

XMC4300

Microcontroller Series
for Industrial Applications

XMC4000 Family

ARM[®] Cortex[®]-M4
32-bit processor core

Data Sheet

V1.2 2023-04

Microcontrollers

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V1.2 2023-04	
10	Updated number of breakpoints from 8 to 6.
99	Added PG-LQFP-100-29 details in Table 60.
102	Added package diagram: PG-LQFP-100-29.

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About this Document

This Data Sheet is addressed to embedded hardware and software developers. It provides the reader with detailed descriptions about the ordering designations, available features, electrical and physical characteristics of the XMC4[12]00 series devices.

The document describes the characteristics of a superset of the XMC4[12]00 series devices. For simplicity, the various device types are referred to by the collective term XMC4[12]00 throughout this manual.

XMC4000 Family User Documentation

The set of user documentation includes:

- **Reference Manual**
 - describes the functionality of the superset of devices.
- **Data Sheets**
 - list the complete ordering designations, available features and electrical characteristics of derivative devices.
- **Errata Sheets**
 - list deviations from the specifications given in the related Reference Manual or Data Sheets. Errata Sheets are provided for the superset of devices.

Attention: Please consult all parts of the documentation set to attain consolidated knowledge about your device.

Application related guidance is provided by **Users Guides** and **Application Notes**.

Please refer to <http://www.infineon.com/xmc4000> to get access to the latest versions of those documents.

1 Summary of Features

The XMC4300 devices are members of the XMC4000 Family of microcontrollers based on the ARM Cortex-M4 processor core. The XMC4000 is a family of high performance and energy efficient microcontrollers optimized for Industrial Connectivity, Industrial Control, Power Conversion, Sense & Control.

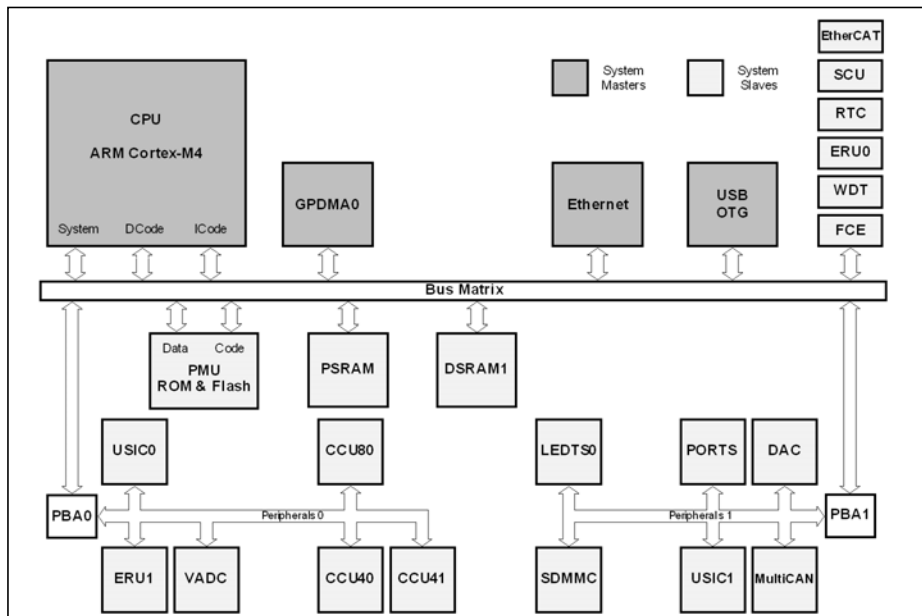


Figure 1 System Block Diagram

CPU Subsystem

- CPU Core
 - High Performance 32-bit ARM Cortex-M4 CPU
 - 16-bit and 32-bit Thumb2 instruction set
 - DSP/MAC instructions
 - System timer (SysTick) for Operating System support
- Floating Point Unit
- Memory Protection Unit
- Nested Vectored Interrupt Controller
- General Purpose DMA with up-to 8 channels
- Event Request Unit (ERU) for programmable processing of external and internal service requests
- Flexible CRC Engine (FCE) for multiple bit error detection

On-Chip Memories

- 16 KB on-chip boot ROM
- 64 KB on-chip high-speed program memory
- 64 KB on-chip high speed data memory
- 256 KB on-chip Flash Memory with 8 KB instruction cache

Communication Peripherals

- Ethernet MAC module capable of 10/100 Mbit/s transfer rates
- EtherCATslave interface (ECAT) capable of 100 Mbit/s transfer rates with 2 MII ports, 8 Fieldbus Memory Management Units (FMMU), 8 Sync Manager, 64 bit distributed clocks
- Universal Serial Bus, USB 2.0 host, Full-Speed OTG, with integrated PHY
- Controller Area Network interface (MultiCAN), Full-CAN/Basic-CAN with 2 nodes, 64 message objects (MO), data rate up to 1 Mbaud
- Four Universal Serial Interface Channels (USIC), providing 4 serial channels, usable as UART, double-SPI, quad-SPI, IIC, IIS and LIN interfaces
- LED and Touch-Sense Controller (LEDTS) for Human-Machine interface
- SD and Multi-Media Card interface (SDMMC) for data storage memory cards

Analog Frontend Peripherals

- Two Analog-Digital Converters (VADC) of 12-bit resolution, 8 channels each, with input out-of-range comparators
- Digital-Analog Converter (DAC) with two channels of 12-bit resolution

Industrial Control Peripherals

- One Capture/Compare Units 8 (CCU8) for motor control and power conversion
- Two Capture/Compare Units 4 (CCU4) for use as general purpose timers
- Window Watchdog Timer (WDT) for safety sensitive applications
- Die Temperature Sensor (DTS)
- Real Time Clock module with alarm support
- System Control Unit (SCU) for system configuration and control

Input/Output Lines

- Programmable port driver control module (PORTS)
- Individual bit addressability
- Tri-stated in input mode
- Push/pull or open drain output mode
- Boundary scan test support over JTAG interface

On-Chip Debug Support

- Full support for debug features: 6 breakpoints, CoreSight, trace
- Various interfaces: ARM-JTAG, SWD, single wire trace

1.1 Ordering Information

The ordering code for an Infineon microcontroller provides an exact reference to a specific product. The code "XMC4<DDD>-<Z><PPP><T><FFFF>" identifies:

- <DDD> the derivatives function set
- <Z> the package variant
 - E: LFBGA
 - F: LQFP
 - Q: VQFN
- <PPP> package pin count
- <T> the temperature range:
 - F: -40°C to 85°C
 - K: -40°C to 125°C
- <FFFF> the Flash memory size.

For ordering codes for the XMC4300 please contact your sales representative or local distributor.

This document describes several derivatives of the XMC4300 series, some descriptions may not apply to a specific product. Please see [Table 1](#).

For simplicity the term **XMC4300** is used for all derivatives throughout this document.

1.2 Device Types

These device types are available and can be ordered through Infineon's direct and/or distribution channels.

Table 1 Synopsis of XMC4300 Device Types

Derivative ¹⁾	Package	Flash Kbytes	SRAM Kbytes
XMC4300-F100x256	PG-LQFP-100	256	128

1) x is a placeholder for the supported temperature range.

Summary of Features

1.3 Device Type Features

The following table lists the available features per device type.

Table 2 Features of XMC4300 Device Types

Derivative ¹⁾	LED TS Intf.	SD MMC Intf.	ETH Intf.	ECAT Slave Intf.	USB Intf.	USIC Chan.	MultiCAN Nodes, MO
XMC4300-F100x256	1	1	RMII	2 x MII	1	2 x 2	N0, N1 MO[0..63]

1) x is a placeholder for the supported temperature range.

Table 3 Features of XMC4300 Device Types

Derivative ¹⁾	ADC Chan.	DAC Chan.	CCU4 Slice	CCU8 Slice
XMC4300-F100x256	16	2	2 x 4	1 x 4

1) x is a placeholder for the supported temperature range.

1.4 Definition of Feature Variants

The XMC4300 types are offered with several memory sizes and number of available VADC channels. [Table 4](#) describes the location of the available Flash memory, [Table 5](#) describes the location of the available SRAMs, [Table 6](#) the available VADC channels.

Table 4 Flash Memory Ranges

Total Flash Size	Cached Range	Uncached Range
256 Kbytes	0800 0000 _H – 0803 FFFF _H	0C00 0000 _H – 0C03 FFFF _H

Table 5 SRAM Memory Ranges

Total SRAM Size	Program SRAM	System Data SRAM
128 Kbytes	1FFF 0000 _H – 1FFF FFFF _H	2000 0000 _H – 2000 FFFF _H

Table 6 ADC Channels¹⁾

Package	VADC G0	VADC G1
PG-LQFP-100	CH0..CH7	CH0..CH7

1) Some pins in a package may be connected to more than one channel. For the detailed mapping see the Port I/O Function table.

1.5 Identification Registers

The identification registers allow software to identify the marking.

Table 7 XMC4300 Identification Registers

Register Name	Value	Marking
SCU_IDCHIP	0004 3001 _H	AA
JTAG IDCODE	101D F083 _H	AA

2 General Device Information

This section summarizes the logic symbols and package pin configurations with a detailed list of the functional I/O mapping.

2.1 Logic Symbols

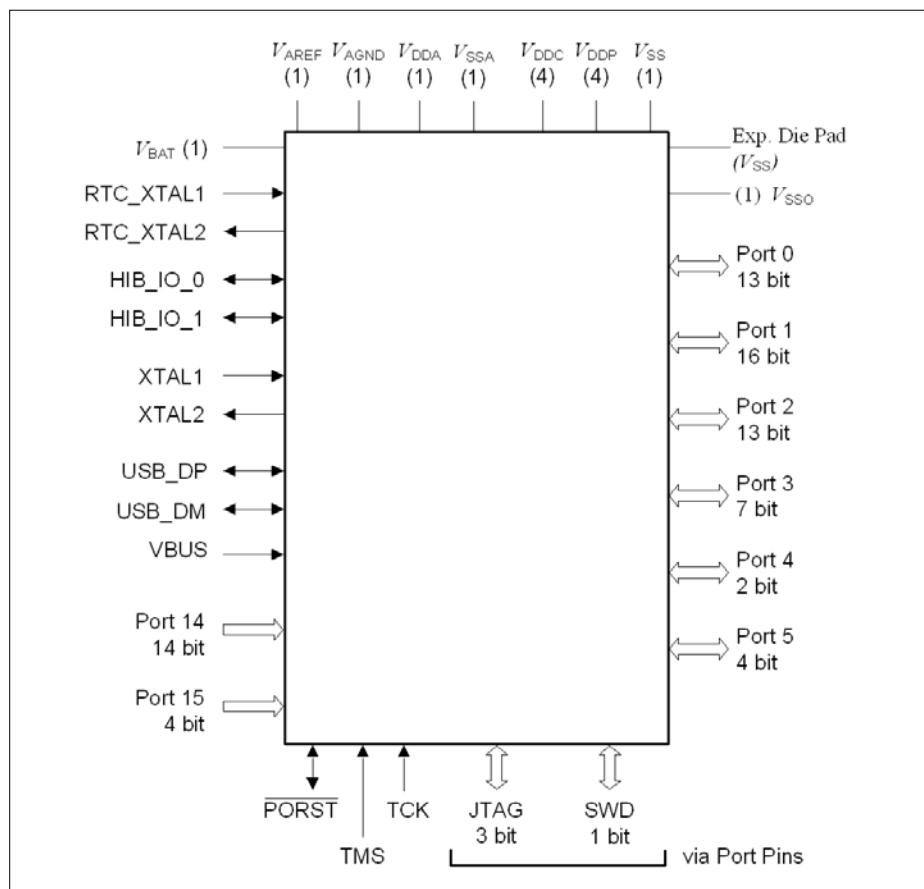


Figure 2 XMC4300 Logic Symbol PG-LQFP-100

2.2 Pin Configuration and Definition

The following figures summarize all pins, showing their locations on the four sides of the different packages.

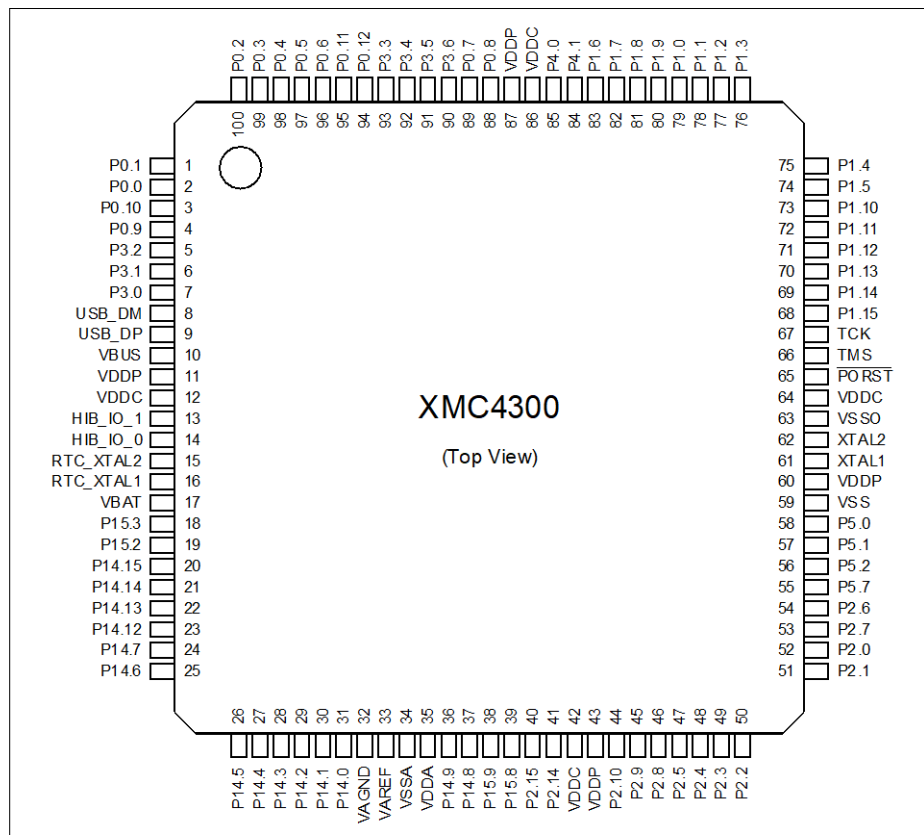


Figure 3 XMC4300 PG-LQFP-100 Pin Configuration (top view)

2.2.1 Package Pin Summary

The following general scheme is used to describe each pin:

Table 8 Package Pin Mapping Description

Function	Package A	Package B	...	Pad Type	Notes
Name	N	Ax	...	A2	

The table is sorted by the “Function” column, starting with the regular Port pins (Px.y), followed by the dedicated pins (i.e. $\overline{\text{PORST}}$) and supply pins.

The following columns, titled with the supported package variants, lists the package pin number to which the respective function is mapped in that package.

The “Pad Type” indicates the employed pad type (A1, A1+, A2, special=special pad, In=input pad, AN/DIG_IN=analog and digital input, Power=power supply). Details about the pad properties are defined in the Electrical Parameters.

In the “Notes”, special information to the respective pin/function is given, i.e. deviations from the default configuration after reset. Per default the regular Port pins are configured as direct input with no internal pull device active.

Table 9 Package Pin Mapping

Function	LQFP-100	Pad Type	Notes
P0.0	2	A1+	
P0.1	1	A1+	
P0.2	100	A2	
P0.3	99	A2	
P0.4	98	A2	
P0.5	97	A2	
P0.6	96	A2	
P0.7	89	A2	After a system reset, via HWSEL this pin selects the DB.TDI function.
P0.8	88	A2	After a system reset, via HWSEL this pin selects the DB. $\overline{\text{TRST}}$ function, with a weak pull-down active.
P0.9	4	A2	
P0.10	3	A1+	
P0.11	95	A1+	
P0.12	94	A1+	

General Device Information
Table 9 Package Pin Mapping (cont'd)

Function	LQFP-100	Pad Type	Notes
P1.0	79	A1+	
P1.1	78	A1+	
P1.2	77	A2	
P1.3	76	A2	
P1.4	75	A1+	
P1.5	74	A1+	
P1.6	83	A2	
P1.7	82	A2	
P1.8	81	A2	
P1.9	80	A2	
P1.10	73	A1+	
P1.11	72	A1+	
P1.12	71	A2	
P1.13	70	A2	
P1.14	69	A2	
P1.15	68	A2	
P2.0	52	A2	
P2.1	51	A2	After a system reset, via HWSEL this pin selects the DB.TDO function.
P2.2	50	A2	
P2.3	49	A2	
P2.4	48	A2	
P2.5	47	A2	
P2.6	54	A1+	
P2.7	53	A1+	
P2.8	46	A2	
P2.9	45	A2	
P2.10	44	A2	
P2.14	41	A2	
P2.15	40	A2	
P3.0	7	A2	
P3.1	6	A2	

General Device Information
Table 9 Package Pin Mapping (cont'd)

Function	LQFP-100	Pad Type	Notes
P3.2	5	A2	
P3.3	93	A1+	
P3.4	92	A1+	
P3.5	91	A2	
P3.6	90	A2	
P4.0	85	A2	
P4.1	84	A2	
P5.0	58	A1+	
P5.1	57	A1+	
P5.2	56	A1+	
P5.7	55	A1+	
P14.0	31	AN/DIG_IN	
P14.1	30	AN/DIG_IN	
P14.2	29	AN/DIG_IN	
P14.3	28	AN/DIG_IN	
P14.4	27	AN/DIG_IN	
P14.5	26	AN/DIG_IN	
P14.6	25	AN/DIG_IN	
P14.7	24	AN/DIG_IN	
P14.8	37	AN/DAC/DIG_IN	
P14.9	36	AN/DAC/DIG_IN	
P14.12	23	AN/DIG_IN	
P14.13	22	AN/DIG_IN	
P14.14	21	AN/DIG_IN	
P14.15	20	AN/DIG_IN	
P15.2	19	AN/DIG_IN	
P15.3	18	AN/DIG_IN	
P15.8	39	AN/DIG_IN	
P15.9	38	AN/DIG_IN	

General Device Information
Table 9 Package Pin Mapping (cont'd)

Function	LQFP-100	Pad Type	Notes
HIB_IO_0	14	A1 special	At the first power-up and with every reset of the hibernate domain this pin is configured as open-drain output and drives "0". As output the medium driver mode is active.
HIB_IO_1	13	A1 special	At the first power-up and with every reset of the hibernate domain this pin is configured as input with no pull device active. As output the medium driver mode is active.
USB_DP	9	special	
USB_DM	8	special	
TCK	67	A1	Weak pull-down active.
TMS	66	A1+	Weak pull-up active. As output the strong-soft driver mode is active.
PORST	65	special	Weak pull-up permanently active, strong pull-down controlled by EVR.
XTAL1	61	clock_IN	
XTAL2	62	clock_O	
RTC_XTAL1	16	clock_IN	
RTC_XTAL2	15	clock_O	
VBAT	17	Power	When VDDP is supplied VBAT has to be supplied as well.
VBUS	10	special	
VAREF	33	AN_Ref	
VAGND	32	AN_Ref	
VDDA	35	AN_Power	
VSSA	34	AN_Power	
VDDC	12	Power	
VDDC	42	Power	
VDDC	64	Power	
VDDC	86	Power	
VDDP	11	Power	

General Device Information

Table 9 Package Pin Mapping (cont'd)

Function	LQFP-100	Pad Type	Notes
VDDP	43	Power	
VDDP	60	Power	
VDDP	87	Power	
VSS	59	Power	
VSSO	63	Power	
VSS	Exp. Pad	Power	Exposed Die Pad The exposed die pad is connected internally to VSS. For proper operation, it is mandatory to connect the exposed pad directly to the common ground on the board. For thermal aspects, please refer to the Data Sheet. Board layout examples are given in an application note.

2.2.2 Port I/O Functions

The following general scheme is used to describe each Port pin:

Table 10 Port I/O Function Description

Function	Outputs			Inputs		
	ALT1	ALTn	HWO0	HWI0	Input	Input
P0.0		MODA.OUT	MODB.OUT	MODB.INA	MODC.INA	
Pn.y	MODA.OUT				MODA.INA	MODC.INB

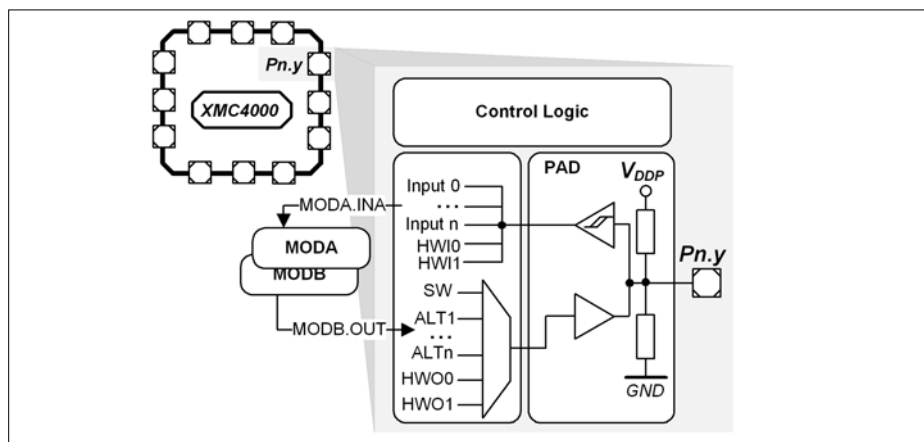


Figure 4 Simplified Port Structure

Pn.y is the port pin name, defining the control and data bits/registers associated with it. As GPIO, the port is under software control. Its input value is read via Pn_IN.y, Pn_OUT defines the output value.

Up to four alternate output functions (ALT1/2/3/4) can be mapped to a single port pin, selected by Pn_IOC.R.PC. The output value is directly driven by the respective module, with the pin characteristics controlled by the port registers (within the limits of the connected pad).

The port pin input can be connected to multiple peripherals. Most peripherals have an input multiplexer to select between different possible input sources.

The input path is also active while the pin is configured as output. This allows to feedback an output to on-chip resources without wasting an additional external pin.

By Pn_HWSEL it is possible to select between different hardware “masters” (HWO0/HWI0). The selected peripheral can take control of the pin(s). Hardware control overrules settings in the respective port pin registers.

2.2.2.1 Port I/O Function Table

Table 11 Port I/O Functions

Function	Output					Input						
	ALT1	ALT2	ALT3	ALT4	HWO0	HWI0	Input	Input	Input	Input	Input	Input
P0.0	ECAT0. PHY_RST	CAN. NO_TXD	CCU00. OUT21	LEDTS0. COL2			UIC1. DIXD	ERU0. 080				ETH0. CLKRXB
P0.1	USB. DRIVE/VEL	UIC1. DOU70		LEDTS0. COL3				ERU0. 0A0				ETH0. RXDV8
P0.2	ECAT0. PL_TXD2	UIC1. SEL01	CCU00. OUT01		UIC0. DOU73	UIC0. HWIN3	ETH0. RXDV8	ERU0. 383				
P0.3	ECAT0. PL_TXD3		CCU00. OUT20		UIC0. DOU72	UIC0. HWIN2	ETH0. RADT8		ERU1. 380			
P0.4	ETH0. TX_EN		CCU00. OUT10		UIC0. DOU71	UIC0. HWIN1	UIC0. DIXA	ERU0. 2B3			ECAT0. PL_RXD3A	
P0.5	ETH0. TXD0	UIC0. DOU70	CCU00. OUT00		UIC0. DOU70	UIC0. HWIN0	UIC0. DIXB	ERU1. 3A0			ECAT0. PL_RXD2A	
P0.6	ETH0. TXD1	UIC0. SEL00	CCU00. OUT30				UIC0. DIXA	ERU0. 382		CCU00. INB3	ECAT0. PL_RXD1A	
P0.7	WWDT. SERVICE_OUT	UIC0. SEL00	ECAT0. LED_ERR		DB. TDI		UIC0. DIXB	ERU0. 2B1		CCU00. IN3A	CCU00. IN3A	
P0.8	SCU. EXTCLK	UIC0. SELKOUT	ECAT0. LED_RUN		DB. TRST		UIC0. DIXB	ERU0. 2A1		CCU00. IN1B		
P0.9		UIC1. SEL00	CCU00. OUT12	LEDTS0. COL0	ETH0. MD0	ETH0. MD1A	UIC1. DIXA	ERU0. 1B9			ECAT0. PL_RX_DVA	
P0.10	ETH0. MD0	UIC1. SELKOUT	CCU00. OUT02	LEDTS0. COL1			UIC1. DIXA	ERU0. 1A0			ECAT0. PL_TX_CLKA	
P0.11	ECAT0. PL_LINK_ACT	UIC0. SELKOUT	CCU00. OUT31	SDMMC. RST			ETH0. RXERB	ERU0. 3A2			ECAT0. PL_RXD0A	
P0.12		UIC1. SEL00	CCU00. OUT3		ECAT0. MD0	ECAT0. MD1A	UIC1. DIXB	ERU0. 2B2				
P1.0		UIC0. SEL00	CCU00. OUT3	ERU1. PROUT3			UIC0. DIXA	ERU0. 380		CCU00. IN3A	ECAT0. PL_TX_CLKA	
P1.1		UIC0. SELKOUT	CCU00. OUT2	ERU1. PROUT2		SDMMC. SDWC	UIC0. DIXA	ERU0. 3A0		CCU00. IN2A	ECAT0. PL_RX_CLKA	
P1.2	ECAT0. P0_TXD3		CCU00. OUT1	ERU1. PROUT1	UIC0. DOU73	UIC0. HWIN3				CCU00. IN1A		
P1.3	ECAT0. P0_TX_ENA	UIC0. SELKOUT	CCU00. OUT0	ERU1. PROUT0	UIC0. DOU72	UIC0. HWIN2			ERU1. 2A0	CCU00. IN3A		
P1.4	WWDT. SERVICE_OUT	CAN. NO_TXD	CCU00. OUT33		UIC0. DOU71	UIC0. HWIN1	UIC0. DIXB	ERU0. 2B0		CCU01. IN0C	ECAT0. PL_RXD0A	
P1.5	CAN. NO_TXD	UIC0. DOU70	CCU00. OUT23		UIC0. DOU70	UIC0. HWIN0	UIC0. DIXA	ERU0. 2A0	ERU1. 0A0	CCU01. IN1C	ECAT0. PL_RXD1A	
P1.6	ECAT0. P0_TXD0	UIC0. SELKOUT		SDMMC. DATA1_OUT	SDMMC. DATA1_IN							

Table 11 Port I/O Functions (cont'd)

Function	Output				Input							
	ALT1	ALT2	ALT3	ALT4	HWO0	HWI0	Input	Input	Input	Input	Input	Input
P1.7	ECAT0. P0_TXD1	UIC0. DOUT0		UIC1. SEL02	SDMMC. DATA2_OUT	SDMMC. DATA2_IN						
P1.8	ECAT0. P0_TXD2	UIC0. SEL01			SDMMC. DATA1_OUT	SDMMC. DATA1_IN						
P1.9	UIC0. SCLKOUT			UIC1. DOUT0	SDMMC. DATA5_OUT	SDMMC. DATA5_IN						ECAT0. P0_RX_DVA
P1.10	ETH0. MDC	UIC0. SCLKOUT		ECAT0. LED_ERR		SDMMC. SDIO0				CCU41. IN2C		ECAT0. P0_RXD2A
P1.11	ECAT0. LED_STATE_R UN	UIC0. SEL03		ECAT0. LED_RUN	ETH0. MDIO	ETH0. MDIO				CCU41. IN2C		ECAT0. P0_RXD3A
P1.12	ETH0. TX_EN	CAN. M1_TXD			SDMMC. DATA3_OUT	SDMMC. DATA3_IN						
P1.13	ETH0. TXD0	UIC0. SEL03		ECAT0. PHY_CLK25	SDMMC. DATA7_OUT	CAN. M1_RXDC						
P1.14	ETH0. TXD1	UIC0. SEL02		ECAT0. SYNC0		UIC0. DX0E						
P1.15	SQU. EXTCLK			UIC0. DOUT0					ERU1. 1A0			ECAT0. P0_LIN8B
P2.0	CAN. M0_TXD			LEDTS0. COL1	ETH0. MDIO	ETH0. MDIOB		ERU0. 0B3		CCU40. IN1C		
P2.1				LEDTS0. COL0	D8.TD0/ TRACESWO	ETH0. CLK_RMIIA	ETH0.	ERU1. 0B0		CCU40. IN0C		ETH0. CLRXVA
P2.2	VAOC. EMUX00			LEDTS0. LINE9	LEDTS0. EXTENDED0	ETH0. TSN0A	ETH0. RXDVA	ERU0. 1B2		CCU41. IN3A		
P2.3	VAOC. EMUX01	UIC0. SEL00		LEDTS0. LINE1	LEDTS0. EXTENDED1	ETH0. TSN1A	ETH0. RXD1A	ERU0. 1A2		CCU41. IN3A		
P2.4	VAOC. EMUX02	UIC0. SCLKOUT		LEDTS0. LINE2	LEDTS0. EXTENDED2	ETH0. TSN2A	ETH0. RXERA	ERU0. 0B2		CCU41. IN1A		
P2.5	ETH0. TX_EN	UIC0. DOUT0		LEDTS0. LINE3	LEDTS0. EXTENDED3	ETH0. TSN3A	ETH0. RXDVA	ERU0. 0A2		CCU41. IN3A		ETH0. CRS_DVA
P2.6		ERU1. P0OUT3		LEDTS0. COL3			CAN. M1_RXDVA	ERU0. 1B3		CCU40. IN2C		ECAT0. P0_RX_ERRB
P2.7	ETH0. MDC	CAN. M1_TXD		LEDTS0. COL2				ERU1. 1B0		CCU40. IN2C		
P2.8	ETH0. TXD0	ERU1. P0OUT1		LEDTS0. LINE4	LEDTS0. EXTENDED4	DAC. TSN4A	DAC. TRIGGERS			CCU40. IN0B		CCU40. IN3B
P2.9	ETH0. TXD1	ERU1. P0OUT2		LEDTS0. LINE5	LEDTS0. EXTENDED5	ETH0. TSN5A	ETH0. TRIGGER4			CCU41. IN0B		CCU41. IN3B
P2.10	VAOC. EMUX10	ERU1. P0OUT0		ECAT0. PHY_RST								
P2.14	VAOC. EMUX11	UIC0. DOUT0						UIC0. DX0D				
P2.15	VAOC. EMUX12	ECAT0. P1_TXD3		LEDTS0. LINE6	LEDTS0. EXTENDED6	ETH0. COLA		UIC0. DX0C				

Table 11 Port I/O Functions (cont'd)

Function	Output				Input							
	ALT1	ALT2	ALT3	ALT4	HWO0	HW0	Input	Input	Input	Input	Input	Input
P3.0		UIC1_SCLKOUT		ECAT0_P1_TX_ENA			UIC1_DX1B			CCU80_IN2C		
P3.1		UIC1_SEL00	ECAT0_P1_TXD0				UIC1_D02B		ERU0_0A1	CCU80_IN1C		
P3.2	USB_DRIVE/VSUS	GAN_NO_TXD	ECAT0_P1_TXD1	LEDTS0_COLA					ERU0_0A1	CCU80_IN0C		
P3.3		UIC1_SEL01		ECAT0_MCLK	SDMMC_LED					CCU80_IN3B		
P3.4		UIC1_SEL02			SDMMC_BUS_POWER					CCU80_IN3B	ECAT0_P1_LINXA	
P3.5		UIC1_SEL03		UIC1_DOUT0	SDMMC_CMD_OUT				ERU0_3B1	ECAT0_P1_RX_ERRA		
P3.6		UIC1_SEL04		UIC1_SCLKOUT	SDMMC_CLK_OUT				ERU0_3A1			
P4.0		ECAT0_PHY_CLK25		UIC0_SCLKOUT	SDMMC_DATA0_OUT		UIC1_DX1C		UIC1_DX0E			ECAT0_P0_RX_ERRA
P4.1		UIC1_MCLKOUT		UIC0_SEL00	SDMMC_DATA1_IN							ECAT0_P0_LINXA
P5.0				ERU1_PROUT0				ETH0_RXD0D	UIC0_DX0D	ECAT0_P0_RXD0B		
P5.1	UIC0_DOUT0			ERU1_PROUT1				ETH0_RXD1D		ECAT0_P0_RXD1B		
P5.2		ECAT0_P0_LINX_ACT		ERU1_PROUT2				ETH0_GRS_DVD		ECAT0_P0_RXD2B		ETH0_RXD2D
P5.7	ECAT0_SYNC0			LEDTS0_COLA						ECAT0_P0_RXD3B		
P14.0							VADC_G0CH0					
P14.1							VADC_G0CH1					
P14.2							VADC_G0CH2					
P14.3							VADC_G0CH3			CAN_NO_RX0B		
P14.4							VADC_G0CH4					ECAT0_LATCH1A
P14.5							VADC_G0CH5					ECAT0_LATCH1A
P14.6							VADC_G0CH6					ECAT0_P1_RX_CLXB
P14.7							VADC_G0CH7					ECAT0_P1_RXD0B
P14.8					DAC_OUT_0			VADC_G1CH0		ETH0_RXD0C		
P14.9					DAC_OUT_1			VADC_G1CH1		ETH0_RXD1C		

Table 11 Port I/O Functions (cont'd)

Function	Output				Input							
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO0	HW0	Input	Input	Input	Input	Input
P14.12								VADC, G1CH4				ECAT0, P1_RXD1B
P14.13								VADC, G1CH5				ECAT0, P1_RXD2B
P14.14								VADC, G1CH6			GIORC6	ECAT0, P1_RXD3B
P14.15								VADC, G1CH7			GIORC7	ECAT0, P1_RX_DVB
P15.2												ECAT0, P1_RX_ERRB
P15.3												ECAT0, P1_LINKB
P15.8										ETH0, CLK_RMIIIC		ETH0, CLK_RXC
P15.9										ETH0, CRS_DVC		ETH0, RNDVC
HIB_IO_0	HIBOUT	WWDT, SERVICE_OUT						WAKEUPA				
HIB_IO_1	HIBOUT	WWDT, SERVICE_OUT						WAKEUPB				
USB_DP												
USB_DM												
TC0							DB_TCK/ SWCLK					
TMS						DB_TMS/ SWDIO						
PORST												
XTAL1								UIC0, DX0F		UIC0, DX0F	UIC1, DX0F	
XTAL2												
RTC_XTAL1										ERU0, IB1		
RTC_XTAL2												

2.3 Power Connection Scheme

Figure 5 shows a reference power connection scheme for the XMC4300.

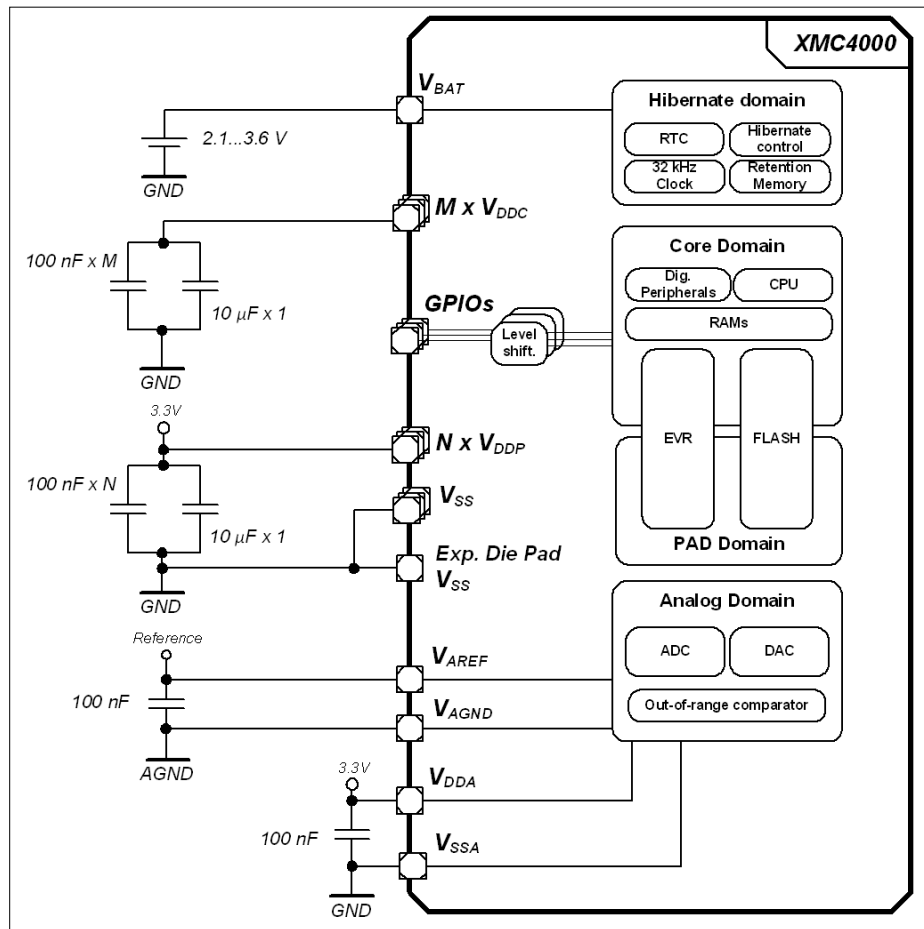


Figure 5 Power Connection Scheme

Every power supply pin needs to be connected. Different pins of the same supply need also to be externally connected. As example, all V_{DDP} pins must be connected externally to one V_{DDP} net. In this reference scheme one 100 nF capacitor is connected at each supply pin against V_{SS} . An additional 10 μF capacitor is connected to the V_{DDP} nets and an additional 10 μF capacitor to the V_{DDC} nets.

The XMC4300 has a common ground concept, all V_{SS} , V_{SSA} and V_{SSO} pins share the same ground potential. In packages with an exposed die pad it must be connected to the common ground as well.

V_{AGND} is the low potential to the analog reference V_{AREF} . Depending on the application it can share the common ground or have a different potential. In devices with shared V_{DDA}/V_{AREF} and V_{SSA}/V_{AGND} pins the reference is tied to the supply. Some analog channels can optionally serve as “Alternate Reference”; further details on this operating mode are described in the Reference Manual.

When V_{DDP} is supplied, V_{BAT} must be supplied as well. If no other supply source (e.g. battery) is connected to V_{BAT} , the V_{BAT} pin can also be connected directly to V_{DDP} .

3 Electrical Parameters

Attention: All parameters in this chapter are preliminary target values and may change based on characterization results.

3.1 General Parameters

3.1.1 Parameter Interpretation

The parameters listed in this section partly represent the characteristics of the XMC4300 and partly its requirements on the system. To aid interpreting the parameters easily when evaluating them for a design, they are marked with a two-letter abbreviation in column “Symbol”:

- **CC**
Such parameters indicate **C**ontroller **C**haracteristics, which are a distinctive feature of the XMC4300 and must be regarded for system design.
- **SR**
Such parameters indicate **S**ystem **R**equirements, which must be provided by the application system in which the XMC4300 is designed in.

3.1.2 Absolute Maximum Ratings

Stresses above the values listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Table 12 Absolute Maximum Rating Parameters

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
Storage temperature	T_{ST}	SR	-65	–	150	°C	–
Junction temperature	T_J	SR	-40	–	150	°C	–
Voltage at 3.3 V power supply pins with respect to V_{SS}	V_{DDP}	SR	–	–	4.3	V	–
Voltage on any Class A and dedicated input pin with respect to V_{SS}	V_{IN}	SR	-1.0	–	$V_{DDP} + 1.0$ or max. 4.3	V	whichever is lower
Voltage on any analog input pin with respect to V_{AGND}	V_{AIN} V_{AREF}	SR	-1.0	–	$V_{DDP} + 1.0$ or max. 4.3	V	whichever is lower
Input current on any pin during overload condition	I_{IN}	SR	-10	–	+10	mA	
Absolute maximum sum of all input circuit currents for one port group during overload condition ¹⁾	ΣI_{IN}	SR	-25	–	+25	mA	
Absolute maximum sum of all input circuit currents during overload condition	ΣI_{IN}	SR	-100	–	+100	mA	

1) The port groups are defined in [Table 16](#).

Figure 6 explains the input voltage ranges of V_{IN} and V_{AIN} and its dependency to the supply level of V_{DDP} . The input voltage must not exceed 4.3 V, and it must not be more than 1.0 V above V_{DDP} . For the range up to $V_{DDP} + 1.0$ V also see the definition of the overload conditions in **“Pin Reliability in Overload”**.

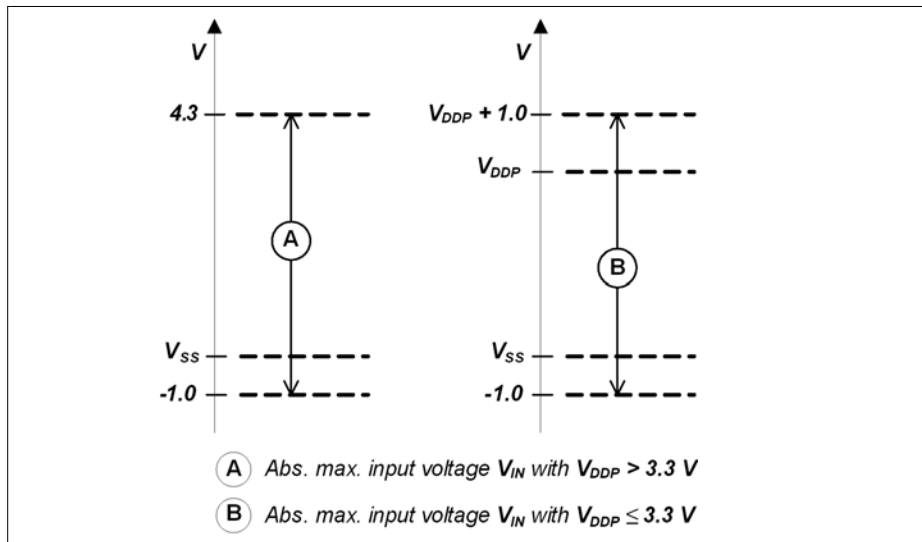


Figure 6 Absolute Maximum Input Voltage Ranges

3.1.3 Pin Reliability in Overload

When receiving signals from higher voltage devices, low-voltage devices experience overload currents and voltages that go beyond their own IO power supplies specification.

Table 13 defines overload conditions that will not cause any negative reliability impact if all the following conditions are met:

- full operation life-time is not exceeded
- **“Operating Conditions”** are met for
 - pad supply levels (V_{DDP} or V_{DDA})
 - temperature

If a pin current is outside of the **“Operating Conditions”** but within the overload conditions, then the parameters of this pin as stated in the Operating Conditions can no longer be guaranteed. Operation is still possible in most cases but with relaxed parameters.

Note: An overload condition on one or more pins does not require a reset.

Note: A series resistor at the pin to limit the current to the maximum permitted overload current is sufficient to handle failure situations like short to battery.

Table 13 Overload Parameters

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
Input current on any port pin during overload condition	I_{OV}	SR	-5	—	5	mA	
Absolute sum of all input circuit currents for one port group during overload condition ¹⁾	I_{OVG}	SR	—	—	20	mA	$\Sigma I_{OVx} $, for all $I_{OVx} < 0$ mA
			—	—	20	mA	$\Sigma I_{OVx} $, for all $I_{OVx} > 0$ mA
Absolute sum of all input circuit currents during overload condition	I_{OVS}	SR	—	—	80	mA	ΣI_{OVG}

1) The port groups are defined in [Table 16](#).

Figure 7 shows the path of the input currents during overload via the ESD protection structures. The diodes against V_{DDP} and ground are a simplified representation of these ESD protection structures.

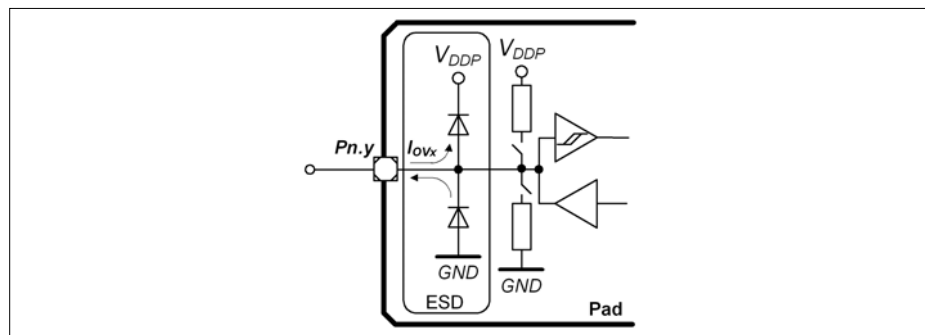


Figure 7 Input Overload Current via ESD structures

[Table 14](#) and [Table 15](#) list input voltages that can be reached under overload conditions. Note that the absolute maximum input voltages as defined in the “**Absolute Maximum Ratings**” must not be exceeded during overload.

Electrical Parameters

Table 14 PN-Junction Characteristics for positive Overload

Pad Type	$I_{OV} = 5 \text{ mA}, T_J = -40 \text{ }^{\circ}\text{C}$	$I_{OV} = 5 \text{ mA}, T_J = 150 \text{ }^{\circ}\text{C}$
A1 / A1+	$V_{IN} = V_{DDP} + 1.0 \text{ V}$	$V_{IN} = V_{DDP} + 0.75 \text{ V}$
A2	$V_{IN} = V_{DDP} + 0.7 \text{ V}$	$V_{IN} = V_{DDP} + 0.6 \text{ V}$
AN/DIG_IN	$V_{IN} = V_{DDP} + 1.0 \text{ V}$	$V_{IN} = V_{DDP} + 0.75 \text{ V}$

Table 15 PN-Junction Characteristics for negative Overload

Pad Type	$I_{OV} = 5 \text{ mA}, T_J = -40 \text{ }^{\circ}\text{C}$	$I_{OV} = 5 \text{ mA}, T_J = 150 \text{ }^{\circ}\text{C}$
A1 / A1+	$V_{IN} = V_{SS} - 1.0 \text{ V}$	$V_{IN} = V_{SS} - 0.75 \text{ V}$
A2	$V_{IN} = V_{SS} - 0.7 \text{ V}$	$V_{IN} = V_{SS} - 0.6 \text{ V}$
AN/DIG_IN	$V_{IN} = V_{DDP} - 1.0 \text{ V}$	$V_{IN} = V_{DDP} - 0.75 \text{ V}$

Table 16 Port Groups for Overload and Short-Circuit Current Sum Parameters

Group	Pins
1	P0.[12:0], P3.[6:0]
2	P14.[15:0], P15.[9:2]
3	P2.[15:0], P5.[7:0]
4	P1.[15:0], P4.[1:0]

3.1.4 Pad Driver and Pad Classes Summary

This section gives an overview on the different pad driver classes and their basic characteristics.

Table 17 Pad Driver and Pad Classes Overview

Class	Power Supply	Type	Sub-Class	Speed Grade	Load	Termination
A	3.3 V	LVTTTL I/O	A1 (e.g. GPIO)	6 MHz	100 pF	No
			A1+ (e.g. serial I/Os)	25 MHz	50 pF	Series termination recommended
			A2 (e.g. ext. Bus)	80 MHz	15 pF	Series termination recommended

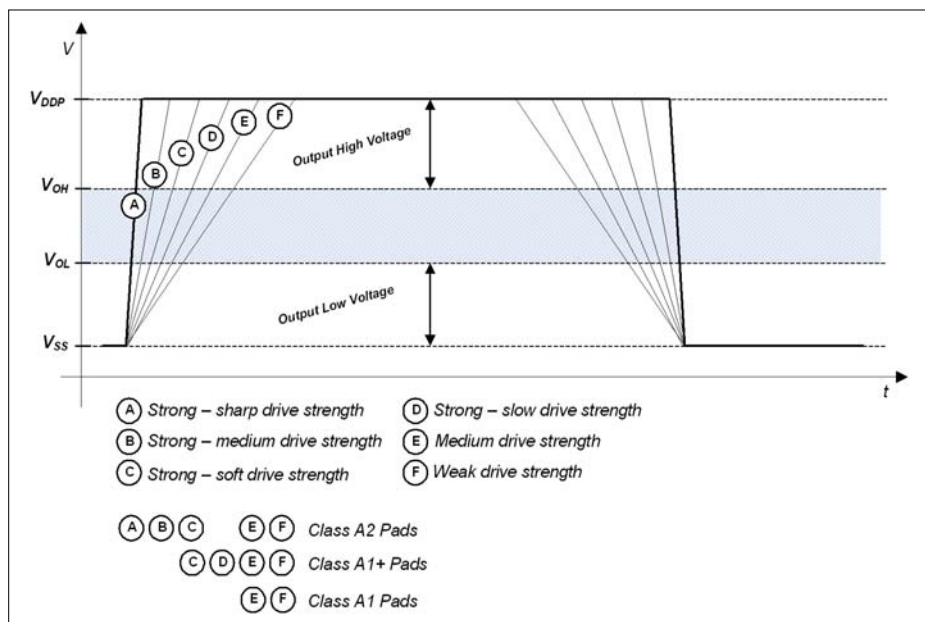


Figure 8 Output Slopes with different Pad Driver Modes

Figure 8 is a qualitative display of the resulting output slope performance with different output driver modes. The detailed input and output characteristics are listed in **“Input/Output Pins”**.

3.1.5 Operating Conditions

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the XMC4300. All parameters specified in the following sections refer to these operating conditions, unless noted otherwise.

Table 18 Operating Conditions Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Ambient Temperature	T_A SR	-40	–	85	°C	Temp. Range F
		-40	–	125	°C	Temp. Range K
Digital supply voltage	V_{DDP} SR	3.13 ¹⁾	3.3	3.63 ²⁾	V	
Core Supply Voltage	V_{DDC} CC	– ¹⁾	1.3	–	V	Generated internally
Digital ground voltage	V_{SS} SR	0	–	–	V	
ADC analog supply voltage	V_{DDA} SR	3.0	3.3	3.6 ²⁾	V	
Analog ground voltage for V_{DDA}	V_{SSA} SR	-0.1	0	0.1	V	
Battery Supply Voltage for Hibernate Domain	V_{BAT} SR	1.95 ³⁾	–	3.63	V	When V_{DDP} is supplied V_{BAT} has to be supplied as well.
System Frequency	f_{SYS} SR	–	–	144	MHz	
Short circuit current of digital outputs	I_{SC} SR	-5	–	5	mA	
Absolute sum of short circuit currents per pin group ⁴⁾	ΣI_{SC_PG} SR	–	–	20	mA	
Absolute sum of short circuit currents of the device	ΣI_{SC_D} SR	–	–	100	mA	

1) See also the Supply Monitoring thresholds, “**Power-Up and Supply Monitoring**”.

2) Voltage overshoot to 4.0 V is permissible at Power-Up and $\overline{PORST}$ low, provided the pulse duration is less than 100 μ s and the cumulated sum of the pulses does not exceed 1 h over lifetime.

3) To start the hibernate domain it is required that $V_{BAT} \geq 2.1$ V, for a reliable start of the oscillation of RTC_XTAL in crystal mode it is required that $V_{BAT} \geq 3.0$ V.

4) The port groups are defined in [Table 16](#).

3.2 DC Parameters

3.2.1 Input/Output Pins

The digital input stage of the shared analog/digital input pins is identical to the input stage of the standard digital input/output pins.

The Pull-up on the $\overline{\text{PORST}}$ pin is identical to the Pull-up on the standard digital input/output pins.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 19 Standard Pad Parameters

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Pin capacitance (digital inputs/outputs)	C_{IO} CC	–	10	pF	
Pull-down current	$ I_{\text{PDL}} $ SR	150	–	μA	$^1)V_{\text{IN}} \geq 0.6 \times V_{\text{DDP}}$
		–	10	μA	$^2)V_{\text{IN}} \leq 0.36 \times V_{\text{DDP}}$
Pull-Up current	$ I_{\text{PUH}} $ SR	–	10	μA	$^2)V_{\text{IN}} \geq 0.6 \times V_{\text{DDP}}$
		100	–	μA	$^1)V_{\text{IN}} \leq 0.36 \times V_{\text{DDP}}$
Input Hysteresis for pads of all A classes ³⁾	HYSA CC	$0.1 \times V_{\text{DDP}}$	–	V	
$\overline{\text{PORST}}$ spike filter always blocked pulse duration	t_{SF1} CC	–	10	ns	
$\overline{\text{PORST}}$ spike filter pass-through pulse duration	t_{SF2} CC	100	–	ns	
$\overline{\text{PORST}}$ pull-down current	$ I_{\text{PPD}} $ CC	13	–	mA	$V_{\text{IN}} = 1.0 \text{ V}$

1) Current required to override the pull device with the opposite logic level ("force current").

With active pull device, at load currents between force and keep current the input state is undefined.

2) Load current at which the pull device still maintains the valid logic level ("keep current").

With active pull device, at load currents between force and keep current the input state is undefined.

3) Hysteresis is implemented to avoid metastable states and switching due to internal ground bounce. It can not be guaranteed that it suppresses switching due to external system noise.

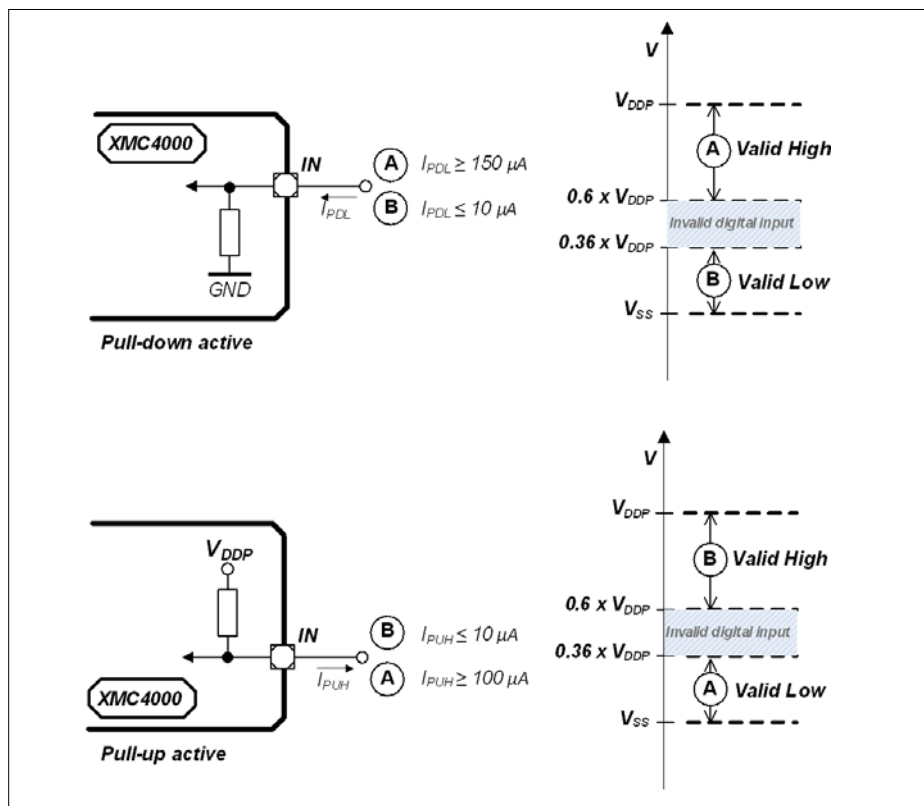


Figure 9 Pull Device Input Characteristics

Figure 9 visualizes the input characteristics with an active internal pull device:

- in the cases "A" the internal pull device is overridden by a strong external driver;
- in the cases "B" the internal pull device defines the input logical state against a weak external load.

Electrical Parameters
Table 20 Standard Pads Class_A1

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input leakage current	I_{OZA1} CC	-500	500	nA	$0\text{ V} \leq V_{\text{IN}} \leq V_{\text{DDP}}$
Input high voltage	V_{IHA1} SR	$0.6 \times V_{\text{DDP}}$	$V_{\text{DDP}} + 0.3$	V	max. 3.6 V
Input low voltage	V_{ILA1} SR	-0.3	$0.36 \times V_{\text{DDP}}$	V	
Output high voltage, POD ⁽¹⁾ = weak	V_{OHA1} CC	$V_{\text{DDP}} - 0.4$	–	V	$I_{\text{OH}} \geq -400\text{ }\mu\text{A}$
		2.4	–	V	$I_{\text{OH}} \geq -500\text{ }\mu\text{A}$
Output high voltage, POD ⁽¹⁾ = medium		$V_{\text{DDP}} - 0.4$	–	V	$I_{\text{OH}} \geq -1.4\text{ mA}$
		2.4	–	V	$I_{\text{OH}} \geq -2\text{ mA}$
Output low voltage	V_{OLA1} CC	–	0.4	V	$I_{\text{OL}} \leq 500\text{ }\mu\text{A};$ POD ⁽¹⁾ = weak
		–	0.4	V	$I_{\text{OL}} \leq 2\text{ mA};$ POD ⁽¹⁾ = medium
Fall time	t_{FA1} CC	–	150	ns	$C_{\text{L}} = 20\text{ pF};$ POD ⁽¹⁾ = weak
		–	50	ns	$C_{\text{L}} = 50\text{ pF};$ POD ⁽¹⁾ = medium
Rise time	t_{RA1} CC	–	150	ns	$C_{\text{L}} = 20\text{ pF};$ POD ⁽¹⁾ = weak
		–	50	ns	$C_{\text{L}} = 50\text{ pF};$ POD ⁽¹⁾ = medium

1) POD = Pin Out Driver

Table 21 Standard Pads Class_A1+

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input leakage current	I_{OZA1+} CC	-1	1	μA	$0\text{ V} \leq V_{IN} \leq V_{DDP}$
Input high voltage	V_{IHA1+} SR	$0.6 \times V_{DDP}$	$V_{DDP} + 0.3$	V	max. 3.6 V
Input low voltage	V_{ILA1+} SR	-0.3	$0.36 \times V_{DDP}$	V	

Electrical Parameters
Table 21 Standard Pads Class_A1+

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Output high voltage, POD ¹⁾ = weak	V _{OHA1+} CC	V _{DDP} - 0.4	–	V	I _{OH} ≥ -400 μA
		2.4	–	V	I _{OH} ≥ -500 μA
Output high voltage, POD ¹⁾ = medium		V _{DDP} - 0.4	–	V	I _{OH} ≥ -1.4 mA
		2.4	–	V	I _{OH} ≥ -2 mA
Output high voltage, POD ¹⁾ = strong		V _{DDP} - 0.4	–	V	I _{OH} ≥ -1.4 mA
		2.4	–	V	I _{OH} ≥ -2 mA
Output low voltage	V _{OLA1+} CC	–	0.4	V	I _{OL} ≤ 500 μA; POD ¹⁾ = weak
		–	0.4	V	I _{OL} ≤ 2 mA; POD ¹⁾ = medium
		–	0.4	V	I _{OL} ≤ 2 mA; POD ¹⁾ = strong
Fall time	t _{FA1+} CC	–	150	ns	C _L = 20 pF; POD ¹⁾ = weak
		–	50	ns	C _L = 50 pF; POD ¹⁾ = medium
		–	28	ns	C _L = 50 pF; POD ¹⁾ = strong; edge = slow
		–	16	ns	C _L = 50 pF; POD ¹⁾ = strong; edge = soft;
Rise time	t _{RA1+} CC	–	150	ns	C _L = 20 pF; POD ¹⁾ = weak
		–	50	ns	C _L = 50 pF; POD ¹⁾ = medium
		–	28	ns	C _L = 50 pF; POD ¹⁾ = strong; edge = slow
		–	16	ns	C _L = 50 pF; POD ¹⁾ = strong; edge = soft

1) POD = Pin Out Driver

Table 22 Standard Pads Class_A2

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input Leakage current	I_{OZA2} CC	-6	6	μA	$0\text{ V} \leq V_{\text{IN}} < 0.5 \cdot V_{\text{DDP}} - 1\text{ V};$ $0.5 \cdot V_{\text{DDP}} + 1\text{ V} < V_{\text{IN}} \leq V_{\text{DDP}}$
		-3	3	μA	$0.5 \cdot V_{\text{DDP}} - 1\text{ V} < V_{\text{IN}} < 0.5 \cdot V_{\text{DDP}} + 1\text{ V}$
Input high voltage	V_{IHA2} SR	$0.6 \times V_{\text{DDP}}$	$V_{\text{DDP}} + 0.3$	V	max. 3.6 V
Input low voltage	V_{ILA2} SR	-0.3	$0.36 \times V_{\text{DDP}}$	V	
Output high voltage, POD = weak	V_{OHA2} CC	$V_{\text{DDP}} - 0.4$	—	V	$I_{\text{OH}} \geq -400\text{ }\mu\text{A}$
		2.4	—	V	$I_{\text{OH}} \geq -500\text{ }\mu\text{A}$
Output high voltage, POD = medium		$V_{\text{DDP}} - 0.4$	—	V	$I_{\text{OH}} \geq -1.4\text{ mA}$
		2.4	—	V	$I_{\text{OH}} \geq -2\text{ mA}$
Output high voltage, POD = strong		$V_{\text{DDP}} - 0.4$	—	V	$I_{\text{OH}} \geq -1.4\text{ mA}$
		2.4	—	V	$I_{\text{OH}} \geq -2\text{ mA}$
Output low voltage, POD = weak	V_{OLA2} CC	—	0.4	V	$I_{\text{OL}} \leq 500\text{ }\mu\text{A}$
Output low voltage, POD = medium		—	0.4	V	$I_{\text{OL}} \leq 2\text{ mA}$
Output low voltage, POD = strong		—	0.4	V	$I_{\text{OL}} \leq 2\text{ mA}$

Electrical Parameters
Table 22 Standard Pads Class_A2

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Fall time	t_{FA2} CC	—	150	ns	$C_L = 20$ pF; POD = weak
		—	50	ns	$C_L = 50$ pF; POD = medium
		—	3.7	ns	$C_L = 50$ pF; POD = strong; edge = sharp
		—	7	ns	$C_L = 50$ pF; POD = strong; edge = medium
		—	16	ns	$C_L = 50$ pF; POD = strong; edge = soft
Rise time	t_{RA2} CC	—	150	ns	$C_L = 20$ pF; POD = weak
		—	50	ns	$C_L = 50$ pF; POD = medium
		—	3.7	ns	$C_L = 50$ pF; POD = strong; edge = sharp
		—	7.0	ns	$C_L = 50$ pF; POD = strong; edge = medium
		—	16	ns	$C_L = 50$ pF; POD = strong; edge = soft

Table 23 HIB_IO Class_A1 special Pads

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input leakage current	I_{OZHIB} CC	-500	500	nA	$0\text{ V} \leq V_{IN} \leq V_{BAT}$
Input high voltage	V_{IHIB} SR	$0.6 \times V_{BAT}$	$V_{BAT} + 0.3$	V	max. 3.6 V
Input low voltage	V_{ILIB} SR	-0.3	$0.36 \times V_{BAT}$	V	
Input Hysteresis for HIB_IO pins ¹⁾	$HYSHIB$ CC	$0.1 \times V_{BAT}$	–	V	$V_{BAT} \geq 3.13\text{ V}$
		$0.06 \times V_{BAT}$	–	V	$V_{BAT} < 3.13\text{ V}$
Output high voltage, POD ¹⁾ = medium	V_{OHIB} CC	$V_{BAT} - 0.4$	–	V	$I_{OH} \geq -1.4\text{ mA}$
Output low voltage	V_{OLIB} CC	–	0.4	V	$I_{OL} \leq 2\text{ mA}$
Fall time	t_{FHIB} CC	–	50	ns	$V_{BAT} \geq 3.13\text{ V}$ $C_L = 50\text{ pF}$
		–	100	ns	$V_{BAT} < 3.13\text{ V}$ $C_L = 50\text{ pF}$
Rise time	t_{RHIB} CC	–	50	ns	$V_{BAT} \geq 3.13\text{ V}$ $C_L = 50\text{ pF}$
		–	100	ns	$V_{BAT} < 3.13\text{ V}$ $C_L = 50\text{ pF}$

1) Hysteresis is implemented to avoid metastable states and switching due to internal ground bounce. It can not be guaranteed that it suppresses switching due to external system noise.

3.2.2 Analog to Digital Converters (VADC)

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 24 VADC Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Analog reference voltage ⁵⁾	V_{AREF} SR	$V_{AGND} + 1$	–	$V_{DDA} + 0.05^{1)}$	V	
Analog reference ground ⁵⁾	V_{AGND} SR	$V_{SSM} - 0.05$	–	$V_{AREF} - 1$	V	
Analog reference voltage range ²⁾⁵⁾	$V_{AREF} - V_{AGND}$ SR	1	–	$V_{DDA} + 0.1$	V	
Analog input voltage	V_{AIN} SR	V_{AGND}	–	V_{DDA}	V	
Input leakage at analog inputs ³⁾	I_{OZ1} CC	-100	–	200	nA	$0.03 \times V_{DDA} < V_{AIN} < 0.97 \times V_{DDA}$
		-500	–	100	nA	$0 \text{ V} \leq V_{AIN} \leq 0.03 \times V_{DDA}$
		-100	–	500	nA	$0.97 \times V_{DDA} \leq V_{AIN} \leq V_{DDA}$
Input leakage current at VAREF	I_{OZ2} CC	-1	–	1	μA	$0 \text{ V} \leq V_{AREF} \leq V_{DDA}$
Input leakage current at VAGND	I_{OZ3} CC	-1	–	1	μA	$0 \text{ V} \leq V_{AGND} \leq V_{DDA}$
Internal ADC clock	f_{ADCI} CC	2	–	36	MHz	$V_{DDA} = 3.3 \text{ V}$
Switched capacitance at the analog voltage inputs ⁴⁾	C_{AINSW} CC	–	4	6.5	pF	
Total capacitance of an analog input	C_{AINTOT} CC	–	12	20	pF	
Switched capacitance at the positive reference voltage input ⁵⁾⁶⁾	C_{AREFSW} CC	–	15	30	pF	
Total capacitance of the voltage reference inputs ⁵⁾	$C_{AREFTOT}$ CC	–	20	40	pF	

Electrical Parameters
Table 24 VADC Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Total Unadjusted Error	TUE_{CC}	-4	–	4	LSB	12-bit resolution; $V_{DDA} = 3.3\text{ V}$; $V_{AREF} = V_{DDA}$ ⁷⁾
Differential Non-Linearity Error ⁸⁾	$EA_{DNL_{CC}}$	-3	–	3	LSB	
Gain Error ⁸⁾	$EA_{GAIN_{CC}}$	-4	–	4	LSB	
Integral Non-Linearity ⁸⁾	$EA_{INL_{CC}}$	-3	–	3	LSB	
Offset Error ⁸⁾	$EA_{OFF_{CC}}$	-4	–	4	LSB	
RMS Noise ⁹⁾	$EN_{RMS_{CC}}$	–	1	2 ¹⁰⁾¹¹⁾	LSB	
Worst case ADC V_{DDA} power supply current per active converter	$I_{DDAA_{CC}}$	–	1.5	2	mA	during conversion $V_{DDP} = 3.6\text{ V}$, $T_J = 150\text{ °C}$
Charge consumption on V_{AREF} per conversion ⁵⁾	$Q_{CONV_{CC}}$	–	30	–	pC	$0\text{ V} \leq V_{AREF} \leq V_{DDA}$ ¹²⁾
ON resistance of the analog input path	$R_{AIN_{CC}}$	–	600	1 200	Ohm	
ON resistance for the ADC test (pull down for AIN7)	$R_{AIN7T_{CC}}$	180	550	900	Ohm	
Resistance of the reference voltage input path	$R_{AREF_{CC}}$	–	700	1 700	Ohm	

- 1) A running conversion may become imprecise in case the normal conditions are violated (voltage overshoot).
- 2) If the analog reference voltage is below V_{DDA} , then the ADC converter errors increase. If the reference voltage is reduced by the factor k ($k < 1$), TUE, DNL, INL, Gain, and Offset errors increase also by the factor $1/k$.
- 3) The leakage current definition is a continuous function, as shown in figure ADCx Analog Inputs Leakage. The numerical values defined determine the characteristic points of the given continuous linear approximation - they do not define step function (see [Figure 12](#)).
- 4) The sampling capacity of the conversion C-network is pre-charged to $V_{AREF}/2$ before the sampling moment. Because of the parasitic elements, the voltage measured at AINx can deviate from $V_{AREF}/2$.
- 5) Applies to AINx, when used as alternate reference input.
- 6) This represents an equivalent switched capacitance. This capacitance is not switched to the reference voltage at once. Instead, smaller capacitances are successively switched to the reference voltage.
- 7) For 10-bit conversions, the errors are reduced to 1/4; for 8-bit conversions, the errors are reduced to 1/16. Never less than ± 1 LSB.
- 8) The sum of DNL/INL/GAIN/OFF errors does not exceed the related total unadjusted error TUE.

Electrical Parameters

- 9) This parameter is valid for soldered devices and requires careful analog board design.
- 10) Resulting worst case combined error is arithmetic combination of TUE and EN_{RMS} .
- 11) Value is defined for one sigma Gauss distribution.
- 12) The resulting current for a conversion can be calculated with $I_{AREF} = Q_{CONV} / t_c$.
The fastest 12-bit post-calibrated conversion of $t_c = 459$ ns results in a typical average current of $I_{AREF} = 65.4 \mu A$.

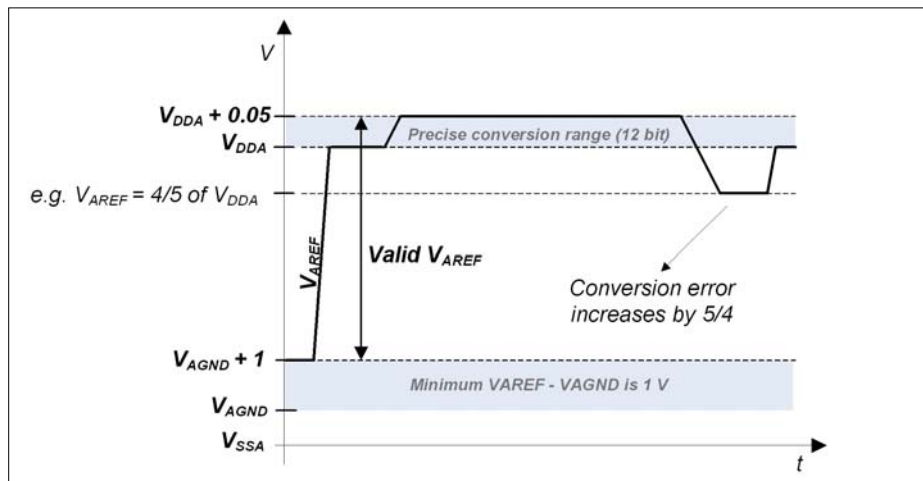


Figure 10 VADC Reference Voltage Range

The power-up calibration of the VADC requires a maximum number of $4\ 352 f_{ADCI}$ cycles.

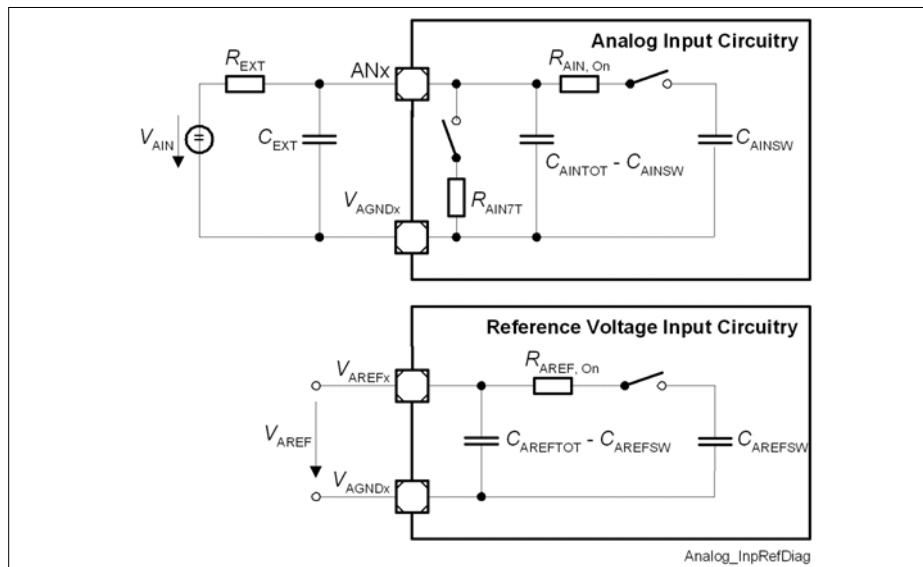


Figure 11 VADC Input Circuits

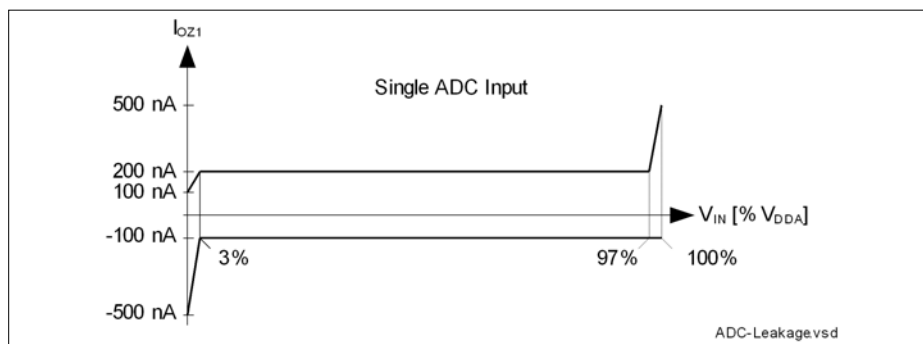


Figure 12 VADC Analog Input Leakage Current

Conversion Time

Table 25 Conversion Time (Operating Conditions apply)

Parameter	Symbol	Values	Unit	Note
Conversion time	t_C CC	$2 \times T_{ADC} + (2 + N + STC + PC + DM) \times T_{ADCI}$	μs	N = 8, 10, 12 for N-bit conversion $T_{ADC} = 1 / f_{PERIPH}$ $T_{ADCI} = 1 / f_{ADCI}$

- STC defines additional clock cycles to extend the sample time
- PC adds two cycles if post-calibration is enabled
- DM adds one cycle for an extended conversion time of the MSB

Conversion Time Examples

System assumptions:

$f_{ADC} = 144 \text{ MHz}$ i.e. $t_{ADC} = 6.9 \text{ ns}$, DIVA = 3, $f_{ADCI} = 36 \text{ MHz}$ i.e. $t_{ADCI} = 27.8 \text{ ns}$

According to the given formulas the following minimum conversion times can be achieved (STC = 0, DM = 0):

12-bit post-calibrated conversion (PC = 2):

$$t_{CN12C} = (2 + 12 + 2) \times t_{ADCI} + 2 \times t_{ADC} = 16 \times 27.8 \text{ ns} + 2 \times 6.9 \text{ ns} = 459 \text{ ns}$$

12-bit uncalibrated conversion:

$$t_{CN12} = (2 + 12) \times t_{ADCI} + 2 \times t_{ADC} = 14 \times 27.8 \text{ ns} + 2 \times 6.9 \text{ ns} = 403 \text{ ns}$$

10-bit uncalibrated conversion:

$$t_{CN10} = (2 + 10) \times t_{ADCI} + 2 \times t_{ADC} = 12 \times 27.8 \text{ ns} + 2 \times 6.9 \text{ ns} = 348 \text{ ns}$$

8-bit uncalibrated:

$$t_{CN8} = (2 + 8) \times t_{ADCI} + 2 \times t_{ADC} = 10 \times 27.8 \text{ ns} + 2 \times 6.9 \text{ ns} = 292 \text{ ns}$$

Electrical Parameters
3.2.3 Digital to Analog Converters (DAC)

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 26 DAC Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
RMS supply current	I_{DD} CC	–	2.5	4	mA	per active DAC channel, without load currents of DAC outputs
Resolution	RES CC	–	12	–	Bit	
Update rate	f_{URATE_A} CC	–		2	Msample/s	data rate, where DAC can follow 64 LSB code jumps to ± 1 LSB accuracy
Update rate	f_{URATE_F} CC	–		5	Msample/s	data rate, where DAC can follow 64 LSB code jumps to ± 4 LSB accuracy
Settling time	t_{SETTLE} CC	–	1	2	μ s	at full scale jump, output voltage reaches target value ± 20 LSB
Slew rate	SR CC	2	5	–	V/ μ s	
Minimum output voltage	V_{OUT_MIN} CC	–	0.3	–	V	code value unsigned: 000 _H ; signed: 800 _H
Maximum output voltage	V_{OUT_MAX} CC	–	2.5	–	V	code value unsigned: FFF _H ; signed: 7FF _H
Integral non-linearity	INL CC	-5.5	± 2.5	5.5	LSB	$R_L \geq 5$ kOhm, $C_L \leq 50$ pF
Differential non-linearity	DNL CC	-2	± 1	2	LSB	$R_L \geq 5$ kOhm, $C_L \leq 50$ pF
Offset error	ED_{OFF} CC		± 20		mV	

Electrical Parameters
Table 26 DAC Parameters (Operating Conditions apply) (cont'd)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Gain error	ED_{G_IN} CC	-6.5	-1.5	3	%	
Startup time	$t_{STARTUP}$ CC	–	15	30	μs	time from output enabling till code valid ± 16 LSB
3dB Bandwidth of Output Buffer	f_{C1} CC	2.5	5	–	MHz	verified by design
Output sourcing current	I_{OUT_SOURCE} CC	–	-30	–	mA	
Output sinking current	I_{OUT_SINK} CC	–	0.6	–	mA	
Output resistance	R_{OUT} CC	–	50	–	Ohm	
Load resistance	R_L SR	5	–	–	kOhm	
Load capacitance	C_L SR	–	–	50	pF	
Signal-to-Noise Ratio	SNR CC	–	70	–	dB	examination bandwidth < 25 kHz
Total Harmonic Distortion	THD CC	–	70	–	dB	examination bandwidth < 25 kHz
Power Supply Rejection Ratio	$PSRR$ CC	–	56	–	dB	to V_{DDA} verified by design

Conversion Calculation

Unsigned:

$$DACxDATA = 4095 \times (V_{OUT} - V_{OUT_MIN}) / (V_{OUT_MAX} - V_{OUT_MIN})$$

Signed:

$$DACxDATA = 4095 \times (V_{OUT} - V_{OUT_MIN}) / (V_{OUT_MAX} - V_{OUT_MIN}) - 2048$$

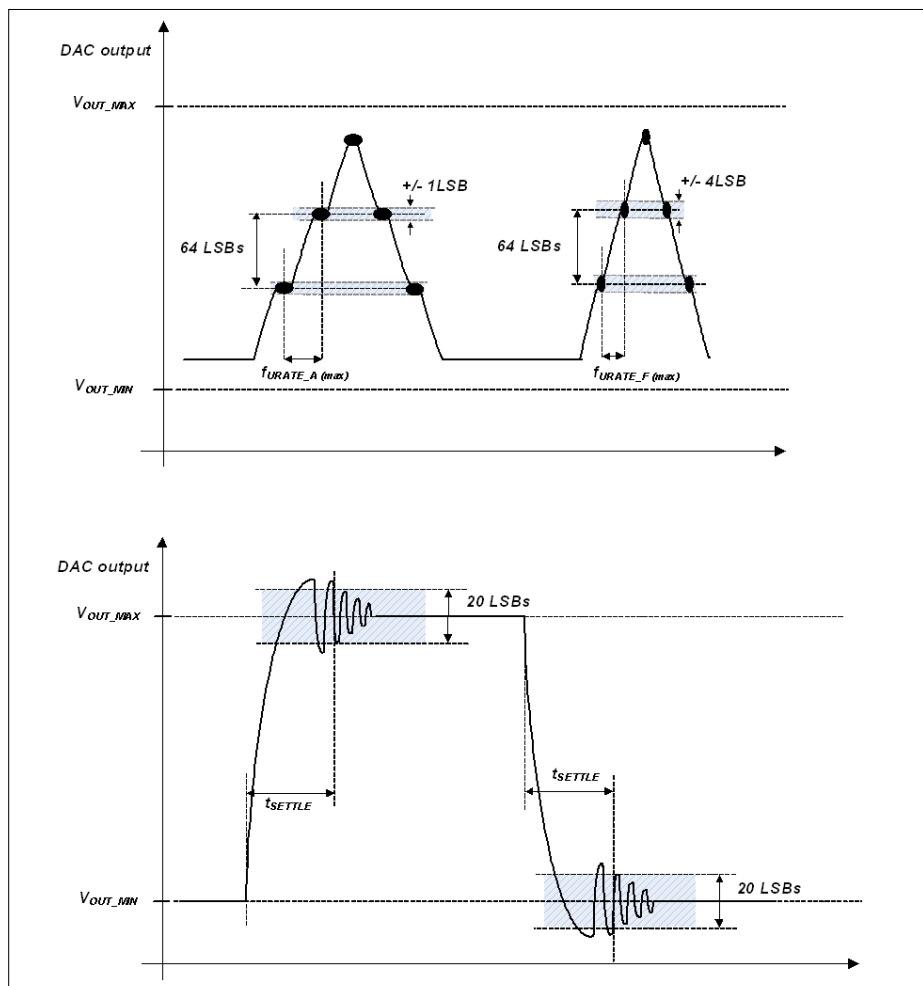


Figure 13 DAC Conversion Examples

Electrical Parameters
3.2.4 Out-of-Range Comparator (ORC)

The Out-of-Range Comparator (ORC) triggers on analog input voltages (V_{AIN}) above the analog reference¹⁾ (V_{AREF}) on selected input pins (GxORCy) and generates a service request trigger (GxORCOUTy).

Note: These parameters are not subject to production test, but verified by design and/or characterization.

The parameters in **Table 27** apply for the maximum reference voltage $V_{AREF} = V_{DDA} + 50 \text{ mV}$.

Table 27 ORC Parameters (Operating Conditions apply)

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
DC Switching Level	V_{ODC}	CC	100	125	210	mV	$V_{AIN} \geq V_{AREF} + V_{ODC}$
Hysteresis	V_{OHYS}	CC	50	–	V_{ODC}	mV	
Detection Delay of a persistent Overvoltage	t_{ODD}	CC	50	–	450	ns	$V_{AIN} \geq V_{AREF} + 210 \text{ mV}$
			45	–	105	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Always detected Overvoltage Pulse	t_{OPDD}	CC	440	–	–	ns	$V_{AIN} \geq V_{AREF} + 210 \text{ mV}$
			90	–	–	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Never detected Overvoltage Pulse	t_{OPDN}	CC	–	–	45	ns	$V_{AIN} \geq V_{AREF} + 210 \text{ mV}$
			–	–	30	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Release Delay	t_{ORD}	CC	65	–	105	ns	$V_{AIN} \leq V_{AREF}$
Enable Delay	t_{OED}	CC	–	100	200	ns	

1) Always the standard VADC reference, alternate references do not apply to the ORC.

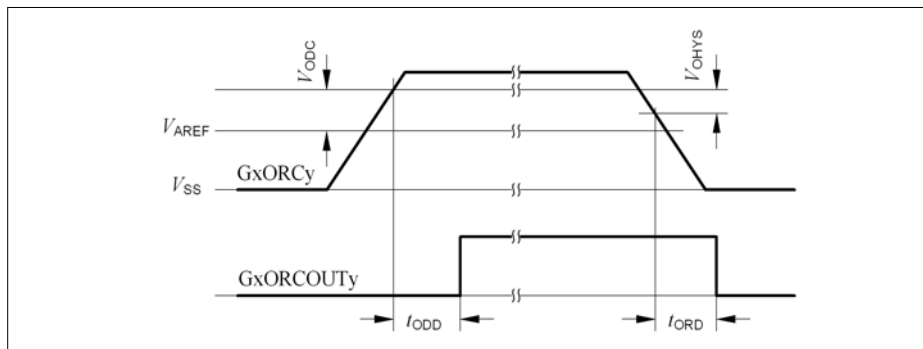


Figure 14 GxORCOUTy Trigger Generation

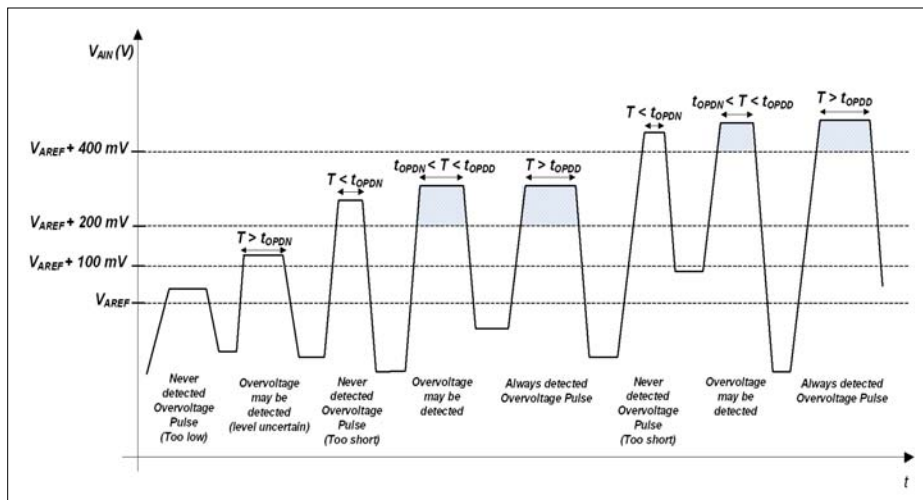


Figure 15 ORC Detection Ranges

3.2.5 Die Temperature Sensor

The Die Temperature Sensor (DTS) measures the junction temperature T_J .

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 28 Die Temperature Sensor Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Temperature sensor range	T_{SR} SR	-40	–	150	°C	
Linearity Error (to the below defined formula)	ΔT_{LE} CC	–	±1	–	°C	per $\Delta T_J \leq 30$ °C
Offset Error	ΔT_{OE} CC	–	±6	–	°C	$\Delta T_{OE} = T_J - T_{DTS}$ $V_{DDP} \leq 3.3$ V ¹⁾
Measurement time	t_M CC	–	–	100	µs	
Start-up time after reset inactive	t_{TSST} SR	–	–	10	µs	

1) At $V_{DDP_max} = 3.63$ V the typical offset error increases by an additional $\Delta T_{OE} = \pm 1$ °C.

The following formula calculates the temperature measured by the DTS in [°C] from the RESULT bit field of the DTSSTAT register.

$$\text{Temperature } T_{DTS} = (\text{RESULT} - 605) / 2.05 \text{ [°C]}$$

This formula and the values defined in **Table 28** apply with the following calibration values:

- DTSCON.BGTRIM = 8_H
- DTSCON.REFTRIM = 4_H

3.2.6 USB OTG Interface DC Characteristics

The Universal Serial Bus (USB) Interface is compliant to the USB Rev. 2.0 Specification and the OTG Specification Rev. 1.3. High-Speed Mode is not supported.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 29 USB OTG VBUS and ID Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
VBUS input voltage range	V_{IN} CC	0.0	–	5.25	V	
A-device VBUS valid threshold	V_{B1} CC	4.4	–	–	V	
A-device session valid threshold	V_{B2} CC	0.8	–	2.0	V	
B-device session valid threshold	V_{B3} CC	0.8	–	4.0	V	
B-device session end threshold	V_{B4} CC	0.2	–	0.8	V	
VBUS input resistance to ground	R_{VBUS_IN} CC	40	–	100	kOhm	
B-device VBUS pull-up resistor	R_{VBUS_PU} CC	281	–	–	Ohm	Pull-up voltage = 3.0 V
B-device VBUS pull-down resistor	R_{VBUS_PD} CC	656	–	–	Ohm	
USB.ID pull-up resistor	R_{UID_PU} CC	14	–	25	kOhm	
VBUS input current	I_{VBUS_IN} CC	–	–	150	μA	$0\text{ V} \leq V_{IN} \leq 5.25\text{ V}$: $T_{AVG} = 1\text{ ms}$

Electrical Parameters
Table 30 USB OTG Data Line (USB_DP, USB_DM) Parameters (Operating Conditions apply)

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
Input low voltage	V_{IL}	SR	–	–	0.8	V	
Input high voltage (driven)	V_{IH}	SR	2.0	–	–	V	
Input high voltage (floating) ¹⁾	V_{IHZ}	SR	2.7	–	3.6	V	
Differential input sensitivity	V_{DIS}	CC	0.2	–	–	V	
Differential common mode range	V_{CM}	CC	0.8	–	2.5	V	
Output low voltage	V_{OL}	CC	0.0	–	0.3	V	1.5 kOhm pull-up to 3.6 V
Output high voltage	V_{OH}	CC	2.8	–	3.6	V	15 kOhm pull-down to 0 V
DP pull-up resistor (idle bus)	R_{PUI}	CC	900	–	1 575	Ohm	
DP pull-up resistor (upstream port receiving)	R_{PUA}	CC	1 425	–	3 090	Ohm	
DP, DM pull-down resistor	R_{PD}	CC	14.25	–	24.8	kOhm	
Input impedance DP, DM	Z_{INP}	CC	300	–	–	kOhm	$0\text{ V} \leq V_{IN} \leq V_{DDP}$
Driver output resistance DP, DM	Z_{DRV}	CC	28	–	44	Ohm	

1) Measured at A-connector with 1.5 kOhm $\pm$ 5% to 3.3 V $\pm$ 0.3 V connected to USB_DP or USB_DM and at B-connector with 15 kOhm $\pm$ 5% to ground connected to USB_DP and USB_DM.

3.2.7 Oscillator Pins

Note: It is strongly recommended to measure the oscillation allowance (negative resistance) in the final target system (layout) to determine the optimal parameters for the oscillator operation. Please refer to the limits specified by the crystal or ceramic resonator supplier.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

The oscillator pins can be operated with an external crystal (see [Figure 16](#)) or in direct input mode (see [Figure 17](#)).

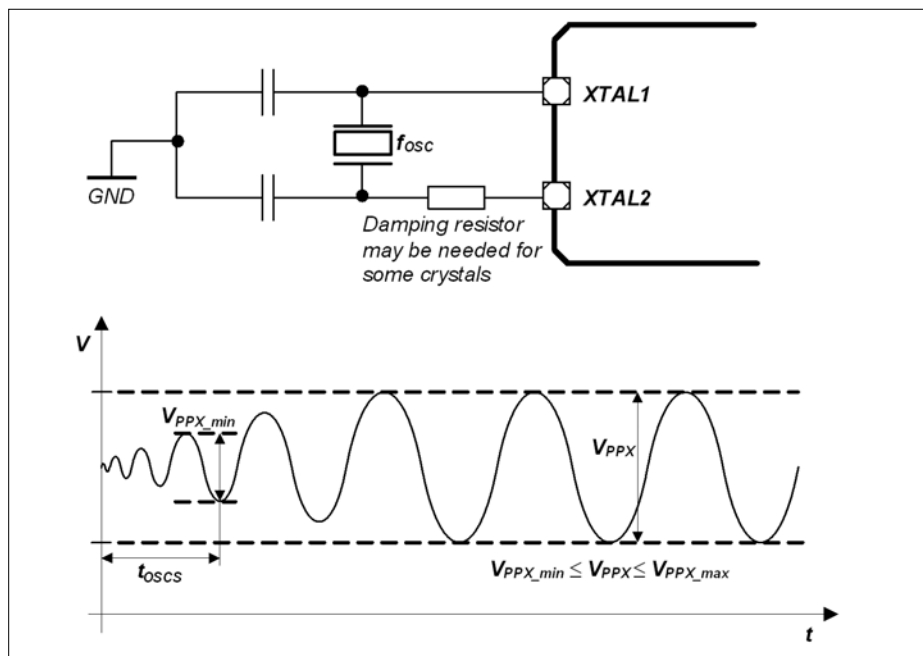


Figure 16 Oscillator in Crystal Mode

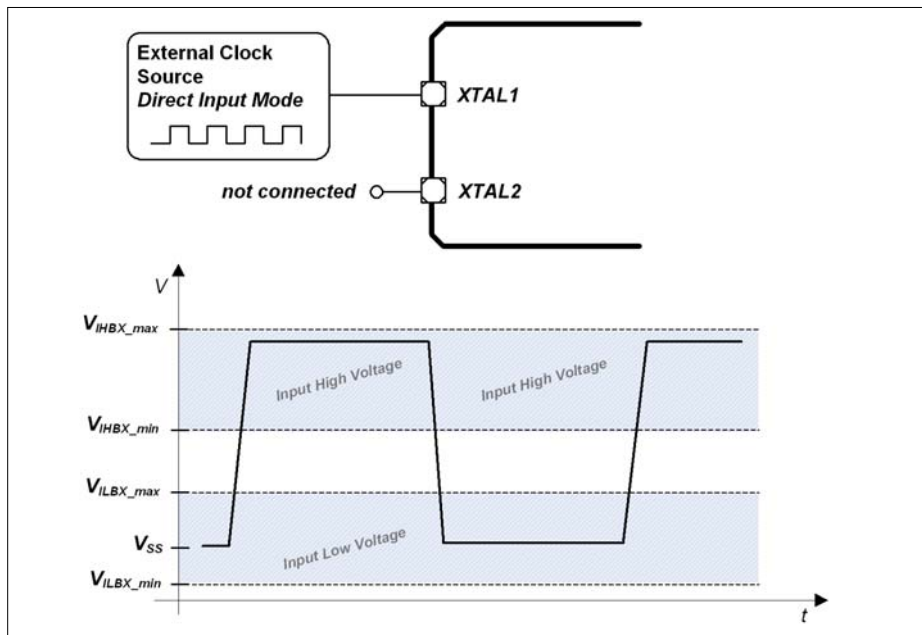


Figure 17 **Oscillator in Direct Input Mode**

Table 31 OSC_XTAL Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input frequency	f_{OSC} SR	4	–	40	MHz	Direct Input Mode selected
		4	–	25	MHz	External Crystal Mode selected
Oscillator start-up time ¹⁾²⁾	t_{OSCS} CC	–	–	10	ms	
Input voltage at XTAL1	V_{IX} SR	-0.5	–	$V_{\text{DDP}} + 0.5$	V	
Input amplitude (peak-to-peak) at XTAL1 ²⁾³⁾	V_{PPX} SR	$0.4 \times V_{\text{DDP}}$	–	$V_{\text{DDP}} + 1.0$	V	
Input high voltage at XTAL1 ⁴⁾	V_{IHBX} SR	1.0	–	$V_{\text{DDP}} + 0.5$	V	
Input low voltage at XTAL1 ⁴⁾	V_{ILBX} SR	-0.5	–	0.4	V	
Input leakage current at XTAL1	I_{ILX1} CC	-100	–	100	nA	Oscillator power down $0 \text{ V} \leq V_{\text{IX}} \leq V_{\text{DDP}}$

1) t_{OSCS} is defined from the moment the oscillator is enabled with SCU_OSCHPCTRL.MODE until the oscillations reach an amplitude at XTAL1 of $0.4 \times V_{\text{DDP}}$.

2) The external oscillator circuitry must be optimized by the customer and checked for negative resistance and amplitude as recommended and specified by crystal suppliers.

3) If the shaper unit is enabled and not bypassed.

4) If the shaper unit is bypassed, dedicated DC-thresholds have to be met.

Table 32 RTC_XTAL Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input frequency	f_{OSC} SR	–	32.768	–	kHz	
Oscillator start-up time ¹⁾²⁾³⁾	t_{OSCS} CC	–	–	5	s	
Input voltage at RTC_XTAL1	V_{IX} SR	-0.3	–	$V_{BAT} + 0.3$	V	
Input amplitude (peak-to-peak) at RTC_XTAL1 ²⁾⁴⁾	V_{PPX} SR	0.4	–	–	V	
Input high voltage at RTC_XTAL1 ⁵⁾	V_{IHBX} SR	$0.6 \times V_{BAT}$	–	$V_{BAT} + 0.3$	V	
Input low voltage at RTC_XTAL1 ⁵⁾	V_{ILBX} SR	-0.3	–	$0.36 \times V_{BAT}$	V	
Input Hysteresis for RTC_XTAL1 ⁵⁾⁶⁾	V_{HYSX} CC	$0.1 \times V_{BAT}$	–	–	V	$3.0 \text{ V} \leq V_{BAT} < 3.6 \text{ V}$
		$0.03 \times V_{BAT}$	–	–	V	$V_{BAT} < 3.0 \text{ V}$
Input leakage current at RTC_XTAL1	I_{ILX1} CC	-100	–	100	nA	Oscillator power down $0 \text{ V} \leq V_{IX} \leq V_{BAT}$

- t_{OSCS} is defined from the moment the oscillator is enabled by the user with SCU_OSCULCTRL.MODE until the oscillations reach an amplitude at RTC_XTAL1 of 400 mV.
- The external oscillator circuitry must be optimized by the customer and checked for negative resistance and amplitude as recommended and specified by crystal suppliers.
- For a reliable start of the oscillation in crystal mode it is required that $V_{BAT} \geq 3.0 \text{ V}$. A running oscillation is maintained across the full V_{BAT} voltage range.
- If the shaper unit is enabled and not bypassed.
- If the shaper unit is bypassed, dedicated DC-thresholds have to be met.
- Hysteresis is implemented to avoid metastable states and switching due to internal ground bounce. It can not be guaranteed that it suppresses switching due to external system noise.

3.2.8 Power Supply Current

The total power supply current defined below consists of a leakage and a switching component.

Application relevant values are typically lower than those given in the following tables, and depend on the customer's system operating conditions (e.g. thermal connection or used application configurations).

Note: These parameters are not subject to production test, but verified by design and/or characterization.

If not stated otherwise, the operating conditions for the parameters in the following table are:

$$V_{DDP} = 3.3 \text{ V}, T_A = 25 \text{ }^{\circ}\text{C}$$

Table 33 Power Supply Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Active supply current ¹⁾¹¹⁾ Peripherals enabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	I_{DDPA} CC	–	135	–	mA	144 / 144 / 144
		–	125	–		144 / 72 / 72
		–	97	–		72 / 72 / 144
		–	80	–		24 / 24 / 24
		–	68	–		1 / 1 / 1
Active supply current Code execution from RAM Flash in Sleep mode	I_{DDPA} CC	–	108	–	mA	144 / 144 / 144
		–	98	–		144 / 72 / 72
Active supply current ²⁾ Peripherals disabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	I_{DDPA} CC	–	86	–	mA	144 / 144 / 144
		–	85	–		144 / 72 / 72
		–	70	–		72 / 72 / 144
		–	55	–		24 / 24 / 24
		–	50	–		1 / 1 / 1
Sleep supply current ³⁾ Peripherals enabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	I_{DDPS} CC	–	127	–	mA	144 / 144 / 144
		–	115	–		144 / 72 / 72
		–	93	–		72 / 72 / 144
		–	57	–		24 / 24 / 24
		–	47	–		1 / 1 / 1
		–	48	–		100 / 100 / 100
$f_{CPU} / f_{PERIPH} / f_{CCU}$ in kHz						

Electrical Parameters
Table 33 Power Supply Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Sleep supply current ⁴⁾ Peripherals disabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	I_{DDPS} CC	–	77	–	mA	144 / 144 / 144
		–	76	–		144 / 72 / 72
		–	65	–		72 / 72 / 144
		–	53	–		24 / 24 / 24
		–	46	–		1 / 1 / 1
		–	47	–		100 / 100 / 100
$f_{CPU} / f_{PERIPH} / f_{CCU}$ in kHz						
Deep Sleep supply current ⁵⁾ Flash in Sleep mode Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz $f_{CPU} / f_{PERIPH} / f_{CCU}$ in kHz	I_{DDPD} CC	–	11	–	mA	24 / 24 / 24
		–	7.0	–		4 / 4 / 4
		–	6.6	–		1 / 1 / 1
		–	7.6	–		100 / 100 / 100 ⁶⁾
Hibernate supply current RTC on ⁷⁾	I_{DDPH} CC	–	8.7	–	μ A	$V_{BAT} = 3.3$ V
		–	6.5	–		$V_{BAT} = 2.4$ V
		–	5.7	–		$V_{BAT} = 2.0$ V
Hibernate supply current RTC off ⁸⁾	I_{DDPH} CC	–	8.0	–	μ A	$V_{BAT} = 3.3$ V
		–	6.0	–		$V_{BAT} = 2.4$ V
		–	5.0	–		$V_{BAT} = 2.0$ V
Hibernate off ⁹⁾	I_{DDPH} CC	–	4.4	–	μ A	$V_{BAT} = 3.3$ V
		–	3.5	–		$V_{BAT} = 2.4$ V
		–	3.1	–		$V_{BAT} = 2.0$ V
Worst case active supply current ¹⁰⁾	I_{DDPA} CC	–	–	250 ¹¹⁾	mA	$V_{DDP} = 3.6$ V, $T_J = 150$ °C
V_{DDA} power supply current	I_{DDA} CC	–	–	– ¹²⁾	mA	
I_{DDP} current at PORST Low	I_{DDP_PORST} CC	–	5	10	mA	$V_{DDP} = 3.3$ V, $T_J = 25$ °C
		–	13	55	mA	$V_{DDP} = 3.6$ V, $T_J = 150$ °C
Power Dissipation	P_{DISS} CC	–	–	1.4	W	$V_{DDP} = 3.6$ V, $T_J = 150$ °C

Electrical Parameters

Table 33 Power Supply Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Wake-up time from Sleep to Active mode	t_{SSA} CC	—	6	—	cycles	
Wake-up time from Deep Sleep to Active mode		—	—	—	ms	Defined by the wake-up of the Flash module, see “Flash Memory Parameters”
Wake-up time from Hibernate mode		—	—	—	ms	Wake-up via power-on reset event, see “Power-Up and Supply Monitoring”

- 1) CPU executing code from Flash, all peripherals idle.
- 2) CPU executing code from Flash.
- 3) CPU in sleep, all peripherals idle, Flash in Active mode.
- 4) CPU in sleep, Flash in Active mode.
- 5) CPU in sleep, peripherals disabled, after wake-up code execution from RAM.
- 6) To wake-up the Flash from its Sleep mode, $f_{CPU} \geq 1$ MHz is required.
- 7) OSC_ULP operating with external crystal on RTC_XTAL
- 8) OSC_ULP off, Hibernate domain operating with OSC_SI clock
- 9) V_{BAT} supplied, but Hibernate domain not started; for example state after factory assembly
- 10) Test Power Loop: $f_{SYS} = 144$ MHz, CPU executing benchmark code from Flash, all CCUs in 100kHz timer mode, all ADC groups in continuous conversion mode, USICs as SPI in internal loop-back mode, CAN in 500kHz internal loop-back mode, interrupt triggered DMA block transfers to parity protected RAMs and FCE, DTS measurements and FPU calculations.
The power consumption of each customer application will most probably be lower than this value, but must be evaluated separately.
- 11) I_{DDP} decreases typically by approximately 5 mA when f_{SYS} decreases by 10 MHz, at constant T_J
- 12) Sum of currents of all active converters (ADC and DAC)

Peripheral Idle Currents

Default test conditions:

- f_{sys} and derived clocks at 144 MHz
- $V_{DDP} = 3.3\text{ V}$, $T_a = 25\text{ °C}$
- all peripherals are held in reset (see the PRSTAT registers in the Reset Control Unit of the SCU)
- the peripheral clocks are disabled (see CGATSTAT registers in the Clock Control Unit of the SCU)
- no I/O activity

The given values are a result of differential measurements with asserted and deasserted peripheral reset as well as disabled and enabled clock of the peripheral under test.

The tested peripheral is left in the state after the peripheral reset is deasserted, no further initialisation or configuration is done. E.g. no timer is running in the CCUs, no communication active in the USICs, etc.

Table 34 Peripheral Idle Currents

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
PORTS FCE WDT	$I_{PER\ CC}$	–	≤ 0.3	–	mA	
MultiCAN ERU LEDTSCU0 ETH CCU4x ¹⁾ , CCU8x ¹⁾		–	≤ 1.0	–		
DAC (digital) ²⁾		–	1.3	–		
USICx SDMMC		–	3.0	–		
VADC (digital) ²⁾		–	4.5	–		
DMA0, USB, EtherCAT		–	6.0	–		

1) Enabling the f_{CCU} clock for the CCU4x/CCU8x modules adds approximately $I_{PER} = 4.8\text{ mA}$, disregarding which and how many of those peripherals are enabled.

2) The current consumption of the analog components are given in the dedicated Data Sheet sections of the respective peripheral.

3.2.9 Flash Memory Parameters

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 35 Flash Memory Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Erase Time per 256 Kbyte Sector	t_{ERP} CC	–	5	5.5	s	
Erase Time per 64 Kbyte Sector	t_{ERP} CC	–	1.2	1.4	s	
Erase Time per 16 Kbyte Logical Sector	t_{ERP} CC	–	0.3	0.4	s	
Program time per page ¹⁾	t_{PRP} CC	–	5.5	11	ms	
Erase suspend delay	t_{FL_ErSusp} CC	–	–	15	ms	
Wait time after margin change	$t_{FL_MarginDel}$ CC	10	–	–	μs	
Wake-up time	t_{WU} CC	–	–	270	μs	
Read access time	t_a CC	22	–	–	ns	For operation with $1/f_{CPU} < t_a$ wait states must be configured ²⁾
Data Retention Time, Physical Sector ³⁾⁴⁾	t_{RET} CC	20	–	–	years	Max. 1000 erase/program cycles
Data Retention Time, Logical Sector ³⁾⁴⁾	t_{RETL} CC	20	–	–	years	Max. 100 erase/program cycles
Data Retention Time, User Configuration Block (UCB) ³⁾⁴⁾	t_{RTU} CC	20	–	–	years	Max. 4 erase/program cycles per UCB
Endurance on 64 Kbyte Physical Sector PS4	N_{EPS4} CC	10000	–	–	cycles	Cycling distributed over life time ⁵⁾

Electrical Parameters

- 1) In case the Program Verify feature detects weak bits, these bits will be programmed once more. The reprogramming takes an additional time of 5.5 ms.
- 2) The following formula applies to the wait state configuration: $FCON.WSPFLASH \times (1 / f_{CPU}) \geq t_a$.
- 3) Storage and inactive time included.
- 4) Values given are valid for an average weighted junction temperature of $T_J = 110^\circ\text{C}$.
- 5) Only valid with robust EEPROM emulation algorithm, equally cycling the logical sectors. For more details see the Reference Manual.

3.3 AC Parameters

3.3.1 Testing Waveforms

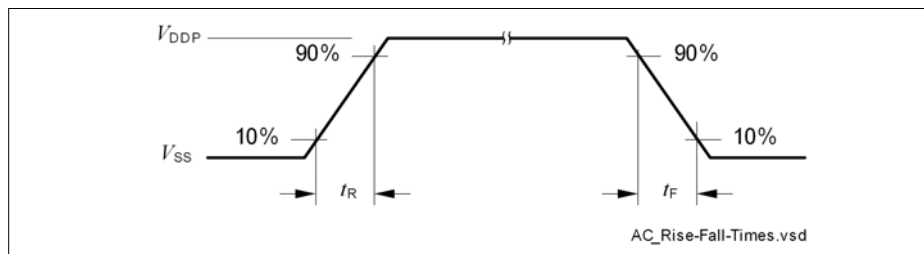


Figure 18 Rise/Fall Time Parameters

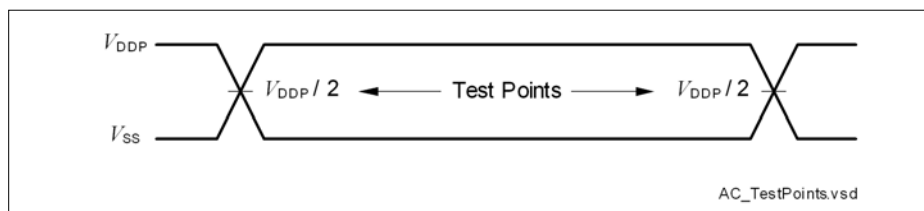


Figure 19 Testing Waveform, Output Delay

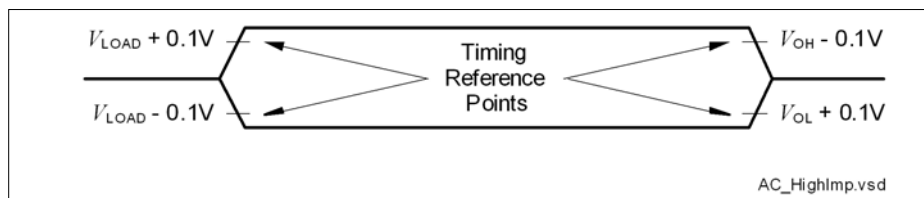


Figure 20 Testing Waveform, Output High Impedance

3.3.2 Power-Up and Supply Monitoring

$\overline{\text{PORST}}$ is always asserted when V_{DDP} and/or V_{DDC} violate the respective thresholds.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

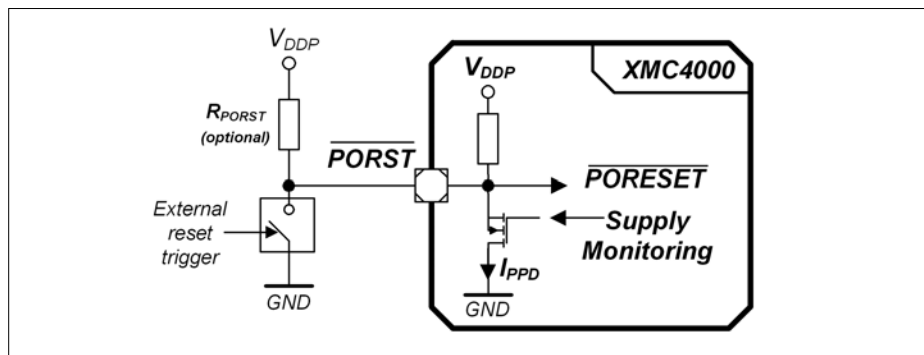


Figure 21 **PORST Circuit**

Table 36 **Supply Monitoring Parameters**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Digital supply voltage reset threshold	V_{POR} CC	2.79 ¹⁾	–	3.05 ²⁾	V	3)
Core supply voltage reset threshold	V_{PV} CC	–	–	1.17	V	
V_{DDP} voltage to ensure defined pad states	V_{DDPPA} CC	–	1.0	–	V	
$\overline{\text{PORST}}$ rise time	t_{PR} SR	–	–	2	μs	4)
Startup time from power-on reset with code execution from Flash	t_{SSW} CC	–	2.5	3.5	ms	Time to the first user code instruction
V_{DDC} ramp up time	t_{VCR} CC	–	550	–	μs	Ramp up after power-on or after a reset triggered by a violation of V_{POR} or V_{PV}

1) Minimum threshold for reset assertion.

Electrical Parameters

- 2) Maximum threshold for reset deassertion.
- 3) The V_{DDP} monitoring has a typical hysteresis of $V_{PORHYS} = 180 \text{ mV}$.
- 4) If t_{PR} is not met, low spikes on $\overline{\text{PORST}}$ may be seen during start up (e.g. reset pulses generated by the supply monitoring due to a slow ramping V_{DDP}).

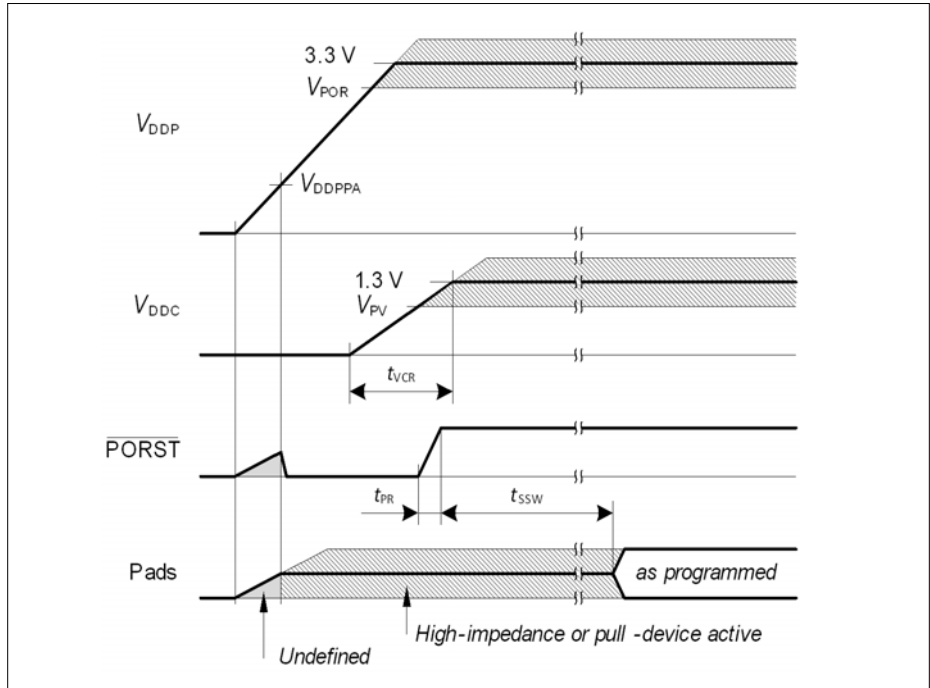


Figure 22 Power-Up Behavior

Electrical Parameters
3.3.3 Power Sequencing

While starting up and shutting down as well as when switching power modes of the system it is important to limit the current load steps. A typical cause for such load steps is changing the CPU frequency f_{CPU} . Load steps exceeding the below defined values may cause a power on reset triggered by the supply monitor.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 37 Power Sequencing Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Positive Load Step Current	ΔI_{PLS} SR	-	—	50	mA	Load increase on V_{DDP} $\Delta t \leq 10 \text{ ns}$
Negative Load Step Current	ΔI_{NLS} SR	-	—	150	mA	Load decrease on V_{DDP} $\Delta t \leq 10 \text{ ns}$
V_{DDC} Voltage Over- / Undershoot from Load Step	ΔV_{LS} CC	-	—	± 100	mV	For maximum positive or negative load step
Positive Load Step Settling Time	t_{PLSS} SR	50	—	-	μs	
Negative Load Step Settling Time	t_{NLSS} SR	100	—	-	μs	
External Buffer Capacitor on V_{DDC}	C_{EXT} SR	-	10	-	μF	In addition $C = 100 \text{ nF}$ capacitor on each V_{DDC} pin

Positive Load Step Examples

System assumptions:

$f_{\text{CPU}} = f_{\text{SYS}}$, target frequency $f_{\text{CPU}} = 144 \text{ MHz}$, main PLL $f_{\text{VCO}} = 288 \text{ MHz}$, stepping done by K2 divider, t_{PLSS} between individual steps:

24 MHz - 48 MHz - 72 MHz - 96 MHz - 144 MHz (K2 steps 12 - 6 - 4 - 3 - 2)

24 MHz - 48 MHz - 96 MHz - 144 MHz (K2 steps 12 - 6 - 3 - 2)

24 MHz - 72 MHz - 144 MHz (K2 steps 12 - 4 - 2)

3.3.4 Phase Locked Loop (PLL) Characteristics

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Main and USB PLL

Table 38 PLL Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Accumulated Jitter	D_P CC	–	–	±5	ns	accumulated over 300 cycles $f_{SYS} = 144$ MHz
Duty Cycle ¹⁾	D_{DC} CC	46	50	54	%	Low pulse to total period, assuming an ideal input clock source
PLL base frequency	$f_{PLLBASE}$ CC	30	–	140	MHz	
VCO input frequency	f_{REF} CC	4	–	16	MHz	
VCO frequency range	f_{VCO} CC	260	–	520	MHz	
PLL lock-in time	t_L CC	–	–	400	μs	

1) 50% for even K2 divider values, $50 \pm (10/K2)$ for odd K2 divider values.

3.3.5 Internal Clock Source Characteristics

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Fast Internal Clock Source

Table 39 Fast Internal Clock Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Nominal frequency	f_{OFINC} CC	–	36.5	–	MHz	not calibrated
		–	24	–	MHz	calibrated
Accuracy	Δf_{OFI} CC	-0.5	–	0.5	%	automatic calibration ¹⁾²⁾
		-15	–	15	%	factory calibration, $V_{\text{DDP}} = 3.3 \text{ V}$
		-25	–	25	%	no calibration, $V_{\text{DDP}} = 3.3 \text{ V}$
		-7	–	7	%	Variation over voltage range ³⁾ $3.13 \text{ V} \leq V_{\text{DDP}} \leq 3.63 \text{ V}$
Start-up time	t_{OFIS} CC	–	50	–	μs	

1) Error in addition to the accuracy of the reference clock.

2) Automatic calibration compensates variations of the temperature and in the V_{DDP} supply voltage.

3) Deviations from the nominal V_{DDP} voltage induce an additional error to the uncalibrated and/or factory calibrated oscillator frequency.

Electrical Parameters
Slow Internal Clock Source
Table 40 Slow Internal Clock Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Nominal frequency	f_{OSI} CC	–	32.768	–	kHz	
Accuracy	Δf_{OSI} CC	-4	–	4	%	$V_{\text{BAT}} = \text{const.}$ $0\text{ }^{\circ}\text{C} \leq T_{\text{A}} \leq 85\text{ }^{\circ}\text{C}$
		-5	–	5	%	$V_{\text{BAT}} = \text{const.}$ $T_{\text{A}} < 0\text{ }^{\circ}\text{C}$ or $T_{\text{A}} > 85\text{ }^{\circ}\text{C}$
		-5	–	5	%	$2.4\text{ V} \leq V_{\text{BAT}},$ $T_{\text{A}} = 25\text{ }^{\circ}\text{C}$
		-10	–	10	%	$1.95\text{ V} \leq V_{\text{BAT}} < 2.4\text{ V},$ $T_{\text{A}} = 25\text{ }^{\circ}\text{C}$
Start-up time	t_{OSIS} CC	–	50	–	μs	

3.3.6 JTAG Interface Timing

The following parameters are applicable for communication through the JTAG debug interface. The JTAG module is fully compliant with IEEE1149.1-2000.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Note: Operating conditions apply.

Table 41 JTAG Interface Timing Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
TCK clock period	t_1 SR	25	–	–	ns	
TCK high time	t_2 SR	10	–	–	ns	
TCK low time	t_3 SR	10	–	–	ns	
TCK clock rise time	t_4 SR	–	–	4	ns	
TCK clock fall time	t_5 SR	–	–	4	ns	
TDI/TMS setup to TCK rising edge	t_6 SR	6	–	–	ns	
TDI/TMS hold after TCK rising edge	t_7 SR	6	–	–	ns	
TDO valid after TCK falling edge ¹⁾ (propagation delay)	t_8 CC	–	–	13	ns	$C_L = 50 \text{ pF}$
		3	–	–	ns	$C_L = 20 \text{ pF}$
TDO hold after TCK falling edge ¹⁾	t_{18} CC	2	–	–	ns	
TDO high imped. to valid from TCK falling edge ¹⁾²⁾	t_9 CC	–	–	14	ns	$C_L = 50 \text{ pF}$
TDO valid to high imped. from TCK falling edge ¹⁾	t_{10} CC	–	–	13.5	ns	$C_L = 50 \text{ pF}$

1) The falling edge on TCK is used to generate the TDO timing.

2) The setup time for TDO is given implicitly by the TCK cycle time.

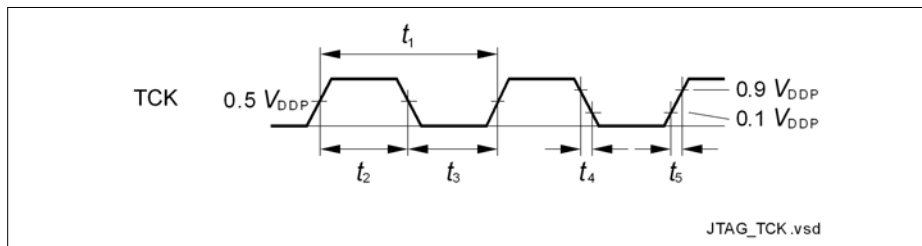


Figure 23 Test Clock Timing (TCK)

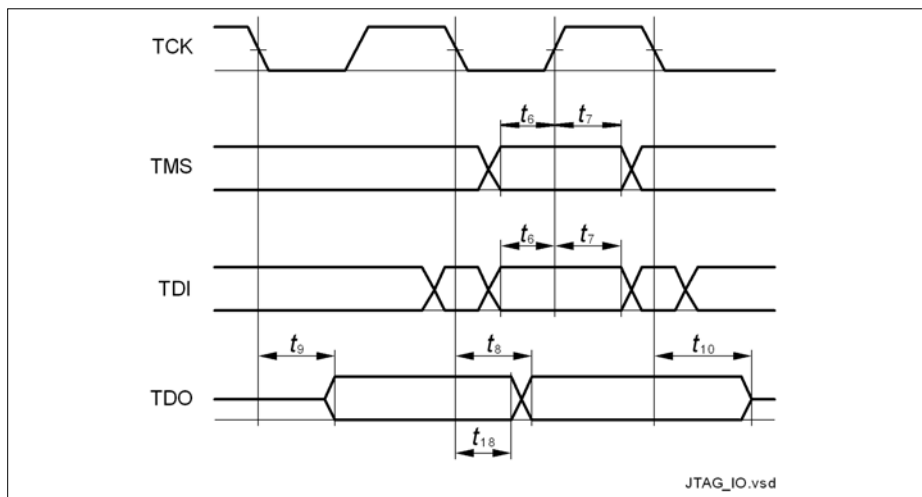


Figure 24 JTAG Timing

3.3.7 Serial Wire Debug Port (SW-DP) Timing

The following parameters are applicable for communication through the SW-DP interface.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Note: Operating conditions apply.

Table 42 SWD Interface Timing Parameters (Operating Conditions apply)

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
SWDCLK clock period	t_{SC}	SR	25	—	—	ns	$C_L = 30$ pF
			40	—	—	ns	$C_L = 50$ pF
SWDCLK high time	t_1	SR	10	—	500000	ns	
SWDCLK low time	t_2	SR	10	—	500000	ns	
SWDIO input setup to SWDCLK rising edge	t_3	SR	6	—	—	ns	
SWDIO input hold after SWDCLK rising edge	t_4	SR	6	—	—	ns	
SWDIO output valid time after SWDCLK rising edge	t_5	CC	—	—	17	ns	$C_L = 50$ pF
			—	—	13	ns	$C_L = 30$ pF
SWDIO output hold time from SWDCLK rising edge	t_6	CC	3	—	—	ns	

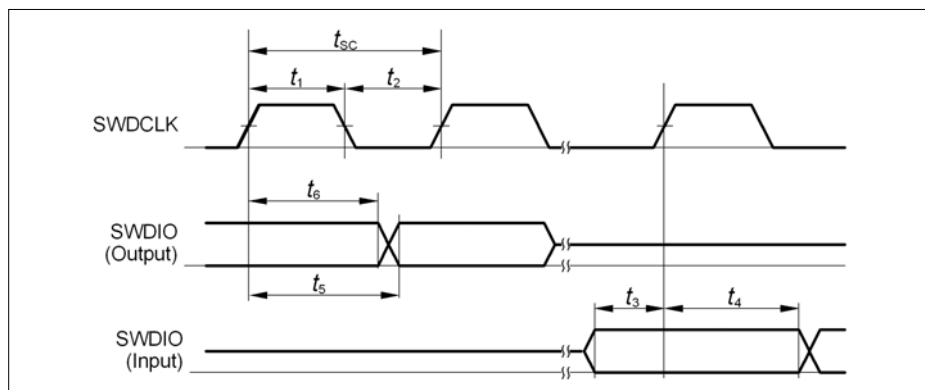


Figure 25 SWD Timing

3.3.8 Peripheral Timing

3.3.8.1 Synchronous Serial Interface (USIC SSC) Timing

The following parameters are applicable for a USIC channel operated in SSC mode.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 43 USIC SSC Master Mode Timing

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
SCLKOUT master clock period	t_{CLK} CC	33.3	–	–	ns	
Slave select output SELO active to first SCLKOUT transmit edge	t_1 CC	$t_{PB} - 6.5^{1)}$	–	–	ns	
Slave select output SELO inactive after last SCLKOUT receive edge	t_2 CC	$t_{PB} - 8.5^{1)}$	–	–	ns	
Data output DOUT[3:0] valid time	t_3 CC	-6	–	8	ns	
Receive data input DX0/DX[5:3] setup time to SCLKOUT receive edge	t_4 SR	23	–	–	ns	
Data input DX0/DX[5:3] hold time from SCLKOUT receive edge	t_5 SR	1	–	–	ns	

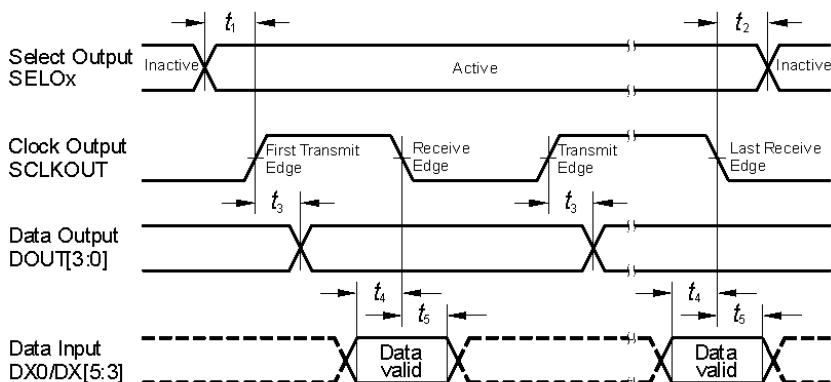
1) $t_{PB} = 1 / f_{PB}$

Table 44 USIC SSC Slave Mode Timing

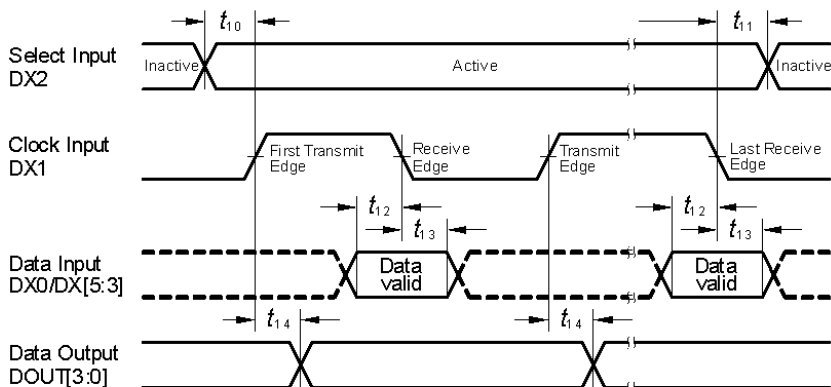
Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
DX1 slave clock period	t_{CLK} SR	66.6	–	–	ns	
Select input DX2 setup to first clock input DX1 transmit edge ¹⁾	t_{10} SR	3	–	–	ns	
Select input DX2 hold after last clock input DX1 receive edge ¹⁾	t_{11} SR	4	–	–	ns	
Receive data input DX0/DX[5:3] setup time to shift clock receive edge ¹⁾	t_{12} SR	6	–	–	ns	
Data input DX0/DX[5:3] hold time from clock input DX1 receive edge ¹⁾	t_{13} SR	4	–	–	ns	
Data output DOUT[3:0] valid time	t_{14} CC	0	–	24	ns	

1) This input timing is valid for asynchronous input signal handling of slave select input, shift clock input, and receive data input (bits DXnCR.DSEN = 0).

Master Mode Timing



Slave Mode Timing



Transmit Edge: with this clock edge transmit data is shifted to transmit data output

Receive Edge: with this clock edge receive data at receive data input is latched

Drawn for BRGH, SCLKCFG = 00_b. Also valid for SCLKCFG = 01_b with inverted SCLKOUT signal

US1C_SSC_TM6X.VSD

Figure 26 USIC - SSC Master/Slave Mode Timing

Note: This timing diagram shows a standard configuration, for which the slave select signal is low-active, and the serial clock signal is not shifted and not inverted.

3.3.8.2 Inter-IC (IIC) Interface Timing

The following parameters are applicable for a USIC channel operated in IIC mode.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 45 USIC IIC Standard Mode Timing¹⁾

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Fall time of both SDA and SCL	t_1 CC/SR	-	-	300	ns	
Rise time of both SDA and SCL	t_2 CC/SR	-	-	1000	ns	
Data hold time	t_3 CC/SR	0	-	-	μs	
Data set-up time	t_4 CC/SR	250	-	-	ns	
LOW period of SCL clock	t_5 CC/SR	4.7	-	-	μs	
HIGH period of SCL clock	t_6 CC/SR	4.0	-	-	μs	
Hold time for (repeated) START condition	t_7 CC/SR	4.0	-	-	μs	
Set-up time for repeated START condition	t_8 CC/SR	4.7	-	-	μs	
Set-up time for STOP condition	t_9 CC/SR	4.0	-	-	μs	
Bus free time between a STOP and START condition	t_{10} CC/SR	4.7	-	-	μs	
Capacitive load for each bus line	C_b SR	-	-	400	pF	

1) Due to the wired-AND configuration of an IIC bus system, the port drivers of the SCL and SDA signal lines need to operate in open-drain mode. The high level on these lines must be held by an external pull-up device, approximately 10 kOhm for operation at 100 kbit/s, approximately 2 kOhm for operation at 400 kbit/s.

Table 46 USIC IIC Fast Mode Timing¹⁾

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Fall time of both SDA and SCL	t_1 CC/SR	20 + $0.1 \cdot C_b$ 2)	-	300	ns	
Rise time of both SDA and SCL	t_2 CC/SR	20 + $0.1 \cdot C_b$ 2)	-	300	ns	
Data hold time	t_3 CC/SR	0	-	-	μs	
Data set-up time	t_4 CC/SR	100	-	-	ns	
LOW period of SCL clock	t_5 CC/SR	1.3	-	-	μs	
HIGH period of SCL clock	t_6 CC/SR	0.6	-	-	μs	
Hold time for (repeated) START condition	t_7 CC/SR	0.6	-	-	μs	
Set-up time for repeated START condition	t_8 CC/SR	0.6	-	-	μs	
Set-up time for STOP condition	t_9 CC/SR	0.6	-	-	μs	
Bus free time between a STOP and START condition	t_{10} CC/SR	1.3	-	-	μs	
Capacitive load for each bus line	C_b SR	-	-	400	pF	

1) Due to the wired-AND configuration of an IIC bus system, the port drivers of the SCL and SDA signal lines need to operate in open-drain mode. The high level on these lines must be held by an external pull-up device, approximately 10 kOhm for operation at 100 kbit/s, approximately 2 kOhm for operation at 400 kbit/s.

2) C_b refers to the total capacitance of one bus line in pF.

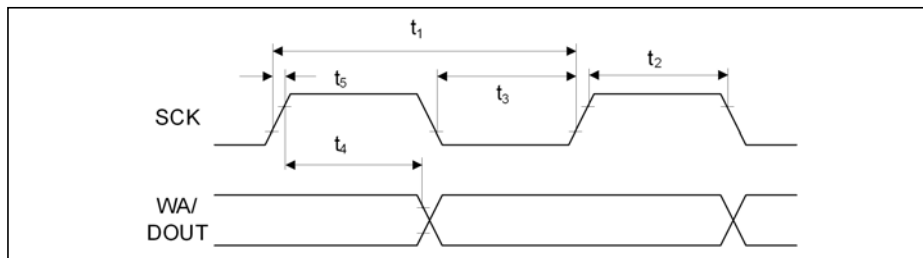


Figure 28 USIC IIS Master Transmitter Timing

Table 48 USIC IIS Slave Receiver Timing

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Clock period	t_6 SR	66.6	—	—	ns	
Clock high time	t_7 SR	$0.35 \times t_{6min}$	—	—	ns	
Clock low time	t_8 SR	$0.35 \times t_{6min}$	—	—	ns	
Set-up time	t_9 SR	$0.2 \times t_{6min}$	—	—	ns	
Hold time	t_{10} SR	0	—	—	ns	

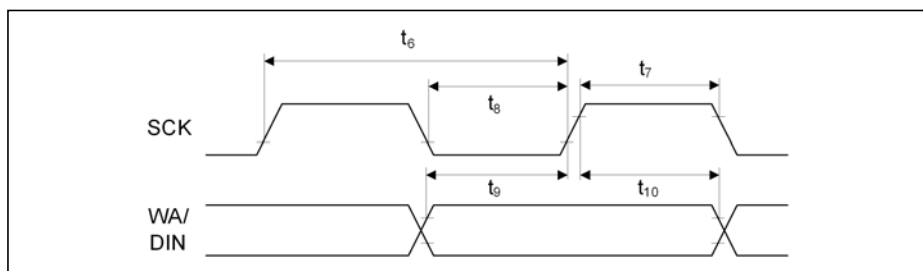


Figure 29 USIC IIS Slave Receiver Timing

3.3.8.4 SDMMC Interface Timing

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Note: Operating Conditions apply, total external capacitive load $C_L = 40$ pF.

AC Timing Specifications (Full-Speed Mode)

Table 49 SDMMC Timing for Full-Speed Mode

Parameter	Symbol		Values		Unit	Note/ Test Condition
			Min.	Max.		
Clock frequency in full speed transfer mode ($1/t_{pp}$)	f_{pp}	CC	0	24	MHz	
Clock cycle in full speed transfer mode	t_{pp}	CC	40	–	ns	
Clock low time	t_{WL}	CC	10	–	ns	
Clock high time	t_{WH}	CC	10	–	ns	
Clock rise time	t_{TLH}	CC	–	10	ns	
Clock fall time	t_{THL}	CC	–	10	ns	
Inputs setup to clock rising edge	t_{ISU_F}	SR	2	–	ns	
Inputs hold after clock rising edge	t_{IH_F}	SR	2	–	ns	
Outputs valid time in full speed mode	t_{ODLY_F}	CC	–	10	ns	
Outputs hold time in full speed mode	t_{OH_F}	CC	0	–	ns	

Table 50 SD Card Bus Timing for Full-Speed Mode¹⁾

Parameter	Symbol	Values		Unit	Note/ Test Condition
		Min.	Max.		
SD card input setup time	t_{ISU}	5	—	ns	
SD card input hold time	t_{IH}	5	—	ns	
SD card output valid time	t_{ODLY}	—	14	ns	
SD card output hold time	t_{OH}	0	—	ns	

1) Reference card timing values for calculation examples. Not subject to production test and not characterized.

Full-Speed Output Path (Write)

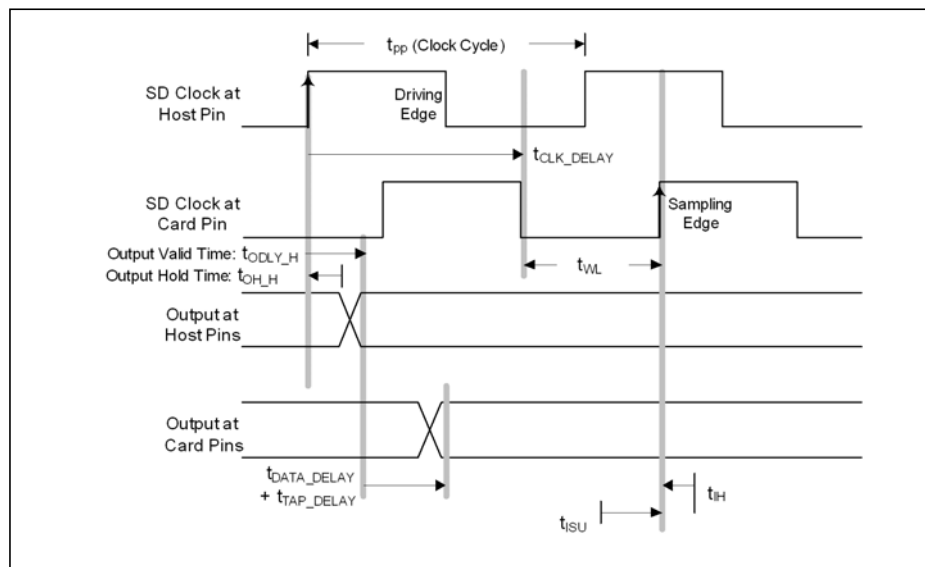


Figure 30 Full-Speed Output Path

Full-Speed Write Meeting Setup (Maximum Delay)

The following equations show how to calculate the allowed skew range between the SD_CLK and SD_DAT/CMD signals on the PCB.

No clock delay:

$$t_{ODLY_F} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ISU} < t_{WL} \quad (1)$$

With clock delay:

$$t_{ODLY_F} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ISU} < t_{WL} + t_{CLK_DELAY} \quad (2)$$

$$t_{DATA_DELAY} + t_{TAP_DELAY} + t_{WL} < t_{PP} + t_{CLK_DELAY} - t_{ISU} - t_{ODLY_F} \quad (3)$$

$$t_{DATA_DELAY} + t_{TAP_DELAY} + 20 < 40 + t_{CLK_DELAY} - 5 - 10$$

$$t_{DATA_DELAY} < 5 + t_{CLK_DELAY} - t_{TAP_DELAY}$$

The data can be delayed versus clock up to 5 ns in ideal case of $t_{WL} = 20$ ns.

Full-Speed Write Meeting Hold (Minimum Delay)

The following equations show how to calculate the allowed skew range between the SD_CLK and SD_DAT/CMD signals on the PCB.

$$t_{CLK_DELAY} < t_{WL} + t_{OH_F} + t_{DATA_DELAY} + t_{TAP_DELAY} - t_{IH} \quad (4)$$

$$t_{CLK_DELAY} < 20 + t_{DATA_DELAY} + t_{TAP_DELAY} - 5$$

$$t_{DATA_DELAY} < 15 + t_{CLK_DELAY} + t_{TAP_DELAY}$$

The clock can be delayed versus data up to 18.2 ns (external delay line) in ideal case of $t_{WL} = 20$ ns, with maximum $t_{TAP_DELAY} = 3.2$ ns programmed.

Full-Speed Input Path (Read)

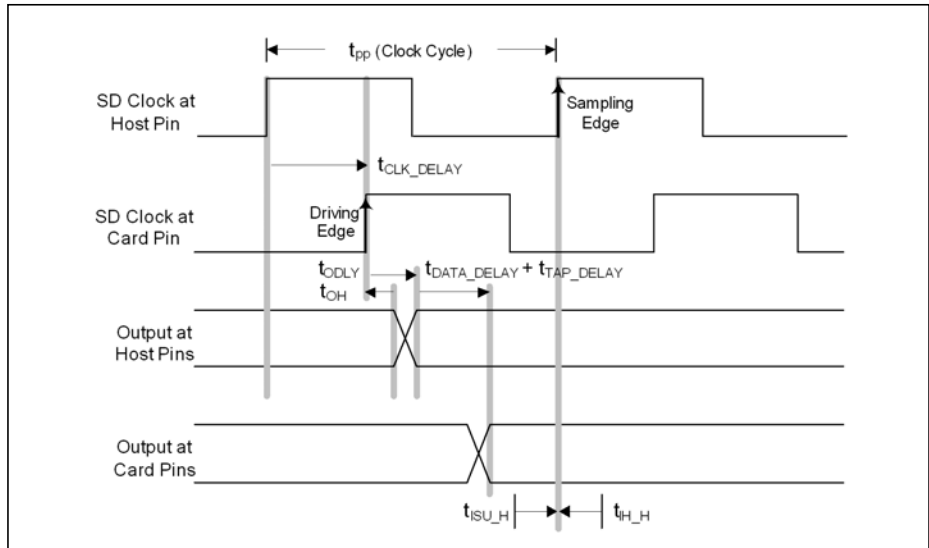


Figure 31 Full-Speed Input Path

Full-Speed Read Meeting Setup (Maximum Delay)

The following equations show how to calculate the allowed combined propagation delay range of the SD_CLK and SD_DAT/CMD signals on the PCB.

(5)

$$t_{CLK_DELAY} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ODLY} + t_{ISU_F} < 0.5 \times t_{pp}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} < 0.5 \times t_{pp} - t_{ODLY} - t_{ISU_F} - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} < 20 - 14 - 2 - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} < 4 - t_{TAP_DELAY}$$

The data + clock delay can be up to 4 ns for a 40 ns clock cycle.

Electrical Parameters
Full-Speed Read Meeting Hold (Minimum Delay)

The following equations show how to calculate the allowed combined propagation delay range of the SD_CLK and SD_DAT/CMD signals on the PCB.

(6)

$$t_{CLK_DELAY} + t_{OH} + t_{DATA_DELAY} + t_{TAP_DELAY} > t_{IH_F}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} > t_{IH_F} - t_{OH} - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} > 2 - t_{TAP_DELAY}$$

The data + clock delay must be greater than 2 ns if t_{TAP_DELAY} is not used.

If the t_{TAP_DELAY} is programmed to at least 2 ns, the data + clock delay must be greater than 0 ns (or less). This is always fulfilled.

AC Timing Specifications (High-Speed Mode)
Table 51 SDMMC Timing for High-Speed Mode

Parameter	Symbol		Values		Unit	Note/ Test Condition
			Min.	Max.		
Clock frequency in high speed transfer mode ($1/t_{pp}$)	f_{pp}	CC	0	48	MHz	
Clock cycle in high speed transfer mode	t_{pp}	CC	20	—	ns	
Clock low time	t_{WL}	CC	7	—	ns	
Clock high time	t_{WH}	CC	7	—	ns	
Clock rise time	t_{TLH}	CC	—	3	ns	
Clock fall time	t_{THL}	CC	—	3	ns	
Inputs setup to clock rising edge	t_{ISU_H}	SR	2	—	ns	
Inputs hold after clock rising edge	t_{IH_H}	SR	2	—	ns	
Outputs valid time in high speed mode	t_{ODLY_H}	CC	—	14	ns	
Outputs hold time in high speed mode	t_{OH_H}	CC	2	—	ns	

Table 52 SD Card Bus Timing for High-Speed Mode¹⁾

Parameter	Symbol	Values		Unit	Note/ Test Condition
		Min.	Max.		
SD card input setup time	t_{ISU}	6	—	ns	
SD card input hold time	t_{IH}	2	—	ns	
SD card output valid time	t_{ODLY}	—	14	ns	
SD card output hold time	t_{OH}	2.5	—	ns	

1) Reference card timing values for calculation examples. Not subject to production test and not characterized.

High-Speed Output Path (Write)

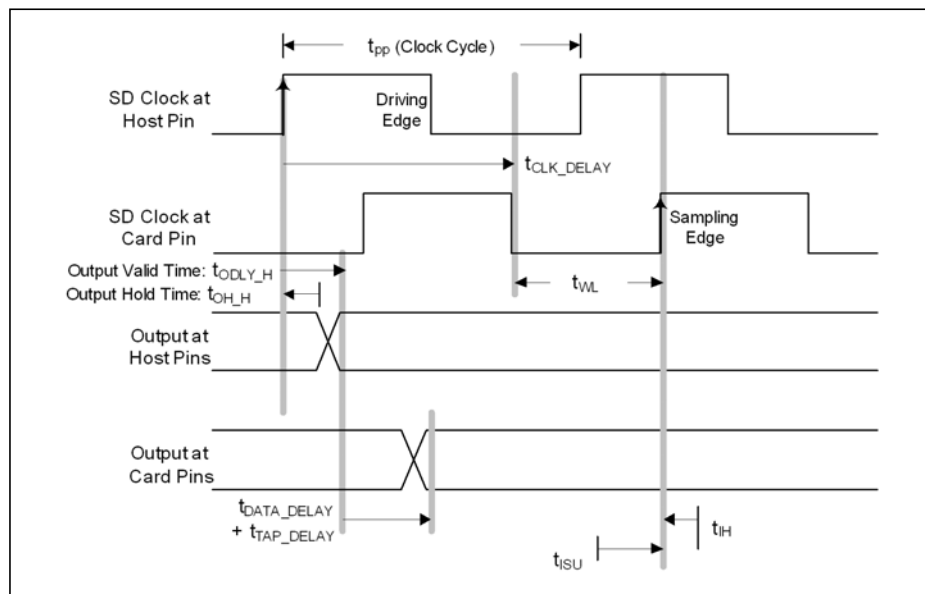


Figure 32 High-Speed Output Path

High-Speed Write Meeting Setup (Maximum Delay)

The following equations show how to calculate the allowed skew range between the SD_CLK and SD_DAT/CMD signals on the PCB.

No clock delay:

$$t_{ODLY_H} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ISU} < t_{WL} \quad (7)$$

With clock delay:

$$t_{ODLY_H} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ISU} < t_{WL} + t_{CLK_DELAY} \quad (8)$$

$$t_{DATA_DELAY} + t_{TAP_DELAY} - t_{CLK_DELAY} < t_{WL} - t_{ISU} - t_{ODLY_H} \quad (9)$$

$$t_{DATA_DELAY} - t_{CLK_DELAY} < t_{WL} - t_{ISU} - t_{ODLY_H} - t_{TAP_DELAY}$$

$$t_{DATA_DELAY} - t_{CLK_DELAY} < 10 - 6 - 14 - t_{TAP_DELAY}$$

$$t_{DATA_DELAY} - t_{CLK_DELAY} < -10 - t_{TAP_DELAY}$$

The data delay is less than the clock delay by at least 10 ns in the ideal case where $t_{WL} = 10$ ns.

High-Speed Write Meeting Hold (Minimum Delay)

The following equations show how to calculate the allowed skew range between the SD_CLK and SD_DAT/CMD signals on the PCB.

$$t_{CLK_DELAY} < t_{WL} + t_{OH_H} + t_{DATA_DELAY} + t_{TAP_DELAY} - t_{IH} \quad (10)$$

$$t_{CLK_DELAY} - t_{DATA_DELAY} < t_{WL} + t_{OH_H} + t_{TAP_DELAY} - t_{IH}$$

$$t_{CLK_DELAY} - t_{DATA_DELAY} < 10 + 2 + t_{TAP_DELAY} - 2$$

$$t_{CLK_DELAY} - t_{DATA_DELAY} < 10 + t_{TAP_DELAY}$$

Electrical Parameters

The clock can be delayed versus data up to 13.2 ns (external delay line) in ideal case of $t_{WL} = 10$ ns, with maximum $t_{TAP_DELAY} = 3.2$ ns programmed.

High-Speed Input Path (Read)

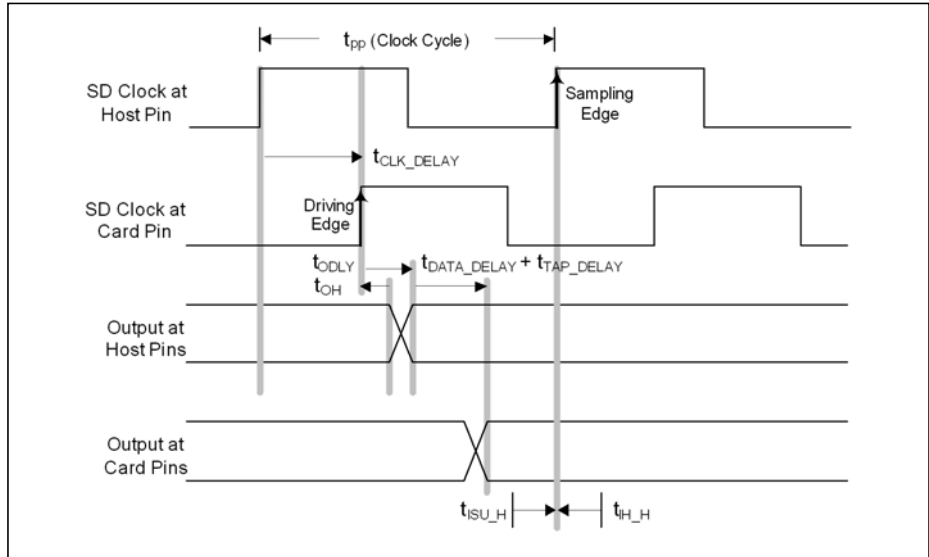


Figure 33 High-Speed Input Path

High-Speed Read Meeting Setup (Maximum Delay)

The following equations show how to calculate the allowed combined propagation delay range of the SD_CLK and SD_DAT/CMD signals on the PCB.

(11)

$$t_{CLK_DELAY} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ODLY} + t_{ISU_H} < t_{pp}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} < t_{pp} - t_{ODLY} - t_{ISU_H} - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} < 20 - 14 - 2 - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} < 4 - t_{TAP_DELAY}$$

The data + clock delay can be up to 4 ns for a 20 ns clock cycle.

Electrical Parameters

High-Speed Read Meeting Hold (Minimum Delay)

The following equations show how to calculate the allowed combined propagation delay range of the SD_CLK and SD_DAT/CMD signals on the PCB.

(12)

$$t_{CLK_DELAY} + t_{OH} + t_{DATA_DELAY} + t_{TAP_DELAY} > t_{IH_H}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} > t_{IH_H} - t_{OH} - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} > 2 - 2.5 - t_{TAP_DELAY}$$

$$t_{CLK_DELAY} + t_{DATA_DELAY} > -0.5 - t_{TAP_DELAY}$$

The data + clock delay must be greater than -0.5 ns for a 20 ns clock cycle. This is always fulfilled.

3.3.9 USB Interface Characteristics

The Universal Serial Bus (USB) Interface is compliant to the USB Rev. 2.0 Specification and the OTG Specification Rev. 1.3. High-Speed Mode is not supported.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

Table 53 **USB Timing Parameters** (operating conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Rise time	t_R CC	4	—	20	ns	$C_L = 50$ pF
Fall time	t_F CC	4	—	20	ns	$C_L = 50$ pF
Rise/Fall time matching	t_R/t_F CC	90	—	111.11	%	$C_L = 50$ pF
Crossover voltage	V_{CRS} CC	1.3	—	2.0	V	$C_L = 50$ pF

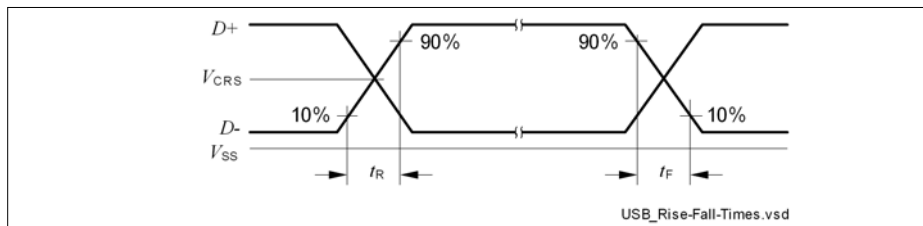


Figure 34 USB Signal Timing

3.3.10 Ethernet Interface (ETH) Characteristics

For proper operation of the Ethernet Interface it is required that $f_{\text{SYS}} \geq 100 \text{ MHz}$.

Note: These parameters are not subject to production test, but verified by design and/or characterization.

3.3.10.1 ETH Measurement Reference Points

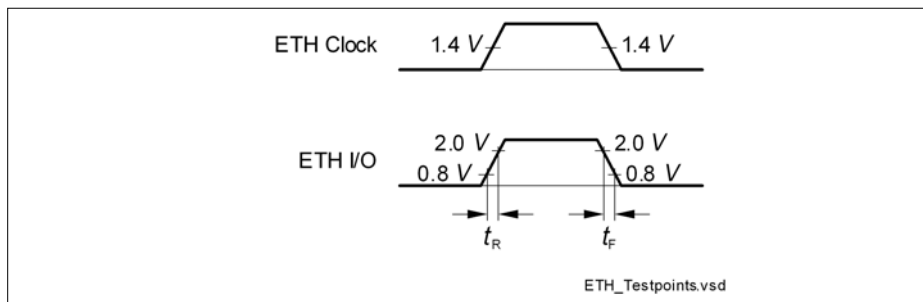


Figure 35 ETH Measurement Reference Points

3.3.10.2 ETH Management Signal Parameters (ETH_MDC, ETH_MDIO)

Table 54 ETH Management Signal Timing Parameters

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
ETH_MDC period	t_1	CC	400	—	—	ns	$C_L = 25 \text{ pF}$
ETH_MDC high time	t_2	CC	160	—	—	ns	
ETH_MDC low time	t_3	CC	160	—	—	ns	
ETH_MDIO setup time (output)	t_4	CC	10	—	—	ns	
ETH_MDIO hold time (output)	t_5	CC	10	—	—	ns	
ETH_MDIO data valid (input)	t_6	SR	0	—	300	ns	

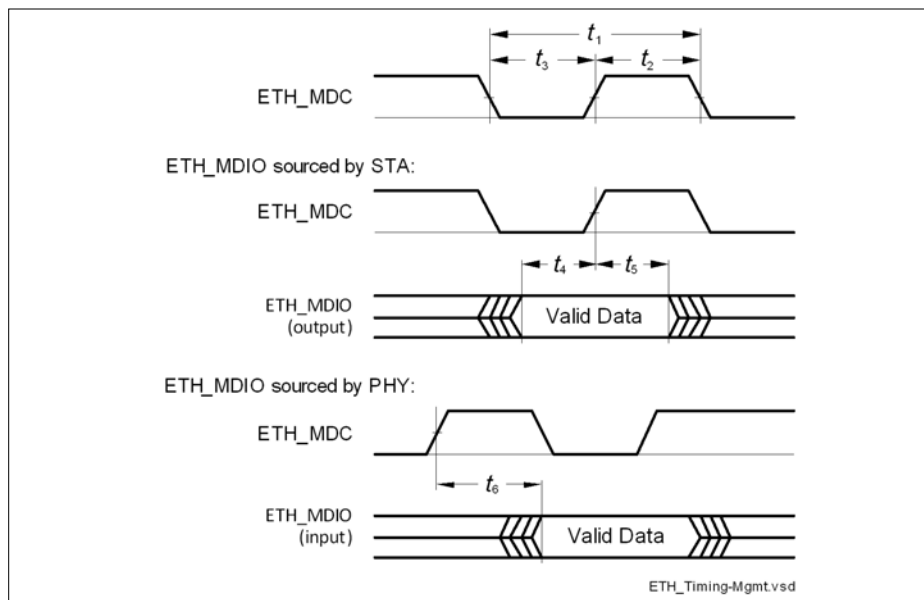


Figure 36 ETH Management Signal Timing

3.3.10.3 ETH RMII Parameters

In the following, the parameters of the RMII (Reduced Media Independent Interface) are described.

Table 55 ETH RMII Signal Timing Parameters

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
ETH_RMII_REF_CL clock period	t_{13}	SR	20	–	–	ns	$C_L = 25 \text{ pF}$; 50 ppm
ETH_RMII_REF_CL clock high time	t_{14}	SR	7	–	13	ns	$C_L = 25 \text{ pF}$
ETH_RMII_REF_CL clock low time	t_{15}	SR	7	–	13	ns	
ETH_RMII_RXD[1:0], ETH_RMII_CRS setup time	t_{16}	SR	4	–	–	ns	
ETH_RMII_RXD[1:0], ETH_RMII_CRS hold time	t_{17}	SR	2	–	–	ns	
ETH_RMII_TXD[1:0], ETH_RMII_TXEN data valid	t_{18}	CC	4	–	15	ns	

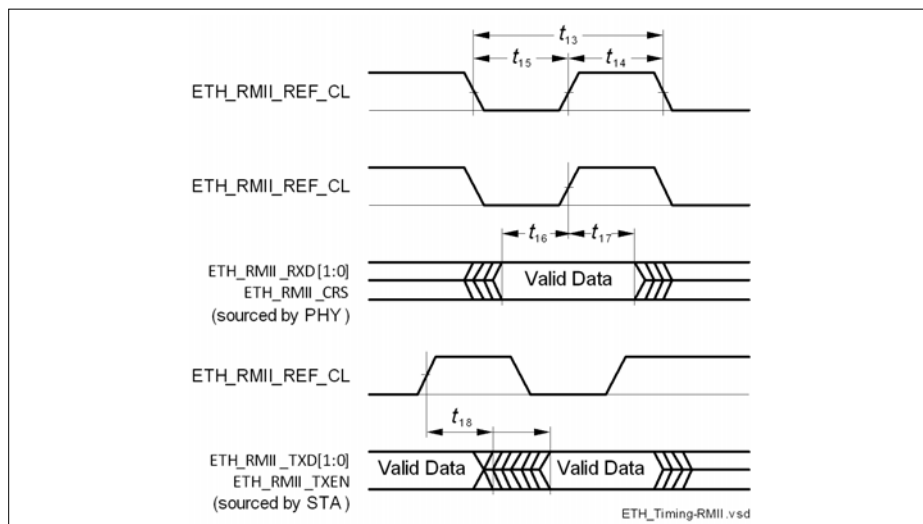


Figure 37 ETH RMII Signal Timing

3.3.11 EtherCAT (ECAT) Characteristics

3.3.11.1 ECAT Measurement Reference Points

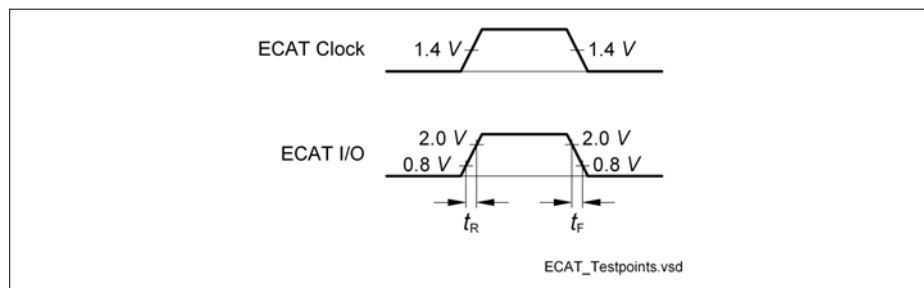


Figure 38 Measurement Reference Points

3.3.11.2 ETH Management Signal Parameters (MCLK, MDIO)

Table 56 ECAT Management Signal Timing Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
ECAT_MCLK period	t_{MCLK} CC	—	400	—	ns	IEEE802.3 requirement (2.5 MHz) $C_L = 25 \text{ pF}$
ECAT_MCLK high time	t_{MCLK_h} CC	160	—	—	ns	
ECAT_MCLK low time	t_{MCLK_l} CC	160	—	—	ns	
ECAT_MDIO setup time (output)	t_{D_setup} CC	10	—	—	ns	
ECAT_MDIO hold time (output)	t_{D_hold} CC	10	—	—	ns	
ECAT_MDIO data valid (input)	t_{D_valid} SR	0	—	300	ns	

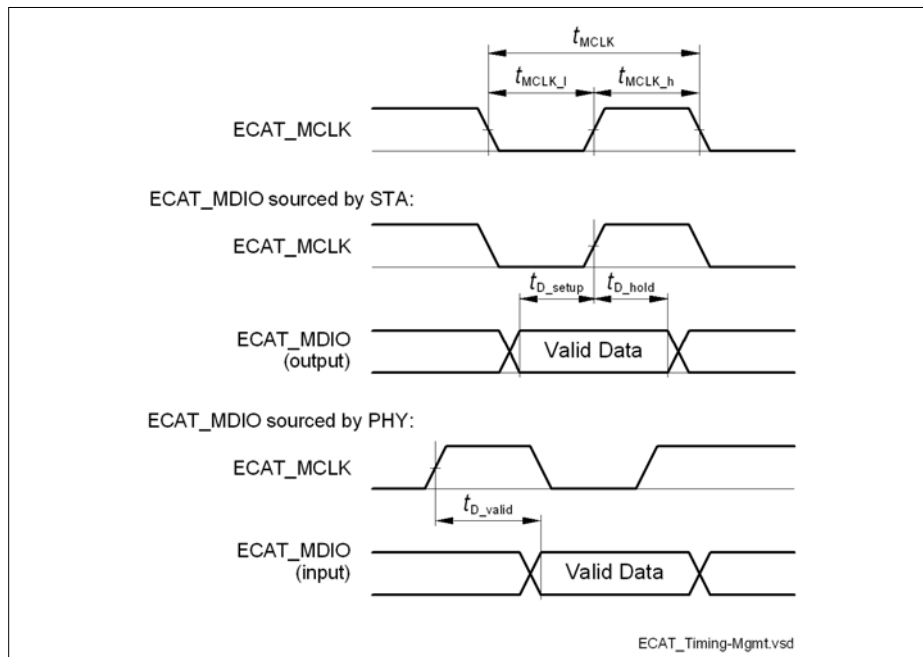


Figure 39 ECAT Management Signal Timing

3.3.11.3 MII Timing TX Characteristics

Table 57 ETH MII TX Signal Timing Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
PHY_CLK25, TX_CLK period	t_{TX_CLK} SR	—	40	—	ns	
Delay between PHY clock source PHY_CLK25 and TX_CLK output of the PHY	t_{PHY_delay} SR	—	—	—	ns	PHY dependent

Electrical Parameters

Table 57 ETH MII TX Signal Timing Parameters (cont'd)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
PHY setup requirement: TXEN/TXD[3:0] with respect to TX_CLK	t_{TX_setup} SR	15	—	0	ns	PHY dependent IEEE802.3 limit is 15 ns
PHY hold requirement: TXEN/TXD[3:0] with respect to TX_CLK	t_{TX_hold} CC	0	—	25	ns	PHY dependent IEEE802.3 limit is 0 ns

Note: ECAT0_CONPx.TX_SHIFT can be adjusted by displaying TX_CLK of a PHY and TXEN/TXD[3:0] on an oscilloscope. TXEN/TXD[3:0] is allowed to change between 0 ns and 25 ns after a rising edge of TX_CLK (according to IEEE802.3 – check your PHY's documentation). Configure TX_SHIFT so that TXEN/TXD[3:0] change near the middle of this range. It is sufficient to check just one of the TXEN/TXD[3:0] signals, because they are nearly generated at the same time.

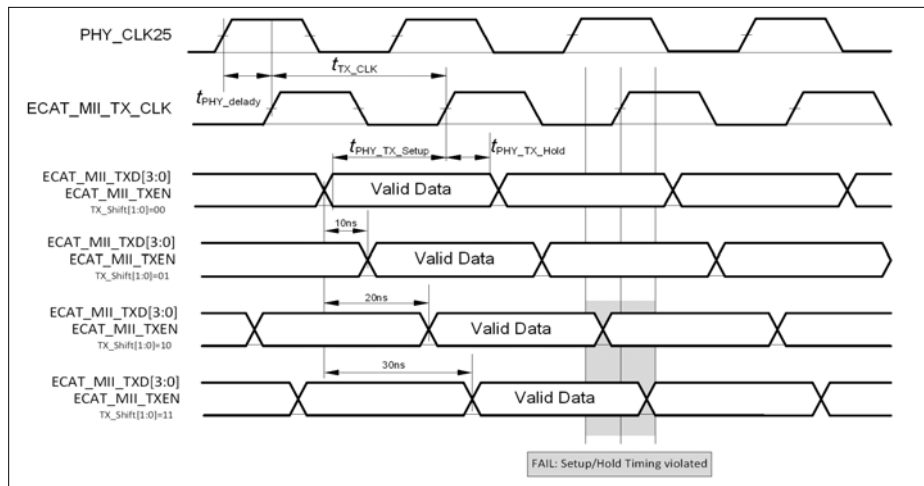
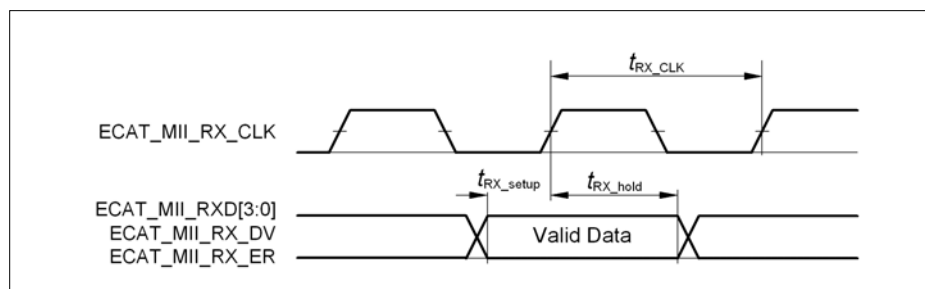


Figure 40 MII TX Characteristics

3.3.11.4 MII Timing RX Characteristics

Table 58 ETH MII RX Signal Timing Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
RX_CLK period	t_{RX_CLK} SR	—	40	—	ns	$C_L = 25\text{ pF}$, IEEE802.3 requirement
RX_DV/RX_DV/RXD[3:0] valid before rising edge of RX_CLK	t_{RX_setup} SR	10	—	—	ns	
RX_DV/RX_DV/RXD[3:0] valid after rising edge of RX_CLK	t_{RX_hold} SR	10	—	—	ns	


Figure 41 MII RX characteristics

3.3.11.5 Sync/Latch Timings

Table 59 **Sync/Latch Timings**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
SYNC0/1	$t_{DC_SYNC_SR}$ Jitter	—	—	11 + m ¹⁾	ns	
LATCH0/1	$t_{DC_LATCH_SR}$	12 + n ²⁾	—	—	ns	

1) additional delay form logic and pad, number is added after characterization

2) additional shaping delay, number is added after characterization

Note: SYNC0/1 pulse length are initially loaded by EEPROM content ADR 0x0002. The actual used value can be read back from Register DC_PULSE_LEN.

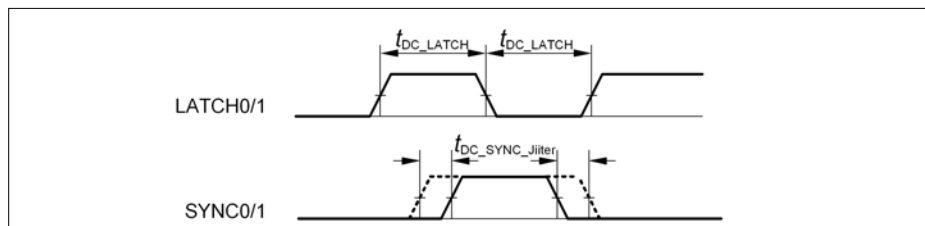


Figure 42 **Sync/Latch Timings**

4 Package and Reliability

The XMC4300 is a member of the XMC4000 Family of microcontrollers. It is also compatible to a certain extent with members of similar families or subfamilies.

Each package is optimized for the device it houses. Therefore, there may be slight differences between packages of the same pin-count but for different device types. In particular, the size of the Exposed Die Pad may vary.

If different device types are considered or planned for an application, it must be ensured that the board layout fits all packages under consideration.

4.1 Package Parameters

Table 60 provides the thermal characteristics of the packages used in XMC4300.

Table 60 Thermal Characteristics of the Packages

Parameter	Symbol	Limit Values		Unit	Package Types
		Min.	Max.		
Exposed Die Pad dimensions including U-Groove	$E_x \times E_y$ CC	-	7.0×7.0	mm	PG-LQFP-100-25
Exposed Die Pad dimensions excluding U-Groove	$A_x \times A_y$ CC	-	6.2×6.2	mm	PG-LQFP-100-25
Exposed Die Pad dimensions	-	-	7.0×7.0	mm	PG-LQFP-100-29
Thermal resistance Junction-Ambient $T_J \leq 150\text{ °C}$	$R_{\Theta JA}$ CC	-	22.5	K/W	PG-LQFP-100-25 ¹⁾ PG-LQFP-100-29 ¹⁾

1) Device mounted on a 4-layer JEDEC board (JESD 51-7) with thermal vias; exposed pad soldered.

Note: For electrical reasons, it is required to connect the exposed pad to the board ground V_{SS} , independent of EMC and thermal requirements.

4.1.1 Thermal Considerations

When operating the XMC4300 in a system, the total heat generated in the chip must be dissipated to the ambient environment to prevent overheating and the resulting thermal damage.

The maximum heat that can be dissipated depends on the package and its integration into the target board. The “Thermal resistance $R_{\Theta JA}$ ” quantifies these parameters. The power dissipation must be limited so that the average junction temperature does not exceed 150 °C.

The difference between junction temperature and ambient temperature is determined by $\Delta T = (P_{INT} + P_{IOSTAT} + P_{IODYN}) \times R_{\Theta JA}$

The internal power consumption is defined as

$$P_{INT} = V_{DDP} \times I_{DDP} \text{ (switching current and leakage current).}$$

The static external power consumption caused by the output drivers is defined as

$$P_{IOSTAT} = \Sigma((V_{DDP} - V_{OH}) \times I_{OH}) + \Sigma(V_{OL} \times I_{OL})$$

The dynamic external power consumption caused by the output drivers (P_{IODYN}) depends on the capacitive load connected to the respective pins and their switching frequencies.

If the total power dissipation for a given system configuration exceeds the defined limit, countermeasures must be taken to ensure proper system operation:

- Reduce V_{DDP} , if possible in the system
- Reduce the system frequency
- Reduce the number of output pins
- Reduce the load on active output drivers

4.2 Package Outlines

The exposed die pad dimensions are listed in **Table 60**.

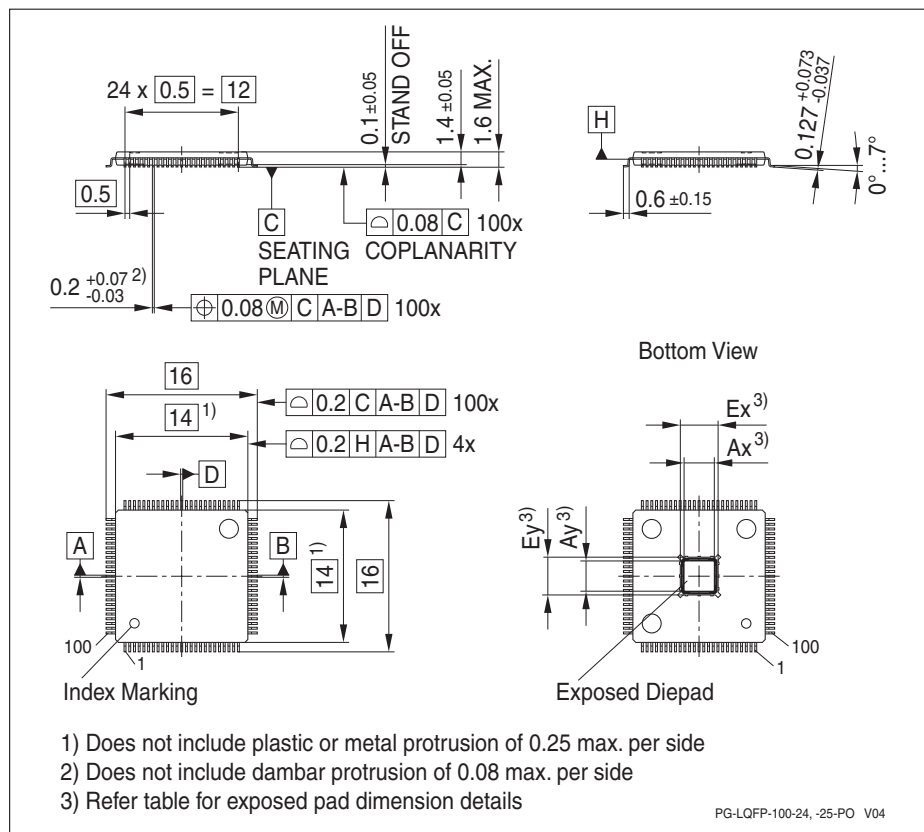


Figure 43 PG-LQFP-100-25 (Plastic Green Low Profile Quad Flat Package)

5 Quality Declarations

The qualification of the XMC4300 is executed according to the JEDEC standard JESD471.

Note: For automotive applications refer to the Infineon automotive microcontrollers.

Table 61 Quality Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Operation lifetime	t_{OP} CC	20	–	–	a	$T_J \leq 109^\circ\text{C}$, device permanent on
ESD susceptibility according to Human Body Model (HBM)	V_{HBM} SR	–	–	3 000	V	EIA/JESD22-A114-B
ESD susceptibility according to Charged Device Model (CDM)	V_{CDM} SR	–	–	1 000	V	Conforming to JESD22-C101-C
Moisture sensitivity level	MSL CC	–	–	3	–	JEDEC J-STD-020D
Soldering temperature	T_{SDR} SR	–	–	260	$^\circ\text{C}$	Profile according to JEDEC J-STD-020D

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