

Kinetis K65 Sub-Family

180 MHz ARM® Cortex®-M4F Microcontroller.

The K65 sub-family members provide greater performance, memory options up to 2 MB total flash and 256 KB of SRAM, as well as higher peripheral integration with features such as Dual USB and a 10/100 Mbit/s Ethernet MAC. These devices maintain hardware and software compatibility with the existing Kinetis family. This product also offers:

- Integration of a High Speed USB Physical Transceiver
- Greater performance flexibility with a High Speed Run mode
- Smarter peripherals with operation in Stop modes

MK65FN2M0VMI18
MK65FX1M0VMI18



169 MAPBGA (MI)
9 mm x 9 mm Pitch 0.65 mm

Performance

- Up to 180 MHz ARM Cortex-M4 based core with DSP instructions and Single Precision Floating Point unit

System and Clocks

- Multiple low-power modes to provide power optimization based on application requirements
- Memory protection unit with multi-master protection
- 3 to 32 MHz main crystal oscillator
- 32 kHz low power crystal oscillator
- 48 MHz internal reference

Security

- Hardware random-number generator
- Supports DES, AES, SHA accelerator (CAU)
- Multiple levels of embedded flash security

Timers

- Four Periodic interrupt timers
- 16-bit low-power timer
- Two 16-bit low-power timer PWM modules
- Two 8-channel motor control/general purpose/PWM timers
- Two 2-ch quad decoder/general purpose timers
- Real-time clock

Human-machine interface

- Low-power hardware touch sensor interface (TSI)
- General-purpose input/output

Memories and memory expansion

- Up to 2 MB program flash memory on non-FlexMemory devices with 256 KB RAM
- Up to 1 MB program flash memory and 256 KB of FlexNVM on FlexMemory devices
- 4 KB FlexRAM on FlexMemory devices
- FlexBus external bus interface and SDRAM controller

Analog modules

- Two 16-bit SAR ADCs and two 12-bit DAC
- Four analog comparators (CMP) containing a 6-bit DAC and programmable reference input
- Voltage reference 1.2V

Communication interfaces

- Ethernet controller with MII and RMII interface to external PHY and hardware IEEE 1588 capability
- USB high-/full-/low-speed On-the-Go with on-chip high speed transceiver
- USB full-/low-speed OTG with on-chip transceiver
- Two CAN, three SPI and four I2C modules
- Low Power Universal Asynchronous Receiver/Transmitter 0 (LPUART0) and five standard UARTs
- Secure Digital Host Controller (SDHC)
- I2S module

Operating Characteristics

- Voltage/Flash write voltage range: 1.71 to 3.6 V
- Temperature range (ambient): -40 to 105°C

Ordering Information 1

| Part Number | Memory | | Maximum number of I/O's |
|----------------|---------|--------|-------------------------|
| | Flash | SRAM | |
| MK65FN2M0VMI18 | 2 MB | 256 KB | 116 |
| MK65FX1M0VMI18 | 1.25 MB | 256 KB | 116 |

1. To confirm current availability of orderable part numbers, go to <http://www.nxp.com> and perform a part number search.

Related Resources

| Type | Description | Resource |
|------------------|--|--|
| Selector Guide | The NXP Solution Advisor is a web-based tool that features interactive application wizards and a dynamic product selector. | Solution Advisor |
| Reference Manual | The Reference Manual contains a comprehensive description of the structure and function (operation) of a device. | K65P169M180SF5RMV2 ¹ |
| Data Sheet | The Data Sheet includes electrical characteristics and signal connections. | This document. |
| Chip Errata | The chip mask set Errata provides additional or corrective information for a particular device mask set. | Kinetis_K_ON65N ¹ |
| Package drawing | Package dimensions are provided in package drawings. | MAPBGA 169-pin : 98ASA00628D ¹ |

1. To find the associated resource, go to <http://www.nxp.com> and perform a search using this term.

Kinetic K65 Sub-Family

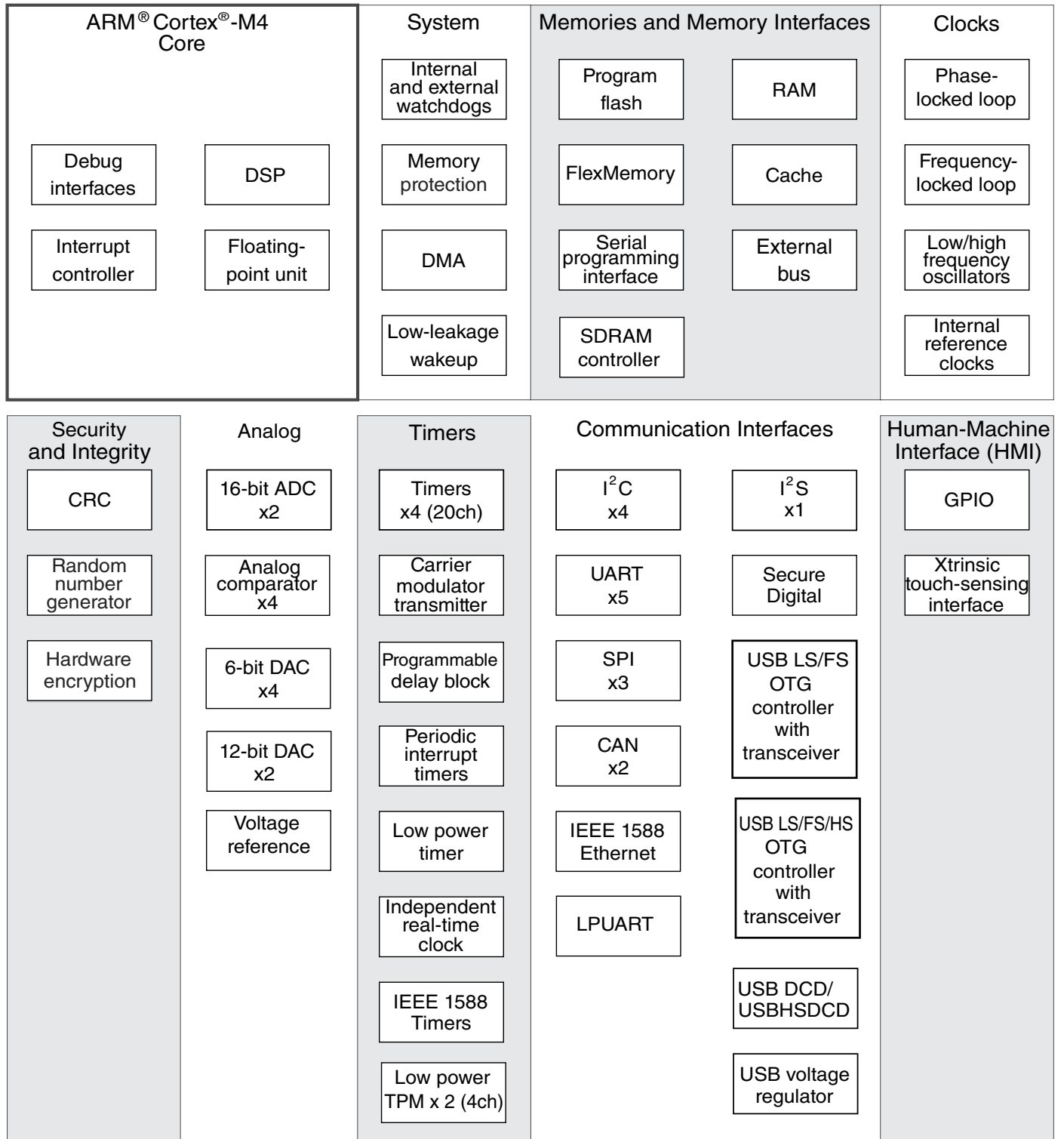


Figure 1. K65 Block Diagram

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1 Ratings

1.1 Thermal handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|-------------------------------|------|------|------|-------|
| T _{STG} | Storage temperature | -55 | 150 | °C | 1 |
| T _{SDR} | Solder temperature, lead-free | — | 260 | °C | 2 |

1. Determined according to JEDEC Standard JESD22-A103, *High Temperature Storage Life*.
2. Determined according to IPC/JEDEC Standard J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

1.2 Moisture handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|----------------------------|------|------|------|-------|
| MSL | Moisture sensitivity level | — | 3 | — | 1 |

1. Determined according to IPC/JEDEC Standard J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

1.3 ESD handling ratings

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|---|-------|-------|------|-------|
| V _{HBM} | Electrostatic discharge voltage, human body model | -2000 | +2000 | V | 1 |
| V _{CDM} | Electrostatic discharge voltage, charged-device model | -500 | +500 | V | 2 |
| I _{LAT} | Latch-up current at ambient temperature of 105°C | -100 | +100 | mA | 3 |

1. Determined according to JEDEC Standard JESD22-A114, *Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)*.
2. Determined according to JEDEC Standard JESD22-C101, *Field-Induced Charged-Device Model Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic Components*.
3. Determined according to JEDEC Standard JESD78, *IC Latch-Up Test*.

1.4 Voltage and current operating ratings

General

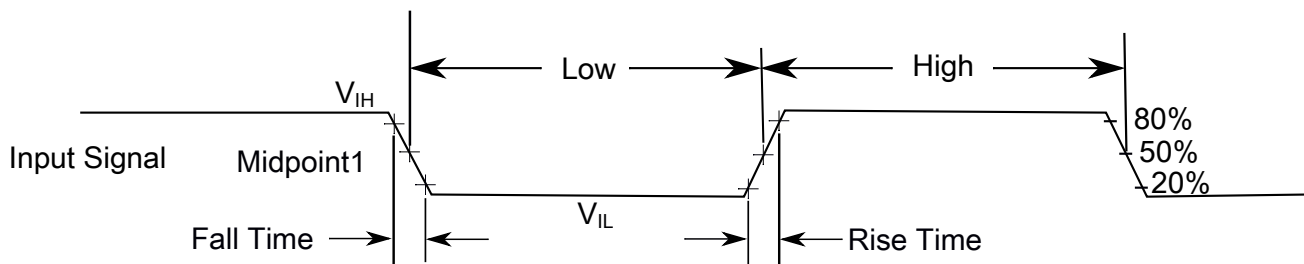
| Symbol | Description | Min. | Max. | Unit |
|-----------------------|---|----------------|----------------|------|
| V_{DD} | Digital supply voltage | -0.3 | 3.8 | V |
| I_{DD} | Digital supply current | — | 300 | mA |
| V_{DIO} | Digital ¹ input voltage, including RESET_b | -0.3 | $V_{DD} + 0.3$ | V |
| V_{AIO} | Analog ¹ input voltage, including EXTAL32 and XTAL32 | -0.3 | $V_{DD} + 0.3$ | V |
| I_D | Maximum current single pin limit (digital output pins) | -25 | 25 | mA |
| V_{DDA} | Analog supply voltage | $V_{DD} - 0.3$ | $V_{DD} + 0.3$ | V |
| V_{USB0_DP} | USB0_DP input voltage | -0.3 | 3.63 | V |
| V_{USB1_DP} | USB1_DP input voltage | -0.3 | 3.63 | V |
| V_{USB0_DM} | USB0_DM input voltage | -0.3 | 3.63 | V |
| V_{USB1_DM} | USB1_DM input voltage | -0.3 | 3.63 | V |
| V_{USB1_VBUS} | USB1_VBUS detect voltage | -0.3 | 6.0 | V |
| VREG_IN0, VREG_IN1 | USB regulator input | -0.3 | 6.0 | V |
| V_{BAT} | RTC battery supply voltage | -0.3 | 3.8 | V |

1. Digital pins have a general purpose I/O port assigned (e.g. PTA0). Analog pins do not have an associated general purpose I/O port.

2 General

2.1 AC electrical characteristics

Unless otherwise specified, propagation delays are measured from the 50% to the 50% point, and rise and fall times are measured at the 20% and 80% points, as shown in the following figure.



The midpoint is $V_{IL} + (V_{IH} - V_{IL}) / 2$

Figure 2. Input signal measurement reference

All digital I/O switching characteristics assume:

1. output pins

- have $C_L=30\text{pF}$ loads,
 - are slew rate disabled, and
 - are normal drive strength
2. input pins
- have their passive filter disabled ($\text{PORTx_PCRn[PFE]}=0$)

2.2 Nonswitching electrical specifications

2.2.1 Voltage and current operating requirements

Table 1. Voltage and current operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------------------|--|---|---|--------|-------|
| V_{DD} | Supply voltage | 1.71 | 3.6 | V | |
| V_{DDA} | Analog supply voltage | 1.71 | 3.6 | V | |
| $V_{DD} - V_{DDA}$ | V_{DD} -to- V_{DDA} differential voltage | -0.1 | 0.1 | V | |
| $V_{SS} - V_{SSA}$ | V_{SS} -to- V_{SSA} differential voltage | -0.1 | 0.1 | V | |
| V_{BAT} | RTC battery supply voltage | 1.71 | 3.6 | V | |
| V_{IH} | Input high voltage <ul style="list-style-type: none"> • $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ • $1.71\text{ V} \leq V_{DD} \leq 2.7\text{ V}$ | $0.7 \times V_{DD}$ $0.75 \times V_{DD}$ | — — | V V | |
| V_{IL} | Input low voltage <ul style="list-style-type: none"> • $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ • $1.71\text{ V} \leq V_{DD} \leq 2.7\text{ V}$ | — — | $0.35 \times V_{DD}$ $0.3 \times V_{DD}$ | V V | |
| V_{HYS} | Input hysteresis | $0.06 \times V_{DD}$ | — | V | |
| I_{ICDIO} | Digital ¹ input pin negative DC injection current — single pin <ul style="list-style-type: none"> • $V_{IN} < V_{SS}-0.3\text{V}$ | -5 | — | mA | 2 |
| I_{ICAIO} | Analog ¹ input pin DC injection current — single pin <ul style="list-style-type: none"> • $V_{IN} < V_{SS}-0.3\text{V}$ (Negative current injection) | -5 | — | mA | 2 |
| I_{ICcont} | Contiguous pin DC injection current —regional limit, includes sum of negative injection currents of 16 contiguous pin <ul style="list-style-type: none"> • Negative current injection | -25 | — | mA | |
| V_{ODPU} | Pseudo Open drain pullup voltage level | V_{DD} | V_{DD} | V | 3 |
| V_{RAM} | V_{DD} voltage required to retain RAM | 1.2 | — | V | |
| V_{RFVBAT} | V_{BAT} voltage required to retain the VBAT register file | V_{POR_VBAT} | — | V | |

General

1. Digital pins have a general purpose I/O port assigned (e.g. PTA0). Analog pins do not have an associated general purpose I/O port.
2. All digital and analog I/O pins are internally clamped to V_{SS} through an ESD protection diode. There is no diode connection to V_{DD} . If V_{IN} is less than $V_{SS}-0.3V$, a current limiting resistor is required. The minimum negative DC injection current limiting resistor value is calculated as $R=(-0.3-V_{IN})/|I_{ICDIO}|$ or $R=(-0.3-V_{IN})/|I_{ICAI0}|$. The actual resistor should be an order of magnitude higher to tolerate transient voltages.
3. Open drain outputs must be pulled to VDD.

2.2.2 LVD and POR operating requirements

Table 2. V_{DD} supply LVD and POR operating requirements

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-------------|--|------|------|------|---------|-------|
| V_{POR} | Falling VDD POR detect voltage | 0.8 | 1.1 | 1.5 | V | |
| V_{LVDH} | Falling low-voltage detect threshold — high range (LVDV=01) | 2.48 | 2.56 | 2.64 | V | |
| V_{LVW1H} | Low-voltage warning thresholds — high range <ul style="list-style-type: none"> • Level 1 falling (LVWV=00) • Level 2 falling (LVWV=01) • Level 3 falling (LVWV=10) • Level 4 falling (LVWV=11) | 2.62 | 2.70 | 2.78 | V | 1 |
| V_{LVW2H} | | 2.72 | 2.80 | 2.88 | V | |
| V_{LVW3H} | | 2.82 | 2.90 | 2.98 | V | |
| V_{LVW4H} | | 2.92 | 3.00 | 3.08 | V | |
| V_{HYSH} | Low-voltage inhibit reset/recover hysteresis — high range | — | 80 | — | mV | |
| V_{LVDL} | Falling low-voltage detect threshold — low range (LVDV=00) | 1.54 | 1.60 | 1.66 | V | |
| V_{LVW1L} | Low-voltage warning thresholds — low range <ul style="list-style-type: none"> • Level 1 falling (LVWV=00) • Level 2 falling (LVWV=01) • Level 3 falling (LVWV=10) • Level 4 falling (LVWV=11) | 1.74 | 1.80 | 1.86 | V | 1 |
| V_{LVW2L} | | 1.84 | 1.90 | 1.96 | V | |
| V_{LVW3L} | | 1.94 | 2.00 | 2.06 | V | |
| V_{LVW4L} | | 2.04 | 2.10 | 2.16 | V | |
| V_{HYSL} | Low-voltage inhibit reset/recover hysteresis — low range | — | 60 | — | mV | |
| V_{BG} | Bandgap voltage reference | 0.97 | 1.00 | 1.03 | V | |
| t_{LPO} | Internal low power oscillator period — factory trimmed | 900 | 1000 | 1100 | μs | |

1. Rising threshold is the sum of falling threshold and hysteresis voltage

Table 3. VBAT power operating requirements

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------|--|------|------|------|------|-------|
| V_{POR_VBAT} | Falling VBAT supply POR detect voltage | 0.8 | 1.1 | 1.5 | V | |

2.2.3 Voltage and current operating behaviors

Table 4. Voltage and current operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|----------------------------|---|------------------------|-------|------|------|-------|
| V _{OH} | Output high voltage — normal drive pad <ul style="list-style-type: none"> • 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -10mA • 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = -5mA | V _{DD} - 0.5 | — | — | V | |
| | | V _{DD} - 0.5 | — | — | V | |
| | Output high voltage — High drive pad <ul style="list-style-type: none"> • 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -20mA • 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = -10mA | V _{DD} - 0.5 | — | — | V | |
| | | V _{DD} - 0.5 | — | — | V | |
| I _{OHT} | Output high current total for all ports | — | — | 100 | mA | |
| V _{OH_RTC_WAKEUP} | Output high voltage— normal drive pad <ul style="list-style-type: none"> • 2.7 V ≤ V_{BAT} ≤ 3.6 V, I_{OH} = -5 mA • 1.71 V ≤ V_{BAT} ≤ 2.7 V, I_{OH} = -2.5 mA | V _{BAT} - 0.5 | — | | V | |
| | | V _{BAT} - 0.5 | — | | V | |
| I _{OH_RTC_WAKEUP} | Output high current total for RTC_WAKEUP pins | — | — | 100 | mA | |
| V _{OL} | Output low voltage — normal drive pad <ul style="list-style-type: none"> • 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 10 mA • 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 5 mA | — | — | 0.5 | V | |
| | | — | — | 0.5 | V | |
| | Output low voltage — high drive pad <ul style="list-style-type: none"> • 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 20 mA • 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 10 mA | — | — | 0.5 | V | |
| | | — | — | 0.5 | V | |
| I _{OLT} | Output low current total for all ports | — | — | 100 | mA | |
| V _{OL_RTC_WAKEUP} | Output low voltage— normal drive pad <ul style="list-style-type: none"> • 2.7 V ≤ V_{BAT} ≤ 3.6 V, I_{OL} = 5 mA • 1.71 V ≤ V_{BAT} ≤ 2.7 V, I_{OL} = 2.5mA | — | | 0.5 | V | |
| | | — | | 0.5 | V | |
| I _{OL_RTC_WAKEUP} | Output low current total for RTC_WAKEUP pins | — | — | 100 | mA | |
| I _{IN} | Input leakage current, analog and digital pins <ul style="list-style-type: none"> • V_{SS} ≤ V_{IN} ≤ V_{DD} | — | 0.002 | 0.5 | μA | 1 |
| I _{OZ_RTC_WAKEUP} | Hi-Z (off-state) leakage current (per RTC_WAKEUP pin) | — | — | 0.25 | μA | |
| R _{PU} | Internal pullup resistors | 20 | — | 50 | kΩ | 2 |
| R _{PD} | Internal pulldown resistors | 20 | — | 50 | kΩ | 3 |

1. Measured at V_{DD}=3.6V

2. Measured at V_{DD} supply voltage = V_{DD} min and V_{input} = V_{SS}

General

3. Measured at V_{DD} supply voltage = V_{DD} min and $V_{input} = V_{DD}$

2.2.4 Power mode transition operating behaviors

All specifications except t_{POR} , and $VLLSx \rightarrow RUN$ recovery times in the following table assume this clock configuration:

- CPU and system clocks = 100MHz
- Bus clock = 50MHz
- FlexBus clock = 50 MHz
- Flash clock = 25 MHz
- MCG mode=FEI

Table 5. Power mode transition operating behaviors

| Symbol | Description | Min. | Max. | Unit | Notes |
|-----------|--|------|------|---------|-------|
| t_{POR} | After a POR event, amount of time from the point V_{DD} reaches 1.71 V to execution of the first instruction across the operating temperature range of the chip. | — | 300 | μs | |
| | • $VLLS0 \rightarrow RUN$ | — | 172 | μs | |
| | • $VLLS1 \rightarrow RUN$ | — | 172 | μs | |
| | • $VLLS2 \rightarrow RUN$ | — | 94 | μs | |
| | • $VLLS3 \rightarrow RUN$ | — | 94 | μs | |
| | • $LLS2 \rightarrow RUN$ | — | 5.8 | μs | |
| | • $LLS3 \rightarrow RUN$ | — | 5.8 | μs | |
| | • $VLPS \rightarrow RUN$ | — | 5.4 | μs | |
| | • $STOP \rightarrow RUN$ | — | 5.4 | μs | |

Table 6. Low power mode peripheral adders — typical value

| Symbol | Description | Temperature ($^{\circ}C$) | | | | | | Unit |
|-------------------|--|-----------------------------|----|----|----|----|-----|---------|
| | | -40 | 25 | 50 | 70 | 85 | 105 | |
| $I_{REFSTEN4MHz}$ | 4 MHz internal reference clock (IRC) adder. Measured by entering STOP or VLPS mode with 4 MHz IRC enabled. | 56 | 56 | 56 | 56 | 56 | 56 | μA |

Table continues on the next page...

Table 6. Low power mode peripheral adders — typical value (continued)

| Symbol | Description | Temperature (°C) | | | | | | Unit |
|---------------------------------------|--|------------------|-----|-----|-----|-----|-----|------|
| | | -40 | 25 | 50 | 70 | 85 | 105 | |
| I _{IREFSTEN32KH_z} | 32 kHz internal reference clock (IRC) adder. Measured by entering STOP mode with the 32 kHz IRC enabled. | 52 | 52 | 52 | 52 | 52 | 52 | μA |
| I _{IREFSTEN4MH_z} | External 4 MHz crystal clock adder. Measured by entering STOP or VLPS mode with the crystal enabled. | 206 | 228 | 237 | 245 | 251 | 258 | μA |
| I _{IREFSTEN32K_{Hz}} | External 32 kHz crystal clock adder by means of the OSC0_CR[EREFSTEN and EREFSTEN] bits. Measured by entering all modes with the crystal enabled. | | | | | | | nA |
| | VLLS1 | 440 | 490 | 540 | 560 | 570 | 580 | |
| | VLLS3 | 440 | 490 | 540 | 560 | 570 | 580 | |
| | LLS2 | 490 | 490 | 540 | 560 | 570 | 680 | |
| | LLS3 | 490 | 490 | 540 | 560 | 570 | 680 | |
| | VLPS | 510 | 560 | 560 | 560 | 610 | 680 | |
| | STOP | 510 | 560 | 560 | 560 | 610 | 680 | |
| I _{48MIRC} | 48MHz IRC | 511 | 520 | 545 | 556 | 563 | 576 | μA |
| I _{CMP} | CMP peripheral adder measured by placing the device in VLLS1 mode with CMP enabled using the 6-bit DAC and a single external input for compare. Includes 6-bit DAC power consumption. | 22 | 22 | 22 | 22 | 22 | 22 | μA |
| I _{RTC} | RTC peripheral adder measured by placing the device in VLLS1 mode with external 32 kHz crystal enabled by means of the RTC_CR[OSCE] bit and the RTC ALARM set for 1 minute. Includes ERCLK32K (32 kHz external crystal) power consumption. | 432 | 357 | 388 | 475 | 532 | 810 | nA |
| I _{UART} | UART peripheral adder measured by placing the device in STOP or VLPS mode with selected clock source waiting for RX data at 115200 baud rate. Includes selected clock source power consumption. | | | | | | | μA |
| | MCGIRCLK (4 MHz internal reference clock) | 66 | 66 | 66 | 66 | 66 | 66 | |
| | OSCERCLK (4 MHz external crystal) | 214 | 234 | 246 | 254 | 260 | 268 | |
| I _{BG} | Bandgap adder when BGEN bit is set and device is placed in VLPx, LLS, or VLLSx mode. | 45 | 45 | 45 | 45 | 45 | 45 | μA |
| I _{ADC} | ADC peripheral adder combining the measured values at V _{DD} and V _{DDA} by placing the device in STOP or VLPS mode. ADC is configured for low power mode using the internal clock and continuous conversions. | 366 | 366 | 366 | 366 | 366 | 366 | μA |

2.2.5 Power consumption operating behaviors

NOTE

The maximum values represent characterized results equivalent to the mean plus three times the standard deviation (mean + 3 sigma)

Table 7. Power consumption operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------------|---|------|------|----------|------|-------|
| I _{DDA} | Analog supply current | — | — | See note | mA | 1 |
| I _{DD_RUN} | Run mode current — all peripheral clocks disabled, code executing from flash <ul style="list-style-type: none"> • @ 1.8V • @ 3.0V | — | 32.3 | 71.03 | mA | 2 |
| I _{DD_RUN} | Run mode current — all peripheral clocks enabled, code executing from flash <ul style="list-style-type: none"> • @ 1.8V • @ 3.0V <ul style="list-style-type: none"> • @ 25°C • @ 105°C | — | 50.5 | 89.58 | mA | 3, 4 |
| I _{DD_RUNC} O | Run mode current in compute operation - 120 MHz core / 24 MHz flash / bus clock disabled, code of while(1) loop executing from flash <ul style="list-style-type: none"> • at 3.0 V | — | 28.5 | 67.74 | mA | 5 |
| I _{DD_HSRUN} | Run mode current — all peripheral clocks disabled, code executing from flash <ul style="list-style-type: none"> • @ 1.8V • @ 3.0V | — | 47.2 | 91.25 | mA | 6 |
| I _{DD_HSRUN} | Run mode current — all peripheral clocks enabled, code executing from flash <ul style="list-style-type: none"> • @ 1.8V • @ 3.0V <ul style="list-style-type: none"> • @ 25°C • @ 105°C | — | 71.4 | 103.58 | mA | 7, 4 |
| I _{DD_HSRUN} CO | HSRun mode current in compute operation – 168 MHz core/ 28 MHz flash / bus clock disabled, code of while(1) loop executing from flash at 3.0V | — | 42.9 | 91.97 | mA | 5 |
| I _{DD_WAIT} | Wait mode high frequency current at 3.0 V — all peripheral clocks disabled | — | 16.9 | 45.2 | mA | 8 |

Table continues on the next page...

Table 7. Power consumption operating behaviors (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|----------------------------|--|------|-------|---------|------|-------|
| I _{DD_WAIT} | Wait mode reduced frequency current at 3.0 V — all peripheral clocks enabled | — | 35 | 62.81 | mA | 8 |
| I _{DD_VLPR} | Very-low-power run mode current at 3.0 V — all peripheral clocks disabled | — | 1.1 | 9.56 | mA | 9 |
| I _{DD_VLPR} | Very-low-power run mode current at 3.0 V — all peripheral clocks enabled | — | 2 | 9.88 | mA | 10 |
| I _{DD_VLPRC} O | Very-low-power run mode current in compute operation - 4 MHz core / 1 MHz flash / bus clock disabled, LPTMR running with 4 MHz internal reference clock <ul style="list-style-type: none"> • at 3.0 V | — | 986 | 9.47 | μA | 11 |
| I _{DD_VLPW} | Very-low-power wait mode current at 3.0 V — all peripheral clocks disabled | — | 0.690 | 9.25 | mA | 12 |
| I _{DD_VLPW} | Very-low-power wait mode current at 3.0 V — all peripheral clocks enabled | — | 1.5 | 10.00 | mA | |
| I _{DD_STOP} | Stop mode current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 0.791 | 2.39 | mA | |
| | | — | 3.8 | 6.91 | mA | |
| | | — | 13.2 | 18.91 | mA | |
| I _{DD_VLPS} | Very-low-power stop mode current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 202 | 353.77 | μA | |
| | | — | 1400 | 2464.54 | μA | |
| | | — | 5100 | 8949.06 | μA | |
| I _{DD_LLS3} | Low leakage stop mode current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 9.0 | 16.5 | μA | |
| | | — | 76.3 | 88.63 | μA | |
| | | — | 402 | 656.08 | μA | |
| I _{DD_LLS2} | Low leakage stop mode current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 5.7 | 9.7 | μA | |
| | | — | 41.3 | 55.80 | μA | |
| | | — | 229 | 276.81 | μA | |
| I _{DD_VLLS3} | Very low-leakage stop mode 3 current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 5.5 | 7.31 | μA | |
| | | — | 46.3 | 58.33 | μA | |
| | | — | 249 | 380.77 | μA | |
| I _{DD_VLLS2} | Very low-leakage stop mode 2 current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 2.7 | 3.24 | μA | |
| | | — | 13.1 | 18.72 | μA | |
| | | — | 76.6 | 84.77 | μA | |

Table continues on the next page...

Table 7. Power consumption operating behaviors (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------|--|------|-------|-------|------|-------|
| I _{DD_VLLS1} | Very low-leakage stop mode 1 current at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 0.847 | 1.48 | μA | |
| | | — | 6.5 | 11.31 | μA | |
| | | — | 46.7 | 81.78 | μA | |
| I _{DD_VLLS0} | Very low-leakage stop mode 0 current at 3.0 V with POR detect circuit enabled <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 0.551 | .65 | μA | |
| | | — | 6.3 | 7.12 | μA | |
| | | — | 49.6 | 53.68 | μA | |
| I _{DD_VLLS0} | Very low-leakage stop mode 0 current at 3.0 V with POR detect circuit disabled <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 0.254 | 0.445 | μA | |
| | | — | 6.3 | 10.99 | μA | |
| | | — | 48.7 | 85.27 | μA | |
| I _{DD_VBAT} | Average current with RTC and 32kHz disabled at 3.0 V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 0.19 | 0.22 | μA | |
| | | — | 0.49 | 0.64 | μA | |
| | | — | 2.2 | 3.2 | μA | |
| I _{DD_VBAT} | Average current when CPU is not accessing RTC registers <ul style="list-style-type: none"> • @ 1.8V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C • @ 3.0V <ul style="list-style-type: none"> • @ -40 to 25°C • @ 70°C • @ 105°C | — | 0.68 | 0.8 | μA | 13 |
| | | — | 1.2 | 1.56 | μA | |
| | | — | 3.6 | 5.3 | μA | |
| | | — | 0.81 | 0.96 | μA | |
| | | — | 1.45 | 1.89 | μA | |
| | | — | 4.3 | 6.33 | μA | |
| | | — | 4.3 | 6.33 | μA | |

1. The analog supply current is the sum of the active or disabled current for each of the analog modules on the device. See each module's specification for its supply current.
2. 120 MHz core and system clock, 60 MHz bus and FlexBus clock, and 24 MHz flash clock. MCG configured for PEE mode. All peripheral clocks disabled.
3. 120 MHz core and system clock, 60 MHz bus and FlexBus clock, and 24 MHz flash clock. MCG configured for PEE mode. All peripheral clocks enabled.
4. Max values are measured with CPU executing DSP instructions.
5. MCG configured for PEE mode.
6. 168 MHz core and system clock, 56 MHz bus and FlexBus clock, and 28 MHz flash clock. MCG configured for PEE mode. All peripheral clocks disabled.
7. 168 MHz core and system clock, 56 MHz bus and FlexBus clock, and 28 MHz flash clock. MCG configured for PEE mode. All peripheral clocks enabled.

8. 120 MHz core and system clock, 60MHz bus clock, and FlexBus. MCG configured for PEE mode.
9. 4 MHz core, system, FlexBus, and bus clock and 1 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks disabled. Code executing from flash.
10. 4 MHz core, system, FlexBus, and bus clock and 1 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks enabled but peripherals are not in active operation. Code executing from flash.
11. MCG configured for BLPI mode. CoreMark benchmark compiled using IAR 6.40 with optimization level high, optimized for balanced.
12. 4 MHz core, system, FlexBus, and bus clock and 1 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks disabled.
13. Includes 32kHz oscillator current and RTC operation.

2.2.5.1 Diagram: Typical IDD_RUN operating behavior

The following data was measured under these conditions:

- USB regulator disabled
- No GPIOs toggled
- Code execution from flash with cache enabled
- For the ALLOFF curve, all peripheral clocks are disabled except FTFE

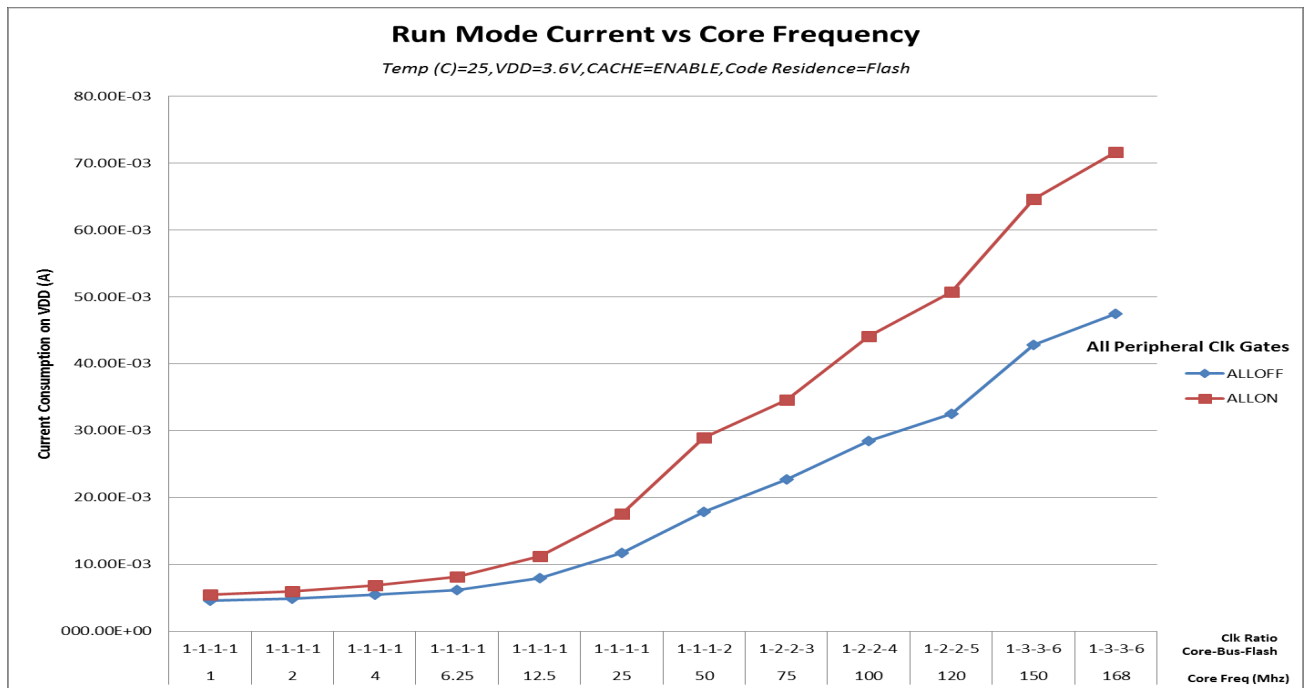


Figure 3. Run mode supply current vs. core frequency

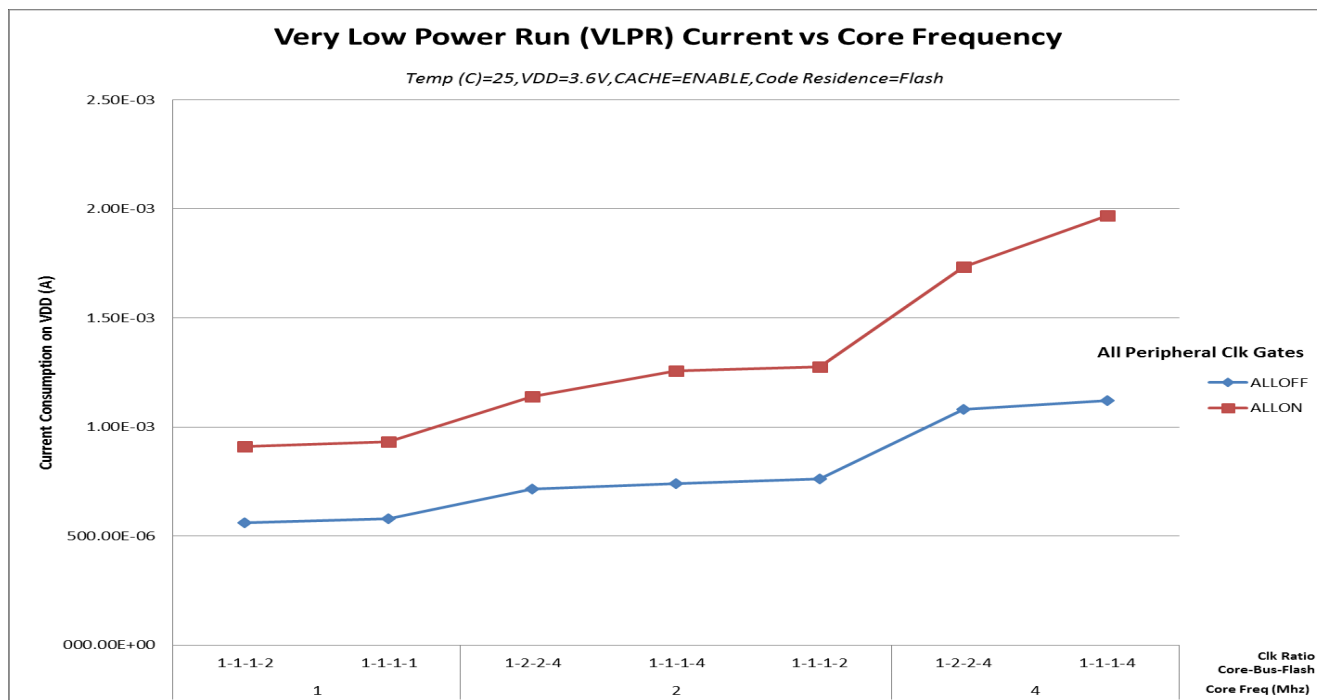


Figure 4. VLPR mode supply current vs. core frequency

2.2.6 EMC radiated emissions operating behaviors

Table 8. EMC radiated emissions operating behaviors

| Symbol | Description | Frequency band (MHz) | Typ. | Unit | Notes |
|---------------------|------------------------------------|----------------------|------|------|-------|
| V _{RE1} | Radiated emissions voltage, band 1 | 0.15–50 | 23 | dBμV | 1, 2 |
| V _{RE2} | Radiated emissions voltage, band 2 | 50–150 | 27 | dBμV | |
| V _{RE3} | Radiated emissions voltage, band 3 | 150–500 | 28 | dBμV | |
| V _{RE4} | Radiated emissions voltage, band 4 | 500–1000 | 14 | dBμV | |
| V _{RE_IEC} | IEC level | 0.15–1000 | K | — | 2, 3 |

1. Determined according to IEC Standard 61967-1, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 1: General Conditions and Definitions* and IEC Standard 61967-2, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 2: Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*. Measurements were made while the microcontroller was running basic application code.

The reported emission level is the value of the maximum measured emission, rounded up to the next whole number, from among the measured orientations in each frequency range.

2. $V_{DD} = 3.3\text{ V}$, $T_A = 25\text{ °C}$, $f_{OSC} = 12\text{ MHz}$ (crystal), $f_{SYS} = \text{MHz}$, $f_{BUS} = \text{MHz}$
3. Specified according to Annex D of IEC Standard 61967-2, *Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*

2.2.7 Designing with radiated emissions in mind

To find application notes that provide guidance on designing your system to minimize interference from radiated emissions.

1. Go to nxp.com
2. Perform a keyword search for “EMC design.”

2.2.8 Capacitance attributes

Table 9. Capacitance attributes

| Symbol | Description | Min. | Max. | Unit |
|-------------|---------------------------------|------|------|------|
| C_{IN_A} | Input capacitance: analog pins | — | 7 | pF |
| C_{IN_D} | Input capacitance: digital pins | — | 7 | pF |

2.3 Switching specifications

2.3.1 Device clock specifications

Table 10. Device clock specifications

| Symbol | Description | Min. | Max. | Unit | Notes |
|--|---|------|------|------|-------|
| High Speed run mode | | | | | |
| f_{SYS} | System and core clock | — | 180 | MHz | |
| Normal run mode (and High Speed run mode unless otherwise specified above) | | | | | |
| f_{SYS} | System and core clock | — | 120 | MHz | |
| | System and core clock when Full Speed USB in operation | 20 | — | MHz | |
| f_{SYS_USBHS} | System and core clock when High Speed USB in operation | 100 | — | MHz | |
| f_{ENET} | System and core clock when ethernet in operation | | | MHz | |
| | <ul style="list-style-type: none"> • 10 Mbps • 100 Mbps | 5 | — | | |
| | | 50 | — | | |

Table continues on the next page...

Table 10. Device clock specifications (continued)

| Symbol | Description | Min. | Max. | Unit | Notes |
|----------------------------|----------------------------------|------|------|------|-------|
| f _{BUS} | Bus clock | — | 60 | MHz | |
| FB_CLK | FlexBus clock | — | 60 | MHz | |
| f _{FLASH} | Flash clock | — | 28 | MHz | |
| f _{LPTMR} | LPTMR clock | — | 25 | MHz | |
| VLPR mode ¹ | | | | | |
| f _{SYS} | System and core clock | — | 4 | MHz | |
| f _{BUS} | Bus clock | — | 4 | MHz | |
| FB_CLK | FlexBus clock | — | 4 | MHz | |
| f _{FLASH} | Flash clock | — | 1 | MHz | |
| f _{ERCLK} | External reference clock | — | 16 | MHz | |
| f _{LPTMR_pin} | LPTMR clock | — | 25 | MHz | |
| f _{FlexCAN_ERCLK} | FlexCAN external reference clock | — | 8 | MHz | |
| f _{I2S_MCLK} | I2S master clock | — | 12.5 | MHz | |
| f _{I2S_BCLK} | I2S bit clock | — | 4 | MHz | |

1. The frequency limitations in VLPR mode here override any frequency specification listed in the timing specification for any other module.

2.3.2 General switching specifications

These general purpose specifications apply to all signals configured for GPIO, UART, CAN, CMT, IEEE 1588 timer, timers, and I²C signals.

Table 11. General switching specifications

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|---|------|------|------------------|-------|
| | GPIO pin interrupt pulse width (digital glitch filter disabled) — Synchronous path | 1.5 | — | Bus clock cycles | 1, 2 |
| | GPIO pin interrupt pulse width (digital glitch filter disabled, analog filter enabled) — Asynchronous path | 100 | — | ns | 3 |
| | GPIO pin interrupt pulse width (digital glitch filter disabled, analog filter disabled) — Asynchronous path | 50 | — | ns | 3 |
| | External reset pulse width (digital glitch filter disabled) | 100 | — | ns | 3 |
| | Mode select ($\overline{\text{EZP_CS}}$) hold time after reset deassertion | 2 | — | Bus clock cycles | |
| | Port rise and fall time (high drive strength) | | | | 4 |
| | <ul style="list-style-type: none"> Slew enabled | — | 25 | ns | |
| | | — | 15 | ns | |

Table continues on the next page...

Table 11. General switching specifications (continued)

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|---|------|------|------|-------|
| | <ul style="list-style-type: none"> • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ • Slew disabled • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ | — | 7 | ns | |
| | <ul style="list-style-type: none"> • Slew disabled • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ | — | 7 | ns | |
| | Port rise and fall time (low drive strength) | | | | 5 |
| | <ul style="list-style-type: none"> • Slew enabled • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ | — | 25 | ns | |
| | <ul style="list-style-type: none"> • Slew disabled • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ | — | 15 | ns | |
| | <ul style="list-style-type: none"> • Slew disabled • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ | — | 7 | ns | |
| | <ul style="list-style-type: none"> • Slew disabled • $1.71 \leq V_{DD} \leq 2.7V$ • $2.7 \leq V_{DD} \leq 3.6V$ | — | 7 | ns | |

1. This is the minimum pulse width that is guaranteed to pass through the pin synchronization circuitry. Shorter pulses may or may not be recognized. In Stop, VLPS, LLS, and VLLSx modes, the synchronizer is bypassed so shorter pulses can be recognized in that case.
2. The greater synchronous and asynchronous timing must be met.
3. This is the minimum pulse width that is guaranteed to be recognized as a pin interrupt request in Stop, VLPS, LLS, and VLLSx modes.
4. 75 pF load
5. 15 pF load

2.4 Thermal specifications

2.4.1 Thermal operating requirements

Table 12. Thermal operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|--------|--------------------------|------|------|------|-------|
| T_J | Die junction temperature | -40 | 125 | °C | |
| T_A | Ambient temperature | -40 | 105 | °C | 1 |

1. Maximum T_A can be exceeded only if the user ensures that T_J does not exceed maximum T_J . The simplest method to determine T_J is: $T_J = T_A + R_{\theta JA} \times \text{chip power dissipation}$.

2.4.2 Thermal attributes

| Board type | Symbol | Description | 169 MAPBGA | Unit | Notes |
|-------------------|------------------|---|------------|------|-------|
| Single-layer (1s) | $R_{\theta JA}$ | Thermal resistance, junction to ambient (natural convection) | 38 | °C/W | 1 |
| Four-layer (2s2p) | $R_{\theta JA}$ | Thermal resistance, junction to ambient (natural convection) | 21.9 | °C/W | 1 |
| Single-layer (1s) | $R_{\theta JMA}$ | Thermal resistance, junction to ambient (200 ft./min. air speed) | 30 | °C/W | 1 |
| Four-layer (2s2p) | $R_{\theta JMA}$ | Thermal resistance, junction to ambient (200 ft./min. air speed) | 18.6 | °C/W | 1 |
| — | $R_{\theta JB}$ | Thermal resistance, junction to board | 14.4 | °C/W | 2 |
| — | $R_{\theta JC}$ | Thermal resistance, junction to case | 8.2 | °C/W | 3 |
| — | Ψ_{JT} | Thermal characterization parameter, junction to package top outside center (natural convection) | 0.2 | °C/W | 4 |

1. Determined according to JEDEC Standard JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions—Natural Convection (Still Air)*, or EIA/JEDEC Standard JESD51-6, *Integrated Circuit Thermal Test Method Environmental Conditions—Forced Convection (Moving Air)*.
2. Determined according to JEDEC Standard JESD51-8, *Integrated Circuit Thermal Test Method Environmental Conditions—Junction-to-Board*.
3. Determined according to Method 1012.1 of MIL-STD 883, *Test Method Standard, Microcircuits*, with the cold plate temperature used for the case temperature. The value includes the thermal resistance of the interface material between the top of the package and the cold plate.
4. Determined according to JEDEC Standard JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions—Natural Convection (Still Air)*.

3 Peripheral operating requirements and behaviors

3.1 Core modules

3.1.1 Debug trace timing specifications

Table 13. Debug trace operating behaviors

| Symbol | Description | Min. | Max. | Unit |
|-----------|--------------------------|---------------------|------|------|
| T_{cyc} | Clock period | Frequency dependent | | MHz |
| T_{wl} | Low pulse width | 2 | — | ns |
| T_{wh} | High pulse width | 2 | — | ns |
| T_r | Clock and data rise time | — | 3 | ns |
| T_f | Clock and data fall time | — | 3 | ns |
| T_s | Data setup | 1.5 | — | ns |
| T_h | Data hold | 1.0 | — | ns |

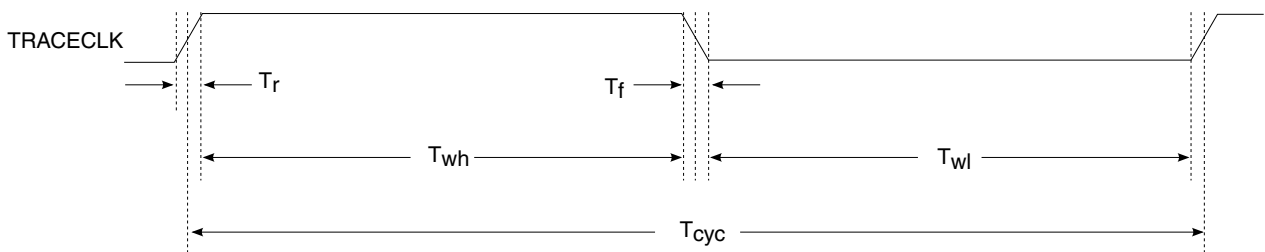


Figure 5. TRACE_CLKOUT specifications

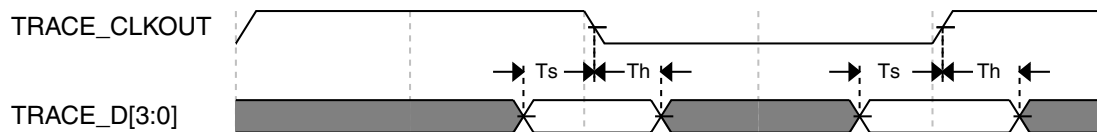


Figure 6. Trace data specifications

3.1.2 JTAG electricals

Table 14. JTAG limited voltage range electricals

| Symbol | Description | Min. | Max. | Unit |
|--------|-------------------|------|------|------|
| | Operating voltage | 2.7 | 3.6 | V |

Table continues on the next page...

Table 14. JTAG limited voltage range electricals (continued)

| Symbol | Description | Min. | Max. | Unit |
|--------|---|------|------|------|
| J1 | TCLK frequency of operation | | | MHz |
| | • Boundary Scan | 0 | 10 | |
| | • JTAG and CJTAG | 0 | 25 | |
| | • Serial Wire Debug | 0 | 50 | |
| J2 | TCLK cycle period | 1/J1 | — | ns |
| J3 | TCLK clock pulse width | | | |
| | • Boundary Scan | 50 | — | ns |
| | • JTAG and CJTAG | 20 | — | ns |
| | • Serial Wire Debug | 10 | — | ns |
| J4 | TCLK rise and fall times | — | 3 | ns |
| J5 | Boundary scan input data setup time to TCLK rise | 20 | — | ns |
| J6 | Boundary scan input data hold time after TCLK rise | 2.0 | — | ns |
| J7 | TCLK low to boundary scan output data valid | — | 28 | ns |
| J8 | TCLK low to boundary scan output high-Z | — | 25 | ns |
| J9 | TMS, TDI input data setup time to TCLK rise | 8 | — | ns |
| J10 | TMS, TDI input data hold time after TCLK rise | 1 | — | ns |
| J11 | TCLK low to TDO data valid | — | 19 | ns |
| J12 | TCLK low to TDO high-Z | — | 17 | ns |
| J13 | $\overline{\text{TRST}}$ assert time | 100 | — | ns |
| J14 | $\overline{\text{TRST}}$ setup time (negation) to TCLK high | 8 | — | ns |

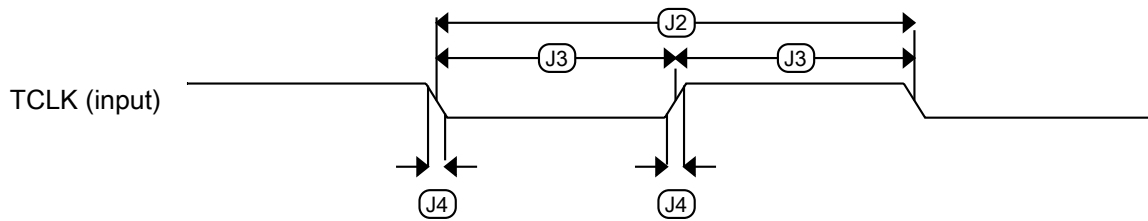
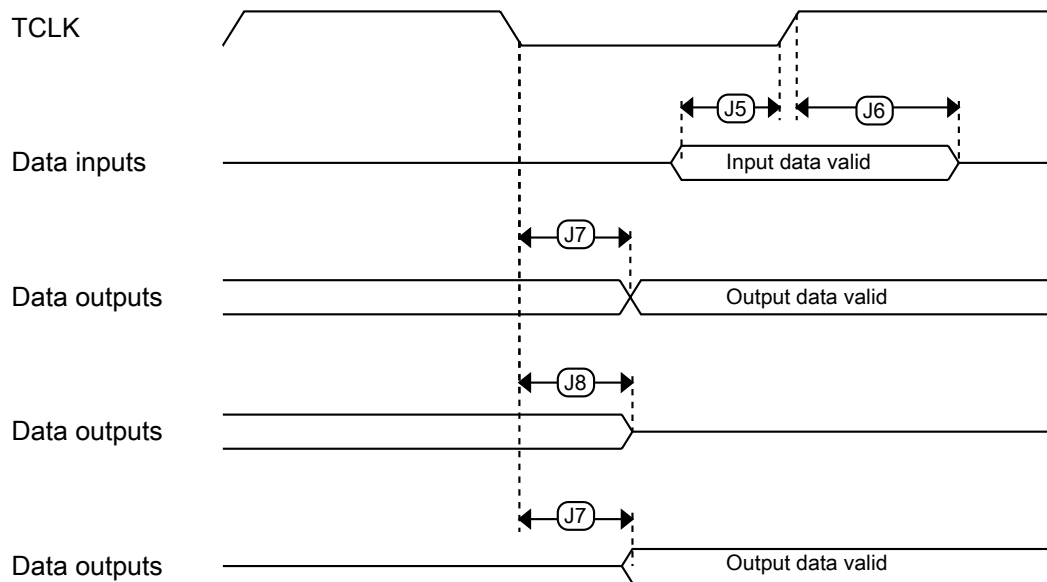
Table 15. JTAG full voltage range electricals

| Symbol | Description | Min. | Max. | Unit |
|--------|--|------|------|------|
| | Operating voltage | 1.71 | 3.6 | V |
| J1 | TCLK frequency of operation | | | MHz |
| | • Boundary Scan | 0 | 10 | |
| | • JTAG and CJTAG | 0 | 20 | |
| | • Serial Wire Debug | 0 | 40 | |
| J2 | TCLK cycle period | 1/J1 | — | ns |
| J3 | TCLK clock pulse width | | | |
| | • Boundary Scan | 50 | — | ns |
| | • JTAG and CJTAG | 25 | — | ns |
| | • Serial Wire Debug | 12.5 | — | ns |
| J4 | TCLK rise and fall times | — | 3 | ns |
| J5 | Boundary scan input data setup time to TCLK rise | 20 | — | ns |

Table continues on the next page...

Table 15. JTAG full voltage range electricals (continued)

| Symbol | Description | Min. | Max. | Unit |
|--------|--|------|------|------|
| J6 | Boundary scan input data hold time after TCLK rise | 2.0 | — | ns |
| J7 | TCLK low to boundary scan output data valid | — | 30.6 | ns |
| J8 | TCLK low to boundary scan output high-Z | — | 25 | ns |
| J9 | TMS, TDI input data setup time to TCLK rise | 8 | — | ns |
| J10 | TMS, TDI input data hold time after TCLK rise | 1.0 | — | ns |
| J11 | TCLK low to TDO data valid | — | 19.0 | ns |
| J12 | TCLK low to TDO high-Z | — | 17.0 | ns |
| J13 | TRST assert time | 100 | — | ns |
| J14 | TRST setup time (negation) to TCLK high | 8 | — | ns |

**Figure 7. Test clock input timing****Figure 8. Boundary scan (JTAG) timing**

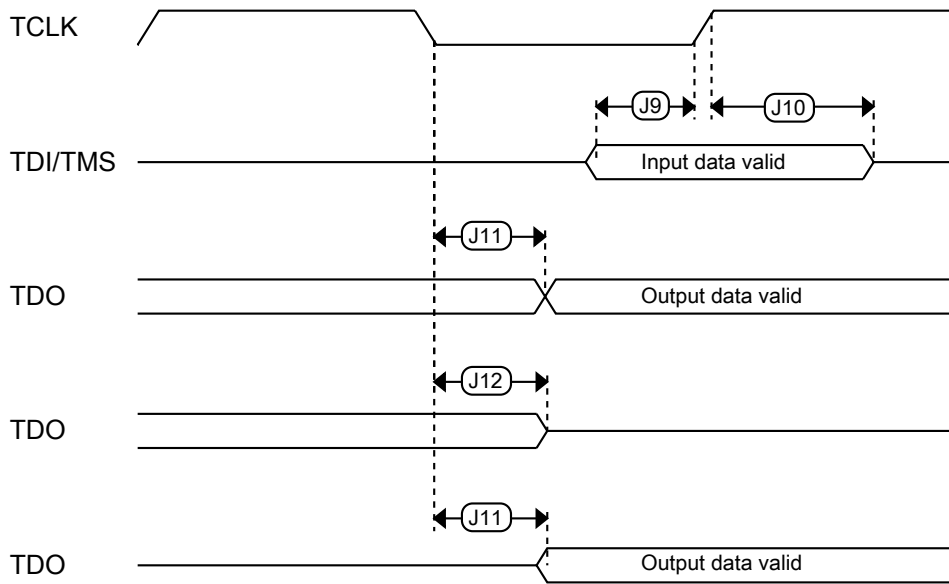


Figure 9. Test Access Port timing

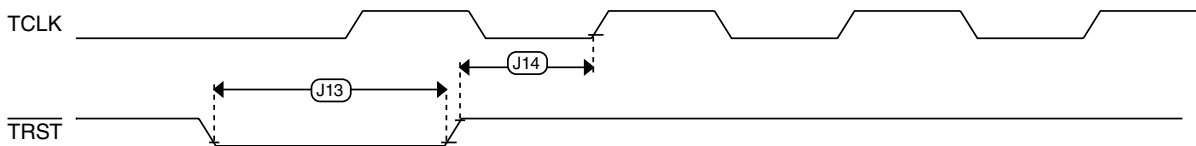


Figure 10. TRST timing

3.2 System modules

There are no specifications necessary for the device's system modules.

3.3 Clock modules

3.3.1 MCG specifications

Table 16. MCG specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes | |
|--------------------------|---|--|--------|---------|-------------|-------|---|
| f_{ints_ft} | Internal reference frequency (slow clock) — factory trimmed at nominal VDD and 25 °C | — | 32.768 | — | kHz | | |
| f_{ints_t} | Internal reference frequency (slow clock) — user trimmed | 31.25 | — | 39.0625 | kHz | | |
| I_{ints} | Internal reference (slow clock) current | — | 20 | — | μA | | |
| $\Delta f_{dco_res_t}$ | Resolution of trimmed average DCO output frequency at fixed voltage and temperature — using SCTRIM and SCFTRIM | — | ± 0.3 | ± 0.6 | % f_{dco} | 1 | |
| $\Delta f_{dco_res_t}$ | Resolution of trimmed average DCO output frequency at fixed voltage and temperature — using SCTRIM only | — | ± 0.2 | ± 0.5 | % f_{dco} | 1 | |
| Δf_{dco_t} | Total deviation of trimmed average DCO output frequency over voltage and temperature | — | ± 0.5 | ± 2 | % f_{dco} | 1 | |
| Δf_{dco_t} | Total deviation of trimmed average DCO output frequency over fixed voltage and temperature range of 0–70°C | — | ± 0.3 | 1.5 | % f_{dco} | 1 | |
| f_{intf_ft} | Internal reference frequency (fast clock) — factory trimmed at nominal VDD and 25°C | — | 4 | — | MHz | | |
| f_{intf_t} | Internal reference frequency (fast clock) — user trimmed at nominal VDD and 25 °C | 3 | — | 5 | MHz | | |
| I_{intf} | Internal reference (fast clock) current | — | 25 | — | μA | | |
| f_{loc_low} | Loss of external clock minimum frequency — RANGE = 00 ext clk freq: above $(3/5)f_{int}$ never reset ext clk freq: between $(2/5)f_{int}$ and $(3/5)f_{int}$ maybe reset (phase dependency) ext clk freq: below $(2/5)f_{int}$ always reset | $(3/5) \times f_{ints_t}$ | — | — | kHz | | |
| f_{loc_high} | Loss of external clock minimum frequency — RANGE = 01, 10, or 11 ext clk freq: above $(16/5)f_{int}$ never reset ext clk freq: between $(15/5)f_{int}$ and $(16/5)f_{int}$ maybe reset (phase dependency) ext clk freq: below $(15/5)f_{int}$ always reset | $(16/5) \times f_{ints_t}$ | — | — | kHz | | |
| FLL | | | | | | | |
| f_{fill_ref} | FLL reference frequency range | 31.25 | — | 39.0625 | kHz | | |
| f_{dco_ut} | DCO output frequency range — untrimmed | Low range (DRS=00, DMX32=0) $640 \times f_{ints_ut}$ | 16.0 | 23.04 | 26.66 | MHz | 2 |
| | | Mid range (DRS=01, DMX32=0) $1280 \times f_{ints_ut}$ | 32.0 | 46.08 | 53.32 | | |

Table continues on the next page...

Table 16. MCG specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes | |
|----------------------------|----------------------------|--|-------|--------|--------|-------|------|
| | | Mid-high range (DRS=10, DMX32=0) $1920 \times f_{\text{ints_ut}}$ | 48.0 | 69.12 | 79.99 | | |
| | | High range (DRS=11, DMX32=0) $2560 \times f_{\text{ints_ut}}$ | 64.0 | 92.16 | 106.65 | | |
| | | Low range (DRS=00, DMX32=1) $732 \times f_{\text{ints_ut}}$ | 18.3 | 26.35 | 30.50 | | |
| | | Mid range (DRS=01, DMX32=1) $1464 \times f_{\text{ints_ut}}$ | 36.6 | 52.70 | 60.99 | | |
| | | Mid-high range (DRS=10, DMX32=1) $2197 \times f_{\text{ints_ut}}$ | 54.93 | 79.09 | 91.53 | | |
| | | High range (DRS=11, DMX32=1) $2929 \times f_{\text{ints_ut}}$ | 73.23 | 105.44 | 122.02 | | |
| f_{dco} | DCO output frequency range | Low range (DRS=00) $640 \times f_{\text{fill_ref}}$ | 20 | 20.97 | 25 | MHz | 3, 4 |
| | | Mid range (DRS=01) $1280 \times f_{\text{fill_ref}}$ | 40 | 41.94 | 50 | MHz | |
| | | Mid-high range (DRS=10) $1920 \times f_{\text{fill_ref}}$ | 60 | 62.91 | 75 | MHz | |
| | | High range (DRS=11) $2560 \times f_{\text{fill_ref}}$ | 80 | 83.89 | 100 | MHz | |
| $f_{\text{dco_t_DMX32}}$ | DCO output frequency | Low range (DRS=00) $732 \times f_{\text{fill_ref}}$ | — | 23.99 | — | MHz | 5, 6 |
| | | Mid range (DRS=01) $1464 \times f_{\text{fill_ref}}$ | — | 47.97 | — | MHz | |
| | | Mid-high range (DRS=10) $2197 \times f_{\text{fill_ref}}$ | — | 71.99 | — | MHz | |
| | | High range (DRS=11) $2929 \times f_{\text{fill_ref}}$ | — | 95.98 | — | MHz | |
| $J_{\text{cyc_fill}}$ | FLL period jitter | | — | 180 | — | ps | |
| | | <ul style="list-style-type: none"> • $f_{\text{DCO}} = 48 \text{ MHz}$ • $f_{\text{DCO}} = 98 \text{ MHz}$ | — | 150 | — | | |

Table continues on the next page...

Table 16. MCG specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|---------------------------|--|------------|------------|---|----------|-------|
| $t_{\text{fll_acquire}}$ | FLL target frequency acquisition time | — | — | 1 | ms | 7 |
| PLL | | | | | | |
| $f_{\text{pll_ref}}$ | PLL reference frequency range | 8 | — | 16 | MHz | |
| $f_{\text{vcoclk_2x}}$ | VCO output frequency | 180 | — | 360 | MHz | |
| f_{vcoclk} | PLL output frequency | 90 | — | 180 | MHz | |
| $f_{\text{vcoclk_90}}$ | PLL quadrature output frequency | 90 | — | 180 | MHz | |
| I_{pll} | PLL operating current • VCO @ 184 MHz ($f_{\text{osc_hi_1}} = 32$ MHz, $f_{\text{pll_ref}} = 8$ MHz, VDIV multiplier = 23) | — | 2.8 | — | mA | 8 |
| I_{pll} | PLL operating current • VCO @ 360 MHz ($f_{\text{osc_hi_1}} = 32$ MHz, $f_{\text{pll_ref}} = 8$ MHz, VDIV multiplier = 45) | — | 3.6 | — | mA | 8 |
| $J_{\text{cyc_pll}}$ | PLL period jitter (RMS) • $f_{\text{vco}} = 180$ MHz • $f_{\text{vco}} = 360$ MHz | — — | 100 75 | — — | ps ps | 9 |
| $J_{\text{acc_pll}}$ | PLL accumulated jitter over 1 μ s (RMS) • $f_{\text{vco}} = 180$ MHz • $f_{\text{vco}} = 360$ MHz | — — | 600 300 | — — | ps ps | 9 |
| D_{unl} | Lock exit frequency tolerance | ± 4.47 | — | ± 5.97 | % | |
| $t_{\text{pll_lock}}$ | Lock detector detection time | — | — | 150×10^{-6} + $1075(1/f_{\text{pll_ref}})$ | s | 10 |

1. This parameter is measured with the internal reference (slow clock) being used as a reference to the FLL (FEI clock mode).
2. This applies when SCTRIM at value (0x80) and SCFTRIM control bit at value (0x0).
3. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=0.
4. The resulting system clock frequencies should not exceed their maximum specified values. The DCO frequency deviation ($\Delta f_{\text{dco_t}}$) over voltage and temperature should be considered.
5. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=1.
6. The resulting clock frequency must not exceed the maximum specified clock frequency of the device.
7. This specification applies to any time the FLL reference source or reference divider is changed, trim value is changed, DMX32 bit is changed, DRS bits are changed, or changing from FLL disabled (BLPE, BLPI) to FLL enabled (FEI, FEE, FBE, FBI). If a crystal/resonator is being used as the reference, this specification assumes it is already running.
8. Excludes any oscillator currents that are also consuming power while PLL is in operation.
9. This specification was obtained using a NXP developed PCB. PLL jitter is dependent on the noise characteristics of each PCB and results will vary.
10. This specification applies to any time the PLL VCO divider or reference divider is changed, or changing from PLL disabled (BLPE, BLPI) to PLL enabled (PBE, PEE). If a crystal/resonator is being used as the reference, this specification assumes it is already running.

3.3.2 IRC48M specifications

Table 17. IRC48M specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------------|---|------|-----------|-----------|----------------|-------|
| V_{DD} | Supply voltage | 1.71 | — | 3.6 | V | |
| I_{DD48M} | Supply current | — | 520 | — | μ A | |
| f_{irc48m} | Internal reference frequency | — | 48 | — | MHz | |
| $\Delta f_{irc48m_ol_lv}$ | Open loop total deviation of IRC48M frequency at low voltage ($V_{DD}=1.71V-1.89V$) over full temperature <ul style="list-style-type: none"> Regulator disable ($USB_CLK_RECOVER_IRC_EN[REG_EN]=0$) Regulator enable ($USB_CLK_RECOVER_IRC_EN[REG_EN]=1$) | — | ± 0.4 | ± 1.0 | $\%f_{irc48m}$ | 1 |
| $\Delta f_{irc48m_ol_hv}$ | Open loop total deviation of IRC48M frequency at high voltage ($V_{DD}=1.89V-3.6V$) over 0—70°C <ul style="list-style-type: none"> Regulator enable ($USB_CLK_RECOVER_IRC_EN[REG_EN]=1$) | — | ± 0.2 | ± 0.5 | $\%f_{irc48m}$ | 1 |
| $\Delta f_{irc48m_ol_hv}$ | Open loop total deviation of IRC48M frequency at high voltage ($V_{DD}=1.89V-3.6V$) over full temperature <ul style="list-style-type: none"> Regulator enable ($USB_CLK_RECOVER_IRC_EN[REG_EN]=1$) | — | ± 0.4 | ± 1.0 | $\%f_{irc48m}$ | 1 |
| Δf_{irc48m_cl} | Closed loop total deviation of IRC48M frequency over voltage and temperature | — | — | ± 0.1 | $\%f_{host}$ | 2 |
| J_{cyc_irc48m} | Period Jitter (RMS) | — | 35 | 150 | ps | |
| $t_{irc48mst}$ | Startup time | — | 2 | 3 | μ s | 3 |

- The maximum value represents characterized results equivalent to mean plus or minus three times the standard deviation (mean \pm 3 sigma)
- Closed loop operation of the IRC48M is only feasible for USB device operation; it is not usable for USB host operation. It is enabled by configuring for USB Device, selecting IRC48M as USB clock source, and enabling the clock recover function ($USB_CLK_RECOVER_IRC_CTRL[CLOCK_RECOVER_EN]=1$, $USB_CLK_RECOVER_IRC_EN[IRC_EN]=1$).
- IRC48M startup time is defined as the time between clock enablement and clock availability for system use. Enable the clock by one of the following settings:
 - $USB_CLK_RECOVER_IRC_EN[IRC_EN]=1$, or
 - $MCG_C7[OSCSEL]=10$, or
 - $SIM_SOPT2[PLLFLSEL]=11$

3.3.3 Oscillator electrical specifications

3.3.3.1 Oscillator DC electrical specifications

Table 18. Oscillator DC electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------|---|-----------------------|------|------|------------|-------|
| V_{DD} | Supply voltage | 1.71 | — | 3.6 | V | |
| I_{DDOSC} | Supply current — low-power mode (HGO=0) | | | | | 1 |
| | • 32 kHz | — | 600 | — | nA | |
| | • 4 MHz | — | 200 | — | μ A | |
| | • 8 MHz (RANGE=01) | — | 300 | — | μ A | |
| | • 16 MHz | — | 950 | — | μ A | |
| | • 24 MHz | — | 1.2 | — | mA | |
| I_{DDOSC} | Supply current — high gain mode (HGO=1) | | | | | 1 |
| | • 32 kHz | — | 7.5 | — | μ A | |
| | • 4 MHz | — | 500 | — | μ A | |
| | • 8 MHz (RANGE=01) | — | 650 | — | μ A | |
| | • 16 MHz | — | 2.5 | — | mA | |
| | • 24 MHz | — | 3.25 | — | mA | |
| C_x | EXTAL load capacitance | — | — | — | | 2, 3 |
| | C_y | XTAL load capacitance | — | — | — | 2, 3 |
| R_F | Feedback resistor — low-frequency, low-power mode (HGO=0) | — | — | — | M Ω | 2, 4 |
| | Feedback resistor — low-frequency, high-gain mode (HGO=1) | — | 10 | — | M Ω | |
| | Feedback resistor — high-frequency, low-power mode (HGO=0) | — | — | — | M Ω | |
| | Feedback resistor — high-frequency, high-gain mode (HGO=1) | — | 1 | — | M Ω | |
| R_S | Series resistor — low-frequency, low-power mode (HGO=0) | — | — | — | k Ω | |
| | Series resistor — low-frequency, high-gain mode (HGO=1) | — | 200 | — | k Ω | |
| | Series resistor — high-frequency, low-power mode (HGO=0) | — | — | — | k Ω | |
| | Series resistor — high-frequency, high-gain mode (HGO=1) | — | 0 | — | k Ω | |
| V_{pp} ⁵ | Peak-to-peak amplitude of oscillation (oscillator mode) — low-frequency, low-power mode (HGO=0) | — | 0.6 | — | V | |

Table continues on the next page...

Table 18. Oscillator DC electrical specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--------|--|------|-----------------|------|------|-------|
| | Peak-to-peak amplitude of oscillation (oscillator mode) — low-frequency, high-gain mode (HGO=1) | — | V _{DD} | — | V | |
| | Peak-to-peak amplitude of oscillation (oscillator mode) — high-frequency, low-power mode (HGO=0) | — | 0.6 | — | V | |
| | Peak-to-peak amplitude of oscillation (oscillator mode) — high-frequency, high-gain mode (HGO=1) | — | V _{DD} | — | V | |

1. V_{DD}=3.3 V, Temperature =25 °C, Internal capacitance = 20 pf
2. See crystal or resonator manufacturer's recommendation
3. C_x, C_y can be provided by using either the integrated capacitors or by using external components.
4. When low power mode is selected, R_F is integrated and must not be attached externally.
5. The EXTAL and XTAL pins should only be connected to required oscillator components and must not be connected to any other devices.

3.3.3.2 Oscillator frequency specifications

Table 19. Oscillator frequency specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-----------------------|---|------|------|------|------|-------|
| f _{osc_lo} | Oscillator crystal or resonator frequency — low-frequency mode (MCG_C2[RANGE]=00) | 32 | — | 40 | kHz | |
| f _{osc_hi_1} | Oscillator crystal or resonator frequency — high-frequency mode (low range) (MCG_C2[RANGE]=01) | 3 | — | 8 | MHz | |
| f _{osc_hi_2} | Oscillator crystal or resonator frequency — high frequency mode (high range) (MCG_C2[RANGE]=1x) | 8 | — | 32 | MHz | |
| f _{ec_extal} | Input clock frequency (external clock mode) | — | — | 50 | MHz | 1, 2 |
| t _{dc_extal} | Input clock duty cycle (external clock mode) | 40 | 50 | 60 | % | |
| t _{cst} | Crystal startup time — 32 kHz low-frequency, low-power mode (HGO=0) | — | 750 | — | ms | 3, 4 |
| | Crystal startup time — 32 kHz low-frequency, high-gain mode (HGO=1) | — | 250 | — | ms | |
| | Crystal startup time — 8 MHz high-frequency (MCG_C2[RANGE]=01), low-power mode (HGO=0) | — | 0.6 | — | ms | |
| | Crystal startup time — 8 MHz high-frequency (MCG_C2[RANGE]=01), high-gain mode (HGO=1) | — | 1 | — | ms | |

1. Other frequency limits may apply when external clock is being used as a reference for the FLL or PLL.
2. When transitioning from FEI or FBI to FBE mode, restrict the frequency of the input clock so that, when it is divided by FRDIV, it remains within the limits of the DCO input clock frequency.
3. Proper PC board layout procedures must be followed to achieve specifications.

- Crystal startup time is defined as the time between the oscillator being enabled and the OSCINIT bit in the MCG_S register being set.

NOTE

The 32 kHz oscillator works in low power mode by default and cannot be moved into high power/gain mode.

3.3.4 32 kHz oscillator electrical characteristics

3.3.4.1 32 kHz oscillator DC electrical specifications

Table 20. 32kHz oscillator DC electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|-----------------------|---|------|------|------|-----------|
| V_{BAT} | Supply voltage | 1.71 | — | 3.6 | V |
| R_F | Internal feedback resistor | — | 100 | — | $M\Omega$ |
| C_{para} | Parasitical capacitance of EXTAL32 and XTAL32 | — | 5 | 7 | pF |
| V_{pp} ¹ | Peak-to-peak amplitude of oscillation | — | 0.6 | — | V |

- When a crystal is being used with the 32 kHz oscillator, the EXTAL32 and XTAL32 pins should only be connected to required oscillator components and must not be connected to any other devices.

3.3.4.2 32 kHz oscillator frequency specifications

Table 21. 32 kHz oscillator frequency specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|-------------------|---|------|--------|-----------|------|-------|
| f_{osc_lo} | Oscillator crystal | — | 32.768 | — | kHz | |
| t_{start} | Crystal start-up time | — | 1000 | — | ms | 1 |
| $f_{ec_extal32}$ | Externally provided input clock frequency | — | 32.768 | — | kHz | 2 |
| $V_{ec_extal32}$ | Externally provided input clock amplitude | 700 | — | V_{BAT} | mV | 2, 3 |

- Proper PC board layout procedures must be followed to achieve specifications.
- This specification is for an externally supplied clock driven to EXTAL32 and does not apply to any other clock input. The oscillator remains enabled and XTAL32 must be left unconnected.
- The parameter specified is a peak-to-peak value and V_{IH} and V_{IL} specifications do not apply. The voltage of the applied clock must be within the range of V_{SS} to V_{BAT} .

3.4 Memories and memory interfaces

3.4.1 Flash (FTFE) electrical specifications

This section describes the electrical characteristics of the FTFE module.

3.4.1.1 Flash timing specifications — program and erase

The following specifications represent the amount of time the internal charge pumps are active and do not include command overhead.

Table 22. NVM program/erase timing specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|----------------------------------|--|------|------|------|---------------|-------|
| $t_{hvp\text{pgm}8}$ | Program Phrase high-voltage time | — | 7.5 | 18 | μs | |
| $t_{h\text{versscr}}$ | Erase Flash Sector high-voltage time | — | 13 | 113 | ms | 1 |
| $t_{h\text{versblk}256\text{k}}$ | Erase Flash Block high-voltage time for 256 KB | — | 208 | 1808 | ms | 1 |
| $t_{h\text{versblk}512\text{k}}$ | Erase Flash Block high-voltage time for 512 KB | — | 416 | 3616 | ms | 1 |

1. Maximum time based on expectations at cycling end-of-life.

3.4.1.2 Flash timing specifications — commands

Table 23. Flash command timing specifications

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--------------------------------|---|------|------|--------|---------------|-------|
| $t_{rd1\text{blk}256\text{k}}$ | Read 1s Block execution time | | | | | |
| | • 256 KB data flash | — | — | 1.0 | ms | |
| $t_{rd1\text{blk}512\text{k}}$ | • 512 KB program flash | — | — | 1.8 | ms | |
| $t_{rd1\text{sec}4\text{k}}$ | Read 1s Section execution time (4 KB flash) | — | — | 100 | μs | 1 |
| $t_{pgm\text{chk}}$ | Program Check execution time | — | — | 95 | μs | 1 |
| $t_{rd\text{rsrc}}$ | Read Resource execution time | — | — | 40 | μs | 1 |
| t_{pgm8} | Program Phrase execution time | — | 90 | 150 | μs | |
| $t_{ers\text{blk}256\text{k}}$ | Erase Flash Block execution time | | | | | 2 |
| | • 256 KB data flash | — | 220 | 1850 | ms | |
| $t_{ers\text{blk}512\text{k}}$ | • 512 KB program flash | — | 435 | 3700 | ms | |
| $t_{ers\text{scr}}$ | Erase Flash Sector execution time | — | 15 | 115 | ms | 2 |
| $t_{pgm\text{sec}1\text{k}}$ | Program Section execution time (1 KB flash) | — | 5 | — | ms | |
| $t_{rd1\text{allx}}$ | Read 1s All Blocks execution time | | | | | |
| | • FlexNVM devices | — | — | 5.9 | ms | |
| $t_{rd1\text{alln}}$ | • Program flash only devices | — | — | 6.7 | ms | |
| $t_{rd\text{once}}$ | Read Once execution time | — | — | 30 | μs | 1 |
| $t_{pgm\text{once}}$ | Program Once execution time | — | 90 | — | μs | |
| $t_{ers\text{all}}$ | Erase All Blocks execution time | — | 1750 | 14,800 | ms | 2 |

Table continues on the next page...

Table 23. Flash command timing specifications (continued)

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|--------------------------|--|------|------|------|---------------|-------|
| t_{vfykey} | Verify Backdoor Access Key execution time | — | — | 30 | μs | 1 |
| | Swap Control execution time | | | | | |
| t_{swapx01} | • control code 0x01 | — | 200 | — | μs | |
| t_{swapx02} | • control code 0x02 | — | 90 | 150 | μs | |
| t_{swapx04} | • control code 0x04 | — | 90 | 150 | μs | |
| t_{swapx08} | • control code 0x08 | — | — | 30 | μs | |
| t_{swapx10} | • control code 0x10 | — | 90 | 150 | μs | |
| | Program Partition for EEPROM execution time | | | | | |
| $t_{\text{pgmpart32k}}$ | • 32 KB EEPROM backup | — | 70 | — | ms | |
| $t_{\text{pgmpart256k}}$ | • 256 KB EEPROM backup | — | 78 | — | ms | |
| | Set FlexRAM Function execution time: | | | | | |
| t_{setramff} | • Control Code 0xFF | — | 70 | — | μs | |
| $t_{\text{setram32k}}$ | • 32 KB EEPROM backup | — | 0.8 | 1.2 | ms | |
| $t_{\text{setram64k}}$ | • 64 KB EEPROM backup | — | 1.3 | 1.9 | ms | |
| $t_{\text{setram128k}}$ | • 128 KB EEPROM backup | — | 2.4 | 3.1 | ms | |
| $t_{\text{setram256k}}$ | • 256 KB EEPROM backup | — | 4.5 | 5.5 | ms | |
| | Byte-write to FlexRAM execution time: | | | | | |
| $t_{\text{eewr8b32k}}$ | • 32 KB EEPROM backup | — | 385 | 1700 | μs | |
| $t_{\text{eewr8b64k}}$ | • 64 KB EEPROM backup | — | 475 | 2000 | μs | |
| $t_{\text{eewr8b128k}}$ | • 128 KB EEPROM backup | — | 650 | 2350 | μs | |
| $t_{\text{eewr8b256k}}$ | • 256 KB EEPROM backup | — | 1000 | 3250 | μs | |
| | 16-bit write to FlexRAM execution time: | | | | | |
| $t_{\text{eewr16b32k}}$ | • 32 KB EEPROM backup | — | 385 | 1700 | μs | |
| $t_{\text{eewr16b64k}}$ | • 64 KB EEPROM backup | — | 475 | 2000 | μs | |
| $t_{\text{eewr16b128k}}$ | • 128 KB EEPROM backup | — | 650 | 2350 | μs | |
| $t_{\text{eewr16b256k}}$ | • 256 KB EEPROM backup | — | 1000 | 3250 | μs | |
| $t_{\text{eewr32bers}}$ | 32-bit write to erased FlexRAM location execution time | — | 360 | 1500 | μs | |
| | 32-bit write to FlexRAM execution time: | | | | | |
| $t_{\text{eewr32b32k}}$ | • 32 KB EEPROM backup | — | 630 | 2000 | μs | |
| $t_{\text{eewr32b64k}}$ | • 64 KB EEPROM backup | — | 810 | 2250 | μs | |
| $t_{\text{eewr32b128k}}$ | • 128 KB EEPROM backup | — | 1200 | 2650 | μs | |
| $t_{\text{eewr32b256k}}$ | • 256 KB EEPROM backup | — | 1900 | 3500 | μs | |

1. Assumes 25MHz or greater flash clock frequency.
2. Maximum times for erase parameters based on expectations at cycling end-of-life.

3.4.1.3 Flash high voltage current behaviors

Table 24. Flash high voltage current behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit |
|---------------------|---|------|------|------|------|
| I _{DD_PGM} | Average current adder during high voltage flash programming operation | — | 3.5 | 7.5 | mA |
| I _{DD_ERS} | Average current adder during high voltage flash erase operation | — | 1.5 | 4.0 | mA |

3.4.1.4 Reliability specifications

Table 25. NVM reliability specifications

| Symbol | Description | Min. | Typ. ¹ | Max. | Unit | Notes |
|--------------------------|--|--------|-------------------|------|--------|-------|
| Program Flash | | | | | | |
| t _{nvmretp10k} | Data retention after up to 10 K cycles | 5 | 50 | — | years | |
| t _{nvmretp1k} | Data retention after up to 1 K cycles | 20 | 100 | — | years | |
| n _{nvmcyccp} | Cycling endurance | 10 K | 50 K | — | cycles | 2 |
| Data Flash | | | | | | |
| t _{nvmretd10k} | Data retention after up to 10 K cycles | 5 | 50 | — | years | |
| t _{nvmretd1k} | Data retention after up to 1 K cycles | 20 | 100 | — | years | |
| n _{nvmcyccd} | Cycling endurance | 10 K | 50 K | — | cycles | 2 |
| FlexRAM as EEPROM | | | | | | |
| t _{nvmretee100} | Data retention up to 100% of write endurance | 5 | 50 | — | years | |
| t _{nvmretee10} | Data retention up to 10% of write endurance | 20 | 100 | — | years | |
| n _{nvmcycee} | Cycling endurance for EEPROM backup | 20 K | 50 K | — | cycles | 2 |
| n _{nvmwree16} | Write endurance | | | | | 3 |
| n _{nvmwree128} | • EEPROM backup to FlexRAM ratio = 16 | 140 K | 400 K | — | writes | |
| n _{nvmwree512} | • EEPROM backup to FlexRAM ratio = 128 | 1.26 M | 3.2 M | — | writes | |
| n _{nvmwree2k} | • EEPROM backup to FlexRAM ratio = 512 | 5 M | 12.8 M | — | writes | |
| n _{nvmwree2k} | • EEPROM backup to FlexRAM ratio = 2,048 | 20 M | 50 M | — | writes | |
| n _{nvmwree8k} | • EEPROM backup to FlexRAM ratio = 8,192 | 80 M | 200 M | — | writes | |

1. Typical data retention values are based on measured response accelerated at high temperature and derated to a constant 25°C use profile. Engineering Bulletin EB618 does not apply to this technology. Typical endurance defined in Engineering Bulletin EB619.
2. Cycling endurance represents number of program/erase cycles at -40°C ≤ T_j ≤ 125°C.
3. Write endurance represents the number of writes to each FlexRAM location at -40°C ≤ T_j ≤ 125°C influenced by the cycling endurance of the FlexNVM and the allocated EEPROM backup per subsystem. Minimum and typical values assume all 16-bit or 32-bit writes to FlexRAM; all 8-bit writes result in 50% less endurance.

3.4.1.5 Write endurance to FlexRAM for EEPROM

When the FlexNVM partition code is not set to full data flash, the EEPROM data set size can be set to any of several non-zero values.

The bytes not assigned to data flash via the FlexNVM partition code are used by the FTFE to obtain an effective endurance increase for the EEPROM data. The built-in EEPROM record management system raises the number of program/erase cycles that can be attained prior to device wear-out by cycling the EEPROM data through a larger EEPROM NVM storage space.

While different partitions of the FlexNVM are available, the intention is that a single choice for the FlexNVM partition code and EEPROM data set size is used throughout the entire lifetime of a given application. The EEPROM endurance equation and graph shown below assume that only one configuration is ever used.

$$\text{Writes_subsystem} = \frac{\text{EEPROM} - 2 \times \text{EEESPLIT} \times \text{EEESIZE}}{\text{EEESPLIT} \times \text{EEESIZE}} \times \text{Write_efficiency} \times n_{\text{nvmcycee}}$$

where

- Writes_subsystem — minimum number of writes to each FlexRAM location for subsystem (each subsystem can have different endurance)
- EEPROM — allocated FlexNVM for each EEPROM subsystem based on DEPART; entered with the Program Partition command
- EEESPLIT — FlexRAM split factor for subsystem; entered with the Program Partition command
- EEESIZE — allocated FlexRAM based on DEPART; entered with the Program Partition command
- Write_efficiency —
 - 0.25 for 8-bit writes to FlexRAM
 - 0.50 for 16-bit or 32-bit writes to FlexRAM
- n_{nvmcycee} — EEPROM-backup cycling endurance

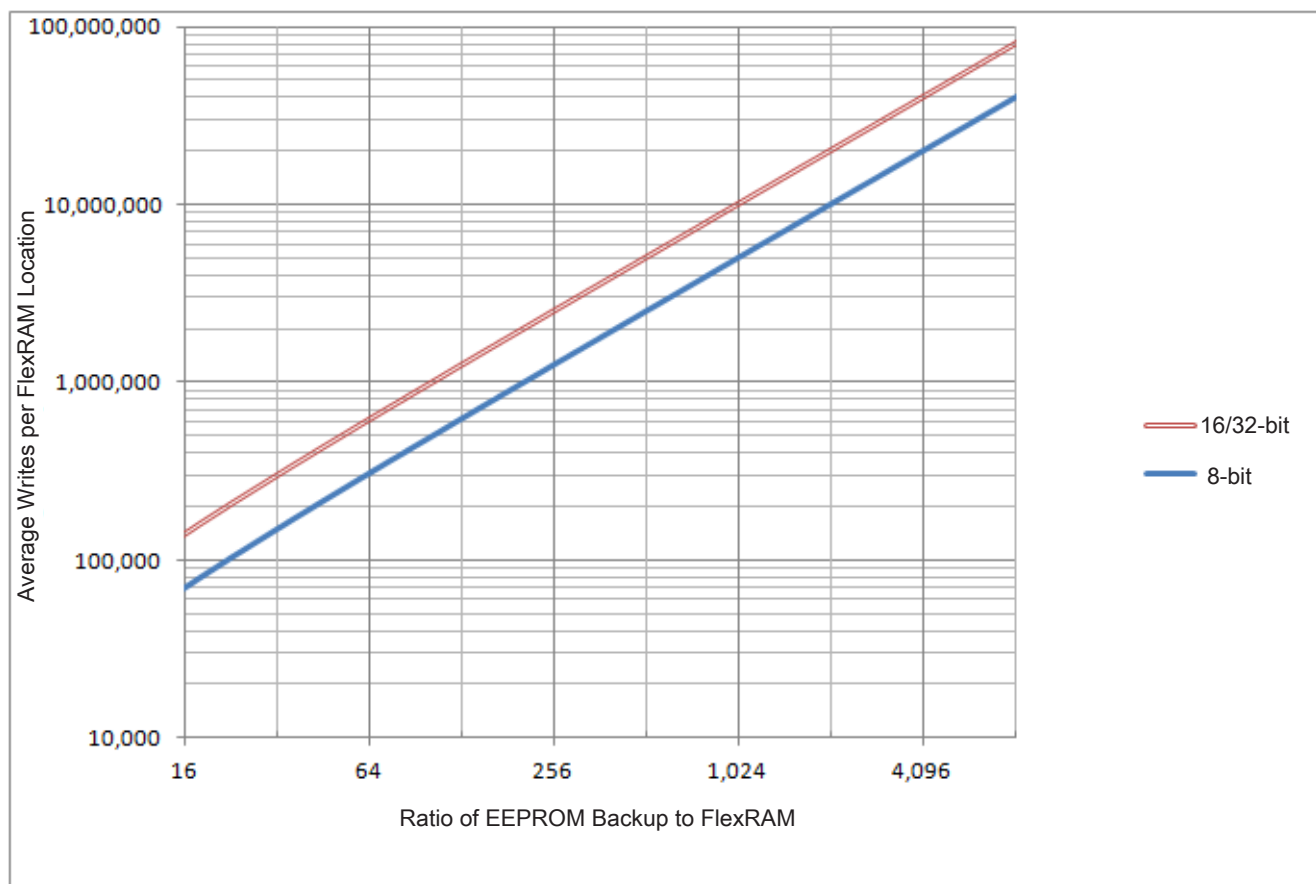


Figure 11. EEPROM backup writes to FlexRAM

3.4.2 EzPort switching specifications

Table 26. EzPort full voltage range switching specifications

| Num | Description | Min. | Max. | Unit |
|------|--|------------------------|-------------|------|
| | Operating voltage | 1.71 | 3.6 | V |
| EP1 | EZP_CK frequency of operation (all commands except READ) | — | $f_{SYS}/2$ | MHz |
| EP1a | EZP_CK frequency of operation (READ command) | — | $f_{SYS}/8$ | MHz |
| EP2 | $\overline{EZP_CS}$ negation to next $\overline{EZP_CS}$ assertion | $2 \times t_{EZP_CK}$ | — | ns |
| EP3 | EZP_CS input valid to EZP_CK high (setup) | 5 | — | ns |
| EP4 | EZP_CK high to $\overline{EZP_CS}$ input invalid (hold) | 5 | — | ns |
| EP5 | EZP_D input valid to EZP_CK high (setup) | 2 | — | ns |
| EP6 | EZP_CK high to EZP_D input invalid (hold) | 5 | — | ns |
| EP7 | EZP_CK low to EZP_Q output valid | — | 14 | ns |
| EP8 | EZP_CK low to EZP_Q output invalid (hold) | 0 | — | ns |
| EP9 | $\overline{EZP_CS}$ negation to EZP_Q tri-state | — | 12 | ns |

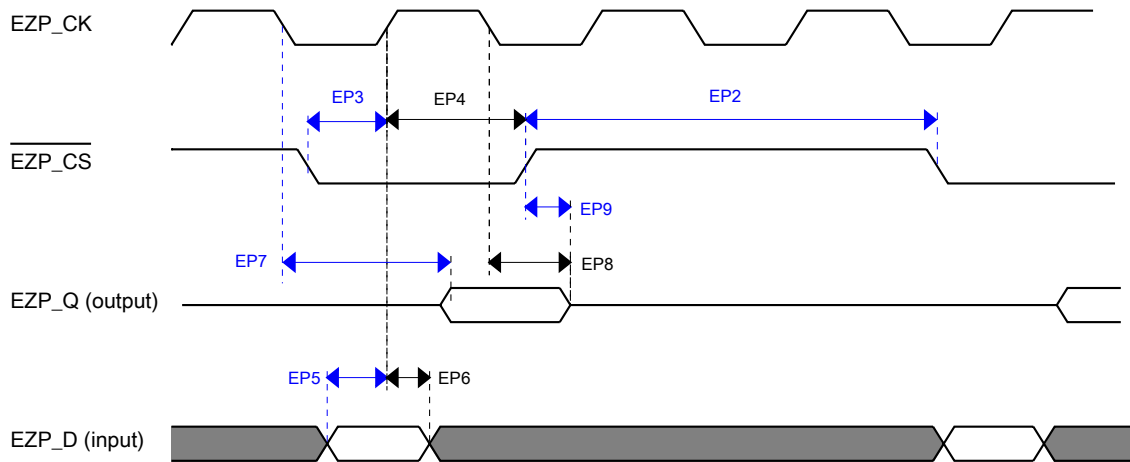


Figure 12. EzPort Timing Diagram

3.4.3 Flexbus switching specifications

All processor bus timings are synchronous; input setup/hold and output delay are given in respect to the rising edge of a reference clock, FB_CLK. The FB_CLK frequency may be the same as the internal system bus frequency or an integer divider of that frequency.

The following timing numbers indicate when data is latched or driven onto the external bus, relative to the Flexbus output clock (FB_CLK). All other timing relationships can be derived from these values.

Table 27. Flexbus limited voltage range switching specifications

| Num | Description | Min. | Max. | Unit | Notes |
|-----|---|----------|--------|------|-------|
| | Operating voltage | 2.7 | 3.6 | V | |
| | Frequency of operation | — | FB_CLK | MHz | |
| FB1 | Clock period | 1/FB_CLK | — | ns | |
| FB2 | Address, data, and control output valid | — | 11.8 | ns | |
| FB3 | Address, data, and control output hold | 1.0 | — | ns | 1 |
| FB4 | Data and $\overline{\text{FB_TA}}$ input setup | 11.9 | — | ns | |
| FB5 | Data and $\overline{\text{FB_TA}}$ input hold | 0.0 | — | ns | 2 |

1. Specification is valid for all FB_AD[31:0], $\overline{\text{FB_BE/BWE}n}$, $\overline{\text{FB_CS}n}$, $\overline{\text{FB_OE}}$, $\overline{\text{FB_R/W}}$, $\overline{\text{FB_TBST}}$, $\overline{\text{FB_TSIZ}}[1:0]$, $\overline{\text{FB_ALE}}$, and $\overline{\text{FB_TS}}$.

Peripheral operating requirements and behaviors

2. Specification is valid for all FB_AD[31:0] and $\overline{\text{FB_TA}}$.

Table 28. Flexbus full voltage range switching specifications

| Num | Description | Min. | Max. | Unit | Notes |
|-----|---|----------|--------|------|-------|
| | Operating voltage | 1.71 | 3.6 | V | |
| | Frequency of operation | — | FB_CLK | MHz | |
| FB1 | Clock period | 1/FB_CLK | — | ns | |
| FB2 | Address, data, and control output valid | — | 12.6 | ns | |
| FB3 | Address, data, and control output hold | 1.0 | — | ns | 1 |
| FB4 | Data and $\overline{\text{FB_TA}}$ input setup | 12.5 | — | ns | |
| FB5 | Data and $\overline{\text{FB_TA}}$ input hold | 0 | — | ns | 2 |

1. Specification is valid for all FB_AD[31:0], $\overline{\text{FB_BE/BWEn}}$, $\overline{\text{FB_CSn}}$, $\overline{\text{FB_OE}}$, FB_R/W, FB_TBST, FB_TSIZ[1:0], FB_ALE, and FB_TS.
2. Specification is valid for all FB_AD[31:0] and $\overline{\text{FB_TA}}$.

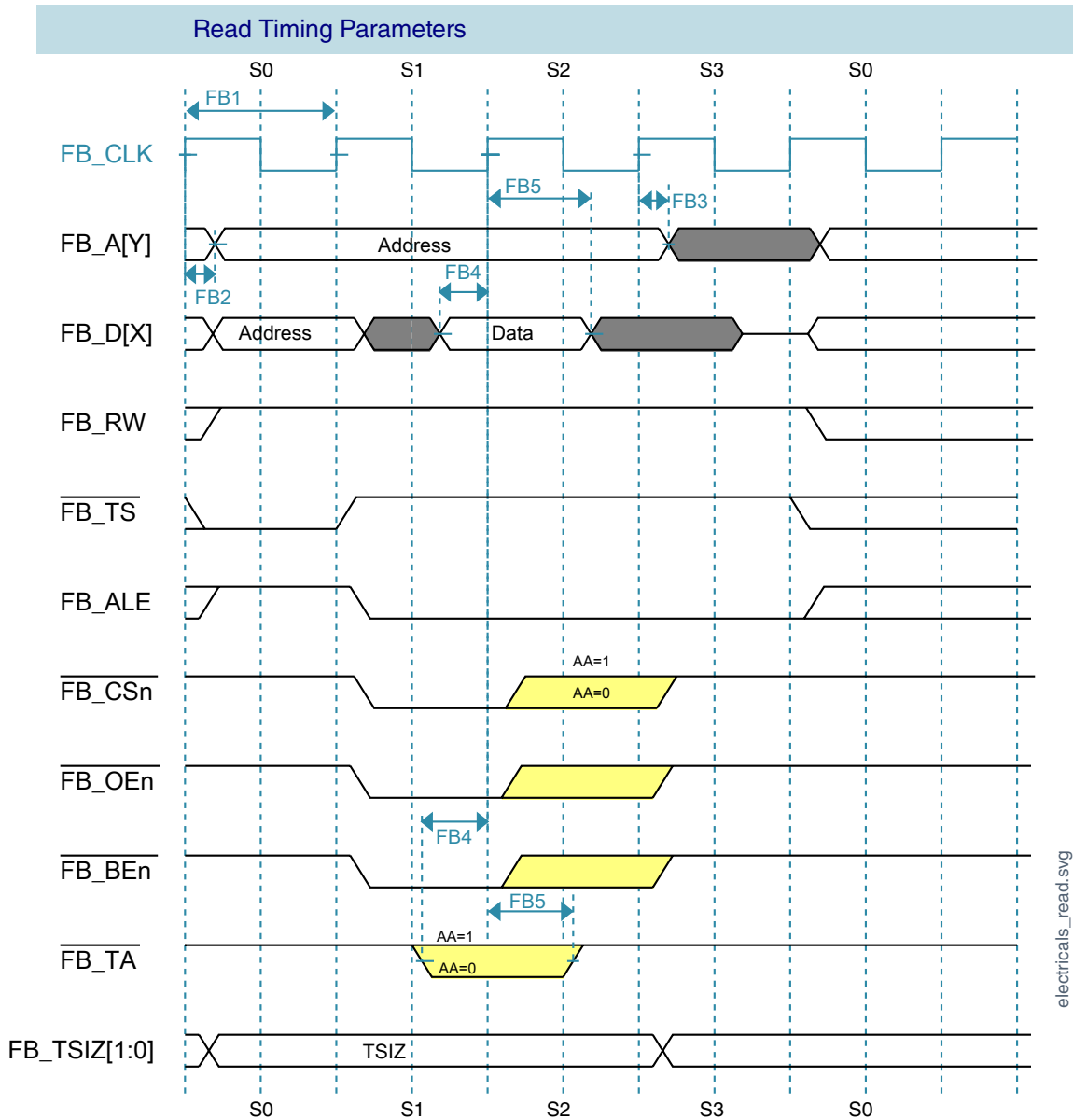


Figure 13. FlexBus read timing diagram

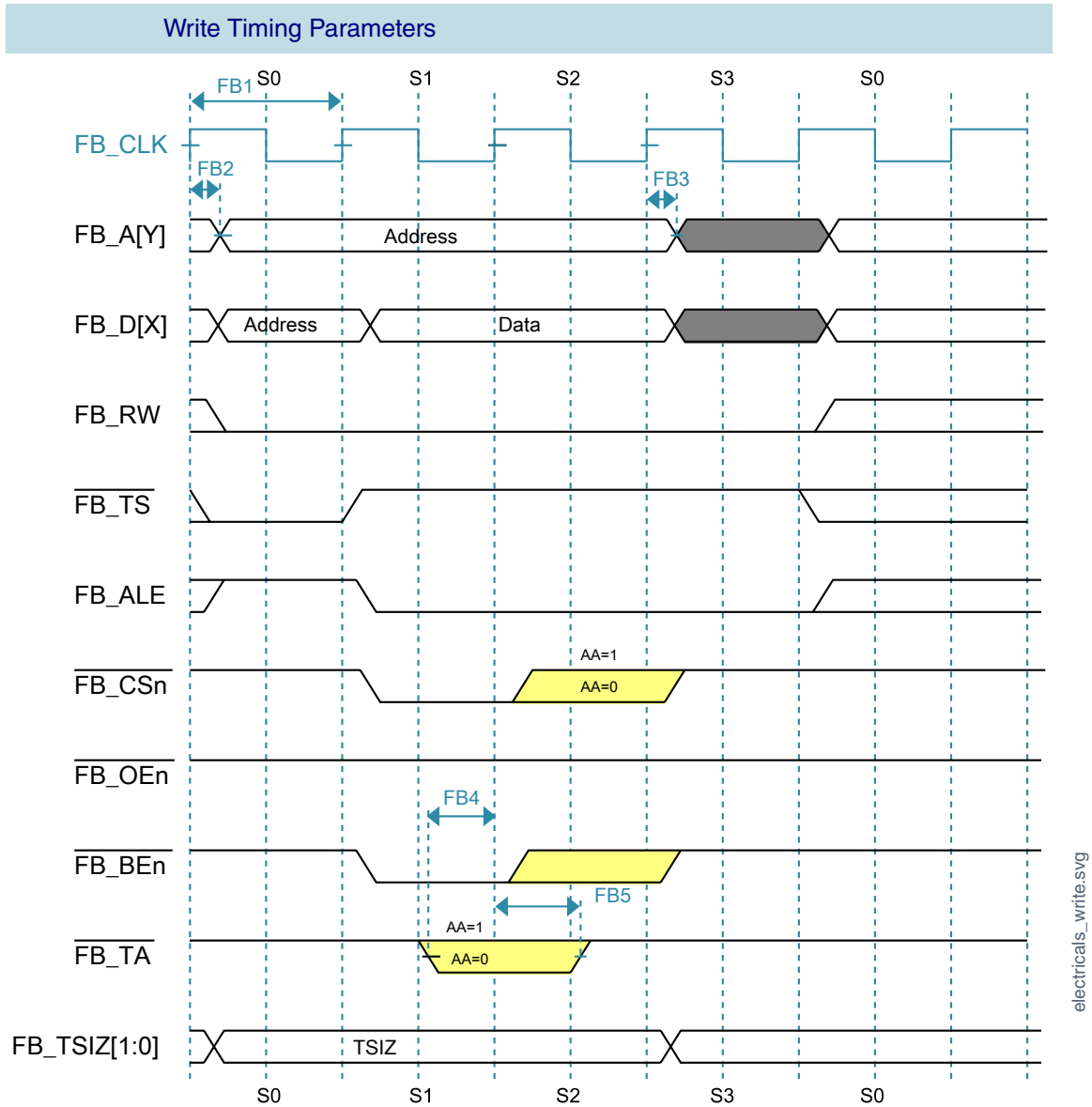
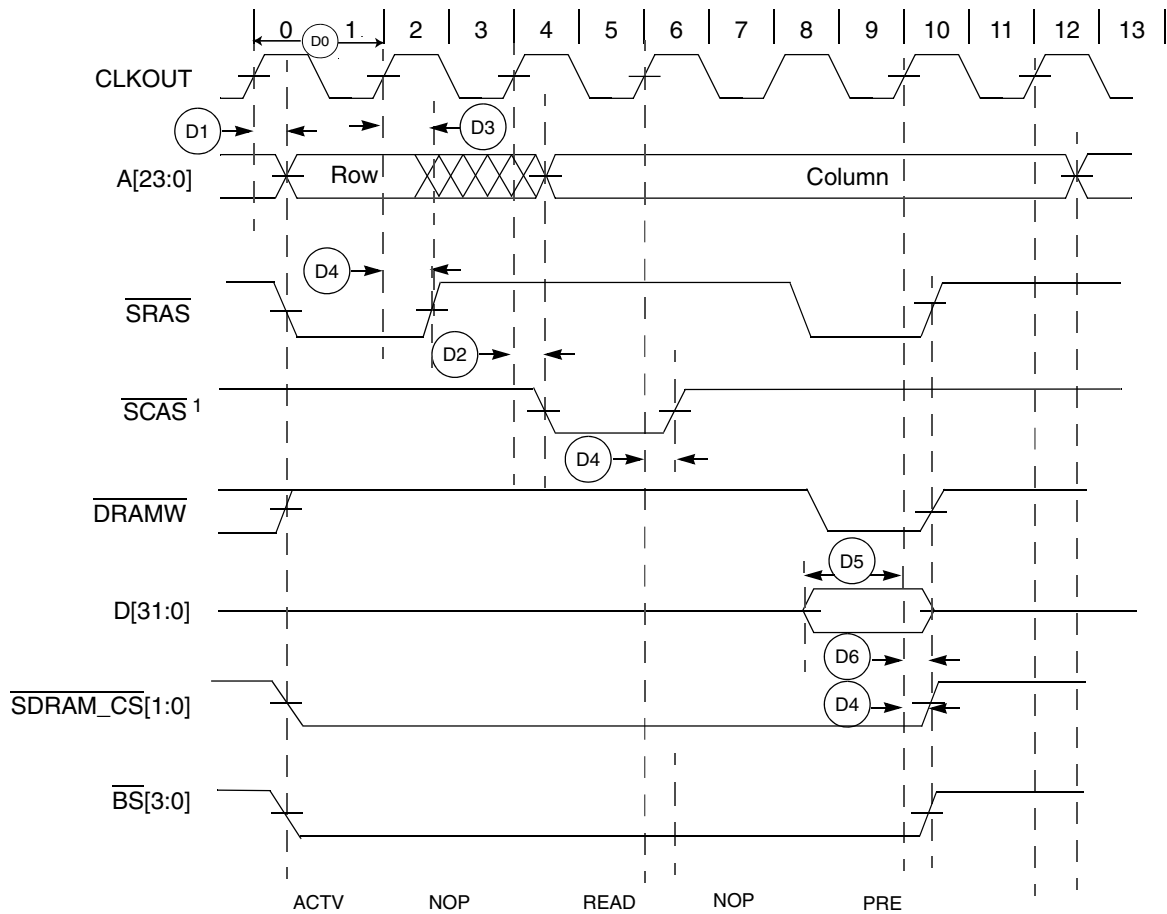


Figure 14. FlexBus write timing diagram

3.4.4 SDRAM controller specifications

Following figure shows SDRAM read cycle.



¹DACR[CASL] = 2

Figure 15. SDRAM read timing diagram

Table 29. SDRAM Timing (Full voltage range)

| NUM | Characteristic ¹ | Symbol | Min | Max | Unit |
|-----------------|--------------------------------------|---------------------|--------|------|-------------------|
| | Operating voltage | 1.71 | 3.6 | V | |
| | Frequency of operation | — | CLKOUT | MHz | |
| D0 | Clock period | 1/CLKOUT | — | ns | 2 |
| D1 | CLKOUT high to SDRAM address valid | t_{CHDAV} | - | 11.2 | ns |
| D2 | CLKOUT high to SDRAM control valid | t_{CHDCV} | | 11.1 | ns |
| D3 | CLKOUT high to SDRAM address invalid | t_{CHDAI} | 1.0 | - | ns |
| D4 | CLKOUT high to SDRAM control invalid | t_{CHDCI} | 1.0 | - | ns |
| D5 | SDRAM data valid to CLKOUT high | t_{DDVCH} | 12.0 | - | ns |
| D6 | CLKOUT high to SDRAM data invalid | t_{CHDDI} | 1.0 | - | ns |
| D7 ³ | CLKOUT high to SDRAM data valid | t_{CHDDVW} | - | 12.0 | ns |
| D8 ³ | CLKOUT high to SDRAM data invalid | t_{CHDDIW} | 1.0 | - | ns |

1. All timing specifications are based on taking into account, a 25pF load on the SDRAM output pins.

2. CLKOUT is same as FB_CLK, maximum frequency can be 60 MHz

Peripheral operating requirements and behaviors

3. D7 and D8 are for write cycles only.

Table 30. SDRAM Timing (Limited voltage range)

| NUM | Characteristic ¹ | Symbol | Min | Max | Unit |
|-----------------|--------------------------------------|---------------------|--------|------|-------------------|
| | Operating voltage | 2.7 | 3.6 | V | |
| | Frequency of operation | — | CLKOUT | MHz | |
| D0 | Clock period | 1/CLKOUT | — | ns | 2 |
| D1 | CLKOUT high to SDRAM address valid | t _{CHDAV} | - | 11.1 | ns |
| D2 | CLKOUT high to SDRAM control valid | t _{CHDCV} | | 11.1 | ns |
| D3 | CLKOUT high to SDRAM address invalid | t _{CHDAI} | 1.0 | - | ns |
| D4 | CLKOUT high to SDRAM control invalid | t _{CHDCI} | 1.0 | - | ns |
| D5 | SDRAM data valid to CLKOUT high | t _{DDVCH} | 11.3 | - | ns |
| D6 | CLKOUT high to SDRAM data invalid | t _{CHDDI} | 1.0 | - | ns |
| D7 ³ | CLKOUT high to SDRAM data valid | t _{CHDDVW} | - | 11.1 | ns |
| D8 ³ | CLKOUT high to SDRAM data invalid | t _{CHDDIW} | 1.0 | - | ns |

1. All timing specifications are based on taking into account, a 25pF load on the SDRAM output pins.

2. CLKOUT is same as FB_CLK, maximum frequency can be 60 MHz

3. D7 and D8 are for write cycles only.

Following figure shows an SDRAM write cycle.

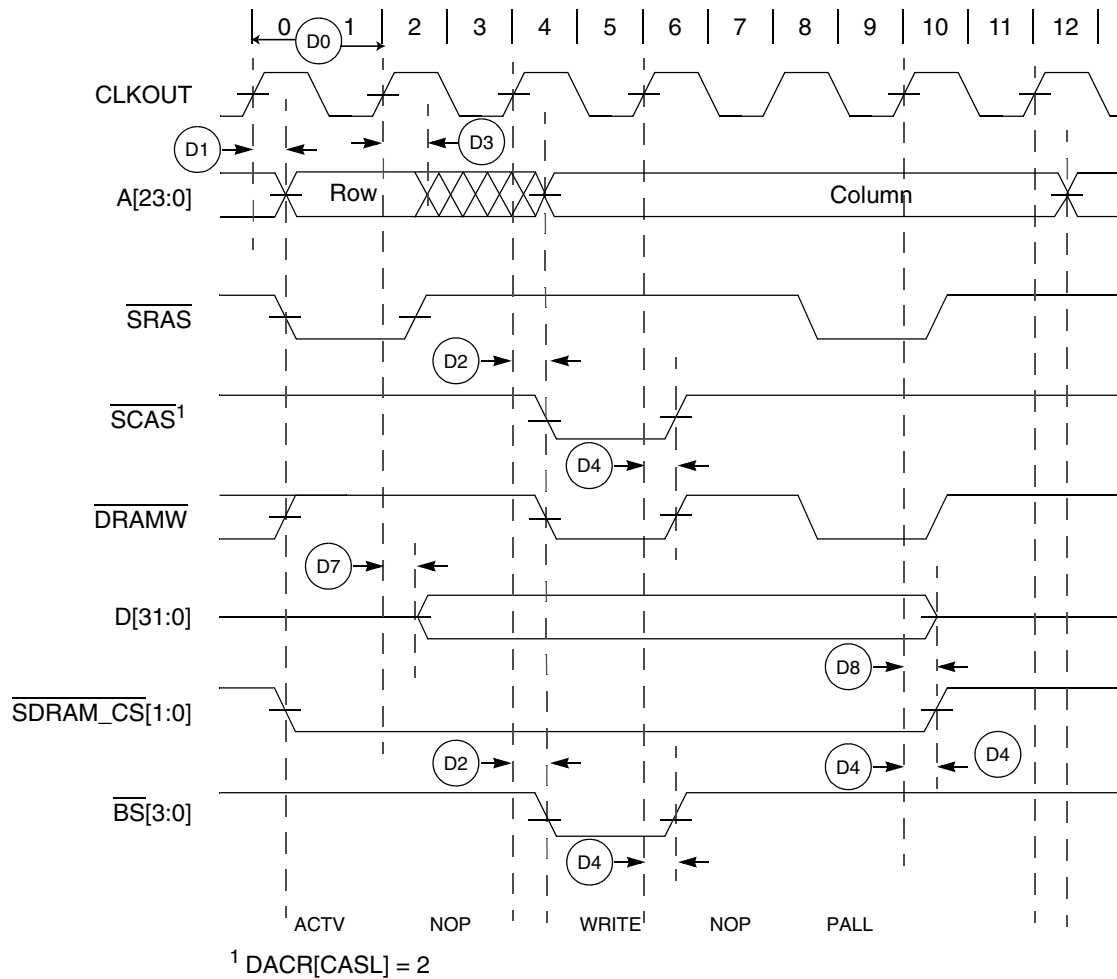


Figure 16. SDRAM read timing diagram

3.5 Security and integrity modules

There are no specifications necessary for the device's security and integrity modules.

3.6 Analog

3.6.1 ADC electrical specifications

The 16-bit accuracy specifications listed in [Table 31](#) and [Table 32](#) are achievable on the differential pins ADCx_DP0, ADCx_DM0.

All other ADC channels meet the 13-bit differential/12-bit single-ended accuracy specifications.

3.6.1.1 16-bit ADC operating conditions

Table 31. 16-bit ADC operating conditions

| Symbol | Description | Conditions | Min. | Typ. ¹ | Max. | Unit | Notes |
|-------------------|-------------------------------------|---|--|-------------------|--|------|-------|
| V _{DDA} | Supply voltage | Absolute | 1.71 | — | 3.6 | V | — |
| ΔV _{DDA} | Supply voltage | Delta to V _{DD} (V _{DD} – V _{DDA}) | -100 | 0 | +100 | mV | 2 |
| ΔV _{SSA} | Ground voltage | Delta to V _{SS} (V _{SS} – V _{SSA}) | -100 | 0 | +100 | mV | 2 |
| V _{REFH} | ADC reference voltage high | | 1.13 | V _{DDA} | V _{DDA} | V | |
| V _{REFL} | ADC reference voltage low | | V _{SSA} | V _{SSA} | V _{SSA} | V | |
| V _{ADIN} | Input voltage | <ul style="list-style-type: none"> 16-bit differential mode All other modes | V _{REFL} V _{REFL} | — — | 31/32 * V _{REFH} V _{REFH} | V | — |
| C _{ADIN} | Input capacitance | <ul style="list-style-type: none"> 16-bit mode 8-bit / 10-bit / 12-bit modes | — — | 8 4 | 10 5 | pF | — |
| R _{ADIN} | Input series resistance | | — | 2 | 5 | kΩ | — |
| R _{AS} | Analog source resistance (external) | 13-bit / 12-bit modes f _{ADCK} < 4 MHz | — | — | 5 | kΩ | 3 |
| f _{ADCK} | ADC conversion clock frequency | ≤ 13-bit mode | 1.0 | — | 24 | MHz | 4 |
| f _{ADCK} | ADC conversion clock frequency | 16-bit mode | 2.0 | — | 12.0 | MHz | 4 |
| C _{rate} | ADC conversion rate | ≤ 13-bit modes No ADC hardware averaging Continuous conversions enabled, subsequent conversion time | 20.000 | — | 1200 | kS/s | 5 |
| C _{rate} | ADC conversion rate | 16-bit mode No ADC hardware averaging Continuous conversions enabled, subsequent conversion time | 37.037 | — | 461.467 | kS/s | 5 |

1. Typical values assume V_{DDA} = 3.0 V, Temp = 25 °C, f_{ADCK} = 1.0 MHz, unless otherwise stated. Typical values are for reference only, and are not tested in production.
2. DC potential difference.
3. This resistance is external to MCU. To achieve the best results, the analog source resistance must be kept as low as possible. The results in this data sheet were derived from a system that had < 8 Ω analog source resistance. The R_{AS}/C_{AS} time constant should be kept to < 1 ns.

4. To use the maximum ADC conversion clock frequency, CFG2[ADHSC] must be set and CFG1[ADLPC] must be clear.
5. For guidelines and examples of conversion rate calculation, download the [ADC calculator tool](#).

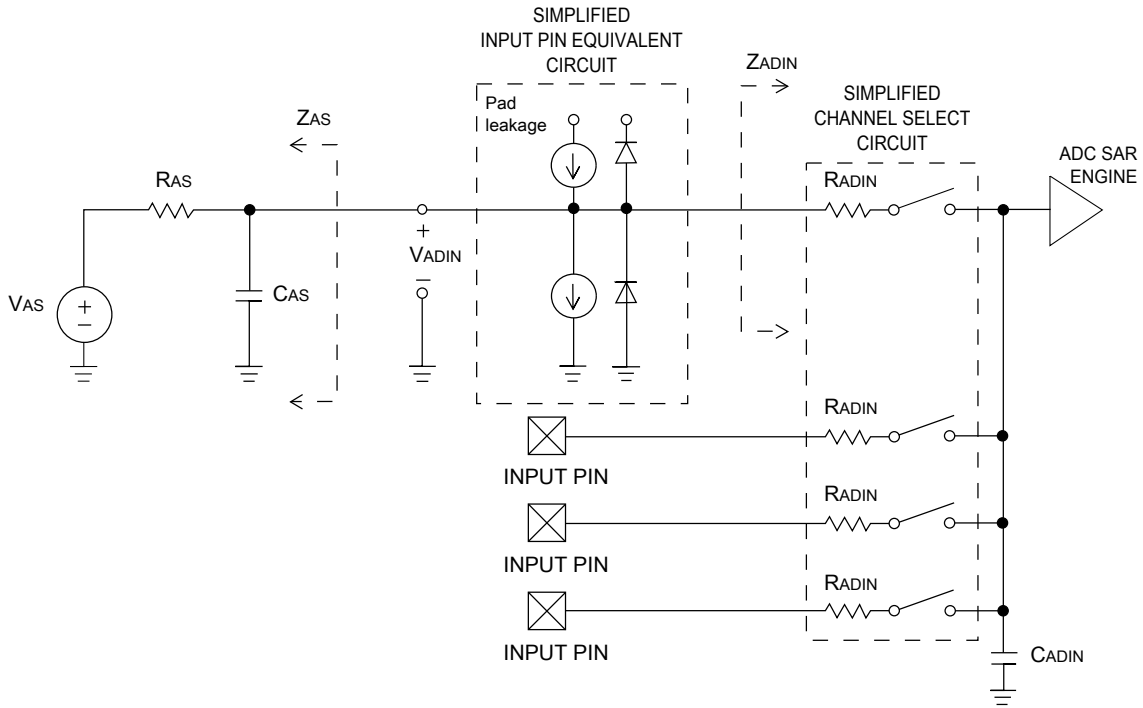


Figure 17. ADC input impedance equivalency diagram

3.6.1.2 16-bit ADC electrical characteristics

Table 32. 16-bit ADC characteristics ($V_{REFH} = V_{DDA}$, $V_{REFL} = V_{SSA}$)

| Symbol | Description | Conditions ¹ | Min. | Typ. ² | Max. | Unit | Notes |
|----------------|-------------------------------|--|-------|-------------------|--------------|------------------|---------------------------|
| I_{DDA_ADC} | Supply current | | 0.215 | — | 1.7 | mA | 3 |
| f_{ADACK} | ADC asynchronous clock source | <ul style="list-style-type: none"> • ADLPC = 1, ADHSC = 0 • ADLPC = 1, ADHSC = 1 • ADLPC = 0, ADHSC = 0 • ADLPC = 0, ADHSC = 1 | 1.2 | 2.4 | 3.9 | MHz | $t_{ADACK} = 1/f_{ADACK}$ |
| | | | 2.4 | 4.0 | 6.1 | MHz | |
| | | | 3.0 | 5.2 | 7.3 | MHz | |
| | | | 4.4 | 6.2 | 9.5 | MHz | |
| | Sample Time | See Reference Manual chapter for sample times | | | | | |
| TUE | Total unadjusted error | <ul style="list-style-type: none"> • 12-bit modes • <12-bit modes | — | ±4 | ±6.8 | LSB ⁴ | 5 |
| DNL | Differential non-linearity | <ul style="list-style-type: none"> • 12-bit modes • <12-bit modes | — | ±0.7 | -1.1 to +1.9 | LSB ⁴ | 5 |
| | | | — | ±0.2 | -0.3 to 0.5 | | |

Table continues on the next page...

Table 32. 16-bit ADC characteristics ($V_{REFH} = V_{DDA}$, $V_{REFL} = V_{SSA}$) (continued)

| Symbol | Description | Conditions ¹ | Min. | Typ. ² | Max. | Unit | Notes |
|---------------------|---------------------------------|---|-----------------------------------|-------------------|--------------|------------------|--|
| INL | Integral non-linearity | <ul style="list-style-type: none"> 12-bit modes <12-bit modes | — | ±1.0 | -2.7 to +1.9 | LSB ⁴ | 5 |
| E _{FS} | Full-scale error | <ul style="list-style-type: none"> 12-bit modes <12-bit modes | — | -4 | -5.4 | LSB ⁴ | V _{ADIN} = V _{DDA} ⁵ |
| E _Q | Quantization error | <ul style="list-style-type: none"> 16-bit modes ≤13-bit modes | — | -1 to 0 | — | LSB ⁴ | |
| ENOB | Effective number of bits | 16-bit differential mode <ul style="list-style-type: none"> Avg = 32 Avg = 4 16-bit single-ended mode <ul style="list-style-type: none"> Avg = 32 Avg = 4 | 12.8 11.9 | 14.5 13.8 | — — | bits bits | 6 |
| SINAD | Signal-to-noise plus distortion | See ENOB | 6.02 × ENOB + 1.76 | | | dB | |
| THD | Total harmonic distortion | 16-bit differential mode <ul style="list-style-type: none"> Avg = 32 16-bit single-ended mode <ul style="list-style-type: none"> Avg = 32 | — | -94 | — | dB dB | 7 |
| SFDR | Spurious free dynamic range | 16-bit differential mode <ul style="list-style-type: none"> Avg = 32 16-bit single-ended mode <ul style="list-style-type: none"> Avg = 32 | 82 | 95 | — | dB dB | 7 |
| E _{IL} | Input leakage error | | I _{in} × R _{AS} | | | mV | I _{in} = leakage current (refer to the MCU's voltage and current operating ratings) |
| | Temp sensor slope | Across the full temperature range of the device | 1.55 | 1.62 | 1.69 | mV/°C | 8 |
| V _{TEMP25} | Temp sensor voltage | 25 °C | 706 | 716 | 726 | mV | 8 |

1. All accuracy numbers assume the ADC is calibrated with $V_{REFH} = V_{DDA}$

2. Typical values assume $V_{DDA} = 3.0\text{ V}$, $\text{Temp} = 25\text{ }^\circ\text{C}$, $f_{\text{ADCK}} = 2.0\text{ MHz}$ unless otherwise stated. Typical values are for reference only and are not tested in production.
3. The ADC supply current depends on the ADC conversion clock speed, conversion rate and `ADC_CFG1[ADLPC]` (low power). For lowest power operation, `ADC_CFG1[ADLPC]` must be set, the `ADC_CFG2[ADHSC]` bit must be clear with 1 MHz ADC conversion clock speed.
4. $1\text{ LSB} = (V_{\text{REFH}} - V_{\text{REFL}})/2^N$
5. ADC conversion clock < 16 MHz, Max hardware averaging (`AVGE = %1`, `AVGS = %11`)
6. Input data is 100 Hz sine wave. ADC conversion clock < 12 MHz.
7. Input data is 1 kHz sine wave. ADC conversion clock < 12 MHz.
8. ADC conversion clock < 3 MHz

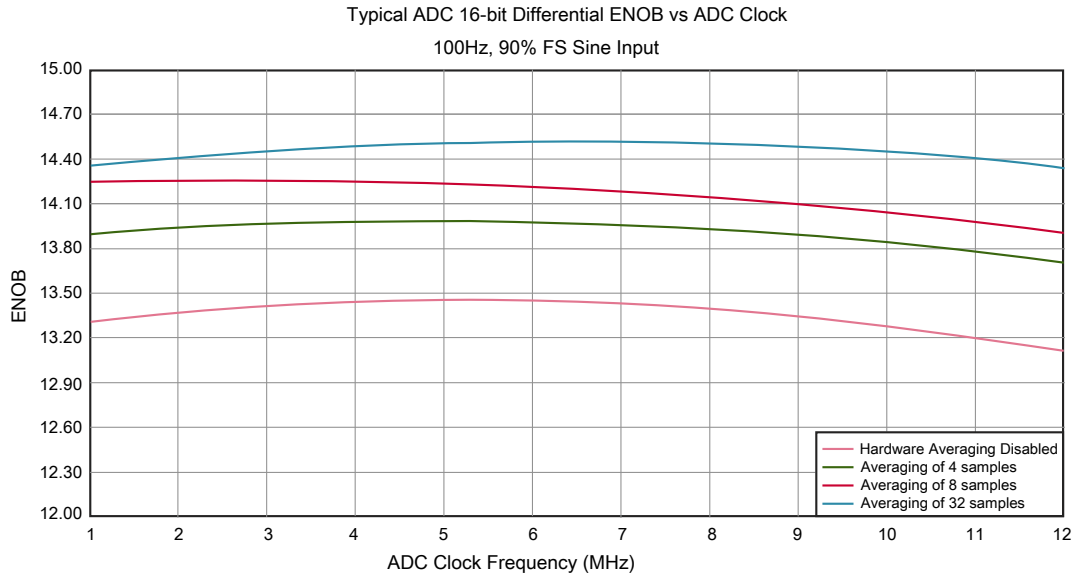


Figure 18. Typical ENOB vs. ADC_CLK for 16-bit differential mode

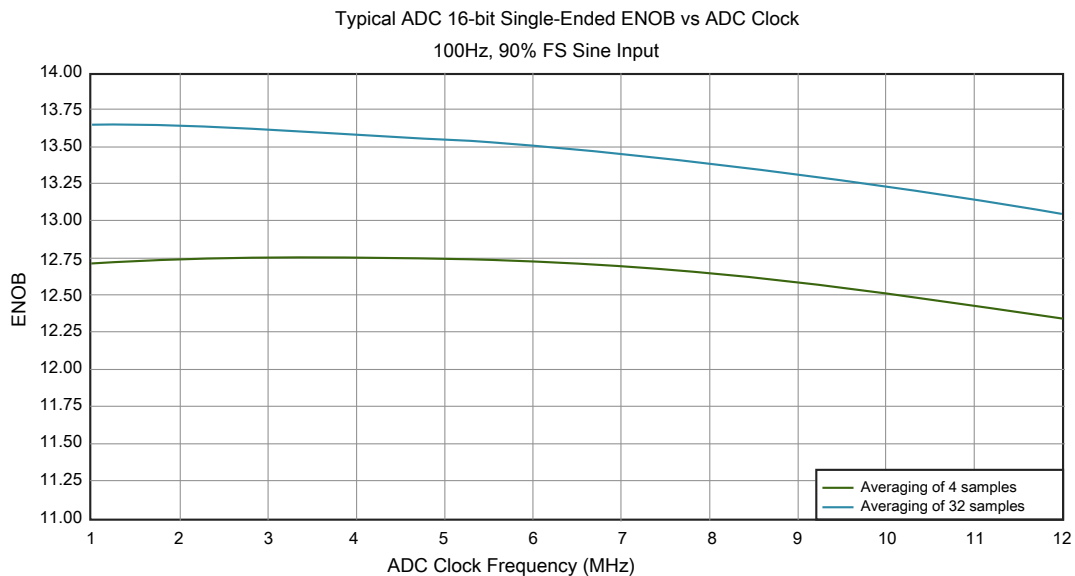


Figure 19. Typical ENOB vs. ADC_CLK for 16-bit single-ended mode

3.6.2 CMP and 6-bit DAC electrical specifications

Table 33. Comparator and 6-bit DAC electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|-------------|--|----------------|---------------------|----------|----------------------|
| V_{DD} | Supply voltage | 1.71 | — | 3.6 | V |
| I_{DDHS} | Supply current, High-speed mode (EN=1, PMODE=1) | — | — | 200 | μ A |
| I_{DDL5} | Supply current, low-speed mode (EN=1, PMODE=0) | — | — | 20 | μ A |
| V_{AIN} | Analog input voltage | $V_{SS} - 0.3$ | — | V_{DD} | V |
| V_{AIO} | Analog input offset voltage | — | — | 20 | mV |
| V_H | Analog comparator hysteresis ¹ <ul style="list-style-type: none"> • CR0[HYSTCTR] = 00 • CR0[HYSTCTR] = 01 • CR0[HYSTCTR] = 10 • CR0[HYSTCTR] = 11 | — | 5 10 20 30 | — | mV mV mV mV |
| V_{CMPOh} | Output high | $V_{DD} - 0.5$ | — | — | V |
| V_{CMPOl} | Output low | — | — | 0.5 | V |
| t_{DHS} | Propagation delay, high-speed mode (EN=1, PMODE=1) | 20 | 50 | 200 | ns |
| t_{DLS} | Propagation delay, low-speed mode (EN=1, PMODE=0) | 80 | 250 | 600 | ns |
| | Analog comparator initialization delay ² | — | — | 40 | μ s |
| I_{DAC6b} | 6-bit DAC current adder (enabled) | — | 7 | — | μ A |
| INL | 6-bit DAC integral non-linearity | -0.5 | — | 0.5 | LSB ³ |
| DNL | 6-bit DAC differential non-linearity | -0.3 | — | 0.3 | LSB |

1. Typical hysteresis is measured with input voltage range limited to 0.6 to $V_{DD}-0.6$ V.
2. Comparator initialization delay is defined as the time between software writes to change control inputs (Writes to CMP_DACCR[DACEN], CMP_DACCR[VRSEL], CMP_DACCR[VOSEL], CMP_MUXCR[PSEL], and CMP_MUXCR[MSEL]) and the comparator output settling to a stable level.
3. 1 LSB = $V_{reference}/64$

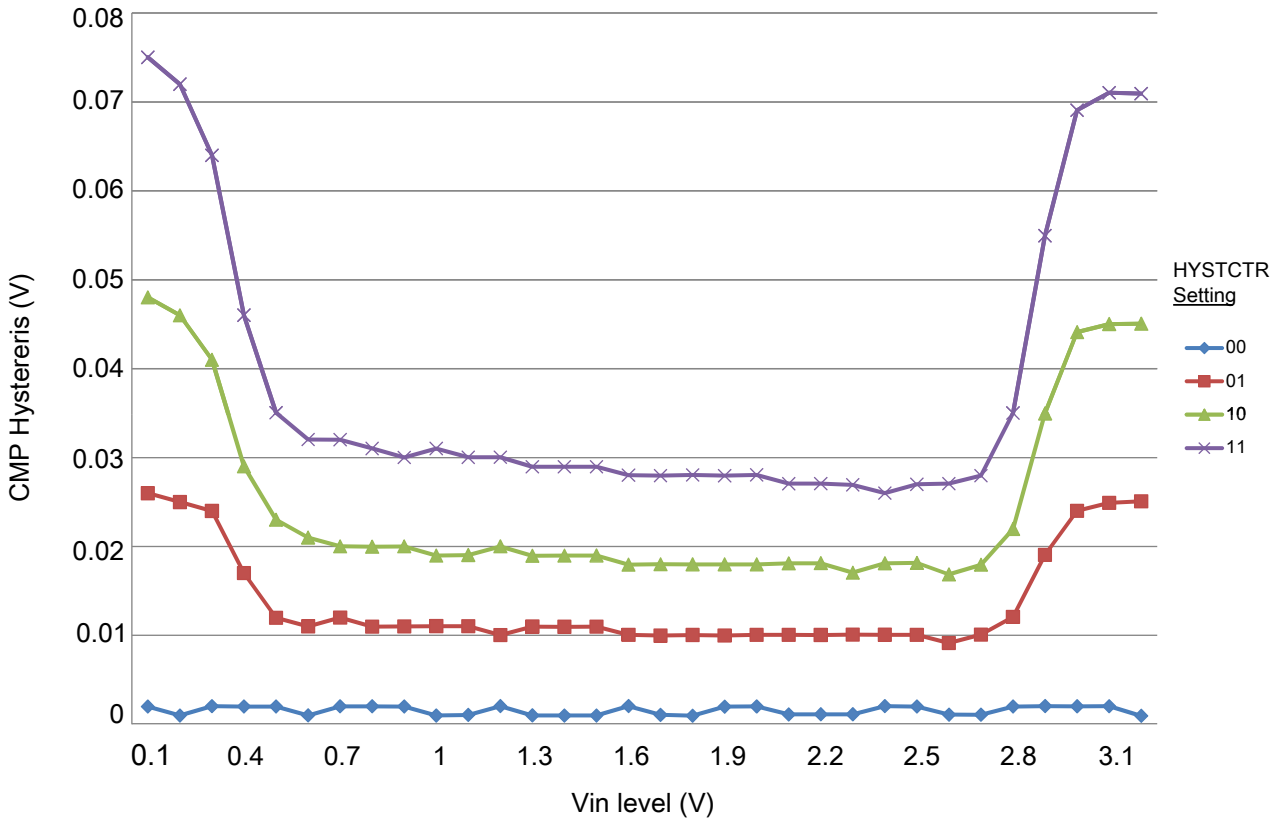


Figure 20. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 0)

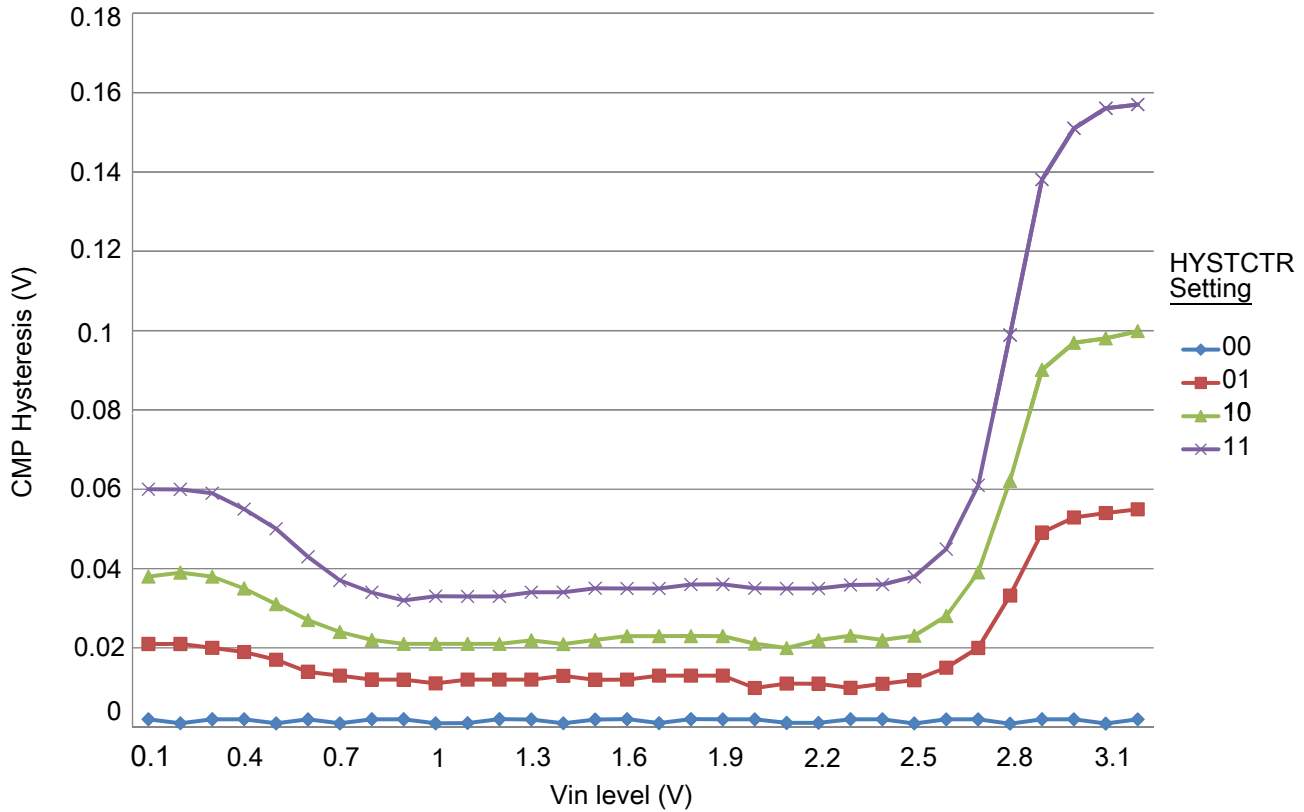


Figure 21. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 1)

3.6.3 12-bit DAC electrical characteristics

3.6.3.1 12-bit DAC operating requirements

Table 34. 12-bit DAC operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------|-------------------------|------|------|------|-------|
| V_{DDA} | Supply voltage | | 3.6 | V | |
| V_{DACR} | Reference voltage | 1.13 | 3.6 | V | 1 |
| C_L | Output load capacitance | — | 100 | pF | 2 |
| I_L | Output load current | — | 1 | mA | |

1. The DAC reference can be selected to be V_{DDA} or V_{REFH} .
2. A small load capacitance (47 pF) can improve the bandwidth performance of the DAC.

3.6.3.2 12-bit DAC operating behaviors

Table 35. 12-bit DAC operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|------------------|---|------------------|-------------|------------|-------------------------|-------|
| I_{DDA_DACLP} | Supply current — low-power mode | — | — | 150 | μA | |
| I_{DDA_DACHP} | Supply current — high-speed mode | — | — | 700 | μA | |
| t_{DACLP} | Full-scale settling time (0x080 to 0xF7F) — low-power mode | — | 100 | 200 | μs | 1 |
| t_{DACHP} | Full-scale settling time (0x080 to 0xF7F) — high-power mode | — | 15 | 30 | μs | 1 |
| $t_{CCDACLP}$ | Code-to-code settling time (0xBF8 to 0xC08) — low-power mode and high-speed mode | — | 0.7 | 1 | μs | 1 |
| $V_{dacoutl}$ | DAC output voltage range low — high-speed mode, no load, DAC set to 0x000 | — | — | 100 | mV | |
| $V_{dacouth}$ | DAC output voltage range high — high-speed mode, no load, DAC set to 0xFFFF | $V_{DACR} - 100$ | — | V_{DACR} | mV | |
| INL | Integral non-linearity error — high speed mode | — | — | ± 8 | LSB | 2 |
| DNL | Differential non-linearity error — $V_{DACR} > 2\text{ V}$ | — | — | ± 1 | LSB | 3 |
| DNL | Differential non-linearity error — $V_{DACR} = V_{REF_OUT}$ | — | — | ± 1 | LSB | 4 |
| V_{OFFSET} | Offset error | — | ± 0.4 | ± 0.8 | %FSR | 5 |
| E_G | Gain error | — | ± 0.1 | ± 0.6 | %FSR | 5 |
| PSRR | Power supply rejection ratio, $V_{DDA} \geq 2.4\text{ V}$ | 60 | — | 90 | dB | |
| T_{CO} | Temperature coefficient offset voltage | — | 3.7 | — | $\mu\text{V}/\text{C}$ | 6 |
| T_{GE} | Temperature coefficient gain error | — | 0.000421 | — | %FSR/C | |
| A_C | Offset aging coefficient | — | — | 100 | $\mu\text{V}/\text{yr}$ | |
| R_{op} | Output resistance (load = 3 k Ω) | — | — | 250 | Ω | |
| SR | Slew rate -80h → F7Fh → 80h <ul style="list-style-type: none"> High power (SP_{HP}) Low power (SP_{LP}) | 1.2 0.05 | 1.7 0.12 | — — | $\text{V}/\mu\text{s}$ | |
| CT | Channel to channel cross talk | — | — | -80 | dB | |
| BW | 3dB bandwidth <ul style="list-style-type: none"> High power (SP_{HP}) Low power (SP_{LP}) | 550 40 | — — | — — | kHz | |

- Settling within ± 1 LSB
- The INL is measured for 0 + 100 mV to $V_{DACR} - 100\text{ mV}$
- The DNL is measured for 0 + 100 mV to $V_{DACR} - 100\text{ mV}$
- The DNL is measured for 0 + 100 mV to $V_{DACR} - 100\text{ mV}$ with $V_{DDA} > 2.4\text{ V}$
- Calculated by a best fit curve from $V_{SS} + 100\text{ mV}$ to $V_{DACR} - 100\text{ mV}$

Peripheral operating requirements and behaviors

- 6. $V_{DDA} = 3.0\text{ V}$, reference select set for V_{DDA} ($\text{DACx_CO:DACRFS} = 1$), high power mode ($\text{DACx_C0:LPEN} = 0$), DAC set to 0x800, temperature range is across the full range of the device

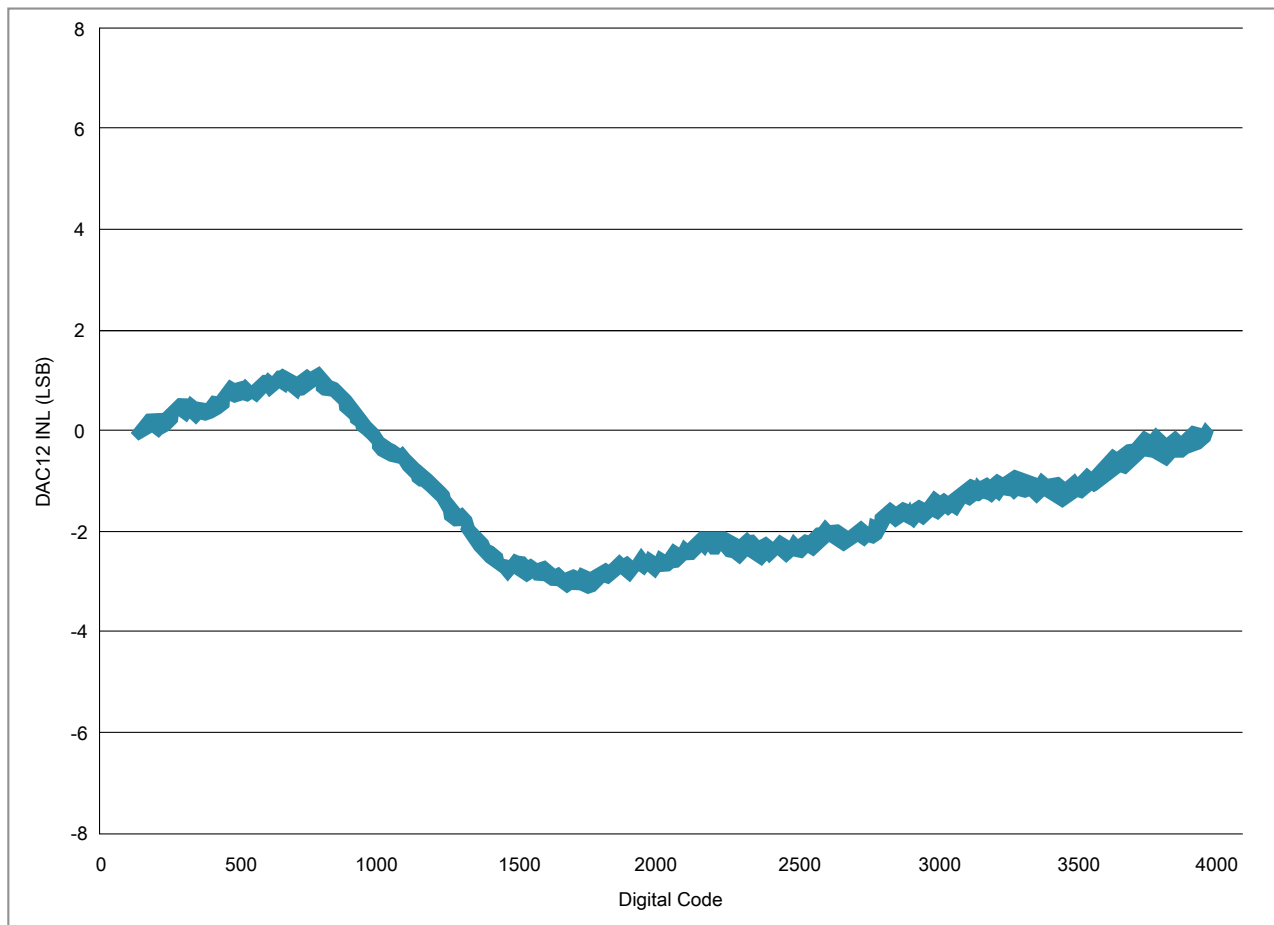


Figure 22. Typical INL error vs. digital code

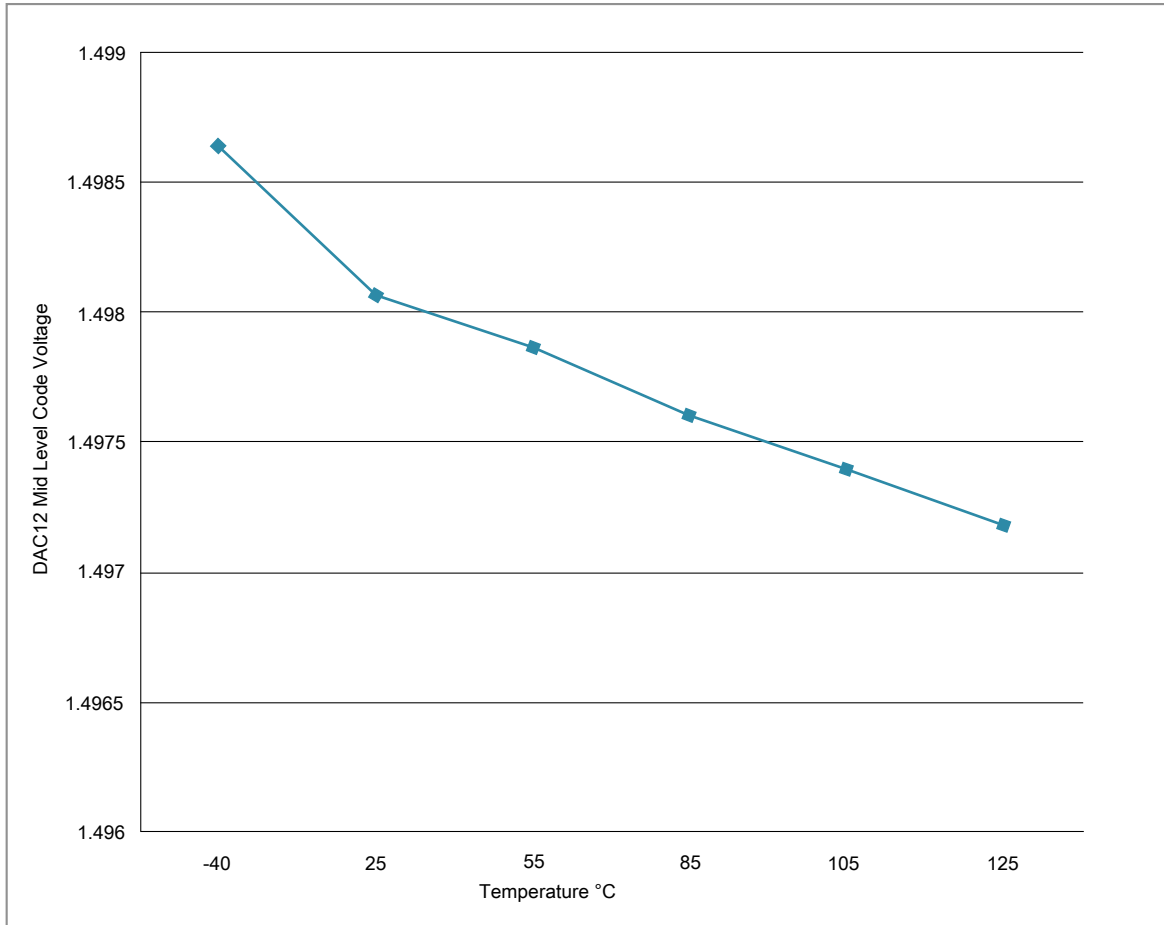


Figure 23. Offset at half scale vs. temperature

3.6.4 Voltage reference electrical specifications

Table 36. VREF full-range operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|-----------|-------------------------|---|------|------|-------|
| V_{DDA} | Supply voltage | | 3.6 | V | |
| T_A | Temperature | Operating temperature range of the device | | °C | |
| C_L | Output load capacitance | 100 | | nF | 1, 2 |

1. C_L must be connected to VREF_OUT if the VREF_OUT functionality is being used for either an internal or external reference.
2. The load capacitance should not exceed +/-25% of the nominal specified C_L value over the operating temperature range of the device.

Table 37. VREF full-range operating behaviors

| Symbol | Description | Min. | Typ. | Max. | Unit | Notes |
|---------------------------------|--|--------|-------|--------|-------|-------|
| V _{out} | Voltage reference output with factory trim at nominal V _{DDA} and temperature=25C | 1.190 | 1.195 | 1.200 | V | 1 |
| V _{out} | Voltage reference output — factory trim | 1.1584 | — | 1.2376 | V | 1 |
| V _{out} | Voltage reference output — user trim | 1.193 | — | 1.197 | V | 1 |
| V _{step} | Voltage reference trim step | — | 0.5 | — | mV | 1 |
| V _{tdrift} | Temperature drift (V _{max} -V _{min} across the full temperature range) | — | — | 80 | mV | 1 |
| Ac | Aging coefficient | — | — | 400 | uV/yr | — |
| I _{bg} | Bandgap only current | — | — | 80 | μA | 1 |
| ΔV _{LOAD} | Load regulation • current = ± 1.0 mA | — | 200 | — | μV | 1, 2 |
| T _{stup} | Buffer startup time | — | — | 100 | μs | — |
| T _{chop_osc_st up} | Internal bandgap start-up delay with chop oscillator enabled | — | — | 35 | ms | — |
| V _{vdrift} | Voltage drift (V _{max} -V _{min} across the full voltage range) | — | 2 | — | mV | 1 |

1. See the chip's Reference Manual for the appropriate settings of the VREF Status and Control register.
2. Load regulation voltage is the difference between the VREF_OUT voltage with no load vs. voltage with defined load

Table 38. VREF limited-range operating requirements

| Symbol | Description | Min. | Max. | Unit | Notes |
|----------------|-------------|------|------|------|-------|
| T _A | Temperature | 0 | 50 | °C | |

Table 39. VREF limited-range operating behaviors

| Symbol | Description | Min. | Max. | Unit | Notes |
|------------------|--|-------|-------|------|-------|
| V _{out} | Voltage reference output with factory trim | 1.173 | 1.225 | V | |

3.7 Timers

See [General switching specifications](#).

3.8 Communication interfaces

3.8.1 Ethernet switching specifications

The following timing specs are defined at the chip I/O pin and must be translated appropriately to arrive at timing specs/constraints for the physical interface.

3.8.1.1 MII signal switching specifications

The following timing specs meet the requirements for MII style interfaces for a range of transceiver devices.

Table 40. MII signal switching specifications (limited voltage range)

| Symbol | Description | Min. | Max. | Unit |
|--------|---------------------------------------|------|------|--------------|
| — | Operating Voltage | 2.7 | 3.6 | V |
| — | RXCLK frequency | — | 25 | MHz |
| MII1 | RXCLK pulse width high | 35% | 65% | RXCLK period |
| MII2 | RXCLK pulse width low | 35% | 65% | RXCLK period |
| MII3 | RXD[3:0], RXDV, RXER to RXCLK setup | 5 | — | ns |
| MII4 | RXCLK to RXD[3:0], RXDV, RXER hold | 5 | — | ns |
| — | TXCLK frequency | — | 25 | MHz |
| MII5 | TXCLK pulse width high | 35% | 65% | TXCLK period |
| MII6 | TXCLK pulse width low | 35% | 65% | TXCLK period |
| MII7 | TXCLK to TXD[3:0], TXEN, TXER invalid | 2 | — | ns |
| MII8 | TXCLK to TXD[3:0], TXEN, TXER valid | — | 25 | ns |

Table 41. MII signal switching specifications (full voltage range)

| Symbol | Description | Min. | Max. | Unit |
|--------|-------------------------------------|------|------|--------------|
| — | Operating Voltage | 1.7 | 3.6 | V |
| — | RXCLK frequency | — | 25 | MHz |
| MII1 | RXCLK pulse width high | 35% | 65% | RXCLK period |
| MII2 | RXCLK pulse width low | 35% | 65% | RXCLK period |
| MII3 | RXD[3:0], RXDV, RXER to RXCLK setup | 5 | — | ns |

Table continues on the next page...

**Table 41. MII signal switching specifications (full voltage range)
(continued)**

| Symbol | Description | Min. | Max. | Unit |
|--------|---------------------------------------|------|------|--------------|
| MII4 | RXCLK to RXD[3:0], RXDV, RXER hold | 5 | — | ns |
| — | TXCLK frequency | — | 25 | MHz |
| MII5 | TXCLK pulse width high | 35% | 65% | TXCLK period |
| MII6 | TXCLK pulse width low | 35% | 65% | TXCLK period |
| MII7 | TXCLK to TXD[3:0], TXEN, TXER invalid | 2 | — | ns |
| MII8 | TXCLK to TXD[3:0], TXEN, TXER valid | — | 25 | ns |

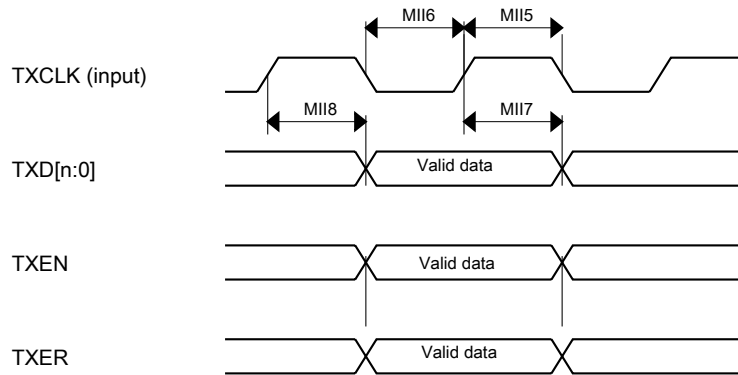


Figure 24. RMII/MII transmit signal timing diagram

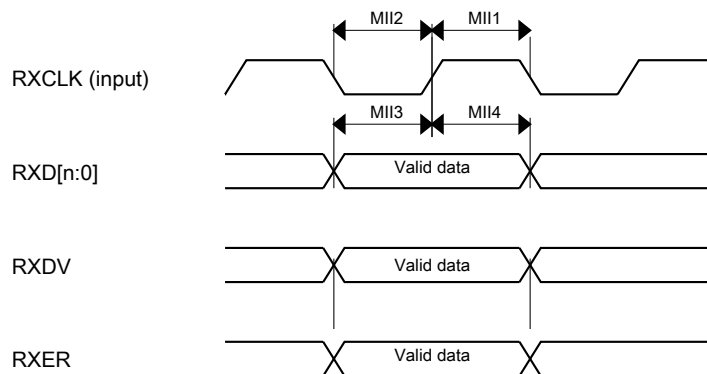


Figure 25. RMII/MII receive signal timing diagram

3.8.1.2 RMII signal switching specifications

The following timing specs meet the requirements for RMII style interfaces for a range of transceiver devices.

Table 42. RMII signal switching specifications (limited voltage range)

| Num | Description | Min. | Max. | Unit |
|-------|---|------|------|-----------------|
| — | Operating Voltage | 2.7 | 3.6 | |
| — | EXTAL frequency (RMII input clock RMII_CLK) | — | 50 | MHz |
| RMII1 | RMII_CLK pulse width high | 35% | 65% | RMII_CLK period |
| RMII2 | RMII_CLK pulse width low | 35% | 65% | RMII_CLK period |
| RMII3 | RXD[1:0], CRS_DV, RXER to RMII_CLK setup | 4 | — | ns |
| RMII4 | RMII_CLK to RXD[1:0], CRS_DV, RXER hold | 2 | — | ns |
| RMII7 | RMII_CLK to TXD[1:0], TXEN invalid | 4 | — | ns |
| RMII8 | RMII_CLK to TXD[1:0], TXEN valid | — | 15.4 | ns |

Table 43. RMII signal switching specifications (full voltage range)

| Num | Description | Min. | Max. | Unit |
|-------|---|------|------|-----------------|
| — | Operating Voltage | 1.7 | 3.6 | |
| — | EXTAL frequency (RMII input clock RMII_CLK) | — | 50 | MHz |
| RMII1 | RMII_CLK pulse width high | 35% | 65% | RMII_CLK period |
| RMII2 | RMII_CLK pulse width low | 35% | 65% | RMII_CLK period |
| RMII3 | RXD[1:0], CRS_DV, RXER to RMII_CLK setup | 4 | — | ns |
| RMII4 | RMII_CLK to RXD[1:0], CRS_DV, RXER hold | 2 | — | ns |
| RMII7 | RMII_CLK to TXD[1:0], TXEN invalid | 4 | — | ns |
| RMII8 | RMII_CLK to TXD[1:0], TXEN valid | — | 17.5 | ns |

3.8.1.3 MDIO serial management timing specifications

Table 44. MDIO serial management channel signal timing

| Num | Characteristic | Symbol | Min | Max | Unit |
|-----|----------------------------|-----------|-----|-----|-------------|
| E10 | MDC cycle time | t_{MDC} | 400 | — | ns |
| E11 | MDC pulse width | | 40 | 60 | % t_{MDC} |
| E12 | MDC to MDIO output valid | | — | 375 | ns |
| E13 | MDC to MDIO output invalid | | 25 | — | ns |
| E14 | MDIO input to MDC setup | | 10 | — | ns |
| E15 | MDIO input to MDC hold | | 0 | — | ns |

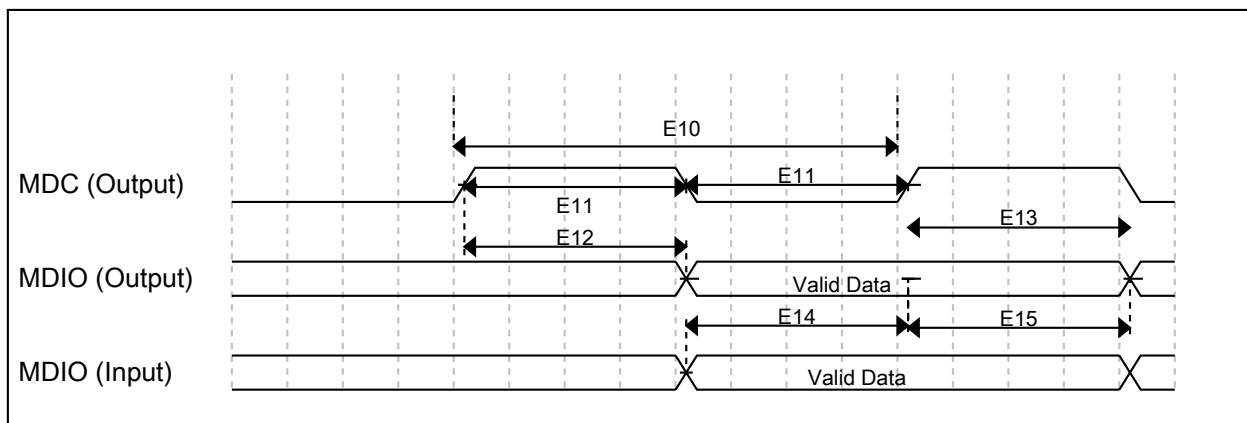


Figure 26. MDIO serial management channel timing diagram

3.8.2 USB Voltage Regulator Electrical Specifications

Table 45. USB VREG electrical specifications

| Symbol | Description | Min. | Typ. ¹ | Max. | Unit | Notes |
|---|--|----------|-------------------|------------|--------|-------|
| VREG_IN0 VREG_IN1 | Regulator selectable input supply voltages | 2.7 | — | 5.5 | V | 2 |
| I _{DDon} VREG_IN0 VREG_IN1 | Quiescent current — Run mode, load current equal zero, input supply (VREG_IN*) > 3.6 V | — | 157 | — | μA | |
| I _{DDstby} VREG_IN0 VREG_IN1 | Quiescent current — Standby mode, load current equal zero | — | 2 | — | μA | |
| I _{DDoff} VREG_IN0 VREG_IN1 | Quiescent current — Shutdown mode • VREG_IN* = 5.0 V and temperature = 25 °C | — | 680 920 | — | nA | |
| I _{LOADrun} | Maximum load current — Run mode | — | — | 150 | mA | 3 |
| I _{LOADstby} | Maximum load current — Standby mode | — | — | 1 | mA | |
| V _{DROPOUT} | Regulator drop-out voltage — Run mode at maximum load current with inrush current limit disabled | 300 | — | — | mV | |
| VREG_OUT | Regulator programmable output target voltage — Selected input supply > programmed output target voltage + V _{DROPOUT} • Run mode • Standby mode | 3 2.1 | 3.3 2.8 | 3.6 3.6 | V V | 4 |

Table continues on the next page...

**Table 45. USB VREG electrical specifications
(continued)**

| Symbol | Description | Min. | Typ. ¹ | Max. | Unit | Notes |
|---------------------|--|------|-------------------|------|------|----------------|
| C _{OUT} | External output capacitor | 1.76 | 2.2 | 8.16 | μF | |
| ESR | External output capacitor equivalent series resistance | 1 | — | 100 | mΩ | |
| I _{LIM} | Short circuit current | — | 350 | — | mA | 5 |
| I _{INRUSH} | Inrush current limit | 40 | — | 100 | mA | 6, 7, 8, 9, 10 |

1. Typical values assume the selected input supply is 5.0 V, Temp = 25 °C unless otherwise stated.
2. Operation range is 2.7 V to 5.5 V; tolerance voltage is up to 6 V.
3. 150mA is inclusive of the run mode current of the on-chip USB modules. Available load outside of the chip depends on USB operation and device power dissipation limits.
4. The target voltage for the regulator is programmable, accounting for the range of the max and min values
5. Current limit disabled.
6. Current limit should be disabled after the powers have stabilized to allow full functionality of the regulator.
7. Limited Characterization
8. I_{INRUSH} with VREG_{INx}=4.0 V to 5.5 V
9. The minimum value of I_{INRUSH} is stated for operation when only one of VREG_IN0 / VREG_IN1 is powered, or when VREG_IN0 and VREG_IN1 both have the same voltage level. When VREG_IN0 and VREG_IN1 are operated at different voltage levels with the selected VREG_IN lower than the non-selected VREG_IN, the minimum value of I_{INRUSH} may decrease to a lower value.
10. Total current load on startup should be less than I_{INRUSH} min over full input voltage range of the regulator.

3.8.3 USB Full Speed Transceiver and High Speed PHY specifications

This section describes the USB0 port Full Speed/Low Speed transceiver and USB1 port USB-PHY High Speed Phy parameters. The high speed phy is capable of full and low speed signalling as well.

The USB0 (FS/LS Transceiver) and USB1 ((USB HS/FS/LS) meet the electrical compliance requirements defined in the Universal Serial Bus Revision 2.0 Specification with the amendments below.

- USB ENGINEERING CHANGE NOTICE
 - Title: 5V Short Circuit Withstand Requirement Change
 - Applies to: Universal Serial Bus Specification, Revision 2.0
- Errata for USB Revision 2.0 April 27, 2000 as of 12/7/2000
- USB ENGINEERING CHANGE NOTICE
 - Title: Pull-up/Pull-down resistors
 - Applies to: Universal Serial Bus Specification, Revision 2.0
- USB ENGINEERING CHANGE NOTICE

Peripheral operating requirements and behaviors

- Title: Suspend Current Limit Changes
- Applies to: Universal Serial Bus Specification, Revision 2.0
- On-The-Go and Embedded Host Supplement to the USB Revision 2.0 Specification
 - Revision 2.0 version 1.1a July 27, 2012
- Battery Charging Specification (available from USB-IF)
 - Revision 1.2 (including errata and ECNs through March 15, 2012), March 15, 2012

USB1_VBUS pin is a detector function which is 5v tolerant and complies with the above specifications without needing any external voltage division components.

3.8.4 USB DCD electrical specifications

Table 46. USB DCD electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|--|---|-------|------|------|------------|
| V _{DP_SRC} , V _{DM_SRC} | USB_DP and USB_DM source voltages (up to 250 μ A) | 0.5 | — | 0.7 | V |
| V _{LGC} | Threshold voltage for logic high | 0.8 | — | 2.0 | V |
| I _{DP_SRC} | USB_DP source current | 7 | 10 | 13 | μ A |
| I _{DM_SINK} , I _{DP_SINK} | USB_DM and USB_DP sink currents | 50 | 100 | 150 | μ A |
| R _{DM_DWN} | D- pulldown resistance for data pin contact detect | 14.25 | — | 24.8 | k Ω |
| V _{DAT_REF} | Data detect voltage | 0.25 | 0.33 | 0.4 | V |

3.8.5 CAN switching specifications

See [General switching specifications](#).

3.8.6 DSPI switching specifications (limited voltage range)

The DMA Serial Peripheral Interface (DSPI) provides a synchronous serial bus with master and slave operations. Many of the transfer attributes are programmable. The tables below provide DSPI timing characteristics for classic SPI timing modes. Refer to the DSPI chapter of the Reference Manual for information on the modified transfer formats used for communicating with slower peripheral devices.

Table 47. Master mode DSPI timing (limited voltage range)

| Num | Description | Min. | Max. | Unit | Notes |
|-----|-------------------------------------|---------------------------------|--------------------------|------|-------|
| | Operating voltage | 2.7 | 3.6 | V | |
| | Frequency of operation | — | 30 | MHz | |
| DS1 | DSPI_SCK output cycle time | $2 \times t_{\text{BUS}}$ | — | ns | |
| DS2 | DSPI_SCK output high/low time | $(t_{\text{SCK}}/2) - 2$ | $(t_{\text{SCK}}/2) + 2$ | ns | |
| DS3 | DSPI_PCSn valid to DSPI_SCK delay | $(t_{\text{BUS}} \times 2) - 2$ | — | ns | 1 |
| DS4 | DSPI_SCK to DSPI_PCSn invalid delay | $(t_{\text{BUS}} \times 2) - 2$ | — | ns | 2 |
| DS5 | DSPI_SCK to DSPI_SOUT valid | — | 15.0 | ns | |
| DS6 | DSPI_SCK to DSPI_SOUT invalid | 1.0 | — | ns | |
| DS7 | DSPI_SIN to DSPI_SCK input setup | 15.8 | — | ns | |
| DS8 | DSPI_SCK to DSPI_SIN input hold | 0 | — | ns | |

1. The delay is programmable in SPIx_CTARn[PSSCK] and SPIx_CTARn[CSSCK].
2. The delay is programmable in SPIx_CTARn[PASC] and SPIx_CTARn[ASC].

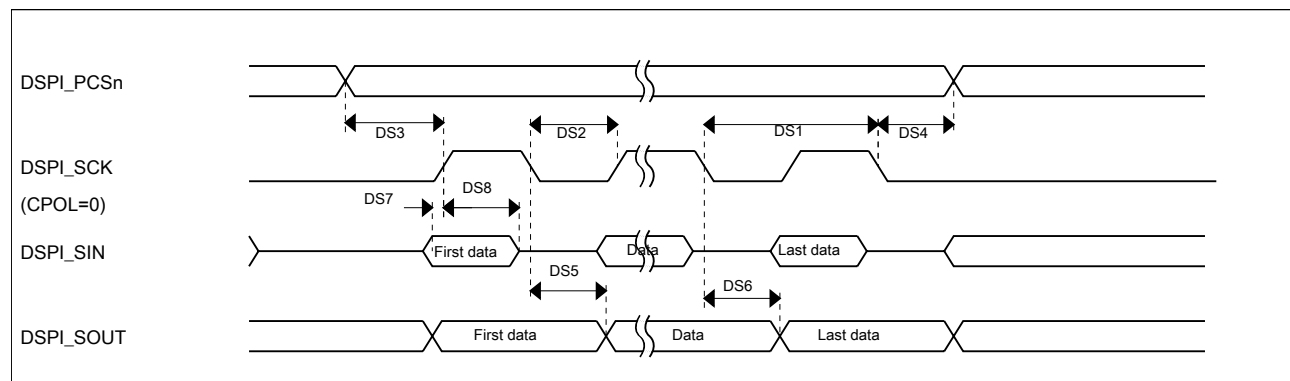


Figure 27. DSPI classic SPI timing — master mode

Table 48. Slave mode DSPI timing (limited voltage range)

| Num | Description | Min. | Max. | Unit |
|-----|------------------------|------|-----------------|------|
| | Operating voltage | 2.7 | 3.6 | V |
| | Frequency of operation | | 15 ¹ | MHz |

Table continues on the next page...

Table 48. Slave mode DSPI timing (limited voltage range) (continued)

| Num | Description | Min. | Max. | Unit |
|------|--|---------------------------|---------------------------|------|
| DS9 | DSPI_SCK input cycle time | 4 x t _{BUS} | — | ns |
| DS10 | DSPI_SCK input high/low time | (t _{SCK} /2) - 2 | (t _{SCK} /2) + 2 | ns |
| DS11 | DSPI_SCK to DSPI_SOUT valid | — | 23.0 | ns |
| DS12 | DSPI_SCK to DSPI_SOUT invalid | 0 | — | ns |
| DS13 | DSPI_SIN to DSPI_SCK input setup | 2.7 | — | ns |
| DS14 | DSPI_SCK to DSPI_SIN input hold | 7.0 | — | ns |
| DS15 | DSPI_SS active to DSPI_SOUT driven | — | 13 | ns |
| DS16 | DSPI_SS inactive to DSPI_SOUT not driven | — | 13 | ns |

- The maximum operating frequency is measured with non-continuous CS and SCK. When DSPI is configured with continuous CS and SCK, there is a constraint that SPI clock should not be greater than 1/6 of bus clock, for example, when bus clock is 60MHz, SPI clock should not be greater than 10MHz.

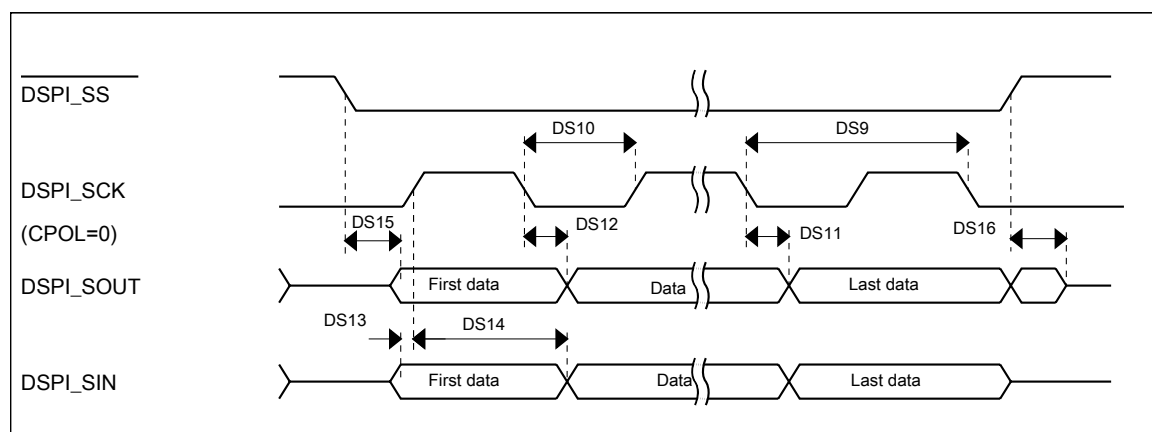


Figure 28. DSPI classic SPI timing — slave mode

3.8.7 DSPI switching specifications (full voltage range)

The DMA Serial Peripheral Interface (DSPI) provides a synchronous serial bus with master and slave operations. Many of the transfer attributes are programmable. The tables below provides DSPI timing characteristics for classic SPI timing modes. Refer to the DSPI chapter of the Reference Manual for information on the modified transfer formats used for communicating with slower peripheral devices.

Table 49. Master mode DSPI timing (full voltage range)

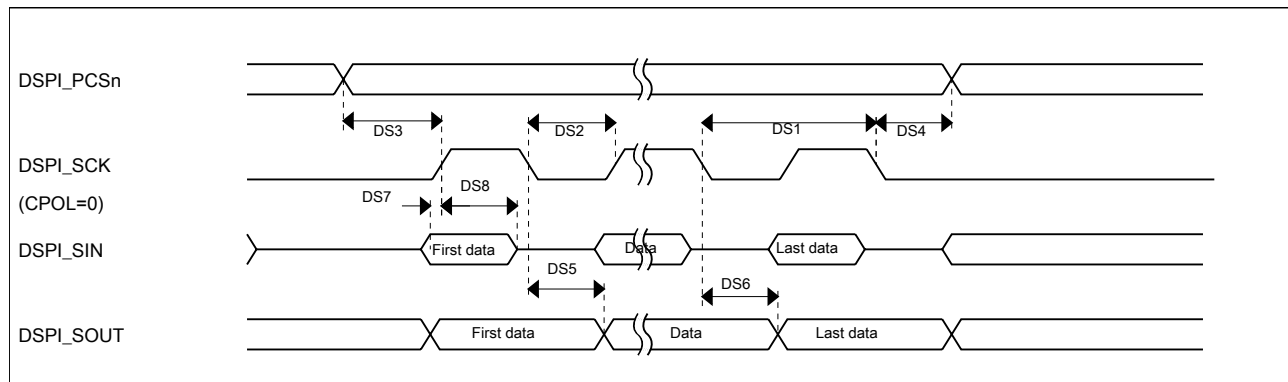
| Num | Description | Min. | Max. | Unit | Notes |
|-----|------------------------|------|------|------|-------|
| | Operating voltage | 1.71 | 3.6 | V | 1 |
| | Frequency of operation | — | 15 | MHz | |

Table continues on the next page...

Table 49. Master mode DSPI timing (full voltage range) (continued)

| Num | Description | Min. | Max. | Unit | Notes |
|-----|---|--------------------------|-------------------|------|-------|
| DS1 | DSPI_SCK output cycle time | $4 \times t_{BUS}$ | — | ns | |
| DS2 | DSPI_SCK output high/low time | $(t_{SCK/2}) - 4$ | $(t_{SCK/2}) + 4$ | ns | |
| DS3 | DSPI_PCS _n valid to DSPI_SCK delay | $(t_{BUS} \times 2) - 4$ | — | ns | 2 |
| DS4 | DSPI_SCK to DSPI_PCS _n invalid delay | $(t_{BUS} \times 2) - 4$ | — | ns | 3 |
| DS5 | DSPI_SCK to DSPI_SOUT valid | — | 15 | ns | |
| DS6 | DSPI_SCK to DSPI_SOUT invalid | 1.0 | — | ns | |
| DS7 | DSPI_SIN to DSPI_SCK input setup | 15.8 | — | ns | |
| DS8 | DSPI_SCK to DSPI_SIN input hold | 0 | — | ns | |

1. The DSPI module can operate across the entire operating voltage for the processor, but to run across the full voltage range the maximum frequency of operation is reduced.
2. The delay is programmable in SPIx_CTARn[PSSCK] and SPIx_CTARn[CSSCK].
3. The delay is programmable in SPIx_CTARn[PASC] and SPIx_CTARn[ASC].

**Figure 29. DSPI classic SPI timing — master mode****Table 50. Slave mode DSPI timing (full voltage range)**

| Num | Description | Min. | Max. | Unit |
|------|--|--------------------|-------------------|------|
| | Operating voltage | 1.71 | 3.6 | V |
| | Frequency of operation | — | 7.5 | MHz |
| DS9 | DSPI_SCK input cycle time | $8 \times t_{BUS}$ | — | ns |
| DS10 | DSPI_SCK input high/low time | $(t_{SCK/2}) - 4$ | $(t_{SCK/2}) + 4$ | ns |
| DS11 | DSPI_SCK to DSPI_SOUT valid | — | 23.1 | ns |
| DS12 | DSPI_SCK to DSPI_SOUT invalid | 0 | — | ns |
| DS13 | DSPI_SIN to DSPI_SCK input setup | 2.6 | — | ns |
| DS14 | DSPI_SCK to DSPI_SIN input hold | 7.0 | — | ns |
| DS15 | $\overline{DSPI_SS}$ active to DSPI_SOUT driven | — | 13.0 | ns |
| DS16 | $\overline{DSPI_SS}$ inactive to DSPI_SOUT not driven | — | 13.0 | ns |

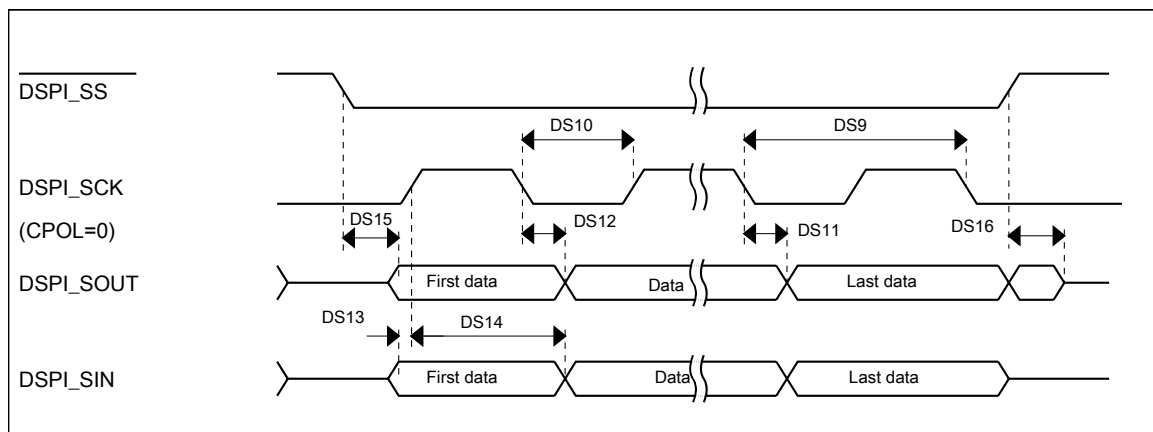


Figure 30. DSPI classic SPI timing — slave mode

3.8.8 Inter-Integrated Circuit Interface (I²C) timing

Table 51. I²C timing

| Characteristic | Symbol | Standard Mode | | Fast Mode | | Unit |
|--|---------------|------------------|-------------------|----------------------------|------------------|---------|
| | | Minimum | Maximum | Minimum | Maximum | |
| SCL Clock Frequency | f_{SCL} | 0 | 100 | 0 | 400 | kHz |
| Hold time (repeated) START condition. After this period, the first clock pulse is generated. | $t_{HD}; STA$ | 4 | — | 0.6 | — | μs |
| LOW period of the SCL clock | t_{LOW} | 4.7 | — | 1.25 | — | μs |
| HIGH period of the SCL clock | t_{HIGH} | 4 | — | 0.6 | — | μs |
| Set-up time for a repeated START condition | $t_{SU}; STA$ | 4.7 | — | 0.6 | — | μs |
| Data hold time for I ² C bus devices | $t_{HD}; DAT$ | 0 ¹ | 3.45 ² | 0 ³ | 0.9 ¹ | μs |
| Data set-up time | $t_{SU}; DAT$ | 250 ⁴ | — | 100 ^{2, 5} | — | ns |
| Rise time of SDA and SCL signals | t_r | — | 1000 | $20 + 0.1C_b$ ⁶ | 300 | ns |
| Fall time of SDA and SCL signals | t_f | — | 300 | $20 + 0.1C_b$ ⁵ | 300 | ns |
| Set-up time for STOP condition | $t_{SU}; STO$ | 4 | — | 0.6 | — | μs |
| Bus free time between STOP and START condition | t_{BUF} | 4.7 | — | 1.3 | — | μs |
| Pulse width of spikes that must be suppressed by the input filter | t_{SP} | N/A | N/A | 0 | 50 | ns |

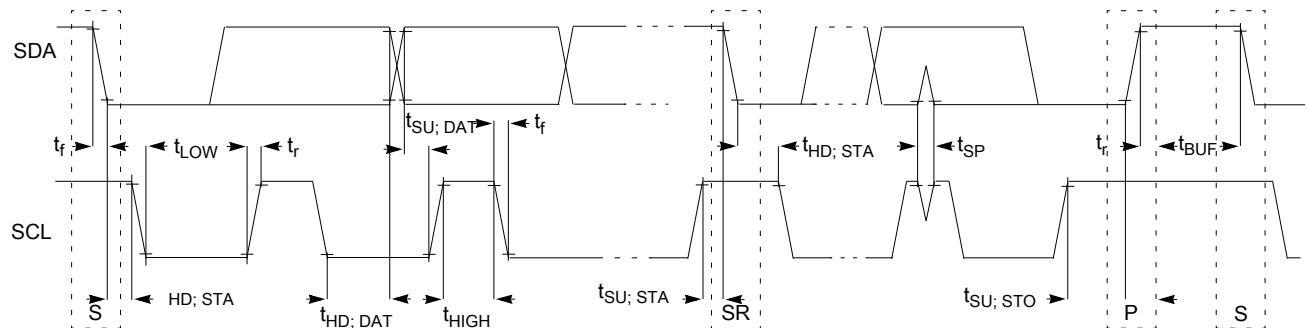
1. The master mode I²C deasserts ACK of an address byte simultaneously with the falling edge of SCL. If no slaves acknowledge this address byte, then a negative hold time can result, depending on the edge rates of the SDA and SCL lines.
2. The maximum $t_{HD}; DAT$ must be met only if the device does not stretch the LOW period (t_{LOW}) of the SCL signal.
3. Input signal Slew = 10 ns and Output Load = 50 pF
4. Set-up time in slave-transmitter mode is 1 IPBus clock period, if the TX FIFO is empty.
5. A Fast mode I²C bus device can be used in a Standard mode I²C bus system, but the requirement $t_{SU}; DAT \geq 250$ ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such

- a device does stretch the LOW period of the SCL signal, then it must output the next data bit to the SDA line $t_{rmax} + t_{SU}$; $t_{HD; DAT} = 1000 + 250 = 1250$ ns (according to the Standard mode I²C bus specification) before the SCL line is released.
6. C_b = total capacitance of the one bus line in pF.

Table 52. I²C 1 Mbps timing

| Characteristic | Symbol | Minimum | Maximum | Unit |
|--|---------------|----------------------------|----------------|---------|
| SCL Clock Frequency | f_{SCL} | 0 | 1 ¹ | MHz |
| Hold time (repeated) START condition. After this period, the first clock pulse is generated. | $t_{HD; STA}$ | 0.26 | — | μ s |
| LOW period of the SCL clock | t_{LOW} | 0.5 | — | μ s |
| HIGH period of the SCL clock | t_{HIGH} | 0.26 | — | μ s |
| Set-up time for a repeated START condition | $t_{SU; STA}$ | 0.26 | — | μ s |
| Data hold time for I ² C bus devices | $t_{HD; DAT}$ | 0 | — | μ s |
| Data set-up time | $t_{SU; DAT}$ | 50 | — | ns |
| Rise time of SDA and SCL signals | t_r | $20 + 0.1C_b$ ² | 120 | ns |
| Fall time of SDA and SCL signals | t_f | $20 + 0.1C_b$ ² | 120 | ns |
| Set-up time for STOP condition | $t_{SU; STO}$ | 0.26 | — | μ s |
| Bus free time between STOP and START condition | t_{BUF} | 0.5 | — | μ s |
| Pulse width of spikes that must be suppressed by the input filter | t_{SP} | 0 | 50 | ns |

- The maximum SCL clock frequency of 1 Mbps can support maximum bus loading when using the High drive pins across the full voltage range.
- C_b = total capacitance of the one bus line in pF.

**Figure 31. Timing definition for devices on the I²C bus**

3.8.9 UART switching specifications

See [General switching specifications](#).

3.8.10 Low Power UART switching specifications

See [General switching specifications](#).

3.8.11 SDHC specifications

The following timing specs are defined at the chip I/O pin and must be translated appropriately to arrive at timing specs/constraints for the physical interface.

Table 53. SDHC full voltage range switching specifications

| Num | Symbol | Description | Min. | Max. | Unit |
|---|------------------|---|------|---------|------|
| | | Operating voltage | 1.71 | 3.6 | V |
| Card input clock | | | | | |
| SD1 | fpp | Clock frequency (low speed) | 0 | 400 | kHz |
| | fpp | Clock frequency (SD\SDIO full speed\high speed) | 0 | 25\50 | MHz |
| | fpp | Clock frequency (MMC full speed\high speed) | 0 | 20\50 | MHz |
| | f _{OD} | Clock frequency (identification mode) | 0 | 400 | kHz |
| SD2 | t _{WL} | Clock low time | 7 | — | ns |
| SD3 | t _{WH} | Clock high time | 7 | — | ns |
| SD4 | t _{TLH} | Clock rise time | — | 3 | ns |
| SD5 | t _{THL} | Clock fall time | — | 3 | ns |
| SDHC output / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK) | | | | | |
| SD6 | t _{OD} | SDHC output delay (output valid) | -5 | 8.6 8.3 | ns |
| SDHC input / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK) | | | | | |
| SD7 | t _{ISU} | SDHC input setup time | 5 | — | ns |
| SD8 | t _{IH} | SDHC input hold time | 0 | — | ns |

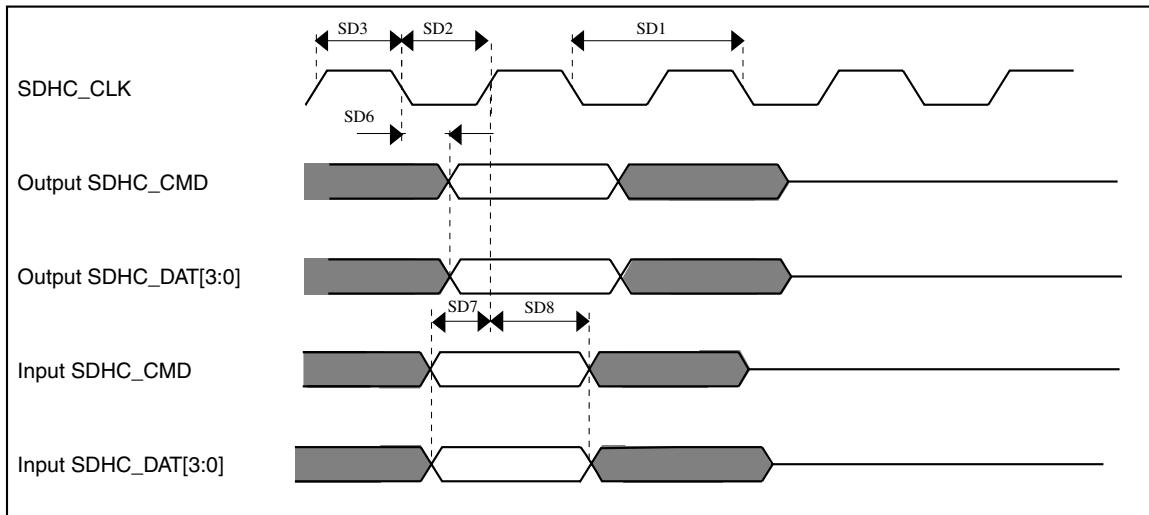
Table 54. SDHC limited voltage range switching specifications

| Num | Symbol | Description | Min. | Max. | Unit |
|-------------------------|------------------|---|------|-------|------|
| | | Operating voltage | 2.7 | 3.6 | V |
| Card input clock | | | | | |
| SD1 | fpp | Clock frequency (low speed) | 0 | 400 | kHz |
| | fpp | Clock frequency (SD\SDIO full speed\high speed) | 0 | 25\50 | MHz |
| | fpp | Clock frequency (MMC full speed\high speed) | 0 | 20\50 | MHz |
| | f _{OD} | Clock frequency (identification mode) | 0 | 400 | kHz |
| SD2 | t _{WL} | Clock low time | 7 | — | ns |
| SD3 | t _{WH} | Clock high time | 7 | — | ns |
| SD4 | t _{TLH} | Clock rise time | — | 3 | ns |
| SD5 | t _{THL} | Clock fall time | — | 3 | ns |

Table continues on the next page...

Table 54. SDHC limited voltage range switching specifications (continued)

| Num | Symbol | Description | Min. | Max. | Unit |
|---|-----------|----------------------------------|------|---------|------|
| SDHC output / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK) | | | | | |
| SD6 | t_{OD} | SDHC output delay (output valid) | -5 | 7.6 8.3 | ns |
| SDHC input / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK) | | | | | |
| SD7 | t_{ISU} | SDHC input setup time | 5 | — | ns |
| SD8 | t_{IH} | SDHC input hold time | 0 | — | ns |

**Figure 32. SDHC timing**

3.8.12 I²S switching specifications

This section provides the AC timings for the I²S in master (clocks driven) and slave modes (clocks input). All timings are given for non-inverted serial clock polarity (TCR[TSCKP] = 0, RCR[RSCKP] = 0) and a non-inverted frame sync (TCR[TFSI] = 0, RCR[RFSI] = 0). If the polarity of the clock and/or the frame sync have been inverted, all the timings remain valid by inverting the clock signal (I2S_BCLK) and/or the frame sync (I2S_FS) shown in the figures below.

Table 55. I2S master mode timing (limited voltage range)

| Num | Description | Min. | Max. | Unit |
|-----|-------------------------------|------|------|-------------|
| | Operating voltage | 2.7 | 3.6 | V |
| S1 | I2S_MCLK cycle time | 40 | — | ns |
| S2 | I2S_MCLK pulse width high/low | 45% | 55% | MCLK period |
| S3 | I2S_BCLK cycle time | 80 | — | ns |

Table continues on the next page...

Table 55. I2S master mode timing (limited voltage range) (continued)

| Num | Description | Min. | Max. | Unit |
|-----|--|------|------|-------------|
| S4 | I2S_BCLK pulse width high/low | 45% | 55% | BCLK period |
| S5 | I2S_BCLK to I2S_FS output valid | — | 15 | ns |
| S6 | I2S_BCLK to I2S_FS output invalid | 0 | — | ns |
| S7 | I2S_BCLK to I2S_TXD valid | — | 15 | ns |
| S8 | I2S_BCLK to I2S_TXD invalid | 0 | — | ns |
| S9 | I2S_RXD/I2S_FS input setup before I2S_BCLK | 15 | — | ns |
| S10 | I2S_RXD/I2S_FS input hold after I2S_BCLK | 0 | — | ns |

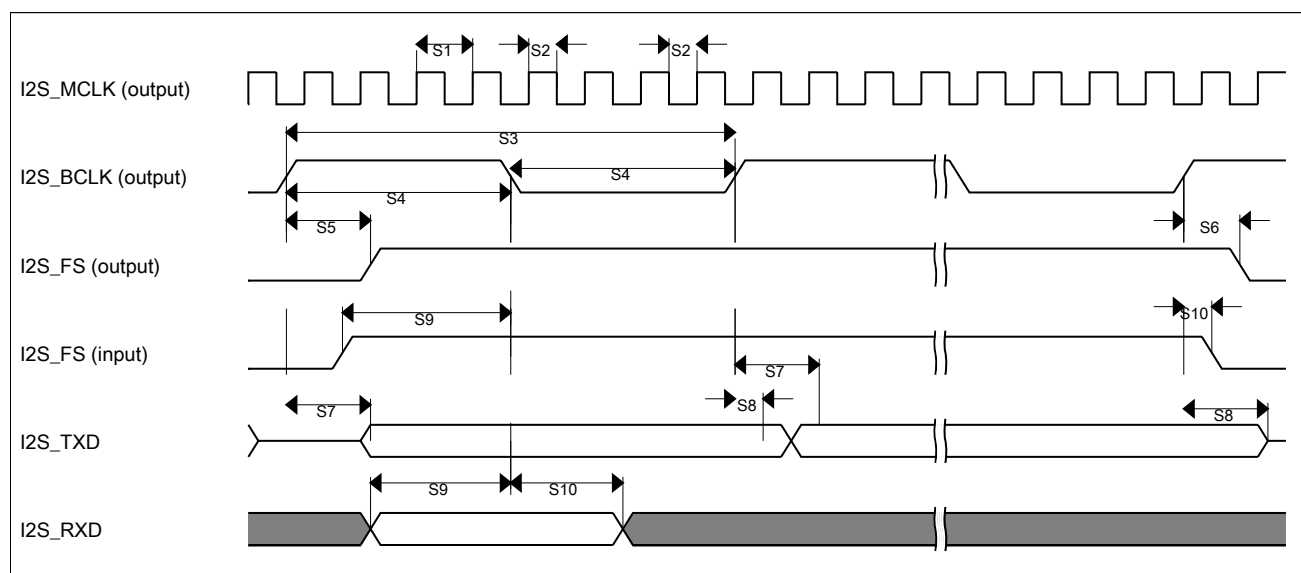
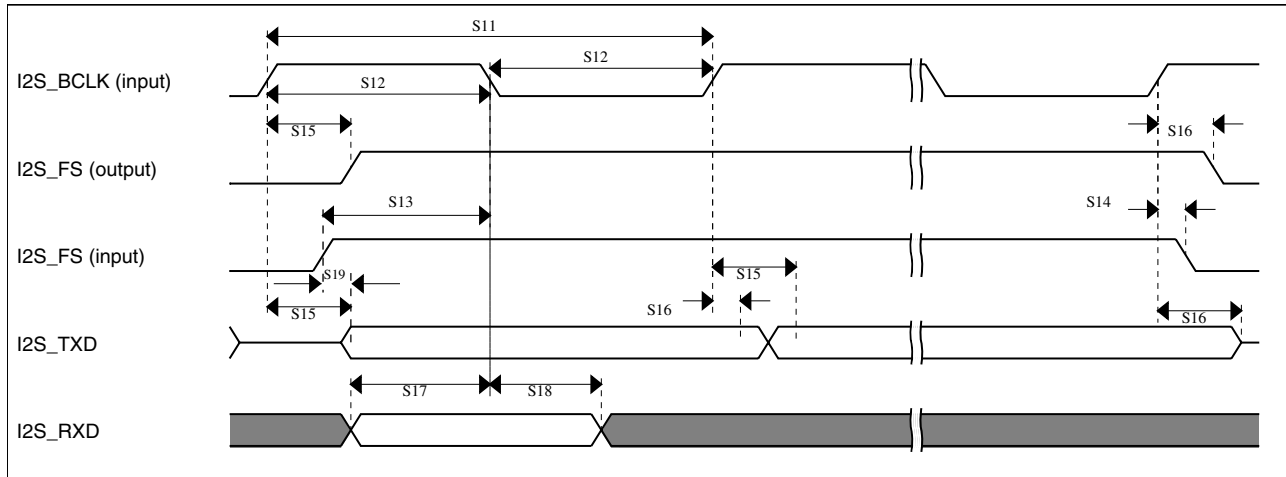


Figure 33. I2S timing — master mode

Table 56. I2S slave mode timing (limited voltage range)

| Num | Description | Min. | Max. | Unit |
|-----|--|------|------|-------------|
| | Operating voltage | 2.7 | 3.6 | V |
| S11 | I2S_BCLK cycle time (input) | 80 | — | ns |
| S12 | I2S_BCLK pulse width high/low (input) | 45% | 55% | MCLK period |
| S13 | I2S_FS input setup before I2S_BCLK | 4.5 | — | ns |
| S14 | I2S_FS input hold after I2S_BCLK | 2 | — | ns |
| S15 | I2S_BCLK to I2S_TXD/I2S_FS output valid | — | 20 | ns |
| S16 | I2S_BCLK to I2S_TXD/I2S_FS output invalid | 0 | — | ns |
| S17 | I2S_RXD setup before I2S_BCLK | 4.5 | — | ns |
| S18 | I2S_RXD hold after I2S_BCLK | 2 | — | ns |
| S19 | I2S_TX_FS input assertion to I2S_TXD output valid ¹ | | 25 | ns |

1. Applies to first bit in each frame and only if the TCR4[FSE] bit is clear

Figure 34. I²S timing — slave modes

3.8.12.1 Normal Run, Wait and Stop mode performance over the full operating voltage range

This section provides the operating performance over the full operating voltage for the device in Normal Run, Wait and Stop modes.

Table 57. I2S/SAI master mode timing

| Num. | Characteristic | Min. | Max. | Unit |
|------|---|------|------|-------------|
| | Operating voltage | 1.71 | 3.6 | V |
| S1 | I2S_MCLK cycle time | 40 | — | ns |
| S2 | I2S_MCLK (as an input) pulse width high/low | 45% | 55% | MCLK period |
| S3 | I2S_TX_BCLK/I2S_RX_BCLK cycle time (output) | 80 | — | ns |
| S4 | I2S_TX_BCLK/I2S_RX_BCLK pulse width high/low | 45% | 55% | BCLK period |
| S5 | I2S_TX_BCLK/I2S_RX_BCLK to I2S_TX_FS/ I2S_RX_FS output valid | — | 15 | ns |
| S6 | I2S_TX_BCLK/I2S_RX_BCLK to I2S_TX_FS/ I2S_RX_FS output invalid | 0 | — | ns |
| S7 | I2S_TX_BCLK to I2S_TXD valid | — | 15 | ns |
| S8 | I2S_TX_BCLK to I2S_TXD invalid | 0 | — | ns |
| S9 | I2S_RXD/I2S_RX_FS input setup before I2S_RX_BCLK | 15 | — | ns |
| S10 | I2S_RXD/I2S_RX_FS input hold after I2S_RX_BCLK | 0 | — | ns |

Peripheral operating requirements and behaviors

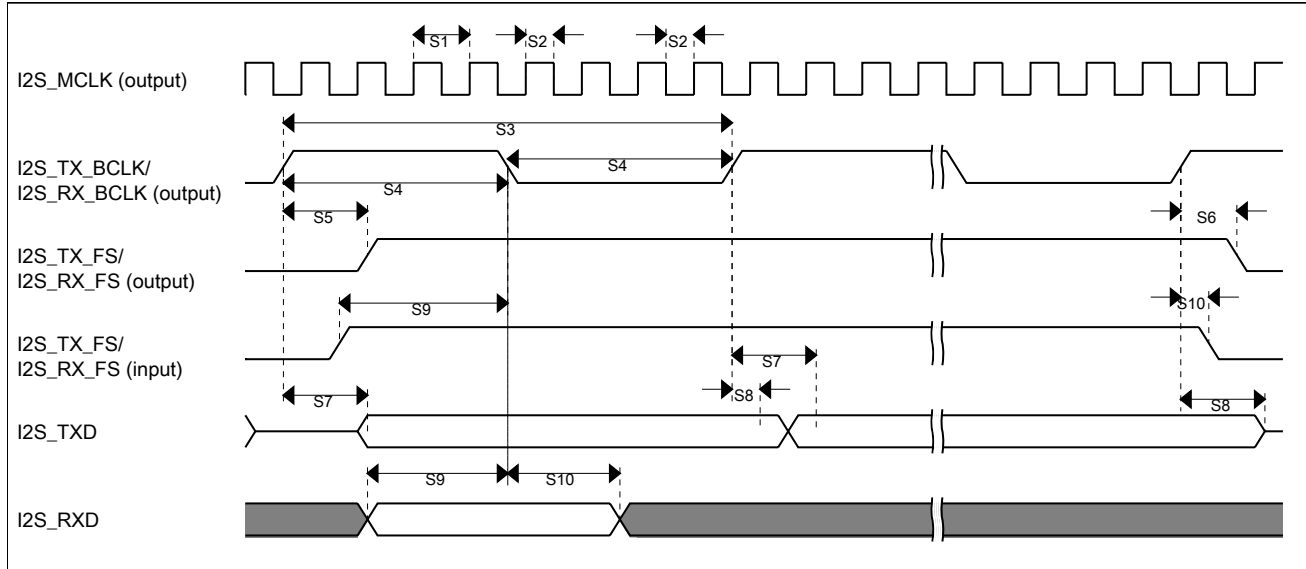


Figure 35. I2S/SAI timing — master modes

Table 58. I2S/SAI slave mode timing

| Num. | Characteristic | Min. | Max. | Unit |
|------|--|------|------|-------------|
| | Operating voltage | 1.71 | 3.6 | V |
| S11 | I2S_TX_BCLK/I2S_RX_BCLK cycle time (input) | 80 | — | ns |
| S12 | I2S_TX_BCLK/I2S_RX_BCLK pulse width high/low (input) | 45% | 55% | MCLK period |
| S13 | I2S_TX_FS/I2S_RX_FS input setup before I2S_TX_BCLK/I2S_RX_BCLK | 4.5 | — | ns |
| S14 | I2S_TX_FS/I2S_RX_FS input hold after I2S_TX_BCLK/I2S_RX_BCLK | 2 | — | ns |
| S15 | I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output valid | — | 23.1 | ns |
| S16 | I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output invalid | 0 | — | ns |
| S17 | I2S_RXD setup before I2S_RX_BCLK | 4.5 | — | ns |
| S18 | I2S_RXD hold after I2S_RX_BCLK | 2 | — | ns |
| S19 | I2S_TX_FS input assertion to I2S_TXD output valid ¹ | — | 25 | ns |

1. Applies to first bit in each frame and only if the TCR4[FSE] bit is clear

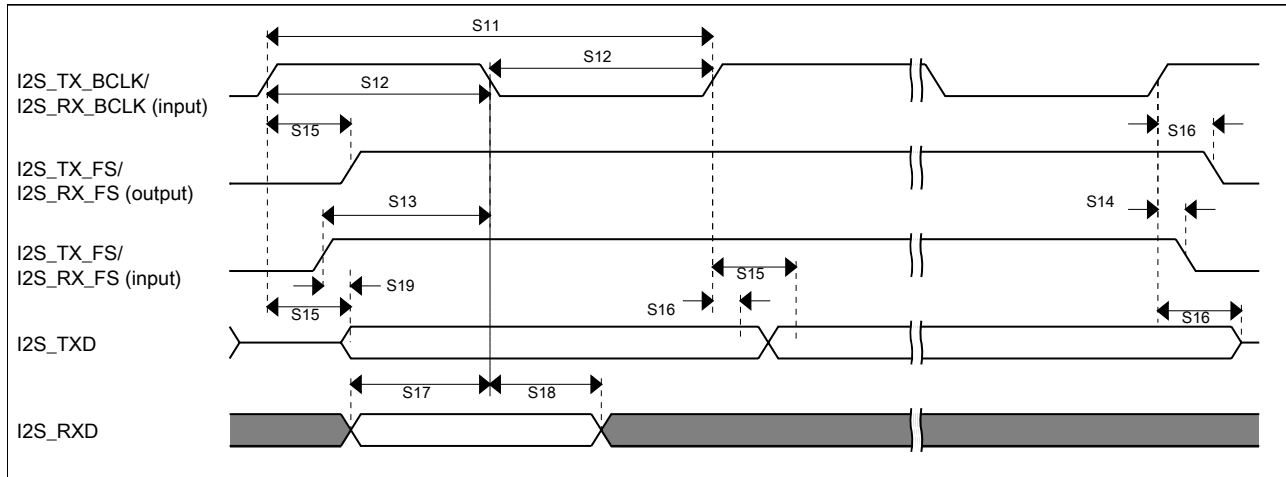


Figure 36. I2S/SAI timing — slave modes

3.8.12.2 VLPR, VLPW, and VLPS mode performance over the full operating voltage range

This section provides the operating performance over the full operating voltage for the device in VLPR, VLPW, and VLPS modes.

Table 59. I2S/SAI master mode timing in VLPR, VLPW, and VLPS modes (full voltage range)

| Num. | Characteristic | Min. | Max. | Unit |
|------|---|------|------|-------------|
| | Operating voltage | 1.71 | 3.6 | V |
| S1 | I2S_MCLK cycle time | 62.5 | — | ns |
| S2 | I2S_MCLK pulse width high/low | 45% | 55% | MCLK period |
| S3 | I2S_TX_BCLK/I2S_RX_BCLK cycle time (output) | 250 | — | ns |
| S4 | I2S_TX_BCLK/I2S_RX_BCLK pulse width high/low | 45% | 55% | BCLK period |
| S5 | I2S_TX_BCLK/I2S_RX_BCLK to I2S_TX_FS/ I2S_RX_FS output valid | — | 45 | ns |
| S6 | I2S_TX_BCLK/I2S_RX_BCLK to I2S_TX_FS/ I2S_RX_FS output invalid | 0 | — | ns |
| S7 | I2S_TX_BCLK to I2S_TXD valid | — | 45 | ns |
| S8 | I2S_TX_BCLK to I2S_TXD invalid | 0 | — | ns |
| S9 | I2S_RXD/I2S_RX_FS input setup before I2S_RX_BCLK | 45 | — | ns |
| S10 | I2S_RXD/I2S_RX_FS input hold after I2S_RX_BCLK | 0 | — | ns |

Peripheral operating requirements and behaviors



Figure 37. I2S/SAI timing — master modes

Table 60. I2S/SAI slave mode timing in VLPR, VLPW, and VLPS modes (full voltage range)

| Num. | Characteristic | Min. | Max. | Unit |
|------|--|------|------|-------------|
| | Operating voltage | 1.71 | 3.6 | V |
| S11 | I2S_TX_BCLK/I2S_RX_BCLK cycle time (input) | 250 | — | ns |
| S12 | I2S_TX_BCLK/I2S_RX_BCLK pulse width high/low (input) | 45% | 55% | MCLK period |
| S13 | I2S_TX_FS/I2S_RX_FS input setup before I2S_TX_BCLK/I2S_RX_BCLK | 30 | — | ns |
| S14 | I2S_TX_FS/I2S_RX_FS input hold after I2S_TX_BCLK/I2S_RX_BCLK | 5 | — | ns |
| S15 | I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output valid | — | 56.5 | ns |
| S16 | I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output invalid | 0 | — | ns |
| S17 | I2S_RXD setup before I2S_RX_BCLK | 30 | — | ns |
| S18 | I2S_RXD hold after I2S_RX_BCLK | 5 | — | ns |
| S19 | I2S_TX_FS input assertion to I2S_TXD output valid ¹ | — | 72 | ns |

1. Applies to first bit in each frame and only if the TCR4[FSE] bit is clear

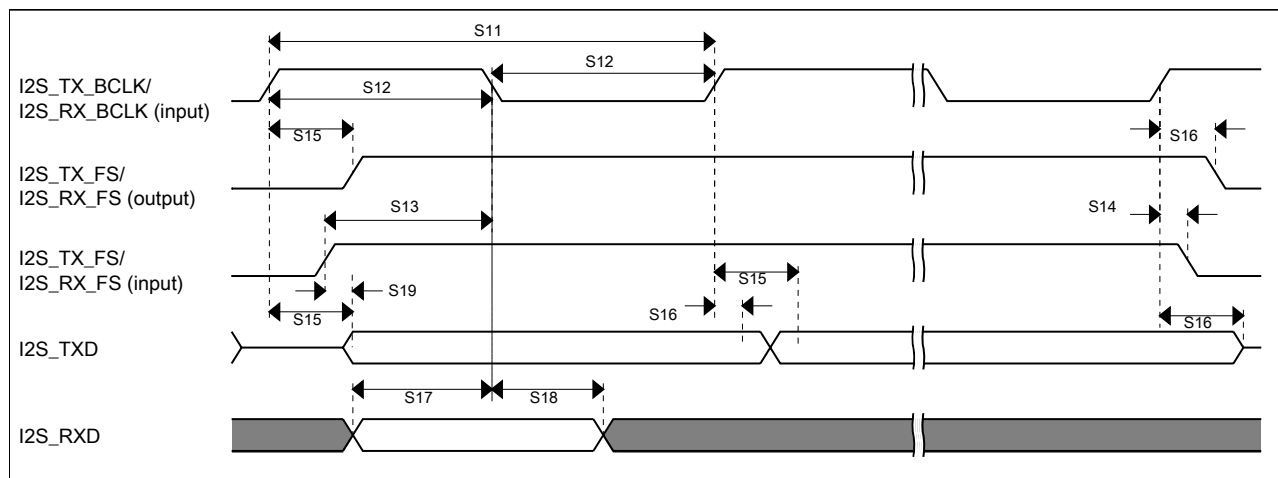


Figure 38. I2S/SAI timing — slave modes

3.9 Human-machine interfaces (HMI)

3.9.1 TSI electrical specifications

Table 61. TSI electrical specifications

| Symbol | Description | Min. | Typ. | Max. | Unit |
|-----------|--|------|------|------|------|
| TSI_RUNF | Fixed power consumption in run mode | — | 100 | — | μA |
| TSI_RUNV | Variable power consumption in run mode (depends on oscillator's current selection) | 1.0 | — | 128 | μA |
| TSI_EN | Power consumption in enable mode | — | 100 | — | μA |
| TSI_DIS | Power consumption in disable mode | — | 1.2 | — | μA |
| TSI_TEN | TSI analog enable time | — | 66 | — | μs |
| TSI_CREF | TSI reference capacitor | — | 1.0 | — | pF |
| TSI_DVOLT | Voltage variation of VP & VM around nominal values | 0.19 | — | 1.03 | V |

4 Dimensions

4.1 Obtaining package dimensions

Package dimensions are provided in package drawings.

Pinout

To find a package drawing, go to nxp.com and perform a keyword search for the drawing's document number:

| If you want the drawing for this package | Then use this document number |
|--|-------------------------------|
| 169-pin MAPBGA | 98ASA00628D |

5 Pinout

5.1 K65_169BGA Signal Multiplexing and Pin Assignments

The following table shows the signals available on each pin and the locations of these pins on the devices supported by this document. The Port Control Module is responsible for selecting which ALT functionality is available on each pin.

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------|----------------|-----------|-----------|----------------|-----------|-------------|--------------|---------------|----------|--------------|--------|
| A1 | PTE0 | ADC1_SE4a | ADC1_SE4a | PTE0 | SPI1_PCS1 | UART1_TX | SDHC0_D1 | TRACE_CLKOUT | I2C1_SDA | RTC_CLKOUT | |
| B1 | PTE1/LLWU_P0 | ADC1_SE5a | ADC1_SE5a | PTE1/LLWU_P0 | SPI1_SOUT | UART1_RX | SDHC0_D0 | TRACE_D3 | I2C1_SCL | SPI1_SIN | |
| C1 | PTE2/LLWU_P1 | ADC1_SE6a | ADC1_SE6a | PTE2/LLWU_P1 | SPI1_SCK | UART1_CTS_b | SDHC0_DCLK | TRACE_D2 | | | |
| D1 | PTE3 | ADC1_SE7a | ADC1_SE7a | PTE3 | SPI1_SIN | UART1_RTS_b | SDHC0_CMD | TRACE_D1 | | SPI1_SOUT | |
| G5 | VDD | VDD | VDD | | | | | | | | |
| C3 | VSS | VSS | VSS | | | | | | | | |
| E1 | PTE4/LLWU_P2 | DISABLED | | PTE4/LLWU_P2 | SPI1_PCS0 | UART3_TX | SDHC0_D3 | TRACE_D0 | | | |
| D2 | PTE5 | DISABLED | | PTE5 | SPI1_PCS2 | UART3_RX | SDHC0_D2 | | FTM3_CH0 | | |
| E2 | PTE6/LLWU_P16 | DISABLED | | PTE6/LLWU_P16 | SPI1_PCS3 | UART3_CTS_b | I2S0_MCLK | | FTM3_CH1 | USB0_SOF_OUT | |
| E3 | PTE7 | DISABLED | | PTE7 | | UART3_RTS_b | I2S0_RXD0 | | FTM3_CH2 | | |
| E4 | PTE8 | DISABLED | | PTE8 | I2S0_RXD1 | | I2S0_RX_FS | LPUART0_TX | FTM3_CH3 | | |
| F3 | PTE9/LLWU_P17 | DISABLED | | PTE9/LLWU_P17 | I2S0_TXD1 | | I2S0_RX_BCLK | LPUART0_RX | FTM3_CH4 | | |
| F4 | PTE10/LLWU_P18 | DISABLED | | PTE10/LLWU_P18 | I2C3_SDA | | I2S0_TXD0 | LPUART0_CTS_b | FTM3_CH5 | USB1_ID | |
| G4 | PTE11 | DISABLED | | PTE11 | I2C3_SCL | | I2S0_TX_FS | LPUART0_RTS_b | FTM3_CH6 | | |

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------|-----------|-----------------|------------------|------|-----------------|------------|--------|
| H4 | PTE12 | DISABLED | | PTE12 | | | I2S0_TX_ BCLK | | FTM3_CH7 | | |
| G6 | VDD | VDD | VDD | | | | | | | | |
| G8 | VSS | VSS | VSS | | | | | | | | |
| H3 | PTE16 | ADC0_SE4a | ADC0_SE4a | PTE16 | SPI0_PCS0 | UART2_TX | FTM_CLKIN0 | | FTM0_FLT3 | TPM_CLKIN0 | |
| F5 | PTE17/ LLWU_P19 | ADC0_SE5a | ADC0_SE5a | PTE17/ LLWU_P19 | SPI0_SCK | UART2_RX | FTM_CLKIN1 | | LPTMR0_ ALT3 | TPM_CLKIN1 | |
| F6 | PTE18/ LLWU_P20 | ADC0_SE6a | ADC0_SE6a | PTE18/ LLWU_P20 | SPI0_SOUT | UART2_CTS_ b | I2C0_SDA | | | | |
| F7 | PTE19 | ADC0_SE7a | ADC0_SE7a | PTE19 | SPI0_SIN | UART2_RTS_ b | I2C0_SCL | | CMP3_OUT | | |
| G3 | VSS | VSS | VSS | | | | | | | | |
| G1 | USB0_DP | USB0_DP | USB0_DP | | | | | | | | |
| F1 | USB0_DM | USB0_DM | USB0_DM | | | | | | | | |
| G2 | VREG_OUT | VREG_OUT | VREG_OUT | | | | | | | | |
| F2 | VREG_IN0 | VREG_IN0 | VREG_IN0 | | | | | | | | |
| H2 | VREG_IN1 | DISABLED | VREG_IN1 | | | | | | | | |
| K1 | USB1_VSS | DISABLED | USB1_VSS | | | | | | | | |
| J1 | USB1_DP | DISABLED | USB1_DP | | | | | | | | |
| H1 | USB1_DM | DISABLED | USB1_DM | | | | | | | | |
| J2 | USB1_VBUS | DISABLED | USB1_VBUS | | | | | | | | |
| L1 | ADC1_DP1 | ADC1_DP1 | ADC1_DP1 | | | | | | | | |
| M1 | ADC1_DM1 | ADC1_DM1 | ADC1_DM1 | | | | | | | | |
| M2 | ADC0_DP0/ ADC1_DP3 | ADC0_DP0/ ADC1_DP3 | ADC0_DP0/ ADC1_DP3 | | | | | | | | |
| L2 | ADC0_DM0/ ADC1_DM3 | ADC0_DM0/ ADC1_DM3 | ADC0_DM0/ ADC1_DM3 | | | | | | | | |
| N1 | ADC1_DP0/ ADC0_DP3 | ADC1_DP0/ ADC0_DP3 | ADC1_DP0/ ADC0_DP3 | | | | | | | | |
| N2 | ADC1_DM0/ ADC0_DM3 | ADC1_DM0/ ADC0_DM3 | ADC1_DM0/ ADC0_DM3 | | | | | | | | |
| J3 | VDDA | VDDA | VDDA | | | | | | | | |
| K3 | VREFH | VREFH | VREFH | | | | | | | | |
| K4 | VREFL | VREFL | VREFL | | | | | | | | |
| J4 | VSSA | VSSA | VSSA | | | | | | | | |
| M3 | ADC1_SE16/ CMP2_IN2/ ADC0_SE22 | ADC1_SE16/ CMP2_IN2/ ADC0_SE22 | ADC1_SE16/ CMP2_IN2/ ADC0_SE22 | | | | | | | | |
| L3 | ADC0_SE16/ CMP1_IN2/ ADC0_SE21 | ADC0_SE16/ CMP1_IN2/ ADC0_SE21 | ADC0_SE16/ CMP1_IN2/ ADC0_SE21 | | | | | | | | |

Pinout

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|--|--|--|--------------------|-------------------------------------|-----------------|----------|-------------------|----------------|------------------------|---------|
| N3 | VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18 | VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18 | VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18 | | | | | | | | |
| M4 | DAC0_OUT/ CMP1_IN3/ ADC0_SE23 | DAC0_OUT/ CMP1_IN3/ ADC0_SE23 | DAC0_OUT/ CMP1_IN3/ ADC0_SE23 | | | | | | | | |
| N4 | DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23 | DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23 | DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23 | | | | | | | | |
| M5 | TAMPER0/ RTC_ WAKEUP_B | TAMPER0/ RTC_ WAKEUP_B | TAMPER0/ RTC_ WAKEUP_B | | | | | | | | |
| L4 | TAMPER1 | TAMPER1 | TAMPER1 | | | | | | | | |
| L5 | TAMPER2 | TAMPER2 | TAMPER2 | | | | | | | | |
| K5 | TAMPER3 | TAMPER3 | TAMPER3 | | | | | | | | |
| L6 | TAMPER4 | TAMPER4 | TAMPER4 | | | | | | | | |
| K6 | TAMPER5 | TAMPER5 | TAMPER5 | | | | | | | | |
| N5 | XTAL32 | XTAL32 | XTAL32 | | | | | | | | |
| N6 | EXTAL32 | EXTAL32 | EXTAL32 | | | | | | | | |
| M6 | VBAT | VBAT | VBAT | | | | | | | | |
| J6 | TAMPER6 | TAMPER6 | TAMPER6 | | | | | | | | |
| J5 | TAMPER7 | TAMPER7 | TAMPER7 | | | | | | | | |
| G7 | VDD | VDD | VDD | | | | | | | | |
| N7 | VSS | VSS | VSS | | | | | | | | |
| L7 | PTE24 | ADC0_SE17 | ADC0_SE17 | PTE24 | CAN1_TX | UART4_TX | | I2C0_SCL | EWM_OUT_b | | |
| K7 | PTE25/ LLWU_P21 | ADC0_SE18 | ADC0_SE18 | PTE25/ LLWU_P21 | CAN1_RX | UART4_RX | | I2C0_SDA | EWM_IN | | |
| K8 | PTE26 | DISABLED | | PTE26 | ENET_1588_ CLKIN | UART4_CTS_ b | | | RTC_ CLKOUT | USB0_CLKIN | |
| L8 | PTE27 | DISABLED | | PTE27 | | UART4_RTS_ b | | | | | |
| M7 | PTE28 | DISABLED | | PTE28 | | | | | | | |
| N8 | PTA0 | JTAG_TCLK/ SWD_CLK/ EZP_CLK | TSIO_CH1 | PTA0 | UART0_CTS_ b/ UART0_COL_ b | FTM0_CH5 | | LPUART0_ CTS_b | | JTAG_TCLK/ SWD_CLK | EZP_CLK |
| N9 | PTA1 | JTAG_TDI/ EZP_DI | TSIO_CH2 | PTA1 | UART0_RX | FTM0_CH6 | I2C3_SDA | LPUART0_RX | | JTAG_TDI | EZP_DI |
| M9 | PTA2 | JTAG_TDO/ TRACE_ SWO/ EZP_DO | TSIO_CH3 | PTA2 | UART0_TX | FTM0_CH7 | I2C3_SCL | LPUART0_TX | | JTAG_TDO/ TRACE_SWO | EZP_DO |

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|--------------------|----------------------|-----------|--------------------|-----------------|-------------------------------------|--------------------------------|--------------------------|------------------------------|------------------------------|----------|
| M8 | PTA3 | JTAG_TMS/ SWD_DIO | TSIO_CH4 | PTA3 | UART0_RTS_ b | FTM0_CH0 | | LPUART0_ RTS_b | | JTAG_TMS/ SWD_DIO | |
| L9 | PTA4/ LLWU_P3 | NMI_b/ EZP_CS_b | TSIO_CH5 | PTA4/ LLWU_P3 | | FTM0_CH1 | | | | NMI_b | EZP_CS_b |
| N10 | PTA5 | DISABLED | | PTA5 | USB0_CLKIN | FTM0_CH2 | RMII0_RXER/ MII0_RXER | CMP2_OUT | I2S0_TX_ BCLK | JTAG_TRST_ b | |
| H5 | VDD | VDD | VDD | | | | | | | | |
| H8 | VSS | VSS | VSS | | | | | | | | |
| M10 | PTA6 | DISABLED | | PTA6 | | FTM0_CH3 | | CLKOUT | | TRACE_ CLKOUT | |
| L10 | PTA7 | ADC0_SE10 | ADC0_SE10 | PTA7 | | FTM0_CH4 | | RMII0_MDIO/ MII0_MDIO | | TRACE_D3 | |
| K9 | PTA8 | ADC0_SE11 | ADC0_SE11 | PTA8 | | FTM1_CH0 | | RMII0_MDC/ MII0_MDC | FTM1_QD_ PHA/ TPM1_CH0 | TRACE_D2 | |
| K10 | PTA9 | DISABLED | | PTA9 | | FTM1_CH1 | MII0_RXD3 | | FTM1_QD_ PHB/ TPM1_CH1 | TRACE_D1 | |
| N11 | PTA10/ LLWU_P22 | DISABLED | | PTA10/ LLWU_P22 | | FTM2_CH0 | MII0_RXD2 | | FTM2_QD_ PHA/ TPM2_CH0 | TRACE_D0 | |
| M11 | PTA11/ LLWU_P23 | DISABLED | | PTA11/ LLWU_P23 | | FTM2_CH1 | MII0_RXCLK | I2C2_SDA | FTM2_QD_ PHB/ TPM2_CH1 | | |
| L12 | PTA12 | CMP2_IN0 | CMP2_IN0 | PTA12 | CAN0_TX | FTM1_CH0 | RMII0_RXD1/ MII0_RXD1 | I2C2_SCL | I2S0_TXD0 | FTM1_QD_ PHA/ TPM1_CH0 | |
| L11 | PTA13/ LLWU_P4 | CMP2_IN1 | CMP2_IN1 | PTA13/ LLWU_P4 | CAN0_RX | FTM1_CH1 | RMII0_RXD0/ MII0_RXD0 | I2C2_SDA | I2S0_TX_FS | FTM1_QD_ PHB/ TPM1_CH1 | |
| K13 | PTA14 | DISABLED | | PTA14 | SPI0_PCS0 | UART0_TX | RMII0_CRS_ DV/ MII0_RXDV | I2C2_SCL | I2S0_RX_ BCLK | I2S0_TXD1 | |
| K12 | PTA15 | CMP3_IN1 | CMP3_IN1 | PTA15 | SPI0_SCK | UART0_RX | RMII0_TXEN/ MII0_TXEN | | I2S0_RXD0 | | |
| J13 | PTA16 | CMP3_IN2 | CMP3_IN2 | PTA16 | SPI0_SOUT | UART0_CTS_ b/ UART0_COL_ b | RMII0_TXD0/ MII0_TXD0 | | I2S0_RX_FS | I2S0_RXD1 | |
| J12 | PTA17 | ADC1_SE17 | ADC1_SE17 | PTA17 | SPI0_SIN | UART0_RTS_ b | RMII0_TXD1/ MII0_TXD1 | | I2S0_MCLK | | |
| N12 | VDD | VDD | VDD | | | | | | | | |
| M12 | VSS | VSS | VSS | | | | | | | | |
| N13 | PTA18 | EXTAL0 | EXTAL0 | PTA18 | | FTM0_FLT2 | FTM_CLKIN0 | | | TPM_CLKIN0 | |
| M13 | PTA19 | XTAL0 | XTAL0 | PTA19 | | FTM1_FLT0 | FTM_CLKIN1 | | LPTMR0_ ALT1 | TPM_CLKIN1 | |

Pinout

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|------------------|------------------------------------|------------------------------------|------------------|-----------------|-------------------------------------|--------------------------|-----------------------|------------------------------|------|--------|
| L13 | RESET_b | RESET_b | RESET_b | | | | | | | | |
| K11 | PTA24 | CMP3_IN4 | CMP3_IN4 | PTA24 | | | MII0_TXD2 | FB_A15/ SDRAM_D15 | FB_A29 | | |
| J11 | PTA25 | CMP3_IN5 | CMP3_IN5 | PTA25 | | | MII0_TXCLK | FB_A14/ SDRAM_D14 | FB_A28 | | |
| J10 | PTA26 | DISABLED | | PTA26 | | | MII0_TXD3 | FB_A13/ SDRAM_D13 | FB_A27 | | |
| H13 | PTA27 | DISABLED | | PTA27 | | | MII0_CRS | FB_A12/ SDRAM_D12 | FB_A26 | | |
| H12 | PTA28 | DISABLED | | PTA28 | | | MII0_TXER | | FB_A25 | | |
| H11 | PTA29 | DISABLED | | PTA29 | | | MII0_COL | | FB_A24 | | |
| H10 | PTA30 | DISABLED | | PTA30 | CAN0_TX | | | FB_A11/ SDRAM_D11 | | | |
| J9 | PTA31 | DISABLED | | PTA31 | CAN0_RX | | | FB_A10/ SDRAM_D10 | | | |
| G13 | PTB0/ LLWU_P5 | ADC0_SE8/ ADC1_SE8/ TSIO_CH0 | ADC0_SE8/ ADC1_SE8/ TSIO_CH0 | PTB0/ LLWU_P5 | I2C0_SCL | FTM1_CH0 | RMII0_MDIO/ MII0_MDIO | SDRAM_ CAS_b | FTM1_QD_ PHA/ TPM1_CH0 | | |
| G12 | PTB1 | ADC0_SE9/ ADC1_SE9/ TSIO_CH6 | ADC0_SE9/ ADC1_SE9/ TSIO_CH6 | PTB1 | I2C0_SDA | FTM1_CH1 | RMII0_MDC/ MII0_MDC | SDRAM_ RAS_b | FTM1_QD_ PHB/ TPM1_CH1 | | |
| G11 | PTB2 | ADC0_SE12/ TSIO_CH7 | ADC0_SE12/ TSIO_CH7 | PTB2 | I2C0_SCL | UART0_RTS_ b | ENET0_ 1588_TMR0 | SDRAM_WE | FTM0_FLT3 | | |
| G10 | PTB3 | ADC0_SE13/ TSIO_CH8 | ADC0_SE13/ TSIO_CH8 | PTB3 | I2C0_SDA | UART0_CTS_ b/ UART0_COL_ b | ENET0_ 1588_TMR1 | SDRAM_ CS0_b | FTM0_FLT0 | | |
| H9 | PTB4 | ADC1_SE10 | ADC1_SE10 | PTB4 | | | ENET0_ 1588_TMR2 | SDRAM_ CS1_b | FTM1_FLT0 | | |
| F13 | PTB5 | ADC1_SE11 | ADC1_SE11 | PTB5 | | | ENET0_ 1588_TMR3 | | FTM2_FLT0 | | |
| F12 | PTB6 | ADC1_SE12 | ADC1_SE12 | PTB6 | | | | FB_AD23/ SDRAM_D23 | | | |
| F11 | PTB7 | ADC1_SE13 | ADC1_SE13 | PTB7 | | | | FB_AD22/ SDRAM_D22 | | | |
| F10 | PTB8 | DISABLED | | PTB8 | | UART3_RTS_ b | | FB_AD21/ SDRAM_D21 | | | |
| F9 | PTB9 | DISABLED | | PTB9 | SPI1_PCS1 | UART3_CTS_ b | | FB_AD20/ SDRAM_D20 | | | |
| G9 | PTB10 | ADC1_SE14 | ADC1_SE14 | PTB10 | SPI1_PCS0 | UART3_RX | | FB_AD19/ SDRAM_D19 | FTM0_FLT1 | | |
| E13 | PTB11 | ADC1_SE15 | ADC1_SE15 | PTB11 | SPI1_SCK | UART3_TX | | FB_AD18/ SDRAM_D18 | FTM0_FLT2 | | |
| E12 | PTB12 | DISABLED | | PTB12 | UART3_RTS_ b | FTM1_CH0 | FTM0_CH4 | FB_A9/ SDRAM_D9 | FTM1_QD_ PHA/ TPM1_CH0 | | |

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|-------------------|--------------------------------------|--------------------------------------|-------------------|-------------|--------------|--------------|-----------------------|--------------------------|------------|--------|
| E11 | PTB13 | DISABLED | | PTB13 | UART3_CTS_b | FTM1_CH1 | FTM0_CH5 | FB_A8/ SDRAM_D8 | FTM1_QD_PHB/ TPM1_CH1 | | |
| E10 | PTB14 | DISABLED | | PTB14 | CAN1_TX | | | FB_A7/ SDRAM_D7 | | | |
| E9 | PTB15 | DISABLED | | PTB15 | CAN1_RX | | | FB_A6/ SDRAM_D6 | | | |
| F8 | PTB16 | TSIO_CH9 | TSIO_CH9 | PTB16 | SPI1_SOUT | UART0_RX | FTM_CLKIN0 | FB_AD17/ SDRAM_D17 | EWM_IN | TPM_CLKIN0 | |
| D13 | PTB17 | TSIO_CH10 | TSIO_CH10 | PTB17 | SPI1_SIN | UART0_TX | FTM_CLKIN1 | FB_AD16/ SDRAM_D16 | EWM_OUT_b | TPM_CLKIN1 | |
| D12 | PTB18 | TSIO_CH11 | TSIO_CH11 | PTB18 | CAN0_TX | FTM2_CH0 | I2S0_TX_BCLK | FB_AD15/ SDRAM_A23 | FTM2_QD_PHA/ TPM2_CH0 | | |
| D11 | PTB19 | TSIO_CH12 | TSIO_CH12 | PTB19 | CAN0_RX | FTM2_CH1 | I2S0_TX_FS | FB_OE_b | FTM2_QD_PHB/ TPM2_CH1 | | |
| D10 | PTB20 | DISABLED | | PTB20 | SPI2_PCS0 | | | FB_AD31/ SDRAM_D31 | CMP0_OUT | | |
| D9 | PTB21 | DISABLED | | PTB21 | SPI2_SCK | | | FB_AD30/ SDRAM_D30 | CMP1_OUT | | |
| C13 | PTB22 | DISABLED | | PTB22 | SPI2_SOUT | | | FB_AD29/ SDRAM_D29 | CMP2_OUT | | |
| C12 | PTB23 | DISABLED | | PTB23 | SPI2_SIN | SPI0_PCS5 | | FB_AD28/ SDRAM_D28 | CMP3_OUT | | |
| B13 | PTC0 | ADC0_SE14/ TSIO_CH13 | ADC0_SE14/ TSIO_CH13 | PTC0 | SPI0_PCS4 | PDB0_EXTRG | USB0_SOF_OUT | FB_AD14/ SDRAM_A22 | I2S0_TXD1 | | |
| B12 | PTC1/ LLWU_P6 | ADC0_SE15/ TSIO_CH14 | ADC0_SE15/ TSIO_CH14 | PTC1/ LLWU_P6 | SPI0_PCS3 | UART1_RTS_b | FTM0_CH0 | FB_AD13/ SDRAM_A21 | I2S0_TXD0 | | |
| A13 | PTC2 | ADC0_SE4b/ CMP1_IN0/ TSIO_CH15 | ADC0_SE4b/ CMP1_IN0/ TSIO_CH15 | PTC2 | SPI0_PCS2 | UART1_CTS_b | FTM0_CH1 | FB_AD12/ SDRAM_A20 | I2S0_TX_FS | | |
| A12 | PTC3/ LLWU_P7 | CMP1_IN1 | CMP1_IN1 | PTC3/ LLWU_P7 | SPI0_PCS1 | UART1_RX | FTM0_CH2 | CLKOUT | I2S0_TX_BCLK | | |
| C11 | VSS | VSS | VSS | | | | | | | | |
| H6 | VDD | VDD | VDD | | | | | | | | |
| B11 | PTC4/ LLWU_P8 | DISABLED | | PTC4/ LLWU_P8 | SPI0_PCS0 | UART1_TX | FTM0_CH3 | FB_AD11/ SDRAM_A19 | CMP1_OUT | | |
| A11 | PTC5/ LLWU_P9 | DISABLED | | PTC5/ LLWU_P9 | SPI0_SCK | LPTMR0_ALT2 | I2S0_RXD0 | FB_AD10/ SDRAM_A18 | CMP0_OUT | FTM0_CH2 | |
| A10 | PTC6/ LLWU_P10 | CMP0_IN0 | CMP0_IN0 | PTC6/ LLWU_P10 | SPI0_SOUT | PDB0_EXTRG | I2S0_RX_BCLK | FB_AD9/ SDRAM_A17 | I2S0_MCLK | | |
| B10 | PTC7 | CMP0_IN1 | CMP0_IN1 | PTC7 | SPI0_SIN | USB0_SOF_OUT | I2S0_RX_FS | FB_AD8/ SDRAM_A16 | | | |
| C10 | PTC8 | ADC1_SE4b/ CMP0_IN2 | ADC1_SE4b/ CMP0_IN2 | PTC8 | | FTM3_CH4 | I2S0_MCLK | FB_AD7/ SDRAM_A15 | | | |

Pinout

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|--------------------|------------------------|------------------------|--------------------|----------|-------------------|---------------------|---|-----------|------------|--------|
| C9 | PTC9 | ADC1_SE5b/ CMP0_IN3 | ADC1_SE5b/ CMP0_IN3 | PTC9 | | FTM3_CH5 | I2S0_RX_ BCLK | FB_AD6/ SDRAM_A14 | FTM2_FLT0 | | |
| A8 | PTC10 | ADC1_SE6b | ADC1_SE6b | PTC10 | I2C1_SCL | FTM3_CH6 | I2S0_RX_FS | FB_AD5/ SDRAM_A13 | | | |
| A9 | PTC11/ LLWU_P11 | ADC1_SE7b | ADC1_SE7b | PTC11/ LLWU_P11 | I2C1_SDA | FTM3_CH7 | I2S0_RXD1 | FB_RW_b | | | |
| B9 | PTC12 | DISABLED | | PTC12 | | UART4_RTS_ b | FTM_CLKIN0 | FB_AD27/ SDRAM_D27 | FTM3_FLT0 | TPM_CLKIN0 | |
| B8 | PTC13 | DISABLED | | PTC13 | | UART4_CTS_ b | FTM_CLKIN1 | FB_AD26/ SDRAM_D26 | | TPM_CLKIN1 | |
| C8 | PTC14 | DISABLED | | PTC14 | | UART4_RX | | FB_AD25/ SDRAM_D25 | | | |
| D8 | PTC15 | DISABLED | | PTC15 | | UART4_TX | | FB_AD24/ SDRAM_D24 | | | |
| E8 | PTC16 | DISABLED | | PTC16 | CAN1_RX | UART3_RX | ENET0_ 1588_TMR0 | FB_CS5_b/ FB_TSIZ1/ FB_BE23_ 16_BLS15_8_ b/ SDRAM_ DQM2 | | | |
| E7 | PTC17 | DISABLED | | PTC17 | CAN1_TX | UART3_TX | ENET0_ 1588_TMR1 | FB_CS4_b/ FB_TSIZ0/ FB_BE31_ 24_BLS7_0_ b/ SDRAM_ DQM3 | | | |
| D7 | PTC18 | DISABLED | | PTC18 | | UART3_RTS_ b | ENET0_ 1588_TMR2 | FB_TBST_b/ FB_CS2_b/ FB_BE15_8_ BLS23_16_b/ SDRAM_ DQM1 | | | |
| C7 | PTC19 | DISABLED | | PTC19 | | UART3_CTS_ b | ENET0_ 1588_TMR3 | FB_CS3_b/ FB_BE7_0_ BLS31_24_b/ SDRAM_ DQM0 | FB_TA_b | | |
| B7 | PTC24 | DISABLED | | PTC24 | | LPUART0_TX | | FB_A5/ SDRAM_D5 | | | |
| A7 | PTC25 | DISABLED | | PTC25 | | LPUART0_RX | | FB_A4/ SDRAM_D4 | | | |
| E6 | PTC26 | DISABLED | | PTC26 | | LPUART0_ CTS_b | ENET0_ 1588_TMR0 | FB_A3/ SDRAM_D3 | | | |
| D6 | PTC27 | DISABLED | | PTC27 | | LPUART0_ RTS_b | ENET0_ 1588_TMR1 | FB_A2/ SDRAM_D2 | | | |

| 169 MAP BGA | Pin Name | Default | ALT0 | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | EzPort |
|-------------------|--------------------|-----------|-----------|--------------------|-----------|-----------------------------|-----------------|---------------------------------|-----------|-----------|--------|
| C6 | PTC28 | DISABLED | | PTC28 | I2C3_SDA | | ENET0_1588_TMR2 | FB_A1/SDRAM_D1 | | | |
| B6 | PTC29 | DISABLED | | PTC29 | I2C3_SCL | | ENET0_1588_TMR3 | FB_A0/SDRAM_D0 | | | |
| A6 | PTD0/ LLWU_P12 | DISABLED | | PTD0/ LLWU_P12 | SPI0_PCS0 | UART2_RTS_b | FTM3_CH0 | FB_ALE/ FB_CS1_b/ FB_TS_b | | | |
| A5 | PTD1 | ADC0_SE5b | ADC0_SE5b | PTD1 | SPI0_SCK | UART2_CTS_b | FTM3_CH1 | FB_CS0_b | | | |
| A4 | PTD2/ LLWU_P13 | DISABLED | | PTD2/ LLWU_P13 | SPI0_SOUT | UART2_RX | FTM3_CH2 | FB_AD4/ SDRAM_A12 | | I2C0_SCL | |
| B4 | PTD3 | DISABLED | | PTD3 | SPI0_SIN | UART2_TX | FTM3_CH3 | FB_AD3/ SDRAM_A11 | | I2C0_SDA | |
| B5 | PTD4/ LLWU_P14 | DISABLED | | PTD4/ LLWU_P14 | SPI0_PCS1 | UART0_RTS_b | FTM0_CH4 | FB_AD2/ SDRAM_A10 | EWM_IN | SPI1_PCS0 | |
| C4 | PTD5 | ADC0_SE6b | ADC0_SE6b | PTD5 | SPI0_PCS2 | UART0_CTS_b/ UART0_COL_b | FTM0_CH5 | FB_AD1/ SDRAM_A9 | EWM_OUT_b | SPI1_SCK | |
| C5 | PTD6/ LLWU_P15 | ADC0_SE7b | ADC0_SE7b | PTD6/ LLWU_P15 | SPI0_PCS3 | UART0_RX | FTM0_CH6 | FB_AD0 | FTM0_FLT0 | SPI1_SOUT | |
| J8 | VSS | VSS | VSS | | | | | | | | |
| H7 | VDD | VDD | VDD | | | | | | | | |
| E5 | PTD7 | DISABLED | | PTD7 | CMT_IRO | UART0_TX | FTM0_CH7 | SDRAM_CKE | FTM0_FLT1 | SPI1_SIN | |
| D5 | PTD8/ LLWU_P24 | DISABLED | | PTD8/ LLWU_P24 | I2C0_SCL | | | LPUART0_RX | FB_A16 | | |
| D4 | PTD9 | DISABLED | | PTD9 | I2C0_SDA | | | LPUART0_TX | FB_A17 | | |
| D3 | PTD10 | DISABLED | | PTD10 | | | | LPUART0_RTS_b | FB_A18 | | |
| C2 | PTD11/ LLWU_P25 | DISABLED | | PTD11/ LLWU_P25 | SPI2_PCS0 | | SDHC0_CLKIN | LPUART0_CTS_b | FB_A19 | | |
| B2 | PTD12 | DISABLED | | PTD12 | SPI2_SCK | FTM3_FLT0 | SDHC0_D4 | | FB_A20 | | |
| B3 | PTD13 | DISABLED | | PTD13 | SPI2_SOUT | | SDHC0_D5 | | FB_A21 | | |
| A2 | PTD14 | DISABLED | | PTD14 | SPI2_SIN | | SDHC0_D6 | | FB_A22 | | |
| A3 | PTD15 | DISABLED | | PTD15 | SPI2_PCS1 | | SDHC0_D7 | | FB_A23 | | |
| J7 | NC | NC | NC | | | | | | | | |
| K2 | NC | NC | NC | | | | | | | | |

5.2 Recommended connection for unused analog and digital pins

Table 62 shows the recommended connections for analog interface pins if those analog interfaces are not used in the customer's application

Table 62. Recommended connection for unused analog interfaces

| Pin Type | K65 | Short recommendation | Detailed recommendation |
|-----------------|--------------------|---|---|
| Analog/non GPIO | ADCx/CMPx | Float | Analog input - Float |
| Analog/non GPIO | VREF_OUT | Float | Analog output - Float |
| Analog/non GPIO | DAC0_OUT, DAC1_OUT | Float | Analog output - Float |
| Analog/non GPIO | RTC_WAKEUP_B | Float | Analog output - Float |
| Analog/non GPIO | XTAL32 | Float | Analog output - Float |
| Analog/non GPIO | EXTAL32 | Float | Analog input - Float |
| GPIO/Analog | PTA18/EXTAL0 | Float | Analog input - Float |
| GPIO/Analog | PTA19/XTAL0 | Float | Analog output - Float |
| GPIO/Analog | PTx/ADCx | Float | Float (default is analog input) |
| GPIO/Analog | PTx/CMPx | Float | Float (default is analog input) |
| GPIO/Analog | PTx/TSIOx | Float | Float (default is analog input) |
| GPIO/Digital | PTA0/JTAG_TCLK | Float | Float (default is JTAG with pulldown) |
| GPIO/Digital | PTA1/JTAG_TDI | Float | Float (default is JTAG with pullup) |
| GPIO/Digital | PTA2/JTAG_TDO | Float | Float (default is JTAG with pullup) |
| GPIO/Digital | PTA3/JTAG_TMS | Float | Float (default is JTAG with pullup) |
| GPIO/Digital | PTA4/NMI_b | 10k Ω pullup or disable and float | Pull high or disable in PCR & FOPT and float |
| GPIO/Digital | PTx | Float | Float (default is disabled) |
| USB | USB0_DP | Float | Float |
| USB | USB0_DM | Float | Float |
| USB | VREG_OUT | Tie to input and ground through 10k Ω | Tie to input and ground through 10k Ω |
| USB | VREG_IN0 | Tie to output and ground through 10k Ω | Tie to output and ground through 10k Ω |
| USB | VREG_IN1 | Tie to output and ground through 10k Ω | Tie to output and ground through 10k Ω |
| USB | USB1_VSS | Always connect to VSS | Always connect to VSS |
| USB | USB1_DP | Float | Float |
| USB | USB1_DM | Float | Float |
| USB | USB1_VBUS | Float | Float |
| VBAT | VBAT | Float | Float |
| VDDA | VDDA | Always connect to VDD potential | Always connect to VDD potential |
| VREFH | VREFH | Always connect to VDD potential | Always connect to VDD potential |
| VREFL | VREFL | Always connect to VSS potential | Always connect to VSS potential |

Table continues on the next page...

Table 62. Recommended connection for unused analog interfaces (continued)

| Pin Type | K65 | Short recommendation | Detailed recommendation |
|----------|------|---------------------------------|---------------------------------|
| VSSA | VSSA | Always connect to VSS potential | Always connect to VSS potential |

5.3 K65 Pinouts

The below figure shows the pinout diagram for the devices supported by this document. Many signals may be multiplexed onto a single pin. To determine what signals can be used on which pin, see the previous section.

Ordering parts

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
|---|-----------------------|-----------------------|--|--|------------------------------|--------------------|--------------------|-------|--------------------|-------------------|--------------------|------------------|------------------|---|
| A | PTE0 | PTD14 | PTD15 | PTD2/ LLWU_P13 | PTD1 | PTD0/ LLWU_P12 | PTC25 | PTC10 | PTC11/ LLWU_P11 | PTC6/ LLWU_P10 | PTC5/ LLWU_P9 | PTC3/ LLWU_P7 | PTC2 | A |
| B | PTE1/ LLWU_P0 | PTD12 | PTD13 | PTD3 | PTD4/ LLWU_P14 | PTC29 | PTC24 | PTC13 | PTC12 | PTC7 | PTC4/ LLWU_P8 | PTC1/ LLWU_P6 | PTC0 | B |
| C | PTE2/ LLWU_P1 | PTD11/ LLWU_P25 | VSS | PTD5 | PTD6/ LLWU_P15 | PTC28 | PTC19 | PTC14 | PTC9 | PTC8 | VSS | PTB23 | PTB22 | C |
| D | PTE3 | PTE5 | PTD10 | PTD9 | PTD8/ LLWU_P24 | PTC27 | PTC18 | PTC15 | PTB21 | PTB20 | PTB19 | PTB18 | PTB17 | D |
| E | PTE4/ LLWU_P2 | PTE6/ LLWU_P16 | PTE7 | PTE8 | PTD7 | PTC26 | PTC17 | PTC16 | PTB15 | PTB14 | PTB13 | PTB12 | PTB11 | E |
| F | USB0_DM | VREG_IN0 | PTE9/ LLWU_P17 | PTE10/ LLWU_P18 | PTE17/ LLWU_P19 | PTE18/ LLWU_P20 | PTE19 | PTB16 | PTB9 | PTB8 | PTB7 | PTB6 | PTB5 | F |
| G | USB0_DP | VREG_OUT | VSS | PTE11 | VDD | VDD | VDD | VSS | PTB10 | PTB3 | PTB2 | PTB1 | PTB0/ LLWU_P5 | G |
| H | USB1_DM | VREG_IN1 | PTE16 | PTE12 | VDD | VDD | VDD | VSS | PTB4 | PTA30 | PTA29 | PTA28 | PTA27 | H |
| J | USB1_DP | JSB1_VBUS | VDDA | VSSA | TAMPER7 | TAMPER6 | NC | VSS | PTA31 | PTA26 | PTA25 | PTA17 | PTA16 | J |
| K | USB1_VSS | NC | VREFH | VREFL | TAMPER3 | TAMPER5 | PTE25/ LLWU_P21 | PTE26 | PTA8 | PTA9 | PTA24 | PTA15 | PTA14 | K |
| L | ADC1_DP1 | ADC0_DM0/ ADC1_DM3 | ADC0_SE16/ CMP1_IN2/ ADC0_SE21 | TAMPER1 | TAMPER2 | TAMPER4 | PTE24 | PTE27 | PTA4/ LLWU_P3 | PTA7 | PTA13/ LLWU_P4 | PTA12 | RESET_b | L |
| M | ADC1_DM1 | ADC0_DP0/ ADC1_DP3 | ADC1_SE16/ CMP2_IN2/ ADC0_SE22 | DAC0_OUT/ CMP1_IN3/ ADC0_SE23 | TAMPER0/ RTC_ WAKEUP_B | VBAT | PTE28 | PTA3 | PTA2 | PTA6 | PTA11/ LLWU_P23 | VSS | PTA19 | M |
| N | ADC1_DP0/ ADC0_DP3 | ADC1_DM0/ ADC0_DM3 | VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18 | DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23 | XTAL32 | EXTAL32 | VSS | PTA0 | PTA1 | PTA5 | PTA10/ LLWU_P22 | VDD | PTA18 | N |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |

Figure 39. K65 169 MAPBGA Pinout Diagram

6 Ordering parts

6.1 Determining valid orderable parts

Valid orderable part numbers are provided on the web. To determine the orderable part numbers for this device, go to nxp.com and perform a part number search for the following device numbers: PK65 and MK65

7 Part identification

7.1 Description

Part numbers for the chip have fields that identify the specific part. You can use the values of these fields to determine the specific part you have received.

7.2 Format

Part numbers for this device have the following format:

Q K## A M FFF R T PP CC N

7.3 Fields

This table lists the possible values for each field in the part number (not all combinations are valid):

| Field | Description | Values |
|-------|---------------------------|--|
| Q | Qualification status | <ul style="list-style-type: none"> M = Fully qualified, general market flow P = Prequalification |
| K## | Kinetis family | <ul style="list-style-type: none"> K65 K66 |
| A | Key attribute | <ul style="list-style-type: none"> D = Cortex-M4 w/ DSP F = Cortex-M4 w/ DSP and FPU |
| M | Flash memory type | <ul style="list-style-type: none"> N = Program flash only X = Program flash and FlexMemory |
| FFF | Program flash memory size | <ul style="list-style-type: none"> 32 = 32 KB 64 = 64 KB 128 = 128 KB 256 = 256 KB 512 = 512 KB 768 = 768 KB |

Table continues on the next page...

Terminology and guidelines

| Field | Description | Values |
|-------|-----------------------------|--|
| | | <ul style="list-style-type: none">• 1M0 = 1 MB• 2M0 = 2 MB |
| R | Silicon revision | <ul style="list-style-type: none">• Z = Initial• (Blank) = Main• A = Revision after main |
| T | Temperature range (°C) | <ul style="list-style-type: none">• V = -40 to 105• C = -40 to 85 |
| PP | Package identifier | <ul style="list-style-type: none">• FM = 32 QFN (5 mm x 5 mm)• FT = 48 QFN (7 mm x 7 mm)• LF = 48 LQFP (7 mm x 7 mm)• LH = 64 LQFP (10 mm x 10 mm)• MP = 64 MAPBGA (5 mm x 5 mm)• LK = 80 LQFP (12 mm x 12 mm)• LL = 100 LQFP (14 mm x 14 mm)• MC = 121 MAPBGA (8 mm x 8 mm)• LQ = 144 LQFP (20 mm x 20 mm)• MD = 144 MAPBGA (13 mm x 13 mm)• MI = 169 MAPBGA (9 mm x 9 mm)• AC = 169 WLCSP (5.6 mm x 5.5 mm) |
| CC | Maximum CPU frequency (MHz) | <ul style="list-style-type: none">• 5 = 50 MHz• 7 = 72 MHz• 10 = 100 MHz• 12 = 120 MHz• 15 = 150 MHz• 16 = 168 MHz• 18 = 180 MHz |
| N | Packaging type | <ul style="list-style-type: none">• R = Tape and reel• (Blank) = Trays |

7.4 Example

This is an example part number:

MK65FN2M0VMI18

8 Terminology and guidelines

8.1 Definitions

Key terms are defined in the following table:

| Term | Definition |
|-----------------------|--|
| Rating | <p>A minimum or maximum value of a technical characteristic that, if exceeded, may cause permanent chip failure:</p> <ul style="list-style-type: none"> • <i>Operating ratings</i> apply during operation of the chip. • <i>Handling ratings</i> apply when the chip is not powered. <p>NOTE: The likelihood of permanent chip failure increases rapidly as soon as a characteristic begins to exceed one of its operating ratings.</p> |
| Operating requirement | A specified value or range of values for a technical characteristic that you must guarantee during operation to avoid incorrect operation and possibly decreasing the useful life of the chip |
| Operating behavior | A specified value or range of values for a technical characteristic that are guaranteed during operation if you meet the operating requirements and any other specified conditions |
| Typical value | <p>A specified value for a technical characteristic that:</p> <ul style="list-style-type: none"> • Lies within the range of values specified by the operating behavior • Is representative of that characteristic during operation when you meet the typical-value conditions or other specified conditions <p>NOTE: Typical values are provided as design guidelines and are neither tested nor guaranteed.</p> |

8.2 Examples

Operating rating:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|---------------------------|------|------|------|
| V _{DD} | 1.0 V core supply voltage | -0.3 | 1.2 | V |

Operating requirement:

| Symbol | Description | Min. | Max. | Unit |
|-----------------|---------------------------|------|------|------|
| V _{DD} | 1.0 V core supply voltage | 0.9 | 1.1 | V |

Operating behavior that includes a typical value:

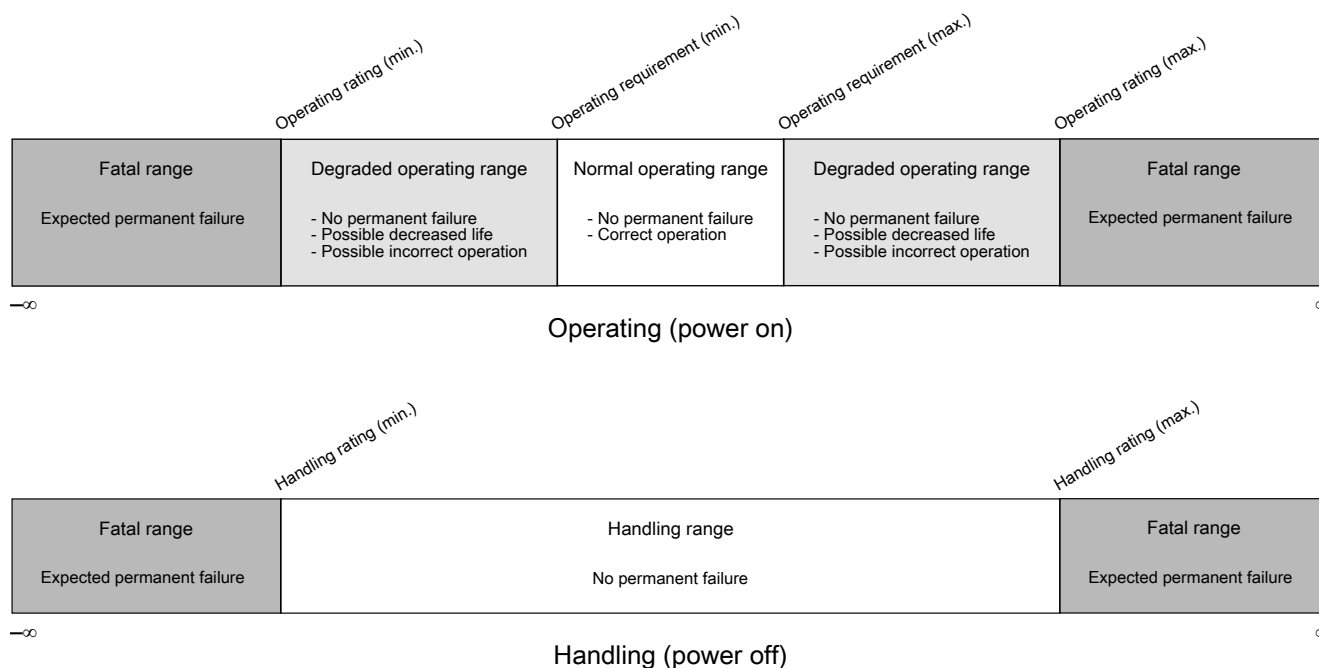
| Symbol | Description | Min. | Typ. | Max. | Unit |
|-----------------|--|------|------|------|------|
| I _{WP} | Digital I/O weak pullup/pulldown current | 10 | 70 | 130 | μA |

8.3 Typical-value conditions

Typical values assume you meet the following conditions (or other conditions as specified):

| Symbol | Description | Value | Unit |
|-----------------|---------------------|-------|------|
| T _A | Ambient temperature | 25 | °C |
| V _{DD} | Supply voltage | 3.3 | V |

8.4 Relationship between ratings and operating requirements



8.5 Guidelines for ratings and operating requirements

Follow these guidelines for ratings and operating requirements:

- Never exceed any of the chip’s ratings.
- During normal operation, don’t exceed any of the chip’s operating requirements.
- If you must exceed an operating requirement at times other than during normal operation (for example, during power sequencing), limit the duration as much as possible.

9 Revision History

The following table provides a revision history for this document.

Table 63. Revision History

| Rev. No. | Date | Substantial Changes |
|----------|---------|---|
| 0 | 02/2015 | Initial Release |
| 1 | 04/2015 | <ul style="list-style-type: none"> • Editorial change • Updated OTG/EH and BC rev. 1.2 specification references in USB Full Speed Transceiver and High Speed PHY specifications section • Updated USBDCD electrical specifications table • Updated the typical values and maximum values of specs in Power consumption operating behaviors table • Removed PSTOP2 current from Power consumption operating behaviors table • Updated the values of DS5 and DS7 in Master mode DSPI timing (full voltage range) table • Updated the footnote and description of V_{DIO}, V_{AIO} and I_D in Voltage and current operating ratings table • Updated the values and description of specs in Voltage and current operating requirements table • Updated the leakage current specs in Voltage and current operating behaviors table • Added Notes column in Thermal operating requirements • Updated the values of 48MHz IRC in Low power mode peripheral adders table • Added new footnotes for I_{INRUSH} in USB VREG electrical specifications table to better document operation. • Updated the figures "SDRAM write timing diagram" and SDRAM read timing diagram" in the section "SDRAM controller specifications." • Updated the pinout table, and pinout diagrams in the section "Pinouts." |
| 2 | 05/2015 | <ul style="list-style-type: none"> • Added new footnotes for I_{INRUSH} in USB VREG electrical specifications table to better document operation. |
| 3 | 01/2016 | <ul style="list-style-type: none"> • Updated the symbol in footnote of Thermal Operating specs • Updated the description of PLL operating current in MCG specifications table • Updated the values of IRC48M specifications table • Added USB FS and USB HS logo in front page • Updated Terminology and guidelines section • Updated the maximum values of I_{DD_LLS2} and I_{DD_LLS3} in Power consumption operating behaviors table |
| 4 | 03/2017 | <ul style="list-style-type: none"> • Removed the verbiage of "except RTC_WAKEUP pins" from the description for R_{PU} and R_{PD} in Voltage and current operating behaviors table • Updated the unit of ADC conversion rate from "Kbps" to "kS/s" in 16-bit ADC operating conditions table • Added MII signal switching specifications table and RMII signal switching specifications table for full voltage range • Added MDIO serial management timing specifications section • Updated I2C switching specifications section • Updated the minimum and maximum value of Voltage reference output with factory trim in VREF full-range operating requirements table in Voltage reference electrical specifications section |

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