



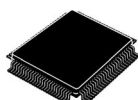
SR5 E1 line of Stellar electrification MCUs — 32-bit Arm® Cortex®-M7 automotive MCU 2x cores, 300 MHz, 2 MB flash, rich analog, 104 ps 24-channel high-resolution timer, HSM, and ASIL D



eTQFP100
(14 × 14 × 1.0 mm)




eTQFP144
(20 × 20 × 1.0 mm)



eLQFP176
(24 × 24 × 1.4 mm)



Features

- AEC-Q100 automotive qualified 
- SR5 high-performance analog MCUs offering:
 - Digital and analog high-frequency control requested by new wide-bandgap technologies (silicon carbide and gallium nitride)
 - Superior real-time and functional safety performance (ASIL-D capability)
 - Built-in fast and cost-optimized OTA (over-the-air) reprogramming capability (with built-in dual-image storage)
 - High-speed security cryptographic services (HSM)

Cores

- 2× 32-bit Arm® Cortex®-M7 with double-precision FPU, L1 cache and DSP instructions running at up to 300 MHz to reach 1284 DMIPS/2.14 DMIPS/MHz/core (Dhrystone 2.1)
 - Split-lock configuration, allowing either 2 cores in parallel or 1 core in lockstep configuration
- 2 DMA engines in lockstep configuration

Memories

- Up to 2 MB on-chip flash memory with read while write support
 - 1920 KB code flash memory split in two banks allowing 960 KB OTA reprogramming
 - 160 KB HSM dedicated code flash memory
- 96 KB data flash memory (64 KB + 32 KB dedicated to HSM)
- 488 KB on-chip general-purpose SRAM:
 - 2× 32 KB instruction TCM + 2× 64 KB data TCM
 - 256 KB system RAM
 - 40 KB HSM dedicated system RAM

Security: hardware security module (HSM)

- Cybersecurity ISO/SAE 21434 compliance (refer to the cybersecurity reference manual for details)
- On-chip high-performance security module with EVITA medium support with dedicated RAM and flash memory
- Based on a Cortex®-M0+ core running at up to 150 MHz
- Hardware accelerator for symmetric cryptography

Product status link

| Part number | Package |
|-------------|----------|
| SR5E1E3 | eTQFP100 |
| SR5E1E5 | eTQFP144 |
| SR5E1E7 | eLQFP176 |

Safety: comprehensive new generation ASIL-D safety concept

- State-of-the-art safety measures at all levels of the architecture for the most efficient implementation of ISO 26262 ASIL-D functionalities
- FCCU for collection and reaction to failure notifications with enhanced configurability
- Memory error management unit (MEMU) for collection and reporting of error events in memories
- Cyclic redundancy check (CRC) unit

Enhanced peripherals for fast control loop capability

- 12 timers:
 - 2× HRTIM (high-resolution and complex waveform builder) in total: 12× 16-bit counters, up to 102 ps resolution, 24 PWM
 - 2× 16-bit 6-channel advanced control timers in total, with up to 12× PWM
 - 2× 32-bit general-purpose timers in total, with up to 8× IC/OC/PWM or pulse counter and quadrature encoder input
 - 4× 16-bit general-purpose timers in total, with up to 11× PWM, 2 of which paired
 - 2× 16-bit basic timers
- Enhanced analog-to-digital converter system with:
 - 5 separate 12-bit SAR analog converters, 8 channels each. Sampling rate up to 2.5 MSPS in single mode, 5 MSPS in dual mode
 - 2 separate 16-bit sigma-delta analog converters
- 12-bit digital-to-analog converters (DAC)
 - 2 buffered external channels 1 MSPS
 - 8 unbuffered internal channels 15 MSPS
- 8 rail-to-rail analog comparators, 50 ns propagation delay
- Hardware accelerator
 - 1× CORDIC for trigonometric function acceleration

Communication interfaces

- 4 modular controller area network (MCAN) modules, all supporting flexible data rate (ISO CAN-FD)
- 3 UART modules with LIN functionality
- 4 serial peripheral interface (SPI) modules, 2 multiplexed with I²S interfaces
- 2 I²C modules

Advanced debug and trace for high-performance automotive application development

- Built around Arm® CoreSight™-600
- Debug interface: Arm® CoreSight™ JTAG (IEEE 1149.1) or SWD
- 4 KB embedded trace FIFO for both on- and off-chip tracing
- Trace port for off-chip tracing: parallel trace port configurable from 1 to 8 data lines

Others

- Power efficiency management, through separate power modes for any selected cores, peripherals or memories
- Boot assist flash (BAF) supports factory programming using a serial loader through CAN or UART
- Junction temperature range -40°C to 150°C
- Integrated power supply scheme:
 - Integrated internal SMPS regulator
 - 3.3 V supply & GPIOs

1 Introduction

1.1 Document overview

This document provides electrical specifications, pin assignments, and package diagrams for the SR5E1E3, SR5E1E5, SR5E1E7 microcontroller units (MCUs). For functional characteristics, refer to the device reference manual.

Note: For information on the Cortex®-M7 and Cortex®-M0+ cores, refer to the technical reference manuals, available from the www.arm.com website.

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1.2 Description

The SR5E1E3, SR5E1E5, SR5E1E7 MCU family has been designed to meet the enhanced digital control and high-performance analog requirements requested by the new wide bandgap power technologies, silicon carbide and GAN, from power conversion applications such as on-board charger and DC/DC converters as well as advanced motor control like traction inverter applications.

SR5E1E3, SR5E1E5, SR5E1E7 also offer superior real-time and safe performance with the highest ASIL-D capability, security cryptographic services (HSM) and high efficiency OTA reprogramming capability.

1.3 Device features

The following table lists a summary of major features for the SR5E1E3, SR5E1E5, SR5E1E7. A detailed description of the functionality provided by each on-chip module is given later in this document.

Table 1. Features list

| Feature | Description |
|---|---|
| Cores/memories | |
| Cortex®-M7 | |
| Number of cores/checker cores | 2 decoupled cores in split mode / 1 core with checker core in lock mode |
| Nominal frequency | 300 MHz |
| Tightly coupled memory (TCM) | 2× 32 KB instruction in split mode or 1× 64 KB instruction in lock mode 2× 64 KB data in split mode or 1× 128 KB data in lock mode |
| Floating-point unit | Single and double precision |
| Cache | 8 KB instruction (2 ways) for each core 16 KB data (4 ways) for each core |
| System memories | |
| On-chip code flash memory | 2 MB |
| On-chip data flash memory | 64 KB |
| Built-in memory replication for OTA reprogramming | Up to 960 KB flash available |
| System RAM | 2× 128 KB (not including HSM dedicated RAM - see HSM) |
| Others | |
| Multichannel eDMA (paired in lockstep) | 2 DMA engines, 8 streams each |
| Interrupt broadcasting system in lockstep | Up to 190 sources |
| Watchdogs | 2 independent and 2 window watchdogs |
| Security: hardware security module (HSM) | |
| Core | Cortex®-M0 @ 150 MHz, which is half the device frequency. |

| Feature | Description |
|--|--|
| C3 cryptography engine | Symmetric: <ul style="list-style-type: none"> AES-128/256, ECB, CBC, CMAC, GCM TRNG |
| Dedicated flash memory | 160 KB |
| Dedicated system RAM | 40 KB |
| Dedicated data flash | 32 KB |
| Peripheral, I/Os | |
| Timer modules | |
| High-resolution timer | 2 modules, 6× 16-bit channels each, up to 102 ps resolution Up to 24× PWM signals (or 12× paired) |
| Advance control timer | 2 modules, 16-bit timer Up to 8 input capture, 12 output compare (8 of which paired) |
| General-purpose timer | 2 modules, 32-bit timer. Up to 8 input capture/output compare 4 modules, 16-bit timer. Up to 11 capture/output compare inputs (2 of which paired) |
| Basic timer | 2 modules, 16-bit timer |
| Enhanced analog-to-digital converter system | |
| 12-bit SAR analog converters | 5 modules, 8 channels each Fast conversion, up to 2.5 MSPS in single mode, 5 MSPS in dual mode |
| 16-bit sigma-delta analog converters | 2 modules, 2 channels each (available only in eLQFP176 and eTQFP144 packages) Output conversion rate of 333 ksps (OSR = 24) |
| 12-bit analog comparators | 8 modules, rail-to-rail, 50 ns propagation delay |
| 12-bit digital-to-analog converters | 2 buffered external channels, 1 MSPS 8 unbuffered internal digital-to-analog channels, 15 MSPS |
| Hardware accelerator | |
| CORDIC (for trigonometric function acceleration) | 1 module |
| Communication interfaces | |
| UART modules (with LIN function) | 3 |
| MCAN supporting CAN-FD according to ISO 11898-1 2015 | 4 CAN shared message RAM: 4 KB / MCAN (16 KB in total) |
| Serial peripheral interface (SPI) | 4 |
| I ² C | 2 |
| Software development/emulation features | |
| Arm® CoreSight™ -600 libs | CoreSight™ -600 libs for trace links, trace sink, and control components CoreSight™ -400 libs for debug and trace source components |
| Debug interfaces | Arm® CoreSight™ -600 compliant <ul style="list-style-type: none"> Debug port (JTAG+SWD) |
| Trace types | Cortex®-M7 instruction and data trace |
| Off-chip trace | Arm® CoreSight™ parallel trace port (1 to 8 data lines, shared with user pins, not available in the eTQFP100 package) |
| Advance cross-trigger and performance measurement | CoreSight™ -600 CTI & CTM |
| Timestamp distribution | Arm® CoreSight™ timestamp generator |
| Security | Arm® CoreSight™ authentication |

| Feature | Description |
|-------------------------|---|
| | Password challenge with HSM |
| Debug controller | External tool-host CPU mailbox Host-based debugging Debug-under-reset |
| Others | |
| Low power mode | Clock gating management for selected cores, peripherals, and/or memories Smart wake-up mechanisms through events or interrupts |
| Temperature sensor | Yes |
| Self-test controller | Yes |
| PLL | 2 individual PLLs: 1 with a stable clock source for peripherals and 1 supporting frequency modulation for cores |
| Power supply | Single internal SMPS regulator for 3.3 V supply and GPIOs |
| Boot assist flash (BAF) | Supports factory programming using a serial loader through the asynchronous CAN or UART |
| CRC channel(s) | 1 |

Table 2. SR5E1E3, SR5E1E5, SR5E1E7 product selector

| Features | | SR5E1E3, SR5E1E5, SR5E1E7 |
|--|-------------------------------|--|
| Cortex®-M7 cores | | 2 cores, either decoupled or in lockstep |
| Nominal frequency in MHz | | 300 |
| Floating-point unit | | Single and double precision |
| Cache (instruction/data) per core in Kbyte | | 8 / 16 |
| Code flash in Mbyte | Overall included HSM in Mbyte | 2 |
| User code flash in Kbyte | | 1920 |
| HSM code NVM in Kbyte | | 160 |
| Code flash built-in memory replication for OTA reprogramming (not supported by HSM) in Kbyte | | Up to 2× 960 |
| Data flash in Kbyte | Overall included HSM | 96 |
| | User data flash | 64 |
| | HSM data flash | 32 |
| RAM in Kbyte | Overall | 488 |
| | TCM (instruction / data) | 64 / 128 |
| | User system RAM | 256 |
| | HSM system RAM | 40 |
| Hardware security module (HSM) | | Yes |
| DMA engines (number of channels) | Engine | 2 |
| | Channel | 2× 8 |
| Low power mode and smart wake-up schemes | | Yes |
| LIN and UART | | 3 |
| CAN (with CAN-FD) | | 4 |
| SPI | | 4 |
| Timers | Advanced control | 2 (16-bit) |
| | High-resolution | 2 (16-bit) |
| | General-purpose | 2 (32-bit) 4 (16-bit) |
| | Basic | 2 (16-bit) |
| 12-bit SAR analog converters | | 5 |
| 16-bit sigma-delta analog converters | | 2 |
| 12-bit analog comparators (with internal DAC) | | 8 |
| 12-bit external DAC | | 2 |
| Debug port | Main debug port (JTAG+SWD) | Yes |
| | Secondary debug port (SWD) | No |
| Max temperature (target) | Ambient temperature | 125°C |
| Junction temperature | | 150°C |
| Packages | eTQFP100 | X |
| | eTQFP144 | X |
| | eLQFP176 | X |

1.4

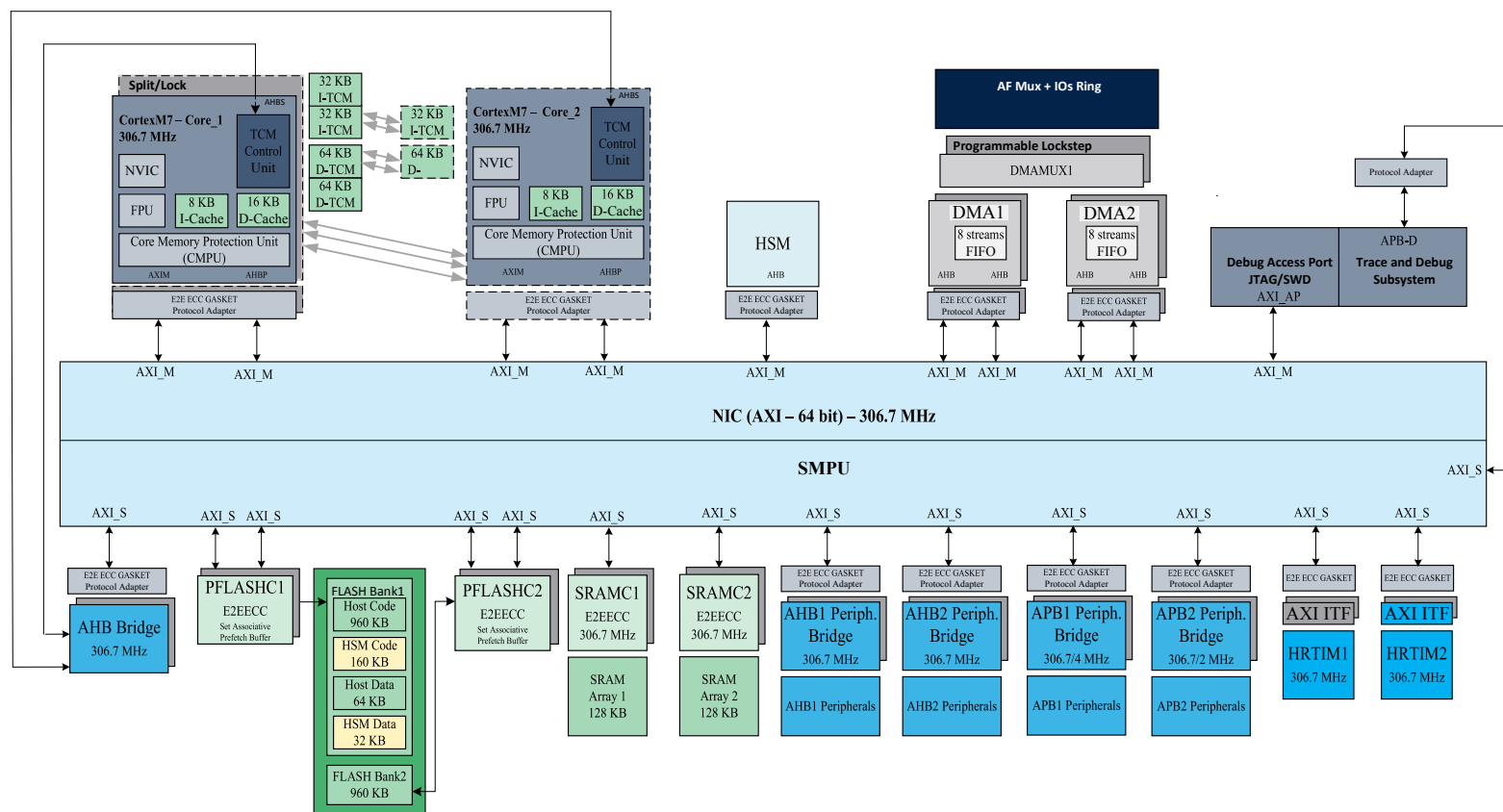
Block diagram

The figure below shows the top-level block diagram.

Figure 1. Block diagram

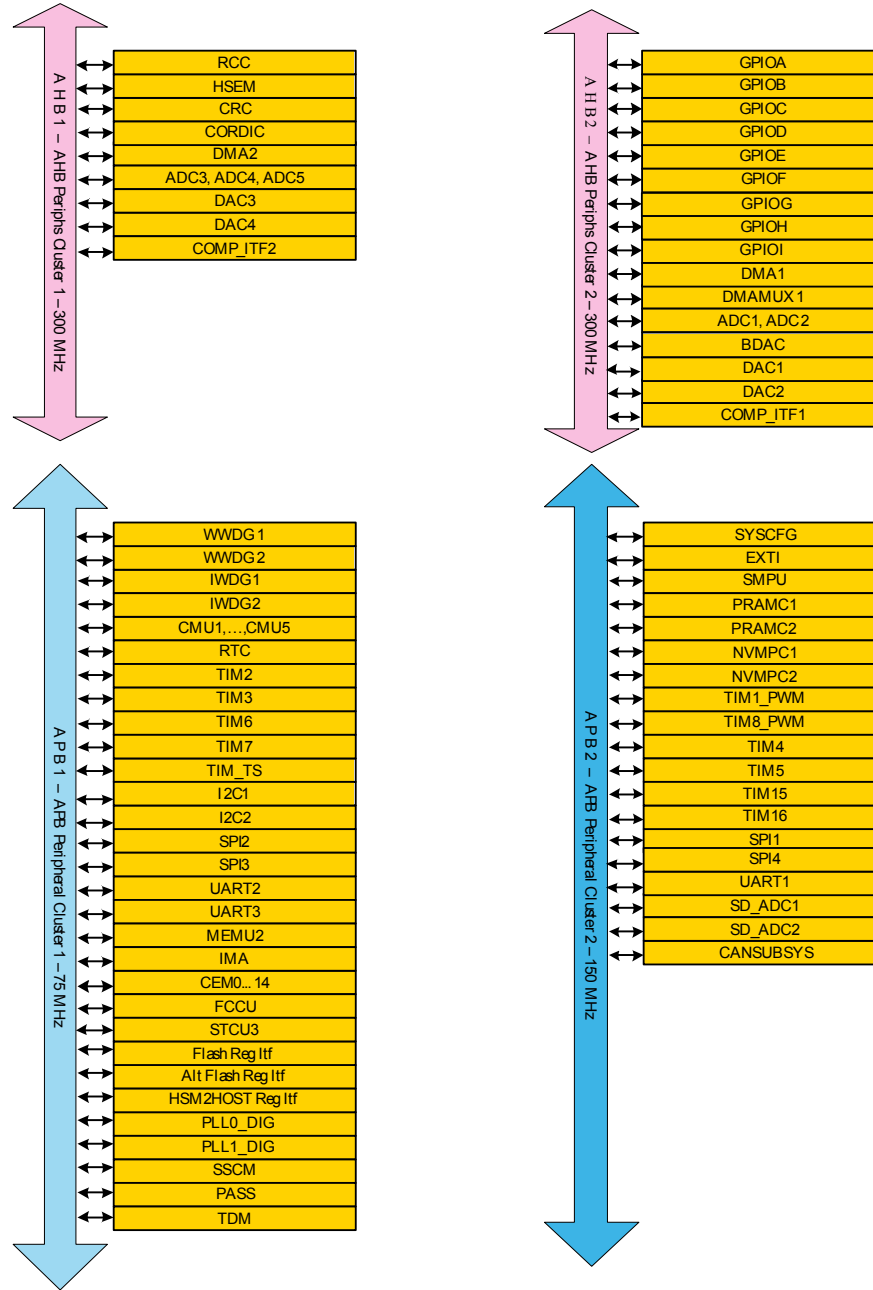
Dashed Core is implemented as Split/Lock configuration

All shadowed modules are in delay Lockstep configuration



The figure below shows the peripheral block diagram.

Figure 2. Peripheral allocation



2 Package pinouts and signal descriptions

Refer to the SR5E1E3, SR5E1E5, SR5E1E7 I/O definition Excel[®] file attached to the “Architecture mapping tables” technical note.

- Package pinouts
- Pin descriptions:
 - Power supply and reference voltage pins
 - System pins
 - Generic pins

3 Electrical characteristics

3.1 Introduction

In the tables where the device logic provides signals with their respective timing characteristics, the symbol “CC” (controller characteristics) is included in the “Symbol” column.

In the tables where the external system must provide signals with their respective timing characteristics to the device, the symbol “SR” (system requirement) is included in the “Symbol” column.

The electrical parameters shown in this document are classified by various methods. To give the customer a better understanding, the classifications listed in the table below are used and the parameters are tagged accordingly in the tables where appropriate.

Table 3. Parameter classifications

| Classification tag | Tag description |
|--------------------|--|
| P | Those parameters are tested in production on each individual device. |
| C | Those parameters are achieved by the design characterization by measuring a statistically relevant sample size across process variations. |
| T | Those parameters are achieved by design characterization on a small sample size from typical devices under typical conditions unless otherwise noted. All values shown in the typical column are within this category. |
| D | Those parameters are derived mainly from simulations. |

3.2 Absolute maximum ratings

The table below describes the maximum ratings for the device. Absolute maximum ratings are stress ratings only, and functional operation at the maxima is not guaranteed. Stress beyond the listed maxima may affect device reliability or cause permanent damage to the device.

Table 4. Absolute maximum ratings

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|------------------------------------|------|--|---|-------|-----|------|-------|
| | | | | Min | Typ | Max | |
| V _{SS} | SR D | Ground supply for the device. This is covering both V _{SS_LV} and V _{SS_HV} for the exposed pad device, unless specific notations. | — | -0.3 | — | 0.3 | V |
| V _{DD_LV} | CC D | Core voltage operating life range ⁽¹⁾ | — | -0.3 | — | 1.45 | V |
| V _{SS_HV_OSC} | SR D | Ground supply for oscillator | — | -0.3 | — | 0.3 | V |
| V _{DD_HV_OSC} | SR D | High voltage power supply for oscillator ⁽²⁾ | Reference to V _{SS_HV_OSC} | -0.3 | — | 3.6 | V |
| V _{DD_HV_IO} | SR D | I/O supply voltage and high voltage power supply for internal power management unit ⁽²⁾ | Reference to V _{SS} | -0.3 | — | 3.8 | V |
| V _{DD_HV_FLA} | SR D | High voltage power supply for flash ⁽²⁾ | — | -0.3 | — | 3.8 | V |
| V _{DD_HV_SAR} | SR D | SARADC supply voltage ⁽²⁾ | — | -0.3 | — | 3.8 | V |
| V _{DD_HV_SD_DAC_COMP} | SR D | High voltage power supply for SDADC, DAC and comparator ⁽²⁾ | — | -0.3 | — | 3.8 | V |
| HV_REFL_SD | SR D | SDADC ground reference | — | -0.3 | — | 0.3 | V |
| HV_REFH_SD | SR D | SDADC voltage reference | Reference to HV_REFL_SD | -0.3 | — | 3.8 | V |
| HV_REFL_SD - V _{SS} | SR D | SDADC ground reference differential voltage | — | -0.3 | — | 0.3 | V |
| HV_REFL_SAR | SR D | SARADC ground reference and SARADC analog ground | — | -0.3 | — | 0.3 | V |
| HV_REFH_SAR | SR D | SARADC voltage reference | Reference to HV_REFL_SAR | -0.3 | — | 3.8 | V |
| HV_REFL_SAR - V _{SS} | SR D | SARADC ground reference differential voltage | — | -0.3 | — | 0.3 | V |
| HV_REFL_DAC_COMP | SR D | Ground reference for DAC and comparator | — | -0.3 | — | 0.3 | V |
| HV_REFH_DAC_COMP | SR D | Voltage reference for DAC and comparator | Reference to HV_REFL_DAC_COMP | -0.3 | — | 3.8 | V |
| HV_REFL_DAC_COMP - V _{SS} | SR D | DAC and comparator ground reference differential voltage | — | -0.3 | — | 0.3 | V |
| V _{IN} | SR D | I/O input voltage range ⁽³⁾⁽⁴⁾ | Relative to V _{SS} | -0.3 | — | 3.8 | V |
| T _{TRIN} | SR D | Digital input pad transition time ⁽⁵⁾ | — | — | — | 1 | ns |
| I _{INJ} | SR T | Maximum DC injection current for each analog/digital PAD ⁽⁶⁾ | — | -5 | — | 5 | mA |
| T _{STG} | SR D | Maximum non-operating Storage temperature range | — | -55 | — | 125 | °C |
| T _{STORAGE} | SR D | Maximum storage time, assembled part programmed in ECU | No supply; storage temperature in range -40°C to 60°C | — | — | 20 | years |
| T _{SDR} | SR T | Maximum solder temperature Pb-free packaged ⁽⁷⁾ | — | — | — | 260 | °C |
| MSL | SR T | Moisture sensitivity level ⁽⁸⁾ | — | — | — | 3 | — |

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|------------------------|----|-----------|-----------------------------|---|-----|-----|------|
| | | | | Min | Typ | Max | |
| T _{XRAY} dose | SR | T | Maximum cumulated XRAY dose | Typical range for X-rays source during inspection: 80 - 130 KV; 20 - 50 μ A | | | gray |

1. V_{DD_LV} : allowed 1.36 V - 1.45 V for 1 hour cumulative time at the given temperature profile. Remaining time allowed 1.345 V - 1.36 V for 10 hours cumulative time at the given temperature profile. Remaining time as defined in [Section 3.3: Operating conditions](#).
2. $V_{DD_HV_}$: allowed 3.45 V - 3.8 V (a maximum of 3.6 V for $V_{DD_HV_OSC}$) for 1 hour cumulative time at the given temperature profile, for 10 hours cumulative time with the device in reset at the given temperature profile. Remaining time as defined in [Section 3.3: Operating conditions](#).
3. The maximum input voltage on an I/O pin depends on the maximum associated I/O supply voltage. For the injection current condition on a pin, the voltage is equal to the supply plus the voltage drop across the internal ESD diode from I/O pin to supply. The diode voltage varies greatly across process and temperature, but a value of 0.3 V can be used for nominal calculations.
4. The relative value can be exceeded if design measures are taken to ensure the injection current limitation (parameter I_{INJ}).
5. This limitation applies to pads with digital input buffer enabled. If the digital input buffer is disabled, there are no maximum limits to the transition time.
6. The limits for the sum of all normal and injected currents on all pads within the same supply segment can be found in [Section 3.8.3: I/O pad current specifications](#). It is important to ensure that the sum of the injected currents does not exceed the current induced by the application on this supply domain. Exceeding such a value can cause the voltage on the supply domain to raise above the absolute maximum rating of this supply domain.
7. Solder profile per IPC/JEDEC J-STD-020D.
8. Moisture sensitivity per JEDEC test method A112.

Related links

- [3.3 Operating conditions on page 12](#)
- [3.8.3 I/O pad current specifications on page 24](#)
- [3.8.1 I/O input DC characteristics on page 18](#)
- [3.12.1 ADC input description on page 35](#)
- [3.12.2 SARADC 12-bit electrical specification on page 36](#)

3.3 Operating conditions

The table below describes the operating conditions for the device, and for which all the specifications in the data sheet are valid, except where explicitly noted. The device operating conditions must not be exceeded or the functionality of the device is not guaranteed.

Table 5. Operating conditions

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|------------------------|----|-----------|--|------------------------|----------------------|----------------------|------|
| | | | | Min | Typ | Max | |
| F _{SYS} | SR | P | Operating system clock frequency ⁽²⁾ | — | — | 306.7 | MHz |
| T _J | SR | P | Operating Junction temperature | High temperature range | | | °C |
| T _A | SR | P | Operating Ambient temperature | — | — | 125 | °C |
| V _{DD_LV} | CC | D | Core supply voltage ⁽³⁾ | — | 1.225 ⁽⁴⁾ | 1.345 ⁽⁵⁾ | V |
| V _{SS_HV_OSC} | SR | C | Ground supply for oscillator | — | — | 0.3 | V |
| V _{DD_HV_OSC} | SR | C | High voltage supply for oscillator | — | 3.15 ⁽⁶⁾ | 3.45 | V |
| V _{DD_HV_IO} | SR | P | IO supply voltage and high voltage power supply for internal power management unit | — | 3.15 ⁽⁶⁾ | 3.45 ⁽⁷⁾ | V |
| V _{DD_HV_SAR} | SR | P | SARADC supply voltage | — | 3.15 ⁽⁶⁾ | 3.45 ⁽⁷⁾ | V |

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|---|----|-----------|--|-------------------------------|---------------------|-----------------------|------|
| | | | | Min | Typ | Max | |
| V _{DD_HV_SD_DAC_COMP} | SR | P | High voltage power supply for SDADC, DAC and comparator | — | 3.15 ⁽⁶⁾ | 3.45 ⁽⁷⁾ | V |
| V _{DD_HV_FL} | SR | P | High voltage power supply for flash | — | 3.15 ⁽⁶⁾ | 3.45 ⁽⁷⁾ | V |
| HV_REFH_SD | SR | P | SDADC supply reference voltage ⁽⁸⁾ | — | 2.9 | 3.45 | V |
| HV_REFH_SD - V _{DD_HV_SD_DAC_COMP} | SR | D | SDADC reference differential voltage | — | — | 0 (Not allowed) | mV |
| HV_REFL_SD | SR | P | SDADC ground reference voltage | — | — | 0 | V |
| HV_REFL_SD - V _{SS} | SR | D | SDADC ground differential voltage | — | -25 | 25 | mV |
| HV_REFH_SAR | SR | P | SARADC supply reference voltage ⁽⁹⁾ | — | 2.7 | 3.45 | V |
| HV_REFH_SAR - V _{DD_HV_SAR} | SR | D | SARADC reference differential voltage | — | — | 0 (Not allowed) | mV |
| HV_REFL_SAR | SR | P | SARADC ground reference voltage and SARADC analog ground | — | 0 | 0.1 | V |
| HV_REFL_SAR - V _{SS} | SR | D | SARADC ground differential voltage | — | -25 | 25 | mV |
| HV_REFL_DAC_COMP | SR | P | Ground reference for DAC and comparator | — | — | 0 | V |
| HV_REFH_DAC_COMP | SR | P | Voltage reference for DAC and comparator | Reference to HV_REFL_DAC_COMP | 3.0 | 3.45 | V |
| HV_REFL_DAC_COMP - V _{SS} | SR | D | DAC and comparator ground reference differential voltage | — | -25 | 25 | mV |
| V _{RAMP_HV} | SR | D | Slew rate on HV power supply | — | 33 | 100 | V/ms |
| V _{IN} | SR | P | I/O input voltage range and high voltage power supply for internal power management unit | — | 0 | V _{DD_HV_IO} | V |
| I _{INJ1} | SR | T | Injection current (per pin) without performance degradation ⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾ | Digital pins and analog pins | -3 | 3 | mA |
| I _{INJ2} | SR | D | Dynamic injection current (per pin) with performance degradation ⁽¹⁰⁾⁽¹³⁾ | Digital pins and analog pins | -10 | 10 | mA |

1. The ranges in this table are design targets and actual data may vary in the given range.
2. Maximum operating frequency is applicable to the cores and platform of the device. Refer to the device reference manual, Clocking chapter, for more information on the clock limitations for the various IP blocks on the device.
3. Core voltage is measured on device pin to ensure published silicon performance. This value is provided as information, but it is controlled internally by PMU. External low voltage supply is not supported in functional mode.
4. In the range [1.265-1.225] V the device functionality and specifications are ensured, but this interval is to be considered as a transient, in accordance with the mission profile, to ensure the product reliability. In the range [1.225-1.222] V, the device functionality is ensured, but this interval is to be considered as a transient. In the range [1.222-1.188] V, the device functionality is granted and the device is expected to receive a flag by the internal LVD119 monitors to warn that the regulator providing the V_{DD_LV} supply, exited the expected operating conditions. If the internal LVD119 monitors are disabled by the application, then an external voltage monitor with minimum threshold of V_{DD_LV(min)} = 1.19 V measured at the device pad, has to be implemented. Refer to Section 3.13.3: Voltage monitors for the list of available internal monitors and to the device reference manual for the configurability of the monitors.

5. In the range [1.31-1.345] V the device functionality and specifications are ensured, but this interval is to be considered as a transient, in accordance with the mission profile, to ensure the product reliability. In the range [1.345-1.361] V, the device functionality is ensured, but this interval is to be considered as a transient. In the range [1.361-1.399] V, the device functionality is granted and the device is expected to receive a flag by the internal HVD140 monitors to warn that the regulator providing the V_{DD_LV} supply, exited the expected operating conditions. Refer to [Section 3.13.3: Voltage monitors](#) for the list of available internal monitors and to the device reference manual for the configurability of the monitors. Possible permanent failure over 1.4 V.
6. In the range [3.012-3.15] V, the device functionality is ensured, but this interval is to be considered as a transient, in accordance with the mission profile, to ensure the product reliability. In the range [3.012-2.898] the device functionality is granted and the device is expected to receive a flag by the internal LVD290 monitors. Refer to [Section 3.13.3: Voltage monitors](#) for the list of available internal monitors and to the Reference Manual for the configurability of the monitors.
7. In the range [3.45-3.651] V, the device functionality is ensured, but this interval is to be considered as a transient, in accordance with the mission profile, to ensure the product reliability. In the range [3.651-3.799] the device functionality is granted and the device is expected to receive a flag by the internal UVD380 monitors. Refer to [Section 3.13.3: Voltage monitors](#) for the list of available internal monitors and to the Reference Manual for the configurability of the monitors.
8. To be always ensured $V_{DD_HV_SD_DAC_COMP} \geq HV_REFH_SD$.
9. To be always ensured $V_{DD_HV_SAR} \geq HV_REFH_SAR$.
10. The limits for the sum of all normal and injected currents on all pads within the same supply segment can be found in [Section 3.8.3: I/O pad current specifications](#).
11. The I/O pins on the device are clamped to the I/O supply rails by ESD protection. When the voltage of the input pins is above the supply rail, the current is injected through the clamp diode to the supply rails, with diode voltage drop varying across the temperature.
12. Full device lifetime. I/O and analog input specifications are only valid if the injection current on adjacent pins is within these limits. Refer to [Section 3.2: Absolute maximum ratings](#) for maximum input current for reliability requirements.
13. Positive and negative dynamic current injection pulses are allowed up to this limit, with different specifications for I/O, ADC accuracy and analog input. Refer to the dedicated chapters for the different specification limits. See the [Table 4. Absolute maximum ratings](#) for maximum input current for reliability requirements. Refer to the following pulses definitions: Pulse1 (ISO 7637-2:2011), Pulse 2a(ISO 7637-2:2011 5.6.2), Pulse 3a (ISO 7637-2:2011 5.6.3), Pulse 3b (ISO 7637-2:2011 5.6.3).

Table 6. TCM wait state configuration

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-----------------------|----|--|------------|-------|-----|-----|------|
| | | | | Min | Typ | Max | |
| Core ITCM wait states | CC | D ITCM access wait state from own core | — | 0 | | | WS |
| Core DTCM wait states | CC | D DTCM access wait state from own core | — | 0 | | | WS |

Table 7. PRAM wait state configuration

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-------------------|----|------------------------------------|------------|-------|-----|-----|------|
| | | | | Min | Typ | Max | |
| PRAMC MEMACC_WAIT | SR | D System RAM read/write wait state | — | 0 | 0 | 0 | WS |

Related links

- [3.2 Absolute maximum ratings on page 11](#)
- [3.8.3 I/O pad current specifications on page 24](#)
- [3.12.1 ADC input description on page 35](#)
- [3.13.3 Voltage monitors on page 57](#)

3.3.1 Power domains and power-up/-down sequencing

The following table shows the constraints and relationships for the different power domains. Supply1 (on rows) can exceed Supply2 (on columns), only if the cell at the given row and column is reporting 'ok'. This limitation is valid during power-up and power-down phases, as well as during normal device operation.

Table 8. Device supply relation during power-up/-down sequence

| | | Supply2 | | | | | | | |
|---------|--------------------------------|-----------------------|------------------------|-------------------------|------------------------|--------------------------------|-------------|------------|------------------|
| | | V _{DD_HV_IO} | V _{DD_HV_OSC} | V _{DD_HV_FL A} | V _{DD_HV_SAR} | V _{DD_HV_SD_DAC_COMP} | HV_REFH_SAR | HV_REFH_SD | HV_REFH_DAC_COMP |
| Supply1 | V _{DD_HV_IO} | | OK | OK | OK | OK | OK | OK | OK |
| | V _{DD_HV_OSC} | OK | | OK | OK | OK | OK | OK | OK |
| | V _{DD_HV_FL A} | OK | OK | | OK | OK | OK | OK | OK |
| | V _{DD_HV_SAR} | OK | OK | OK | | OK | OK | OK | OK |
| | V _{DD_HV_SD_DAC_COMP} | Not allowed | OK | OK | OK | | OK | OK | OK |
| | HV_REFH_SAR | OK | OK | OK | Not allowed | OK | | OK | OK |
| | HV_REFH_SD | Not allowed | OK | OK | OK | Not allowed | OK | | OK |
| | HV_REFH_DAC_COMP | OK | OK | OK | OK | Not allowed | OK | OK | |

During power-up, all functional terminals are maintained in a known state as described in the SR5E1E3, SR5E1E5, SR5E1E7 I/O definition Excel[®] file attached to the "Architecture mapping tables" technical note.

3.4 Electrostatic discharge (ESD)

The following table describes the ESD ratings of the device.

Table 9. ESD ratings

| Symbol | C | T | Parameter ⁽¹⁾⁽²⁾ | Conditions | Value | | | Unit |
|---------|----|---|---|------------------|-------|-----|------|------|
| | | | | | Min | Typ | Max | |
| ESD_HBM | SR | T | ESD for human body model (HBM) ⁽³⁾ | All pins | — | — | 2000 | V |
| ESD_CDM | SR | T | ESD for field induced charged device model (CDM) ⁽⁴⁾ | All terminals | — | — | 500 | V |
| | SR | T | | Corner terminals | — | — | 750 | V |

1. The device does not meet the device specification requirements after exposure to ESD pulses. This includes the complete DC parametrics and functional testing at room temperature and hot temperature. The maximum DC parametrics variation is within 10% of the maximum specification.
2. All ESD testing is in conformity with CDF-AEC-Q100 stress test qualification for automotive grade integrated circuits.
3. This parameter tested in conformity with ANSI/ESD STM5.1-2007 electrostatic discharge sensitivity testing.
4. This parameter tested in conformity with ANSI/ESD STM5.3-1990 charged device model - component level.

3.5 Electromagnetic emission characteristics

EMC measurements at integrated circuit level IEC standards can be requested to STMicroelectronics.

The 300 MHz nominal frequency is not suggested as the operating frequency due to possible EMC emissions in the GNSS band. The suggested (max) operating frequency is 306.7 MHz, refer to the "Clock tree" and PLL divider registers (PLL0DV and PLL1DV) in the reference manual.

3.6 Temperature profile

The device is qualified in accordance to AEC-Q100 Grade1 and customers' requirements.

3.7 Device consumption

The total device consumption seen from the HV domain is the sum of the total dynamic current on the high-voltage supply and the leakage current seen on the high-voltage domain (from LV domain through SMPS) for the selected temperature. So, it is: $I_{TOT} = I_{DD_HV} + I_{DD_HV_SMPS_LKG}$.

The following table reports each single contributor factor to the device consumption.

Refer to [Figure 3. Device consumption measurement](#) to see where each contributor is measured.

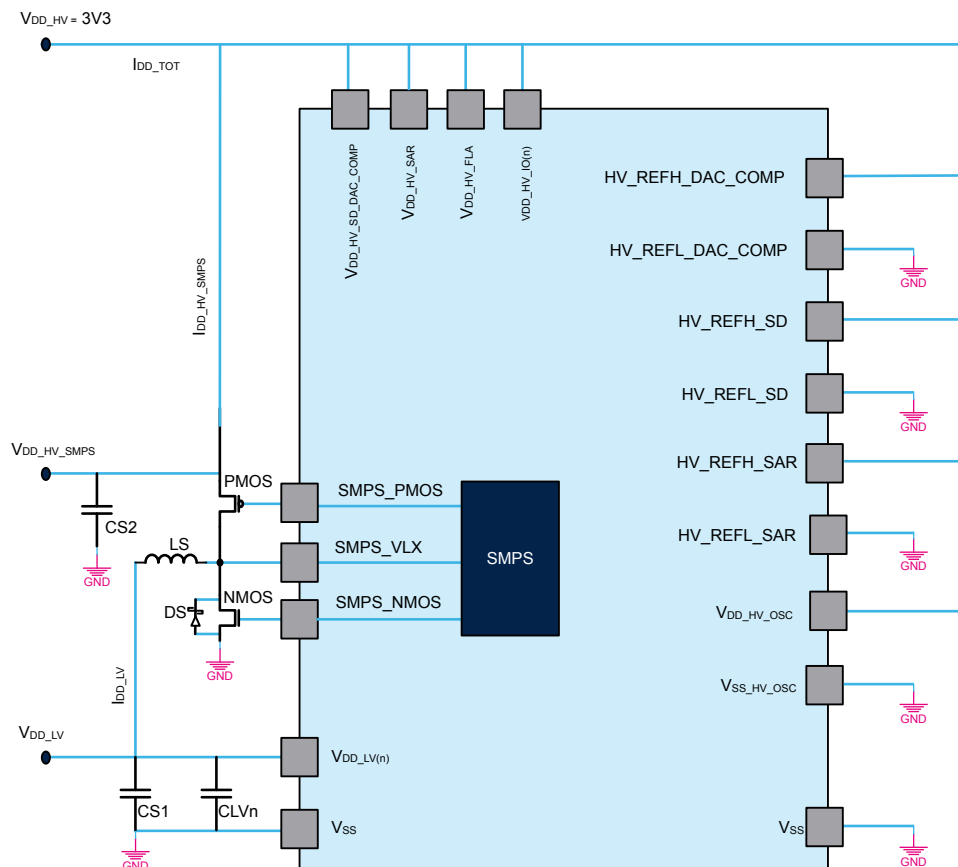
Table 10. Device consumption

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit | |
|--|----|-----------|--|--|-----|-----|------|-------|
| | | | | Min | Typ | Max | | |
| High-voltage domain (V _{DD_HV}) | | | | | | | | |
| I _{DD_HV} | CC | P | Total dynamic current on a high-voltage supply (V _{DD_HV}) | Motor control application profile ⁽²⁾ Freq = 300 MHz | — | 105 | 150 | mA |
| | | P | | Full case profile ⁽³⁾ Freq = 300 MHz | — | 150 | 205 | mA |
| I _{DD_HV_SMPS_LKG} ⁽⁴⁾ | CC | C | Leakage current is seen on the high-voltage domain (from LV domain through SMPS) | T _{amb} = 25°C | — | 10 | 40 | mA |
| | | P | | T _{amb} = 125°C | — | 105 | 430 | |
| I _{DD_HV_SMPS} ⁽⁴⁾ | CC | P | Dynamic current on external MOSFETs | Motor control application profile ⁽²⁾ Freq = 300 MHz | — | 90 | 135 | mA |
| | | P | | Full case profile ⁽³⁾ Freq = 300 MHz | — | 125 | 180 | mA |
| Low voltage domain (V _{DD_LV}) | | | | | | | | |
| I _{DD_LKG} ⁽⁵⁾⁽⁶⁾ | CC | C | Leakage current on digital supply (V _{DD_LV}) | T _{amb} = 25°C | — | 21 | 80 | mA |
| | | P | | T _{amb} = 125°C | — | 170 | 750 | |
| I _{DD_LV} ⁽⁶⁾ | CC | T | Dynamic current on digital supply (V _{DD_LV}) | Motor control application profile ⁽²⁾ Freq = 300 MHz | — | 205 | 240 | mA |
| | | T | | Full case profile ⁽³⁾ Freq = 300 MHz | — | 270 | 310 | mA |
| I _{DD_MAIN_m7} | CC | T | Main core dynamic current | Motor control application based ⁽⁷⁾ Freq = 300 MHz | — | 42 | 48 | mA |
| I _{DD_MAIN_Csleep} | CC | T | Dynamic current reduction with main core in CSleep | Full case profile ⁽⁸⁾ Freq = 300 MHz | — | 4 | 8 | mA |
| I _{SPIKE} | CC | T | Maximum short term current spike ⁽⁹⁾ | < 20 μs observation window | — | — | 100 | mA |
| dI | SR | D | Current difference ratio to average current (dI/avg(I)) | 20 μs observation window | — | — | 20 | % |
| I _{SR} ⁽¹⁰⁾ | CC | D | Current variation during power-up/-down | Refer to footnote ⁽¹¹⁾ | — | — | 2 | mA/ns |
| I _{DDOFF} | CC | T | Power-off current on high-voltage supply rails ⁽¹²⁾ | V _{DD_HV} = 2.5 V | 100 | — | — | μA |

1. The ranges in this table are design targets and actual data may vary in the given range.

2. Motor control application configured to drive single field-oriented control (FOC) 3-phase permanent magnet motors with ICS topology power stage (in open-loop). Position sensors used are encoder and sensor-less algorithms. IPs involved: Single core, 2× ADC channels, 6× timer channels (PWM generation), 2× timer channels (encoder), UART, DAC, CORDIC, xx I/O pins (yy configured as toggling output pins at different frequencies), GPIOs.
3. Full case profile - 2× M7 cores in lockstep. IPs involved: 5× SARADCs, 2× SDADCs, COMPs, 6× timer channels (PWM generation), 24× HRTIM channels (PWM generation), UART, DAC, CORDIC, 2× SPIs, CAN, 65 I/O pins (40 configured as toggling output pins at different frequencies), GPIOs.
4. $I_{DD_HV_SMPS_LKG}$ (leakage current) and $I_{DD_HV_SMPS}$ (dynamic current) are reported as separate parameters, to give an indication of the consumption contributors. The tests used in validation, characterization and production are verifying that the total consumption (leakage+dynamic) is lower than or equal to the sum of the maximum values provided ($I_{DD_HV_SMPS_LKG} + I_{DD_HV_SMPS}$). The two parameters, measured separately, may exceed the maximum reported for each, depending on the operative conditions and the software profile used.
5. The leakage considered is the sum of core logic and RAM memories. The contribution of analog modules is not considered, and it is computed in the dynamic I_{DD_LV} and I_{DD_HV} parameters.
6. I_{DD_LKG} (leakage current) and I_{DD_LV} (dynamic current) are reported as separate parameters, to give an indication of the consumption contributors. The tests used in validation, characterization and production verify that the total consumption (leakage+dynamic) is lower than or equal to the sum of the maximum values provided ($I_{DD_LKG} + I_{DD_LV}$). The two parameters, measured separately, may exceed the maximum reported for each, depending on the operative conditions and the software profile used.
7. Main core dynamic consumption contribution based on motor control profile. Dedicated I/D-caches and I/D-TCMs contribution are not included.
8. Dynamic current reduction with the main core in CSleep, based on the full case profile.
9. The current spike can occur during a normal operation that is above the average current, measured on the application-specific pattern. Internal schemes must be used (for example frequency ramping, feature enable) to ensure that incremental demands are made on the external power supply. Refer to [Section 3.13: Power management](#) for the details and the external component requirements.
10. This specification is the maximum value and is a boundary for the dl specification.
11. Condition 1: for power, on period from 0 V up to normal operation with reset asserted. Condition 2: from reset asserted until PLL running free. Condition 3: increasing PLL from free frequency to full frequency. Condition 4: reverse order for power down to 0 V.
12. I_{DDOFF} is the minimum ensured consumption of the device during power-up.

Figure 3. Device consumption measurement



3.8 I/O pad specification

The following table describes the different pad type configurations.

Table 11. I/O pad specification descriptions

| Pad type | Description |
|-------------------------|---|
| Slow configuration | Provides a good compromise between transition time and low electromagnetic emission. |
| Medium configuration | Provides transition fast enough for the serial communication channels with controlled current to reduce electromagnetic emission. |
| Fast configuration | Provides fast transition speed; used for fast interface. |
| Very fast configuration | Provides maximum speed and controlled symmetric behavior for rise and fall transition. Used for fast interface requiring fine control of rising/falling edge jitter. |
| Input only pads | These low input leakage pads are associated with the ADC channels. |

Note: Each I/O pin on the device supports specific drive configurations. Refer to the signal description table in the device reference manual for the available drive configurations for each I/O pin.

3.8.1 I/O input DC characteristics

The following table provides input DC electrical characteristics, as described in the following figure.

Figure 4. I/O input electrical characteristics

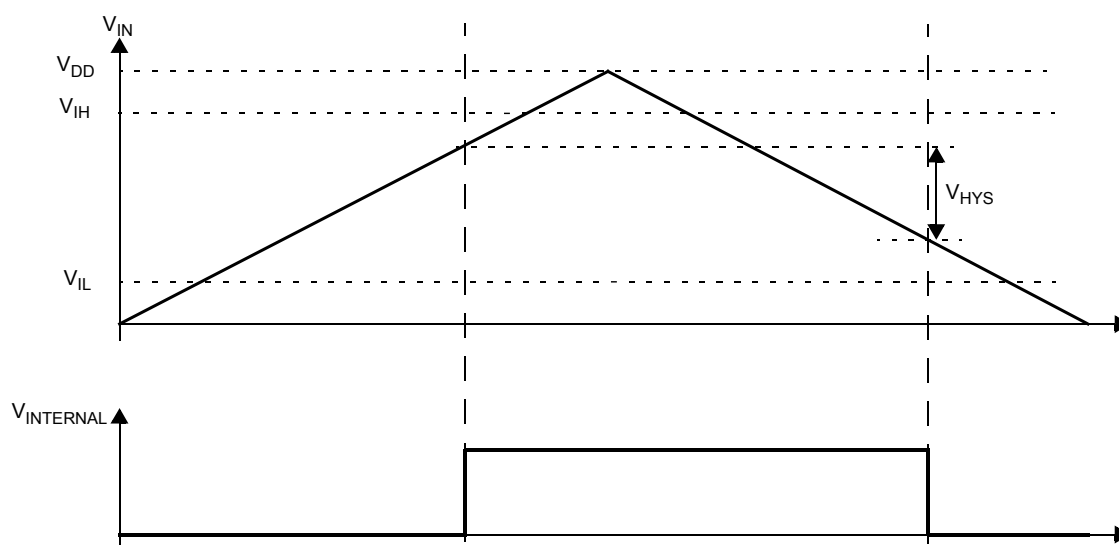


Table 12. I/O input electrical characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit | |
|---------------------|----|-----------|-------------------------------------|-------|------|-----|-----------------------------|---|
| | | | | Min | Typ | Max | | |
| TTL | | | | | | | | |
| V _{ihttl} | SR | P | Input high level TTL ⁽¹⁾ | — | 2 | — | V _{DD_HV_IO} + 0.3 | V |
| V _{ilttl} | SR | P | Input low level TTL ⁽¹⁾ | — | -0.3 | — | 0.8 | V |
| V _{hysttl} | CC | C | Input hysteresis TTL ⁽¹⁾ | — | 0.3 | — | — | V |

| Symbol | C | Parameter | Conditions | Value | | | Unit | |
|------------------------------------|----|--|--|---|------------------------------|------|------------------------------|----|
| | | | | Min | Typ | Max | | |
| Automotive | | | | | | | | |
| V _{ihaut} ⁽²⁾ | SR | P | Input high level AUTO | V _{DD_HV_IO} = 3.3 V ± 5% | 0.75 * V _{DD_HV_IO} | — | V _{DD_HV_IO} + 0.3 | V |
| V _{ilaut} ⁽³⁾ | SR | P | Input low level AUTO | V _{DD_HV_IO} = 3.3 V ± 5% | -0.3 | — | 0.35 * V _{DD_HV_IO} | V |
| V _{hysaut} ⁽⁴⁾ | CC | C | Input hysteresis AUTO | V _{DD_HV_IO} = 3.3 V ± 5% | 0.11 * V _{DD_HV_IO} | — | — | V |
| CMOS | | | | | | | | |
| V _{ihcmos} | SR | P | Input high level CMOS ⁽¹⁾ | — | 0.65 * V _{DD_HV_IO} | — | V _{DD_HV_IO} + 0.3 | V |
| V _{ilcmos} | SR | P | Input low level CMOS ⁽¹⁾ | — | -0.3 | — | 0.35 * V _{DD_HV_IO} | V |
| V _{hyscmos} | CC | C | Input hysteresis CMOS ⁽¹⁾ | — | 0.10 * V _{DD_HV_IO} | — | — | V |
| Common | | | | | | | | |
| I _{LKG} | CC | P | Pad input leakage ⁽¹⁾ | Input-only pads, static leakage characteristics V _{DD_HV_IO} = 3.3 V ± 5% T _J = 150°C | — | — | 200 | nA |
| | | Fast pads, static leakage characteristics V _{DD_HV_IO} = 3.3 V ± 5% T _J = 150°C | | — | — | 800 | | |
| | | Very fast pads, static leakage characteristics V _{DD_HV_IO} = 3.3 V ± 5% T _J = 150°C | | — | — | 1000 | | |
| C _{P1} | CC | D | Pad capacitance | — | — | — | 3.5 | pF |
| V _{drift} | CC | D | Input V _{il} /V _{ih} temperature drift | In a 1 ms period, with a temperature variation <30°C | -50 | — | +50 | mV |

1. In the case of current injection pulses on one pad under the conditions and limits described in the parameter I_{INJ2} in [Section 3.2: Absolute maximum ratings](#), other pads of the same supply segment have a drift of 4 % above the maximum V_{il} and 4 % below the minimum V_{ih} limits. Similarly the parameter V_{hys} is decreased by 4 %.
2. A good approximation of the variation of the minimum value with the supply is given by the formula: 3.3 V range: $V_{IHAUT} = 0.75 * V_{DD_HV_IO}$
3. A good approximation of the variation of the maximum value with the supply is given by the formula: 3.3 V range: $V_{ILAUT} = 0.35 * V_{DD_HV_IO}$
4. A good approximation of the variation of the minimum value with the supply is given by the formula: 3.3 V range: $V_{HysAUT} = 0.11 * V_{DD_HV_IO}$

Table 13. I/O pull-up/pull-down electrical characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-----------|----|-----------|---------------------------------------|---|-----|-----|---------------|
| | | | | Min | Typ | Max | |
| I_{WPU} | CC | C | Weak pull-up current absolute value | $V_{IN} = 1.1\text{ V}^{(1)}$ | — | 130 | μA |
| | | P | | $V_{IN} = 0.69 * V_{DD_HV_IO}^{(2)}$ | 15 | — | |
| R_{WPU} | CC | D | Weak pull-up resistance | $V_{DD_HV_IO} = 3.3\text{ V} \pm 5\%$ | 24 | 45 | K Ω |
| I_{WPD} | CC | C | Weak pull-down current absolute value | $V_{IN} = 0.69 * V_{DD_HV_IO}^{(1)}$ | — | 130 | μA |
| | | P | | $V_{IN} = 0.9\text{ V}^{(2)}$ | 15 | — | |
| R_{WPD} | CC | D | Weak pull-down resistance | $V_{DD_HV_IO} = 3.3\text{ V} \pm 5\%$ | 20 | 38 | K Ω |

1. Maximum current when forcing a change in the pin level opposite to the pull configuration.
2. Minimum current when keeping the same pin level state as the pull configuration.

Related links

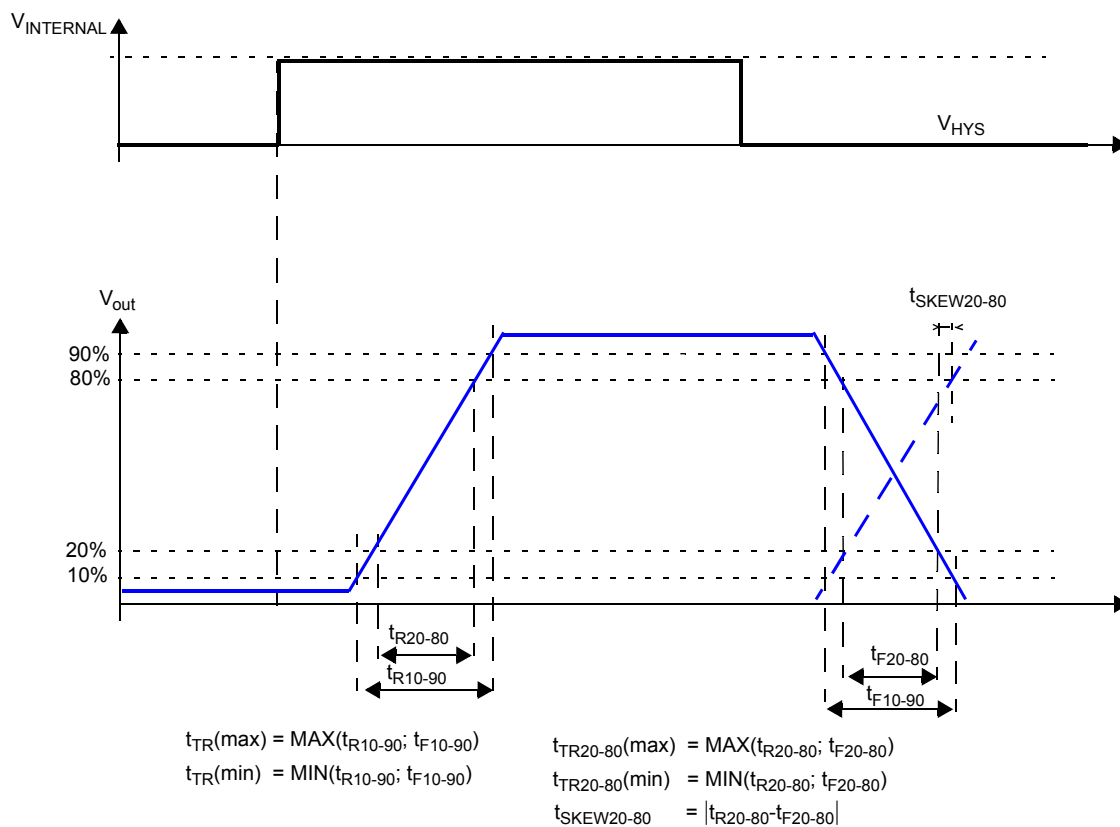
- [3.2 Absolute maximum ratings on page 11](#)
- [3.12.1 ADC input description on page 35](#)

3.8.2

I/O output DC characteristics

The figure below describes the output DC electrical characteristics.

Figure 5. I/O output DC electrical characteristics definition



The following tables provide DC characteristics for bidirectional pads.

Related links

- [3.15.1.2 JTAG interface timing on page 64](#)

3.8.2.1 Slow I/O output characteristics

The following table provides output driver characteristics for I/O pads in slow configuration.

Table 14. Slow I/O output characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-----------------|----|-----------|---|------------------------|-----|------------------------|----------|
| | | | | Min | Typ | Max | |
| V_{OL_S} | CC | D | Output low voltage for slow type pads $I_{OL} = 0.5 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | $0.1 * V_{DD_HV_IO}$ | V |
| V_{OH_S} | CC | D | Output high voltage for slow type pads $I_{OH} = 0.5 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | $0.9 * V_{DD_HV_IO}$ | — | — | V |
| R_S | CC | P | $V_{OL} = 0.1 * V_{DD_HV_IO}$ (static driver sink impedance) | 256 | — | 600 | Ω |
| | | | $V_{OH} = 0.9 * V_{DD_HV_IO}$ (static driver source impedance) | 256 | — | 600 | |
| F_{max_S} | CC | T | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | — | — | 2 | MHz |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | — | — | 1 | MHz |
| t_{TR_S} | CC | T | $V_{DD_HV_IO} = 3.3 \text{ V} + 5\%$ $C_L = 25 \text{ pF}$ | 23 | — | 83 | ns |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | 40 | — | 150 | ns |
| $ t_{SKEW_S} $ | CC | T | Rise / fall skew ($T_r - T_f$) / $\text{Max}[T_r, T_f]$ | — | — | 30 | % |
| I_{DCMAX_S} | CC | D | Maximum DC current $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | 0.5 | mA |

3.8.2.2 Medium I/O output characteristics

The following table provides output driver characteristics for I/O pads in medium configuration.

Table 15. Medium I/O output characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-----------------|----|-----------|---|----------------------------|-----|----------------------------|----------|
| | | | | Min | Typ | Max | |
| V_{OL_M} | CC | D | Output low voltage for medium type pads $I_{OL} = 2.0 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | $0.1 \cdot V_{DD_HV_IO}$ | V |
| V_{OH_M} | CC | D | Output high voltage for medium type pads $I_{OH} = 2.0 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | $0.9 \cdot V_{DD_HV_IO}$ | — | — | V |
| $R_{M_}$ | CC | P | Output impedance for medium type pads $V_{OL} = 0.1 \cdot V_{DD_HV_IO}$ (static driver sink impedance) | 64 | — | 150 | Ω |
| | | | $V_{OH} = 0.9 \cdot V_{DD_HV_IO}$ (static driver source impedance) | 64 | — | 150 | |
| F_{max_M} | CC | T | Maximum output frequency for medium type pads $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | — | — | 12 | MHz |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | — | — | 6 | MHz |
| t_{TR_M} | CC | T | Transition time output pin medium configuration, 10%-90% $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | 6 | — | 20 | ns |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | 11 | — | 40 | ns |
| $ t_{SKEW_M} $ | CC | T | Rise / fall skew ($T_r - T_f$) / $\text{Max}[T_r, T_f]$ | — | — | 30 | % |
| I_{DCMAX_M} | CC | D | Maximum DC current $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | 2 | mA |

3.8.2.3 Fast I/O output characteristics

The following table provides output driver characteristics for I/O pads in fast configuration.

Table 16. Fast I/O output characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-----------------|----|-----------|--|-----------------------------|-----|-----------------------------|----------|
| | | | | Min | Typ | Max | |
| V_{ol_F} | CC | D | Output low voltage for fast type pads $I_{ol} = 5.7 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | $0.15 \cdot V_{DD_HV_IO}$ | V |
| V_{oh_F} | CC | D | Output high voltage for fast type pads $I_{oh} = 5.7 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | $0.85 \cdot V_{DD_HV_IO}$ | — | — | V |
| R_F | CC | P | Output impedance for fast type pads $V_{OL} = 0.15 \cdot V_{DD_HV_IO}$ (static driver sink impedance) | 28 | — | 66 | Ω |
| | | | $V_{OH} = 0.85 \cdot V_{DD_HV_IO}$ (static driver source impedance) | 28 | — | 66 | |
| F_{max_F} | CC | T | Maximum output frequency for fast type pads $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | — | — | 50 | MHz |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | — | — | 25 | MHz |
| t_{TR_F} | CC | T | Transition time output pin, fast configuration, 10%-90% $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | 2.5 | — | 7 | ns |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | 4 | — | 10 | |
| $ t_{SKEW_F} $ | CC | T | Rise / fall skew (T_r - T_f) / $\text{Max}[T_r, T_f]$ | — | — | 30 | % |
| I_{DCMAX_F} | CC | D | Maximum DC current | — | — | 5.7 | mA |

3.8.2.4 Very fast I/O output characteristics

The following table provides output driver characteristics for I/O pads in very fast configuration.

Table 17. Very fast I/O output characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|----------------------|----|-----------|---|-----------------------------|-----|--|----------|
| | | | | Min | Typ | Max | |
| V_{OL_V} | CC | D | Output low voltage for very fast type pads $I_{OL} = 10 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | $0.15 \cdot V_{DD_HV_IO}$ | V |
| V_{OH_V} | CC | D | Output high voltage for very fast type pads $I_{OH} = 10 \text{ mA}$ $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | $0.85 \cdot V_{DD_HV_IO}$ | — | — | V |
| R_V | CC | P | Output impedance for very fast type pads $V_{OL} = 0.15 \cdot V_{DD_HV_IO}$ (static driver sink impedance) | 16 | — | 38 | Ω |
| | | | $V_{OH} = 0.85 \cdot V_{DD_HV_IO}$ (static driver source impedance) | 16 | — | 38 | |
| F_{max_V} | CC | T | Maximum output frequency for very fast type pads $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | — | — | 50 | MHz |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 50 \text{ pF}$ | — | — | 25 | MHz |
| t_{TR_V} | CC | T | 10-90% threshold transition time output pin very fast configuration $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ $C_L = 25 \text{ pF}$ | 1.3 | — | 4 | ns |
| | | | $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ Tx line with $T_d = 0.6 \text{ ns}$ $C_L = 10 \text{ pF}$ | 1.0 | — | 6.5 | |
| $t_{TR20-V_20_80}$ | CC | T | 20-80% threshold transition time output pin very fast configuration $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ Tx line with $T_d = 0.6 \text{ ns}$ $C_L = 10 \text{ pF}$ | 0.5 | — | $T_r + T_f < 9T_r$ $T_f = 4.5 \text{ ns}$ | ns |
| I_{DCMAX_V} | CC | D | Maximum DC current $V_{DD_HV_IO} = 3.3 \text{ V} \pm 5\%$ | — | — | 10 | mA |

3.8.3 I/O pad current specifications

The I/O pads are distributed across the I/O supply segment. Each I/O supply segment is associated with a V_{DD}/V_{SS} supply pair as described in the SR5E1E3, SR5E1E5, SR5E1E7 I/O definition Excel[®] file attached to the “Architecture mapping tables” technical note.

The table below provides I/O consumption figures.

To ensure the device reliability, the average current of the I/O on a single segment must remain below the I_{RMSSEG} maximum value.

To ensure the device functionality, the sum of the dynamic and static current of the I/O on a single segment must remain below the I_{DYNSEG} maximum value.

Pad mapping on each segment can be optimized using the pad usage information provided on the I/O signal description table.

Table 18. I/O consumption

| Symbol | C | | Parameter | Conditions | Value | | | Unit |
|------------------------------------|----|---|--|--|-------|-----|-----|------|
| | | | | | Min | Typ | Max | |
| Average consumption ⁽¹⁾ | | | | | | | | |
| I _{RMSSEG} | SR | D | Sum of all the DC I/O current within a supply segment ⁽²⁾ | — | — | — | 120 | mA |
| I _{RMS_S} | CC | D | RMS I/O current for Slow configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF, 2 MHz | — | — | 1 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 50 pF, 1 MHz | — | — | 1 | |
| I _{RMS_M} | CC | D | RMS I/O current for Medium configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF, 12 MHz | — | — | 4.5 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 50 pF, 6 MHz | — | — | 4.5 | |
| I _{RMS_F} | CC | D | RMS I/O current for Fast configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF, 50 MHz | — | — | 15 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 50 pF, 25 MHz | — | — | 15 | |
| I _{RMS_V} | CC | D | RMS I/O current for Very Fast configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF, 50 MHz | — | — | 20 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 10 pF, 25 MHz | — | — | 8 | |
| Dynamic consumption ⁽³⁾ | | | | | | | | |
| I _{DYN_SEG} | SR | D | Sum of all the dynamic and DC I/O current within a supply segment | V _{DD_HV_IO} = 3.3 V ± 5% | — | — | 360 | mA |
| I _{DYN_S} | CC | D | Dynamic I/O current for Slow configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF | — | — | 6.6 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 50 pF | — | — | 6.6 | |
| I _{DYN_M} | CC | D | Dynamic I/O current for Medium configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF | — | — | 15 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 50 pF | — | — | 16 | |
| I _{DYN_F} | CC | D | Dynamic I/O current for Fast configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF | — | — | 34 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 50 pF | — | — | 36 | |
| I _{DYN_V} | CC | D | Dynamic I/O current for Very Fast configuration | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 25 pF | — | — | 60 | mA |
| | | | | V _{DD_HV_IO} = 3.3 V ± 5% C _L = 10 pF | — | — | 48 | |

1. Average consumption in one pad toggling cycle.

- The I/O supplies are well distributed around the device to sustain the different drive capability of each pad. The only limitation is related (for all packages) to the Very Fast configuration for the segment including the JTAG pads until PAD_PG[5..12]: PAD_PG[5..12] can be configured in very fast mode, toggling at the same time, but JTAG pads must not be used, or vice versa.
- The stated maximum values represent the peak consumption that lasts only a few ns during the I/O transition. When possible (timed output) it is recommended to delay the transition between pads by a few cycles to reduce noise and consumption.

Related links

- [3.2 Absolute maximum ratings on page 11](#)
- [3.3 Operating conditions on page 12](#)

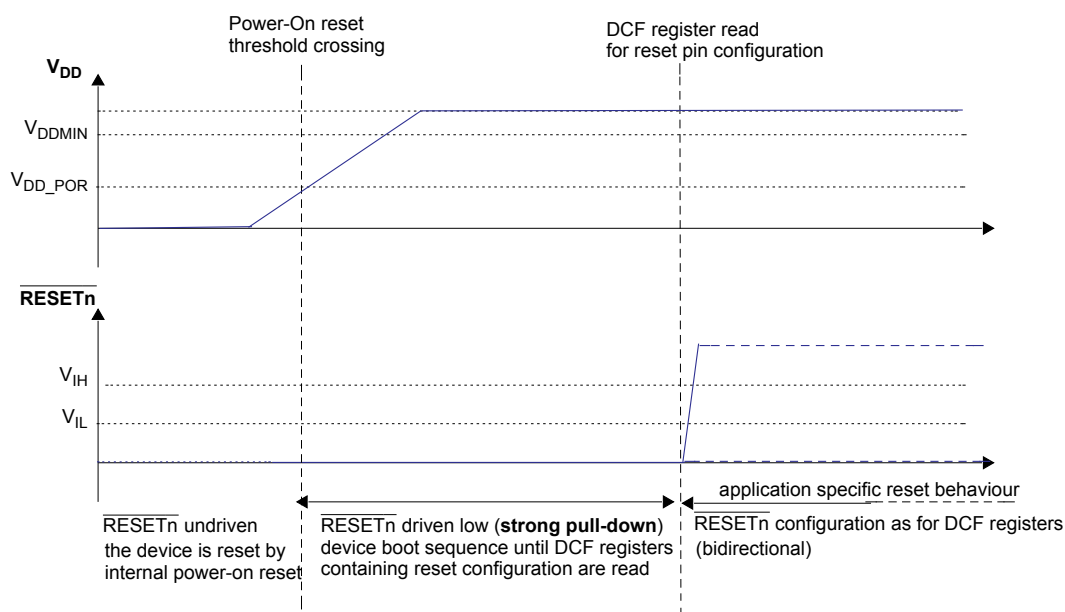
3.9 Reset pad (RESETn) electrical characteristics

The device implements a reset pin pad: RESETn is configured as a reset input/output.

The configuration is read during the boot initialization process as described in the device reference manual, Reset and boot chapter. When samples are delivered, in the default configuration, RESETn pin does not require active control.

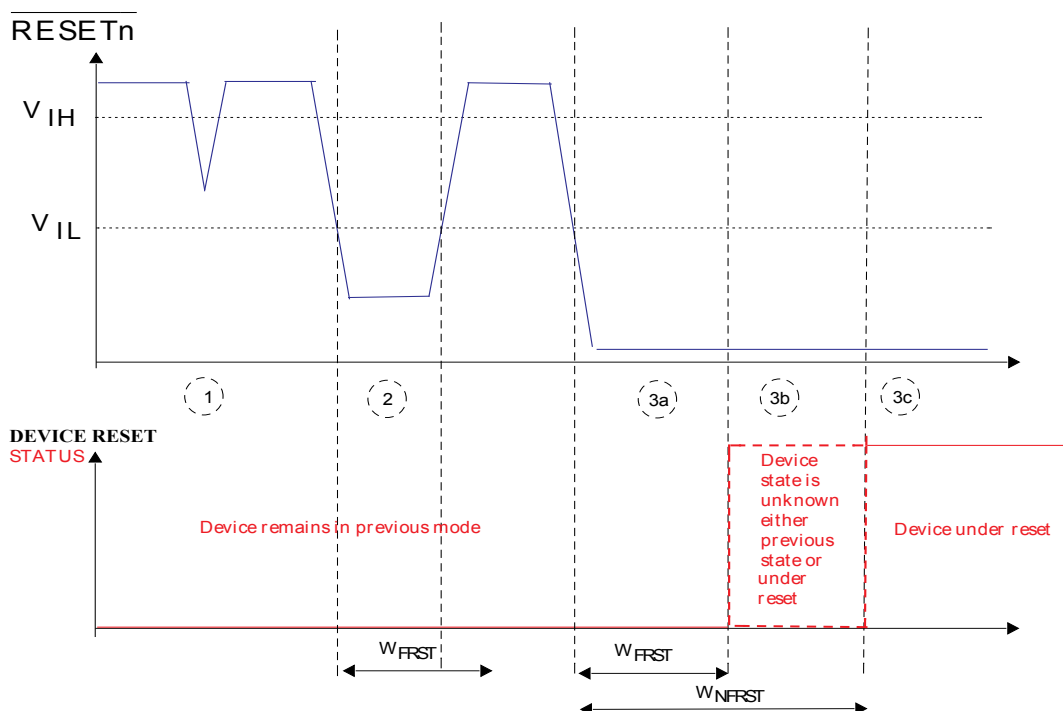
The following figure describes RESETn behavior during the power-up sequence.

Figure 6. RESETn behavior during power-up sequence



The RESETn pin implements an input filtering mechanism. The following figure describes the possible conditions:

- The amplitude of the low pulse is too low: it is filtered by input buffer hysteresis. The device remains in current state.
- The duration of the low pulse is too short: it is filtered by low-pass filter. The device remains in current state.
- Low pulse is generating a reset:
 - Signal is low but initially filtered during at least W_{FRST} . The device remains initially in the current state.
 - Signal potentially filtered until W_{NFRST} . The device state is unknown. It may be under reset or still be in the previous mode depending on extra conditions (temperature, voltage, device).
 - Signal asserted for longer than W_{NFRST} . The device is under reset.

Figure 7. Input reset filter

Table 19. Reset pad electrical characteristics

| Symbol | | C | Parameter | Conditions | Value | | | Unit |
|---------------------|----|---|--|---|-------|-----|----------------------------|------|
| | | | | | Min | Typ | Max | |
| V _{IHRES} | SR | P | Input high level TTL | V _{DD_HV_IO} = 3.3 V ± 5% | 2 | — | V _{DD_HV_IO} +0.3 | V |
| V _{ILRES} | SR | P | Input low level TTL | V _{DD_HV_IO} = 3.3 V ± 5% | -0.3 | — | 0.8 | V |
| V _{HYSRES} | CC | C | Input hysteresis TTL | V _{DD_HV_IO} = 3.3 V ± 5% | 0.3 | — | — | V |
| V _{DD_POR} | CC | D | Minimum supply for strong pull-down activation | V _{DD_HV_IO} = 3.3 V ± 5% | — | — | 1.6 | V |
| I _{OL_R} | CC | P | Strong pull-down current ⁽¹⁾ | V _{DD_HV_IO} = 3.3 V ± 5% | 3 | — | — | mA |
| I _{WPU} | CC | P | Weak pull-up current absolute value | V _{IN} = 1.1 V ⁽²⁾ V _{DD_HV_IO} = 3.3 V ± 5% | 15 | — | 130 | μA |
| I _{WPD} | CC | P | Weak pull-down current absolute value | V _{IN} = 0.9 V ⁽²⁾⁽³⁾ V _{DD_HV_IO} = 3.3 V ± 5% | 15 | — | 130 | μA |
| W _{FRST} | CC | P | Input filtered pulse | V _{DD_HV_IO} = 3.3 V ± 5% | — | — | 500 | ns |
| W _{NFRST} | CC | P | Input not filtered pulse | V _{DD_HV_IO} = 3.3 V ± 5% | 2000 | — | — | ns |

- I_{OL_R} applies to RESETEn: strong pull-down is active until the DCF containing the RESETEn configuration is read. Refer to the device reference manual, Reset and boot chapter.
- Maximum current when forcing a change in the pin level opposite to the pull configuration.
- Minimum current when keeping the same pin level state as the pull configuration.

Table 20. RESETn settings

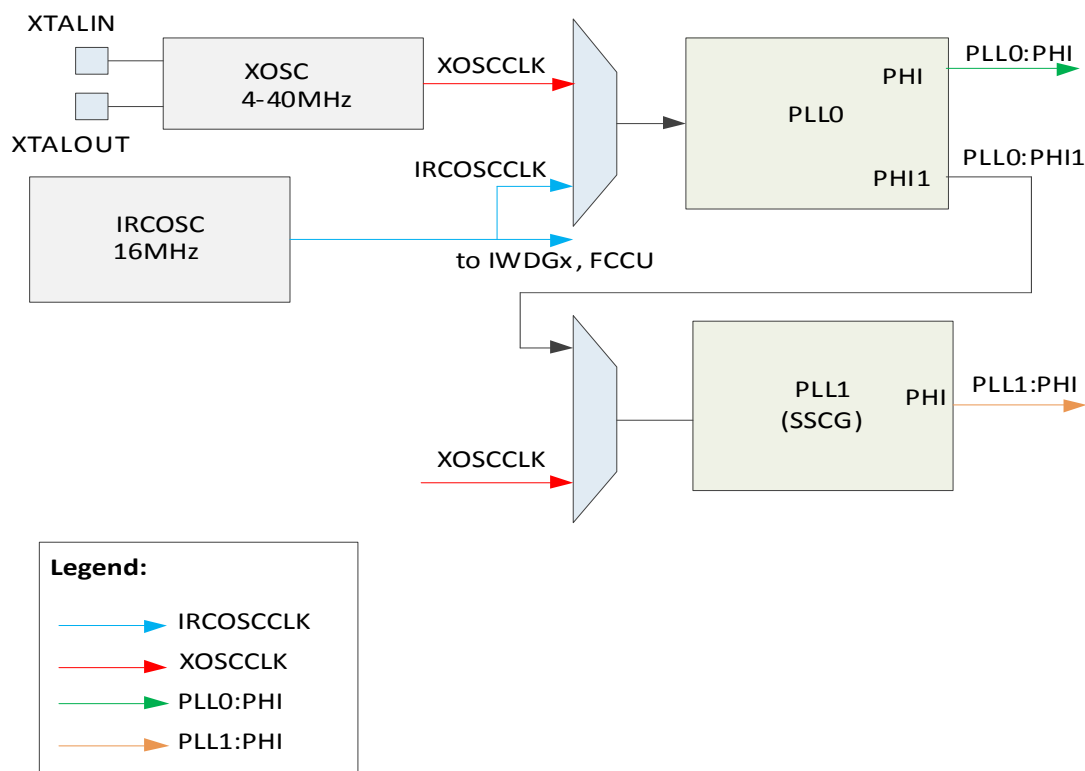
| Input conditions | | Behavior (set at power-on) | | |
|--|---|-------------------------------------|---|----------------|
| Life cycle | DCF RESET_CFG [RESN_PDOWN_EN] Description : RESETn pull-down enable | From power on till DCFs are read | Any non-power on reset phase (either destructive or functional) after internal RESETOUT release | SW Run time |
| ST production, customer delivery | NOT programmed | Strong pull-down | Bidirectional with weak pull-up Pad level as forced from outside | |
| OEM production, in- field, failure analysis | NOT programmed | Strong pull-down | Bidirectional with weak pull-down Pad level as forced from outside | |
| Don't care | Programmed to 0 | Strong pull-down | Bidirectional with weak pull-down Pad level as forced from outside | |

When the reset pin is configured as reset bidirectional with weak pull-down capability, it is possible to drive the pin with an external pull-up to ensure correct reset exit sequence. The recommended value is 4.7 kΩ.

3.10 PLLs

Two phase-locked loop (PLL) modules are implemented to generate system and auxiliary clocks on the device. The figure below depicts the integration of the two PLLs. Refer to the device reference manual for more detailed schematic.

Figure 8. PLLs integration



3.10.1 PLL0

Table 21. PLL0 electrical characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|--------------------------|----|-----------|---|--------|-----|--------------------|------|
| | | | | Min | Typ | Max | |
| f_{PLL0IN} | SR | — | PLL0 input clock ⁽¹⁾ | 8 | — | 56 ⁽²⁾ | MHz |
| Δ_{PLL0IN} | SR | — | PLL0 input clock duty cycle ⁽¹⁾ | 40 | — | 60 | % |
| f_{INFIN} | SR | C | PLL0 PFD (phase frequency detector) input clock frequency | 8 | — | 20 | MHz |
| $f_{PLL0VCO}$ | CC | P | PLL0 VCO frequency | 600 | — | 1400 | MHz |
| $f_{PLL0PHI0}$ | CC | D | PLL0 output frequency | 4.7620 | — | 700 | MHz |
| $f_{PLL0PHI1}$ | CC | D | PLL0 output clock PHI1 | 20 | — | 175 ⁽³⁾ | MHz |
| $t_{PLL0LOCK}$ | CC | P | PLL0 lock time | — | — | 100 | μs |
| $ \Delta_{PLL0PHISPJ} $ | CC | T | PLL0_PHI single period jitter $f_{PLL0IN} = 8$ MHz (resonator) | — | — | 435 | ps |
| $ \Delta_{PLL0PHI1SPJ} $ | CC | T | PLL0_PHI1 single period jitter $f_{PLL0IN} = 8$ MHz (resonator) | — | — | 210 | ps |
| $\Delta_{PLL0LTJ}$ | CC | T | PLL0 output long term jitter $f_{PLL0IN} = 8$ MHz (resonator) VCO frequency = 640 MHz | — | — | ±500 | ps |
| I_{PLL0} | CC | T | PLL0 consumption Fine lock state | — | — | 5.4 | mA |

1. $PLL0IN$ clock retrieved directly from either internal IRCOSC or external XOSC clock. Input characteristics are granted when the internal oscillator or external oscillator is used in functional mode.
2. Since XOSC the max frequency is 40 MHz, the 40-56 MHz range can only be reached with external reference clock (XOSC bypass).
3. If the $PLL0_PHI1$ is used as an input for PLL1, then the $PLL0_PHI1$ frequency obeys the maximum input frequency limit set for PLL1 (refer to f_{PLL1IN} in Table 22. PLL1 electrical characteristics).

Related links

[3.10.2 PLL1 on page 31](#)

3.10.2 PLL1

PLL1 is a frequency modulated PLL with spread spectrum clock generation (SSCG) support.

Table 22. PLL1 electrical characteristics

| Symbol | | C | Parameter | Conditions | Value | | | Unit |
|-------------------------|----|---|--|---|-------|-----|------|------|
| | | | | | Min | Typ | Max | |
| f _{PLL1IN} | SR | — | PLL1 input clock ⁽¹⁾ | — | 37.5 | — | 87.5 | MHz |
| Δ _{PLL1IN} | SR | — | PLL1 input clock duty cycle ⁽¹⁾ | — | 35 | — | 65 | % |
| f _{INFIN} | SR | C | PLL1 PFD (phase frequency detector) input clock frequency | — | 37.5 | | 87.5 | MHz |
| f _{PLL1VCO} | CC | P | PLL1 VCO frequency | — | 600 | — | 1400 | MHz |
| f _{PLL1PHI} | CC | D | PLL1 output clock PHI | — | 4.762 | — | 700 | MHz |
| t _{PLL1LOCK} | CC | P | PLL1 lock time | — | — | — | 50 | μs |
| f _{PLL1MOD} | CC | T | PLL1 modulation frequency | — | — | — | 250 | kHz |
| δ _{PLL1MOD} | CC | T | PLL1 modulation depth (when enabled) | Center spread ⁽²⁾ | 0.25 | — | 2 | % |
| | | | | Down spread | 0.5 | — | 4 | % |
| Δ _{PLL1PHISPJ} | CC | T | PLL1_PHI single period peak to peak jitter with modulation activated (md = ± 2%) | f _{PLL1PHI} = 300 MHz, 6-sigma pk-pk | — | — | 250 | ps |
| I _{PLL1} | CC | T | PLL1 consumption | FINE LOCK state | — | — | 6.25 | mA |

1. $PLL1IN$ clock retrieved directly from either internal PLL0 or external FXOSC clock. Input characteristics are granted when using internal PLL0 or external oscillator is used in functional mode.
2. The device maximum operating frequency F_{SYS} (max) includes the frequency modulation. If center modulation is selected, the F_{SYS} must be below the maximum by MD (modulation depth percentage), such that $F_{SYS(max)} = F_{SYS}(1 + MD\%)$. Refer to the device reference manual for the PLL programming details.

Related links

[3.10.1 PLL0 on page 30](#)

3.11 Oscillators

3.11.1 Low-speed internal RC oscillator (LSI)

Table 23. 1024 kHz internal RC oscillator electrical characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|---------------------|----|-----------|--|-------------------|------|-----|------|
| | | | | Min | Typ | Max | |
| F _{sirc} | CC | T | Slow internal RC oscillator frequency | — | 1024 | — | kHz |
| df _{var_T} | CC | P | Frequency variation across temperature | −40°C < T < 150°C | −9 | +9 | % |
| df _{var_V} | CC | P | Frequency variation across voltage | — | −5 | +5 | % |
| I _{sirc} | CC | D | Slow internal RC oscillator current | T = 55°C | — | 6 | μA |
| T _{sirc} | CC | D | Start up time, after switching ON the internal regulator | — | — | 12 | μs |

3.11.2 External crystal oscillator 40 MHz (XOSC)

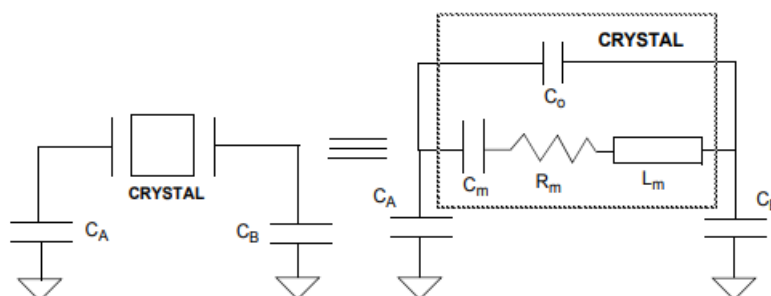
Table 24. External 40 MHz oscillator electrical specifications

| Symbol | | C | Parameter | Conditions | Value | | | Unit |
|----------------------|----|---|--|--|------------------------------|-----|-----------------|------|
| | | | | | Min | Typ | Max | |
| f _{XTAL} | CC | D | Crystal frequency range ⁽¹⁾⁽²⁾⁽³⁾ | XOSC_freq_sel[1:0]= 00 | 4 | — | 10 | MHz |
| | | | | XOSC_freq_sel[1:0]= 01 | 10 | — | 20 | |
| | | | | XOSC_freq_sel[1:0]= 10 | 20 | — | 30 | |
| | | | | XOSC_freq_sel[1:0]= 11 | 30 | — | 40 | |
| f _{EXTAL} | SR | T | External frequency range (bypass) | — | — | — | 100 | MHz |
| t _{cst} | CC | D | Crystal startup time ⁽⁴⁾⁽⁵⁾ | 4MHz-10MHz | — | — | 12 | ms |
| | | | | 10MHz-20MHz | — | — | 7.5 | |
| | | | | 20MHz-30MHz | — | — | 6 | |
| | | | | 30MHz-40MHz | — | — | 5 | |
| t _{rec} | CC | D | Crystal recovery time ⁽⁶⁾ | — | — | — | as startup time | ms |
| V _{IHEXT} | CC | D | EXTAL input high voltage (external reference) ⁽⁷⁾ | — | V _{DD_HV_OSC} - 0.6 | — | — | V |
| V _{ILEXT} | CC | D | EXTAL input low voltage (external reference) ⁽⁷⁾ | — | — | — | 0.6 | V |
| C _{S_EXTAL} | CC | D | Total on-chip stray capacitance on EXTAL pin ⁽⁸⁾ | Cpar = C_IPinternal + C_IOs | 5.6 | 7 | 8.4 | pF |
| C _{S_XTAL} | CC | D | Total on-chip stray capacitance on XTAL pin ⁽⁸⁾ | Cpar = C_IPinternal + C_IOs | 5.6 | 7 | 8.4 | pF |
| g _m | CC | P | Oscillator transconductance | T _J = −40°C to 150°C, f _{XTAL} = 4 - 10 MHz, XOSC_freq_sel[1:0]= 00 | 2.73 | — | 9.77 | mA/V |
| | | D | | T _J = −40°C to 150°C f _{XTAL} = 10 - 20 MHz XOSC_freq_sel[1:0]= 01 | 5.70 | — | 20.50 | |
| | | D | | T _J = −40°C to 150°C f _{XTAL} = 20 - 30 MHz XOSC_freq_sel[1:0]= 10 | 9.73 | — | 34.50 | |
| | | D | | | | | | |

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-------------------|----|-----------|--|-------|-----|--------------------------|------|
| | | | | Min | Typ | Max | |
| g_m | CC | P | Oscillator transconductance $T_J = -40^{\circ}\text{C}$ to 150°C $f_{\text{XTAL}} = 30 - 40 \text{ MHz}$ $\text{XOSC_freq_sel}[1:0] = 11$ | 12.70 | — | 46.15 | mA/V |
| V_{XTAL} | CC | T | Oscillation amplitude on the XTAL pin after startup ⁽⁹⁾ $T_J = -40^{\circ}\text{C}$ to 150°C , pk-pk @40MHz | 0.5 | — | $V_{\text{DD_HV_OSC}}$ | V |

1. The range is selectable by UTEST miscellaneous DCF clients XOSC_FREQUENCY [1:0].
2. Refer to Table 25. Crystal parameters and load conditions for supported crystal parameters and load conditions.
3. The XTAL frequency, if used to feed the PLL0 (or PLL1), has to obey the minimum input frequency limit set for PLL0 (or PLL1).
4. Proper PC board layout procedures must be followed to achieve these specifications.
5. This value is determined by the crystal manufacturer and board design.
6. Crystal recovery time is the time for the oscillator to settle to the correct frequency after adjustment of the integrated load capacitor value.
7. Applies to an external clock input and not to crystal mode.
8. See the crystal manufacturer's specification for recommended load capacitor (C_L) values. Total capacitance on XTAL net must be $2 \times C_L$. On-chip stray capacitance ($\text{CS_EXTAL}/\text{CS_XTAL}$) and PCB capacitance must be accounted when selecting a load capacitor value. External capacitance or integrated load capacitor value can be used. Integrated load capacitance can be selected via software to match the crystal manufacturer's specification. The stray capacitance (C_{par}) on chip value here reported, takes into account the sum of total parasitic capacitance inside the SOC (IP, routing inside SOC, IO pad) + package.
9. Amplitude on the XTAL pin after startup is determined by the automatic level control circuit (ALC) block. The function of the ALC is to provide high drive current during oscillator startup, but reduce current after oscillation to reduce power, distortion, and RFI, and to avoid over driving the crystal. The operating point of the ALC is dependent on the crystal value and loading conditions.

Figure 9. Equivalent mode of crystal



- C_0 is the shunt or static capacitance of the crystal. The parameter equals the sum of capacitance measured from pin to pin, including the electrode and the mounting structure. This capacitance is usually specified as a maximum value, for example, 2 pF maximum.
- L_m , R_m , and C_m are in the motional arm of the crystal. Their circuit affects only exist when the crystal is oscillating.
 - L_m , the motional inductance, is determined by the mechanical mass of quartz in motion.
 - C_m is determined by the stiffness of the quartz (constant), the area of the electrode, and the thickness and shape of the quartz wafer. C_m is dependent on the specified frequency of the crystal. C_m is usually less than 0.02 pF.
 - R_m is the equivalent series resistance when oscillating. It is a function of mechanical losses during vibration. Low resistance indicates low mechanical losses. The lower the resistance is, the more easily the crystal oscillates. R_m is usually specified as a maximum value, for example, 50 maximum.

Internal trimmable capacitance

Two capacitance blocks are connected between A and AGND and ZO and AGND inside the oscillator. For the internal capacitance array to be selected, ext_load_en should be low.

Capacitance is implemented using metal fringe.

The capacitance offered by this array is decided by load_cap_sel[4:0].

The formula to calculate the capacitance offered is $C_{\text{var}} = n \cdot C_u$

Where,

- C_u = unit capacitance (for a typical corner, $C_u = 0.48$ pF. Across the process, the variation is $\pm 10\%$)
- $n = \text{load_cap_sel}[4] \times 2^4 + \text{load_cap_sel}[3] \times 2^3 + \text{load_cap_sel}[2] \times 2^2 + \text{load_cap_sel}[1] \times 2^1 + \text{load_cap_sel}[0] \times 2^0$

For example:

- For $\text{load_cap_sel}[4:0]=00000$, $C_{\text{var}} = 0$ pF at A & ZO each.
- For $\text{load_cap_sel}[4:0]=10000$, $C_{\text{var}} = 7.68$ pF at A & ZO each.
- For $\text{load_cap_sel}[4:0]=11111$, $C_{\text{var}} = 14.88$ pF at A & ZO each.

Refer to the UTEST miscellaneous DCF client described in the device reference manual (chapter Device configuration format DCF records).

Table 25. Crystal parameters and load conditions

| Crystal frequency range (MHz) ⁽¹⁾ | Maximum crystal ESR supported (Ω) ⁽²⁾ | C_0 (max) (pF) (2)(3) | C_L (min) (pF) ⁽²⁾ | C_L (max) (pF) ⁽²⁾ | Drive level (max) (μ W) |
|---|--|-------------------------------|------------------------------------|------------------------------------|---------------------------------|
| 4-10 | 220 | 2 | 5 | 10 | 100 |
| 10-20 | 120 | 2 | 5 | 10 | 200 |
| 20-30 | 80 | 2 | 5 | 6 | 200 |
| | | | 7 | 8 | 250 |
| | | | 9 | 10 | 300 |
| 30-40 | 50 | 2 | 5 | 5 | 200 |
| | | | 6 | 7 | 250 |
| | | | 8 | 8 | 300 |

1. Crystal frequency range values are related to F_{XTAL} defined by $\text{freq_sel}[1:0]$ settings (refer to Table 24. External 40 MHz oscillator electrical specifications)

2. Where:

- $ESR = R_m \times \left(1 + \frac{C_0}{C_L}\right)^2$
- C_L is the load capacitance.
- C_0 is the shunt capacitance.
- $C_A = C_B = 2 \times C_L$.

3. C_A , C_B , and C_0 include the parasitic capacitance due to the crystal, PCB board traces, package parasitics etc.

3.11.3 Internal RC 16 MHz oscillator (IRCOSC)

Table 26. Internal RC oscillator electrical specifications

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|------------------------------|----|---|----------------------------------|-------|-----------|------|---------|
| | | | | Min | Typ | Max | |
| f_{Target} | CC | D IRC target frequency | — | — | 16 | — | MHz |
| $\delta f_{\text{var_noT}}$ | CC | P IRC frequency variation without temperature compensation | $T < 150^\circ\text{C}$ | -5 | — | 5 | % |
| $\delta f_{\text{var_T}}$ | CC | T IRC frequency variation with temperature compensation | $T < 150^\circ\text{C}$ | -3 | — | 3 | % |
| $\delta f_{\text{var_SW}}$ | — | T IRC software trimming accuracy | Trimming temperature | -0.5 | ± 0.3 | 0.5 | % |
| $T_{\text{start_noT}}$ | CC | T Startup time to reach within $f_{\text{var_noT}}$ | Factory trimming already applied | — | — | 5 | μ s |
| $T_{\text{start_T}}$ | CC | T Startup time to reach within $f_{\text{var_T}}$ | Factory trimming already applied | — | — | 120 | μ s |
| I_{FIRC} | CC | T Current consumption on analog power supply ⁽¹⁾ | After $T_{\text{start_T}}$ | — | — | 1600 | μ A |

1. The additional contribution of the core logic clocked by the RCOSC16M affects the RCOSC16M consumption. This core logic cannot be turned off during the measurement at device level.
In any case, the design specifies the parameter at 1200 μ A.

3.12 Analog subsystem

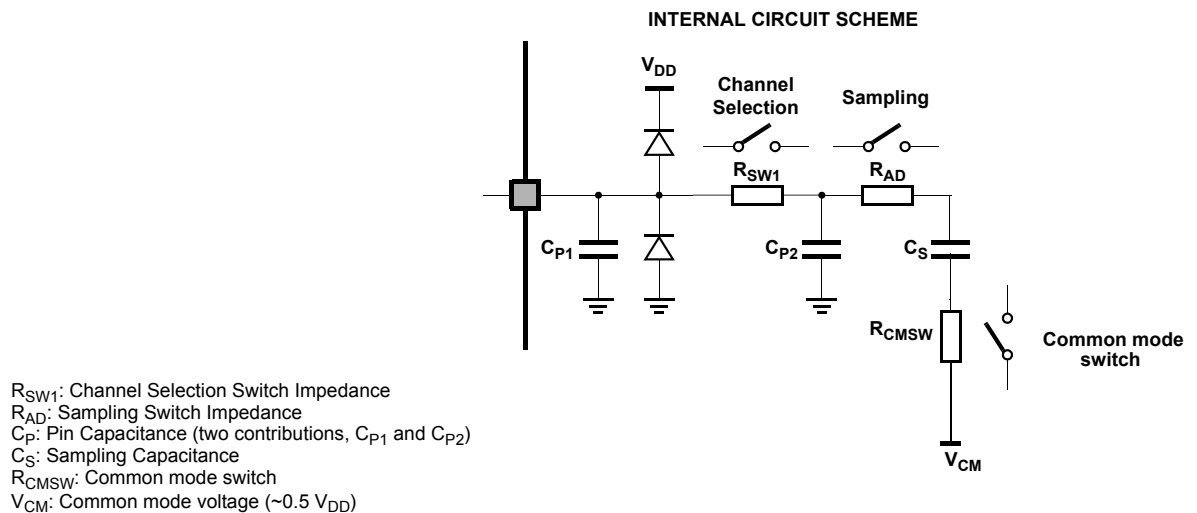
The SR5E1E3, SR5E1E5, SR5E1E7 analog subsystem contains:

- 5 SARADC modules with up to eight channels coming from pads,
- 2 SDADC modules,
- 8 Fast-DACs,
- 8 analog comparators,
- 2 buffered-DACs that is with buffer to bring analog output on pads,
- 1 temperature sensor,
- 1 ADCBIAS_COMP module to generate 4 reference voltages for runtime diagnosis of comparators,
- 1 ADCBIAS_SAR module to generate 4 reference voltages for runtime diagnosis of SAR_ADCs in single ended mode.

3.12.1 ADC input description

The figure below shows the input equivalent circuit for SARn channels.

Figure 10. Input equivalent circuit (Fast SARn channels)



The above figure can be used as approximation circuitry for external filtering definition.

- Note:**
- For input leakage current, refer to I_{LKG} in Section 3.8.1: I/O input DC characteristics,
 - For injection current 1, refer to I_{INJ1} in Section 3.3: Operating conditions,
 - For pad capacitance 1, refer to C_{P1} in Section 3.8.1: I/O input DC characteristics.

Table 27. ADC pin specification

| Symbol ⁽¹⁾ | | C | Parameter | Conditions | Value | | | Unit |
|-----------------------|----|---|--|------------------------------------|-------|-----|-----|------|
| | | | | | Min | Typ | Max | |
| C _{P2} | CC | D | Internal routing capacitance | SARn 12-bit channels | — | — | 700 | fF |
| C _S | CC | D | SAR ADC sampling capacitance | SARn 12-bit | — | — | 2 | pF |
| R _{SW1} | CC | D | Analog switches resistance | SARn 12-bit channels | 0 | — | 3 | kΩ |
| R _{AD} | CC | D | ADC input analog switches resistance | SARn 12-bit | — | — | 1.2 | kΩ |
| R _{CMSW} | CC | D | Common mode switch resistance | Sum of the two resistances | — | — | 1 | kΩ |
| R _{SAFE PD} | CC | D | Discharge resistance for ADC input-only pins (strong pull-down for safety) | V _{DD_HV_IO} = 3.3 V ± 5% | — | — | 3 | kΩ |

1. All specifications in this table valid for the full input voltage range for the analog inputs.

Related links

- [3.2 Absolute maximum ratings on page 11](#)
- [3.3 Operating conditions on page 12](#)
- [3.8.1 I/O input DC characteristics on page 18](#)
- [3.12.2 SARADC 12-bit electrical specification on page 36](#)
- [3.13.1 Power management integration on page 52](#)

3.12.2 SARADC 12-bit electrical specification

The SARn ADCs are 12-bit successive approximation register analog-to-digital converters with full capacitive DAC. The SARn architecture allows input channel multiplexing.

Table 28. SARn ADC electrical specification

| Symbol ⁽¹⁾ | | C | Parameter | Conditions | Value | | | Unit |
|-------------------------------------|----|---|-------------------------------------|--|--------------------------------------|-------------------------------|-------------------------------------|-------------------------|
| | | | | | Min | Typ | Max | |
| V _{IN} | SR | D | Full scale input range | Single ended | HV_REFL_SAR | — | HV_REFH_SAR | V |
| | | | | Differential ended | 2*(HV_REFH_SAR – HV_REFL_SAR) | | | V _{PP} DIFF |
| V _{IN_COM} | SR | D | Input signal common mode | Only in differential mode | [HV_REFH_SAR + HV_REFL_SAR]/2 – 10% | [HV_REFH_SAR + HV_REFL_SAR]/2 | [HV_REFH_SAR + HV_REFL_SAR]/2 + 10% | V |
| f _{ADCK} | SR | P | Clock frequency | — ⁽²⁾ | — | — | 40 | MHz |
| t _{ADCINIT} | CC | D | Setting time | — | — | — | 4 | μs |
| t _{ADCBIASINIT} | CC | D | Bias setting time | — | — | — | 4 | μs |
| t _{ADCSAMPLE} | SR | T | ADC sample time ⁽³⁾ | Fast channels | 3.5/f _{ADCK} ⁽⁴⁾ | — | 640.5/f _{ADCK} | μs |
| | | T | | Slow channels | 12.5/f _{ADCK} | — | | |
| | | D | | Conversion of BIAS test channels through 20 kΩ input. | 67/f _{ADCK} | — | | |
| t _{ADCVREG_STUP} | CC | D | ADC voltage regulator start-up time | From enadc=L, enldo=L to enadc=L, enldo=H (LDO start-up Tup_ldo) | — | — | 10 | μs |
| t _{ADCEVAL} ⁽⁵⁾ | SR | D | ADC evaluation time | 12-bit configuration | 12.5/f _{ADCK} | — | — | μs |

| Symbol ⁽¹⁾ | | C | Parameter | Conditions | Value | | | Unit |
|-------------------------------------|----|---|--|---|------------------------|-----|------|-----------|
| | | | | | Min | Typ | Max | |
| t _{ADCEVAL} ⁽⁵⁾ | SR | D | ADC evaluation time | 10-bit configuration | 10.5/f _{ADCK} | — | — | μs |
| I _{ADV_S} | CC | P | V _{DD_HV_SAR} power supply current | Run mode (for each ADC) | — | — | 0.46 | mA |
| | | D | | Power down mode (for each ADC) | — | — | 0.01 | |
| TUE ₁₂ ⁽⁶⁾ | CC | P | Total unadjusted error in 12-bit configuration ⁽⁷⁾ | T _J < 150°C in all conditions | -7 | — | 7 | LSB (12b) |
| TUE ₁₀ ⁽⁶⁾ | CC | D | Total unadjusted error in 10-bit configuration ⁽⁷⁾ | T _J < 150°C in all conditions | -4 | — | 4 | LSB (10b) |
| TUE _{INJ2} | CC | T | TUE degradation addition, due to current injection in I _{INJ2} range ⁽⁸⁾ | See Table 4. Absolute maximum ratings, I _{INJ2} parameter. | +10 | | | LSB |
| DNL ⁽⁷⁾ | CC | P | Differential non-linearity | In all V _{DD_HV_SAR} voltage range. | -1 | — | 2 | LSB (12b) |

- Functional operating conditions are given in the DC electrical specifications. Absolute maximum ratings are stress ratings only, and functional operation at the maxima is not guaranteed. Stress beyond the listed maxima may affect device reliability or cause permanent damage to the device. All specifications in this table are valid for one ADC operating at a time.
- Max frequency can be reached under specific device clocks configuration. Refer to the device reference manual, Clocking chapter for details.
- Minimum ADC sample times are dependent on adequate charge transfer from the external driving circuit to the internal sample capacitor. The time constant of the entire circuit must allow the sampling capacitor to charge within 1/2 LSB within the sampling window. Refer to Figure 10. Input equivalent circuit (Fast SARn channels) for models of the internal ADC circuit, and the values to use in external RC sizing and calculating the sampling window duration.
- The minimum sampling time of 2.5 ADC clock cycles requires the setting of the ADC_SMPR1.SMPPLUS bit to 1. The overall minimum sampling time is $3.5/f_{ADCK}$ μs.
- It is referring to the "successive approximation time (T_{sar})" defined in the device reference manual, ADC timing chapter.
- After calibration.
- TUE and DNL are granted with injection current within the range defined in Table 27. ADC pin specification for parameters classified as T and D.
- All channels of all 12-bit SARADCs are impacted with the same degradation, independently of the ADC and the channel subject to current injection.

Related links

[3.2 Absolute maximum ratings on page 11](#)

[3.12.1 ADC input description on page 35](#)

3.12.3 SDADC electrical specification

The SDn ADCs are sigma delta 16-bit analog-to-digital converters with up to 300 Ksps output rate.

Note: The SDADCs are not available in the eTQFP100 package.

Table 29. SDn ADC electrical specification

| Symbol ⁽¹⁾ | | C | Parameter | Conditions | Value | | | Unit |
|--------------------------------------|----|---|---|--|--------------------|---------------|-------------------|------|
| | | | | | Min | Typ | Max | |
| V _{IN_PK2PK} ⁽²⁾ | SR | D | Input range peak to peak V _{IN_PK2PK} = V _{INP} ⁽³⁾ – V _{INM} ⁽⁴⁾ | Single-ended V _{INM} = V _{SS} | HV_REFH_SD/GAIN | | | V |
| | | D | | Single-ended V _{INM} = 0.5*HV_REFH_SD GAIN = 1 | ±0.5*HV_REFH_SD | | | |
| | | D | | Single-ended V _{INM} = 0.5*HV_REFH_SD GAIN = 2, 4, 8, 16 | ±HV_REFH_SD/GAIN | | | |
| | | D | | Differential, 0 < V _{IN} < V _{DD_HV_IO} | ±HV_REFH_SD/GAIN | | | |
| f _{ADCD_M} | SR | P | S/D modulator input Clock 3 ⁽⁵⁾ | T _J < 150°C | 14.4 | — | 16 | MHz |
| f _{IN} | SR | P | Input signal frequency | — | 0.01 | — | 75 ⁽⁶⁾ | KHz |
| f _{ADCD_S} | SR | D | Output conversion rate | Default filter mode ⁽⁷⁾ effective OSR = 24 | — | — | 333 | ksps |
| | | | | Bypass FIR Mode ⁽⁷⁾ effective OSR = 24 | — | — | 333 | |
| — | CC | D | Oversampling ratio | Internal modulator | 24 | — | 256 | — |
| | | | | External modulator | — | — | 256 | — |
| RESOLUTION | CC | D | S/D register resolution | 2's complement notation | 16 | | | bit |
| GAIN | SR | D | ADC gain | Defined via ADC_SD[PGA] register. Only integer powers of 2 are valid gain values. | 1 | — | 16 | — |
| δ _{GAIN} | CC | C | Absolute value of the ADC gain error ⁽⁸⁾⁽¹⁰⁾ | Before calibration (applies to gain setting = 1) | — | — | 1 | % |
| | | T | | After calibration, ΔHV_REFH_SD < 10% ΔV _{DD_HV_SD_DAC_COMP} < 10% –40°C < T _J < 150°C | — | — | 8 | mV |
| V _{OFFSET} | CC | P | Conversion offset ⁽⁸⁾⁽⁹⁾⁽¹⁰⁾ | Before calibration GAIN = 1 | — | 10*(1+1/gain) | 40 | mV |
| | | D | | Before calibration GAIN = 2, 4, 8, 16 | — | 10*(1+1/gain) | 40 | |
| | | T | | After calibration, ΔHV_REFH_SD < 10% –40°C < T _J < 150°C | — | — | 5 | mV |
| SNR _{DIFF150} | CC | P | Signal-to-noise ratio in differential mode 150 ksps output rate | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 1 T _J < 150°C | 80 ⁽¹¹⁾ | — | — | dBFS |

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|------------------------|----|--|---|--------------------|-----|-----|------|
| | | | | Min | Typ | Max | |
| SNR _{DIFF150} | CC | Signal-to-noise ratio in differential mode 150 ksp/s output rate | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 2 T _J < 150°C | 77 | — | — | dBFS |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 4 T _J < 150°C | 74 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 8 T _J < 150°C | 71 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 16 T _J < 150°C | 68 | — | — | |
| SNR _{DIFF333} | CC | Signal-to-noise ratio in differential mode 333 ksp/s output rate | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 1 T _J < 150°C | 71 ⁽¹¹⁾ | — | — | dBFS |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 2 T _J < 150°C | 68 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 4 T _J < 150°C | 65 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 8 T _J < 150°C | 62 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 16 T _J < 150°C | 60 | — | — | |

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|-----------------------|----|--|---|--------------------|-----|-----|------|
| | | | | Min | Typ | Max | |
| SNR _{SE333} | CC | Signal-to-noise ratio in single-ended mode 333 ksp/s output rate | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 1 T _J < 150°C | 65 ⁽¹¹⁾ | — | — | dBFS |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 2 T _J < 150°C | 62 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 4 T _J < 150°C | 59 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 8 T _J < 150°C | 56 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 16 T _J < 150°C | 54 | — | — | |
| SNR _{SE150} | CC | Signal-to-noise ratio in single-ended mode 150 ksp/s output rate | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 1 T _J < 150°C | 74 ⁽¹¹⁾ | — | — | dBFS |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 2 T _J < 150 °C | 71 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 4 T _J < 150 °C | 68 | — | — | |
| | | | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 8 T _J < 150 °C | 65 | — | — | |

| Symbol ⁽¹⁾ | | C | Parameter | Conditions | Value | | | Unit |
|-----------------------|----|---|--|--|-------|---|-----------------------------|------|
| | | | | | Min | Typ | Max | |
| SNR _{SE150} | CC | D | Signal-to-noise ratio in single-ended mode 150 ksp/s output rate | In all V _{DD_HV_SD_DAC_COMP} supply range. HV_REFH_SD = V _{DD_HV_SD_DAC_COMP} GAIN = 16 T _J < 150 °C | 62 | — | — | dBFS |
| SFDR | CC | P | Spurious free dynamic range | GAIN = 1 | 60 | — | — | dBc |
| | | C | | GAIN = 2 | 60 | — | — | |
| | | C | | GAIN = 4 | 60 | — | — | |
| | | C | | GAIN = 8 | 60 | — | — | |
| | | D | | GAIN = 16 | 60 | — | — | |
| Z _{DIFF} | CC | D | Differential input impedance (f _{ADCD_M} = 8 MHz) | GAIN = 1 | 360 | 450 | 540 | kΩ |
| | | D | | GAIN = 2 | 224 | 280 | 336 | |
| | | D | | GAIN = 4 | 128 | 160 | 192 | |
| | | D | | GAIN = 8 | 65 | 85 | 105 | |
| | | D | | GAIN = 16 | 65 | 85 | 105 | |
| Z _{CM} | CC | D | Common mode input impedance (f _{ADCD_M} = 8 MHz) | GAIN = 1 | 450 | 560 | 670 | kΩ |
| | | D | | GAIN = 2 | 340 | 430 | 520 | |
| | | D | | GAIN = 4 | 250 | 310 | 370 | |
| | | D | | GAIN = 8 | 170 | 210 | 250 | |
| | | D | | GAIN = 16 | 170 | 210 | 250 | |
| R _{BIAS} | CC | D | Bias resistance | — | 120 | 160 | 200 | kΩ |
| ΔR _{BIAS} | CC | D | R _{BIAS} positive/negative terminal impedance mismatch | — | -5 | — | +5 | % |
| V _{BIAS} | CC | D | Bias voltage | — | — | (V _{DD_HV_SD_DAC_COMP} – V _{SS})/2 | — | V |
| ΔV _{INTCM} | CC | D | Common mode input reference voltage | — | –12 | (V _{DD_HV_SD_DAC_COMP} + V _{SS})/2 | +12 | % |
| δV _{BIAS} | CC | D | Bias voltage accuracy | — | –2.5 | — | +2.5 | % |
| V _{cmrr} | CC | T | Common mode rejection ratio | — | 40 | — | — | dB |
| R _{Caaf} | SR | D | Anti-aliasing filter | External series resistance | — | — | 20 | kΩ |
| | CC | D | | Filter capacitances | 180 | — | — | pF |
| f _{PASSBAND} | CC | D | Pass band ⁽¹³⁾ | Default filter mode Bypass FIR mode | 0.01 | — | 0.333 * f _{ADCD_S} | kHz |
| | | | | Modified bandwidth mode | | — | 0.166 * f _{ADCD_S} | |
| | | | | External filter mode (OSR = 75) | | — | 0.066 * f _{ADCD_S} | |
| | | | | External filter mode (All OSR, expect 75) | | — | 0.083 * f _{ADCD_S} | |
| δ _{RIPPLE} | CC | D | Pass band ripple ⁽¹⁴⁾ | 0.333 * f _{ADCD_S} | –1 | — | 1 | % |
| F _{rolloff} | CC | D | Stop band attenuation Default filter mode ⁽¹⁵⁾ | [0.5 * f _{ADCD_S} , 1.0 * f _{ADCD_S}] | 1 | — | — | dB |

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|-----------------------|----|-----------|--|--|-----|-----|--------|
| | | | | Min | Typ | Max | |
| F _{rolloff} | CC | D | Stop band attenuation Default filter mode ⁽¹⁵⁾ | [1.0 * f _{ADCD_S} , 1.5 * f _{ADCD_S}] | 40 | — | dB |
| | | | | [1.5 * f _{ADCD_S} , 2.0 * f _{ADCD_S}] | 47 | — | |
| | | | | [2.0 * f _{ADCD_S} , 2.5 * f _{ADCD_S}] | 54 | — | |
| | | | | [2.5 * f _{ADCD_S} , f _{ADCD_M/2}] | 64 | — | |
| F _{rolloff} | CC | D | Stop band attenuation Modified bandwidth mode ⁽¹⁵⁾ | [0.25 * f _{ADCD_S} , 0.5 * f _{ADCD_S}] | 40 | — | dB |
| | | | | [0.5 * f _{ADCD_S} , 0.75 * f _{ADCD_S}] | 55 | — | |
| | | | | [0.75 * f _{ADCD_S} , 1.0 * f _{ADCD_S}] | 86 | — | |
| | | | | [1.0 * f _{ADCD_S} , 1.25 * f _{ADCD_S}] | 109 | — | |
| | | | | [1.25 * f _{ADCD_S} , f _{ADCD_M/2}] | 99 | — | |
| F _{rolloff} | CC | D | Stop band attenuation External filter mode ⁽¹⁵⁾ | [0.5 * f _{ADCD_S} , 1.0 * f _{ADCD_S}] | 2 | — | dB |
| | | | | [1.0 * f _{ADCD_S} , 1.5 * f _{ADCD_S}] | 11 | — | |
| | | | | [1.5 * f _{ADCD_S} , 2.0 * f _{ADCD_S}] | 31 | — | |
| | | | | [2.0 * f _{ADCD_S} , 2.5 * f _{ADCD_S}] | 44 | — | |
| | | | | [2.5 * f _{ADCD_S} , f _{ADCD_M/2}] | 39 | — | |
| F _{rolloff} | CC | D | Stop band attenuation Bypass FIR mode ⁽¹⁵⁾ | [0.5 * f _{ADCD_S} , 1.0 * f _{ADCD_S}] | 3 | — | dB |
| | | | | [1.0 * f _{ADCD_S} , 1.5 * f _{ADCD_S}] | 15 | — | |
| | | | | [1.5 * f _{ADCD_S} , 2.0 * f _{ADCD_S}] | 41 | — | |
| | | | | [2.0 * f _{ADCD_S} , 2.5 * f _{ADCD_S}] | 59 | — | |
| | | | | [2.5 * f _{ADCD_S} , f _{ADCD_M/2}] | 52 | — | |
| δ _{GROUP} | CC | D | Group delay Default filter mode ⁽¹⁵⁾ | Within pass band – Tclk is time period of f _{ADCD_M} /2 freq. = 2/f _{ADCD_M} | — | — | — |
| | | | | OSR = 24 | — | — | 197.9 |
| | | | | OSR = 28 | — | — | 230 |
| | | | | OSR = 32 | — | — | 262.1 |
| | | | | OSR = 36 | — | — | 294.2 |
| | | | | OSR = 40 | — | — | 326.3 |
| | | | | OSR = 44 | — | — | 358.4 |
| | | | | OSR = 48 | — | — | 390.4 |
| | | | | OSR = 56 | — | — | 454.6 |
| | | | | OSR = 64 | — | — | 518.8 |
| | | | | OSR = 72 | — | — | 582.9 |
| | | | | OSR = 75 | — | — | 509.1 |
| | | | | OSR = 80 | — | — | 647.1 |
| | | | | OSR = 88 | — | — | 711.3 |
| | | | | OSR = 96 | — | — | 775.4 |
| | | | | OSR = 112 | — | — | 903.8 |
| | | | | OSR = 128 | — | — | 1032.1 |
| | | | | OSR = 144 | — | — | 1160.4 |

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|-------------------------|----|---|---|-------|-----|--------|------|
| | | | | Min | Typ | Max | |
| δ_{GROUP} | CC | D Group delay Default filter mode ⁽¹⁵⁾ | OSR = 160 | — | — | 1288.8 | Tclk |
| | | | OSR = 176 | — | — | 1417.1 | |
| | | | OSR = 192 | — | — | 1545.4 | |
| | | | OSR = 224 | — | — | 1802.1 | |
| | | | OSR = 256 | — | — | 2058.8 | |
| | | | OSR = 512 | — | — | 4112.1 | |
| | | | OSR = 1024 | — | — | 8218.7 | |
| δ_{GROUP} | CC | D Group delay Modified bandwidth mode ⁽¹⁵⁾ | Within pass band – Tclk is time period of $f_{\text{ADCD_M}}/2$ freq. = $2/f_{\text{ADCD_M}}$ | — | — | — | — |
| | | | OSR = 24 | — | — | 217.3 | Tclk |
| | | | OSR = 28 | — | — | 252 | |
| | | | OSR = 32 | — | — | 286.6 | |
| | | | OSR = 36 | — | — | 321.3 | |
| | | | OSR = 40 | — | — | 355.9 | |
| | | | OSR = 44 | — | — | 390.6 | |
| | | | OSR = 48 | — | — | 425.3 | |
| | | | OSR = 56 | — | — | 494.6 | |
| | | | OSR = 64 | — | — | 563.9 | |
| | | | OSR = 72 | — | — | 633.3 | |
| | | | OSR = 75 | — | — | 589 | |
| | | | OSR = 80 | — | — | 702.6 | |
| | | | OSR = 88 | — | — | 771.9 | |
| | | | OSR = 96 | — | — | 841.3 | |
| | | | OSR = 112 | — | — | 979.9 | |
| | | | OSR = 128 | — | — | 1118.6 | |
| | | | OSR = 144 | — | — | 1257.3 | |
| | | | OSR = 160 | — | — | 1395.9 | |
| | | | OSR = 176 | — | — | 1534.6 | |
| | | | OSR = 192 | — | — | 1673.2 | |
| | | | OSR = 224 | — | — | 1950.6 | |
| | | | OSR = 256 | — | — | 2227.9 | |
| | | | OSR = 512 | — | — | 4446.5 | |
| | | | OSR = 1024 | — | — | 8883.7 | |
| δ_{GROUP} | CC | D Group delay Bypass FIR mode ⁽¹⁵⁾ | Within pass band – Tclk is time period of $f_{\text{ADCD_M}}/2$ freq. = $2/f_{\text{ADCD_M}}$ | — | — | — | — |
| | | | OSR = 24 | — | — | 73.7 | Tclk |
| | | | OSR = 28 | — | — | 85.2 | |
| | | | OSR = 32 | — | — | 96.8 | |
| | | | OSR = 36 | — | — | 108.4 | |

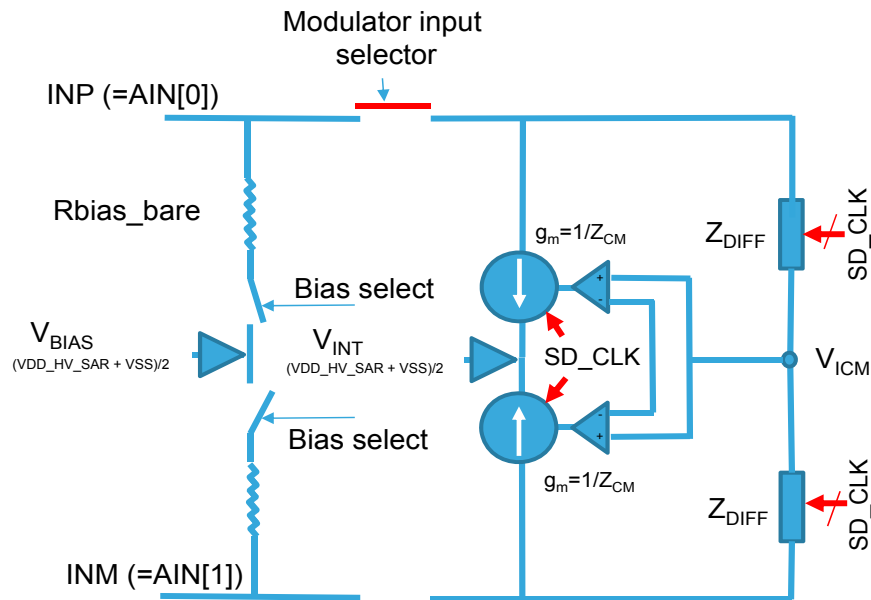
| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|-------------------------|----|--|---|-------|-----|--------|------|
| | | | | Min | Typ | Max | |
| δ_{GROUP} | CC | D Group delay Bypass FIR mode ⁽¹⁵⁾ | OSR = 40 | — | — | 119.9 | Tclk |
| | | | OSR = 44 | — | — | 131.5 | |
| | | | OSR = 48 | — | — | 143.1 | |
| | | | OSR = 56 | — | — | 166.2 | |
| | | | OSR = 64 | — | — | 189.3 | |
| | | | OSR = 72 | — | — | 212.4 | |
| | | | OSR = 75 | — | — | 198.2 | |
| | | | OSR = 80 | — | — | 235.6 | |
| | | | OSR = 88 | — | — | 258.7 | |
| | | | OSR = 96 | — | — | 281.8 | |
| | | | OSR = 112 | — | — | 328.1 | |
| | | | OSR = 128 | — | — | 374.4 | |
| | | | OSR = 144 | — | — | 420.6 | |
| | | | OSR = 160 | — | — | 466.9 | |
| | | | OSR = 176 | — | — | 513.1 | |
| | | | OSR = 192 | — | — | 559.4 | |
| | | | OSR = 224 | — | — | 651.9 | |
| | | | OSR = 256 | — | — | 744.4 | |
| | | | OSR = 512 | — | — | 1484.6 | |
| | | | OSR = 1024 | — | — | 2964 | |
| δ_{GROUP} | CC | D Group delay External filter mode ⁽¹⁵⁾ | Within pass band – Tclk is time period of $f_{\text{ADCD_M}}/2$ freq. = $2/f_{\text{ADCD_M}}$ | — | — | — | — |
| | | | OSR = 24 | — | — | 31.25 | Tclk |
| | | | OSR = 28 | — | — | 36.25 | |
| | | | OSR = 32 | — | — | 41.25 | |
| | | | OSR = 36 | — | — | 46.25 | |
| | | | OSR = 40 | — | — | 51.25 | |
| | | | OSR = 44 | — | — | 56.25 | |
| | | | OSR = 48 | — | — | 61.25 | |
| | | | OSR = 56 | — | — | 71.25 | |
| | | | OSR = 64 | — | — | 81.25 | |
| | | | OSR = 72 | — | — | 91.25 | |
| | | | OSR = 75 | — | — | 76.25 | |
| | | | OSR = 80 | — | — | 101.25 | |
| | | | OSR = 88 | — | — | 111.25 | |
| | | | OSR = 96 | — | — | 121.25 | |
| | | | OSR = 112 | — | — | 141.25 | |
| | | | OSR = 128 | — | — | 161.25 | |
| | | | OSR = 144 | — | — | 181.25 | |
| | | | OSR = 160 | — | — | 201.25 | |

| Symbol ⁽¹⁾ | C | Parameter | Conditions | Value | | | Unit |
|-------------------------|----|-----------|---|--|-----|--|---------------|
| | | | | Min | Typ | Max | |
| δ_{GROUP} | CC | D | Group delay External filter mode ⁽¹⁵⁾ | OSR = 176 | — | 221.25 | Tclk |
| | | | | OSR = 192 | — | 241.25 | |
| | | | | OSR = 224 | — | 281.25 | |
| | | | | OSR = 256 | — | 321.25 | |
| | | | | OSR = 512 | — | 641.25 | |
| | | | | OSR = 1024 | — | 1281.25 | |
| f_{HIGH} | CC | D | High pass filter 3dB frequency | Enabled | — | $16e-5 \cdot f_A$ DCD_S | — |
| t_{STARTUP} | CC | D | Start-up time from power down state | — | — | 100 | μs |
| t_{LATENCY} | CC | D | Latency between input data and converted data (input mux not changed) ⁽¹⁶⁾ | HPF = ON | — | $\delta_{\text{GROUP}} + 2/f_{\text{ADCD_S}}$ | — |
| | | | | HPF = OFF | — | $\delta_{\text{GROUP}} + 1/f_{\text{ADCD_S}}$ | — |
| t_{SETTLING} | CC | D | Settling time after mux change | Analog inputs are muxed HPF = ON | — | $2 \cdot \delta_{\text{GROUP}} + 3 \cdot 1/f_{\text{ADCD_S}}$ | — |
| | | | | HPF = OFF | — | $2 \cdot \delta_{\text{GROUP}} + 2 \cdot 1/f_{\text{ADCD_S}}$ | — |
| $t_{\text{ODRECOVERY}}$ | CC | D | Overdrive recovery time | After input comes within range from saturation HPF = ON | — | $2 \cdot \delta_{\text{GROUP}} + 2/f_{\text{ADCD_S}}$ | — |
| | | | | HPF = OFF | — | $2 \cdot \delta_{\text{GROUP}} + 2/f_{\text{ADCD_S}}$ | — |
| $C_{\text{S_D}}$ | CC | D | SDADC sampling capacitance after sampling switch ⁽¹⁷⁾ | GAIN = 1, 2, 4, 8 | — | $160 \cdot \text{GAIN}$ | fF |
| | | D | | GAIN = 16 | — | 1280 | fF |
| $I_{\text{ADV_BIAS}}$ | CC | D | Bias consumption | At least 1 SDADC enabled | — | 1 | mA |
| $I_{\text{ADV_D}}$ | CC | C | $V_{\text{DD_HV_SD_DAC_COMP}}$ Power supply current (each ADC) | SDADC enabled | — | 2.5 | mA |
| $I_{\text{ADR_BIAS}}$ | CC | D | BIAS module current ⁽¹⁸⁾ | — | — | 4 | μA |
| $I_{\text{ADR_SD}}$ | CC | T | Single SD reference current | — | — | 2 | μA |

- Functional operating conditions are given in the DC electrical specifications. Absolute maximum ratings are stress ratings only, and functional operation at the maxima is not guaranteed. Stress beyond the listed maxima may affect device reliability or cause permanent damage to the device.
- For input voltage above the maximum and below the clamp voltage of the input pad, there is no latch-up concern, and the signal is only 'clipped'.
- V_{INP} is the input voltage applied to the positive terminal of the SDADC.
- V_{INM} is the input voltage applied to the negative terminal of the SDADC.
- Sampling is generated internally $f_{\text{SAMPLING}} = f_{\text{ADCD_M}}/2$.

6. Maximum input of 166.67 KHz supported with reduced accuracy. See SNR specifications. Tested in production till 20 kHz, covered at bench till 75 kHz (as T parameter).
7. Configured oversampling rate: $SDADC_MCR[PDR] = 24$.
8. Calibration of gain is possible when gain = 1. Offset calibration should be done with respect to $0.5 \cdot HV_REFH_SD$ for "differential mode" and "single-ended mode with negative input = $0.5 \cdot HV_REFH_SD$ ". Offset calibration should be done with respect to 0 for "single-ended mode with negative input = 0". Both offset and gain calibration is ensured for $\pm 10\%$ variation of HV_REFH_SD , $\pm 10\%$ variation of $V_{DD_HV_SD_DAC_COMP}$, on all operating temperature ranges.
9. Conversion offset error must be divided by the applied gain factor (1, 2, 4, 8, or 16) to obtain the actual input referred offset error.
10. Offset and gain error due to temperature drift can occur in either direction (\pm) for each of the SDADCs on the device.
11. This value is tested in production on each individual device to ensure a correct screening with a tolerance of ~ 2 dBFS, due to the noise. This value (without tolerance) is however ensured by the measurement carried out on a small number of samples in the analog validation environment. Therefore, the performance is specified by bench, while the screening is specified by tester.
12. All channels of all SDADCs are impacted with same degradation, independently from the ADC and the channel subject to current injection.
13. SNR value ensured only if external noise on the ADC input pin is attenuated by the required SNR value in the frequency range of $f_{ADCD_M} - f_{ADCD_S}$ to $f_{ADCD_M} + f_{ADCD_S}$, where f_{ADCD_M} is the input sampling frequency, and f_{ADCD_S} is the output sample frequency. A proper external input filter must be used to remove any interfering signals in this frequency range.
14. The $\pm 1\%$ passband ripple specification is equivalent to $20 \cdot \log_{10}(0.99) = 0.087$ dB.
15. For details, refer to [Section 3.12.4: SDADC filter modes](#).
16. Propagation of the information from the pin to the register $CDR[CDATA]$ and flags $SFR[DFFEF]$, $SFR[DFFFF]$ is given by the different modules that need to be crossed: delta/sigma filters, high pass filter, fifo module, clock domain synchronizers. The time elapsed between data availability at pin and internal S/D module registers is given by the below formula: $REGISTER\ LATENCY = t_{LATENCY} + 0.5/f_{ADCD_S} + 2(\sim +1)/f_{ADCD_M} + 2(\sim +1)f_{PBRIDGE_CLK}$ where f_{ADCD_S} is the frequency of the sampling clock, f_{ADCD_M} is the frequency of the modulator, and $f_{PBRIDGE_CLK}$ is the frequency of the peripheral bridge clock feeds to the SDADC module. The ($\sim +1$) symbol refers to the number of clock cycles uncertainty (from 0 to 1 clock cycle) to be added due to resynchronization of the signal during clock domain crossing. Some further latency may be added by the target module (core, DMA, interrupt) controller to process the data received from the SDADC module.
17. This capacitance does not include pin capacitance, that can be considered together with external capacitance, before sampling switch.
18. Single bias module providing reference to 2 S/D.

Figure 11. S/D impedance generic model



$$I_{INP} = \frac{V_{INP} - V_{INM}}{2 \cdot Z_{DIFF}} + \frac{V_{ICM} - V_{INT}}{Z_{CM}} = \frac{V_{INP} - V_{ICM}}{Z_{DIFF}} + \frac{V_{ICM} - V_{INT}}{Z_{CM}} \quad (1)$$

$$I_{INM} = \frac{V_{INM} - V_{INP}}{2 \cdot Z_{DIFF}} + \frac{V_{ICM} - V_{INT}}{Z_{CM}} = \frac{V_{INM} - V_{ICM}}{Z_{DIFF}} + \frac{V_{ICM} - V_{INT}}{Z_{CM}} \quad (2)$$

Related links

[3.12.4 SDADC filter modes on page 47](#)

3.12.4

SDADC filter modes

The following table describes the 4 SDADC filter modes which are controlled by bits BANDSEL, FSEL and EXTFILTER of the module configuration register (MCR).

Gain calibration must be done using the same OSR configuration, FIR filter selection mode and output data rate band selection as the target application, since full-scale values may vary slightly with these settings (normal mode and bypass FIR mode). Refer to [Table 31. Digital output codes in full scale](#) for full-scale values (with MCR[GECEEN] = 1) with different OSR settings, both for normal and bypass FIR modes.

Table 30. Filter modes

| BANDSEL ⁽¹⁾ | FSEL | EXTFILTER | Filter mode |
|------------------------|------|-----------|-------------------------|
| 0 | 0 | 0 | Normal/default mode |
| 1 | 0 | 0 | Modified bandwidth mode |
| X | 1 | 0 | Bypass FIR mode |
| X | X | 1 | External filter mode |

1. For details, refer to the device reference manual.

In normal/default mode, modified bandwidth mode and bypass FIR mode, the output values are not normalized by hardware. To apply normalization by software the following table lists the digital output codes in these modes when input signal is full range.

Table 31. Digital output codes in full scale

| OSR | MCR[FSEL] = 1 MCR[GECEEN] = 1 | MCR[FSEL] = 0 MCR[BANDSEL] = 0 MCR[GECEEN] = 1 | MCR[FSEL] = 0 MCR[BANDSEL] = 1 MCR[GECEEN] = 1 |
|-----|----------------------------------|--|--|
| 24 | 29160 | 31081 | 31095 |
| 28 | 29157 | 31077 | 31092 |
| 32 | 29158 | 31079 | 31093 |
| 36 | 29155 | 31075 | 31090 |
| 40 | 29109 | 31026 | 31042 |
| 44 | 29121 | 31040 | 31054 |
| 48 | 29160 | 31081 | 31095 |
| 56 | 29157 | 31077 | 31092 |
| 64 | 29158 | 31079 | 31093 |
| 72 | 29155 | 31075 | 31090 |
| 75 | 29064 | 31128 | 31143 |
| 80 | 29109 | 31026 | 31042 |
| 88 | 29121 | 31040 | 31054 |
| 96 | 29160 | 31081 | 31095 |
| 112 | 29157 | 31078 | 31092 |
| 128 | 29158 | 31079 | 31093 |
| 144 | 29155 | 31076 | 31089 |
| 160 | 29109 | 31026 | 31042 |

| OSR | MCR[FSEL] = 1 MCR[GECEN] = 1 | MCR[FSEL] = 0 MCR[BANDSEL] = 0 MCR[GECEN] = 1 | MCR[FSEL] = 0 MCR[BANDSEL] = 1 MCR[GECEN] = 1 |
|------|---------------------------------|---|---|
| 176 | 29121 | 31040 | 31054 |
| 192 | 29160 | 31081 | 31095 |
| 224 | 29157 | 31078 | 31092 |
| 256 | 29158 | 31079 | 31093 |
| 512 | 29158 | 31079 | 31093 |
| 1024 | 29158 | 31079 | 31093 |

Related links

[3.12.3 SDADC electrical specification on page 38](#)

3.12.5

Temperature sensor

The following table describes the temperature sensor electrical characteristics.

Table 32. Temperature sensor electrical characteristics

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|------------------------|----|-----------|---|--------------------------------|------|------|------|
| | | | | Min | Typ | Max | |
| — | CC | — | Temperature monitoring range | — | — | 150 | °C |
| ΔT_{ACC} | CC | P | Temperature monitor accuracy | -40°C < T _J < 150°C | -3°C | +3°C | °C |
| I _{TEMP_SENS} | CC | C | Power (V _{DD_HV_SAR} power supply current) | — | — | 900 | μA |
| T _{flagm40} | CC | T | -40°C temperature flag threshold | — | — | -37 | °C |
| T _{flag150} | CC | T | 150°C temperature flag threshold | — | — | 155 | °C |

3.12.6 Fast-DAC

This block is a 12-bit digital to analog converter (DAC) and is used to drive internal SoC cells. It can drive capacitive load at high speed. The input digital word is latched at the rising edge of the clock signal.

Table 33. Fast-DAC electrical specification

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|----------------------------|----|-----------|--|-------|------|------|-------|
| | | | | Min | Typ | Max | |
| RESOLUTION | CC | D | DAC register resolution | 12 | | | bit |
| DAC _{output_rate} | CC | D | Output data rate | — | — | 15 | Msp/s |
| DNL | CC | C | Differential non-linearity ⁽¹⁾ | −2.5 | — | 3.5 | LSB |
| INL | CC | C | Integral non-linearity ⁽²⁾ | −4 | — | 4 | LSB |
| TUE | CC | C | Total unadjusted error ⁽³⁾ | −6 | — | 6 | LSB |
| Gain_err | CC | C | Gain error ⁽⁴⁾ | — | — | ±0.5 | % |
| Z _{out} | CC | T | DAC output impedance | — | 1800 | — | Ω |
| T _{settling} | CC | D | Normal mode (DAC_MCR_MODEx=<011>) Capacitive load on DAC output: C _L =500 fF | — | 35 | 45 | ns |
| | | | Normal mode (DAC_MCR_MODEx=<011>) Capacitive load on DAC output: C _L =2 pF | — | 55 | 65 | |
| | | | Normal mode (DAC_MCR_MODEx=<011>) Capacitive load on DAC output: C _L =5 pF | — | 100 | 125 | |
| T _{update} | CC | D | Update rate ⁽⁶⁾ | — | 40 | 55 | ns |
| T _{wakeup} | CC | D | Wakeup time ⁽⁷⁾ | — | 0,6 | 1 | μs |
| T _{samp} | CC | D | Sampling time in sample and hold mode ⁽⁸⁾ | — | — | 1,2 | μs |
| V _{drift_hold} | CC | D | Voltage decay rate in sample and hold mode, during hold phase (dV/dt during hold phase) | — | — | 45 | mV/ms |
| I _{on} | CC | T | Current consumption | — | — | 955 | μA |
| I _{off} | CC | D | Current consumption | — | — | 0,15 | μA |

1. Difference between two consecutive codes - 1 LSB. These values are related to Fast-DAC with 12-bit resolution (for 11-bit resolutions, a /2 factor to be considered). There are no limitations at system level due to these values because of the lower resolution of the comparator modules, which use the output of Fast-DAC modules.
2. Difference between measured value at code "i" and the value at code "i" on a line drawn between code 0 and last code 4095. Offset error is included. Parameter specified by design on entire temperature range and measured at cold temperature by design characterization.
3. Difference between expected value and measured value at code "i". Parameter specified by design on entire temperature range and measured at cold temperature by design characterization.
4. Difference between ideal slope of the transfer function and measured slope computed from code 0 to code 4095.
5. Full scale: 12-bit code transition between the lowest and the highest input codes (from code 0 to code 4095) when DAC output reaches final value.
6. Time taken for ±0.5 LSB settling (code: 2047 to 2048).
7. Wakeup time from off state (setting the ENx bit in the DAC Control register) until final value ±1 LSB taken on DAC output.
8. Code transition between the lowest input code and the highest input code when DAC output reaches final value ±1 LSB.

3.12.7 Buffered-DAC

This block is a 12-bit resistive ladder based on a digital-to-analog converter (DAC) to drive the resistive load up to 5 kΩ and the capacitive load up to 50 pF. The input digital word is latched at the rising edge of the clock signal.

Table 34. Buffered-DAC electrical specification

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|------------------------------|----|-----------|--|---------------------|-----|--|------|
| | | | | Min | Typ | Max | |
| RESOLUTION | CC | D | DAC register resolution | 12 | | | bit |
| DAC _{output_rate} | CC | T | Output data rate | — | — | 1 | Msps |
| R _L | SR | D | Resistive load to ground DAC output buffer ON, with DAC_MCR_MODEx=000,001 | 5 | — | — | KΩ |
| | | D | Resistive load to supply DAC output buffer ON, with DAC_MCR_MODEx=000,001 | 25 | — | — | |
| R _{BON} | SR | D | Output impedance DAC output buffer ON in Sample&Hold mode | — | — | 2 | KΩ |
| R _{BOFF} | SR | D | Output impedance DAC output buffer OFF in Sample&Hold mode | — | — | 16.5 | KΩ |
| C _L | SR | D | Capacitive load Without Sample&Hold: DAC_MCR_MODEx<2>=0 | — | — | 50 | pF |
| C _{SH} | SR | D | Capacitive load With Sample&Hold: DAC_MCR_MODEx<2>=1 | — | — | 100 | nF |
| DAC _{output_min} | CC | T | Lower DACOUT voltage With Buffer ON: DAC_MCR_MODEx=X00, X01 | 0.2 ⁽¹¹⁾ | — | — | V |
| | | T | With Buffer OFF: DAC_MCR_MODEx=X10, X11 | 0 | — | — | |
| DAC _{output_max} | CC | T | Higher DACOUT voltage With Buffer ON: DAC_MCR_MODEx=X00, X01 | — | — | HV_REFH_DAC_COMP - 0.2 ⁽¹¹⁾ | V |
| | | T | With Buffer OFF: DAC_MCR_MODEx=X10, X11 | — | — | HV_REFH_DAC_COMP | |
| DNL | CC | C | Differential non-linearity ⁽¹⁾ DAC_MCR_MODEx = 000,001 | -2 | — | 2.5 | LSB |
| INL | CC | C | Integral nonlinearity ⁽²⁾ DAC_MCR_MODEx = 000,001 | -4 | — | 4 | LSB |
| TUE | CC | P | Total unadjusted error ⁽³⁾ DAC_MCR_MODEx = 000,001 | -20 | — | +20 | LSB |
| Gain_err | CC | C | Gain error ⁽⁴⁾ DAC_MCR_MODEx = 000,001 | — | — | ±1 | % |
| Offset_err_cal | CC | T | Offset error after calibration ⁽⁵⁾ Difference between Vref/2 and actual output at middle code | — | — | 5 | LSB |
| T _{settling_buff} | CC | D | Settling time with Buffer ON (Full scale) ⁽⁶⁾ DAC_MCR_MODEx=<000>, <001> Capacitive load on DAC output: C _L < 50 pF | — | 1.7 | 3 | μs |
| | | D | DAC_MCR_MODEx=V12=<100>, <101> Capacitive load on DAC output: C _L < 100 nF | — | — | 1900 | |
| T _{settling_unbuff} | CC | D | Settling time with Buffer OFF (Full scale) ⁽⁶⁾ DAC_MCR_MODEx=<010>, <011> Capacitive load on DAC output: C _L < 10 pF | — | — | 2 | μs |
| | | D | DAC_MCR_MODEx=V12=<110> Capacitive load on DAC output: C _L < 100 nF | — | — | 12500 | |

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-------------------|----|-----------|--|-------|-----|------|---------|
| | | | | Min | Typ | Max | |
| T_{update} | CC | D | Update rate ⁽⁷⁾ Capacitance load: $C_L < 50$ pF; DAC_MCR_MODEx=<000>, <001> | — | 1 | — | μs |
| T_{wakeup} | CC | D | Wake-up time ⁽⁸⁾ Capacitance load: $C_L < 50$ pF; DAC_MCR_MODEx=<000>, <001> | — | — | 7.5 | μs |
| T_{smp} | — | D | Sampling time in sample and hold mode ⁽⁹⁾ DAC_MCR_MODEx=<101> | — | — | 100 | μs |
| T_{trim} | CC | D | Waiting time between two trimming code changes DAC output buffer ON, with DAC_MCR_MODEx=000, 001, 100, 101 | 100 | — | — | μs |
| V_{drift_hold} | CC | D | Voltage decay rate in sample and hold mode, during hold phase (dV/dt during hold phase) | — | — | 12 | mV/ms |
| PSRR | CC | D | Analog supply rejection ratio @100kHz | — | 25 | — | dB |
| SNR | CC | C | Signal to noise ratio ⁽¹⁰⁾ | — | 69 | — | dB |
| THD | CC | C | Total harmonic distortion ⁽¹⁰⁾ | — | -67 | — | db |
| I_{on} | — | T | Current consumption In normal operation mode DAC_MCR_MODEx=<011> | — | — | 1200 | μA |
| I_{off} | — | D | Current consumption In power down mode | — | — | 0.5 | μA |

1. Difference between two consecutive codes - 1 LSB.
2. Difference between the measured value at code 'i' and the value at code 'i' on a line drawn between code 0 and last code 4095. Offset error is included.
3. Difference between expected value and measured value at code 'i'.
4. Difference between ideal slope of the transfer function and measured slope computed from code 0 to code 4095.
5. The calibration must be adjusted in the user application when temperature and supply/reference conditions change.
6. Full scale: 12-bit code transition between the lowest and the highest input codes (from code 0 to code 4095) when DAC output reaches final value.
7. Time taken for ± 0.5 LSB settling (code: 2047 to 2048).
8. Wake-up time from off state (setting the ENx bit in the DAC control register) until final value ± 1 LSB taken on DAC output.
9. Code transition between the lowest input code and the highest input code when DAC output reaches final value ± 1 LSB.
10. To be measured at 1 kHz.
11. In case of Buffer ON, the parameter specifies the maximum allowable output range of the buffer to maintain the digital-to-analog converter (DAC) linearity. If the output voltage exceeds these limits, the linearity of the converter degrades.

3.12.8 Comparator

This block is a reconfigurable rail-to-rail comparator. This takes input from the DAC.

Table 35. Comparator electrical specification

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-----------|----|-----------|---|-------|-----|-----------------------------|------|
| | | | | Min | Typ | Max | |
| V_{IN} | SR | D | Comparator input voltage range Rail to rail | 0 | — | $V_{DD_HV_SD_DAC_COMP}$ | V |
| V_{OFF} | CC | C | Comparator offset voltage Supply voltage = 3.3 V and typical temperature (25 °C) | — | — | ± 10 | mV |

| Symbol | | C | Parameter | Conditions | Value | | | Unit |
|--------------------|----|----------------|--------------------------------------|--|-------|----------------------------------|---|------|
| | | | | | Min | Typ | Max | |
| V _{OFF} | | | Comparator offset voltage | TRIMOFF<3:0> = 1010; 3 sigma | | | | mV |
| | CC | C | | Full supply voltage range, full temperature range | — | — | ±12 | |
| | | | | TRIMOFF<3:0> = 1010; 3 sigma | | | | |
| I _{DDA} | CC | D | Static current consumption | In power down mode (temperature = 150 °C) | — | — | 1 | µA |
| | | T | | In functional mode (temperature = 150 °C) | — | — | 920 | |
| V _{hys} | CC | C | Comparator hysteresis ⁽¹⁾ | HYST[2:0] = 0 | −5 | 0 | 5 | mV |
| | | C | | HYST[2:0] = 1 | 2 | 10 | 20 | |
| | | C | | HYST[2:0] = 2 | 8 | 19 | 40 | |
| | | C | | HYST[2:0] = 3 | 12 | 28 | 60 | |
| | | C | | HYST[2:0] = 4 | 16 | 38 | 80 | |
| | | C | | HYST[2:0] = 5 | 20 | 47 | 100 | |
| | | C | | HYST[2:0] = 6 | 25 | 57 | 120 | |
| | | C | | HYST[2:0] = 7 | 30 | 67 | 142 | |
| | | T _P | | CC | D | Propagation delay ⁽²⁾ | Step response, with 200 mV step with 100 mV overdrive, rising time for 1 ns slope | |
| T _{start} | CC | D | Comparator startup time | Comparator startup time to reach propagation delay specification | — | — | 5 | µs |

1. Hysteresis voltage defined when COMPOUT goes from high to low state, threshold voltage at INP = INM-VHYST.

2. With full supply voltage range (V_{DD_HV_SD_DAC_COMP} = 3 to 3.45 V).

3.13 Power management

The power management module monitors the different power supplies and generates the required internal supplies. The regulator is based on an internal switching mode power supply (SMPS) regulator, using external MOSFETs to generate the low voltage supply (V_{DD_LV} for core logic).

3.13.1 Power management integration

Use the integration scheme provided here after to ensure the proper device function.

Place capacitances on the board as near as possible to the associated pins and limit the serial inductance of the board to less than 5 nH.

Figure 12. SMPS regulator mode

Refer to the device pinout IO definition excel file for the list of available PMU control pins for each device and package.

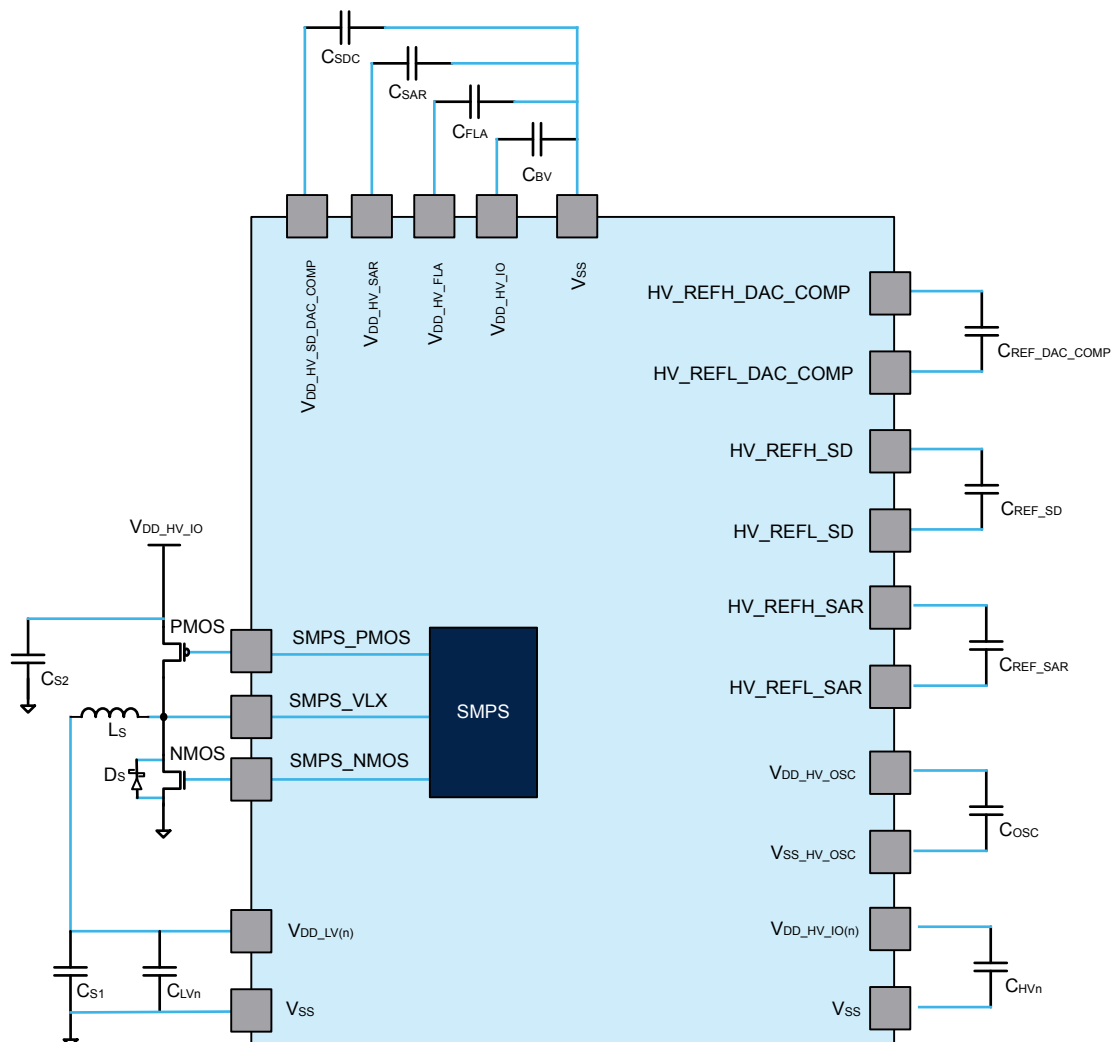


Table 36. External component integration

| Symbol | C | | Parameter | Conditions | Value | | | Unit |
|--|----|---|--|---|-------|-----|------|------|
| | | | | | Min | Typ | Max | |
| Common components | | | | | | | | |
| C _{LVn} | SR | D | Internal voltage regulator decoupling external capacitance ⁽¹⁾⁽²⁾ | Each V _{DD_LV} /V _{SS} pair | — | 47 | — | nF |
| R _{LVn} | SR | D | Stability capacitor equivalent serial resistance | — | — | — | 50 | mΩ |
| C _{BV} | SR | D | Bulk capacitance for HV supply ⁽³⁾ | — | — | 4.7 | — | μF |
| C _{HVn} | SR | D | Decoupling capacitance for I/Os ⁽³⁾⁽⁴⁾⁽⁵⁾ | Each V _{DD_HV_IO} /V _{SS} pair | — | 100 | — | nF |
| C _{FLA} | SR | D | Decoupling capacitance for flash supply ⁽³⁾ | — | — | 100 | — | nF |
| C _{SAR} | SR | D | SARADC supply external capacitance ⁽²⁾ ⁽⁶⁾⁽⁸⁾ | — | — | 10 | — | μF |
| C _{SDC} | SR | D | SDADC, DAC, COMP supply external capacitance ⁽²⁾⁽⁸⁾ | — | — | 10 | — | μF |
| C _{REF_DAC_COMP} | SR | D | DAC, COMP reference external capacitance ⁽²⁾⁽⁸⁾ | — | — | 1 | — | μF |
| C _{REF_SD} | SR | D | SDADC reference external capacitance ⁽²⁾ ⁽⁸⁾ | — | — | 1 | — | μF |
| C _{REF_SAR} | SR | D | SARADC reference external capacitance ⁽²⁾⁽⁸⁾ | — | — | 1 | — | μF |
| C _{OSC} | SR | D | Oscillator supply external capacitance ⁽²⁾ ⁽⁷⁾⁽⁹⁾ | — | — | 10 | — | μF |
| SMPS regulator mode ⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾ | | | | | | | | |
| C _{S1} | SR | D | SMPS external capacitance on LV supply ⁽⁴⁾⁽⁶⁾⁽⁸⁾⁽⁹⁾ | — | -50% | 20 | +30% | μF |
| C _{S2} ⁽¹³⁾⁽¹⁴⁾ | SR | D | SMPS external capacitance on HV supply ⁽⁴⁾⁽⁶⁾⁽⁸⁾⁽⁹⁾ | — | -50% | 47 | +35% | μF |
| L _S ⁽¹⁵⁾ | SR | D | SMPS external inductance | — | -30% | 10 | +30% | μH |
| PMOS for SMPS regular mode ⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾⁽¹⁶⁾ | | | | | | | | |
| V _{GSth} | SR | D | Gate-source threshold voltage | I _D = -250 μA; V _{GS} = 0 V; T _j = 25°C | — | -1 | — | V |
| R _{DSon} | SR | D | Drain-source on-state resistance | V _{GS} = -4.5 V; I _D = -3.2 A; T _j = 25°C | — | — | 125 | mΩ |
| Q _{G(tot)} | SR | D | Total gate charge | V _{DS} = -10 V; I _D = -3.2 A; V _{GS} = -4.5 V; T _j = 25°C | — | — | 5 | nC |
| T _j | SR | D | Junction temperature range | — | -55 | — | 150 | °C |
| R _{th} | SR | D | Thermal resistance (Junction to Ambient) | In free air | — | — | 80 | k/W |
| V _{(BR)DSS} | SR | D | Drain-source breakdown voltage | I _D = -250 μA; V _{GS} = 0 V; T _j = 25°C | — | — | -10 | V |
| I _D | SR | D | Drain current | V _{GS} = -4.5 V; T _{amb} = 100°C | — | — | -2 | A |
| NMOS for SMPS regular mode ⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾⁽¹⁶⁾ | | | | | | | | |
| V _{GSth} | SR | D | Gate-source threshold voltage | I _D = 250 μA; V _{DS} = V _{GS} ; T _j = 25°C | — | 1 | — | V |
| R _{DSon} | SR | D | Drain-source on-state resistance | V _{GS} = 4.5 V; I _D = 3.8 A; T _j = 25°C | — | — | 75 | mΩ |
| Q _{G(tot)} | SR | D | Total gate charge | V _{DS} = 15 V; I _D = 3.6 A; V _{GS} = 4.5 V; T _j = 25°C | — | — | 5 | nC |
| T _j | SR | D | Junction temperature range | — | -55 | — | 150 | °C |

| Symbol | | C | Parameter | Conditions | Value | | | Unit |
|--|----|---|--|---|-------|-----|------|------|
| | | | | | Min | Typ | Max | |
| R _{th} | SR | D | Thermal resistance (Junction to ambient) | In free air | — | — | 80 | k/W |
| V _{(BR)DSS} | SR | D | Drain-source breakdown voltage | I _D = 250 μA; V _{GS} = 0 V; T _j = 25°C | 10 | — | — | V |
| I _D | SR | D | Drain current | V _{GS} = 4.5 V; T _{amb} = 100°C | — | — | 2.25 | A |
| Schottky diode for SMPS regular mode ⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾ | | | | | | | | |
| I _{F(AV)} | SR | D | Average forward current | f = 20 kHz; square wave; T _{amb} ≤ 85°C | — | — | 3 | A |
| V _F | SR | D | Forward voltage | I _F = 1 A; T _j = 25°C | — | — | 300 | mV |
| T _{amb} | SR | D | Junction temperature range | — | -55 | — | 150 | °C |
| R _{th(j-a)} | SR | D | Thermal resistance (Junction to Ambient) | In free air | — | — | 80 | k/W |

- $V_{DD_HV_IO} = 3.3 V \pm 5\%$, $T_J = -40 / 150^\circ C$.
- For noise filtering, add a high frequency bypass capacitance of 10 nF, as close as possible to the terminal.
- Recommended X7R capacitors.
- For optimal EMC performance, consider adding a 10 nF on every supply rail. The intention is to have a decoupling scheme covering the wider possible frequency range.
- To sustain the high voltage of the SMPS external MOSFET, add a 10 μF on $V_{DD_HV_IO}$.
- External capacitance is required both in internal and external (test) regulator modes.
- For noise filtering, add a high frequency bypass capacitance of 47 nF as close as possible to the terminal.
- For noise filtering, add a high frequency bypass capacitance of 100 nF as close as possible to the terminal.
- For noise filtering, add a high frequency bypass capacitance of 1 nF as close as possible to the terminal.
- The parameters of the selected external components of the SMPS must be equal to or greater than the recommended specifications. The selected components must comply with ESD protection requirements.
- Based on the device power dissipation, the customer must ensure adequate heat dissipation to prevent overheating. Overheating may lead to performance issues, device failure, and reduced lifespan and reliability.
- The final selection of components must be reviewed with ST.
- Recommended X7R or X5R ceramic $-50\% / +35\%$ variation across process, temperature, voltage and after aging.
- The value of the capacitance on the high voltage supply reported in this datasheet is a general recommendation. The application can select a different number, based on the external regulator and EMC requirements.
- Recommended current saturation greater than or equal to 2 A with a resistance DCR less than or equal to 50 m Ω .
- The device is mounted on an FR4 printed circuit board (PCB) with single-sided copper and tin-plated finish. The mounting pad for the drain measures 6 cm².

Related links

[3.12.1 ADC input description on page 35](#)

3.13.2 Voltage regulators

Table 37. SMPS regulator specifications

| Symbol | | C | Parameter | Conditions | Value | | | Unit |
|-----------------------|----|---|---|--------------------------|-------|-------|------|------|
| | | | | | Min | Typ | Max | |
| V _{DD_HV_IO} | SR | P | SMPS regulator supply voltage | — | 3.15 | — | 3.45 | V |
| V _{SMPS} | CC | P | SMPS regulator output voltage | After trimming, max load | 1.23 | 1.285 | 1.34 | V |
| F _{SMPS} | CC | T | SMPS regulator switching frequency | — | -8% | 750 | +8% | kHz |
| I _{DDSMPS} | CC | T | SMPS regulator current provided to V _{DD_LV} domain | — | — | — | 1000 | mA |
| I _{DDCLAMP} | CC | D | SMPS regulator rush current sunked from V _{DD_HV_IO} domain during V _{DD_LV} domain loading | Power-up condition | — | — | 400 | mA |
| ΔI _{DDSMPS} | CC | T | SMPS regulator current variation | 20 μs observation window | -100 | — | 100 | mA |

3.13.3 Voltage monitors

The monitors and their associated levels for the device are given in Table 38. Voltage monitor electrical characteristics. The following figure shows how the voltage monitor threshold works.

Figure 13. Voltage monitor threshold definition

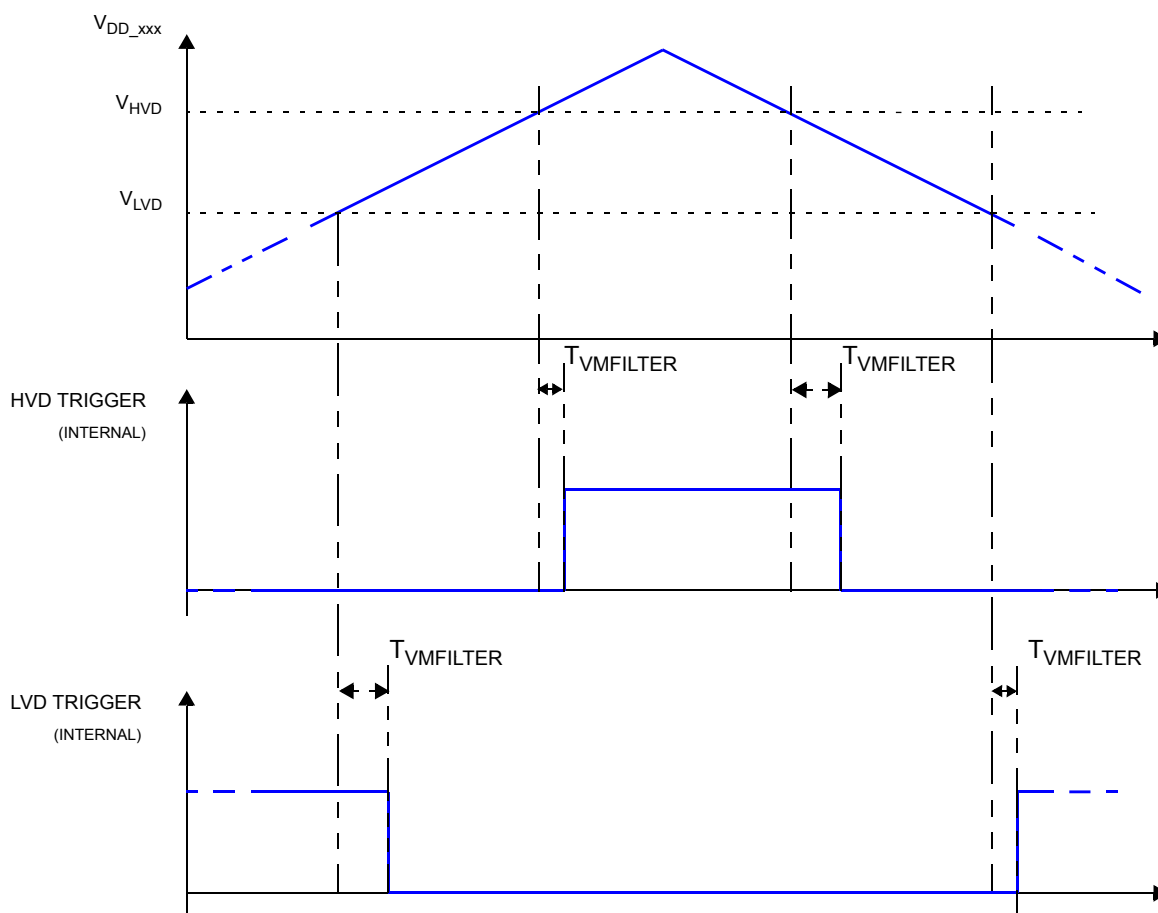


Table 38. Voltage monitor electrical characteristics

| Symbol | C | Parameter | Conditions | Value ⁽¹⁾ | | | Unit | |
|---|----|-----------|---|----------------------|-------|-------|-------|---|
| | | | | Min | Typ | Max | | |
| Minimum voltage detectors (LV supplies) | | | | | | | | |
| V _{DD_LV} | CC | P | POR031_C Low voltage supply power-on reset voltage monitor V _{DD_LV} | — | 0.290 | 0.600 | 0.900 | V |
| | CC | P | MVD102T_C LV supply core minimum voltage detector V _{DD_LV} | — | 1.005 | 1.030 | 1.055 | V |
| | CC | P | MVD114_C LV supply core low range minimum voltage detector V _{DD_LV} | — | 1.133 | 1.150 | 1.167 | V |
| | CC | P | MVD114_FL LV supply flash minimum voltage detector V _{DD_LV_FLA} | — | 1.133 | 1.150 | 1.167 | V |

| Symbol | C | | Parameter | Conditions | Value ⁽¹⁾ | | | Unit |
|---|----|---|--|------------|----------------------|-------|-------|------|
| | | | | | Min | Typ | Max | |
| Low voltage detectors (LV supplies) | | | | | | | | |
| V _{DD_LV} | CC | P | LVD119_C LV supply core low voltage detector V _{DD_LV} | — | 1.188 | 1.205 | 1.222 | V |
| | CC | P | LVD119_FL LV supply flash low voltage detector V _{DD_LV_FLA} | — | 1.188 | 1.205 | 1.222 | V |
| | CC | P | LVD119_PLL0 LV supply PLL0 low voltage detector V _{DD_LV_PLL0} | — | 1.188 | 1.205 | 1.222 | V |
| | CC | P | LVD119_PLL1 LV supply PLL1 low voltage detector V _{DD_LV_PLL1} | — | 1.188 | 1.205 | 1.222 | V |
| | CC | P | LVD119_DD LV supply DLL & DelayLanes low voltage detector V _{DD_LV_DD} | — | 1.188 | 1.205 | 1.222 | V |
| | CC | P | LVD119_RC LV supply RCOSC low voltage detector V _{DD_LV} | — | 1.188 | 1.205 | 1.222 | V |
| High and upper voltage detectors (LV supplies) | | | | | | | | |
| V _{DD_LV} | CC | P | HVD140_C LV supply core high voltage detector V _{DD_LV} | — | 1.361 | 1.38 | 1.399 | V |
| | CC | P | UVD145_C LV supply core upper voltage detector V _{DD_LV} | — | 1.411 | 1.430 | 1.449 | V |
| | CC | P | UVD145_RC LV supply RCOSC upper voltage detector V _{DD_LV} | — | 1.411 | 1.430 | 1.449 | V |
| Minimum and low voltage detectors (HV supplies) | | | | | | | | |
| V _{DD_HV_IO} | CC | P | POR200_C High voltage supply power-on reset voltage monitor V _{DD_HV_PMU} | — | 1.760 | 1.960 | 2.160 | V |
| | CC | P | MVD240T_C HV supply core minimum voltage monitor V _{DD_HV_PMU} | — | 2.456 | 2.525 | 2.594 | V |
| | CC | P | MVD240_SMPS HV supply core minimum voltage monitor V _{DD_HV_SMPS} | — | 2.456 | 2.525 | 2.594 | V |
| | CC | P | MVD270_C HV supply core minimum voltage monitor V _{DD_HV_PMU} | — | 2.794 | 2.850 | 2.906 | V |
| | CC | P | LVD290_C HV supply core low voltage monitor V _{DD_HV_PMU} | — | 2.898 | 2.955 | 3.012 | V |
| | CC | P | LVD290_IO1 HV supply I/O low voltage monitor V _{DD_HV_IO1} segment | — | 2.898 | 2.955 | 3.012 | V |
| | CC | P | LVD290_IO0 | — | 2.898 | 2.955 | 3.012 | V |

| Symbol | C | | Parameter | Conditions | Value ⁽¹⁾ | | | Unit |
|---------------------------------------|----|---|---|------------|----------------------|-------|-------|------|
| | | | | | Min | Typ | Max | |
| V _{DD_HV_IO} | | | HV supply I/O low voltage monitor V _{DD_HV_IO0} segment | | | | | |
| V _{DD_HV_FLA} | CC | P | MVD270_FL HV supply flash minimum voltage monitor V _{DD_HV_FLA} | — | 2.794 | 2.850 | 2.906 | V |
| | CC | P | LVD290_FL HV supply flash low voltage monitor V _{DD_HV_FLA} | — | 2.898 | 2.955 | 3.012 | V |
| V _{DD_HV_SD_DAC_COMP} | CC | P | LVD290_AD HV supply SD-ADC low voltage monitor V _{DD_HV_SD} | — | 2.898 | 2.955 | 3.012 | V |
| | CC | P | LVD290_DACCMP HV supply DAC & COMP low voltage monitor V _{DD_HV_DAC} | — | 2.898 | 2.955 | 3.012 | V |
| V _{DD_HV_SAR} | CC | P | LVD290_AS HV supply SAR-ADC low voltage monitor V _{DD_HV_SAR} | — | 2.898 | 2.955 | 3.012 | V |
| V _{DD_HV_OSC} | CC | P | LVD290_OSC HV supply OSC low voltage monitor V _{DD_HV_OSC} | — | 2.898 | 2.955 | 3.012 | V |
| Upper voltage detectors (HV supplies) | | | | | | | | |
| V _{DD_HV_IO} | CC | P | UVD380_C HV supply core upper voltage monitor V _{DD_HV_PMU} | — | 3.651 | 3.725 | 3.799 | V |
| | CC | P | UVD380_IO0 HV supply I/O upper voltage monitor V _{DD_HV_IO0} segment | — | 3.651 | 3.725 | 3.799 | V |
| V _{DD_HV_FLA} | CC | P | UVD380_FL HV supply flash upper voltage monitor V _{DD_HV_FLA} | — | 3.651 | 3.725 | 3.799 | V |
| V _{DD_HV_SAR} | CC | P | UVD380_AS HV supply SAR-ADC upper voltage monitor V _{DD_HV_SAR} | — | 3.651 | 3.725 | 3.799 | V |
| V _{DD_HV_SD_DAC_COMP} | CC | P | UVD380_DACCMP HV supply DAC & COMP upper voltage monitor V _{DD_HV_DAC} | — | 3.651 | 3.725 | 3.799 | V |
| T _{VMFILTER} | CC | D | Voltage monitor filter ⁽²⁾ | — | 3 | | 20 | µs |

1. The values are trimmed during boot process.

2. See [Figure 13. Voltage monitor threshold definition](#). Transitions shorter than minimum are filtered. Transitions longer than maximum are not filtered, and are delayed by T_{VMFILTER} time. Transitions between minimum and maximum can be filtered or not filtered, according to temperature, process and voltage variations.

Related links

[3.3 Operating conditions on page 12](#)

3.14 Embedded flash memory

The following table shows the wait state configuration.

Table 39. Wait state configuration

| APC | RWSC | Core frequency (MHz) |
|--------------------|------|----------------------|
| 000 ⁽¹⁾ | ≤1 | f ≤ 34 |
| | 2 | f ≤ 68 |
| | 3 | f ≤ 136 |
| | 4 | f ≤ 170 |
| | 5 | f ≤ 204 |
| | 6 | f ≤ 238 |
| | 7 | f ≤ 273 |
| | 8 | f ≤ 307 |
| 100 ⁽²⁾ | ≤1 | f ≤ 34 |
| | 2 | f ≤ 68 |
| | 3 | f ≤ 136 |
| | 4 | f ≤ 170 |
| | 5 | f ≤ 204 |
| | 6 | f ≤ 238 |
| | 7 | f ≤ 273 |
| | 8 | f ≤ 307 |
| 001 ⁽³⁾ | 3 | 55 < f ≤ 120 |
| | 4 | 55 < f ≤ 160 |
| | 5 | 55 < f ≤ 200 |
| | 6 | 55 < f ≤ 233 |
| | 7 | 55 < f ≤ 267 |
| | 8 | 55 < f ≤ 307 |

1. No pipeline.

2. No pipeline with 1 Tclk access delay.

3. Pipeline.

Table 40. Flash memory program and erase specifications

| Symbol | Characteristics ⁽¹⁾⁽²⁾ | Value | | | | | | | | Unit | |
|---------------------------|--|--------------------|---|----------------------|-------------------------|---|------------------------------------|-----------------------------|----------------|------|----|
| | | Typ ⁽³⁾ | C | Initial max | | | Typical end of life ⁽⁴⁾ | Lifetime max ⁽⁵⁾ | | | C |
| | | | | 25 °C ⁽⁶⁾ | All temp ⁽⁷⁾ | C | | < 1 K cycles | < 250 K cycles | | |
| t _{dwprogram} | Double word (64 bits) program time (partition 0 & 3) | 43 | C | 130 | — | — | 140 | 500 | | C | μs |
| t _{pprogram} | Page (256 bits) program time | 72 | C | 240 | — | — | 240 | 1000 | | C | μs |
| t _{pprogrameep} | Page (256 bits) program time (partition 0 & 3) | 83 | C | 264 | — | — | 276 | 1000 | | C | μs |
| t _{qprogram} | Quad page (1024 bits) program time | 220 | C | 1040 | 1200 | P | 850 | 2000 | | C | μs |
| t _{qprogrammeep} | Quad page (1024 bits) program time (partition 0 & 3) | 245 | C | 1140 | 1320 | P | 978 | 2000 | | C | μs |

| Symbol | Characteristics ⁽¹⁾⁽²⁾ | Value | | | | | | | | | Unit |
|-----------------------------|--|--------------------|---|----------------------|-------------------------|---|------------------------------------|-----------------------------|----------------|---|------|
| | | Typ ⁽³⁾ | C | Initial max | | | Typical end of life ⁽⁴⁾ | Lifetime max ⁽⁵⁾ | | C | |
| | | | | 25 °C ⁽⁶⁾ | All temp ⁽⁷⁾ | C | | < 1 K cycles | < 250 K cycles | | |
| t _{16kpperase0} | 16 KB block pre-program and erase time (partition 0) | 230 | C | 495 | 550 | P | 300 | 600 | — | C | ms |
| t _{32kpperase0} | 32 KB block pre-program and erase time (partition 0) | 345 | C | 700 | 825 | P | 400 | 1000 | — | C | ms |
| t _{64kpperase0} | 64 KB block pre-program and erase time (partition 0) | 530 | C | 910 | 1150 | P | 600 | 1600 | — | C | ms |
| t _{64kpperase} | 64 KB pre-program and erase time | 460 | C | 700 | 750 | P | 420 | 1200 | — | C | ms |
| t _{256kpperase} | 256 KB block pre-program and erase time | 1140 | C | 2000 | 2600 | P | 1300 | 2800 | — | C | ms |
| t _{16kprogram0} | 16 KB block program time (partition 0) | 30 | C | 52 | 58 | P | 40 | 100 | — | C | ms |
| t _{32kprogram0} | 32 KB block program time (partition 0) | 60 | C | 105 | 120 | P | 75 | 200 | — | C | ms |
| t _{64kprogram0} | 64 KB block program time (partition 0) | 120 | C | 200 | 250 | P | 150 | 400 | — | C | ms |
| t _{64kprogram} | 64 KB block program time | 102 | C | 175 | 200 | P | 150 | 400 | — | C | ms |
| t _{256kprogram} | 256 KB block program time | 410 | C | 700 | 800 | P | 590 | 1000 | — | C | ms |
| t _{16kprogrameep} | Program 16 KB data flash - EEPROM (partition 3) | 30 | C | 52 | 58 | P | 64 | 200 | | C | ms |
| t _{16keraseeep} | Erase 16 KB data flash - EEPROM (partition 3) | 230 | C | 495 | 550 | P | 400 | 1000 | | C | ms |
| t _{16kprogramheep} | Program 16 KB HSM data flash - EEPROM (partition 3) | 30 | C | 52 | 58 | P | 64 | 200 | | C | ms |
| t _{16keraseheep} | Erase 16 KB HSM data flash - EEPROM (partition 3) | 230 | C | 495 | 550 | P | 400 | 1000 | | C | ms |
| t _{tr} | Program rate ⁽⁸⁾ | 1.7 | C | 2.8 | 3.40 | C | 2.4 | — | | C | s/MB |
| t _{pr} | Erase rate ⁽⁸⁾ | 4.8 | C | 7.2 | 9.6 | C | 6.4 | — | | C | s/MB |
| t _{tpfrm} | Program rate factory mode ⁽⁸⁾ | 1.12 | C | 1.4 | 1.6 | C | — | — | | C | s/MB |
| t _{erfm} | Erase rate factory mode ⁽⁸⁾ | 4.0 | C | 5.2 | 5.8 | C | — | — | | C | s/MB |
| t _{ffprogram} | Full flash programming time ⁽⁹⁾ | 3.4 | C | 5.0 | 6.0 | P | 3.8 | — | — | C | s |
| t _{fferase} | Full flash erasing time ⁽⁹⁾ | 9.9 | C | 17.0 | 20.0 | P | 11.0 | — | — | C | s |
| t _{ESRT} | Erase suspend request rate ⁽¹⁰⁾ | 200 | T | — | — | — | — | — | | — | μs |
| t _{PSRT} | Program suspend request rate ⁽¹⁰⁾ | 30 | T | — | — | — | — | — | | — | μs |
| t _{AMRT} | Array integrity check - margin read suspend request rate | 15 | T | — | — | — | — | — | | — | μs |
| t _{PSUS} | Program suspend latency ⁽¹¹⁾ | — | — | — | — | — | — | 15 | | T | μs |
| t _{ESUS} | Erase suspend latency ⁽¹¹⁾ | — | — | — | — | — | — | 30 | | T | μs |
| t _{AIC0S} | Array integrity check (1920 KB, sequential) ⁽¹²⁾ | 11.3 | T | — | — | — | — | — | — | — | ms |
| t _{AIC256KS} | Array integrity check (256 KB, sequential) ⁽¹²⁾ | 1.5 | T | — | — | — | — | — | — | — | ms |
| t _{AIC0P} | Array integrity check (1920 KB, proprietary) ⁽¹²⁾ | 4.0 | T | — | — | — | — | — | — | — | s |
| t _{MR0S} | Margin read (1920 KB, sequential) ⁽¹²⁾ | 30 | T | — | — | — | — | — | — | — | ms |
| t _{MR256KS} | Margin read (256 KB, sequential) ⁽¹²⁾ | 4.0 | T | — | — | — | — | — | — | — | ms |

| Symbol | Characteristics ⁽¹⁾⁽²⁾ | Value | | | | | | | Unit | |
|-------------------|-------------------------------------|--------------------|---|----------------------|-------------------------|------------------------------------|-----------------------------|--------------|------|----|
| | | Typ ⁽³⁾ | C | Initial max | | Typical end of life ⁽⁴⁾ | Lifetime max ⁽⁵⁾ | | | C |
| | | | | 25 °C ⁽⁶⁾ | All temp ⁽⁷⁾ | | C | < 1 K cycles | | |
| t _{AABT} | Array integrity check abort latency | — | — | — | — | — | — | 10 | T | μs |
| t _{MABT} | Margin read abort latency | — | — | — | — | — | — | 10 | T | μs |

- Actual hardware operation times; this does not include software overhead.
- Characteristics are valid both for data flash and code flash, unless specified in the characteristics column.
- Typical program and erase times assume nominal supply values and operation at 25 °C.
- Typical end of life program and erase times represent the median performance and assume nominal supply values. Typical end of life program and erase values may be used for throughput calculations. These values are characteristic, but not tested.
- Lifetime maximum program and erase times apply across the voltages and temperatures and occur after the specified number of program/erase cycles. These maximum values are characterized but not tested or guaranteed.
- Initial factory condition: < 100 program/erase cycles, 25 °C typical junction temperature and nominal (±5%) supply voltages.
- Initial maximum "All temp" program and erase times provide guidance for time-out limits used in the factory and apply for less than or equal to 100 program or erase cycles, -40 °C < T_J < 150 °C junction temperature and nominal (±5%) supply voltages.
- Rate computed based on 256 KB sectors.
- Only code sectors, not including EEPROM, neither UTEST and BAF.
- Time between suspend resume and next suspend. Value stated actually represents min value specification.
- Timings specified by design.
- AIC is done using system clock, thus all timing is dependent on system frequency and number of wait states. Timing in the table is calculated at max frequency.

All the flash operations require the presence of the system clock for internal synchronization. About 50 synchronization cycles are needed: this means that the timings of the previous table can be longer if a low frequency system clock is used.

Table 41. Flash memory life specification

| Symbol | Characteristics ⁽¹⁾⁽²⁾ | Value | | | | Unit |
|----------------------|---|-------|---|-----|---|---------|
| | | Min | C | Typ | C | |
| N _{CER16K} | 16 KB code flash endurance | 10 | — | 100 | — | Kcycles |
| N _{CER32K} | 32 KB code flash endurance | 10 | — | 100 | — | Kcycles |
| N _{CER64K} | 64 KB code flash endurance | 10 | — | 100 | — | Kcycles |
| N _{CER256K} | 256 KB code flash endurance | 1 | — | 100 | — | Kcycles |
| | 256 KB code flash endurance ⁽³⁾ | 10 | — | 100 | — | Kcycles |
| N _{DER16K} | 16 KB data EEPROM flash endurance | 250 | — | — | — | Kcycles |
| N _{DER16K} | 16 KB HSM data EEPROM flash endurance | 100 | — | — | — | Kcycles |
| t _{DR1k} | Minimum data retention blocks with 0 - 1 000 P/E cycles | 25 | — | — | — | Years |
| t _{DR10k} | Minimum data retention blocks with 1 001 - 10 000 P/E cycles | 20 | — | — | — | Years |
| t _{DR100k} | Minimum data retention blocks with 10 001 - 100 000 P/E cycles | 15 | — | — | — | Years |
| t _{DR250k} | Minimum data retention blocks with 100 001 - 250 000 P/E cycles | 10 | — | — | — | Years |

- It is recommended that the application enables the core cache memory.
- Program and erase cycles supported across specified temperature specifications.
- 10 Kcycles on 4-256 KB blocks are not intended for production. Reduced reliability and degraded erase time are possible.

3.15 AC specifications

All AC timing specifications are valid at up to 150°C.

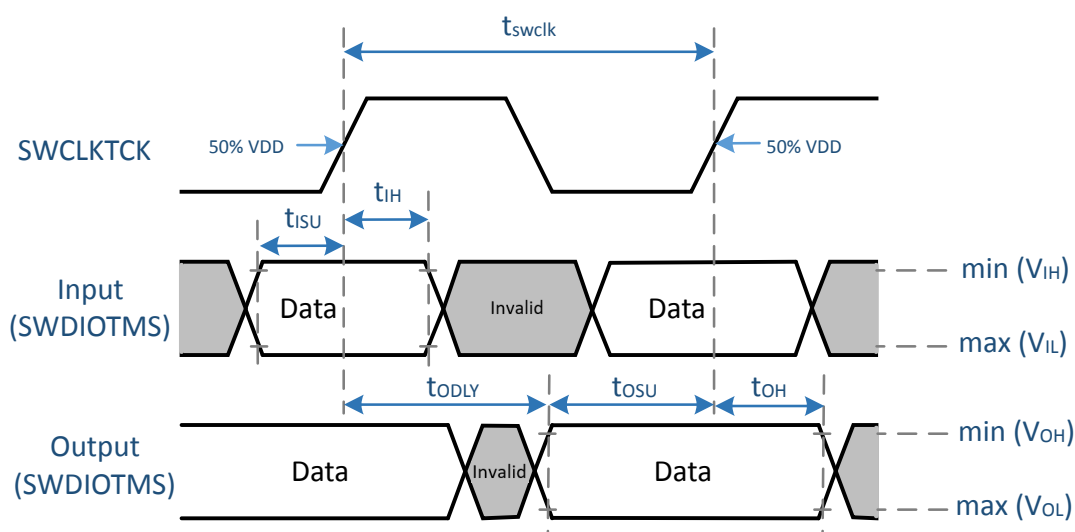
3.15.1 Debug and calibration interface timing

3.15.1.1 SWD interface timing

Table 42. SWD timings and delay adjustment

| Symbol | C | | Characteristics | Condition | Value | | | Unit | # |
|------------------------|----|---|---|------------|-------|-----|-----|------|----|
| | | | | | Min | Typ | Max | | |
| Clock (SWCLK) | | | | | | | | | |
| f _{swclkck} | CC | D | SWCLKTCK frequency | — | — | — | 25 | MHz | 1 |
| t _{swclkck} | CC | D | SWCLKTCK period | — | 40 | — | — | ns | 2 |
| Input (SWDIOTMS) | | | | | | | | | |
| t _{ISU} | CC | D | SWDIOTMS input setup time | — | 15 | — | — | ns | 3 |
| t _{IH} | CC | D | SWDIOTMS input hold time | — | 3 | — | — | ns | 4 |
| Output (SWDIOTMS) | | | | | | | | | |
| t _{ODLY} | CC | D | SWDIOTMS output delay time during data transfer | CL = 25 pF | — | — | 30 | ns | 5 |
| T _{OSU} | CC | D | SWDIOTMS output setup time | CL = 25 pF | 5 | — | — | ns | 6 |
| t _{OH} | CC | D | SWDIOTMS output hold time | CL = 25 pF | 1 | — | — | ns | 7 |
| t _{RISE} | CC | D | SWDIOTMS output rise time | CL = 25 pF | 2.2 | — | — | ns | 8 |
| t _{FALL} | CC | D | SWDIOTMS output fall time | CL = 25 pF | 2.2 | — | — | ns | 9 |
| t _{SKEW_TRAN} | CC | D | SWDIOTMS output SKEW | CL = 25 pF | 1 | — | — | ns | 10 |

Figure 14. SWD timings



3.15.1.2 JTAG interface timing

Table 43. JTAG pin test and debug timings

| Symbol ⁽¹⁾⁽²⁾ | C | Characteristics | Condition | Value | | | Unit | # |
|--------------------------|----|-----------------|--|-------|-----|--------------------|------|----|
| | | | | Min | Typ | Max | | |
| t_{JCYC} | CC | D | TCK cycle time | 40 | — | — | ns | 1 |
| t_{JDC} | CC | D | TCK clock pulse width | 19 | — | — | ns | 2 |
| $t_{TCKRISE}$ | CC | D | TCK rise and fall times (40%-70%) | — | — | 3 | ns | 3 |
| t_{TMSS}, t_{TDIS} | CC | D | TMS, TDI data setup time | 15 | — | — | ns | 4 |
| t_{TMSH}, t_{TDIH} | CC | D | TMS, TDI data hold time | 3 | — | — | ns | 5 |
| t_{TDOV} | CC | D | TCK low to TDO data valid | — | — | 15 ⁽³⁾ | ns | 6 |
| t_{TDOI} | CC | D | TCK low to TDO data invalid | 1 | — | — | ns | 7 |
| t_{TDOHZ} | CC | D | TCK low to TDO high impedance | — | — | 15 | ns | 8 |
| t_{JCMPPW} | CC | D | JCOMP assertion time | 40 | — | — | ns | 9 |
| t_{JCMPs} | CC | D | JCOMP setup time to TCK low | 40 | — | — | ns | 10 |
| t_{BSDV} | CC | D | TCK falling edge to output valid | — | — | 600 ⁽⁴⁾ | ns | 11 |
| t_{BSDVZ} | CC | D | TCK falling edge to output valid out of high impedance | — | — | 600 | ns | 12 |
| t_{BSDHZ} | CC | D | TCK falling edge to output high impedance | — | — | 600 | ns | 13 |
| t_{BSDST} | CC | D | Boundary scan input valid to TCK rising edge | 15 | — | — | ns | 14 |
| t_{BSDHT} | CC | D | TCK rising edge to boundary scan input invalid | 15 | — | — | ns | 15 |

1. These specifications apply to JTAG boundary scan only.
2. JTAG timing specified at $V_{DD_HV_IO} = 3.15$ to 3.45 V and maximum loading per pad type as specified in the I/O section of the datasheet.
3. Timing includes TCK pad delay, clock tree delay, logic delay and TDO output pad delay.
4. Applies to all pins, limited by pad slew rate. Refer to [Section 3.8.2: I/O output DC characteristics](#) and add 20 ns for JTAG delay.

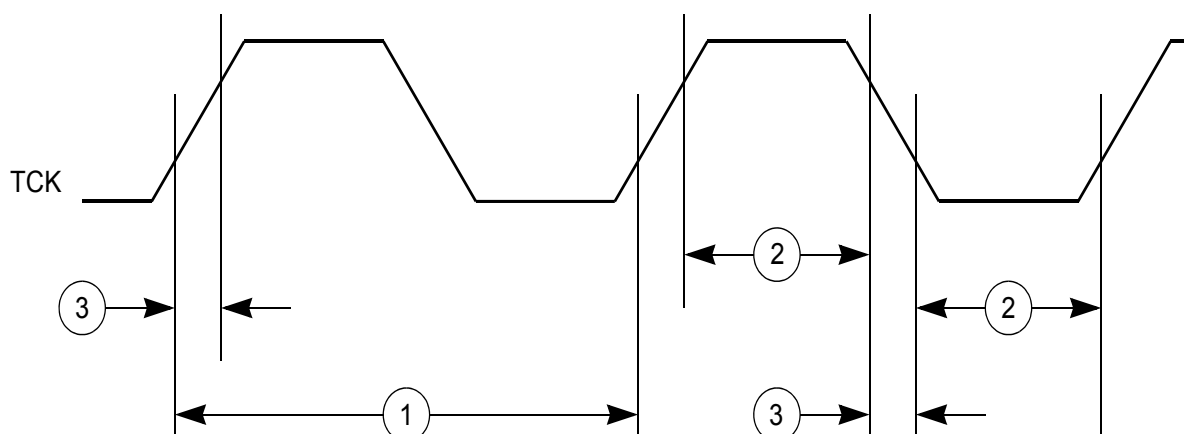
Figure 15. JTAG test clock input timing


Figure 16. JTAG test access port timing

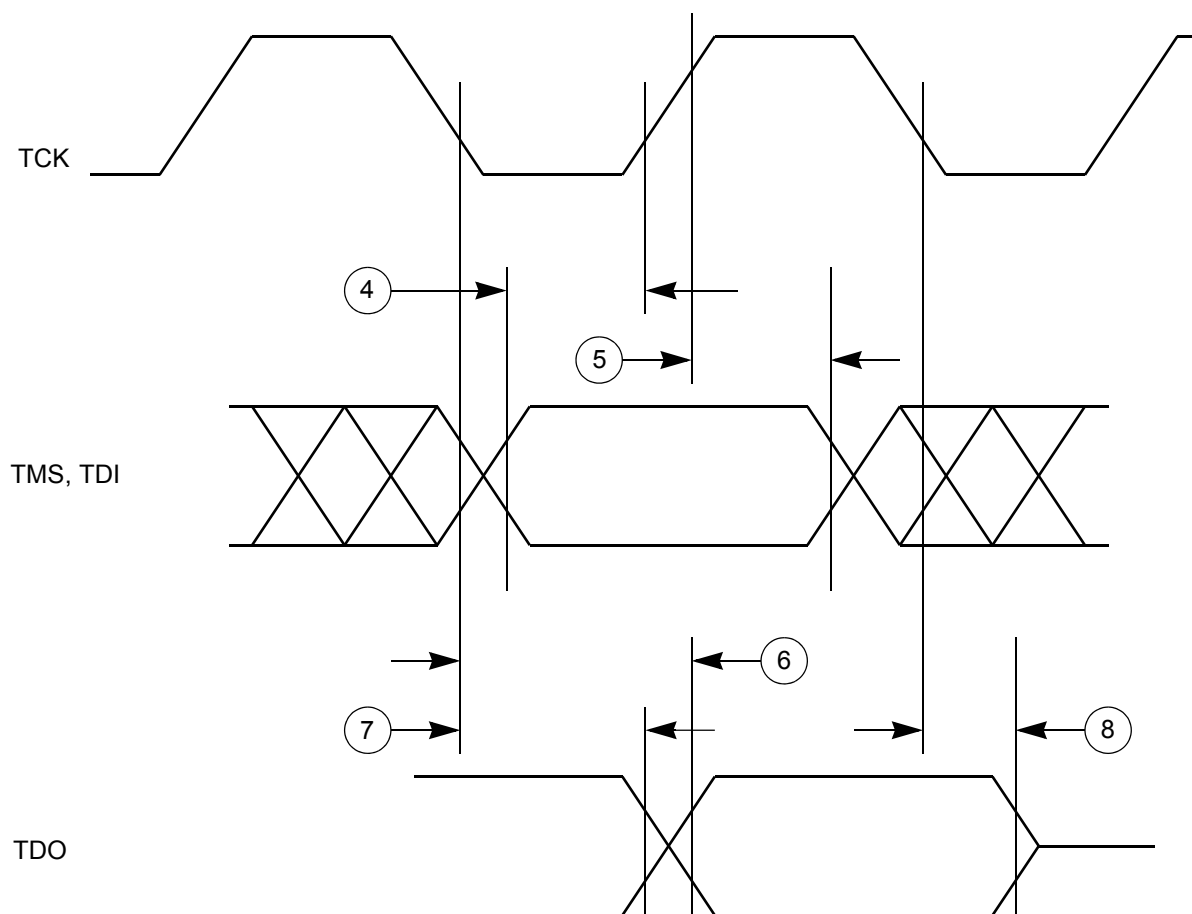


Figure 17. JTAG JCOMP timing

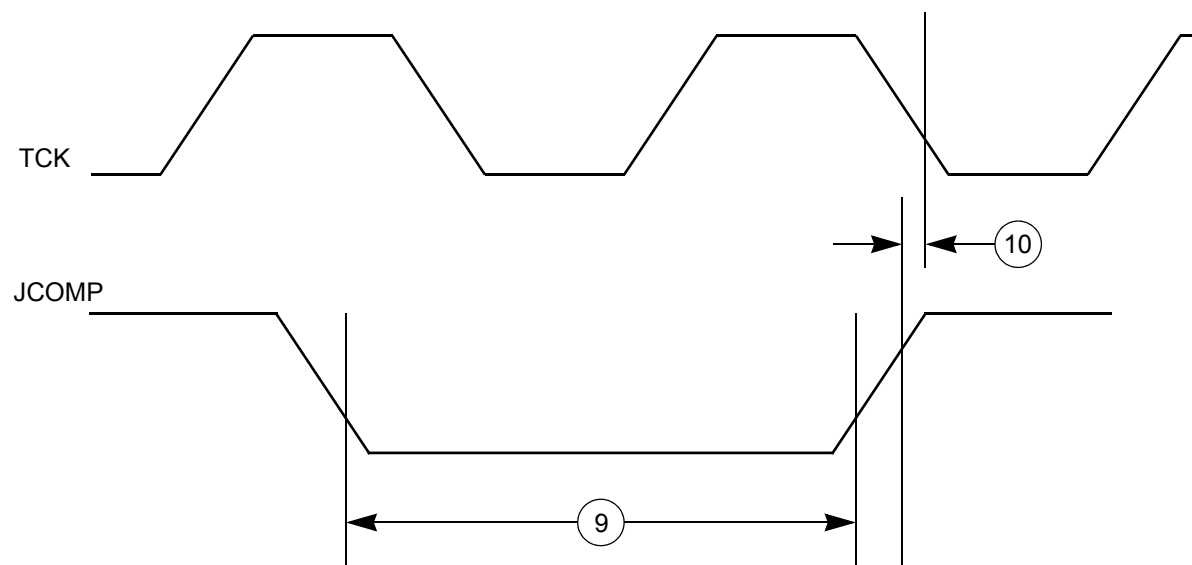
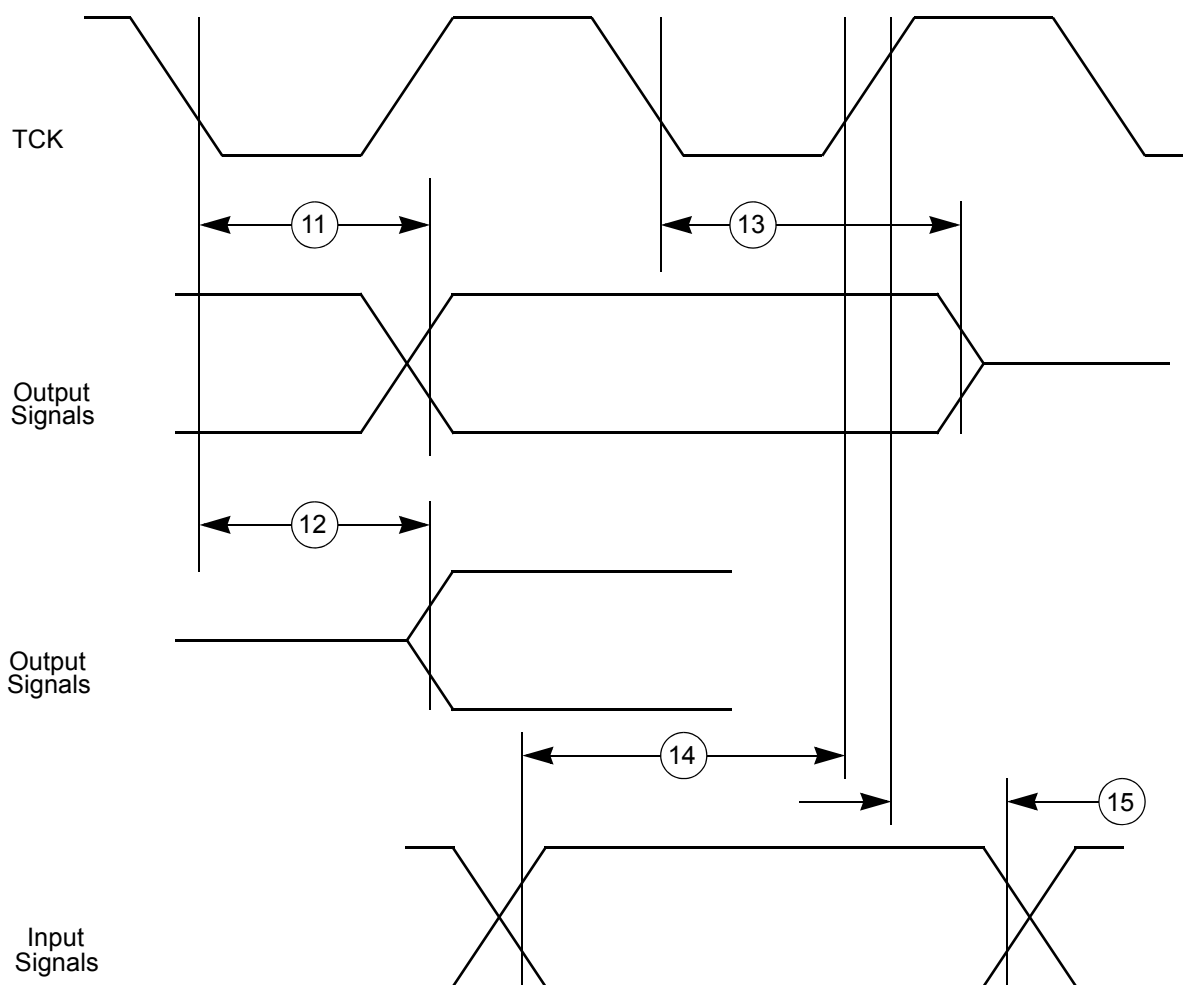


Figure 18. JTAG boundary scan timing



Related links

[3.8.2 I/O output DC characteristics on page 20](#)

3.15.2

Extended interrupt and event controller input (EXTI)

The pulse on the interrupt input must have a minimal length in order to ensure that it is detected by the event controller.

Table 44. External interrupt timing

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|------------|----|-----------|--------------------------------------|-------|-----|-----|------|
| | | | | Min | Typ | Max | |
| t_{ICYC} | SR | D | IRQ edge to edge time ⁽¹⁾ | 10 | — | — | ns |

1. Applies when IRQ pins are configured for rising edge or falling edge events, but not both.

3.15.3 SPI timing

3.15.3.1 SPI — Single ended operation

Table 45. SPI single-ended mode AC specifications — Very Fast IO output characteristics

| Symbol | C | D | Parameter | Conditions ⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾⁽⁶⁾ | Value | | | Unit |
|------------------------|----|---|------------------------------------|--|------------------------|------------|--------------|------|
| | | | | | Min | Typ | Max | |
| f_{SCK} | CC | D | SPI clock frequency ⁽⁷⁾ | Master mode SPI1, SPI4 | — | — | 50 | MHz |
| | CC | D | | Master mode SPI2, SPI3 | — | — | 37.5 | |
| | CC | D | | Slave receiver mode SPI1, SPI2, SPI3, SPI4 | — | — | 50 | |
| $t_{su}(NSS)$ | CC | D | NSS setup time | Slave mode | $2ns+2 \cdot T_{PCLK}$ | — | — | ns |
| $t_h(NSS)$ | CC | D | NSS hold time | Slave mode | 3 | — | — | ns |
| $t_w(SCKH), t_w(SCKL)$ | CC | D | SCK high and low time | Master mode | $T_{PCLK}-2$ | T_{PCLK} | $T_{PCLK}+2$ | ns |
| $t_{su}(MI)$ | CC | D | Data input setup time | Master mode | 2 | — | — | ns |
| $t_{su}(SI)$ | CC | D | | Slave mode | 2 | — | — | ns |
| $t_h(MI)$ | CC | D | Data input hold time | Master mode | 4 | — | — | ns |
| $t_h(SI)$ | CC | D | | Slave mode | 3 | — | — | ns |
| $t_v(SO)$ | CC | D | Data output valid time | Master mode | — | — | 15 | ns |
| $t_v(MO)$ | CC | D | | Slave mode | — | — | 4 | ns |
| $t_h(SO)$ | CC | D | Data output hold time | Master mode | 4 | — | — | ns |
| $t_h(MO)$ | CC | D | | Slave mode | -2 | — | — | ns |

1. All timing values for output signals in this table are measured to 50% of the output voltage.
2. All output timing is the worst case and includes the mismatching of rise and fall times of the output pads.
3. All timing values are valid for $V_{DD_HV_IO} = 3.3$ V.
4. Input timing assumes an input slew rate of 1 ns (10% – 90%) and uses TTL / automotive voltage thresholds.
5. Very Fast IO output characteristics
6. Capacitive Load $C_L = 25pF$
7. Max frequency can be reached under specific device clocks configuration. Refer to the device reference manual, Clocking chapter for details.

Figure 19. SPI timing diagram — slave mode and CPHA = 1

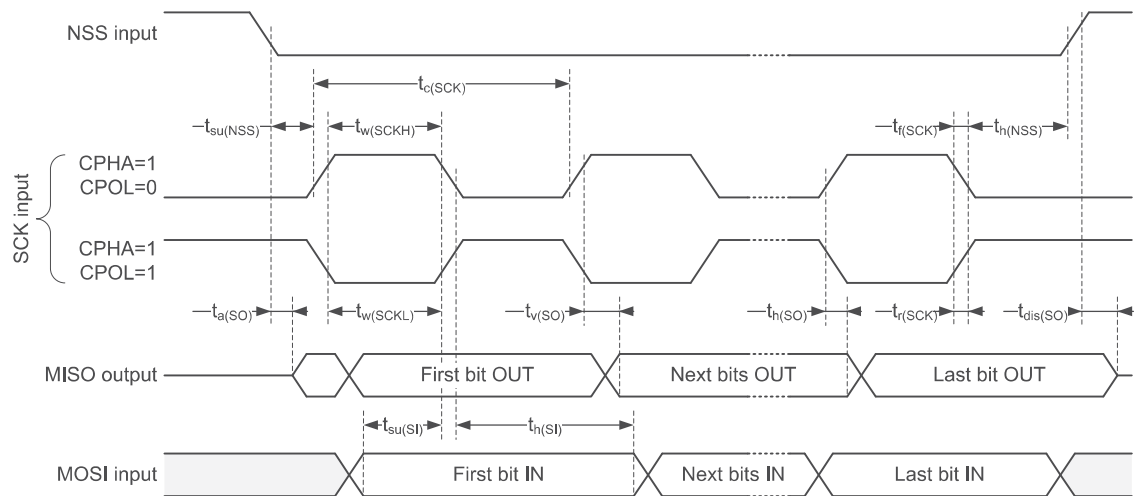
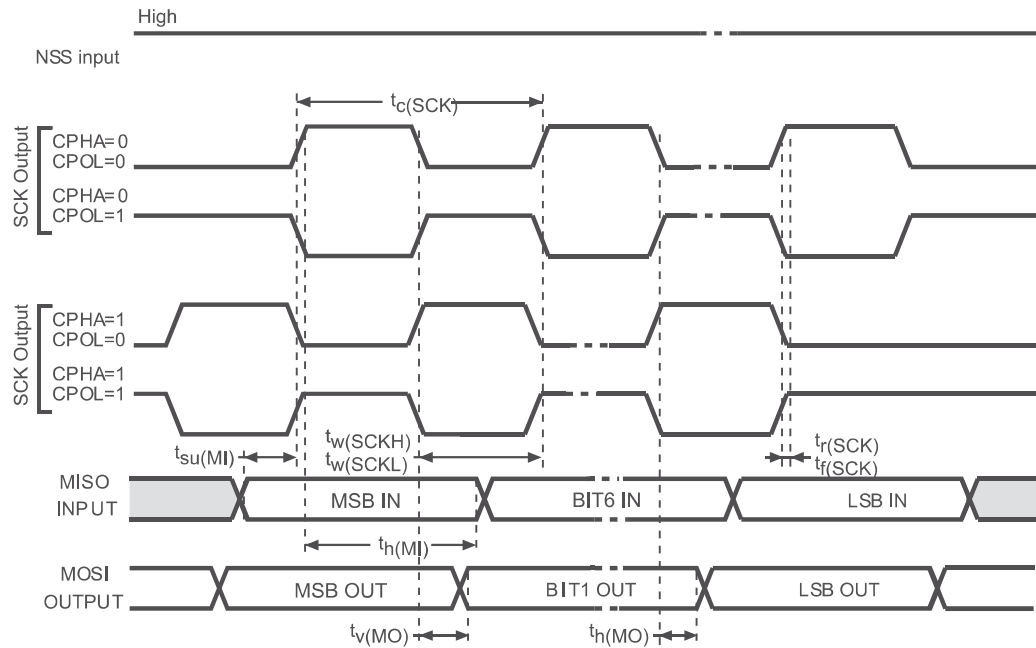


Figure 20. SPI timing diagram — master mode



3.15.4 I²S timing

The instances SPI2 and SPI3 support the inter-IC sound (I²S) protocol.

Table 46. I²S dynamic characteristics

| Symbol | C | Parameter | Conditions ⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾⁽⁶⁾ | Value | | | Unit |
|------------------|----|-----------|--|-------|-----|----------------------------------|------|
| | | | | Min | Typ | Max | |
| f _{MCK} | CC | D | I ² S main clock output | — | — | 256F _S ⁽⁷⁾ | MHz |
| f _{CK} | CC | D | Master data | — | — | 64F _S | MHz |
| | CC | D | Slave data | — | — | 64F _S | |

| Symbol | C | D | Parameter | Conditions ⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾⁽⁶⁾ | Value | | | Unit |
|------------------|----|---|------------------------|--|-------|-----|-----|------|
| | | | | | Min | Typ | Max | |
| $t_{v(WS)}$ | CC | D | WS valid time | Master mode | — | — | 4 | ns |
| $t_{h(WS)}$ | CC | D | WS hold time | Master mode | -3 | — | — | ns |
| $t_{su(WS)}$ | CC | D | WS setup time | Slave mode | 2 | — | — | ns |
| $t_{h(WS)}$ | CC | D | WS hold time | Slave mode | 3 | — | — | ns |
| $t_{su(SD_MR)}$ | CC | D | Data input setup time | Master receiver | 2 | — | — | ns |
| $t_{su(SD_SR)}$ | CC | D | | Slave receiver | 3 | — | — | ns |
| $t_{h(SD_MR)}$ | CC | D | Data input hold time | Master receiver | 4 | — | — | ns |
| $t_{h(SD_SR)}$ | CC | D | | Slave receiver | 3 | — | — | ns |
| $t_{v(SD_ST)}$ | CC | D | Data output valid time | Slave transmitter (after enable edge) | — | — | 15 | ns |
| $t_{v(SD_MT)}$ | CC | D | | Master transmitter (after enable edge) | — | — | 4 | ns |
| $t_{h(SD_ST)}$ | CC | D | Data output hold time | Slave transmitter (after enable edge) | 4 | — | — | ns |
| $t_{h(SD_MT)}$ | CC | D | | Master transmitter (after enable edge) | -2 | — | — | ns |

1. All timing values for output signals in this table are measured to 50% of the output voltage.
2. All output timing is the worst case and includes the mismatching of rise and fall times of the output pads.
3. All timing values are valid for $V_{DD_HV_IO} = 3.3\text{ V}$.
4. Input timing assumes an input slew rate of 1 ns (10% – 90%) and uses TTL / automotive voltage thresholds.
5. Very Fast IO output characteristics.
6. Capacitive Load $C_L = 25\text{ pF}$.
7. F_s is the audio sampling frequency.

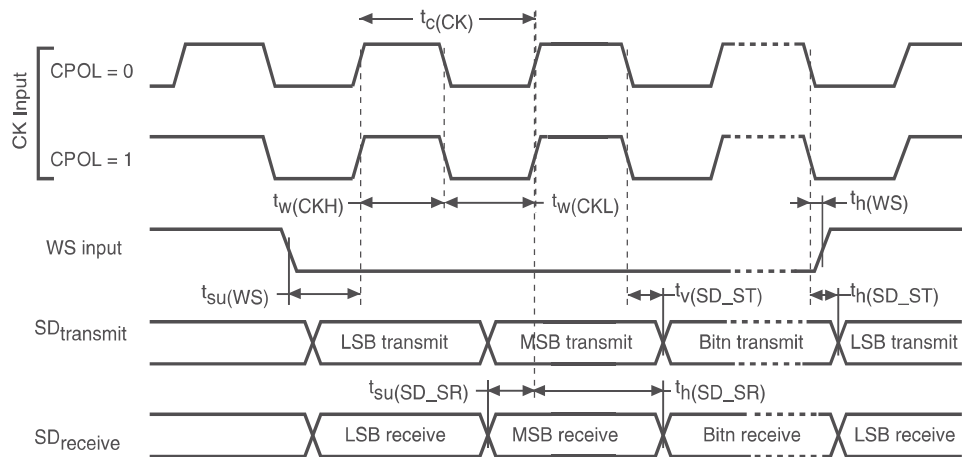
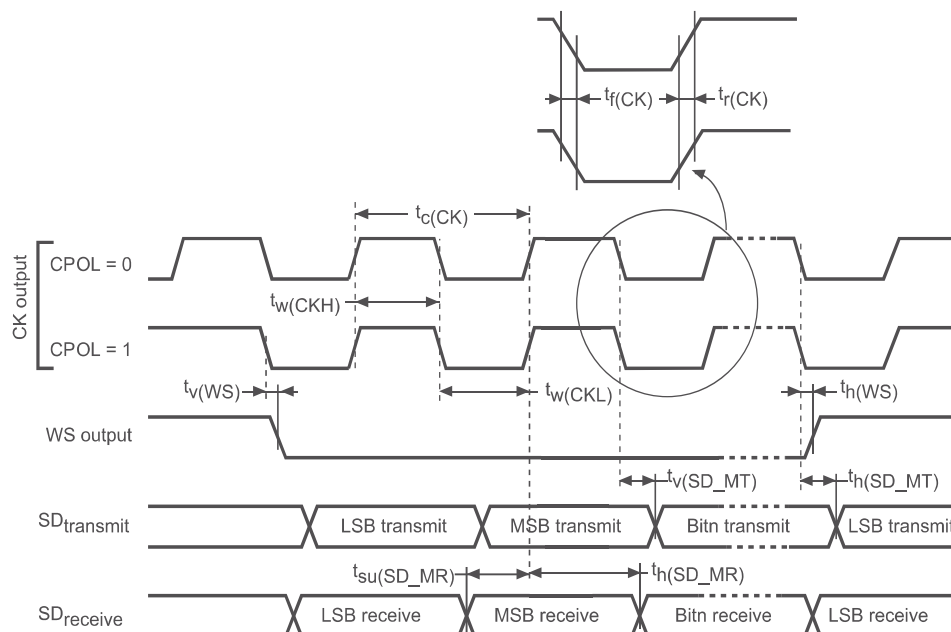
Figure 21. I²S slave timing diagram


Figure 22. I²S master timing diagram


3.15.5 CAN timing

The following table describes the CAN timing.

Table 47. CAN timing

| Symbol | C | Parameter | Condition | Value | | | Unit |
|----------------|----|---|-----------------------------------|-------|-----|-----|------|
| | | | | Min | Typ | Max | |
| $t_{P(RX:TX)}$ | CC | CAN controller propagation delay time standard pads | Fast type pads $C_L = 25$ pF | — | — | 65 | ns |
| | CC | | Very Fast type pads $C_L = 25$ pF | — | — | 60 | |

3.15.6 UART timing

UART channel frequency support is shown in the following table.

Table 48. UART frequency support

| UART_CLK (MHz) | Oversampling rate | Condition | Max usable frequency (Mbaud) |
|----------------|-------------------|-----------|------------------------------|
| 100 | 16 | — | 6.25 |
| | 8 | | 12.5 |

3.15.7 I²C timing

The I²C AC timing specifications are provided in the following tables.

Table 49. I²C input timing specifications — SCL and SDA

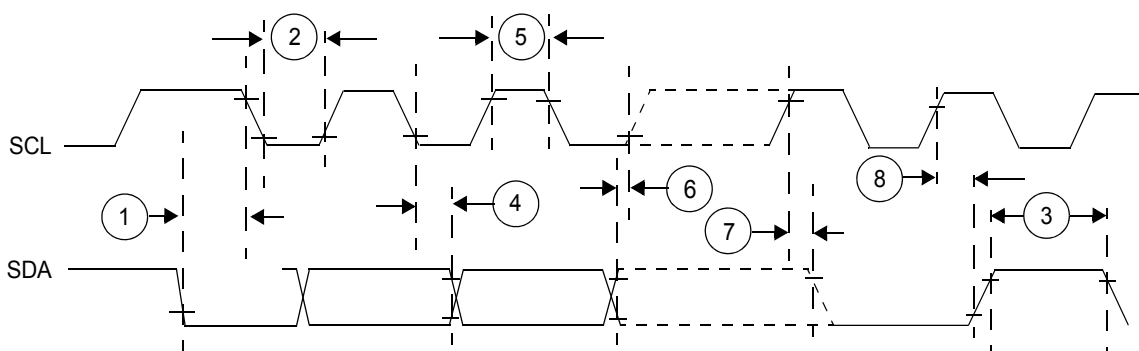
| Symbol ⁽¹⁾ | C | D | Parameter | Condition | Value | | | Unit | # |
|-----------------------|----|---|--|-----------|-------|-----|-----|------------------------------|---|
| | | | | | Min | Typ | Max | | |
| t _{SCHT} | CC | D | Start condition hold time | — | 2 | — | — | PER_CLK Cycle ⁽²⁾ | 1 |
| t _{CLT} | CC | D | Clock low time | — | 8 | — | — | PER_CLK Cycle | 2 |
| t _{BFT} | CC | D | Bus free time between Start and Stop condition | — | 4.7 | — | — | μs | 3 |
| t _{DHT} | CC | D | Data hold time | — | 0.0 | — | — | ns | 4 |
| t _{CHT} | CC | D | Clock high time | — | 4 | — | — | PER_CLK Cycle | 5 |
| t _{DST} | CC | D | Data setup time | — | 0.0 | — | — | ns | 6 |
| t _{START} | CC | D | Start condition setup time (for repeated start condition only) | — | 2 | — | — | PER_CLK Cycle | 7 |
| t _{STOP} | CC | D | Stop condition setup time | — | 2 | — | — | PER_CLK Cycle | 8 |

1. I²C input timing is valid for automotive and TTL inputs levels, hysteresis enabled, and an input edge rate no slower than 1 ns (10% - 90%).
2. PER_CLK is the SoC peripheral clock, which drives the I²C BIU and module clock inputs. Refer to the device reference manual, Clocking chapter for more details.

Table 50. I²C output timing specifications — SCL and SDA

| Symbol | C | D | Parameters ⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾ | Condition | Value | | | Unit | # |
|--------------------|----|---|--|-----------|-------|-----|-----|------------------------------|---|
| | | | | | Min | Typ | Max | | |
| t _{SCHT} | CC | D | Start condition hold time | — | 6 | — | — | PER_CLK Cycle ⁽⁵⁾ | 1 |
| t _{CLT} | CC | D | Clock low time | — | 10 | — | — | PER_CLK Cycle | 2 |
| t _{BFT} | CC | D | Bus free time between start and stop condition | — | 4.7 | — | — | μs | 3 |
| t _{DHT} | CC | D | Data hold time | — | 7 | — | — | PER_CLK Cycle | 4 |
| t _{CHT} | CC | D | Clock high time | — | 10 | — | — | PER_CLK Cycle | 5 |
| t _{DST} | CC | D | Data setup time | — | 2 | — | — | PER_CLK Cycle | 6 |
| t _{START} | CC | D | Start condition setup time (for repeated start condition only) | — | 20 | — | — | PER_CLK Cycle | 7 |
| t _{STOP} | CC | D | Stop condition setup time | — | 10 | — | — | PER_CLK Cycle | 8 |

1. Programming the I2C_TIMINGR register (I²C bus frequency divider) with the maximum frequency results in the minimum output timings listed. The I²C interface is designed to scale the data transition time, moving it to the middle of the SCL low period. The actual position is affected by the pre-scale and division values programmed in the I2C_TIMINGR register.
2. Timing is specified to same drive capabilities for all signals, mixing of pad drives may reduce operating speeds and may cause incorrect operation.
3. Output parameters are valid for CL = 25 pF, where CL is the external load to the device (lumped). The internal package capacitance is accounted for, and does not need to be subtracted from the 25 pF value.
4. All output timing is the worst case and includes the mismatching of rise and fall times of the output pads.
5. PER_CLK is the SoC peripheral clock, which drives the I²C BIU and module clock inputs. Refer to the device reference manual, Clocking chapter for more details.

Figure 23. I2C input/output timing


3.15.8 DLL block

DLL block is used to calibrate digital code for 1 period delay, which will be used by the HRTimer to provide the appropriate code for the required delay from any DELAY block.

Table 51. DLL electrical specifications

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|---------------------|----|--|-------------------------------|-------|--------------------|-------|--------------------|
| | | | | Min | Typ | Max | |
| F_{HRTIM} | CC | D Input clock frequency (DLL_CK) | — | 200 | — | 306.7 | MHz |
| T_{HRTIM} | CC | D Input clock frequency (DLL_CK) | — | 3.26 | — | 5 | ns |
| T_{RES} | CC | D High-resolution step size Tperiod/32 | $F_{HRTIM} = 306.7\text{MHz}$ | — | 102 | — | ps |
| T_{RF} | CC | D Input clock rise/fall time (DLL_CK) | — | — | — | 0.1 | ns |
| Δ_{DLL_CK} | CC | D Input clock duty cycle (DLL_CK) | — | 40 | 50 | 60 | % |
| T_{LOCK} | CC | D Lock time | In term of input clock cycles | — | — | 650 | Input clock cycles |
| I_{AVG_CAL} | CC | D Current consumption during calibration phase | Calibration mode | — | 8 ⁽¹⁾ | 10.6 | mA |
| I_{AVG_PDn} | CC | D Current consumption in power mode | Power down | — | 3.8 ⁽¹⁾ | 1100 | μA |
| $I_{AVG_TM}^{(2)}$ | CC | D Current consumption in test mode | Test mode | — | 7.8 ⁽¹⁾ | 12.3 | mA |

1. Typical power consumption is at the typical process, typical temperature (25 °C) and typical voltage (1.26 V).
2. Test mode power consumption is based on the testing at the mid-code of the calibration delay line (TEST_CMD_IN<10:0> = 111010 0000; Natural code = 704) and assuming that both delay lines are being tested at the same time. TEST_DELAY_EN=H, TEST_MODE_DELAY_0=H and TEST_MODE_DELAY_CMD=H.

3.15.9 Delay block

The delay block is used to generate the desired pulse width modulation. When the command which allowed the DLL to be locked is applied, the global duration of this delay block is 1 clock period. The HRTimer calculates from this value the command to be applied to obtain a delay equal to a fraction (1/32 to 31/32) of the clock period. One delay block is used for one PWM output.

Table 52. Delay electrical specifications

| Symbol | C | Parameter | Conditions | Value | | | Unit |
|-------------------------------------|----|---|-------------------------------|-------|--------------------|------|------|
| | | | | Min | Typ | Max | |
| T _{RES} | CC | D High-resolution step size Tperiod/32 | F _{HRTIM} = 306.7MHz | — | 102 | — | ps |
| I _{AVG} | CC | D Current consumption | Normal mode | — | 940 ⁽¹⁾ | 1125 | μA |
| I _{AVG_PDn} ⁽²⁾ | CC | D Current consumption in power mode | Power down | — | 0.7 ⁽¹⁾ | 130 | μA |
| I _{AVG_TM} ⁽³⁾ | CC | D Current consumption in test mode | Test mode | — | 1.1 ⁽¹⁾ | 1.9 | mA |
| C _L | CC | D Capacitive load | Output drive for DELAY_OUT. | — | — | 20 | fF |

1. Typical power consumption is at the typical process, typical temperature (25 °C) and typical voltage (1.26 V).
2. Power down mode power consumption mentioned is for DELAY_IN=L, TEST_MODE=L.
3. Test mode power consumption is at the mid-code of the delay line (DLL_CMD<10:0> = 111010 0000; Natural code = 704). DELAY_IN=H and TEST_MODE_DELAY=H.

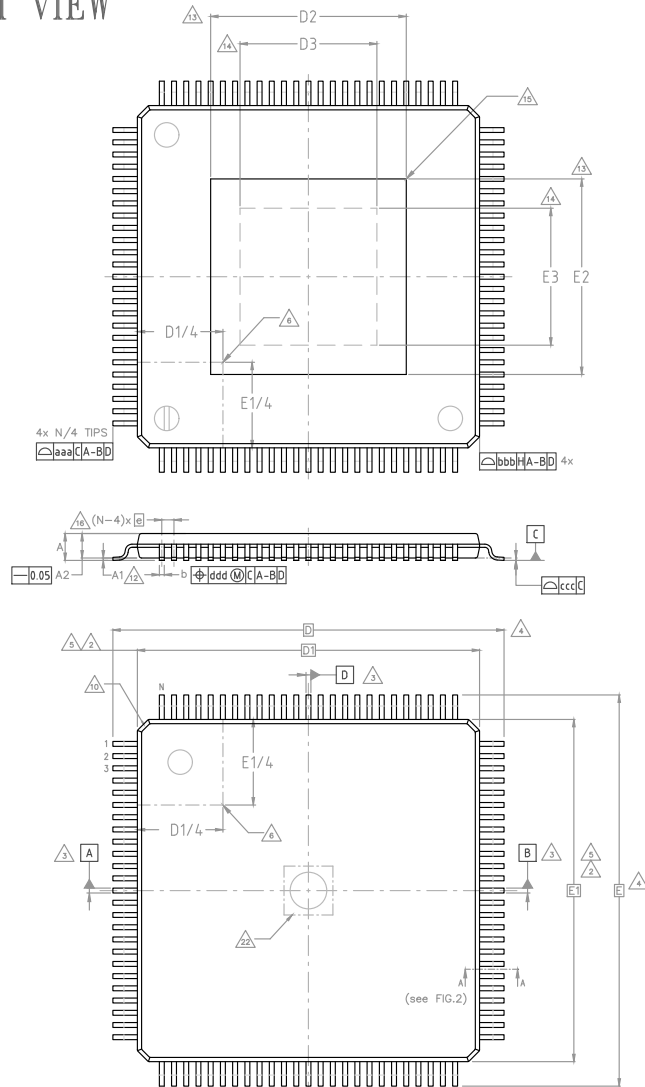
4 Package information

To meet environmental requirements, ST offers these devices in different grades of **ECOPACK** packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions, and product status are available at: www.st.com. ECOPACK is an ST trademark.

4.1 eTQPF100 package information

Figure 24. eTQPF100 package outline

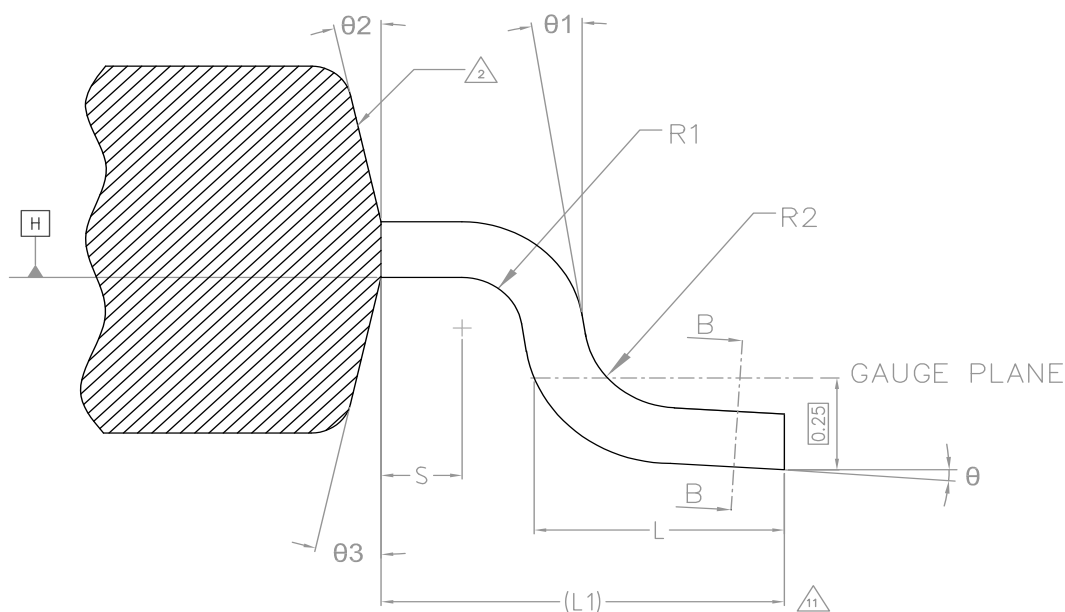
BOTTOM VIEW



TOP VIEW

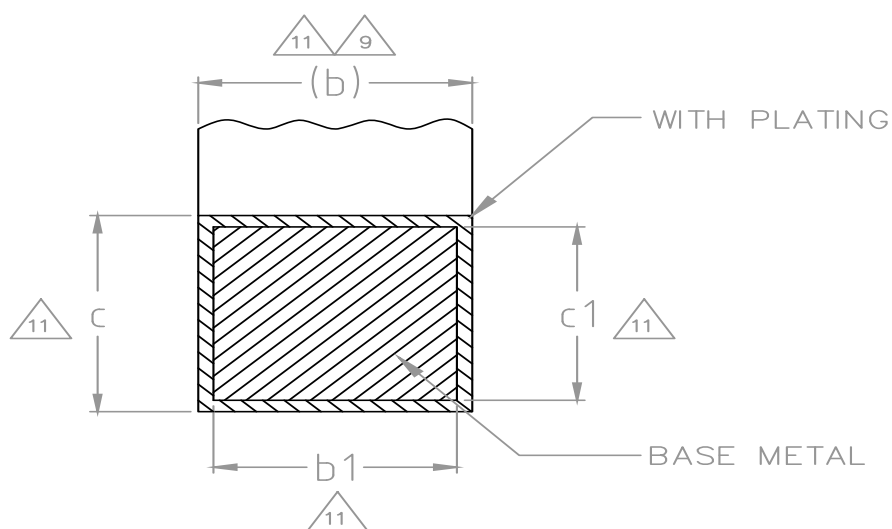
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is "0.25 mm" per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
10. The exact shape of each corner is optional.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located (if present). It includes all metal protrusions from the exposed pad itself. The type of exposed pad is variable depending on leadframe pad design (T1, T2, T3), as shown in the figure below. The end user has to verify D2 and E2 dimensions according to the specific device application.
14. Dimensions D3 and E3 show the minimum solderable area, defined as the portion of the exposed pad, which is ensured to be free from resin flashes/bleeds, bordered by an internal edge of the inner groove.
15. The optional exposed pad is generally coincident with the top or bottom side of the package and not allowed to protrude beyond that surface.
16. "N" is the number of terminal positions for the specified body size.
22. Notch may be present in this area (max 2.0 mm square) if center top gate molding technology is applied. Resin gate residual not protruding out of package top surface.

Figure 25. eTQPF100 section A-A



2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.

Figure 26. eTQPF100 section B-B



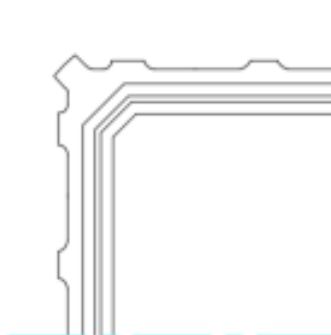
9. Dimension "b" does not include a dambar protrusion. Allowable dambar protrusion does not cause the lead width to exceed the maximum "b" dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.

Table 53. eTQPF100 package mechanical data

| Symbol | Dimensions ⁽¹⁾⁽²⁾ | | |
|-------------------------|------------------------------|------|------|
| | Min. | Typ. | Max. |
| Θ | 0° | 3.5° | 7° |
| $\Theta 1$ | 0° | — | — |
| $\Theta 2$ | 10° | 12° | 14° |
| $\Theta 3$ | 10° | 12° | 14° |
| A ⁽³⁾ | — | — | 1.20 |
| A1 ⁽⁴⁾ | 0.05 | — | 0.15 |
| A2 ⁽³⁾ | 0.95 | 1.00 | 1.05 |
| b ⁽⁵⁾⁽⁶⁾⁽⁷⁾ | 0.17 | 0.22 | 0.27 |
| b1 ⁽⁷⁾ | 0.17 | 0.20 | 0.23 |
| c ⁽⁷⁾ | 0.09 | — | 0.20 |
| c1 ⁽⁷⁾ | 0.09 | — | 0.16 |
| D ⁽⁸⁾ | 16.00 BSC | | |
| D1 ⁽⁹⁾⁽¹⁰⁾ | 14.00 BSC | | |
| D2 ⁽¹¹⁾ | — | — | 6.77 |
| D3 ⁽¹²⁾ | 5.10 | — | — |
| e | 0.50 BSC | | |
| E ⁽⁸⁾ | 16.00 BSC | | |
| E1 ⁽⁹⁾⁽¹⁰⁾ | 14.00 BSC | | |
| E2 ⁽¹¹⁾ | — | — | 6.77 |
| E3 ⁽¹²⁾ | 5.10 | — | — |
| L | 0.45 | 0.60 | 0.75 |
| L1 | 1.00 REF | | |
| N ⁽¹³⁾ | 100 | | |
| R1 | 0.08 | — | — |
| R2 | 0.08 | — | 0.20 |
| S | 0.20 | — | — |
| aaa ⁽¹⁴⁾⁽¹⁵⁾ | 0.20 | | |
| bbb ⁽¹⁴⁾⁽¹⁵⁾ | 0.20 | | |
| ccc ⁽¹⁴⁾⁽¹⁵⁾ | 0.08 | | |
| ddd ⁽¹⁴⁾⁽¹⁵⁾ | 0.08 | | |

1. All Dimensions are in millimeters.
2. Critical dimensions: a. Stand-off, b. Overall width, c. Lead coplanarity.
3. The optional exposed pad is generally coincident with the top or bottom side of the package and not allowed to protrude beyond that surface.
4. A1 is defined as the distance from the seating plane to the lowest point on the package body.
5. No intrusion is allowed inwards the leads.
6. Dimension "b" does not include a dambar protrusion. Allowable dambar protrusion does not cause the lead width to exceed the maximum "b" dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
7. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
8. To be determined at seating datum plane C.

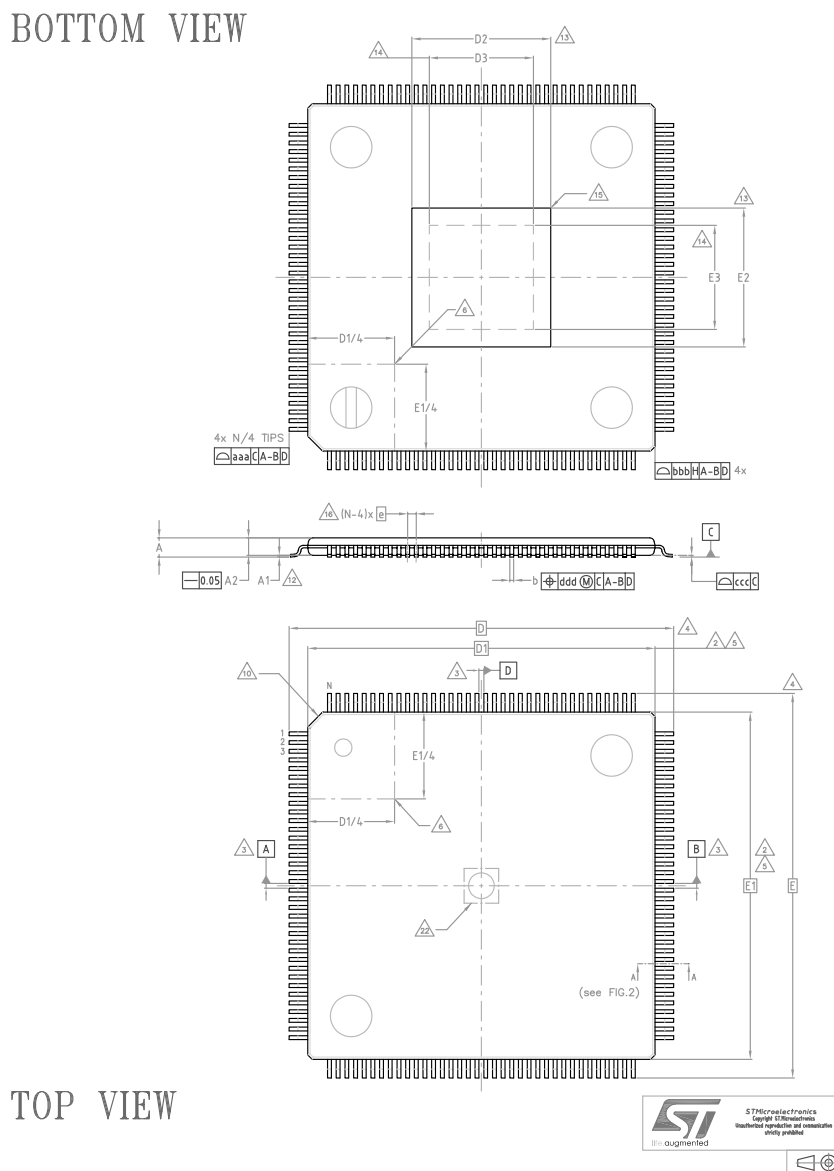
9. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
10. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is "0.25 mm" per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch.
11. Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located (if present). It includes all metal protrusions from the exposed pad itself. The type of exposed pad is variable depending on leadframe pad design (T1, T2, T3), as shown in the figure below. The end user has to verify D2 and E2 dimensions according to the specific device application.
12. Dimensions D3 and E3 show the minimum solderable area, defined as the portion of the exposed pad, which is ensured to be free from resin flashes/bleeds, bordered by an internal edge of the inner groove.
13. "N" is the number of terminal positions for the specified body size.
14. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
15. For Symbols, recommended values and tolerances see "Package symbol definition" table.

Figure 27. eTQPF100 leadframe pad design

Table 54. eTQPF100 symbol definitions

| Symbol | Definition | Notes |
|--------|---|---|
| aaa | The tolerance that controls the position of the terminal pattern with respect to datum A and B. The center of the tolerance zone for each terminal is defined by a basic dimension e as related to Datum A and B. | For flange-molded packages, this tolerance also applies for basic dimensions D1 and E1. For packages tooled with intentional terminal tip protrusions, aaa does not apply to those protrusions. |
| bbb | The bilateral profile tolerance that controls the position of the plastic body sides. The centers of the profile zones are defined by the basic dimensions D and E. | — |
| ccc | The unilateral tolerance located above the seating plane where in the bottom surface of all terminals must be located. | This tolerance is commonly known as the "coplanarity" of the package terminals. |
| ddd | The tolerance that controls the position of the terminals to each other. The centers of the profile zones are defined by basic dimension e. | This tolerance is normally compounded with a tolerance zone defined by "b". |

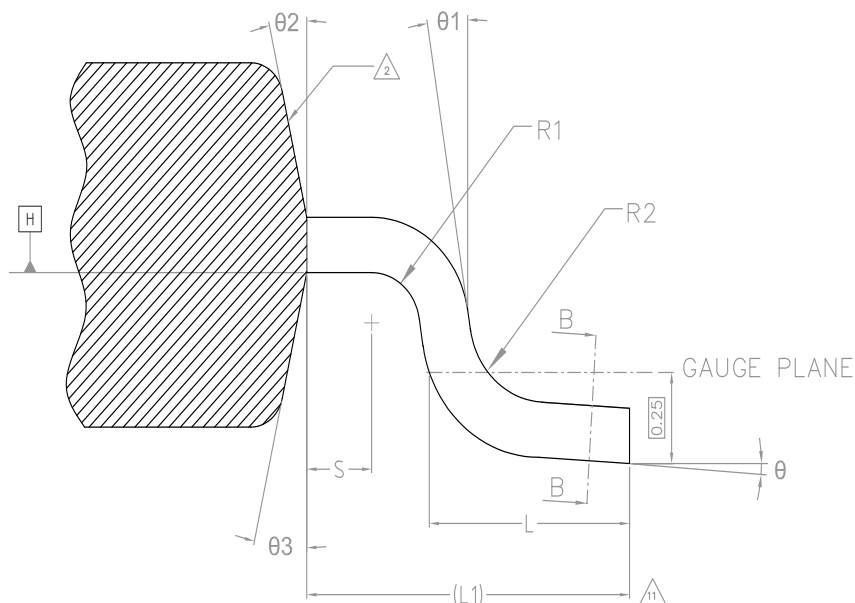
4.2 eTQFP144 package information

Figure 28. eTQFP144 package outline



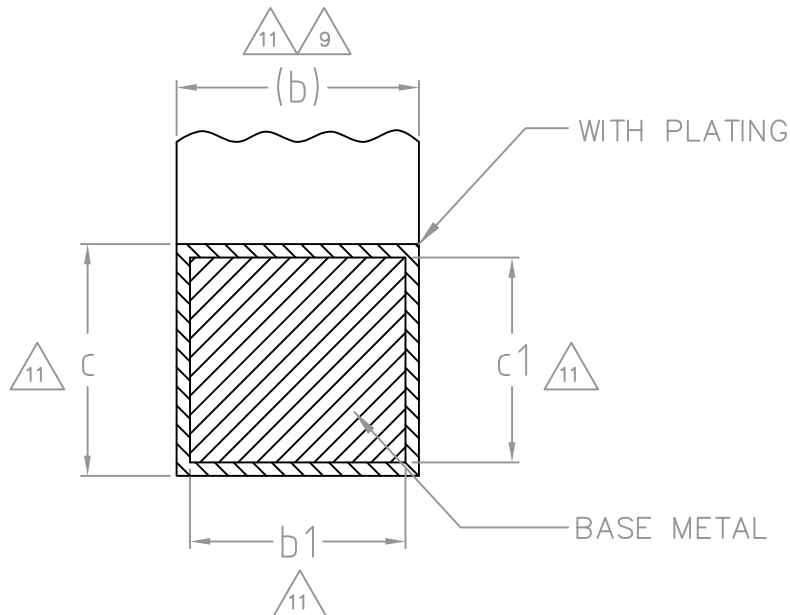
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is "0.25 mm" per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
10. The exact shape of each corner is optional.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located (if present). It includes all metal protrusions from the exposed pad itself. The type of exposed pad is variable depending on leadframe pad design (T1, T2, T3), as shown in the figure below. The end user has to verify D2 and E2 dimensions according to the specific device application.
14. Dimensions D3 and E3 show the minimum solderable area, defined as the portion of the exposed pad, which is ensured to be free from resin flashes/bleeds, bordered by an internal edge of the inner groove.
15. The optional exposed pad is generally coincident with the top or bottom side of the package and not allowed to protrude beyond that surface.
16. "N" is the number of terminal positions for the specified body size.
22. Notch may be present in this area (max 2.0 mm square) if center top gate molding technology is applied. Resin gate residual not protruding out of package top surface.

Figure 29. eTQFP144 section A-A (not to scale)



2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.

Figure 30. eTQFP144 section B-B (not to scale)



9. Dimension "b" does not include a dambar protrusion. Allowable dambar protrusion does not cause the lead width to exceed the maximum "b" dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.

Table 55. eTQFP144 package mechanical data

| Symbol | Dimensions ⁽¹⁾⁽²⁾ | | |
|-------------------------|------------------------------|----------|-------|
| | Min. | Typ. | Max. |
| Θ | 0.0° | 3.5° | 7.0° |
| Θ_1 | 0.0° | — | — |
| Θ_2 | 10.0° | 12.0° | 14.0° |
| Θ_3 | 10.0° | 12.0° | 14.0° |
| A ⁽³⁾ | — | — | 1.20 |
| A1 ⁽⁴⁾ | 0.05 | — | 0.15 |
| A2 ⁽³⁾ | 0.95 | 1.00 | 1.05 |
| b ⁽⁵⁾⁽⁶⁾⁽⁷⁾ | 0.17 | 0.22 | 0.27 |
| b1 ⁽⁷⁾ | 0.17 | 0.20 | 0.23 |
| c ⁽⁷⁾ | 0.09 | — | 0.20 |
| c1 ⁽⁷⁾ | 0.09 | — | 0.16 |
| D ⁽⁸⁾ | 22.00 BSC | | |
| D1 ⁽⁹⁾⁽¹⁰⁾ | 20.00 BSC | | |
| D2 ⁽¹¹⁾ | 6.76 | | |
| D3 ⁽¹²⁾ | 5.1 | | |
| e | 0.50 BSC | | |
| E ⁽⁸⁾ | 22.00 BSC | | |
| E1 ⁽⁹⁾⁽¹⁰⁾ | 20.00 BSC | | |
| E2 ⁽¹¹⁾ | 6.76 | | |
| E3 ⁽¹²⁾ | 5.1 | | |
| L | 0.45 | 0.60 | 0.75 |
| L1 | — | 1.00 REF | — |
| N ⁽¹³⁾ | 144 | | |
| R1 | 0.08 | — | — |
| R2 | 0.08 | — | 0.20 |
| S | 0.20 | — | — |
| aaa ⁽¹⁴⁾⁽¹⁵⁾ | 0.20 | | |
| bbb ⁽¹⁴⁾⁽¹⁵⁾ | 0.20 | | |
| ccc ⁽¹⁴⁾⁽¹⁵⁾ | 0.08 | | |
| ddd ⁽¹⁴⁾⁽¹⁵⁾ | 0.08 | | |

1. All Dimensions are in millimeters.
2. Critical dimensions: a. Stand-off, b. Overall width, c. Lead coplanarity.
3. The optional exposed pad is generally coincident with the top or bottom side of the package and not allowed to protrude beyond that surface.
4. A1 is defined as the distance from the seating plane to the lowest point on the package body.
5. No intrusion is allowed inwards the leads.
6. Dimension "b" does not include a dambar protrusion. Allowable dambar protrusion does not cause the lead width to exceed the maximum "b" dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
7. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
8. To be determined at seating datum plane C.

9. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
10. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is "0.25 mm" per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch.
11. Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located (if present). It includes all metal protrusions from the exposed pad itself. The type of exposed pad is variable depending on leadframe pad design (T1, T2, T3), as shown in the figure below. The end user has to verify D2 and E2 dimensions according to the specific device application.
12. Dimensions D3 and E3 show the minimum solderable area, defined as the portion of the exposed pad, which is ensured to be free from resin flashes/bleeds, bordered by an internal edge of the inner groove.
13. "N" is the number of terminal positions for the specified body size.
14. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
15. For Symbols, recommended values and tolerances see "Package symbol definition" table.

Figure 31. eTQFP144 leadframe pad design

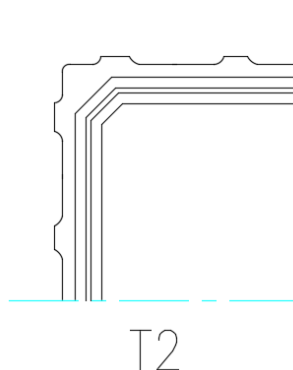


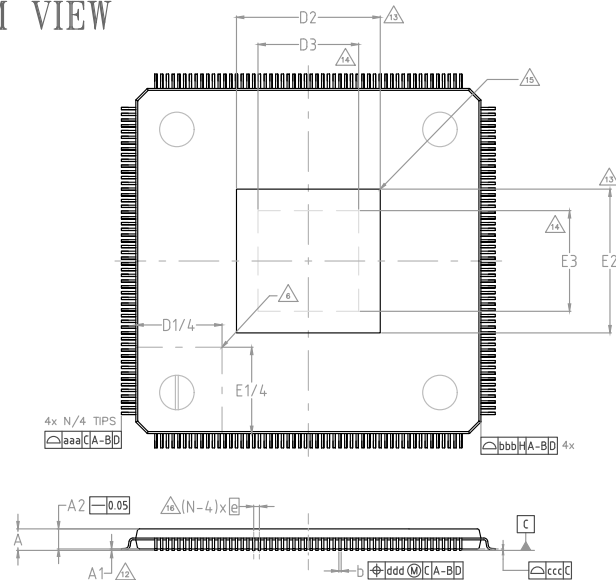
Table 56. eTQFP144 symbol definitions

| Symbol | Definition | Notes |
|--------|---|---|
| aaa | The tolerance that controls the position of the terminal pattern with respect to datum A and B. The center of the tolerance zone for each terminal is defined by a basic dimension e as related to Datum A and B. | For flange-molded packages, this tolerance also applies for basic dimensions D1 and E1. For packages tooled with intentional terminal tip protrusions, aaa does not apply to those protrusions. |
| bbb | The bilateral profile tolerance that controls the position of the plastic body sides. The centers of the profile zones are defined by the basic dimensions D and E. | — |
| ccc | The unilateral tolerance located above the seating plane where in the bottom surface of all terminals must be located. | This tolerance is commonly known as the "coplanarity" of the package terminals. |
| ddd | The tolerance that controls the position of the terminals to each other. The centers of the profile zones are defined by basic dimension e. | This tolerance is normally compounded with a tolerance zone defined by "b". |

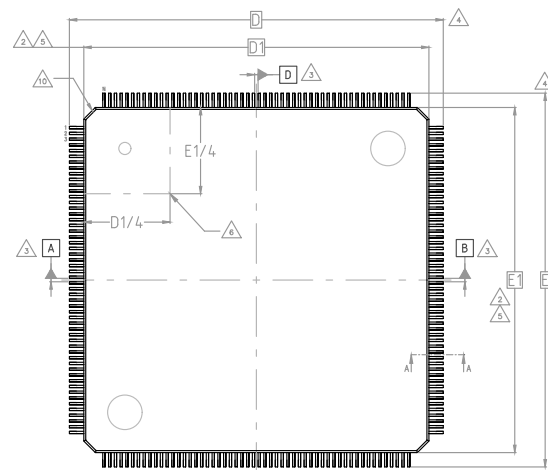
4.3 eLQFP176 package information

Figure 32. eLQFP176 package outline

BOTTOM VIEW

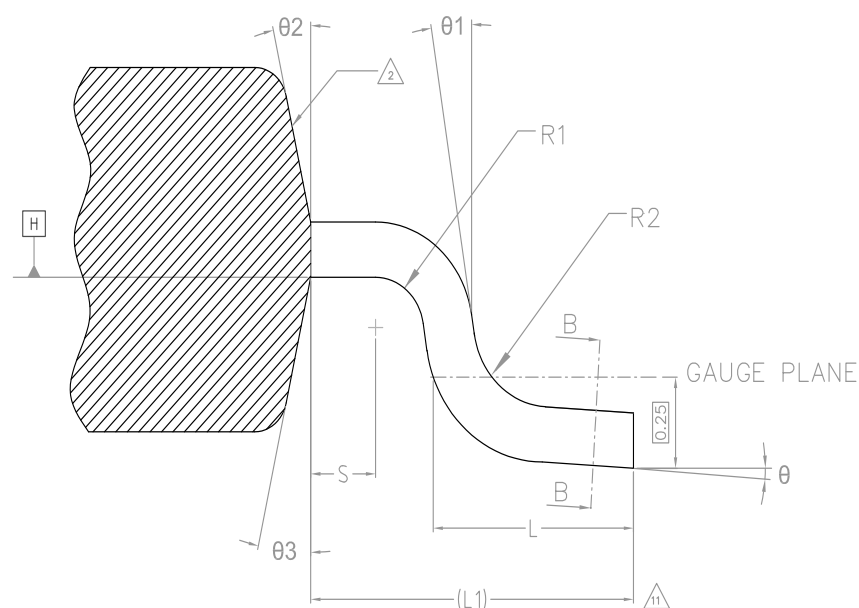


TOP VIEW



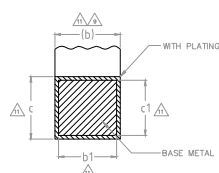
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is "0.25 mm" per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
10. The exact shape of each corner is optional.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located (if present). It includes all metal protrusions from the exposed pad itself. The type of exposed pad is variable depending on leadframe pad design (T1, T2, T3), as shown in the figure below. The end user has to verify D2 and E2 dimensions according to the specific device application.
14. Dimensions D3 and E3 show the minimum solderable area, defined as the portion of the exposed pad, which is ensured to be free from resin flashes/bleeds, bordered by an internal edge of the inner groove.
15. The optional exposed pad is generally coincident with the top or bottom side of the package and not allowed to protrude beyond that surface.
16. "N" is the number of terminal positions for the specified body size.

Figure 33. eLQFP176 section A-A



2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.

Figure 34. eLQFP176 section B-B



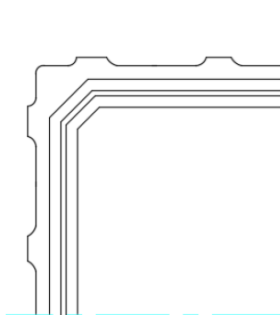
9. Dimension "b" does not include a dambar protrusion. Allowable dambar protrusion does not cause the lead width to exceed the maximum "b" dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.

Table 57. eLQFP176 package mechanical data

| Symbol | Dimensions ⁽¹⁾⁽²⁾ | | |
|-------------------------|------------------------------|------|------|
| | Min. | Nom. | Max. |
| Θ | 0° | 3.5° | 7° |
| $\Theta 1$ | 0° | — | — |
| $\Theta 2$ | 10° | 12° | 14° |
| $\Theta 3$ | 10° | 12° | 14° |
| A ⁽³⁾ | — | — | 1.60 |
| A1 ⁽⁴⁾ | 0.05 | — | 0.15 |
| A2 ⁽³⁾ | 1.35 | 1.40 | 1.45 |
| b ⁽⁵⁾⁽⁶⁾⁽⁷⁾ | 0.17 | 0.22 | 0.27 |
| b1 ⁽⁷⁾ | 0.17 | 0.20 | 0.23 |
| c ⁽⁷⁾ | 0.09 | — | 0.20 |
| c1 ⁽⁷⁾ | 0.09 | — | 0.16 |
| D ⁽⁸⁾ | 26.00 BSC | | |
| D1 ⁽⁹⁾⁽¹⁰⁾ | 24.00 BSC | | |
| D2 ⁽¹¹⁾ | — | — | 7.77 |
| D3 ⁽¹²⁾ | 6.10 | — | — |
| e | 0.50 BSC | | |
| E ⁽⁸⁾ | 26.00 BSC | | |
| E1 ⁽⁹⁾⁽¹⁰⁾ | 24.00 BSC | | |
| E2 ⁽¹¹⁾ | — | — | 7.77 |
| E3 ⁽¹²⁾ | 6.10 | — | — |
| L | 0.45 | 0.60 | 0.75 |
| L1 | 1.00 REF | | |
| N ⁽¹³⁾ | 176 | | |
| R1 | 0.08 | — | — |
| R2 | 0.08 | — | 0.20 |
| S | 0.20 | — | — |
| aaa ⁽¹⁴⁾⁽¹⁵⁾ | 0.20 | | |
| bbb ⁽¹⁴⁾⁽¹⁵⁾ | 0.20 | | |
| ccc ⁽¹⁴⁾⁽¹⁵⁾ | 0.08 | | |
| ddd ⁽¹⁴⁾⁽¹⁵⁾ | 0.08 | | |

1. All Dimensions are in millimeters.
2. Critical dimensions: a. Stand-off, b. Overall width, c. Lead coplanarity.
3. The optional exposed pad is generally coincident with the top or bottom side of the package and not allowed to protrude beyond that surface.
4. A1 is defined as the distance from the seating plane to the lowest point on the package body.
5. No intrusion is allowed inwards the leads.
6. Dimension "b" does not include a dambar protrusion. Allowable dambar protrusion does not cause the lead width to exceed the maximum "b" dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between the protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
7. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
8. To be determined at seating datum plane C.

9. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
10. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is "0.25 mm" per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch.
11. Dimensions D2 and E2 show the maximum exposed metal area on the package surface where the exposed pad is located (if present). It includes all metal protrusions from the exposed pad itself. The type of exposed pad is variable depending on leadframe pad design (T1, T2, T3), as shown in the figure below. The end user has to verify D2 and E2 dimensions according to the specific device application.
12. Dimensions D3 and E3 show the minimum solderable area, defined as the portion of the exposed pad, which is ensured to be free from resin flashes/bleeds, bordered by an internal edge of the inner groove.
13. "N" is the number of terminal positions for the specified body size.
14. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
15. For Symbols, recommended values and tolerances see "Package symbol definition" table.

Figure 35. eLQFP176 leadframe pad design

Table 58. eLQFP176 symbol definitions

| Symbol | Definition | Notes |
|--------|---|---|
| aaa | The tolerance that controls the position of the terminal pattern with respect to datum A and B. The center of the tolerance zone for each terminal is defined by a basic dimension e as related to Datum A and B. | For flange-molded packages, this tolerance also applies for basic dimensions D1 and E1. For packages tooled with intentional terminal tip protrusions, aaa does not apply to those protrusions. |
| bbb | The bilateral profile tolerance that controls the position of the plastic body sides. The centers of the profile zones are defined by the basic dimensions D and E. | — |
| ccc | The unilateral tolerance located above the seating plane where in the bottom surface of all terminals must be located. | This tolerance is commonly known as the "coplanarity" of the package terminals. |
| ddd | The tolerance that controls the position of the terminals to each other. The centers of the profile zones are defined by basic dimension e. | This tolerance is normally compounded with a tolerance zone defined by "b". |

4.4 Package thermal characteristics

This section describes the thermal characteristics of the device.

The parameters in this chapter have been evaluated by considering the device consumption configuration reported in the [Section 3.7: Device consumption](#).

4.4.1 eTQFP100 thermal characteristics

Table 59. eTQFP100 thermal characteristics

| Symbol | C | Parameter ⁽¹⁾ | Conditions | Value | Unit |
|------------------------|----|--------------------------|--|-------------------------|-----------|
| R _{θJA} | CC | D | Junction-to-Ambient, Natural Convection ⁽²⁾ | Four layer board (2s2p) | 22.4 °C/W |
| R _{θJB} | CC | D | Junction-to-board ⁽³⁾ | — | 7.5 °C/W |
| R _{θJCTop} | CC | D | Junction-to-case top ⁽⁴⁾ | — | 9.9 °C/W |
| R _{θJCbottom} | CC | D | Junction-to-case bottom ⁽⁵⁾ | — | 1.6 °C/W |
| Ψ _{JT} | CC | D | Junction-to-package top ⁽⁶⁾ | Natural convection | 0.4 °C/W |

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, power dissipation of other components on the board, and board thermal resistance.
2. Per JEDEC JESD51-6 with the board (JESD51-7) horizontal.
3. Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
4. Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).
5. Thermal resistance between the die and the exposed pad ground on the bottom of the package based on simulation without any interface resistance.
6. Thermal characterization parameter indicating the temperature difference between package top and the junction temperature per JEDEC JESD51-2.

4.4.2 eTQFP144 thermal characteristics

Table 60. eTQFP144 thermal characteristics

| Symbol | C | Parameter ⁽¹⁾ | Conditions | Value | Unit |
|------------------------|----|--------------------------|--|-------------------------|-----------|
| R _{θJA} | CC | D | Junction-to-ambient, natural convection ⁽²⁾ | Four layer board (2s2p) | 21.9 °C/W |
| R _{θJB} | CC | D | Junction-to-board ⁽³⁾ | — | 8.6 °C/W |
| R _{θJCTop} | CC | D | Junction-to-case top ⁽⁴⁾ | — | 11.5 °C/W |
| R _{θJCbottom} | CC | D | Junction-to-case bottom ⁽⁵⁾ | — | 1.6 °C/W |
| Ψ _{JT} | CC | D | Junction-to-package top ⁽⁶⁾ | Natural convection | 0.4 °C/W |

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.
2. Per JEDEC JESD51-6 with the board (JESD51-7) horizontal.
3. Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
4. Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).
5. Thermal resistance between the die and the exposed pad ground on the bottom of the package based on simulation without any interface resistance.
6. Thermal characterization parameter indicating the temperature difference between package top and the junction temperature per JEDEC JESD51-2.

4.4.3 eLQFP176 thermal characteristics

Table 61. eLQFP176 thermal characteristics

| Symbol | C | D | Parameter ⁽¹⁾ | Conditions | Value | Unit |
|-----------------------|----|---|--|-------------------------|-------|------|
| R _{θJA} | CC | D | Junction-to-Ambient, Natural Convection ⁽²⁾ | Four layer board (2s2p) | 20.8 | °C/W |
| R _{θJB} | CC | D | Junction-to-board ⁽³⁾ | — | 8.6 | °C/W |
| R _{θJTop} | CC | D | Junction-to-case top ⁽⁴⁾ | — | 12.2 | °C/W |
| R _{θJBottom} | CC | D | Junction-to-case bottom ⁽⁵⁾ | — | 1.6 | °C/W |
| Ψ _{JT} | CC | D | Junction-to-package top ⁽⁶⁾ | Natural convection | 0.5 | °C/W |

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.
2. Per JEDEC JESD51-6 with the board (JESD51-7) horizontal.
3. Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
4. Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).
5. Thermal resistance between the die and the exposed pad ground on the bottom of the package based on simulation without any interface resistance.
6. Thermal characterization parameter indicating the temperature difference between package top and the junction temperature per JEDEC JESD51-2.

4.4.4 General notes for specifications at maximum junction temperature

An estimation of the chip junction temperature, T_J, can be obtained from the equation:

$$T_J = T_A + (R_{\theta JA} \times P_D) \quad (3)$$

Where:

- T_A = ambient temperature for the package (°C)
- R_{θJA} = junction-to-ambient thermal resistance (°C/W)
- P_D = power dissipation in the package (W)

The thermal resistance values used are based on the JEDEC JESD51 series of standards to provide consistent values for estimations and comparisons. The differences between the values determined for the single-layer (1s) board compared to a four-layer board that has two signal layers, a power, and a ground plane (2s2p), demonstrate that the effective thermal resistance is not a constant. The thermal resistance depends on the:

- Construction of the application board (number of planes)
- Effective size of the board, which cools the component
- Quality of the thermal and electrical connections to the planes
- Power dissipated by adjacent components

Connect all the ground and power balls to the respective planes with one via per ball. Using fewer vias to connect the package to the planes reduces the thermal performance. Thinner planes also reduce the thermal performance. When the clearance between the vias leaves the planes virtually disconnected, the thermal performance is also greatly reduced.

As a general rule, the value obtained on a single-layer board is within the normal range for the tightly packed printed circuit board. The value obtained on a board with the internal planes is usually within the normal range if the application board has:

- One oz. (35 micron nominal thickness) internal planes
- Components are well separated
- Overall power dissipation on the board is less than 0.02 W/cm²

The thermal performance of any component depends on the power dissipation of the surrounding components. In addition, the ambient temperature varies widely within the application. Very often, for natural convection and especially closed box applications, the board temperature at the perimeter (edge) of the package is approximately the same as the local air temperature near the device. Specifying the local ambient conditions explicitly as the board temperature provides a more precise description of the local ambient conditions that determine the temperature of the device.

At a known board temperature, the junction temperature is estimated using the following equation:

$$T_J = T_B + (R_{\theta JB} \times P_D) \quad (4)$$

Where:

- T_B = board temperature for the package perimeter (°C)
- $R_{\theta JB}$ = junction-to-board thermal resistance (°C/W) per JESD51-8
- P_D = power dissipation in the package (W)

When the heat loss from the package case to the air does not factor into the calculation, the junction temperature is predictable if the application board is similar to the thermal test condition: with the component soldered to a board with internal planes.

The thermal resistance is expressed as the sum of the junction-to-case thermal resistance plus the case-to-ambient thermal resistance:

$$R_{\theta JA} = R_{\theta JC} + R_{\theta CA} \quad (5)$$

Where:

- $R_{\theta JA}$ = junction-to-ambient thermal resistance (°C/W)
- $R_{\theta JC}$ = junction-to-case thermal resistance (°C/W)
- $R_{\theta CA}$ = case-to-ambient thermal resistance (°C/W)

$R_{\theta JC}$ is device-related and is not affected by other factors. The thermal environment can be controlled to change the case-to-ambient thermal resistance, $R_{\theta CA}$. For example, change the air flow around the device, add a heat sink, change the mounting arrangement on the printed circuit board, or change the thermal dissipation on the printed circuit board surrounding the device. This description is most useful for packages with heat sinks where 90% of the heat flow is through the case to the heat sink to the ambient environment. For most packages, a better model is required.

A more accurate two-resistor thermal model can be constructed from the junction-to-board thermal resistance and the junction-to-case thermal resistance. The junction-to-case thermal resistance describes when a heat sink is used or where a substantial amount of heat is dissipated from the top of the package. The junction-to-board thermal resistance describes the thermal performance when most of the heat is conducted to the printed circuit board. This model can be used to generate simple estimations and for computational fluid dynamics (CFD) thermal models. More accurate compact Flotherm models can be generated upon request.

To determine the junction temperature of the device in the application on a prototype board, use the thermal characterization parameter (Ψ_{JT}) to determine the junction temperature by measuring the temperature at the top center of the package case using the following equation:

$$T_J = T_T + (\psi_{JT} \times P_D) \quad (6)$$

Where:

- T_T = thermocouple temperature on the top of the package (°C)
- Ψ_{JT} = thermal characterization parameter (°C/W)
- P_D = power dissipation in the package (W)

The thermal characterization parameter is measured in compliance with the JESD51-2 specification using a 40-gauge type T thermocouple epoxied to the top center of the package case. Position the thermocouple so that the thermocouple junction rests on the package. Place a small amount of epoxy on the thermocouple junction and on approximately 1 mm of wire extending from the junction. Place the thermocouple wire flat against the package case to avoid measurement errors caused by the cooling effects of the thermocouple wire.

When the board temperature is perfectly defined below the device, it is possible to use the thermal characterization parameter (Ψ_{JPB}) to determine the junction temperature by measuring the temperature at the bottom center of the package case (exposed pad) using the following equation:

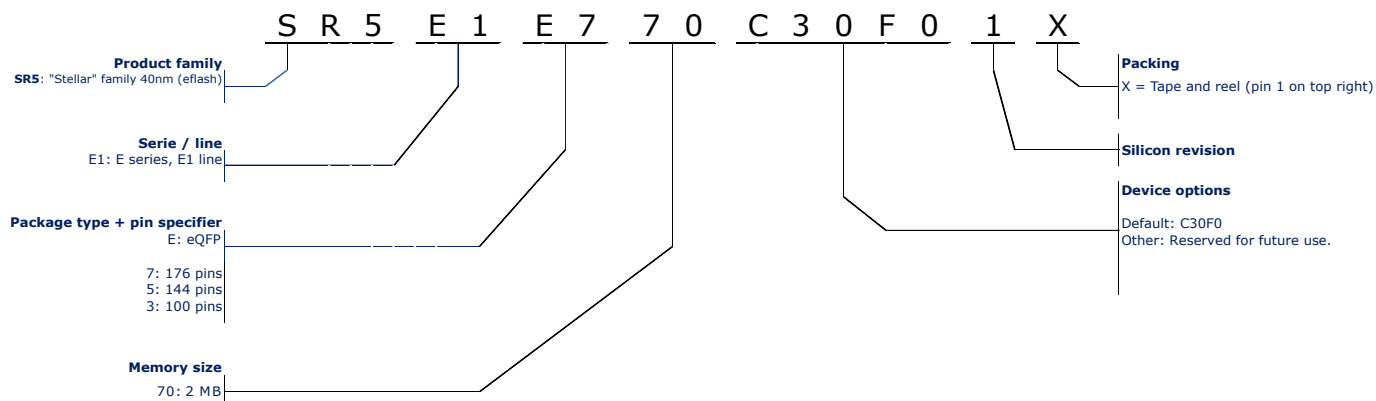
$$T_J = T_B + (\psi_{JPB} \times P_D) \quad (7)$$

Where:

- T_B = board temperature for the package perimeter (°C)
- Ψ_{JPB} = junction temperature parameter (°C/W)
- P_D = power dissipation in the package (W)

5 Ordering information

Figure 36. Ordering information scheme



Revision history

Table 62. Document revision history

| Date | Revision | Changes |
|-------------|----------|--|
| 07-Apr-2022 | 1 | Initial internal release. |
| 02-Jan-2023 | 2 | Second internal release. |
| 02-Feb-2023 | 3 | Third internal release. |
| 24-Oct-2023 | 4 | Fourth internal release. |
| 18-Dec-2023 | 5 | <p>First public release</p> <ul style="list-style-type: none"> Changed the confidentiality level of the document In the whole document: <ul style="list-style-type: none"> replaced SR5E1x with part numbers minor editorial changes Table 5. Operating conditions: IINJ2, updated Min, Typ, and Max values Table 12. I/O input electrical characteristics: <ul style="list-style-type: none"> ILKG, updated the Max value of "INPUT-ONLY pads" CP1, updated the Max value Table 14. Slow I/O output characteristics: IDCMAX_S, updated Max value Table 15. Medium I/O output characteristics: IDCMAX_M, updated Max value Table 16. Fast I/O output characteristics: IDCMAX_F, updated Max value Table 17. Very fast I/O output characteristics: IDCMAX_V, updated Max value Table 27. ADC pin specification: CP2, updated Max value Table 32. Temperature sensor electrical characteristics: <ul style="list-style-type: none"> Temperature monitoring range, updated "C" column Tflagm40, updated "C" column Tflagm150, updated "C" column Table 34. Buffered-DAC electrical specification: <ul style="list-style-type: none"> DNL, updated Max value TUE, updated Min and Max values. Removed the note GAIN_err, updated Max value Table 38. Voltage monitor electrical characteristics: VDD_LV, updated Max value of parameter "POR031_C" |
| 19-Dec-2023 | 6 | <ul style="list-style-type: none"> Section 5: Ordering information: pin specifier, added the option "5: 144 pins" |
| 02-Oct-2024 | 7 | <p>In the whole document:</p> <ul style="list-style-type: none"> minor editorial changes replaced master/slave by inclusive terms Cover page: <ul style="list-style-type: none"> added package TQFP144 added a title to the table added product SR5E1E5 Section Features: AEC-Q100 automotive indicated as qualified Security: hardware security module (HSM): added "Cybersecurity ISO/SAE 21434..." bullet Section 1.1: Document overview: removed "This device is a preliminary..." Section 3.1: Introduction: removed note Table 4. Absolute maximum ratings: <ul style="list-style-type: none"> in VDD_HV_OSC, VDD_HV_FLTA, VDD_HV_SAR and VDD_HV_SD_DAC_COMP, added a footnote "VDD_HV_*: allowed 3.45 V - 3.8 V..." in TTRIN, updated max value and unit columns footnote 1, 2 and 3 reformulated in footnote 2, added content between parenthesis and replaced VDD_HV_IO with VDD_HV_* in footnote 6, added content "It is important to ensure that..." |

| Date | Revision | Changes |
|-------------|----------|---|
| | | <ul style="list-style-type: none"> Table 5. Operating conditions: <ul style="list-style-type: none"> in note 4, 5, 6 and 7, updated range values and removed "to reduce the false LVD triggers recurrence" added range [1.225-1.222] in note 4 and [1.345-1.361] in note 5 in note 6 and 7, removed "...and specifications are..." updated note 11 Table 10. Device consumption: <ul style="list-style-type: none"> in IDD_HV_SMPS, updated max value column added a note to IDD_HV_SMPS_LKG and IDD_HV_SMPS in ISR, updated max value and unit columns added note to ISPIKE added I/O pins element in notes 3 and 4 Table 13. I/O pull-up/pull-down electrical characteristics: in IWPU and IWPDP, updated C column Table 28. SARn ADC electrical specification: removed ΔVPRECH Table 29. SDn ADC electrical specification: <ul style="list-style-type: none"> in VIN_PK2PK, updated Value column in each δGROUP, added condition OSR = 75 in Vcmrr, updated Min value in VOFFSET, updated C and Max values removed ΔSNRINJ2 in IADR_SD and IADR_BIAS, updated C column updated VOFFSET row Table 33. Fast-DAC electrical specification and Table 34. Buffered-DAC electrical specification: replaced DACMOD_v12 occurrences by DAC_MCR_MODEx Table 33. Fast-DAC electrical specification: in DNL, updated Max value Table 34. Buffered-DAC electrical specification: <ul style="list-style-type: none"> added Ttrim parameter added RBON and RBOFF split CL row with CSH in DNL, updated Min value in Offset_err_cal, updated C column and added a note in Parameter column updated Tsettling_buff and Tsettling_unbuff values Table 36. External components integration: removed note 12 from PMPB100XPEAX and instead added it for PMPB55XNEAX Table 37. SMPS regulator specifications: <ul style="list-style-type: none"> removed note 1 updated min value and max value in VDD_HV_IO and VSMPS updated max value in IDDCLAMP Table 43. JTAG pin test and debug timings: updated tJDC row Section 4: Package information: removed "Package case numbers" table. JEDEC specification reference specified in the respective package subsection. |
| 07-Nov-2025 | 8 | <p>Following are the changes in this version of the datasheet:</p> <ul style="list-style-type: none"> Table 5. Operating conditions: updated note 4 Table 28. SARn ADC electrical specification: updated the min, typ, and max values of V_{IN_COM} Table 34. Buffered-DAC electrical specification: added notes to min value of DAC_{output_min} and max value of DAC_{output_max} Table 36. External component integration: <ul style="list-style-type: none"> added note to L_S updated and added parameters for SMPS regulator mode Section 4.2: eTQFP144 package information: updated eLQFP144 to eTQFP144, throughout the section Figure 25. eTQFP100 section A-A: updated the figure Figure 33. eLQFP176 section A-A: updated the figure Section 5: Ordering information: updated package type, packing and replaced reserved with Silicon revision. |

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Glossary

AC Alternating current

ADC Analog-to-digital converter

AEC Automotive Electronics Council. Also known as CDF-AEC for Chrysler-Delco-Ford Automotive Electronics Council. Shortened to AEC.

AHB Advanced high-performance bus

ALC Automatic level control

ANSI American National Standards Institute

APB Advanced peripheral bus

ASIL Automotive safety integrity level - a risk classification system defined by the ISO 26262 standard for the functional safety of road vehicles; there are four ASILs identified by ISO 26262 — A, B, C, and D, from the lowest to the highest degree of automotive hazard

AXI Advanced extensible interface

CAN Controller area network

CAN FD[®] Controller area network flexible data rate

CBC Cipher block chaining

CDM Charged device model

CITO Controller input target output

CMAC Cipher-based message authentication code

CMOS Complementary metal-oxide-semiconductor

COTI Controller output target input

CPHA Clock phase bit. Selects the clock phase.

CPOL Clock polarity bit. Selects the clock polarity.

CPU Central processing unit

CTI Arm[®] CoreSight[™] cross-trigger interface

CTM Cross-trigger matrix

DAC Digital-to-analog converter

DC Direct current

DCF Device configuration format

DMA Direct memory access

DNL Differential nonlinearity

ECB Electronic code book

ECC Error correction code

ECU Engine control unit

eDMA Enhanced direct memory access

EEPROM Electrically erasable programmable read-only memory

EMC Electromagnetic compatibility

ESD Electrostatic discharge

ESR Equivalent series resistance

EVITA e-safety vehicle intrusion protected applications

EXTAL External oscillator input

FCCU Fault collection and control unit

FIFO First in, first out

FIR Finite-impulse response

FPU Floating-point unit

GCM Galois/counter mode

GNSS Global navigation satellite system

GPIO General-purpose input/output

HBM Human body model

HRTIM High-resolution and complex waveform builder

| | |
|---|---|
| HSM Hardware security module | NMOS N-type metal–oxide–semiconductor |
| I/O Input/output | NVM Nonvolatile memory - a memory that retains its contents even when powered down, such as flash memory or EEPROM |
| IEC International Electrotechnical Commission | OSR Oversampling ratio |
| IEEE Institute of Electrical and Electronics Engineers | OTA Over the air |
| IP Intellectual property | PC Printed circuit |
| IPC Institute of Printed Circuits | PCB Printed-circuit board |
| IRCOSC Internal RC oscillator | PHI PLL output clock |
| IRQ Interrupt request | PLL Phase-locked loop |
| ISO International Organization for Standardization | PWM Pulse-width modulation |
| I²C Inter-integrated circuit | RAM Random access memory |
| I²S Integrated interchip sound | RC Resistor-capacitor |
| JCOMP JTAG compliance (pin) | SAR Successive approximation register |
| JEDEC Joint Electron Device Engineering Council | SARADC Successive-approximation register analog-to-digital converter |
| JTAG Joint Test Action Group | SAR SV SAR supervisor |
| KB Kilobyte | SCK SPI clock (SPI and other SPI-related specifications such as queued SPI) |
| LIN Local interconnect network | SCL Serial clock line (I ² C signal) |
| LSB Least significant byte | SD Secure digital |
| LV Low voltage | SDADC Sigma-delta analog-to-digital converter |
| LVD Low-voltage detector | SDIO Secure digital input/output |
| MB Megabyte | SoC System on chip |
| MCR Module configuration register | SPI Serial peripheral interface |
| MCU Microcontroller unit | SRAM Static random-access memory |
| MD Modulation depth | SSCG Spread-spectrum clock generation |
| MEMU Memory error management unit | SWD Serial wire debug |
| MOSFET Metal-oxide-semiconductor field-effect transistor | |

TCK Test clock (JTAG standard)

TCM Tightly coupled memory

TMS Test mode select

TRNG True random number generator

TTL Transistor-to-transistor logic

TUE Total unadjusted error

UART Universal asynchronous receiver/transmitter

UTEST User-programmed DCF records. Some UTEST DCF records are written at the factory during production testing. Others are written by the end user and programmed at the same time as the application code.

UVD Maximum-voltage detector

VCO Voltage-controlled oscillator

WS Wait state

XOSC Crystal oscillator

XTAL External oscillator output

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