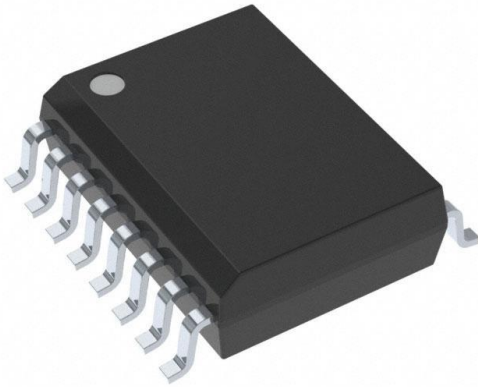


BQ24450DW Datasheet

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BQ24450DW

<https://www.DiGi-Electronics.com>

| | |
|------------------------------|-----------------------------------|
| DiGi Electronics Part Number | BQ24450DW-DG |
| Manufacturer | Texas Instruments |
| Manufacturer Product Number | BQ24450DW |
| Description | IC BATT CHG LEAD ACID 16SOIC |
| Detailed Description | Charger IC Lead Acid 16-SOIC |



Tel: +00 852-30501935

RFQ Email: Info@DiGi-Electronics.com

DiGi is a global authorized distributor of electronic components.

Purchase and inquiry

Manufacturer Product Number:

BQ24450DW

Series:

-

Battery Chemistry:

Lead Acid

Current - Charging:

-

Fault Protection:

-

Battery Pack Voltage:

-

Interface:

-

Mounting Type:

Surface Mount

Supplier Device Package:

16-SOIC

Manufacturer:

Texas Instruments

Product Status:

Active

Number of Cells:

-

Programmable Features:

-

Charge Current - Max:

-

Voltage - Supply (Max):

40V

Operating Temperature:

-40°C ~ 70°C (TJ)

Package / Case:

16-SOIC (0.295", 7.50mm Width)

Base Product Number:

BQ24450

Environmental & Export classification

RoHS Status:

ROHS3 Compliant

REACH Status:

REACH Unaffected

HTSUS:

8542.39.0001

Moisture Sensitivity Level (MSL):

2 (1 Year)

ECCN:

EAR99

INTEGRATED CHARGE CONTROLLER FOR LEAD-ACID BATTERIES

Check for Samples: [bq24450](#)

FEATURES

- Regulates Both Voltage and Current During Charging
- Precision Temperature-Compensated Reference:
 - Maximizes Battery Capacity Over Temperature
 - Ensures Safety While Charging Over Temperature
- Optimum Control to Maximize Battery Capacity and Life

- Supports Different Configurations
- Minimum External Components
- Available in 16-Pin SOIC (DW)

APPLICATIONS

- Emergency Lighting Systems
- Security and Alarm Systems
- Telecommunication Backup Power
- Uninterruptible Power Supplies

DESCRIPTION

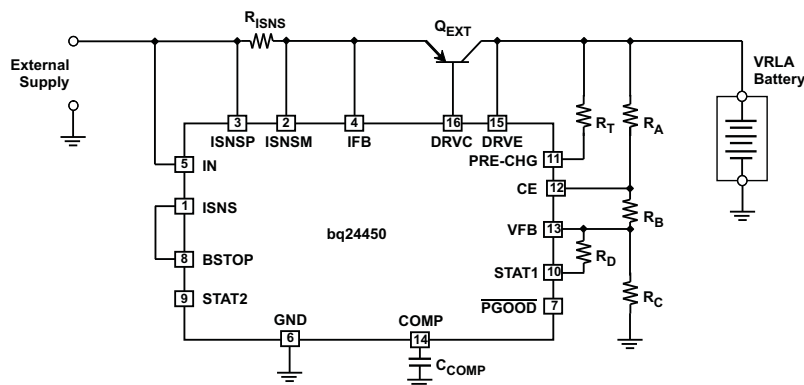
The bq24450 contains all the necessary circuitry to optimally control the charging of valve-regulated lead-acid batteries. The IC controls the charging current as well as the charging voltage to safely and efficiently charge the battery, maximizing battery capacity and life. Depending on the application, the IC can be configured as a simple constant-voltage float charge controller or a dual-voltage float-cum-boost charge controller.

The built-in precision voltage reference is especially temperature-compensated to track the characteristics of lead-acid cells, and maintains optimum charging voltage over an extended temperature range without using any external components. The IC's low current consumption allows for accurate temperature monitoring by minimizing self-heating effects.

The IC can support a wide range of battery capacities and charging currents, limited only by the selection of the external pass transistor. The versatile driver for the external pass transistor supports both NPN and PNP types and provides at least 25mA of base drive.

In addition to the voltage- and current-regulating amplifiers, the IC features comparators that monitor the charging voltage and current. These comparators feed into an internal state machine that sequences the charge cycle. Some of these comparator outputs are made available as status signals at external pins of the IC. These status and control pins can be connected to a processor, or they can be connected up in flexible ways for standalone applications.

Figure 1. TYPICAL APPLICATION SCHEMATIC



A dual-level Float-cum-Boost Charger with Pre-Charge



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.

bq24450

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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

| DEVICE PACKAGE | PACKING | ORDERABLE PART NUMBER | MARKING |
|----------------|--------------|-----------------------|----------|
| SOIC (D) | Tube of 50 | bq24450D | bq24450D |
| | Reel of 2500 | bq24450DR | bq24450D |

ABSOLUTE MAXIMUM RATINGS^{(1) (2) (3)}

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

| | | VALUE | UNIT |
|---|------------------------------|------------|------------------|
| Input Voltage | IN | -0.3 to 40 | V |
| | PGOOD, STAT1, STAT2, ISNS | -0.3 to 40 | V |
| | VFB, IFB, ISNSP, ISNSM | -0.3 to 40 | V |
| | BSTOP | -0.3 to 40 | V |
| Voltage | PRE-CHG (with respect to IN) | -32 | V |
| Input Current | ISNS | 80 | mA |
| | STAT1, STAT2, PGOOD | 20 | mA |
| Output Current | PRE-CHG | -40 | mA |
| Input Current | DRVIC | 80 | mA |
| Output Current | DRVE | -80 | mA |
| Power Dissipation at $T_A = 25^\circ\text{C}$ | | 1000 | mW |
| Junction temperature, T_J | | -40 to 150 | $^\circ\text{C}$ |
| Storage temperature, T_{STG} | | -65 to 150 | $^\circ\text{C}$ |

- (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 voltage values are with respect to the ground terminal (pin 6) unless otherwise noted.
- (3) Positive currents are into, and negative currents out of, the specified terminal.

RECOMMENDED OPERATING CONDITIONS

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

| | | MIN | MAX | UNITS |
|-----------------------------------|--|-----|-----|------------------|
| V_{IN} | IN voltage range | 5 | 40 | V |
| $I_{STAT1}, I_{STAT2}, I_{PGOOD}$ | Input current, open-collector status pins | | 5 | mA |
| I_{ISNS} | Input current, open-collector ISNS comparator output | | 25 | mA |
| T_J | Junction Temperature | -40 | 70 | $^\circ\text{C}$ |

ELECTRICAL CHARACTERISTICS

Over junction temperature range $-40^{\circ}\text{C} \leq T_J \leq 70^{\circ}\text{C}$, $V_{IN} = 10\text{V}$, $T_J = T_A$. (Positive currents are into, and negative currents out of, the specified terminal)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|---|-------|-------|-------|------------------------|
| INPUT | | | | | | |
| UVLO | Input power detected threshold | V_{IN} increasing from 0V to 5V | 4.2 | 4.5 | 4.8 | V |
| $V_{HYS-UVLO}$ | Hysteresis on UVLO | V_{IN} decreasing from 5V to 0V | | 200 | 300 | mV |
| I_{IN} | Operating current | $V_{IN} = 10\text{V}$ | | 1.6 | 3.3 | mA |
| | | $V_{IN} = 40\text{V}$ | | 1.8 | 3.6 | |
| | | $V_{IN} = 40\text{V}$, $T_A = -40^{\circ}\text{C}$ to 85°C | | 1.8 | 4 | |
| INTERNAL REFERENCE (V_{REF}) | | | | | | |
| V_{REF} | Reference voltage level | Measured as regulating level on VFB pin when device is in FLOAT mode. $T_J = 25^{\circ}\text{C}$ | 2.275 | 2.300 | 2.325 | V |
| dV_{REF}/dT | Temperature coefficient of V_{REF} | | | -3.5 | | mV/ $^{\circ}\text{C}$ |
| ΔV_{REF} | Line regulation of V_{REF} | $V_{IN} = 5\text{V}$ to 40V | | 3 | 8 | mV |
| VOLTAGE AMPLIFIER | | | | | | |
| I_{VFB} | Input bias current | $V_{VFB} = 2.30\text{V}$ | -500 | -200 | | nA |
| A_{OV} | Open-loop gain | Driver current = 1mA | 50 | 65 | | dB |
| V_O | Output voltage swing (above GND or below V_{IN}) | | | 200 | | mV |
| CURRENT LIMIT AMPLIFIER | | | | | | |
| I_{IFB} | Input bias current | | | 0.2 | 1 | μA |
| V_{ILIM} | Threshold voltage (wrt V_{IN}) | | 225 | 250 | 275 | mV |
| ΔV_{ILIM} | Sensitivity of V_{ILIM} to V_{IN} | $V_{IN} = 5\text{V}$ to 40V | | 0.03 | 0.25 | %/V |
| DRIVER TRANSISTOR | | | | | | |
| V_{CE} | Minimum collector to emitter differential | $V_{DRVC} = V_{IN}$, $I_{DRVE} = 10\text{mA}$ | | 2 | 2.2 | V |
| $I_{DRVE-MAX}$ | Maximum output current | $V_{DRVC} - V_{DRVE} = 2\text{V}$ | 25 | 40 | | mA |
| PRE-CHG | | | | | | |
| I_{PRE} | Maximum output current $V_{PRE} = V_{IN} - 3\text{V}$ | | -40 | -25 | | mA |
| V_{PRE} | Maximum output voltage ($V_{IN} - V_{PRE-CHG}$) | $I_{PRE} = -10\text{mA}$ | | 2 | 2.6 | V |
| $V_{PRE-REV}$ | PRE-CHG reverse hold-off voltage | $V_{IN} = 0\text{V}$, $I_{PRE} = -10\mu\text{A}$ | | 6.3 | 7 | V |
| ENABLE COMPARATOR | | | | | | |
| V_{TH-CE} | Threshold voltage ($\times V_{REF}$) | | 0.99 | 1.00 | 1.01 | V/V |
| I_{CE} | Input bias current | | -500 | -200 | | nA |
| CURRENT SENSE COMPARATOR | | | | | | |
| $I_{IB-ISNS}$ | Input bias current | | | 100 | 500 | nA |
| $I_{OS-ISNS}$ | Input offset current | | | 10 | 200 | nA |
| V_{ISNS} | Threshold voltage ($V_{ISNSP} - V_{ISNSM}$) | | 20 | 25 | 30 | mV |
| $\Delta V_{ISNS}/\Delta V_{IN}$ | Threshold sensitivity to V_{IN} | $V_{IN} = 5\text{V}$ to 40V | | 0.05 | 0.35 | %/V |
| $\Delta V_{ISNS}/\Delta V_{CM}$ | Threshold sensitivity to common-mode voltage | $V_{CM} = 2\text{V}$ to V_{IN} | | 0.05 | 0.35 | %/V |
| I_{ISNS} | Maximum sink current, ISNS pin | $V_{ISNS} = 2\text{V}$ | | 25 | 40 | mA |
| $V_{ISNS-SAT}$ | Saturation voltage, ISNS pin | $I_{ISNS} = 10\text{mA}$ | | 200 | 450 | mV |
| VOLTAGE SENSE COMPARATOR | | | | | | |
| V_{VSNS} | Threshold voltage ($\times V_{REF}$) | L1 = RESET | 0.94 | 0.95 | 0.96 | |
| | | L1 = SET | 0.895 | 0.90 | 0.910 | |
| INPUT LOGIC LEVELS – BSTOP | | | | | | |
| V_{TH-BS} | Threshold voltage | | 0.7 | 1 | 1.3 | V |
| I_{PU-BS} | Internal pull-up current | $V_{BSTOP} = V_{TH-BS}$ | | 10 | | μA |
| OUTPUT LOGIC LEVELS – STAT1, STAT2, PGOOD | | | | | | |
| $I_{SINK-MAX}$ | Maximum sink current | $V_{PIN} = 2\text{V}$, output transistor ON | 2.5 | 5 | | mA |
| V_{SAT} | Output saturation voltage | $I_{SINK} = 1.6\text{mA}$ | | 250 | 450 | mV |
| | | $I_{SINK} = 50\mu\text{A}$ | | 30 | 50 | mV |
| I_{lkg} | Leakage current | $V_{PIN} = 40\text{V}$, output transistor OFF | | 1 | 3 | μA |

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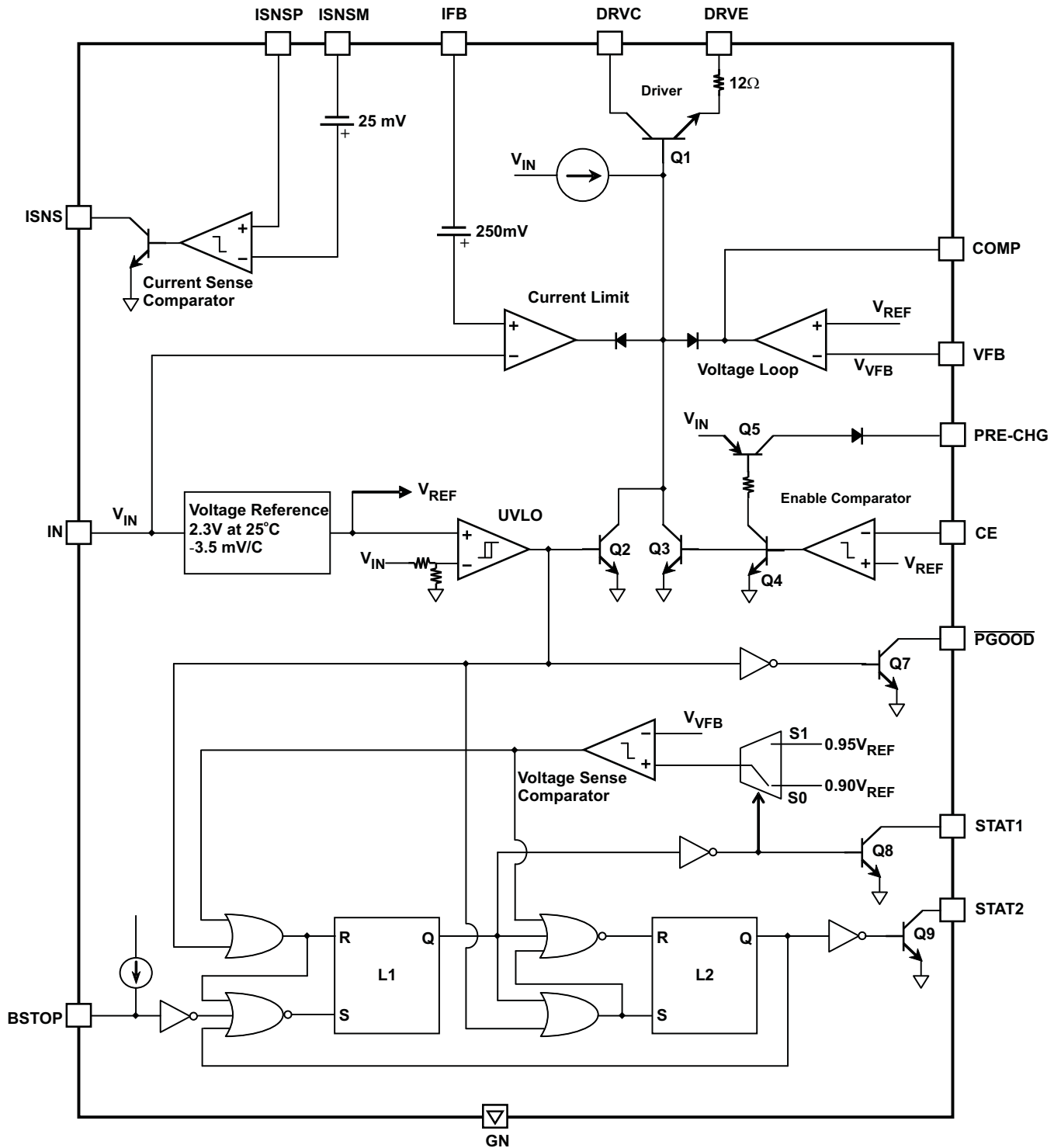


Figure 2. Simplified Block Diagram

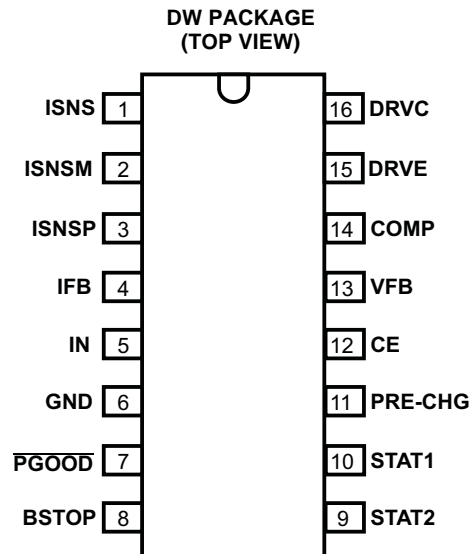
PIN FUNCTIONS

| PIN | | I/O | DESCRIPTION |
|-----|---------|-----|--|
| NO. | NAME | | |
| 1 | ISNS | O | Output of the current-sense comparator. Open-Collector. |
| 2 | ISNSM | I | Negative input of the current-sense comparator. |
| 3 | ISNSP | I | Positive input of the current-sense comparator. |
| 4 | IFB | I | Input for the current-regulating loop. External resistor between IN and IFB sets the charging current value. |
| 5 | IN | I | Supply voltage pin. Connect to external DC source. |
| 6 | GND | – | Ground terminal. |
| 7 | PGOOD | O | Open-collector output, indicates supply status at IN pin. Active low. |
| 8 | BSTOP | I | Control input. Taking this pin from low to high transitions the charger from Boost Mode to Float Mode. Internally pulled up through a 10µA current source. |
| 9 | STAT2 | O | Open-collector status outputs. See table below. |
| 10 | STAT1 | O | |
| 11 | PRE-CHG | O | Can be used to trickle-charge the battery till its voltage rises to a safe value. PRE-CHG will source current as long as the control voltage on the CE pin is below VREF. If using, connect to battery pack through external resistor. |
| 12 | CE | I | Charge enable control. If the voltage on the CE pin is below VREF, the driver transistor will be off and the PRE-CHG pin will source current. |
| 13 | VFB | I | Voltage feedback pin. Connect to battery through external resistive divider. |
| 14 | COMP | I/O | Compensation terminal for voltage loop. Connect a capacitor from this pin to GND. |
| 15 | DRVE | O | Emitter of the internal (NPN) driver transistor. |
| 16 | DRVC | I | Collector of the internal (NPN) driver transistor. |

PINOUT

| STAT1 | STAT2 | CONDITION |
|-------|-------|------------|
| Hi-Z | Hi-Z | Float Mode |

| STAT1 | STAT2 | CONDITION |
|-------|-------|-------------|
| On | Hi-Z | Bulk Charge |
| On | On | Boost Mode |



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TYPICAL OPERATING PERFORMANCE

Compensated Voltage Reference

vs

Temperature

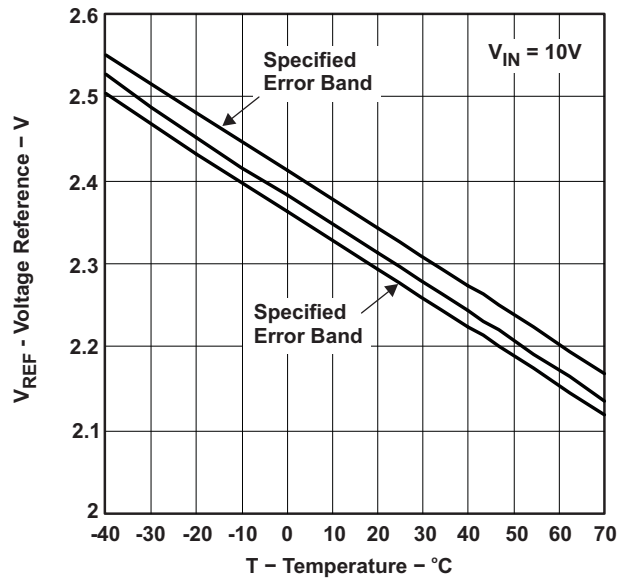


Figure 3. -

DETAILED FUNCTIONAL DESCRIPTION

The bq24450 contains all the necessary circuitry to optimally control the charging of sealed lead-acid batteries. The IC controls the charging current as well as the charging voltage to safely and efficiently charge the battery, maximizing battery capacity and life. Depending on the application, the IC can be configured in various ways: examples are a constant-voltage float charger, a dual-voltage float-cum-boost charger or a dual step current charger.

Only an external pass transistor and minimum number of external passive components are required along with the IC to implement a charger for sealed lead-acid batteries. The IC's internal driver transistor Q1 (see [Figure 2](#)) supports NPN as well as PNP pass transistors, and provides enough drive current (25mA specified) to support a wide range of charging rates.

The driver transistor is controlled by a voltage regulating loop and a current limiting-limiting loop (see [Figure 2](#)). The current-limiting loop reduces drive when the voltage between the IN pin and the IFB pin increases towards V_{ILIM} (250mV typical). The voltage regulating loop tries to maintain the voltage on the VFB pin at V_{REF} . Together, these two loops constitute a current-limited precision constant-voltage system, which is the heart of any lead-acid charger. The voltage regulating amplifier needs an external compensation circuit which depends on the type of external pass transistor (see Application Information section).

An important feature of the bq24450 is the precision reference voltage. The reference voltage is specially temperature compensated to track the temperature characteristics of lead-acid cells. Additionally, the IC operates with low supply current, only 1.6mA, minimizing on-chip dissipation and permitting the accurate sensing of the operating environmental temperature by avoiding self-heating effects. To take full advantage of the temperature-compensated reference, the IC should be in the same thermal environment as the battery.

An undervoltage lock-out circuit is also provided (see [Figure 2](#)). This circuit disables the driver transistor as long as the input voltage is below UVLO (4.5V typical). The UVLO circuit also drives an open-collector output PGOOD.

Voltage-sense and current-sense comparators are available in the IC. The current-sense comparator is uncommitted. Its open-collector output is OFF when the difference between the ISNSP and ISNSM pins is less than V_{ISNS} (25mV typical), and ON when the difference is more than V_{ISNS} . Depending on the application, this comparator may be used to switch to float charging after the boost phase is over. The voltage sense comparator can be used to sense the voltage level of the battery to initiate a new charge cycle.

Latches L1 and L2 constitute a state-machine to control the charging sequence. The internal inputs to the state-machine come from the UVLO circuit and the voltage-sense comparator. One external input is provided, the BSTOP pin. The outputs of the L1 and L2 latches are available at the STAT1 and STAT2 pins. The BSTOP pin is internally pulled up through a 10 μ A current source. The states of the state-machine are:

| Q(L1) | Q(L2) | STAT1 | STAT2 | Condition | State # |
|-------|-------|-------|-------|-------------|---------|
| LOW | HIGH | ON | OFF | Bulk Charge | State 1 |
| LOW | LOW | ON | ON | Boost Mode | State 2 |
| HIGH | HIGH | OFF | OFF | Float Mode | State 3 |

A small bias current source is available at the PRE-CHG pin to provide pre-charge to deeply discharged batteries. The PRE-CHG pin sources current when the voltage at the CE pin is below V_{REF} . Driver transistor Q1 is turned OFF when the PRE-CHG current is ON.

As charging proceeds, the voltage at the VFB pin increases further to V_{REF} . At this point, the voltage regulating amplifier prevents the voltage at the VFB pin from rising further, maintaining the battery voltage at V_{BOOST} . [(4) in Figure 4].

$$V_{BOOST} = V_{REF} \times (R_A + R_B / R_C) \div R_B / R_C$$

I_{CHG} keeps flowing into the battery. As the battery approaches full charge, the current into the battery decreases, while the battery terminal voltage is maintained at V_{BOOST} .

At (5), the charging current I_{CHG} reduces to a value I_{TAPER} such that the voltage across R_{ISNS} becomes less than V_{ISNS} (25mV typical)

$$I_{TAPER} = V_{ISNS} \div R_{ISNS}$$

Q6 at the output of the current sense comparator turns OFF. The internal current source pulls the BSTOP pin HIGH, latch L1 is forced to SET, in turn forcing L2 to SET. The reference voltage on the voltage sense comparator is now $0.9V_{REF}$. STAT1 turns OFF, and the voltage on the battery settles to:

$$V_{FLOAT} = V_{REF} \times (R_A + R_B) \div R_B$$

As long as the peak load current is less than $I_{MAX-CHG}$, it will be supplied by Q_{EXT} , and the voltage across the battery will be maintained at V_{FLOAT} . But if the peak load current exceeds $I_{MAX-CHG}$, the battery will have to provide the excess current, and the battery terminal voltage will drop. Once it drops below $0.9V_{REF}$, at (6) in Figure 4, a new charge cycle is initiated. The battery voltage V_{BAT} at this point, V_{RCH} , is given by:

$$V_{RCH} = 0.9V_{REF} \times (R_A + R_B) / R_B$$

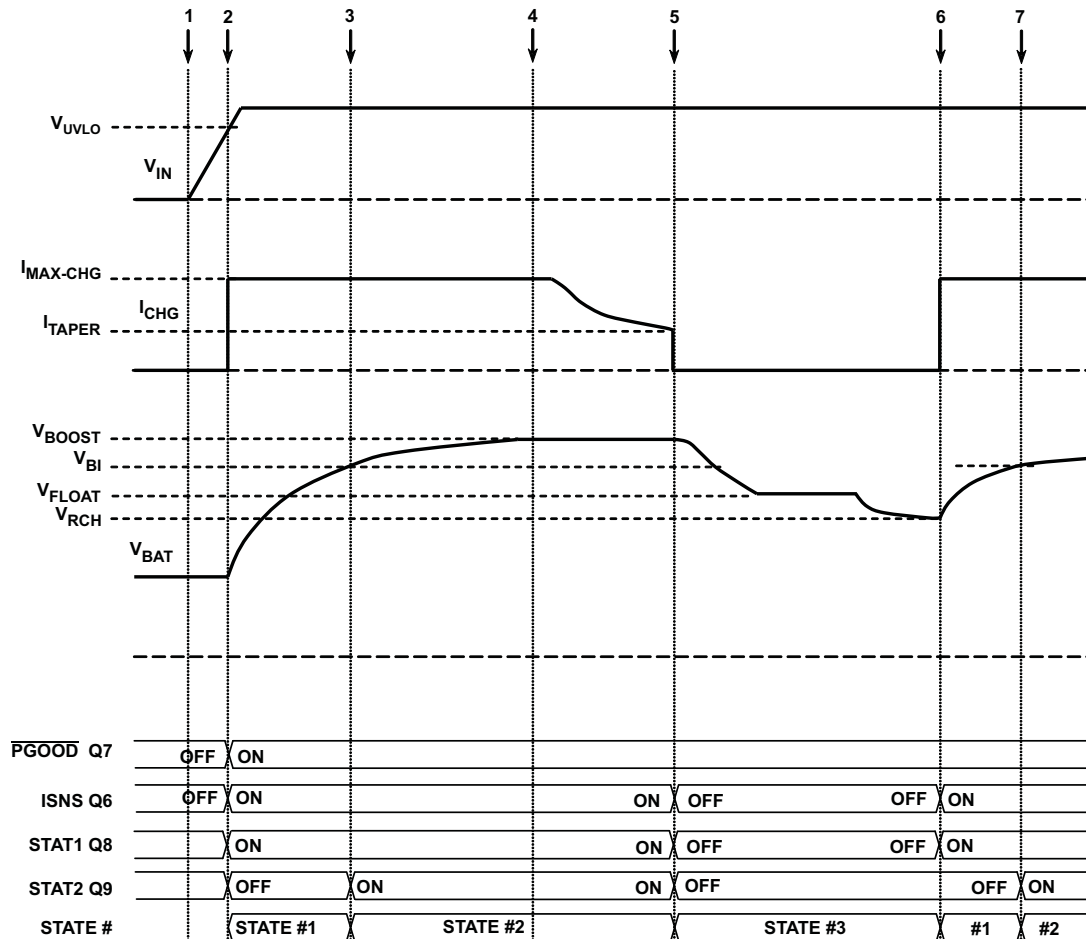


Figure 5.

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An Improved Dual-Level Float-Cum-Boost Charger with Pre-Charge

The problem with the charger circuit shown in Figure 4 is that even with deeply discharged batteries, charging starts at full current level $I_{MAX-CHG}$. This can sometimes be hazardous, resulting in out-gassing from the battery. The bq24450 can be configured to pre-charge the battery till the voltage levels rise to levels safe enough to permit charging at $I_{MAX-CHG}$.

In the circuit of Figure 6, the CE pin is used to detect the battery voltage. As long as the voltage at the CE pin is below V_{REF} , the enable comparator turns ON Q3 and Q4. This turns OFF Q1 and turns ON Q5, permitting a pre-charge current I_{PRE} to flow from the PRE-CHG pin through R_T into the battery. In the following equation, V_{PRE} is the voltage drop across the internal transistor, Q5, and the internal diode.

$$I_{PRE} = (V_{IN} - V_{PRE} - V_{BAT}) \div R_T$$

Once the battery voltage rises above a safe threshold V_{TH} at (2) in Figure 7, the enable comparator turns OFF Q3 and Q4, thus turning OFF Q5 and enabling Q1. Q_{EXT} then provides $I_{MAX-CHG}$, and the circuit after this performs as described before.

$$V_{TH} = V_{REF} \times (R_A + R_B + R_C // R_D) \div (R_B + R_C // R_D)$$

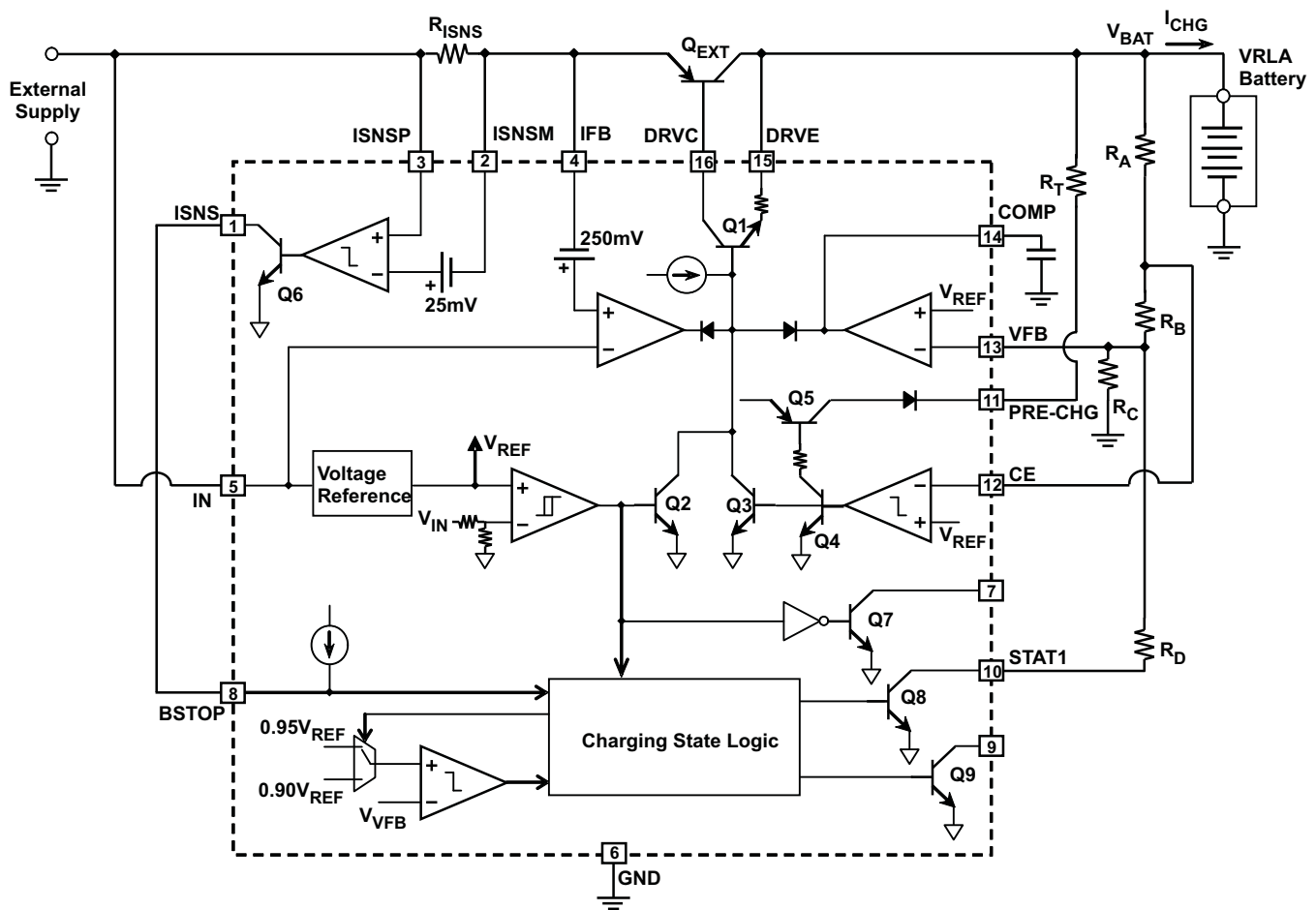


Figure 6.

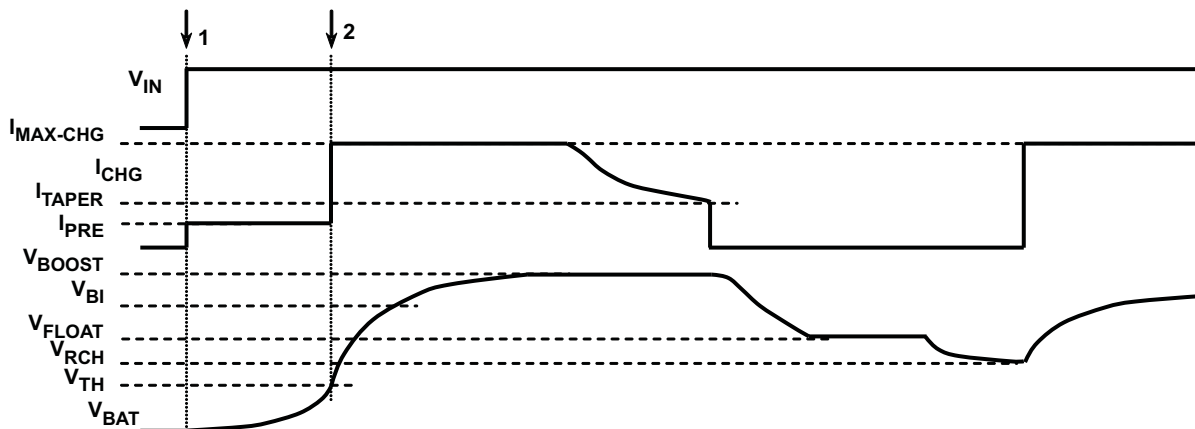


Figure 7.

Further Improvements to the Circuit of Figure 6

In applications where the load current is low, the current through the V_{BAT} voltage divider can be a non-negligible proportion of the load current. Current flowing back through Q_{EXT} when the input power is removed constitutes another drainage path. The modifications in Figure 8 fix both these issues.

The addition of D_{EXT} (see Figure 8) fixes the reverse current problem. Returning the voltage feedback divider chain to the PGOOD pin instead of to GND ensures that the divider does not draw any current when the input supply is not present. (When sinking $50\mu A$, the saturation voltage of the PGOOD transistor is typically only 30mV).

Selecting the External Pass Transistor

All the examples so far have used a PNP transistor for the external pass element. But the driver transistor in the bq24450 can be configured to drive many different types of pass transistors. This section will look at some of the different configurations that are possible. In all configurations, though, these factors hold:

1. The external pass device must have sufficient voltage rating for the application, and must have the current and power handling capabilities to charge at the desired rate at the maximum input to output differential in the application.
2. The device must have enough current gain at the required charging current to keep the drive current below 25mA.

The choice of the pass device and the configuration of the internal driver transistor have an effect on the following:

1. The minimum and maximum practical charging current.
2. The open-loop gains of the current and voltage loops, and hence the value of the compensation capacitor at the COMP pin. In battery charging applications, dynamic response is not a requirement, and the values of C_{COMP} given below should give stable operation under all conditions.
3. The IC's power dissipation and thus its self-heating. The IC typically has a thermal resistance of 100°C/W. An external resistance R_P can be added to share some of the power dissipation and reduce the IC's self-heating.
4. The minimum differential voltage ΔV (from the input to the battery) required to operate.

The next section addresses a few topologies, and gives values for the charge current range, the minimum input to output differential ΔV , power dissipation P_D in the IC, R_P and C_{COMP} for each of the topologies. (In the expressions below, h_{FE} is the current gain of the external transistor).

Common-Emitter PNP

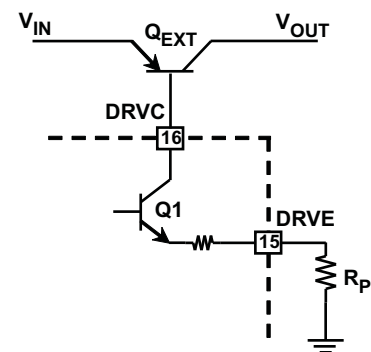
$I_{MAX-CHG}$ range: 25mA to 1000mA

Minimum ΔV : 0.5V

$$R_P = (V_{IN(MIN)} - 2.0V) \div I_{MAX-CHG} \times h_{FE(MIN)}$$

$$P_D = (V_{IN(MAX)} - 0.7V) \div h_{FE} \times I_{MAX-CHG} - (I_{MAX-CHG})^2 \div (h_{FE})^2 \times R_P$$

$$C_{COMP} = 0.1 \mu F$$



PNP in a Quasi-Darlington With Internal Driver

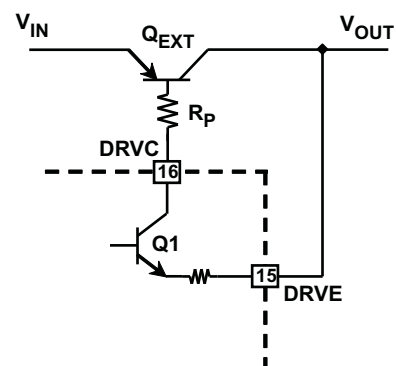
$I_{MAX-CHG}$ range: 25mA to 1000mA

Minimum ΔV : 2V

$$R_P = (V_{IN(MIN)} - V_{OUT(MAX)} - 1.2V) \div I_{MAX-CHG} \times h_{FE(MIN)}$$

$$P_D = (V_{IN(MAX)} - V_{OUT} - 0.7V) \div h_{FE} \times I_{MAX-CHG} - (I_{MAX-CHG})^2 \div (h_{FE})^2 \times R_P$$

$$C_{COMP} = 0.01 \mu F \text{ to } 0.047 \mu F$$



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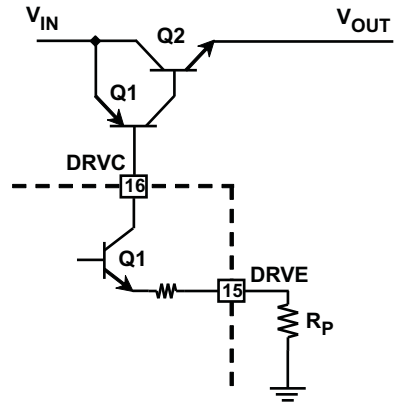
External Quasi-Darlington

 $I_{\text{MAX-CHG}}$ range: 0.6A to 15A
Minimum ΔV : 1.2V

$$R_P = (V_{\text{IN(MIN)}} - 0.7 \text{ V}) \div I_{\text{MAX-CHG}} \times h_{\text{FE1(MIN)}} h_{\text{FE2(MIN)}}$$

$$P_D = (V_{\text{IN(MAX)}} - 0.7 \text{ V}) \div (h_{\text{FE1}} \times h_{\text{FE2}}) \times I_{\text{MAX-CHG}} - (I_{\text{MAX-CHG}})^2 \div (h_{\text{FE1}} \times h_{\text{FE2}})^2 \times R_P$$

$$C_{\text{COMP}} = 0.22 \mu\text{F} \text{ with } 470 \Omega \text{ series resistor to GND}$$



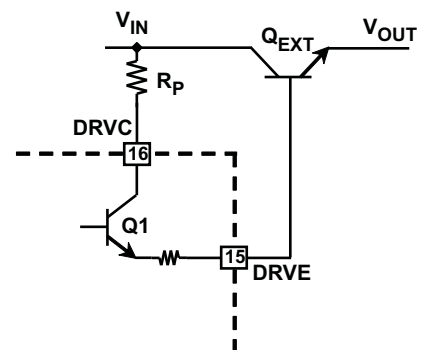
NPN Emitter-Follower

 $I_{\text{MAX-CHG}}$ range: 25mA to 1000mA
Minimum ΔV : 2.7V

$$R_P = (V_{\text{IN(MIN)}} - V_{\text{OUT(MAX)}} - 1.2 \text{ V}) \div I_{\text{MAX-CHG}} \times h_{\text{FE(MIN)}}$$

$$P_D = (V_{\text{IN(MAX)}} - V_{\text{OUT}} - 0.7 \text{ V}) \div h_{\text{FE}} \times I_{\text{MAX-CHG}} - (I_{\text{MAX-CHG}})^2 \div (h_{\text{FE}})^2 \times R_P$$

$$C_{\text{COMP}} = 0.01 \mu\text{F} \text{ to } 0.047 \mu\text{F}$$



DESIGN EXAMPLE

This section covers the design of a dual-level charger for a 6V 4Ah sealed lead-acid battery. The application is a system where the battery is used in standby mode, and the load on the battery when it powers the system is 250mA (0.06C).

The battery parameters are (see References 1 and 2)

| | | | |
|-------------------------|----------------|--------------------|----------------------|
| Final discharge voltage | 1.75V per cell | 5.25V | V_{TH} |
| Float voltage | 2.30V per cell | 6.9V | V_{FLOAT} |
| Voltage in boost mode | 2.45V per cell | 7.35V | V_{BOOST} |
| Charge rate | 0.05C to 0.3C | Use 0.15C = 600 mA | $I_{\text{MAX-CHG}}$ |
| $V_{\text{BAT(MIN)}}$ | | 4V | |
| Trickle charge rate | | 10 mA | |

The charger is required to operate from a supply voltage of 9V to 13V. Therefore, the minimum input to output differential is 1.65V. To block reverse current from the battery to the input supply use a blocking diode as in [Figure 8](#). This leaves only 0.65V as the differential across the external transistor, forcing the use of the [Common-Emitter PNP](#) topology.

[Figure 10](#) is the schematic for this charger (from [Figure 8](#), with the pass transistor topology changed), with the remaining task being the calculation of all the component values.

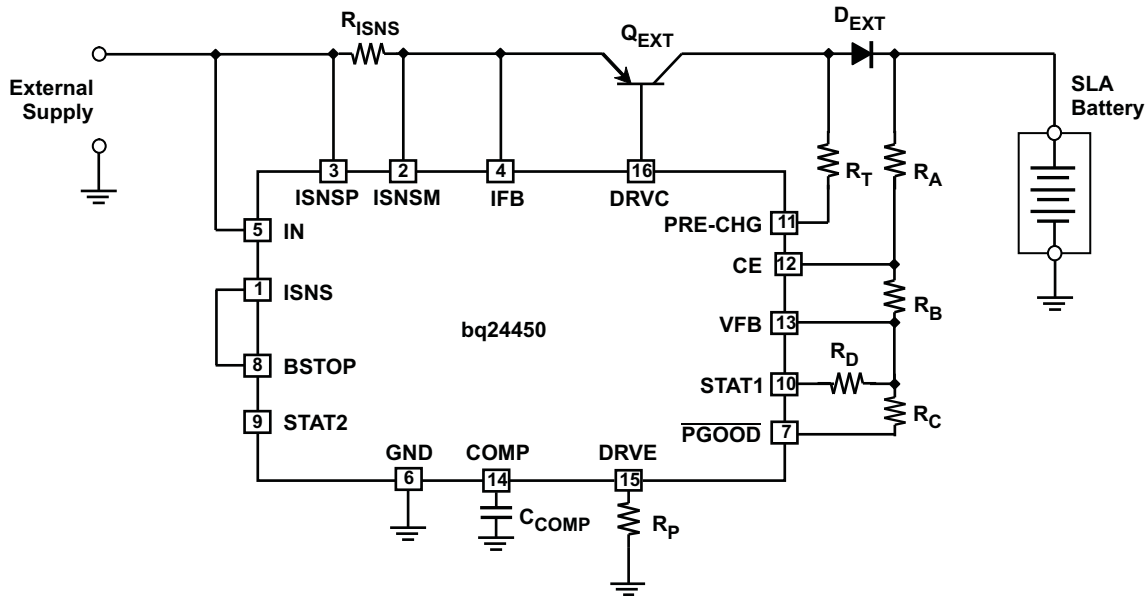


Figure 10.

The first step is to decide on the value of the current in the voltage divider resistor string in FLOAT mode. This should be substantially higher than the input bias current in the CE and VFB pins and the leakage current in the STAT1 pin, but low enough such that the voltage on the PGOOD pin does not introduce errors. A value of 50µA is suitable.

In FLOAT mode, STAT1 is OFF, so there is no current in R_D. The voltage on the VFB pin (V_{REF}) is 2.3V.

$$R_C = 2.30V \div 50\mu A = 46k\Omega. \text{ The closest 1\% value is } 46.4k\Omega.$$

$$V_{\text{FLOAT}} = V_{\text{REF}} \times (R_A + R_B + R_C) \div R_C \rightarrow R_A + R_B = 2 \times R_C = 92.8k\Omega.$$

$$V_{\text{BOOST}} = V_{\text{REF}} \times (R_A + R_B + R_C // R_D) \div R_C // R_D \rightarrow R_D = 474.3k\Omega. \text{ Pick the closest 1\% value of } 475k\Omega.$$

$$V_{\text{TH}} = V_{\text{REF}} \times (R_A + R_B + R_C // R_D) \div (R_B + R_C // R_D) \rightarrow R_B = 16.9k\Omega.$$

$$R_A = 92.8k\Omega - R_B = 75.9k\Omega. \text{ The closest standard value is } 75k\Omega.$$

$$I_{\text{PRE}} = (V_{\text{IN}} - V_{\text{PRE}} - V_{\text{D_EXT}} - V_{\text{BAT}}) \div R_T. \text{ Select } R_T = 634\Omega.$$

$$\text{For example: } I_{\text{PRE}} = (13 - 2 - 0.7 - 4) / 634 = 10\text{mA}$$

$$I_{\text{MAX-CHG}} = V_{\text{ILIM}} \div R_{\text{ISNS}} \rightarrow R_{\text{ISNS}} = 250\text{mV} \div 600\text{mA} = 0.417\Omega. \text{ The closest 1\% value is } 0.422\Omega.$$

For Q_{EXT}, the BD242 is suitable, and a 1N4001 will do for D_{EXT}

$$R_P = (V_{\text{IN(MIN)}} - 2.0V) \div I_{\text{MAX-CHG}} \times h_{\text{FE(MIN)}} = 7 \div 0.6 \times 25 = 291.6\Omega. \text{ Pick } 294\Omega \text{ from the standard values.}$$

$$P_D = (V_{\text{IN(MAX)}} - 0.7V) \div h_{\text{FE}} \times I_{\text{MAX-CHG}} - (I_{\text{MAX-CHG}})^2 \div (h_{\text{FE}})^2 \times R_P = 126\text{mW} \text{ under worst case conditions.}$$

Choose C_{COMP} = 0.1µF.

REFERENCES

1. Yuasa Battery Co., NP Valve Regulated Lead Acid Battery Manual
2. Panasonic, Methods of charging the Valve-Regulated Lead-Acid Battery

bq24450

SLUS929C – APRIL 2009 – REVISED FEBRUARY 2012

www.ti.com**REVISION HISTORY**

NOTE: Page numbers of previous versions may differ from current version.

| Changes from Original (April 2009) to Revision A | Page |
|---|-------------|
| • Deleted PDIP package option from Features | 1 |
| • Deleted PDIP package from Ordering Information table | 2 |
| • Changed equations to correct typo/formatting errors (3 equations) | 8 |
| • Changed equations to correct typo/formatting errors | 9 |
| • Changed equation to correct typo/formatting errors | 10 |
| • Changed three equations to correct typo/formatting errors | 15 |
| • Changed component values in "Design Example" calculations. | 15 |

| Changes from Revision A (January 2010) to Revision B | Page |
|--|-------------|
| • Added V_{PRE} with definition | 10 |
| • Changed component values in the I_{PRE} calculations | 15 |

| Changes from Revision B (October 2010) to Revision C | Page |
|---|-------------|
| • Changed component values in the I_{PRE} calculations in FLOAT mode description..... FROM "332" TO "634"; FROM "5) /332 = 16mA" TO "4)/634 = 10mA" | 15 |

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) |
|-----------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| BQ24450DW | Active | Production | SOIC (DW) 16 | 40 TUBE | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 70 | BQ24450DW |
| BQ24450DW.A | Active | Production | SOIC (DW) 16 | 40 TUBE | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 70 | BQ24450DW |
| BQ24450DWTR | Active | Production | SOIC (DW) 16 | 2000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 70 | BQ24450DW |
| BQ24450DWTR.A | Active | Production | SOIC (DW) 16 | 2000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 70 | BQ24450DW |

⁽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.

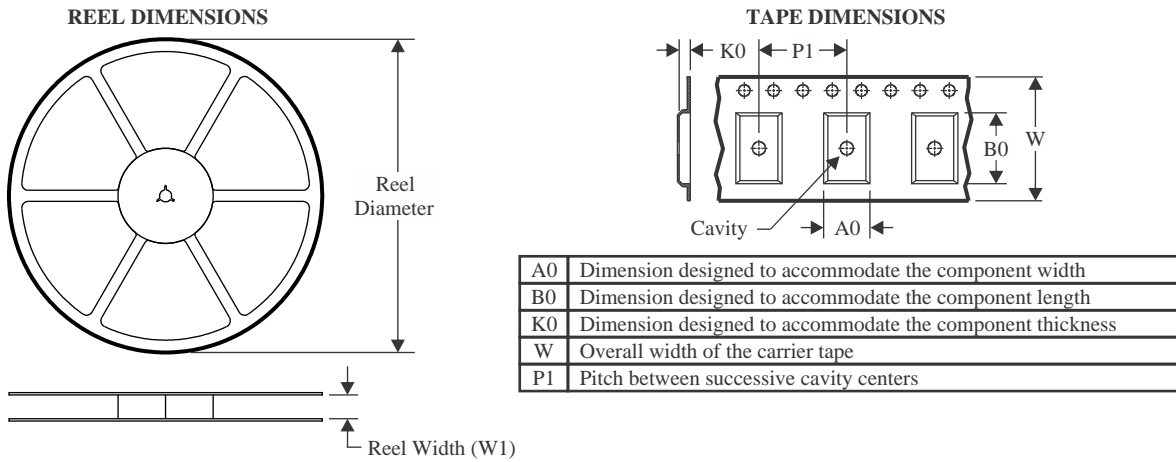
⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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.

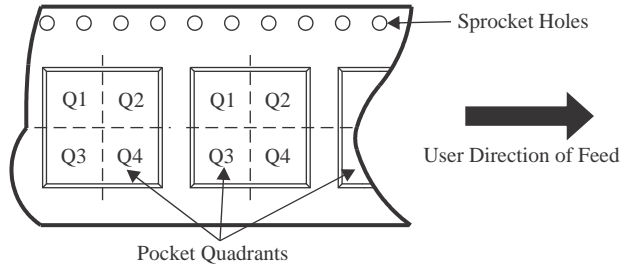
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TAPE AND REEL INFORMATION



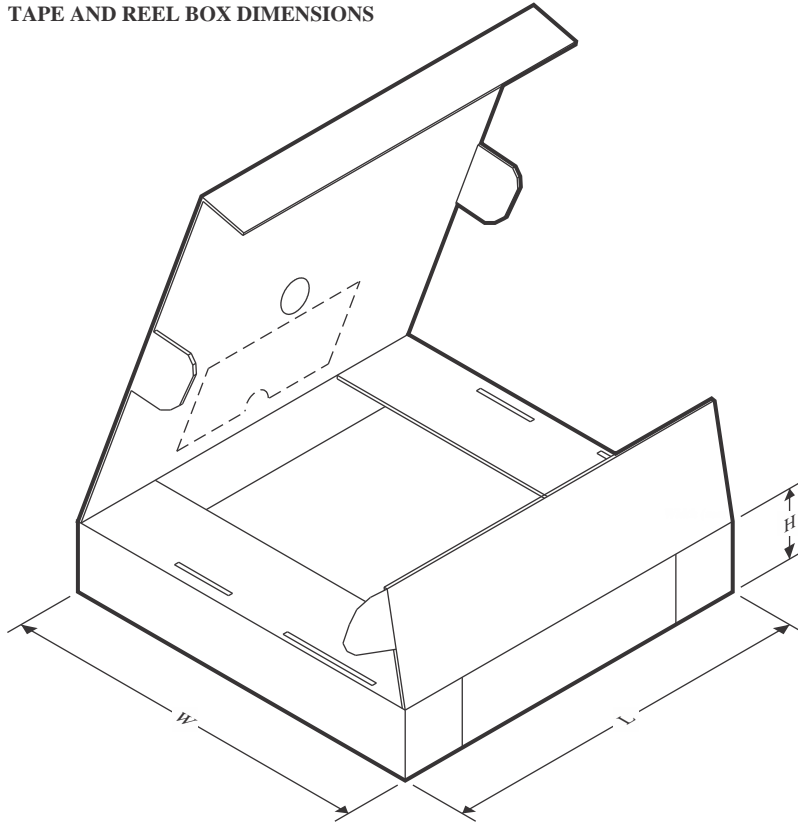
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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 |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ24450DWTR | SOIC | DW | 16 | 2000 | 330.0 | 16.4 | 10.75 | 10.7 | 2.7 | 12.0 | 16.0 | Q1 |

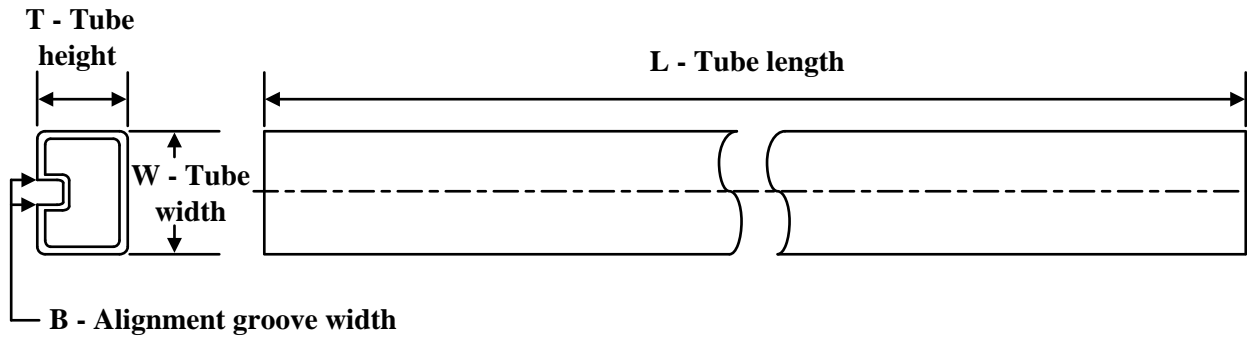
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ24450DWTR | SOIC | DW | 16 | 2000 | 353.0 | 353.0 | 32.0 |

TUBE



*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| BQ24450DW | DW | SOIC | 16 | 40 | 507 | 12.83 | 5080 | 6.6 |
| BQ24450DW.A | DW | SOIC | 16 | 40 | 507 | 12.83 | 5080 | 6.6 |

GENERIC PACKAGE VIEW

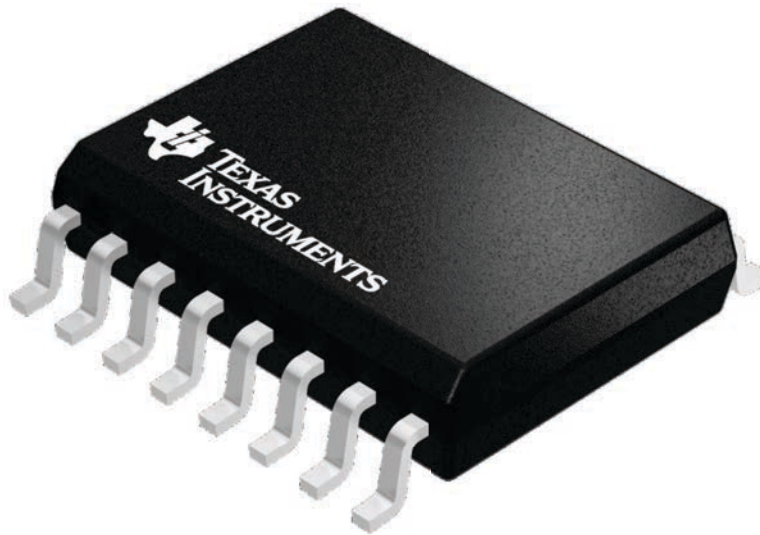
DW 16

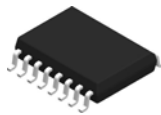
SOIC - 2.65 mm max height

7.5 x 10.3, 1.27 mm pitch

SMALL OUTLINE INTEGRATED CIRCUIT

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



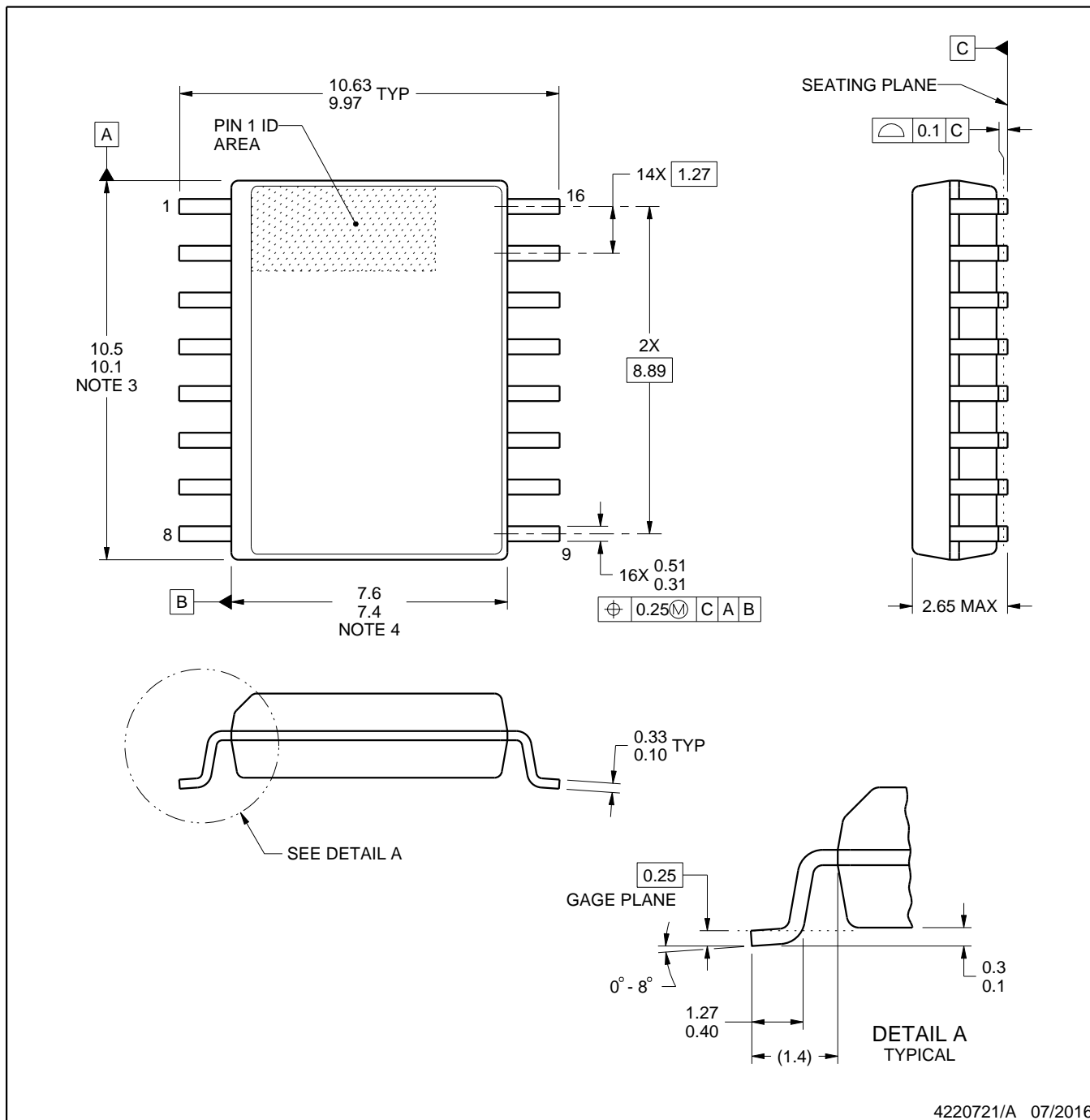


PACKAGE OUTLINE

DW0016A

SOIC - 2.65 mm max height

SOIC



4220721/A 07/2016

NOTES:

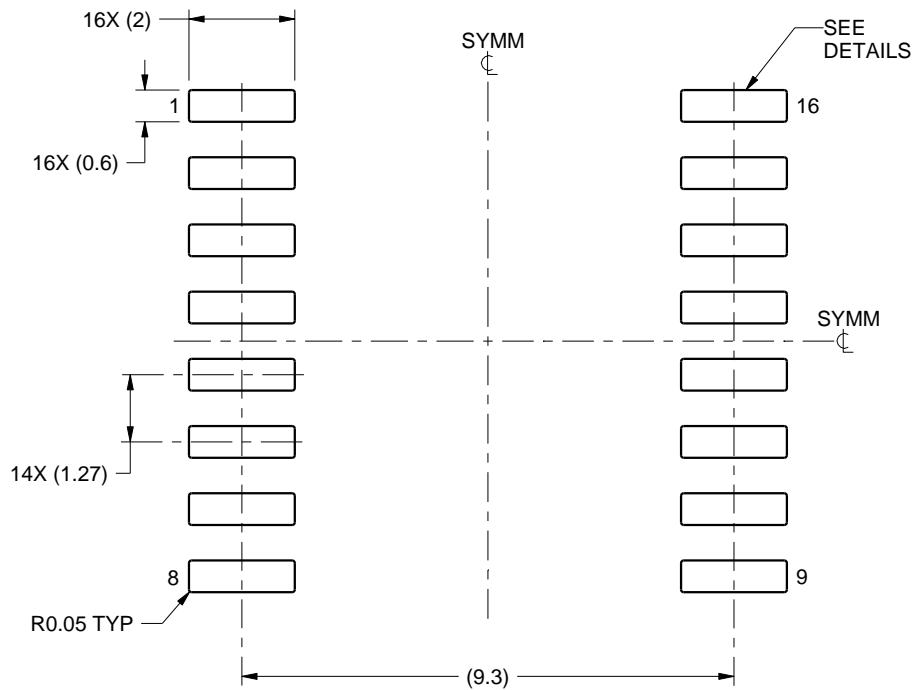
1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate 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 MS-013.

EXAMPLE BOARD LAYOUT

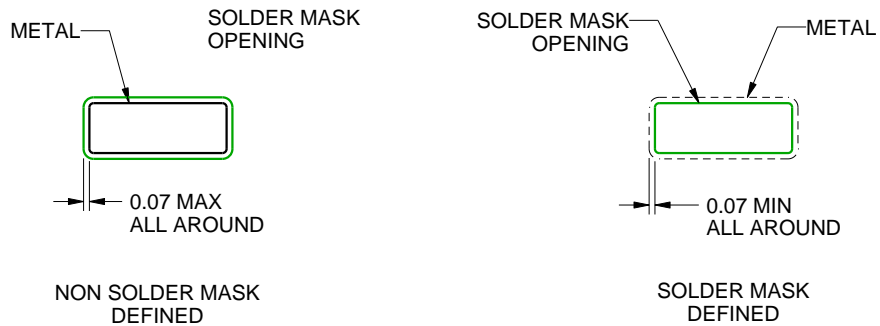
DW0016A

SOIC - 2.65 mm max height

SOIC



LAND PATTERN EXAMPLE
SCALE:7X



SOLDER MASK DETAILS

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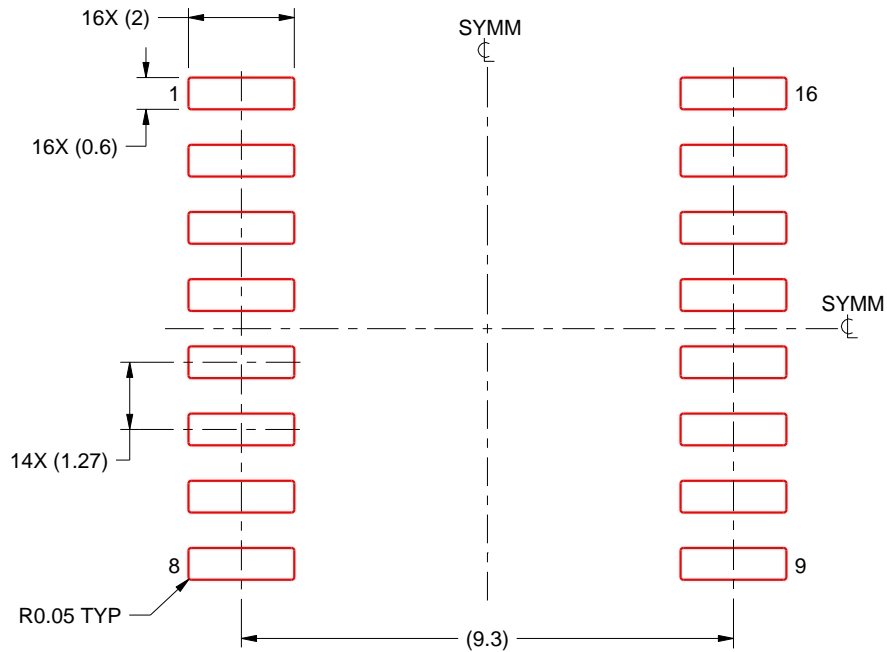
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN**DW0016A****SOIC - 2.65 mm max height**

SOIC



SOLDER PASTE EXAMPLE
 BASED ON 0.125 mm THICK STENCIL
 SCALE:7X

4220721/A 07/2016

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.

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