

SBS 1.1-COMPLIANT GAS GAUGE AND PROTECTION ENABLED WITH IMPEDANCE TRACK™

Check for Samples: [bq20z655](#)

FEATURES

- **Next Generation Patented Impedance Track™ Technology Accurately Measures Available Charge in Li-Ion and Li-Polymer Batteries**
 - Better Than 1% Error Over the Lifetime of the Battery
- **Supports the Smart Battery Specification SBS V1.1**
- **Flexible Configuration for 2-Series to 4-Series Li-Ion and Li-Polymer Cells**
- **Powerful 8-Bit RISC CPU with Ultralow Power Modes**
- **Charge Enable (CE) Affects the Normal Operation on the Charge FET when the Battery Is in Charge/Relax Mode**
- **Full Array of Programmable Protection Features**
 - Voltage, Current, and Temperature
- **Satisfies JEITA Guidelines**
- **Added Flexibility to Handle More Complex Charging Profiles**
- **Lifetime Data Logging**
- **Drives 3, 4, or 5 Segment Liquid Crystal Display and LED for Battery-Pack Conditions**
- **Supports SHA-1 Authentication**
- **Complete Battery Protection and Gas Gauge Solution in One Package**
- **Available in a 44-Pin TSSOP (DBT) Package**

APPLICATIONS

- **Medical and Test Equipment**
- **Portable Instrumentation**
- **Rechargeable Battery Packs**
- **Industrial Equipment**

DESCRIPTION

The bq20z655 SBS-compliant gas gauge and protection IC, incorporating patented Impedance Track™ technology, is a single IC solution designed for battery-pack or in-system installation. The bq20z655 measures and maintains an accurate record of available charge in Li-Ion or Li-Polymer batteries using its integrated high-performance analog peripherals. The bq20z655 monitors capacity change, battery impedance, open-circuit voltage, and other critical parameters of the battery pack which reports the information to the system host controller over a serial-communication bus. Together with the integrated analog front-end (AFE) short-circuit and overload protection, the bq20z655 maximizes functionality and safety while minimizing external component count, cost, and size in smart battery circuits.

The implemented Impedance Track™ gas gauging technology continuously analyzes the battery impedance, resulting in superior gas-gauging accuracy. This enables remaining capacity to be calculated with discharge rate, temperature, and cell aging all accounted for during each stage of every cycle with high accuracy.

Table 1. AVAILABLE OPTIONS

| T _A | PACKAGE ⁽¹⁾ | |
|----------------|----------------------------|----------------------------------|
| | 44-PIN TSSOP (DBT) Tube | 44-PIN TSSOP (DBT) Tape and Reel |
| –40°C to 85°C | bq20z655DBT ⁽²⁾ | bq20z655DBTR ⁽³⁾ |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

(2) A single tube quantity is 40 units.

(3) A single reel quantity is 2000 units.



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.

Impedance Track is a trademark of Texas Instruments.



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

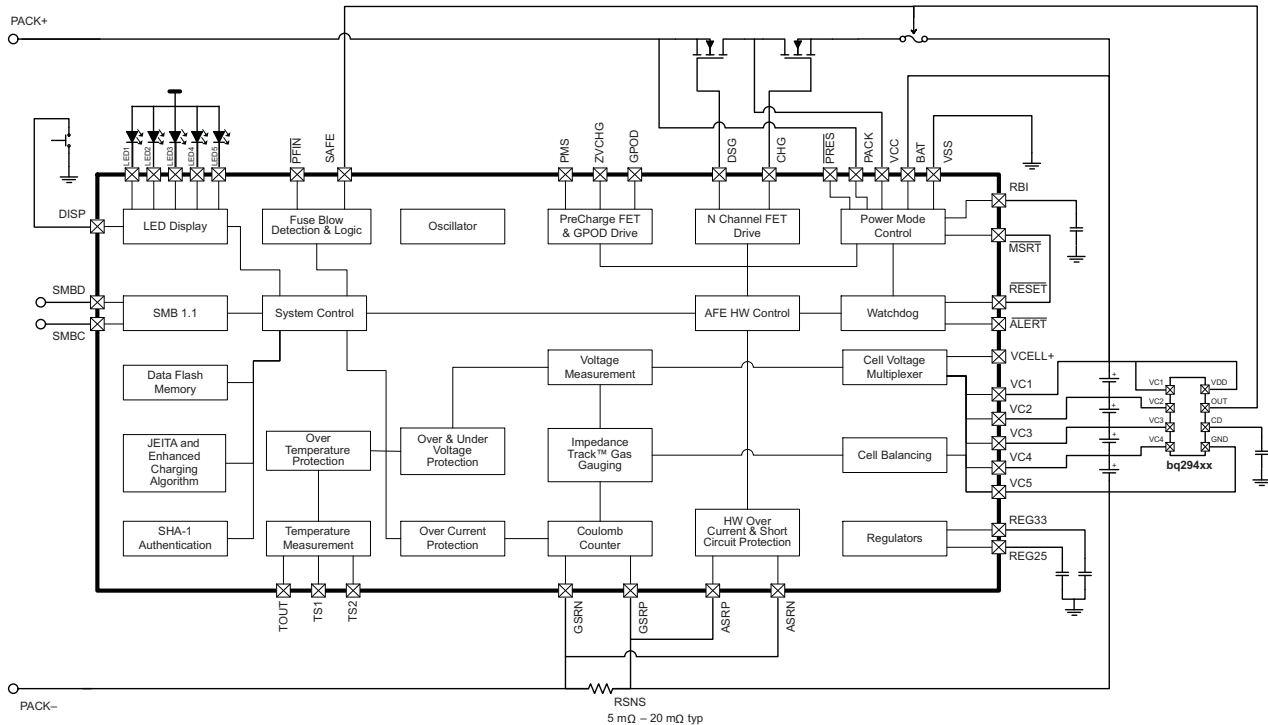
PACKAGE THERMAL DATA

THERMAL INFORMATION

| THERMAL METRIC ⁽¹⁾ | | bq20z655 | |
|-------------------------------|-------------------------------------------------------------|----------|-------|
| | | TSSOP | |
| | | 44 PINS | |
| | | | UNITS |
| θ_{JA} , High K | Junction-to-ambient thermal resistance ⁽²⁾ | 60.9 | °C/W |
| $\theta_{JC(top)}$ | Junction-to-case(top) thermal resistance ⁽³⁾ | 15.3 | |
| θ_{JB} | Junction-to-board thermal resistance ⁽⁴⁾ | 30.2 | |
| ψ_{JT} | Junction-to-top characterization parameter ⁽⁵⁾ | 0.3 | |
| ψ_{JB} | Junction-to-board characterization parameter ⁽⁶⁾ | 27.2 | |
| $\theta_{JC(bottom)}$ | Junction-to-case(bottom) thermal resistance ⁽⁷⁾ | n/a | |

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) The junction-to-ambient thermal resistance under natural convection is obtained in a simulation on a JEDEC-standard, high-K board, as specified in JESD51-7, in an environment described in JESD51-2a.
- (3) The junction-to-case (top) thermal resistance is obtained by simulating a cold plate test on the package top. No specific JEDEC-standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.
- (4) The junction-to-board thermal resistance is obtained by simulating in an environment with a ring cold plate fixture to control the PCB temperature, as described in JESD51-8.
- (5) The junction-to-top characterization parameter, ψ_{JT} , estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining θ_{JA} , using a procedure described in JESD51-2a (sections 6 and 7).
- (6) The junction-to-board characterization parameter, ψ_{JB} , estimates the junction temperature of a device in a real system and is extracted from the simulation data for obtaining θ_{JA} , using a procedure described in JESD51-2a (sections 6 and 7).
- (7) The junction-to-case (bottom) thermal resistance is obtained by simulating a cold plate test on the exposed (power) pad. No specific JEDEC standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.

SYSTEM PARTITIONING DIAGRAM



PACKAGE PINOUT DIAGRAM

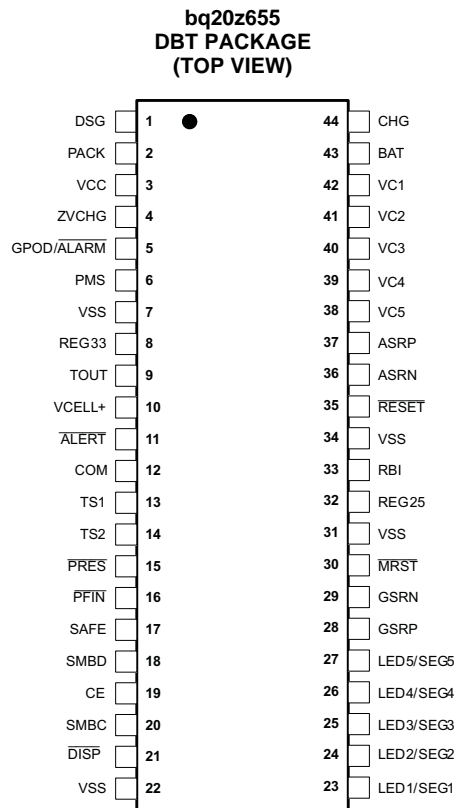


Figure 1. Package Pinout

TYPICAL LCD IMPLEMENTATION

Figure 2 shows a typical LCD implementation.

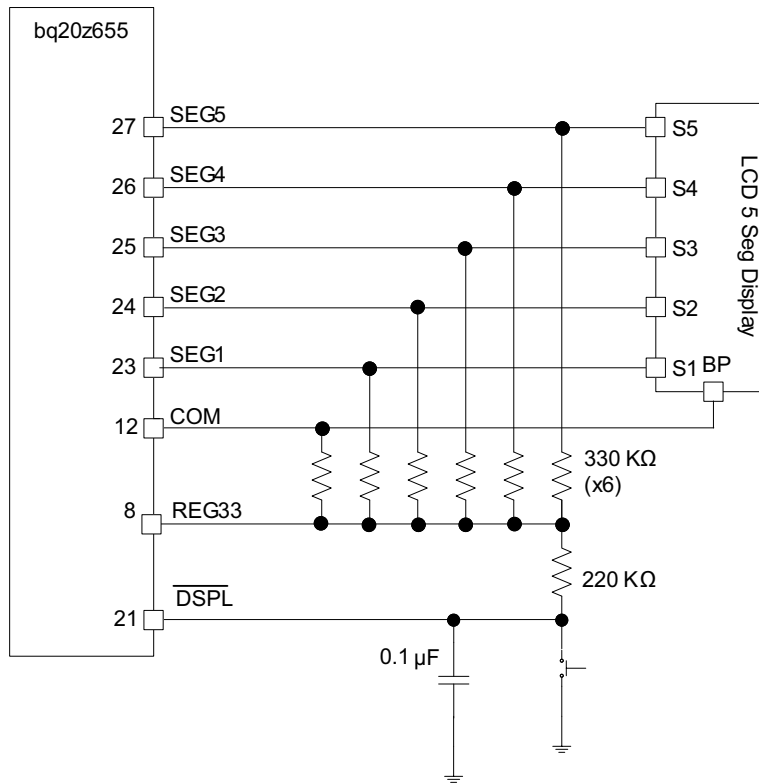


Figure 2. Typical LCD Implementation

TERMINAL FUNCTIONS

| TERMINAL | | I/O ⁽¹⁾ | DESCRIPTION |
|----------|---------------------------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NO. | NAME | | |
| 1 | DSG | O | High side N-chan discharge FET gate drive |
| 2 | PACK | IA, P | Battery pack input voltage sense input. It also serves as device wake up when device is in shutdown mode. |
| 3 | VCC | P | Positive device supply input. Connect to the center connection of the CHG FET and DSG FET to ensure device supply either from battery stack or battery pack input. |
| 4 | ZVCHG | O | P-chan pre-charge FET gate drive |
| 5 | GPOD | OD | High voltage general purpose open drain output. It can be configured to be used in pre-charge condition. |
| 6 | PMS | I | Pre-charge mode setting input. Connect to PACK to enable 0v pre-charge using charge FET connected at CHG pin. Connect to VSS to disable 0-V pre-charge using charge FET connected at CHG pin. |
| 7 | VSS | P | Negative supply voltage input. Connect all VSS pins together for operation of device. |
| 8 | REG33 | P | 3.3-V regulator output. Connect at least a 2.2- μ F capacitor to REG33 and VSS. |
| 9 | TOUT | P | Thermistor bias supply output |
| 10 | VCELL+ | — | Internal cell voltage multiplexer and amplifier output. Connect a 0.1- μ F capacitor to VCELL+ and VSS. |
| 11 | $\overline{\text{ALERT}}$ | OD | Alert output. In case of short circuit condition, overload condition, and watchdog time out, this pin will be triggered. |
| 12 | COM/TP | — | Output/open drain: LCD common connection |
| 13 | TS1 | IA | 1 st Thermistor voltage input connection to monitor temperature |
| 14 | TS2 | IA | 2 nd Thermistor voltage input connection to monitor temperature |
| 15 | $\overline{\text{PRES}}$ | I | Active low input to sense system insertion. Typically requires additional ESD protection. |
| 16 | $\overline{\text{PFIN}}$ | I | Active low input to detect secondary protector status, and to allow the bq20z655 to report the status of the 2 nd level protection input |
| 17 | SAFE | OD | Active high output to enforce additional level of safety protection; e.g., fuse blow |
| 18 | SMBD | I/OD | SMBus data open-drain bidirectional pin used to transfer address and data to and from the bq20z655 |
| 19 | CE | — | A logical high on this pin only affects the normal operation on the charge FET when the battery is in charge/relax mode. For a logic low, the normal bq20z655 firmware controls the charge FET. |
| 20 | SMBC | I/OD | SMBus clock open-drain bidirectional pin used to clock the data transfer to and from the bq20z655 |
| 21 | $\overline{\text{DISP}}$ | I | Input: In LED mode, this is the display enable input. |
| 22 | VSS | P | Negative supply voltage input. Connect all VSS pins together for operation of device. |
| 23 | LED1/SEG1 | I | Output/open drain: LED 1 current sink. LCD segment 1 |
| 24 | LED2/SEG2 | I | Output/open drain: LED 2 current sink. LCD segment 2 |
| 25 | LED3/SEG3 | I | Output/open drain: LED 3 current sink. LCD segment 3 |
| 26 | LED4/SEG4 | I | Output/open drain: LED 4 current sink. LCD segment 4 |
| 27 | LED5/SEG5 | I | Output/open drain: LED 5 current sink. LCD segment 5 |
| 28 | GSRP | IA | Coulomb counter differential input. Connect to one side of the sense resistor. |
| 29 | GSRN | IA | Coulomb counter differential input. Connect to one side of the sense resistor. |
| 30 | $\overline{\text{MRST}}$ | I | Master reset input that forces the device into reset when held low. Must be held high for normal operation. Connect to $\overline{\text{RESET}}$ for correct operation of device. |
| 31 | VSS | P | Negative supply voltage input. Connect all VSS pins together for operation of device. |
| 32 | REG25 | P | 2.5-V regulator output. Connect at least a 1-mF capacitor to REG25 and VSS. |
| 33 | RBI | P | RAM / Register backup input. Connect a capacitor to this pin and VSS to protect loss of RAM/Register data in case of short circuit condition. |
| 34 | VSS | P | Negative supply voltage input. Connect all VSS pins together for operation of device. |
| 35 | $\overline{\text{RESET}}$ | O | Reset output. Connect to $\overline{\text{MRST}}$. |
| 36 | ASRN | IA | Short circuit and overload detection differential input. Connect to sense resistor. |
| 37 | ASRP | IA | Short circuit and overload detection differential input. Connect to sense resistor. |

(1) I = Input, IA = Analog input, I/O = Input/output, I/OD = Input/Open-drain output, O = Output, OA = Analog output, P = Power

TERMINAL FUNCTIONS (continued)

| TERMINAL | | I/O ⁽¹⁾ | DESCRIPTION |
|----------|------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NO. | NAME | | |
| 38 | VC5 | IA, P | Cell voltage sense input and cell balancing input for the negative voltage of the bottom cell in cell stack. |
| 39 | VC4 | IA, P | Cell voltage sense input and cell balancing input for the positive voltage of the bottom cell and the negative voltage of the second lowest cell in cell stack. |
| 40 | VC3 | IA, P | Cell voltage sense input and cell balancing input for the positive voltage of the second lowest cell in cell stack and the negative voltage of the second highest cell in 4-cell applications. |
| 41 | VC2 | IA, P | Cell voltage sense input and cell balancing input for the positive voltage of the second highest cell and the negative voltage of the highest cell in 4 cell applications. Connect to VC3 in 2-cell stack applications. |
| 42 | VC1 | IA, P | Cell voltage sense input and cell balancing input for the positive voltage of the highest cell in cell stack in 4 cell applications. Connect to VC2 in 2- or 3-stack applications. |
| 43 | BAT | I, P | Battery stack voltage sense input |
| 44 | CHG | O | High side N-channel charge FET gate drive |

ABSOLUTE MAXIMUM RATINGSOver operating free-air temperature (unless otherwise noted) ⁽¹⁾

| | PIN | UNIT |
|-------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------|
| V_{SS} Supply voltage range | BAT, VCC | -0.3 V to 34 V |
| | PACK, PMS | -0.3 V to 34 V |
| | $VC(n) - VC(n+1)$; n = 1, 2, 3, 4 | -0.3 V to 8.5 V |
| | VC1, VC2, VC3, VC4 | -0.3 V to 34 V |
| | VC5 | -0.3 V to 1 V |
| V_{IN} Input voltage range | \overline{PFIN} , SMBD, SMBC, LED1, LED2, LED3, LED4, LED5, DISP | -0.3 V to 6 V |
| | TS1, TS2, SAFE, VCELL+, \overline{PRES} , \overline{ALERT} | -0.3 V to $V_{(REG25)} + 0.3$ V |
| | \overline{MRST} , GSRN, GSRP, RBI | -0.3 V to $V_{(REG25)} + 0.3$ V |
| | ASRN, ASRP | -1 V to 1 V |
| V_{OUT} Output voltage range | DSG, CHG, GPOD | -0.3 V to 34 V |
| | ZVCHG | -0.3 V to $V_{(BAT)}$ |
| | TOUT, \overline{ALERT} , REG33 | -0.3 V to 6 V |
| | \overline{RESET} | -0.3 V to 7 V |
| | REG25 | -0.3 V to 2.75 V |
| I_{SS} Maximum combined sink current for input pins | \overline{PRES} , \overline{PFIN} , SMBD, SMBC, LED1, LED2, LED3, LED4, LED5 | 50 mA |
| T_A Operating free-air temperature range | | -40°C to 85°C |
| T_F Functional temperature | | -40°C to 100°C |
| T_{stg} Storage temperature range | | -65°C to 150°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.

RECOMMENDED OPERATING CONDITIONS

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

| | PIN | MIN | NOM | MAX | UNIT |
|-----------------------------------------|----------------|-----|-----|-----|------|
| V_{SS} Supply voltage | VCC, BAT | 4.5 | | 25 | V |
| $V_{(STARTUP)}$ Minimum startup voltage | VCC, BAT, PACK | 5.5 | | | V |

RECOMMENDED OPERATING CONDITIONS (continued)

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

| | | PIN | MIN | NOM | MAX | UNIT |
|----------------|------------------------------------------|------------------------------|------|-----|----------|------------|
| V_{IN} | Input voltage range | VC(n) – VC(n+1); n = 1,2,3,4 | 0 | | 5 | V |
| | | VC1, VC2, VC3, VC4 | 0 | | V_{SS} | V |
| | | VC5 | 0 | | 0.5 | V |
| | | ASRN, ASRP | -0.5 | | 0.5 | V |
| | | PACK, PMS | 0 | | 25 | V |
| $V_{(GPOD)}$ | Output voltage range | GPOD | 0 | | 25 | V |
| $I_{(GPOD)}$ | Drain current ⁽¹⁾ | GPOD | | | 1 | mA |
| $C_{(REG25)}$ | 2.5V LDO capacitor | REG25 | 1 | | | μ F |
| $C_{(REG33)}$ | 3.3V LDO capacitor | REG33 | 2.2 | | | μ F |
| $C_{(VCELL+)}$ | Cell voltage output capacitor | VCELL+ | 0.1 | | | μ F |
| $R_{(PACK)}$ | PACK input block resistor ⁽²⁾ | PACK | 1 | | | k Ω |

(1) Use an external resistor to limit the current to GPOD to 1 mA in high voltage application.

(2) Use an external resistor to limit the inrush current PACK pin required.

ELECTRICAL CHARACTERISTICS

 Over operating free-air temperature range (unless otherwise noted), $T_A = -40^\circ\text{C}$ to 85°C , $V_{(REG25)} = 2.41\text{ V}$ to 2.59 V , $V_{(BAT)} = 14\text{ V}$, $C_{(REG25)} = 1\ \mu\text{F}$, $C_{(REG33)} = 2.2\ \mu\text{F}$; typical values at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|------|-----------|---------------------|----|
| SUPPLY CURRENT | | | | | | |
| $I_{(NORMAL)}$ | Firmware running | | 550 | | μ A | |
| $I_{(SLEEP)}$ | Sleep mode | CHG FET on; DSG FET on | | 124 | μ A | |
| | | CHG FET off; DSG FET on | | 90 | μ A | |
| | | CHG FET off; DSG FET off | | 52 | μ A | |
| $I_{(SHUTDOWN)}$ | Shutdown mode | | 0.1 | 1 | μ A | |
| SHUTDOWN WAKE; $T_A = 25^\circ\text{C}$ (unless otherwise noted) | | | | | | |
| $I_{(PACK)}$ | Shutdown exit at $V_{STARTUP}$ threshold | | | 1 | μ A | |
| SRx WAKE FROM SLEEP; $T_A = 25^\circ\text{C}$ (unless otherwise noted) | | | | | | |
| $V_{(WAKE)}$ | Positive or negative wake threshold with 1.00 mV, 2.25 mV, 4.5 mV and 9 mV programmable options | 1.25 | | 10 | mV | |
| $V_{(WAKE_ACR)}$ | Accuracy of $V_{(WAKE)}$ | $V_{(WAKE)} = 1\text{ mV};$ $I_{(WAKE)} = 0, RSNS1 = 0, RSNS0 = 1$ | -0.7 | | 0.7 | mV |
| | | $V_{(WAKE)} = 2.25\text{ mV};$ $I_{(WAKE)} = 1, RSNS1 = 0, RSNS0 = 1;$ $I_{(WAKE)} = 0, RSNS1 = 1, RSNS0 = 0$ | -0.8 | | 0.8 | |
| | | $V_{(WAKE)} = 4.5\text{ mV};$ $I_{(WAKE)} = 1, RSNS1 = 1, RSNS0 = 1;$ $I_{(WAKE)} = 0, RSNS1 = 1, RSNS0 = 0$ | -1.0 | | 1.0 | |
| | | $V_{(WAKE)} = 9\text{ mV};$ $I_{(WAKE)} = 1, RSNS1 = 1, RSNS0 = 1$ | -1.4 | | 1.4 | |
| $V_{(WAKE_TCO)}$ | Temperature drift of $V_{(WAKE)}$ accuracy | | 0.5 | | %/ $^\circ\text{C}$ | |
| $t_{(WAKE)}$ | Time from application of current and wake of bq20z655 | | 1 | 10 | ms | |
| WATCHDOG TIMER | | | | | | |
| t_{WDTINT} | Watchdog start up detect time | 250 | 500 | 1000 | ms | |
| t_{WDWT} | Watchdog detect time | 50 | 100 | 150 | μ s | |
| 2.5V LDO; $I_{(REG33OUT)} = 0\text{ mA}; T_A = 25^\circ\text{C}$ (unless otherwise noted) | | | | | | |
| $V_{(REG25)}$ | Regulator output voltage | 4.5 < VCC or BAT < 25 V; $I_{(REG25OUT)} \leq 16\text{ mA};$ $T_A = -40^\circ\text{C}$ to 100°C | 2.41 | 2.5 | 2.59 | V |
| $\Delta V_{(REG25STEM)}$ | Regulator output change with temperature | $I_{(REG25OUT)} = 2\text{ mA};$ $T_A = -40^\circ\text{C}$ to 100°C | | ± 0.2 | | % |
| $\Delta V_{(REG25LINE)}$ | Line regulation | 5.4 < VCC or BAT < 25 V; $I_{(REG25OUT)} = 2\text{ mA}$ | | 3 | 10 | mV |

ELECTRICAL CHARACTERISTICS (continued)

Over operating free-air temperature range (unless otherwise noted), $T_A = -40^\circ\text{C}$ to 85°C , $V_{(\text{REG25})} = 2.41\text{ V}$ to 2.59 V , $V_{(\text{BAT})} = 14\text{ V}$, $C_{(\text{REG25})} = 1\ \mu\text{F}$, $C_{(\text{REG33})} = 2.2\ \mu\text{F}$; typical values at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|------------------------|------------------------------------|---------------|
| $\Delta V_{(\text{REG25LOA D})}$ | Load regulation | $0.2\text{ mA} \leq I_{(\text{REG25OUT})} \leq 2\text{ mA}$ | | 7 | 25 | mV |
| | | $0.2\text{ mA} \leq I_{(\text{REG25OUT})} \leq 16\text{ mA}$ | | 25 | 50 | |
| $I_{(\text{REG25MAX})}$ | Current limit | drawing current until REG25 = 2 V to 0 V | 5 | 40 | 75 | mA |
| 3.3V LDO; $I_{(\text{REG25OUT})} = 0\text{ mA}$; $T_A = 25^\circ\text{C}$ (unless otherwise noted) | | | | | | |
| $V_{(\text{REG33})}$ | Regulator output voltage | $4.5 < \text{VCC or BAT} < 25\text{ V}$; $I_{(\text{REG33OUT})} \leq 25\text{ mA}$; $T_A = -40^\circ\text{C}$ to 100°C | 3 | 3.3 | 3.6 | V |
| $\Delta V_{(\text{REG33TEM P})}$ | Regulator output change with temperature | $I_{(\text{REG33OUT})} = 2\text{ mA}$; $T_A = -40^\circ\text{C}$ to 100°C | | ± 0.2 | | % |
| $\Delta V_{(\text{REG33LINE})}$ | Line regulation | $5.4 < \text{VCC or BAT} < 25\text{ V}$; $I_{(\text{REG33OUT})} = 2\text{ mA}$ | | 3 | 10 | mV |
| $\Delta V_{(\text{REG33LOA D})}$ | Load regulation | $0.2\text{ mA} \leq I_{(\text{REG33OUT})} \leq 2\text{ mA}$ | | 7 | 17 | mV |
| | | $0.2\text{ mA} \leq I_{(\text{REG33OUT})} \leq 25\text{ mA}$ | | 40 | 100 | |
| $I_{(\text{REG33MAX})}$ | Current limit | drawing current until REG33 = 3 V | 25 | 100 | 145 | mA |
| | | short REG33 to VSS, REG33 = 0 V | 12 | | 65 | |
| THERMISTOR DRIVE | | | | | | |
| $V_{(\text{TOUT})}$ | Output voltage | $I_{(\text{TOUT})} = 0\text{ mA}$; $T_A = 25^\circ\text{C}$ | | $V_{(\text{REG25})}$ | | V |
| $R_{\text{DS(on)}}$ | TOUT pass element resistance | $I_{(\text{TOUT})} = 1\text{ mA}$; $R_{\text{DS(on)}} = (V_{(\text{REG25})} - V_{(\text{TOUT})}) / 1\text{ mA}$; $T_A = -40^\circ\text{C}$ to 100°C | | 50 | 100 | Ω |
| LED OUTPUTS | | | | | | |
| V_{OL} | Output low voltage | LED1, LED2, LED3, LED4, LED5 | | | 0.4 | V |
| VCELL+ HIGH VOLTAGE TRANSLATION | | | | | | |
| $V_{(\text{VCELL+OUT})}$ | Translation output | $\text{VC}(n) - \text{VC}(n+1) = 0\text{ V}$; $T_A = -40^\circ\text{C}$ to 100°C | 0.950 | 0.975 | 1 | V |
| | | $\text{VC}(n) - \text{VC}(n+1) = 4.5\text{ V}$; $T_A = -40^\circ\text{C}$ to 100°C | 0.275 | 0.3 | 0.375 | |
| $V_{(\text{VCELL+REF})}$ | Translation output | internal AFE reference voltage ; $T_A = -40^\circ\text{C}$ to 100°C | 0.965 | 0.975 | 0.985 | V |
| $V_{(\text{VCELL+PACK})}$ | | Voltage at PACK pin; $T_A = -40^\circ\text{C}$ to 100°C | $0.98 \times V_{(\text{PACK})}/18$ | $V_{(\text{PACK})}/18$ | $1.02 \times V_{(\text{PACK})}/18$ | |
| $V_{(\text{VCELL+BAT})}$ | | Voltage at BAT pin; $T_A = -40^\circ\text{C}$ to 100°C | $0.98 \times V_{(\text{BAT})}/18$ | $V_{(\text{BAT})}/18$ | $1.02 \times V_{(\text{BAT})}/18$ | |
| CMMR | Common mode rejection ratio | VCELL+ | 40 | | | dB |
| K | Cell scale factor | $K = \{\text{VCELL+ output (VC5=0 V; VC4=4.5 V)} - \text{VCELL+ output (VC5=0 V; VC4=0 V)}\}/4.5$ | 0.147 | 0.150 | 0.153 | |
| | | $K = \{\text{VCELL+ output (VC2=13.5 V; VC1=18 V)} - \text{VCELL+ output (VC5=13.5 V; VC1=13.5 V)}\}/4.5$ | 0.147 | 0.150 | 0.153 | |
| $I_{(\text{VCELL+OUT})}$ | Drive Current to VCELL+ capacitor | $\text{VC}(n) - \text{VC}(n+1) = 0\text{ V}$; $\text{VCELL+} = 0\text{ V}$; $T_A = -40^\circ\text{C}$ to 100°C | 12 | 18 | | μA |
| $V_{(\text{VCELL+O})}$ | CELL offset error | CELL output (VC2 = VC1 = 18 V) - CELL output (VC2 = VC1 = 0 V) | -18 | -1 | 18 | mV |
| I_{VcnL} | VC(n) pin leakage current | VC1, VC2, VC3, VC4, VC5 = 3 V | -1 | 0.01 | 1 | μA |
| CELL BALANCING | | | | | | |
| R_{BAL} | internal cell balancing FET resistance | $R_{\text{DS(on)}}$ for internal FET switch at $V_{\text{DS}} = 2\text{ V}$; $T_A = 25^\circ\text{C}$ | 200 | 400 | 600 | Ω |
| HARDWARE SHORT CIRCUIT AND OVERLOAD PROTECTION; $T_A = 25^\circ\text{C}$ (unless otherwise noted) | | | | | | |
| $V_{(\text{OL})}$ | OL detection threshold voltage accuracy | $V_{\text{OL}} = 25\text{ mV}$ (min) | 15 | 25 | 35 | mV |
| | | $V_{\text{OL}} = 100\text{ mV}$; $\text{RSNS} = 0, 1$ | 90 | 100 | 110 | |
| | | $V_{\text{OL}} = 205\text{ mV}$ (max) | 185 | 205 | 225 | |
| $V_{(\text{SCC})}$ | SCC detection threshold voltage accuracy | $V_{(\text{SCC})} = 50\text{ mV}$ (min) | 30 | 50 | 70 | mV |
| | | $V_{(\text{SCC})} = 200\text{ mV}$; $\text{RSNS} = 0, 1$ | 180 | 200 | 220 | |
| | | $V_{(\text{SCC})} = 475\text{ mV}$ (max) | 428 | 475 | 523 | |

ELECTRICAL CHARACTERISTICS (continued)

Over operating free-air temperature range (unless otherwise noted), $T_A = -40^\circ\text{C}$ to 85°C , $V_{(\text{REG25})} = 2.41\text{ V}$ to 2.59 V , $V_{(\text{BAT})} = 14\text{ V}$, $C_{(\text{REG25})} = 1\text{ }\mu\text{F}$, $C_{(\text{REG33})} = 2.2\text{ }\mu\text{F}$; typical values at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------|-------------|------------------------------|
| $V_{(\text{SCD})}$ | SCD detection threshold voltage accuracy | $V_{(\text{SCD})} = -50\text{ mV (min)}$ | -30 | -50 | -70 | mV |
| | | $V_{(\text{SCD})} = -200\text{ mV}$; $\text{RSNS} = 0, 1$ | -180 | -200 | -220 | |
| | | $V_{(\text{SCD})} = -475\text{ mV (max)}$ | -428 | -475 | -523 | |
| t_{da} | Delay time accuracy | | ± 15.25 | | | μs |
| t_{pd} | Protection circuit propagation delay | | 50 | | | μs |
| FET DRIVE CIRCUIT; $T_A = 25^\circ\text{C}$ (unless otherwise noted) | | | | | | |
| $V_{(\text{DSGON})}$ | DSG pin output on voltage | $V_{(\text{DSGON})} = V_{(\text{DSG})} - V_{(\text{PACK})}$; $V_{(\text{GS})} = 10\text{ M}\Omega$; DSG and CHG on; $T_A = -40^\circ\text{C}$ to 100°C | 8 | 12 | 16 | V |
| $V_{(\text{CHGON})}$ | CHG pin output on voltage | $V_{(\text{CHGON})} = V_{(\text{CHG})} - V_{(\text{BAT})}$; $V_{(\text{GS})} = 10\text{ M}\Omega$; DSG and CHG on; $T_A = -40^\circ\text{C}$ to 100°C | 8 | 12 | 16 | V |
| $V_{(\text{DSGOFF})}$ | DSG pin output off voltage | $V_{(\text{DSGOFF})} = V_{(\text{DSG})} - V_{(\text{PACK})}$ | | | 0.2 | V |
| $V_{(\text{CHGOFF})}$ | CHG pin output off voltage | $V_{(\text{CHGOFF})} = V_{(\text{CHG})} - V_{(\text{BAT})}$ | | | 0.2 | V |
| t_r | Rise time | $C_i = 4700\text{ pF}$ $V_{(\text{CHG})}: V_{(\text{PACK})} \geq V_{(\text{PACK})} + 4\text{ V}$ $V_{(\text{DSG})}: V_{(\text{BAT})} \geq V_{(\text{BAT})} + 4\text{ V}$ | | 400 | 1000 | μs |
| | | | | 400 | 1000 | |
| t_f | Fall time | $C_i = 4700\text{ pF}$ $V_{(\text{CHG})}: V_{(\text{PACK})} + V_{(\text{CHGON})} \geq V_{(\text{PACK})} + 1\text{ V}$ $V_{(\text{DSG})}: V_{\text{C1}} + V_{(\text{DSGON})} \geq V_{\text{C1}} + 1\text{ V}$ | | 40 | 200 | μs |
| | | | | 40 | 200 | |
| $V_{(\text{ZVCHG})}$ | ZVCHG clamp voltage | BAT = 4.5 V | 3.3 | 3.5 | 3.7 | V |
| LOGIC; $T_A = -40^\circ\text{C}$ to 100°C (unless otherwise noted) | | | | | | |
| $R_{(\text{PULLUP})}$ | Internal pullup resistance | $\overline{\text{ALERT}}$ | 60 | 100 | 200 | k Ω |
| | | RESET | 1 | 3 | 6 | |
| V_{OL} | Logic low output voltage level | $\overline{\text{ALERT}}$ | | | 0.2 | V |
| | | RESET; $V_{(\text{BAT})} = 7\text{ V}$; $V_{(\text{REG25})} = 1.5\text{ V}$; $I_{(\text{RESET})} = 200\text{ }\mu\text{A}$ | | | 0.4 | |
| | | GPOD; $I_{(\text{GPOD})} = 50\text{ }\mu\text{A}$ | | | 0.6 | |
| LOGIC SMBC, SMBD, $\overline{\text{PFIN}}$, $\overline{\text{PRES}}$, SAFE, ALERT, $\overline{\text{DISP}}$ | | | | | | |
| V_{IH} | High-level input voltage | | 2.0 | | | V |
| V_{IL} | Low-level input voltage | | | | 0.8 | V |
| V_{OH} | Output voltage high ⁽¹⁾ | $I_L = -0.5\text{ mA}$ | $V_{\text{REG25}} - 0.5$ | | | V |
| V_{OL} | Low-level output voltage | $\overline{\text{PRES}}$, $\overline{\text{PFIN}}$, $\overline{\text{ALERT}}$, $\overline{\text{DISP}}$; $I_L = 7\text{ mA}$ | | | 0.4 | V |
| C_i | Input capacitance | | | 5 | | pF |
| $I_{(\text{SAFE})}$ | SAFE source currents | SAFE active, $\text{SAFE} = V_{(\text{REG25})} - 0.6\text{ V}$ | -3 | | | mA |
| $I_{\text{ikg}(\text{SAFE})}$ | SAFE leakage current | SAFE inactive | -0.2 | | 0.2 | μA |
| I_{ikg} | Input leakage current | | | | 1 | μA |
| ADC⁽²⁾ | | | | | | |
| | Input voltage range | TS1, TS2, using Internal V_{ref} | -0.2 | | 1 | V |
| | Conversion time | | | 31.5 | | ms |
| | Resolution (no missing codes) | | 16 | | | bits |
| | Effective resolution | | 14 | 15 | | bits |
| | Integral nonlinearity | | | | ± 0.03 | %FSR ⁽³⁾ |
| | Offset error ⁽⁴⁾ | | | 140 | 250 | μV |
| | Offset error drift ⁽⁴⁾ | $T_A = 25^\circ\text{C}$ to 85°C | | 2.5 | 18 | $\mu\text{V}/^\circ\text{C}$ |
| | Full-scale error ⁽⁵⁾ | | | $\pm 0.1\%$ | $\pm 0.7\%$ | |
| | Full-scale error drift | | | 50 | | PPM/ $^\circ\text{C}$ |

(1) RC[0:7] bus

(2) Unless otherwise specified, the specification limits are valid at all measurement speed modes.

(3) Full-scale reference

(4) Post-calibration performance and no I/O changes during conversion with SRN as the ground reference.

(5) Uncalibrated performance. This gain error can be eliminated with external calibration.

ELECTRICAL CHARACTERISTICS (continued)

Over operating free-air temperature range (unless otherwise noted), $T_A = -40^\circ\text{C}$ to 85°C , $V_{(\text{REG25})} = 2.41\text{ V}$ to 2.59 V , $V_{(\text{BAT})} = 14\text{ V}$, $C_{(\text{REG25})} = 1\ \mu\text{F}$, $C_{(\text{REG33})} = 2.2\ \mu\text{F}$; typical values at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------------------------------------------------------|------------------------------------------------|-------|--------|--------|--------|
| Effective input resistance ⁽⁶⁾ | | 8 | | | MΩ |
| COULOMB COUNTER | | | | | |
| Input voltage range | | -0.20 | | 0.20 | V |
| Conversion time | Single conversion | | 250 | | ms |
| Effective resolution | Single conversion | 15 | | | bits |
| Integral nonlinearity | -0.1 V to 0.20 V | | ±0.007 | ±0.034 | %FSR |
| | -0.20 V to -0.1 V | | ±0.007 | | |
| Offset error ⁽⁷⁾ | $T_A = 25^\circ\text{C}$ to 85°C | | 10 | | μV |
| Offset error drift | | | 0.4 | 0.7 | μV/°C |
| Full-scale error ⁽⁸⁾ ⁽⁹⁾ | | | ±0.35% | | |
| Full-scale error drift | | | 150 | | PPM/°C |
| Effective input resistance ⁽¹⁰⁾ | $T_A = 25^\circ\text{C}$ to 85°C | 2.5 | | | MΩ |
| INTERNAL TEMPERATURE SENSOR | | | | | |
| $V_{(\text{TEMP})}$ Temperature sensor voltage ⁽¹¹⁾ | | | -2.0 | | mV/°C |
| VOLTAGE REFERENCE | | | | | |
| Output voltage | | 1.215 | 1.225 | 1.230 | V |
| Output voltage drift | | | 65 | | PPM/°C |
| HIGH FREQUENCY OSCILLATOR | | | | | |
| $f_{(\text{OSC})}$ Operating frequency | | | 4.194 | | MHz |
| $f_{(\text{EIO})}$ Frequency error ⁽¹²⁾ ⁽¹³⁾ | | -3% | 0.25% | 3% | |
| | $T_A = 20^\circ\text{C}$ to 70°C | -2% | 0.25% | 2% | |
| $t_{(\text{SXO})}$ Start-up time ⁽¹⁴⁾ | | | 2.5 | 5 | ms |
| LOW FREQUENCY OSCILLATOR | | | | | |
| $f_{(\text{LOSC})}$ Operating frequency | | | 32.768 | | kHz |
| $f_{(\text{LEIO})}$ Frequency error ⁽¹⁵⁾ ⁽¹⁶⁾ | | -2.5% | 0.25% | 2.5% | |
| | $T_A = 20^\circ\text{C}$ to 70°C | -1.5% | 0.25% | 1.5% | |
| $t_{(\text{LSXO})}$ Start-up time ⁽¹⁴⁾ | | | | 500 | μs |

(6) The A/D input is a switched-capacitor input. Since the input is switched, the effective input resistance is a measure of the average resistance.

(7) Post-calibration performance

(8) Reference voltage for the coulomb counter is typically $V_{\text{ref}}/3.969$ at $V_{(\text{REG25})} = 2.5\text{ V}$, $T_A = 25^\circ\text{C}$.

(9) Uncalibrated performance. This gain error can be eliminated with external calibration.

(10) The CC input is a switched capacitor input. Since the input is switched, the effective input resistance is a measure of the average resistance.

(11) $-53.7\text{ LSB}/^\circ\text{C}$

(12) The frequency error is measured from 4.194 MHz.

(13) The frequency drift is included and measured from the trimmed frequency at $V_{(\text{REG25})} = 2.5\text{ V}$, $T_A = 25^\circ\text{C}$.

(14) The startup time is defined as the time it takes for the oscillator output frequency to be $\pm 3\%$.

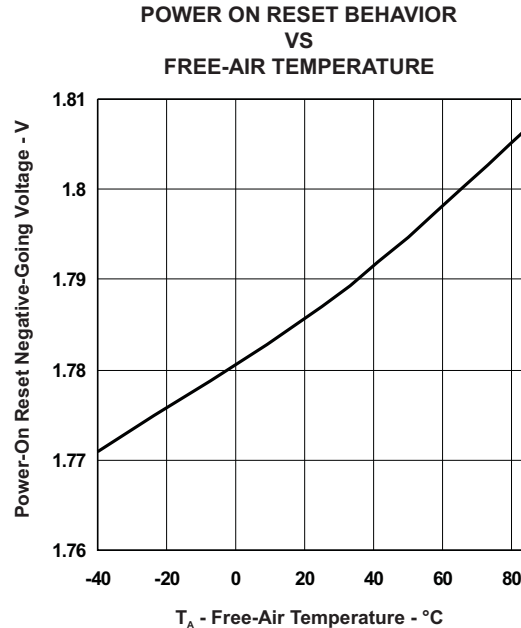
(15) The frequency drift is included and measured from the trimmed frequency at $V_{(\text{REG25})} = 2.5\text{ V}$, $T_A = 25^\circ\text{C}$.

(16) The frequency error is measured from 32.768 kHz.

POWER-ON RESET

Over operating free-air temperature range (unless otherwise noted), $T_A = -40^\circ\text{C}$ to 85°C , $V_{(\text{REG25})} = 2.41\text{ V}$ to 2.59 V , $V_{(\text{BAT})} = 14\text{ V}$, $C_{(\text{REG25})} = 1\ \mu\text{F}$, $C_{(\text{REG33})} = 2.2\ \mu\text{F}$; typical values at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------------------------|--------------------------------------------------|-----|-----|-----|---------------|
| VIT- Negative-going voltage input | | 1.7 | 1.8 | 1.9 | V |
| VHYS Power-on reset hysteresis | | 5 | 125 | 200 | mV |
| t_{RST} RESET active low time | Active low time after power up or watchdog reset | 100 | 250 | 560 | μs |



DATA FLASH CHARACTERISTICS OVER RECOMMENDED OPERATING TEMPERATURE AND SUPPLY VOLTAGE

Typical values at $T_A = 25^\circ\text{C}$ and $V_{(\text{REG25})} = 2.5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|-----|------|------|--------|
| Data retention | | 10 | | | Years |
| Flash programming write-cycles | | 20k | | | Cycles |
| $t_{(\text{ROWPROG})}$ Row programming time | See (1) | | 2 | | ms |
| $t_{(\text{MASSERASE})}$ Mass-erase time | | | 200 | | ms |
| $t_{(\text{PAGEERASE})}$ Page-erase time | | | 20 | | ms |
| $I_{(\text{DDPROG})}$ Flash-write supply current | | | 5 | 10 | mA |
| $I_{(\text{DDERASE})}$ Flash-erase supply current | | | 5 | 10 | mA |
| RAM/REGISTER BACKUP | | | | | |
| $I_{(\text{RB})}$ RB data-retention input current | $V_{(\text{RB})} > V_{(\text{RB})\text{MIN}}$, $V_{\text{REG25}} < V_{\text{IT-}}$, $T_A = 85^\circ\text{C}$ | | 1000 | 2500 | nA |
| | $V_{(\text{RB})} > V_{(\text{RB})\text{MIN}}$, $V_{\text{REG25}} < V_{\text{IT-}}$, $T_A = 25^\circ\text{C}$ | | 90 | 220 | |
| $V_{(\text{RB})}$ RB data-retention input voltage ⁽¹⁾ | | 1.7 | | | V |

(1) Specified by design. Not production tested.

SMBus TIMING CHARACTERISTICS

$T_A = -40^\circ\text{C}$ to 85°C Typical Values at $T_A = 25^\circ\text{C}$ and $V_{\text{REG25}} = 2.5\text{ V}$ (Unless Otherwise Noted)

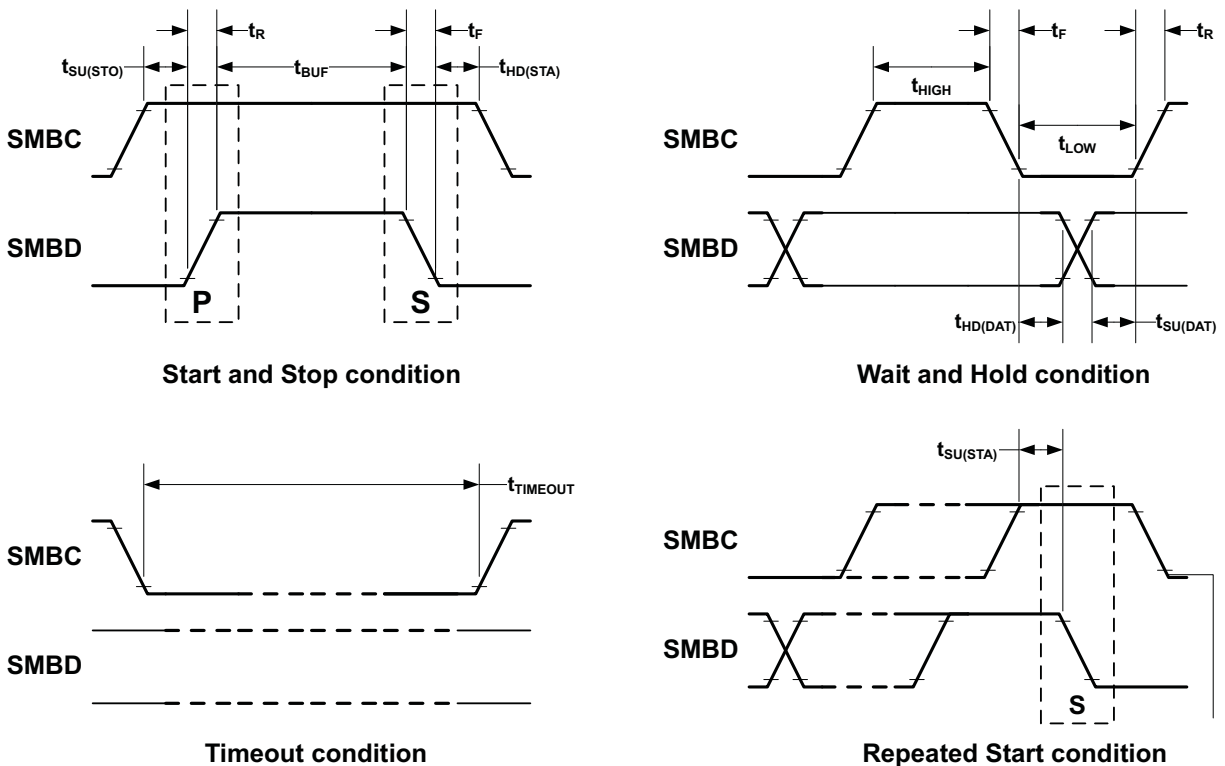
| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------------------------------|----------------------------------------|-----|------|-----|------|
| $f_{(\text{SMB})}$ SMBus operating frequency | Slave mode, SMBC 50% duty cycle | 10 | | 100 | kHz |
| $f_{(\text{MAS})}$ SMBus master clock frequency | Master mode, No clock low slave extend | | 51.2 | | kHz |

SMBus TIMING CHARACTERISTICS (continued)

$T_A = -40^{\circ}\text{C}$ to 85°C Typical Values at $T_A = 25^{\circ}\text{C}$ and $V_{\text{REG}25} = 2.5\text{ V}$ (Unless Otherwise Noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------|--------------------------------------------------------|-----------------|-----|-----|------|---------------|
| $t_{\text{(BUF)}}$ | Bus free time between start and stop (see Figure 3) | | 4.7 | | | μs |
| $t_{\text{(HD:STA)}}$ | Hold time after (repeated) start (see Figure 3) | | 4 | | | μs |
| $t_{\text{(SU:STA)}}$ | Repeated start setup time (see Figure 3) | | 4.7 | | | μs |
| $t_{\text{(SU:STO)}}$ | Stop setup time (see Figure 3) | | 4 | | | μs |
| $t_{\text{(HD:DAT)}}$ | Data hold time (see Figure 3) | Receive mode | 0 | | | ns |
| | | Transmit mode | 300 | | | |
| $t_{\text{(SU:DAT)}}$ | Data setup time (see Figure 3) | | 250 | | | ns |
| $t_{\text{(TIMEOUT)}}$ | Error signal/detect (see Figure 3) | See (1) | 25 | | 35 | μs |
| $t_{\text{(LOW)}}$ | Clock low period (see Figure 3) | | 4.7 | | | μs |
| $t_{\text{(HIGH)}}$ | Clock high period (see Figure 3) | See (2) | 4 | | 50 | μs |
| $t_{\text{(LOW:SEXT)}}$ | Cumulative clock low slave extend time | See (3) | | | 25 | ms |
| $t_{\text{(LOW:MEXT)}}$ | Cumulative clock low master extend time (see Figure 3) | See (4) | | | 10 | ms |
| t_f | Clock/data fall time | See (5) | | | 300 | ns |
| t_r | Clock/data rise time | See (6) | | | 1000 | ns |

- (1) The bq20z655 times out when any clock low exceeds $t_{\text{(TIMEOUT)}}$.
- (2) $t_{\text{(HIGH)}}$, Max, is the minimum bus idle time. $\text{SMBC} = \text{SMBD} = 1$ for $t > 50\text{ ms}$ causes reset of any transaction involving bq20z655 that is in progress. This specification is valid when the NC_SMB control bit remains in the default cleared state ($\text{CLK}[0]=0$).
- (3) $t_{\text{(LOW:SEXT)}}$ is the cumulative time a slave device is allowed to extend the clock cycles in one message from initial start to the stop.
- (4) $t_{\text{(LOW:MEXT)}}$ is the cumulative time a master device is allowed to extend the clock cycles in one message from initial start to the stop.
- (5) Rise time $t_r = \text{VILMAX} - 0.15$ to $(\text{VIHMIN} + 0.15)$
- (6) Fall time $t_f = 0.9 V_{\text{DD}}$ to $(\text{VILMAX} - 0.15)$



A. SCLKACK is the acknowledge-related clock pulse generated by the master.

Figure 3. SMBus Timing Diagram

FEATURE SET

Primary (1st Level) Safety Features

The bq20z655 supports a wide range of battery and system protection features that can easily be configured. The primary safety features include:

- Cell over/undervoltage protection
- Charge and discharge overcurrent
- Short Circuit protection
- Charge and discharge overtemperature with independent alarms and thresholds for each thermistor
- AFE Watchdog

Secondary (2nd Level) Safety Features

The secondary safety features of the bq20z655 can be used to indicate more serious faults via the SAFE pin. This pin can be used to blow an in-line fuse to permanently disable the battery pack from charging or discharging. The secondary safety protection features include:

- Safety overvoltage
- Safety undervoltage
- 2nd level protection IC input
- Safety overcurrent in charge and discharge
- Safety over-temperature in charge and discharge with independent alarms and thresholds for each thermistor
- Charge FET and zero-volt charge FET fault
- Discharge FET fault
- Cell imbalance detection (active and at rest)
- Open thermistor detection
- Fuse blow detection
- AFE communication fault

Charge Control Features

The bq20z655 charge control features include:

- Supports JEITA temperature ranges. Reports charging voltage and charging current according to the active temperature range
- Handles more complex charging profiles. Allows for splitting the standard temperature range into two sub-ranges and allows for varying the charging current according to the cell voltage
- Reports the appropriate charging current needed for constant current charging and the appropriate charging voltage needed for constant voltage charging to a smart charger using SMBus broadcasts
- Determines the chemical state of charge of each battery cell using Impedance Track and can reduce the charge difference of the battery cells in fully charged state of the battery pack gradually using cell balancing algorithm during charging. This prevents fully charged cells from overcharging and causing excessive degradation and also increases the usable pack energy by preventing premature charge termination.
- Supports pre-charging/zero-volt charging
- Supports charge inhibit and charge suspend if battery pack temperature is out of temperature range
- Reports charging fault and also indicate charge status via charge and discharge alarms

Gas Gauging

The bq20z655 uses the Impedance Track technology to measure and calculate the available charge in battery cells. The achievable accuracy is better than 1% error over the lifetime of the battery and there is no full charge discharge learning cycle required.

See the *Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm* application note ([SLUA364](#)) for further details.

Lifetime Data Logging Features

The bq20z655 offers lifetime data logging, where important measurements are stored for warranty and analysis purposes. The data monitored include:

- Lifetime maximum temperature
- Lifetime maximum temperature count
- Lifetime maximum temperature duration
- Lifetime minimum temperature
- Lifetime maximum battery cell voltage
- Lifetime maximum battery cell voltage count
- Lifetime maximum battery cell voltage duration
- Lifetime minimum battery cell voltage
- Lifetime maximum battery pack voltage
- Lifetime minimum battery pack voltage
- Lifetime maximum charge current
- Lifetime maximum discharge current
- Lifetime maximum charge power
- Lifetime maximum discharge power
- Lifetime maximum average discharge current
- Lifetime maximum average discharge power
- Lifetime average temperature

Authentication

The bq20z655 supports authentication by the host using SHA-1.

Power Modes

The bq20z655 supports three different power modes to reduce power consumption:

- In Normal Mode, the bq20z655 performs measurements, calculations, protection decisions and data updates in 1 second intervals. Between these intervals, the bq20z655 is in a reduced power stage.
- In Sleep Mode, the bq20z655 performs measurements, calculations, protection decisions and data update in adjustable time intervals. Between these intervals, the bq20z655 is in a reduced power stage. The bq20z655 has a wake function that enables exit from Sleep mode, when current flow or failure is detected.
- In Shutdown Mode, the bq20z655 is completely disabled.

CONFIGURATION

Oscillator Function

The bq20z655 fully integrates the system oscillators therefore, no external components are required for this feature.

System Present Operation

The bq20z655 periodically verifies the PRES pin and detects that the battery is present in the system via a low state on a PRES input. When this occurs, the bq20z655 enters normal operating mode. When the pack is removed from the system and the PRES input is high, the bq20z655 enters the battery-removed state, disabling the charge, discharge, and ZVCHG FETs. The PRES input is ignored and can be left floating when non-removal mode is set in the data flash.

BATTERY PARAMETER MEASUREMENTS

The bq20z655 uses an integrating delta-sigma analog-to-digital converter (ADC) for current measurement, and a second delta-sigma ADC for individual cell and battery voltage, and temperature measurement.

Charge and Discharge Counting

The integrating delta-sigma ADC measures the charge/discharge flow of the battery by measuring the voltage drop across a small-value sense resistor between the SR1 and SR2 pins. The integrating ADC measures bipolar signals from -0.25 V to 0.25 V. The bq20z655 detects charge activity when $V_{SR} = V_{(SRP)} - V_{(SRN)}$ is positive and discharge activity when $V_{SR} = V_{(SRP)} - V_{(SRN)}$ is negative. The bq20z655 continuously integrates the signal over time, using an internal counter. The fundamental rate of the counter is 0.65 nVh.

Voltage

The bq20z655 updates the individual series cell voltages at one second intervals. The internal ADC of the bq20z655 measures the voltage, scales and calibrates it appropriately. This data is also used to calculate the impedance of the cell for the Impedance Track gas-gauging.

Current

The bq20z655 uses the SRP and SRN inputs to measure and calculate the battery charge and discharge current using a 5-mΩ to 20-mΩ typ. sense resistor.

Wake Function

The bq20z655 can exit sleep mode, if enabled, by the presence of a programmable level of current signal across SRP and SRN.

Auto Calibration

The bq20z655 provides an auto-calibration feature to cancel the voltage offset error across SRN and SRP for maximum charge measurement accuracy. The bq20z655 performs auto-calibration when the SMBus lines stay low continuously for a minimum of a programmable amount of time.

Temperature

The bq20z655 has an internal temperature sensor and 2 external temperature sensor inputs, TS1 and TS2, used in conjunction with two identical NTC thermistors (default are Semitec 103AT) to sense the battery environmental temperature. The bq20z655 can be configured to use the internal temperature sensor or up to 2 external temperature sensors.

COMMUNICATIONS

The bq20z655 uses SMBus v1.1 with Master Mode and package error checking (PEC) options per the SBS specification.

SMBus On and Off State

The bq20z655 detects an SMBus off state when SMBC and SMBD are logic-low for ≥ 2 seconds. Clearing this state requires either SMBC or SMBD to transition high. Within 1 ms, the communication bus is available.

SBS Commands

Table 2. SBS COMMANDS

| SBS CMD | MODE | NAME | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------------------------|------------------|---------------|-----------|-------------|---------------|---------------|
| 0x00 | R/W | ManufacturerAccess | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x01 | R/W | RemainingCapacityAlarm | Integer | 2 | 0 | 700 or 1000 | 300 or 432 | mAh or 10 mWh |
| 0x02 | R/W | RemainingTimeAlarm | Unsigned integer | 2 | 0 | 30 | 10 | min |
| 0x03 | R/W | BatteryMode | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x04 | R/W | AtRate | Integer | 2 | -32,768 | 32,767 | — | mA or 10 mW |
| 0x05 | R | AtRateTimeToFull | Unsigned integer | 2 | 0 | 65,535 | — | min |
| 0x06 | R | AtRateTimeToEmpty | Unsigned integer | 2 | 0 | 65,535 | — | min |
| 0x07 | R | AtRateOK | Unsigned integer | 2 | 0 | 65,535 | — | — |
| 0x08 | R | Temperature | Unsigned integer | 2 | 0 | 65,535 | — | 0.1°K |
| 0x09 | R | Voltage | Unsigned integer | 2 | 0 | 20,000 | — | mV |
| 0x0a | R | Current | Integer | 2 | -32,768 | 32,767 | — | mA |
| 0x0b | R | AverageCurrent | Integer | 2 | -32,768 | 32,767 | — | mA |
| 0x0c | R | MaxError | Unsigned integer | 1 | 0 | 100 | — | % |
| 0x0d | R | RelativeStateOfCharge | Unsigned integer | 1 | 0 | 100 | — | % |
| 0x0e | R | AbsoluteStateOfCharge | Unsigned integer | 1 | 0 | 100+ | — | % |
| 0x0f | R/W | RemainingCapacity | Unsigned integer | 2 | 0 | 65,535 | — | mAh or 10 mWh |
| 0x10 | R | FullChargeCapacity | Unsigned integer | 2 | 0 | 65,535 | — | mAh or 10 mWh |
| 0x11 | R | RunTimeToEmpty | Unsigned integer | 2 | 0 | 65,534 | — | min |
| 0x12 | R | AverageTimeToEmpty | Unsigned integer | 2 | 0 | 65,534 | — | min |
| 0x13 | R | AverageTimeToFull | Unsigned integer | 2 | 0 | 65,534 | — | min |
| 0x14 | R | ChargingCurrent | Unsigned integer | 2 | 0 | 65,534 | — | mA |
| 0x15 | R | ChargingVoltage | Unsigned integer | 2 | 0 | 65,534 | — | mV |
| 0x16 | R | BatteryStatus | Hex | 2 | 0x0000 | 0xdbff | — | — |
| 0x17 | R/W | CycleCount | Unsigned integer | 2 | 0 | 65,535 | 0 | — |
| 0x18 | R/W | DesignCapacity | Integer | 2 | 0 | 32,767 | 4400 or 6336 | mAh or 10 mWh |
| 0x19 | R/W | DesignVoltage | Integer | 2 | 7000 | 18,000 | 14,400 | mV |

Table 2. SBS COMMANDS (continued)

| SBS CMD | MODE | NAME | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-------------------|------------------|---------------|-----------|-----------|-------------------|------|
| 0x1a | R/W | SpecificationInfo | Hex | 2 | 0x0000 | 0xffff | 0x0031 | — |
| 0x1b | R/W | ManufactureDate | Unsigned integer | 2 | 0 | 65,535 | 0 | — |
| 0x1c | R/W | SerialNumber | Hex | 2 | 0x0000 | 0xffff | 0x0000 | — |
| 0x20 | R/W | ManufacturerName | String | 20+1 | — | — | Texas Instruments | — |
| 0x21 | R/W | DeviceName | String | 20+1 | — | — | bq20z655 | — |
| 0x22 | R/W | DeviceChemistry | String | 4+1 | — | — | LION | — |
| 0x23 | R | ManufacturerData | String | 14+1 | — | — | — | — |
| 0x2f | R/W | Authenticate | String | 20+1 | — | — | — | — |
| 0x3c | R | CellVoltage4 | Unsigned integer | 2 | 0 | 65,535 | — | mV |
| 0x3d | R | CellVoltage3 | Unsigned integer | 2 | 0 | 65,535 | — | mV |
| 0x3e | R | CellVoltage2 | Unsigned integer | 2 | 0 | 65,535 | — | mV |
| 0x3f | R | CellVoltage1 | Unsigned integer | 2 | 0 | 65,535 | — | mV |

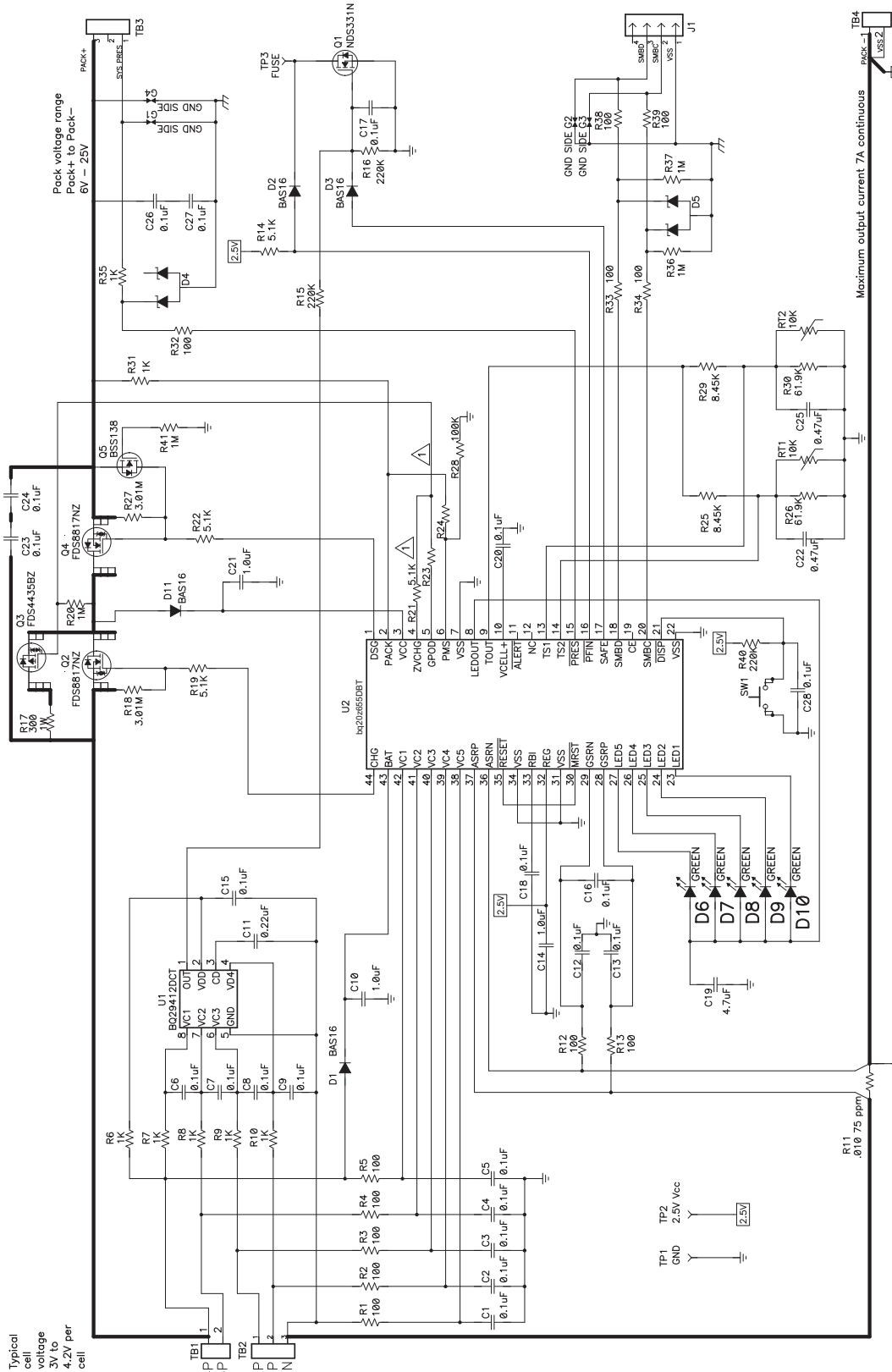
Table 3. EXTENDED SBS COMMANDS

| SBS CMD | MODE | NAME | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|-----------------|------------------|---------------|------------|------------|---------------|-------|
| 0x45 | R | AFEDData | String | 11+1 | — | — | — | — |
| 0x46 | R/W | FETControl | Hex | 2 | 0x00 | 0xff | — | — |
| 0x4f | R | StateOfHealth | Hex | 2 | 0x0000 | 0xffff | — | % |
| 0x51 | R | SafetyStatus | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x52 | R | PFAAlert | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x53 | R | PFStatus | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x54 | R | OperationStatus | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x55 | R | ChargingStatus | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x57 | R | ResetData | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x58 | R | WDRresetData | Unsigned integer | 2 | 0 | 65,535 | — | — |
| 0x5a | R | PackVoltage | Unsigned integer | 2 | 0 | 65,535 | — | mV |
| 0x5d | R | AverageVoltage | Unsigned integer | 2 | 0 | 65,535 | — | mV |
| 0x5e | R | TS1Temperature | Integer | 2 | -400 | 1200 | — | 0.1°C |
| 0x5f | R | TS2Temperature | Integer | 2 | -400 | 1200 | — | 0.1°C |
| 0x60 | R/W | UnSealKey | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x61 | R/W | FullAccessKey | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x62 | R/W | PFKey | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x63 | R/W | AuthenKey3 | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x64 | R/W | AuthenKey2 | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x65 | R/W | AuthenKey1 | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x66 | R/W | AuthenKey0 | Hex | 4 | 0x00000000 | 0xffffffff | — | — |
| 0x68 | R | SafetyAlert2 | Hex | 2 | 0x0000 | 0x000f | — | — |
| 0x69 | R | SafetyStatus2 | Hex | 2 | 0x0000 | 0x000f | — | — |
| 0x6a | R | PFAAlert2 | Hex | 2 | 0x0000 | 0x000f | — | — |
| 0x6b | R | PFStatus2 | Hex | 2 | 0x0000 | 0x000f | — | — |

Table 3. EXTENDED SBS COMMANDS (continued)

| SBS CMD | MODE | NAME | FORMAT | SIZE IN BYTES | MIN VALUE | MAX VALUE | DEFAULT VALUE | UNIT |
|---------|------|------------------------|------------------|---------------|-----------|-----------|---------------|-------------|
| 0x6c | R | ManufBlock1 | String | 20 | — | — | — | — |
| 0x6d | R | ManufBlock2 | String | 20 | — | — | — | — |
| 0x6e | R | ManufBlock3 | String | 20 | — | — | — | — |
| 0x6f | R | ManufBlock4 | String | 20 | — | — | — | — |
| 0x70 | R/W | ManufacturerInfo | String | 31+1 | — | — | — | — |
| 0x71 | R/W | SenseResistor | Unsigned integer | 2 | 0 | 65,535 | — | $\mu\Omega$ |
| 0x72 | R | TempRange | Hex | 2 | — | — | — | — |
| 0x73 | R | LifetimeData1 | String | 32+1 | — | — | — | — |
| 0x74 | R | LifetimeData2 | String | 8+1 | — | — | — | — |
| 0x77 | R/W | DataFlashSubClassID | Hex | 2 | 0x0000 | 0xffff | — | — |
| 0x78 | R/W | DataFlashSubClassPage1 | Hex | 32 | — | — | — | — |
| 0x79 | R/W | DataFlashSubClassPage2 | Hex | 32 | — | — | — | — |
| 0x7a | R/W | DataFlashSubClassPage3 | Hex | 32 | — | — | — | — |
| 0x7b | R/W | DataFlashSubClassPage4 | Hex | 32 | — | — | — | — |
| 0x7c | R/W | DataFlashSubClassPage5 | Hex | 32 | — | — | — | — |
| 0x7d | R/W | DataFlashSubClassPage6 | Hex | 32 | — | — | — | — |
| 0x7e | R/W | DataFlashSubClassPage7 | Hex | 32 | — | — | — | — |
| 0x7f | R/W | DataFlashSubClassPage8 | Hex | 32 | — | — | — | — |

APPLICATION SCHEMATIC



Typical cell voltage 3V to 4.2V per cell

▲ Install these parts for various pre-charge options. See bq20z655 EVM user guide. Default configuration has R23 & R24 NOT installed.

REVISION HISTORY

| Changes from Original (April 2011) to Revision A | Page |
|--------------------------------------------------|-------------------|
| • Changed Thermal Information | 2 |
| • Changed System Partitioning Diagram | 2 |

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 |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| BQ20Z655DBT | ACTIVE | TSSOP | DBT | 44 | 40 | Green (RoHS & no Sb/Br) | NIPDAU | Level-2-250C-1 YEAR | -40 to 85 | BQ20Z655 | Samples |
| BQ20Z655DBTR | ACTIVE | TSSOP | DBT | 44 | 2000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | BQ20Z655 | Samples |

(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.

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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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ20Z655DBTR | TSSOP | DBT | 44 | 2000 | 330.0 | 24.4 | 6.8 | 11.7 | 1.6 | 12.0 | 24.0 | Q1 |

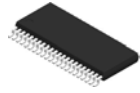
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ20Z655DBTR | TSSOP | DBT | 44 | 2000 | 350.0 | 350.0 | 43.0 |

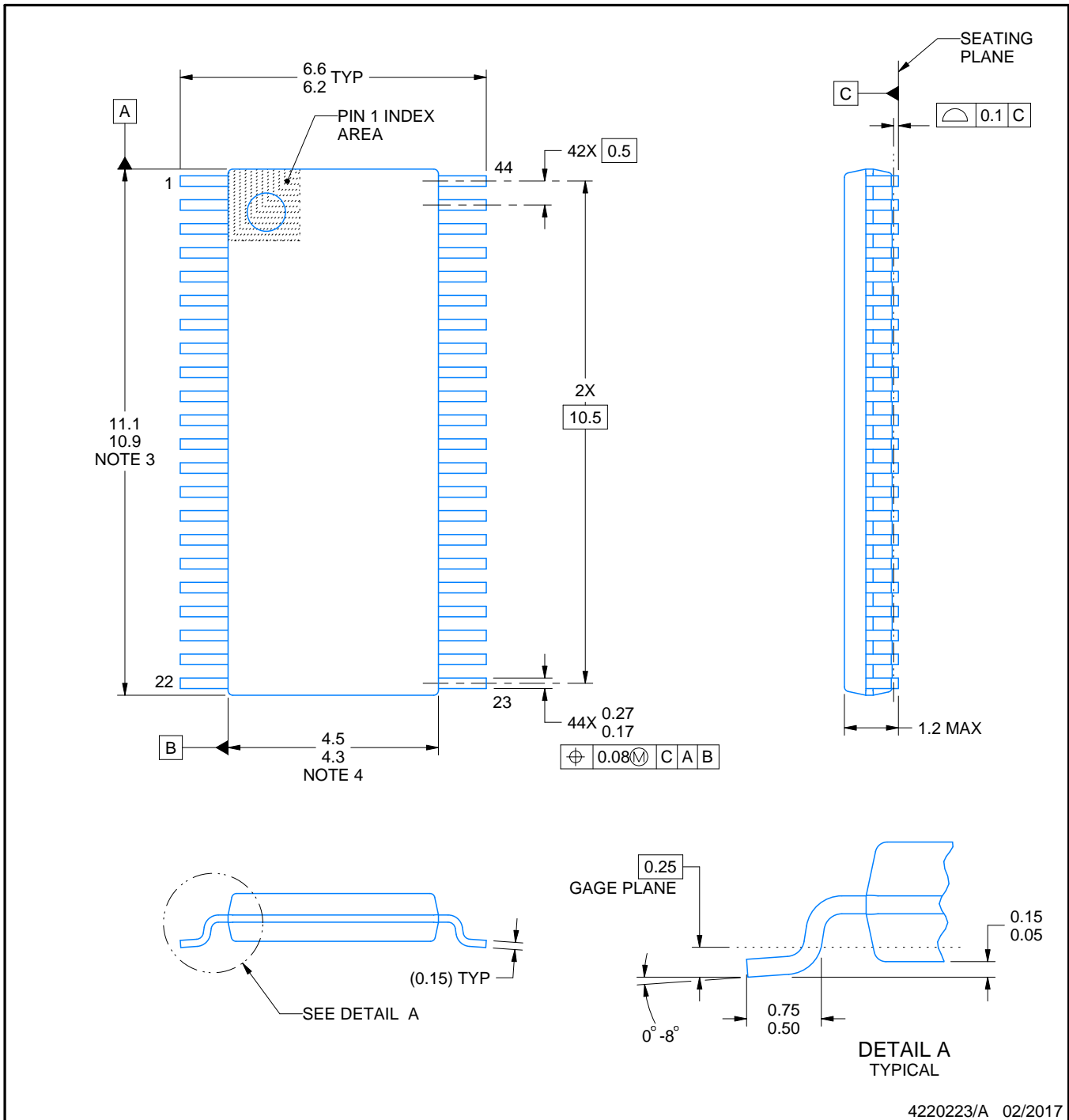
DBT0044A



PACKAGE OUTLINE

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



NOTES:

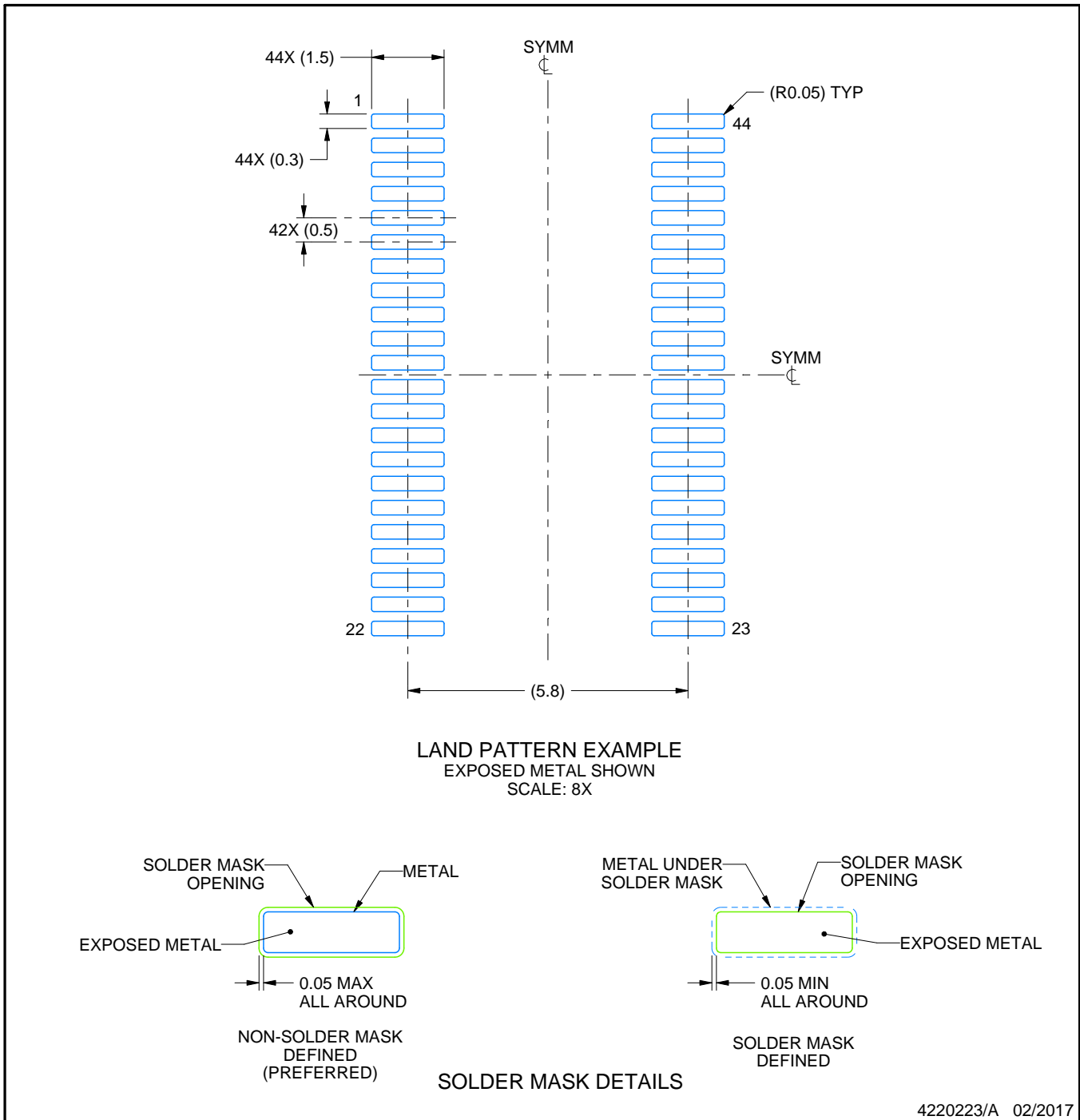
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or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

EXAMPLE BOARD LAYOUT

DBT0044A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



NOTES: (continued)

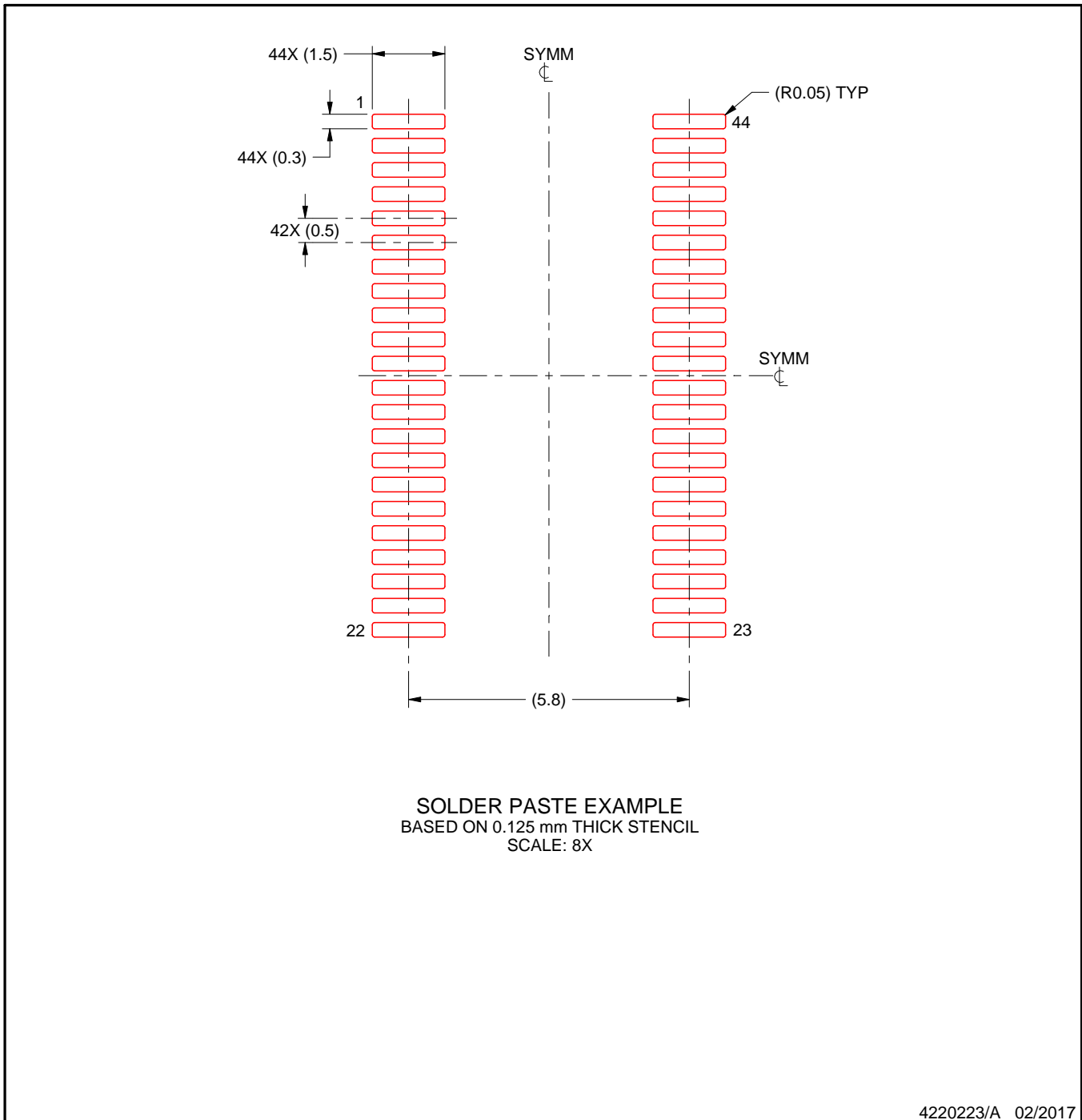
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBT0044A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



NOTES: (continued)

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

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