

## VOLTAGE PROTECTION FOR 2-, 3-, OR 4-CELL Li-Ion BATTERIES (2<sup>nd</sup>-LEVEL PROTECTION)

### FEATURES

- 2-, 3-, or 4-Cell Secondary Protection
- Low Power Consumption  $I_{CC} < 2 \mu A$   
[ $V_{CELL(ALL)} < V_{(PROTECT)}$ ]
- Fixed High Accuracy Overvoltage Protection Threshold
  - bq29410 = 4.35 V
  - bq29411 = 4.40 V
  - bq29412 = 4.45 V
  - bq29413 = 4.50 V
  - bq29414 = 4.55 V
  - bq29415 = 4.60 V
- Programmable Delay Time of Detection
- High Power Supply Ripple Rejection
- Stable During Pulse Charge Operation

### APPLICATIONS

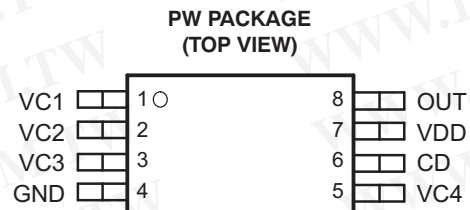
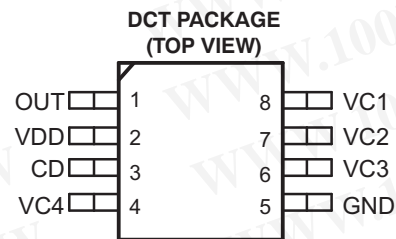
- 2<sup>nd</sup>-Level Overvoltage Protection in Li-Ion Battery Packs in:
  - Notebook Computers
  - Portable Instrumentation
  - Portable Equipment

### DESCRIPTION

The bq2941x is a secondary overvoltage protection IC for 2-, 3-, or 4-cell lithium-ion battery packs that incorporates a high-accuracy precision overvoltage detection circuit. It includes a programmable delay circuit for overvoltage detection time.

### FUNCTION

Each cell in a multiple-cell pack is compared to an internal reference voltage. If one cell reaches an overvoltage condition, the protection sequence begins. The bq2941x device starts charging an external capacitor through the CD pin. When the CD pin voltage reaches 1.2 V, the OUT pin changes from a low level to a high level.



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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.



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.

### ORDERING INFORMATION<sup>(1)</sup>

T <sub>A</sub>	V <sub>(PROTECT)</sub> <sup>(2)</sup>	PACKAGE <sup>(3)</sup>			
		MSOP (DCT)	SYMBOL	SSOP (PW)	
–40°C to 110°C	4.35 V	bq29410DCT3R	CJG	bq29410PW bq29410PWG4	bq29410PWR bq29410PWRG4
		bq29410DCTR			
		bq29410DCTT			
	4.40 V	bq29411DCT3R	CJH	bq29411PW bq29411PWG4	bq29411PWR bq29411PWRG4
		bq29411DCTR			
		bq29411DCTT			
	4.45 V	bq29412DCT3R	CJJ	bq29412PW bq29412PWG4	bq29412PWR bq29412PWRG4
		bq29412DCTR			
		bq29412DCTT			
	4.50 V	bq29413DCTR	CJk	bq29413PW	bq29413PWR
		bq29413DCTT			
	4.55 V	bq29414DCTR <sup>(4)</sup>	CJL	bq29414PW <sup>(4)</sup>	bq29414PWR <sup>(4)</sup>
		bq29414DCTT <sup>(4)</sup>			
	4.60 V	bq29415DCTR <sup>(4)</sup>	CJM	bq29415PW <sup>(4)</sup>	bq29415PWR <sup>(4)</sup>
		bq29415DCTT <sup>(4)</sup>			

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at [www.ti.com](http://www.ti.com).
- (2) Contact your local Texas Instruments representative or sales office for alternative overvoltage threshold options.
- (3) The "R" suffix indicates tape-and-reel packaging.
- (4) Product Preview

### ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted<sup>(1)(2)</sup>

		UNIT
Supply voltage range	VDD	–0.3 V to 28 V
Input voltage range	VC1, VC2, VC3, VC4	–0.3 V to 28 V
	VC1 TO VC2, VC2 TO VC3, VC3 TO VC4, VC4 TO GND	–0.3 V to 8 V
Output voltage range	OUT	–0.3 V to 28 V
	CD	–0.3 V to 28 V
Continuous total power dissipation		See Dissipation Rating Table
Storage temperature range, T <sub>stg</sub>		–65°C to 150°C
Lead temperature (soldering, 10 s)		300°C

- (1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages are with respect to ground of this device except the differential voltage of VC1-VC2, VC2-VC3, VC3-VC4, and VC4-GND.

### PACKAGE DISSIPATION RATINGS

PACKAGE	T <sub>A</sub> = 25°C POWER RATING	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> = 70°C POWER RATING	T <sub>A</sub> = 85°C POWER RATING
DCT	412 mW	3.3 mW/°C	264 mW	214 mW
PW	525 mW	4.2 mW/°C	336 mW	273 mW

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## RECOMMENDED OPERATING CONDITIONS

		MIN	NOM	MAX	UNIT
V <sub>DD</sub>	Supply voltage	4		25	V
V <sub>I</sub>	Input voltage range	VC1, VC2, VC3, VC4			V
		VCn – VC (n=1), (n=1, 2, 3), VC4 – GND			
t <sub>d(CD)</sub>	Delay time capacitance		0.22		μF
R <sub>IN</sub>	Voltage-monitor filter resistance	100	1k		Ω
C <sub>IN</sub>	Voltage-monitor filter capacitance	0.01	0.1		μF
R <sub>VD</sub>	Supply-voltage filter resistance	0		1	kΩ
C <sub>VD</sub>	Supply-voltage filter capacitance		0.1		μF
T <sub>A</sub>	Operating ambient temperature range	–40		110	°C

## ELECTRICAL CHARACTERISTICS

over recommended operating free-air temperature range, T<sub>A</sub> = 25°C (unless otherwise noted)

PARAMETER	TEST CONDITION	MIN	NOM	MAX	UNIT
V <sub>(OA)</sub>	T <sub>A</sub> = 25°C		25	35	mV
	T <sub>A</sub> = –20°C to 85°C		25	50	
	T <sub>A</sub> = –40°C to 110°C			80	
V <sub>(PROTECT)</sub>	bq29410		4.35		V
	bq29411		4.40		
	bq29412		4.45		
	bq29413		4.50		
	bq29414		4.55		
	bq29415		4.60		
V <sub>hys</sub>	Overvoltage detection hysteresis <sup>(1)</sup>		300		mV
I <sub>IN</sub>	Input current V2, V3, VC4 input, V <sub>DD</sub> = VC1 VC1 = VC2 = VC3 = VC4 = 3.5 V (see Figure 1)			0.3	μA
t <sub>D1</sub>	Overvoltage detection delay time V <sub>DD</sub> = VC1, CD = 0.22 μF	1	1.5	2	S
I <sub>(CD_dis)</sub>	CD GND clamp current V <sub>DD</sub> = VC1, CD = 1 V	5	12		μA
I <sub>CC</sub>	V <sub>DD</sub> = VC1, VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 3.5 V (see Figure 1)		2	3	μA
	V <sub>DD</sub> = VC1, VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 2.3 V (see Figure 1)		1.5	2.5	
V <sub>(OUT)</sub>	VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = V <sub>(PROTECT)Max</sub> , V <sub>DD</sub> = VC1, I <sub>OH</sub> = 0 mA		7		V
	VC1 = VC2 = VC3 = VC4 = V <sub>(PROTECT)Max</sub> , V <sub>DD</sub> = 4.3 V, T <sub>A</sub> = 0°C to 70°C, I <sub>OH</sub> = 40 μA	1.5	2	2.5	
I <sub>OH</sub>	High-level output current OUT = 3 V, VC1 = VC2 = VC3 = VC4 = 4.7 V	–1			mA
I <sub>OL</sub>	Low-level output current OUT = 0.1 V, V <sub>DD</sub> = VC1, VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 3.5 V	5			μA

(1) Levels of the overvoltage detection and the hysteresis can be adjusted. For assistance, contact a Texas Instruments sales representative.

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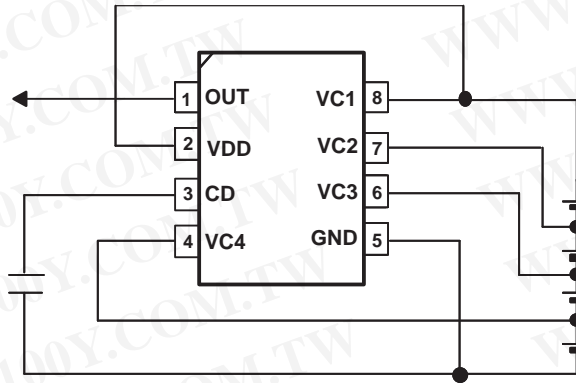


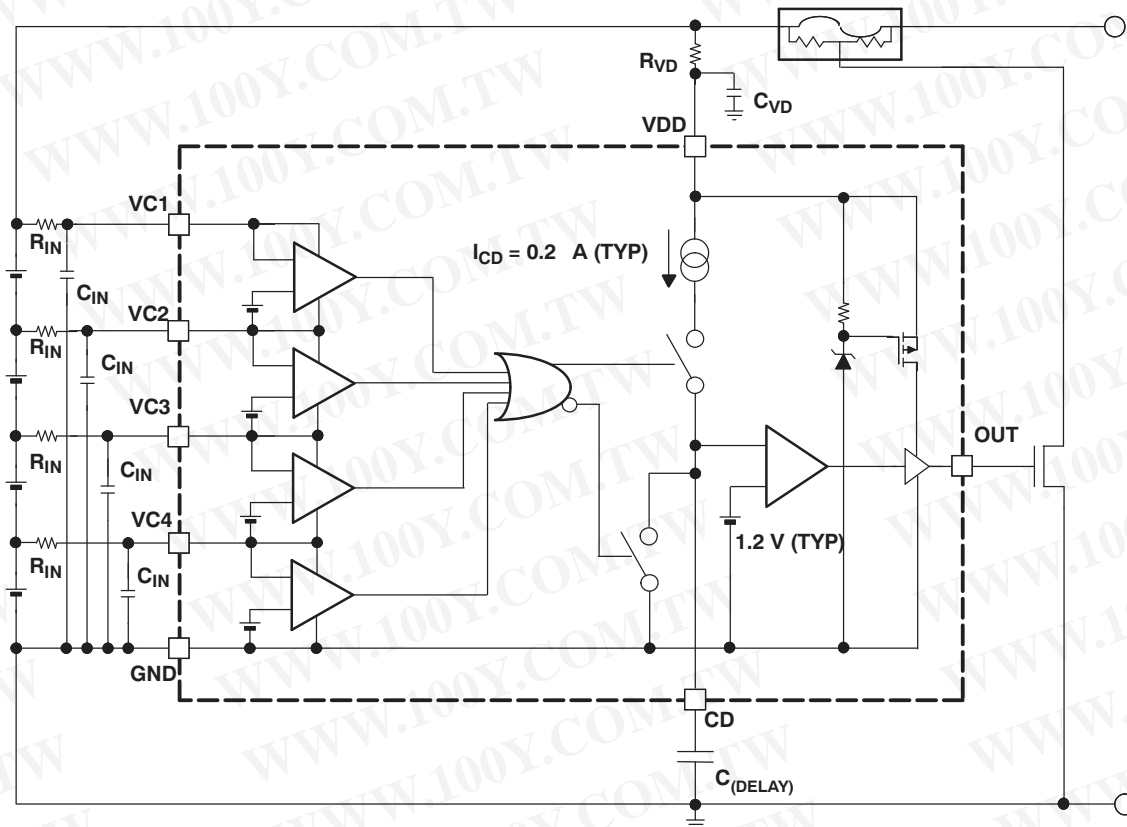
Figure 1.  $I_{CC}$ ,  $I_{IN}$  Measurement (DCT Package)

### Terminal Functions

TERMINAL			DESCRIPTION
MSOP (DCT)	TSSOP (PW)	NAME	
8	1	VC1	Sense voltage input for most positive cell
7	2	VC2	Sense voltage input for second most positive cell
6	3	VC3	Sense voltage input for third most positive cell
5	4	GND	Ground pin
4	5	VC4	Sense voltage input for least positive cell
3	6	CD	An external capacitor is connected to determine the programmable delay time
2	7	VDD	Power supply
1	8	OUT	Output

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FUNCTIONAL BLOCK DIAGRAM



OVERVOLTAGE PROTECTION

When one of the cell voltages exceeds  $V_{(PROTECT)}$ , an internal current source begins to charge the capacitor,  $C_{(DELAY)}$ , connected to the CD pin. If the voltage at the CD pin,  $V_{CD}$ , reaches 1.2 V, the OUT pin is activated and transitions high. An externally connected NCH FET is activated and blows the external fuse in the positive battery rail; see the functional block diagram.

If all cell voltages fall below  $V_{(PROTECT)}$  before the voltage at pin CD reaches 1.2 V, the delay time does not run out. An internal switch clamps the CD pin to GND and discharges the capacitor,  $C_{(DELAY)}$ , and secures the full delay time for the next occurring overvoltage event.

Once the pin OUT is activated, it transitions back from high to low after all battery cells reach  $V_{(PROTECT)} - V_{hys}$ .

DELAY TIME CALCULATION

The delay time is calculated as follows:

$$t_d = \frac{1.2 \text{ V} \times C_{(DELAY)}}{I_{CD}}$$

$$C_{(DELAY)} = \frac{t_d \times I_{CD}}{1.2 \text{ V}}$$

Where  $I_{(CD)}$  = CD current source = 0.18  $\mu$ A

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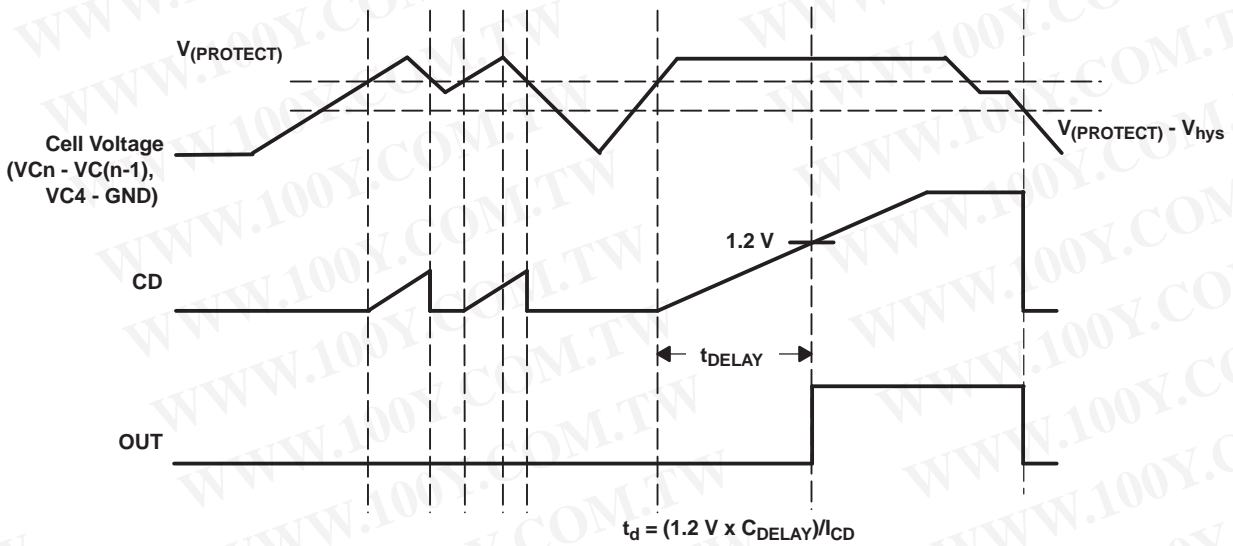


Figure 2. Timing for Overvoltage Sensing

## APPLICATION INFORMATION

### BATTERY CONNECTIONS

The following diagrams show the DCT package device in different cell configurations.

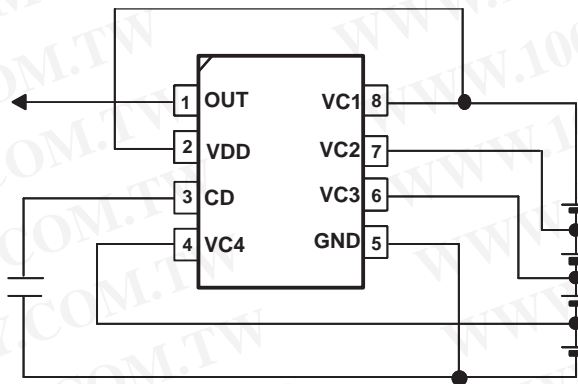


Figure 3. 4-Series Cell Configuration

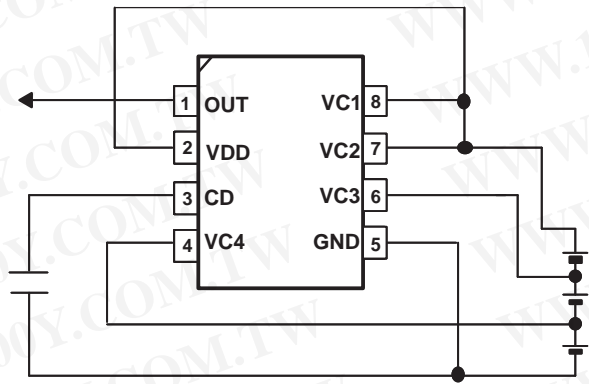


Figure 4. 3-Series Cell Configuration  
(Connect together VC1 and VC2)

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## APPLICATION INFORMATION (continued)

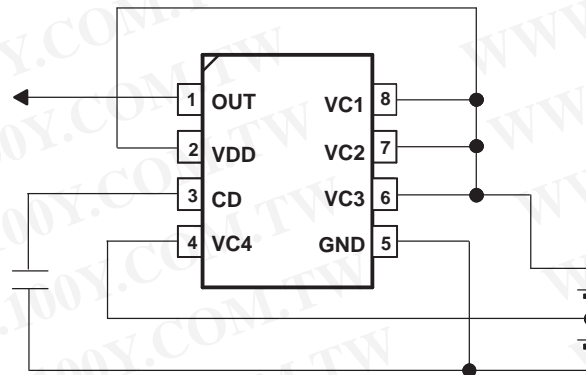


Figure 5. 2-Series Cell Configuration

### CELL CONNECTIONS

To prevent incorrect output activation, the following connection sequences must be used.

#### 4-Series Cell Configuration

- VC1(=VDD) → VC2 → VC3 → VC4 → GND or
- GND → VC4 → VC3 → VC2 → VC1(=VDD)

#### 3-Series Cell Configuration

- VC1(=VC2=VDD) → VC3 → VC4 → GND or
- GND → VC4 → VC3 → VC1(=VC2=VDD)

#### 2-Series Cell Configuration

- VC1(=VC2=VC3=VDD) → VC4 → GND or
- GND → VC4 → VC1(=VC2=VC3=VDD)

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**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
BQ29410DCT3R	ACTIVE	SM8	DCT	8	3000	Pb-Free (RoHS)	CU SNBI	Level-1-260C-UNLIM
BQ29410DCT3RE6	ACTIVE	SM8	DCT	8	3000	Pb-Free (RoHS)	CU SNBI	Level-1-260C-UNLIM
BQ29410DCTR	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29410DCTRG4	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29410DCTT	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29410DCTTG4	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29410PW	ACTIVE	TSSOP	PW	8	150	TBD	CU NIPDAU	Level-1-220C-UNLIM
BQ29410PWR	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
BQ29410PWRG4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29411DCT3R	ACTIVE	SM8	DCT	8	3000	Pb-Free (RoHS)	CU SNBI	Level-1-260C-UNLIM
BQ29411DCT3RE6	ACTIVE	SM8	DCT	8	3000	Pb-Free (RoHS)	CU SNBI	Level-1-260C-UNLIM
BQ29411DCTR	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29411DCTRG4	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29411DCTT	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29411DCTTG4	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29411PW	ACTIVE	TSSOP	PW	8	150	TBD	CU NIPDAU	Level-1-220C-UNLIM
BQ29411PWR	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
BQ29411PWRG4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29412DCT3R	ACTIVE	SM8	DCT	8	3000	Pb-Free (RoHS)	CU SNBI	Level-1-260C-UNLIM
BQ29412DCT3RE6	ACTIVE	SM8	DCT	8	3000	Pb-Free (RoHS)	CU SNBI	Level-1-260C-UNLIM
BQ29412DCT3T	PREVIEW			8		TBD	Call TI	Call TI
BQ29412DCTR	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29412DCTRG4	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29412DCTT	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29412DCTTG4	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29412PW	ACTIVE	TSSOP	PW	8	150	TBD	CU NIPDAU	Level-1-220C-UNLIM
BQ29412PWG4	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

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Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
BQ29412PWR	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-220C-UNLIM
BQ29412PWGR4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29413DCTR	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29413DCTRG4	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29413DCTT	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29413DCTTG4	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29413PW	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29413PWG4	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29413PWR	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29413PWGR4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29414DCTR	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29414DCTRG4	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29414DCTT	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29414DCTTG4	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29414PW	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29414PWG4	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29414PWR	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29414PWGR4	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29415DCTR	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29415DCTRG4	ACTIVE	SM8	DCT	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29415DCTT	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29415DCTTG4	ACTIVE	SM8	DCT	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
BQ29415PW	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29415PWG4	ACTIVE	TSSOP	PW	8	150	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29415PWR	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ29415PWGR4	ACTIVE	TSSOP	PW	8	2000	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.

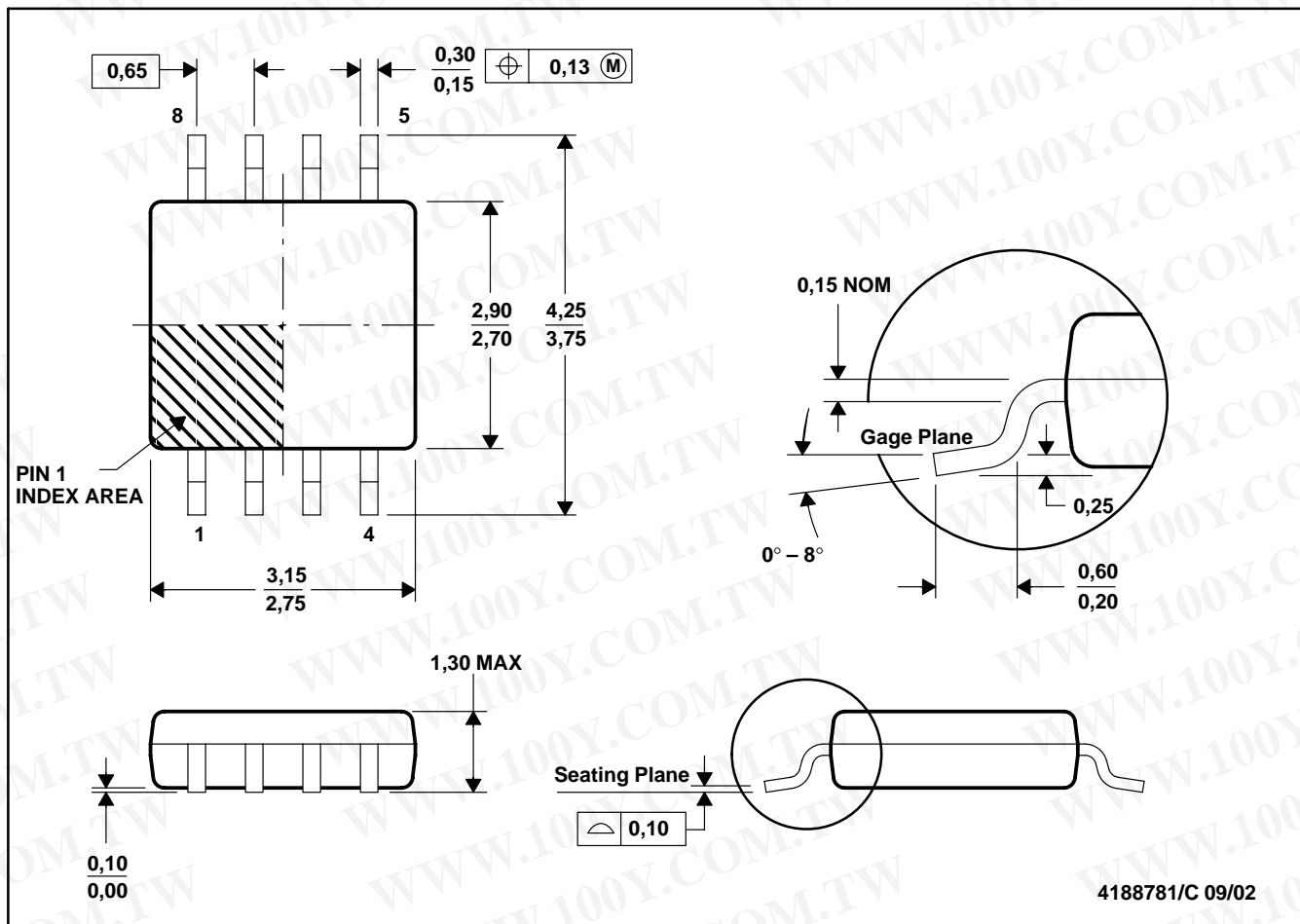
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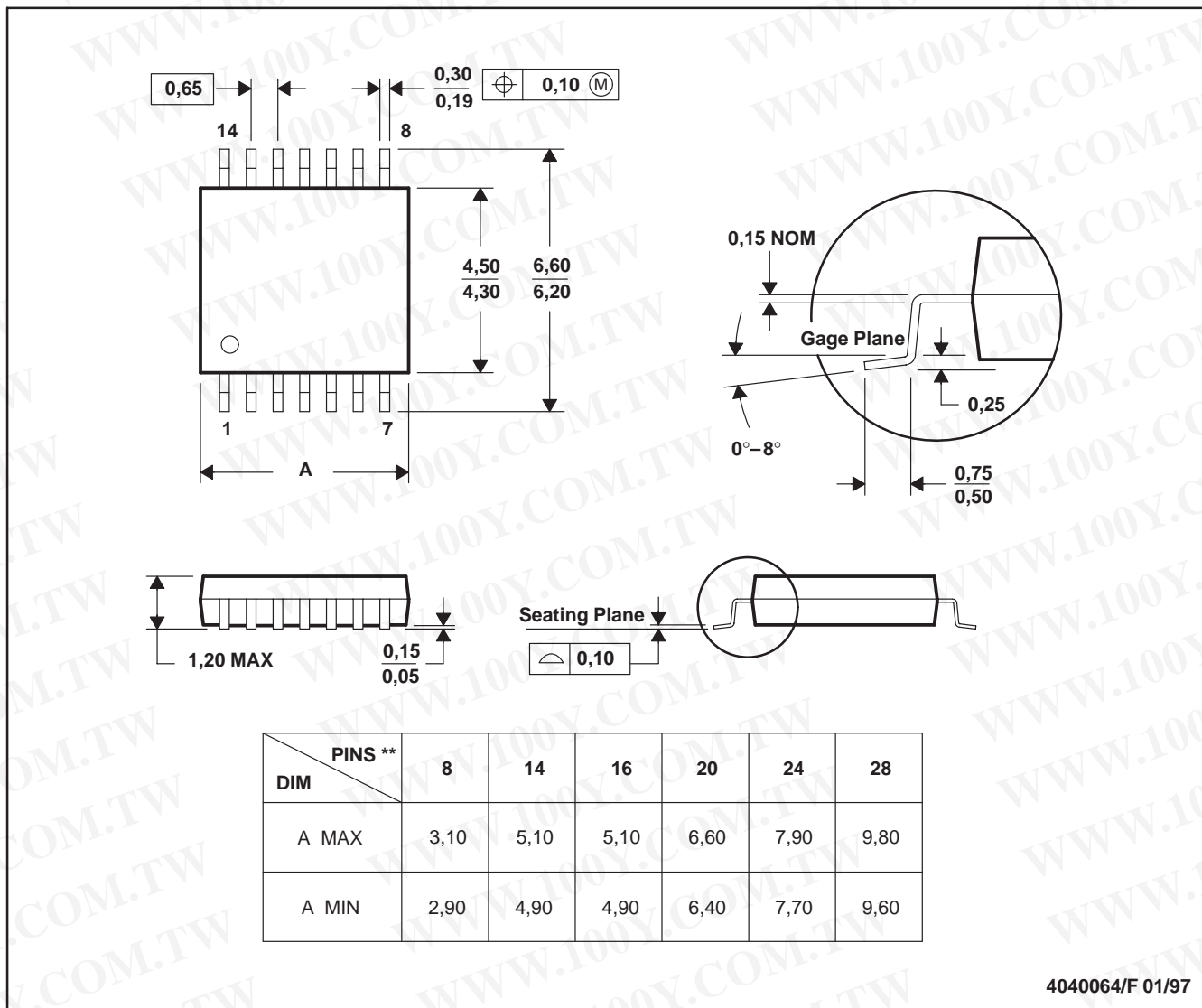
- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion
  - D. Falls within JEDEC MO-187 variation DA.

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14 PINS SHOWN



4040064/F 01/97

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 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.  
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