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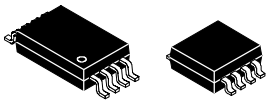




SLUS568C–JULY 2003–REVISED SEPTEMBER 2005

# VOLTAGE PROTECTION FOR 2-, 3-, OR 4-CELL Lion BATTERIES (2nd PROTECTION)

## FEATURES

- **2-, 3-, or 4-Cell Secondary Protection**
- **Low Power Consumption $I_{CC}$ < 2 µA [$VCELL_{(ALL)}$ < $V_{(PROTECT)}$]**
- **High Accuracy Over Sense Voltage:**
  - **bq29400: 4.35 V ±25 mV**
  - **bq29400A: 4.40 V ±25 mV**
  - **bq29401: 4.45 V ±25 mV**
  - **bq29405: 4.65 V ±25 mV**
- **Prefixed Protection Threshold Voltage**
- **Programmable Delay Time**
- **High Power Supply Ripple Rejection**
- **Stable During Pulse Charge Operation**

## APPLICATIONS

- **2nd Level Protection in Lion Battery Packs in**
  - **Notebook PCs**
  - **Portable Instrumentation**
  - **Medical and Test Equipment**

## DESCRIPTION

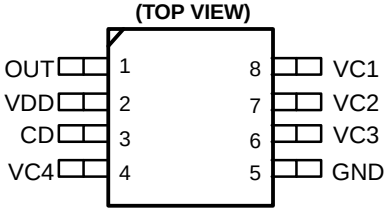
The bq29400, bq29400A, bq29401, and bq29405 are BiCMOS secondary protection ICs for 2-, 3-, or 4-cell Lithium-Ion battery packs that incorporate a high-accuracy precision over voltage detection circuit. They include a programmable delay circuit for over voltage detection time.

## 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 bq2940x 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.

**PW PACKAGE**
**(TOP VIEW)**


**DCT PACKAGE**
**(TOP VIEW)**




### ORDERING INFORMATION

| $T_A$ | $V_{(PROTECT)}$ | PACKAGE | | | |
|---|---|---|---|---|---|
| | | MSSOP (DCT3) | SYMBOL | TSSOP (PW)(1) | SYMBOL |
| –25°C to 85°C | 4.35 V | bq29400DCT3 | CIQ | bq29400PW | 2400 |
| | 4.40 V | bq29400ADCT3 | CIT | Not Available | - |
| | 4.45 V | bq29401DCT3 | CIR | bq29401PW | 2401 |
| | 4.65 V | bq29405DCT3 | CIS | Not Available | - |

(1) The bq29400, bq29400A, bq29401, and bq29405 are available taped and reeled. Add an R suffix to the device type (e.g., bq29400PWR) to order tape and reel version.

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

over operating free-air temperature range unless otherwise noted(1)(2)

| | | UNIT |
|---|---|---|
| Supply voltage range | (VDD) | –0.3 V to 28 V |
| Input voltage range | (VC1, VC2, VC3, VC4) | –0.3 V to 28 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, $T_{stg}$ | | –65°C to 150°C |
| Lead temperature (soldering, 10 sec) | | 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 | $T_A$ = 25°C POWER RATING | DERATING FACTOR ABOVE $T_A$ = 25°C | $T_A$ = 70°C POWER RATING | $T_A$ = 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 |

## RECOMMENDED OPERATING CONDITIONS

| | | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Supply Voltage | | 4.0 | | 25 | V |
| $V_I$ | Input voltage range | VC1, VC2, VC3, VC4 | 0 | | $V_{DD}$+0.3 | V |
| $t_{d(CD)}$ | Delay time capacitance | | | 0.22 | | µF |
| $R_{IN}$ | Voltage-monitor filter resistance | | 100 | 1k | | Ω |
| $C_{IN}$ | Voltage-monitor filter capacitance | | 0.01 | 0.1 | | µF |
| $R_{VD}$ | Supply-voltage filter resistance | | 0 | | 1 | kΩ |
| $C_{VD}$ | Supply-voltage filter capacitance | | | 0.1 | | µF |
| $T_A$ | Operating ambient temperature range | | –25 | | 85 | °C |

## ELECTRICAL CHARACTERISTICS

over recommended operating free-air temperature range, $T_A$ = 25°C (unless otherwise noted)(1)

| PARAMETER | | | TEST CONDITION | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{(OA)}$ | Over voltage detection accuracy | | | | 25 | 35 | mV |
| | | | $T_A$ = –20°C to 85°C | | 25 | 50 | |
| $V_{(PROTECT)}$ | Over voltage detection voltage(1) | bq29400 | | | 4.35 | | V |
| | | bq2940A | | | 4.40 | | |
| | | bq29401 | | | 4.45 | | |
| | | bq29405 | | | 4.65 | | |
| $V_{hys}$ | Over voltage detection hysteresis(1) | | | | 300 | | mV |
| $I_I$ | Input current | | V2, V3 , VC4 input = VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 3.5 V | | | 0.3 | µA |
| $t_{D1}$ | Over voltage detection delay time | | CD = 0.22 µF | 1.0 | 1.5 | 2.0 | S |
| $I_{(CD\_dis)}$ | CD GND clamp current | | CD = 1 V | 5 | 12 | | µA |
| $I_{CC}$ | Supply current | | VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 3.5 V (see Figure 1) | | 2.0 | 3.0 | µA |
| | | | VC1 = VC2 = VC3 = VC4 = VC3–VC4 = VC4–GND = 2.3 V (see Figure 1) | | 1.5 | 2.5 | |
| $V_{(OUT)}$ | OUT pin drive voltage | | VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = $V_{(PROTECT)}$MAX, VDD = VC1, IOH = 0 mA | | 7 | | V |
| | | | VC1=VC2=VC3=VC4=$V_{(PROTECT)}$MAX, VDD=4.3V, $T_A$= 0°C to 70°C, IOH = – 40µA | 1.5 | 2.0 | 2.5 | V |
| $I_{OH}$ | High-level output current | | OUT = 3V, VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 4.7 V | –1 | | | mA |
| $I_{OL}$ | Low-level output current | | OUT = 0.1 V VC1–VC2 = VC2–VC3 = VC3–VC4 = VC4–GND = 3.5 V | 5 | | | µA |

(1) Levels of the over-voltage detection and the hysteresis can be adjusted. For assistance contact Texas Instruments sales representative.

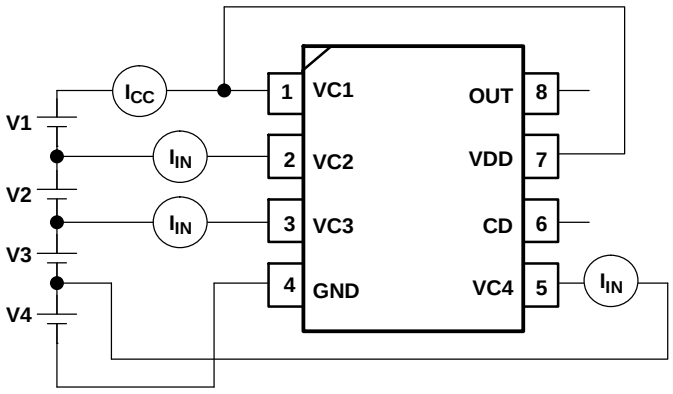



**Figure 1. $I_{CC}$, $I_{IN}$ Measurement (TSSOP Package)**

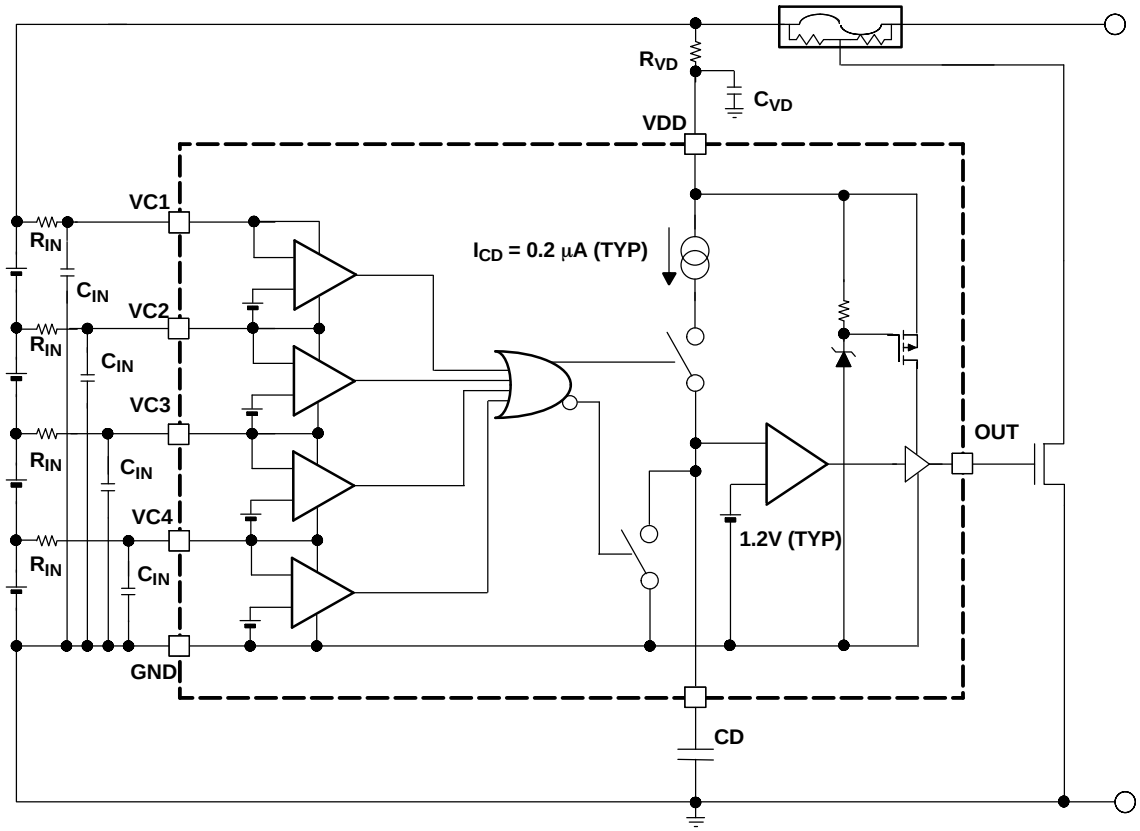
### Terminal Functions

| TERMINAL | | | DESCRIPTION |
|---|---|---|---|
| MSOP (DTC) | 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 |

**Terminal Functions (continued)**

| TERMINAL | | | DESCRIPTION |
|---|---|---|---|
| MSOP (DTC) | TSSOP (PW) | NAME | |
| 3 | 6 | CD | An external capacitor is connected to determine the programmable delay time |
| 2 | 7 | VDD | Power supply |
| 1 | 8 | OUT | Output |

**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 activiated and blows the external fuse in the positive battery rail, see Figure 1.

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:

$$t_d = \frac{\left[1.2\ V \times C_{(DELAY)}\right]}{I_{CD}}$$

$$C_{(DELAY)} = \frac{\left[t_d \times I_{CD}\right]}{1.2\ V}$$

Where $I_{(CD)}$ = CD current source = 0.2 µA

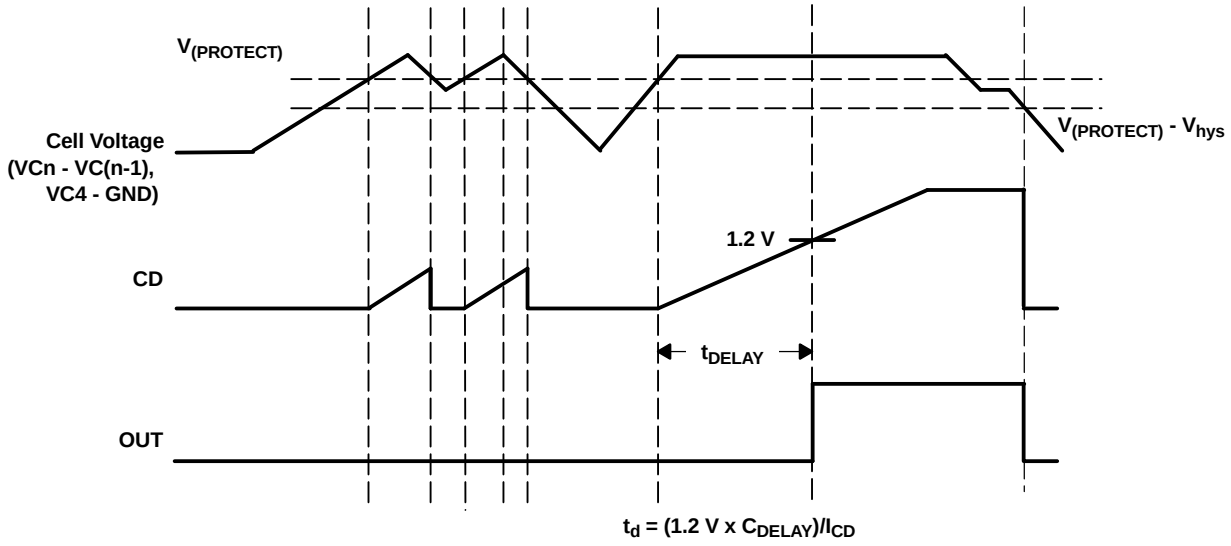



**Figure 2. Timing for Overvoltage Sensing**

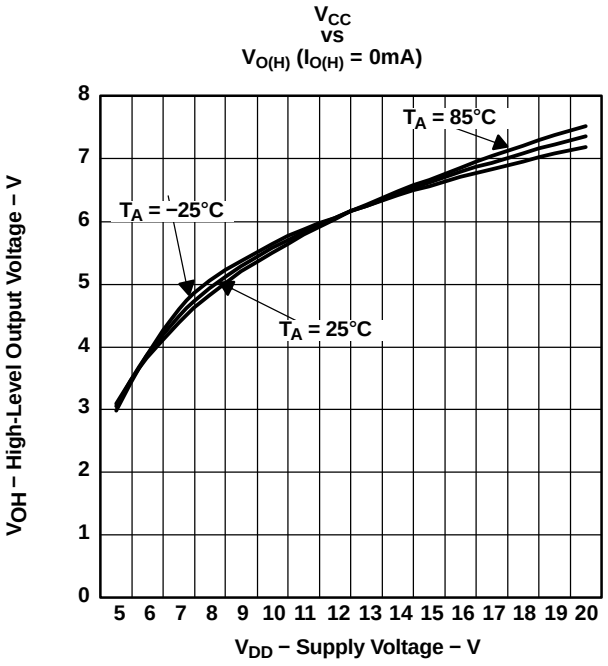



**Figure 3.**

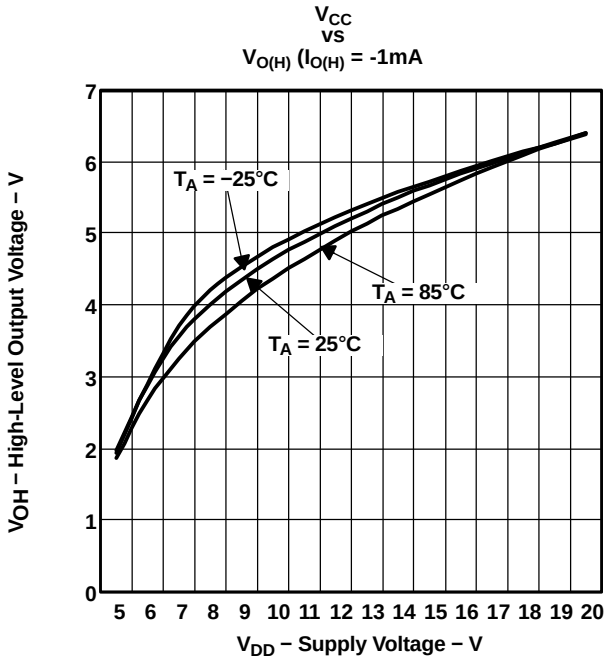



**Figure 4.**

## APPLICATION INFORMATION

### BATTERY CONNECTIONS

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

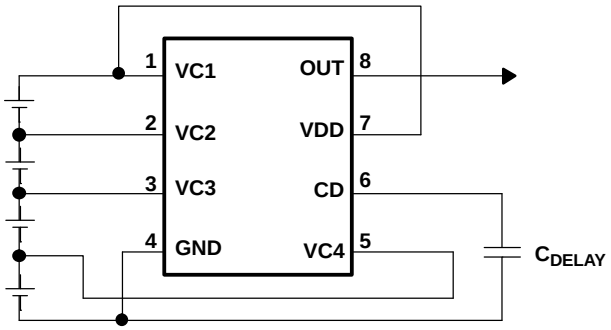



Figure 5. 4-Series Cell Configuration

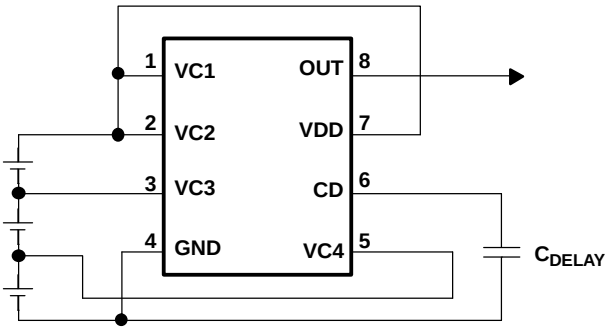



Figure 6. 3-Series Cell Configuration
(Connect together VC1 and VC2)

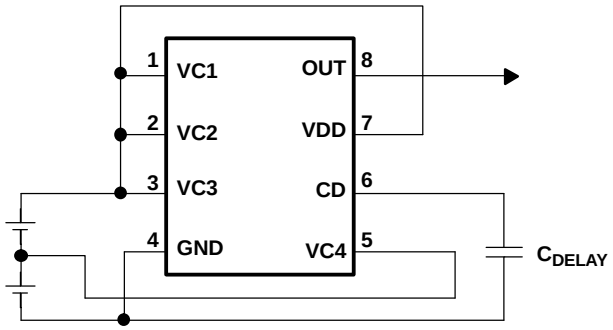



Figure 7. 2-Series Cell Configuration

### 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)

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BQ29400DCT3 | NRND | SM8 | DCT | 8 | 3000 | Pb-Free (RoHS) | CU SNBI | Level-1-260C-UNLIM | | CIQ | |
| BQ29400DCT3E6 | NRND | SM8 | DCT | 8 | 3000 | Pb-Free (RoHS) | CU SNBI | Level-1-260C-UNLIM | | CIQ | |
| BQ29400PW | NRND | TSSOP | PW | 8 | 150 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -25 to 85 | 29400 | |
| BQ29401PW | NRND | TSSOP | PW | 8 | 150 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -20 to 85 | 29401 | |
| BQ29405DCT3 | NRND | SM8 | DCT | 8 | 3000 | Pb-Free (RoHS) | CU SNBI | Level-1-260C-UNLIM | -25 to 85 | CIS W | |

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

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

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

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

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

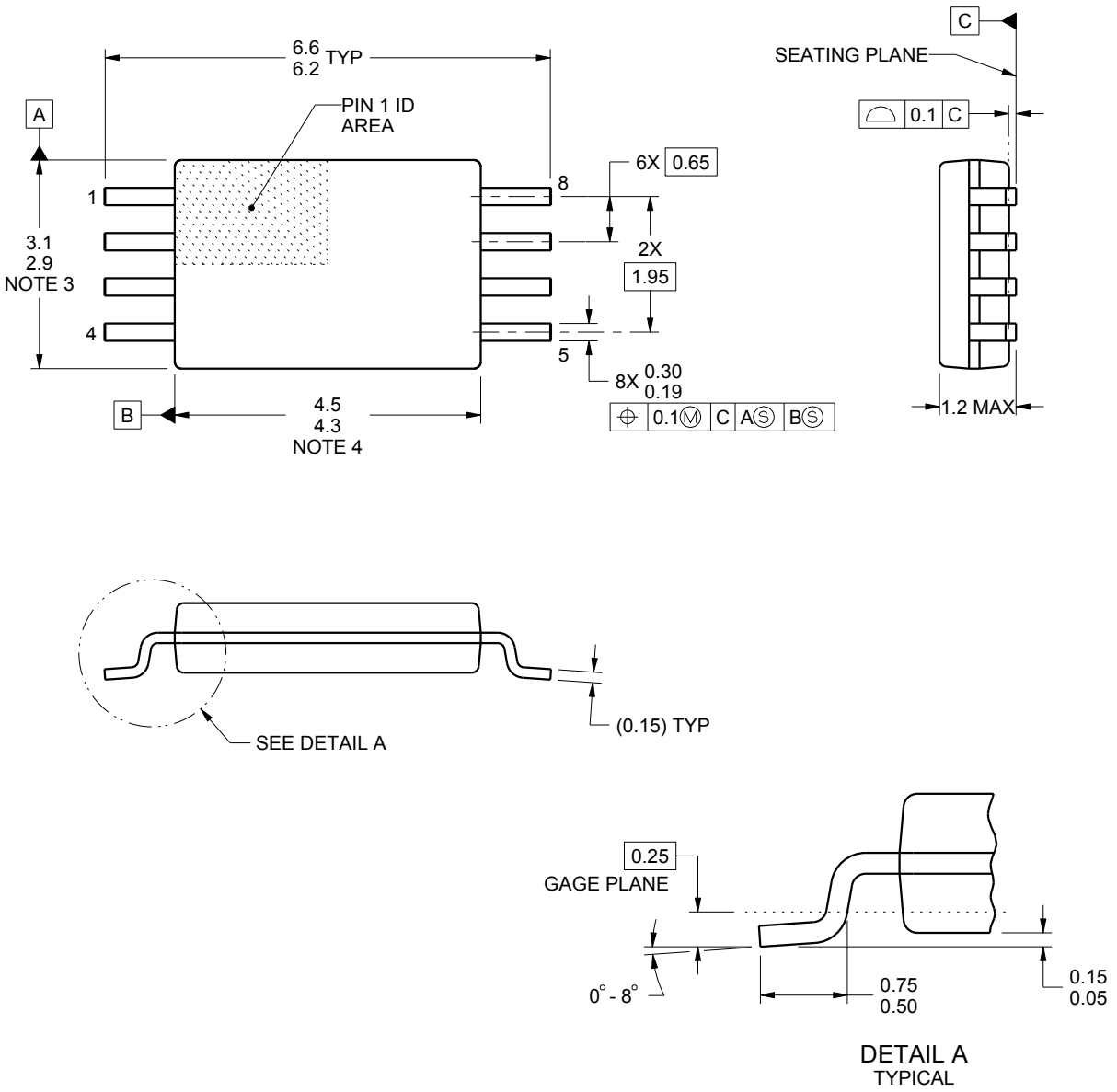
**(6)** Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

# PACKAGE OUTLINE

## PW0008A

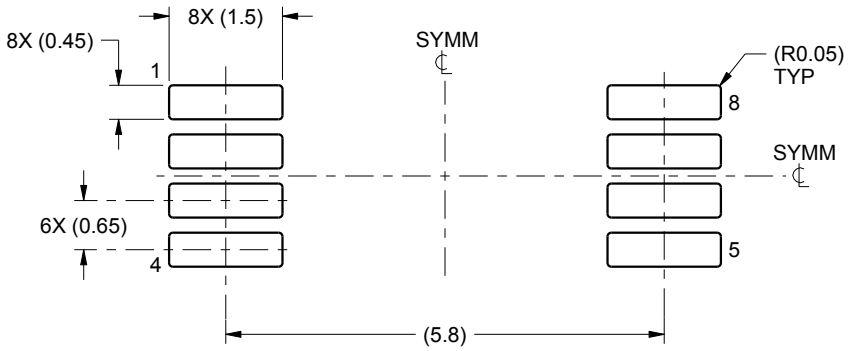
## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

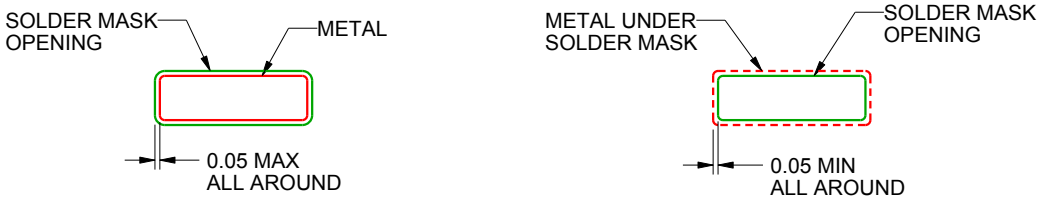



NOTES:

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.




LAND PATTERN EXAMPLE
SCALE:10X

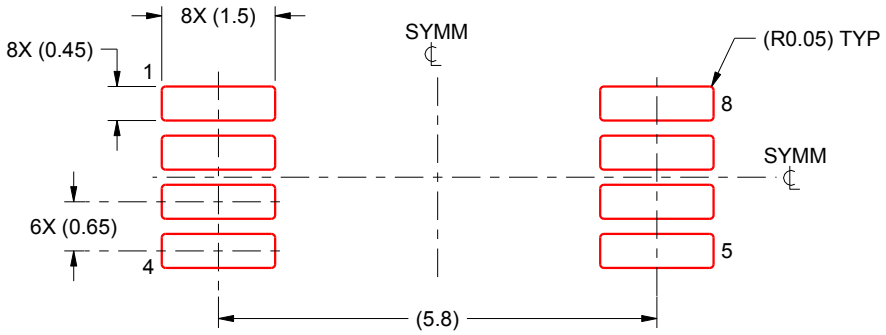



SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

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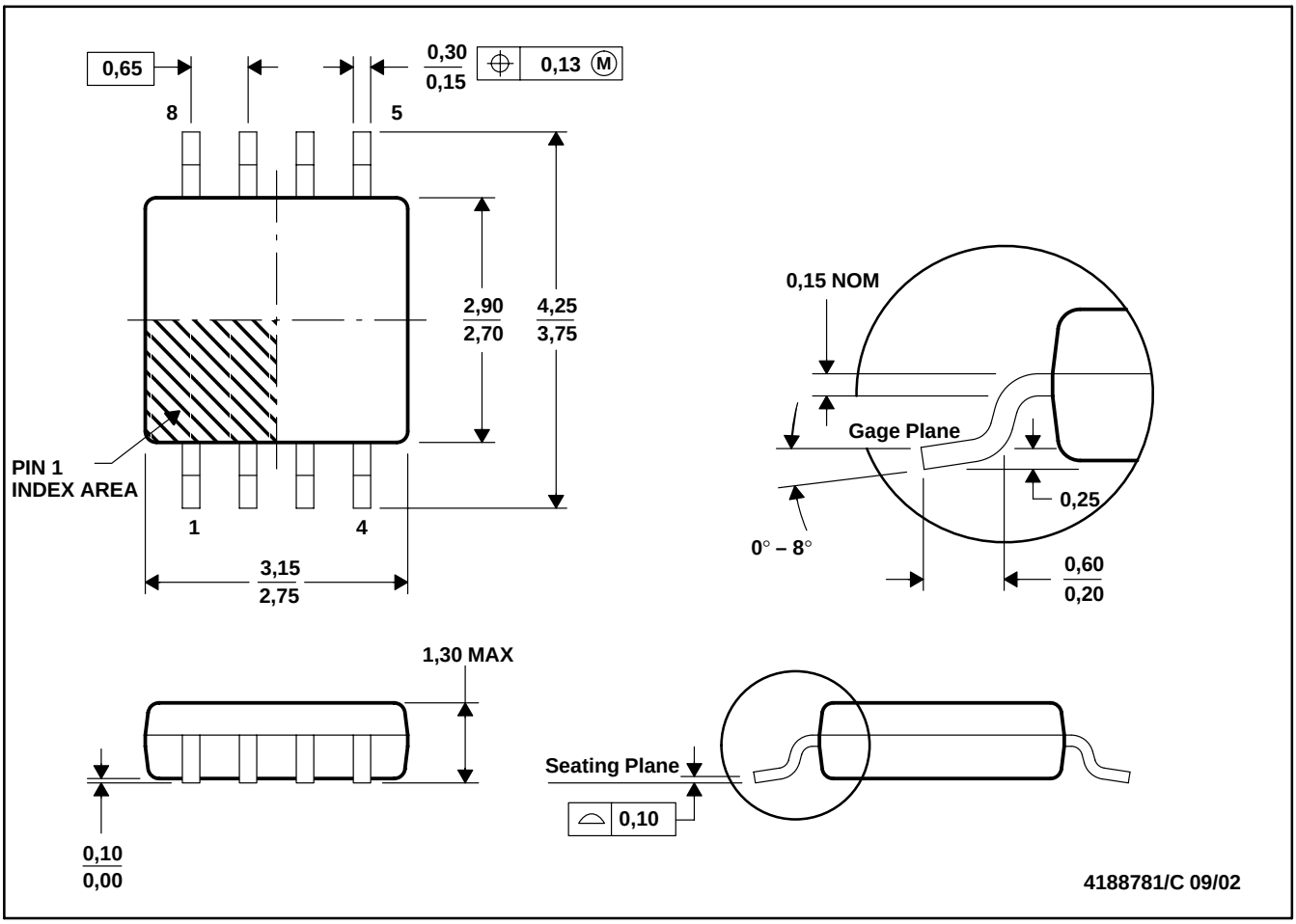
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

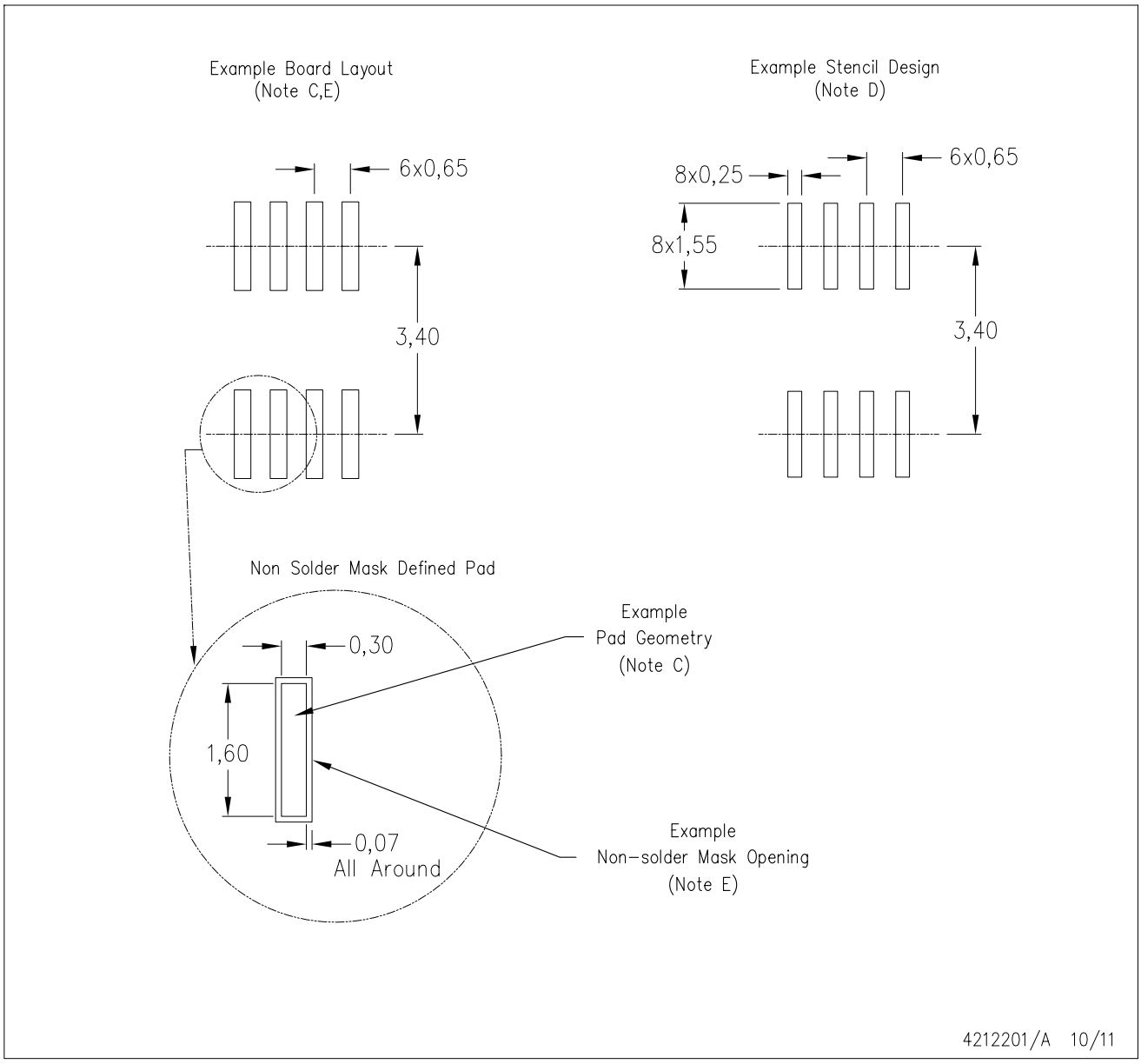
MPDS049B – MAY 1999 – REVISED OCTOBER 2002

**DCT (R-PDSO-G8)** **PLASTIC SMALL-OUTLINE PACKAGE**




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.

DCT (R–PDSO–G8) PLASTIC SMALL OUTLINE




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. 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.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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