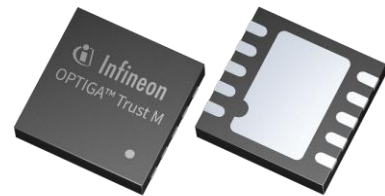


OPTIGA™ Trust M1

Datasheet

Key Features

- High-end security controller
- Common Criteria Certified EAL6+ (high) hardware
- Turnkey solution
- Up to 10kB user memory
- PG-USON-10-2 package (3 x 3 mm)
- Standard, Extreme & Extended temperature ranges
- I2C interface with Shielded Connection (encrypted communication)
- Cryptographic support: ECC NIST P256/P384, SHA-256, TRNG, DRNG, RSA® 1024/2048
- OPTIGA™ Trust M1 Software Framework on Github (<https://github.com/Infineon/optiga-trust-m>)
- Crypto ToolBox commands with ECC NIST P256/P384, SHA-256 (sign, verify, key generation, ECDH(E), key derivation), RSA® 1024/2048 (sign, verify, key generation, encrypt and decrypt)
- Device Security Monitor
- 4 Monotonic up counters
- Hibernate for zero power consumption
- Lifetime for Industrial Automation and Infrastructure is 20 years and 15 years for other Application Profiles



Benefits

- Protection of IP and data
- Protection of business case
- Protection of corporate image
- Safeguarding of quality and safety

Applications

- Industrial control and automation
- Consumer electronics and Smart Home
- Medical devices

About this document

Scope and purpose

This Datasheet provides information to enable integration of a security device, and includes package, connectivity and technical data.

Intended audience

This Datasheet is intended for device integrators and board manufacturers.

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About this document

1 Introduction

As embedded systems (e.g. IoT devices) are increasingly gaining the attention of attackers, Infineon offers the OPTIGA™ Trust M1 as a turnkey security solution for industrial automation systems, smart homes, consumer devices and medical devices. This high-end security controller comes with full system integration support for easy and cost-effective deployment of high-end security for your assets.

1.1 Broad range of benefits

Integrated into your device, the OPTIGA™ Trust M1 supports protection of your brand and business case, differentiates your product from your competitors, and adds value to your product, making it stronger against cyberattacks.

1.2 Enhanced security

The OPTIGA™ Trust M1 is based on an advanced security controller with built-in tamper proof NVM for secure storage and Symmetric/Asymmetric crypto engines to support ECC 256/384, RSA® 1024/2048 and SHA-256. This new security technology greatly enhances your overall system security.

1.3 Fast and easy integration

The turnkey setup – with full system integration and all key/certificate material preprogrammed – reduces your efforts for design, integration and deployment to a minimum. As a turnkey solution, the OPTIGA™ Trust M1 comes with preprogrammed OS/Application code locked and with host-side modules to integrate with host micro controller software. The temperature range of –40°C to +105°C combined with a standardized I2C interface and the small PG-USON-10-2 footprint will facilitate onboarding in your existing ecosystem. Almost 30 years in a market-leading position with nearly 20 billion security controllers shipped worldwide are the results of Infineon's strong expertise and its commitment to make security a success factor for you.

1.4 Applications

The OPTIGA™ Trust M1 covers a broad range of use cases necessary for many types of applications that include the following:

- a) Network node protection using Mutual Authentication such as TLS or DTLS
- b) Protect the Authenticity, Integrity and Confidentiality of your product, data and IP
- c) Secure Communication
- d) Datastore Protection
- e) Lifecycle Management
- f) Platform Integrity Protection
- g) Secure Updates

1.5 Device Features

The OPTIGA™ Trust M1 comes with up to 10kB user memory that can be used to store X.509 certificates and data. OPTIGA™ Trust M1 is based on Common Criteria (CC) Certified EAL6+ (high) hardware enabling it to prevent physical attacks on the device itself and providing high assurance that the keys or arbitrary data stored cannot be accessed by an unauthorized entity. The CC certificate can be found at www.bsi.bund.de by searching for BSI-DSZ-CC-0961-V2-2018 (Hardware Identifier IFX_CCI_00000Bh). OPTIGA™ Trust M1 supports a highspeed I2C communication interface of up to 1MHz (FM+).

About this document

Table 1 Products

| Type | Description | Temperature range | Package |
|------------------------------------|--|--|--------------|
| OPTIGA™ Trust M1 SLS 32AIA010MC | Embedded security solution for connected devices | –25°C to +105°C Extreme Temperature Range (XTR) | PG-USON-10-2 |
| OPTIGA™ Trust M1 SLS 32AIA010MH | Embedded security solution for connected devices | –40°C to +105°C Extended Temperature Range (ETR) | PG-USON-10-2 |
| OPTIGA™ Trust M1 SLS 32AIA010MS | Embedded security solution for connected devices | –25°C to +85°C Standard Temperature Range (STR) | PG-USON-10-2 |
| Evaluation Kit | Includes a host micro controller connected to the OPTIGA™ Trust M1 as well as USB/Ethernet adapter to connect to the outside world, enabling you to evaluate the OPTIGA™ Trust M1 features and start the Design-In activities. | | Board |

Infineon and its distribution partners offer a wide range of customization options (e.g. X.509 certificate generation and key provisioning) for the security chip.

Table 2 Abbreviations

| Abbreviation | Definition |
|--------------|--|
| AES | Advanced Encryption Standard |
| API | Application Programming Interface |
| CA | Certification Authority |
| CC | Common Criteria |
| DRNG | Deterministic Random Number Generator |
| DTLS | Datagram Transport Layer Security |
| EAL | Evaluation Assurance Level |
| ECC | Elliptic Curve Cryptography |
| ECDH | Elliptic Curve Diffie Hellman |
| ECDSA | Elliptic Curve Digital Signature Algorithm |
| ETR | Extended Temperature Range |
| I2C | Inter-Integrated Circuit |
| IETF | Internet Engineering Task Force |
| IFX | Infineon |
| IOT | Internet of Things |
| IP | Intellectual Property |
| NIST | National Institute of Standards and Technology |
| OS | Operating System |
| PAL | Platform Abstraction Layer |
| PKI | Public Key Infrastructure |
| RFC | Request For Comments |
| SHA | Secure Hash Algorithm |

About this document

| Abbreviation | Definition |
|--------------|------------------------------|
| SKU | Stock Keeping Unit |
| STR | Standard Temperature Range |
| TLS | Transport Layer Security |
| TRNG | True Random Number Generator |
| USB | Universal Synchronous Bus |
| XTR | Extreme Temperature Range |

About this document

2 System Block Diagram

The following figure depicts the system block diagram for OPTIGA™ Trust M1.

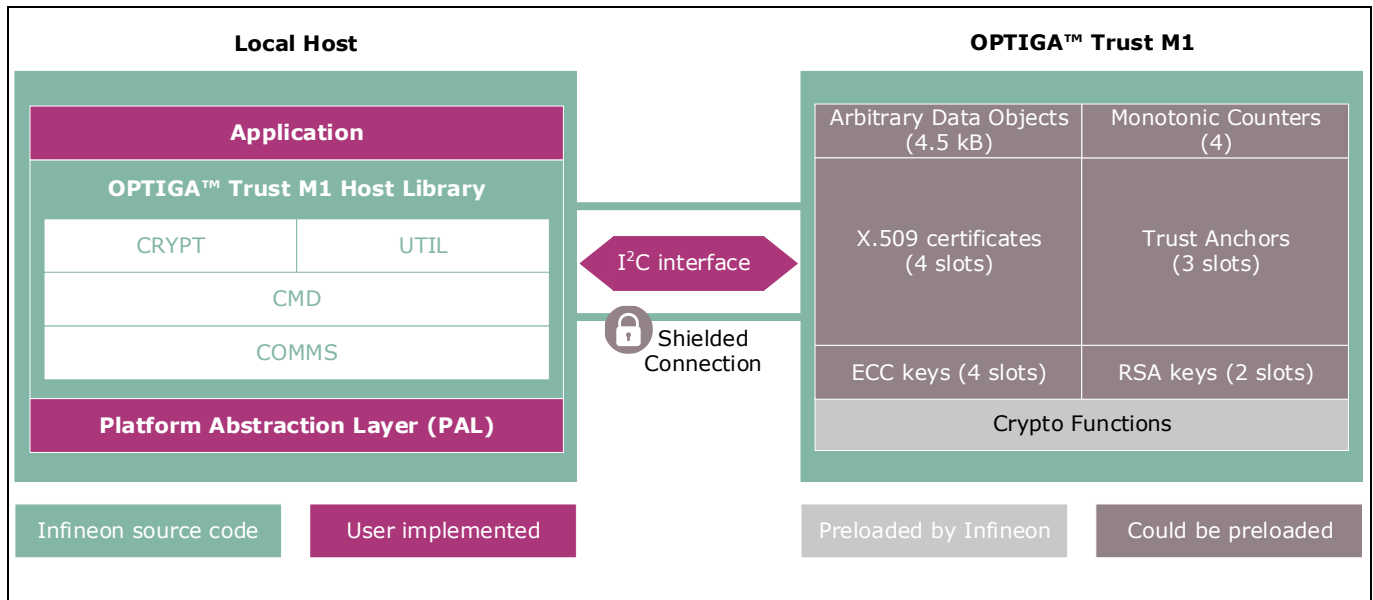


Figure 1 System Block Diagram

The System Block Diagram is explained below for each layer.

1. Local Host

- Local Host Application – This is the target application which utilizes OPTIGA™ Trust M1 for its security needs
- OPTIGA™ Trust M1 Host Library
 - CRYPT – Provides APIs to perform cryptographic functionalities. Any TLS stack can be integrated on Local Host as part of 3rd party Crypto Library to offload crypto operations to OPTIGA™ Trust M1.
 - UTIL – Provides APIs such as read/write, protected update of data objects and open/close application (e.g. Hibernate)
 - CMD – Provides APIs to send and receive commands (Section 7) to and from OPTIGA™ Trust M1
 - COMMS – Provides wrapper APIs for communication (optional encrypted communication using Shielded Connection) with OPTIGA™ Trust M1 which internally uses Infineon I2C Protocol (IFX I2C)
- PAL – A layer that abstracts platform specific drivers (e.g. I2C, Timer, GPIO, platform crypto library etc.)

2. OPTIGA™ Trust M1

- Arbitrary Data Objects – The target application can store up to 4.5kB (~4600 bytes) of data into OPTIGA™ Trust M1. The data could be additional Trust Anchors, certificates and shared secret.
- Monotonic Counters - Provides 4 monotonic counting data objects (up counters). These can be used as general purpose counter or as linked counter to other objects.

For more information, please refer to Solution Reference Manual document available as part of the package.

About this document

- X.509 – Up to 4 X.509 based Certificates can be stored
- Keys – Up to 4 ECC and 2 RSA based keys can be stored
- Trust Anchors – 3 slots, for Mutual Authentication (TLS/DTLS) and Firmware Updates can be stored
- Crypto Functions - OPTIGA™ Trust M1 provides cryptographic functions that can be invoked via local host

Note:

Unique ECC/RSA private keys and X.509 Certificates – During production at Infineon fab, unique asymmetric keys (private and public) are generated. The public key is signed by customer specific CA and the resulting X.509 certificate issued is securely stored in the OPTIGA™ Trust M1. Special measures are taken to prevent the leakage and modification of private key material at the Common Criteria Certified production site

About this document

3 Interface and Schematics

This section explains the schematics of the product and gives some recommendations as to how the controller should be externally connected.

3.1 System Integration Schematics

The following figure illustrates how to integrate OPTIGA™ Trust M1 with your local host.

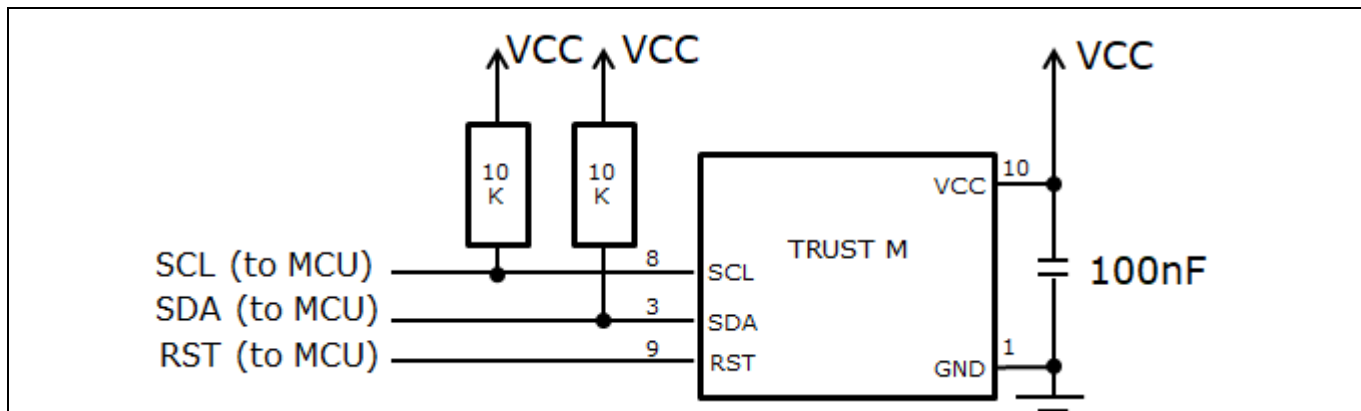


Figure 2 System Integration Schematic Diagram

Note: Value of the pullup resistors depend on the target application circuit and the targeted I2C frequency.

3.2 System Integration Schematics with Hibernation support

The following figure illustrates how to integrate OPTIGA™ Trust M1 with hibernation, with your local host.

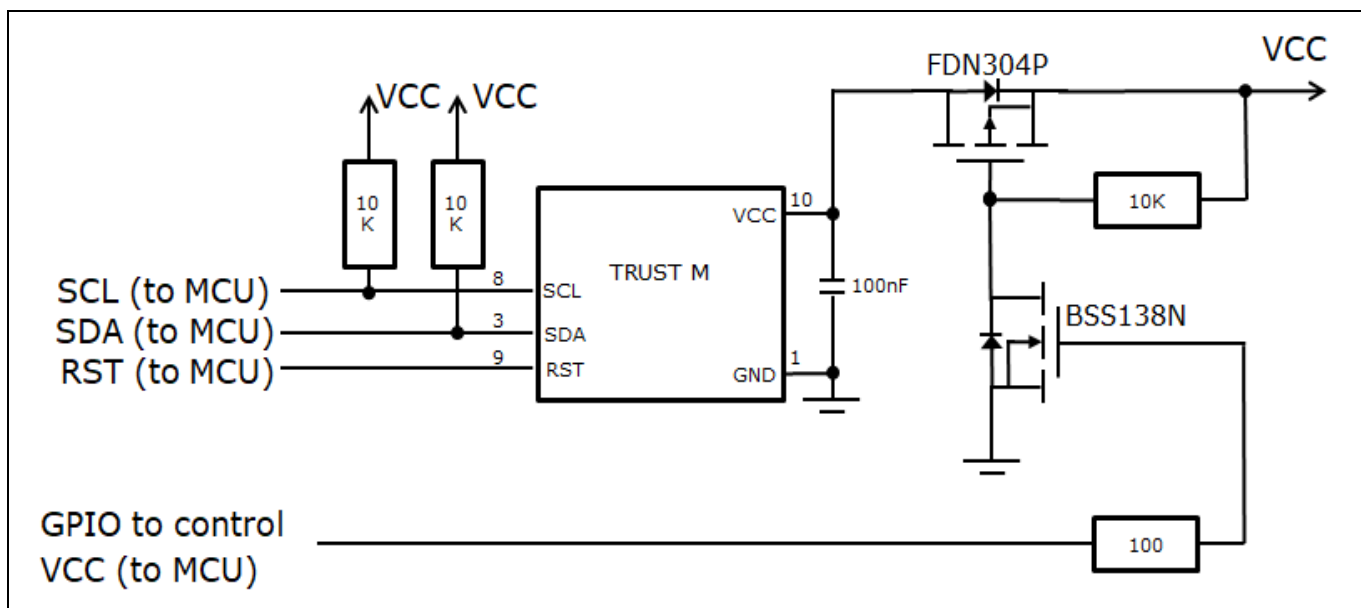


Figure 3 System Integration Schematic Diagram with Hibernation

Note: Value of the pullup resistors depend on the target application circuit and the targeted I2C frequency.

About this document

4 Description of packages

This chapter provides information on the package types and how the interfaces of each product are assigned to the package pins. For further information on compliance of the packages with European Parliament Directives, see “RoHS Compliance” on Page 30.

For details and recommendations regarding the assembly of packages on PCBs, please see the following:
<http://www.infineon.com/cms/en/product/technology/packages/>

4.1 PG-USON-10-2

The package dimensions (in mm) of the controller in PG-USON-10-2 packages are given below.

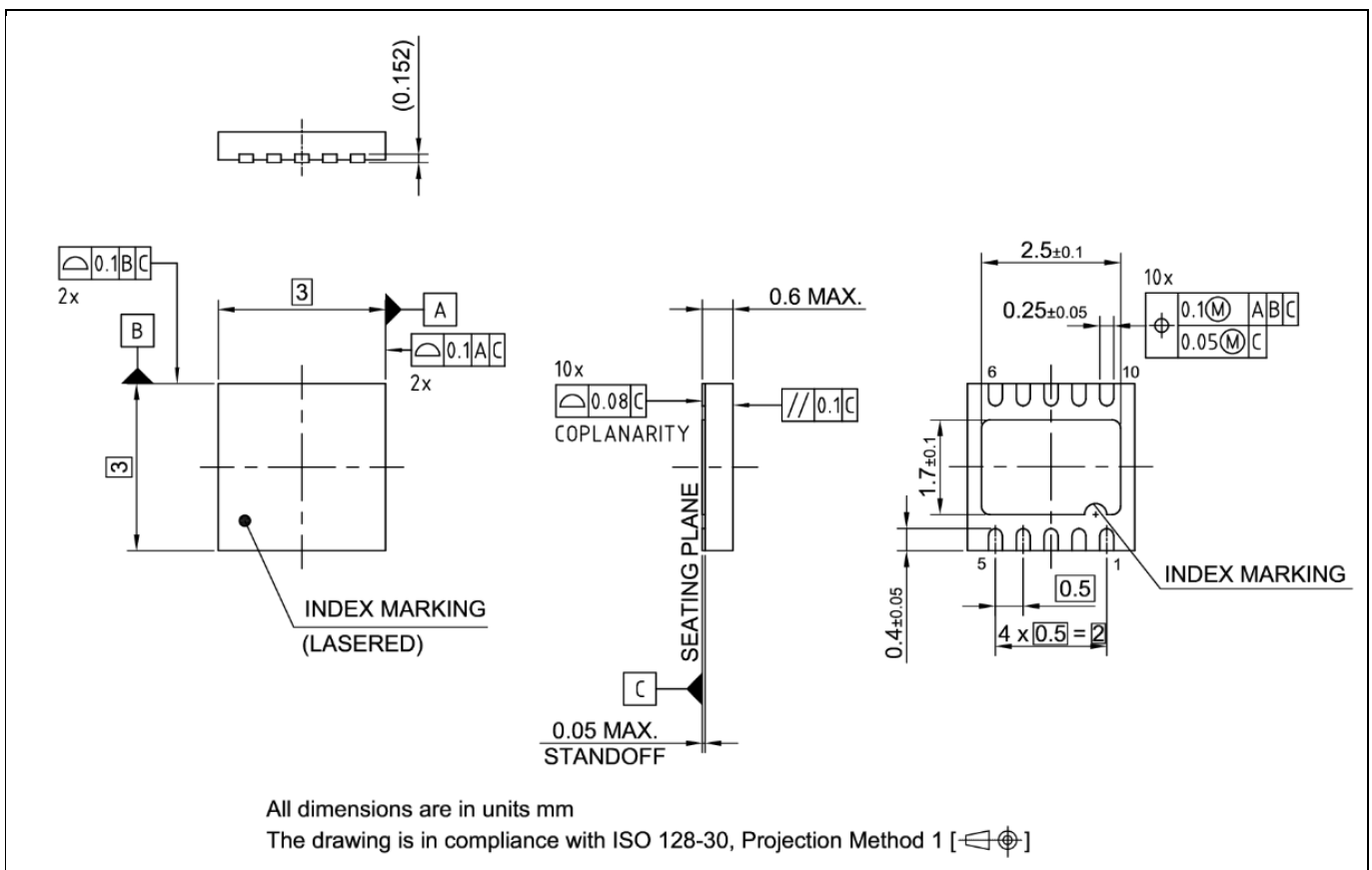


Figure 4 PG-USON-10-2 Package Outline

The following figure shows the footprint of the PG-USON-10-2 package:

About this document

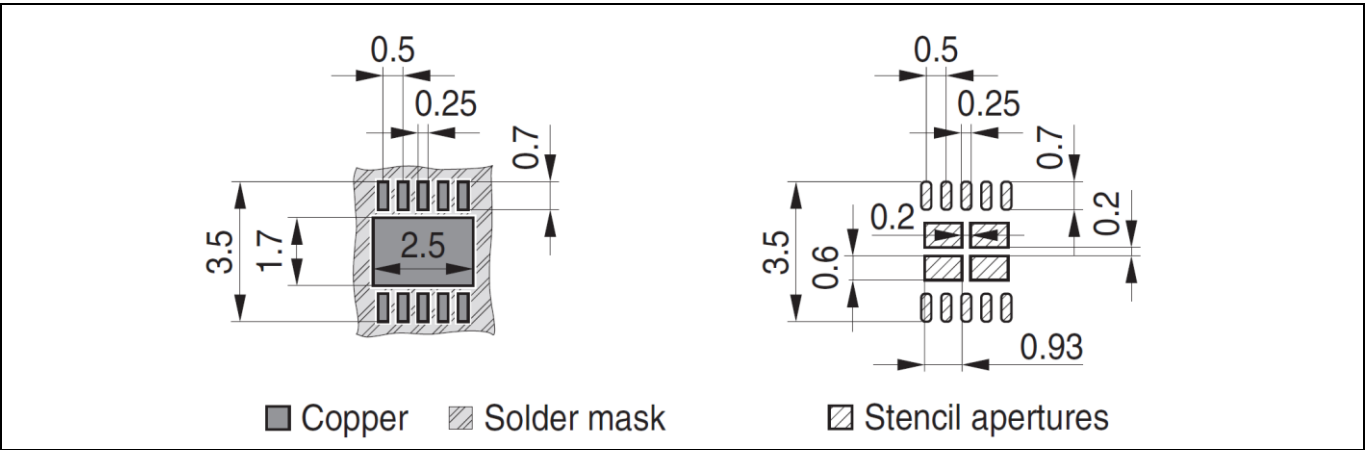


Figure 5 PG-USON-10-2 Package Footprint

The following figure shows the PG-USON-10-2 in top view:

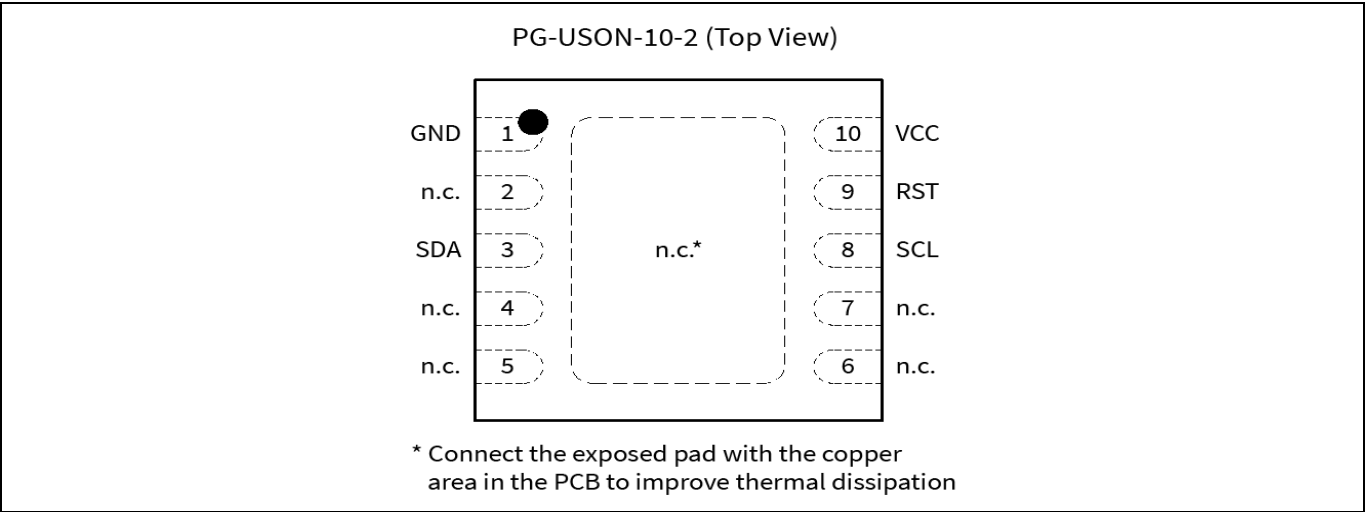


Figure 6 PG-USON-10-2 top view

4.2 Production sample marking pattern

The following figure describes the productive sample marking pattern on PG-USON-10-2.

About this document

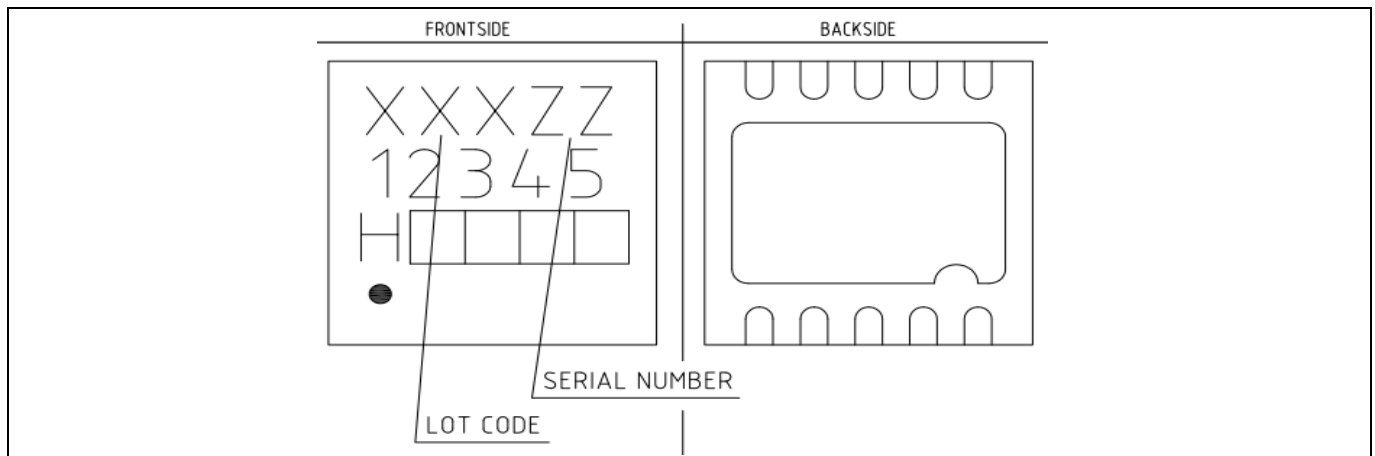


Figure 7 PG-USON-10-2 sample marking pattern

The black dot indicates pin 01 for the chip. The following [Table 3](#) describes the sample marking pattern:

Table 3 Marking table for PG-USON-10-2 packages

| Indicator | Description |
|-----------|---|
| LOT CODE | Defined and inserted during fabrication |
| ZZ | Indicates the Certifying Authority Serial Number / SKU#, e.g. "00" would mean "SKU#00" |
| H/E | H = "Halogen-free", E = "Engineering samples" This indicator is followed by "YYWW", where YY is the "Year" and WW is the "Work Week" of the production. This is inserted during fabrication. Engineering samples have "E YYWW" and productive samples have "H YYWW" |
| 12345 | Convention: T&#\$@ where: <ul style="list-style-type: none"> • The letter "T" indicates the OPTIGA Trust family • & indicates the product is a Trust M controller • # indicates the controller is a XTR (X) variant • \$ specifies the OPTIGA™ Trust M1 release version number • @ specifies the software version Example: "TMX10" means 'OPTIGA™ Trust M1', 'XTR variant', 'release version 1', 'software version 0' |

The contacts and their functionality are given in the [Table 4](#) below.

Table 4 Contact definitions and functions of PG-USON-10-2 packages

| Pin | Type | Function |
|-----|------|---|
| 01 | GND | Supply voltage (Ground) |
| 02 | NC | Not connected / Do not connect externally |
| 03 | I/O | Serial Data Line (SDA) |
| 04 | NC | Not connected / Do not connect externally |

About this document

| Pin | Type | Function |
|-----|------|---|
| 05 | NC | Not connected / Do not connect externally |
| 06 | NC | Not connected / Do not connect externally |
| 07 | NC | Not connected / Do not connect externally |
| 08 | I/O | Serial Clock Line (SCL) |
| 09 | IN | Active Low Reset (RST) |
| 10 | PWR | Supply voltage (V_{CC}) |

About this document

5 Technical Data

This section summarizes the technical data of the product. It provides the operational characteristics as well as the electrical DC and AC characteristics.

5.1 I2C Interface Characteristics

Table 5 I2C Operation Supply and Input Voltages

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|------------------------|---------------|--------|------|---|------|--|
| | | Min. | Typ. | Max. | | |
| Supply voltage | V_{CC_I2C} | 1.62 | – | 5.5 | V | |
| SDA, SCL input voltage | V_{IN_I2C} | –0.3 | – | $V_{CC_I2C} + 0.5$ or 5.5 ¹ | V | V_{CC_I2C} is in the operational supply range |
| | | –0.3 | – | 5.5 | V | V_{CC_I2C} is switched off |

1) Whichever is lower

5.1.1 I2C Standard/Fast Mode Interface Characteristics

For operation of the I2C interface, the electrical characteristics are compliant with the I²C bus specification Rev. 4 for "standard-mode" (f_{SCL} up to 100 kHz) and "fast-mode" (f_{SCL} up to 400 kHz), with certain deviations as stated in the table below.

Note: T_A as given for the operating temperature range of the controller unless otherwise stated.

Table 6 I2C Standard Mode Interface Characteristics

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|--|-----------|--------|------|-------------------------|------|---|
| | | Min. | Typ. | Max. | | |
| SCL clock frequency | f_{SCL} | 0 | – | 100 | kHz | |
| Input low-level | V_{IL} | –0.3 | – | $0.3 \cdot V_{CC_I2C}$ | V | |
| Low-level output voltage | V_{OL1} | 0 | – | 0.4 | V | Sink current 3 mA; $V_{CC_I2C} \geq 2.7$ V Sink current 2 mA; $V_{CC_I2C} < 2.7$ V |
| Low-level output current | I_{OL} | 3 2 | – | – | mA | $V_{OL} = 0.4$ V; $V_{CC_I2C} \geq 2.7$ V $V_{OL} = 0.4$ V; $V_{CC_I2C} < 2.7$ V |
| Output fall time from V_{IHmin} to V_{ILmax} (at device pin) | t_{oF} | – | – | 250 | ns | $C_b \leq 400$ pF; $V_{CC_I2C} \geq 2.7$ V $C_b \leq 200$ pF; $V_{CC_I2C} < 2.7$ V |
| Capacitive load for each bus line | C_b | – | – | 400 200 | pF | $V_{CC_I2C} \geq 2.7$ V $V_{CC_I2C} < 2.7$ V |

About this document

Table 7 I2C Fast Mode Interface Characteristics

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|--|-----------|--|------|-------------------------|------|---|
| | | Min. | Typ. | Max. | | |
| SCL clock frequency | f_{SCL} | 0 | – | 400 | kHz | |
| Input low-level | V_{IL} | –0.3 | – | $0.3 \cdot V_{CC_I2C}$ | V | |
| Low-level output voltage | V_{OL1} | 0 | – | 0.4 | V | Sink current 3 mA; $V_{CC_I2C} \geq 2.7\text{ V}$ Sink current 2 mA; $V_{CC_I2C} < 2.7\text{ V}$ |
| Low-level output current | I_{OL} | 3 2 | – | – | mA | $V_{OL} = 0.4\text{ V}; V_{CC_I2C} \geq 2.7\text{ V}$ $V_{OL} = 0.4\text{ V}; V_{CC_I2C} < 2.7\text{ V}$ |
| Output fall time from V_{IHmin} to V_{ILmax} (at device pin) | t_{OF} | 20 * $V_{CC_I2C} / 5.5\text{ V}^1$ | – | 250 | ns | $C_b \leq 400\text{ pF}; V_{CC_I2C} \geq 2.7\text{ V}$ $C_b \leq 200\text{ pF}; V_{CC_I2C} < 2.7\text{ V}$ |
| Capacitive load for each bus line | C_b | 15 ² | – | 400 200 | pF | $V_{CC_I2C} \geq 2.7\text{ V}$ $V_{CC_I2C} < 2.7\text{ V}$ |

1) A min. capacitive load is necessary to reach t_{OF} 2) A min. capacitive load is necessary to reach t_{fmin}

5.1.2 I2C Fast Mode Plus Interface Characteristics

For operation of the I2C interface, the electrical characteristics are compliant with the I²C bus specification Rev. 4 for "fast mode plus" (f_{SCL} up to 1 MHz), with certain deviations as stated in the table below.

Note: T_A as given for the operating temperature range of the controller unless otherwise stated.

Table 8 I2C Fast Mode Plus Interface Characteristics

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|--|-----------|--|------|-------------------------|------|---|
| | | Min. | Typ. | Max. | | |
| SCL clock frequency | f_{SCL} | 0 | – | 1000 | kHz | |
| Input low-level | V_{IL} | –0.3 | – | $0.3 \cdot V_{CC_I2C}$ | V | |
| Low-level output voltage | V_{OL1} | 0 | – | 0.4 | V | Sink current 3 mA; $V_{CC_I2C} \geq 2.7\text{ V}$ Sink current 2 mA; $V_{CC_I2C} < 2.7\text{ V}$ |
| Low-level output current | I_{OL} | 3 2 | – | – | mA | $V_{OL} = 0.4\text{ V}; V_{CC_I2C} \geq 2.7\text{ V}$ $V_{OL} = 0.4\text{ V}; V_{CC_I2C} < 2.7\text{ V}$ |
| Output fall time from V_{IHmin} to V_{ILmax} (at device pin) | t_{OF} | 20 * $V_{CC_I2C} / 5.5\text{ V}^1$ | – | 120 | ns | $C_b \leq 150\text{ pF}$ |
| Capacitive load for each bus line | C_b | 15 ¹ | – | 150 | pF | |

1) A min. capacitive load is necessary to reach t_{OF}

About this document

5.1.3 Electrical Characteristics

Note: T_A as given for the operating temperature range of the controller unless otherwise stated. All currents flowing into the controller are considered positive.

5.1.4 DC Electrical Characteristics

T_A as given for the controller's operating ambient temperature range unless otherwise stated.

All currents flowing into the controller are considered positive.

Table 9 Electrical Characteristics

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|-------------------------------|---------------|--------------------|------|--------------------|---------------|---|
| | | Min. | Typ. | Max. | | |
| Supply voltage | V_{CC} | 1.62 | – | 5.5 | V | Overall functional range |
| | V_{CC_I2C} | 1.62 | – | 5.5 | V | Supply voltage range for operation of I2C |
| Supply current ¹ | I_{CCAVG} | – | 20.0 | – | mA | While running a typical authentication profile $T_A = 25^\circ\text{C}$; $V_{CC} = 5.0\text{ V}$ |
| Supply current, in sleep mode | I_{CCS3} | – | 70 | 100 | μA | $T_A = 25^\circ\text{C}$; $V_{CC_I2C} = 3.3\text{ V}$; I2C ready for operation (no bus activity), all other inputs at V_{CC} , no other interface activity |
| RST input low voltage | V_{IL} | –0.3 | – | $0.2 \cdot V_{CC}$ | V | $I_{IL} = -50\text{ }\mu\text{A}$ to $+20\text{ }\mu\text{A}$ |
| RST input high voltage | V_{IH} | $0.7 \cdot V_{CC}$ | – | $V_{CC} + 0.3$ | V | $I_{IL} = -50\text{ }\mu\text{A}$ to $+20\text{ }\mu\text{A}$ |

1) Supply current can be limited from 6mA to 15mA by software commands.

5.1.5 AC Electrical Characteristics

T_A as given for the controller's operating ambient temperature range unless otherwise stated.

All currents flowing into the controller are considered positive.

Table 10 AC Characteristics

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|----------------------|------------|--------|------|------|---------------|---|
| | | Min. | Typ. | Max. | | |
| V_{CC} rampup time | t_{VCCR} | 1 | – | 1000 | μs | 400 mV to 90% of V_{CC} target voltage ramp |

The V_{CC} ramp is depicted in [Figure 8](#). 90% of the target supply voltage must be reached within t_{VCCR} after it has exceeded 400 mV. Moreover, its variation must be kept within a $\pm 10\%$ range.

About this document

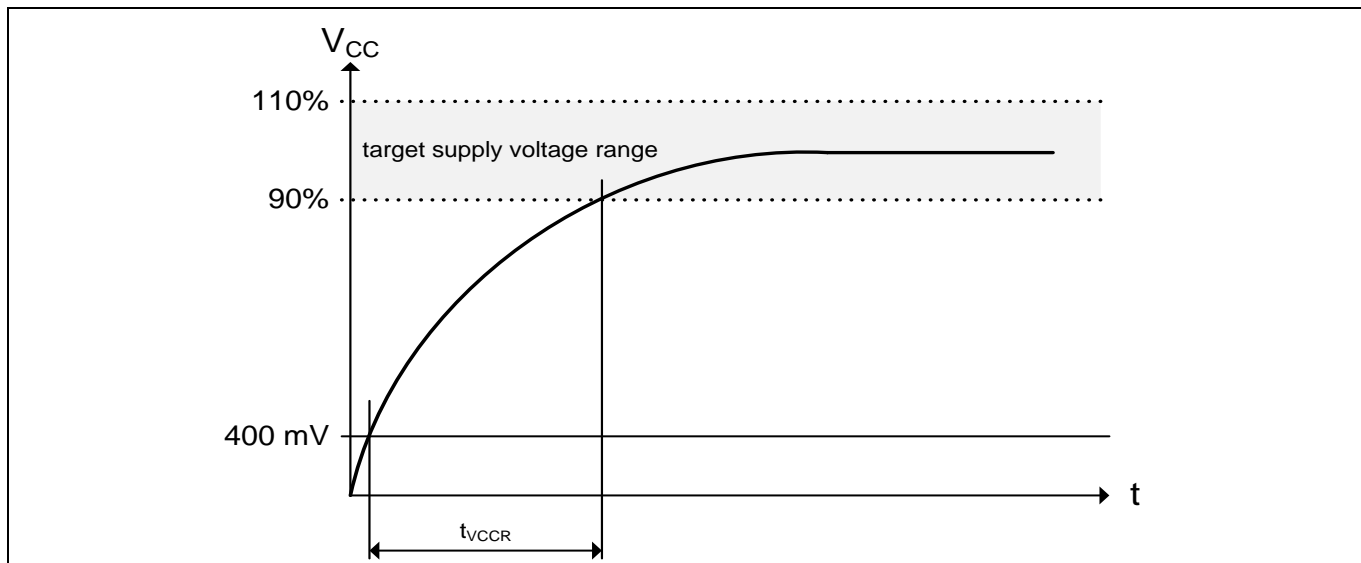


Figure 8 V_{CC} Rampup

5.1.6 Start-Up of I2C Interface

There are 2 variants possible for performing the startup procedure:

- Startup after power-on
- Startup for warm resets

5.1.6.1 Startup after Power-On

The activation of the I2C interface after power-on needs the following reset procedure.

- VCC is powered up and the state of the SDA and SCL line are set to high level during power-up
- The first transmission may start at the earliest $t_{STARTUP}$ after power-up of the device

The following figure shows the startup timing of the I2C interface for this case.

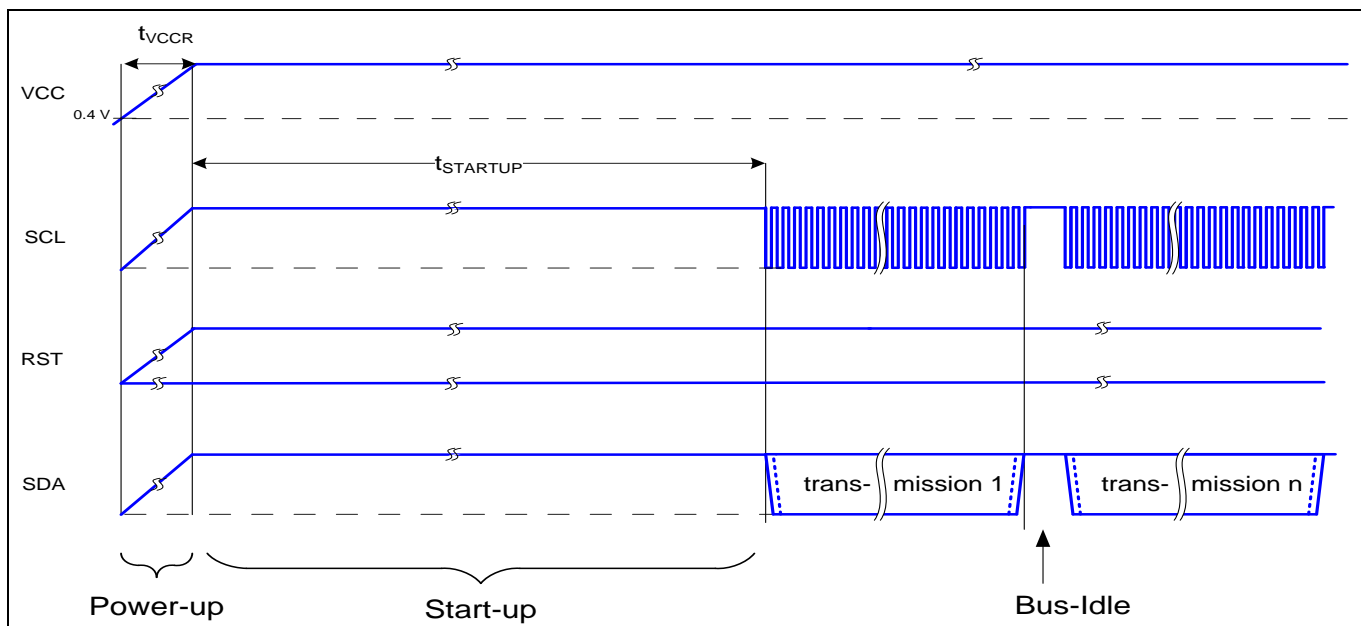


Figure 9 Startup of I2C Interface after Power-On

About this document

Table 11 Startup of I2C Interface After Power-On

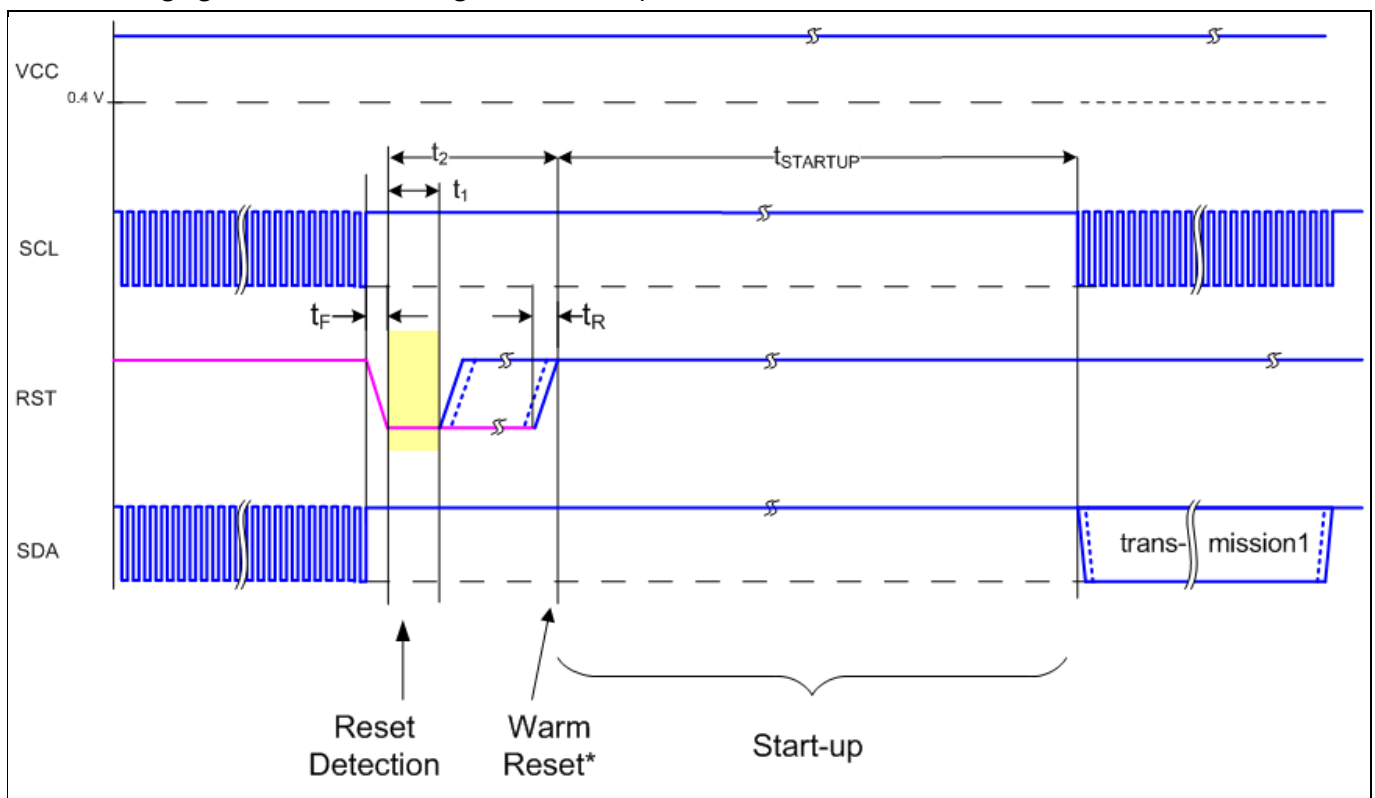
| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|--------------|----------------------|--------|------|------|------|------------------------|
| | | Min. | Typ. | Max. | | |
| Startup time | t_{STARTUP} | 15 | | | ms | |

5.1.6.2 Startup for Warm Resets

When using the reset signal for triggering a warm reset after power-on, the activation of the I2C interface needs the following reset procedure

- VCC remains powered up.
- The terminal stops I2C communication. SDA and SCL lines are set to high level before RST is set to low level.
- After its falling edge, RST has to be kept at low level for at least t_1 . At the latest t_2 after the falling edge of RST, the terminal must set RST to high level.
- The first transmission may start at the earliest t_{STARTUP} after the rising edge of RST

The following figure shows the timing for this startup case.


Figure 10 Startup of I2C Interface for Warm Resets

Note: If NVM programming was requested prior to the reset, t_{STARTUP} will be extended from a typical value of 15 ms to a maximum of 20 ms.

About this document

Table 12 Startup of I2C Interface for Warm Resets¹

| Parameter | Symbol | Values | | | Unit | Note or Test Condition |
|-----------------|----------------------|--------|------|------|---------------|-------------------------------------|
| | | Min. | Typ. | Max. | | |
| Startup time | t_{STARTUP} | 15 | | | ms | |
| Rise time | t_{R} | | | 1 | μs | From 10% to 90% of signal amplitude |
| Fall time | t_{F} | | | 1 | μs | From 10% to 90% of signal amplitude |
| Reset detection | t_1 | 10 | | | μs | |
| Reset low | | 10 | | 2500 | μs | |

1) Reset triggered by software (without power off/on cycle)

About this document

6 Connecting to Host

6.1 OPTIGA™ Trust M1 Host Software Architecture

The OPTIGA™ Trust M1 Host Library layers were explained in System Block Diagram [Figure 1](#). In following sections, we will cover how to communicate with OPTIGA™ Trust M1 using I2C.

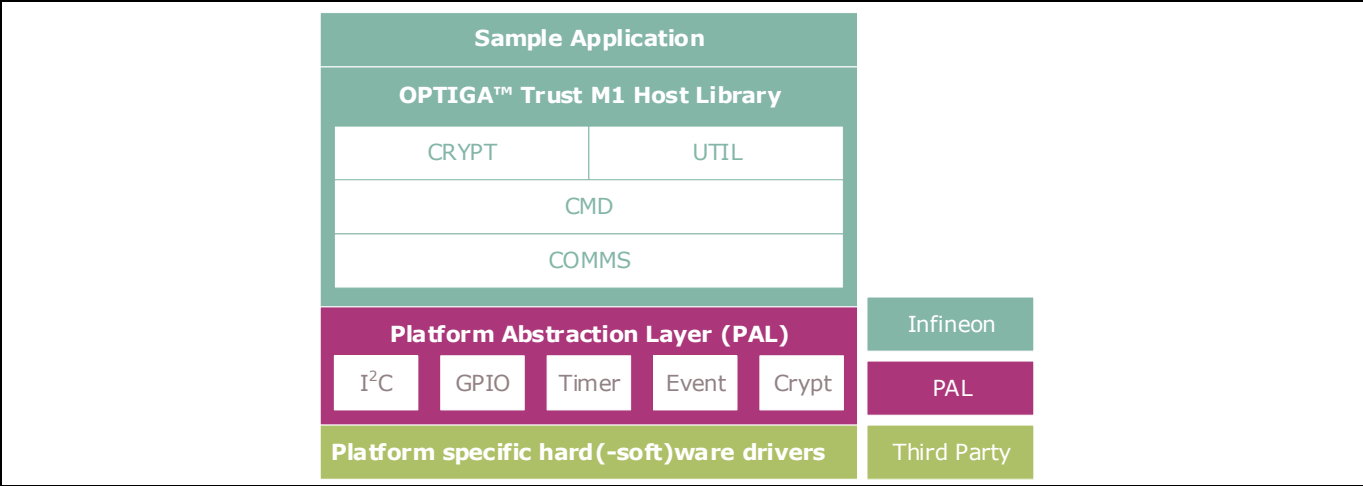


Figure 11 OPTIGA™ Trust M1 Host Software Architecture

6.2 Release Package Folder Structure

The following figure shows the release package structure when OPTIGA™ Trust M1 is installed/extracted on PC.

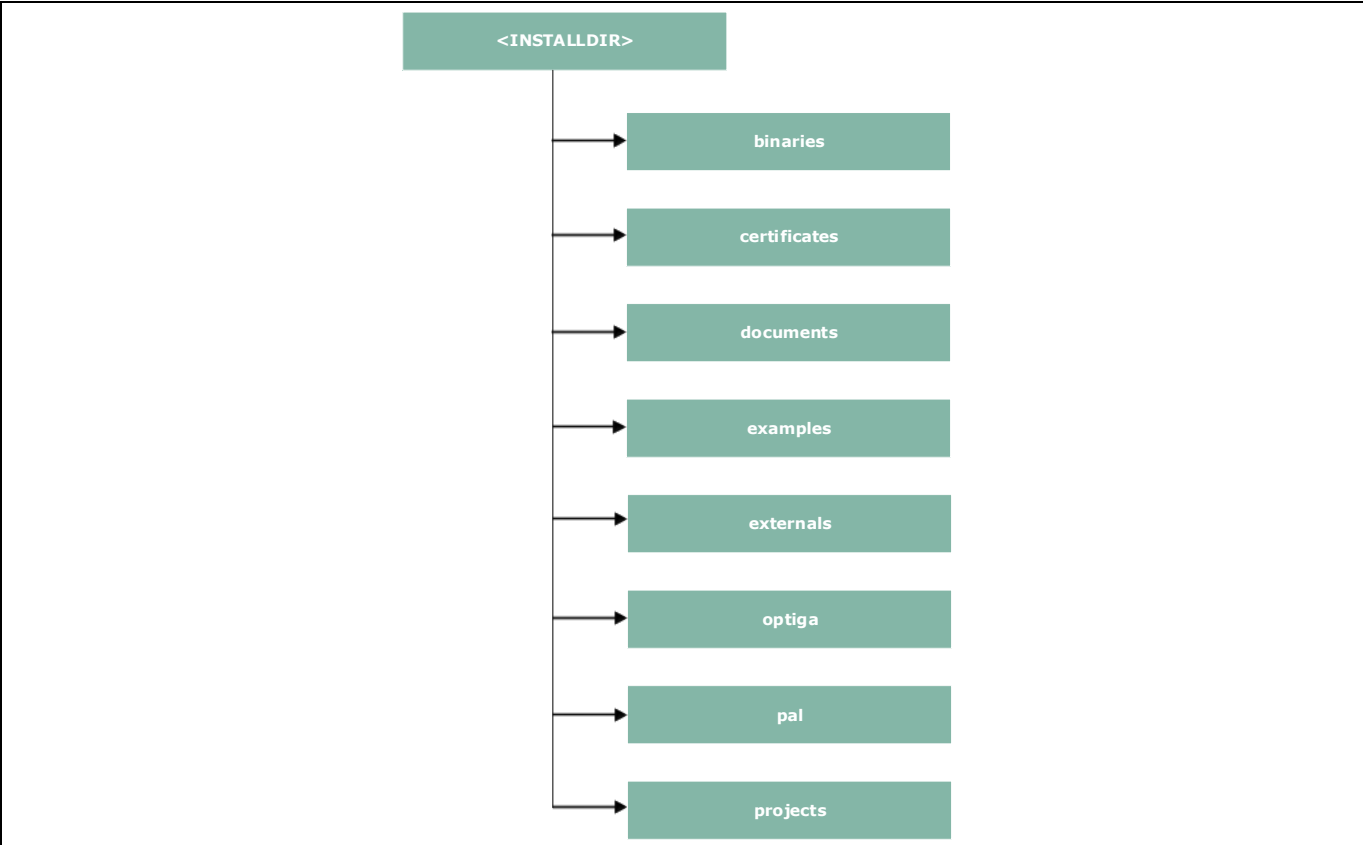


Figure 12 Release Package Folder Structure

About this document

1. <INSTALLDIR>

The root directory to which the release contents are installed or extracted. The content of each subdirectory in the installation directory <INSTALLDIR> is explained below.

2. Binaries

This directory contains binaries for OPTIGA™ Trust M1 Host Software.

3. Certificates

This directory contains OPTIGA™ Trust M1 Test and Productive CA certificates.

4. Documents

This directory contains all common OPTIGA™ Trust M1 documentation.

5. Examples

This directory contains the examples code for demonstration of crypt and util APIs.

6. Externals

This directory contains the external source code e.g. mbedTLS or wolfSSL etc.

7. Optiga

This directory contains OPTIGA™ Trust M1 host library source code which is platform agnostic.

8. Pal

This directory contains Platform Abstraction Layer source code which needs to be ported, depending on the platform (e.g. XMC4500)

9. Projects

This directory contains project files for build/compilation (e.g. XMC4500 based on Keil)

Further the following figure elaborates the OPTIGA™ Trust M1 Host Software folder structure.

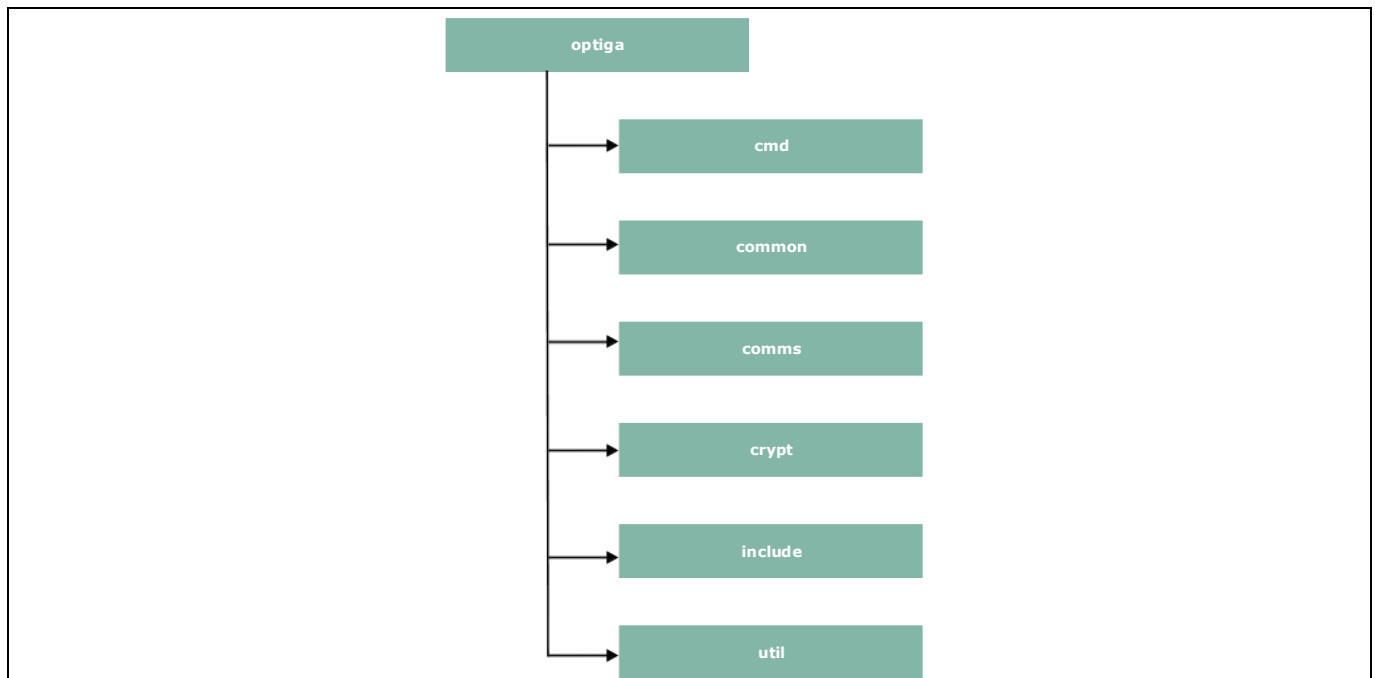


Figure 13 Host Source Folder Structure

1. cmd – This folder contains sources for all OPTIGA™ Trust M1 commands
2. common – This folder contains the common functions used across all the modules
3. comms – This folder contains the driver to communicate with OPTIGA™ Trust M1
4. crypt – This folder contains sources for cryptographic functionalities

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5. include – This folder contains header files for all OPTIGA™ Trust M1 Host Software
6. util – This folder contains utility functions e.g. read/write and open/close application

6.3 Porting Notes

The implementation of the Platform Abstraction Layer (PAL) need to be updated in order to migrate to a new target platform.

The PAL reference code for the XMC4500 Relax kit is provided as part of package which can be used. The implementation can be found in “<INSTALLDIR>/pal/xmc4500” and the header files are available in “<INSTALLDIR>/optiga/include” with the required APIs used by upper layers. The header files are platform agnostic and would not require any changes. The low level drivers used by PAL for XMC4500 are configured and generated using DAVE™.

6.4 Communication with OPTIGA™ Trust M1

The hardware/platform resource configuration with respect to I2C master and GPIOs (Vdd and Reset) are to be updated in [pal_ifx_i2c_config.c](#). These configurations are used by the IFX I2C implementation to communicate with OPTIGA™ Trust M1.

1. Update I2C master platform specific context[e.g. (void*)&i2c_master_0]

```

001      /**
002      * \brief PAL I2C configuration for OPTIGA
003      */
004      pal_i2c_t optiga_pal_i2c_context_0 =
005      {
006          /// Pointer to I2C master platform specific context
007          (void*)&i2c_master_0,
008          /// Slave address
009          0x30,
010          /// Upper layer context
011          NULL,
012          /// Callback event handler
013          NULL
014      };

```

2. Update platform specific context for GPIOs (Vdd and Reset) [e.g. (void*)&pin_3_4]

```

001      /**
002      * \brief Vdd pin configuration for OPTIGA
003      */
004      pal_gpio_t optiga_vdd_0 =
005      {
006          // Platform specific GPIO context for the pin used to toggle Vdd
007          (void*)&pin_3_4
008      };
009
010      /**
011      * \brief Reset pin configuration for OPTIGA
012      */
013      pal_gpio_t optiga_reset_0 =
014      {
015          // Platform specific GPIO context for the pin used to toggle Reset
016          (void*)&pin_3_3
017      };

```

About this document

3. Update PAL I2C APIs [[pal_i2c.c](#)] to communicate with OPTIGA™ Trust M1

The `pal_i2c` is expected to provide the APIs for I2C driver initialization, de-initialization, read, write and set bitrate kind of operations

- a) [pal_i2c_init](#)
- b) [pal_i2c_deinit](#)
- c) [pal_i2c_read](#)
- d) [pal_i2c_write](#)
- e) [pal_i2c_set_bitrate](#)

A few target platforms, the I2C master driver initialization ([pal_i2c_init](#)) is done during the platform start up. In such an environment, there is no need to implement [pal_i2c_init](#) and [pal_i2c_deinit](#) functions. Otherwise, these ([pal_i2c_init](#) & [pal_i2c_deinit](#)) functions must be implemented as per the upper layer expectations based on the need. The details of these expectations are available in the Host library API documentation (chm).

The reference implementation of PAL I2C based on XMC4500 Relax kit does not need to have the platform I2C driver initialization explicitly done as part of [pal_i2c_init](#) as it is taken care by the DAVE™ library initialization. Hence [pal_i2c_init](#) & [pal_i2c_deinit](#) are not implemented.

In addition to the above specified APIs, the PAL I2C must handle the events from the low level I2C driver and invoke the upper layer handlers registered with PAL I2C context for the respective transaction as shown in the below example.

```

001      //I2C driver callback function when the transmit is completed successfully
002      void i2c_master_end_of_transmit_callback(void)
003      {
004          invoke_upper_layer_callback(gp_pal_i2c_current_ctx,
005                                     (uint8_t) PAL_I2C_EVENT_TX_SUCCESS);
006      }
```

In above example the I2C driver callback, when transmission is successful invokes the handler to inform the result.

4. Update PAL GPIO [[pal_gpio.c](#)] to power on and reset the OPTIGA™ Trust M1

- a) [pal_gpio_set_high](#)
- b) [pal_gpio_set_low](#)

5. Update PAL Timer [[pal_os_timer.c](#)] to enable timer

- a) [pal_os_timer_get_time_in_milliseconds](#)
- b) [pal_os_timer_delay_in_milliseconds](#)

6. Update Event management for the asynchronous interactions for IFX I2C [[pal_os_event.c](#)]

- a) [pal_os_event_register_callback_oneshot](#)
- b) [pal_os_event_trigger_registered_callback](#)

The [pal_os_event_register_callback_oneshot](#) function is expected to register the handler and context provided as part of input parameters and triggers the timer for the requested time. The `p_pal_os_event` is an event instance created using [pal_os_event_create](#).

```

001      void pal_os_event_register_callback_oneshot(
002          pal_os_event_t * p_pal_os_event,
003          register_callback callback,
004          void* callback_args,
005          uint32_t time_us)
```

About this document

```

006      {
007          p_pal_os_event->callback_registered = callback;
008          p_pal_os_event->callback_ctx = callback_args;
009
010          //lint --e{534} suppress "Return value is not required to be checked"
011          TIMER_SetTimeInterval(&scheduler_timer, (time_us*100));
012          TIMER_Start(&scheduler_timer);
013      }

```

The handler registered must be invoked once the timer has elapsed as shown in [pal_os_event_trigger_registered_callback](#). The [pal_os_event_trigger_registered_callback](#) is to be registered with event timer interrupt to get triggered when the timer expires. The pal_os_event_0 is the instance in the pal_os_event used to store the registered callback and context.

```

001      void pal_os_event_trigger_registered_callback(void)
002      {
003          register_callback callback;
004
005          TIMER_ClearEvent(&scheduler_timer);
006          //lint --e{534} suppress "Return value is not required to be checked"
007          TIMER_Stop(&scheduler_timer);
008          TIMER_Clear(&scheduler_timer);
009
010          if (pal_os_event_0.callback_registered)
011          {
012              Callback = pal_os_event_0.callback_registered;
013              callback ((void*)callback_ctx);
014          }
015      }

```

6.5 Reference code on XMC4500 for communicating with OPTIGA™ Trust M1

```

001      static volatile uint32_t optiga_pal_event_status;
002      static void optiga_pal_i2c_event_handler(void* upper_layer_ctx,
003      uint8_t event);
004
005      pal_i2c_t optiga_pal_i2c_context_0 =
006      {
007          /// Pointer to I2C master platform specific context
008          (void*)&i2c_master_0,
009          /// Slave address
010          0x30,
011          /// Upper layer context
012          NULL,
013          /// Callback event handler
014          NULL,
015      };
016
017      // OPTIGA pal i2c event handler
018      static void optiga_pal_i2c_event_handler(void* upper_layer_ctx,
019      uint8_t event)
020      {
021          optiga_pal_event_status = event;
022      }

```


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```

023      /* Function to verify I2C communication with OPTIGA */
024      pal_status_t test_optiga_communication(void)
025      {
026          pal_status_t pal_return_status;
027          uint8_t data_buffer[10] = {0x82};
028
029          // set callback handler for pal i2c
030          optiga_pal_i2c_context_0.upper_layer_event_handler =
031              optiga_pal_i2c_event_handler;
032
033          // Send 0x82 to read I2C_STATE from optiga
034          do
035          {
036              optiga_pal_event_status = PAL_I2C_EVENT_BUSY;
037              pal_return_status =
038                  pal_i2c_write(&optiga_pal_i2c_context_0,
039                              data_buffer,
040                              1);
041              if (PAL_STATUS_FAILURE == pal_return_status)
042              {
043                  // Pal I2C write failed due to I2C busy is in busy
044                  // state or low level driver failures
045                  break;
046              }
047
048              // Wait until writing to optiga is completed
049          } while (PAL_I2C_EVENT_SUCCESS != optiga_pal_event_status);
050
051
052          // Read the I2C_STATE from OPTIGA
053          do
054          {
055              optiga_pal_event_status = PAL_I2C_EVENT_BUSY;
056              pal_return_status =
057                  pal_i2c_read(&optiga_pal_i2c_context_0 ,
058                              data_buffer ,
059                              4);
060              // Pal I2C read failed due to I2C busy is in busy
061              // state or low level driver failures
062              if (PAL_STATUS_FAILURE == pal_return_status)
063              {
064                  break;
065              }
066              // Wait until reading from optiga is completed
067          } while (PAL_I2C_EVENT_SUCCESS != optiga_pal_event_status);
068
069          return pal_return_status;
070      }
071
072      /* Main Function */
073      int32_t main(void)
074      {
075          DAVE_STATUS_t status;
076          pal_status_t pal_return_status;
077
078          // Initialisation of DAVE Apps

```

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```
079         status = DAVE_Init();
080
081         // Stop if DAVE init fails
082         if (DAVE_STATUS_FAILURE == status)
083         {
084             while (1U)
085             {;}
086         }
087         pal_return_status = test_optiga_communication();
088
089         return (int32_t)pal_return_status;
090     }
```

About this document

7 OPTIGA™ Trust M1 External Interface

7.1 Commands

This section provides short description of the commands exposed by the OPTIGA™ Trust M1 security chip and mapping of these commands w.r.t Use Cases.

Table 13 Command table

| Command Name | Description |
|--------------------|--|
| OpenApplication | Command to launch an application |
| CloseApplication | Command to close/hibernate an application |
| GetDataObject | Command to get (read) a data object |
| SetDataObject | Command to set (write) a data object |
| SetObjectProtected | Command to set (write) data objects protected (integrity protection) |
| GetRandom | Command to generate a random stream |
| CalcHash | Command to calculate a Hash |
| CalcSign | Command to calculate a signature |
| VerifySign | Command to verify a signature |
| CalcSSec | Command to execute a Diffie-Hellmann key agreement |
| DeriveKey | Command to derive keys |
| GenKeyPair | Command to generate public/private key pairs |
| EncryptAsym | Command to encrypt a message |
| DecryptAsym | Command to decrypt a message |

Table 14 Mapping of commands with Use cases

| Use Case | OPTIGA™ Trust M1 commands used |
|---|---|
| Secure Communication with (D)TLS | GetRandom, CalcHash, CalcSign, VerifySign, CalcSSec, DeriveKey, GenKeyPair, EncryptAsym and DecryptAsym |
| Datastore (user memory ~ 10kB) | GetDataObject and SetDataObject |
| Secure Firmware Update | VerifySign and DeriveKey |
| Secure update of Trust Anchors on Security Chip | SetObjectProtected command |

7.2 Crypto Performance

The performance metrics for various schemes are provided by the [Table 15](#) below. If not particularly mentioned, the performance is measured @ OPTIGA™ Trust M1 I/O interface with:

- I2C FM (400KHz)
- Without power limitation
- @ 25°C
- VCC = 3.3V
- RSA Signature scheme: RSA SSA PKCS#1 v1.5 without hashing
- ECDSA Signature scheme: ECDSA FIPS 186-3 without hashing
- Encryption/Decryption scheme: RSAES PKCS#1 v1.5
- Hash scheme: SHA256
- Key Derivation scheme: TLS v1.2 PRF SHA256

About this document

- RSA Key size: 2048 bits
- ECC Key size: 256 bits (NIST P-256)

Table 15 Crypto performance

| Scheme | Algorithm | Performance in ms ¹ | Performance with Shielded Connection in ms ¹ | Notes |
|------------------------------|---------------------|--------------------------------|---|---|
| Calculate signature | RSA | ~ 310 | ~ 315 | Doesn't include message hashing before calling a toolbox function |
| | ECDSA | ~ 60 | ~ 65 | |
| Verify signature | RSA | ~ 45 | ~ 55 | |
| | ECDSA | ~ 85 | ~ 90 | |
| Diffie-Hellman key agreement | ECC | ~ 60 | ~ 65 | Based on ephemeral key pair |
| Key pair generation | RSA | ~ 2900 ² | ~ 2910 | Generate 2048 bit RSA key pair |
| | ECC | ~ 75 | ~ 80 | Generate 256 bit ECC key pair |
| Encryption | RSA | ~ 30 | ~ 45 | Encrypt 127 bytes |
| Decryption | RSA | ~ 310 | ~ 320 | Decrypt 127 bytes |
| Key derivation | PRF as per TLS v1.2 | ~135 | ~ 150 | |
| Hash calculation | SHA256 | ~ 5 Kbyte/s | ~ 4.5 Kbyte/s | In blocks of 500 bytes |

¹Minimum Execution of the entire sequence in milli seconds, except the External World timings

²RSA key pair generation performance is not predictable and typically have a variation in performance. This could be significantly higher or lower as the one specified in the table which is an average value over collected samples.

About this document

8 Security Monitor

The Security Monitor is a central component which enforces the security policy of the OPTIGA™ Trust M1. It consumes security events sent by security aware parts of the OPTIGA™ Trust M1 embedded SW and takes actions accordingly as specified in Security Policy below.

8.1 Security Events

The events below actively influence the security monitor.

Table 16 Security Events

| Event | Description |
|-------------------------|---|
| Private Key Use | This event occurs in case the internal services are going to use an OPTIGA™ Trust M1 hosted private key. |
| Key Derivation | This event occurs in case the DeriveKey command gets applied on a persistent data object (not volatile data object as session context). In that case the persistent data object gets used as pre-shared secret. |
| Suspect System Behavior | This event occurs in case the embedded software detects inconsistencies with the expected behavior of the system. Those inconsistencies might be redundant information which doesn't fit to their counterpart. |

8.2 Security Policy

Security Monitor judges the notified security events regarding the number of occurrence over time and in case those violate the permitted usage profile of the system takes actions to throttle down the performance and thus the possible frequency of attacks.

The permitted usage profile is defined as:

1. t_{\max} is set to 5 seconds ($\pm 5\%$)
2. A Suspect System Behavior event is never permitted and will cause setting the Security Event Counter (SEC) to its maximum (= 255).
3. One protected operation (refer to [Table 16](#)) events per t_{\max} period.

In other words it must not allow more than one out of the protected operations per t_{\max} period (worst case, ref to bullet 3. above). This condition must be stable, at least after 500 uninterrupted executions of protected operations.

For more information, please refer to Solution Reference Manual document available as part of the package.

About this document

9 RoHS Compliance

On January 27, 2003 the European Parliament and the council adopted the directives:

- 2002/95/EC on the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment ("RoHS")
- 2002/96/EC on Waste Electrical and Electrical and Electronic Equipment ("WEEE")

Some of these restricted (lead) or recycling-relevant (brominated flame retardants) substances are currently found in the terminations (e.g. lead finish, bumps, balls) and substrate materials or mold compounds.

The European Union has finalized the Directives. It is the member states' task to convert these Directives into national laws. Most national laws are available, some member states have extended timelines for implementation. The laws arising from these Directives have come into force in 2006 or 2007.

The electro and electronic industry has to eliminate lead and other hazardous materials from their products. In addition, discussions are on-going with regard to the separate recycling of certain materials, e.g. plastic containing brominated flame retardants.

Infineon Technologies is fully committed to giving its customers maximum support in their efforts to convert to lead-free and halogen-free¹ products. For this reason, Infineon Technologies' "Green Products" are ROHS-compliant.

Since all hazardous substances have been removed, Infineon Technologies calls its lead-free and halogen-free semiconductor packages "green." Details on Infineon Technologies' definition and upper limits for the restricted materials can be found here.

The assembly process of our high-technology semiconductor chips is an integral part of our quality strategy. Accordingly, we will accurately evaluate and test alternative materials in order to replace lead and halogen so that we end up with the same or higher quality standards for our products.

The use of lead-free solders for board assembly results in higher process temperatures and increased requirements for the heat resistivity of semiconductor packages. This issue is addressed by Infineon Technologies by a new classification of the Moisture Sensitivity Level (MSL). In a first step the existing products have been classified according to the new requirements.



¹Any material used by Infineon Technologies is PBB and PBDE-free. Plastic containing brominated flame retardants, as mentioned in the WEEE directive, will be replaced if technically/economically beneficial.

About this document

10 Appendix A – Infineon I2C Protocol Registry Map

OPTIGA™ Trust M1 supports I2C v2.01 and is implemented as I2C slave, which uses different address locations for status, control and data communication registers. These registers with description are outlined below in the following table.

Table 17 I2C Registry Map Table

| Register Address | Name | Size in Bytes | Description | Master Access |
|------------------|----------------------------|---------------|--|---------------|
| 0x80 | DATA | DATA_REG_LEN | This is the location where data shall be read from or written to the I2C slave | Read / Write |
| 0x81 | DATA_REG_LEN | 2 | This register holds the maximum data register (Addr 0x80) length. The allowed values are 0x0010 up to 0xFFFF. After writing the new data register length it becomes effective with the next I2C master access. However, in case the slave could not accept the new length it indicates its maximum possible length within this register. Therefore it is recommended to read the value back after writing it to be sure the I2C slave did accept the new value. Note: the value of MAX_PACKET_SIZE is derived from this value or vice versa (MAX_PACKET_SIZE= DATA_REG_LEN-5) | Read / Write |
| 0x82 | I2C_STATE | 4 | Bits 31:24 of this register provides the I2C state in regards to the supported features (e.g. clock stretching ...) and whether the device is busy executing a command and/or ready to return a response etc. Bits 15:0 defining the length of the response data block at the physical layer. | Read only |
| 0x83 | BASE_ADDR | 2 | This register holds the I2C base address as specified by Table 18 . Default value is 0x30. After writing a different address the new address become effective with the next I2C master access. In case the bit 15 is set in addition to the new address (bit 6:0) it becomes the new default address at reset (persistent storage). | Write only |
| 0x84 | MAX_SCL_FREQ | 4 | This register holds the maximum clock frequency in KHz supported by the I2C slave. The value gets adjusted to the register I2C_Mode setting. Fast Mode (Fm): The allowed values are 50 up to 400. Fast Mode (Fm+): The allowed values are 50 up to 1000. | Read |
| 0x85 | GUARD_TIME ¹ | 4 | For details refer to Table 21 | Read only |
| 0x86 | TRANS_TIMEOUT ¹ | 4 | For details refer to Table 21 | Read only |

¹ In case the register returns 0xFFFFFFFF the register is not supported and the default values specified in Table 'List of protocol variations' shall be applied.

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| Register Address | Name | Size in Bytes | Description | Master Access |
|------------------|------------|---------------|---|---------------|
| 0x88 | SOFT_RESET | 2 | Writing to this register will cause a device reset. This feature is optional | Write only |
| 0x89 | I2C_MODE | 2 | This register holds the current I2C Mode as defined by Table 19 . The default mode is SM & FM (011B). | Read / Write |

Table 18 Definition of BASE_ADDR

| Fields | Bits | Value | Description |
|-----------|------|-----------|--|
| DEF_ADDR | 15 | 0 1 | Volatile address setting by bit 6:0, lost after reset. Persistent address setting by bit 6:0, becoming default after reset. |
| BASE_ADDR | 6:0 | 0x00-0x7F | I ² C base address specified by Table 17 |

| | | | | | | | |
|----------|-----------|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DEF_ADDR | RFU | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RFU | BASE_ADDR | | | | | | |

| | | | | | | | |
|----------|-----|----|----|----|------|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DEF_MODE | RFU | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RFU | | | | | Mode | | |
| | | | | | | | |

Table 19 Definition of I2C_MODE

| Fields | Bits | Value | Description |
|-------------------|------|--|--|
| DEF_MODE | 15 | 0 1 | Volatile mode setting by bit 2:0, lost after reset. Persistent mode setting by bit 2:0, becoming default after reset. This bit is always read as 0. |
| MODE ² | 2:0 | 001 010 011 100 other values | Sm Fm SM & Fm (fab out default) Fm+ not valid; writing will be ignored |

¹ In case the register returns 0xFFFFFFFF the register and its functionality is not supported

² This mode defines the adherence of the bus signals to the electrical characteristics according standard I2C bus specification

About this document

| | | | | | | | |
|---------------------------------|----------|-----|----|------------|-----------|-----------|----------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| BUSY | RESP_RDY | RFU | | SOFT_RESET | CONT_READ | REP_START | CLK_STRETCHING |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| PRESENT_LAYER | RFU | | | | | | |
| 15-0 | | | | | | | |
| Length of data block to be read | | | | | | | |

Table 20 Definition of I2C_STATE

| Field | Bit(s) | Value | Description |
|----------------|--------|-------|--|
| BUSY | 31 | 0 | Device is not busy |
| | | 1 | Device is busy executing a command |
| RESP_RDY | 30 | 0 | Device is not ready to return a response |
| | | 1 | Device is ready to return a response |
| SOFT_RESET | 27 | 0 | SOFT_RESET not supported |
| | | 1 | SOFT_RESET supported |
| CONT_READ | 26 | 0 | Continue Read not supported |
| | | 1 | Continue Read supported |
| REP_START | 25 | 0 | Repeated start not supported |
| | | 1 | Repeated start supported |
| CLK_STRETCHING | 24 | 0 | Clock stretching not supported |
| | | 1 | Clock stretching supported |
| PRESENT_LAYER | 23 | 0 | Presentation Layer not supported |
| | | 1 | Presentation Layer supported |

10.1 Infineon I2C Protocol Variations

To fit best to application specific requirements the protocol might be tailored by specifying a couple of parameters which is described in the following table.

Table 21 List of Protocol Variations

| Parameter | Default Value | Description |
|-----------------|---------------|--|
| MAX_PACKET_SIZE | 0x110 | Maximum packet size accepted by the receiver. The protocol limits this value to 0xFFFF, but there might be project specific requirements to reduce the transport buffers size for the sake of less RAM footprint in the communication stack. If shortened, it could be statically defined or negotiated at the physical layer. |
| WIN_SIZE | 1 | Window size of the sliding windows algorithm. The value could be 1 up to 2. |
| MAX_NET_CHAN | 1 | Maximum number of network channels. The value could be 1 up to 16. One indicates the OSI Layer 3 is not used and the CHAN field of the PCTR must be set to 0000. |
| CHAINING | TRUE | Chaining on the transport layer is supported (TRUE) or not (FALSE) |
| TRANS_TIMEOUT | 10 ms | (Re) transmission timeout specifies the number of milliseconds to be elapsed until the transmitter considers a frame |

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| Parameter | Default Value | Description |
|---------------|---------------|---|
| | | <p>transmission is lost and retransmits the non-acknowledged frame. The Timer gets started as soon as the complete frame is transmitted. The value could be 1 up to 1000. However, the higher the number, the longer it takes to recover from a frame transmission error.</p> <p><i>Note: The acknowledge timeout on the receiver side must be shorter than the retransmission timeout to avoid unnecessary frame repetitions.</i></p> |
| TRANS_REPEAT | 3 | Number of transmissions to be repeated until the transmitter considers the connection is lost and starts a re-synchronization with the receiver. The value could be 1 up to 4. |
| BASE_ADDR | 0x30 | I2C (base) address. This address could be statically defined or dynamically negotiated by the physical layer. |
| MAX_SCL_FREQ | 1000 kHz | Maximum SCL clock frequency in kHz. |
| GUARD_TIME | 50 μ s | <p>Minimum time to be elapsed at the I2C master measured from read data (STOP condition) until the next write data (Start condition) is allowed to happen.</p> <p><i>Note 1: For two consecutive accesses on the same device GUARD_TIME re-specifies the value of t_{BUF} as specified by [I2Cbus].</i></p> <p><i>Note 2: Even if another I2C address is accessed in between GUARD_TIME has to be respected for two consecutive accesses on the same device.</i></p> |
| SOFT_RESET | 1 | Any write attempt to the SOFT_RESET register will trigger a warm reset (reset w/o power cycle). This register is optional and its presence is indicated by the I2C_STATE register's "SOFT_RESET" flag. |
| PRESENT_LAYER | 1 | This flag at the I2C_STATE register indicates the optional availability of the presentation layer, which is providing confidentiality and integrity protection of payloads (APDUs) transferred across the I2C interface. The presentation layer is used as part of Shielded Connection. |

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11 Appendix B - OPTIGA™ Trust M1 Command/Response I2C Sample Logs

The default I2C slave address for the OPTIGA™ Trust M1 is 0x30 [I2C_ADDR]. All the values in this section are specified in decimal form unless stated otherwise.

11.1 Sequence of commands to read Coprocessor UID from OPTIGA™ Trust M1

Pre-requisites

1. Ensure that the security device is powered up
2. The OPTIGA™ Trust M1 will not acknowledge the slave address sent by a host if it is either busy or in idle state. Hence the host must retry or repeat the transaction until it is successful or timed out for 100 milliseconds (extreme case).
3. The specified guard time must be applied between each attempt of write / read operation by the Host I2C driver.
4. The log information for OPTIGA™ Trust M1 commands specified in below Tables contains the [IFX I2C] protocol information which comprises sequence numbers and checksum of the transactions.
 - a. A sequence of commands must be strict for the OPTIGA™ Trust M1 (e.g. OpenApplication followed by GetDataObject to read a Coprocessor UID)
 - b. A checksum in the data depends on the data received or sent via write/read operations. So any data change in the transaction is reflected in the check sum. Otherwise the write data transaction will not be accepted/acknowledged by the OPTIGA™ Trust M1.
5. The logs specified below are without the presentation layer (used for the Shielded Connection) of [IFX I2C]

11.1.1 Check the status [I2C_STATE]

This is a very basic register read operation which ensures the behavior of the read/write operations of the local host I2C driver.

Table 22 Check I2C_STATE Register of OPTIGA™ Trust M1

| I2C_ADDR | Transaction Type | Data [values in hexadecimal] |
|----------|--------------------|------------------------------|
| 30 | Write [01 Bytes] | 82 |
| 30 | Read [04 Bytes] | 08 80 00 00 |

11.1.2 Issue OpenApplication command

Before issuing any application specific command; e.g. read Coprocessor UID using GetDataObject, it is a must to send the OpenApplication command to initialize the application on the OPTIGA™ Trust M1 as shown below.

Table 23 OpenApplication on OPTIGA™ Trust M1

| I2C_ADDR | Transaction Type | Data [values in hexadecimal] |
|--|--------------------|--|
| Step 1: Send OpenApplication command to initiate the application context on the OPTIGA™ Trust M1 | | |
| 30 | Write [27 Bytes] | 80 03 00 15 00 70 00 00 10 D2 76 00 00 04 47 65 6E 41 75 74 68 41 70 70 6C 04 |

| I2C_ADDR | Transaction Type | Data [values in hexadecimal] |
|---|--------------------|--------------------------------------|
| Step 2: Read the I2C_STATE register <i>[Repeat this step until the read contains the data as specified below]</i> | | |
| 30 | Write [01 Bytes] | 82 |
| 30 | Read [04 Bytes] | C8 80 00 05 |
| Step 3: Read the DATA register <i>[Acknowledgment from OPTIGA™ Trust M1 for the last data transaction]</i> | | |
| 30 | Write [01 Bytes] | 80 |
| 30 | Read [05 Bytes] | 80 00 00 0C EC |
| Step 4: Read the I2C_STATE register <i>[Repeat this step until the read contains the data as specified below]</i> | | |
| 30 | Write [01 Bytes] | 82 |
| 30 | Read [04 Bytes] | 48 80 00 0A |
| Step 5: Read the DATA register which contains the response for the command issued | | |
| 30 | Write [01 Bytes] | 80 |
| 30 | Read [10 Bytes] | 00 00 05 00 00 00 00 00 14 87 |
| Step 6: Send an acknowledgment for the data read | | |
| 30 | Write [06 Bytes] | 80 80 00 00 0C EC |

About this document

12 Appendix C – Power Management

When operating, the power consumption of OPTIGA™ Trust M1 is limited to meet the requirements regarding the power limitation set by the Host. The power limitation is implemented by utilizing the current limitation feature of the underlying hardware device in steps of 1mA from 6mA to 15 mA with a precision of $\pm 5\%$.

12.1 Hibernation

This maximizes power saving (zero power consumption), while the I2C bus stays connected. In this case OPTIGA™ Trust M1 saves the application context before power-off (switching off V_{CC}) and restores it after power-up. After power-up the application continues seamlessly from the state before hibernate.

12.2 Low Power Sleep Mode

The OPTIGA™ Trust M1 automatically enters a low-power mode after a configurable delay. Once it has entered Sleep mode, the OPTIGA™ Trust M1 resumes normal operation as soon as its address is detected on the I2C bus. In case no command is sent to the OPTIGA™ Trust M1 it behaves as shown in [Figure 14](#).

1. As soon as the OPTIGA™ Trust M1 is idle it starts to count down the “delay to sleep” time (t_{SDY}).
2. In case this time elapses the device enters the “go to sleep” procedure.
3. The “go to sleep” procedure waits until all idle tasks are finished (e.g. counting down the SEC). In case all idle tasks are finished and no command is pending, the OPTIGA™ Trust M1 enters sleep mode.

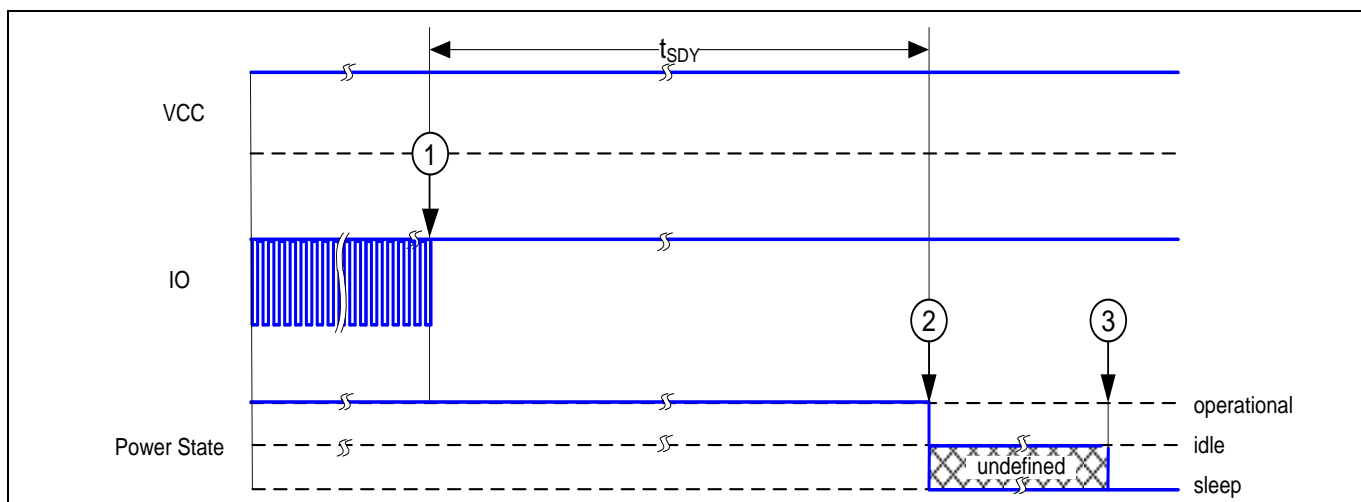


Figure 14 Go-to-Sleep Diagram

Revision history**Revision history**

| Document version | Date of release | Description of changes |
|------------------|-----------------|--|
| 1.60 | 2019-03-15 | RC release version |
| 1.50 | 2019-02-05 | ES release version |
| 1.40 | 2019-01-18 | Internal reviews incorporated |
| 1.30 | 2019-01-07 | Updates to all sections |
| 1.20 | 2018-10-01 | Second release with internal reviews incorporation |
| 1.10 | 2018-09-24 | Updates to all sections |
| 1.00 | 2018-07-07 | First Version Release |
| 0.50 | 2018-06-29 | Initial Version (Internal release) |

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