THE DATASHEET OF

MK64FX512VLL12

Kinetis K64F Sub-Family Data Sheet

120 MHz ARM® Cortex®-M4-based Microcontroller with FPU

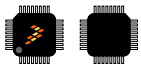
MK64FN1M0Vxx12
MK64FX512Vxx12

The K64 product family members are optimized for cost-sensitive applications requiring low-power, USB/Ethernet connectivity, and up to 256 KB of embedded SRAM. These devices share the comprehensive enablement and scalability of the Kinetis family.

This product offers:

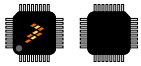
- Run power consumption down to 250 µA/MHz. Static power consumption down to 5.8 µA with full state retention and 5 µs wakeup. Lowest Static mode down to 339 nA
- USB LS/FS OTG 2.0 with embedded 3.3 V, 120 mA LDO Vreg, with USB device crystal-less operation
- 10/100 Mbit/s Ethernet MAC with MII and RMII interfaces

121 XFBGA
8 x 8 x 0.5 mm Pitch
0.65 mm



144 LQFP
20 x 20 x 1.6 mm Pitch
0.5 mm

144 MAPBGA
13 x 13 x 1.46 mm
Pitch 1 mm



100 QFP
14 x 14 x 1.7 mm Pitch
0.5 mm

Performance

- Up to 120 MHz ARM® Cortex®-M4 core with DSP instructions and floating point unit

Memories and memory interfaces

- Up to 1 MB program flash memory and 256 KB RAM
- Upto 128 KB FlexNVM and 4 KB FlexRAM on devices with FlexMemory
- FlexBus external bus interface

System peripherals

- Multiple low-power modes, low-leakage wake-up unit
- Memory protection unit with multi-master protection
- 16-channel DMA controller
- External watchdog monitor and software watchdog

Security and integrity modules

- Hardware CRC module
- Hardware random-number generator
- Hardware encryption supporting DES, 3DES, AES, MD5, SHA-1, and SHA-256 algorithms
- 128-bit unique identification (ID) number per chip

Analog modules

- Two 16-bit SAR ADCs
- Two 12-bit DACs
- Three analog comparators (CMP)
- Voltage reference

Communication interfaces

- Ethernet controller with MII and RMII interface
- USB full-/low-speed On-the-Go controller
- Controller Area Network (CAN) module
- Three SPI modules
- Three I2C modules. Support for up to 1 Mbit/s
- Six UART modules
- Secure Digital Host Controller (SDHC)
- I2S module

Timers

- Two 8-channel Flex-Timers (PWM/Motor control)
- Two 2-channel FlexTimers (PWM/Quad decoder)
- IEEE 1588 timers
- 32-bit PITs and 16-bit low-power timers
- Real-time clock
- Programmable delay block

Clocks

- 3 to 32 MHz and 32 kHz crystal oscillator
- PLL, FLL, and multiple internal oscillators
- 48 MHz Internal Reference Clock (IRC48M)

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

Ordering Information[1]

Part Number	Memory		Maximum number of I\O's
	Flash	SRAM (KB)	
MK64FX512VLL12	512 KB	256	66
MK64FN1M0VLL12	1 MB	256	66
MK64FX512VDC12	512 KB	256	83
MK64FN1M0VDC12	1 MB	256	83
MK64FX512VLQ12	512 KB	256	100
MK64FN1M0VLQ12	1 MB	256	100
MK64FX512VMD12	512 KB	256	100
MK64FN1M0VMD12	1 MB	256	100

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

Related Resources

Type	Description	Resource
Selector Guide	The NXP Solution Advisor is a web-based tool that features interactive application wizards and a dynamic product selector.	Solution Advisor
Product Brief	The Product Brief contains concise overview/summary information to enable quick evaluation of a device for design suitability.	K60PB[1]
Reference Manual	The Reference Manual contains a comprehensive description of the structure and function (operation) of a device.	K64P144M120SF5RM [1]
Data Sheet	The Data Sheet includes electrical characteristics and signal connections.	K64P144M120SF5[1]
Package drawing	Package dimensions are provided in package drawings.	• MAPBGA 144-pin: 98ASA00222D[1] • LQFP 144-pin: 98ASS23177W[1] • LQFP 100-pin: 98ASS23308W[1] • XFBGA 121-pin: 98ASA00595D[1]

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

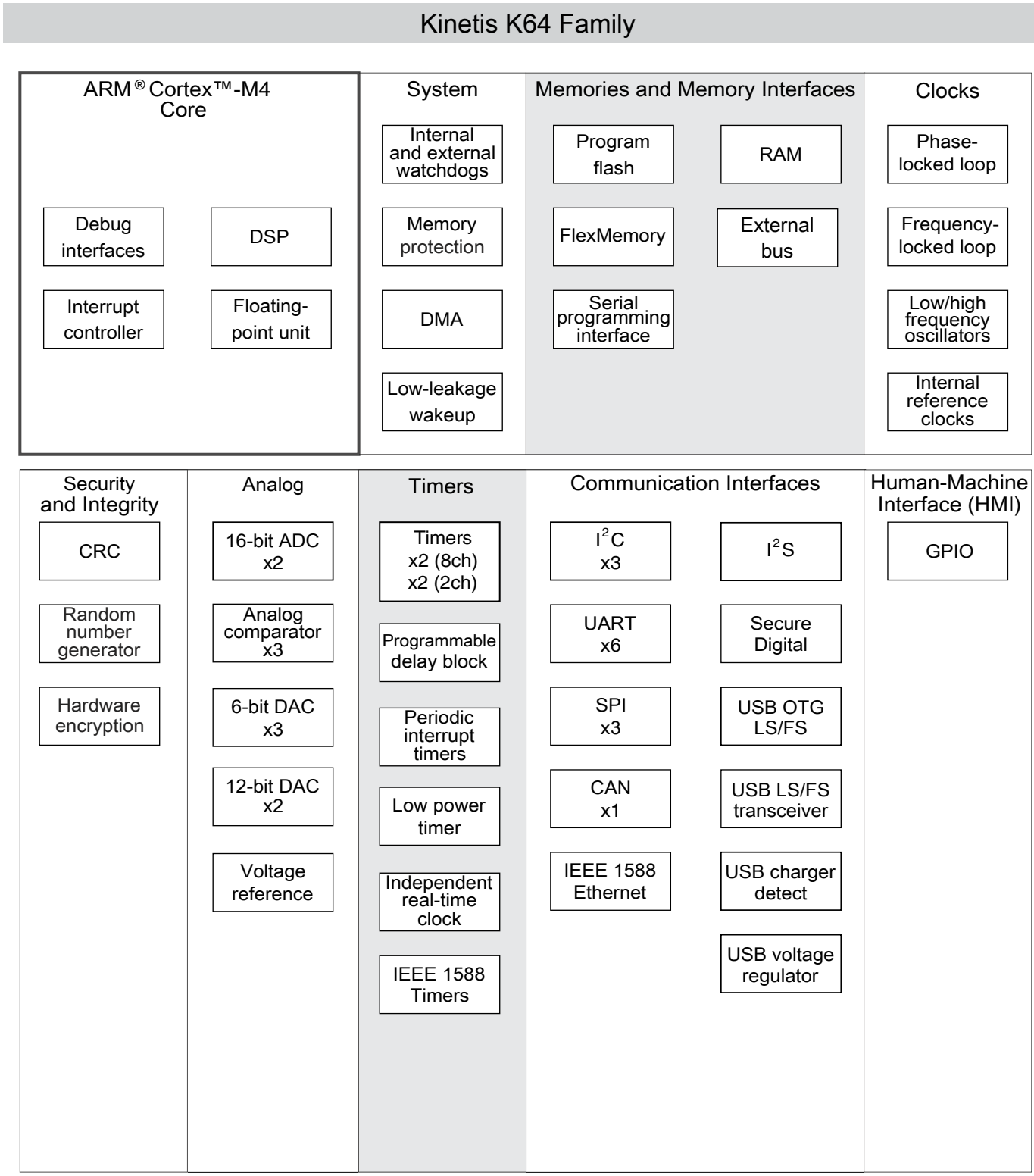


Figure 1. K64 block diagram

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1 Ratings

1.1 Thermal handling ratings

Symbol	Description	Min.	Max.	Unit	Notes
T_{STG}	Storage temperature	–55	150	°C	1
T_{SDR}	Solder temperature, lead-free	—	260	°C	2
	Solder temperature, leaded	—	245		

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

1.2 Moisture handling ratings

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

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

1.3 ESD handling ratings

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

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

1.4 Voltage and current operating ratings

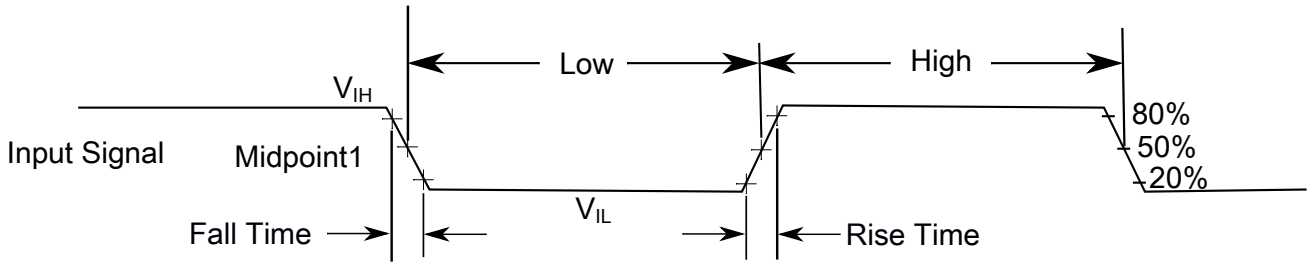
Symbol	Description	Min.	Max.	Unit
V_{DD}	Digital supply voltage	–0.3	3.8	V
I_{DD}	Digital supply current	—	185	mA
V_{DIO}	Digital input voltage (except $\overline{\text{RESET}}$, EXTAL, and XTAL)	–0.3	5.5	V
V_{DRTC_WAKEUP}	RTC Wakeup input voltage	–0.3	V_{BAT} + 0.3	V
V_{AIO}	Analog[1], $\overline{\text{RESET}}$, EXTAL, and XTAL 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_{USB0_DP}	USB0_DP input voltage	–0.3	3.63	V
V_{USB0_DM}	USB0_DM input voltage	–0.3	3.63	V
V_{REGIN}	USB regulator input	–0.3	6.0	V
V_{BAT}	RTC battery supply voltage	–0.3	3.8	V

1. Analog pins are defined as pins that do not have an associated general purpose I/O port function.

2 General

2.1 AC electrical characteristics

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



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

Figure 2. Input signal measurement reference

2.2 Nonswitching electrical specifications

2.2.1 Voltage and current operating requirements

Table 1. Voltage and current operating requirements

Symbol	Description	Min.	Max.	Unit	Notes
V_{DD}	Supply voltage	1.71	3.6	V	
V_{DDA}	Analog supply voltage	1.71	3.6	V	
$V_{DD} – V_{DDA}$	V_{DD}-to-V_{DDA} differential voltage	–0.1	0.1	V	
$V_{SS} – V_{SSA}$	V_{SS}-to-V_{SSA} differential voltage	–0.1	0.1	V	
V_{BAT}	RTC battery supply voltage	1.71	3.6	V	
V_{IH}	Input high voltage • 2.7 V ≤ V_{DD} ≤ 3.6 V • 1.7 V ≤ V_{DD} ≤ 2.7 V	 0.7 × V_{DD} 0.75 × V_{DD}	 — —	 V V	
V_{IL}	Input low voltage • 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	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], EXTAL, and XTAL 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.

2.2.2 LVD and POR operating requirements

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

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
V_{POR}	Falling VDD POR detect voltage	0.8	1.1	1.5	V	
V_{LVDH}	Falling low-voltage detect threshold — high range (LVDV=01)	2.48	2.56	2.64	V	
	Low-voltage warning thresholds — high range					1
V_{LVW1H}	• Level 1 falling (LVWV=00)	2.62	2.70	2.78	V	
V_{LVW2H}	• Level 2 falling (LVWV=01)	2.72	2.80	2.88	V	
V_{LVW3H}	• Level 3 falling (LVWV=10)	2.82	2.90	2.98	V	
V_{LVW4H}	• Level 4 falling (LVWV=11)	2.92	3.00	3.08	V	
V_{HYSH}	Low-voltage inhibit reset/recover hysteresis — high range	—	80	—	mV	
V_{LVDL}	Falling low-voltage detect threshold — low range (LVDV=00)	1.54	1.60	1.66	V	
	Low-voltage warning thresholds — low range					1
V_{LVW1L}	• Level 1 falling (LVWV=00)	1.74	1.80	1.86	V	
V_{LVW2L}	• Level 2 falling (LVWV=01)	1.84	1.90	1.96	V	
V_{LVW3L}	• Level 3 falling (LVWV=10)	1.94	2.00	2.06	V	
V_{LVW4L}	• Level 4 falling (LVWV=11)	2.04	2.10	2.16	V	
V_{HYSL}	Low-voltage inhibit reset/recover hysteresis — low range	—	60	—	mV	
V_{BG}	Bandgap voltage reference	0.97	1.00	1.03	V	
t_{LPO}	Internal low power oscillator period — factory trimmed	900	1000	1100	µs	

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

Table 3. VBAT power operating requirements

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

2.2.3 Voltage and current operating behaviors

Table 4. Voltage and current operating behaviors

Symbol	Description	Min.	Max.	Unit	Notes
V_{OH}	Output high voltage — high drive strength				

Table continues on the next page...

Table 4. Voltage and current operating behaviors (continued)

Symbol	Description	Min.	Max.	Unit	Notes
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -8mA	V_{DD} – 0.5	—	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = -3mA	V_{DD} – 0.5	—	V	
	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	
$V_{OH\_RTC\_WAKEUP}$	Output high voltage — high drive strength	V_{BAT} – 0.5	—	V	
	• 2.7 V ≤ V_{BAT} ≤ 3.6 V, I_{OH} = -10mA	V_{BAT} – 0.5	—	V	
	• 1.71 V ≤ V_{BAT} ≤ 2.7 V, I_{OH} = -3mA				
	Output high voltage — low drive strength	V_{BAT} – 0.5	—	V	
	• 2.7 V ≤ V_{BAT} ≤ 3.6 V, I_{OH} = -2mA	V_{BAT} – 0.5	—	V	
	• 1.71 V ≤ V_{BAT} ≤ 2.7 V, I_{OH} = -0.6mA				
$I_{OH\_RTC\_WAKEUP}$	Output high current total for RTC_WAKEUP pins	—	100	mA	
V_{OL}	Output low voltage — high drive strength				
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 9mA	—	0.5	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 3mA	—	0.5	V	
	Output low voltage — low drive strength				
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 2mA	—	0.5	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 0.6mA	—	0.5	V	
I_{OLT}	Output low current total for all ports	—	100	mA	
$V_{OL\_RTC\_WAKEUP}$	Output low voltage — high drive strength	—	0.5	V	
	• 2.7 V ≤ V_{BAT} ≤ 3.6 V, I_{OL} = 10mA	—	0.5	V	
	• 1.71 V ≤ V_{BAT} ≤ 2.7 V, I_{OL} = 3mA				
	Output low voltage — low drive strength	—	0.5	V	
	• 2.7 V ≤ V_{BAT} ≤ 3.6 V, I_{OL} = 2mA	—	0.5	V	
	• 1.71 V ≤ V_{BAT} ≤ 2.7 V, I_{OL} = 0.6mA				
$I_{OL\_RTC\_WAKEUP}$	Output low current total for RTC_WAKEUP pins	—	100	mA	
I_{IN}	Input leakage current (per pin) for full temperature range	—	1	µA	1
I_{IN}	Input leakage current (per pin) at 25°C	—	0.025	µA	1
$I_{IN\_RTC\_WAKEUP}$	Input leakage current (per RTC_WAKEUP pin) for full temperature range	—	1	µA	
$I_{IN\_RTC\_WAKEUP}$	Input leakage current (per RTC_WAKEUP pin) at 25°C	—	0.025	µA	

Table continues on the next page...

Table 4. Voltage and current operating behaviors (continued)

Symbol	Description	Min.	Max.	Unit	Notes
I_{OZ}	Hi-Z (off-state) leakage current (per pin)	—	0.25	μA	
$I_{OZ\_RTC\_WAKEUP}$	Hi-Z (off-state) leakage current (per RTC_WAKEUP pin)	—	0.25	μA	
R_{PU}	Internal pullup resistors (except RTC_WAKEUP pins)	20	50	kΩ	2
R_{PD}	Internal pulldown resistors (except RTC_WAKEUP pins)	20	50	kΩ	3

1. Measured at VDD=3.6V
2. Measured at V_{DD} supply voltage = V_{DD} min and Vinput = V_{SS}
3. Measured at V_{DD} supply voltage = V_{DD} min and Vinput = V_{DD}

2.2.4 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

Table 5. Power mode transition operating behaviors

Symbol	Description	Min.	Max.	Unit	Notes
t_{POR}	After a POR event, amount of time from the point V_{DD} reaches 1.71 V to execution of the first instruction across the operating temperature range of the chip.	—	300	μs	
	• VLLS0 → RUN	—	156	μs	
	• VLLS1 → RUN	—	156	μs	
	• VLLS2 → RUN	—	78	μs	
	• VLLS3 → RUN	—	78	μs	
	• LLS → RUN	—	4.8	μs	
	• VLPS → RUN	—	4.5	μs	
	• STOP → RUN	—	4.5	μs	

2.2.5 Power consumption operating behaviors

NOTE

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

Table 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					2
	• @ 1.8V	—	31.1	36.65	mA	
	• @ 3.0V	—	31	36.75	mA	
I_{DD_RUN}	Run mode current — all peripheral clocks enabled, code executing from flash					3, 4
	• @ 1.8V	—	42.7	48.35	mA	
	• @ 3.0V					
	• @ 25°C	—	40	41.60	mA	
	• @ 105°C	—	48.33	51.50	mA	
I_{DD_WAIT}	Wait mode high frequency current at 3.0 V — all peripheral clocks disabled	—	17.9	—	mA	2
I_{DD_WAIT}	Wait mode reduced frequency current at 3.0 V — all peripheral clocks disabled	—	6.9	—	mA	5
I_{DD_VLPR}	Very-low-power run mode current at 3.0 V — all peripheral clocks disabled	—	1.0	—	mA	6
I_{DD_VLPR}	Very-low-power run mode current at 3.0 V — all peripheral clocks enabled	—	1.7	—	mA	7
I_{DD_VLPW}	Very-low-power wait mode current at 3.0 V — all peripheral clocks disabled	—	0.678	—	mA	8
I_{DD_STOP}	Stop mode current at 3.0 V					
	• @ –40 to 25°C	—	0.49	1.24	mA	
	• @ 70°C	—	1.18	4.3	mA	
	• @ 105°C	—	3.0	12.5	mA	
I_{DD_VLPS}	Very-low-power stop mode current at 3.0 V					
	• @ –40 to 25°C	—	57	139.31	µA	
	• @ 70°C	—	291	679.33	µA	
	• @ 105°C	—	927.3	1869.85	µA	
I_{DD_LLS}	Low leakage stop mode current at 3.0 V					9

Table continues on the next page...

Table 6. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• @ –40 to 25°C	—	5.8	10.48	µA	
	• @ 70°C	—	26.7	47.99	µA	
	• @ 105°C	—	114.9	196.49	µA	
I_{DD_VLLS3}	Very low-leakage stop mode 3 current at 3.0 V					
	• @ –40 to 25°C	—	4.4	5.54	µA	
	• @ 70°C	—	21	36.46	µA	
	• @ 105°C	—	90.2	150.17	µA	
I_{DD_VLLS2}	Very low-leakage stop mode 2 current at 3.0 V					
	• @ –40 to 25°C	—	2.1	2.34	µA	
	• @ 70°C	—	6.84	10.36	µA	
	• @ 105°C	—	29.4	46.74	µA	
I_{DD_VLLS1}	Very low-leakage stop mode 1 current at 3.0 V					
	• @ –40 to 25°C	—	0.817	0.86	µA	
	• @ 70°C	—	3.97	5.77	µA	
	• @ 105°C	—	21.3	33.99	µA	
I_{DD_VLLS0}	Very low-leakage stop mode 0 current at 3.0 V with POR detect circuit enabled					
	• @ –40 to 25°C	—	0.52	0.62	µA	
	• @ 70°C	—	3.67	5.7	µA	
	• @ 105°C	—	21.20	34.9	µA	
I_{DD_VLLS0}	Very low-leakage stop mode 0 current at 3.0 V with POR detect circuit disabled					
	• @ –40 to 25°C	—	0.339	0.412	µA	
	• @ 70°C	—	3.36	4.2	µA	
	• @ 105°C	—	20.3	29.9	µA	
I_{DD_VBAT}	Average current with RTC and 32 kHz disabled					
	• @ 1.8 V					
	— • @ –40 to 25°C	—	0.16	0.19	µA	
	— • @ 70°C	—	0.55	0.72	µA	
	— • @ 105°C	—	2.5	3.68	µA	
	• @ 3.0 V					
	— • @ –40 to 25°C	—	0.18	0.21	µA	
	— • @ 70°C	—	0.66	0.86	µA	
	— • @ 105°C	—	2.92	4.30	µA	

Table continues on the next page...

Table 6. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
I_{DD_VBAT}	Average current when CPU is not accessing RTC registers					10
	• @ 1.8 V					
	• @ –40 to 25°C	—	0.59	0.70	µA	
	• @ 70°C	—	1.0	1.30	µA	
	• @ 105°C	—	3.0	4.42	µA	
	• @ 3.0 V					
	• @ –40 to 25°C	—	0.71	0.84	µA	
	• @ 70°C	—	1.22	1.59	µA	
	• @ 105°C	—	3.5	5.15	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 clock, 30 MHz Flexbus clock, and 20 MHz flash clock. MCG configured for PEE mode. All peripheral clocks enabled.
4. Max values are measured with CPU executing DSP instructions.
5. 25 MHz core and system clock, 25 MHz bus clock, and 25 MHz FlexBus and flash clock. MCG configured for FEI mode.
6. 4 MHz core, system, FlexBus, and bus clock and 0.5 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks disabled. Code executing from flash.
7. 4 MHz core, system, FlexBus, and bus clock and 0.5 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks enabled but peripherals are not in active operation. Code executing from flash.
8. 4 MHz core, system, FlexBus, and bus clock and 0.5 MHz flash clock. MCG configured for BLPE mode. All peripheral clocks disabled.
9. Data reflects devices with 256 KB of RAM.
10. Includes 32kHz oscillator current and RTC operation.

Table 7. Low power mode peripheral adders — typical value

Symbol	Description	Temperature (°C)						Unit
		-40	25	50	70	85	105	
$I_{IREFSTEN4MHz}$	4 MHz internal reference clock (IRC) adder. Measured by entering STOP or VLPS mode with 4 MHz IRC enabled.	56	56	56	56	56	56	µA
$I_{IREFSTEN32KHz}$	32 kHz internal reference clock (IRC) adder. Measured by entering STOP mode with the 32 kHz IRC enabled.	52	52	52	52	52	52	µA
$I_{EREFSTEN4MHz}$	External 4 MHz crystal clock adder. Measured by entering STOP or VLPS mode with the crystal enabled.	206	228	237	245	251	258	uA
$I_{EREFSTEN32KHz}$	External 32 kHz crystal clock adder by means of the OSC0_CR[EREFSTEN and EREFSTEN] bits. Measured by							

Table continues on the next page...

Table 7. Low power mode peripheral adders — typical value (continued)

Symbol	Description	Temperature (°C)						Unit
		-40	25	50	70	85	105	
	entering all modes with the crystal enabled.	440	490	540	560	570	580	nA
	VLLS1	440	490	540	560	570	580	
	VLLS3	490	490	540	560	570	680	
	LLS	510	560	560	560	610	680	
	VLPS	510	560	560	560	610	680	
	STOP							
I_{48MIRC}	48 Mhz internal reference clock	350	350	350	350	350	350	µA
I_{CMP}	CMP peripheral adder measured by placing the device in VLLS1 mode with CMP enabled using the 6-bit DAC and a single external input for compare. Includes 6-bit DAC power consumption.	22	22	22	22	22	22	µA
I_{RTC}	RTC peripheral adder measured by placing the device in VLLS1 mode with external 32 kHz crystal enabled by means of the RTC_CR[OSCE] bit and the RTC ALARM set for 1 minute. Includes ERCLK32K (32 kHz external crystal) power consumption.	432	357	388	475	532	810	nA
I_{UART}	UART peripheral adder measured by placing the device in STOP or VLPS mode with selected clock source waiting for RX data at 115200 baud rate. Includes selected clock source power consumption.							
	MCGIRCLK (4 MHz internal reference clock)	66	66	66	66	66	66	µA
	OSCERCLK (4 MHz external crystal)	214	237	246	254	260	268	
I_{BG}	Bandgap adder when BGEN bit is set and device is placed in VLPx, LLS, or VLLSx mode.	45	45	45	45	45	45	µA
I_{ADC}	ADC peripheral adder combining the measured values at V_{DD} and V_{DDA} by placing the device in STOP or VLPS mode. ADC is configured for low power mode using the internal clock and continuous conversions.	42	42	42	42	42	42	µA

2.2.5.1 Diagram: Typical IDD_RUN operating behavior

The following data was measured under these conditions:

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

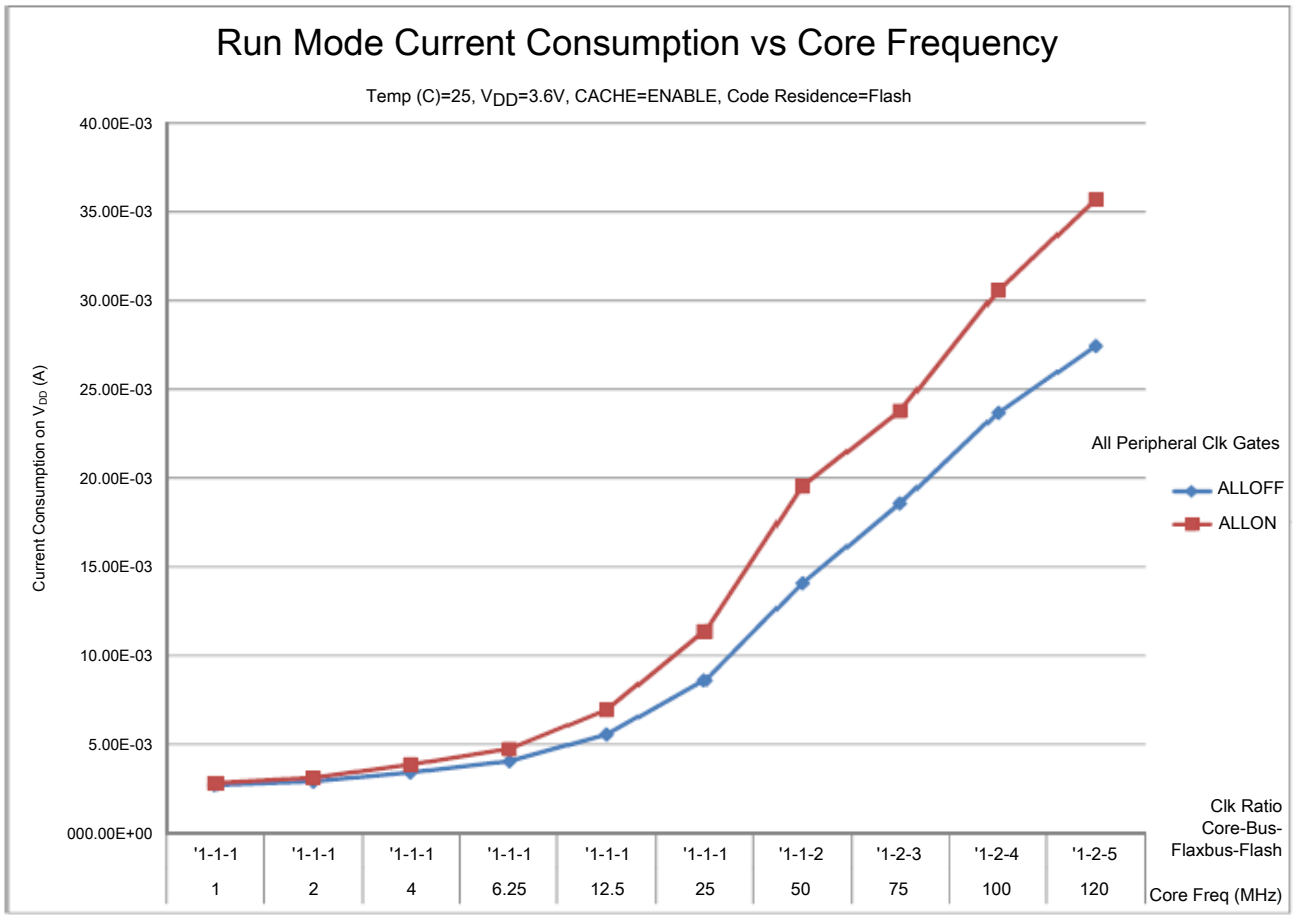


Figure 3. Run mode supply current vs. core frequency

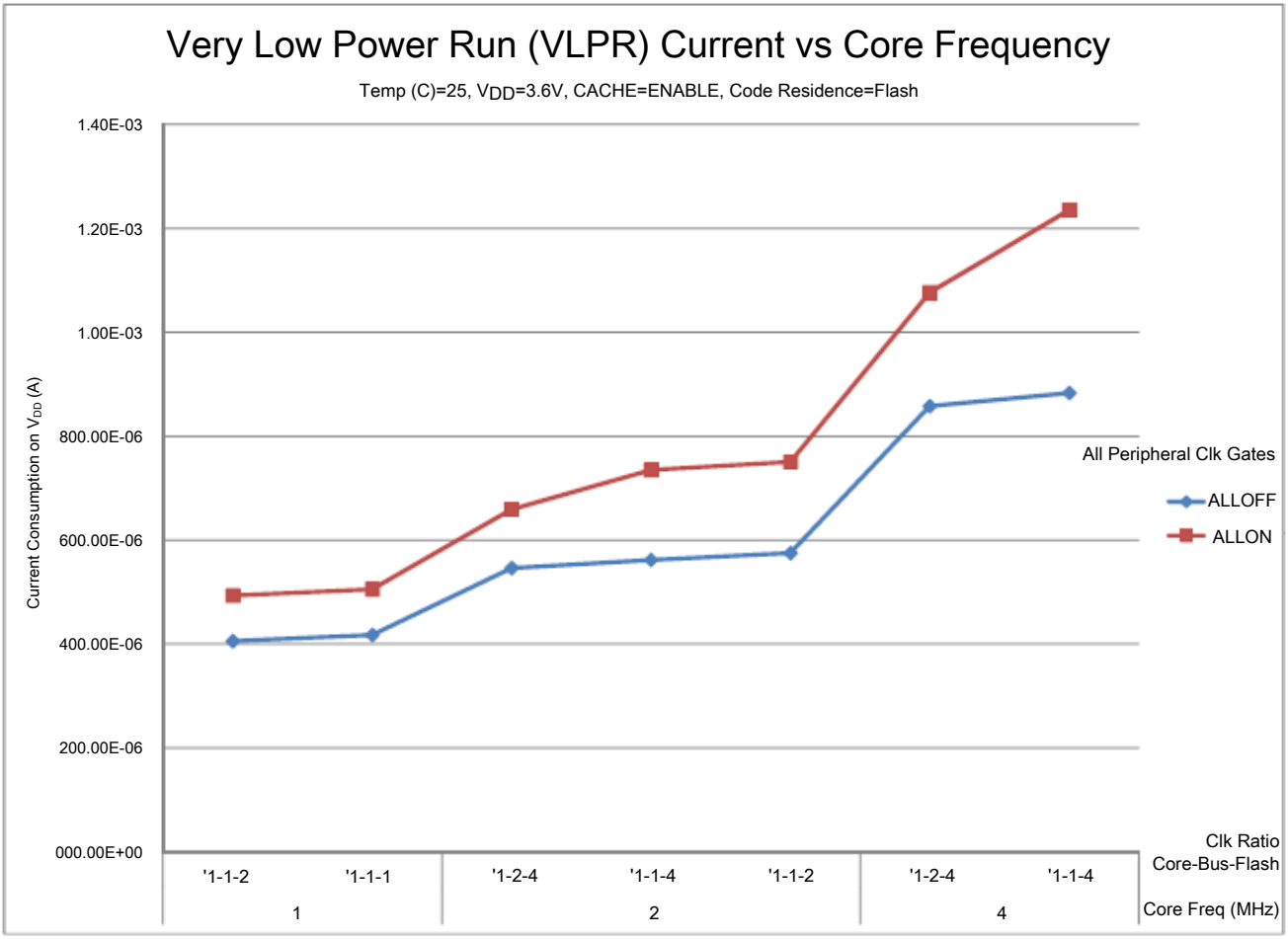


Figure 4. VLPR mode supply current vs. core frequency

2.2.6 EMC radiated emissions operating behaviors

Table 8. EMC radiated emissions operating behaviors

Symbol	Description	Frequency band (MHz)	Typ.	Unit	Notes
			144 LQFP		
V_{RE1}	Radiated emissions voltage, band 1	0.15–50	16	dBµV	1, 2
V_{RE2}	Radiated emissions voltage, band 2	50–150	22	dBµV	
V_{RE3}	Radiated emissions voltage, band 3	150–500	21	dBµV	
V_{RE4}	Radiated emissions voltage, band 4	500–1000	16	dBµV	
V_{RE_IEC}	IEC level	0.15–1000	L	—	2, 3

1. Determined according to IEC Standard 61967-1, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 1: General Conditions and Definitions* and IEC Standard 61967-2, *Integrated Circuits - Measurement of Electromagnetic Emissions, 150 kHz to 1 GHz Part 2: Measurement of Radiated Emissions—TEM Cell and*

Wideband TEM Cell Method. Measurements were made while the microcontroller was running basic application code. The reported emission level is the value of the maximum measured emission, rounded up to the next whole number, from among the measured orientations in each frequency range.

2. V_{DD} = 3.3 V, T_A = 25 °C, f_{OSC} = 12 MHz (crystal), f_{SYS} = 96 MHz, f_{BUS} = 48MHz
3. Specified according to Annex D of IEC Standard 61967-2, *Measurement of Radiated Emissions—TEM Cell and Wideband TEM Cell Method*

2.2.7 Designing with radiated emissions in mind

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

1. Go to www.nxp.com.
2. Perform a keyword search for "EMC design."

2.2.8 Capacitance attributes

Table 9. Capacitance attributes

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

2.3 Switching specifications

2.3.1 Device clock specifications

Table 10. Device clock specifications

Symbol	Description	Min.	Max.	Unit	Notes
Normal run mode					
f_{SYS}	System and core clock	—	120	MHz	
	System and core clock when Full Speed USB in operation	20	—	MHz	
f_{ENET}	System and core clock when ethernet in operation • 10 Mbps • 100 Mbps	 5 50	 — —	MHz	
f_{BUS}	Bus clock	—	60	MHz	
FB_CLK	FlexBus clock	—	50	MHz	
f_{FLASH}	Flash clock	—	25	MHz	

Table continues on the next page...

Table 10. Device clock specifications (continued)

Symbol	Description	Min.	Max.	Unit	Notes
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	—	0.8	MHz	
f_{ERCLK}	External reference clock	—	16	MHz	
f_{LPTMR_pin}	LPTMR clock	—	25	MHz	
f_{LPTMR_ERCLK}	LPTMR external reference clock	—	16	MHz	
$f_{FlexCAN\_ERCLK}$	FlexCAN external reference clock	—	8	MHz	
f_{I2S_MCLK}	I2S master clock	—	12.5	MHz	
f_{I2S_BCLK}	I2S bit clock	—	4	MHz	

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

2.3.2 General switching specifications

These general purpose specifications apply to all signals configured for GPIO, UART, CAN, CMT, IEEE 1588 timer, timers, and I^2C signals.

Table 11. General switching specifications

Symbol	Description	Min.	Max.	Unit	Notes
	GPIO pin interrupt pulse width (digital glitch filter disabled) — Synchronous path	1.5	—	Bus clock cycles	1, 2
	GPIO pin interrupt pulse width (digital glitch filter disabled, analog filter enabled) — Asynchronous path	100	—	ns	3
	GPIO pin interrupt pulse width (digital glitch filter disabled, analog filter disabled) — Asynchronous path	50	—	ns	3
	External reset pulse width (digital glitch filter disabled)	100	—	ns	3
	Mode select ($\overline{EZP\_CS}$) hold time after reset deassertion	2	—	Bus clock cycles	
	Port rise and fall time (high drive strength) - 3 V				4
	• Slew disabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	8	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	6	ns	
	• Slew enabled				
		—	18	ns	

Table continues on the next page...

Table 11. General switching specifications (continued)

Symbol	Description	Min.	Max.	Unit	Notes
	• $1.71 \le V_{DD} \le 2.7V$ • $2.7 \le V_{DD} \le 3.6V$	—	12	ns	
	Port rise and fall time (high drive strength) - 5 V				4
	• Slew disabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	6	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	4	ns	
	• Slew enabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	24	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	14	ns	
	Port rise and fall time (low drive strength) - 3 V				5
	• Slew disabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	12	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	6	ns	
	• Slew enabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	24	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	16	ns	
	Port rise and fall time (low drive strength) - 5 V				5
	• Slew disabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	17	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	10	ns	
	• Slew enabled				
	• $1.71 \le V_{DD} \le 2.7V$	—	36	ns	
	• $2.7 \le V_{DD} \le 3.6V$	—	20	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. 25 pF load
5. 15 pF load

2.4 Thermal specifications

2.4.1 Thermal operating requirements

Table 12. Thermal operating requirements

Symbol	Description	Min.	Max.	Unit
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

2.4.2 Thermal attributes

Table 13. Thermal attributes

Board type	Symbol	Description	144 LQFP	144 MAPBGA	121 XFBGA	100 LQFP	Unit	Notes
Single-layer (1s)	$R_{\theta JA}$	Thermal resistance, junction to ambient (natural convection)	51	38.1	33.3	51	°C/W	1
Four-layer (2s2p)	$R_{\theta JA}$	Thermal resistance, junction to ambient (natural convection)	43	21.6	21.1	39	°C/W	1
Single-layer (1s)	$R_{\theta JMA}$	Thermal resistance, junction to ambient (200 ft./min. air speed)	42	30.8	26.2	41	°C/W	1
Four-layer (2s2p)	$R_{\theta JMA}$	Thermal resistance, junction to ambient (200 ft./min. air speed)	36	18	17.8	32	°C/W	1
—	$R_{\theta JB}$	Thermal resistance, junction to board	30	16.5	16.3	24	°C/W	2
—	$R_{\theta JC}$	Thermal resistance,	11	8.9	12	11	°C/W	3

Table continues on the next page...

Table 13. Thermal attributes (continued)

Board type	Symbol	Description	144 LQFP	144 MAPBGA	121 XFBGA	100 LQFP	Unit	Notes
		junction to case						
—	Ψ_{JT}	Thermal characterization parameter, junction to package top outside center (natural convection)	2	0.9	0.2	2	°C/W	4

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

3 Peripheral operating requirements and behaviors

3.1 Core modules

3.1.1 Debug trace timing specifications

Table 14. Debug trace operating behaviors

Symbol	Description	Min.	Max.	Unit
T_{cyc}	Clock period	Frequency dependent		MHz
T_{wl}	Low pulse width	2	—	ns
T_{wh}	High pulse width	2	—	ns
T_r	Clock and data rise time	—	3	ns
T_f	Clock and data fall time	—	3	ns
T_s	Data setup	1.5	—	ns
T_h	Data hold	1	—	ns

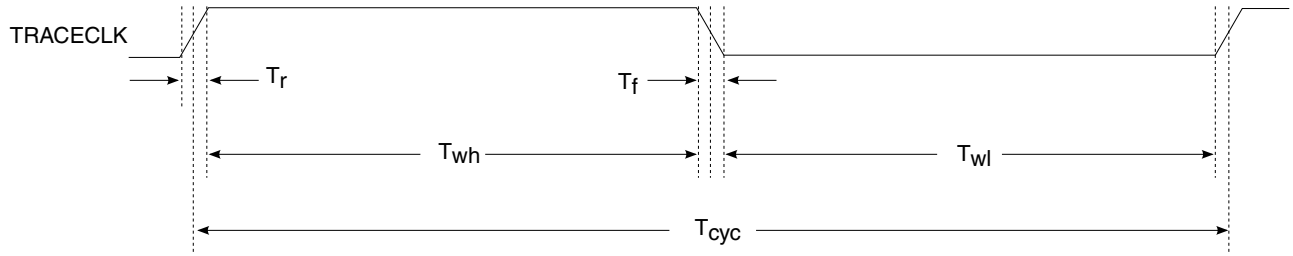


Figure 5. TRACE_CLKOUT specifications

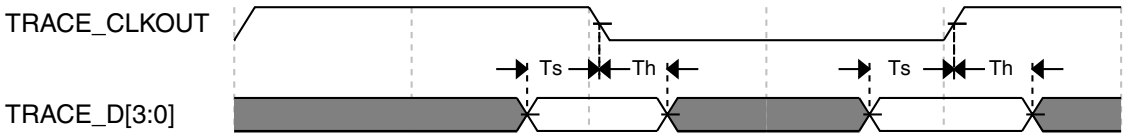


Figure 6. Trace data specifications

3.1.2 JTAG electricals

Table 15. 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	2.6	—	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

Table continues on the next page...

Table 15. JTAG limited voltage range electricals (continued)

Symbol	Description	Min.	Max.	Unit
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 16. JTAG full voltage range electricals

Symbol	Description	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V
J1	TCLK frequency of operation			MHz
	• Boundary Scan	0	10	
	• JTAG and CJTAG	0	20	
	• Serial Wire Debug	0	40	
J2	TCLK cycle period	1/J1	—	ns
J3	TCLK clock pulse width			
	• Boundary Scan	50	—	ns
	• JTAG and CJTAG	25	—	ns
	• Serial Wire Debug	12.5	—	ns
J4	TCLK rise and fall times	—	3	ns
J5	Boundary scan input data setup time to TCLK rise	20	—	ns
J6	Boundary scan input data hold time after TCLK rise	0	—	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	2.9	—	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

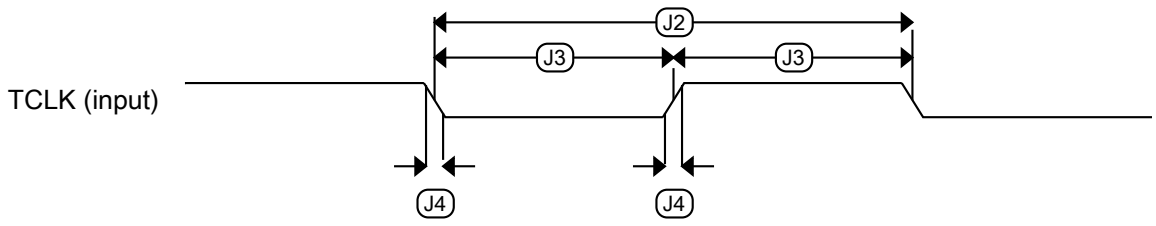


Figure 7. Test clock input timing

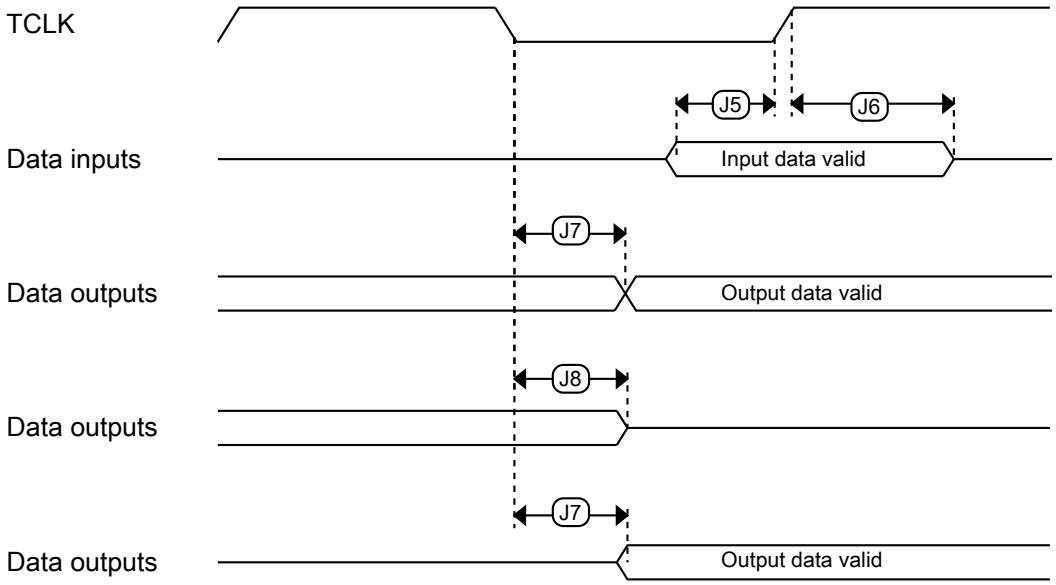


Figure 8. Boundary scan (JTAG) timing

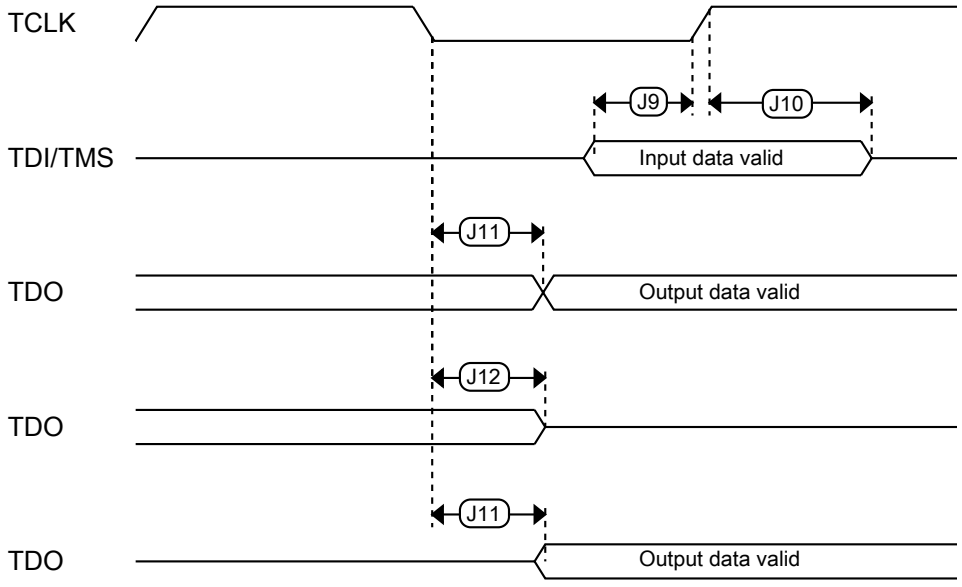


Figure 9. Test Access Port timing

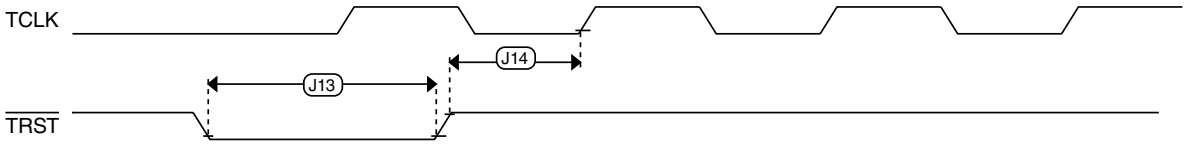


Figure 10. $\overline{\text{TRST}}$ timing

3.2 System modules

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

3.3 Clock modules

3.3.1 MCG specifications

Table 17. MCG specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
f_{ints_ft}	Internal reference frequency (slow clock) — factory trimmed at nominal VDD and 25 °C	—	32.768	—	kHz	
f_{ints_t}	Internal reference frequency (slow clock) — user trimmed	31.25	—	39.0625	kHz	
I_{ints}	Internal reference (slow clock) current	—	20	—	µA	
$\Delta_{fdco\_res\_t}$	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 voltage and temperature	—	± 0.5	± 2	$\%f_{dco}$	1, 2
Δf_{dco_t}	Total deviation of trimmed average DCO output frequency over fixed voltage and temperature range of 0–70°C	—	± 0.3	± 1	$\%f_{dco}$	1
f_{intf_ft}	Internal reference frequency (fast clock) — factory trimmed at nominal VDD and 25°C	—	4	—	MHz	
f_{intf_t}	Internal reference frequency (fast clock) — user trimmed at nominal VDD and 25 °C	3	—	5	MHz	
I_{intf}	Internal reference (fast clock) current	—	25	—	µA	

Table continues on the next page...

Table 17. MCG specifications (continued)

Symbol	Description		Min.	Typ.	Max.	Unit	Notes
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	
f_{dco}	DCO output frequency range	Low range (DRS=00) 640 × f_{fll_ref}	20	20.97	25	MHz	3, 4
		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	5, 6
		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_{DCO} = 48 MHz • f_{DCO} = 98 MHz		— —	180 150	— —	ps	
$t_{fll\_acquire}$	FLL target frequency acquisition time		—	—	1	ms	7
PLL							
f_{vco}	VCO operating frequency		48.0	—	120	MHz	
I_{pll}	PLL operating current • PLL @ 96 MHz ($f_{osc\_hi\_1}$ = 8 MHz, f_{pll_ref} = 2 MHz, VDIV multiplier = 48)		—	1060	—	µA	8
I_{pll}	PLL operating current • PLL @ 48 MHz ($f_{osc\_hi\_1}$ = 8 MHz, f_{pll_ref} = 2 MHz, VDIV multiplier = 24)		—	600	—	µA	8
f_{pll_ref}	PLL reference frequency range		2.0	—	4.0	MHz	
J_{cyc_pll}	PLL period jitter (RMS) • f_{vco} = 48 MHz • f_{vco} = 120 MHz		— —	120 80	— —	ps ps	9
J_{acc_pll}	PLL accumulated jitter over 1µs (RMS)						9

Table continues on the next page...

Table 17. MCG specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• f_{vco} = 48 MHz • f_{vco} = 120 MHz	— —	1350 600	— —	ps ps	
D_{lock}	Lock entry frequency tolerance	± 1.49	—	± 2.98	%	
D_{unl}	Lock exit frequency tolerance	± 4.47	—	± 5.97	%	
t_{pll_lock}	Lock detector detection time	—	—	$150 \times 10^{-6} + 1075(1/f_{pll\_ref})$	s	10

1. This parameter is measured with the internal reference (slow clock) being used as a reference to the FLL (FEI clock mode).
2. 2 V <= VDD <= 3.6 V.
3. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=0.
4. The resulting system clock frequencies should not exceed their maximum specified values. The DCO frequency deviation (Δf_{dco_t}) over voltage and temperature should be considered.
5. These typical values listed are with the slow internal reference clock (FEI) using factory trim and DMX32=1.
6. The resulting clock frequency must not exceed the maximum specified clock frequency of the device.
7. This specification applies to any time the FLL reference source or reference divider is changed, trim value is changed, DMX32 bit is changed, DRS bits are changed, or changing from FLL disabled (BLPE, BLPI) to FLL enabled (FEI, FEE, FBE, FBI). If a crystal/resonator is being used as the reference, this specification assumes it is already running.
8. Excludes any oscillator currents that are also consuming power while PLL is in operation.
9. This specification was obtained using a NXP developed PCB. PLL jitter is dependent on the noise characteristics of each PCB and results will vary.
10. This specification applies to any time the PLL VCO divider or reference divider is changed, or changing from PLL disabled (BLPE, BLPI) to PLL enabled (PBE, PEE). If a crystal/resonator is being used as the reference, this specification assumes it is already running.

3.3.2 IRC48M specifications

Table 18. IRC48M specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
V_{DD}	Supply voltage	1.71	—	3.6	V	
I_{DD48M}	Supply current	—	400	500	µA	
f_{irc48m}	Internal reference frequency	—	48	—	MHz	
$\Delta f_{irc48m\_ol\_lv}$	Open loop total deviation of IRC48M frequency at low voltage (VDD=1.71V-1.89V) over full temperature • Regulator disable (USB_CLK_RECOVER_IRC_EN[REG_EN]=0) • Regulator enable (USB_CLK_RECOVER_IRC_EN[REG_EN]=1)	— —	± 0.5 ± 0.5	± 1.5 ± 2.0	$\%f_{irc48m}$	1
$\Delta f_{irc48m\_ol\_hv}$	Open loop total deviation of IRC48M frequency at high voltage (VDD=1.89V-3.6V) over full temperature • Regulator enable (USB_CLK_RECOVER_IRC_EN[REG_EN]=1)	—	± 0.5	± 1.5	$\%f_{irc48m}$	1

Table continues on the next page...

Table 18. IRC48M specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
$\Delta f_{irc48m\_ol\_hv}$	Open loop total deviation of IRC48M frequency at high voltage (VDD=1.89V-3.6V) over 0 to 85 °C • Regulator enable (USB_CLK_RECOVER_IRC_EN[REG_EN]=1)	—	± 0.5	± 1.0	$\%f_{irc48m}$	1
Δf_{irc48m_cl}	Closed loop total deviation of IRC48M frequency over voltage and temperature	—	—	± 0.1	$\%f_{host}$	2
J_{cyc_irc48m}	Period Jitter (RMS)	—	35	150	ps	
$t_{irc48mst}$	Startup time	—	2	3	µs	3

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

3.3.3 Oscillator electrical specifications

3.3.3.1 Oscillator DC electrical specifications

Table 19. 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	
	• 4 MHz	—	400	—	µA	
	• 8 MHz (RANGE=01)	—	500	—	µA	
	• 16 MHz	—	2.5	—	mA	
	• 24 MHz	—	3	—	mA	
	• 32 MHz	—	4	—	mA	

Table continues on the next page...

Table 19. Oscillator DC electrical specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
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.

3.3.3.2 Oscillator frequency specifications

Table 20. Oscillator frequency specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
f_{osc_lo}	Oscillator crystal or resonator frequency — low-frequency mode (MCG_C2[RANGE]=00)	32	—	40	kHz	
$f_{osc\_hi\_1}$	Oscillator crystal or resonator frequency — high-frequency mode (low range) (MCG_C2[RANGE]=01)	3	—	8	MHz	
$f_{osc\_hi\_2}$	Oscillator crystal or resonator frequency — high frequency mode (high range) (MCG_C2[RANGE]=1x)	8	—	32	MHz	
f_{ec_extal}	Input clock frequency (external clock mode)	—	—	50	MHz	1, 2
t_{dc_extal}	Input clock duty cycle (external clock mode)	40	50	60	%	
t_{cst}	Crystal startup time — 32 kHz low-frequency, low-power mode (HGO=0)	—	750	—	ms	3, 4
	Crystal startup time — 32 kHz low-frequency, high-gain mode (HGO=1)	—	250	—	ms	
	Crystal startup time — 8 MHz high-frequency (MCG_C2[RANGE]=01), low-power mode (HGO=0)	—	0.6	—	ms	
	Crystal startup time — 8 MHz high-frequency (MCG_C2[RANGE]=01), high-gain mode (HGO=1)	—	1	—	ms	

1. Other frequency limits may apply when external clock is being used as a reference for the FLL
2. When transitioning from FEI or FBI to FBE mode, restrict the frequency of the input clock so that, when it is divided by FRDIV, it remains within the limits of the DCO input clock frequency.
3. Proper PC board layout procedures must be followed to achieve specifications.
4. Crystal startup time is defined as the time between the oscillator being enabled and the OSCINIT bit in the MCG_S register being set.

NOTE

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

3.3.4 32 kHz oscillator electrical characteristics

3.3.4.1 32 kHz oscillator DC electrical specifications

Table 21. 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

Table continues on the next page...

Table 21. 32kHz oscillator DC electrical specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit
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.

3.3.4.2 32 kHz oscillator frequency specifications

Table 22. 32 kHz oscillator frequency specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
f_{osc_lo}	Oscillator crystal	—	32.768	—	kHz	
t_{start}	Crystal start-up time	—	1000	—	ms	1
$f_{ec\_extal32}$	Externally provided input clock frequency	—	32.768	—	kHz	2
$v_{ec\_extal32}$	Externally provided input clock amplitude	700	—	V_{BAT}	mV	2, 3

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}.

3.4 Memories and memory interfaces

3.4.1 Flash (FTFE) electrical specifications

This section describes the electrical characteristics of the FTFE module.

3.4.1.1 Flash timing specifications — program and erase

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

Table 23. 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	904	ms	1
$t_{hversblk512k}$	Erase Flash Block high-voltage time for 512 KB	—	416	3616	ms	1

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

3.4.1.2 Flash timing specifications — commands

Table 24. Flash command timing specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	Read 1s Block execution time					
$t_{rd1blk128k}$	• 128 KB data flash	—	—	0.5	ms	
$t_{rd1blk512k}$	• 512 KB program flash	—	—	1.8	ms	
$t_{rd1sec4k}$	Read 1s Section execution time (4 KB flash)	—	—	100	µs	1
t_{pgmchk}	Program Check execution time	—	—	95	µs	1
t_{rdrsrc}	Read Resource execution time	—	—	40	µs	1
t_{pgm8}	Program Phrase execution time	—	90	150	µs	
	Erase Flash Block execution time					2
$t_{ersblk128k}$	• 128 KB data flash	—	110	925	ms	
$t_{ersblk512k}$	• 512 KB program flash	—	435	3700	ms	
t_{ersscr}	Erase Flash Sector execution time	—	15	115	ms	2
$t_{pgmsec1k}$	Program Section execution time (1KB flash)	—	5	—	ms	
	Read 1s All Blocks execution time					
$t_{rd1allx}$	• FlexNVM devices	—	—	2.2	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	—	870	7400	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					
$t_{pgmpart32k}$	• 32 KB FlexNVM	—	70	—	ms	
$t_{pgmpart128k}$	• 128 KB FlexNVM	—	75	—	ms	
	Set FlexRAM Function execution time:					
$t_{setramff}$	• Control Code 0xFF	—	70	—	µs	
$t_{setram32k}$	• 32 KB EEPROM backup	—	0.8	1.2	ms	
$t_{setram64k}$	• 64 KB EEPROM backup	—	1.3	1.9	ms	
$t_{setram128k}$	• 128 KB EEPROM backup	—	2.4	3.1	ms	

Table continues on the next page...

Table 24. Flash command timing specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
$t_{eewr8bers}$	Byte-write to erased FlexRAM location execution time	—	175	275	µs	3
	Byte-write to FlexRAM execution time:					
$t_{eewr8b32k}$	• 32 KB EEPROM backup	—	385	1700	µs	
$t_{eewr8b64k}$	• 64 KB EEPROM backup	—	475	2000	µs	
$t_{eewr8b128k}$	• 128 KB EEPROM backup	—	650	2350	µs	
$t_{eewr16bers}$	16-bit write to erased FlexRAM location execution time	—	175	275	µs	
	16-bit write to FlexRAM execution time:					
$t_{eewr16b32k}$	• 32 KB EEPROM backup	—	385	1700	µs	
$t_{eewr16b64k}$	• 64 KB EEPROM backup	—	475	2000	µs	
$t_{eewr16b128k}$	• 128 KB EEPROM backup	—	650	2350	µs	
$t_{eewr32bers}$	32-bit write to erased FlexRAM location execution time	—	360	550	µs	
	32-bit write to FlexRAM execution time:					
$t_{eewr32b32k}$	• 32 KB EEPROM backup	—	630	2000	µs	
$t_{eewr32b64k}$	• 64 KB EEPROM backup	—	810	2250	µs	
$t_{eewr32b128k}$	• 128 KB EEPROM backup	—	1200	2650	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.

3.4.1.3 Flash high voltage current behaviors

Table 25. Flash high voltage current behaviors

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

3.4.1.4 Reliability specifications

Table 26. 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	

Table continues on the next page...

Table 26. NVM reliability specifications (continued)

Symbol	Description	Min.	Typ.[1]	Max.	Unit	Notes
$t_{nvmretp1k}$	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	
$t_{nvmretd1k}$	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	140 K	400 K	—	writes	
$n_{nvmwree128}$	• EEPROM backup to FlexRAM ratio = 128	1.26 M	3.2 M	—	writes	
$n_{nvmwree512}$	• EEPROM backup to FlexRAM ratio = 512	5 M	12.8 M	—	writes	
$n_{nvmwree2k}$	• EEPROM backup to FlexRAM ratio = 2,048	20 M	50 M	—	writes	
$n_{nvmwree4k}$	• EEPROM backup to FlexRAM ratio = 4,096	40 M	100 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.

3.4.1.5 Write endurance to FlexRAM for EEPROM

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

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

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

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

where

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

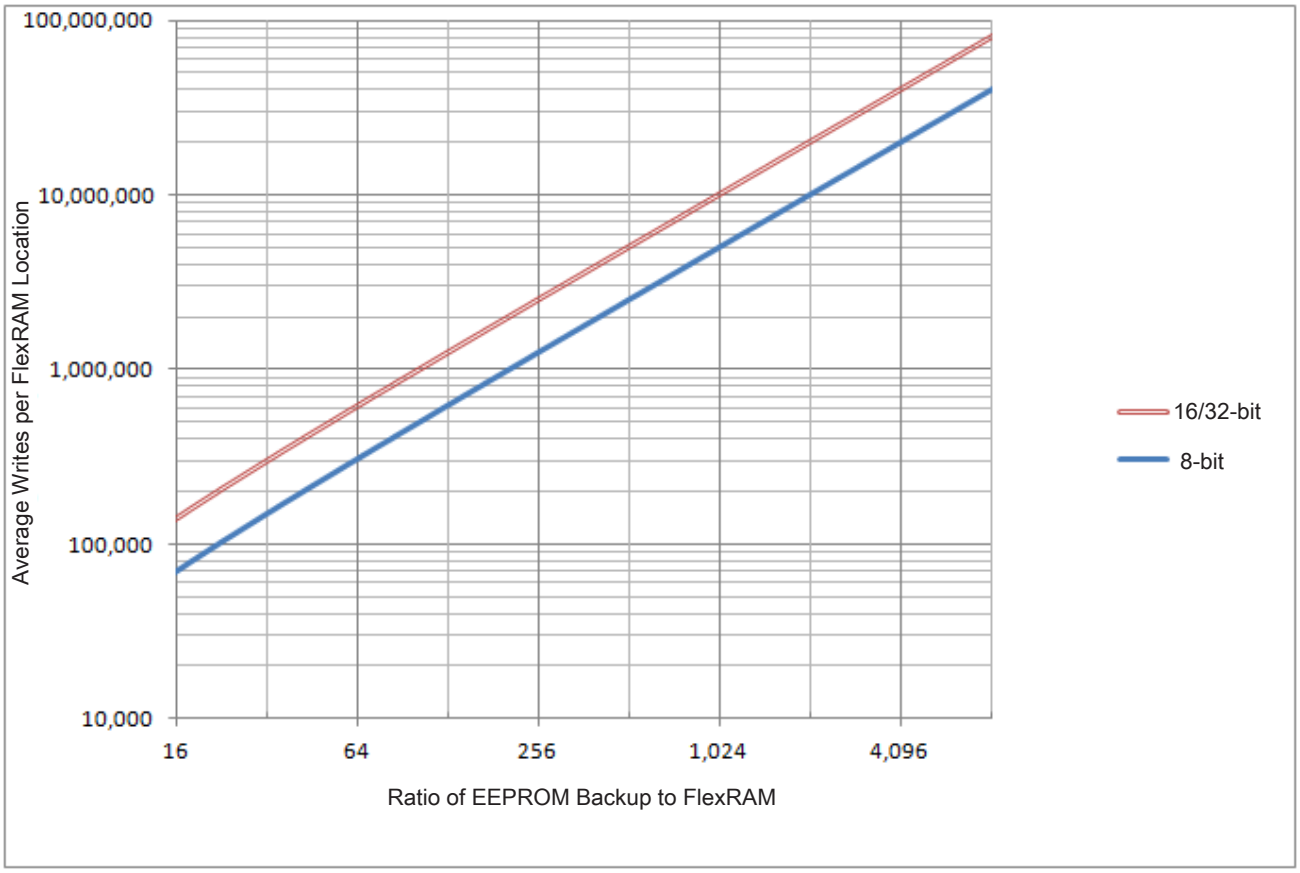


Figure 11. EEPROM backup writes to FlexRAM

3.4.2 EzPort switching specifications

Table 27. EzPort switching specifications

Num	Description	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V
EP1	EZP_CK frequency of operation (all commands except READ)	—	$f_{SYS}/2$	MHz
EP1a	EZP_CK frequency of operation (READ command)	—	$f_{SYS}/8$	MHz
EP2	$\overline{\text{EZP\_CS}}$ 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	—	18	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

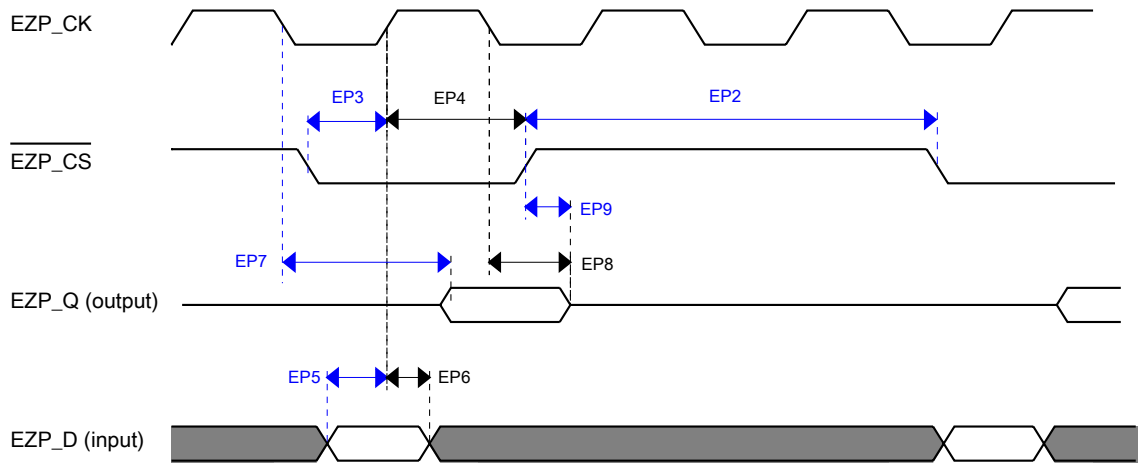


Figure 12. EzPort Timing Diagram

3.4.3 Flexbus switching specifications

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

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

Table 28. 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 29. 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	15.5	—	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 $\overline{\text{FB\_TA}}$.

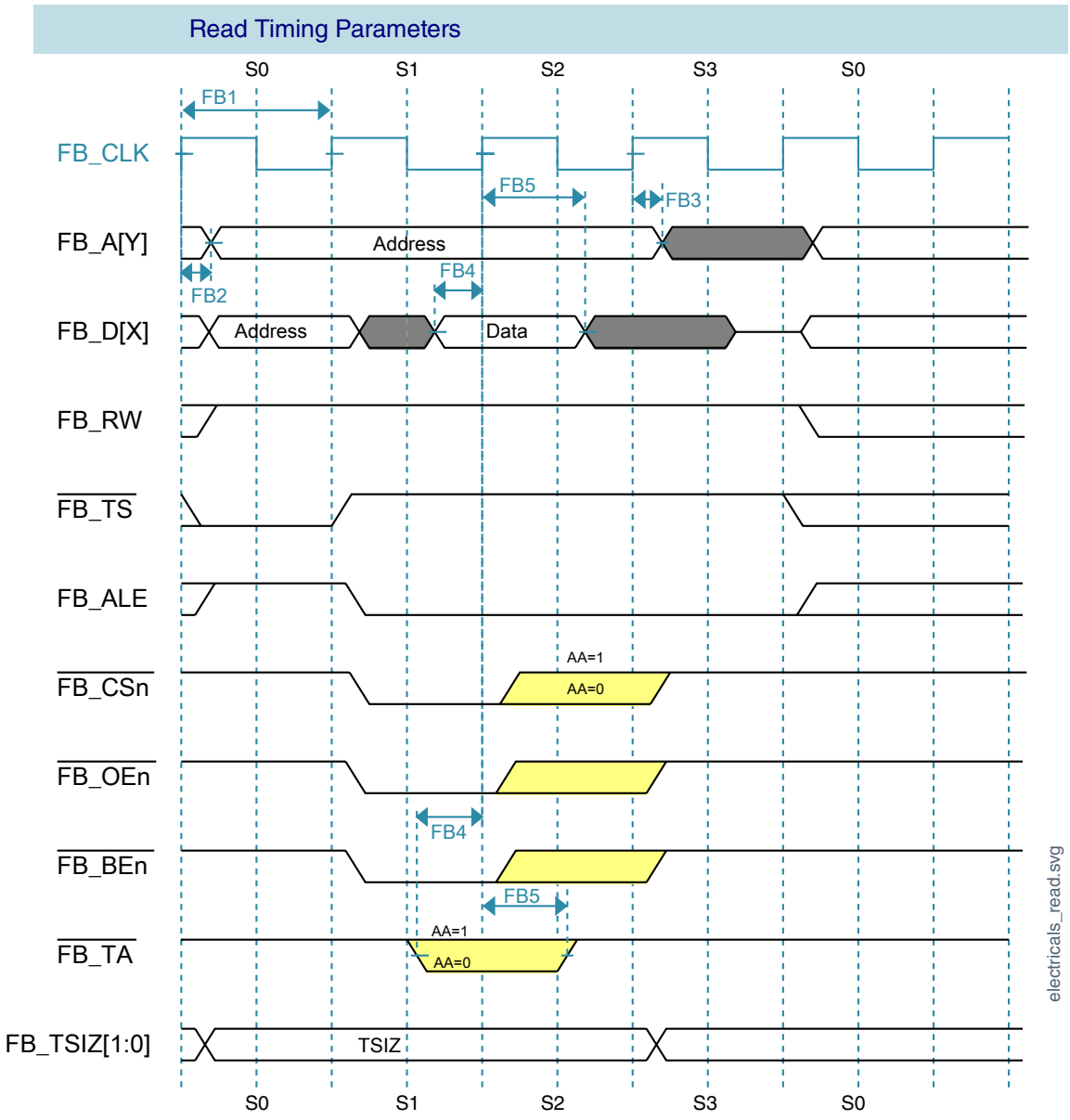


Figure 13. FlexBus read timing diagram

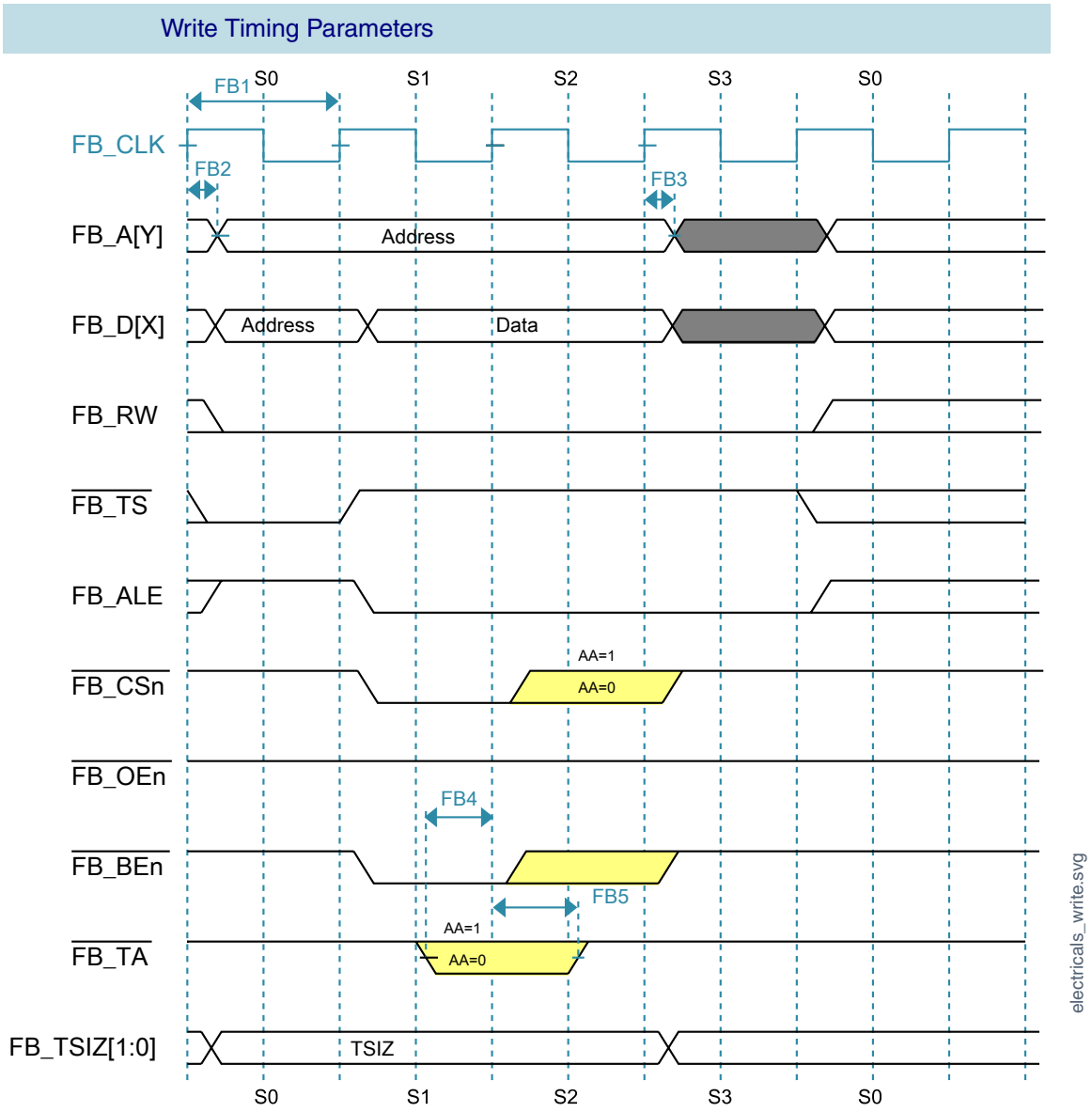


Figure 14. FlexBus write timing diagram

3.5 Security and integrity modules

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

3.6 Analog

3.6.1 ADC electrical specifications

The 16-bit accuracy specifications listed in Table 30 and Table 31 are achievable on the differential pins ADCx_DP0, ADCx_DM0.

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

3.6.1.1 16-bit ADC operating conditions

Table 30. 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		V_{REFL}	—	V_{REFH}	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	ksps	5
C_{rate}	ADC conversion rate	16-bit mode No ADC hardware averaging Continuous conversions enabled, subsequent conversion time	37.037	—	461.467	ksps	5

1. Typical values assume V_{DDA} = 3.0 V, Temp = 25 °C, f_{ADCK} = 1.0 MHz, unless otherwise stated. Typical values are for reference only, and are not tested in production.
2. DC potential difference.
3. This resistance is external to MCU. To achieve the best results, the analog source resistance must be kept as low as possible. The results in this data sheet were derived from a system that had < 8 Ω analog source resistance. The R_{AS}/C_{AS} time constant should be kept to < 1 ns.
4. To use the maximum ADC conversion clock frequency, CFG2[ADHSC] must be set and CFG1[ADLPC] must be clear.
5. For guidelines and examples of conversion rate calculation, download the ADC calculator tool.

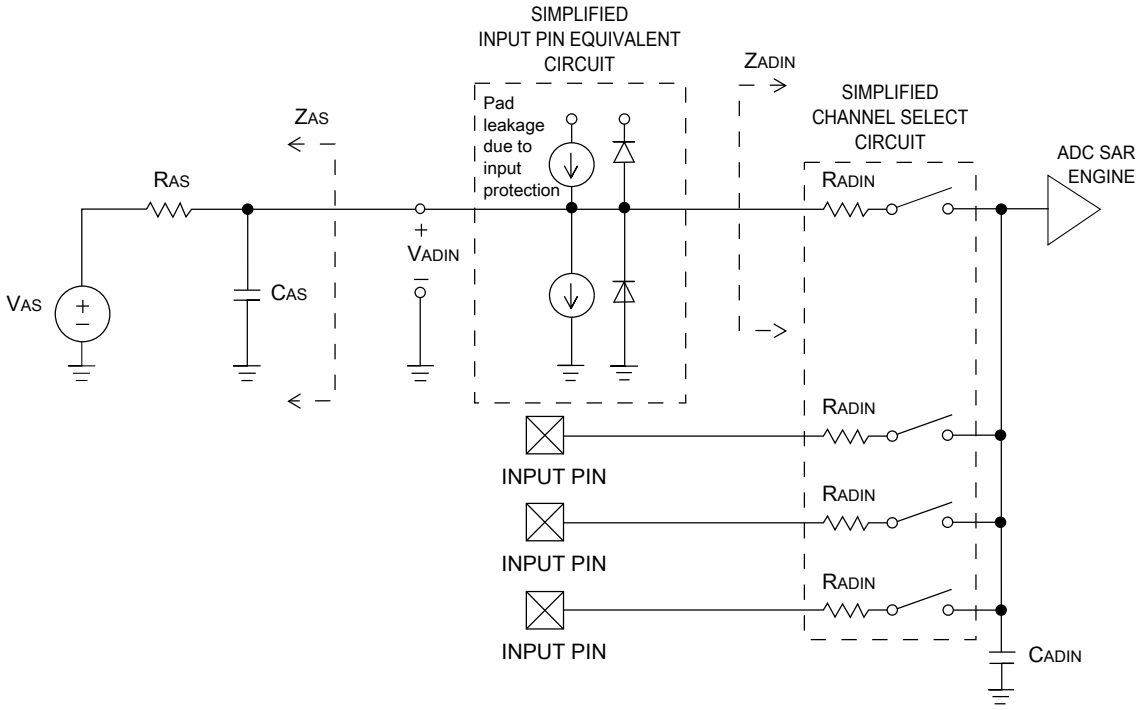


Figure 15. ADC input impedance equivalency diagram

3.6.1.2 16-bit ADC electrical characteristics

Table 31. 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	
		• ADLPC = 0, ADHSC = 0	3.0	5.2	7.3	MHz	
		• ADLPC = 0, ADHSC = 1	4.4	6.2	9.5	MHz	
	Sample Time	See Reference Manual chapter for sample times					

Table continues on the next page...

Table 31. 16-bit ADC characteristics (V_{REFH} = V_{DDA}, V_{REFL} = V_{SSA}) (continued)

Symbol	Description	Conditions[1]	Min.	Typ.[2]	Max.	Unit	Notes
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 (refer to the MCU's voltage and

Table continues on the next page...

Table 31. 16-bit ADC characteristics (V_{REFH} = V_{DDA}, V_{REFL} = V_{SSA}) (continued)

Symbol	Description	Conditions[1]	Min.	Typ.[2]	Max.	Unit	Notes
							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

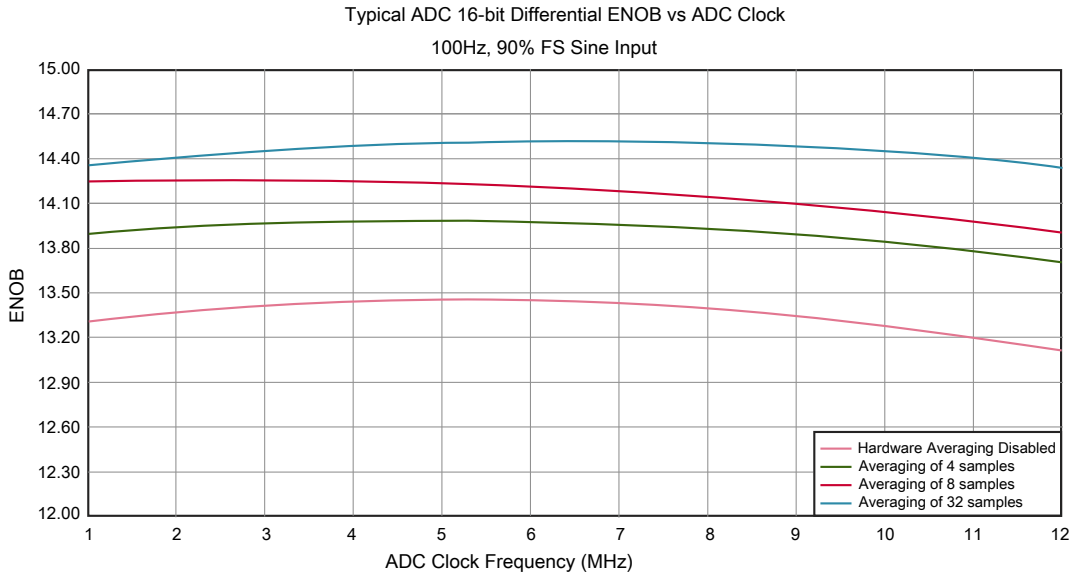


Figure 16. Typical ENOB vs. ADC_CLK for 16-bit differential mode

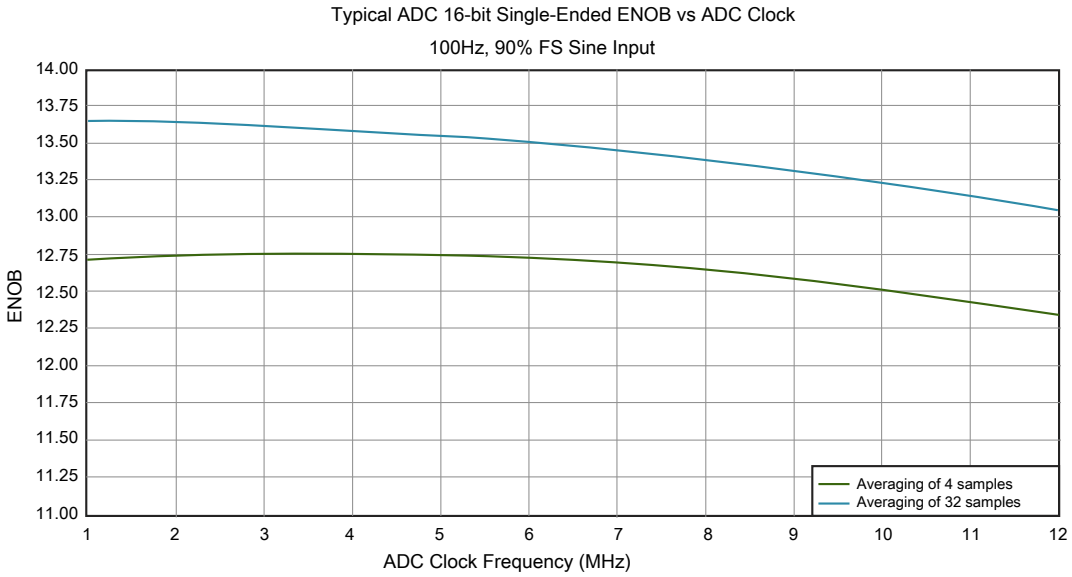


Figure 17. Typical ENOB vs. ADC_CLK for 16-bit single-ended mode

3.6.2 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
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

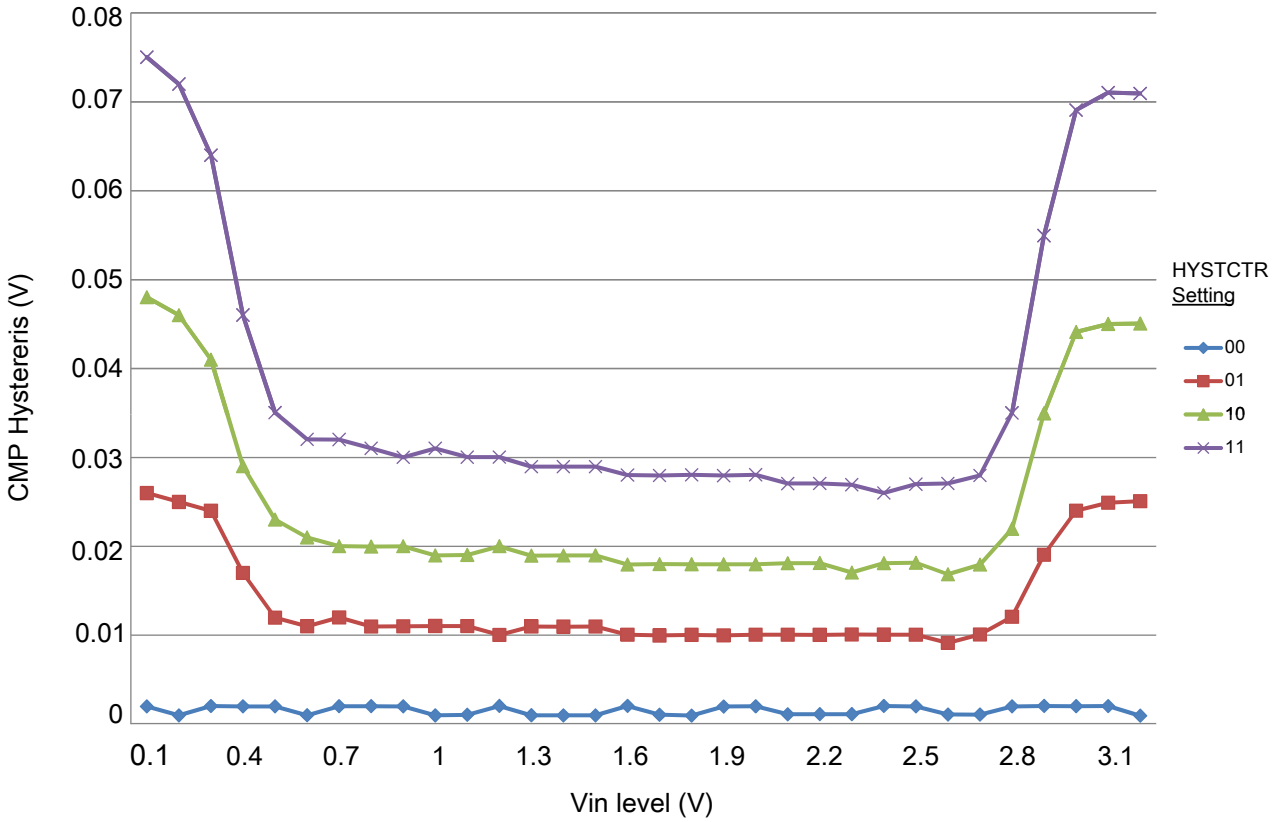


Figure 18. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 0)

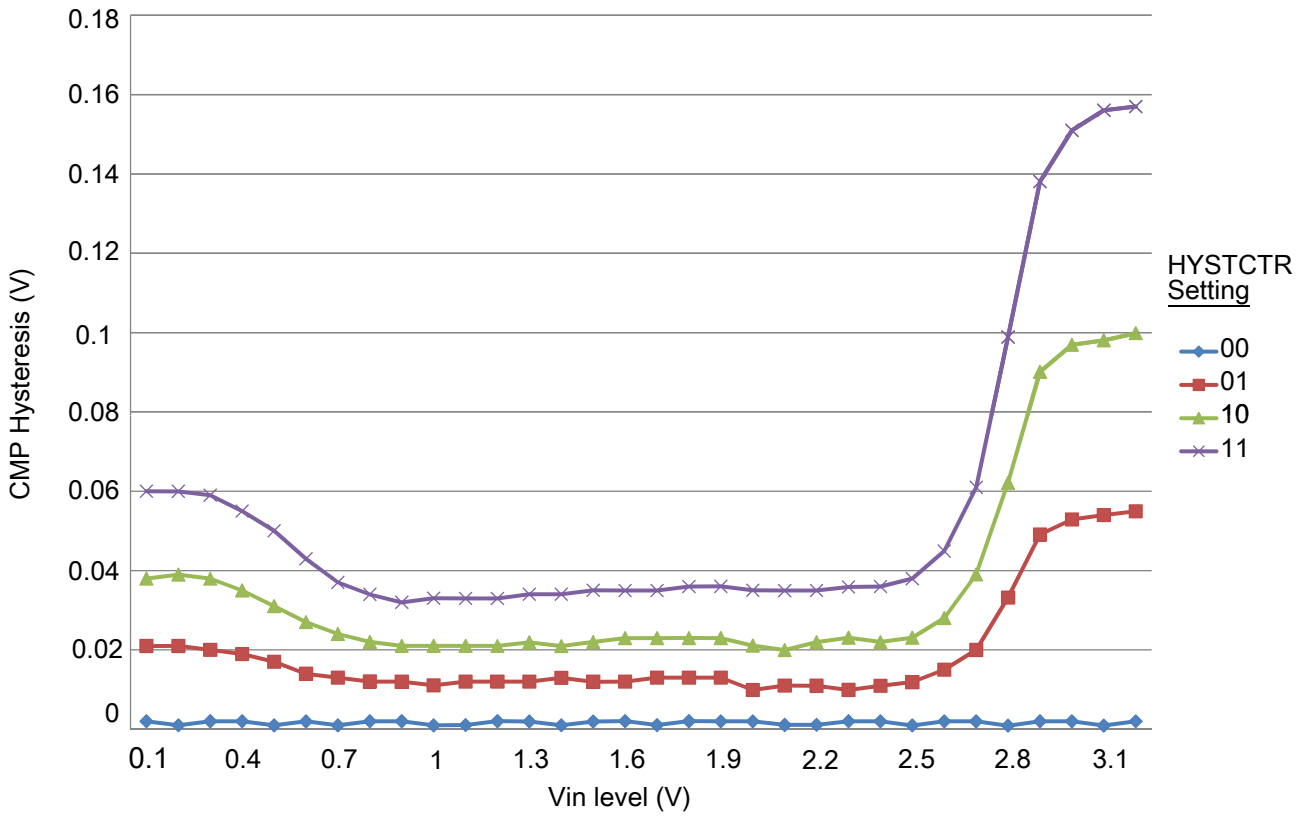


Figure 19. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 1)

3.6.3 12-bit DAC electrical characteristics

3.6.3.1 12-bit DAC operating requirements

Table 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_{REFH}.
2. A small load capacitance (47 pF) can improve the bandwidth performance of the DAC.

3.6.3.2 12-bit DAC operating behaviors

Table 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	
A_C	Offset aging coefficient	—	—	100	µV/yr	
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

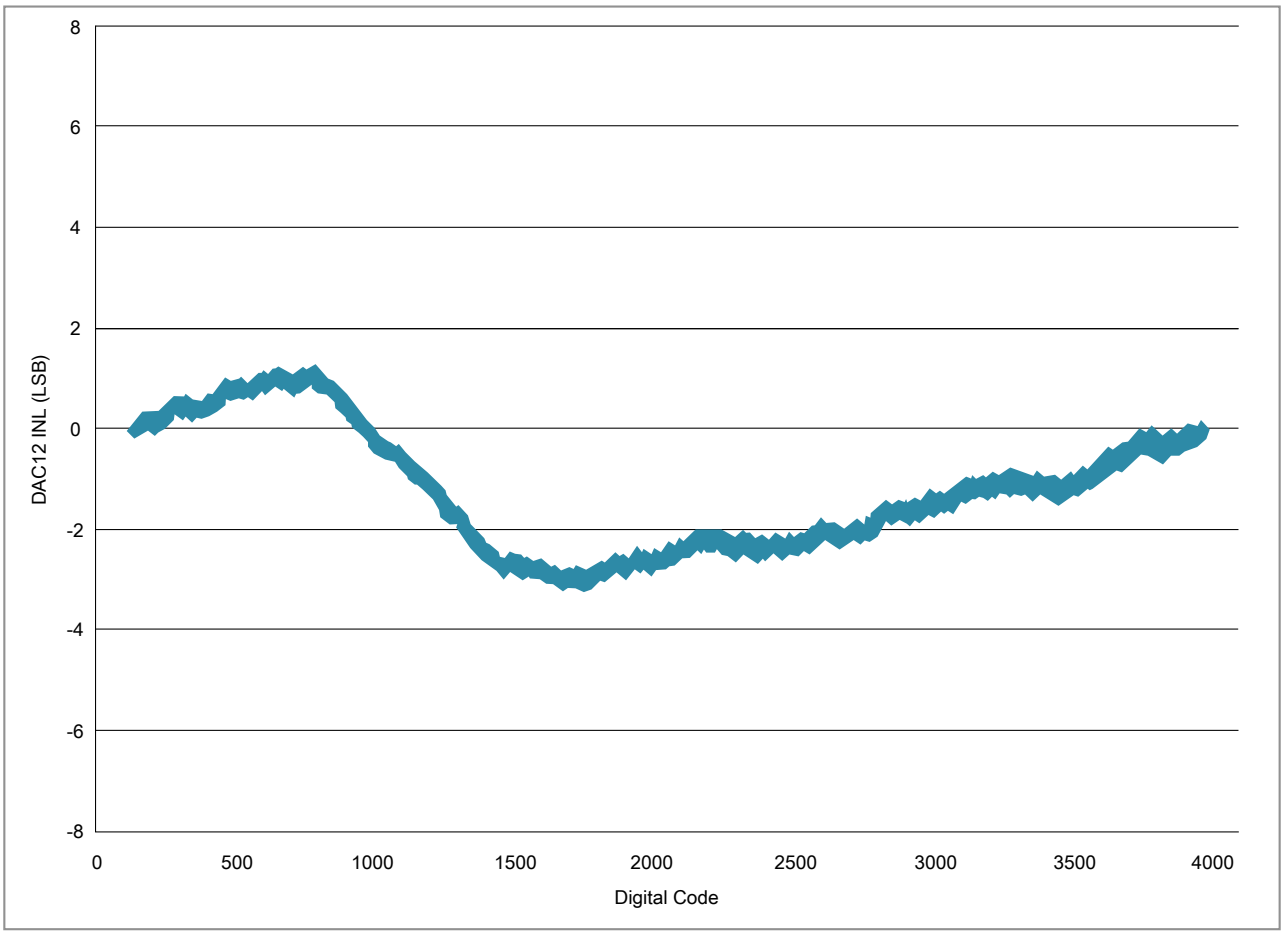


Figure 20. Typical INL error vs. digital code

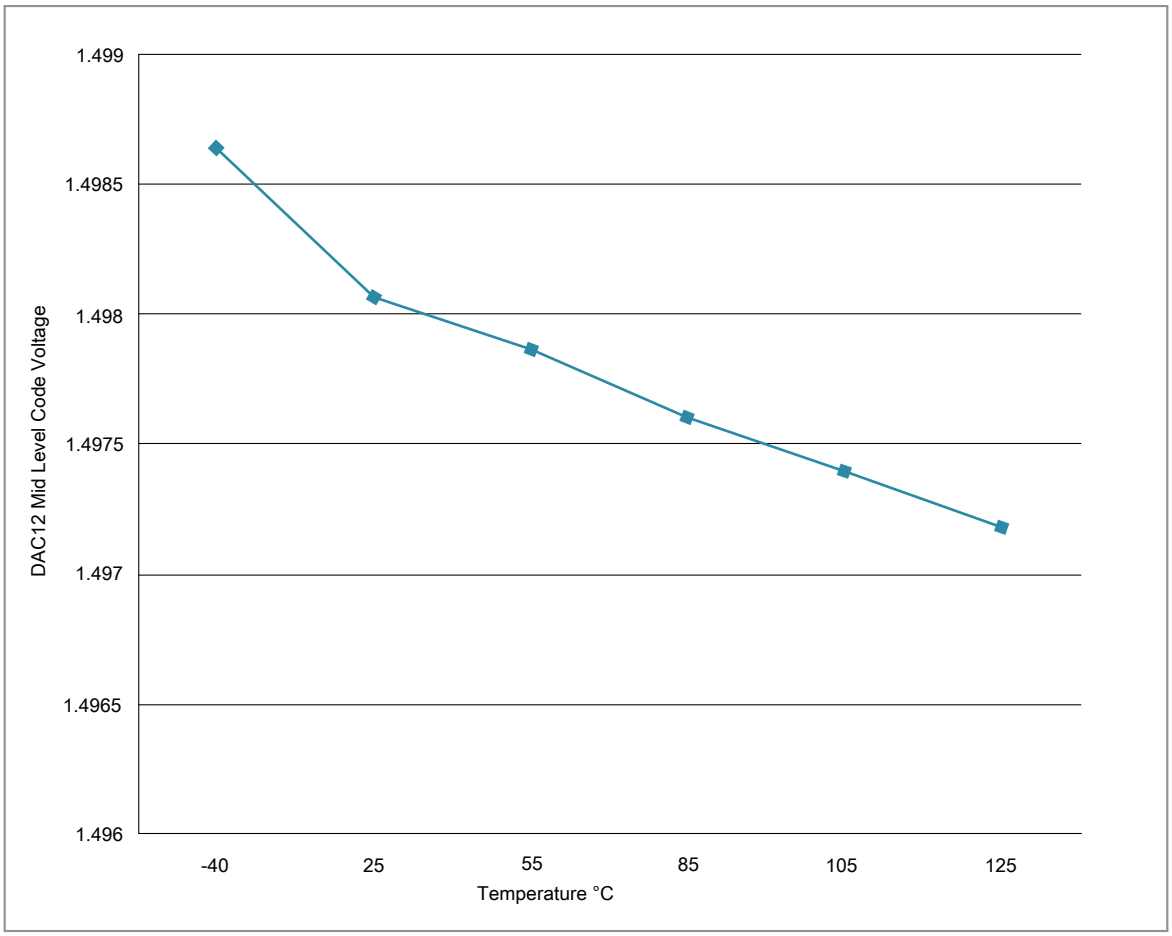


Figure 21. Offset at half scale vs. temperature

3.6.4 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= 25 °C	1.192	1.195	1.198	V	1
V_{out}	Voltage reference output with user trim at nominal V_{DDA} and temperature= 25 °C	1.1945	1.195	1.1955	V	1
V_{step}	Voltage reference trim step	—	0.5	—	mV	1
V_{tdrift}	Temperature drift (Vmax -Vmin across the full temperature range)	—	2	15	mV	1
I_{bg}	Bandgap only current	—	60	80	µA	1
I_{lp}	Low-power buffer current	—	180	360	uA	1
I_{hp}	High-power buffer current	—	480	960	mA	1
ΔV_{LOAD}	Load regulation • current = ± 1.0 mA	— 	200	— 	µV	1, 2
T_{stup}	Buffer startup time	—	—	100	µs	—
$T_{chop\_osc\_stup}$	Internal bandgap start-up delay with chop oscillator enabled			35	ms	
V_{vdrift}	Voltage drift (Vmax -Vmin across the full voltage range)	—	0.5	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	—

3.7 Timers

See General switching specifications.

3.8 Communication interfaces

3.8.1 Ethernet switching specifications

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

3.8.1.1 MII signal switching specifications

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

Table 39. MII signal switching specifications

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

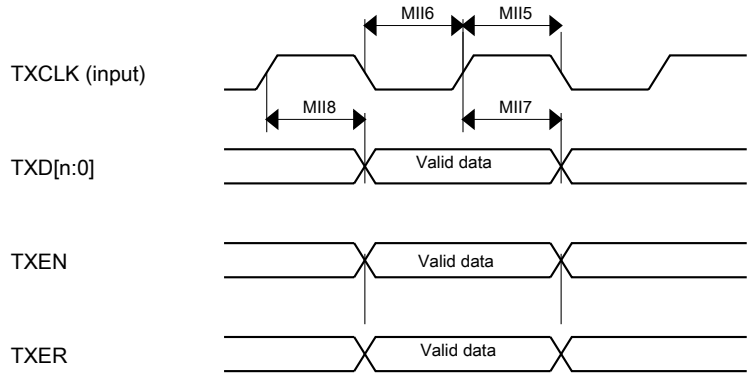


Figure 22. RMII/MII transmit signal timing diagram

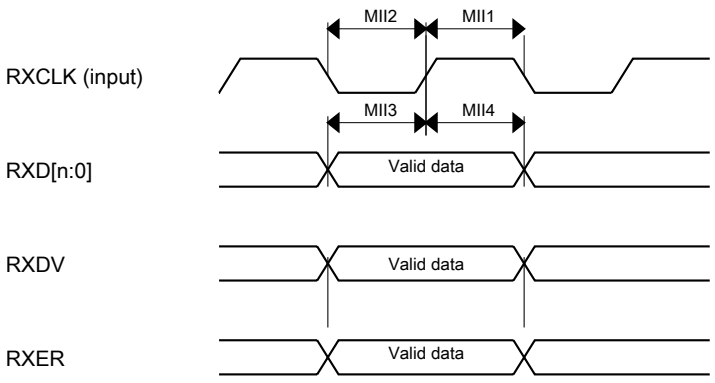


Figure 23. RMII/MII receive signal timing diagram

3.8.1.2 RMII signal switching specifications

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

Table 40. RMII signal switching specifications

Num	Description	Min.	Max.	Unit
—	EXTAL frequency (RMII input clock RMII_CLK)	—	50	MHz
RMII1	RMII_CLK pulse width high	35%	65%	RMII_CLK period
RMII2	RMII_CLK pulse width low	35%	65%	RMII_CLK period
RMII3	RXD[1:0], CRS_DV, RXER to RMII_CLK setup	4	—	ns
RMII4	RMII_CLK to RXD[1:0], CRS_DV, RXER hold	2	—	ns
RMII7	RMII_CLK to TXD[1:0], TXEN invalid	4	—	ns
RMII8	RMII_CLK to TXD[1:0], TXEN valid	—	15	ns

3.8.1.3 MDIO serial management timing specifications

Table 41. MDIO serial management channel signal timing

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

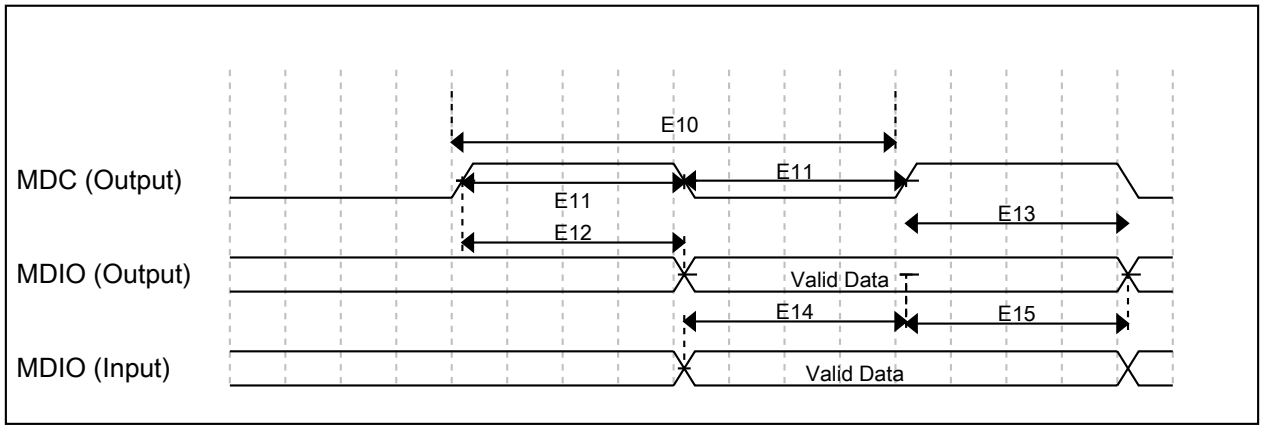


Figure 24. MDIO serial management channel timing diagram

3.8.2 USB electrical specifications

The USB electricals for the USB On-the-Go module conform to the standards documented by the Universal Serial Bus Implementers Forum. For the most up-to-date standards, visit **usb.org**.

NOTE

The MCGPLLCLK meets the USB jitter and signaling rate specifications for certification with the use of an external clock/crystal for both Device and Host modes.

The MCGFLLCLK does not meet the USB jitter or signaling rate specifications for certification.

The IRC48M meets the USB jitter and signaling rate specifications for certification in Device mode when the USB clock recovery mode is enabled. It does not meet the USB signaling rate specifications for certification in Host mode operation.

3.8.3 USB DCD electrical specifications

Table 42. USB0 DCD electrical specifications

Symbol	Description	Min.	Typ.	Max.	Unit
V_{DP_SRC}	USB_DP source voltage (up to 250 µA)	0.5	—	0.7	V
V_{LGC}	Threshold voltage for logic high	0.8	—	2.0	V

Table continues on the next page...

Table 42. USB0 DCD electrical specifications (continued)

Symbol	Description	Min.	Typ.	Max.	Unit
I_{DP_SRC}	USB_DP source current	7	10	13	µA
I_{DM_SINK}	USB_DM sink current	50	100	150	µA
R_{DM_DWN}	D- pulldown resistance for data pin contact detect	14.25	—	24.8	kΩ
V_{DAT_REF}	Data detect voltage	0.25	0.33	0.4	V

3.8.4 USB VREG electrical specifications

Table 43. USB VREG electrical specifications

Symbol	Description	Min.	Typ.[1]	Max.	Unit	Notes
VREGIN	Input supply voltage	2.7	—	5.5	V	
I_{DDon}	Quiescent current — Run mode, load current equal zero, input supply (VREGIN) > 3.6 V	—	125	186	µA	
I_{DDstby}	Quiescent current — Standby mode, load current equal zero	—	1.1	10	µA	
I_{DDoff}	Quiescent current — Shutdown mode • VREGIN = 5.0 V and temperature=25 °C • Across operating voltage and temperature	 — —	 650 —	 — 4	 nA µA	
$I_{LOADrun}$	Maximum load current — Run mode	—	—	120	mA	
$I_{LOADstby}$	Maximum load current — Standby mode	—	—	1	mA	
$V_{Reg33out}$	Regulator output voltage — Input supply (VREGIN) > 3.6 V • Run mode • Standby mode	 3 2.1	 3.3 2.8	 3.6 3.6	 V V	
$V_{Reg33out}$	Regulator output voltage — Input supply (VREGIN) < 3.6 V, pass-through mode	2.1	—	3.6	V	2
C_{OUT}	External output capacitor	1.76	2.2	8.16	µF	
ESR	External output capacitor equivalent series resistance	1	—	100	mΩ	
I_{LIM}	Short circuit current	—	290	—	mA	

1. Typical values assume VREGIN = 5.0 V, Temp = 25 °C unless otherwise stated.
2. Operating in pass-through mode: regulator output voltage equal to the input voltage minus a drop proportional to I_{Load}.

3.8.5 CAN switching specifications

See General switching specifications.

3.8.6 DSPI switching specifications (limited voltage range)

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

Table 44. 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 SPIx_CTARn[PSSCK] and SPIx_CTARn[CSSCK].
2. The delay is programmable in SPIx_CTARn[PASC] and SPIx_CTARn[ASC].

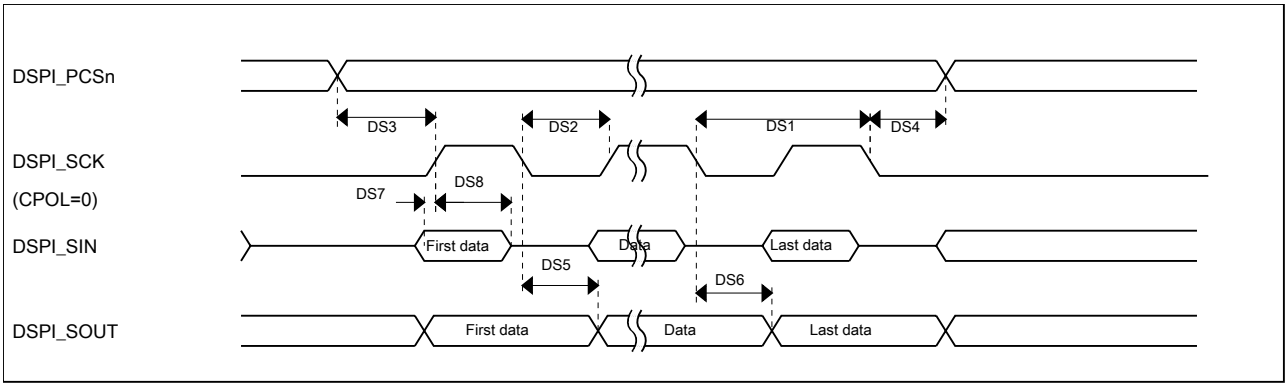


Figure 25. DSPI classic SPI timing — master mode

Table 45. Slave mode DSPI timing (limited voltage range)

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

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

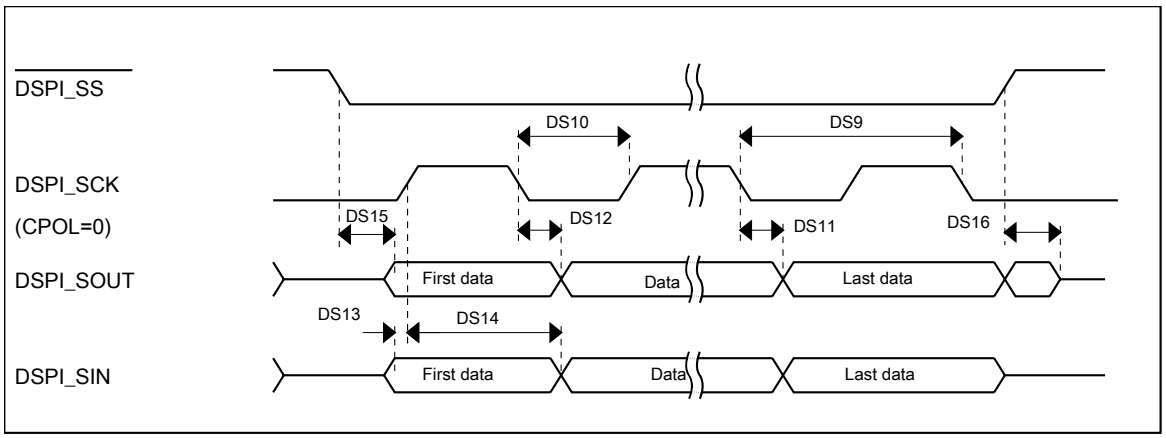


Figure 26. DSPI classic SPI timing — slave mode

3.8.7 DSPI switching specifications (full voltage range)

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

Table 46. Master mode DSPI timing (full voltage range)

Num	Description	Min.	Max.	Unit	Notes
	Operating voltage	1.71	3.6	V	1
	Frequency of operation	—	15	MHz	
DS1	DSPI_SCK output cycle time	4 x t_{BUS}	—	ns	
DS2	DSPI_SCK output high/low time	(t_{SCK}/2) - 4	($t_{SCK/2}$) + 4	ns	
DS3	DSPI_PCS*n* valid to DSPI_SCK delay	(t_{BUS} 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	21	—	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].

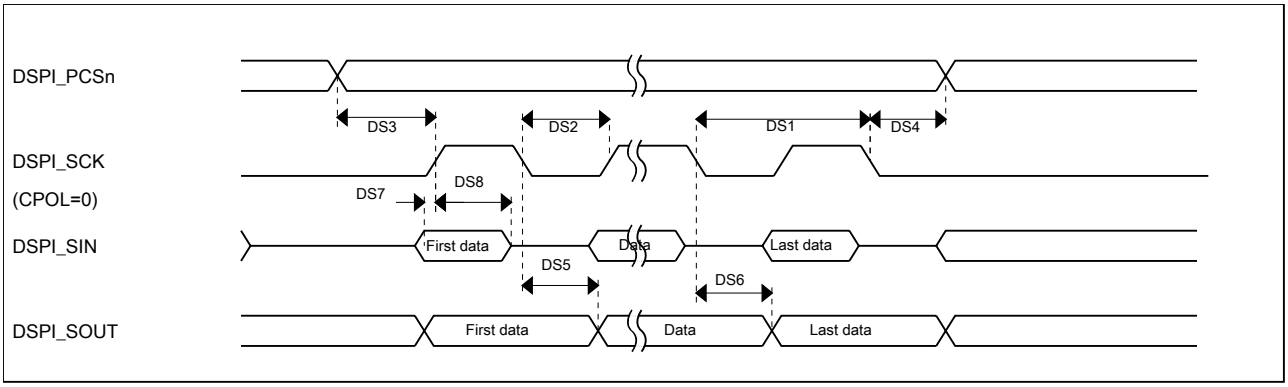


Figure 27. DSPI classic SPI timing — master mode

Table 47. Slave mode DSPI timing (full voltage range)

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

Table continues on the next page...

Table 47. Slave mode DSPI timing (full voltage range) (continued)

Num	Description	Min.	Max.	Unit
	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	—	23.5	ns
DS12	DSPI_SCK to DSPI_SOUT invalid	0	—	ns
DS13	DSPI_SIN to DSPI_SCK input setup	4	—	ns
DS14	DSPI_SCK to DSPI_SIN input hold	7	—	ns
DS15	$\overline{\text{DSPI\_SS}}$ active to DSPI_SOUT driven	—	21	ns
DS16	$\overline{\text{DSPI\_SS}}$ inactive to DSPI_SOUT not driven	—	19	ns

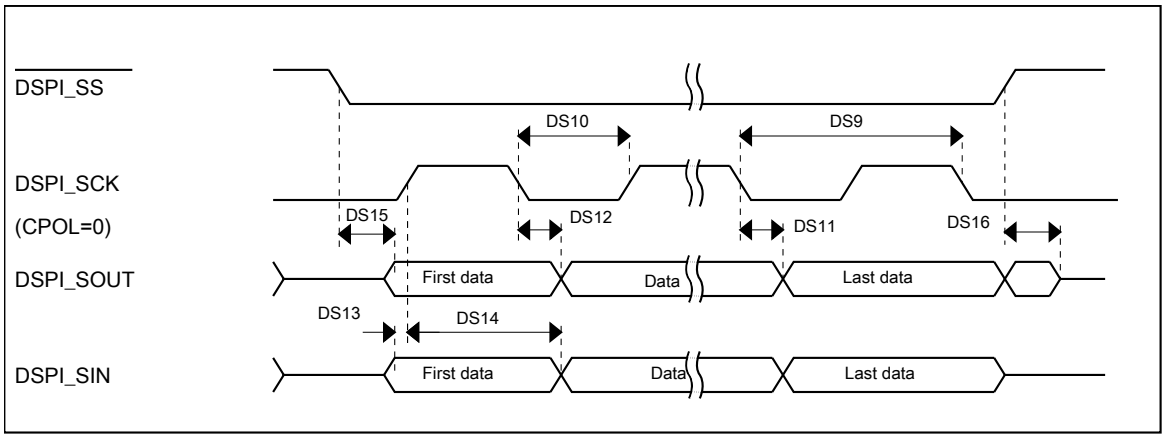


Figure 28. DSPI classic SPI timing — slave mode

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

Table 48. 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

Table continues on the next page...

Table 48. I²C timing (continued)

Characteristic	Symbol	Standard Mode		Fast Mode		Unit
		Minimum	Maximum	Minimum	Maximum	
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 the High drive pins across the full voltage range and when using the Normal drive pins and VDD ≥ 2.7 V.
2. The master mode I²C deasserts ACK of an address byte simultaneously with the falling edge of SCL. If no slaves acknowledge this address byte, then a negative hold time can result, depending on the edge rates of the SDA and SCL lines.
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 I²C bus device can be used in a Standard mode I2C bus system, but the requirement $t_{SU;\ DAT} \geq 250$ ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, then it must output the next data bit to the SDA line $t_{rmax} + t_{SU;\ DAT} = 1000 + 250 = 1250$ ns (according to the Standard mode I²C bus specification) before the SCL line is released.
7. C_b = total capacitance of the one bus line in pF.

Table 49. I²C 1 Mbps timing

Characteristic	Symbol	Minimum	Maximum	Unit
SCL Clock Frequency	f_{SCL}	0	1[1]	MHz
Hold time (repeated) START condition. After this period, the first clock pulse is generated.	t_{HD}; STA	0.26	—	µs
LOW period of the SCL clock	t_{LOW}	0.5	—	µs
HIGH period of the SCL clock	t_{HIGH}	0.26	—	µs
Set-up time for a repeated START condition	t_{SU}; STA	0.26	—	µs
Data hold time for I_2C bus devices	t_{HD}; DAT	0	—	µs
Data set-up time	t_{SU}; DAT	50	—	ns
Rise time of SDA and SCL signals	t_r	20 +0.1C_b[2]	120	ns
Fall time of SDA and SCL signals	t_f	20 +0.1C_b[2]	120	ns
Set-up time for STOP condition	t_{SU}; STO	0.26	—	µs
Bus free time between STOP and START condition	t_{BUF}	0.5	—	µs
Pulse width of spikes that must be suppressed by the input filter	t_{SP}	0	50	ns

1. The maximum SCL clock frequency of 1 Mbps can support maximum bus loading when using the High drive pins across the full voltage range.

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

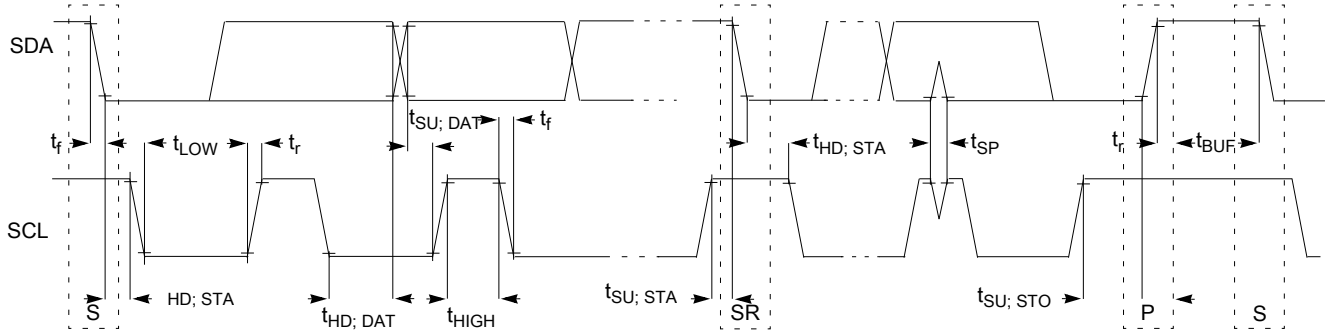


Figure 29. Timing definition for devices on the I²C bus

3.8.9 UART switching specifications

See General switching specifications.

3.8.10 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 50. SDHC switching specifications

Num	Symbol	Description	Min.	Max.	Unit
		Operating voltage	1.71	3.6	V
	Card input clock				
SD1	fpp	Clock frequency (low speed)	0	400	kHz
	fpp	Clock frequency (SD\SDIO full speed\high speed)	0	25\50	MHz
	fpp	Clock frequency (MMC full speed\high speed)	0	20\50	MHz
	f_{OD}	Clock frequency (identification mode)	0	400	kHz
SD2	t_{WL}	Clock low time	7	—	ns
SD3	t_{WH}	Clock high time	7	—	ns
SD4	t_{TLH}	Clock rise time	—	3	ns
SD5	t_{THL}	Clock fall time	—	3	ns
	SDHC output / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK)				
SD6	t_{OD}	SDHC output delay (output valid)	-5	8.3	ns
	SDHC input / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK)				
SD7	t_{ISU}	SDHC input setup time	5.5	—	ns
SD8	t_{IH}	SDHC input hold time	0	—	ns

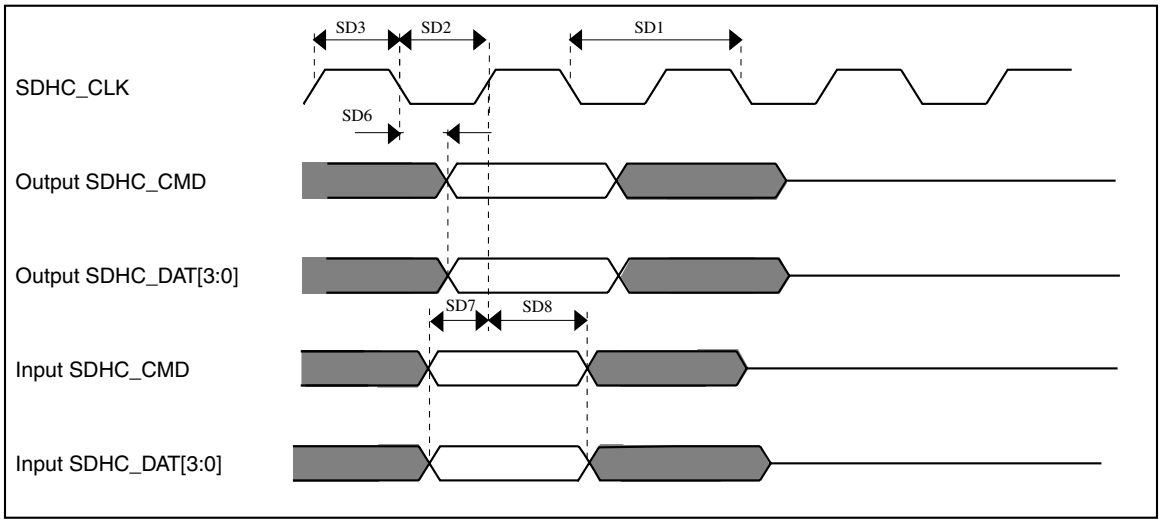


Figure 30. SDHC timing

3.8.11 I²S switching specifications

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

Table 51. I²S master mode timing

Num	Description	Min.	Max.	Unit
	Operating voltage	2.7	3.6	V
S1	I2S_MCLK cycle time	40	—	ns
S2	I2S_MCLK pulse width high/low	45%	55%	MCLK period
S3	I2S_BCLK cycle time	80	—	ns
S4	I2S_BCLK pulse width high/low	45%	55%	BCLK period
S5	I2S_BCLK to I2S_FS output valid	—	15	ns
S6	I2S_BCLK to I2S_FS output invalid	0	—	ns
S7	I2S_BCLK to I2S_TXD valid	—	15	ns
S8	I2S_BCLK to I2S_TXD invalid	0	—	ns
S9	I2S_RXD/I2S_FS input setup before I2S_BCLK	17	—	ns
S10	I2S_RXD/I2S_FS input hold after I2S_BCLK	0	—	ns

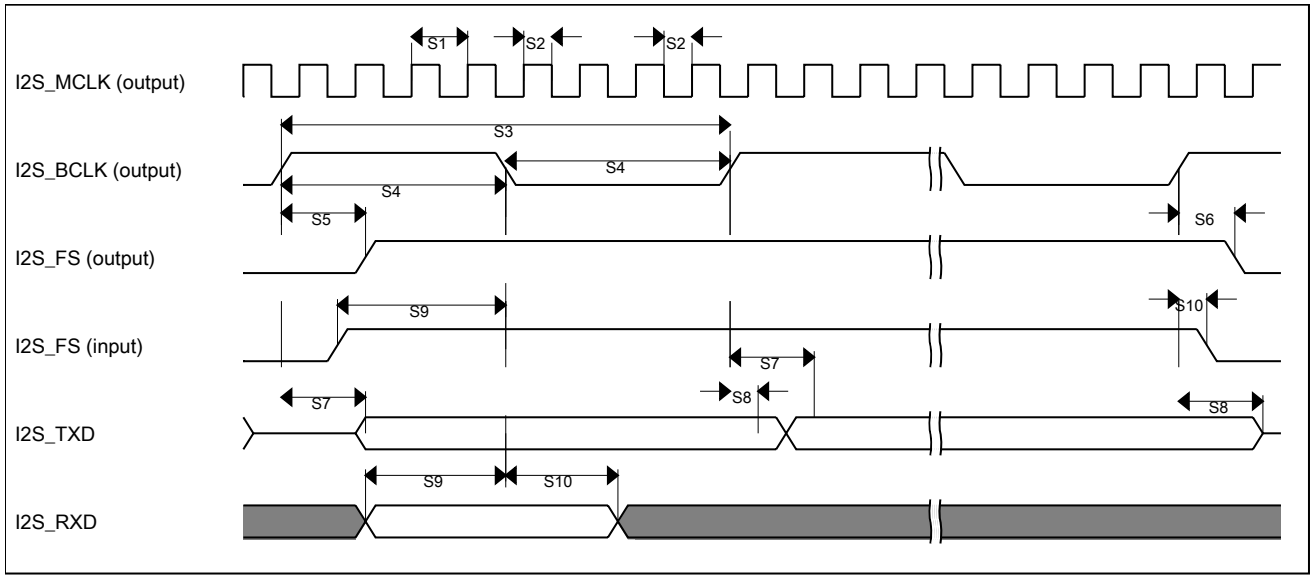


Figure 31. I²S timing — master mode

Table 52. I²S slave mode timing

Num	Description	Min.	Max.	Unit
	Operating voltage	2.7	3.6	V
S11	I2S_BCLK cycle time (input)	80	—	ns
S12	I2S_BCLK pulse width high/low (input)	45%	55%	MCLK period
S13	I2S_FS input setup before I2S_BCLK	5	—	ns
S14	I2S_FS input hold after I2S_BCLK	2	—	ns
S15	I2S_BCLK to I2S_TXD/I2S_FS output valid	—	19.5	ns
S16	I2S_BCLK to I2S_TXD/I2S_FS output invalid	0	—	ns
S17	I2S_RXD setup before I2S_BCLK	5	—	ns
S18	I2S_RXD hold after I2S_BCLK	2	—	ns
S19	I2S_TX_FS input assertion to I2S_TXD output valid[1]		21	ns

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

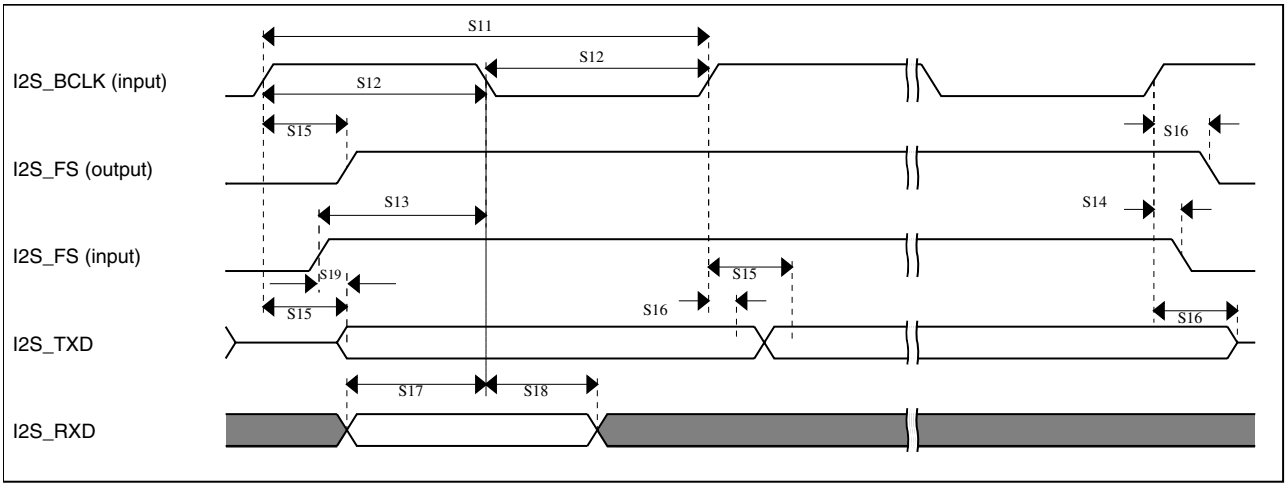


Figure 32. I²S timing — slave modes

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

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

Table 53. I2S/SAI master mode timing

Num.	Characteristic	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V
S1	I2S_MCLK cycle time	40	—	ns
S2	I2S_MCLK (as an input) pulse width high/low	45%	55%	MCLK period
S3	I2S_TX_BCLK/I2S_RX_BCLK cycle time (output)	80	—	ns
S4	I2S_TX_BCLK/I2S_RX_BCLK pulse width high/low	45%	55%	BCLK period
S5	I2S_TX_BCLK/I2S_RX_BCLK to I2S_TX_FS/ I2S_RX_FS output valid	—	15	ns
S6	I2S_TX_BCLK/I2S_RX_BCLK to I2S_TX_FS/ I2S_RX_FS output invalid	-1	—	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	22.5	—	ns
S10	I2S_RXD/I2S_RX_FS input hold after I2S_RX_BCLK	0	—	ns

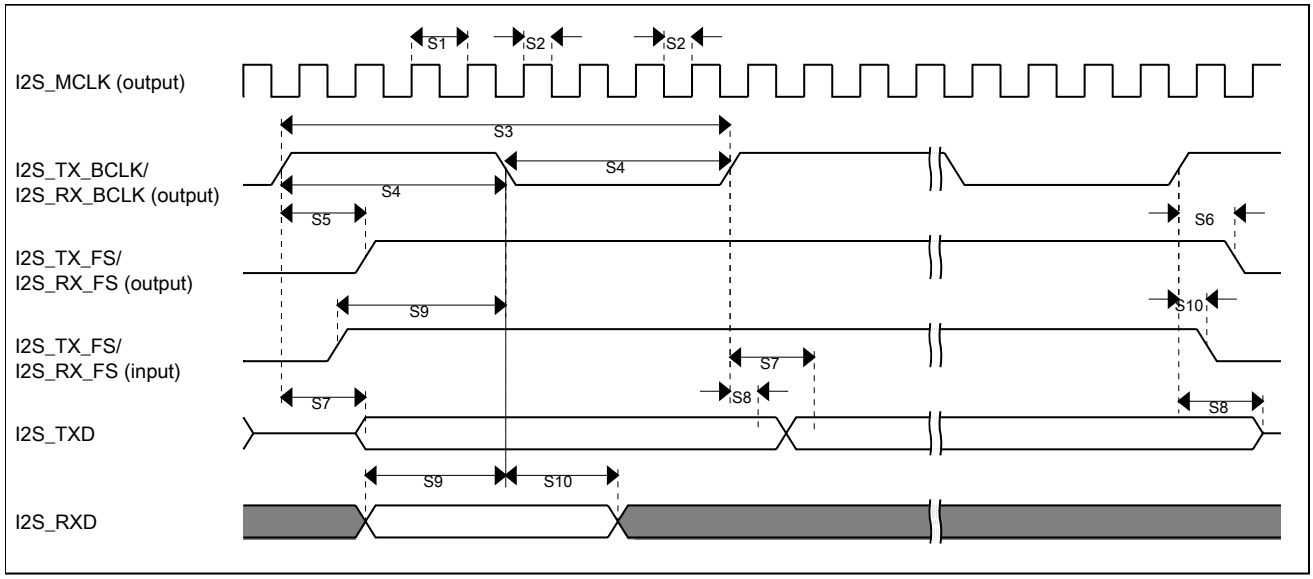


Figure 33. I2S/SAI timing — master modes

Table 54. I2S/SAI slave mode timing

Num.	Characteristic	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V
S11	I2S_TX_BCLK/I2S_RX_BCLK cycle time (input)	80	—	ns
S12	I2S_TX_BCLK/I2S_RX_BCLK pulse width high/low (input)	45%	55%	MCLK period
S13	I2S_TX_FS/I2S_RX_FS input setup before I2S_TX_BCLK/I2S_RX_BCLK	7	—	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	—	25.5	ns
S16	I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output invalid	3	—	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

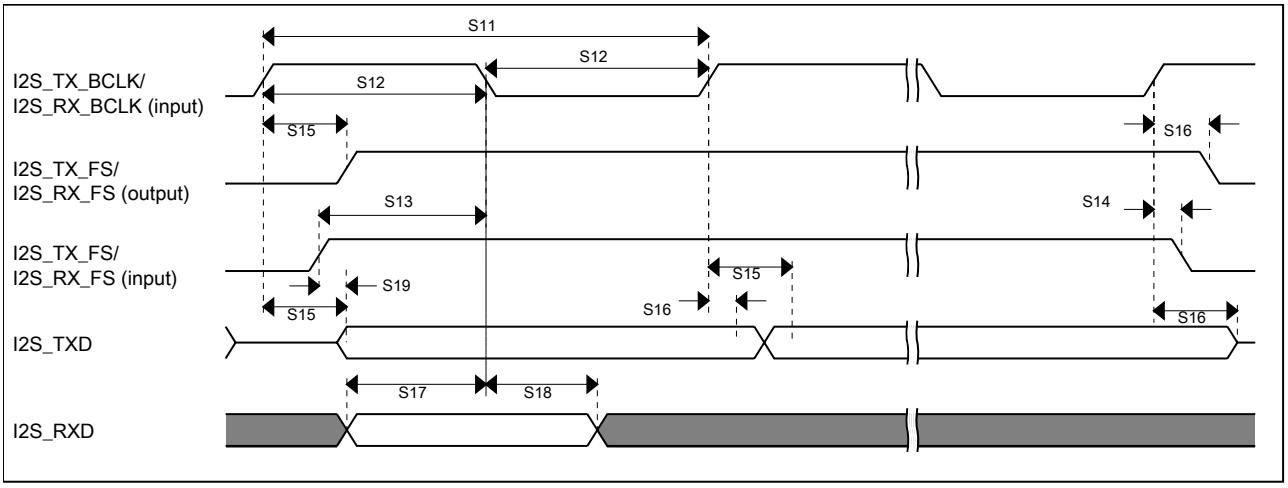


Figure 34. I2S/SAI timing — slave modes

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

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

Table 55. 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		—	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

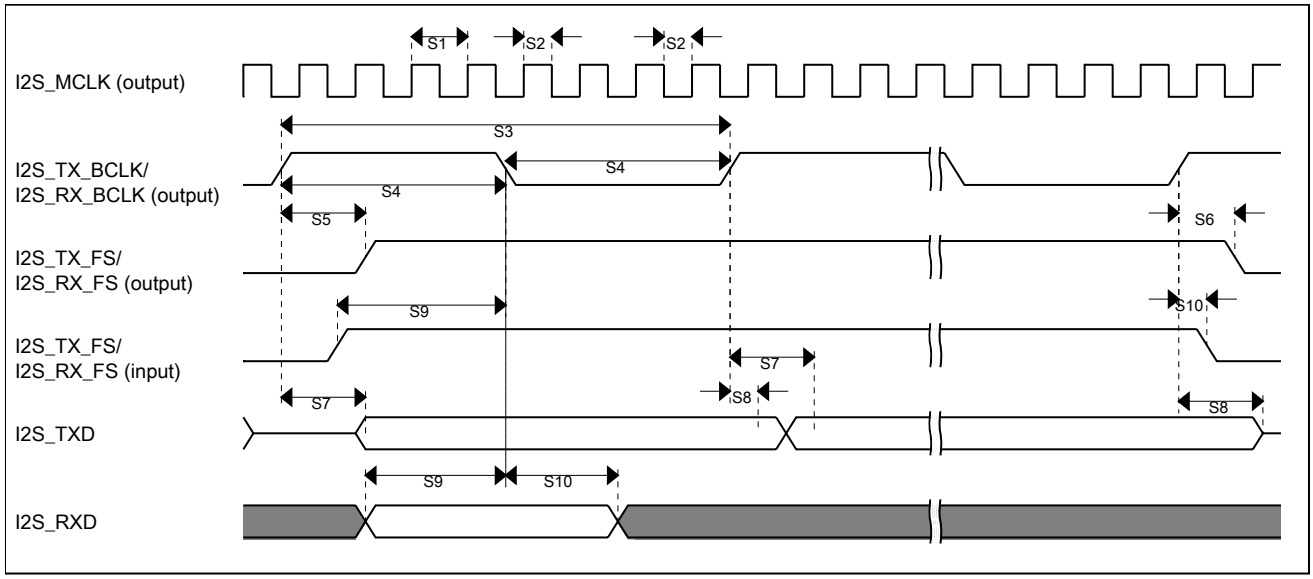


Figure 35. I2S/SAI timing — master modes

Table 56. 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	11	—	ns
S15	I2S_TX_BCLK to I2S_TXD/I2S_TX_FS output valid	—		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	11	—	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

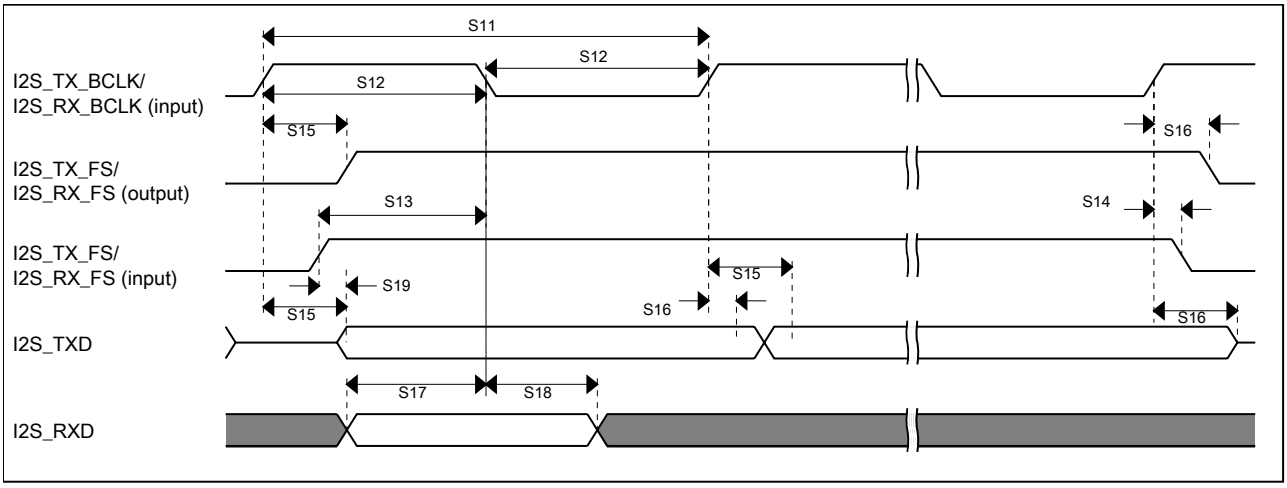


Figure 36. I2S/SAI timing — slave modes

4 Dimensions

4.1 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
100-pin LQFP	98ASS23308W
121-pin XFBGA	98ASA00595D
144-pin LQFP	98ASS23177W
144-pin MAPBGA	98ASA00222D

5 Pinout

5.1 K64 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 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
—	L5	—	TAMPER0/ RTC_ WAKEUP_ B	TAMPER0/ RTC_ WAKEUP_ B										
A1	100	PTD7	CMT_IRO	UART0_TX	FTM0_CH7		FTM0_ FLT1	SPI1_SIN						
A10	—	PTD8 / x_LL WU_ P24	I2C0_SCL	UART5_ RX			FB_A16			x_LLWU_ P24				
A9	—	PTD9	I2C0_SDA	UART5_TX			FB_A17							
B1	—	PTD1 0		UART5_ RTS_b			FB_A18							
C2	—	PTD1 1/ x_LL WU_ P25	SPI2_ PCS0	UART5_ CTS_b	SDHC0_ CLKIN		FB_A19			x_LLWU_ P25				
C1	—	PTD1 2	SPI2_SCK	FTM3_ FLT0	SDHC0_ D4		FB_A20							
D2	—	PTD1 3	SPI2_ SOUT		SDHC0_ D5		FB_A21							
D1	—	PTD1 4	SPI2_SIN		SDHC0_ D6		FB_A22							
E1	—	PTD1 5	SPI2_ PCS1		SDHC0_ D7		FB_A23							
A11	—	NC												
—	—	NC												
—	—	NC												
K3	—	NC												
H4	—	NC												
1	D3	1	ADC1_ SE4a	ADC1_ SE4a	PTE0	SPI1_ PCS1	UART1_TX	SDHC0_ D1	TRACE_ CLKOUT	I2C1_SDA	RTC_ CLKOUT			
2	D2	2	ADC1_ SE5a	ADC1_ SE5a	PTE1/ LLWU_P0	SPI1_ SOUT	UART1_ RX	SDHC0_ D0	TRACE_ D3	I2C1_SCL	SPI1_SIN		LLWU_P0	
3	D1	3	ADC0_ DP2/ ADC1_ SE6a	ADC0_ DP2/ ADC1_ SE6a	PTE2/ LLWU_P1	SPI1_SCK	UART1_ CTS_b	SDHC0_ DCLK	TRACE_ D2				LLWU_P1	

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
4	E4	4	ADC0_ DM2/ ADC1_ SE7a	ADC0_ DM2/ ADC1_ SE7a	PTE3	SPI1_SIN	UART1_ RTS_b	SDHC0_ CMD	TRACE_ D1		SPI1_ SOUT			
5	E5	—	VDD	VDD										
6	F6	—	VSS	VSS										
7	E3	5	DISABLED		PTE4/ LLWU_P2	SPI1_ PCS0	UART3_TX	SDHC0_ D3	TRACE_ D0				LLWU_P2	
8	E2	6	DISABLED		PTE5	SPI1_ PCS2	UART3_ RX	SDHC0_ D2		FTM3_CH0				
9	E1	7	DISABLED		PTE6/ x_LLWU_ P16	SPI1_ PCS3	UART3_ CTS_b	I2S0_ MCLK		FTM3_CH1	USB_ SOF_OUT		x_LLWU_ P16	
10	F4	—	DISABLED		PTE7		UART3_ RTS_b	I2S0_ RXD0		FTM3_CH2				
11	F3	—	DISABLED		PTE8	I2S0_ RXD1	UART5_TX	I2S0_RX_ FS		FTM3_CH3				
12	F2	—	DISABLED		PTE9/ x_LLWU_ P17	I2S0_TXD1	UART5_ RX	I2S0_RX_ BCLK		FTM3_CH4			x_LLWU_ P17	
13	F1	—	DISABLED		PTE10/ x_LLWU_ P18		UART5_ CTS_b	I2S0_TXD0		FTM3_CH5			x_LLWU_ P18	
14	G4	—	DISABLED		PTE11		UART5_ RTS_b	I2S0_TX_ FS		FTM3_CH6				
15	G3	—	DISABLED		PTE12			I2S0_TX_ BCLK		FTM3_CH7				
16	E6	8	VDD	VDD										
17	F7	9	VSS	VSS										
18	H3	—	VSS	VSS										
19	H1	10	USB0_DP	USB0_DP										
20	H2	11	USB0_DM	USB0_DM										
21	G1	12	VOUT33	VOUT33										
22	G2	13	VREGIN	VREGIN										
23	J1	14	ADC0_DP1	ADC0_DP1										
24	J2	15	ADC0_ DM1	ADC0_ DM1										
25	K1	16	ADC1_DP1	ADC1_DP1										
26	K2	17	ADC1_ DM1	ADC1_ DM1										
27	L1	18	ADC0_ DP0/ ADC1_DP3	ADC0_ DP0/ ADC1_DP3										

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
28	L2	19	ADC0_ DM0/ ADC1_ DM3	ADC0_ DM0/ ADC1_ DM3										
29	M1	20	ADC1_ DP0/ ADC0_DP3	ADC1_ DP0/ ADC0_DP3										
30	M2	21	ADC1_ DM0/ ADC0_ DM3	ADC1_ DM0/ ADC0_ DM3										
31	H5	22	VDDA	VDDA										
32	G5	23	VREFH	VREFH										
33	G6	24	VREFL	VREFL										
34	H6	25	VSSA	VSSA										
35	K3	—	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										
37	M3	26	VREF_ OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_ SE18	VREF_ OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_ SE18										
38	L3	27	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										
40	M7	28	XTAL32	XTAL32										
41	M6	29	EXTAL32	EXTAL32										
42	L6	30	VBAT	VBAT										
43	—	—	VDD	VDD										
44	—	—	VSS	VSS										

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
45	M4	31	ADC0_ SE17	ADC0_ SE17	PTE24		UART4_TX		I2C0_SCL	EWM_ OUT_b				
46	K5	32	ADC0_ SE18	ADC0_ SE18	PTE25/ x_LLWU_ P21		UART4_ RX		I2C0_SDA	EWM_IN			x_LLWU_ P21	
47	K4	33	DISABLED		PTE26	ENET_ 1588_ CLKIN	UART4_ CTS_b			RTC_ CLKOUT	USB_ CLKIN			
48	J4	—	DISABLED		PTE27		UART4_ RTS_b							
49	H4	—	DISABLED		PTE28									
50	J5	34	JTAG_ TCLK/ SWD_CLK/ EZP_CLK		PTA0	UART0_ CTS_b/ UART0_ COL_b	FTM0_CH5				JTAG_ TCLK/ SWD_CLK			EZP_CLK
51	J6	35	JTAG_TDI/ EZP_DI		PTA1	UART0_ RX	FTM0_CH6				JTAG_TDI			EZP_DI
52	K6	36	JTAG_ TDO/ TRACE_ SWO/ EZP_DO		PTA2	UART0_TX	FTM0_CH7				JTAG_ TDO/ TRACE_ SWO			EZP_DO
53	K7	37	JTAG_ TMS/ SWD_DIO		PTA3	UART0_ RTS_b	FTM0_CH0				JTAG_ TMS/ SWD_DIO			
54	L7	38	NMI_b/ EZP_CS_b		PTA4/ LLWU_P3		FTM0_CH1				NMI_b		LLWU_P3	EZP_CS_b
55	M8	39	DISABLED		PTA5	USB_ CLKIN	FTM0_CH2	RMII0_ RXER/ MII0_ RXER	CMP2_ OUT	I2S0_TX_ BCLK	JTAG_ TRST_b			
56	E7	40	VDD	VDD										
57	G7	41	VSS	VSS										
58	J7	—	DISABLED		PTA6		FTM0_CH3		CLKOUT		TRACE_ CLKOUT			
59	J8	—	ADC0_ SE10	ADC0_ SE10	PTA7		FTM0_CH4				TRACE_ D3			
60	K8	—	ADC0_ SE11	ADC0_ SE11	PTA8		FTM1_CH0			FTM1_ QD_PHA	TRACE_ D2			
61	L8	—	DISABLED		PTA9		FTM1_CH1	MII0_RXD3		FTM1_ QD_PHB	TRACE_ D1			
62	M9	—	DISABLED		PTA10/ x_LLWU_ P22		FTM2_CH0	MII0_RXD2		FTM2_ QD_PHA	TRACE_ D0		x_LLWU_ P22	
63	L9	—	DISABLED		PTA11/ x_LLWU_ P23		FTM2_CH1	MII0_ RXCLK	I2C2_SDA	FTM2_ QD_PHB			x_LLWU_ P23	

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
64	K9	42	CMP2_IN0	CMP2_IN0	PTA12	CAN0_TX	FTM1_CH0	RMII0_ RXD1/ MII0_RXD1	I2C2_SCL	I2S0_TXD0	FTM1_ QD_PHA			
65	J9	43	CMP2_IN1	CMP2_IN1	PTA13/ LLWU_P4	CAN0_RX	FTM1_CH1	RMII0_ RXD0/ MII0_RXD0	I2C2_SDA	I2S0_TX_ FS	FTM1_ QD_PHB		LLWU_P4	
66	L10	44	DISABLED		PTA14	SPI0_ PCS0	UART0_TX	RMII0_ CRS_DV/ MII0_ RXDV	I2C2_SCL	I2S0_RX_ BCLK	I2S0_TXD1			
67	L11	45	DISABLED		PTA15	SPI0_SCK	UART0_ RX	RMII0_ TXEN/ MII0_TXEN		I2S0_ RXD0				
68	K10	46	DISABLED		PTA16	SPI0_ SOUT	UART0_ CTS_b/ UART0_ COL_b	RMII0_ TXD0/ MII0_TXD0		I2S0_RX_ FS	I2S0_ RXD1			
69	K11	47	ADC1_ SE17	ADC1_ SE17	PTA17	SPI0_SIN	UART0_ RTS_b	RMII0_ TXD1/ MII0_TXD1		I2S0_ MCLK				
70	E8	48	VDD	VDD										
71	G8	49	VSS	VSS										
72	M12	50	EXTAL0	EXTAL0	PTA18		FTM0_ FLT2	FTM_ CLKIN0					EXTAL0	
73	M11	51	XTAL0	XTAL0	PTA19		FTM1_ FLT0	FTM_ CLKIN1		LPTMR0_ ALT1			LPTMR0_ ALT1	
74	L12	52	RESET_b	RESET_b									RESET_b	
75	K12	—	DISABLED		PTA24			MII0_TXD2		FB_A29				
76	J12	—	DISABLED		PTA25			MII0_ TXCLK		FB_A28				
77	J11	—	DISABLED		PTA26			MII0_TXD3		FB_A27				
78	J10	—	DISABLED		PTA27			MII0_CRS		FB_A26				
79	H12	—	DISABLED		PTA28			MII0_TXER		FB_A25				
80	H11	—	DISABLED		PTA29			MII0_COL		FB_A24				
81	H10	53	ADC0_ SE8/ ADC1_SE8	ADC0_ SE8/ ADC1_SE8	PTB0/ LLWU_P5	I2C0_SCL	FTM1_CH0	RMII0_ MDIO/ MII0_MDIO		FTM1_ QD_PHA			LLWU_P5	
82	H9	54	ADC0_ SE9/ ADC1_SE9	ADC0_ SE9/ ADC1_SE9	PTB1	I2C0_SDA	FTM1_CH1	RMII0_ MDC/ MII0_MDC		FTM1_ QD_PHB				
83	G12	55	ADC0_ SE12	ADC0_ SE12	PTB2	I2C0_SCL	UART0_ RTS_b	ENET0_ 1588_ TMR0		FTM0_ FLT3				
84	G11	56	ADC0_ SE13	ADC0_ SE13	PTB3	I2C0_SDA	UART0_ CTS_b/	ENET0_ 1588_ TMR1		FTM0_ FLT0				

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
							UART0_ COL_b							
85	G10	—	ADC1_ SE10	ADC1_ SE10	PTB4			ENET0_ 1588_ TMR2		FTM1_ FLT0				
86	G9	—	ADC1_ SE11	ADC1_ SE11	PTB5			ENET0_ 1588_ TMR3		FTM2_ FLT0				
87	F12	—	ADC1_ SE12	ADC1_ SE12	PTB6				FB_AD23					
88	F11	—	ADC1_ SE13	ADC1_ SE13	PTB7				FB_AD22					
89	F10	—	DISABLED		PTB8		UART3_ RTS_b		FB_AD21					
90	F9	57	DISABLED		PTB9	SPI1_ PCS1	UART3_ CTS_b		FB_AD20					
91	E12	58	ADC1_ SE14	ADC1_ SE14	PTB10	SPI1_ PCS0	UART3_ RX		FB_AD19	FTM0_ FLT1				
92	E11	59	ADC1_ SE15	ADC1_ SE15	PTB11	SPI1_SCK	UART3_TX		FB_AD18	FTM0_ FLT2				
93	H7	60	VSS	VSS										
94	F5	61	VDD	VDD										
95	E10	62	DISABLED		PTB16	SPI1_ SOUT	UART0_ RX	FTM_ CLKIN0	FB_AD17	EWM_IN				
96	E9	63	DISABLED		PTB17	SPI1_SIN	UART0_TX	FTM_ CLKIN1	FB_AD16	EWM_ OUT_b				
97	D12	64	DISABLED		PTB18	CAN0_TX	FTM2_CH0	I2S0_TX_ BCLK	FB_AD15	FTM2_ QD_PHA				
98	D11	65	DISABLED		PTB19	CAN0_RX	FTM2_CH1	I2S0_TX_ FS	FB_OE_b	FTM2_ QD_PHB				
99	D10	66	DISABLED		PTB20	SPI2_ PCS0			FB_AD31	CMP0_ OUT				
100	D9	67	DISABLED		PTB21	SPI2_SCK			FB_AD30	CMP1_ OUT				
101	C12	68	DISABLED		PTB22	SPI2_ SOUT			FB_AD29	CMP2_ OUT				
102	C11	69	DISABLED		PTB23	SPI2_SIN	SPI0_ PCS5		FB_AD28					
103	B12	70	ADC0_ SE14	ADC0_ SE14	PTC0	SPI0_ PCS4	PDB0_ EXTRG	USB_ SOF_OUT	FB_AD14	I2S0_TXD1				
104	B11	71	ADC0_ SE15	ADC0_ SE15	PTC1/ LLWU_P6	SPI0_ PCS3	UART1_ RTS_b	FTM0_CH0	FB_AD13	I2S0_TXD0			LLWU_P6	
105	A12	72	ADC0_ SE4b/ CMP1_IN0	ADC0_ SE4b/ CMP1_IN0	PTC2	SPI0_ PCS2	UART1_ CTS_b	FTM0_CH1	FB_AD12	I2S0_TX_ FS				

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
106	A11	73	CMP1_IN1	CMP1_IN1	PTC3/ LLWU_P7	SPI0_ PCS1	UART1_ RX	FTM0_CH2	CLKOUT/ CLKOUT	I2S0_TX_ BCLK			LLWU_P7	
107	H8	74	VSS	VSS										
108	—	75	VDD	VDD										
109	A9	76	DISABLED		PTC4/ LLWU_P8	SPI0_ PCS0	UART1_TX	FTM0_CH3	FB_AD11	CMP1_ OUT			LLWU_P8	
110	D8	77	DISABLED		PTC5/ LLWU_P9	SPI0_SCK	LPTMR0_ ALT2	I2S0_ RXD0	FB_AD10	CMP0_ OUT	FTM0_CH2		LLWU_P9/ LPTMR0_ ALT2	
111	C8	78	CMP0_IN0	CMP0_IN0	PTC6/ LLWU_P10	SPI0_ SOUT	PDB0_ EXTRG	I2S0_RX_ BCLK	FB_AD9	I2S0_ MCLK			LLWU_P10	
112	B8	79	CMP0_IN1	CMP0_IN1	PTC7	SPI0_SIN	USB_ SOF_OUT	I2S0_RX_ FS	FB_AD8					
113	A8	80	ADC1_ SE4b/ CMP0_IN2	ADC1_ SE4b/ CMP0_IN2	PTC8		FTM3_CH4	I2S0_ MCLK	FB_AD7					
114	D7	81	ADC1_ SE5b/ CMP0_IN3	ADC1_ SE5b/ CMP0_IN3	PTC9		FTM3_CH5	I2S0_RX_ BCLK	FB_AD6	FTM2_ FLT0				
115	C7	82	ADC1_ SE6b	ADC1_ SE6b	PTC10	I2C1_SCL	FTM3_CH6	I2S0_RX_ FS	FB_AD5					
116	B7	83	ADC1_ SE7b	ADC1_ SE7b	PTC11/ LLWU_P11	I2C1_SDA	FTM3_CH7	I2S0_ RXD1	FB_RW_b				LLWU_P11	
117	A7	84	DISABLED		PTC12		UART4_ RTS_b		FB_AD27	FTM3_ FLT0				
118	D6	85	DISABLED		PTC13		UART4_ CTS_b		FB_AD26					
119	C6	86	DISABLED		PTC14		UART4_ RX		FB_AD25					
120	B6	87	DISABLED		PTC15		UART4_TX		FB_AD24					
121	—	88	VSS	VSS										
122	—	89	VDD	VDD										
123	A6	90	DISABLED		PTC16		UART3_ RX	ENET0_ 1588_ TMR0	FB_CS5_b/ FB_TSIZ1/ FB_BE23_ 16_ BLS15_8_ b					
124	D5	91	DISABLED		PTC17		UART3_TX	ENET0_ 1588_ TMR1	FB_CS4_b/ FB_TSIZ0/ FB_BE31_ 24_BLS7_ 0_b					
125	C5	92	DISABLED		PTC18		UART3_ RTS_b	ENET0_ 1588_ TMR2	FB_TBST_ b/ FB_CS2_b/ FB_BE15_					

144 QFP	144 MAP BGA	100 LQFP	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7	ALT8	ALT9
									8_BLS23_16_b					
126	B5	—	DISABLED		PTC19		UART3_CTS_b	ENET0_1588_TMR3	FB_CS3_b/FB_BE7_0_BLS31_24_b	FB_TA_b				
127	A5	93	DISABLED		PTD0/LLWU_P12	SPI0_PCS0	UART2_RTS_b	FTM3_CH0	FB_ALE/FB_CS1_b/FB_TS_b				LLWU_P12	
128	D4	94	ADC0_SE5b	ADC0_SE5b	PTD1	SPI0_SCK	UART2_CTS_b	FTM3_CH1	FB_CS0_b					
129	C4	95	DISABLED		PTD2/LLWU_P13	SPI0_SOUT	UART2_RX	FTM3_CH2	FB_AD4		I2C0_SCL		LLWU_P13	
130	B4	96	DISABLED		PTD3	SPI0_SIN	UART2_TX	FTM3_CH3	FB_AD3		I2C0_SDA			
131	A4	97	DISABLED		PTD4/LLWU_P14	SPI0_PCS1	UART0_RTS_b	FTM0_CH4	FB_AD2	EWM_IN	SPI1_PCS0		LLWU_P14	
132	A3	98	ADC0_SE6b	ADC0_SE6b	PTD5	SPI0_PCS2	UART0_CTS_b/UART0_COL_b	FTM0_CH5	FB_AD1	EWM_OUT_b	SPI1_SCK			
133	A2	99	ADC0_SE7b	ADC0_SE7b	PTD6/LLWU_P15	SPI0_PCS3	UART0_RX	FTM0_CH6	FB_AD0	FTM0_FLT0	SPI1_SOUT		LLWU_P15	
134	M10	—	VSS	VSS										
135	F8	—	VDD	VDD										

5.2 Unused analog interfaces

Table 57. Unused analog interfaces

Module name	Pins	Recommendation if unused
ADC	ADC0_DP1, ADC0_DM1, ADC1_DP1, ADC1_DM1, ADC0_DP0/ADC1_DP3, ADC0_DM0/ADC1_DM3, ADC1_DP0/ADC0_DP3, ADC1_DM0/ADC0_DM3, ADC1_SE16/ADC0_SE22, ADC0_SE16/ADC0_SE21, ADC1_SE18	Ground
DAC [1]	DAC0_OUT, DAC1_OUT	Float
USB	VREGIN, USB0_GND, VOUT33[2]	Connect VREGIN and VOUT33 together and tie to ground through a 10 kΩ resistor. Do not tie directly to ground, as this causes a latch-up risk.
	USB0_DM, USB0_DP	Float

1. Unused DAC signals do not apply to all parts. See the Pinout section for details.
2. USB0_VBUS and USB0_GND are board level signals

5.3 K64 Pinouts

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

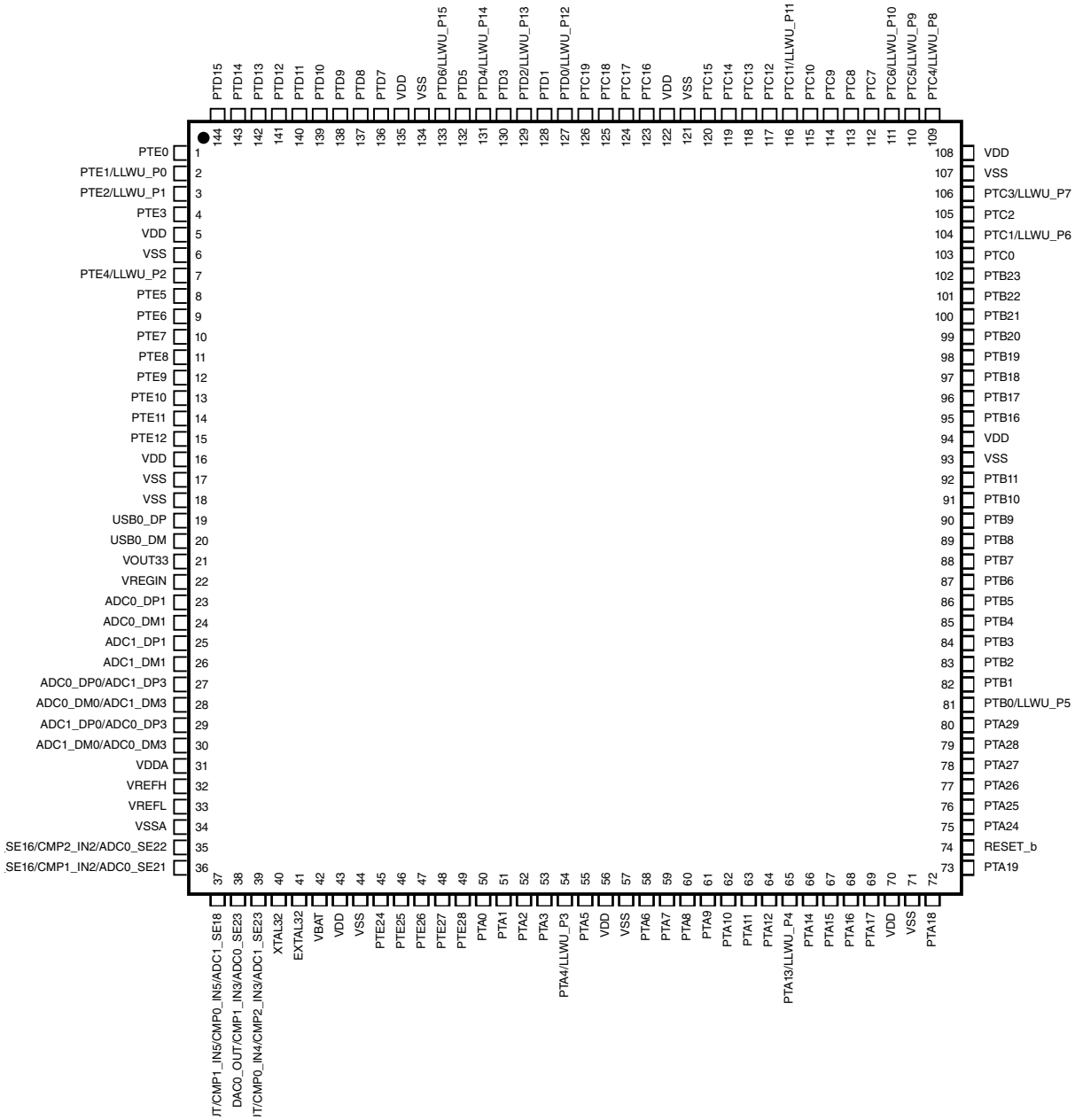


Figure 37. 144 LQFP Pinout Diagram

	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	VOUT33	VREGIN	PTE12	PTE11	VREFH	VREFL	VSS	VSS	PTB5	PTB4	PTB3	PTB2	G
H	USB0_DP	USB0_DM	VSS	PTE28	VDDA	VSSA	VSS	VSS	PTB1	PTB0/ LLWU_P5	PTA29	PTA28	H
J	ADC0_DP1	ADC0_DM1	ADC0_SE16/ CMP1_IN2/ ADC0_SE21	PTE27	PTA0	PTA1	PTA6	PTA7	PTA13/ LLWU_P4	PTA27	PTA26	PTA25	J
K	ADC1_DP1	ADC1_DM1	ADC1_SE16/ CMP2_IN2/ ADC0_SE22	PTE26	PTE25	PTA2	PTA3	PTA8	PTA12	PTA16	PTA17	PTA24	K
L	ADC0_DP0/ ADC1_DP3	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	ADC1_DP0/ ADC0_DP3	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 38. 144 MAPBGA Pinout Diagram

	1	2	3	4	5	6	7	8	9	10	11	
A	PTD7	PTD5	PTD4/ LLWU_P14	PTC19	PTC14	PTC13	PTC8	PTC4/ LLWU_P8	PTD9	PTD8	NC	A
B	PTD10	PTD6/ LLWU_P15	PTD3	PTC18	PTC15	PTC12	PTC7	PTC3/ LLWU_P7	PTC0	PTB16	PTB12	B
C	PTD12	PTD11	PTD2/ LLWU_P13	PTC17	PTC11/ LLWU_P11	PTC10	PTC6/ LLWU_P10	PTC2	PTB19	PTB11	PTB13	C
D	PTD14	PTD13	PTD1	PTD0/ LLWU_P12	PTC16	PTC9	PTC5/ LLWU_P9	PTC1/ LLWU_P6	PTB18	PTB10	PTB8	D
E	PTD15	PTE2/ LLWU_P1	PTE1/ LLWU_P0	PTE0	VDD	VDD	VDD	PTB23	PTB17	PTB9	PTB7	E
F	USB0_DP	USB0_DM	PTE6	PTE3	VDDA	VSSA	VSS	PTB22	PTB21	PTB20	PTB6	F
G	VOUT33	VREGIN	VSS	PTE5	VREFH	VREFL	VSS	PTB3	PTB2	PTB1	PTB0/ LLWU_P5	G
H	ADC0_DP1	ADC0_DM1	ADC0_SE16/ CMP1_IN2/ ADC0_SE21	NC	PTE24	PTE26	PTE4/ LLWU_P2	PTA1	PTA3	PTA17	PTA29	H
J	ADC1_DP1	ADC1_DM1	ADC1_SE16/ CMP2_IN2/ ADC0_SE22	PTA11	PTE25	PTA0	PTA2	PTA4/ LLWU_P3	PTA10	PTA16	RESET_b	J
K	ADC0_DP0/ ADC1_DP3	ADC0_DM0/ ADC1_DM3	NC	DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23	DAC0_OUT/ CMP1_IN3/ ADC0_SE23	VBAT	PTA5	PTA12	PTA14	VSS	PTA19	K
L	ADC1_DP0/ ADC0_DP3	ADC1_DM0/ ADC0_DM3	VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18	XTAL32	EXTAL32	VSS	RTC_ WAKEUP_B	PTA13/ LLWU_P4	PTA15	VDD	PTA18	L
	1	2	3	4	5	6	7	8	9	10	11	

Figure 39. 121 XFBGA Pinout Diagram

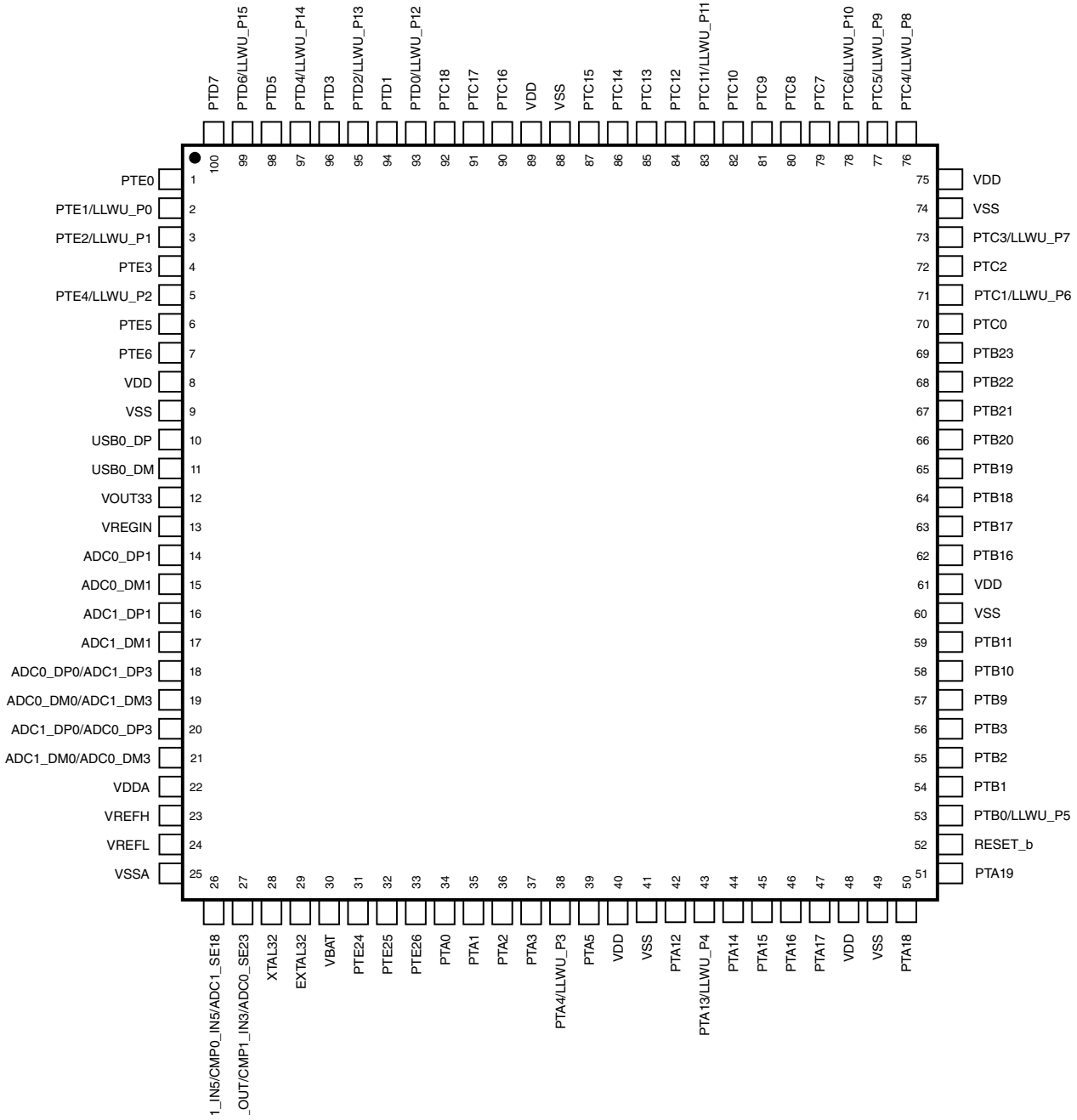


Figure 40. 100 LQFP Pinout Diagram

	1	2	3	4	5	6	7	8	9	10	11	
A	PTC4/ LLWU_P8	PTC7	PTC9	PTC12	PTC15	PTC17	PTD1	PTD5	PTD7	PTD9	PTD14	A
B	PTC3/ LLWU_P7	PTC6/ LLWU_P10	PTC8	PTC11/ LLWU_P11	PTC14	PTC18	PTD3	PTD6/ LLWU_P15	PTD8	PTD12	PTD15	B
C	PTC2	PTC5/ LLWU_P9	PTC10	PTC13	PTC16	PTD2/ LLWU_P13	PTD4/ LLWU_P14	PTD11	PTD13	PTE0	PTE3	C
D	PTB23	PTC0	PTC1/ LLWU_P6	PTB22	PTC19	PTD0/ LLWU_P12	PTD10	PTE1/ LLWU_P0	PTE2/ LLWU_P1	PTE4/ LLWU_P2	PTE5	D
E	PTB18	PTB19	PTB20	PTB21	VDD	VSS	PTE6	PTE7	PTE8	PTE9	PTE10	E
F	PTB16	PTB17	VDD	VSS	VSS	VDD	VDD	ADC0_DP1	PTE11	PTE12	VSS	F
G	PTB10	PTB11	PTB9	PTB8	VDD		VSS	ADC0_DM1	ADC0_DP0/ ADC1_DP3	VOUT33	USB0_DP	G
H	PTB7	PTB6	PTB5	PTB4	VSS	VSS	VDD	VDD	ADC0_DM0/ ADC1_DM3	VREGIN	USB0_DM	H
J	PTB3	PTB2	PTB1	PTB0/ LLWU_P5	PTA14	PTA11	PTA2	PTE27	RTC_ WAKEUP_B	ADC1_DP0/ ADC0_DP3	ADC1_DP1	J
K	PTA29	PTA28	PTA27	PTA26	PTA12	PTA8	PTA1	PTE25	ADC0_SE16/ CMP1_IN2/ ADC0_SE21	ADC1_DM0/ ADC0_DM3	ADC1_DM1	K
L	RESET_b	PTA24	PTA25	PTA16	PTA9	PTA5	PTA0	PTE24	VREF_OUT/ CMP1_IN5/ CMP0_IN5/ ADC1_SE18	VREFH	VDDA	L
M	PTA19	VSS	PTA17	PTA13/ LLWU_P4	PTA7	PTA4/ LLWU_P3	PTE28	VBAT	DAC1_OUT/ CMP0_IN4/ CMP2_IN3/ ADC1_SE23	ADC1_SE16/ CMP2_IN2/ ADC0_SE22	VREFL	M
N	PTA18	VDD	PTA15	PTA10	PTA6	PTA3	PTE26	EXTAL32	XTAL32	DAC0_OUT/ CMP1_IN3/ ADC0_SE23	VSSA	N
	1	2	3	4	5	6	7	8	9	10	11	

Figure 41. 142 CSP Pinout Diagram

6 Ordering parts

6.1 Determining valid orderable parts

Valid orderable part numbers are provided on the web. To determine the orderable part numbers for this device, go to nxp.com and perform a part number search for the following device numbers: MK64

7 Part identification

7.1 Description

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

7.2 Format

Part numbers for this device have the following format:

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

7.3 Fields

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

Field	Description	Values
Q	Qualification status	• M = Fully qualified, general market flow • P = Prequalification
K##	Kinetis family	• K64 = Ethernet with high RAM density
A	Key attribute	• D = Cortex-M4 w/ DSP • 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	• 32 = 32 KB • 64 = 64 KB • 128 = 128 KB • 256 = 256 KB • 512 = 512 KB • 1M0 = 1 MB • 2M0 = 2 MB

Table continues on the next page...

Field	Description	Values
R	Silicon revision	• Z = Initial • (Blank) = Main • A = Revision after main
T	Temperature range (°C)	• V = –40 to 105 • C = –40 to 85
PP	Package identifier	• FM = 32 QFN (5 mm x 5 mm) • FT = 48 QFN (7 mm x 7 mm) • LF = 48 LQFP (7 mm x 7 mm) • LH = 64 LQFP (10 mm x 10 mm) • MP = 64 MAPBGA (5 mm x 5 mm) • LK = 80 LQFP (12 mm x 12 mm) • LL = 100 LQFP (14 mm x 14 mm) • MC = 121 MAPBGA (8 mm x 8 mm) • DC = 121 XFBGA (8 mm x 8 mm x 0.5 mm) • LQ = 144 LQFP (20 mm x 20 mm) • MD = 144 MAPBGA (13 mm x 13 mm)
CC	Maximum CPU frequency (MHz)	• 5 = 50 MHz • 7 = 72 MHz • 10 = 100 MHz • 12 = 120 MHz • 15 = 150 MHz • 16 = 168 MHz • 18 = 180 MHz
N	Packaging type	• R = Tape and reel • (Blank) = Trays

7.4 Example

This is an example part number:

MK64FN1M0VMD12

8 Terminology and guidelines

8.1 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:

Table continues on the next page...

Term	Definition
	• *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.

8.2 Examples

Operating rating:

Symbol	Description	Min.	Max.	Unit
V_{DD}	1.0 V core supply voltage	–0.3	1.2	V

Operating requirement:

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

Operating behavior that includes a *typical value*:

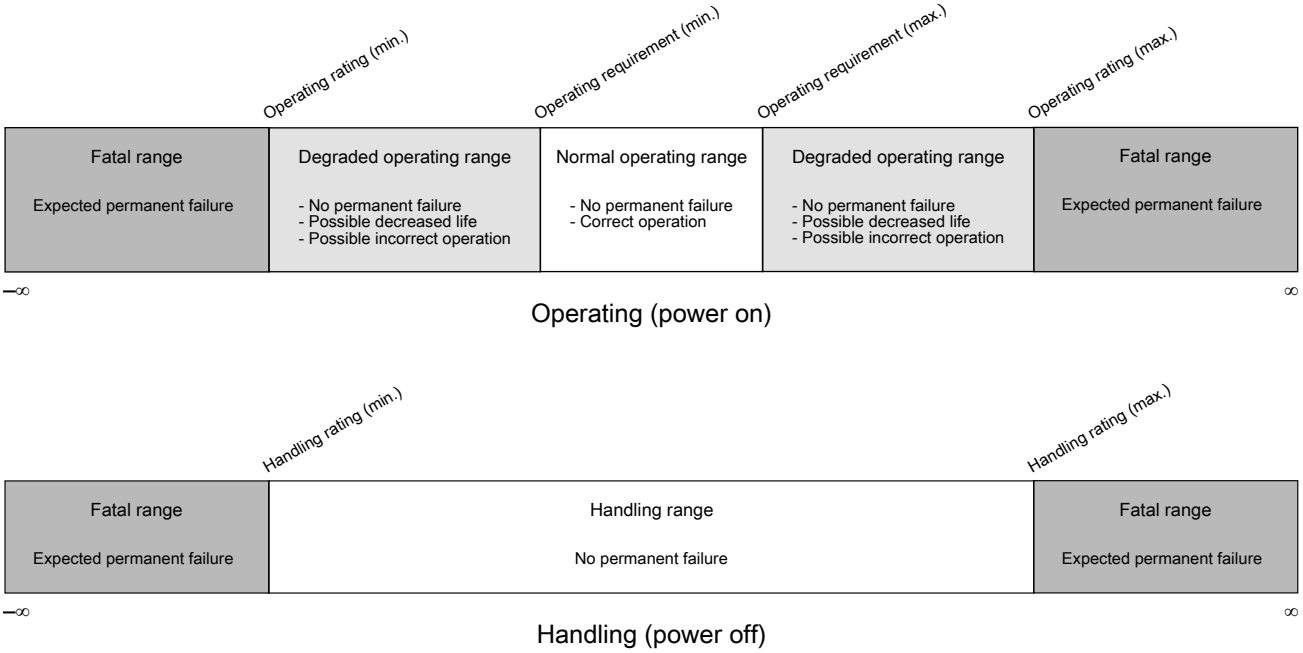
Symbol	Description	Min.	Typ.	Max.	Unit
I_{WP}	Digital I/O weak pullup/pulldown current	10	70	130	µA

8.3 Typical-value conditions

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

Symbol	Description	Value	Unit
T_A	Ambient temperature	25	°C
V_{DD}	Supply voltage	3.3	V

8.4 Relationship between ratings and operating requirements



8.5 Guidelines for ratings and operating requirements

Follow these guidelines for ratings and operating requirements:

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

9 Revision History

The following table provides a revision history for this document.

Table 58. Revision History

Rev. No.	Date	Substantial Changes
2	01/2014	Initial public release.
3	04/2014	• Format changes • Updated Table 23 "Flash command timing specifications."
4	09/2014	• Updated Table 6 "Power consumption operating behavior." • Updated Table 17 "IRC48M specifications • Updated Table 35 "VREF full-range operating behavior"
5	12/2014	• Updated Table 6 "Power consumption operating behavior." • Added a note to the section "Power consumption operating behaviors."
6	08/2015	• Added a footnote to the maximum SCL clock frequency value in the table "I^2C timing" • Changed the title of the table "I^2C 1 MHZ timing" to "I^2C 1 Mbps timing" • Added a footnote and updated the table "IRC48M specifications" for open loop total deviation of IRC48M frequency at high voltage and low voltage. • Added a footnote on the ambient temperature entry to the section "Thermal operating requirements." • Added a note to the section "Power consumption operating behaviors" and updated values in the table "Power consumption operating behaviors." • Added a note to the maximum frequency value in the table "Slave mode DSPI timing (limited voltage range)." • Redeveloped the section "Terminology and guidelines."
7	10/2016	• Updated the values of I_{DD_STOP} and I_{DD_VLLS0} in the table "Power consumption operating behaviors"

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Document Number K64P144M120SF5
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