# OPTIGA™ TPM

## SLB 9645 TPM1.2

## Data Sheet

### Devices

- SLB 9645VQ1.2
- SLB 9645XQ1.2
- SLB 9645TT1.2
- SLB 9645XT1.2

### Key Features

- Compliant to TPM Main Specification, Version 1.2, Rev. 116 (see [1])
- I2C interface
- Approved for Google Chromebook / Chromebox
- Standard (-20°C to +85°C) and enhanced temperature range (-40°C to +85°C)
- PG-VQFN-32-13 or PG-TSSOP-28-2 package
- Optimized for battery operated devices: low standby power consumption (typ. 150µA)
- 24 PCRs
- 6 kByte free NV memory
- Up to 10 concurrent sessions
- Up to eight 2048-bit keys can be loaded into volatile storage
- 16 slots for keys of up to 2048-bit
- 8 monotonic counters
- 1280 Byte I/O buffer
- Built-in support by Linux Kernel

## About this document

### Scope and purpose

This data sheet describes the OPTIGA™ TPM SLB 9645 TPM1.2 Trusted Platform Module together with its features, functionality and programming interface.

### Intended audience

This data sheet is primarily intended for system developers.

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# 1 Overview

The OPTIGA™ TPM SLB 9645 is a Trusted Platform Module. It is available in different packages, see Table 1 below. It only supports the I2C interface and features a dedicated interrupt pin which increases performance (since no polling on the I2C bus is necessary). The I2C interface is compliant to both standard mode operation (up to 100 kHz) and fast mode operation (up to 400 kHz); for details regarding the characteristics in these modes, please refer to Section 4.6.

# 2 Device Types / Ordering Information

The OPTIGA™ TPM SLB 9645 product family features devices with different packages and different temperature ranges. Table 1 shows the available versions.

**Table 1 Device Types**

| Device Name | Package | Remarks |
|---|---|---|
| SLB 9645VQ1.2 | PG-VQFN-32-13 | Standard temperature range |
| SLB 9645XQ1.2 | PG-VQFN-32-13 | Enhanced temperature range |
| SLB 9645TT1.2 | PG-TSSOP-28-2 | Standard temperature range |
| SLB 9645XT1.2 | PG-TSSOP-28-2 | Enhanced temperature range |

# 3 Pin Description

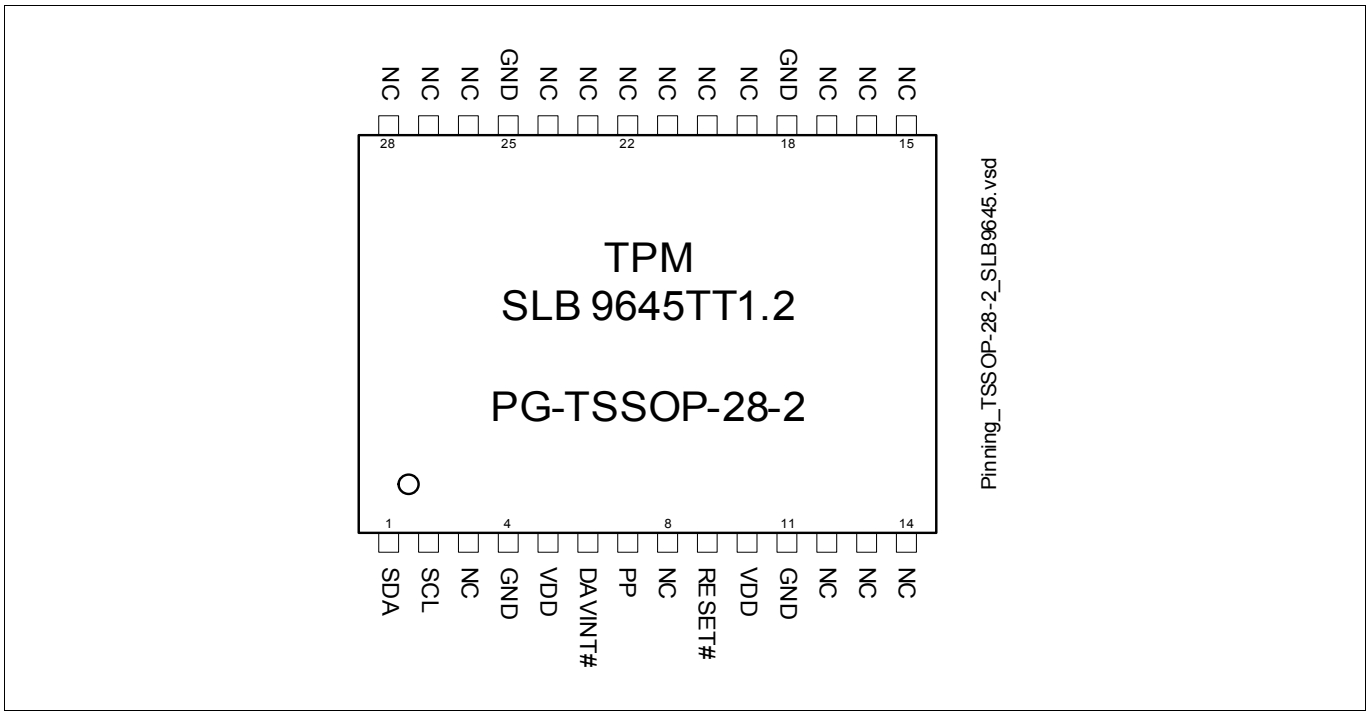


**Figure 1 Pinout of the SLB 9645TT1.2 / SLB 9645XT1.2 (PG-TSSOP-28-2 Package, Top View)**

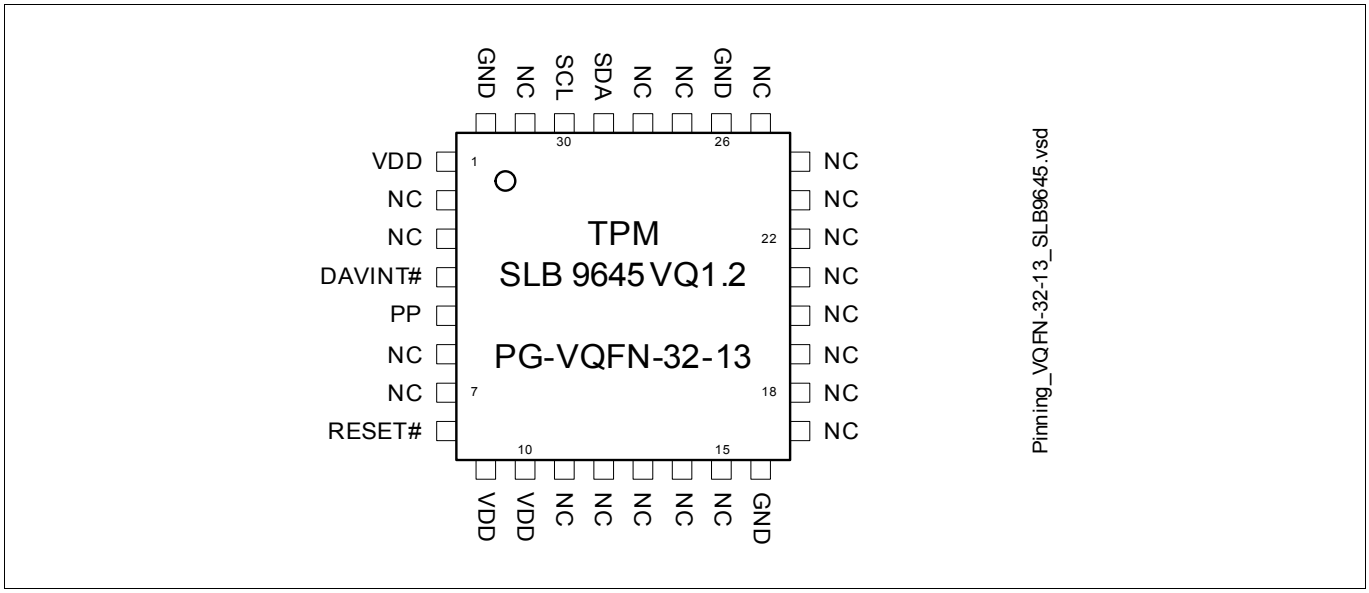


**Figure 2 Pinout of the SLB 9645VQ1.2 / SLB 9645XQ1.2 (PG-VQFN-32-13 Package, Top View)**

**Table 2 Buffer Types**

| Buffer Type | Description |
|---|---|
| TS | Tri-State pin |
| ST | Schmitt-Trigger pin |
| OD | Open-Drain pin |

**Table 3 I/O Signals**

| Pin Number | | Name | Pin Type | Buffer Type | Function |
|---|---|---|---|---|---|
| PG-TSSOP-28-2 | PG-VQFN-32-13 | | | | |
| 1 | 29 | SDA | I/O | OD | **I2C Bus Data Signal**<br>The data line of the I2C bus. |
| 2 | 30 | SCL | I/O | OD | **I2C Bus Clock Signal**<br>The clock signal of the I2C bus. |
| 9 | 8 | RESET# | I | ST | **Reset**<br>External reset signal. Asserting this pin unconditionally resets the device. The signal is active low. |

Table 3 I/O Signals (continued)

| Pin Number | | Name | Pin Type | Buffer Type | Function |
|---|---|---|---|---|---|
| PG-TSSOP-28-2 | PG-VQFN-32-13 | | | | |
| 6 | 4 | DAVINT# | I/O | ST | **Data Available Interrupt**<br>This pin can be connected to the host interrupt controller to allow interrupt driven reads of the response data instead of polling of the TPM_STS_x.dataAvail bit. The signal remains inactive (high) as long as TPM_STS_x.dataAvail is 0. As soon as a response is available, the signal is asserted (low) and remains active until the complete response is read by the host. |
| 7 | 5 | PP | I | ST | **Physical Presence**<br>This pin should be connected to a jumper. The standard position of the jumper should connect the pin to GND. If the pin is connected to VDD, some special commands are enabled (for instance, the command TPM_ForceClear, also refer to [1]).<br>This pin does not have an internal pull-up or pulldown resistor and must not be left floating if it is used for physical presence detection via hardware pin.<br>If physical presence detection via hardware pin is not used, this pin may be left unconnected; however, to minimize power consumption, it shall be connected to a fixed level (either GND or VDD). |

Table 4 Power Supply

| Pin Number | | Name | Pin Type | Buffer Type | Function |
|---|---|---|---|---|---|
| PG-TSSOP-28-2 | PG-VQFN-32-13 | | | | |
| 5, 10 | 1, 9, 10 | VDD | PWR | — | **Power Supply**<br>All VDD pins must be connected externally and should be bypassed to GND via 100 nF capacitors. |
| 4, 11, 18, 25 | 16, 26, 32 | GND | GND | — | **Ground**<br>All GND pins must be connected externally. |

Table 5 Not Connected

| Pin Number | | Name | Pin Type | Buffer Type | Function |
|---|---|---|---|---|---|
| PG-TSSOP-28-2 | PG-VQFN-32-13 | | | | |
| 3, 8, 12 - 17, 19 - 24, 26 - 28 | 2, 3, 6, 7, 11 - 15, 17 - 25, 27, 28, 31 | NC | NU | — | **Not Connected**<br>All NC pins must not be connected externally (must be left floating). |

## 3.1 Typical Schematic

Figure 3 shows the typical schematic for the OPTIGA™ TPM SLB 9645. The power supply pins should be bypassed to GND with capacitors located close to the device. The physical presence input may be connected to a jumper as shown in the schematic; or it may be driven by other devices (this is application- or platform-dependent).

Note that pull-up resistors are needed on the I2C clock and data signals, these are not shown in the schematic.

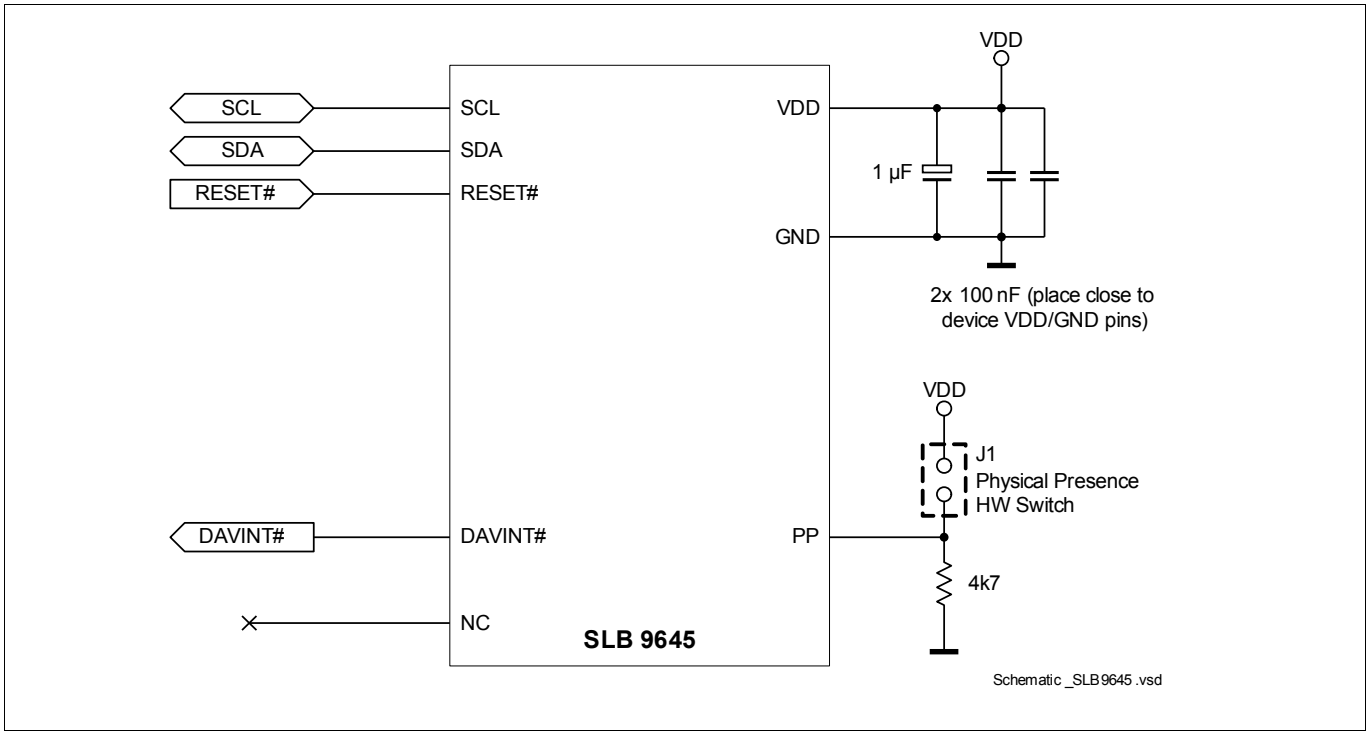


Figure 3 Typical Schematic

# 4 Electrical Characteristics

This chapter lists the maximum and operating ranges for various electrical and timing parameters.

## 4.1 Absolute Maximum Ratings

**Table 6 Absolute Maximum Ratings**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Supply Voltage | $V_{DD}$ | -0.3 | – | 7 | V | – |
| Voltage on any pin | $V_{max}$ | -0.3 | – | $V_{DD}$+0.3 | V | – |
| Ambient temperature | $T_A$ | -40 | – | 85 | °C | – |
| Storage temperature | $T_S$ | -40 | – | 125 | °C | – |
| ESD robustness HBM: 1.5 kΩ, 100 pF | $V_{ESD,HBM}$ | – | – | 2000 | V | According to EIA/JESD22-A114-B |
| ESD robustness | $V_{ESD,CDM}$ | – | – | 500 | V | According to ESD Association Standard STM5.3.1 - 1999 |
| Latchup immunity | $I_{latch}$ | | | 100 | mA | According to EIA/JESD78 |

*Attention: Stresses above the max. values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the integrated circuit.*

## 4.2 Functional Operating Range

**Table 7 Functional Operating Range**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Supply Voltage | $V_{DD}$ | 3.0 | 3.3 | 3.6 | V | 3.3 V system environment |
| Supply Voltage | $V_{DD}$ | 1.62 | 1.8 | 1.98 | V | 1.8 V system environment |
| Ambient temperature | $T_A$ | -20 | – | 85 | °C | Standard temperature range devices |
| Ambient temperature | $T_A$ | -40 | – | 85 | °C | Enhanced temperature range devices |
| Useful lifetime | | – | – | 10 | y | |
| Operating lifetime | | – | – | 10 | y | |
| Average $T_A$ over lifetime | | – | 55 | – | °C | |

## 4.3 DC Characteristics

$T_A$ = 25°C, $V_{DD}$ = 3.3V ± 0.3V or 1.8V ± 0.18V unless otherwise noted

**Table 8 Current Consumption**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Current Consumption in Active Mode | $I_{VDD\_Active}$ | | 3.0 | 25 | mA | $V_{DD}$ = 3.3V ± 0.3V<br>Device is active and is operating internally. Note that since the device is mostly in an internal sleep state in a “typical” application, the typical average current consumption is far less than the maximum value. It is assumed that in a normal environment, the device is in an internal sleep state for approximately 90% of the operating time of the platform. |
| Current Consumption in Sleep Mode | $I_{VDD\_Sleep}$ | | 0.9 | | mA | $V_{DD}$ = 3.3V ± 0.3V<br>Device is active, SCL is toggling but no ongoing internal TPM operation. The device is in an internal sleep state. |
| Current Consumption in Sleep Mode with Stopped Clock | $I_{VDD\_Sleep\_CS}$ | | 150 | | µA | $V_{DD}$ = 3.3V ± 0.3V<br>Device is active, SCL is not toggling and no ongoing internal TPM operation. The device is in an internal sleep state. |

*Note: Current consumption does not include any currents flowing through resistive loads on output pins!*

**Table 9 DC Characteristics**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Input voltage high | $V_{IH}$ | 0.7 $V_{DD}$ | | $V_{DD}$+0.3 | V | All pins except RESET# |
| Input voltage low | $V_{IL}$ | -0.3 | | 0.3 $V_{DD}$ | V | All pins except RESET# |
| Input voltage high | $V_{IH}$ | 0.8 $V_{DD}$ | | $V_{DD}$ | V | Pin RESET# |
| Input voltage low | $V_{IL}$ | 0 | | 0.2 $V_{DD}$ | V | Pin RESET# |
| Input high leakage current | $I_{IH}$ | -15 | | 15 | µA | $V_{IN}$ = $V_{DD}$ |
| Input low leakage current | $I_{IL}$ | -15 | | 15 | µA | $V_{IN}$ = 0V |
| Output high voltage | $V_{OH}$ | $V_{DD}$-0.3 | | | V | $I_{OH}$ = 1mA |
| Output low voltage | $V_{OL}$ | | | 0.3 | V | $I_{OL}$ = 1mA |

## 4.4 AC Characteristics

$T_A$ = 25°C, $V_{DD}$ = 3.3V ± 0.3V or 1.8V ± 0.18V unless otherwise noted

**Table 10 Device Reset**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Cold (Power-On) Reset | $t_{POR}$ | 80 | | | µs | |
| Warm Reset | $t_{WRST}$ | 10 | | | µs | |
| Reset Inactive Time | $t_{RSTIN}$ | 30 | | | ms | |

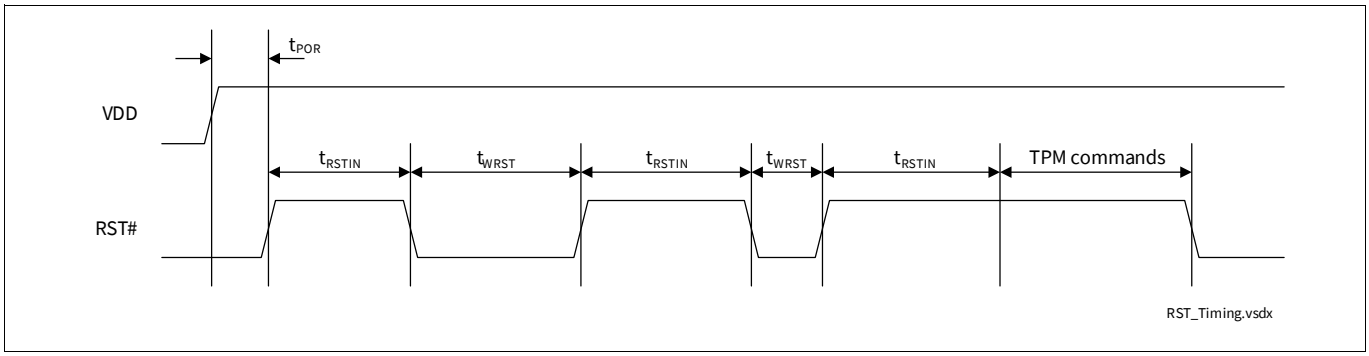


**Figure 4 RST# Timing**

## 4.5 Timing

The TPM_ACCESS_x.tpmEstablishment bit has the correct value and the TPM_ACCESS_x.tpmRegValidSts bit is typically set within 8ms after RESET# is deasserted.

The TPM is ready to receive a command after less than 30 ms.

The OPTIGA™ TPM SLB 9645 features a sophisticated protection mechanism against dictionary attacks on TPM-based authorization data. Basically, the device counts the number of failed authorization attempts in a counter which is located in the non-volatile memory. An attacker who has physical access to the device could try to circumvent that mechanism by resetting the device after the authorization attempt but before the updated failure counter has been written into the NVM.

As a countermeasure, another feature called early reset detection (ERD) has been added to the OPTIGA™ TPM SLB 9645. This mechanism detects external resets and counts them. In certain time windows during power-on or warm boot of the device, such reset events might influence the dictionary attack counters and trigger other security mechanisms as well. In worst case, this might trigger special security defense modes from which a recovery is very complex or even not possible.

To avoid that the OPTIGA™ TPM SLB 9645 reaches such a security defense state, the RST# signal must not be asserted in certain time windows. After the deassertion of the RST# signal, the system should wait for a minimum time of $t_{RSTIN}$ before asserting RST# again (see **Figure 4** and **Table 10**).

TPM commands should only be started after $t_{RSTIN}$ has expired (see **Figure 4** again). If a TPM command is running, RST# should not be asserted; otherwise, this might also trigger some security functions. When the TPM shall be reset, the command TPM_SaveState should be issued before the assertion of the RST# signal.

## 4.6 I2C Standard/Fast Mode Interface Characteristics

The electrical characteristics are compliant to the NXP I²C bus specification [5] and [6] for “standard-mode” ($f_{SCL}$ ≤ 100 kHz) and “fast-mode” ($f_{SCL}$ ≤ 400 kHz), with certain deviations stated in Table 11 and Table 12 below.

For printed circuit board design the reduced output fall time $t_{OF}$ compared to the NXP I²C bus specification needs to be considered!

$T_A$ = 25°C, $V_{DD}$ = 3.3V ± 0.3V unless otherwise noted

**Table 11 I2C Standard Mode Interface Characteristics**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| SCL clock frequency | $f_{SCL}$ | 0 | — | 100 | kHz | — |
| Output fall time from $V_{IHmin}$ to $V_{ILmax}$ (at device pin) | $t_{OF}$ | — | — | 75 | ns | 10 pF ≤ $C_b$ ≤ 400 pF |
| SCL fall time (bus line, output) | $t_{fSCL}$ | — | — | 25 | ns | — |

**Table 12 I2C Fast Mode Interface Characteristics**

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| SCL clock frequency | $f_{SCL}$ | 0 | — | 400 | kHz | — |
| Hysteresis of input stage | $V_{HYS}$ | 0.05 | — | — | V | — |
| Output fall time from $V_{IHmin}$ to $V_{ILmax}$ (at device pin) | $t_{OF}$ | 0.4 | — | 75 | ns | 10 pF ≤ $C_b$ ≤ 400 pF |
| Spikes suppressed by input filter | $t_{SP}$ | — | 20 | — | ns | Input filter implemented for SCL, not for SDA |
| SCL fall time (bus line, output) | $t_{fSCL}$ | — | — | 25 | ns | — |
| Input current (SCL, SDA) | $I_I$ | -10 | — | 10 | µA | $V_{IN}$ between 10% and 90% of the supply voltage $V_{DD}$; the condition “If VDD is switched off, I/O pins of fast-mode devices must not obstruct the SDA and SCL lines” is not fulfilled. |

# 5 Package Dimensions (TSSOP)

All dimensions are given in millimeters (mm) unless otherwise noted. The packages are “green” and RoHS compliant.

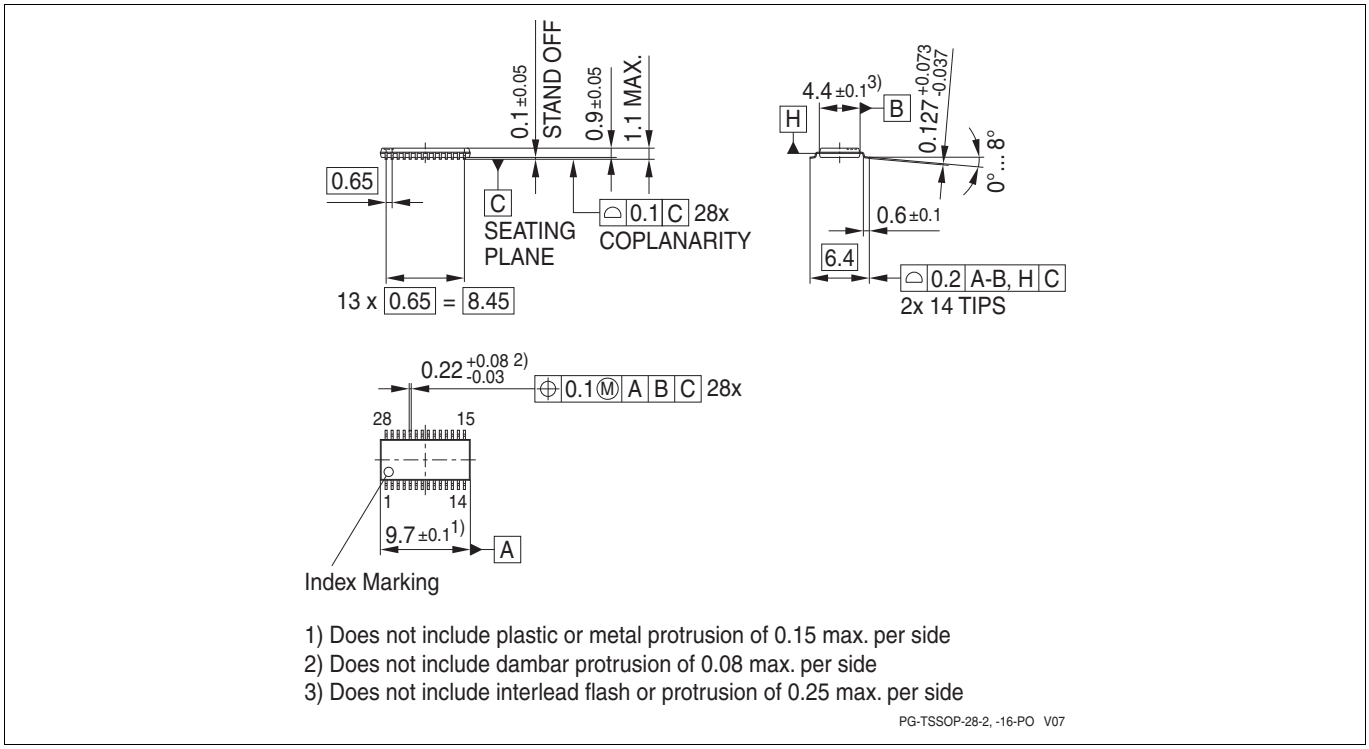


**Figure 5 Package Dimensions PG-TSSOP-28-2**

## 5.1 Packing Type

PG-TSSOP-28-2: Tape & Reel (reel diameter 330mm), 3000 pcs. per reel

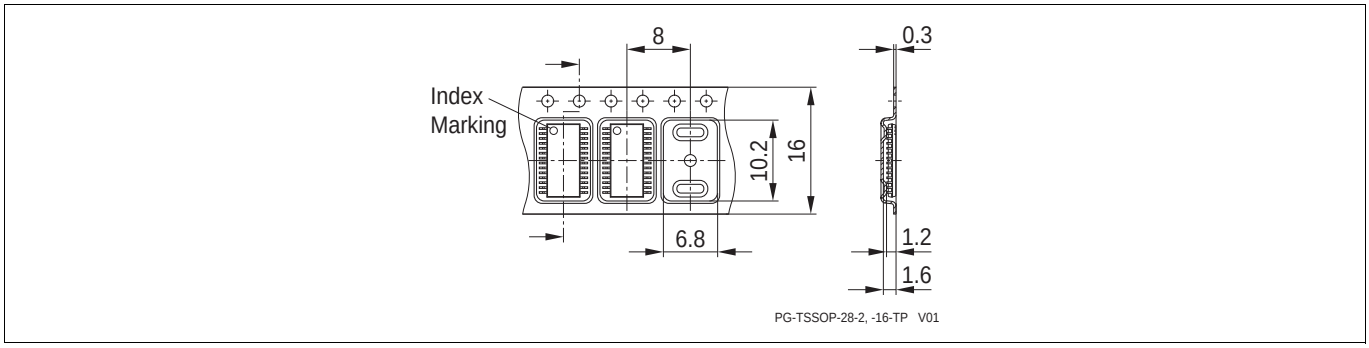


**Figure 6 Tape & Reel Dimensions PG-TSSOP-28-2**

## 5.2 Recommended Footprint

Controlling dimension is millimeters (mm).

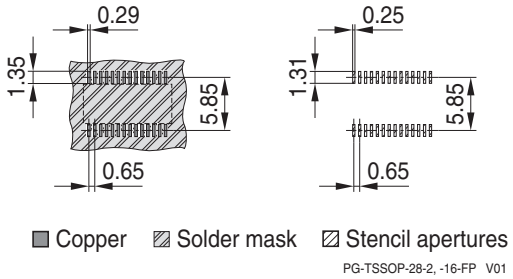


**Figure 7 Recommended Footprint PG-TSSOP-28-2**

## 5.3 Chip Marking

Line 1: SLB9645TT12 or SLB9645XT12 (see Table 1)

Line 2: G <datecode> KMC, <K> indicates assembly site code, <MC> indicates mold compound code

Line 3: 00 <Lot number>, the 00 is an internal FW indication (only at manufacturing due to field upgrade option)

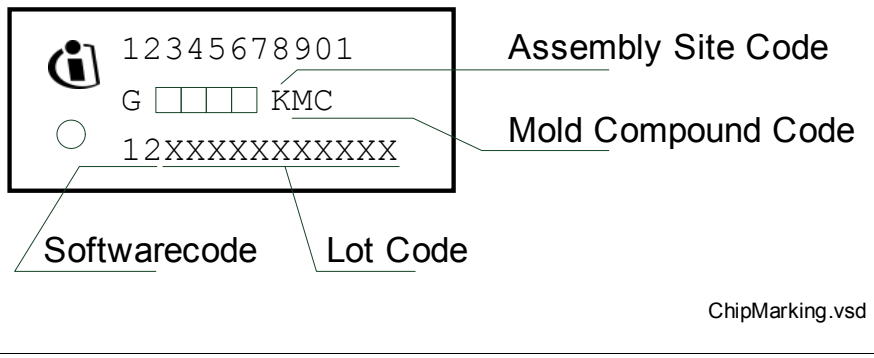


**Figure 8 Chip Marking PG-TSSOP-28-2**

For details and recommendations regarding assembly of packages on PCBs, please refer to http://www.infineon.com/cms/en/product/technology/packages/

# 6 Package Dimensions (VQFN)

All dimensions are given in millimeters (mm) unless otherwise noted. The packages are “green” and RoHS compliant.

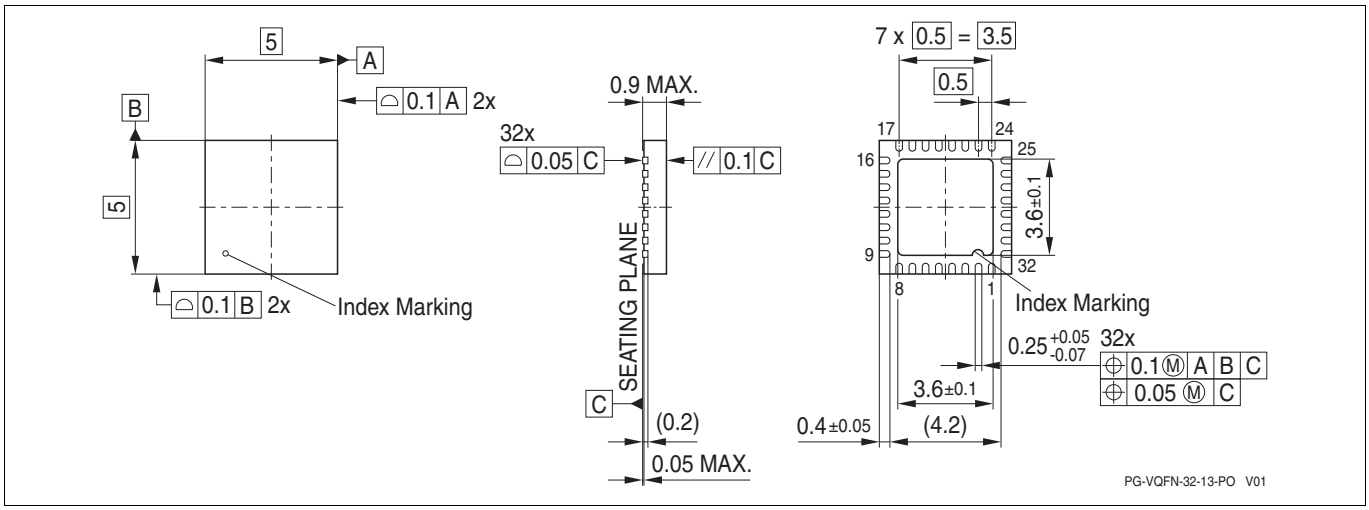


**Figure 9 Package Dimensions PG-VQFN-32-13**

## 6.1 Packing Type

PG-VQFN-32-13: Tape & Reel (reel diameter 330mm), 5000 pcs. per reel

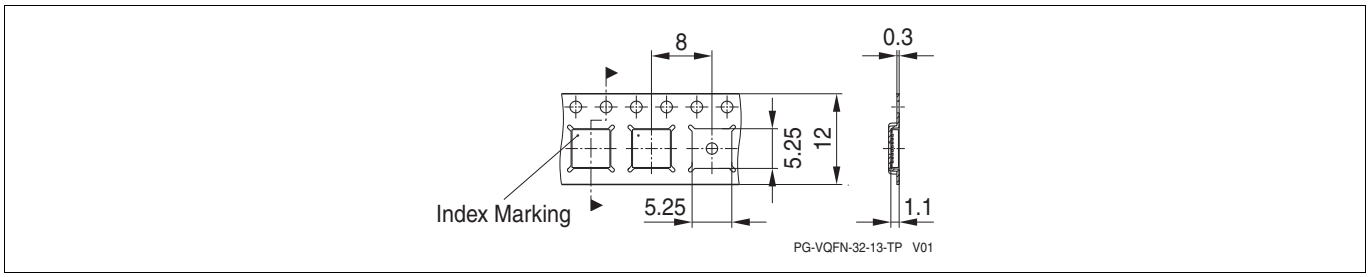


**Figure 10 Tape & Reel Dimensions PG-VQFN-32-13**

## 6.2 Recommended Footprint

Figure 11 shows the recommended footprint for the PG-VQFN-32-13 package. The exposed pad of the package is internally connected to GND. It shall be connected to GND externally as well.

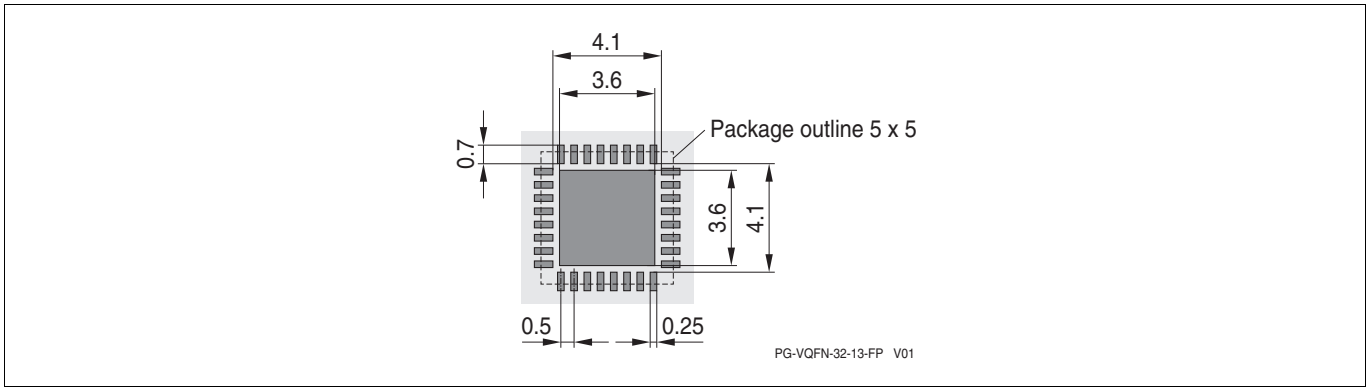


**Figure 11 Recommended Footprint PG-VQFN-32-13**

## 6.3 Chip Marking

Line 1: SLB9645

Line 2: VQ12 yy or XQ12_yy (see Table 1), the <yy> is an internal FW indication

Line 3: <Lot number> H <datecode>

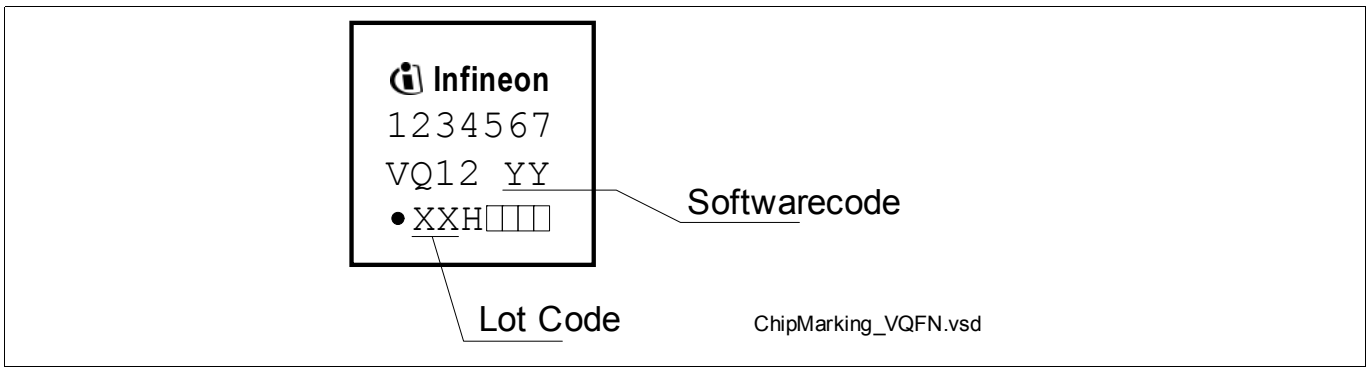


**Figure 12 Chip Marking PG-VQFN-32-13**

For details and recommendations regarding assembly of packages on PCBs, please refer to http://www.infineon.com/cms/en/product/technology/packages/

# References

[1] —, “TPM Main Specification”, Version 1.2, Rev. 116, 2011-03-01, TCG (parts 1-3)

[2] —, “TCG PC Client TPM Interface Specification (TIS)”, Version 1.21, 2011-04-28, TCG

[3] —, “PC Client Implementation Specification”, Version 1.2, 2005-07-13, TCG

[4] —, “TCG Software Stack Specification (TSS)”, Version 1.2, 2005-11-02, TCG

[5] —, “NXP $I^2C$ bus specification, Rev. 03”, 19 June 2007

[6] —, “NXP $I^2C$ bus specification, Rev. 4”, 13 February 2012

# Terminology

| | |
|---|---|
| ERD | Early Reset Detection |
| ESW | Embedded Software |
| HMAC | Hashed Message Authentication Code |
| I2C | Inter-Integrated Circuit |
| PCR | Platform Configuration Register |
| PUBEK | Public Endorsement Key |
| TCG | Trusted Computing Group |
| TPM | Trusted Platform Module |
| TSS | TCG Software Stack |

| Revision History | |
|---|---|
| **Page or Item** | **Subjects (major changes since previous revision)** |
| **Revision 1.2, 2018-09-21** | |
| | New document template. Inserted Section 4.5. |
| **Revision 1.1, 2014-02-12** | |
| | Fixed typos, document references, added note to Table 8. |
| **Revision 1.0, 2013-01-31** | |
| | Initial version |

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