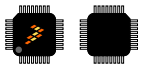
Kinetis KL13 Microcontroller

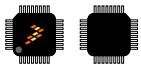
48 MHz ARM® Cortex®-M0+ and 64 KB Flash

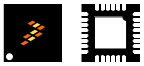
MKL13Z32Vxx4
MKL13Z64Vxx4

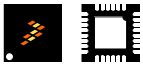
The KL13 series is optimized for cost-sensitive and battery-powered applications requiring low-power general purpose connectivity. The product offers:

- Embedded ROM with boot loader for flexible program upgrade
- High accuracy internal voltage and clock reference
- FlexIO to support any standard and customized serial peripheral emulation
- Hardware CRC module
- Down to 60uA/MHz in very low power run mode and 1.83uA in deep sleep mode (RAM + RTC retained)


64 LQFP
10x10 mm P 0.5 mm


80 LQFP
12x12 mm P 0.5 mm


48 QFN
7x7 mm P 0.5 mm


32 QFN
5x5 mm P 0.5 mm

Core Processor

- ARM® Cortex®-M0+ core up to 48 MHz

Memories

- 32/64 KB program flash memory
- 4/8 KB SRAM
- 8 KB ROM with build-in bootloader
- 32-byte backup register

System

- 4-channel asynchronous DMA controller
- Watchdog
- Low-leakage wakeup unit
- Two-pin Serial Wire Debug (SWD) programming and debug interface
- Micro Trace Buffer
- Bit manipulation engine
- Interrupt controller

Clocks

- 48 MHz high accuracy (up to 0.5%) internal reference clock
- 8MHz/2MHz high accuracy (up to 3%) internal reference clock
- 1KHz reference clock active under all low-power modes (except VLLS0)
- 32–40KHz and 3–32MHz crystal oscillator

Peripherals

- One UART module supporting ISO7816, operating up to 1.5 Mbit/s
- Two low-power UART modules supporting asynchronous operation in low-power modes
- Two I2C modules and I2C0 supporting up to 1 Mbit/s
- Two 16-bit SPI modules supporting up to 24 Mbit/s
- One FlexIO module supporting emulation of additional UART, IrDA, SPI, I2C, PWM and other serial modules, etc.
- One 16-bit 818 ksps ADC module with high accuracy internal voltage reference (Vref) and up to 20 channels
- High-speed analog comparator containing a 6-bit DAC for programmable reference input
- One 12-bit DAC
- 1.2 V internal voltage reference

Timers

- One 6-channel Timer/PWM module
- Two 2-channel Timer/PWM modules
- One low-power timer
- Periodic interrupt timer
- Real time clock

Operating Characteristics

- Voltage range: 1.71 to 3.6 V
- Flash write voltage range: 1.71 to 3.6 V
- Temperature range: –40 to 105 °C

Packages

- 80 LQFP 12mm x 12mm, 0.5mm pitch, 1.6mm thickness
- 64 LQFP 10mm x 10mm, 0.5mm pitch, 1.6mm thickness
- 64 MAPBGA 5mm x 5mm, 0.5mm pitch, 1.23mm thickness (Package Your Way)
- 48 QFN 7mm x 7mm, 0.5mm pitch, 0.65mm thickness (Package Your Way)
- 32 QFN 5mm x 5mm, 0.5mm pitch, 0.65mm thickness (Package Your Way)

Security and Integrity

- 80-bit unique identification number per chip
- Advanced flash security
- Hardware CRC module

I/O

- Up to 70 general-purpose input/output pins (GPIO) and 4 high-drive pad

Low Power

- Down to 60uA/MHz in very low power run mode
- Down to 1.83uA in VLLS3 mode (RAM + RTC retained)
- Six flexible static modes

Ordering Information

Product		Memory		Package		IO and ADC channel		
Part number	Marking (Line1/ Line2)	Flash (KB)	SRAM (KB)	Pin count	Package	GPIOs	GPIOs (INT/HD)[1]	ADC channels (SE/DP)
MKL13Z32VFM4	TBD	32	4	32	QFN	28	28/4	11/2
MKL13Z64VFM4	TBD	64	8	32	QFN	28	28/4	11/2
MKL13Z32VFT4	TBD	32	4	48	QFN	40	40/4	18/3
MKL13Z64VFT4	TBD	64	8	48	QFN	40	40/4	18/3
MKL13Z32VLH4	MKL13Z32/VLH4	32	4	64	LQFP	54	54/4	20/4
MKL13Z64VLH4	MKL13Z64/VLH4	64	8	64	LQFP	54	54/4	20/4
MKL13Z32VMP4	TBD	32	4	64	MAPBGA	54	54/4	20/4
MKL13Z64VMP4	TBD	64	8	64	MAPBGA	54	54/4	20/4
MKL13Z32VLK4	MKL13Z32VLK4	32	4	80	LQFP	70	70/4	20/4
MKL13Z64VLK4	MKL13Z64VLK4	64	8	80	LQFP	70	70/4	20/4

1. INT: interrupt pin numbers; HD: high drive pin numbers

NOTE

The 32 QFN, 48 QFN, and 64 MAPBGA packages supporting MKLx3ZxxVFT4, MKLx3ZxxVFM4, and MKLx3ZxxVMP4 part numbers for this product are not yet available. However, these packages are included in Package Your Way program for Kinetis MCUs. Visit freescale.com/KPYW for more details.

Related Resources

Type	Description	Resource
Selector Guide	The Freescale 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.	KL1xPB[1]

Table continues on the next page...

Related Resources (continued)

Type	Description	Resource
Reference Manual	The Reference Manual contains a comprehensive description of the structure and function (operation) of a device.	KL13P80M48SF3RM[1]
Data Sheet	The Data Sheet includes electrical characteristics and signal connections.	This document.
Chip Errata	The chip mask set Errata provides additional or corrective information for a particular device mask set.	KINETIS_L_0N01P[1]
Package drawing	Package dimensions are provided in package drawings.	• 64-LQFP: 98ASS23234W[1] • 64 MAPBGA: 98ASA00420D[1] • 48 QFN: 98ASA00616D[1] • 80 LQFP: 98ASS23174W[1] • 32 QFN: 98ASA00615D[1]

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

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1 Ratings

1.1 Thermal handling ratings

Table 1. Thermal handling ratings

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

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

1.2 Moisture handling ratings

Table 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

Table 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

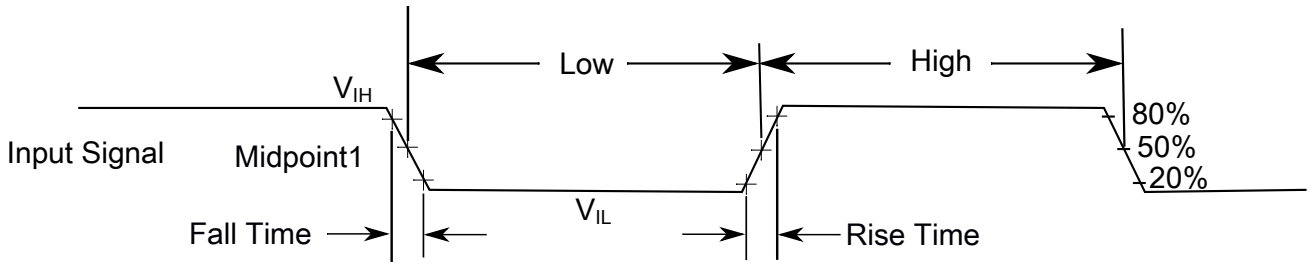
Table 4. Voltage and current operating ratings

Symbol	Description	Min.	Max.	Unit
V_{DD}	Digital supply voltage	–0.3	3.8	V
I_{DD}	Digital supply current	—	120	mA
V_{IO}	IO pin input voltage	–0.3	V_{DD} + 0.3	V
I_D	Instantaneous maximum current single pin limit (applies to all port pins)	–25	25	mA
V_{DDA}	Analog supply voltage	V_{DD} – 0.3	V_{DD} + 0.3	V

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 1. Input signal measurement reference

All digital I/O switching characteristics, unless otherwise specified, assume that the output pins have the following characteristics.

- C_L=30 pF loads
- Slew rate disabled
- Normal drive strength

2.2 Nonswitching electrical specifications

2.2.1 Voltage and current operating requirements

Table 5. 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_{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_{ICIO}	IO pin negative DC injection current — single pin • V_{IN} < V_{SS}-0.3V	-3	—	mA	1
I_{ICcont}	Contiguous pin DC injection current —regional limit, includes sum of negative injection currents of 16 contiguous pins • Negative current injection	 -25	 —	 mA	
V_{ODPU}	Open drain pullup voltage level	V_{DD}	V_{DD}	V	2
V_{SRAM}	V_{DD} voltage required to retain SRAM	1.2	—	V	

1. All I/O pins are internally clamped to V_{SS} through a ESD protection diode. There is no diode connection to V_{DD}. If V_{IN} greater than V_{IO_MIN} (= V_{SS}-0.3 V) is observed, then there is no need to provide current limiting resistors at the pads. If this limit cannot be observed then a current limiting resistor is required. The negative DC injection current limiting resistor is calculated as R = (V_{IO_MIN} - V_{IN})/|I_{ICIO}|.
2. Open drain outputs must be pulled to V_{DD}.

2.2.2 LVD and POR operating requirements

Table 6. V_{DD} supply LVD and POR operating requirements

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
V_{POR}	Falling V_{DD} 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

Table continues on the next page...

Table 6. V_{DD} supply LVD and POR operating requirements (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
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	—	±60	—	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	—	±40	—	mV	—
V_{BG}	Bandgap voltage reference	0.97	1.00	1.03	V	—
t_{LPO}	Internal low power oscillator period — factory trimmed	900	1000	1100	µs	—

1. Rising thresholds are falling threshold + hysteresis voltage

2.2.3 Voltage and current operating behaviors

Table 7. Voltage and current operating behaviors

Symbol	Description	Min.	Max.	Unit	Notes
V_{OH}	Output high voltage — normal drive pad				1
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = –5 mA	V_{DD} – 0.5	—	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = –1.5 mA	V_{DD} – 0.5	—	V	
V_{OH}	Output high voltage — high drive pad				1
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = –18 mA	V_{DD} – 0.5	—	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OH} = –6 mA	V_{DD} – 0.5	—	V	
I_{OHT}	Output high current total for all ports	—	100	mA	
V_{OL}	Output low voltage — normal drive pad				1
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 5 mA	—	0.5	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 1.5 mA	—	0.5	V	
V_{OL}	Output low voltage — high drive pad				1

Table continues on the next page...

Table 7. Voltage and current operating behaviors (continued)

Symbol	Description	Min.	Max.	Unit	Notes
	• 2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 18 mA	—	0.5	V	
	• 1.71 V ≤ V_{DD} ≤ 2.7 V, I_{OL} = 6 mA	—	0.5	V	
I_{OLT}	Output low current total for all ports	—	100	mA	
I_{IN}	Input leakage current (per pin) for full temperature range	—	1	µA	2
I_{IN}	Input leakage current (per pin) at 25 °C	—	0.025	µA	2
I_{IN}	Input leakage current (total all pins) for full temperature range	—	80	µA	2
I_{OZ}	Hi-Z (off-state) leakage current (per pin)	—	1	µA	
R_{PU}	Internal pullup resistors	20	50	kΩ	3

1. PTB0, PTB1, PTC3, and PTD7 I/O have both high drive and normal drive capability selected by the associated PORTx_PCRn[DSE] control bit. All other GPIOs are normal drive only.
2. Measured at V_{DD} = 3.6 V
3. Measured at V_{DD} supply voltage = V_{DD} min and Vinput = V_{SS}

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 = 48 MHz
- Bus and flash clock = 24 MHz
- HIRC clock mode

Table 8. Power mode transition operating behaviors

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
t_{POR}	After a POR event, amount of time from the point V_{DD} reaches 1.8 V to execution of the first instruction across the operating temperature range of the chip.	—	—	300	µs	1
	• VLLS0 → RUN	—	152	166	µs	
	• VLLS1 → RUN	—	152	166	µs	
	• VLLS3 → RUN	—	93	104	µs	
	• LLS → RUN	—	7.5	8	µs	

Table continues on the next page...

Table 8. Power mode transition operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• VLPS → RUN	—	7.5	8	µs	
	• STOP → RUN	—	7.5	8	µs	

1. Normal boot (FTFA_FOPT[LPBOOT]=11)

2.2.5 Power consumption operating behaviors

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

NOTE

The while (1) test is executed with flash cache enabled.

Table 9. Power consumption operating behaviors

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
I_{DDA}	Analog supply current	—	—	See note	mA	1
I_{DD_RUNCO}	Running CoreMark in flash in compute operation mode—48M HIRC mode, 48 MHz core / 24 MHz flash, V_{DD} = 3.0 V					2
	• at 25 °C	—	4.74	4.93	mA	
	• at 105 °C	—	4.9	5.10		
I_{DD_RUNCO}	Running While(1) loop in flash in compute operation mode—48M HIRC mode, 48 MHz core / 24 MHz flash, V_{DD} = 3.0 V					
	• at 25 °C	—	3.27	3.43	mA	
	• at 105 °C	—	3.42	3.59		
I_{DD_RUN}	Run mode current—48M HIRC mode, running CoreMark in Flash all peripheral clock disable 48 MHz core/24 MHz flash, V_{DD} = 3.0 V					2
	• at 25 °C	—	5.63	5.86	mA	
	• at 105 °C	—	5.79	6.02		
I_{DD_RUN}	Run mode current—48M HIRC mode, running CoreMark in flash all peripheral clock disable, 24 MHz core/12 MHz flash, V_{DD} = 3.0 V					2,
	• at 25 °C	—	3.47	3.61		
	• at 105 °C	—	3.63	3.78	mA	

Table continues on the next page...

Table 9. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
I_{DD_RUN}	Run mode current—48M HIRC mode, running CoreMark in Flash all peripheral clock disable 12 MHz core/6 MHz flash, V_{DD} = 3.0 V • at 25 °C • at 105 °C	 — —	 2.37 2.53	 2.56 2.73	 mA	2
I_{DD_RUN}	Run mode current—48M HIRC mode, running CoreMark in Flash all peripheral clock enable 48 MHz core/24 MHz flash, V_{DD} = 3.0 V • at 25 °C • at 105 °C	 — —	 6.91 7.07	 7.19 7.35	 mA	2
I_{DD_RUN}	Run mode current—48M HIRC mode, running While(1) loop in flash all peripheral clock disable, 48 MHz core/24 MHz flash, V_{DD} = 3.0 V • at 25 °C • at 105 °C	 — —	 4.14 4.3	 4.31 4.47	 mA	
I_{DD_RUN}	Run mode current—48M HIRC mode, running While(1) loop in Flash all peripheral clock disable, 24 MHz core/12 MHz flash, V_{DD} = 3.0 V • at 25 °C • at 105 °C	 — —	 2.7 2.86	 2.92 3.09	 mA	
I_{DD_RUN}	Run mode current—48M HIRC mode, Running While(1) loop in Flash all peripheral clock disable, 12 MHz core/6 MHz flash, V_{DD} = 3.0 V • at 25 °C • at 105 °C	 — —	 1.99 2.14	 2.15 2.31	 mA	
I_{DD_RUN}	Run mode current—48M HIRC mode, Running While(1) loop in Flash all peripheral clock enable, 48 MHz core/24 MHz flash, V_{DD} = 3.0 V • at 25 °C • at 105 °C	 — —	 5.39 5.56	 5.61 5.78	 mA	
I_{DD_VLPRCO}	Very Low Power Run Core Mark in Flash in Compute Operation mode: Core@4MHz, Flash @1MHz, V_{DD} = 3.0 V • at 25 °C	 —	 739	 827.68	 µA	
I_{DD_VLPRCO}	Very-low-power-run While(1) loop in SRAM in compute operation mode— 8 MHz LIRC mode, 4 MHz core / 1 MHz flash, V_{DD} = 3.0 V • at 25 °C	 —	 339	 406.8	 µA	
I_{DD_VLPRCO}	Very-low-power run While(1) loop in SRAM in compute operation mode:—2 MHz LIRC mode, 2 MHz core / 0.5 MHz flash, V_{DD} = 3.0 V • at 25 °C	 —	 152	 197.6	 µA	
I_{DD_VLPR}	Very-low-power run mode current— 2 MHz LIRC mode, While(1) loop in flash all peripheral					

Table continues on the next page...

Table 9. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	clock disable, 2 MHz core / 0.5 MHz flash, V_{DD} = 3.0 V • at 25 °C	—	119	178.5	µA	
I_{DD_VLPR}	Very-low-power run mode current— 2 MHz LIRC mode, While(1) loop in flash all peripheral clock disable, 125 kHz core / 31.25 kHz flash, V_{DD} = 3.0 V • at 25 °C	—	41	89.39	µA	
I_{DD_VLPR}	Very-low-power run mode current— 8 MHz LIRC mode, While(1) loop in flash all peripheral clock disable, 4 MHz core / 1 MHz flash, V_{DD} = 3.0 V • at 25 °C	—	277	360.1	µA	
I_{DD_VLPR}	Very-low-power run mode current— 8 MHz LIRC mode, While(1) loop in flash all peripheral clock enable, 4 MHz core / 1 MHz flash, V_{DD} = 3.0 V • at 25 °C	—	343	425.32	µA	
I_{DD_VLPR}	Very-low-power run mode current— 8 MHz LIRC mode, While(1) loop in SRAM in all peripheral clock disable, 4 MHz core / 1 MHz flash, V_{DD} = 3.0 V • at 25 °C	—	375	450	µA	
I_{DD_VLPR}	Very-low-power run mode current— 8 MHz LIRC mode, While(1) loop in SRAM all peripheral clock enable, 4 MHz core / 1 MHz flash, V_{DD} = 3.0 V • at 25 °C	—	441	529.2	µA	
I_{DD_VLPR}	Very-low-power run mode current—2 MHz LIRC mode, While(1) loop in SRAM all peripheral clock disable, 125 kHz core / 31.25 kHz flash, V_{DD} = 3.0 V • at 25 °C	—	45	103.5	µA	
I_{DD_WAIT}	Wait mode current—core disabled, 48 MHz system/24 MHz bus, flash disabled (flash doze enabled), all peripheral clocks disabled, MCG_Lite under HIRC mode, V_{DD} = 3.0 V • at 25 °C	—	2.14	2.50	mA	
I_{DD_WAIT}	Wait mode current—core disabled, 24 MHz system/12 MHz bus, flash disabled (flash doze enabled), all peripheral clocks disabled, MCG_Lite under HIRC mode, V_{DD} = 3.0 V • at 25 °C	—	1.41	1.62	mA	
I_{DD_VLPW}	Very-low-power wait mode current, core disabled, 4 MHz system/ 1 MHz bus and flash, all peripheral clocks disabled, V_{DD} = 3.0 V • at 25 °C	—	193	239.023	µA	

Table continues on the next page...

Table 9. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
I_{DD_VLPW}	Very-low-power wait mode current, core disabled, 2 MHz system/ 0.5 MHz bus and flash, all peripheral clocks disabled, V_{DD} = 3.0 V • at 25 °C	—	78	124.8	µA	
I_{DD_VLPW}	Very-low-power wait mode current, core disabled, 125 kHz system/ 31.25 kHz bus and flash, all peripheral clocks disabled, V_{DD} = 3.0 V • at 25 °C	—	39	78	µA	
I_{DD_PSTOP2}	Partial Stop 2, core and system clock disabled, 12 MHz bus and flash, V_{DD} = 3.0 V • at 25 °C	—	1.72	2.06	mA	
I_{DD_PSTOP2}	Partial Stop 2, core and system clock disabled, flash doze enabled, 12 MHz bus, V_{DD} = 3.0 V • at 25 °C	—	1.1	1.32	mA	
I_{DD_STOP}	Stop mode current at 3.0 V • at 25 °C and below • at 50 °C • at 85 °C • at 105 °C	— — — —	161 171.9 206.8 255.9	178.2 181.17 229.72 302.01	µA	
I_{DD_VLPS}	Very-low-power stop mode current at 3.0 V • at 25 °C and below • at 50 °C • at 85 °C • at 105 °C	— — — —	2.20 4.57 18.02 39.60	3.80 8.03 31.98 65.80	µA	
I_{DD_VLPS}	Very-low-power stop mode current at 1.8 V • at 25 °C and below • at 50 °C • at 85 °C • at 105 °C	— — — —	2.13 4.42 17.53 38.55	3.80 7.94 31.58 65.18	µA	
I_{DD_LLS}	Low-leakage stop mode current, all peripheral disable, at 3.0 V • at 25 °C and below • at 50 °C • at 70 °C • at 85 °C • at 105 °C	— — — — —	1.63 2.42 4.22 7.16 15.34	2.25 3.55 7.08 10.22 22.69	µA	
I_{DD_LLS}	Low-leakage stop mode current with RTC current, at 3.0 V • at 25 °C and below	—	2.3	2.99	µA	

Table continues on the next page...

Table 9. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• at 50 °C	—	3.12	4.50		
	• at 70 °C	—	4.96	7.71		
	• at 85 °C	—	7.93	10.75		
	• at 105 °C	—	16.02	22.99		
I_{DD_LLS}	Low-leakage stop mode current with RTC current, at 1.8 V				μA	3
	• at 25 °C and below	—	2.03	2.55		
	• at 50 °C	—	2.81	3.95		
	• at 70 °C	—	4.53	7.30		
	• at 85 °C	—	7.31	10.25		
	• at 105 °C	—	14.93	22.72		
I_{DD_VLLS3}	Very-low-leakage stop mode 3 current, all peripheral disable, at 3.0 V				μA	
	• at 25 °C and below	—	1.16	1.65		
	• at 50 °C	—	1.72	2.65		
	• at 70 °C	—	3.04	5.70		
	• at 85 °C	—	5.21	7.79		
	• at 105 °C	—	11.33	17.63		
I_{DD_VLLS3}	Very-low-leakage stop mode 3 current with RTC current, at 3.0 V				μA	3
	• at 25 °C and below	—	1.83	2.35		
	• at 50 °C	—	2.43	3.39		
	• at 70 °C	—	3.78	5.95		
	• at 85 °C	—	5.98	8.14		
	• at 105 °C	—	12.02	17.89		
I_{DD_VLLS3}	Very-low-leakage stop mode 3 current with RTC current, at 1.8 V				μA	3
	• at 25 °C and below	—	1.58	1.98		
	• at 50 °C	—	2.13	3.17		
	• at 70 °C	—	3.37	5.80		
	• at 85 °C	—	5.4	7.83		
	• at 105 °C	—	10.99	16.86		
I_{DD_VLLS1}	Very-low-leakage stop mode 1 current all peripheral disabled at 3.0 V				μA	
	• at 25 °C and below	—	0.62	1.06		
	• at 50°C	—	0.99	1.43		
	• at 70°C	—	1.88	2.65		
		—	3.41	4.53		

Table continues on the next page...

Table 9. Power consumption operating behaviors (continued)

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
	• at 85°C • at 105 °C	—	7.89	9.99		
I_{DD_VLLS1}	Very-low-leakage stop mode 1 current RTC enabled at 3.0 V • at 25 °C and below • at 50°C • at 70°C • at 85°C • at 105 °C	 — — — — —	 1.31 1.7 2.6 4.14 8.51	 1.52 2.04 3.20 4.69 10.46	 µA	3
I_{DD_VLLS1}	Very-low-leakage stop mode 1 current RTC enabled at 1.8 V • at 25 °C and below • at 50°C • at 70°C • at 85°C • at 105 °C	 — — — — —	 1.06 1.39 2.18 3.54 7.43	 1.35 1.73 2.83 4.60 9.97	 µA	3
I_{DD_VLLS0}	Very-low-leakage stop mode 0 current all peripheral disabled (SMC_STOPCTRL[PORPO] = 0) at 3.0 V • at 25 °C and below • at 50 °C • at 70 °C • at 85 °C • at 105 °C	 — — — — —	 278 578 1530 3070 7550	 385 1013 2015 3617 9900	 nA	
I_{DD_VLLS0}	Very-low-leakage stop mode 0 current all peripheral disabled (SMC_STOPCTRL[PORPO] = 1) at 3 V • at 25 °C and below • at 50 °C • at 70 °C • at 85 °C • at 105 °C	 — — — — —	 95 412 1350 2900 7380	 218 653 1683 3428 9785	 nA	

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. MCG_Lite configured for HIRC mode. CoreMark benchmark compiled using IAR 7.20 with optimization level high, optimized for balanced.
3. RTC uses external 32 kHz crystal as clock source, and the current includes ERCLK32K power consumption.

Table 10. Low power mode peripheral adders — typical value

Symbol	Description	Temperature (°C)						Unit
		-40	25	50	70	85	105	
$I_{IRC8MHz}$	8 MHz internal reference clock (IRC) adder. Measured by entering STOP or VLPS mode with 8 MHz IRC enabled, MCG_SC[FCRDIV]=000b, MCG_MC[LIRC_DIV2]=000b.	85	87	88	88	89	90	µA
$I_{IRC2MHz}$	2 MHz internal reference clock (IRC) adder. Measured by entering STOP mode with the 2 MHz IRC enabled, MCG_SC[FCRDIV]=000b, MCG_MC[LIRC_DIV2]=000b.	28	28	28	28	28	28	µA
$I_{EREFSTEN4MHz}$	External 4 MHz crystal clock adder. Measured by entering STOP or VLPS mode with the crystal enabled.	206	224	230	238	245	253	µA
$I_{EREFSTEN32KHz}$	External 32 kHz crystal clock adder by means of setting the OSC0_CR[EREFSTEN and EREFSTEN] bits to 1 and SIM_SOPT1[OSC32KSEL] to 01. Measured by entering all modes with the crystal enabled. • VLLS1 • VLLS3 • LLS • VLPS • STOP	440 440 490 510 510	490 490 490 560 560	540 540 540 560 560	560 560 560 560 560	570 570 570 610 610	580 580 680 680 680	nA
I_{LPTMR}	LPTMR peripheral adder measured by placing the device in VLLS1 mode with LPTMR enabled using LPO.	30	30	30	85	100	200	nA
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.	16	16	16	16	16	16	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.	582	627	638	662	682	760	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.							

Table continues on the next page...

Table 10. Low power mode peripheral adders — typical value (continued)

Symbol	Description	Temperature (°C)						Unit
		-40	25	50	70	85	105	
	Includes selected clock source power consumption. • IRC8M (8 MHz internal reference clock) • IRC2M (2 MHz internal reference clock)	105 34	110 34	110 34	111 34	112 34	114 34	µA
I_{TPM}	TPM peripheral adder measured by placing the device in STOP or VLPS mode with selected clock source configured for output compare generating 100 Hz clock signal. No load is placed on the I/O generating the clock signal. Includes selected clock source and I/O switching currents. • IRC8M (8 MHz internal reference clock) • IRC2M (2 MHz internal reference clock)	130 40	130 40	130 40	130 40	130 40	130 40	µA
I_{BG}	Bandgap adder when BGEN bit is set and device is placed in VLPx 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.	320	320	320	320	320	320	µA

2.2.5.1 Diagram: Typical IDD_RUN operating behavior

The following data was measured under these conditions:

- MCG-Lite in HIRC for run mode, and LIRC for VLPR mode
- No GPIOs toggled
- Code execution from flash
- For the ALLOFF curve, all peripheral clocks are disabled except FTFA

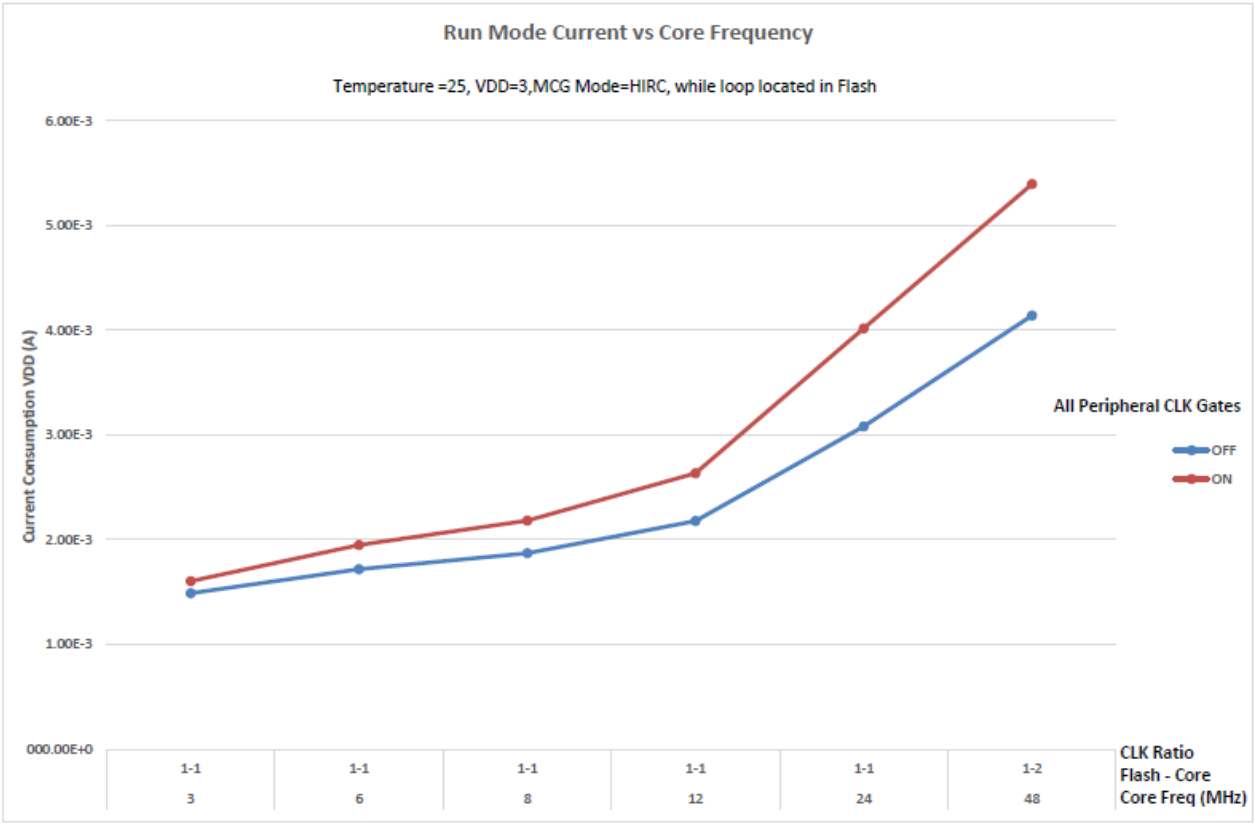
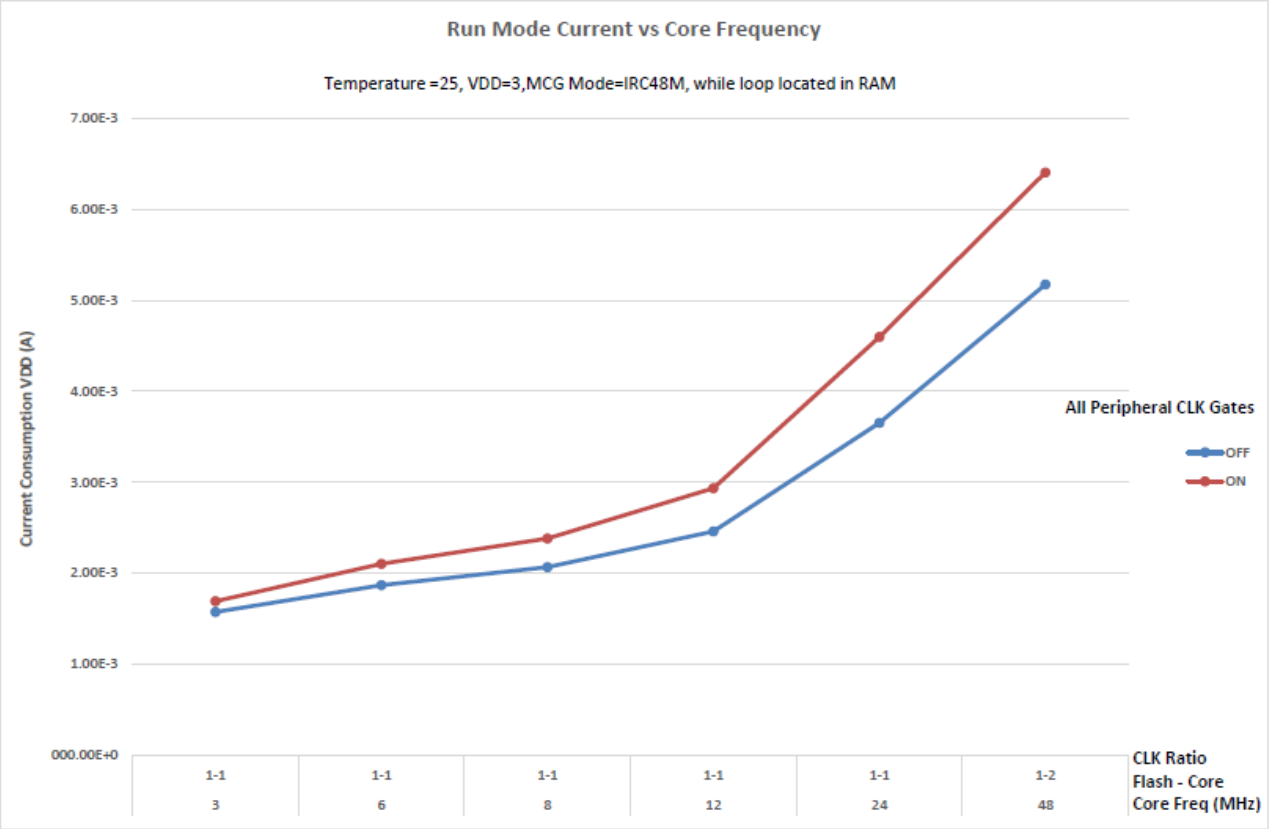


Figure 2. Run mode supply current vs. core frequency


Run Mode Current vs Core Frequency
Temperature =25, VDD=3,MCG Mode=IRC48M, while loop located in RAM
Current Consumption VDD (A)
7.00E-3
6.00E-3
5.00E-3
4.00E-3
3.00E-3
2.00E-3
1.00E-3
000.00E+0
All Peripheral CLK Gates
OFF
ON
1-1 3
1-1 6
1-1 8
1-1 12
1-1 24
1-2 48
CLK Ratio
Flash - Core
Core Freq (MHz)

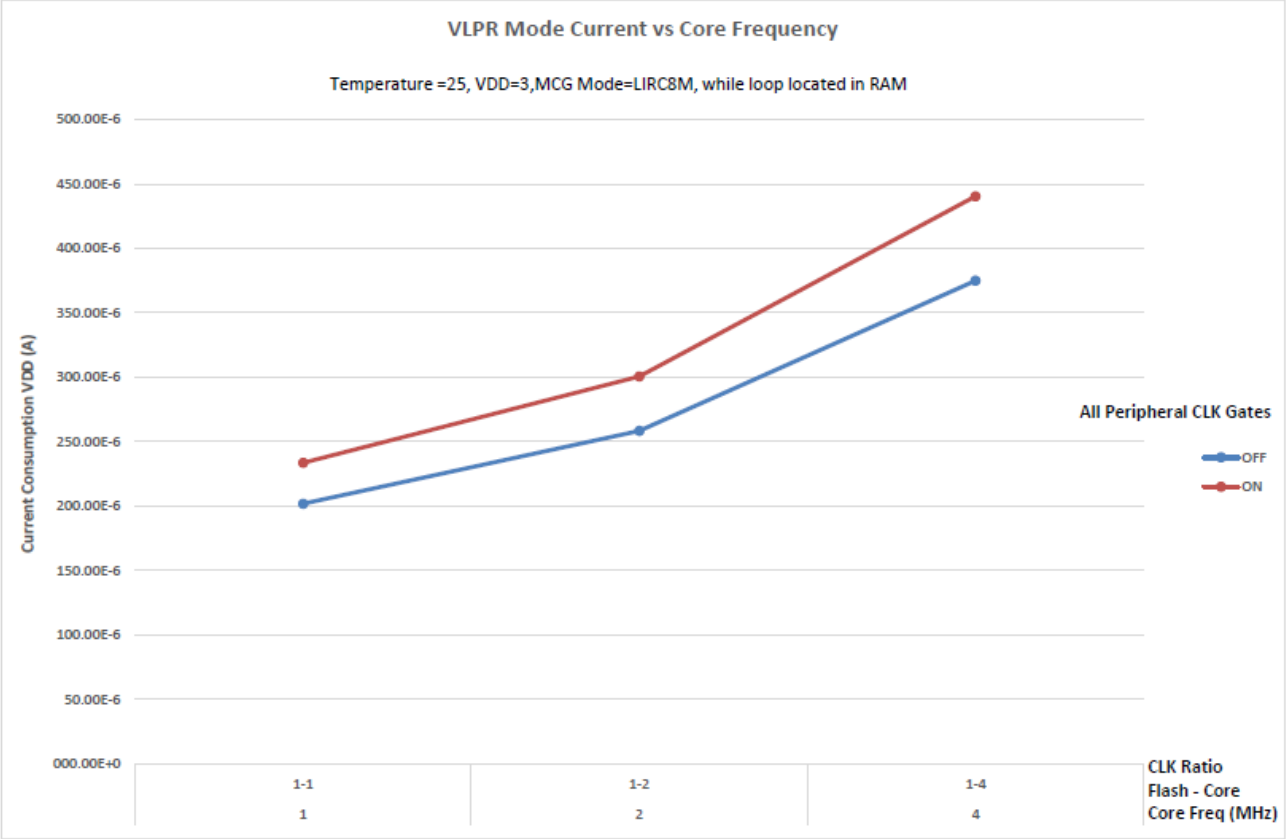


Figure 3. VLPR mode current vs. core frequency

2.2.6 EMC performance

Electromagnetic compatibility (EMC) performance is highly dependent on the environment in which the MCU resides. Board design and layout, circuit topology choices, location and characteristics of external components, and MCU software operation play a significant role in the EMC performance. The system designer can consult the following Freescale applications notes, available on freescale.com for advice and guidance specifically targeted at optimizing EMC performance.

- AN2321: Designing for Board Level Electromagnetic Compatibility
- AN1050: Designing for Electromagnetic Compatibility (EMC) with HCMOS Microcontrollers
- AN1263: Designing for Electromagnetic Compatibility with Single-Chip Microcontrollers
- AN2764: Improving the Transient Immunity Performance of Microcontroller-Based Applications

- AN1259: System Design and Layout Techniques for Noise Reduction in MCU-Based Systems
- KL-QRUG (Kinetis L-series Quick Reference).

2.2.7 Capacitance attributes

Table 11. Capacitance attributes

Symbol	Description	Min.	Max.	Unit
C_{IN}	Input capacitance	—	7	pF

2.3 Switching specifications

2.3.1 Device clock specifications

Table 12. Device clock specifications

Symbol	Description	Min.	Max.	Unit
Normal run mode				
f_{SYS}	System and core clock	—	48	MHz
f_{BUS}	Bus clock	—	24	MHz
f_{FLASH}	Flash clock	—	24	MHz
f_{LPTMR}	LPTMR clock	—	24	MHz
VLPR and VLPS modes[1]				
f_{SYS}	System and core clock	—	4	MHz
f_{BUS}	Bus clock	—	1	MHz
f_{FLASH}	Flash clock	—	1	MHz
f_{LPTMR}	LPTMR clock[2]	—	24	MHz
f_{LPTMR_ERCLK}	LPTMR external reference clock	—	16	MHz
$f_{osc\_hi\_2}$	Oscillator crystal or resonator frequency — high frequency mode (high range) (MCG_C2[RANGE]=1x)	—	16	MHz
f_{TPM}	TPM asynchronous clock	—	8	MHz
$f_{LPUART0/1}$	LPUART0/1 asynchronous clock	—	8	MHz

1. The frequency limitations in VLPR and VLPS modes here override any frequency specification listed in the timing specification for any other module. These same frequency limits apply to VLPS, whether VLPS was entered from RUN or from VLPR.
2. The LPTMR can be clocked at this speed in VLPR or VLPS only when the source is an external pin.

2.3.2 General switching specifications

These general-purpose specifications apply to all signals configured for GPIO and UART signals.

Table 13. General switching specifications

Description	Min.	Max.	Unit	Notes
GPIO pin interrupt pulse width (digital glitch filter disabled) — Synchronous path	1.5	—	Bus clock cycles	1
External RESET and NMI pin interrupt pulse width — Asynchronous path	100	—	ns	2
GPIO pin interrupt pulse width — Asynchronous path	16	—	ns	2
Port rise and fall time	—	36	ns	3

1. The synchronous and asynchronous timing must be met.
2. This is the shortest pulse that is guaranteed to be recognized.
3. 75 pF load

2.4 Thermal specifications

2.4.1 Thermal operating requirements

Table 14. Thermal operating requirements

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

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

2.4.2 Thermal attributes

NOTE

The 48 QFN, 32 QFN, and 64 MAPBGA packages for this product are not yet available. However, these packages are included in Package Your Way program for Kinetis MCUs. Visit freescale.com/KPYW for more details.

Table 15. Thermal attributes

Board type	Symbol	Description	64 LQFP	80 LQFP	Unit	Notes
Single-layer (1S)	$R_{\theta JA}$	Thermal resistance, junction to ambient (natural convection)	71	58	°C/W	1, 2
Four-layer (2s2p)	$R_{\theta JA}$	Thermal resistance, junction to ambient (natural convection)	53	43	°C/W	1, 2
Single-layer (1S)	$R_{\theta JMA}$	Thermal resistance, junction to ambient (200 ft./min. air speed)	60	47	°C/W	1, 3
Four-layer (2s2p)	$R_{\theta JMA}$	Thermal resistance, junction to ambient (200 ft./min. air speed)	46	37	°C/W	1, 3,
—	$R_{\theta JB}$	Thermal resistance, junction to board	35	26	°C/W	4
—	$R_{\theta JC}$	Thermal resistance, junction to case	21	15	°C/W	5
—	Ψ_{JT}	Thermal characterization parameter, junction to package top outside center (natural convection)	5	3	°C/W	6

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.
2. Per JEDEC JESD51-2 with natural convection for horizontally oriented board. Board meets JESD51-9 specification for 1s or 2s2p board, respectively.
3. Per JEDEC JESD51-6 with forced convection for horizontally oriented board. Board meets JESD51-9 specification for 1s or 2s2p board, respectively.
4. Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
5. Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).
6. Thermal characterization parameter indicating the temperature difference between package top and the junction temperature per JEDEC JESD51-2. When Greek letters are not available, the thermal characterization parameter is written as Psi-JT.

3 Peripheral operating requirements and behaviors

3.1 Core modules

3.1.1 SWD electricals

Table 16. SWD full voltage range electricals

Symbol	Description	Min.	Max.	Unit
	Operating voltage	1.71	3.6	V
J1	SWD_CLK frequency of operation			

Table continues on the next page...

Table 16. SWD full voltage range electricals (continued)

Symbol	Description	Min.	Max.	Unit
	• Serial wire debug	0	25	MHz
J2	SWD_CLK cycle period	1/J1	—	ns
J3	SWD_CLK clock pulse width • Serial wire debug	20	—	ns
J4	SWD_CLK rise and fall times	—	3	ns
J9	SWD_DIO input data setup time to SWD_CLK rise	10	—	ns
J10	SWD_DIO input data hold time after SWD_CLK rise	0	—	ns
J11	SWD_CLK high to SWD_DIO data valid	—	32	ns
J12	SWD_CLK high to SWD_DIO high-Z	5	—	ns

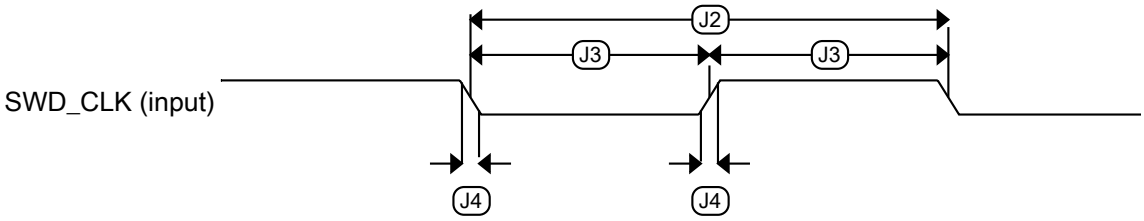


Figure 4. Serial wire clock input timing

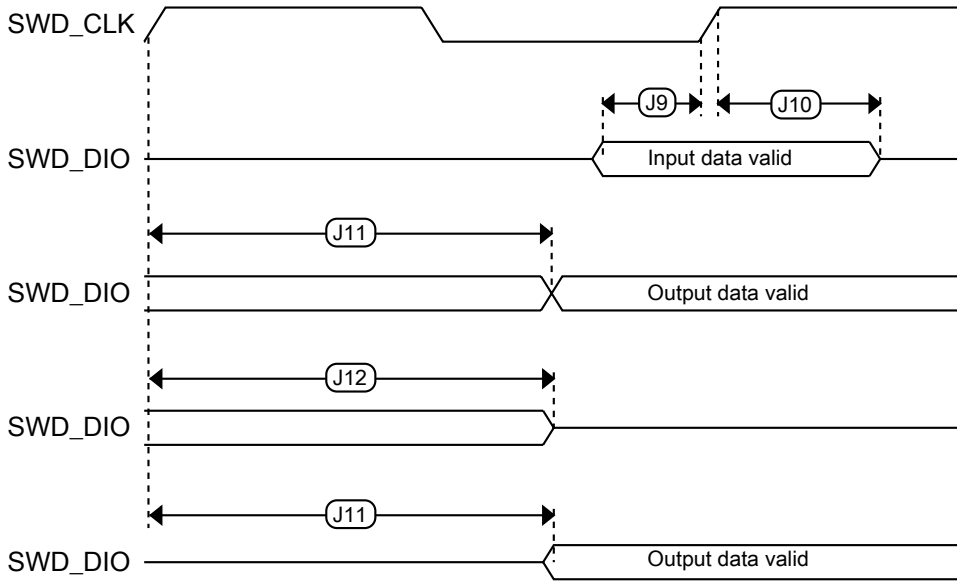


Figure 5. Serial wire data timing

3.2 System modules

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

3.3 Clock modules

3.3.1 MCG-Lite specifications

Table 17. IRC48M specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
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 temperature	—	± 0.5	± 1.5	$\%f_{irc48m}$	
$\Delta f_{irc48m\_ol\_hv}$	Open loop total deviation of IRC48M frequency at high voltage (VDD=1.89V-3.6V) over temperature	—	± 0.5	± 1.0	$\%f_{irc48m}$	
J_{cyc_irc48m}	Period Jitter (RMS)	—	35	150	ps	
$t_{irc48mst}$	Startup time	—	2	3	µs	

Table 18. IRC8M/2M specification

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
I_{DD_2M}	Supply current in 2 MHz mode	—	14	17	µA	—
I_{DD_8M}	Supply current in 8 MHz mode	—	30	35	µA	—
f_{IRC_2M}	Output frequency	—	2	—	MHz	—
f_{IRC_8M}	Output frequency	—	8	—	MHz	—
$f_{IRC\_T\_2M}$	Output frequency range (trimmed)	—	—	±3	$\%f_{IRC}$	—
$f_{IRC\_T\_8M}$	Output frequency range (trimmed)	—	—	±3	$\%f_{IRC}$	—
T_{su_2M}	Startup time	—	—	12.5	µs	—
T_{su_8M}	Startup time	—	—	12.5	µs	—

3.3.2 Oscillator electrical specifications

3.3.2.1 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	
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	

Table continues on the next page...

Table 19. Oscillator DC electrical specifications (continued)

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

1. V_{DD}=3.3 V, Temperature =25 °C
2. See crystal or resonator manufacturer's recommendation
3. C_x,C_y can be provided by using the integrated capacitors when the low frequency oscillator (RANGE = 00) is used. For all other cases external capacitors must be used.
4. When low power mode is selected, R_F is integrated and must not be attached externally.
5. The EXTAL and XTAL pins should only be connected to required oscillator components and must not be connected to any other devices.

3.3.2.2 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)	—	—	48	MHz	
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	1, 2
	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. Proper PC board layout procedures must be followed to achieve specifications.
2. Crystal startup time is defined as the time between the oscillator being enabled and the OSCINIT bit in the MCG_S register being set.

3.4 Memories and memory interfaces

3.4.1 Flash electrical specifications

This section describes the electrical characteristics of the flash memory 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 21. NVM program/erase timing specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
t_{hvpgm4}	Longword Program high-voltage time	—	7.5	18	µs	—
$t_{hversscr}$	Sector Erase high-voltage time	—	13	113	ms	1
$t_{hversall}$	Erase All high-voltage time	—	52	452	ms	1

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

3.4.1.2 Flash timing specifications — commands

Table 22. Flash command timing specifications

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
$t_{rd1sec1k}$	Read 1s Section execution time (flash sector)	—	—	60	µs	1
t_{pgmchk}	Program Check execution time	—	—	45	µs	1
t_{rdrsrc}	Read Resource execution time	—	—	30	µs	1
t_{pgm4}	Program Longword execution time	—	65	145	µs	—
t_{ersscr}	Erase Flash Sector execution time	—	14	114	ms	2
t_{rd1all}	Read 1s All Blocks execution time	—	—	0.9	ms	1
t_{rdonce}	Read Once execution time	—	—	25	µs	1
$t_{pgmonce}$	Program Once execution time	—	65	—	µs	—
t_{ersall}	Erase All Blocks execution time	—	70	575	ms	2
t_{vfykey}	Verify Backdoor Access Key execution time	—	—	30	µs	1
$t_{ersallu}$	Erase All Blocks Unsecure execution time	—	70	575	ms	2

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

3.4.1.3 Flash high voltage current behaviors

Table 23. Flash high voltage current behaviors

Symbol	Description	Min.	Typ.	Max.	Unit
I_{DD_PGM}	Average current adder during high voltage flash programming operation	—	2.5	6.0	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 24. NVM reliability specifications

Symbol	Description	Min.	Typ.[1]	Max.	Unit	Notes
Program Flash						
$t_{nvmretp10k}$	Data retention after up to 10 K cycles	5	50	—	years	—
$t_{nvmretp1k}$	Data retention after up to 1 K cycles	20	100	—	years	—
$n_{nvmcycp}$	Cycling endurance	10 K	50 K	—	cycles	2

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.

3.5 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

Using differential inputs can achieve better system accuracy than using single-end inputs.

3.6.1.1 16-bit ADC operating conditions

Table 25. 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_{ADIN}	Input voltage	• 16-bit differential mode • All other modes	VREFL VREFL	— —	31/32 * VREFH VREFH	V	—
C_{ADIN}	Input capacitance	• 16-bit mode • 8-bit / 10-bit / 12-bit modes	— —	8 4	10 5	pF	—
R_{ADIN}	Input series resistance		—	2	5	kΩ	—
R_{AS}	Analog source resistance (external)	13-bit / 12-bit modes f_{ADCK} < 4 MHz	—	—	5	kΩ	3
f_{ADCK}	ADC conversion clock frequency	≤ 13-bit mode	1.0	—	18.0	MHz	4
f_{ADCK}	ADC conversion clock frequency	16-bit mode	2.0	—	12.0	MHz	4
C_{rate}	ADC conversion rate	≤ 13-bit modes No ADC hardware averaging Continuous conversions enabled, subsequent conversion time	20.000	—	818.330	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.

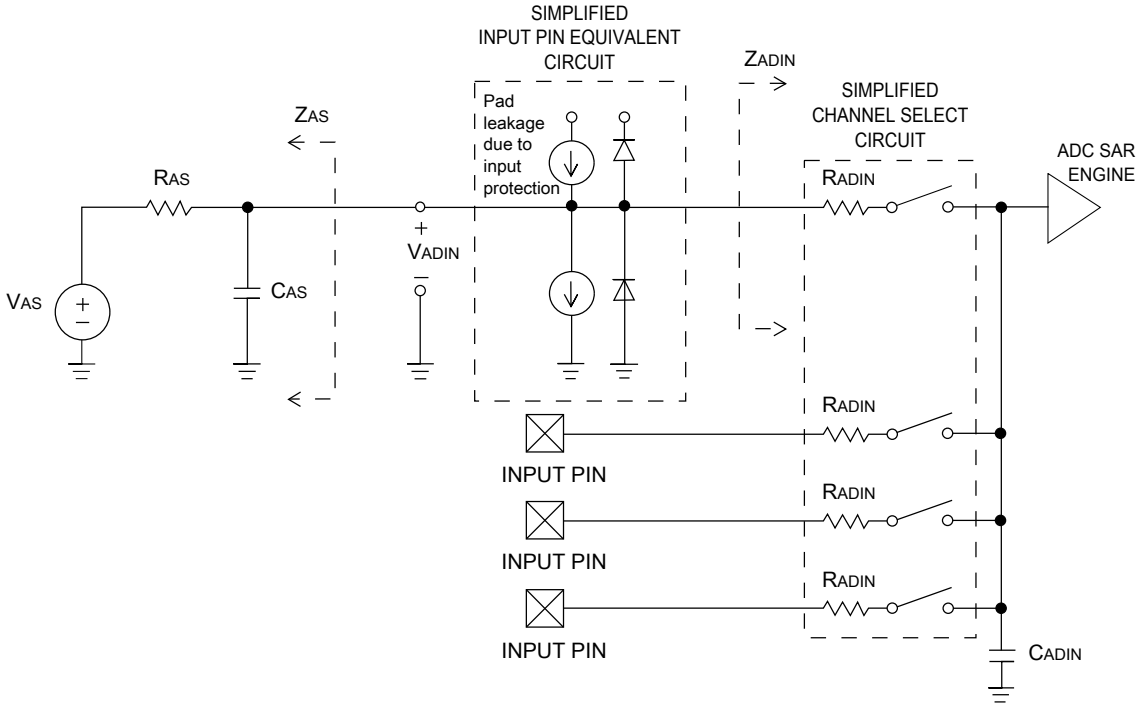


Figure 6. ADC input impedance equivalency diagram

3.6.1.2 16-bit ADC electrical characteristics

Table 26. 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 • ADLPC = 1, ADHSC = 1 • ADLPC = 0, ADHSC = 0 • ADLPC = 0, ADHSC = 1	1.2 2.4 3.0 4.4	2.4 4.0 5.2 6.2	3.9 6.1 7.3 9.5	MHz MHz MHz MHz	t_{ADACK} = $1/f_{ADACK}$
	Sample Time	See Reference Manual chapter for sample times					
TUE	Total unadjusted error	• 12-bit modes • <12-bit modes	— —	±2.5 ±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	—	±0.9	–2.7 to +1.9	LSB[4]	5

Table continues on the next page...

Table 26. 16-bit ADC characteristics (V_{REFH} = V_{DDA}, V_{REFL} = V_{SSA}) (continued)

Symbol	Description	Conditions[1]	Min.	Typ.[2]	Max.	Unit	Notes
		• <12-bit modes	—	±0.4	–0.7 to +0.5		
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 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

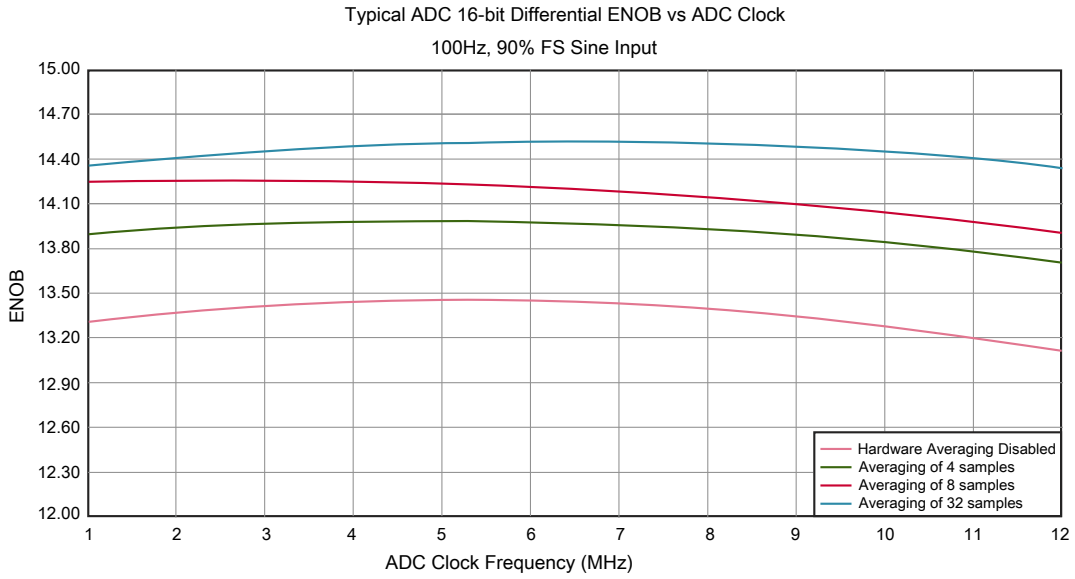


Figure 7. Typical ENOB vs. ADC_CLK for 16-bit differential mode

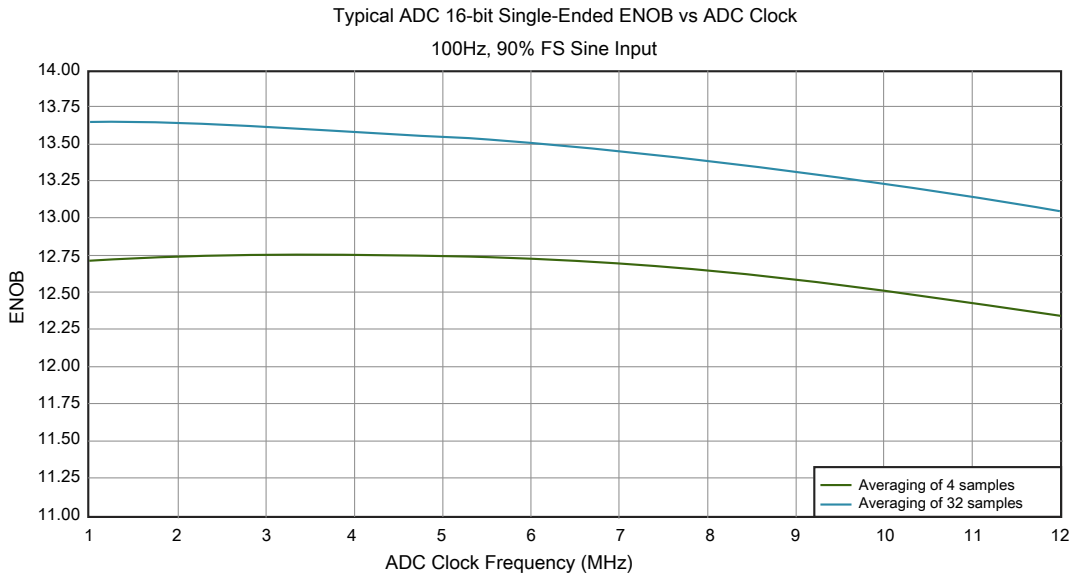


Figure 8. Typical ENOB vs. ADC_CLK for 16-bit single-ended mode

3.6.2 Voltage reference electrical specifications

Table 27. VREF full-range operating requirements

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

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

Table 28 is tested under the condition of setting VREF_TRM[CHOPEN], VREF_SC[REGEN] and VREF_SC[ICOMPEN] bits to 1.

Table 28. VREF full-range operating behaviors

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
V_{out}	Voltage reference output with factory trim at nominal V_{DDA} and temperature=25C	1.1915	1.195	1.1977	V	1
V_{out}	Voltage reference output — factory trim	1.1584	—	1.2376	V	1
V_{out}	Voltage reference output — user trim	1.193	—	1.197	V	1
V_{step}	Voltage reference trim step	—	0.5	—	mV	1
V_{tdrift}	Temperature drift (Vmax -Vmin across the full temperature range: 0 to 70°C)	—	2	15	mV	1
I_{bg}	Bandgap only current	—	—	80	µA	1
I_{lp}	Low-power buffer current	—	—	360	uA	1
I_{hp}	High-power buffer current	—	—	1	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)	—	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 29. VREF limited-range operating requirements

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

Table 30. VREF limited-range operating behaviors

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

3.6.3 CMP and 6-bit DAC electrical specifications

Table 31. 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

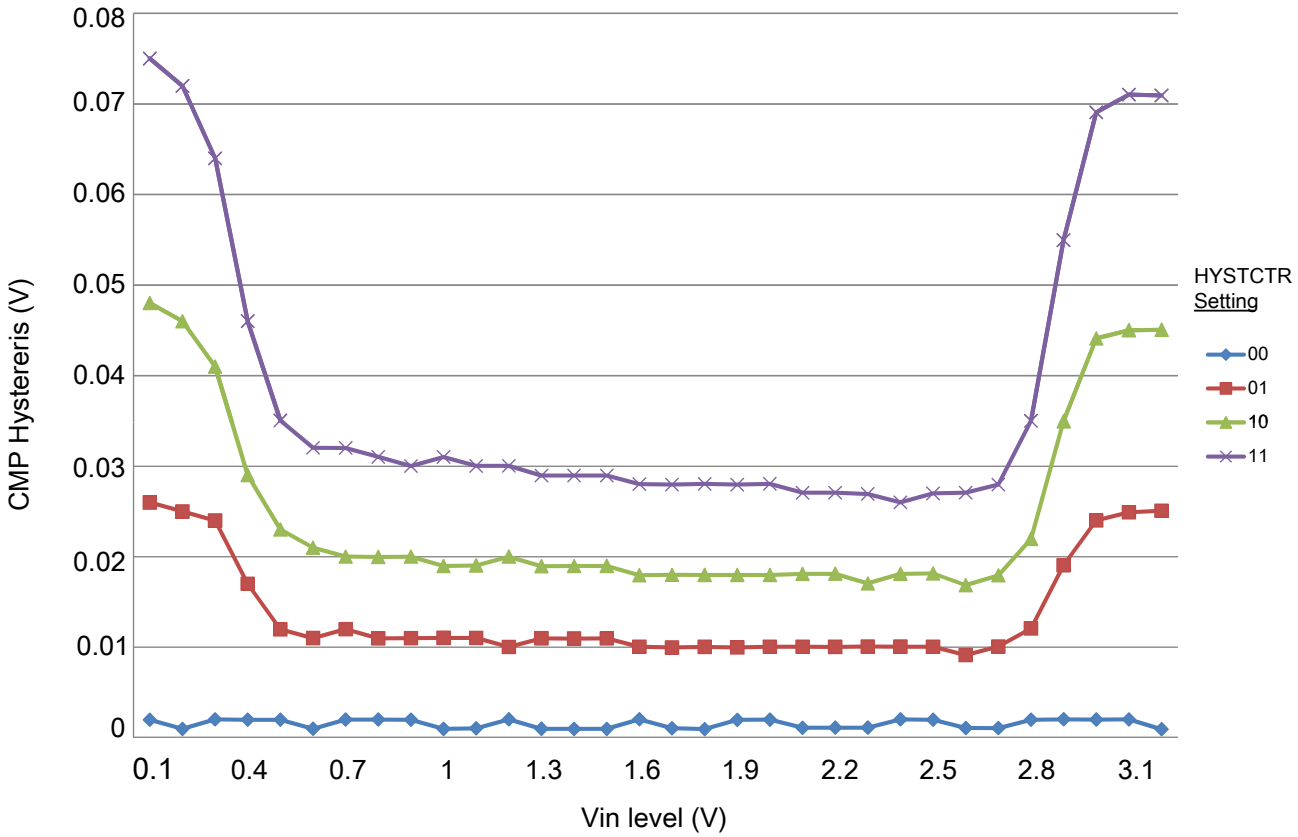


Figure 9. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 0)

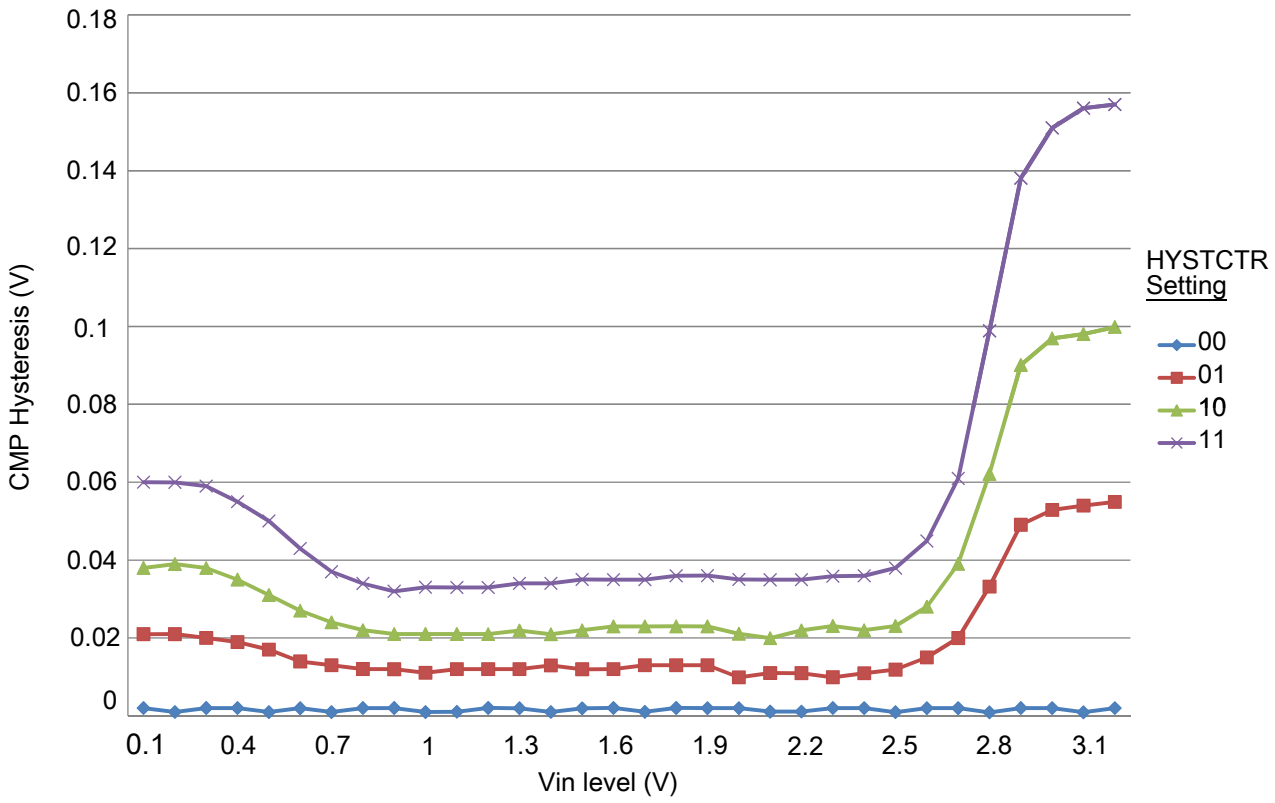


Figure 10. Typical hysteresis vs. Vin level (VDD = 3.3 V, PMODE = 1)

3.6.4 12-bit DAC electrical characteristics

3.6.4.1 12-bit DAC operating requirements

Table 32. 12-bit DAC operating requirements

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

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

3.6.4.2 12-bit DAC operating behaviors

Table 33. 12-bit DAC operating behaviors

Symbol	Description	Min.	Typ.	Max.	Unit	Notes
I_{DDA_DACLP}	Supply current — low-power mode	—	—	250	μA	
I_{DDA_DACHP}	Supply current — high-speed mode	—	—	900	μA	
t_{DACLP}	Full-scale settling time (0x080 to 0xF7F) — low-power mode	—	100	200	μs	1
t_{DACHP}	Full-scale settling time (0x080 to 0xF7F) — high-power mode	—	15	30	μs	1
$t_{CCDACLP}$	Code-to-code settling time (0xBF8 to 0xC08) — low-power mode and high-speed mode	—	0.7	1	μs	1
$V_{dacoutl}$	DAC output voltage range low — high-speed mode, no load, DAC set to 0x000	—	—	100	mV	
$V_{dacouth}$	DAC output voltage range high — high-speed mode, no load, DAC set to 0xFFF	V_{DACR} −100	—	V_{DACR}	mV	
INL	Integral non-linearity error — high speed mode	—	—	±8	LSB	2
DNL	Differential non-linearity error — V_{DACR} > 2 V	—	—	±1	LSB	3
DNL	Differential non-linearity error — V_{DACR} = VREF_OUT	—	—	±1	LSB	4
V_{OFFSET}	Offset error	—	±0.4	±0.8	%FSR	5
E_G	Gain error	—	±0.1	±0.6	%FSR	5
PSRR	Power supply rejection ratio, V_{DDA} ≥ 2.4 V	60	—	90	dB	
T_{CO}	Temperature coefficient offset voltage	—	3.7	—	μV/C	6
T_{GE}	Temperature coefficient gain error	—	0.000421	—	%FSR/C	
Rop	Output resistance (load = 3 kΩ)	—	—	250	Ω	
SR	Slew rate -80h→ F7Fh→ 80h • High power (SP_{HP}) • Low power (SP_{LP})	 1.2 0.05	 1.7 0.12	 — —	V/μs	
BW	3dB bandwidth • High power (SP_{HP}) • Low power (SP_{LP})	 550 40	 — —	 — —	kHz	

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

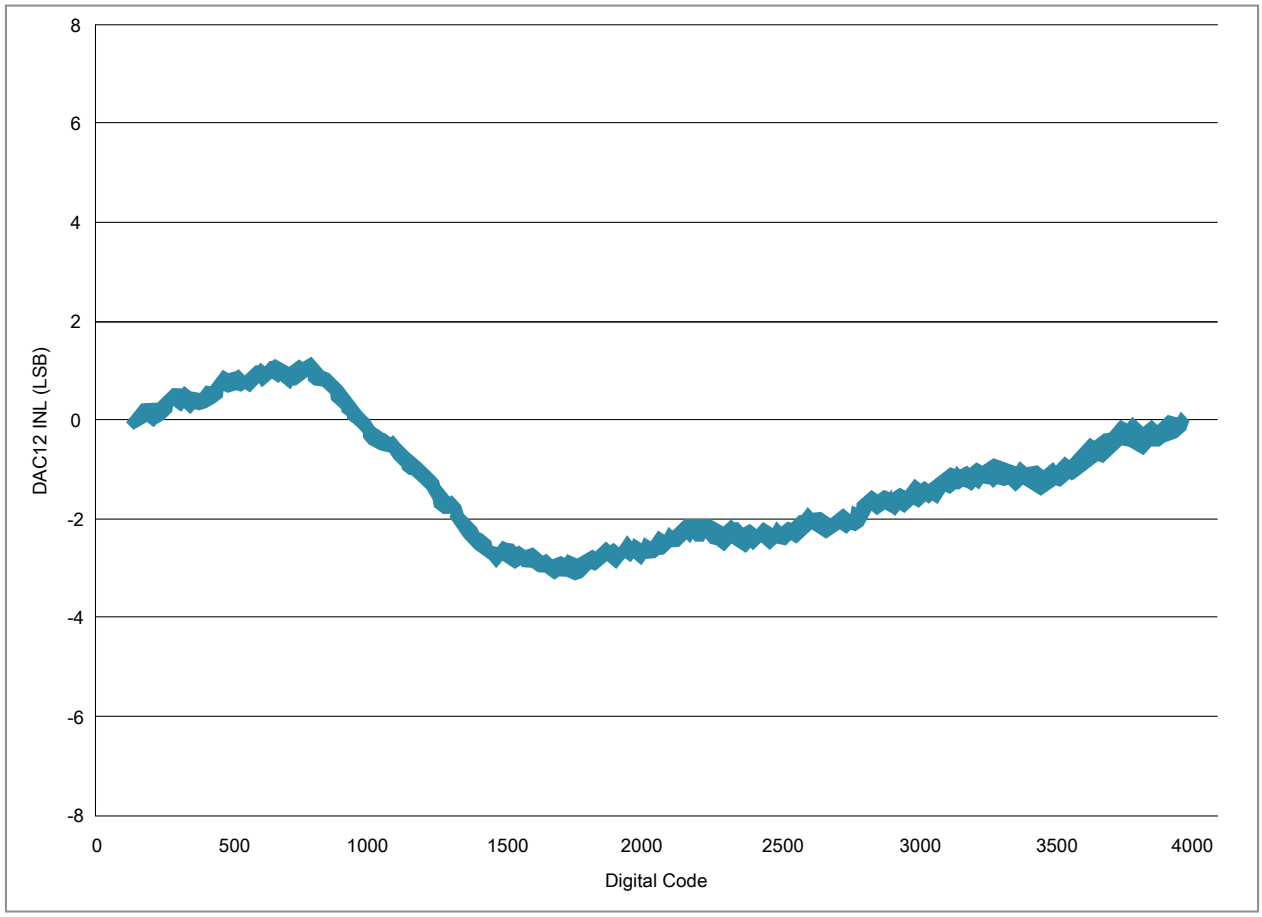


Figure 11. Typical INL error vs. digital code

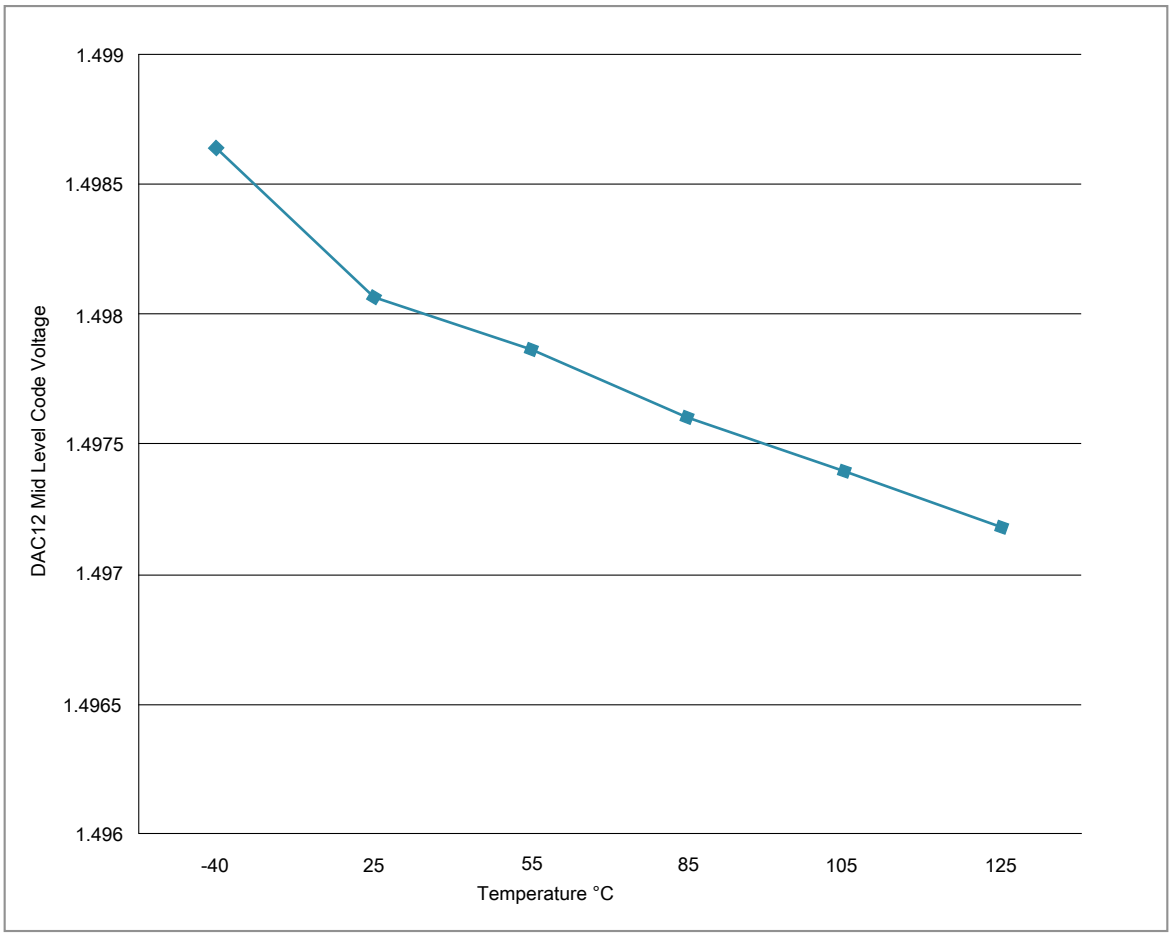


Figure 12. Offset at half scale vs. temperature

4 Timers

See General switching specifications.

5 Communication interfaces

5.1 SPI switching specifications

The Serial Peripheral Interface (SPI) provides a synchronous serial bus with master and slave operations. Many of the transfer attributes are programmable. The following tables provide timing characteristics for classic SPI timing modes. See the SPI chapter of the chip's Reference Manual for information about the modified transfer formats used for communicating with slower peripheral devices.

All timing is shown with respect to 20% V_{DD} and 80% V_{DD} thresholds, unless noted, as well as input signal transitions of 3 ns and a 30 pF maximum load on all SPI pins.

Table 34. SPI master mode timing on slew rate disabled pads

Num.	Symbol	Description	Min.	Max.	Unit	Note
1	f_{op}	Frequency of operation	$f_{periph}/2048$	$f_{periph}/2$	Hz	1
2	t_{SPSCK}	SPSCK period	2 x t_{periph}	2048 x t_{periph}	ns	2
3	t_{Lead}	Enable lead time	1/2	—	t_{SPSCK}	—
4	t_{Lag}	Enable lag time	1/2	—	t_{SPSCK}	—
5	t_{WSPSCK}	Clock (SPSCK) high or low time	t_{periph} - 30	1024 x t_{periph}	ns	—
6	t_{SU}	Data setup time (inputs)	18	—	ns	—
7	t_{HI}	Data hold time (inputs)	0	—	ns	—
8	t_{v}	Data valid (after SPSCK edge)	—	15	ns	—
9	t_{HO}	Data hold time (outputs)	0	—	ns	—
10	t_{RI}	Rise time input	—	t_{periph} - 25	ns	—
	t_{FI}	Fall time input				
11	t_{RO}	Rise time output	—	25	ns	—
	t_{FO}	Fall time output				

1. For SPI0 f_{periph} is the bus clock (f_{BUS}). For SPI1 f_{periph} is the system clock (f_{SYS}).
2. $t_{periph} = 1/f_{periph}$

Table 35. SPI master mode timing on slew rate enabled pads

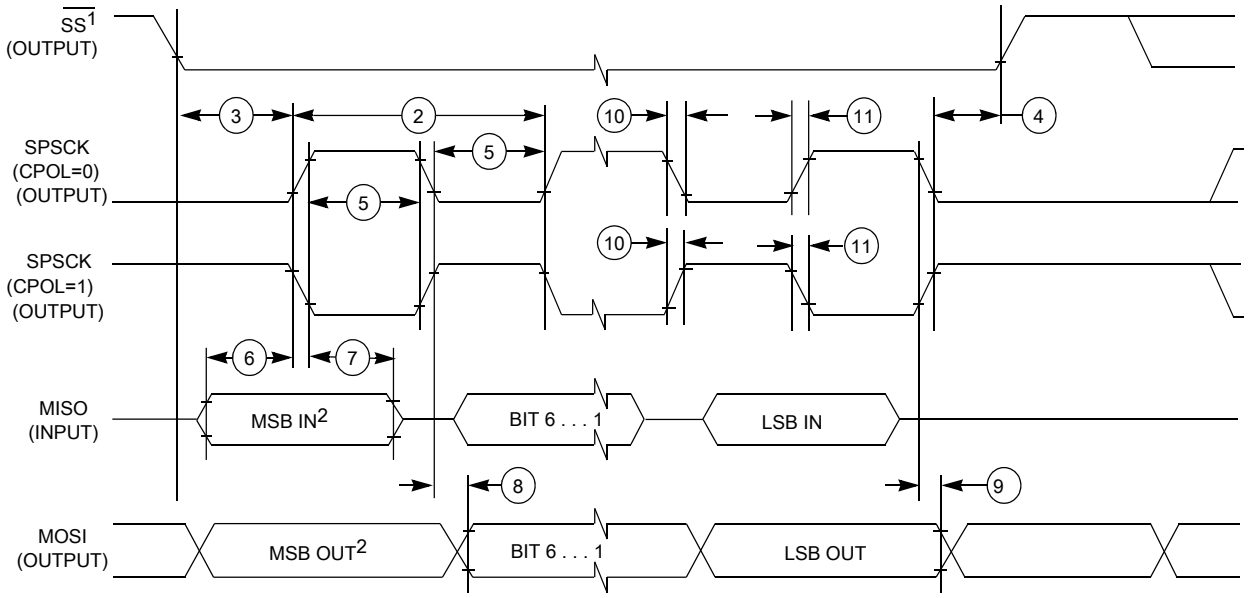
Num.	Symbol	Description	Min.	Max.	Unit	Note
1	f_{op}	Frequency of operation	$f_{periph}/2048$	$f_{periph}/2$	Hz	1
2	t_{SPSCK}	SPSCK period	2 x t_{periph}	2048 x t_{periph}	ns	2
3	t_{Lead}	Enable lead time	1/2	—	t_{SPSCK}	—
4	t_{Lag}	Enable lag time	1/2	—	t_{SPSCK}	—
5	t_{WSPSCK}	Clock (SPSCK) high or low time	t_{periph} - 30	1024 x t_{periph}	ns	—
6	t_{SU}	Data setup time (inputs)	96	—	ns	—
7	t_{HI}	Data hold time (inputs)	0	—	ns	—

Table continues on the next page...

Table 35. SPI master mode timing on slew rate enabled pads (continued)

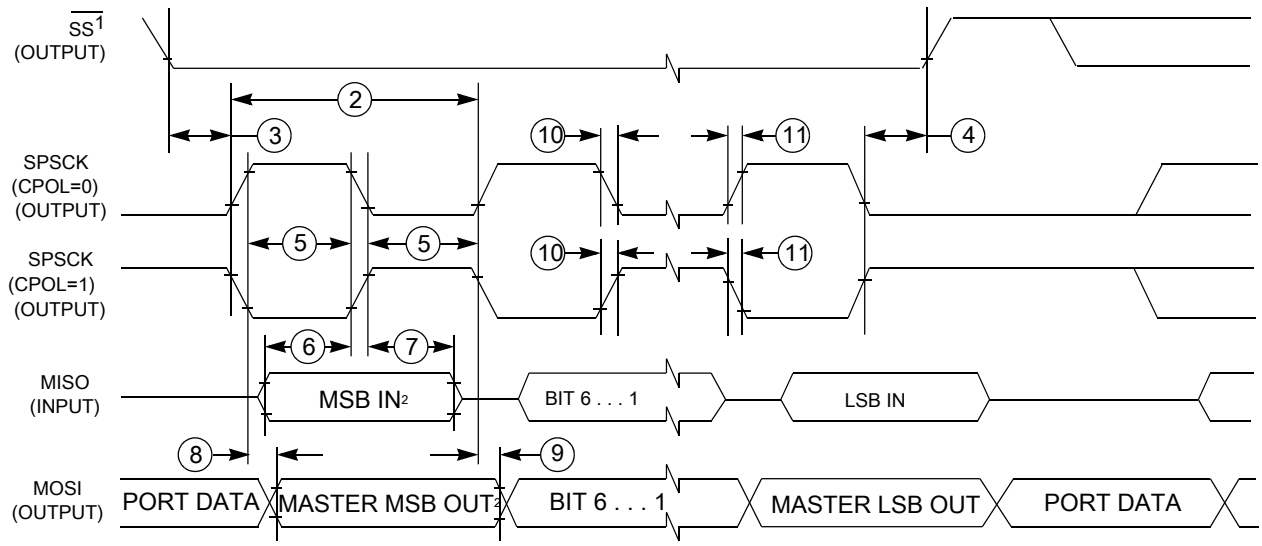
Num.	Symbol	Description	Min.	Max.	Unit	Note
8	t_v	Data valid (after SPSCK edge)	—	83	ns	—
9	t_{HO}	Data hold time (outputs)	0	—	ns	—
10	t_{RI}	Rise time input	—	t_{periph} - 25	ns	—
	t_{FI}	Fall time input				
11	t_{RO}	Rise time output	—	36	ns	—
	t_{FO}	Fall time output				

1. For SPI0 f_{periph} is the bus clock (f_{BUS}). For SPI1 f_{periph} is the system clock (f_{SYS}).
2. $t_{periph} = 1/f_{periph}$



1. If configured as an output.
2. LSBF = 0. For LSBF = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

Figure 13. SPI master mode timing (CPHA = 0)



1.If configured as output

2. LSBF = 0. For LSBF = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

Figure 14. SPI master mode timing (CPHA = 1)

Table 36. SPI slave mode timing on slew rate disabled pads

Num.	Symbol	Description	Min.	Max.	Unit	Note
1	f_{op}	Frequency of operation	0	$f_{periph}/4$	Hz	1
2	t_{SPSCK}	SPSCK period	4 x t_{periph}	—	ns	2
3	t_{Lead}	Enable lead time	1	—	t_{periph}	—
4	t_{Lag}	Enable lag time	1	—	t_{periph}	—
5	t_{WSPSCK}	Clock (SPSCK) high or low time	t_{periph} - 30	—	ns	—
6	t_{SU}	Data setup time (inputs)	2.5	—	ns	—
7	t_{HI}	Data hold time (inputs)	3.5	—	ns	—
8	t_a	Slave access time	—	t_{periph}	ns	3
9	t_{dis}	Slave MISO disable time	—	t_{periph}	ns	4
10	t_v	Data valid (after SPSCK edge)	—	31	ns	—
11	t_{HO}	Data hold time (outputs)	0	—	ns	—
12	t_{RI}	Rise time input	—	t_{periph} - 25	ns	—
	t_{FI}	Fall time input				
13	t_{RO}	Rise time output	—	25	ns	—
	t_{FO}	Fall time output				

1. For SPI0 f_{periph} is the bus clock (f_{BUS}). For SPI1 f_{periph} is the system clock (f_{SYS}).
2. $t_{periph} = 1/f_{periph}$
3. Time to data active from high-impedance state
4. Hold time to high-impedance state

Table 37. SPI slave mode timing on slew rate enabled pads

Num.	Symbol	Description	Min.	Max.	Unit	Note
1	f_{op}	Frequency of operation	0	$f_{periph}/4$	Hz	1
2	t_{SPSCK}	SPSCK period	4 x t_{periph}	—	ns	2
3	t_{Lead}	Enable lead time	1	—	t_{periph}	—
4	t_{Lag}	Enable lag time	1	—	t_{periph}	—
5	t_{WSPSCK}	Clock (SPSCK) high or low time	t_{periph} - 30	—	ns	—
6	t_{SU}	Data setup time (inputs)	2	—	ns	—
7	t_{HI}	Data hold time (inputs)	7	—	ns	—
8	t_a	Slave access time	—	t_{periph}	ns	3
9	t_{dis}	Slave MISO disable time	—	t_{periph}	ns	4
10	t_v	Data valid (after SPSCK edge)	—	130	ns	—
11	t_{HO}	Data hold time (outputs)	0	—	ns	—
12	t_{RI}	Rise time input	—	t_{periph} - 25	ns	—
	t_{FI}	Fall time input				
13	t_{RO}	Rise time output	—	36	ns	—
	t_{FO}	Fall time output				

1. For SPI0 f_{periph} is the bus clock (f_{BUS}). For SPI1 f_{periph} is the system clock (f_{SYS}).
2. $t_{periph} = 1/f_{periph}$
3. Time to data active from high-impedance state
4. Hold time to high-impedance state

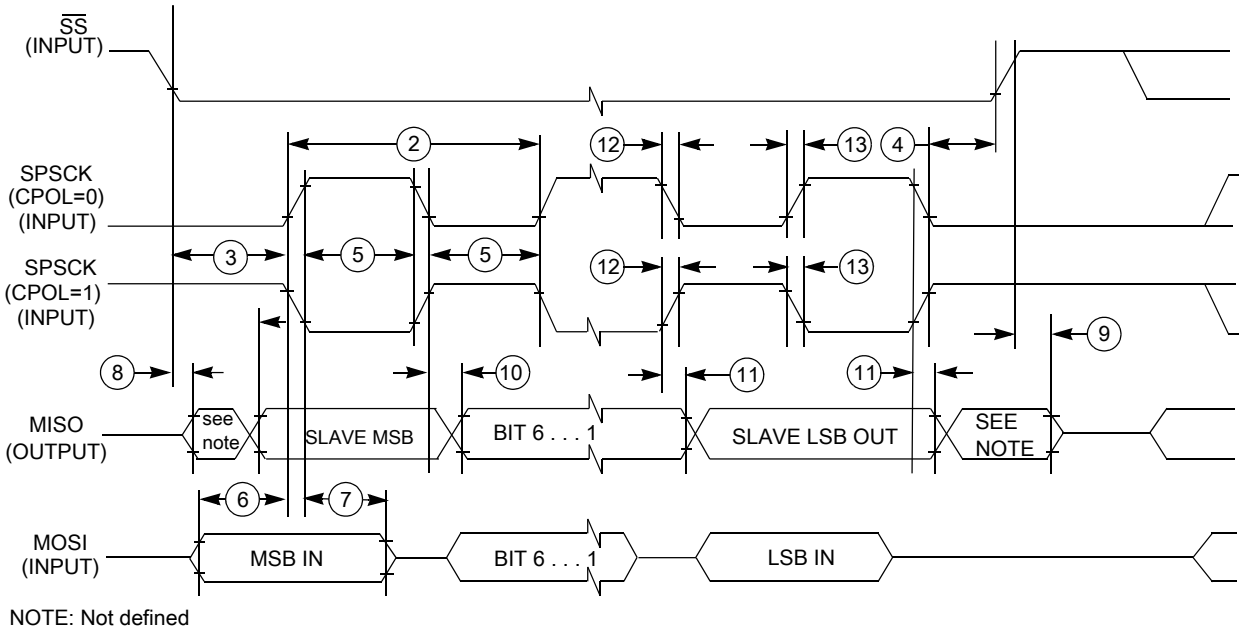
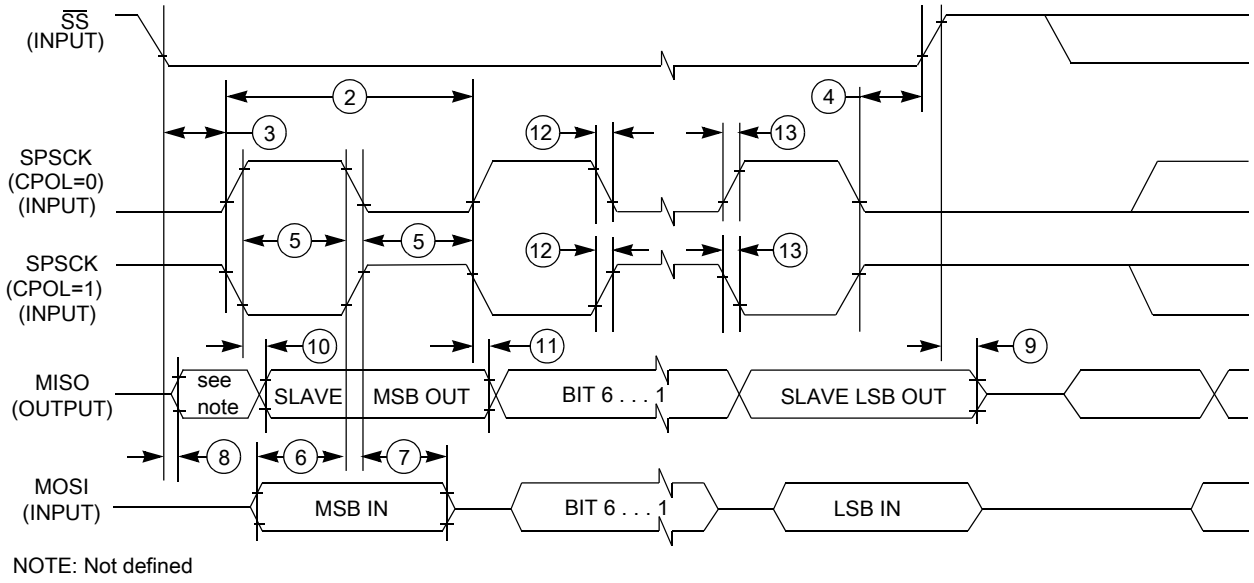


Figure 15. SPI slave mode timing (CPHA = 0)



NOTE: Not defined

Figure 16. SPI slave mode timing (CPHA = 1)

5.2 I²C

5.2.1 Inter-Integrated Circuit Interface (I2C) timing

Table 38. I2C 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 I²C bus devices	t_{HD}; DAT	0[2]	3.45[3]	0[4]	0.9[2]	µs
Data set-up time	t_{SU}; DAT	250[5]	—	100[3, 6]	—	ns
Rise time of SDA and SCL signals	t_r	—	1000	20 +0.1C_b[7]	300	ns
Fall time of SDA and SCL signals	t_f	—	300	20 +0.1C_b[6]	300	ns
Set-up time for STOP condition	t_{SU}; STO	4	—	0.6	—	µs
Bus free time between STOP and START condition	t_{BUF}	4.7	—	1.3	—	µs
Pulse width of spikes that must be suppressed by the input filter	t_{SP}	N/A	N/A	0	50	ns

1. The maximum SCL Clock Frequency in Fast mode with maximum bus loading can only be achieved when using 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 I^2C deasserts ACK of an address byte simultaneously with the falling edge of SCL. If no slaves acknowledge this address byte, then a negative hold time can result, depending on the edge rates of the SDA and SCL lines.
3. The maximum tHD; DAT must be met only if the device does not stretch the LOW period (tLOW) of the SCL signal.
4. Input signal Slew = 10 ns and Output Load = 50 pF
5. Set-up time in slave-transmitter mode is 1 IPBus clock period, if the TX FIFO is empty.
6. A Fast mode I^2C bus device can be used in a Standard mode I2C bus system, but the requirement $t_{SU;\ DAT} \geq 250$ ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, then it must output the next data bit to the SDA line $t_{rmax} + t_{SU;\ DAT} = 1000 + 250 = 1250$ ns (according to the Standard mode I^2C bus specification) before the SCL line is released.
7. C_b = total capacitance of the one bus line in pF.

To achieve 1MHz I2C clock rates, consider the following recommendations:

- To counter the effects of clock stretching, the I2C baud Rate select bits can be configured for faster than desired baud rate.
- Use high drive pad and DSE bit should be set in PORTx_PCRn register.
- Minimize loading on the I2C SDA and SCL pins to ensure fastest rise times for the SCL line to avoid clock stretching.
- Use smaller pull up resistors on SDA and SCL to reduce the RC time constant.

Table 39. I^2C 1Mbit/s 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	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 1Mbit/s 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.

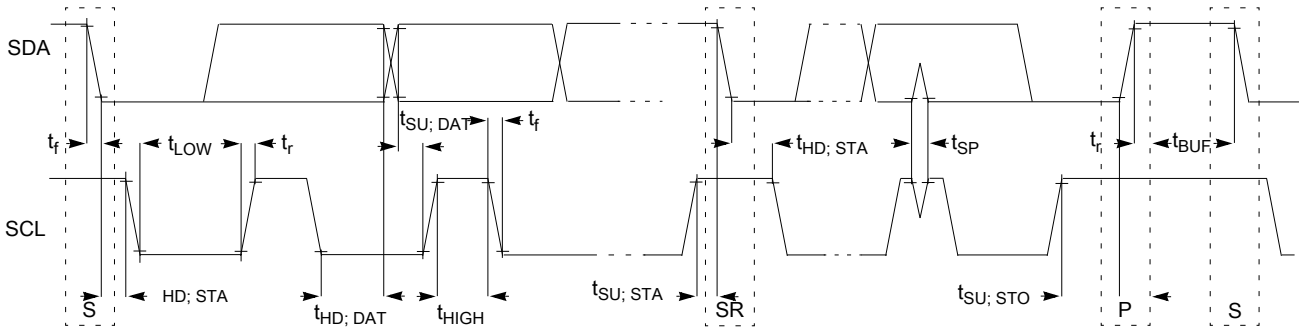


Figure 17. Timing definition for devices on the I²C bus

5.3 UART

See General switching specifications.

6 Design considerations

6.1 Hardware design considerations

This device contains protective circuitry to guard against damage due to high static voltage or electric fields. However, take normal precautions to avoid application of any voltages higher than maximum-rated voltages to this high-impedance circuit.

6.1.1 Printed circuit board recommendations

- Place connectors or cables on one edge of the board and do not place digital circuits between connectors.
- Drivers and filters for I/O functions should be placed as close to the connectors as possible. Connect TVS devices at the connector to a good ground. Connect filter capacitors at the connector to a good ground.
- Physically isolate analog circuits from digital circuits if possible.
- Place input filter capacitors as close to the MCU as possible.
- For best EMC performance, route signals as transmission lines; use a ground plane directly under LQFP packages; and solder the exposed pad (EP) to ground directly under QFN packages.

6.1.2 Power delivery system

Consider the following items in the power delivery system:

- Use a plane for ground.
- Use a plane for MCU VDD supply if possible.
- Always route ground first, as a plane or continuous surface, and never as sequential segments.
- Route power next, as a plane or traces that are parallel to ground traces.
- Place bulk capacitance, 10uF or more, at the entrance of the power plane.
- Place bypass capacitors for MCU power domain as close as possible to each VDD/VSS pair, including VDDA/VSSA and VREFH/VREFL.
- The minimum bypass requirement is to place 0.1 µF capacitors positioned as near as possible to the package supply pins.
- Take special care to minimize noise levels on the VREFH/VREFL inputs. An option is to use the internal reference voltage (output 1.2V typically) as the ADC reference.

NOTE

The internal reference voltage output (VREFO) is bonded to the VREFH pin on some packages and to PTE30 on other packages. When the VREFO output is used, a 0.1uF capacitor is required as a filter. Do not connect any other supply voltage to the pin that has VREFO activated.

6.1.3 Analog design

Each ADC input must have an RC filter as shown in the following figure. The maximum value of R must be RAS max if fast sampling and high resolution are required. The value of C must be chosen to ensure that the RC time constant is very small compared to the sample period.

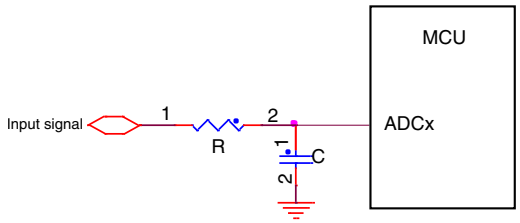


Figure 18. RC circuit for ADC input

High voltage measurement circuits require voltage division, current limiting, and over-voltage protection as shown the following figure. The voltage divider formed by R1 – R4 must yield a voltage less than or equal to VREFH. The current must be limited to less than the injection current limit. Since the ADC pins do not have diodes to VDD, external clamp diodes must be included to protect against transient over-voltages.

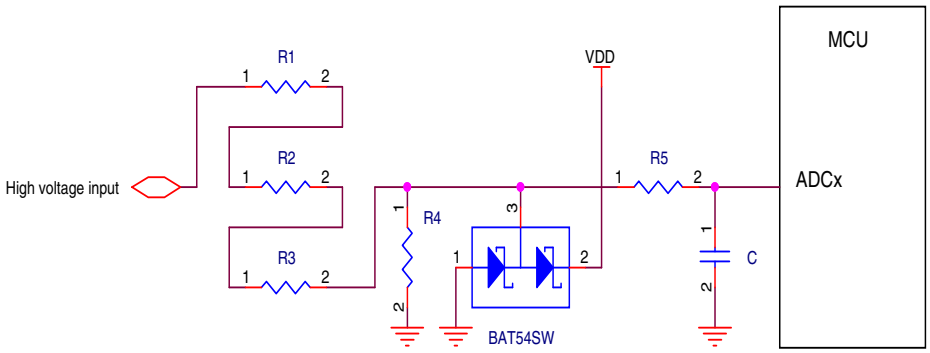


Figure 19. High voltage measurement with an ADC input

6.1.4 Digital design

Ensure that all I/O pins cannot get pulled above VDD (max I/O spec is VDD+0.3V).

CAUTION

Do not provide power to I/O pins prior to VDD, especially the RESET_b pin.

- RESET_b pin

  The RESET_b pin is an open-drain I/O pin that has an internal pullup resistor. An external RC circuit is recommended to filter noise as shown in the following figure. The resistor value must be in the range of 4.7 kΩ to 10 kΩ; the recommended capacitance value is 0.1 µF. The RESET_b pin also has a selectable digital filter to reject spurious noise.

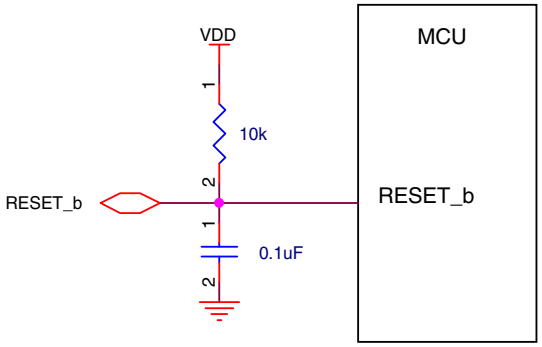


Figure 20. Reset circuit

When an external supervisor chip is connected to the RESET_b pin, a series resistor should be used to avoid damaging the supervisor chip or the RESET_b pin, as shown in Figure 55. The series resistor value (RS below) should be in the range of 100Ω to 1kΩ depending on the external reset chip drive strength. The supervisor chip must have an active high, open-drain output.

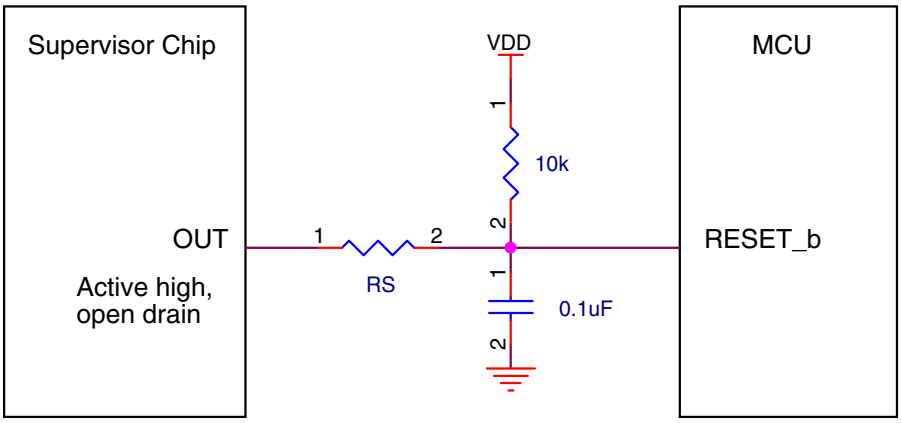


Figure 21. Reset signal connection to external reset chip

- NMI pin

  Because a low level on the NMI_b pin will trigger the Non-maskable interrupt, it is not recommended to add a pull-down resistor or capacitor on this pin. When this pin is enabled as the NMI function an external pull-up resistor (10k) as shown in the following figure is recommended for robustness.

  If the NMI_b pin is used as an I/O pin the Non-maskable interrupt handler is required to disable the NMI function by remapping to another function. The NMI function is disabled by programming the FOPT[NMI_DIS] bit to zero.

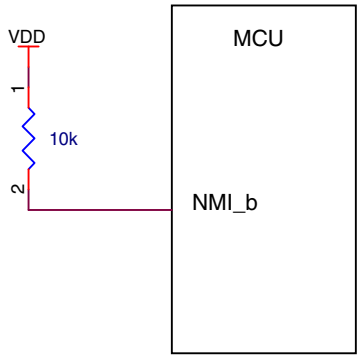


Figure 22. NMI pin biasing

- Debug interface

  This MCU uses the standard ARM SWD interface protocol as shown in the following figure. While pull-up or pull-down resistors are not required (SWD_DIO has an internal pull-up and SWD_CLK has an internal pull-down), external 10kΩ pull resistors are recommended for system robustness. Please note the RESET_b pin recommendations mentioned above.

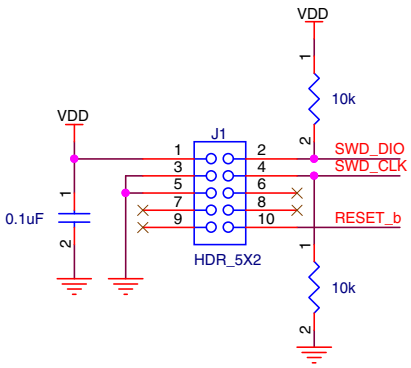


Figure 23. SWD debug interface

- Low leakage stop mode wakeup

  Select low leakage wakeup pins (LLWU_Px) to wake the MCU from one of the low leakage stop modes (LLS/VLLSx). Please refer to the signal multiplexing table for pin selection.

- Unused pin

  Unused GPIO pins should be left floating (no electrical connections) with the MUX field of the pin's PORTx_PCRn register equal to 0:0:0. This disables the digital input path to the MCU.

6.1.5 Crystal oscillator

When using an external crystal or ceramic resonator as the frequency reference for the MCU clock system, refer to the following table and diagrams.

The feedback resistor, RF, is incorporated internally with the low power oscillators. An external feedback is required when using high gain (HGO=1) mode.

The series resistor, RS, is required in high gain (HGO=1) mode when the crystal or resonator frequency is below 2MHz. Otherwise, the low power oscillator (HGO=0) must not have any series resistance; and the high frequency, high gain oscillator with a frequency above 2MHz does not require any series resistance.

Internal load capacitors (Cx, Cy) are provided in the low frequency (32.786kHz) mode. Use the SCxP bits in the OSC0_CR register to adjust the load capacitance for the crystal. Typically, values of 10pf to 16pF are sufficient for 32.768kHz crystals that have a 12.5pF CL specification. The internal load capacitor selection must not be used for high frequency crystals and resonators.

Table 40. External crystal/resonator connections

Oscillator mode	Oscillator mode
Low frequency (32.768kHz), low power	Diagram 1
Low frequency (32.768kHz), high gain	Diagram 2, Diagram 4
High frequency (1-32MHz), low power	Diagram 3
High frequency (1-32MHz), high gain	Diagram 4

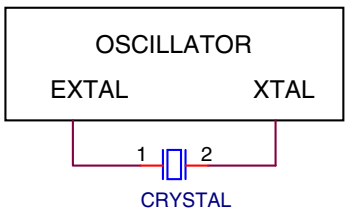


Figure 24. Crystal connection – Diagram 1

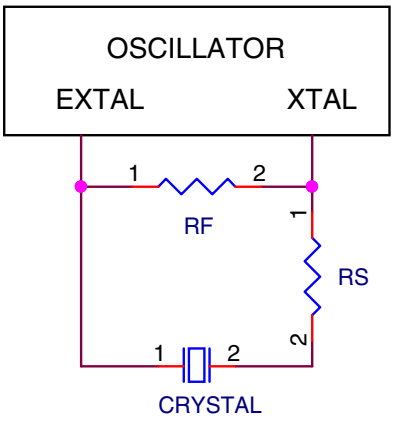


Figure 25. Crystal connection – Diagram 2

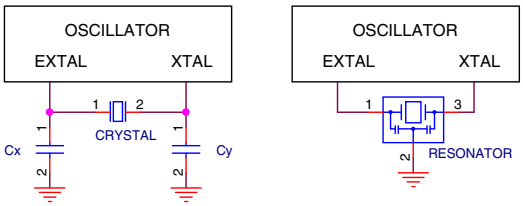


Figure 26. Crystal connection – Diagram 3

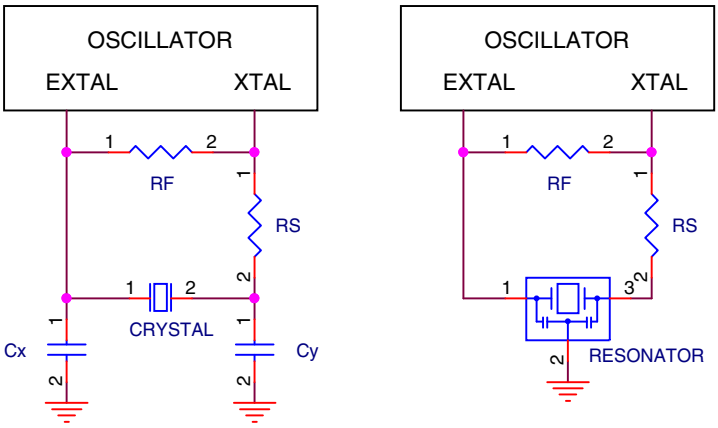


Figure 27. Crystal connection – Diagram 4

6.2 Software considerations

All Kinetis MCUs are supported by comprehensive Freescale and third-party hardware and software enablement solutions, which can reduce development costs and time to market. Featured software and tools are listed below. Visit http://www.freescale.com/kinetis/sw for more information and supporting collateral.

Evaluation and Prototyping Hardware

- Freescale Freedom Development Platform: http://www.freescale.com/freedom
- Tower System Development Platform: http://www.freescale.com/tower

IDEs for Kinetis MCUs

- Kinetis Design Studio IDE: http://www.freescale.com/kds
- Partner IDEs: http://www.freescale.com/kide

Development Tools

- PEG Graphics Software: http://www.freescale.com/peg
- Processor Expert Software and Embedded Components: http://www.freescale.com/processorexpert)

Run-time Software

- Kinetis SDK: http://www.freescale.com/ksdk
- Kinetis Bootloader: http://www.freescale.com/kboot
- ARM mbed Development Platform: http://www.freescale.com/mbed
- MQX RTOS: http://www.freescale.com/mqx

For all other partner-developed software and tools, visit http://www.freescale.com/partners.

7 Dimensions

7.1 Obtaining package dimensions

Package dimensions are provided in package drawings.

To find a package drawing, go to freescale.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
32-pin QFN	98ASA00615D
48-pin QFN	98ASA00616D
64-pin LQFP	98ASS23234W
64-pin MAPBGA	98ASA00420D
80-pin LQFP	98ASS23174W

8 Pinouts and Packaging

8.1 KL13 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.

NOTE

The 32 QFN, 48 QFN, and 64 MAPBGA packages for this product are not yet available. However, these packages are included in Package Your Way program for Kinetis MCUs. Visit freescale.com/KPYW for more details.

80 LQFP	64 LQFP	48 QFN	64 MAP BGA	32 QFN	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7
—	—	—	C5	—	NC	NC	NC							
1	1	—	A1	1	PTE0	DISABLED		PTE0/ CLKOUT32 K	SPI1_MISO	LPUART1_ TX	RTC_ CLKOUT	CMP0_OUT	I2C1_SDA	
2	2	—	B1	2	PTE1	DISABLED		PTE1	SPI1_MOSI	LPUART1_ RX		SPI1_MISO	I2C1_SCL	
3	—	—	—	—	PTE2	DISABLED		PTE2	SPI1_SCK					
4	—	—	—	—	PTE3	DISABLED		PTE3	SPI1_MISO			SPI1_MOSI		
5	—	—	—	—	PTE4	DISABLED		PTE4	SPI1_PCS0					
6	—	—	—	—	PTE5	DISABLED		PTE5						
7	3	1	—	—	VDD	VDD	VDD							
8	4	2	C4	—	VSS	VSS	VSS							
9	5	3	E1	3	PTE16	ADC0_DP1/ ADC0_SE1	ADC0_DP1/ ADC0_SE1	PTE16	SPI0_PCS0	UART2_TX	TPM_ CLKIN0		FXIO0_D0	
10	6	4	D1	4	PTE17	ADC0_ DM1/ ADC0_ SE5a	ADC0_ DM1/ ADC0_ SE5a	PTE17	SPI0_SCK	UART2_RX	TPM_ CLKIN1	LPTMR0_ ALT3	FXIO0_D1	
11	7	5	E2	5	PTE18	ADC0_DP2/ ADC0_SE2	ADC0_DP2/ ADC0_SE2	PTE18	SPI0_MOSI		I2C0_SDA	SPI0_MISO	FXIO0_D2	
12	8	6	D2	6	PTE19	ADC0_ DM2/ ADC0_ SE6a	ADC0_ DM2/ ADC0_ SE6a	PTE19	SPI0_MISO		I2C0_SCL	SPI0_MOSI	FXIO0_D3	
13	9	7	G1	—	PTE20	ADC0_DP0/ ADC0_SE0	ADC0_DP0/ ADC0_SE0	PTE20		TPM1_CH0	LPUART0_ TX		FXIO0_D4	

80 LQFP	64 LQFP	48 QFN	64 MAP BGA	32 QFN	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7
14	10	8	F1	—	PTE21	ADC0_DM0/ ADC0_SE4a	ADC0_DM0/ ADC0_SE4a	PTE21		TPM1_CH1	LPUART0_RX		FXIO0_D5	
15	11	—	G2	—	PTE22	ADC0_DP3/ ADC0_SE3	ADC0_DP3/ ADC0_SE3	PTE22		TPM2_CH0	UART2_TX		FXIO0_D6	
16	12	—	F2	—	PTE23	ADC0_DM3/ ADC0_SE7a	ADC0_DM3/ ADC0_SE7a	PTE23		TPM2_CH1	UART2_RX		FXIO0_D7	
17	13	9	F4	7	VDDA	VDDA	VDDA							
18	14	10	G4	—	VREFH	VREFH	VREFH							
18	14	10	G4	—	VREFO	VREFO (1,2V reference, bond to VREFH)	VREFH							
19	15	11	G3	—	VREFL	VREFL	VREFL							
20	16	12	F3	8	VSSA	VSSA	VSSA							
21	17	13	H1	—	PTE29	CMP0_IN5/ ADC0_SE4b	CMP0_IN5/ ADC0_SE4b	PTE29		TPM0_CH2	TPM_CLKIN0			
22	18	14	H2	9	PTE30	DAC0_OUT/ ADC0_SE23/ CMP0_IN4	DAC0_OUT/ ADC0_SE23/ CMP0_IN4	PTE30		TPM0_CH3	TPM_CLKIN1	LPUART1_TX	LPTMR0_ALT1	
23	19	—	H3	—	PTE31	DISABLED		PTE31		TPM0_CH4				
24	20	15	H4	—	PTE24	DISABLED		PTE24		TPM0_CH0		I2C0_SCL		
25	21	16	H5	—	PTE25	DISABLED		PTE25		TPM0_CH1		I2C0_SDA		
26	22	17	D3	10	PTA0	SWD_CLK		PTA0		TPM0_CH5				SWD_CLK
27	23	18	D4	11	PTA1	DISABLED		PTA1	LPUART0_RX	TPM2_CH0				
28	24	19	E5	12	PTA2	DISABLED		PTA2	LPUART0_TX	TPM2_CH1				
29	25	20	D5	13	PTA3	SWD_DIO		PTA3	I2C1_SCL	TPM0_CH0				SWD_DIO
30	26	21	G5	14	PTA4	NMI_b		PTA4	I2C1_SDA	TPM0_CH1				NMI_b
31	27	—	F5	—	PTA5	DISABLED		PTA5		TPM0_CH2				
32	28	—	H6	—	PTA12	DISABLED		PTA12		TPM1_CH0				
33	29	—	G6	—	PTA13	DISABLED		PTA13		TPM1_CH1				
34	—	—	—	—	PTA14	DISABLED		PTA14	SPI0_PCS0	LPUART0_TX				
35	—	—	—	—	PTA15	DISABLED		PTA15	SPI0_SCK	LPUART0_RX				
36	—	—	—	—	PTA16	DISABLED		PTA16	SPI0_MOSI			SPI0_MISO		

80 LQFP	64 LQFP	48 QFN	64 MAP BGA	32 QFN	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7
37	—	—	—	—	PTA17	DISABLED		PTA17	SPI0_MISO			SPI0_MOSI		
38	30	22	G7	15	VDD	VDD	VDD							
39	31	23	H7	16	VSS	VSS	VSS							
40	32	24	H8	17	PTA18	EXTAL0	EXTAL0	PTA18		LPUART1_ RX	TPM_ CLKIN0			
41	33	25	G8	18	PTA19	XTAL0	XTAL0	PTA19		LPUART1_ TX	TPM_ CLKIN1		LPTMR0_ ALT1	
42	34	26	F8	19	PTA20	RESET_b		PTA20						RESET_b
43	35	27	F7	20	PTB0/ LLWU_P5	ADC0_SE8	ADC0_SE8	PTB0/ LLWU_P5	I2C0_SCL	TPM1_CH0	SPI1_MOSI	SPI1_MISO		
44	36	28	F6	21	PTB1	ADC0_SE9	ADC0_SE9	PTB1	I2C0_SDA	TPM1_CH1	SPI1_MISO	SPI1_MOSI		
45	37	29	E7	—	PTB2	ADC0_ SE12	ADC0_ SE12	PTB2	I2C0_SCL	TPM2_CH0				
46	38	30	E8	—	PTB3	ADC0_ SE13	ADC0_ SE13	PTB3	I2C0_SDA	TPM2_CH1				
47	—	—	—	—	PTB8			PTB8	SPI1_PCS0	EXTRG_IN				
48	—	—	—	—	PTB9			PTB9	SPI1_SCK					
49	—	—	—	—	PTB10			PTB10	SPI1_PCS0					
50	—	—	—	—	PTB11			PTB11	SPI1_SCK					
51	39	31	E6	—	PTB16			PTB16	SPI1_MOSI	LPUART0_ RX	TPM_ CLKIN0	SPI1_MISO		
52	40	32	D7	—	PTB17			PTB17	SPI1_MISO	LPUART0_ TX	TPM_ CLKIN1	SPI1_MOSI		
53	41	—	D6	—	PTB18			PTB18		TPM2_CH0				
54	42	—	C7	—	PTB19			PTB19		TPM2_CH1				
55	43	33	D8	—	PTC0	ADC0_ SE14	ADC0_ SE14	PTC0		EXTRG_IN		CMP0_OUT		
56	44	34	C6	22	PTC1/ LLWU_P6/ RTC_CLKIN	ADC0_ SE15	ADC0_ SE15	PTC1/ LLWU_P6/ RTC_CLKIN	I2C1_SCL		TPM0_CH0			
57	45	35	B7	23	PTC2	ADC0_ SE11	ADC0_ SE11	PTC2	I2C1_SDA		TPM0_CH1			
58	46	36	C8	24	PTC3/ LLWU_P7			PTC3/ LLWU_P7	SPI1_SCK	LPUART1_ RX	TPM0_CH2	CLKOUT		
59	47	—	E3	—	VSS	VSS	VSS							
60	48	—	E4	—	VDD	VDD	VDD							
61	49	37	B8	25	PTC4/ LLWU_P8			PTC4/ LLWU_P8	SPI0_PCS0	LPUART1_ TX	TPM0_CH3	SPI1_PCS0		
62	50	38	A8	26	PTC5/ LLWU_P9			PTC5/ LLWU_P9	SPI0_SCK	LPTMR0_ ALT2			CMP0_OUT	
63	51	39	A7	27	PTC6/ LLWU_P10	CMP0_IN0	CMP0_IN0	PTC6/ LLWU_P10	SPI0_MOSI	EXTRG_IN		SPI0_MISO		
64	52	40	B6	28	PTC7	CMP0_IN1	CMP0_IN1	PTC7	SPI0_MISO			SPI0_MOSI		

80 LQFP	64 LQFP	48 QFN	64 MAP BGA	32 QFN	Pin Name	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7
65	53	—	A6	—	PTC8	CMP0_IN2	CMP0_IN2	PTC8	I2C0_SCL	TPM0_CH4				
66	54	—	B5	—	PTC9	CMP0_IN3	CMP0_IN3	PTC9	I2C0_SDA	TPM0_CH5				
67	55	—	B4	—	PTC10			PTC10	I2C1_SCL					
68	56	—	A5	—	PTC11			PTC11	I2C1_SDA					
69	—	—	—	—	PTC12			PTC12			TPM_ CLKIN0			
70	—	—	—	—	PTC13			PTC13			TPM_ CLKIN1			
71	—	—	—	—	PTC16			PTC16						
72	—	—	—	—	PTC17			PTC17						
73	57	41	C3	—	PTD0			PTD0	SPI0_PCS0		TPM0_CH0		FXIO0_D0	
74	58	42	A4	—	PTD1	ADC0_ SE5b	ADC0_ SE5b	PTD1	SPI0_SCK		TPM0_CH1		FXIO0_D1	
75	59	43	C2	—	PTD2			PTD2	SPI0_MOSI	UART2_RX	TPM0_CH2	SPI0_MISO	FXIO0_D2	
76	60	44	B3	—	PTD3			PTD3	SPI0_MISO	UART2_TX	TPM0_CH3	SPI0_MOSI	FXIO0_D3	
77	61	45	A3	29	PTD4/ LLWU_P14			PTD4/ LLWU_P14	SPI1_PCS0	UART2_RX	TPM0_CH4		FXIO0_D4	
78	62	46	C1	30	PTD5	ADC0_ SE6b	ADC0_ SE6b	PTD5	SPI1_SCK	UART2_TX	TPM0_CH5		FXIO0_D5	
79	63	47	B2	31	PTD6/ LLWU_P15	ADC0_ SE7b	ADC0_ SE7b	PTD6/ LLWU_P15	SPI1_MOSI	LPUART0_ RX	I2C1_SDA	SPI1_MISO	FXIO0_D6	
80	64	48	A2	32	PTD7			PTD7	SPI1_MISO	LPUART0_ TX	I2C1_SCL	SPI1_MOSI	FXIO0_D7	

8.2 KL13 Family Pinouts

Figure below shows the 64 LQFP pinouts:

NOTE

The 32 QFN, 48 QFN, and 64 MAPBGA packages for this product are not yet available. However, these packages are included in Package Your Way program for Kinetis MCUs. Visit freescale.com/KPYW for more details.

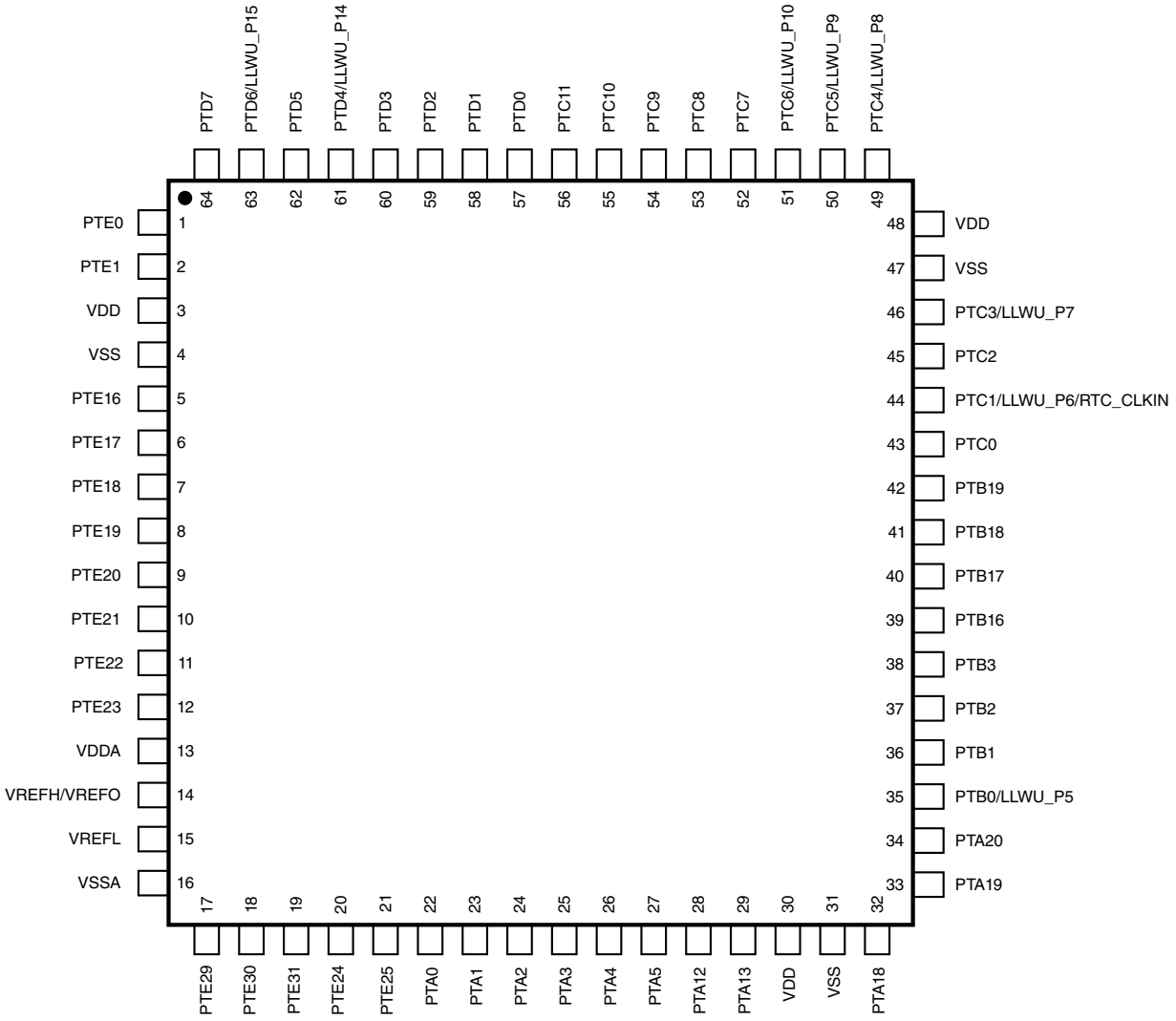


Figure 28. 64 LQFP Pinout diagram

Figure below shows the 80 LQFP pinouts:

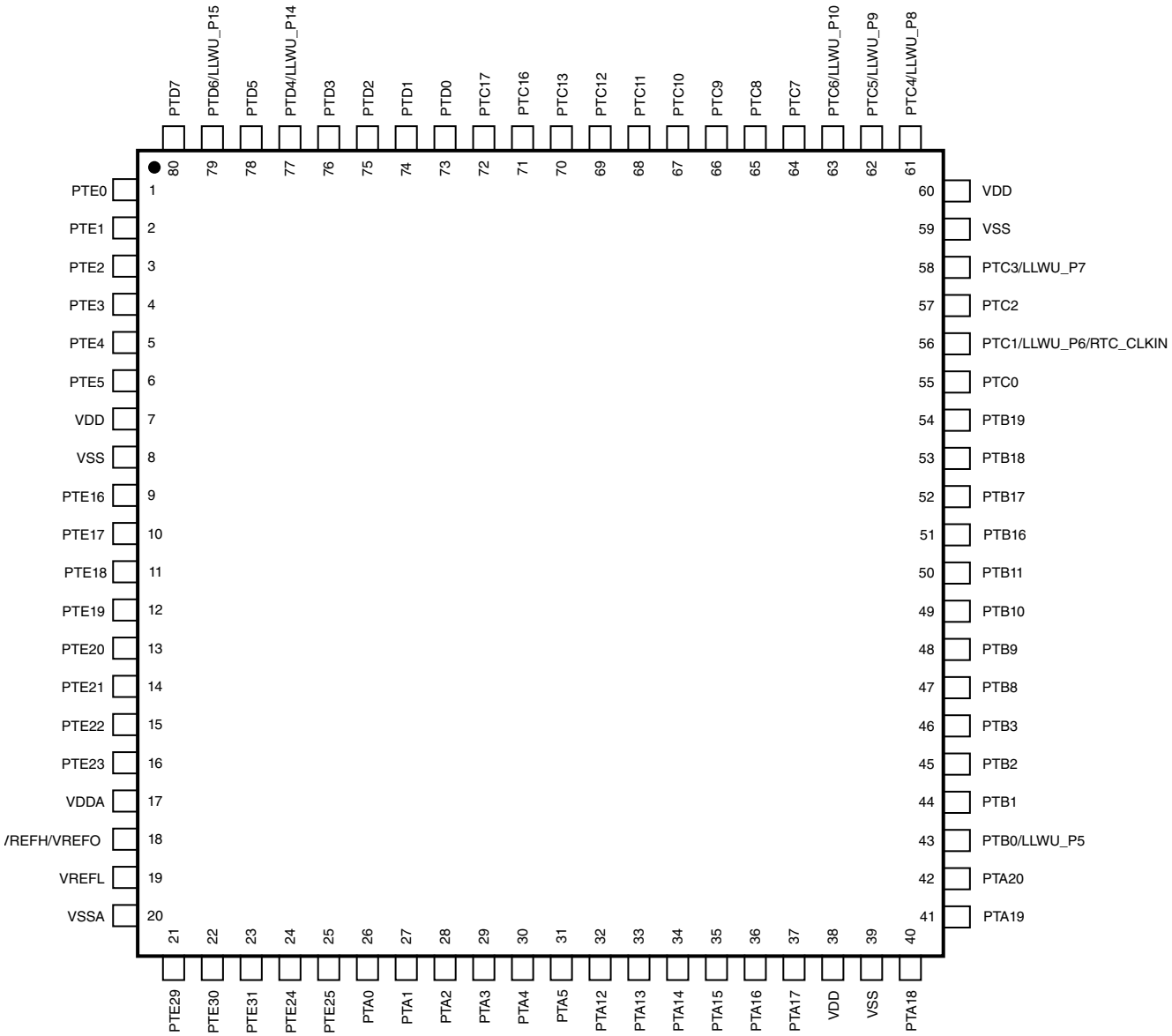


Figure 29. 80 LQFP Pinout diagram

Figure below shows the 64 MAPBGA pinouts:

	1	2	3	4	5	6	7	8	
A	PTE0	PTD7	PTD4/ LLWU_P14	PTD1	PTC11	PTC8	PTC6/ LLWU_P10	PTC5/ LLWU_P9	A
B	PTE1	PTD6/ LLWU_P15	PTD3	PTC10	PTC9	PTC7	PTC2	PTC4/ LLWU_P8	B
C	PTD5	PTD2	PTD0	VSS	NC	PTC1/ LLWU_P6/ RTC_CLKIN	PTB19	PTC3/ LLWU_P7	C
D	PTE17	PTE19	PTA0	PTA1	PTA3	PTB18	PTB17	PTC0	D
E	PTE16	PTE18	VSS	VDD	PTA2	PTB16	PTB2	PTB3	E
F	PTE21	PTE23	VSSA	VDDA	PTA5	PTB1	PTB0/ LLWU_P5	PTA20	F
G	PTE20	PTE22	VREFL	VREFH/ VREFO	PTA4	PTA13	VDD	PTA19	G
H	PTE29	PTE30	PTE31	PTE24	PTE25	PTA12	VSS	PTA18	H
	1	2	3	4	5	6	7	8	

Figure 30. 64 MAPBGA Pinout diagram

Figure below shows the 48 QFN pinouts:

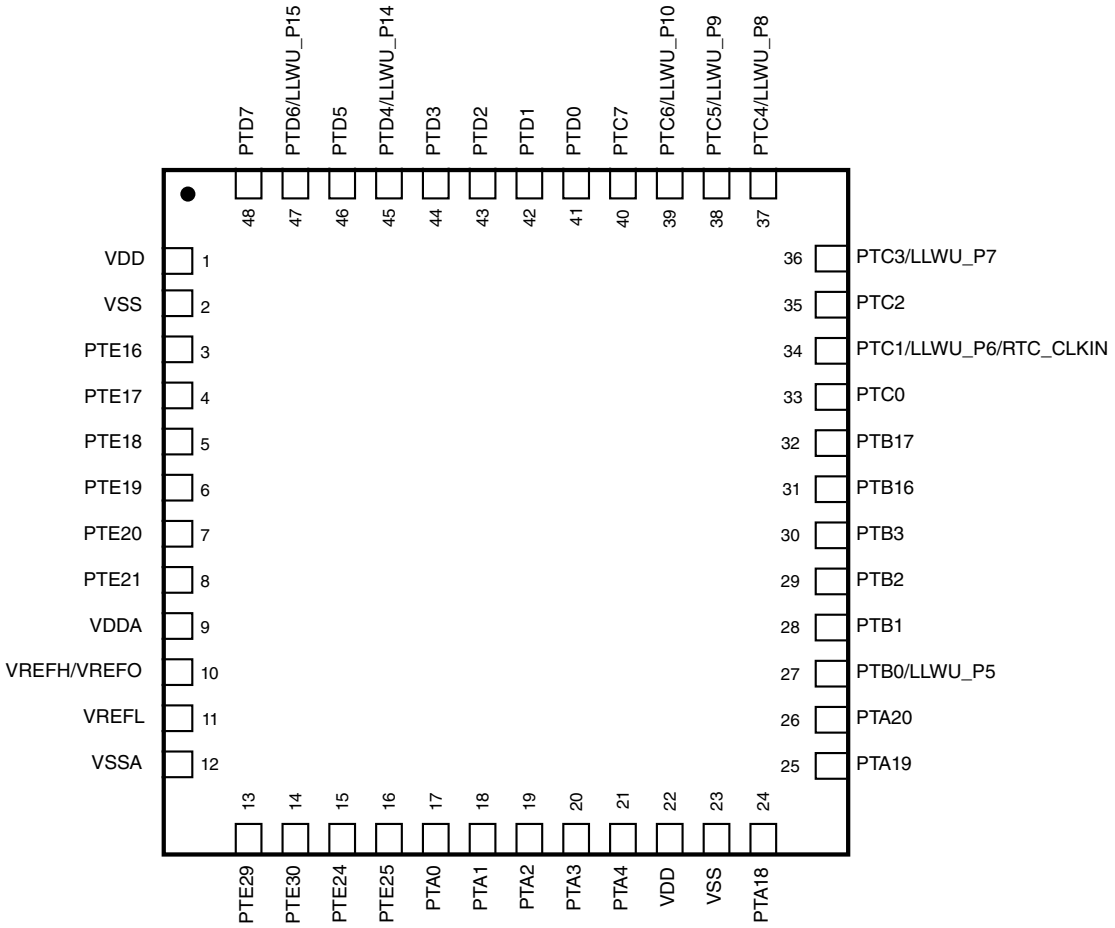


Figure 31. 48 QFN Pinout diagram

Figure below shows the 32 QFN pinouts:

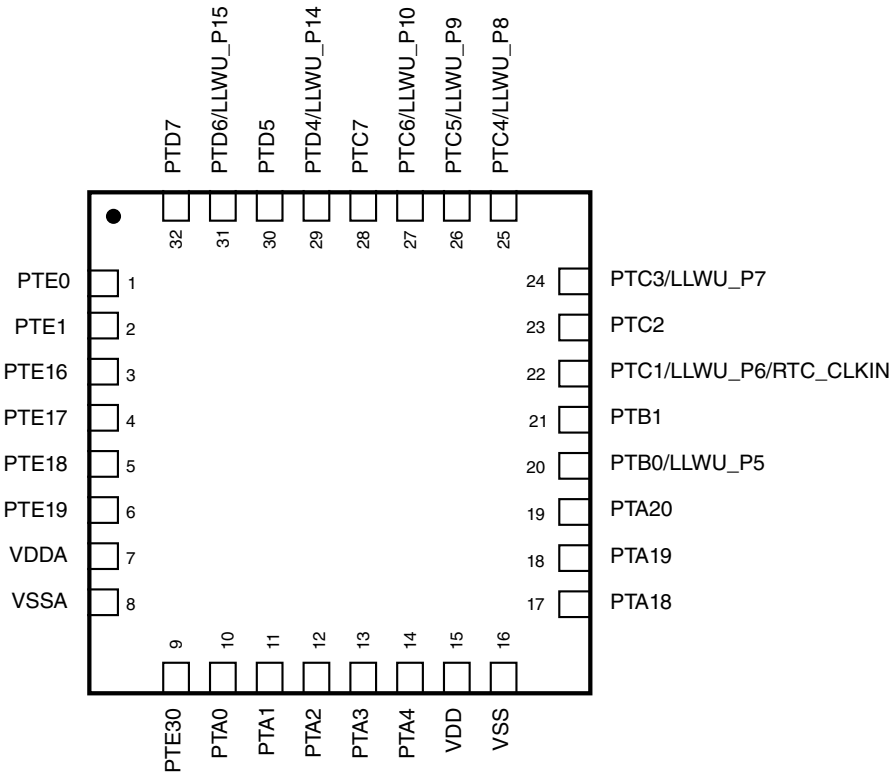


Figure 32. 32 QFN Pinout diagram

9 Ordering parts

9.1 Determining valid orderable parts

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

10 Part identification

10.1 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.

10.2 Format

Part numbers for this device have the following format:

Q KL## A FFF R T PP CC N

10.3 Fields

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

Table 41. Part number fields description

Field	Description	Values
Q	Qualification status	• M = Fully qualified, general market flow • P = Prequalification
KL##	Kinetis family	• KL13
A	Key attribute	• Z = Cortex-M0+
FFF	Program flash memory size	• 32 = 32 KB • 64 = 64 KB
R	Silicon revision	• (Blank) = Main • A = Revision after main
T	Temperature range (°C)	• V = –40 to 105
PP	Package identifier	• FM = 32 QFN (5 mm x 5 mm) [1] • FT = 48 QFN (7 mm x 7 mm)[1,] • LH = 64 LQFP (10 mm x 10 mm) • MP = 64 MAPBGA (5 mm x 5 mm)[1] • LK = 80 LQFP (12 mm x 12 mm)
CC	Maximum CPU frequency (MHz)	• 4 = 48 MHz
N	Packaging type	• R = Tape and reel

1. This package for this product is not yet available. However, it is included in Package Your Way program for Kinetis MCUs. Visit freescale.com/KPYW for more details.

10.4 Example

This is an example part number:

MKL13Z32VLH4

11 Terminology and guidelines

11.1 Definition: Operating requirement

An *operating requirement* is 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.

11.1.1 Example

This is an example of an operating requirement:

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

11.2 Definition: Operating behavior

Unless otherwise specified, an *operating behavior* is 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.

11.2.1 Example

This is an example of an operating behavior:

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

11.3 Definition: Attribute

An *attribute* is a specified value or range of values for a technical characteristic that are guaranteed, regardless of whether you meet the operating requirements.

11.3.1 Example

This is an example of an attribute:

Symbol	Description	Min.	Max.	Unit
CIN_D	Input capacitance: digital pins	—	7	pF

11.4 Definition: Rating

A *rating* is a minimum or maximum value of a technical characteristic that, if exceeded, may cause permanent chip failure:

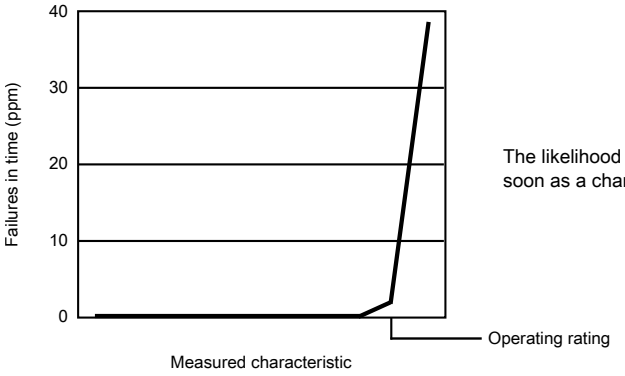
- *Operating ratings* apply during operation of the chip.
- *Handling ratings* apply when the chip is not powered.

11.4.1 Example

This is an example of an operating rating:

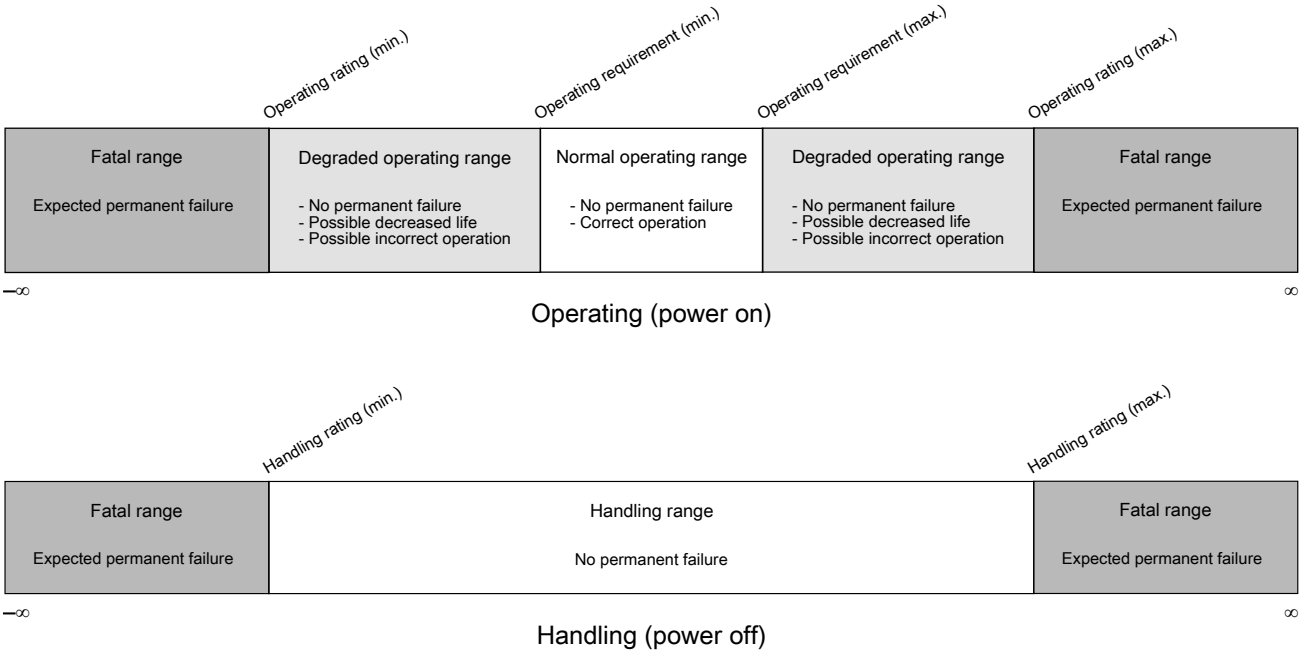
Symbol	Description	Min.	Max.	Unit
V_{DD}	1.0 V core supply voltage	–0.3	1.2	V

11.5 Result of exceeding a rating



The likelihood of permanent chip failure increases rapidly as soon as a characteristic begins to exceed one of its operating ratings.

11.6 Relationship between ratings and operating requirements



11.7 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.

11.8 Definition: Typical value

A *typical value* is a specified value for a technical characteristic that:

- Lies within the range of values specified by the operating behavior
- Given the typical manufacturing process, is representative of that characteristic during operation when you meet the typical-value conditions or other specified conditions

Typical values are provided as design guidelines and are neither tested nor guaranteed.

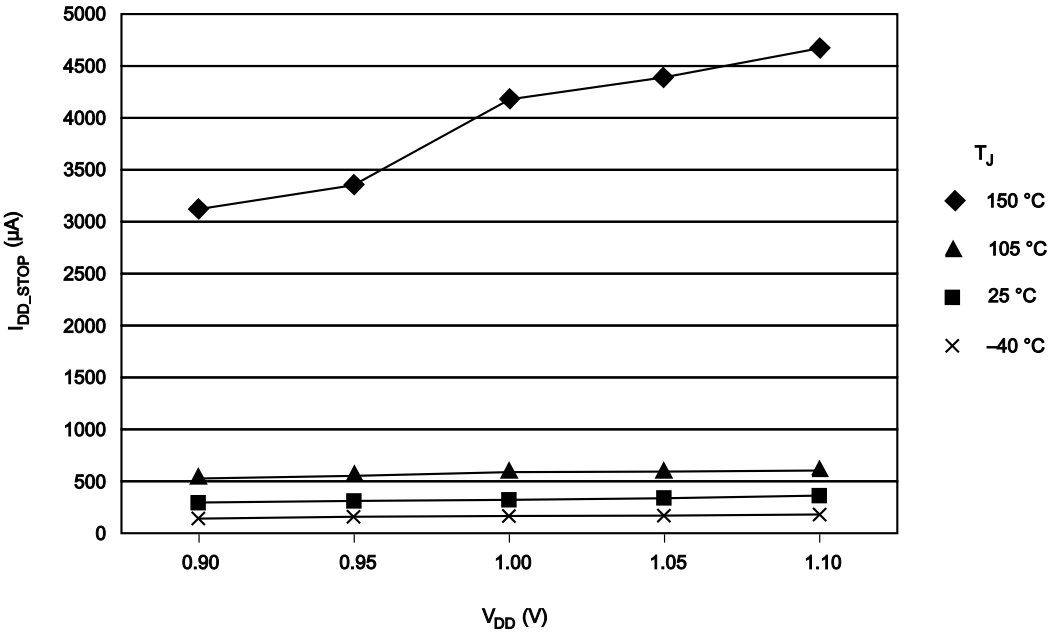
11.8.1 Example 1

This is an example of an 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

11.8.2 Example 2

This is an example of a chart that shows typical values for various voltage and temperature conditions:



11.9 Typical value conditions

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

Table 42. Typical value conditions

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

12 Revision History

The following table provides a revision history for this document.

Table 43. Revision History

Rev. No.	Date	Substantial Changes
1	01 February 2015	• Added new topic "Electrical Design Considerations" as Section 6. • Added a note in Table 14 - Thermal operating requirements. • Footnote 1 in Table 9 was moved in the beginning of the table as text.

Table continues on the next page...

Table 43. Revision History (continued)

Rev. No.	Date	Substantial Changes

2	18 March 2015	• Updated the features and completed the ordering information.
		• Removed thickness dimension from package diagrams.
		• Updated Table 7. Voltage and current operating behaviors.
		  • Specified correct max. value for I_{IN} parameter.
		• Updated Table 8. Power mode transition operating behaviors with Typ. and Max. values.
		• Updated Table 9. Power consumption operating behaviors with Typ. and Max. values.
		• Updated Table 10. Low power mode peripheral adders — typical value.
		• Updated EMC Performance information in section 2.2.6.
		• Updated Table 17. IRC48M specification and Table 18. IRC8M/2M specification.
		• Updated Typ. values of TUE and INL parameters in Table 26. 16-bit ADC characteristics.
		• Updated Table 28. VREF full-range operating behaviors.
		  • Removed A_c(Aging coefficient) row.
		  • Added $T_{chop\_osc\_stup}$ parameter.
		  • Updated typical value of the V_{out} parameter.
		• Added tables: "I2C timing" and "I2C 1Mbit/s timing" under section - I2C.
		• Updated Section 6 - Design Considerations.

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Revision 2, 03/2015