Document Number K10P144M120SF3
Rev. 7, 02/2018

K10P144M120SF3

K10 Sub-Family

Supports the following:
MK10FX512VLQ12,
MK10FN1M0VLQ12,
MK10FX512VMD12,
MK10FN1M0VMD12

Key features

- Operating Characteristics
  - Voltage range: 1.71 to 3.6 V
  - Flash write voltage range: 1.71 to 3.6 V
  - Temperature range (ambient): -40 to 105°C
- Performance
  - Up to 120 MHz Arm® Cortex®-M4 core with DSP instructions delivering 1.25 Dhrystone MIPS per MHz
- Memories and memory interfaces
  - Up to 1024 KB program flash memory on non-FlexMemory devices
  - Up to 512 KB program flash memory on FlexMemory devices
  - Up to 512 KB FlexNVM on FlexMemory devices
  - 16 KB FlexRAM on FlexMemory devices
  - Up to 128 KB RAM
  - Serial programming interface (EzPort)
  - FlexBus external bus interface
  - NAND flash controller interface
- Clocks
  - 3 to 32 MHz crystal oscillator
  - 32 kHz crystal oscillator
  - Multi-purpose clock generator
- System peripherals
  - Multiple low-power modes to provide power optimization based on application requirements
  - Memory protection unit with multi-master protection
  - 32-channel DMA controller, supporting up to 128 request sources
  - External watchdog monitor
  - Software watchdog
  - Low-leakage wakeup unit
- Security and integrity modules
  - Hardware CRC module to support fast cyclic redundancy checks
  - 128-bit unique identification (ID) number per chip
- Human-machine interface
  - Low-power hardware touch sensor interface (TSI)
  - General-purpose input/output
- Analog modules
  - Four 16-bit SAR ADCs
  - Programmable gain amplifier (PGA) (up to x64) integrated into each ADC
  - Two 12-bit DACs
  - Four analog comparators (CMP) containing a 6-bit DAC and programmable reference input
  - Voltage reference
- Timers
  - Programmable delay block
  - Two 8-channel motor control/general purpose/PWM timers
  - Two 2-channel quadrature decoder/general purpose timers
  - Periodic interrupt timers
  - 16-bit low-power timer
  - Carrier modulator transmitter
  - Real-time clock
- Communication interfaces
  - Two Controller Area Network (CAN) modules
  - Three SPI modules
  - Two I2C modules
  - Six UART modules
  - Secure Digital Host Controller (SDHC)
  - Two I2S modules

Table of Contents

1 Ordering parts

1.1 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: PK10 and MK10

2 Part identification

2.1 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.

2.2 Format

Part numbers for this device have the following format:

Q K## A M FFF T PP CC N

2.3 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	• M = Fully qualified, general market flow • P = Prequalification
K##	Kinetis family	• K10
A	Key attribute	• F = Cortex-M4 w/ DSP and FPU
M	Flash memory type	• N = Program flash only • X = Program flash and FlexMemory
FFF	Program flash memory size	• 512 = 512 KB • 1M0 = 1 MB

Table continues on the next page...

Field	Description	Values
T	Temperature range (°C)	• V = –40 to 105 • C = –40 to 85
PP	Package identifier	• LQ = 144 LQFP (20 mm x 20 mm) • MD = 144 MAPBGA (13 mm x 13 mm)
CC	Maximum CPU frequency (MHz)	• 12 = 120 MHz
N	Packaging type	• R = Tape and reel • (Blank) = Trays

2.4 Example

This is an example part number:

MK10FN1M0VLQ12

3 Terminology and guidelines

3.1 Definitions

Key terms are defined in the following table:

Term	Definition
Rating	A minimum or maximum value of a technical characteristic that, if exceeded, may cause permanent chip failure: • *Operating ratings* apply during operation of the chip. • *Handling ratings* apply when the chip is not powered. **NOTE:** The likelihood of permanent chip failure increases rapidly as soon as a characteristic begins to exceed one of its operating ratings.
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	A specified value for a technical characteristic that: • 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 **NOTE:** Typical values are provided as design guidelines and are neither tested nor guaranteed.

3.2 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*:

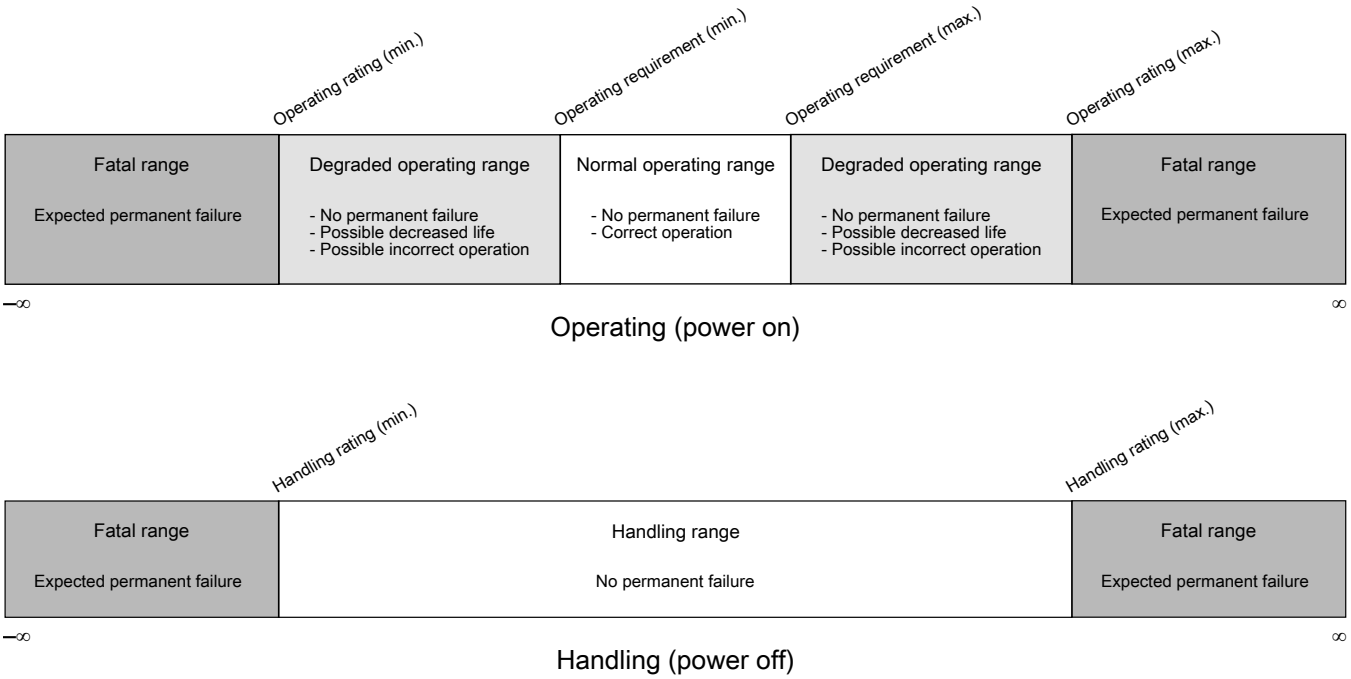
Symbol	Description	Min.	Typ.	Max.	Unit
I_{WP}	Digital I/O weak pullup/pulldown current	10	70	130	µA

3.3 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

3.4 Relationship between ratings and operating requirements



3.5 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.

4 Ratings

4.1 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*.

4.2 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*.

4.3 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*.

4.4 Voltage and current operating ratings

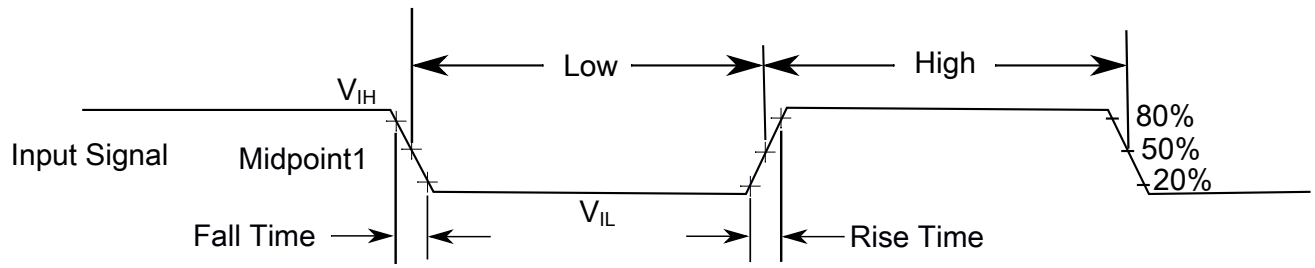
Symbol	Description	Min.	Max.	Unit
V_{DD}	Digital supply voltage[1]	–0.3	3.8	V
I_{DD}	Digital supply current	—	300	mA
V_{DIO}	Digital input voltage (except $\overline{\text{RESET}}$, EXTAL0/XTAL0, and EXTAL1/XTAL1) [2]	–0.3	5.5	V
V_{AIO}	Analog[3], $\overline{\text{RESET}}$, EXTAL0/XTAL0, and EXTAL1/XTAL1 input voltage	–0.3	V_{DD} + 0.3	V
I_D	Maximum current single pin limit (applies to all digital pins)	–25	25	mA
V_{DDA}	Analog supply voltage	V_{DD} – 0.3	V_{DD} + 0.3	V
V_{BAT}	RTC battery supply voltage	–0.3	3.8	V

1. It applies for all port pins.
2. It covers digital pins.
3. Analog pins are defined as pins that do not have an associated general purpose I/O port function.

5 General

5.1 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 1. Input signal measurement reference

All digital I/O switching characteristics assume:

1. output pins
   - have C_L=30pF loads,
   - are configured for fast slew rate (PORTx_PCRn[SRE]=0), and
   - are configured for high drive strength (PORTx_PCRn[DSE]=1)
2. input pins
   - have their passive filter disabled (PORTx_PCRn[PFE]=0)

5.2 Nonswitching electrical specifications

5.2.1 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 (digital pins)	$0.7 \times V_{DD}$	—	V	

Table continues on the next page...

Table 1. Voltage and current operating requirements (continued)

Symbol	Description	Min.	Max.	Unit	Notes
	• 2.7 V ≤ V_{DD} ≤ 3.6 V • 1.7 V ≤ V_{DD} ≤ 2.7 V	0.75 × V_{DD}	—	V	
V_{IL}	Input low voltage (digital pins) • 2.7 V ≤ V_{DD} ≤ 3.6 V • 1.7 V ≤ V_{DD} ≤ 2.7 V	 — —	 0.35 × V_{DD} 0.3 × V_{DD}	 V V	
V_{HYS}	Input hysteresis (digital pins)	0.06 × V_{DD}	—	V	
I_{ICDIO}	Digital pin negative DC injection current — single pin • V_{IN} < V_{SS}-0.3V	-5	—	mA	1
I_{ICAIO}	Analog[2], EXTAL0/XTAL0, and EXTAL1/XTAL1 pin DC injection current — single pin • V_{IN} < V_{SS}-0.3V (Negative current injection) • V_{IN} > V_{DD}+0.3V (Positive current injection)	 -5 —	 — +5	mA	3
I_{ICcont}	Contiguous pin DC injection current — regional limit, includes sum of negative injection currents or sum of positive injection currents of 16 contiguous pins • Negative current injection • Positive current injection	 -25 —	 — +25	mA	
V_{ODPU}	Open drain pullup voltage level	V_{DD}	V_{DD}	V	4
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	

1. All 5 V tolerant digital 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_{DIO_MIN}, a current limiting resistor is required. If V_{IN} greater than V_{DIO_MIN} (=VSS-0.3V) is observed, then there is no need to provide current limiting resistors at the pads. The negative DC injection current limiting resistor is calculated as $R=(V_{DIO\_MIN}-V_{IN})/|I_{ICDIO}|$.
2. Analog pins are defined as pins that do not have an associated general purpose I/O port function. Additionally, EXTAL and XTAL are analog pins.
3. All analog pins are internally clamped to V_{SS} and V_{DD} through ESD protection diodes. If V_{IN} is less than V_{AIO_MIN} or greater than V_{AIO_MAX}, a current limiting resistor is required. The negative DC injection current limiting resistor is calculated as $R=(V_{AIO\_MIN}-V_{IN})/|I_{ICAIO}|$. The positive injection current limiting resistor is calculated as $R=(V_{IN}-V_{AIO\_MAX})/|I_{ICAIO}|$. Select the larger of these two calculated resistances if the pin is exposed to positive and negative injection currents.
4. Open drain outputs must be pulled to VDD.

5.2.2 LVD and POR operating requirements

Table 2. 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} V_{LVW2H} V_{LVW3H} V_{LVW4H}	Low-voltage warning thresholds — high range • Level 1 falling (LVWV=00) • Level 2 falling (LVWV=01) • Level 3 falling (LVWV=10) • Level 4 falling (LVWV=11)	2.62 2.72 2.82 2.92	2.70 2.80 2.90 3.00	2.78 2.88 2.98 3.08	V V V V	1
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} V_{LVW2L} V_{LVW3L} V_{LVW4L}	Low-voltage warning thresholds — low range • Level 1 falling (LVWV=00) • Level 2 falling (LVWV=01) • Level 3 falling (LVWV=10) • Level 4 falling (LVWV=11)	1.74 1.84 1.94 2.04	1.80 1.90 2.00 2.10	1.86 1.96 2.06 2.16	V V V V	1
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 thresholds are falling threshold + 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	

5.2.3 Voltage and current operating behaviors

Table 4. Voltage and current operating behaviors

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
V_{OH}	Output high voltage — high drive strength			—		
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -9mA	V_{DD} – 0.5	—	—	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = -3mA	V_{DD} – 0.5	—		V	

Table continues on the next page...

Table 4. Voltage and current operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	Output high voltage — low drive strength			—		
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -2mA	V_{DD} – 0.5	—	—	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = -0.6mA	V_{DD} – 0.5	—		V	
I_{OHT}	Output high current total for all ports	—	—	100	mA	
I_{OHT_io60}	Output high current total for fast digital ports	—	—	100	mA	
V_{OL}	Output low voltage — high drive strength			—		
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 10 mA	—	—	0.5	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 5 mA	—		0.5	V	
	Output low voltage — low drive strength			—		
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 2 mA	—	—	0.5	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 1 mA	—		0.5	V	
I_{OLT}	Output low current total for all ports	—	—	100	mA	
I_{OLT_io60}	Output low current total for fast digital ports	—	—	100	mA	
I_{INA}	Input leakage current, analog pins and digital pins configured as analog inputs					1, 2
	• V_{SS} ≤ V_{IN} ≤ V_{DD}					
	— All pins except EXTAL32, XTAL32, EXTAL, XTAL	—	0.002	0.5	µA	
	— EXTAL (PTA18) and XTAL (PTA19)	—	0.004	1.5	µA	
	— EXTAL32, XTAL32	—	0.075	10	µA	
I_{IND}	Input leakage current, digital pins					2, 3
	• V_{SS} ≤ V_{IN} ≤ V_{IL}					
	— All digital pins	—	0.002	0.5	µA	
	• V_{IN} = V_{DD}					
	— All digital pins except PTD7	—	0.002	0.5	µA	
	— PTD7	—	0.004	1	µA	
I_{IND}	Input leakage current, digital pins					2, 3, 4
	• V_{IL} < V_{IN} < V_{DD}					
	— V_{DD} = 3.6 V	—	18	26	µA	
	— V_{DD} = 3.0 V	—	12	19	µA	
	— V_{DD} = 2.5 V	—	8	13	µA	
	— V_{DD} = 1.7 V	—	3	6	µA	
I_{IND}	Input leakage current, digital pins					2, 3
	• V_{DD} < V_{IN} < 5.5 V	—	1	50	µA	
Z_{IND}	Input impedance examples, digital pins					2, 5
		—	—	48	kΩ	

Table continues on the next page...

Table 4. Voltage and current operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• V_{DD} = 3.6 V • V_{DD} = 3.0 V • V_{DD} = 2.5 V • V_{DD} = 1.7 V	— — —	— — —	55 57 85	kΩ kΩ kΩ	
R_{PU}	Internal pullup resistors	20	—	50	kΩ	6
R_{PD}	Internal pulldown resistors	20	—	50	kΩ	7

1. Analog pins are defined as pins that do not have an associated general purpose I/O port function.
2. Digital pins have an associated GPIO port function and have 5V tolerant inputs, except EXTAL and XTAL.
3. Internal pull-up/pull-down resistors disabled.
4. Characterized, not tested in production.
5. Examples calculated using V_{IL} relation, V_{DD}, and max I_{IND}: $Z_{IND}=V_{IL}/I_{IND}$. This is the impedance needed to pull a high signal to a level below V_{IL} due to leakage when $V_{IL} < V_{IN} < V_{DD}$. These examples assume signal source low = 0 V. See Figure 2.
6. Measured at V_{DD} supply voltage = V_{DD} min and Vinput = V_{SS}
7. Measured at V_{DD} supply voltage = V_{DD} min and Vinput = V_{DD}

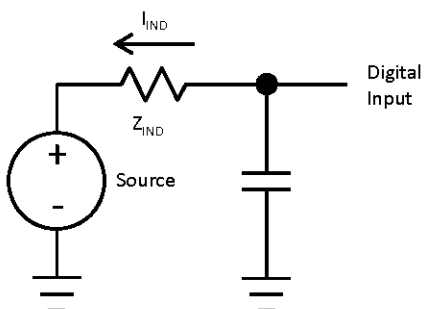


Figure 2. 5 V Tolerant Input IIND Parameter

5.2.4 Power mode transition operating behaviors

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

- CPU and system clocks = 100 MHz
- Bus clock = 50 MHz
- 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. • V_{DD} slew rate ≥ 5.7 kV/s • V_{DD} slew rate < 5.7 kV/s	 — —	 300 1.7 V / (V_{DD} slew rate)	µs	1
	• VLLS1 → RUN	—	160	µs	
	• VLLS2 → RUN	—	114	µs	
	• VLLS3 → RUN	—	114	µs	
	• LLS → RUN	—	5.0	µs	
	• VLPS → RUN	—	5	µs	
	• STOP → RUN	—	4.8	µs	

1. Normal boot (FTFE_FOPT[LPBOOT]=1)

5.2.5 Power consumption operating behaviors

Table 6. 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 • @ 1.8V • @ 3.0V	 — —	 49.28 49.08	 73.85 73.93	 mA mA	2
I_{DD_RUN}	Run mode current — all peripheral clocks enabled, code executing from flash • @ 1.8V • @ 3.0V	 — —	 74.43 74.28	 99.97 100.41	 mA mA	3
I_{DD_WAIT}	Wait mode high frequency current at 3.0 V — all peripheral clocks disabled	—	34.67	58.5	mA	2
I_{DD_WAIT}	Wait mode reduced frequency current at 3.0 V — all peripheral clocks disabled	—	18.03	41.91	mA	4
I_{DD_STOP}	Stop mode current at 3.0 V • @ –40 to 25°C	 —	 1.25	 1.62	 mA	
		—	2.93	4.39	mA	

Table continues on the next page...

Table 6. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• @ 70°C • @ 105°C	—	7.08	10.74	mA	
I_{DD_VLPR}	Very-low-power run mode current at 3.0 V — all peripheral clocks disabled	—	1.03	4.48	mA	5
I_{DD_VLPR}	Very-low-power run mode current at 3.0 V — all peripheral clocks enabled	—	1.58	4.96	mA	5
I_{DD_VLPW}	Very-low-power wait mode current at 3.0 V	—	0.64	4.29	mA	5
I_{DD_VLPS}	Very-low-power stop mode current at 3.0 V					
	• @ –40 to 25°C	—	0.22	0.38	mA	
	• @ 70°C	—	0.78	1.33	mA	
	• @ 105°C	—	2.18	3.56	mA	
I_{DD_LLS}	Low leakage stop mode current at 3.0 V					
	• @ –40 to 25°C	—	0.22	0.37	mA	
	• @ 70°C	—	0.78	1.33	mA	
	• @ 105°C	—	2.16	3.52	mA	
I_{DD_VLLS3}	Very low-leakage stop mode 3 current at 3.0 V					
	• @ –40 to 25°C	—	4.09	5.58	µA	
	• @ 70°C	—	20.98	28.93	µA	
	• @ 105°C	—	84.95	111.15	µA	
I_{DD_VLLS2}	Very low-leakage stop mode 2 current at 3.0 V					
	• @ –40 to 25°C	—	2.68	4.22	µA	
	• @ 70°C	—	8.8	10.74	µA	
	• @ 105°C	—	37.28	43.61	µA	
I_{DD_VLLS1}	Very low-leakage stop mode 1 current at 3.0 V					
	• @ –40 to 25°C	—	2.46	4.02	µA	
	• @ 70°C	—	7.04	8.99	µA	
	• @ 105°C	—	30.68	37.04	µA	
I_{DD_VBAT}	Average current when CPU is not accessing RTC registers at 3.0 V					6
	• @ –40 to 25°C	—	0.89	1.10	µA	
	• @ 70°C	—	1.28	1.85	µA	
	• @ 105°C	—	3.10	4.30	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, 30 MHz FlexBus clock, and 20 MHz flash clock. MCG configured for PEE mode. All peripheral clocks disabled.
3. 120 MHz core and system clock, 60 MHz bus, 30 MHz FlexBus clock, and 20 MHz flash clock. MCG configured for PEE mode. All peripheral clocks enabled, but peripherals are not in active operation.
4. 25 MHz core and system clock, 25 MHz bus clock, and 12.5 MHz FlexBus and flash clock. MCG configured for FEI mode.

5. 4 MHz core, system, 2 MHz FlexBus, and 2 MHz bus clock and 0.5 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks disabled.
6. Includes 32kHz oscillator current and RTC operation.

5.2.5.1 Diagram: Typical IDD_RUN operating behavior

The following data was measured under these conditions:

- MCG in FBE mode for 50 MHz and lower frequencies. MCG in FEE mode at greater than 50 MHz frequencies. MCG in PEE mode at greater than 100 MHz frequencies.
- No GPIOs toggled
- Code execution from flash with cache enabled
- For the ALLOFF curve, all peripheral clocks are disabled except FTFE

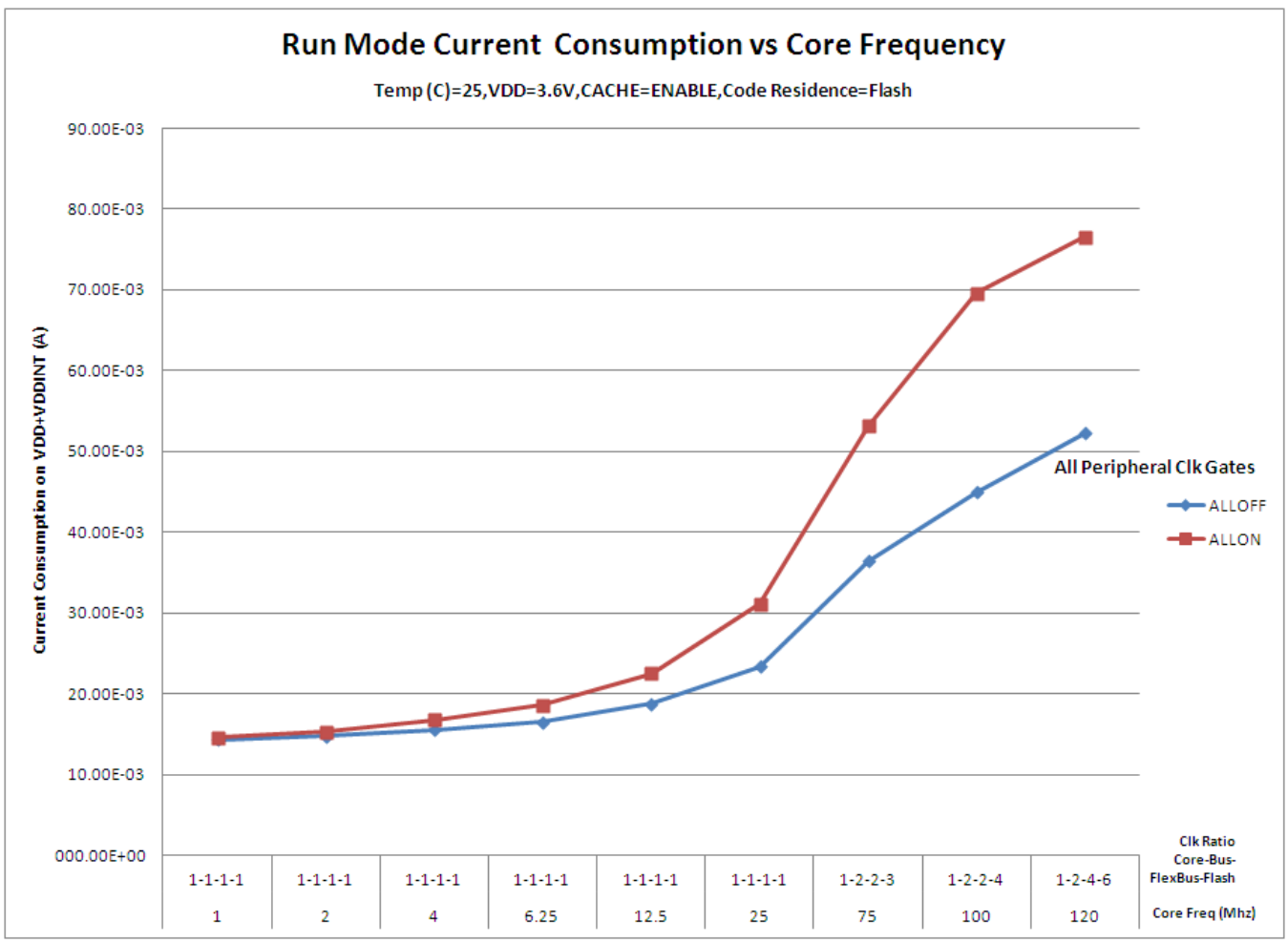


Figure 3. Run mode supply current vs. core frequency

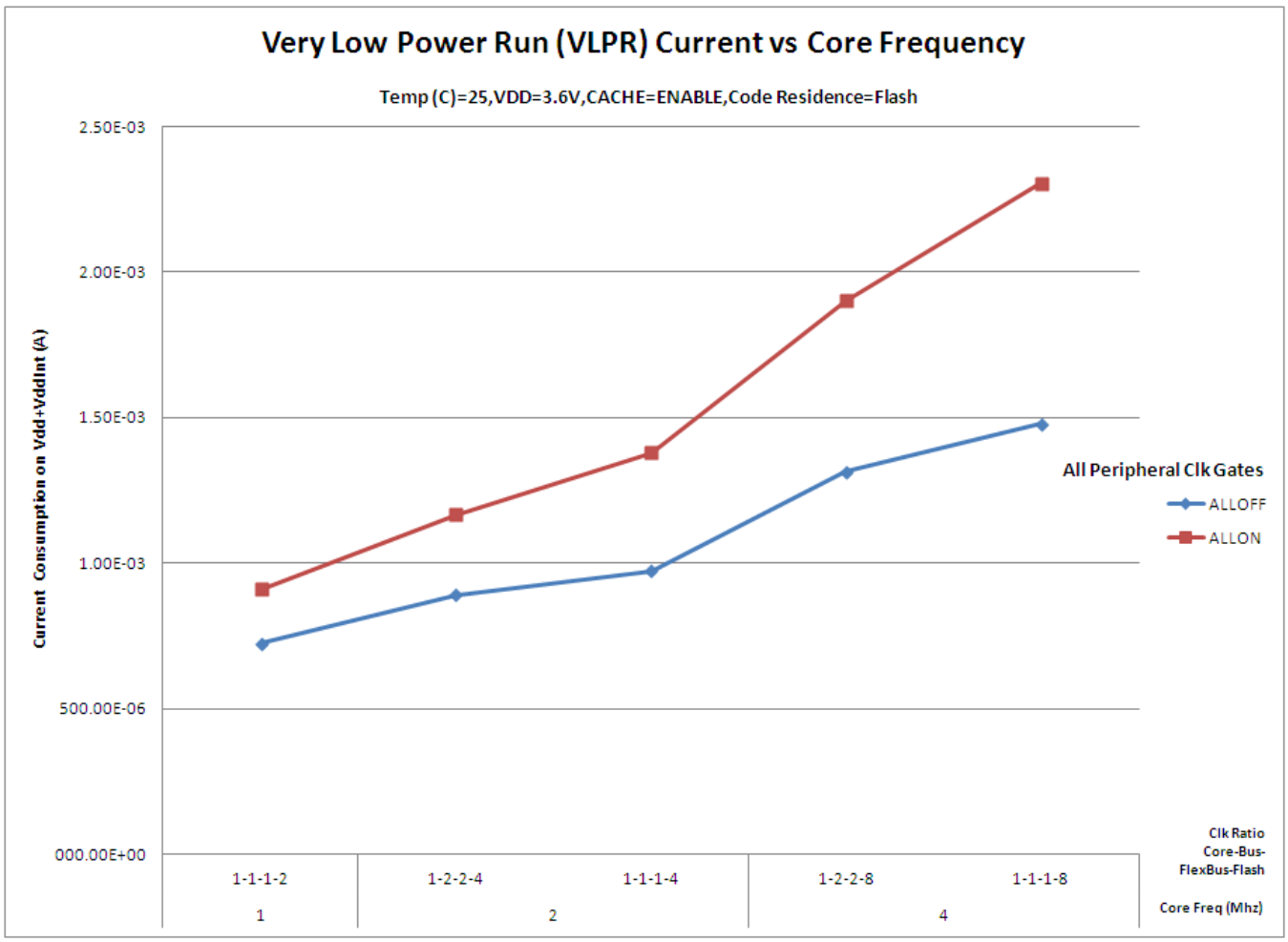


Figure 4. VLPR mode supply current vs. core frequency

5.2.6 EMC radiated emissions operating behaviors

Table 7. EMC radiated emissions operating behaviors for 256MAPBGA

Symbol	Description	Frequency band (MHz)	Typ.	Unit	Notes
V_{RE1}	Radiated emissions voltage, band 1	0.15–50	21	dBµV	1, 2, 3
V_{RE2}	Radiated emissions voltage, band 2	50–150	24	dBµV	
V_{RE3}	Radiated emissions voltage, band 3	150–500	29	dBµV	
V_{RE4}	Radiated emissions voltage, band 4	500–1000	28	dBµV	

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 V, T_A = 25 °C, f_{OSC} = 12 MHz (crystal), f_{SYS} = 72 MHz, f_{BUS} = 72 MHz
3. Determined according to IEC Standard JESD78, *IC Latch-Up Test*

5.2.7 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 www.nxp.com.
2. Perform a keyword search for "EMC design."

5.2.8 Capacitance attributes

Table 8. 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
$C_{IN\_D\_io60}$	Input capacitance: fast digital pins	—	9	pF

5.3 Switching specifications

5.3.1 Device clock specifications

Table 9. Device clock specifications

Symbol	Description	Min.	Max.	Unit	Notes
Normal run mode					
f_{SYS}	System and core clock	—	120	MHz	
f_{BUS}	Bus clock	—	60	MHz	
FB_CLK	FlexBus clock	—	50	MHz	
f_{FLASH}	Flash clock	—	25	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	—	0.5	MHz	
f_{LPTMR}	LPTMR clock	—	4	MHz	

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

5.3.2 General switching specifications

These general purpose specifications apply to all pins configured for:

- GPIO signaling
- Other peripheral module signaling not explicitly stated elsewhere

Table 10. 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	16	—	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) • Slew disabled • $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$ • Slew enabled • $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$	 — — — —	 14 8 36 24	 ns ns ns ns	4
	Port rise and fall time (low drive strength) • Slew disabled • $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$ • Slew enabled • $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$	 — — — —	 14 8 36 24	 ns ns ns ns	5
t_{io50}	Port rise and fall time (high drive strength) • Slew disabled • $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$ • Slew enabled • $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$	 — — — —	 7 3 28 14	 ns ns ns ns	6 — — — —
t_{io50}	Port rise and fall time (low drive strength) • Slew disabled				-1

Table continues on the next page...

Table 10. General switching specifications (continued)

Symbol	Description	Min.	Max.	Unit	Notes
	• $1.71 \le V_{DD} \le 2.7V$	—	18	ns	—
	• $2.7 \le V_{DD} \le 3.6V$	—	9	ns	—
	• Slew enabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	48	ns	—
	• $2.7 \le V_{DD} \le 3.6V$	—	24	ns	—
t_{io60}	Port rise and fall time (high drive strength)				6
	• Slew disabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	6	ns	—
	• $2.7 \le V_{DD} \le 3.6V$	—	3	ns	—
	• Slew enabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	28	ns	—
	• $2.7 \le V_{DD} \le 3.6V$	—	14	ns	—
t_{io60}	Port rise and fall time (low drive strength)				-1
	• Slew disabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	18	ns	—
	• $2.7 \le V_{DD} \le 3.6V$	—	6	ns	—
	• Slew enabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	48	ns	—
	• $2.7 \le V_{DD} \le 3.6V$	—	24	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
6. 25 pF load

5.4 Thermal specifications

5.4.1 Thermal operating requirements

Table 11. Thermal operating requirements

Symbol	Description	Min.	Max.	Unit
T_J	Die junction temperature	–40	125	°C
T_A	Ambient temperature[1]	–40	105	°C

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:

   $T_J = T_A + R_{\theta JA}$ x chip power dissipation

5.4.2 Thermal attributes

Board type	Symbol	Description	144 LQFP	144 MAPBGA	Unit	Notes
Single-layer (1s)	$R_{\theta JA}$	Thermal resistance, junction to ambient (natural convection)	45	50	°C/W	1, 2
Four-layer (2s2p)	$R_{\theta JA}$	Thermal resistance, junction to ambient (natural convection)	36	30	°C/W	1,2, 3
Single-layer (1s)	$R_{\theta JMA}$	Thermal resistance, junction to ambient (200 ft./ min. air speed)	36	41	°C/W	1,3
Four-layer (2s2p)	$R_{\theta JMA}$	Thermal resistance, junction to ambient (200 ft./ min. air speed)	30	27	°C/W	1,3
—	$R_{\theta JB}$	Thermal resistance, junction to board	24	17	°C/W	4
—	$R_{\theta JC}$	Thermal resistance, junction to case	9	10	°C/W	5
—	Ψ_{JT}	Thermal characterization parameter, junction to package top outside center (natural convection)	2	2	°C/W	6

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.
2. Determined according to JEDEC Standard JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions —Natural Convection (Still Air)* with the single layer board horizontal. Board meets JESD51-9 specification.
3. Determined according to JEDEC Standard JESD51-6, *Integrated Circuits Thermal Test Method Environmental Conditions —Forced Convection (Moving Air)* with the board horizontal.
4. Determined according to JEDEC Standard JESD51-8, *Integrated Circuit Thermal Test Method Environmental Conditions —Junction-to-Board*.

5. 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.
6. Determined according to JEDEC Standard JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions —Natural Convection (Still Air)*.

6 Peripheral operating requirements and behaviors

6.1 Core modules

6.1.1 Debug trace timing specifications

Table 12. 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	3	—	ns
T_h	Data hold	2	—	ns

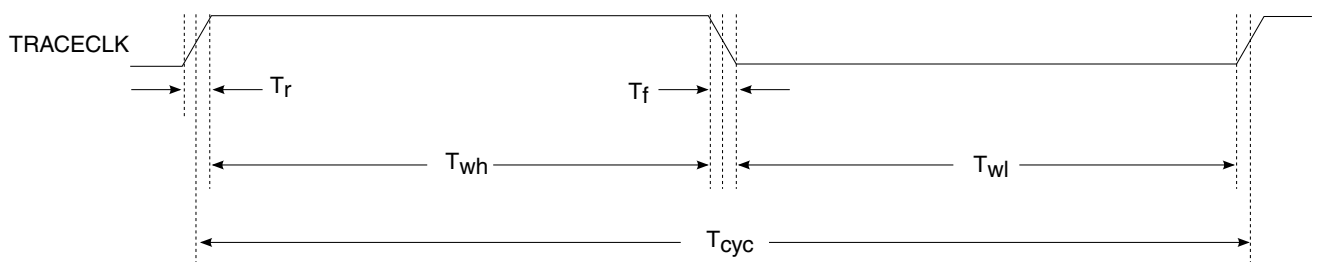


Figure 5. TRACE_CLKOUT specifications

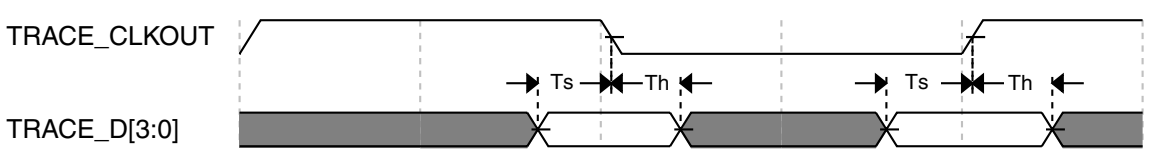


Figure 6. Trace data specifications

6.1.2 JTAG electricals

Table 13. JTAG limited voltage range electricals

Symbol	Description	Min.	Max.	Unit
	Operating voltage	2.7	3.6	V
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	2.4	—	ns
J7	TCLK low to boundary scan output data valid	—	25	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	—	17	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 14. 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
		25	—	ns

Table continues on the next page...

Table 14. JTAG full voltage range electricals (continued)

Symbol	Description	Min.	Max.	Unit
	• JTAG and CJTAG • 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
J6	Boundary scan input data hold time after TCLK rise	2.4	—	ns
J7	TCLK low to boundary scan output data valid	—	25	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	1.4	—	ns
J11	TCLK low to TDO data valid	—	22.1	ns
J12	TCLK low to TDO high-Z	—	22.1	ns
J13	$\overline{\text{TRST}}$ assert time	100	—	ns
J14	$\overline{\text{TRST}}$ setup time (negation) to TCLK high	8	—	ns

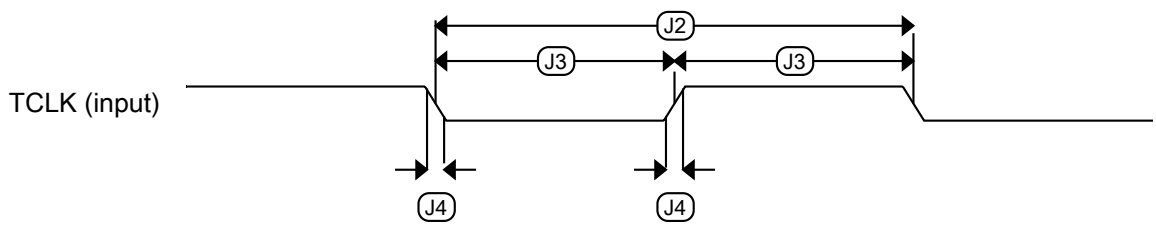


Figure 7. Test clock input timing

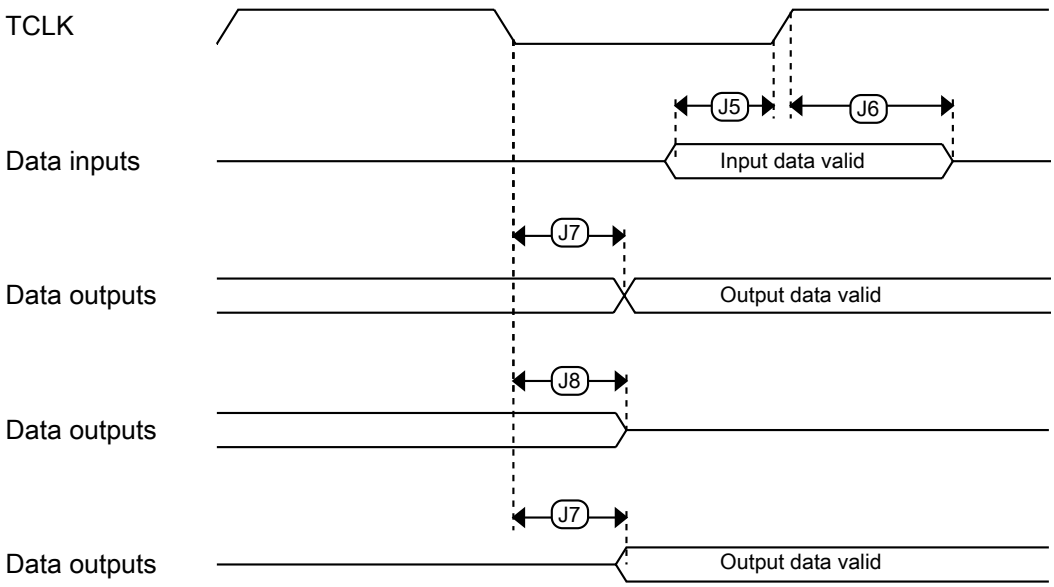


Figure 8. Boundary scan (JTAG) timing

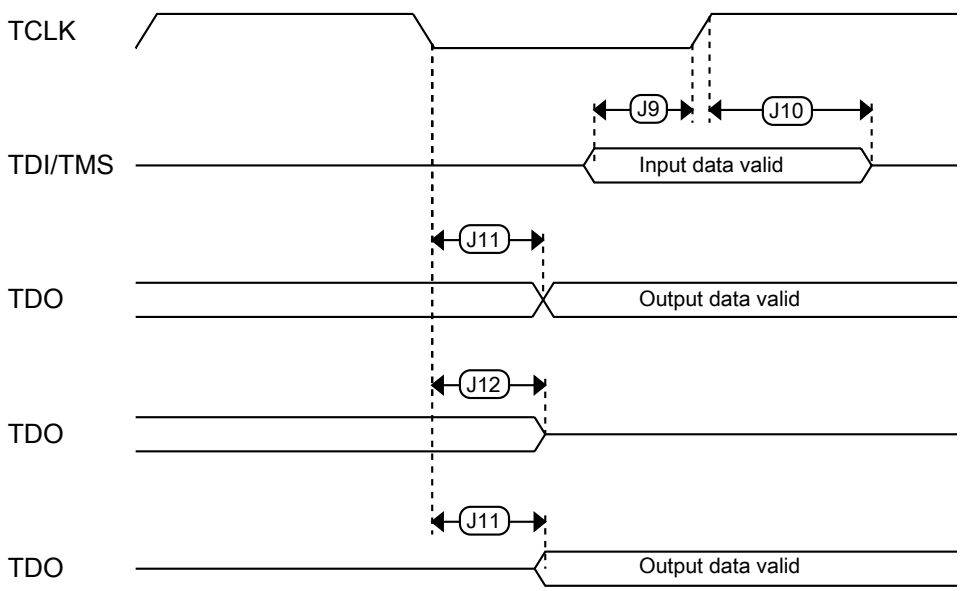


Figure 9. Test Access Port timing

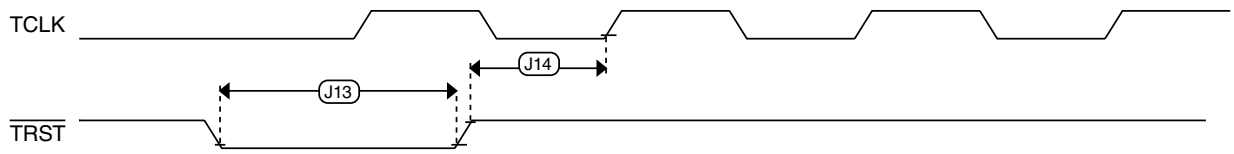


Figure 10. TRST timing

6.2 System modules

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

6.3 Clock modules

6.3.1 MCG specifications

Table 15. 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	
$\Delta_{fdco\_res\_t}$	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 fixed voltage and temperature range of 0–70°C	—	± 4.5	—	$\%f_{dco}$	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	
f_{loc_low}	Loss of external clock minimum frequency — RANGE = 00	(3/5) x f_{ints_t}	—	—	kHz	
f_{loc_high}	Loss of external clock minimum frequency — RANGE = 01, 10, or 11	(16/5) x f_{ints_t}	—	—	kHz	
FLL						
f_{fll_ref}	FLL reference frequency range	31.25	—	39.0625	kHz	

Table continues on the next page...

Table 15. MCG specifications (continued)

Symbol	Description		Min.	Typ.	Max.	Unit	Notes
f_{dco}	DCO output frequency range	Low range (DRS=00) 640 × f_{fll_ref}	20	20.97	25	MHz	2, 3
		Mid range (DRS=01) 1280 × f_{fll_ref}	40	41.94	50	MHz	
		Mid-high range (DRS=10) 1920 × f_{fll_ref}	60	62.91	75	MHz	
		High range (DRS=11) 2560 × f_{fll_ref}	80	83.89	100	MHz	
$f_{dco\_t\_DMX32}$	DCO output frequency	Low range (DRS=00) 732 × f_{fll_ref}	—	23.99	—	MHz	4, 5
		Mid range (DRS=01) 1464 × f_{fll_ref}	—	47.97	—	MHz	
		Mid-high range (DRS=10) 2197 × f_{fll_ref}	—	71.99	—	MHz	
		High range (DRS=11) 2929 × f_{fll_ref}	—	95.98	—	MHz	
J_{cyc_fll}	FLL period jitter • f_{VCO} = 48 MHz • f_{VCO} = 98 MHz		— —	180 150	— —	ps	
$t_{fll\_acquire}$	FLL target frequency acquisition time		—	—	1	ms	6
PLL0,1							
f_{pll_ref}	PLL reference frequency range		8	—	16	MHz	
f_{vcoclk_2x}	VCO output frequency		180	—	360	MHz	
f_{vcoclk}	PLL output frequency		90	—	180	MHz	
f_{vcoclk_90}	PLL quadrature output frequency		90	—	180	MHz	
I_{pll}	PLL0 operating current • VCO @ 184 MHz ($f_{osc\_hi\_1}$ = 32 MHz, f_{pll_ref} = 8 MHz, VDIV multiplier = 23)		—	2.8	—	mA	
I_{pll}	PLL0 operating current • VCO @ 360 MHz ($f_{osc\_hi\_1}$ = 32 MHz, f_{pll_ref} = 8 MHz, VDIV multiplier = 45)		—	4.7	—	mA	7
I_{pll}	PLL1 operating current • VCO @ 184 MHz ($f_{osc\_hi\_1}$ = 32 MHz, f_{pll_ref} = 8 MHz, VDIV multiplier = 23)		—	2.3	—	mA	7
I_{pll}	PLL1 operating current • VCO @ 360 MHz ($f_{osc\_hi\_1}$ = 32 MHz, f_{pll_ref} = 8 MHz, VDIV multiplier = 45)		—	3.6	—	mA	7
t_{pll_lock}	Lock detector detection time		—	—	100×10^{-6} + 1075(1/f_{pll_ref})	s	8
J_{cyc_pll}	PLL period jitter (RMS)						9

Table continues on the next page...

Table 15. MCG specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• f_{vco} = 180 MHz	—	100	—	ps	
	• f_{vco} = 360 MHz	—	75	—	ps	
J_{acc_pll}	PLL accumulated jitter over 1µs (RMS)					10
	• f_{vco} = 180 MHz	—	600	—	ps	
	• f_{vco} = 360 MHz	—	300	—	ps	

1. This parameter is measured with the internal reference (slow clock) being used as a reference to the FLL (FEI clock mode).
2. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=0.
3. The resulting system clock frequencies should not exceed their maximum specified values. The DCO frequency deviation (Δf_{dco_t}) over voltage and temperature should be considered.
4. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=1.
5. The resulting clock frequency must not exceed the maximum specified clock frequency of the device.
6. 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.
7. Excludes any oscillator currents that are also consuming power while PLL is in operation.
8. 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.
9. This specification was obtained using a Freescale developed PCB. PLL jitter is dependent on the noise characteristics of each PCB and results will vary.
10. Accumulated jitter depends on VCO frequency and VDIV.

6.3.2 Oscillator electrical specifications

6.3.2.1 Oscillator DC electrical specifications

Table 16. 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	—	500	—	nA	
	• 4 MHz	—	200	—	µA	
	• 8 MHz (RANGE=01)	—	300	—	µA	
	• 16 MHz	—	950	—	µA	
	• 24 MHz	—	1.2	—	mA	
	• 32 MHz	—	1.5	—	mA	
I_{DDOSC}	Supply current — high-gain mode (HGO=1)					1
	• 32 kHz	—	25	—	µA	
		—	400	—	µA	

Table continues on the next page...

Table 16. Oscillator DC electrical specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• 4 MHz • 8 MHz (RANGE=01) • 16 MHz • 24 MHz • 32 MHz	— — — —	500 2.5 3 4	— — — —	µA mA mA 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)	—	—	—	MΩ	2, 4
	Feedback resistor — low-frequency, high-gain mode (HGO=1)	—	10	—	MΩ	
	Feedback resistor — high-frequency, low-power mode (HGO=0)	—	—	—	MΩ	
	Feedback resistor — high-frequency, high-gain mode (HGO=1)	—	1	—	MΩ	
R_S	Series resistor — low-frequency, low-power mode (HGO=0)	—	—	—	kΩ	
	Series resistor — low-frequency, high-gain mode (HGO=1)	—	200	—	kΩ	
	Series resistor — high-frequency, low-power mode (HGO=0)	—	—	—	kΩ	
	Series resistor — high-frequency, high-gain mode (HGO=1)	—	0	—	kΩ	
V_{pp}[5]	Peak-to-peak amplitude of oscillation (oscillator mode) — low-frequency, low-power mode (HGO=0)	—	0.6	—	V	
	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
2. See crystal or resonator manufacturer's recommendation
3. C_x and C_y can be provided by using either integrated capacitors or 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 device.

6.3.2.2 Oscillator frequency specifications

Table 17. 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	1
$f_{osc\_hi\_2}$	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)	—	—	60	MHz	2, 3
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)	—	1000	—	ms	4, 5
	Crystal startup time — 32 kHz low-frequency, high-gain mode (HGO=1)	—	500	—	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. Frequencies less than 8 MHz are not in the PLL range.
2. Other frequency limits may apply when external clock is being used as a reference for the FLL
3. 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.
4. Proper PC board layout procedures must be followed to achieve specifications.
5. 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.

6.3.3 32 kHz oscillator electrical characteristics

6.3.3.1 32 kHz oscillator DC electrical specifications

Table 18. 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	—	MΩ
C_{para}	Parasitical capacitance of EXTAL32 and XTAL32	—	5	7	pF
V_{pp}[1]	Peak-to-peak amplitude of oscillation	—	0.6	—	V

1. 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.

6.3.3.2 32 kHz oscillator frequency specifications

Table 19. 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
$v_{ec\_extal32}$	Externally provided input clock amplitude	700	—	V_{BAT}	mV	2, 3

1. Proper PC board layout procedures must be followed to achieve specifications.
2. 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.
3. 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}.

6.4 Memories and memory interfaces

6.4.1 Flash (FTFE) electrical specifications

This section describes the electrical characteristics of the FTFE module.

6.4.1.1 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 20. NVM program/erase timing specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
t_{hvpgm8}	Program Phrase high-voltage time	—	7.5	18	µs	
$t_{hversscr}$	Erase Flash Sector high-voltage time	—	13	113	ms	1
$t_{hversblk128k}$	Erase Flash Block high-voltage time for 128 KB	—	104	1808	ms	1
$t_{hversblk256k}$	Erase Flash Block high-voltage time for 256 KB	—	208	3616	ms	1

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

6.4.1.2 Flash timing specifications — commands

Table 21. Flash command timing specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	Read 1s Block execution time					

Table continues on the next page...

Table 21. Flash command timing specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
$t_{rd1blk128k}$	• 128 KB data flash	—	—	0.5	ms	
$t_{rd1blk256k}$	• 256 KB program flash 256 KB data flash	—	—	1.0	ms	
$t_{rd1sec4k}$	Read 1s Section execution time (4 KB flash)	—	—	100	µs	1
t_{pgmchk}	Program Check execution time	—	—	80	µs	1
t_{rdrsrc}	Read Resource execution time	—	—	40	µs	1
t_{pgm8}	Program Phrase execution time	—	70	150	µs	
	Erase Flash Block execution time					2
$t_{ersblk128k}$	• 128 KB data flash	—	110	925	ms	
$t_{ersblk256k}$	• 256 KB program flash 256 KB data flash	—	220	1850	ms	
t_{ersscr}	Erase Flash Sector execution time	—	15	115	ms	2
$t_{pgmsec4k}$	Program Section execution time (4KB flash)	—	20	—	ms	
	Read 1s All Blocks execution time					
$t_{rd1allx}$	• FlexNVM devices	—	—	3.4	ms	
$t_{rd1alln}$	• Program flash only devices	—	—	3.4	ms	
t_{rdonce}	Read Once execution time	—	—	30	µs	1
$t_{pgmonce}$	Program Once execution time	—	70	—	µs	
t_{ersall}	Erase All Blocks execution time	—	650	5600	ms	2
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	—	70	150	µs	
$t_{swapx04}$	• control code 0x04	—	70	150	µs	
$t_{swapx08}$	• control code 0x08	—	—	30	µs	
	Program Partition for EEPROM execution time					
$t_{pgmpart64k}$	• 64 KB EEPROM backup	—	235	—	ms	
$t_{pgmpart256k}$	• 256 KB EEPROM backup	—	240	—	ms	
	Set FlexRAM Function execution time:					
$t_{setramff}$	• Control Code 0xFF	—	205	—	µs	
$t_{setram64k}$	• 64 KB EEPROM backup	—	1.6	2.5	ms	
$t_{setram128k}$	• 128 KB EEPROM backup	—	2.7	3.8	ms	
$t_{setram256k}$	• 256 KB EEPROM backup	—	4.8	6.2	ms	
$t_{eewr8bers}$	Byte-write to erased FlexRAM location execution time	—	140	225	µs	3
	Byte-write to FlexRAM execution time:					
$t_{eewr8b64k}$		—	400	1700	µs	

Table continues on the next page...

Table 21. Flash command timing specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
$t_{eewr8b128k}$	• 64 KB EEPROM backup	—	450	1800	µs	
$t_{eewr8b256k}$	• 128 KB EEPROM backup	—	525	2000	µs	
	• 256 KB EEPROM backup					
$t_{eewr16bers}$	16-bit write to erased FlexRAM location execution time	—	140	225	µs	
	16-bit write to FlexRAM execution time:					
$t_{eewr16b64k}$	• 64 KB EEPROM backup	—	400	1700	µs	
$t_{eewr16b128k}$	• 128 KB EEPROM backup	—	450	1800	µs	
$t_{eewr16b256k}$	• 256 KB EEPROM backup	—	525	2000	µs	
$t_{eewr32bers}$	32-bit write to erased FlexRAM location execution time	—	180	275	µs	
	32-bit write to FlexRAM execution time:					
$t_{eewr32b64k}$	• 64 KB EEPROM backup	—	475	1850	µs	
$t_{eewr32b128k}$	• 128 KB EEPROM backup	—	525	2000	µs	
$t_{eewr32b256k}$	• 256 KB EEPROM backup	—	600	2200	µs	

1. Assumes 25MHz or greater flash clock frequency.
2. Maximum times for erase parameters based on expectations at cycling end-of-life.
3. For byte-writes to an erased FlexRAM location, the aligned word containing the byte must be erased.

6.4.1.3 Flash high voltage current behaviors

Table 22. 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

6.4.1.4 Reliability specifications

Table 23. 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	
$n_{nvmcycp}$	Cycling endurance	10 K	50 K	—	cycles	2
Data Flash						
$t_{nvmretd10k}$	Data retention after up to 10 K cycles	5	50	—	years	

Table continues on the next page...

Table 23. NVM reliability specifications (continued)

Symbol	Description	Min.	Typ.[1]	Max.	Unit	Notes
$t_{nvmretd1k}$	Data retention after up to 1 K cycles	20	100	—	years	
$n_{nvmcycd}$	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
	Write endurance					3
$n_{nvmwree16}$	• EEPROM backup to FlexRAM ratio = 16	70 K	175 K	—	writes	
$n_{nvmwree128}$	• EEPROM backup to FlexRAM ratio = 128	630 K	1.6 M	—	writes	
$n_{nvmwree512}$	• EEPROM backup to FlexRAM ratio = 512	2.5 M	6.4 M	—	writes	
$n_{nvmwree2k}$	• EEPROM backup to FlexRAM ratio = 2,048	10 M	25 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 ≤Tj ≤ 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.

6.4.1.5 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.

$$\text{Writes\_subsystem} = \frac{\text{EEPROM} - 2 \times \text{EEESPLIT} \times \text{EEESIZE}}{\text{EEESPLIT} \times \text{EEESIZE}} \times \text{Write\_efficiency} \times n_{nvmcycee}$$

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

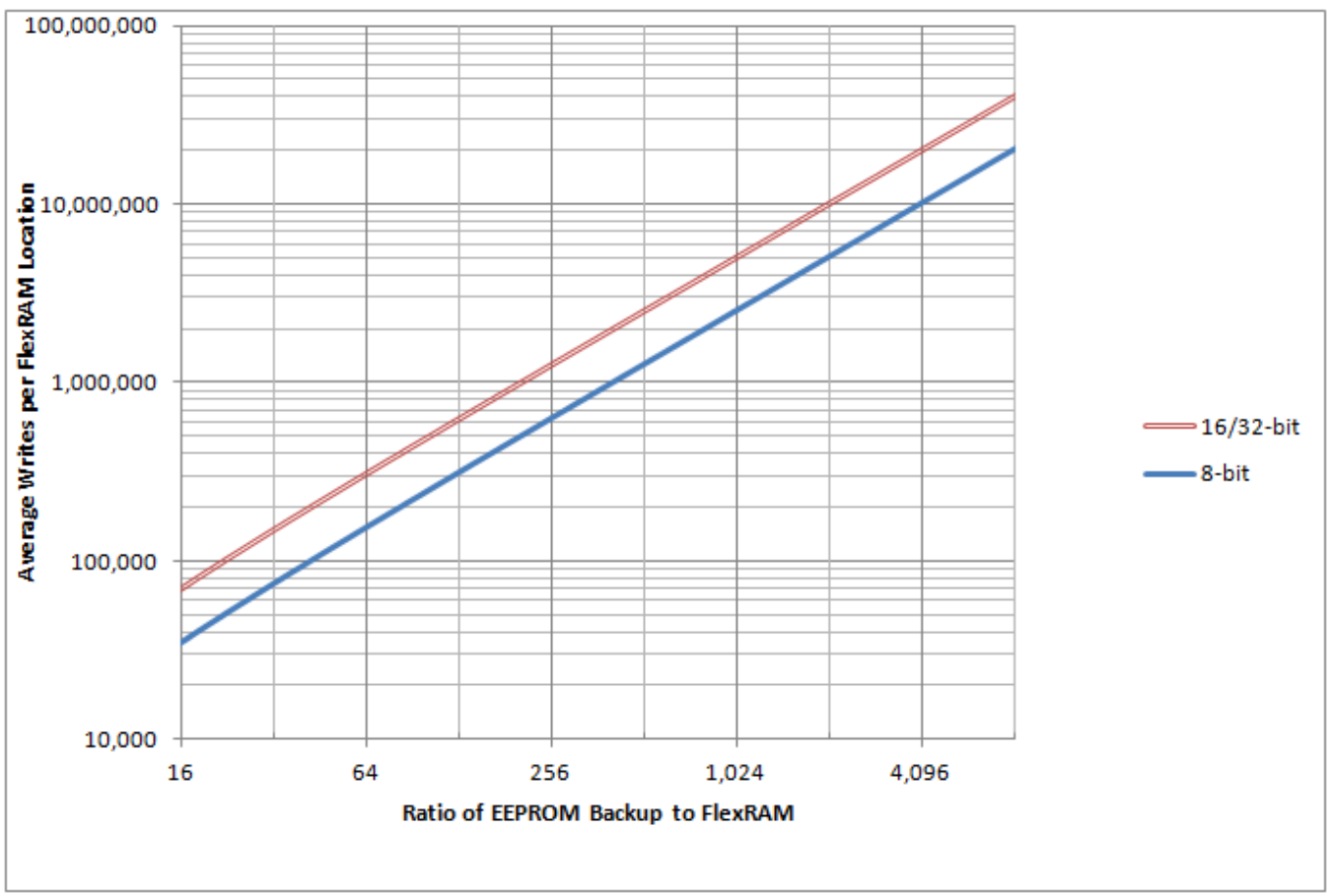


Figure 11. EEPROM backup writes to FlexRAM

6.4.2 EzPort switching specifications

Table 24. EzPort switching specifications

Num	Description	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V

Table continues on the next page...

Table 24. EzPort switching specifications (continued)

Num	Description	Min.	Max.	Unit
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	$\overline{\text{EZP\_CS}}$ negation to next $\overline{\text{EZP\_CS}}$ assertion	2 x t_{EZP_CK}	—	ns
EP3	$\overline{\text{EZP\_CS}}$ input valid to EZP_CK high (setup)	5	—	ns
EP4	EZP_CK high to $\overline{\text{EZP\_CS}}$ 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	—	16	ns
EP8	EZP_CK low to EZP_Q output invalid (hold)	0	—	ns
EP9	$\overline{\text{EZP\_CS}}$ negation to EZP_Q tri-state	—	12	ns

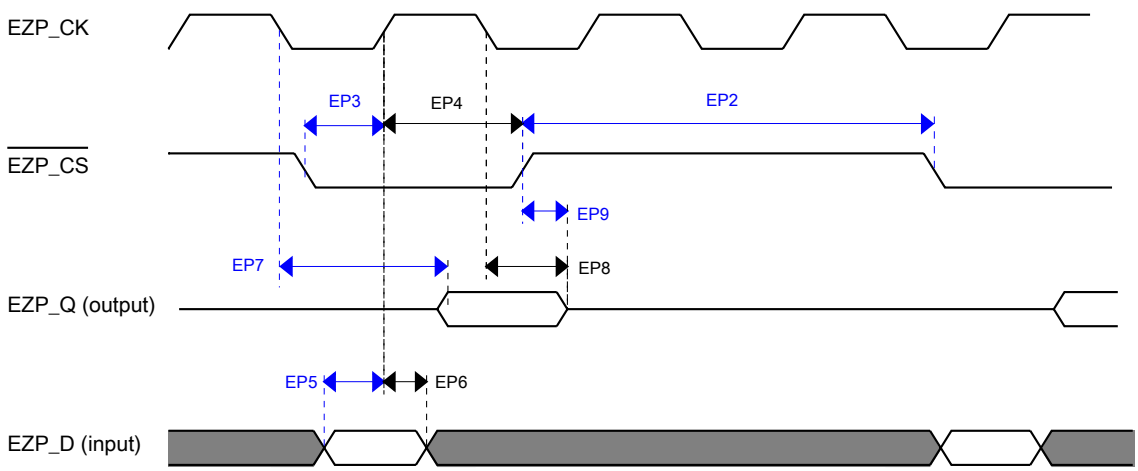


Figure 12. EzPort Timing Diagram

6.4.3 NAND flash controller specifications

The NAND flash controller (NFC) implements the interface to standard NAND flash memory devices. This section describes the timing parameters of the NFC.

In the following table:

- T_H is the flash clock high time and
- T_L is flash clock low time,

which are defined as:

$$T_{NFC} = T_L + T_H = \frac{T_{input\ clock}}{SCALER}$$

The SCALER value is derived from the fractional divider specified in the SIM's CLKDIV4 register:

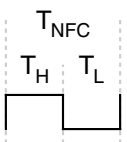
$$SCALER = \frac{SIM\_CLKDIV4[NFCFRAC] + 1}{SIM\_CLKDIV4[NFCDIV] + 1}$$

In case the reciprocal of SCALER is an integer, the duty cycle of NFC clock is 50%, means $T_H = T_L$. In case the reciprocal of SCALER is not an integer:

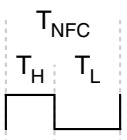
$$T_L = (1 + SCALER / 2) \times \frac{T_{NFC}}{2}$$

$$T_H = (1 - SCALER / 2) \times \frac{T_{NFC}}{2}$$

For example, if SCALER is 0.2, then $T_H = T_L = T_{NFC}/2$.



However, if SCALER is 0.667, then $T_L = 2/3 \times T_{NFC}$ and $T_H = 1/3 \times T_{NFC}$.



NOTE

The reciprocal of SCALER must be a multiple of 0.5. For example, 1, 1.5, 2, 2.5, etc.

Table 25. NFC specifications

Num	Description	Min.	Max.	Unit
t_{CLS}	NFC_CLE setup time	$2T_H + T_L - 1$	—	ns
t_{CLH}	NFC_CLE hold time	$T_H + T_L - 1$	—	ns
t_{CS}	$\overline{\text{NFC\_CEn}}$ setup time	$2T_H + T_L - 1$	—	ns
t_{CH}	$\overline{\text{NFC\_CEn}}$ hold time	$T_H + T_L$	—	ns
t_{WP}	$\overline{\text{NFC\_WP}}$ pulse width	$T_L - 1$	—	ns
t_{ALS}	NFC_ALE setup time	$2T_H + T_L$	—	ns

Table continues on the next page...

Table 25. NFC specifications (continued)

Num	Description	Min.	Max.	Unit
t_{ALH}	NFC_ALE hold time	$T_H + T_L$	—	ns
t_{DS}	Data setup time	$T_L - 1$	—	ns
t_{DH}	Data hold time	$T_H - 1$	—	ns
t_{WC}	Write cycle time	$T_H + T_L - 1$	—	ns
t_{WH}	$\overline{\text{NFC\_WE}}$ hold time	$T_H - 1$	—	ns
t_{RR}	Ready to $\overline{\text{NFC\_RE}}$ low	$4T_H + 3T_L + 90$	—	ns
t_{RP}	$\overline{\text{NFC\_RE}}$ pulse width	$T_L + 1$	—	ns
t_{RC}	Read cycle time	$T_L + T_H - 1$	—	ns
t_{REH}	$\overline{\text{NFC\_RE}}$ high hold time	$T_H - 1$	—	ns
t_{IS}	Data input setup time	11	—	ns

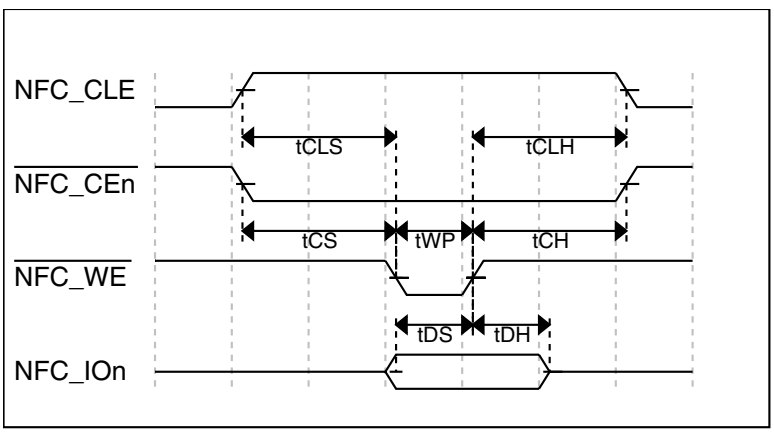


Figure 13. Command latch cycle timing

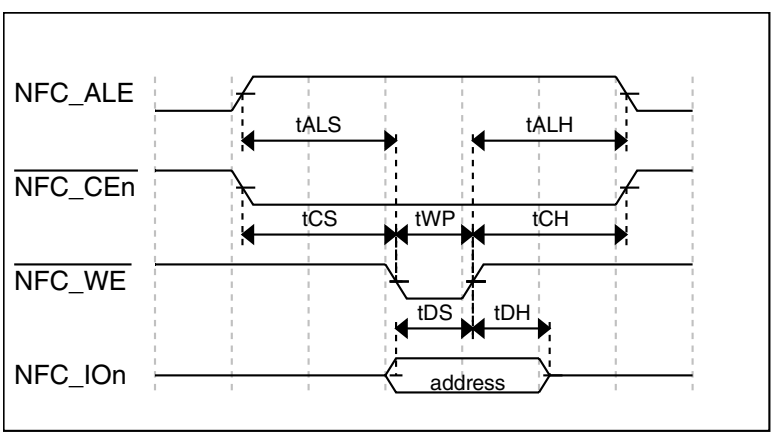


Figure 14. Address latch cycle timing

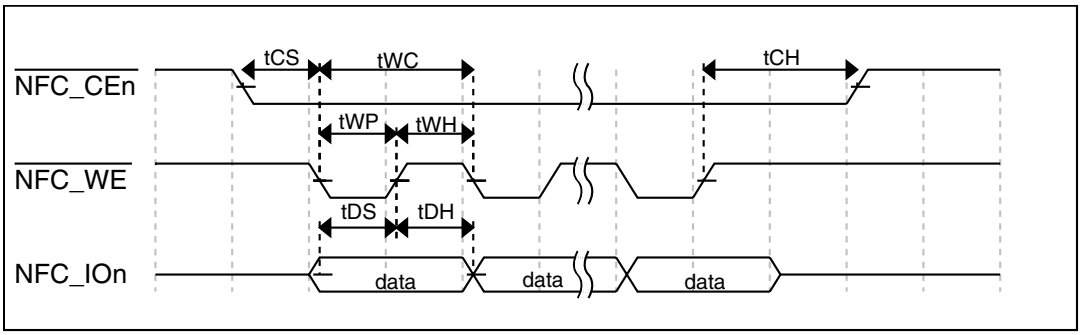


Figure 15. Write data latch cycle timing

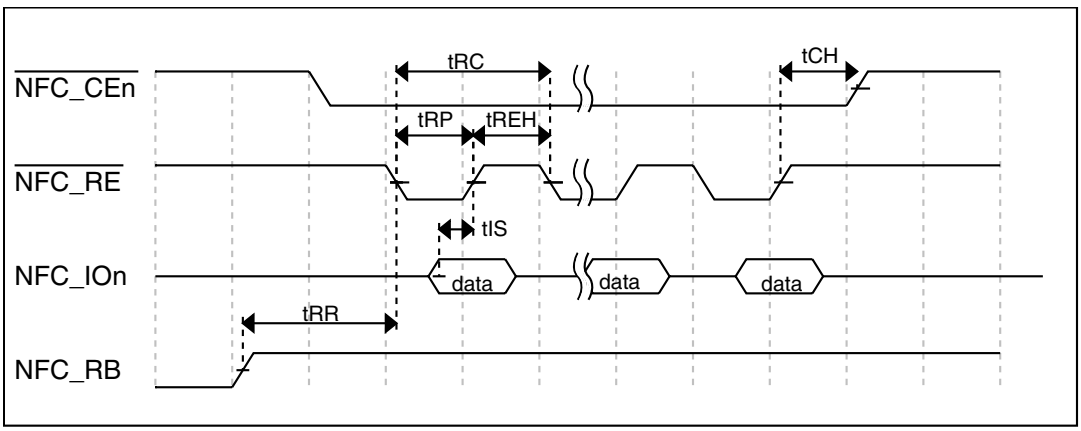


Figure 16. Read data latch cycle timing in Slow mode

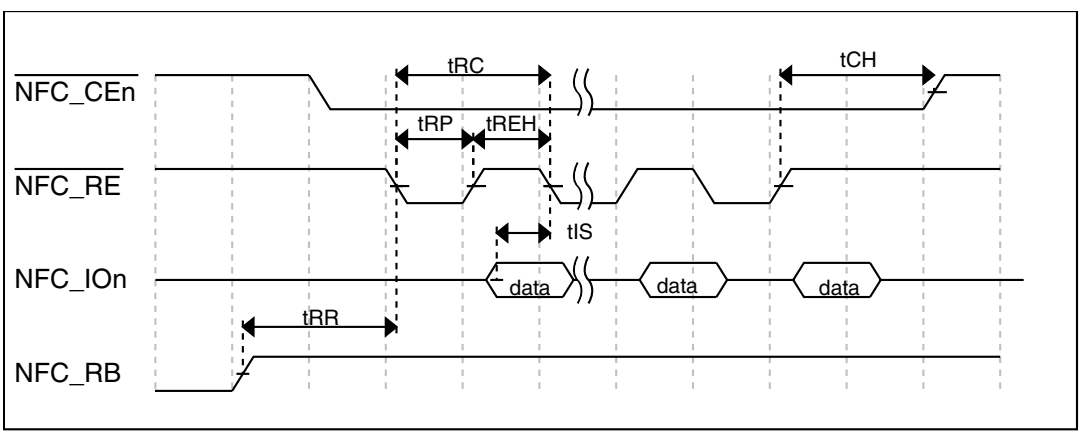


Figure 17. Read data latch cycle timing in Fast mode and EDO mode

6.4.4 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 26. 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	20	—	ns	
FB2	Address, data, and control output valid	—	11.5	ns	1
FB3	Address, data, and control output hold	0.5	—	ns	1
FB4	Data and $\overline{\text{FB\_TA}}$ input setup	8.5	—	ns	2
FB5	Data and $\overline{\text{FB\_TA}}$ input hold	0.5	—	ns	2

1. Specification is valid for all FB_AD[31:0], $\overline{\text{FB\_BE/BWE}n}$, $\overline{\text{FB\_CS}n}$, $\overline{\text{FB\_OE}}$, FB_R/$\overline{\text{W}}$,$\overline{\text{FB\_TBST}}$, FB_TSIZ[1:0], FB_ALE, and $\overline{\text{FB\_TS}}$.
2. Specification is valid for all FB_AD[31:0] and $\overline{\text{FB\_TA}}$.

Table 27. 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	—	13.5	ns	1
FB3	Address, data, and control output hold	0	—	ns	1
FB4	Data and $\overline{\text{FB\_TA}}$ input setup	13.7	—	ns	2
FB5	Data and $\overline{\text{FB\_TA}}$ input hold	0.5	—	ns	2

1. Specification is valid for all FB_AD[31:0], $\overline{\text{FB\_BE/BWE}n}$, $\overline{\text{FB\_CS}n}$, $\overline{\text{FB\_OE}}$, FB_R/$\overline{\text{W}}$,$\overline{\text{FB\_TBST}}$, FB_TSIZ[1:0], FB_ALE, and $\overline{\text{FB\_TS}}$.
2. Specification is valid for all FB_AD[31:0] and $\overline{\text{FB\_TA}}$.

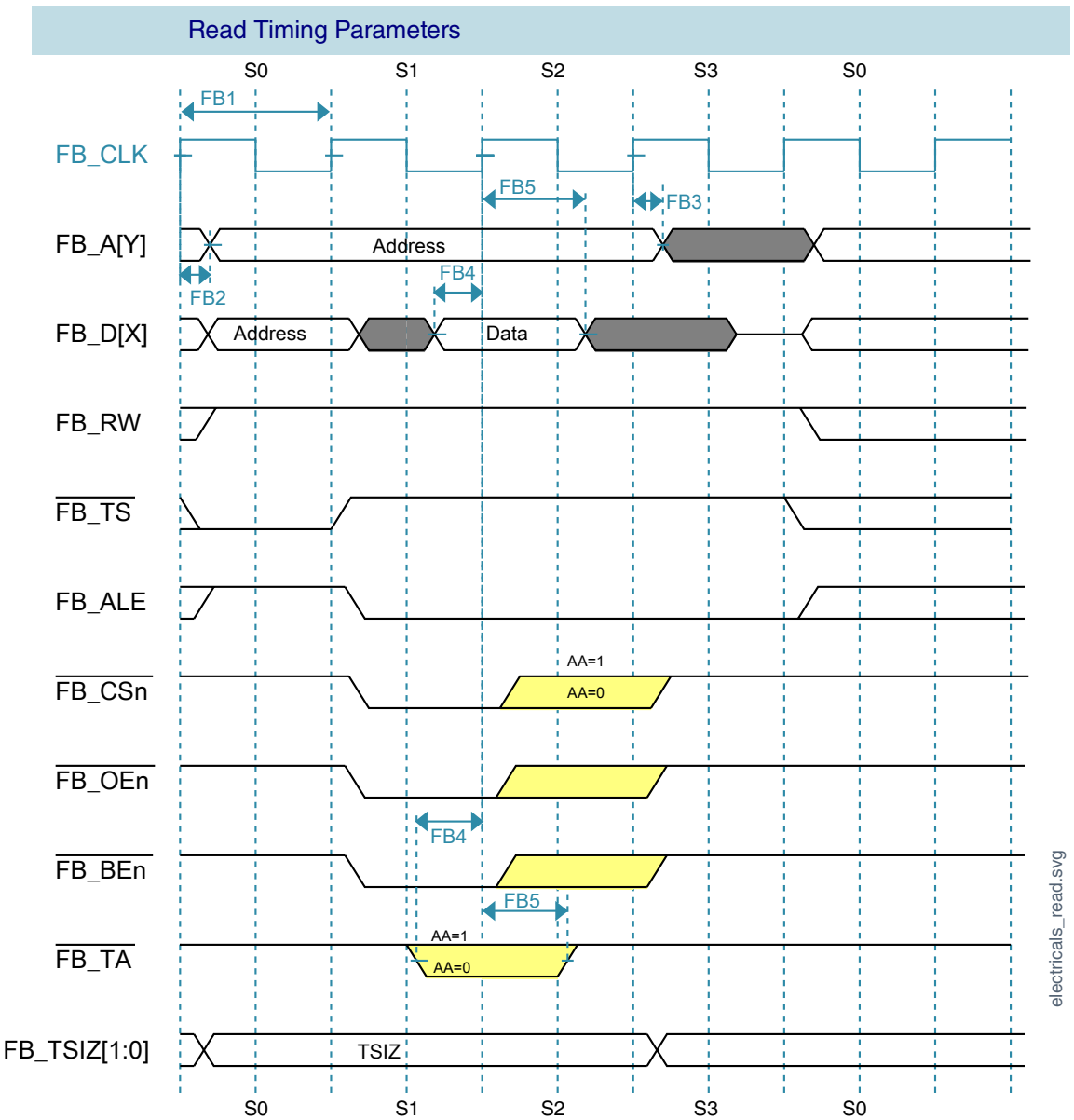


Figure 18. FlexBus read timing diagram

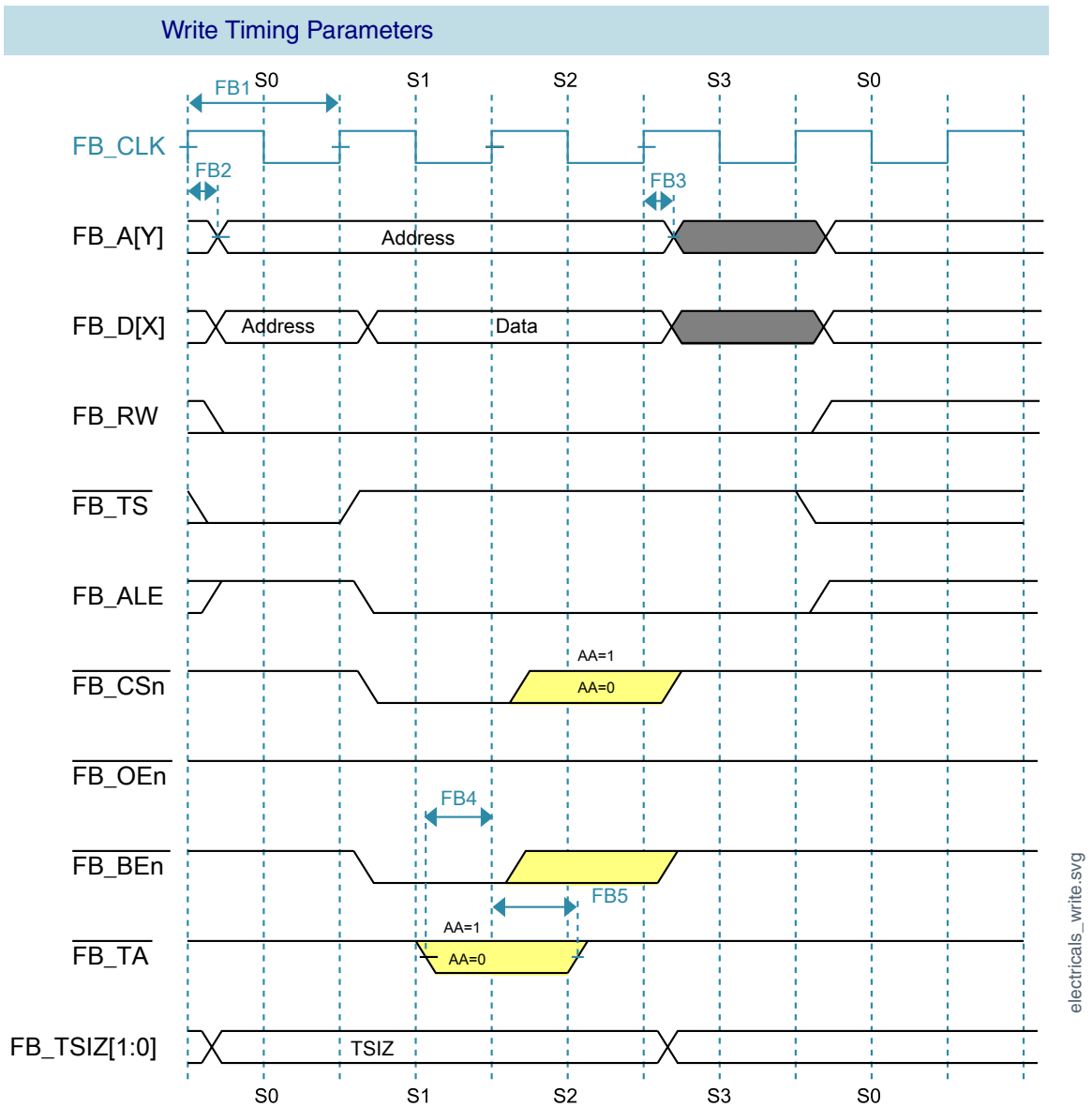


Figure 19. FlexBus write timing diagram

6.5 Security and integrity modules

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

6.6 Analog

6.6.1 ADC electrical specifications

The 16-bit accuracy specifications listed in Table 28 and Table 29 are achievable on the differential pins ADCx_DP0, ADCx_DM0.

The ADCx_DP2 and ADCx_DM2 ADC inputs are connected to the PGA outputs and are not direct device pins. Accuracy specifications for these pins are defined in Table 30 and Table 31.

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

6.6.1.1 16-bit ADC operating conditions

Table 28. 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	• 16-bit differential mode • All other modes	VREFL VREFL	— —	31/32 × VREFH VREFH	V	
C_{ADIN}	Input capacitance	• 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	—	18.0	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	—	818.330	kS/s	5
C_{rate}	ADC conversion rate	16-bit mode No ADC hardware averaging	37.037	—	461.467	kS/s	5

Table 28. 16-bit ADC operating conditions

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
		Continuous conversions enabled, subsequent conversion time					

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.

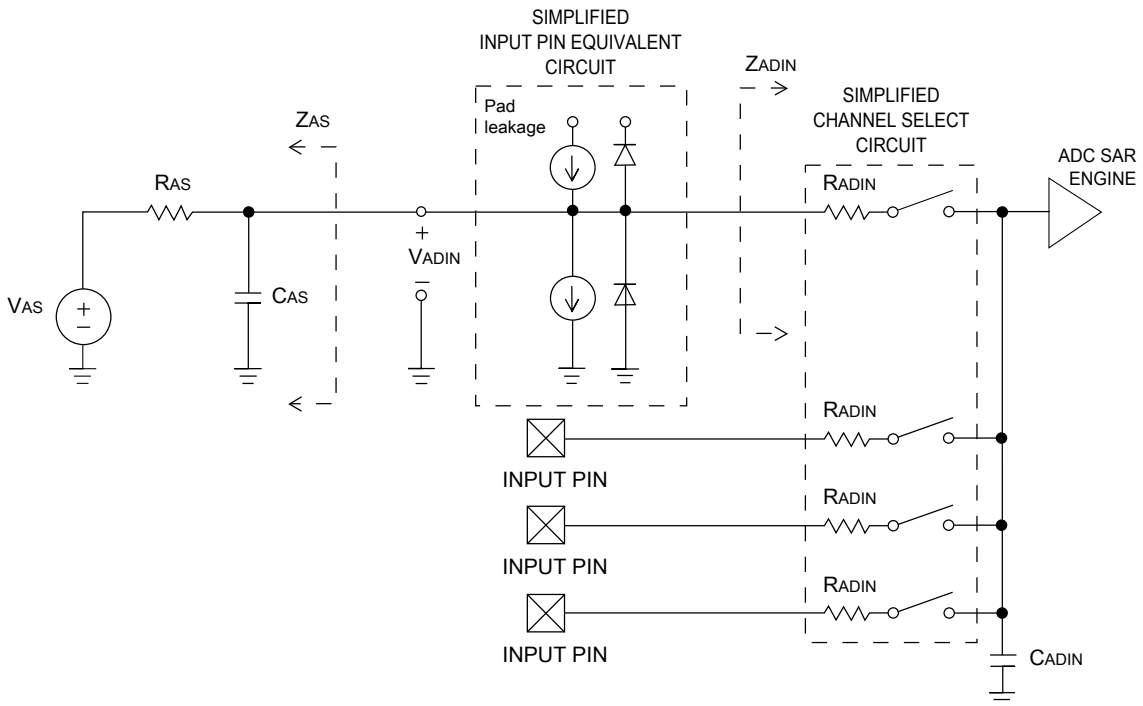


Figure 20. ADC input impedance equivalency diagram

6.6.1.2 16-bit ADC electrical characteristics

Table 29. 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	• ADLPC = 1, ADHSC = 0	1.2	2.4	3.9	MHz	t_{ADACK} = 1/ f_{ADACK}
		• ADLPC = 1, ADHSC = 1	2.4	4.0	6.1	MHz	

Table continues on the next page...

Table 29. 16-bit ADC characteristics (V_{REFH} = V_{DDA}, V_{REFL} = V_{SSA}) (continued)

Symbol	Description	Conditions[1]	Min.	Typ.[2]	Max.	Unit	Notes
		• ADLPC = 0, ADHSC = 0 • ADLPC = 0, ADHSC = 1	3.0 4.4	5.2 6.2	7.3 9.5	MHz MHz	
	Sample Time	See Reference Manual chapter for sample times					
TUE	Total unadjusted error	• 12-bit modes • <12-bit modes	— —	±4 ±1.4	±6.8 ±2.1	LSB[4]	5
DNL	Differential non-linearity	• 12-bit modes • <12-bit modes	— —	±0.7 ±0.2	–1.1 to +1.9 –0.3 to 0.5	LSB[4]	5
INL	Integral non-linearity	• 12-bit modes • <12-bit modes	— —	±1.0 ±0.5	–2.7 to +1.9 –0.7 to +0.5	LSB[4]	5
E_{FS}	Full-scale error	• 12-bit modes • <12-bit modes	— —	–4 –1.4	–5.4 –1.8	LSB[4]	V_{ADIN} = V_{DDA}[5]
E_Q	Quantization error	• 16-bit modes • ≤13-bit modes	— —	–1 to 0 —	— ±0.5	LSB[4]	
ENOB	Effective number of bits	16-bit differential mode • Avg = 32 • Avg = 4 16-bit single-ended mode • Avg = 32 • Avg = 4	 12.8 11.9 12.2 11.4	 14.5 13.8 13.9 13.1	 — — — —	 bits bits 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 • Avg = 32 16-bit single-ended mode • Avg = 32	 — —	 -94 -85	 — —	dB dB	7
SFDR	Spurious free dynamic range	16-bit differential mode • Avg = 32 16-bit single-ended mode • Avg = 32	 82 78	 95 90	 — — 	dB dB	7
E_{IL}	Input leakage error		I_{In} × R_{AS}			mV	I_{In} = leakage current

Table continues on the next page...

Table 29. 16-bit ADC characteristics (V_{REFH} = V_{DDA}, V_{REFL} = V_{SSA}) (continued)

Symbol	Description	Conditions[1]	Min.	Typ.[2]	Max.	Unit	Notes
							(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 V, Temp = 25 °C, f_{ADCK} = 2.0 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 LSB = (V_{REFH} - V_{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

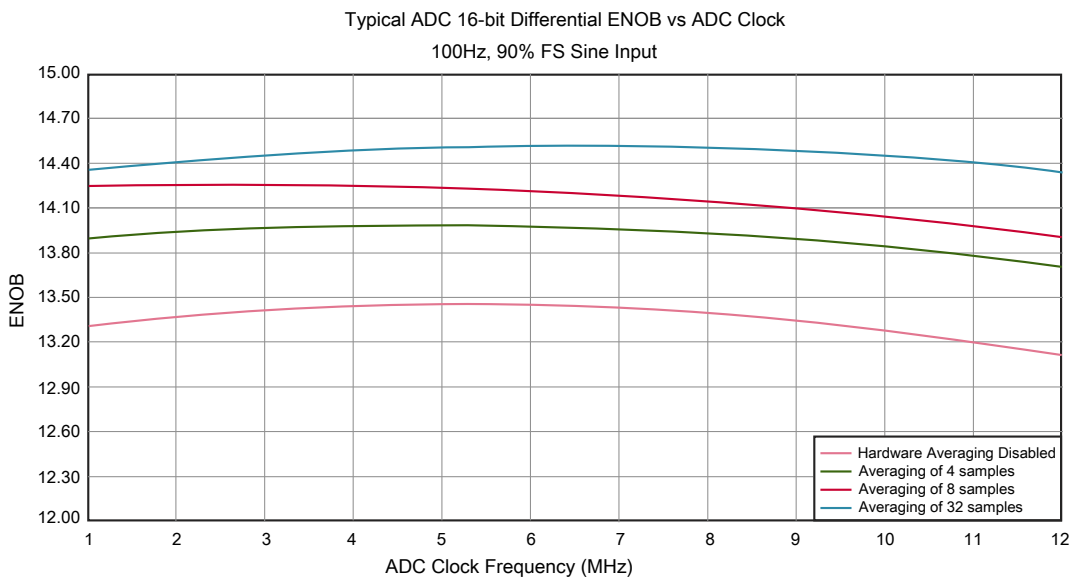


Figure 21. Typical ENOB vs. ADC_CLK for 16-bit differential mode

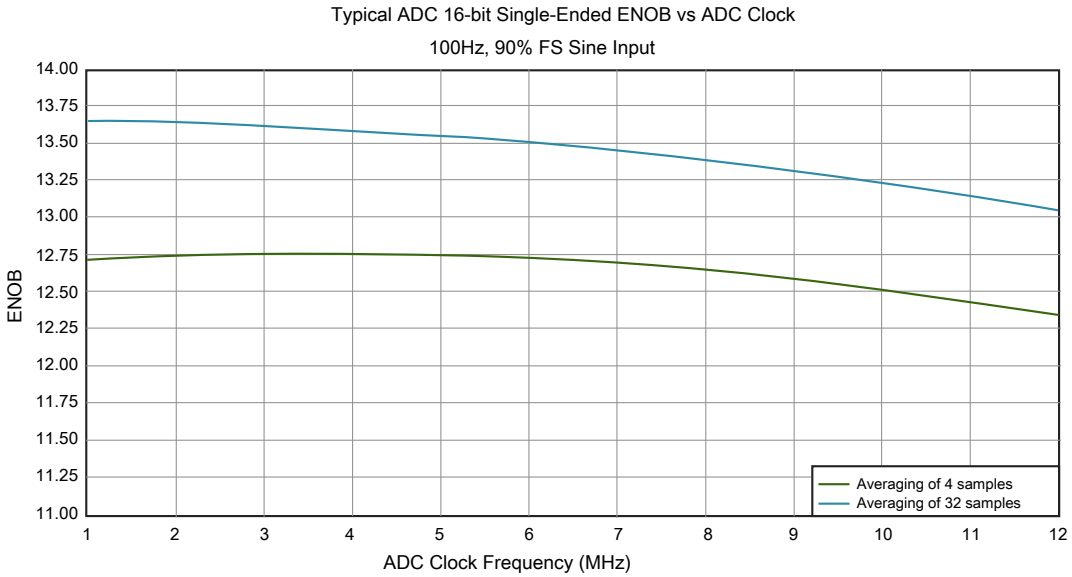


Figure 22. Typical ENOB vs. ADC_CLK for 16-bit single-ended mode

6.6.1.3 16-bit ADC with PGA operating conditions

Table 30. 16-bit ADC with PGA operating conditions

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
V_{DDA}	Supply voltage	Absolute	1.71	—	3.6	V	
V_{REFPGA}	PGA ref voltage		VREF_OUT	VREF_OUT	VREF_OUT	V	2, 3
V_{ADIN}	Input voltage		V_{SSA}	—	V_{DDA}	V	
V_{CM}	Input Common Mode range		V_{SSA}	—	V_{DDA}	V	
R_{PGAD}	Differential input impedance	Gain = 1, 2, 4, 8	—	128	—	kΩ	IN+ to IN-[4]
		Gain = 16, 32	—	64	—		
		Gain = 64	—	32	—		
R_{AS}	Analog source resistance		—	100	—	Ω	5
T_S	ADC sampling time		1.25	—	—	μs	6
C_{rate}	ADC conversion rate	≤ 13 bit modes No ADC hardware averaging Continuous conversions enabled Peripheral clock = 50 MHz	18.484	—	450	Ksps	7
		16 bit modes	37.037	—	250	Ksps	8

Table 30. 16-bit ADC with PGA operating conditions

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
		No ADC hardware averaging Continuous conversions enabled Peripheral clock = 50 MHz					

1. Typical values assume V_{DDA} = 3.0 V, Temp = 25°C, f_{ADCK} = 6 MHz unless otherwise stated. Typical values are for reference only and are not tested in production.
2. ADC must be configured to use the internal voltage reference (VREF_OUT)
3. PGA reference is internally connected to the VREF_OUT pin. If the user wishes to drive VREF_OUT with a voltage other than the output of the VREF module, the VREF module must be disabled.
4. For single ended configurations the input impedance of the driven input is $R_{PGAD}/2$
5. The analog source resistance (R_{AS}), external to MCU, should be kept as minimum as possible. Increased R_{AS} causes drop in PGA gain without affecting other performances. This is not dependent on ADC clock frequency.
6. The minimum sampling time is dependent on input signal frequency and ADC mode of operation. A minimum of 1.25µs time should be allowed for F_{in}=4 kHz at 16-bit differential mode. Recommended ADC setting is: ADLSMP=1, ADLSTS=2 at 8 MHz ADC clock.
7. ADC clock = 18 MHz, ADLSMP = 1, ADLST = 00, ADHSC = 1
8. ADC clock = 12 MHz, ADLSMP = 1, ADLST = 01, ADHSC = 1

6.6.1.4 16-bit ADC with PGA characteristics

Table 31. 16-bit ADC with PGA characteristics

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
I_{DDA_PGA}	Supply current	Low power (ADC_PGA[PGALPb]=0)	—	420	644	µA	2
I_{DC_PGA}	Input DC current		$\frac{2}{R_{PGAD}}\left(\frac{(V_{REFPGA}\times 0.583)-V_{CM}}{(Gain+1)}\right)$			A	3
		Gain =1, V_{REFPGA}=1.2V, V_{CM}=0.5V	—	1.54	—	µA	
		Gain =64, V_{REFPGA}=1.2V, V_{CM}=0.1V	—	0.57	—	µA	
G	Gain[4]	• PGAG=0	0.95	1	1.05		R_{AS} < 100Ω
		• PGAG=1	1.9	2	2.1		
		• PGAG=2	3.8	4	4.2		
		• PGAG=3	7.6	8	8.4		
		• PGAG=4	15.2	16	16.6		
		• PGAG=5	30.0	31.6	33.2		
		• PGAG=6	58.8	63.3	67.8		
BW	Input signal bandwidth	• 16-bit modes	—	—	4	kHz	
		• < 16-bit modes	—	—	40	kHz	
PSRR	Power supply rejection ratio	Gain=1	—	-84	—	dB	V_{DDA}= 3V ±100mV,

Table continues on the next page...

Table 31. 16-bit ADC with PGA characteristics (continued)

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
							f_{VDDA}= 50Hz, 60Hz
CMRR	Common mode rejection ratio	• Gain=1 • Gain=64	— —	-84 -85	— —	dB dB	V_{CM}= 500mVpp, f_{VCM}= 50Hz, 100Hz
V_{OFS}	Input offset voltage	• Chopping disabled (ADC_PGA[PGACHPb] =1) • Chopping enabled (ADC_PGA[PGACHPb] =0)	— —	2.4 0.2	— —	mV mV	Output offset = V_{OFS}*(Gain+1)
T_{GSW}	Gain switching settling time		—	—	10	µs	5
dG/dT	Gain drift over full temperature range	• Gain=1 • Gain=64	— —	6 31	10 42	ppm/°C ppm/°C	
dG/dV_{DDA}	Gain drift over supply voltage	• Gain=1 • Gain=64	— —	0.07 0.14	0.21 0.31	%/V %/V	V_{DDA} from 1.71 to 3.6V
E_{IL}	Input leakage error	All modes	$I_{In} \times R_{AS}$			mV	I_{In} = leakage current (refer to the MCU's voltage and current operating ratings)
$V_{PP,DIFF}$	Maximum differential input signal swing		$\left(\frac{(\min(V_X, V_{DDA}-V_X)-0.2)\times 4}{\text{Gain}}\right)$ where $V_X = V_{REFPGA} \times 0.583$			V	6
SNR	Signal-to-noise ratio	• Gain=1 • Gain=64	80 52	90 66	— —	dB dB	16-bit differential mode, Average=32
THD	Total harmonic distortion	• Gain=1 • Gain=64	85 49	100 95	— —	dB dB	16-bit differential mode, Average=32, f_{in}=100Hz
SFDR	Spurious free dynamic range	• Gain=1 • Gain=64	85 53	105 88	— —	dB dB	16-bit differential mode, Average=32, f_{in}=100Hz
ENOB	Effective number of bits	• Gain=1, Average=4 • Gain=1, Average=8 • Gain=64, Average=4 • Gain=64, Average=8	11.6 8.0 7.2 6.3 12.8	13.4 13.6 9.6 9.6 14.5	— — — — —	bits bits bits bits bits	16-bit differential mode,f_{in}=100Hz

Table continues on the next page...

Table 31. 16-bit ADC with PGA characteristics (continued)

Symbol	Description	Conditions	Min.	Typ.[1]	Max.	Unit	Notes
		• Gain=1, Average=32	11.0	14.3	—	bits	
		• Gain=2, Average=32	7.9	13.8	—	bits	
		• Gain=4, Average=32	7.3	13.1	—	bits	
		• Gain=8, Average=32	6.8	12.5	—	bits	
		• Gain=16, Average=32	6.8	11.5	—	bits	
		• Gain=32, Average=32	7.5	10.6	—	bits	
		• Gain=64, Average=32					
SINAD	Signal-to-noise plus distortion ratio	See ENOB	6.02 × ENOB + 1.76			dB	

1. Typical values assume V_{DDA} =3.0V, Temp=25°C, f_{ADCK}=6MHz unless otherwise stated.
2. This current is a PGA module adder, in addition to ADC conversion currents.
3. Between IN+ and IN-. The PGA draws a DC current from the input terminals. The magnitude of the DC current is a strong function of input common mode voltage (V_{CM}) and the PGA gain.
4. Gain = 2^{PGAG}
5. After changing the PGA gain setting, a minimum of 2 ADC+PGA conversions should be ignored.
6. Limit the input signal swing so that the PGA does not saturate during operation. Input signal swing is dependent on the PGA reference voltage and gain setting.

6.6.2 CMP and 6-bit DAC electrical specifications

Table 32. 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	µA
I_{DDLS}	Supply current, low-speed mode (EN=1, PMODE=0)	—	—	20	µA
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]				
	• CR0[HYSTCTR] = 00	—	5	—	mV
	• CR0[HYSTCTR] = 01	—	10	—	mV
	• CR0[HYSTCTR] = 10	—	20	—	mV
	• CR0[HYSTCTR] = 11	—	30	—	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	µs
I_{DAC6b}	6-bit DAC current adder (enabled)	—	7	—	µA

Table continues on the next page...

Table 32. Comparator and 6-bit DAC electrical specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit
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

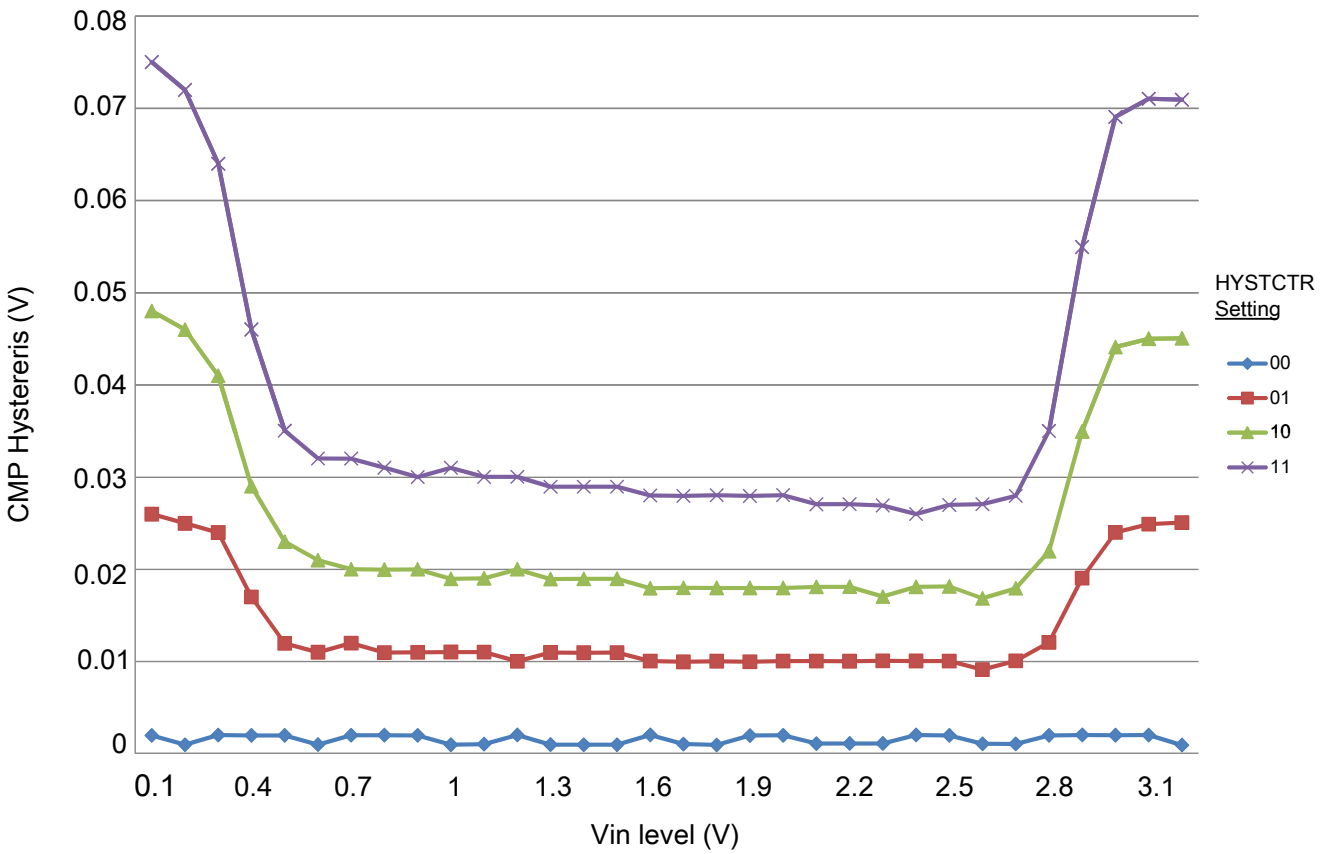


Figure 23. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 0)

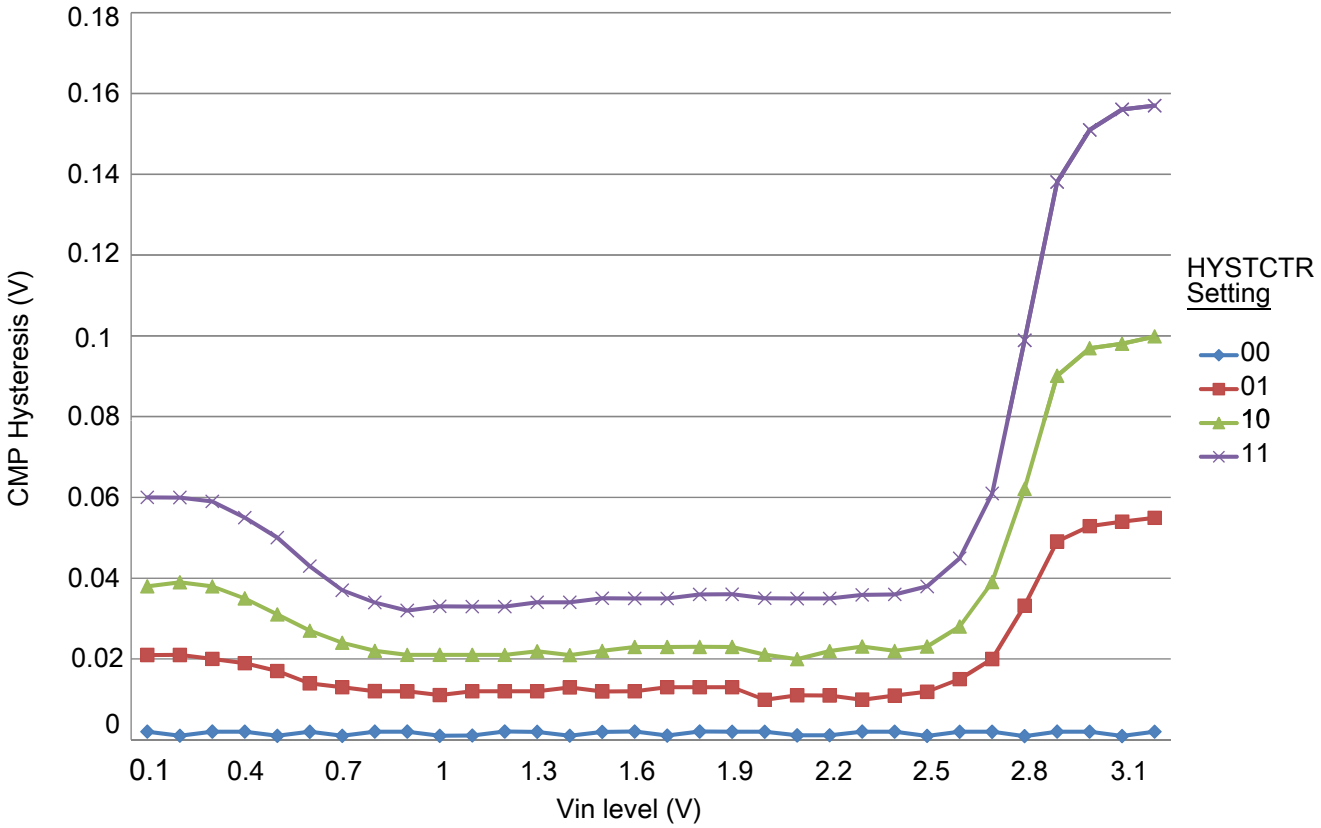


Figure 24. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 1)

6.6.3 12-bit DAC electrical characteristics

6.6.3.1 12-bit DAC operating requirements

Table 33. 12-bit DAC operating requirements

Symbol	Desciption	Min.	Max.	Unit	Notes
V_{DDA}	Supply voltage	1.71	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_{REF_OUT}.
2. A small load capacitance (47 pF) can improve the bandwidth performance of the DAC.

6.6.3.2 12-bit DAC operating behaviors

Table 34. 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 0xFFF	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 V	—	—	±1	LSB	3
DNL	Differential non-linearity error — V_{DACR} = VREF_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} ≥ 2.4 V	60	—	90	dB	
T_{CO}	Temperature coefficient offset voltage	—	3.7	—	µV/C	6
T_{GE}	Temperature coefficient gain error	—	0.000421	—	%FSR/C	
Rop	Output resistance (load = 3 kΩ)	—	—	250	Ω	
SR	Slew rate -80h→ F7Fh→ 80h				V/µs	
	• High power (SP_{HP})	1.2	1.7	—		
	• Low power (SP_{LP})	0.05	0.12	—		
CT	Channel to channel cross talk	—	—	-80	dB	
BW	3dB bandwidth				kHz	
	• High power (SP_{HP})	550	—	—		
	• Low power (SP_{LP})	40	—	—		

1. Settling within ±1 LSB
2. The INL is measured for 0 + 100 mV to V_{DACR} −100 mV
3. The DNL is measured for 0 + 100 mV to V_{DACR} −100 mV
4. The DNL is measured for 0 + 100 mV to V_{DACR} −100 mV with V_{DDA} > 2.4 V
5. Calculated by a best fit curve from V_{SS} + 100 mV to V_{DACR} − 100 mV
6. V_{DDA} = 3.0 V, reference select set for V_{DDA} (DACx_CO:DACRFS = 1), high power mode (DACx_C0:LPEN = 0), DAC set to 0x800, temperature range is across the full range of the device

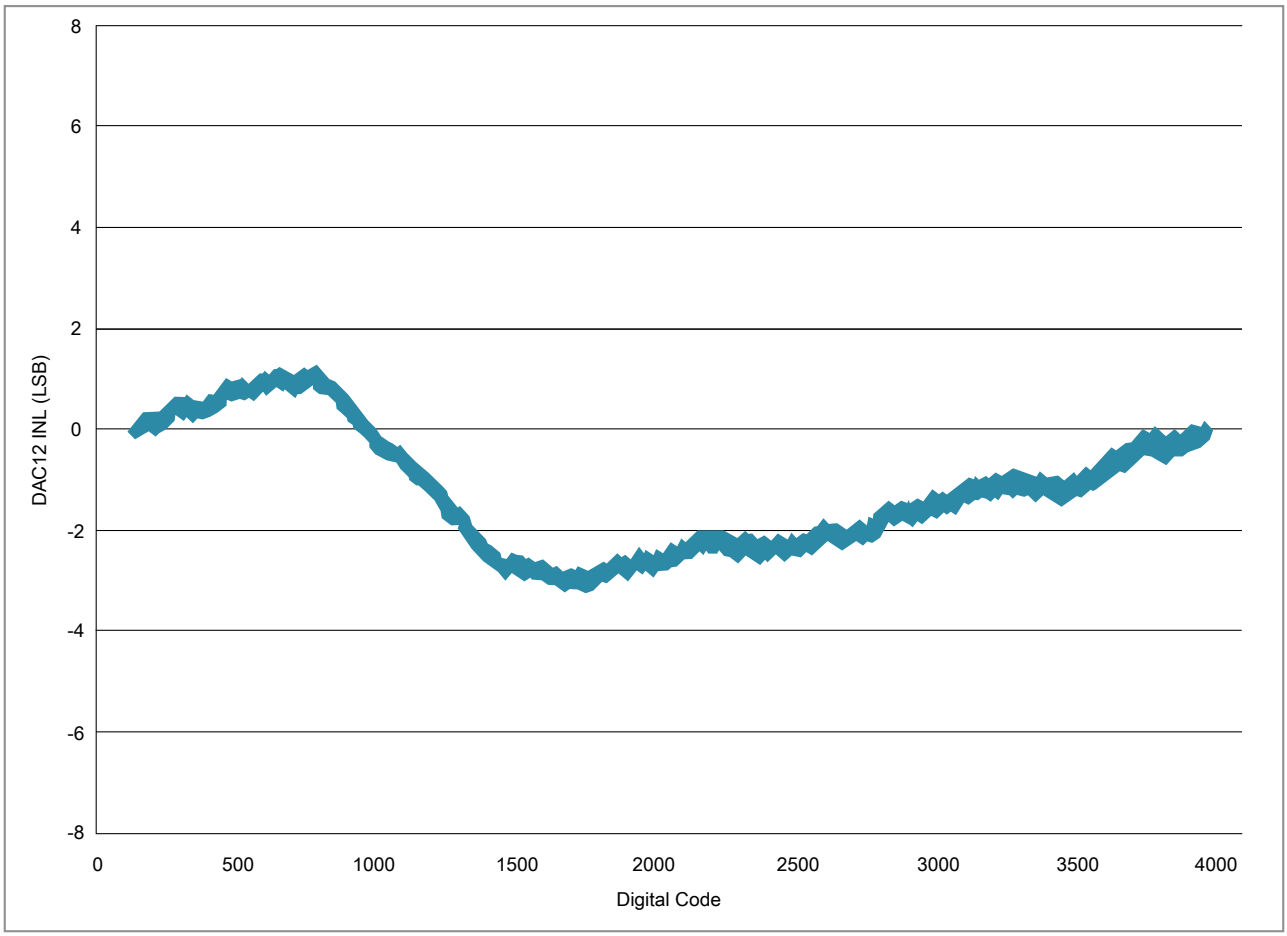


Figure 25. Typical INL error vs. digital code

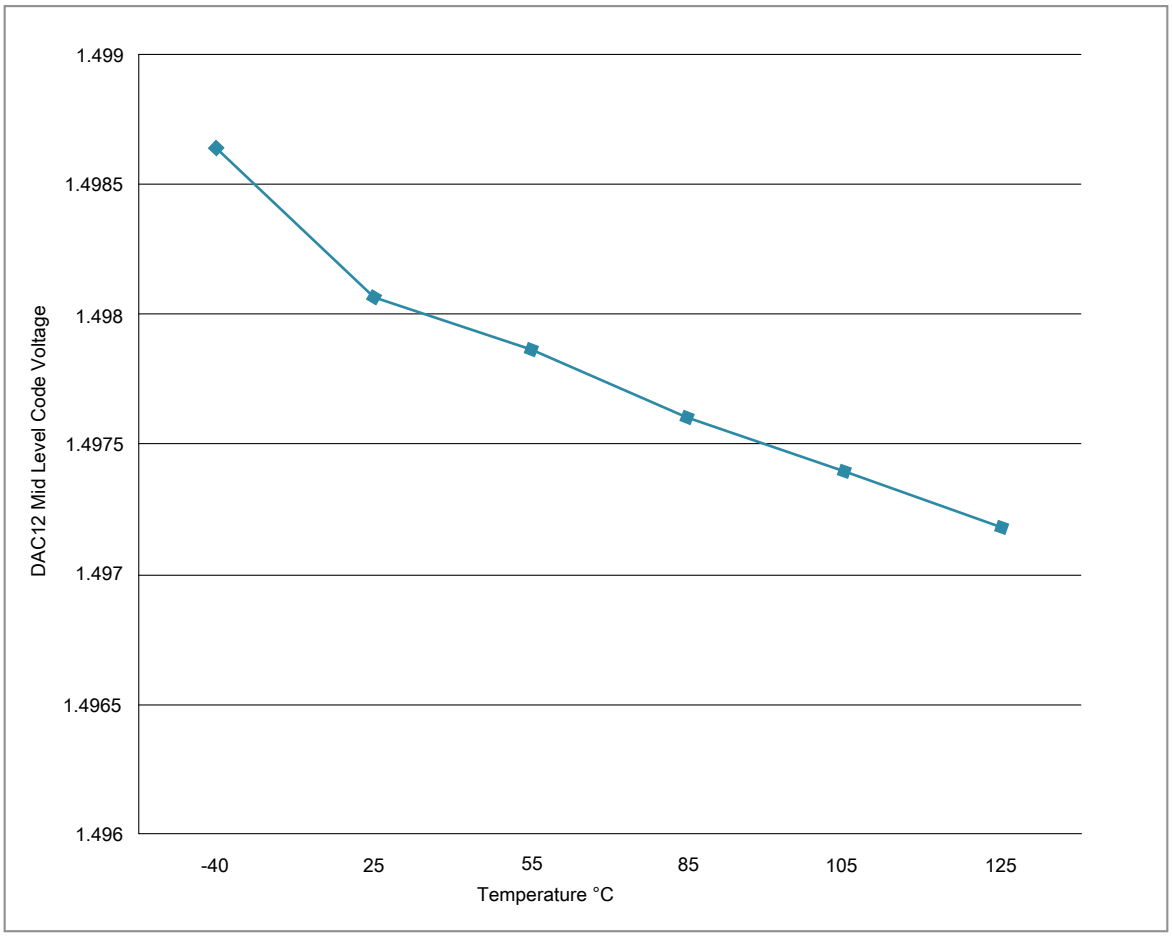


Figure 26. Offset at half scale vs. temperature

6.6.4 Voltage reference electrical specifications

Table 35. VREF full-range operating requirements

Symbol	Description	Min.	Max.	Unit	Notes
V_{DDA}	Supply voltage	1.71	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 36. 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	1.1915	1.195	1.1977	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 (Vmax -Vmin across the full temperature range)	—	—	80	mV	1
I_{bg}	Bandgap only current	—	—	80	µA	1
I_{hp}	High-power buffer current	—	—	1	mA	1
ΔV_{LOAD}	Load regulation				mV	1, 2
	• current = + 1.0 mA	—	2	—		
	• current = - 1.0 mA	—	5	—		
T_{stup}	Buffer startup time	—	—	100	µs	
V_{vdrift}	Voltage drift (Vmax -Vmin 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 37. VREF limited-range operating requirements

Symbol	Description	Min.	Max.	Unit	Notes
T_A	Temperature	0	50	°C	

Table 38. VREF limited-range operating behaviors

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

6.7 Timers

See General switching specifications.

6.8 Communication interfaces

6.8.1 CAN switching specifications

See General switching specifications.

6.8.2 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 DSPI 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 39. 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 x t_{BUS}	—	ns	
DS2	DSPI_SCK output high/low time	(t_{SCK}/2) – 2	(t_{SCK}/2) + 2	ns	
DS3	DSPI_PCS*n* valid to DSPI_SCK delay	(t_{BUS} x 2) – 2	—	ns	1
DS4	DSPI_SCK to DSPI_PCS*n* invalid delay	(t_{BUS} x 2) – 2	—	ns	2
DS5	DSPI_SCK to DSPI_SOUT valid	—	8.5	ns	
DS6	DSPI_SCK to DSPI_SOUT invalid	–2	—	ns	
DS7	DSPI_SIN to DSPI_SCK input setup	15	—	ns	
DS8	DSPI_SCK to DSPI_SIN input hold	0	—	ns	

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

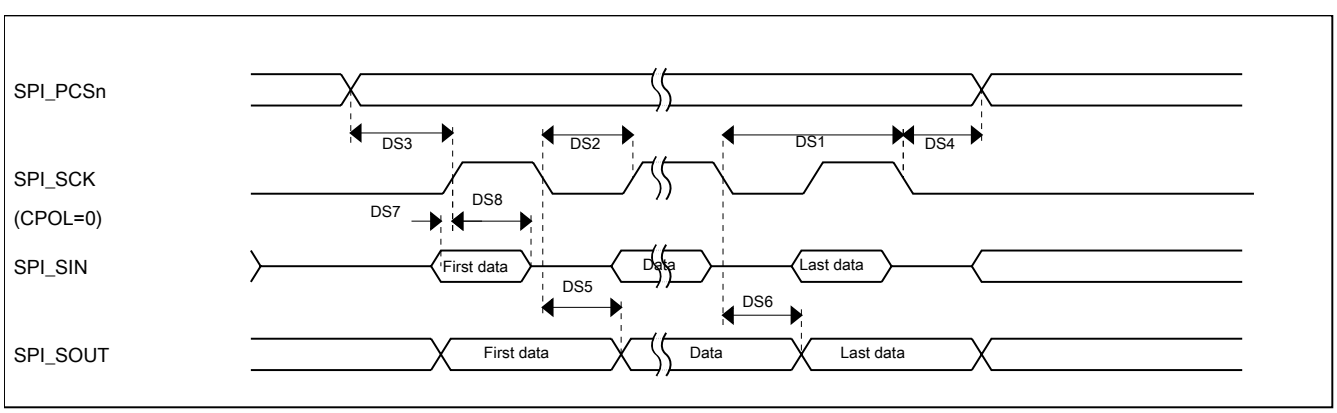


Figure 27. DSPI classic DSPI timing — master mode

Table 40. Slave mode DSPI timing (limited voltage range)

Num	Description	Min.	Max.	Unit
	Operating voltage	2.7	3.6	V
	Frequency of operation		15	MHz
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	—	10	ns
DS12	DSPI_SCK to DSPI_SOUT invalid	0	—	ns
DS13	DSPI_SIN to DSPI_SCK input setup	2	—	ns
DS14	DSPI_SCK to DSPI_SIN input hold	7	—	ns
DS15	$\overline{\text{DSPI\_SS}}$ active to DSPI_SOUT driven	—	14	ns
DS16	$\overline{\text{DSPI\_SS}}$ inactive to DSPI_SOUT not driven	—	14	ns

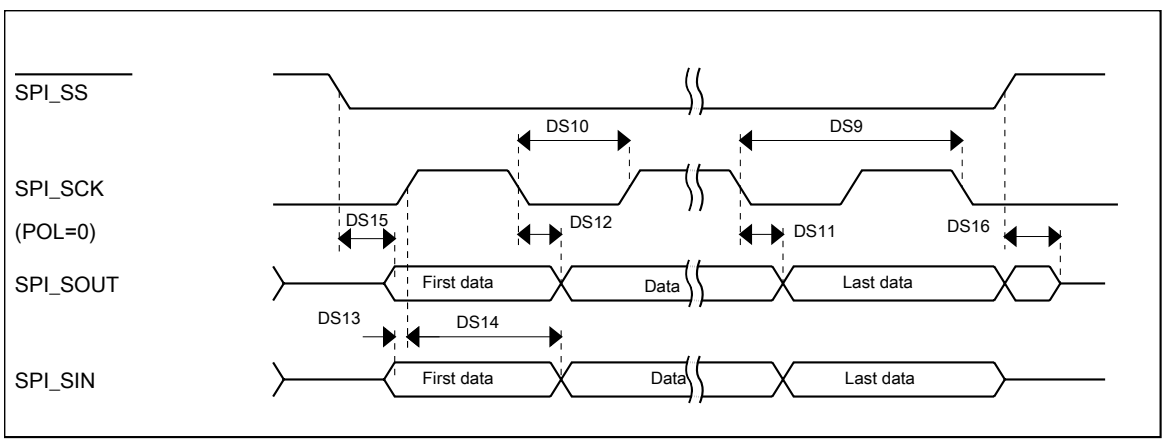


Figure 28. DSPI classic DSPI timing — slave mode

6.8.3 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 41. Master mode DSPItiming (full voltage range)

Num	Description	Min.	Max.	Unit	Notes
	Operating voltage	1.71	3.6	V	1
	Frequency of operation	—	15	MHz	
DS1	DSPI_SCK output cycle time	4 x t_{BUS}	—	ns	

Table continues on the next page...

Table 41. Master mode DSPItiming (full voltage range) (continued)

Num	Description	Min.	Max.	Unit	Notes
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} x 2) – 4	—	ns	2
DS4	DSPI_SCK to DSPI_PCS*n* invalid delay	(t_{BUS} x 2) – 4	—	ns	3
DS5	DSPI_SCK to DSPI_SOUT valid	—	10	ns	
DS6	DSPI_SCK to DSPI_SOUT invalid	-4.5	—	ns	
DS7	DSPI_SIN to DSPI_SCK input setup	20.5	—	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].

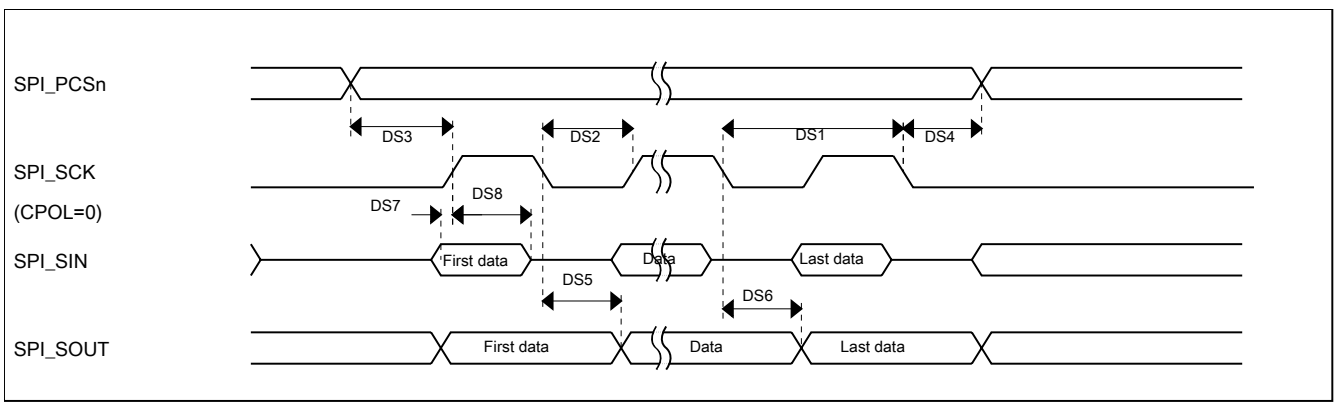


Figure 29. DSPI classic SPI timing — master mode

Table 42. 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 x 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	—	20	ns
DS12	DSPI_SCK to DSPI_SOUT invalid	0	—	ns
DS13	DSPI_SIN to DSPI_SCK input setup	2	—	ns
DS14	DSPI_SCK to DSPI_SIN input hold	7	—	ns
DS15	$\overline{\text{DSPI\_SS}}$ active to DSPI_SOUT driven	—	19	ns
DS16	$\overline{\text{DSPI\_SS}}$ inactive to DSPI_SOUT not driven	—	19	ns

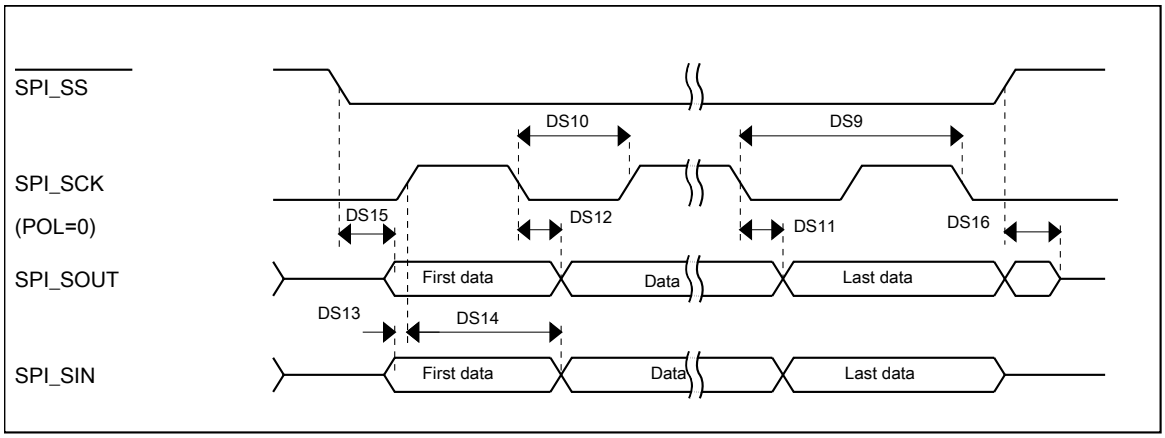


Figure 30. DSPI classic SPI timing — slave mode

6.8.4 Inter-Integrated Circuit Interface (I^2C) timing

Table 43. I^2C timing

Characteristic	Symbol	Standard Mode		Fast Mode		Unit
		Minimum	Maximum	Minimum	Maximum	
SCL Clock Frequency	f_{SCL}	0	100	0	400 [1]	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^2C bus devices	t_{HD}; DAT	0[2]	3.45[3]	0[4]	0.9[2]	µs
Data set-up time	t_{SU}; DAT	250[5]	—	100[3,6]	—	ns
Rise time of SDA and SCL signals	t_r	—	1000	20 +0.1C_b[7]	300	ns
Fall time of SDA and SCL signals	t_f	—	300	20 +0.1C_b[6]	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 maximum SCL Clock Frequency in Fast mode with maximum bus loading can only be achieved when using a pin configured for high drive across the full voltage range and when using the a pin configured for low drive with VDD ≥ 2.7 V.
2. The master mode I^2C 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.
3. The maximum tHD; DAT must be met only if the device does not stretch the LOW period (tLOW) of the SCL signal.
4. Input signal Slew = 10 ns and Output Load = 50 pF
5. Set-up time in slave-transmitter mode is 1 IPBus clock period, if the TX FIFO is empty.
6. A Fast mode I^2C 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 $t_{rmax} + t_{SU; DAT}$ = 1000 + 250 = 1250 ns (according to the Standard mode I^2C bus specification) before the SCL line is released.

7. C_b = total capacitance of the one bus line in pF.

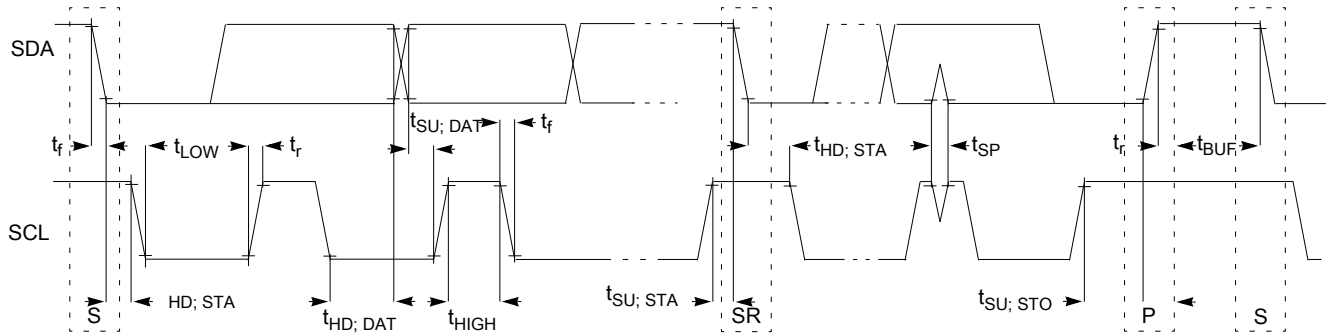


Figure 31. Timing definition for fast and standard mode devices on the I^2C bus

6.8.5 UART switching specifications

See General switching specifications.

6.8.6 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 44. SDHC switching specifications over a limited operating voltage range

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\40	MHz
	fpp	Clock frequency (MMC full speed\high speed)	0	25\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	6.5	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 45. SDHC switching specifications over the full operating voltage range

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\40	MHz
	fpp	Clock frequency (MMC full speed\high speed)	0	25\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	6.5	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	1.3	—	ns

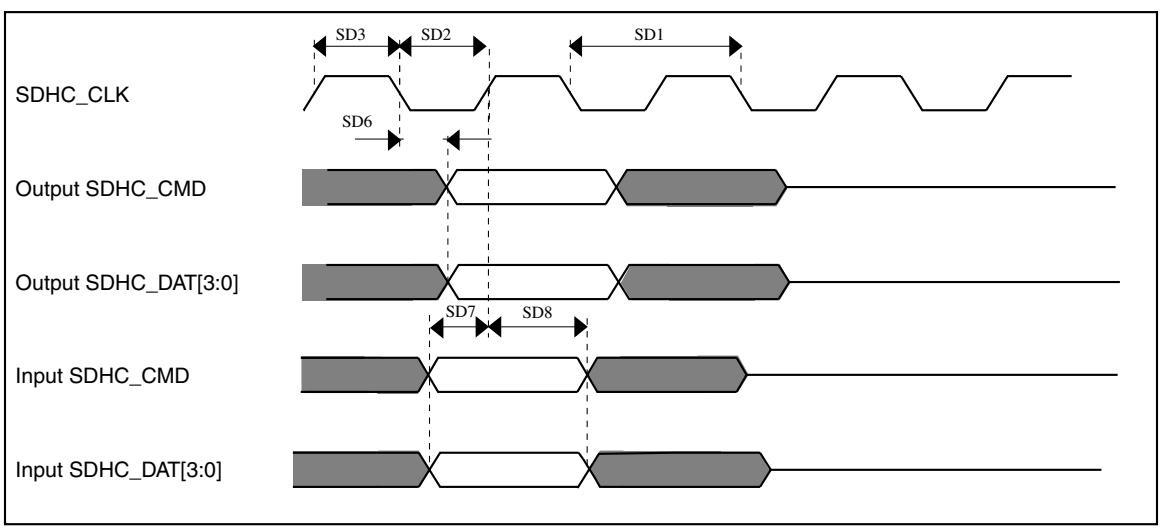


Figure 32. SDHC timing

6.8.7 I2S/SAI switching specifications

This section provides the AC timing for the I2S/SAI module in master mode (clocks are driven) and slave mode (clocks are input). All timing is given for noninverted serial clock polarity (TCR2[BCP] is 0, RCR2[BCP] is 0) and a noninverted frame sync (TCR4[FSP]

is 0, RCR4[FSP] is 0). If the polarity of the clock and/or the frame sync have been inverted, all the timing remains valid by inverting the bit clock signal (BCLK) and/or the frame sync (FS) signal shown in the following figures.

6.8.7.1 Normal Run, Wait and Stop mode performance over a limited operating voltage range

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

Table 46. I2S/SAI master mode timing in Normal Run, Wait and Stop modes (limited voltage range)

Num.	Characteristic	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_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

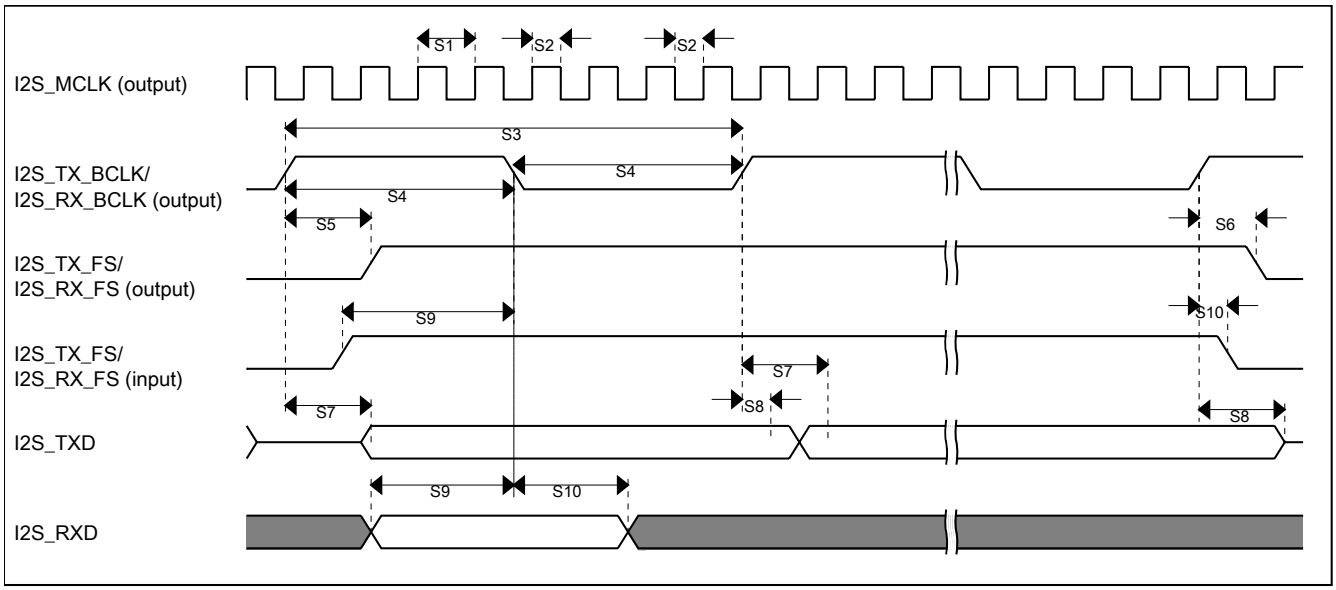


Figure 33. I2S/SAI timing — master modes

Table 47. I2S/SAI slave mode timing in Normal Run, Wait and Stop modes (limited voltage range)

Num.	Characteristic	Min.	Max.	Unit
	Operating voltage	2.7	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 • Multiple SAI Synchronous mode • All other modes	 — —	 21 15	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

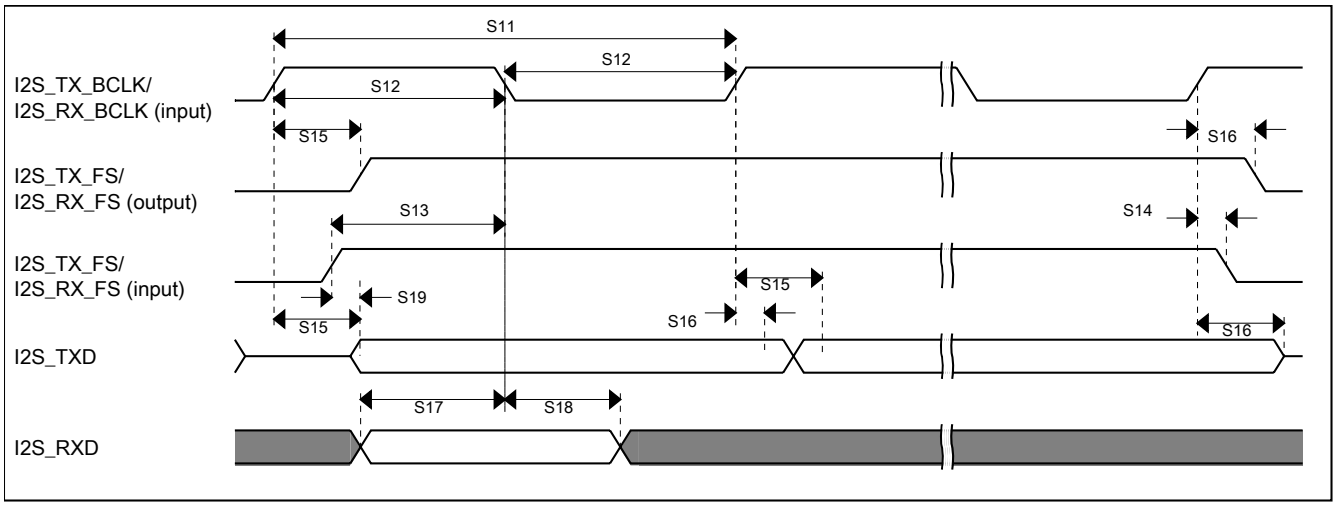


Figure 34. I2S/SAI timing — slave modes

6.8.7.2 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 48. I2S/SAI master mode timing in Normal Run, Wait and Stop modes (full voltage range)

Num.	Characteristic	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V
S1	I2S_MCLK cycle time	40	—	ns
S2	I2S_MCLK 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	-1.0	—	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	20.5	—	ns
S10	I2S_RXD/I2S_RX_FS input hold after I2S_RX_BCLK	0	—	ns

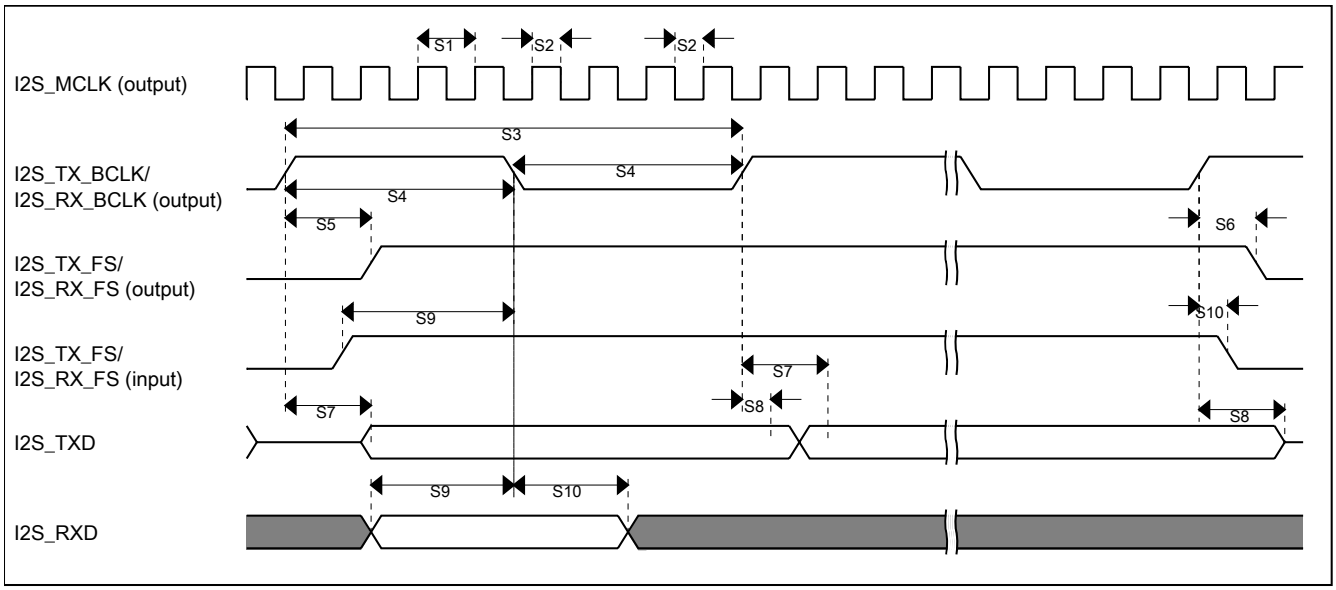


Figure 35. I2S/SAI timing — master modes

Table 49. I2S/SAI slave mode timing in Normal Run, Wait and Stop 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)	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	5.8	—	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 • Multiple SAI Synchronous mode • All other modes	 — —	 24 20.6	ns
S16	I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output invalid	0	—	ns
S17	I2S_RXD setup before I2S_RX_BCLK	5.8	—	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

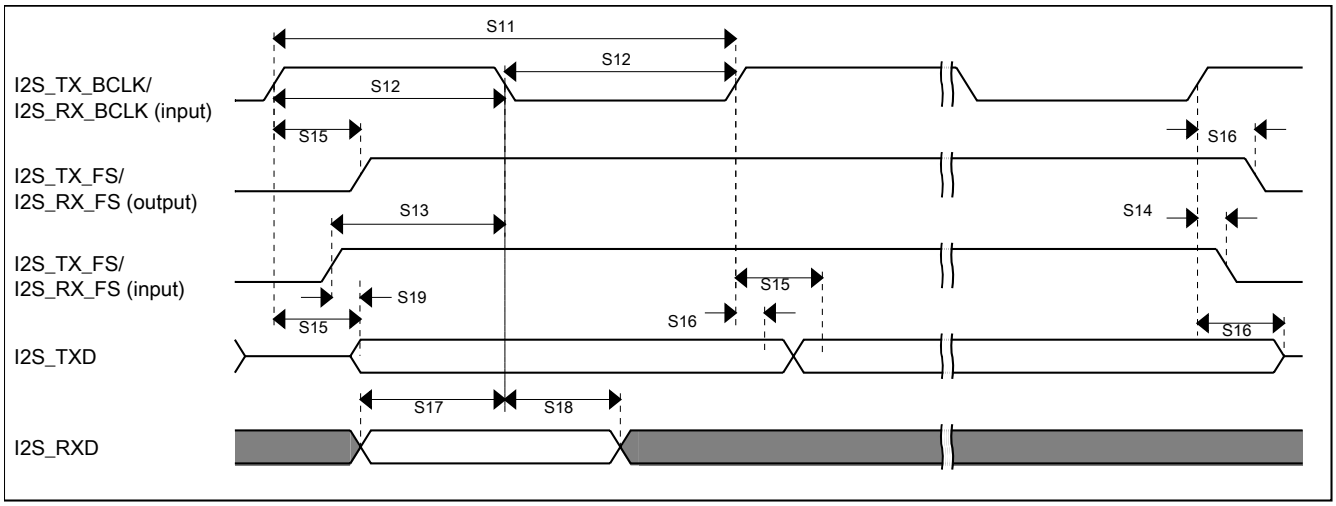


Figure 36. I2S/SAI timing — slave modes

6.8.7.3 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 50. 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	-1.6	—	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

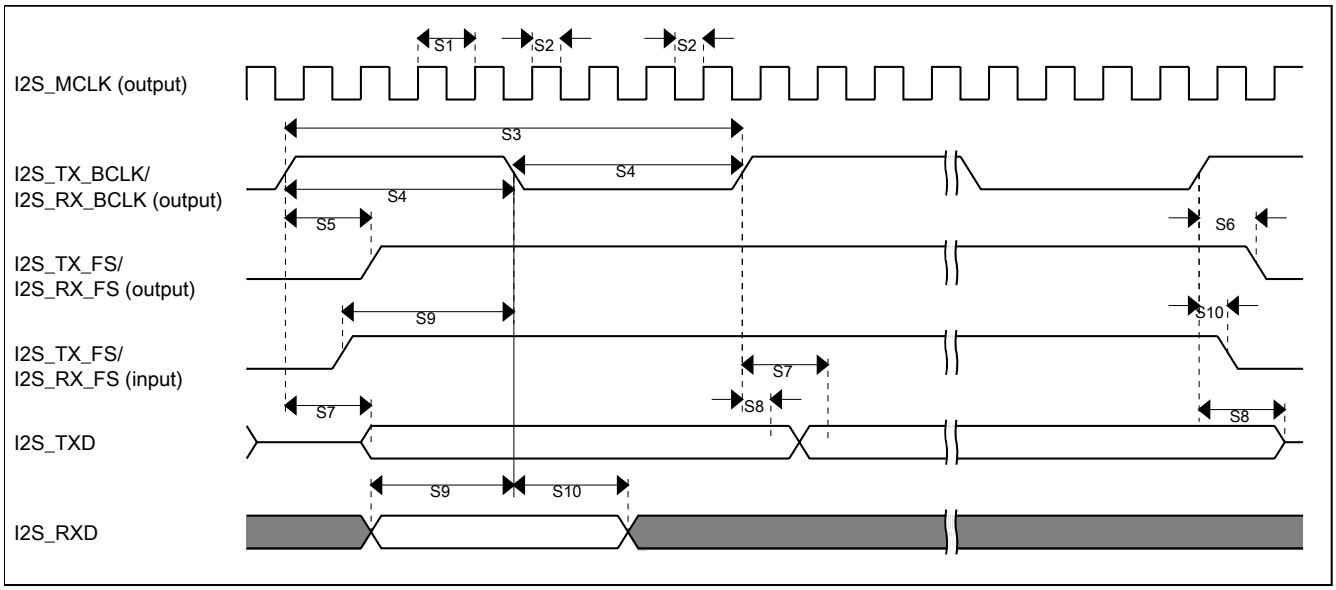


Figure 37. I2S/SAI timing — master modes

Table 51. 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	3	—	ns
S15	I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output valid	—	63	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	2	—	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

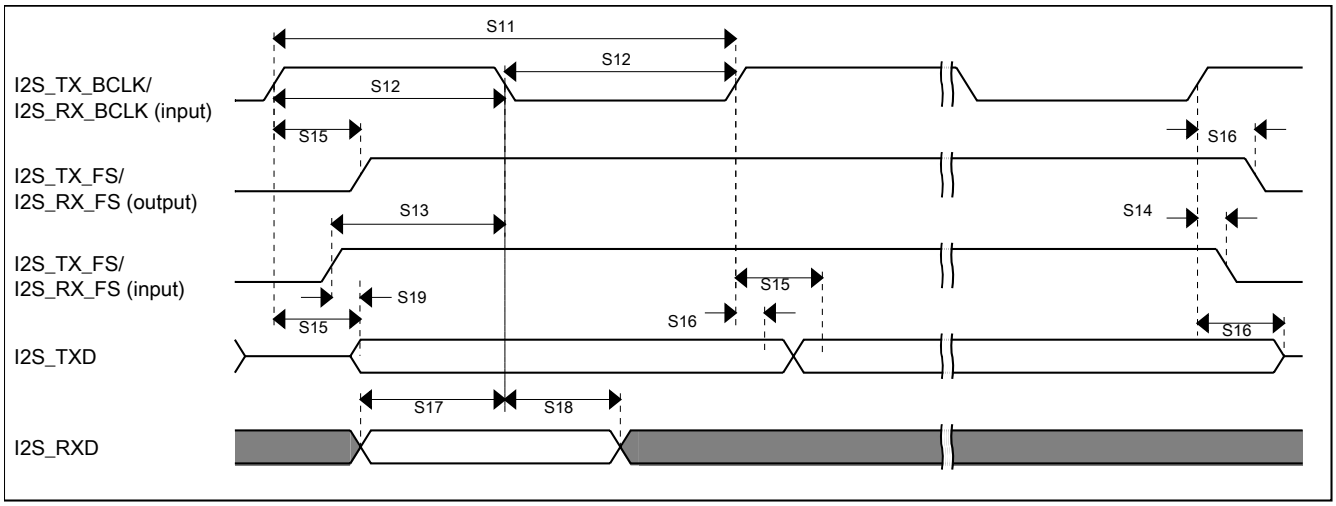


Figure 38. I2S/SAI timing — slave modes

6.9 Human-machine interfaces (HMI)

6.9.1 TSI electrical specifications

Table 52. TSI electrical specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
V_{DDTSI}	Operating voltage	1.71	—	3.6	V	
C_{ELE}	Target electrode capacitance range	1	20	500	pF	1
f_{REFmax}	Reference oscillator frequency	—	8	15	MHz	2, 3
f_{ELEmax}	Electrode oscillator frequency	—	1	1.8	MHz	2, 4
C_{REF}	Internal reference capacitor	—	1	—	pF	
V_{DELTA}	Oscillator delta voltage	—	600	—	mV	2, 5
I_{REF}	Reference oscillator current source base current • 2 µA setting (REFCHRG = 0) • 32 µA setting (REFCHRG = 15)	— —	2 36	3 50	µA	2, 6
I_{ELE}	Electrode oscillator current source base current • 2 µA setting (EXTCHRG = 0) • 32 µA setting (EXTCHRG = 15)	— —	2 36	3 50	µA	2, 7
Pres5	Electrode capacitance measurement precision	—	8.3333	38400	fF/count	8
Pres20	Electrode capacitance measurement precision	—	8.3333	38400	fF/count	9
Pres100	Electrode capacitance measurement precision	—	8.3333	38400	fF/count	10
MaxSens	Maximum sensitivity	0.008	1.46	—	fF/count	11
Res	Resolution	—	—	16	bits	
T_{Con20}	Response time @ 20 pF	8	15	25	µs	12
I_{TSI_RUN}	Current added in run mode	—	55	—	µA	
I_{TSI_LP}	Low power mode current adder	—	1.3	2.5	µA	13

1. The TSI module is functional with capacitance values outside this range. However, optimal performance is not guaranteed.
2. Fixed external capacitance of 20 pF.
3. REFCHRG = 2, EXTCHRG=0.
4. REFCHRG = 0, EXTCHRG = 10.
5. V_{DD} = 3.0 V.
6. The programmable current source value is generated by multiplying the SCANC[REFCHRG] value and the base current.
7. The programmable current source value is generated by multiplying the SCANC[EXTCHRG] value and the base current.
8. Measured with a 5 pF electrode, reference oscillator frequency of 10 MHz, PS = 128, NSCN = 8; Iext = 16.
9. Measured with a 20 pF electrode, reference oscillator frequency of 10 MHz, PS = 128, NSCN = 2; Iext = 16.
10. Measured with a 20 pF electrode, reference oscillator frequency of 10 MHz, PS = 16, NSCN = 3; Iext = 16.
11. Sensitivity defines the minimum capacitance change when a single count from the TSI module changes. Sensitivity depends on the configuration used. The documented values are provided as examples calculated for a specific configuration of operating conditions using the following equation: (C_{ref} * I_{ext})/(I_{ref} * PS * NSCN)

    The typical value is calculated with the following configuration:

    I_{ext} = 6 µA (EXTCHRG = 2), PS = 128, NSCN = 2, I_{ref} = 16 µA (REFCHRG = 7), C_{ref} = 1.0 pF

    The minimum value is calculated with the following configuration:

    I_{ext} = 2 µA (EXTCHRG = 0), PS = 128, NSCN = 32, I_{ref} = 32 µA (REFCHRG = 15), C_{ref} = 0.5 pF

    The highest possible sensitivity is the minimum value because it represents the smallest possible capacitance that can be measured by a single count.
12. Time to do one complete measurement of the electrode. Sensitivity resolution of 0.0133 pF, PS = 0, NSCN = 0, 1 electrode, EXTCHRG = 7.
13. REFCHRG=0, EXTCHRG=4, PS=7, NSCN=0F, LPSCNITV=F, LPO is selected (1 kHz), and fixed external capacitance of 20 pF. Data is captured with an average of 7 periods window.

7 Dimensions

7.1 Obtaining package dimensions

Package dimensions are provided in package drawings.

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
144-pin LQFP	98ASS23177W
144-pin MAPBGA	98ASA00222D

8 Pinout

8.1 Pins with active pull control after reset

The following pins are actively pulled up or down after reset:

Table 53. Pins with active pull control after reset

Pin	Active pull direction after reset
PTA0	pulldown
PTA1	pullup
PTA3	pullup
PTA4	pullup
RESET_b	pullup

8.2 K10 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.

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
—	L5	RTC_ WAKEUP_B	RTC_ WAKEUP_B	RTC_ WAKEUP_B								
—	M5	NC	NC	NC								
—	A10	NC	NC	NC								
—	B10	NC	NC	NC								
—	C10	NC	NC	NC								
1	D3	PTE0	ADC1_SE4a	ADC1_SE4a	PTE0	SPI1_PCS1	UART1_TX	SDHC0_D1		I2C1_SDA	RTC_ CLKOUT	
2	D2	PTE1/ LLWU_P0	ADC1_SE5a	ADC1_SE5a	PTE1/ LLWU_P0	SPI1_SOUT	UART1_RX	SDHC0_D0		I2C1_SCL	SPI1_SIN	
3	D1	PTE2/ LLWU_P1	ADC1_SE6a	ADC1_SE6a	PTE2/ LLWU_P1	SPI1_SCK	UART1_ CTS_b	SDHC0_ DCLK				
4	E4	PTE3	ADC1_SE7a	ADC1_SE7a	PTE3	SPI1_SIN	UART1_ RTS_b	SDHC0_CMD			SPI1_SOUT	
5	E5	VDD	VDD	VDD								
6	F6	VSS	VSS	VSS								
7	E3	PTE4/ LLWU_P2	DISABLED		PTE4/ LLWU_P2	SPI1_PCS0	UART3_TX	SDHC0_D3				
8	E2	PTE5	DISABLED		PTE5	SPI1_PCS2	UART3_RX	SDHC0_D2		FTM3_CH0		
9	E1	PTE6	DISABLED		PTE6	SPI1_PCS3	UART3_ CTS_b	I2S0_MCLK		FTM3_CH1		
10	F4	PTE7	DISABLED		PTE7		UART3_ RTS_b	I2S0_RXD0		FTM3_CH2		
11	F3	PTE8	ADC2_SE16	ADC2_SE16	PTE8	I2S0_RXD1	UART5_TX	I2S0_RX_FS		FTM3_CH3		
12	F2	PTE9	ADC2_SE17	ADC2_SE17	PTE9	I2S0_TXD1	UART5_RX	I2S0_RX_ BCLK		FTM3_CH4		

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
13	F1	PTE10	DISABLED		PTE10		UART5_ CTS_b	I2S0_TXD0		FTM3_CH5		
14	G4	PTE11	ADC3_SE16	ADC3_SE16	PTE11		UART5_ RTS_b	I2S0_TX_FS		FTM3_CH6		
15	G3	PTE12	ADC3_SE17	ADC3_SE17	PTE12			I2S0_TX_ BCLK		FTM3_CH7		
16	E6	VDD	VDD	VDD								
17	F7	VSS	VSS	VSS								
18	H1	PTE16	ADC0_SE4a	ADC0_SE4a	PTE16	SPI0_PCS0	UART2_TX	FTM_CLKIN0		FTM0_FLT3		
19	H2	PTE17	ADC0_SE5a	ADC0_SE5a	PTE17	SPI0_SCK	UART2_RX	FTM_CLKIN1		LPTMR0_ ALT3		
20	G1	PTE18	ADC0_SE6a	ADC0_SE6a	PTE18	SPI0_SOUT	UART2_ CTS_b	I2C0_SDA				
21	G2	PTE19	ADC0_SE7a	ADC0_SE7a	PTE19	SPI0_SIN	UART2_ RTS_b	I2C0_SCL		CMP3_OUT		
22	H3	VSS	VSS	VSS								
23	J1	PGA2_DP/ ADC2_DP0/ ADC3_DP3/ ADC0_DP1	PGA2_DP/ ADC2_DP0/ ADC3_DP3/ ADC0_DP1	PGA2_DP/ ADC2_DP0/ ADC3_DP3/ ADC0_DP1								
24	J2	PGA2_DM/ ADC2_DM0/ ADC3_DM3/ ADC0_DM1	PGA2_DM/ ADC2_DM0/ ADC3_DM3/ ADC0_DM1	PGA2_DM/ ADC2_DM0/ ADC3_DM3/ ADC0_DM1								
25	K1	PGA3_DP/ ADC3_DP0/ ADC2_DP3/ ADC1_DP1	PGA3_DP/ ADC3_DP0/ ADC2_DP3/ ADC1_DP1	PGA3_DP/ ADC3_DP0/ ADC2_DP3/ ADC1_DP1								
26	K2	PGA3_DM/ ADC3_DM0/ ADC2_DM3/ ADC1_DM1	PGA3_DM/ ADC3_DM0/ ADC2_DM3/ ADC1_DM1	PGA3_DM/ ADC3_DM0/ ADC2_DM3/ ADC1_DM1								
27	L1	PGA0_DP/ ADC0_DP0/ ADC1_DP3	PGA0_DP/ ADC0_DP0/ ADC1_DP3	PGA0_DP/ ADC0_DP0/ ADC1_DP3								
28	L2	PGA0_DM/ ADC0_DM0/ ADC1_DM3	PGA0_DM/ ADC0_DM0/ ADC1_DM3	PGA0_DM/ ADC0_DM0/ ADC1_DM3								
29	M1	PGA1_DP/ ADC1_DP0/ ADC0_DP3	PGA1_DP/ ADC1_DP0/ ADC0_DP3	PGA1_DP/ ADC1_DP0/ ADC0_DP3								
30	M2	PGA1_DM/ ADC1_DM0/ ADC0_DM3	PGA1_DM/ ADC1_DM0/ ADC0_DM3	PGA1_DM/ ADC1_DM0/ ADC0_DM3								
31	H5	VDDA	VDDA	VDDA								
32	G5	VREFH	VREFH	VREFH								
33	G6	VREFL	VREFL	VREFL								
34	H6	VSSA	VSSA	VSSA								

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
35	K3	ADC1_SE16/ CMP2_IN2/ ADC0_SE22	ADC1_SE16/ CMP2_IN2/ ADC0_SE22	ADC1_SE16/ CMP2_IN2/ ADC0_SE22								
36	J3	ADC0_SE16/ CMP1_IN2/ ADC0_SE21	ADC0_SE16/ CMP1_IN2/ ADC0_SE21	ADC0_SE16/ CMP1_IN2/ ADC0_SE21								
37	M3	VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18	VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18	VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18								
38	L3	DAC0_OUT/ CMP1_IN3/ ADC0_SE23	DAC0_OUT/ CMP1_IN3/ ADC0_SE23	DAC0_OUT/ CMP1_IN3/ ADC0_SE23								
39	L4	DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23	DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23	DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23								
40	M7	XTAL32	XTAL32	XTAL32								
41	M6	EXTAL32	EXTAL32	EXTAL32								
42	L6	VBAT	VBAT	VBAT								
43	—	VDD	VDD	VDD								
44	—	VSS	VSS	VSS								
45	M4	PTE24	ADC0_SE17/ EXTAL1	ADC0_SE17/ EXTAL1	PTE24	CAN1_TX	UART4_TX	I2S1_TX_FS		EWM_OUT_b	I2S1_RXD1	
46	K5	PTE25	ADC0_SE18/ XTAL1	ADC0_SE18/ XTAL1	PTE25	CAN1_RX	UART4_RX	I2S1_TX_ BCLK		EWM_IN	I2S1_TXD1	
47	K4	PTE26	ADC3_SE5b	ADC3_SE5b	PTE26		UART4_ CTS_b	I2S1_TXD0		RTC_ CLKOUT		
48	J4	PTE27	ADC3_SE4b	ADC3_SE4b	PTE27		UART4_ RTS_b	I2S1_MCLK				
49	H4	PTE28	ADC3_SE7a	ADC3_SE7a	PTE28							
50	J5	PTA0	JTAG_TCLK/ SWD_CLK/ EZP_CLK	TSI0_CH1	PTA0	UART0_ CTS_b/ UART0_ COL_b	FTM0_CH5				JTAG_TCLK/ SWD_CLK	EZP_CLK
51	J6	PTA1	JTAG_TDI/ EZP_DI	TSI0_CH2	PTA1	UART0_RX	FTM0_CH6				JTAG_TDI	EZP_DI
52	K6	PTA2	JTAG_TDO/ TRACE_ SWO/ EZP_DO	TSI0_CH3	PTA2	UART0_TX	FTM0_CH7				JTAG_TDO/ TRACE_ SWO	EZP_DO
53	K7	PTA3	JTAG_TMS/ SWD_DIO	TSI0_CH4	PTA3	UART0_ RTS_b	FTM0_CH0				JTAG_TMS/ SWD_DIO	
54	L7	PTA4/ LLWU_P3	NMI_b/ EZP_CS_b	TSI0_CH5	PTA4/ LLWU_P3		FTM0_CH1				NMI_b	EZP_CS_b
55	M8	PTA5	DISABLED		PTA5		FTM0_CH2		CMP2_OUT	I2S0_TX_ BCLK	JTAG_TRST_ b	
56	E7	VDD	VDD	VDD								

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
57	G7	VSS	VSS	VSS								
58	J7	PTA6	ADC3_SE6a	ADC3_SE6a	PTA6		FTM0_CH3	I2S1_RXD0	CLKOUT		TRACE_ CLKOUT	
59	J8	PTA7	ADC0_SE10	ADC0_SE10	PTA7		FTM0_CH4	I2S1_RX_ BCLK			TRACE_D3	
60	K8	PTA8	ADC0_SE11	ADC0_SE11	PTA8		FTM1_CH0	I2S1_RX_FS		FTM1_QD_ PHA	TRACE_D2	
61	L8	PTA9	ADC3_SE5a	ADC3_SE5a	PTA9		FTM1_CH1			FTM1_QD_ PHB	TRACE_D1	
62	M9	PTA10	ADC3_SE4a	ADC3_SE4a	PTA10		FTM2_CH0			FTM2_QD_ PHA	TRACE_D0	
63	L9	PTA11	ADC3_SE15	ADC3_SE15	PTA11		FTM2_CH1			FTM2_QD_ PHB		
64	K9	PTA12	CMP2_IN0	CMP2_IN0	PTA12	CAN0_TX	FTM1_CH0			I2S0_TXD0	FTM1_QD_ PHA	
65	J9	PTA13/ LLWU_P4	CMP2_IN1	CMP2_IN1	PTA13/ LLWU_P4	CAN0_RX	FTM1_CH1			I2S0_TX_FS	FTM1_QD_ PHB	
66	L10	PTA14	CMP3_IN0	CMP3_IN0	PTA14	SPI0_PCS0	UART0_TX			I2S0_RX_ BCLK	I2S0_TXD1	
67	L11	PTA15	CMP3_IN1	CMP3_IN1	PTA15	SPI0_SCK	UART0_RX			I2S0_RXD0		
68	K10	PTA16	CMP3_IN2	CMP3_IN2	PTA16	SPI0_SOUT	UART0_ CTS_b/ UART0_ COL_b			I2S0_RX_FS	I2S0_RXD1	
69	K11	PTA17	ADC1_SE17	ADC1_SE17	PTA17	SPI0_SIN	UART0_ RTS_b			I2S0_MCLK		
70	E8	VDD	VDD	VDD								
71	G8	VSS	VSS	VSS								
72	M12	PTA18	EXTAL0	EXTAL0	PTA18		FTM0_FLT2	FTM_CLKIN0				
73	M11	PTA19	XTAL0	XTAL0	PTA19		FTM1_FLT0	FTM_CLKIN1		LPTMR0_ ALT1		
74	L12	RESET_b	RESET_b	RESET_b								
75	K12	PTA24	CMP3_IN4	CMP3_IN4	PTA24					FB_A29		
76	J12	PTA25	CMP3_IN5	CMP3_IN5	PTA25					FB_A28		
77	J11	PTA26	ADC2_SE15	ADC2_SE15	PTA26					FB_A27		
78	J10	PTA27	ADC2_SE14	ADC2_SE14	PTA27					FB_A26		
79	H12	PTA28	ADC2_SE13	ADC2_SE13	PTA28					FB_A25		
80	H11	PTA29	ADC2_SE12	ADC2_SE12	PTA29					FB_A24		
81	H10	PTB0/ LLWU_P5	ADC0_SE8/ ADC1_SE8/ ADC2_SE8/ ADC3_SE8/ TSI0_CH0	ADC0_SE8/ ADC1_SE8/ ADC2_SE8/ ADC3_SE8/ TSI0_CH0	PTB0/ LLWU_P5	I2C0_SCL	FTM1_CH0			FTM1_QD_ PHA		
82	H9	PTB1	ADC0_SE9/ ADC1_SE9/ ADC2_SE9/	ADC0_SE9/ ADC1_SE9/ ADC2_SE9/	PTB1	I2C0_SDA	FTM1_CH1			FTM1_QD_ PHB		

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
			ADC3_SE9/ TSI0_CH6	ADC3_SE9/ TSI0_CH6								
83	G12	PTB2	ADC0_SE12/ TSI0_CH7	ADC0_SE12/ TSI0_CH7	PTB2	I2C0_SCL	UART0_ RTS_b			FTM0_FLT3		
84	G11	PTB3	ADC0_SE13/ TSI0_CH8	ADC0_SE13/ TSI0_CH8	PTB3	I2C0_SDA	UART0_ CTS_b/ UART0_ COL_b			FTM0_FLT0		
85	G10	PTB4	ADC1_SE10	ADC1_SE10	PTB4					FTM1_FLT0		
86	G9	PTB5	ADC1_SE11	ADC1_SE11	PTB5					FTM2_FLT0		
87	F12	PTB6	ADC1_SE12	ADC1_SE12	PTB6				FB_AD23			
88	F11	PTB7	ADC1_SE13	ADC1_SE13	PTB7				FB_AD22			
89	F10	PTB8	DISABLED		PTB8		UART3_ RTS_b		FB_AD21			
90	F9	PTB9	DISABLED		PTB9	SPI1_PCS1	UART3_ CTS_b		FB_AD20			
91	E12	PTB10	ADC1_SE14	ADC1_SE14	PTB10	SPI1_PCS0	UART3_RX	I2S1_TX_ BCLK	FB_AD19	FTM0_FLT1		
92	E11	PTB11	ADC1_SE15	ADC1_SE15	PTB11	SPI1_SCK	UART3_TX	I2S1_TX_FS	FB_AD18	FTM0_FLT2		
93	H7	VSS	VSS	VSS								
94	F5	VDD	VDD	VDD								
95	E10	PTB16	TSI0_CH9	TSI0_CH9	PTB16	SPI1_SOUT	UART0_RX	I2S1_TXD0	FB_AD17	EWM_IN		
96	E9	PTB17	TSI0_CH10	TSI0_CH10	PTB17	SPI1_SIN	UART0_TX	I2S1_TXD1	FB_AD16	EWM_OUT_b		
97	D12	PTB18	TSI0_CH11	TSI0_CH11	PTB18	CAN0_TX	FTM2_CH0	I2S0_TX_ BCLK	FB_AD15	FTM2_QD_ PHA		
98	D11	PTB19	TSI0_CH12	TSI0_CH12	PTB19	CAN0_RX	FTM2_CH1	I2S0_TX_FS	FB_OE_b	FTM2_QD_ PHB		
99	D10	PTB20	ADC2_SE4a	ADC2_SE4a	PTB20	SPI2_PCS0			FB_AD31/ NFC_ DATA15	CMP0_OUT		
100	D9	PTB21	ADC2_SE5a	ADC2_SE5a	PTB21	SPI2_SCK			FB_AD30/ NFC_ DATA14	CMP1_OUT		
101	C12	PTB22	DISABLED		PTB22	SPI2_SOUT			FB_AD29/ NFC_ DATA13	CMP2_OUT		
102	C11	PTB23	DISABLED		PTB23	SPI2_SIN	SPI0_PCS5		FB_AD28/ NFC_ DATA12	CMP3_OUT		
103	B12	PTC0	ADC0_SE14/ TSI0_CH13	ADC0_SE14/ TSI0_CH13	PTC0	SPI0_PCS4	PDB0_ EXTRG		FB_AD14/ NFC_ DATA11	I2S0_TXD1		
104	B11	PTC1/ LLWU_P6	ADC0_SE15/ TSI0_CH14	ADC0_SE15/ TSI0_CH14	PTC1/ LLWU_P6	SPI0_PCS3	UART1_ RTS_b	FTM0_CH0	FB_AD13/ NFC_ DATA10	I2S0_TXD0		

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
105	A12	PTC2	ADC0_SE4b/ CMP1_IN0/ TSI0_CH15	ADC0_SE4b/ CMP1_IN0/ TSI0_CH15	PTC2	SPI0_PCS2	UART1_ CTS_b	FTM0_CH1	FB_AD12/ NFC_DATA9	I2S0_TX_FS		
106	A11	PTC3/ LLWU_P7	CMP1_IN1	CMP1_IN1	PTC3/ LLWU_P7	SPI0_PCS1	UART1_RX	FTM0_CH2	CLKOUT	I2S0_TX_ BCLK		
107	H8	VSS	VSS	VSS								
108	—	VDD	VDD	VDD								
109	A9	PTC4/ LLWU_P8	DISABLED		PTC4/ LLWU_P8	SPI0_PCS0	UART1_TX	FTM0_CH3	FB_AD11/ NFC_DATA8	CMP1_OUT	I2S1_TX_ BCLK	
110	D8	PTC5/ LLWU_P9	DISABLED		PTC5/ LLWU_P9	SPI0_SCK	LPTMR0_ ALT2	I2S0_RXD0	FB_AD10/ NFC_DATA7	CMP0_OUT	I2S1_TX_FS	
111	C8	PTC6/ LLWU_P10	CMP0_IN0	CMP0_IN0	PTC6/ LLWU_P10	SPI0_SOUT	PDB0_ EXTRG	I2S0_RX_ BCLK	FB_AD9/ NFC_DATA6	I2S0_MCLK		
112	B8	PTC7	CMP0_IN1	CMP0_IN1	PTC7	SPI0_SIN		I2S0_RX_FS	FB_AD8/ NFC_DATA5			
113	A8	PTC8	ADC1_SE4b/ CMP0_IN2	ADC1_SE4b/ CMP0_IN2	PTC8		FTM3_CH4	I2S0_MCLK	FB_AD7/ NFC_DATA4			
114	D7	PTC9	ADC1_SE5b/ CMP0_IN3	ADC1_SE5b/ CMP0_IN3	PTC9		FTM3_CH5	I2S0_RX_ BCLK	FB_AD6/ NFC_DATA3	FTM2_FLT0		
115	C7	PTC10	ADC1_SE6b	ADC1_SE6b	PTC10	I2C1_SCL	FTM3_CH6	I2S0_RX_FS	FB_AD5/ NFC_DATA2	I2S1_MCLK		
116	B7	PTC11/ LLWU_P11	ADC1_SE7b	ADC1_SE7b	PTC11/ LLWU_P11	I2C1_SDA	FTM3_CH7	I2S0_RXD1	FB_RW_b/ NFC_WE			
117	A7	PTC12	DISABLED		PTC12		UART4_ RTS_b		FB_AD27	FTM3_FLT0		
118	D6	PTC13	DISABLED		PTC13		UART4_ CTS_b		FB_AD26			
119	C6	PTC14	DISABLED		PTC14		UART4_RX		FB_AD25			
120	B6	PTC15	DISABLED		PTC15		UART4_TX		FB_AD24			
121	—	VSS	VSS	VSS								
122	—	VDD	VDD	VDD								
123	A6	PTC16	DISABLED		PTC16	CAN1_RX	UART3_RX		FB_CS5_b/ FB_TSIZ1/ FB_BE23_ 16_b	NFC_RB		
124	D5	PTC17	DISABLED		PTC17	CAN1_TX	UART3_TX		FB_CS4_b/ FB_TSIZ0/ FB_BE31_ 24_b	NFC_CE0_b		
125	C5	PTC18	DISABLED		PTC18		UART3_ RTS_b		FB_TBST_b/ FB_CS2_b/ FB_BE15_8_ b	NFC_CE1_b		
126	B5	PTC19	DISABLED		PTC19		UART3_ CTS_b		FB_CS3_b/ FB_BE7_0_b	FB_TA_b		
127	A5	PTD0/ LLWU_P12	DISABLED		PTD0/ LLWU_P12	SPI0_PCS0	UART2_ RTS_b	FTM3_CH0	FB_ALE/ FB_CS1_b/ FB_TS_b	I2S1_RXD1		

144 LQFP	144 MAP BGA	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	EzPort
128	D4	PTD1	ADC0_SE5b	ADC0_SE5b	PTD1	SPI0_SCK	UART2_ CTS_b	FTM3_CH1	FB_CS0_b	I2S1_RXD0		
129	C4	PTD2/ LLWU_P13	DISABLED		PTD2/ LLWU_P13	SPI0_SOUT	UART2_RX	FTM3_CH2	FB_AD4	I2S1_RX_FS		
130	B4	PTD3	DISABLED		PTD3	SPI0_SIN	UART2_TX	FTM3_CH3	FB_AD3	I2S1_RX_ BCLK		
131	A4	PTD4/ LLWU_P14	DISABLED		PTD4/ LLWU_P14	SPI0_PCS1	UART0_ RTS_b	FTM0_CH4	FB_AD2/ NFC_DATA1	EWM_IN		
132	A3	PTD5	ADC0_SE6b	ADC0_SE6b	PTD5	SPI0_PCS2	UART0_ CTS_b/ UART0_ COL_b	FTM0_CH5	FB_AD1/ NFC_DATA0	EWM_OUT_b		
133	A2	PTD6/ LLWU_P15	ADC0_SE7b	ADC0_SE7b	PTD6/ LLWU_P15	SPI0_PCS3	UART0_RX	FTM0_CH6	FB_AD0	FTM0_FLT0		
134	M10	VSS	VSS	VSS								
135	F8	VDD	VDD	VDD								
136	A1	PTD7	DISABLED		PTD7	CMT_IRO	UART0_TX	FTM0_CH7		FTM0_FLT1		
137	C9	PTD8	DISABLED		PTD8	I2C0_SCL	UART5_RX			FB_A16/ NFC_CLE		
138	B9	PTD9	DISABLED		PTD9	I2C0_SDA	UART5_TX			FB_A17/ NFC_ALE		
139	B3	PTD10	DISABLED		PTD10		UART5_ RTS_b			FB_A18/ NFC_RE		
140	B2	PTD11	DISABLED		PTD11	SPI2_PCS0	UART5_ CTS_b	SDHC0_ CLKIN		FB_A19		
141	B1	PTD12	DISABLED		PTD12	SPI2_SCK	FTM3_FLT0	SDHC0_D4		FB_A20		
142	C3	PTD13	DISABLED		PTD13	SPI2_SOUT		SDHC0_D5		FB_A21		
143	C2	PTD14	DISABLED		PTD14	SPI2_SIN		SDHC0_D6		FB_A22		
144	C1	PTD15	DISABLED		PTD15	SPI2_PCS1		SDHC0_D7		FB_A23		

8.3 K10 pinouts

The figure below 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.

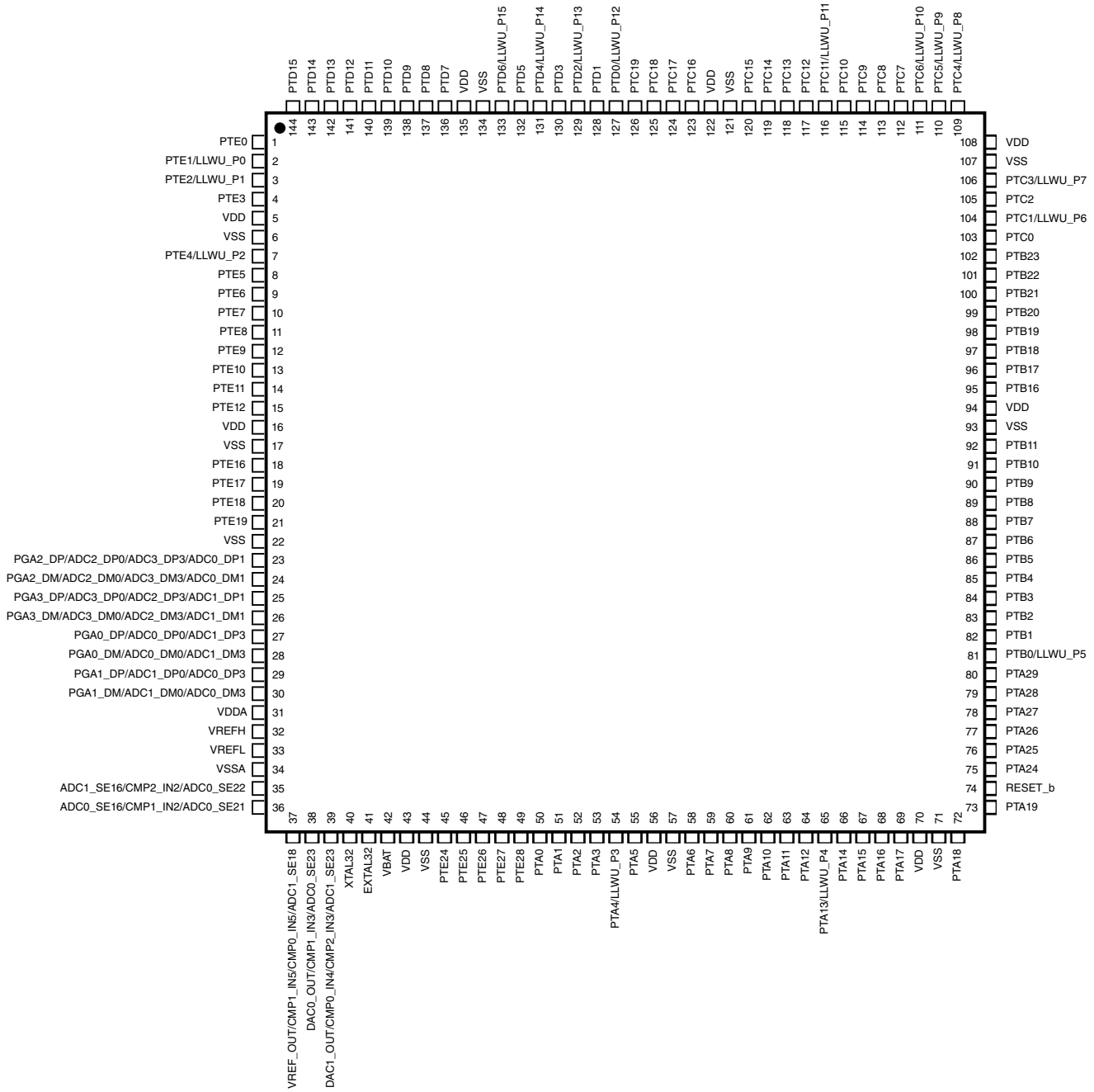
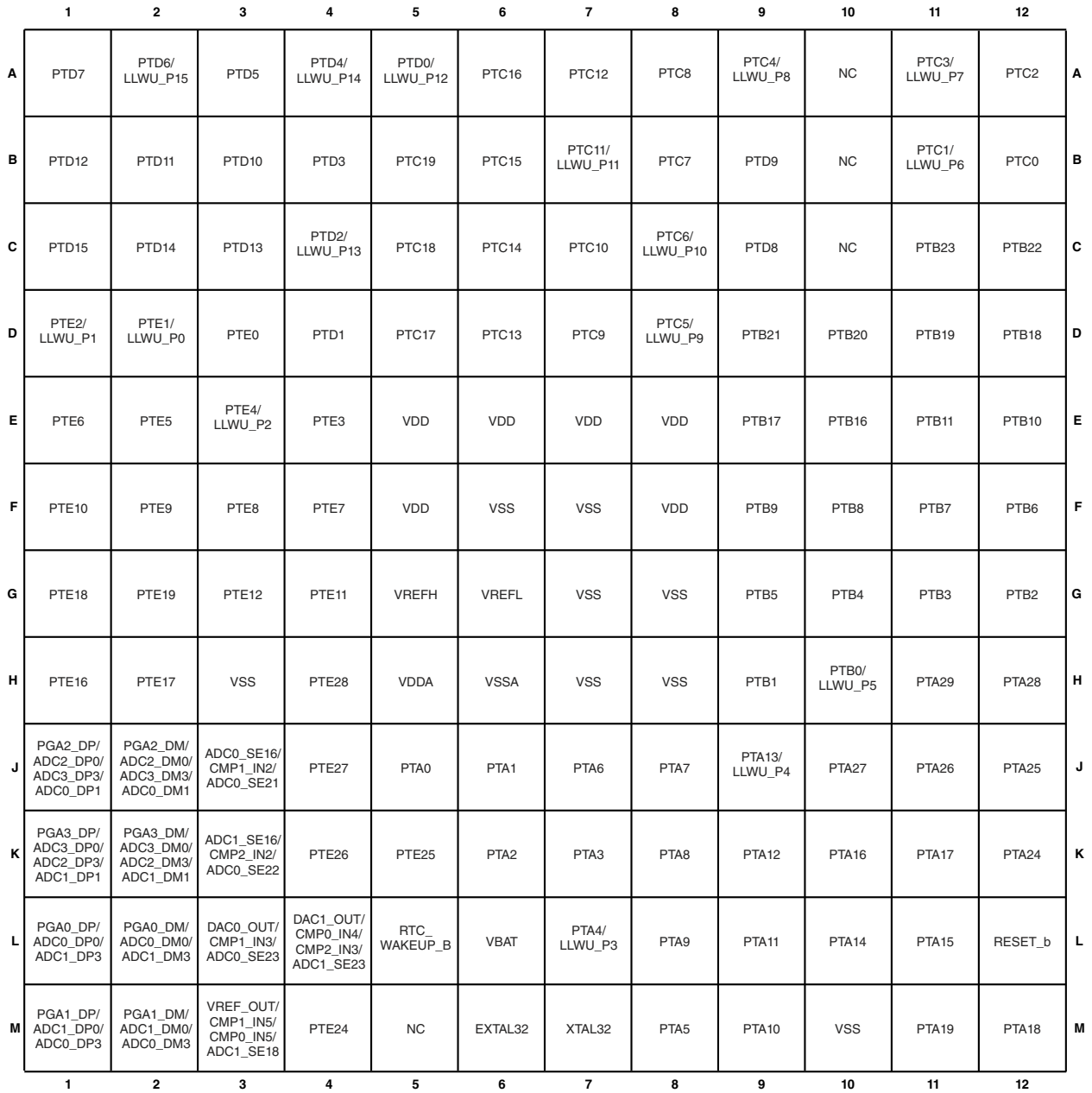


Figure 39. K10 144 LQFP Pinout Diagram



	1	2	3	4	5	6	7	8	9	10	11	12	
A	PTD7	PTD6/ LLWU_P15	PTD5	PTD4/ LLWU_P14	PTD0/ LLWU_P12	PTC16	PTC12	PTC8	PTC4/ LLWU_P8	NC	PTC3/ LLWU_P7	PTC2	A
B	PTD12	PTD11	PTD10	PTD3	PTC19	PTC15	PTC11/ LLWU_P11	PTC7	PTD9	NC	PTC1/ LLWU_P6	PTC0	B
C	PTD15	PTD14	PTD13	PTD2/ LLWU_P13	PTC18	PTC14	PTC10	PTC6/ LLWU_P10	PTD8	NC	PTB23	PTB22	C
D	PTE2/ LLWU_P1	PTE1/ LLWU_P0	PTE0	PTD1	PTC17	PTC13	PTC9	PTC5/ LLWU_P9	PTB21	PTB20	PTB19	PTB18	D
E	PTE6	PTE5	PTE4/ LLWU_P2	PTE3	VDD	VDD	VDD	VDD	PTB17	PTB16	PTB11	PTB10	E
F	PTE10	PTE9	PTE8	PTE7	VDD	VSS	VSS	VDD	PTB9	PTB8	PTB7	PTB6	F
G	PTE18	PTE19	PTE12	PTE11	VREFH	VREFL	VSS	VSS	PTB5	PTB4	PTB3	PTB2	G
H	PTE16	PTE17	VSS	PTE28	VDDA	VSSA	VSS	VSS	PTB1	PTB0/ LLWU_P5	PTA29	PTA28	H
J	PGA2_DP/ ADC2_DP0/ ADC3_DP3/ ADC0_DP1	PGA2_DM/ ADC2_DM0/ ADC3_DM3/ ADC0_DM1	ADC0_SE16/ CMP1_IN2/ ADC0_SE21	PTE27	PTA0	PTA1	PTA6	PTA7	PTA13/ LLWU_P4	PTA27	PTA26	PTA25	J
K	PGA3_DP/ ADC3_DP0/ ADC2_DP3/ ADC1_DP1	PGA3_DM/ ADC3_DM0/ ADC2_DM3/ ADC1_DM1	ADC1_SE16/ CMP2_IN2/ ADC0_SE22	PTE26	PTE25	PTA2	PTA3	PTA8	PTA12	PTA16	PTA17	PTA24	K
L	PGA0_DP/ ADC0_DP0/ ADC1_DP3	PGA0_DM/ ADC0_DM0/ ADC1_DM3	DAC0_OUT/ CMP1_IN3/ ADC0_SE23	DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23	RTC_ WAKEUP_B	VBAT	PTA4/ LLWU_P3	PTA9	PTA11	PTA14	PTA15	RESET_b	L
M	PGA1_DP/ ADC1_DP0/ ADC0_DP3	PGA1_DM/ ADC1_DM0/ ADC0_DM3	VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18	PTE24	NC	EXTAL32	XTAL32	PTA5	PTA10	VSS	PTA19	PTA18	M
	1	2	3	4	5	6	7	8	9	10	11	12	

Figure 40. K10 144 MAPBGA Pinout Diagram

9 Revision History

The following table provides a revision history for this document.

Table 54. Revision History

Rev. No.	Date	Substantial Changes
3	3/2012	Initial public release

Table continues on the next page...

Table 54. Revision History (continued)

Rev. No.	Date	Substantial Changes
4	10/2012	Replaced TBDs throughout.
5	10/2013	Changes for 4N96B mask set: • Min VDD operating requirement specification updated to support operation down to 1.71V. New specifications: • Updated Vdd_ddr min specification. • Added Vodpu specification. • Removed Ioz, Ioz_ddr, and Ioz_tamper Hi-Z leakage specfications. They have been replaced by new Iina, Iind, and Zind specifications. • Fpll_ref_acc specification has been added. • I^2C module was previously covered by the general switching specifications. To provide more detail on I^2C operation a dedicated Inter-Integrated Circuit Interface (I^2C) timing section has been added. Modified specifications: • Vref_ddr max spec has been updated. • Tpor spec has been split into two specifications based on VDD slew rate. • Trd1allx and Trd1alln max have been updated. • 16-bit ADC Temp sensor slope and Temp sensor voltage (Vtemp25) have been modified. The typical values that were listed previously have been updated, and min and max specifications have been added. Corrections: • Some versions of the datasheets listed incorrect clock mode information in the "Diagram: Typical IDD_RUN operating behavior section." These errors have been corrected. • Fintf_ft specification was previously shown as a max value. It has been corrected to be shown as a typical value as originally intended. • Corrected DDR write and read timing diagrams to show the correct location of the Tcmv specification. • SDHC peripheral 50MHz high speed mode options were left out of the last datasheet. These have been added to the SDHC specifications section.
6	09/2015	• Updated the footnotes of Thermal Attributes table • Removed Power Sequencing section • Added footnote to ambient temperature specification of Thermal Operating requirements • Updated Terminology and guidelines section • Updated the footnotes and the values of Power consumption operating behaviors table • Updated I2C timing table
7	02/2018	• Updated maximum SDHC frequency in SDHC specifications

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