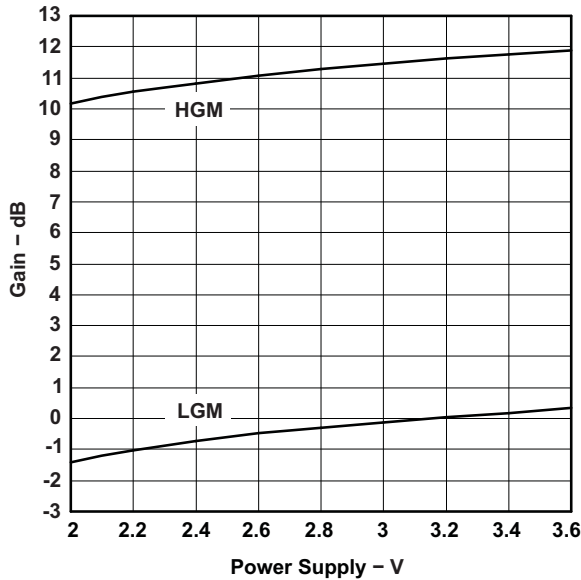


Figure 5.

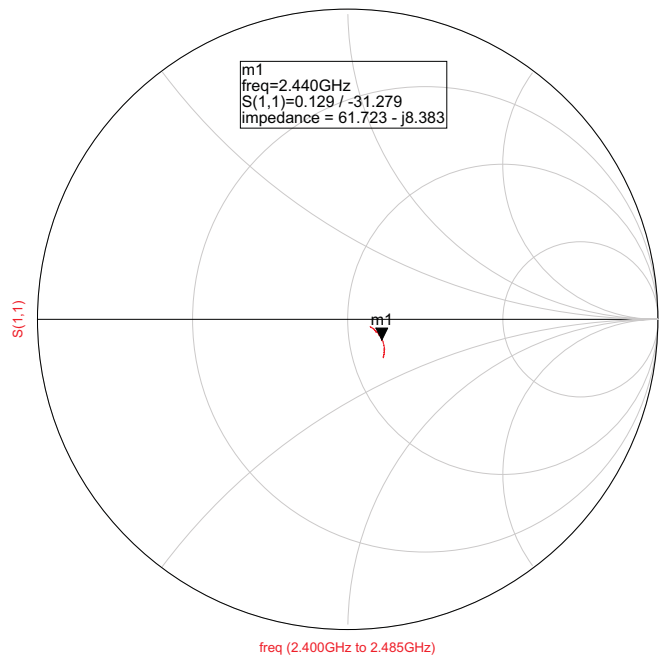


Figure 6. Input Impedance of LNA Measured from Antenna Port on CC2590EM

**CC2590**



SWRS080-SEPTEMBER 2008

www.ti.com

**TYPICAL CHARACTERISTICS (continued)**

**OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs INPUT POWER**

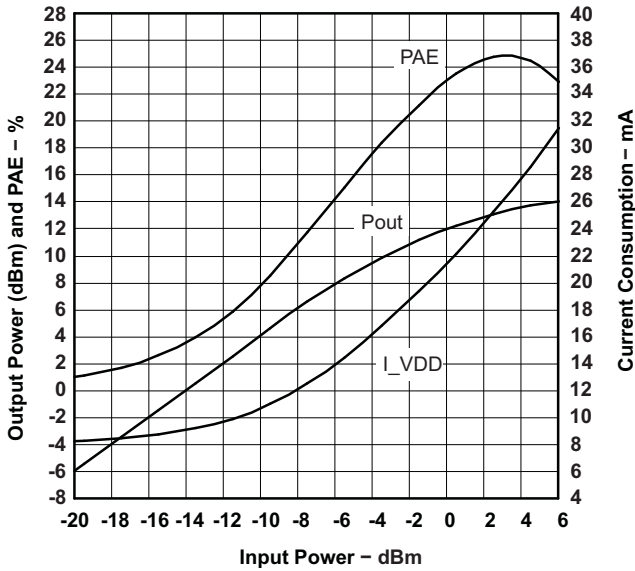


Figure 7.

**OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs FREQUENCY**

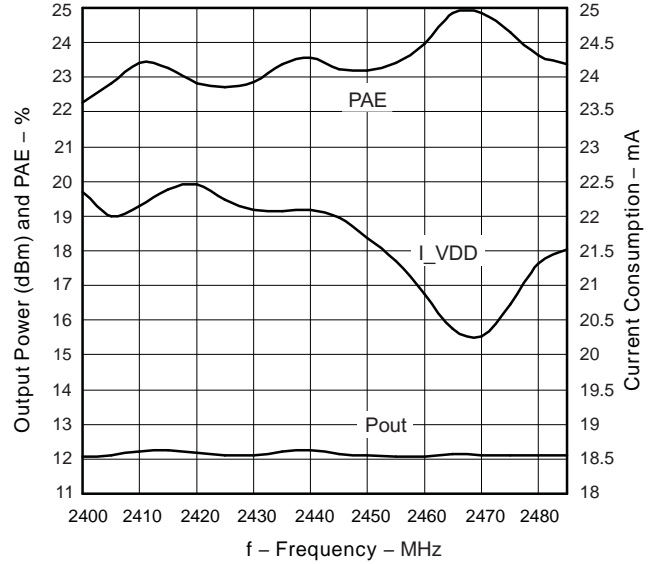


Figure 8.

**OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs TEMPERATURE**

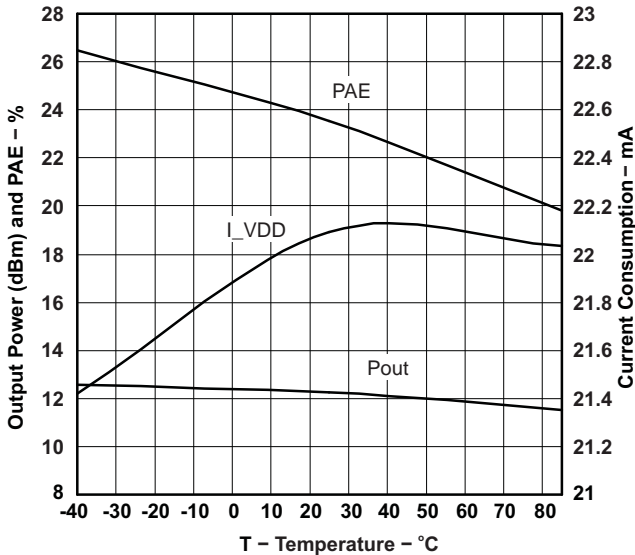


Figure 9.

**OUTPUT POWER, PAE AND CURRENT CONSUMPTION vs POWER SUPPLY**

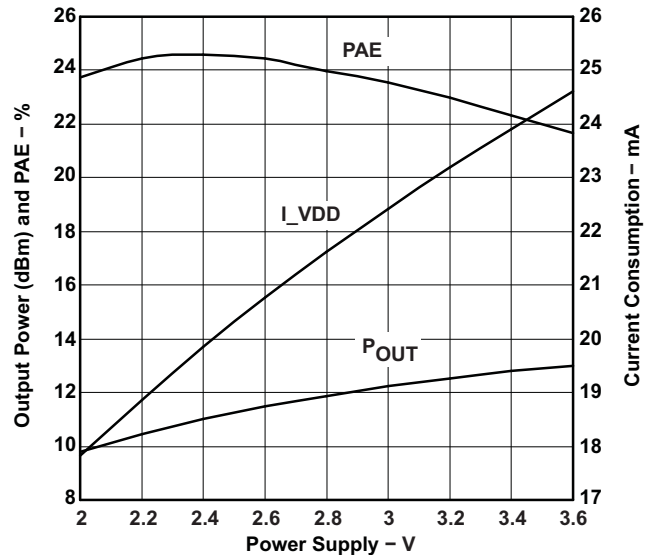


Figure 10.



**Controlling the Output Power from CC2590**

The output power of CC2590 is controlled by controlling the input power. The CC2590 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 CC2590 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'.

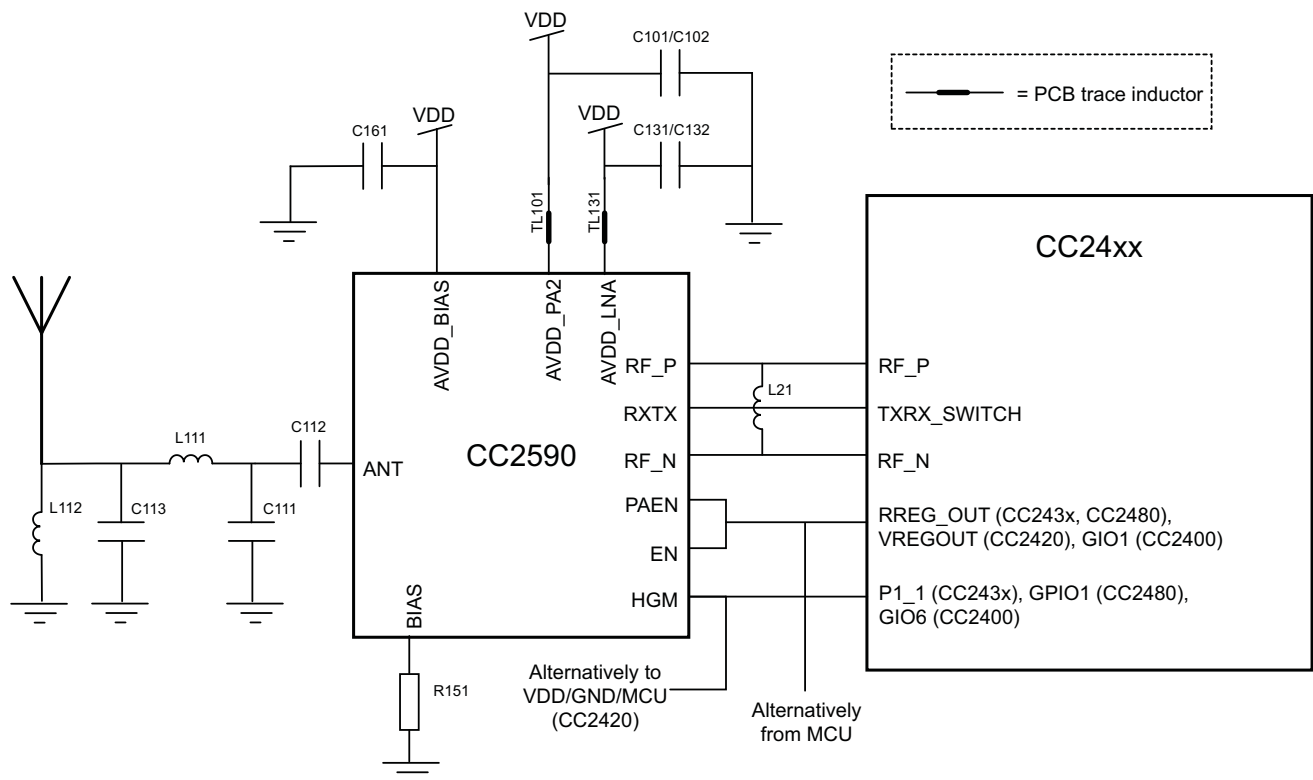
An example of the above would be that RXTX is connected directly to the RXTX pin on CC24xx, but the global supply voltage is 3.6-V. The RXTX pin on CC24xx will switch between 0-V (RX) and 1.8-V(TX), which is still a high enough voltage to control the mode of CC2590.

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

**Connecting CC2590 to a CC24xx Device**

**Table 3. Control Logic for Connecting CC2590 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 11. CC2590 + CC24xx Application Circuit**

**CC2590**



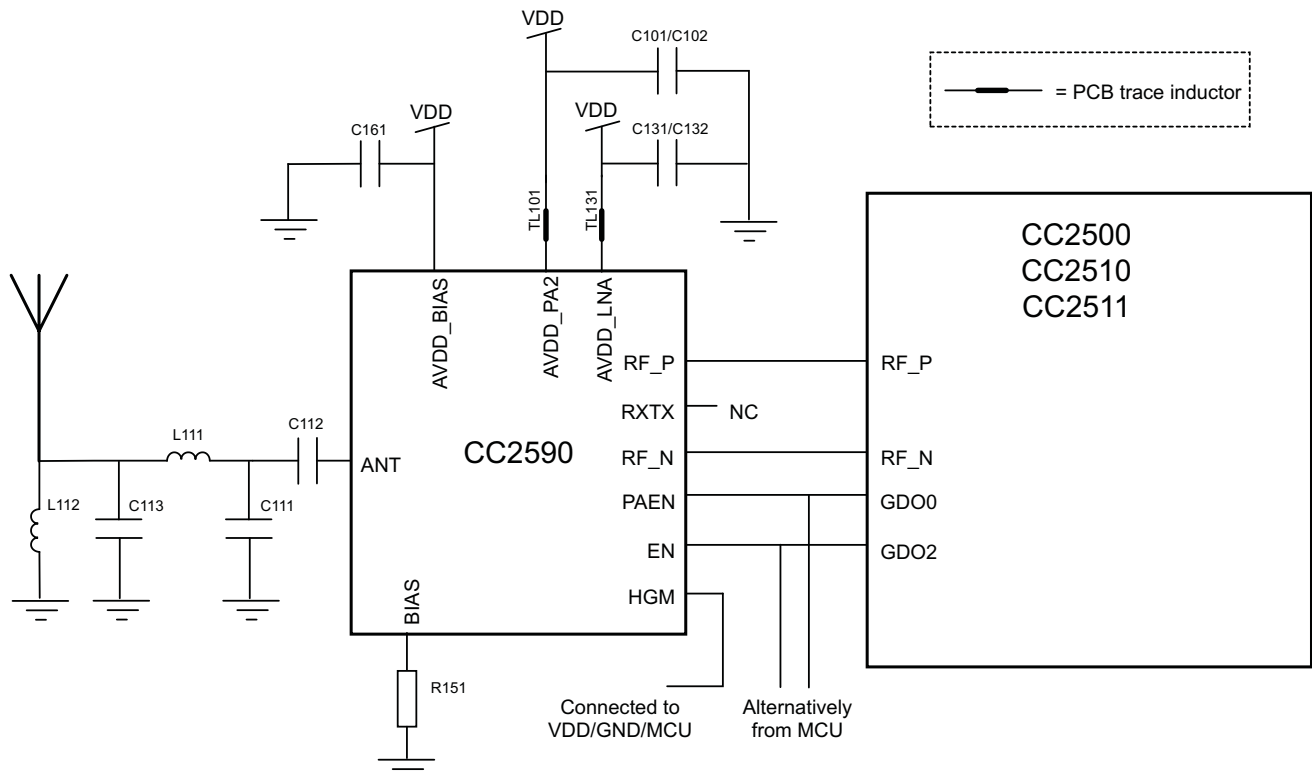
SWRS080-SEPTEMBER 2008

www.ti.com

**Connecting CC2590 to the CC2500, CC2510, or CC2511 Device**

**Table 4. Control Logic for Connecting CC2590 to a CC2500/10/11 Devices**

PAEN	EN	RXTX	HGM	MODE OF OPERATION
0	0	NC	X	Power Down
0	1	NC	0	RX Low Gain Mode
0	1	NC	1	RX High Gain Mode
1	0	NC	X	TX
1	1	NC	X	Not allowed

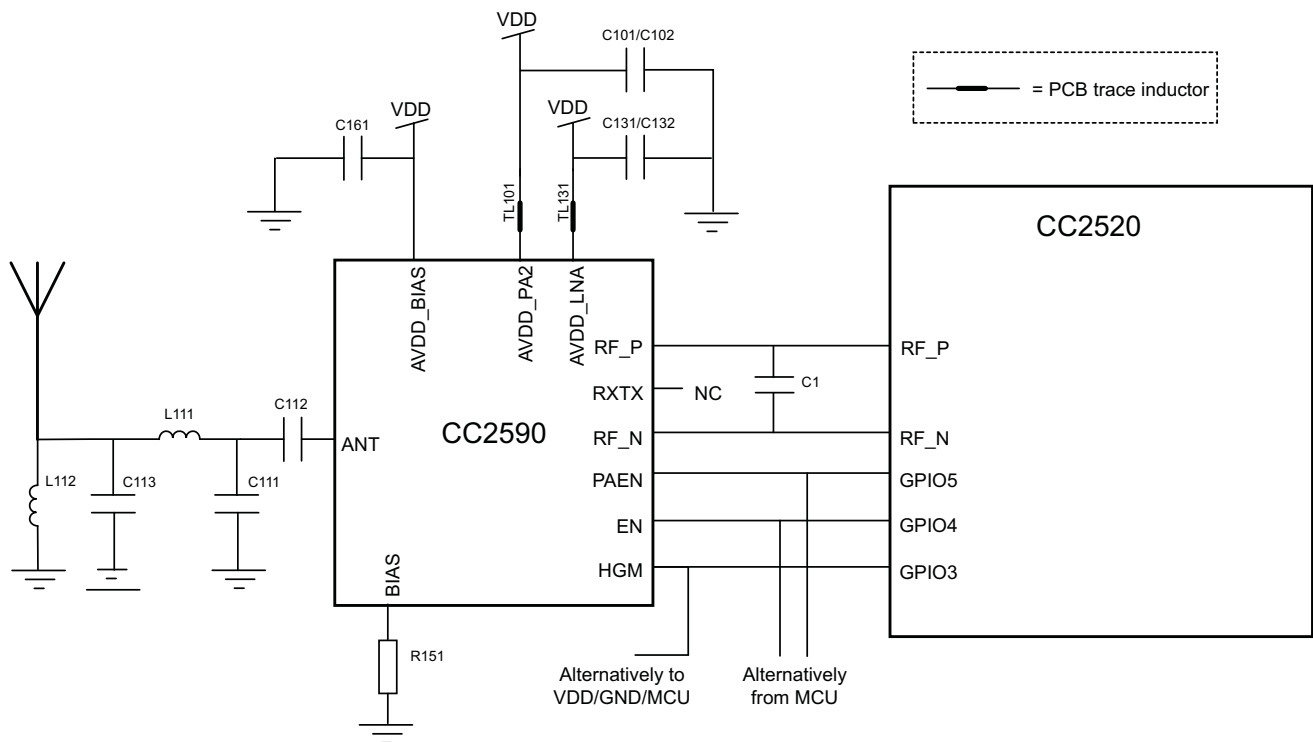


**Figure 12. CC2590 + CC2500/10/11 Device Application Circuit**

**Connecting CC2590 to a CC2520 Device**

**Table 5. Control Logic for Connecting CC2590 to a CC2520 Device**

PAEN	EN	RXTX	HGM	MODE OF OPERATION
0	0	NC	X	Power Down
0	1	NC	0	RX Low Gain Mode
0	1	NC	1	RX High Gain Mode
1	0	NC	X	TX
1	1	NC	X	Not allowed



**Figure 13. CC2590 + CC2520 Application Circuit**

**PCB Layout Guidelines**

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 CC2590 is mounted onto layer 1.

PCB trace inductors are used to be able to optimize the inductance value, and they are too small to be replaced by discrete inductors. The placement of the power supply decoupling capacitors C101/C102 and C131/C132 are important to set the PCB trace inductance values accurately.



**PACKAGE OPTION ADDENDUM**

www.ti.com

11-Apr-2013

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
CC2590RGVR	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	CC2590	<a href="#">Samples</a>
CC2590RGVRG4	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	CC2590	<a href="#">Samples</a>
CC2590RGVT	ACTIVE	VQFN	RGV	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	CC2590	<a href="#">Samples</a>
CC2590RGVTG4	ACTIVE	VQFN	RGV	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	CC2590	<a href="#">Samples</a>

(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.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

**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.



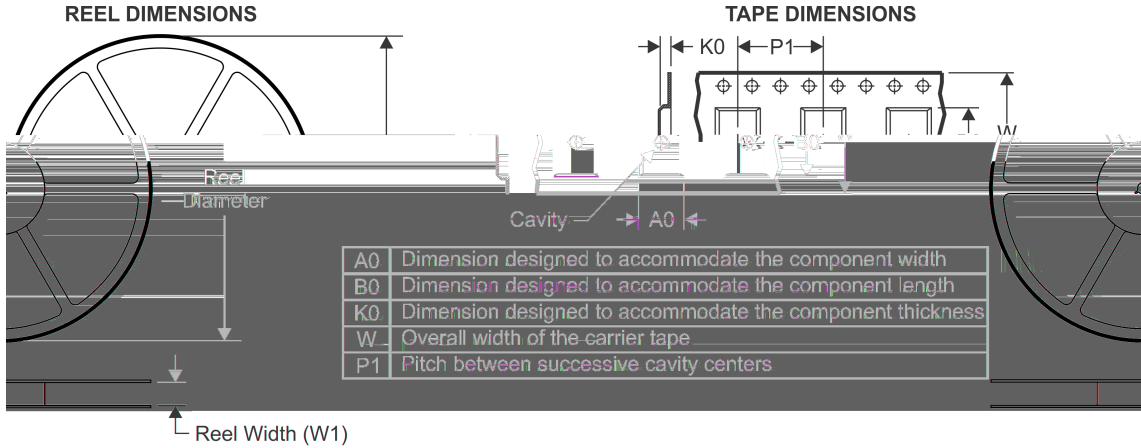


**PACKAGE MATERIALS INFORMATION**

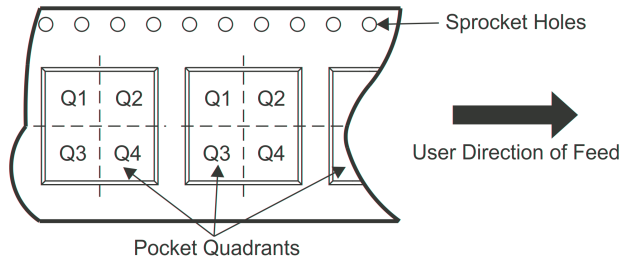
www.ti.com

21-Mar-2013

**TAPE AND REEL INFORMATION**



**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
CC2590RGVR	VQFN	RGV	16	2500	330.0	12.4	4.3	4.3	1.5	8.0	12.0	Q2
CC2590RGVT	VQFN	RGV	16	250	180.0	12.4	4.3	4.3	1.5	8.0	12.0	Q2

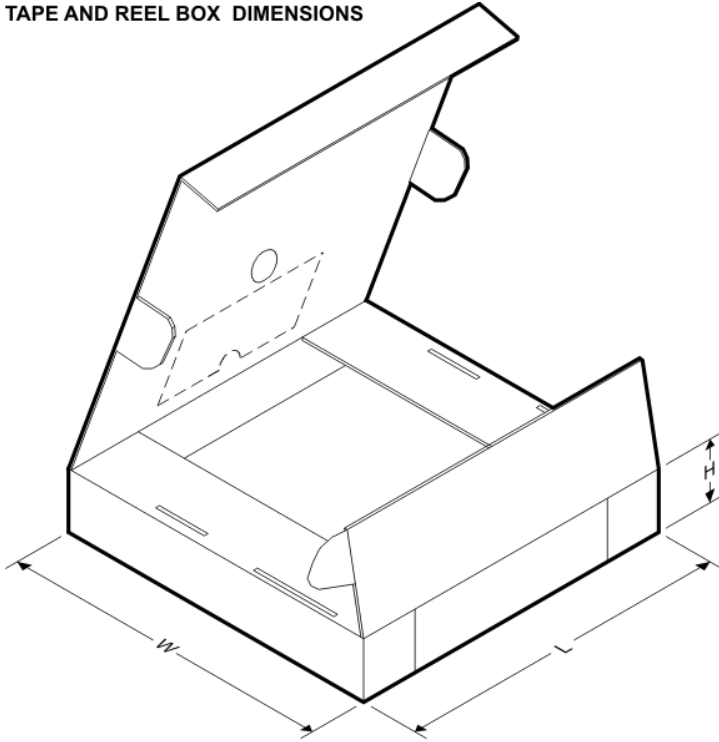


**PACKAGE MATERIALS INFORMATION**

www.ti.com

21-Mar-2013

**TAPE AND REEL BOX DIMENSIONS**



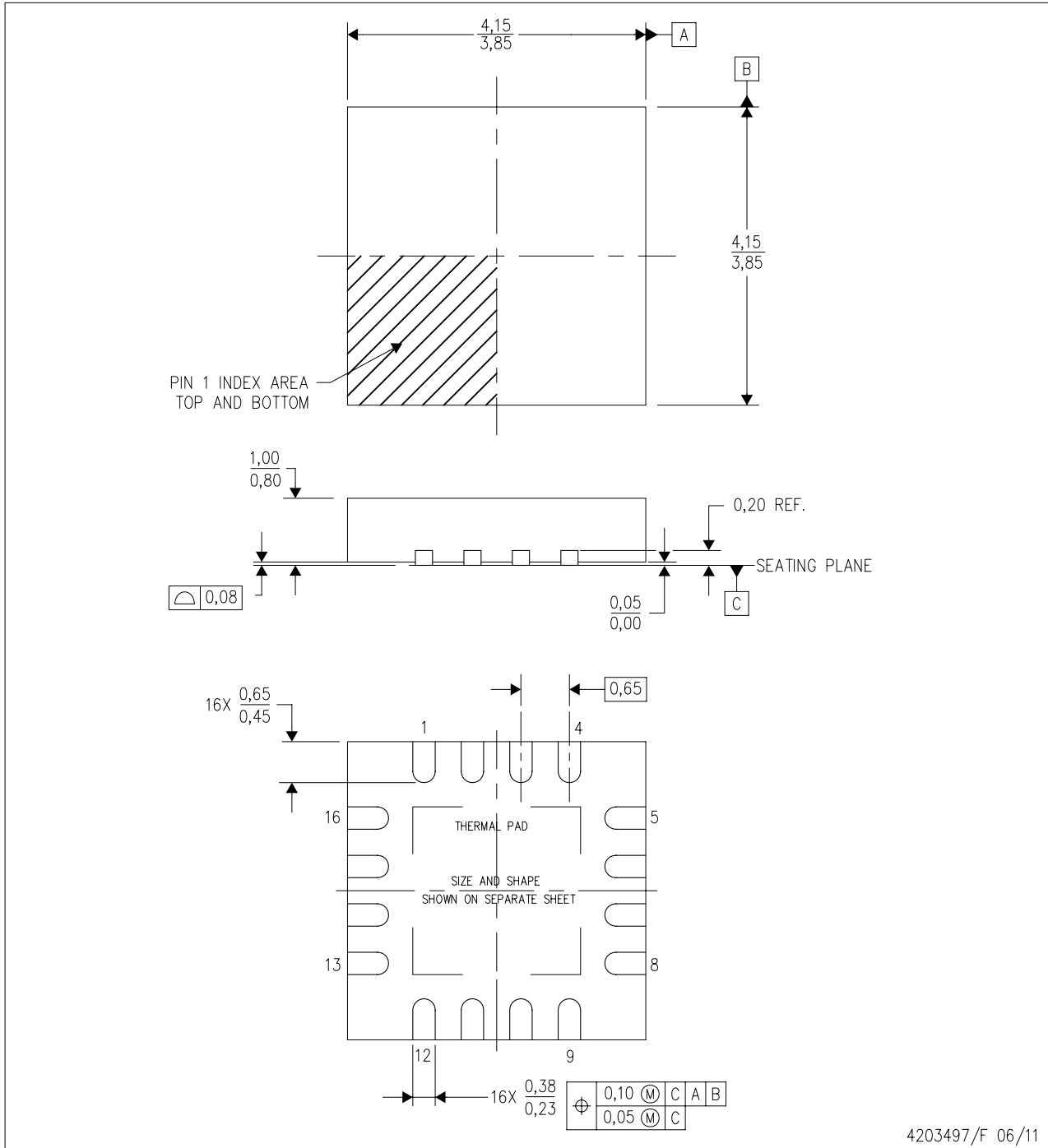
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CC2590RGVR	VQFN	RGV	16	2500	338.1	338.1	20.6
CC2590RGVT	VQFN	RGV	16	250	210.0	185.0	35.0

**MECHANICAL DATA**

RGV (S-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



- 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.
  - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - F. Falls within JEDEC MO-220.



**THERMAL PAD MECHANICAL DATA**

RGV (S-PVQFN-N16)

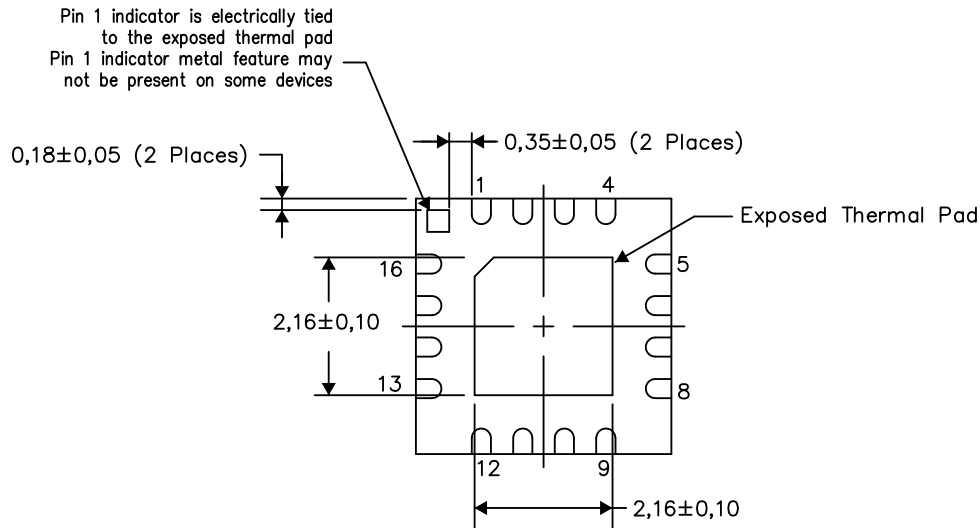
PLASTIC QUAD FLATPACK NO-LEAD

**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](http://www.ti.com).

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



Bottom View

Exposed Thermal Pad Dimensions

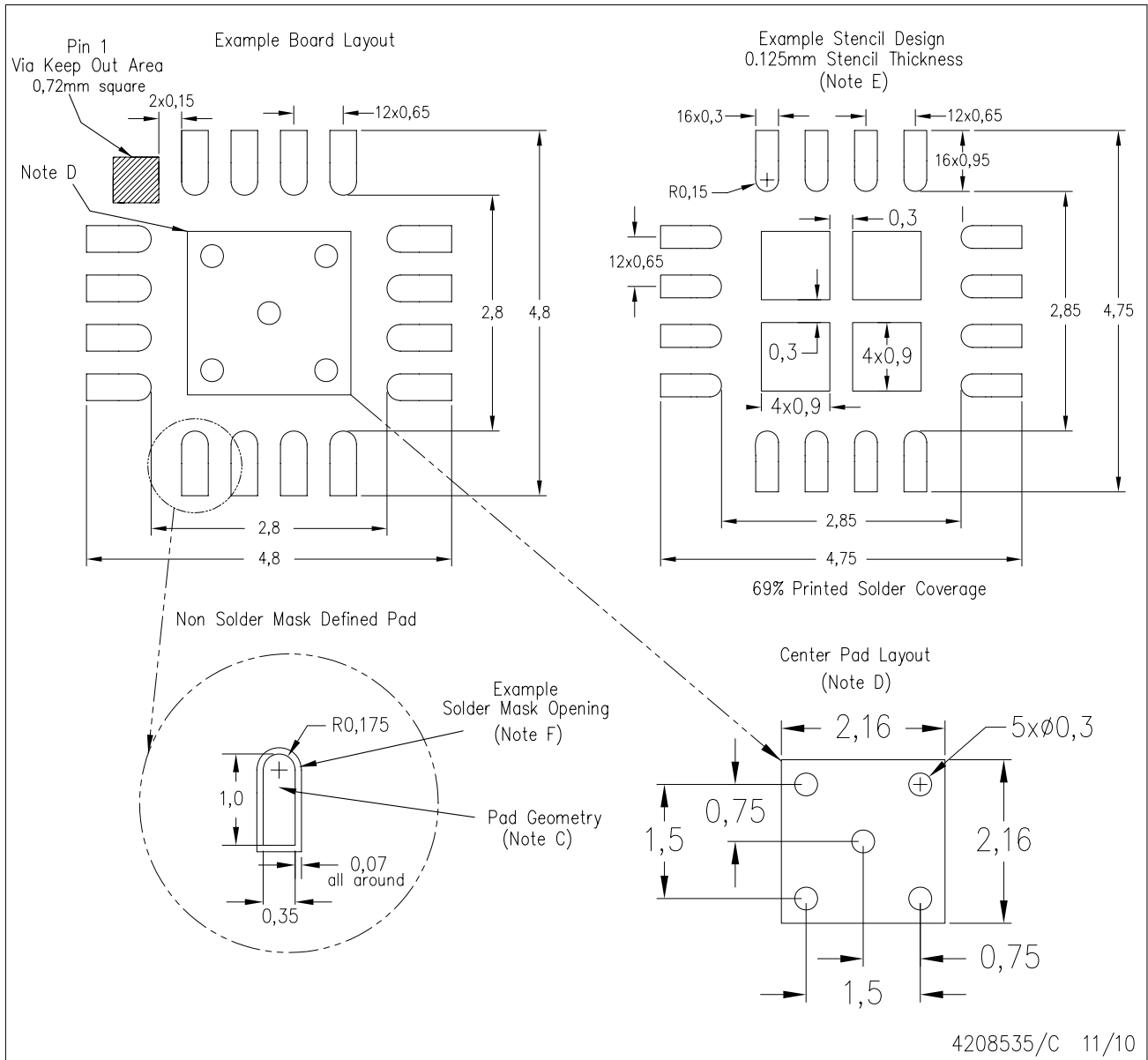
4206351-2/L 05/13

NOTE: All linear dimensions are in millimeters

**LAND PATTERN DATA**

RGV (S-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



- 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) <<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.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)