

## XMC4500

### Microcontroller Series for Industrial Applications

ARM® Cortex®-M4

32-bit processor core

### About this Document

This datasheet 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 XMC4500 series devices.

The document describes the characteristics of a superset of the XMC4500 series devices. For simplicity, the various device types are referred to by the collective term XMC4500 throughout this manual.

### XMC4000 Family User Documentation

The set of user documentation includes:

- **Reference Manual**
  - describes the functionality of the superset of devices.
- **Datasheets**
  - 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 Datasheets. 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.

**Table of contents**

**Table of contents**

<b>About this Document</b>	1
<b>Table of contents</b>	2
<b>1 Summary of Features</b>	4
1.1 Ordering Information	6
1.2 Device Types	6
1.3 Device Type Features	7
1.4 Definition of Feature Variants	8
1.5 Identification Registers	9
<b>2 General Device Information</b>	10
2.1 Logic Symbols	10
2.2 Pin Configuration and Definition	12
2.2.1 Package Pin Summary	14
2.2.2 Port I/O Functions	21
2.2.2.1 Port I/O Function Table	22
2.3 Power Connection Scheme	38
<b>3 Electrical Parameters</b>	39
3.1 General Parameters	39
3.1.1 Parameter Interpretation	39
3.1.2 Absolute Maximum Ratings	39
3.1.3 Pin Reliability in Overload	40
3.1.4 Pad Driver and Pad Classes Summary	42
3.1.5 Operating Conditions	43
3.2 DC Parameters	44
3.2.1 Input/Output Pins	44
3.2.2 Analog to Digital Converters (VADC)	49
3.2.3 Digital to Analog Converters (DAC)	52
3.2.4 Out-of-Range Comparator (ORC)	55
3.2.5 Die Temperature Sensor	56
3.2.6 USB OTG Interface DC Characteristics	57
3.2.7 Oscillator Pins	59
3.2.8 Power Supply Current	62
3.2.9 Flash Memory Parameters	64
3.3 AC Parameters	65
3.3.1 Testing Waveforms	65
3.3.2 Power-Up and Supply Monitoring	66
3.3.3 Power Sequencing	67
3.3.4 Phase Locked Loop (PLL) Characteristics	68
3.3.5 Internal Clock Source Characteristics	69

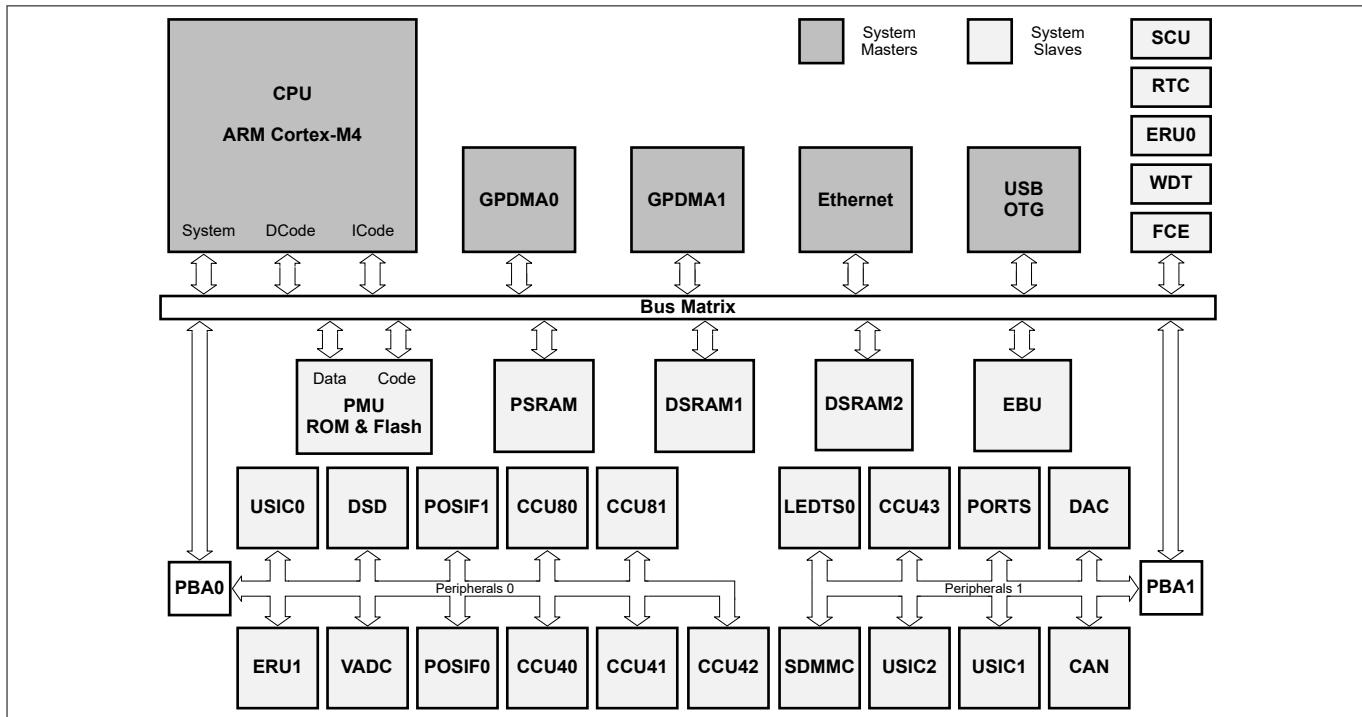
**Table of contents**

3.3.6	JTAG Interface Timing .....	70
3.3.7	Serial Wire Debug Port (SW-DP) Timing .....	71
3.3.8	Embedded Trace Macro Cell (ETM) Timing .....	72
3.3.9	Peripheral Timing .....	73
3.3.9.1	Delta-Sigma Demodulator Digital Interface Timing .....	73
3.3.9.2	Synchronous Serial Interface (USIC SSC) Timing .....	74
3.3.9.3	Inter-IC (IIC) Interface Timing .....	77
3.3.9.4	Inter-IC Sound (IIS) Interface Timing .....	79
3.3.9.5	SDMMC Interface Timing .....	81
3.3.10	EBU Timing .....	88
3.3.10.1	EBU Asynchronous Timing .....	88
3.3.10.2	EBU Burst Mode Access Timing .....	94
3.3.10.3	EBU Arbitration Signal Timing .....	96
3.3.10.4	EBU SDRAM Access Timing .....	97
3.3.11	USB Interface Characteristics .....	101
3.3.12	Ethernet Interface (ETH) Characteristics .....	101
3.3.12.1	ETH Measurement Reference Points .....	101
3.3.12.2	ETH Management Signal Parameters (ETH_MDC, ETH_MDIO) .....	102
3.3.12.3	ETH MII Parameters .....	103
3.3.12.4	ETH RMII Parameters .....	104
<b>4</b>	<b>Package and Reliability .....</b>	<b>105</b>
4.1	Package Parameters .....	105
4.1.1	Thermal Considerations .....	106
4.2	Package Outlines .....	107
<b>5</b>	<b>Quality Declarations .....</b>	<b>111</b>
	<b>Revision history .....</b>	<b>112</b>
	<b>Disclaimer .....</b>	<b>113</b>

## 1 Summary of Features

# 1 Summary of Features

The XMC4500 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
- Two General Purpose DMA with up-to 12 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
- 32 KB on-chip high-speed communication
- 1024 KB on-chip Flash Memory with 4 KB instruction cache

## 1 Summary of Features

### Communication Peripherals

- Ethernet MAC module capable of 10/100 Mbit/s transfer rates
- Universal Serial Bus, USB 2.0 host, Full-Speed OTG, with integrated PHY
- Controller Area Network interface (MultiCAN), Full-CAN/Basic-CAN with 3 nodes, 64 message objects (MO), data rate up to 1MBit/s
- Six Universal Serial Interface Channels (USIC), providing 6 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
- External Bus Interface Unit (EBU) enabling communication with external memories and off-chip peripherals

### Analog Frontend Peripherals

- Four Analog-Digital Converters (VADC) of 12-bit resolution, 8 channels each, with input out-of-range comparators
- Delta Sigma Demodulator with four channels, digital input stage for A/D signal conversion
- Digital-Analogue Converter (DAC) with two channels of 12-bit resolution

### Industrial Control Peripherals

- Two Capture/Compare Units 8 (CCU8) for motor control and power conversion
- Four Capture/Compare Units 4 (CCU4) for use as general purpose timers
- Two Position Interfaces (POSIF) for servo motor positioning
- 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: 8 breakpoints, CoreSight, trace
- Various interfaces: ARM-JTAG, SWD, single wire trace

## 1 Summary of Features

### 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
  - X: -40°C to 105°C
  - K: -40°C to 125°C
- <FFFF> the Flash memory size

For ordering codes for the XMC4500 please contact your sales representative or local distributor.

This document describes several derivatives of the XMC4500 series, some descriptions may not apply to a specific product.

For simplicity the term **XMC4500** 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 XMC4500 Device Types**

Derivative <sup>1)</sup>	Package	Flash Kbytes	SRAM Kbytes
XMC4500-E144x1024	PG-LFBGA-144	1024	160
XMC4500-F144x1024	PG-LQFP-144	1024	160
XMC4500-F100x1024	PG-LQFP-100	1024	160
XMC4500-F144x768	PG-LQFP-144	768	160
XMC4500-F100x768	PG-LQFP-100	768	160
XMC4502-F100x768	PG-LQFP-100	768	160
XMC4504-F144x512	PG-LQFP-144	512	128
XMC4504-F100x512	PG-LQFP-100	512	128

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

## 1 Summary of Features

### 1.3 Device Type Features

The following table lists the available features per device type.

**Table 2 Features of XMC4500 Device Types**

Derivative <sup>1)</sup>	LEDTS Intf.	SDMMC Intf.	EBU Intf. <sup>2)</sup>	ETH Intf. <sup>3)</sup>	USB Intf.	USIC Chan.	MultiCAN Nodes, MO
XMC4500-E144x1024	1	1	SDM	MR	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F144x1024	1	1	SDM	MR	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F100x1024	1	1	M16	R	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F144x768	1	1	SDM	MR	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F100x768	1	1	M16	R	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4502-F100x768	1	1	M16	-	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4504-F144x512	1	1	SDM	-	-	3 x 2	-
XMC4504-F100x512	1	1	M16	-	-	3 x 2	-

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

2) Memory types supported S=SDRAM, D=DEMUX, M=MUX 16-bit and 32-bit, M16=MUX 16-bit.

3) Supported interfaces, M=MI, R=RMII.

**Table 3 Features of XMC4500 Device Types**

Derivative <sup>1)</sup>	ADC Chan.	DSD Chan.	DAC Chan.	CCU4 Slice	CCU8 Slice	POSIF Intf.
XMC4500-E144x1024	32	4	2	4 x 4	2 x 4	2
XMC4500-F144x1024	32	4	2	4 x 4	2 x 4	2
XMC4500-F100x1024	24	4	2	4 x 4	2 x 4	2
XMC4500-F144x768	32	4	2	4 x 4	2 x 4	2
XMC4500-F100x768	24	4	2	4 x 4	2 x 4	2
XMC4502-F100x768	24	4	2	4 x 4	2 x 4	2

(table continues...)

## 1 Summary of Features

**Table 3** (continued) Features of XMC4500 Device Types

Derivative <sup>1)</sup>	ADC Chan.	DSD Chan.	DAC Chan.	CCU4 Slice	CCU8 Slice	POSIF Intf.
XMC4504-F144x512	32	4	2	4 x 4	2 x 4	2
XMC4504-F100x512	24	4	2	4 x 4	2 x 4	2

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

## 1.4 Definition of Feature Variants

The XMC4500 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
512 Kbytes	0800 0000 <sub>H</sub> – 0807 FFFF <sub>H</sub>	0C00 0000 <sub>H</sub> – 0C07 FFFF <sub>H</sub>
768 Kbytes	0800 0000 <sub>H</sub> – 080B FFFF <sub>H</sub>	0C00 0000 <sub>H</sub> – 0C0B FFFF <sub>H</sub>
1,024 Kbytes	0800 0000 <sub>H</sub> – 080F FFFF <sub>H</sub>	0C00 0000 <sub>H</sub> – 0C0F FFFF <sub>H</sub>

**Table 5** SRAM Memory Ranges

Total SRAM Size	Program SRAM	System Data SRAM	Communication Data SRAM
128 Kbytes	1000 0000 <sub>H</sub> – 1000 FFFF <sub>H</sub>	2000 0000 <sub>H</sub> – 2000 FFFF <sub>H</sub>	–
160 Kbytes	1000 0000 <sub>H</sub> – 1000 FFFF <sub>H</sub>	2000 0000 <sub>H</sub> – 2000 FFFF <sub>H</sub>	3000 0000 <sub>H</sub> – 3000 7FFF <sub>H</sub>

**Table 6** ADC Channels<sup>1)</sup>

Package	VADC G0	VADC G1	VADC G2	VADC G3
PG-LQFP-144	CH0..CH7	CH0..CH7	CH0..CH7	CH0..CH7
PG-LFBGA-144				
PG-LQFP-100	CH0..CH7	CH0..CH7	CH0..CH3	CH0..CH3

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.

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## 1 Summary of Features

### 1.5 Identification Registers

The identification registers allow software to identify the marking.

**Table 7 XMC4500 Identification Registers**

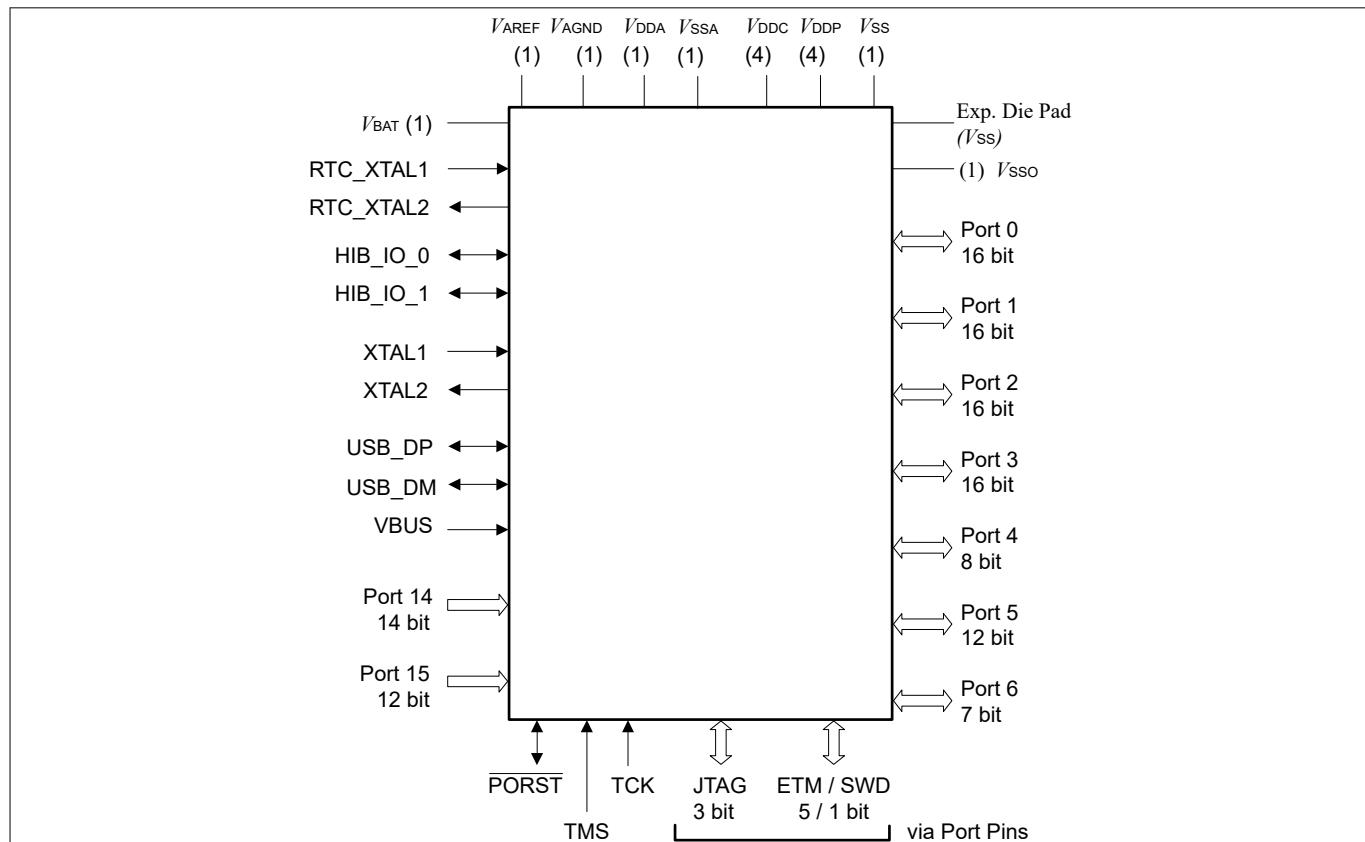
Register Name	Value	Marking
SCU_IDCHIP	0004 5002 <sub>H</sub>	EES-AA, ES-AA
SCU_IDCHIP	0004 5003 <sub>H</sub>	ES-AB, AB
SCU_IDCHIP	0004 5004 <sub>H</sub>	AC
JTAG IDCODE	101D B083 <sub>H</sub>	EES-AA, ES-AA
JTAG IDCODE	101D B083 <sub>H</sub>	ES-AB, AB
JTAG IDCODE	401D B083 <sub>H</sub>	AC

## 2 General Device Information

# 2 General Device Information

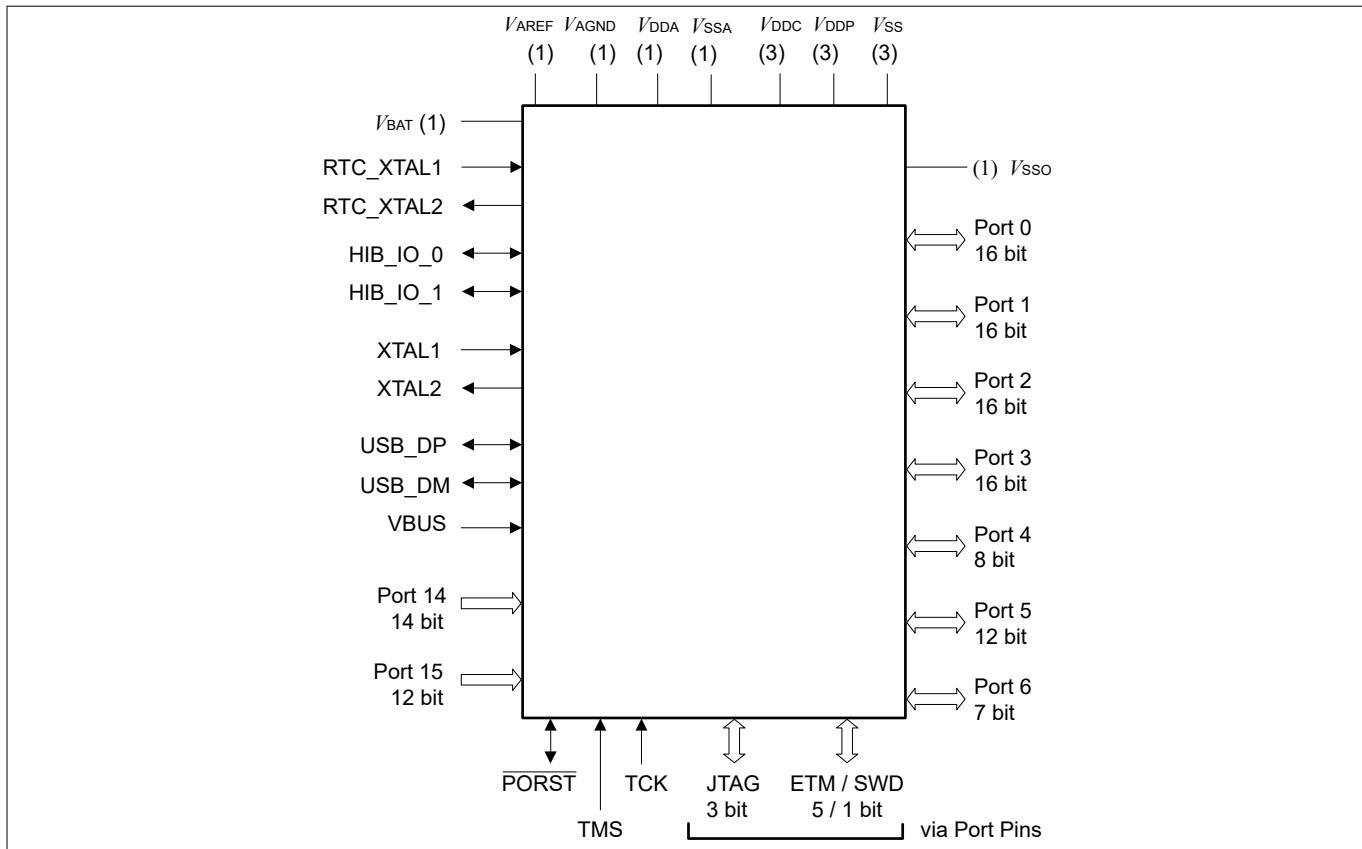
This section summarizes the logic symbols and package pin configurations with a detailed list of the functional I/O mapping.

## 2.1 Logic Symbols

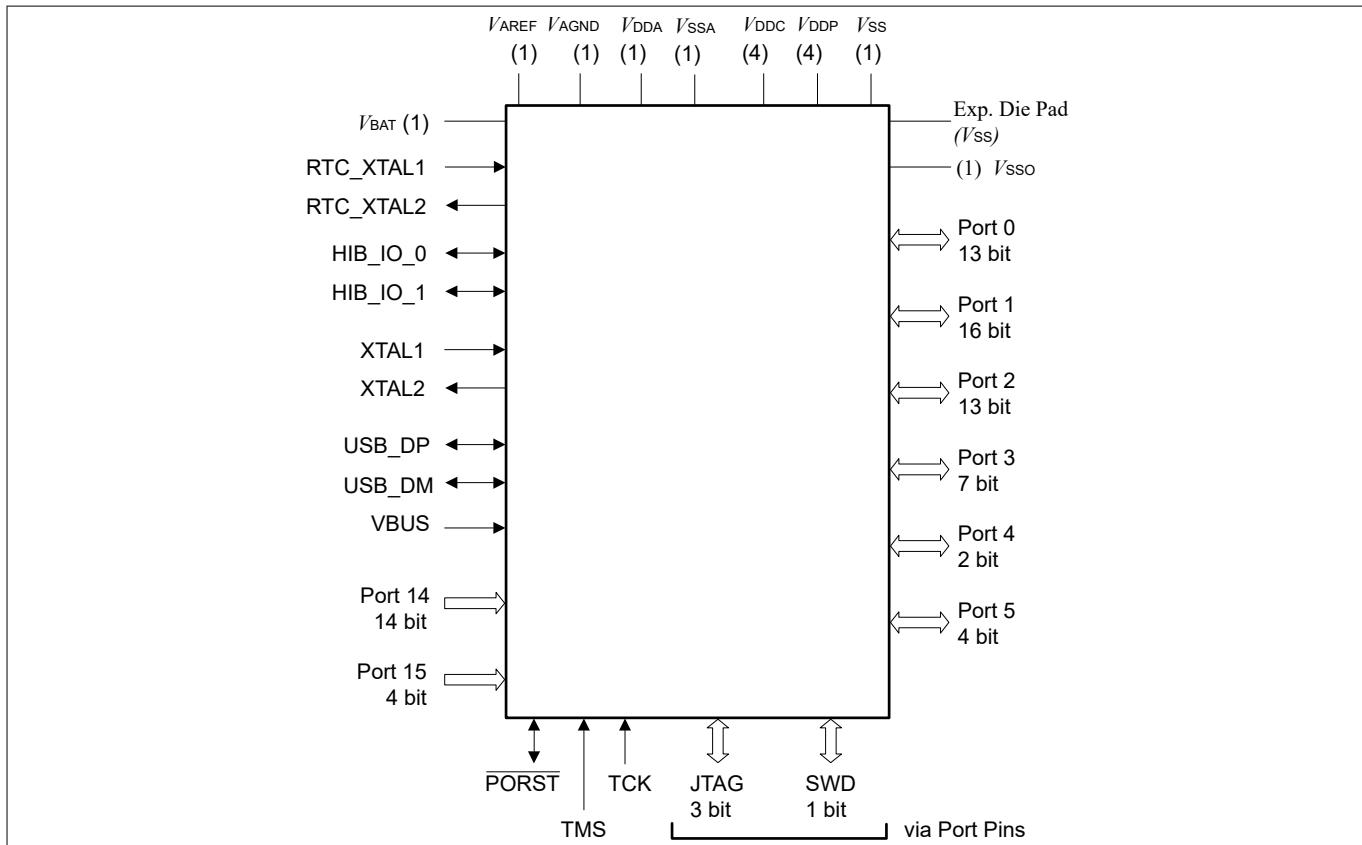


**Figure 2 XMC4500 Logic Symbol PG-LQFP-144**

## 2 General Device Information



**Figure 3** XMC4500 Logic Symbol PG-LFBGA-144

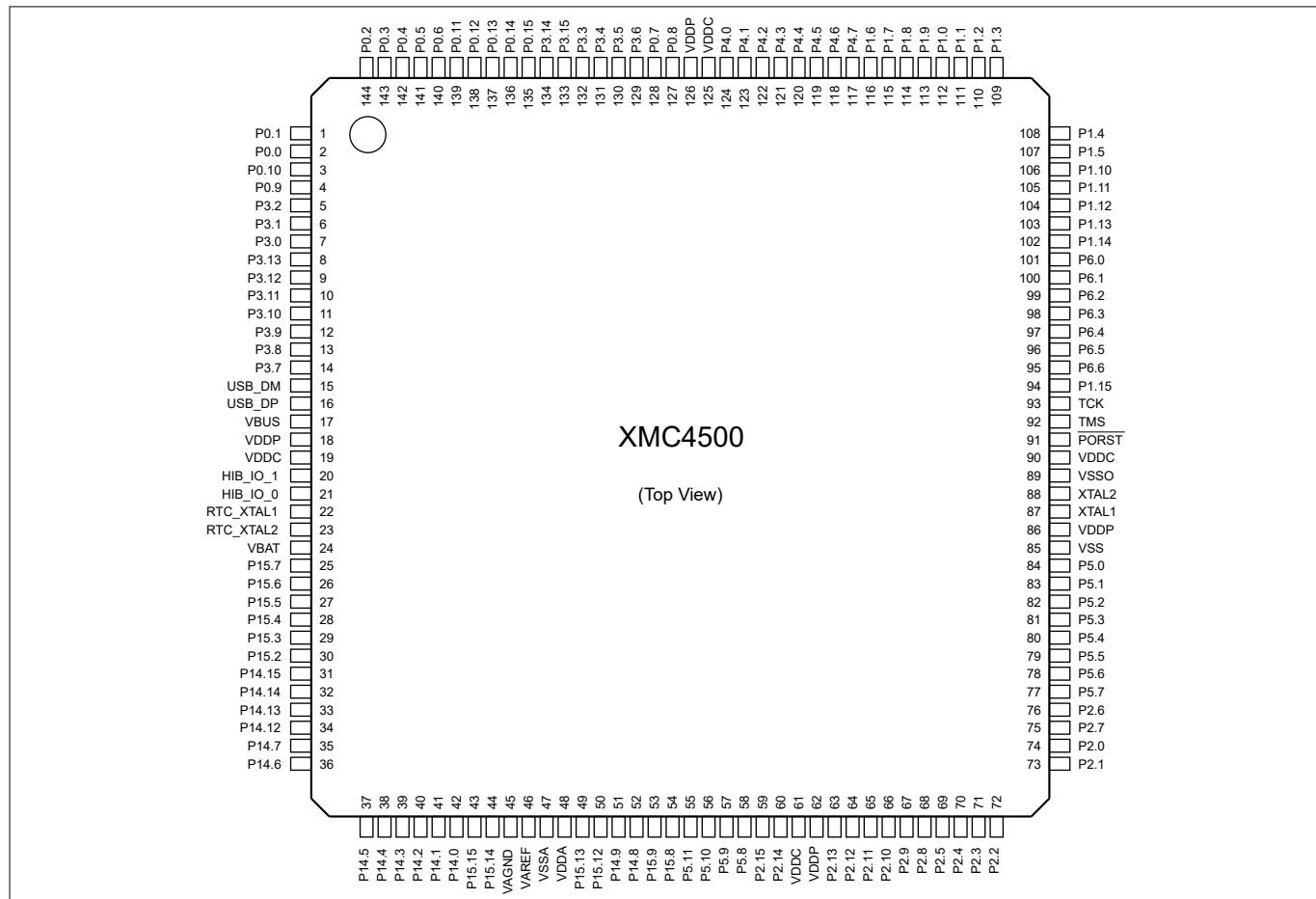


**Figure 4** XMC4500 Logic Symbol PG-LQFP-100

## 2 General Device Information

### 2.2 Pin Configuration and Definition

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



**Figure 5**

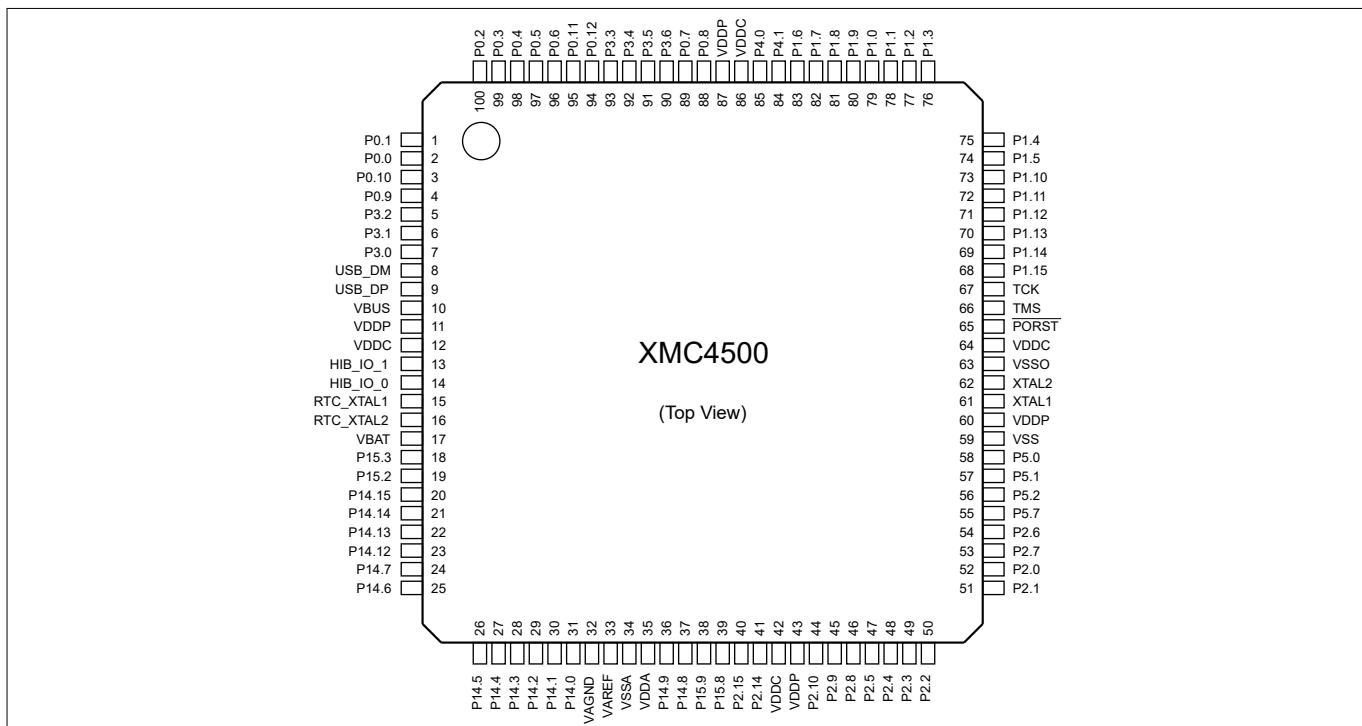
**XMC4500 PG-LQFP-144 Pin Configuration (top view)**

## 2 General Device Information

	1	2	3	4	5	6	7	8	9	10	11	12	
A	VSS	VDDC	P0.2	P0.3	P0.5	P0.6	P3.6	P0.8	P4.1	P1.8	VDDP	VSS	A
B	VDDP	P3.1	P3.2	P0.10	P0.4	P3.5	P0.7	P4.0	P1.6	P1.7	P1.9	VDDC	B
C	P3.0	P3.13	P0.1	P0.0	P0.13	P0.15	P4.4	P4.6	P4.7	P1.4	P1.2	P1.3	C
D	USB_DM	P3.12	P3.11	P0.9	P0.12	P3.14	P3.15	P4.5	P1.0	P1.5	P1.11	P1.10	D
E	USB_DP	VBUS	P3.8	P3.7	P0.11	P0.14	P3.4	P4.2	P1.1	P1.14	P1.12	P1.13	E
F	RTC_X_TAL1	RTC_X_TAL2	HIB_IO_1	HIB_IO_0	P3.9	P3.10	P3.3	P4.3	P6.1	P6.4	P6.5	P6.6	F
G	VBAT	P15.3	P15.5	P15.4	P15.6	P15.7	TMS	TCK	P6.3	P6.0	PORST	P1.15	G
H	P15.2	P14.15	P14.14	P14.13	P5.10	P5.8	P5.2	P5.1	P5.0	P6.2	XTAL1	XTAL2	H
J	P14.12	P14.7	P14.6	P14.3	P5.11	P2.15	P5.7	P5.5	P2.6	P5.3	P2.0	VSSO	J
K	P14.4	P14.5	P14.2	P15.15	P15.12	P5.9	P2.14	P5.6	P2.7	P5.4	P2.2	P2.1	K
L	VDDA	P14.1	P14.0	P15.14	P14.9	P15.9	P2.12	P2.10	P2.8	P2.4	P2.3	VDDP	L
M	VSSA	VAGND	VAREF	P15.13	P14.8	P15.8	P2.13	P2.11	P2.9	P2.5	VDDC	VSS	M

XMC4500 -(top view)

**Figure 6 XMC4500 PG-LFBGA-144 Pin Configuration (top view)**



**Figure 7 XMC4500 PG-LQFP-100 Pin Configuration (top view)**

## 2 General Device Information

### 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. 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, that is 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-144	LFBGA-144	LQFP-100	Pad Type	Notes
P0.0	2	C4	2	A1+	
P0.1	1	C3	1	A1+	
P0.2	144	A3	100	A2	
P0.3	143	A4	99	A2	
P0.4	142	B5	98	A2	
P0.5	141	A5	97	A2	
P0.6	140	A6	96	A2	
P0.7	128	B7	89	A2	After a system reset, via HWSEL this pin selects the DB.TDI function.
P0.8	127	A8	88	A2	After a system reset, via HWSEL this pin selects the DB.TRST function, with a weak pull-down active.
P0.9	4	D4	4	A2	
P0.10	3	B4	3	A1+	
P0.11	139	E5	95	A1+	
P0.12	138	D5	94	A1+	

(table continues...)

## 2 General Device Information

**Table 9** (continued) Package Pin Mapping

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P0.13	137	C5	-	A1+	
P0.14	136	E6	-	A1+	
P0.15	135	C6	-	A1+	
P1.0	112	D9	79	A1+	
P1.1	111	E9	78	A1+	
P1.2	110	C11	77	A2	
P1.3	109	C12	76	A2	
P1.4	108	C10	75	A1+	
P1.5	107	D10	74	A1+	
P1.6	116	B9	83	A2	
P1.7	115	B10	82	A2	
P1.8	114	A10	81	A2	
P1.9	113	B11	80	A2	
P1.10	106	D12	73	A1+	
P1.11	105	D11	72	A1+	
P1.12	104	E11	71	A2	
P1.13	103	E12	70	A2	
P1.14	102	E10	69	A2	
P1.15	94	G12	68	A2	
P2.0	74	J11	52	A2	
P2.1	73	K12	51	A2	After a system reset, via HWSEL this pin selects the DB.TDO function.
P2.2	72	K11	50	A2	
P2.3	71	L11	49	A2	
P2.4	70	L10	48	A2	
P2.5	69	M10	47	A2	
P2.6	76	J9	54	A1+	
P2.7	75	K9	53	A1+	
P2.8	68	L9	46	A2	
P2.9	67	M9	45	A2	
P2.10	66	L8	44	A2	
P2.11	65	M8	-	A2	

(table continues...)

## 2 General Device Information

**Table 9 (continued) Package Pin Mapping**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P2.12	64	L7	-	A2	
P2.13	63	M7	-	A2	
P2.14	60	K7	41	A2	
P2.15	59	J6	40	A2	
P3.0	7	C1	7	A2	
P3.1	6	B2	6	A2	
P3.2	5	B3	5	A2	
P3.3	132	F7	93	A1+	
P3.4	131	E7	92	A1+	
P3.5	130	B6	91	A2	
P3.6	129	A7	90	A2	
P3.7	14	E4	-	A1+	
P3.8	13	E3	-	A1+	
P3.9	12	F5	-	A1+	
P3.10	11	F6	-	A1+	
P3.11	10	D3	-	A1+	
P3.12	9	D2	-	A2	
P3.13	8	C2	-	A2	
P3.14	134	D6	-	A1+	
P3.15	133	D7	-	A1+	
P4.0	124	B8	85	A2	
P4.1	123	A9	84	A2	
P4.2	122	E8	-	A1+	
P4.3	121	F8	-	A1+	
P4.4	120	C7	-	A1+	
P4.5	119	D8	-	A1+	
P4.6	118	C8	-	A1+	
P4.7	117	C9	-	A1+	
P5.0	84	H9	58	A1+	
P5.1	83	H8	57	A1+	
P5.2	82	H7	56	A1+	
P5.3	81	J10	-	A2	
P5.4	80	K10	-	A2	

(table continues...)

## 2 General Device Information

**Table 9 (continued) Package Pin Mapping**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P5.5	79	J8	-	A2	
P5.6	78	K8	-	A2	
P5.7	77	J7	55	A1+	
P5.8	58	H6	-	A2	
P5.9	57	K6	-	A2	
P5.10	56	H5	-	A1+	
P5.11	55	J5	-	A1+	
P6.0	101	G10	-	A2	
P6.1	100	F9	-	A2	
P6.2	99	H10	-	A2	
P6.3	98	G9	-	A1+	
P6.4	97	F10	-	A2	
P6.5	96	F11	-	A2	
P6.6	95	F12	-	A2	
P14.0	42	L3	31	AN/DIG_IN	
P14.1	41	L2	30	AN/DIG_IN	
P14.2	40	K3	29	AN/DIG_IN	
P14.3	39	J4	28	AN/DIG_IN	
P14.4	38	K1	27	AN/DIG_IN	
P14.5	37	K2	26	AN/DIG_IN	
P14.6	36	J3	25	AN/DIG_IN	
P14.7	35	J2	24	AN/DIG_IN	
P14.8	52	M5	37	AN/DAC/DIG_IN	
P14.9	51	L5	36	AN/DAC/DIG_IN	
P14.12	34	J1	23	AN/DIG_IN	
P14.13	33	H4	22	AN/DIG_IN	
P14.14	32	H3	21	AN/DIG_IN	
P14.15	31	H2	20	AN/DIG_IN	
P15.2	30	H1	19	AN/DIG_IN	
P15.3	29	G2	18	AN/DIG_IN	
P15.4	28	G4	-	AN/DIG_IN	
P15.5	27	G3	-	AN/DIG_IN	
P15.6	26	G5	-	AN/DIG_IN	

(table continues...)

## 2 General Device Information

**Table 9 (continued) Package Pin Mapping**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P15.7	25	G6	-	AN/DIG_IN	
P15.8	54	M6	39	AN/DIG_IN	
P15.9	53	L6	38	AN/DIG_IN	
P15.12	50	K5	-	AN/DIG_IN	
P15.13	49	M4	-	AN/DIG_IN	
P15.14	44	L4	-	AN/DIG_IN	
P15.15	43	K4	-	AN/DIG_IN	
USB_DP	16	E1	9	special	
USB_DM	15	D1	8	special	
HIB_IO_0	21	F4	14	A1 special	<p>At the first power-up and with every reset of the hibernate domain this pin is configured as open-drain output and drives "0".</p> <p>As output the medium driver mode is active.</p>
HIB_IO_1	20	F3	13	A1 special	<p>At the first power-up and with every reset of the hibernate domain this pin is configured as input with no pull device active.</p> <p>As output the medium driver mode is active.</p>
TCK	93	G8	67	A1	Weak pull-down active.
TMS	92	G7	66	A1+	<p>Weak pull-up active.</p> <p>As output the strong-soft driver mode is active.</p>

(table continues...)

## 2 General Device Information

**Table 9 (continued) Package Pin Mapping**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
PORST	91	G11	65	special	Weak pull-up permanently active, strong pull-down controlled by EVR.
XTAL1	87	H11	61	clock_IN	
XTAL2	88	H12	62	clock_O	
RTC_XTAL1	22	F2	15	clock_IN	
RTC_XTAL2	23	F1	16	clock_O	
VBAT	24	G1	17	Power	When VDDP is supplied VBAT has to be supplied as well.
VBUS	17	E2	10	special	
VAREF	46	M3	33	AN_Ref	
VAGND	45	M2	32	AN_Ref	
VDDA	48	L1	35	AN_Power	
VSSA	47	M1	34	AN_Power	
VDDC	19	-	12	Power	
VDDC	61	-	42	Power	
VDDC	90	-	64	Power	
VDDC	125	-	86	Power	
VDDC	-	A2	-	Power	
VDDC	-	B12	-	Power	
VDDC	-	M11	-	Power	
VDDP	18	-	11	Power	
VDDP	62	-	43	Power	
VDDP	86	-	60	Power	
VDDP	126	-	87	Power	
VDDP	-	A11	-	Power	
VDDP	-	B1	-	Power	
VDDP	-	L12	-	Power	
VSS	85	-	59	Power	
VSS	-	A1	-	Power	
VSS	-	A12	-	Power	

(table continues...)

## 2 General Device Information

**Table 9** (continued) Package Pin Mapping

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
VSS	-	M12	-	Power	
VSSO	89	J12	63	Power	
VSS	Exp. Pad	-	Exp. Pad	Power	<p><b>Exposed Die Pad</b></p> <p>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.</p> <p>For thermal aspects, please refer to the Datasheet. Board layout examples are given in an application note.</p>

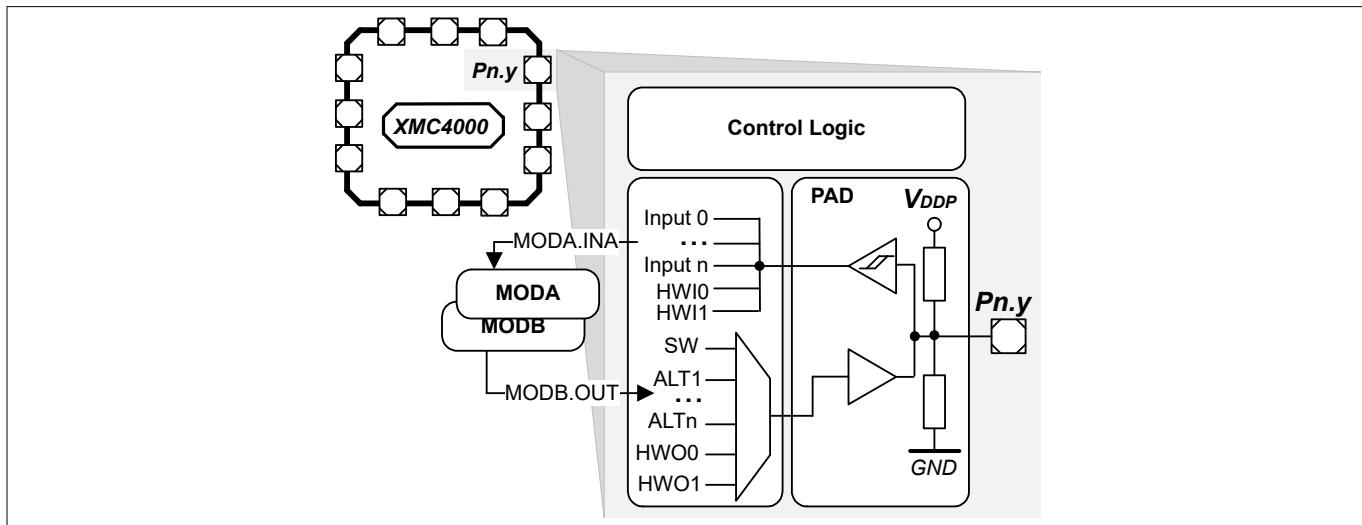
## 2 General Device Information

### 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 8**      **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\_IOCR.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, HWO1/HWI1). The selected peripheral can take control of the pin(s). Hardware control overrules settings in the respective port pin registers.

## 2 General Device Information

### 2.2.2.1 Port I/O Function Table

**Table 11 Port I/O Functions**

Function	Outputs				Inputs				Input	Input
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1		
P0.0	CAN. N0_TX D	CCU80 .OUT21	LEDTS 0. COL2				U1C1. DX0D	ETH0. CLK_R MII_B	ERU0. 0B0	ETH0. CLK_RX B
P0.1	USB. DRIVE VBUS	U1C1. DOUT 0	CCU80 .OUT11	LEDTS 0. COL3				ETH0. CRS_D VB	ERU0. 0A0	ETH0. RXDV_B
P0.2	U1C1. SEL01	CCU80 .OUT01	U1C0. DOUT 3	EBU. AD0	U1C0. HWIN3	EBU. D0	ETH0. RXD0B		ERU0. 3B3	
P0.3		CCU80 .OUT20	U1C0. DOUT 2	EBU. AD1	U1C0. HWIN2	EBU. D1	ETH0. RXD1B		ERU1. 3B0	
P0.4	ETH0. TX_EN	CCU80 .OUT10	U1C0. DOUT 1	EBU. AD2	U1C0. HWIN1	EBU. D2		U1C0. DX0A	ERU0. 2B3	
P0.5	ETH0. TXD0	U1C0. DOUT 0	CCU80 .OUT00	U1C0. DOUT 0	EBU. AD3	EBU. HWIN0	U1C0. D3	DX0B		ERU1. 3A0
P0.6	ETH0. TXD1	U1C0. SEL00	CCU80 .OUT30					U1C0. DX2A	ERU0. 3B2	CCU80 .IN2B

(table continues...)

## 2 General Device Information

Table 1.1 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P0.7	WWDT. SERVI CE_O UT	U0C0. SEL00			EBU. AD6	DB. TDI	EBU. D6	U0C0. DX2B
P0.8	SCU. EXTCL K	U0C0. SCLK0 UT			EBU. AD7	<u>DB.</u> <u>TRST</u>	EBU. D7	U0C0. DX1B
P0.9	U1C1. SEL00	CCU80 .OUT12	LEDTS 0. COL0	ETH0. MDO	<u>EBU.</u> <u>CS1</u>	ETH0. MDA	U1C1. DX2A	U1C1. DX1B
P0.10	ETH0. MDC	U1C1. SCLK0 UT	CCU80 .OUT02	LEDTS 0. COL1			U1C1. DX1A	ERU0. 1A0
P0.11	U1C0. SCLK0 UT	CCU80 .OUT31		<u>SDMMC.EBU.</u> <u>RST</u>	<u>SDMMC.EBU.</u> <u>BREQ</u>		ETH0. RXERB	U1C0. DX1A
P0.12	U1C1. SEL00	CCU40 .OUT3			<u>EBU.</u> <u>HLDA</u>		U1C1. DX2B	ERU0. 3A2
P0.13	U1C1. SCLK0 UT	CCU40 .OUT2					U1C1. DX1B	ERU0. 2A2
P0.14	U1C0. SEL01	CCU40 .OUT1	U1C1. DOUT 3		U1C1. HWIN3			CCU42 .IN3C

(table continues...)

## 2 General Device Information

Table 1.1 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P0.15	U1C0. SEL02	CCU40 .OUT0	U1C1. DOUT 2		U1C1. HWIN2			
P1.0	DSD. CGPW MN	U0C0. SEL00	CCU40 .OUT3	ERU1. PDOU T3			U0C0. DX2A	
P1.1	DSD. CGPW MP	U0C0. SCLKO UT	CCU40 .OUT2	ERU1. PDOU T2	SDMM C. SDWC	U0C0. DX1A	POSIF 0. IN2A	
P1.2			CCU40 .OUT1	ERU1. PDOU T1	U0C0. DOUT 3	EBU. AD14	EBU. HWIN3 D14	POSIF 0. IN1A
P1.3		U0C0. MCLK OUT	CCU40 .OUT0	ERU1. PDOU T0	U0C0. DOUT 2	EBU. AD15	EBU. HWIN2 D15	POSIF 0. IN0A
P1.4	WWDT. SERV CE_O UT	CAN. NO_TX D	CCU80 .OUT33	CCU81 .OUT20	U0C0. DOUT 1	U0C0. HWIN1	U0C0. DX0B N1_RX DD	ERU0. 2B0
P1.5	CAN. N1_TX D	U0C0. DOUT 0	CCU80 .OUT23	CCU81 .OUT10	U0C0. DOUT 0	U0C0. HWIN0	CAN. DX0A NO_RX DA	ERU1. 2A0
P1.6		U0C0. SCLKO UT			SDMM C. DATA1 _OUT	EBU. AD10	DSD. D10 DATA1 _IN	CCU41 .IN1C

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P1.7	U0C0. DOUT 0	DSD. MCLK2	SDMM C. DATA2 _OUT	EBU. AD11	SDMM C. DATA2 _IN	EBU. D11	DSD. MCLK2 A	
P1.8	U0C0. SEL01	DSD. MCLK1	SDMM C. DATA4 _OUT	EBU. AD12	SDMM C. DATA4 _IN	EBU. D12	CAN. N2_RX DA	DSD. MCLK1 A
P1.9	CAN. N2_TX D		SDMM C. DATA5 _OUT	EBU. AD13	SDMM C. DATA5 _IN	EBU. D13	DSD. MCLK0 A	
P1.10	ETH0. MDC	U0C0. SCLK0 .UT	CCU81 .OUT21		SDMMC. SDCD			CCU41 .IN2C
P1.11	U0C0. SEL00		CCU81 .OUT11	ETH0. MDO		ETH0. MDIC		CCU41 .IN3C
P1.12	ETH0. TX_EN	CAN. N1_TX D	CCU81 .OUT01	SDMM C. DATA6 _OUT	EBU. AD16	SDMM C. DATA6 _IN	EBU. D16	
P1.13	ETH0. TXD0	U0C1. SEL03	CCU81 .OUT20	SDMM C. DATA7 _OUT	EBU. AD17	SDMM C. DATA7 _IN	EBU. D17	CAN. N1_RX DC

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P1.14	ETH0. TXD1	U0C1. SELO2	CCU81 .OUT10		EBU. AD18	EBU. D18		
P1.15	SCU. EXTCL K	DSD. MCLK2	CCU81 .OUT00		EBU. AD19	EBU. D19		
P2.0	CCU81 .OUT21	DSD. CGPW MN	LEDTS 0. COL1	ETH0. MDO	EBU. AD20	EBU. D20		
P2.1	CCU81 .OUT11	DSD. CGPW MP	LEDTS 0. COL0	DB.TD O/ TRACE SWO	EBU. AD21	EBU. D21	ETH0. CLK_R MIIA	
P2.2	VADC. EMUX 00	CCU81 .OUT01	CCU41 .LINE0	LEDTS 0. EXTEN DED0	EBU. AD22	LEDTS 0. TSIN0 A	ETH0. RXD0A	UOC1. DX0A
P2.3	VADC. EMUX 01	U0C1. SELO0	CCU41 .OUT2	LEDTS 0. LINE1	EBU. AD23	LEDTS 0. TSIN1 A	ETH0. RXD1A	ERU0. DX2A
P2.4	VADC. EMUX 02	U0C1. SCLKO UT	CCU41 .OUT1	LEDTS 0. LINE2	EBU. AD24	LEDTS 0. TSIN2 A	ETH0. RXERA	UOC1. DX1A

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P2.5	ETH0. TX_EN	U0C1. DOUT 0	CCU41. .OUT0	LEDTS 0. LINE3	LEDTS AD25 EXTEN DED3	EBU. 0. TSIN3 A	LEDTS D25 TSIN3 A	ETH0. RXDVA
P2.6	U2C0. SEL04	CCU80. .OUT13	LEDTS 0. COL3	U2C0. DOUT 3	U2C0. HWIN3	DSD. DIN1B	CAN. N1_RX DA	ERU0. 1B3
P2.7	ETH0. MDC	CAN. N1_TX D	CCU80. .OUT03	LEDTS 0. COL2	LEDTS 0. EXTEN DED4	EBU. AD26 TSIN4 A	DSD. DIN0B	ERU1. 1B0
P2.8	ETH0. TXD0	CCU80. .OUT32	LEDTS 0. LINE4	LEDTS 0. EXTEN DED4	EBU. AD26 TSIN4 A	LEDTS 0. TSIN4 A	DAC. TRIGG ER5	CCU40 .IN2C
P2.9	ETH0. TXD1	CCU80. .OUT22	LEDTS 0. LINE5	LEDTS 0. EXTEN DED5	EBU. AD27 TSIN5 A	LEDTS 0. TSIN5 A	DAC. TRIGG ER4	CCU41 .IN0B
P2.10	VADC. EMUX 10			DB. ETM_T RACED ATA3	EBU. AD28	EBU. D28		IN1B IN2B IN3B
P2.11	ETH0. TXER	CCU80. .OUT22	DB. ETM_T RACED ATA2	EBU. AD29	EBU. D29			

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P2.12	ETH0. TXD2	CCU81 .OUT33	ETH0. TXD0	DB. ETM_T RACED ATA1	EBU. AD30	EBU. D30		
P2.13	ETH0. TXD3		ETH0. TXD1	DB. ETM_T RACED ATA0	EBU. AD31	EBU. D31		
P2.14	VADC. EMUX 11	U1C0. DOUT 0	CCU80 .OUT21	DB. ETM_T RACEC LK	EBU. <u>BC0</u>		U1C0. DX0D	
P2.15	VADC. EMUX 12	CCU80 .OUT11	LEDTS 0. LINE6	LEDTS 0. EXTEN DED6	EBU. <u>BC1</u>	LEDTS 0. TSIN6 A	ETH0. COLA	U1C0. DX0C
P3.0	U2C1. SEL00	U0C1. SCLKO UT	CCU42 .OUT0		EBU. <u>RD</u>		U0C1. DX1B	
P3.1		U0C1. SEL00			EBU. <u>RD_WR</u>		U0C1. DX2B	ERU0. 0B1
P3.2	USB. DRIVE VBUS	CAN. NO_TX D			EBU. <u>CS0</u>			ERU0. 0A1

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P3.3	U1C1. SEL01	CCU42 .OUT3	SDMM C. LED			EBU. WAIT	DSD. DIN3B	
P3.4	U2C1. MCLK OUT	U1C1. SEL02	DSD. MCLK3 .OUT2	SDMM C. BUS_P OWER		EBU. HOLD	U2C1. DX0B	DSD. MCLK3 B
P3.5	U2C1. DOUT 0	U1C1. SEL03	CCU42 .OUT1	U0C1. DOUT 0	SDMM C. CMD_ OUT	EBU. AD4	U2C1. DX0A	ERU0. 3B1
P3.6	U2C1. SCLK0 UT	U1C1. SEL04	CCU42 .OUT0	U0C1. SCLK0 UT	SDMM C. CLK_O UT	EBU. AD5	U2C1. DX1B	ERU0. 3A1
P3.7	CAN. N2_TX D	CCU41 .OUT3	LEDTS 0. LINE0				U2C0. DX0C	
P3.8	U2C0. DOUT 0	U0C1. SEL03	CCU41 .OUT2	LEDTS 0. LINE1			CAN. N2_RX DB	
P3.9	U2C0. SCLK0 UT	CAN. N1_TX D	CCU41 .OUT1	LEDTS 0. LINE2				POSIF 1. IN2B
								POSIF 1. IN1B

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P3.10	U2C0. SELO0	CAN. NO_TX D	CCU41. .OUT0	LEDTS 0. LINE3	U0C1. DOUT 3	U0C1. HWIN3	U0C1. HWIN3	
P3.11	U2C1. DOUT 0	U0C1. SEL02	CCU42. .OUT3	LEDTS 0. LINE4	U0C1. DOUT 2	U0C1. HWIN2	CAN. N1_RX DB	
P3.12		U0C1. SEL01	CCU42. .OUT2	LEDTS 0. LINE5	U0C1. DOUT 1	U0C1. HWIN1	CAN. N0_RX DC	
P3.13	U2C1. SCLK0 UT	U0C1. DOUT 0	CCU42. .OUT1	LEDTS 0. LINE6	U0C1. DOUT 0	U0C1. HWIN0	U2C1. DX0D	
P3.14		U1C0. SEL03			U1C1. DOUT 1	U1C1. HWIN1		
P3.15		U1C1. DOUT 0			U1C1. DOUT 0	U1C1. HWIN0	U1C1. DX0A	
P4.0		DSD. MCLK1		SDMM C. DATA0 _OUT	EBU. AD8	SDMM C. DATA0 _IN	U1C1. DX1C B	DSD. MCLK1 B
P4.1	U2C1. SELO0	DSD. MCLK0	U0C1. SEL00	SDMM C. DATA3 _OUT	EBU. AD9	SDMM C. DATA3 _IN	U2C1. DX2B B	DSD. MCLK0 B

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P4.2	U2C1. SEL01	U1C1. DOUT 0	U2C1. SCLKO UT				U1C1. DX0C	
P4.3	U2C1. SEL02	U0C0. SEL05	CCU43 .OUT3				U2C1. DX1A	U2C1. IN1C
P4.4		U0C0. SEL04	CCU43 .OUT2	U2C1. DOUT 3	U2C1. HWIN3			CCU43 .IN3A
P4.5		U0C0. SEL03	CCU43 .OUT1	U2C1. DOUT 2	U2C1. HWIN2			CCU43 .IN2A
P4.6		U0C0. SEL02	CCU43 .OUT0	U2C1. DOUT 1	U2C1. HWIN1	CAN. N2_RX DC		CCU43 .IN1A
P4.7		CAN. N2_TX D		U2C1. DOUT 0	U2C1. HWIN0	U0C0. DX0C		CCU43 .IN0A
P5.0	U2C0. DOUT 0	DSD. CGPW MN	CCU81 .OUT33	U2C0. DOUT 0	U2C0. HWIN0	U2C0. DX0B	ETH0. RXD0D	CCU81 .IN0C
P5.1	U0C0. DOUT 0	DSD. CGPW MP	CCU81 .OUT32	U2C0. DOUT 1	U2C0. HWIN1	U2C0. DX0A	ETH0. RXD1D	CCU81 .IN0B

(table continues...)

## 2 General Device Information

Table 1.1 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P5.2 U2C0. SCLKO UT	CCU81 . . OUT23	CCU81 . . OUT22	EBU. CKE	EBU. A20	U2C0. DX1A	ETH0. CRSD VD	CCU81 . . IN1B	ETH0. RXDVD
P5.3 U2C0. SELO0	CCU81 . . OUT22	EBU. CKE	EBU. A20	U2C0. DX2A	ETH0. RXERD	CCU81 . . IN2B		
P5.4 U2C0. SELO1	CCU81 . . OUT13	EBU. RAS	EBU. A21		ETH0. CRSD	CCU81 . . IN3B		
P5.5 U2C0. SELO2	CCU81 . . OUT12	EBU. CAS	EBU. A22		ETH0. COLD			
P5.6 U2C0. SELO3	CCU81 . . OUT03	EBU. BFCLK 0	EBU. A23		EBU. BFCLK 1			
P5.7	CCU81 . . OUT02	LEDTS 0. COLA	U2C0. DOUT 2	U2C0. HWIN2				
P5.8	U1C0. SCLKO UT	CCU80 . . OUT01	EBU. SDCLK 0	EBU. CS2		ETH0. RXD2A	U1C0. DX1B	
P5.9	U1C0. SEL00	CCU80 . . OUT20	ETH0. TX_EN	EBU. CS3		ETH0. RXD3A	U1C0. DX2B	

(table continues...)

## 2 General Device Information

Table 1.1 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P5.10	U1C0. MCLK OUT	CCU80 .OUT10	LEDTS 0. LINE7	LEDTS 0. EXTEN DED7	LEDTS 0. TSIN7 A	ETH0. CLK_T XA		
P5.11	U1C0. SEL01	CCU80 .OUT00				ETH0. CRSA		
P6.0	ETH0. TXD2	U0C1. SEL01	CCU81 .OUT31	DB. ETM_T RACEC LK	EBU. ETM_T A16			
P6.1	ETH0. TXD3	U0C1. SEL00	CCU81 .OUT30	DB. ETM_T RACED ATA3	EBU. ETM_T A17		U0C1. DX2C	
P6.2	ETH0. TXER	U0C1. SCLKO UT	CCU43 .OUT3	DB. ETM_T RACED ATA2	EBU. ETM_T A18		U0C1. DX1C	
P6.3			CCU43 .OUT2				U0C1. DX0C	ETH0. RXD3B
P6.4		U0C1. DOUT 0	CCU43 .OUT1	EBU. SDCLK O	EBU. SDCLK I		EBU. ETH0. RXD2B	

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P6.5	U0C1. MCLK OUT	CCU43 .OUT0			DB. ETM_T RACED ATA1	$\overline{EBU}$ . $\overline{BC2}$		
P6.6		DSD. MCLK3			DB. ETM_T RACED ATA0	$\overline{EBU}$ . $\overline{BC3}$		
P14.0							VADC. G0CH0	
P14.1							VADC. G0CH1	
P14.2							VADC. G0CH2	G1CH2
P14.3							VADC. G0CH3	G1CH3
P14.4							VADC. G0CH4	G2CH0
P14.5							VADC. G0CH5	G2CH1
P14.6							VADC. G0CH6	

(table continues...)

## 2 General Device Information

Table 11 (continued) Port I/O Functions

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P14.7							VADC. G0CH7	
P14.8			DAC. OUT_0				VADC. G1CH0	
P14.9			DAC. OUT_1				VADC. G1CH1	
P14.12						VADC. G1CH4		
P14.13						VADC. G1CH5		
P14.14						VADC. G1CH6		
P14.15						VADC. G1CH7		
P15.2							VADC. G2CH2	
P15.3							VADC. G2CH3	
P15.4							VADC. G2CH4	
P15.5							VADC. G2CH5	

(table continues...)

## 2 General Device Information

**Table 11 (continued) Port I/O Functions**

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
P15.6							VADC. G2CH6	
P15.7							VADC. G2CH7	
P15.8							VADC. G3CH0	ETH0. CLKRX C
P15.9							VADC. G3CH1	ETH0. RXDVC
P15.12							VADC. G3CH4	
P15.13							VADC. G3CH5	
P15.14							VADC. G3CH6	
P15.15							VADC. G3CH7	
USB_D P								
USB_D M								

(table continues...)

## 2 General Device Information

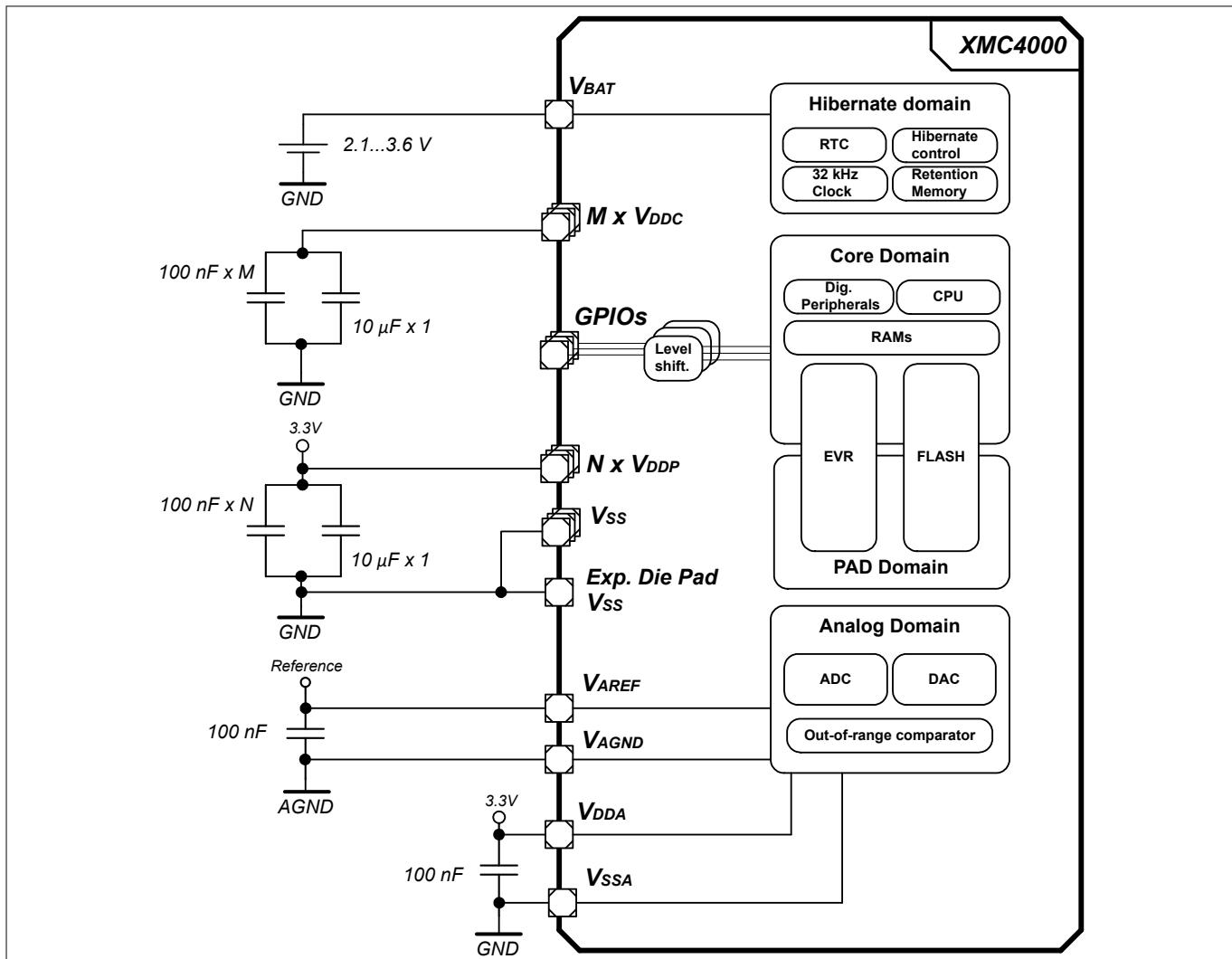
**Table 1.1 (continued) Port I/O Functions**

Function	Outputs				Inputs			
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1
HIB_IO_0_T	HIBOU_WWDT.						WAKE_UPA	
HIB_IO_1_T	HIBOU_WWDT.	SERVI_CE_O_UT					WAKE_UPB	
TCK					DB.TC_K/ SWCL_K			
TMS					DB.TM_S/ SWDIO			
<b>PORST</b>								
XTAL1						U0C0. DX0F	U1C1. DX0F	U2C0. DX0F
XTAL2								U2C1. DX0F
RTC_XT_AL1							ERU0. 1B1	
RTC_XT_AL2								

## 2 General Device Information

### 2.3 Power Connection Scheme

Figure 9 shows a reference power connection scheme for the XMC4500.



**Figure 9** 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  $\mu$ F capacitor is connected to the  $V_{DDP}$  nets and an additional 10 uF capacitor to the  $V_{DDC}$  nets.

The XMC4500 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.

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

## 3 Electrical Parameters

### 3.1 General Parameters

#### 3.1.1 Parameter Interpretation

The parameters listed in this section partly represent the characteristics of the XMC4500 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 **Controller Characteristics**, which are a distinctive feature of the XMC4500 and must be regarded for system design

- SR**

Such parameters indicate **System Requirements**, which must be provided by the application system in which the XMC4500 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 <sup>1)</sup>	$\Sigma I_{IN}$ SR	-25	-	+25	mA	
Absolute maximum sum of all input circuit currents during overload condition	$\Sigma I_{IN}$ SR	-100	-	+100	mA	

1) The port groups are defined in [Pin Reliability in Overload](#).

### 3 Electrical Parameters

Figure 10 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 [Section 3.1.3](#).

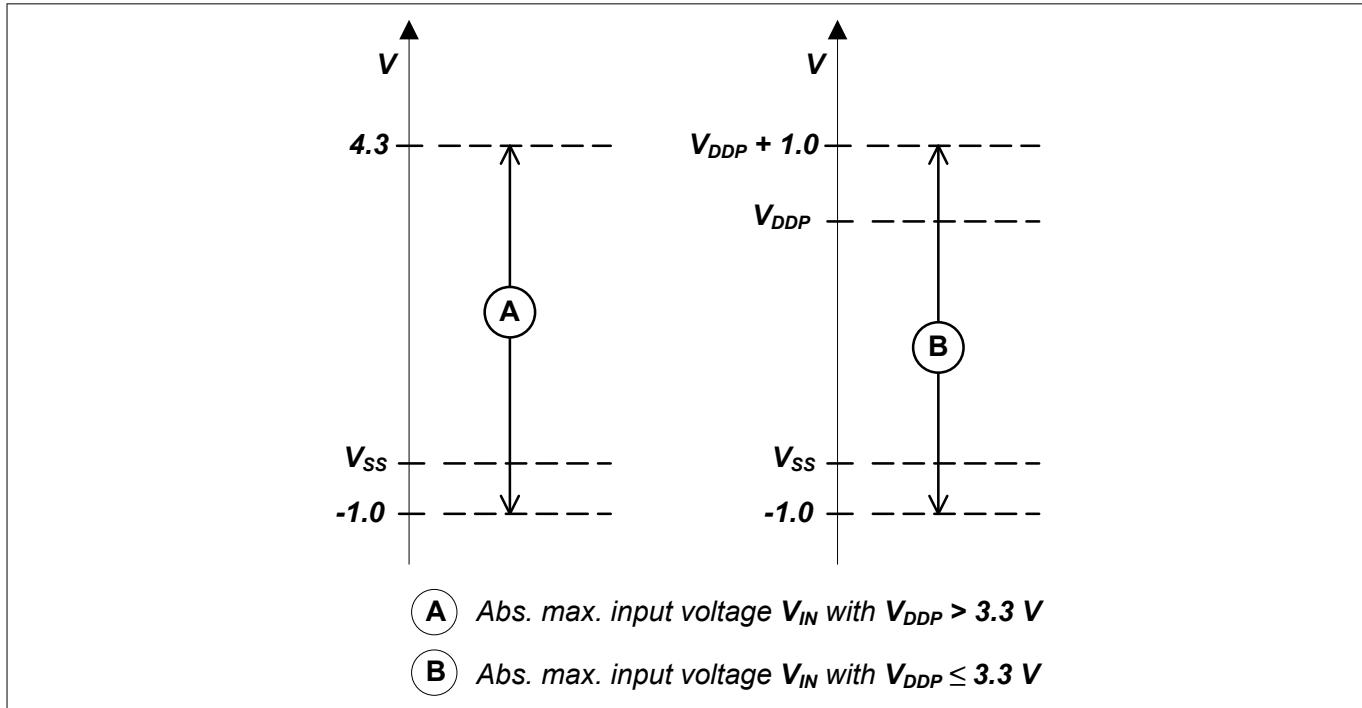


Figure 10

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.

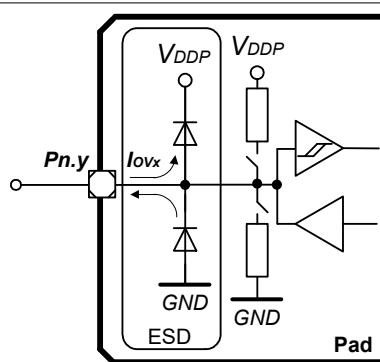
### 3 Electrical Parameters

**Table 13 Overload Parameters**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>			<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Typ.</b>	<b>Max.</b>		
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 <sup>1)</sup>	$I_{OVG\ SR}$	-	-	20	mA	$\sum I_{OVx} $ , for all $I_{OVx} < 0$ mA
		-	-	20	mA	$\sum I_{OVx} $ , for all $I_{OVx} > 0$ mA
Absolute sum of all input circuit currents during overload condition	$I_{OVS\ SR}$	-	-	80	mA	$\sum I_{OVG}$

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

[Figure 11](#) 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 11 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.

**Table 14 PN-Junction Characteristics for positive Overload**

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

**Table 15 PN-Junction Characteristics for negative Overload**

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

### 3 Electrical Parameters

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

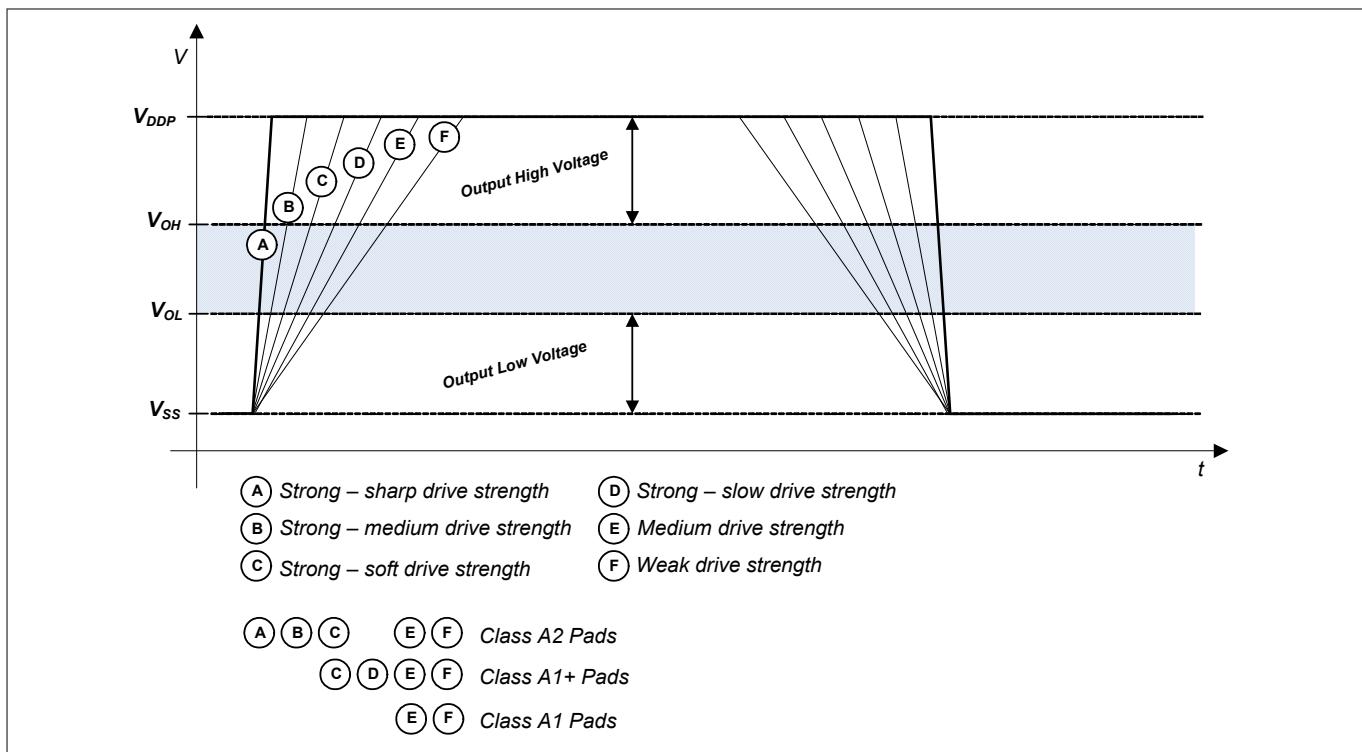
Group	Pins
1	P0.[15:0], P3.[15:0]
2	P14.[15:0], P15.[15:0]
3	P2.[15:0], P5.[11:0]
4	P1.[15:0], P4.[7:0], P6.[6:0]

#### 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
<b>A</b>	3.3 V	LVTTI I/O	<b>A1</b> (e.g. GPIO)	6 MHz	100 pF	No
			<b>A1+</b> (e.g. serial I/Os)	25 MHz	50 pF	Series termination recommended
			<b>A2</b> (e.g. ext. Bus)	80 MHz	15 pF	Series termination recommended



**Figure 12 Output Slopes with different Pad Driver Modes**

Figure 12 is a qualitative display of the resulting output slope performance with different output driver modes. The detailed input and output characteristics are listed in [Section 3.2.1](#).

### 3 Electrical Parameters

#### 3.1.5 Operating Conditions

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the XMC4500. 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	–	105	°C	Temp. Range X
		-40	–	125	°C	Temp. Range K
Digital supply voltage	$V_{DDP}$ SR	3.13 <sup>1)</sup>	3.3	3.63 <sup>2)</sup>	V	
Core Supply Voltage	$V_{DDC}$ CC	– <sup>1)</sup>	1.3	–	V	Generated internally
Digital ground voltage	$V_{SS}$ SR	0	–	–	V	
Analog supply voltage	$V_{DDA}$ SR	3.0	3.3	3.6 <sup>2)</sup>	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 <sup>3)</sup>	–	3.63	V	When $V_{DDP}$ is supplied $V_{BAT}$ has to be supplied as well.
System Frequency	$f_{SYS}$ SR	–	–	120	MHz	
Short circuit current of digital outputs	$I_{SC}$ SR	-5	–	5	mA	
Absolute sum of short circuit currents per pin group <sup>4)</sup> .	$\Sigma I_{SC\_PG}$ SR	–	–	20	mA	
Absolute sum of short circuit currents of the device	$\Sigma I_{SC\_D}$ SR	–	–	100	mA	

1) See also the Supply Monitoring thresholds, [Section 3.3.2](#).

2) Voltage overshoot to 4.0 V is permissible at Power-Up and  $\overline{PORST}$  low, provided the pulse duration is less than 100  $\mu$ 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 Electrical Parameters

## 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.

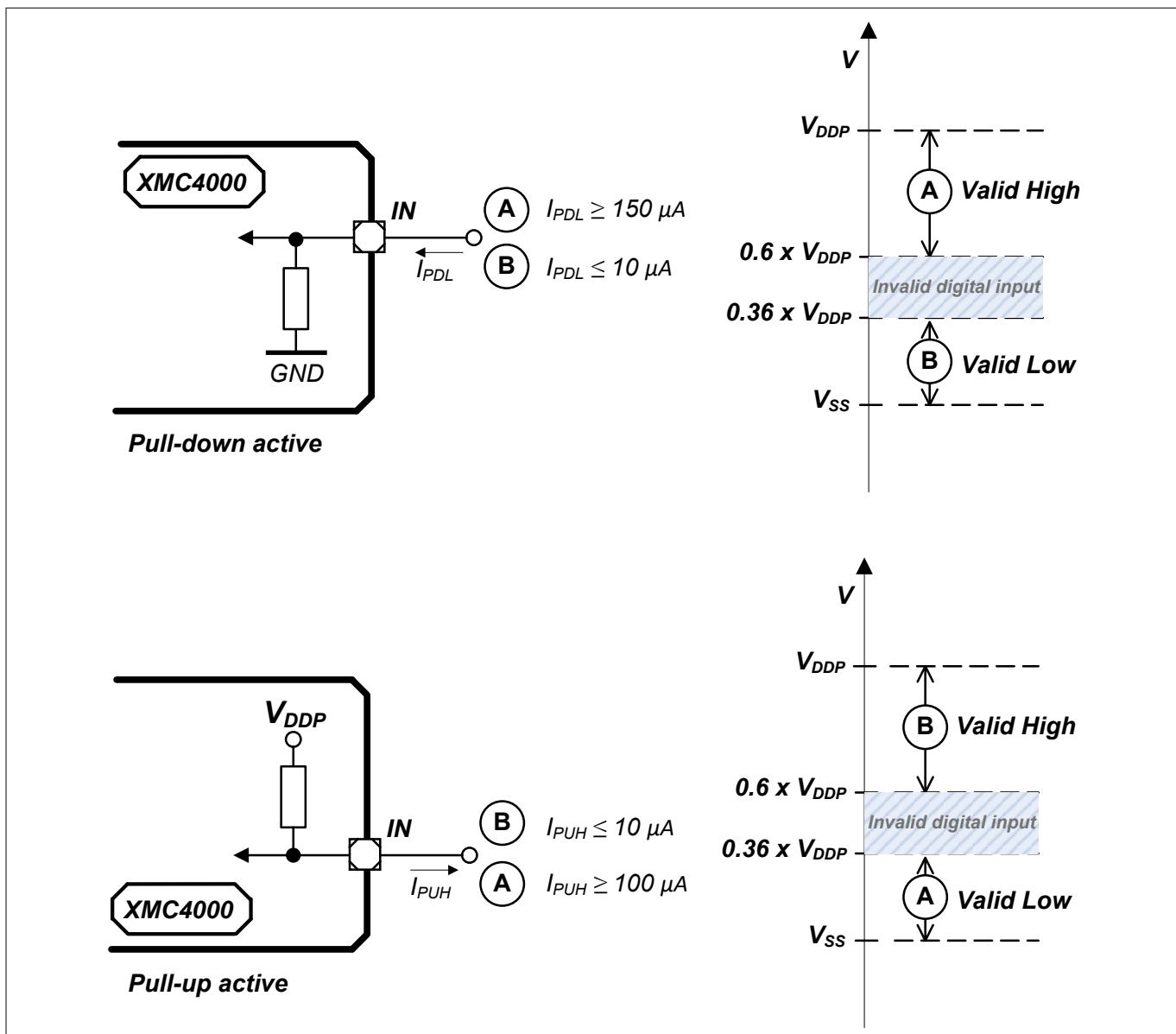
**Note:** *These parameters are not subject to production test, but verified by design and/or characterization.*

**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_{PDL} $ CC	150	–	$\mu\text{A}$	<sup>1)</sup> $V_{IN} \geq 0.6 \times V_{DDP}$
		–	10	$\mu\text{A}$	<sup>2)</sup> $V_{IN} \leq 0.36 \times V_{DDP}$
Pull-up current	$ I_{PUH} $ CC	–	10	$\mu\text{A}$	<sup>2)</sup> $V_{IN} \geq 0.6 \times V_{DDP}$
		100	–	$\mu\text{A}$	<sup>1)</sup> $V_{IN} \leq 0.36 \times V_{DDP}$
Input Hysteresis for pads of all A classes <sup>3)</sup>	$HYSA$ CC	$0.1 \times V_{DDP}$	–	V	
PORST spike filter always blocked pulse duration	$t_{SF1}$ CC	–	10	ns	
PORST spike filter pass-through pulse duration	$t_{SF2}$ CC	100	–	ns	
PORST pull-down current	$ I_{PPD} $ CC	13	–	mA	$V_{IN} = 1.0 \text{ V}$

- 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.

### 3 Electrical Parameters



**Figure 13**      **Pull Device Input Characteristics**

Figure 13 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

**Table 20**      **Standard Pads Class\_A1**

Parameter	Symbol	Values		Unit	Note/Test Condition
		Min.	Max.		
Input leakage current	$I_{OZA1\ CC}$	-500	500	nA	$0 \text{ V} \leq V_{IN} \leq V_{DDP}$
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	

(table continues...)

### 3 Electrical Parameters

**Table 20 (continued) Standard Pads Class\_A1**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>		<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Max.</b>		
Output high voltage, POD <sup>1)</sup> = weak	$V_{OHA1}$ CC	$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -400 \mu A$
		2.4	-	V	$I_{OH} \geq -500 \mu A$
Output high voltage, POD <sup>1)</sup> = medium	$V_{OLA1}$ CC	$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -1.4 mA$
		2.4	-	V	$I_{OH} \geq -2 mA$
Output low voltage	$V_{OLA1}$ CC	-	0.4	V	$I_{OL} \leq 500 \mu A$ ; POD <sup>1)</sup> = weak
		-	0.4	V	$I_{OL} \leq 2 mA$ ; POD <sup>1)</sup> = medium
Fall time	$t_{FA1}$ CC	-	150	ns	$C_L = 20 pF$ ; POD <sup>1)</sup> = weak
		-	50	ns	$C_L = 50 pF$ ; POD <sup>1)</sup> = medium
Rise time	$t_{RA1}$ CC	-	150	ns	$C_L = 20 pF$ ; POD <sup>1)</sup> = weak
		-	50	ns	$C_L = 50 pF$ ; POD <sup>1)</sup> = medium

1) POD = Pin Out Driver.

**Table 21 Standard Pads Class\_A1+**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>		<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Max.</b>		
Input leakage current	$I_{OZA1+}$ CC	-1	1	$\mu A$	$0 V \leq V_{IN} \leq V_{DDP}$
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	
Output high voltage, POD <sup>1)</sup> = weak	$V_{OHA1+}$ CC	$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -400 \mu A$
		2.4	-	V	$I_{OH} \geq -500 \mu A$
Output high voltage, POD <sup>1)</sup> = medium	$V_{OHA1+}$ CC	$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -1.4 mA$
		2.4	-	V	$I_{OH} \geq -2 mA$
Output high voltage, POD <sup>1)</sup> = strong	$V_{OHA1+}$ CC	$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -1.4 mA$
		2.4	-	V	$I_{OH} \geq -2 mA$
Output low voltage	$V_{OLA1+}$ CC	-	0.4	V	$I_{OL} \leq 500 \mu A$ ; POD <sup>1)</sup> = weak

(table continues...)

### 3 Electrical Parameters

**Table 21** (continued) Standard Pads Class\_A1+

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>		<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Max.</b>		
		-	0.4	V	$I_{OL} \leq 2 \text{ mA}$ ; POD <sup>1)</sup> = medium
		-	0.4	V	$I_{OL} \leq 2 \text{ mA}$ ; POD <sup>1)</sup> = strong
Fall time	$t_{FA1+} \text{ CC}$	-	150	ns	$C_L = 20 \text{ pF}$ ; POD <sup>1)</sup> = weak
		-	50	ns	$C_L = 50 \text{ pF}$ ; POD <sup>1)</sup> = medium
		-	28	ns	$C_L = 50 \text{ pF}$ ; POD <sup>1)</sup> = strong; edge = slow
		-	16	ns	$C_L = 50 \text{ pF}$ ; POD <sup>1)</sup> = strong; edge = soft;
Rise time	$t_{RA1+} \text{ CC}$	-	150	ns	$C_L = 20 \text{ pF}$ ; POD <sup>1)</sup> = weak
		-	50	ns	$C_L = 50 \text{ pF}$ ; POD <sup>1)</sup> = medium
		-	28	ns	$C_L = 50 \text{ pF}$ ; POD <sup>1)</sup> = strong; edge = slow
		-	16	ns	$C_L = 50 \text{ pF}$ ; POD <sup>1)</sup> = strong; edge = soft

1) POD = Pin Out Driver.

**Table 22** Standard Pads Class\_A2

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>		<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Max.</b>		
Input Leakage current	$I_{OZA2} \text{ CC}$	-6	6	$\mu\text{A}$	$0 \text{ V} \leq V_{IN} < 0.5 * V_{DDP} - 1 \text{ V}$ ; $0.5 * V_{DDP} + 1 \text{ V} < V_{IN} \leq V_{DDP}$
		-3	3	$\mu\text{A}$	$0.5 * V_{DDP} - 1 \text{ V} < V_{IN} < 0.5 * V_{DDP} + 1 \text{ V}$

(table continues...)

### 3 Electrical Parameters

**Table 22** (continued) Standard Pads Class\_A2

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>		<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Max.</b>		
Input high voltage	$V_{IHA2}$ SR	$0.6 \times V_{DDP}$	$V_{DDP} + 0.3$	V	max. 3.6 V
Input low voltage	$V_{ILA2}$ SR	-0.3	$0.36 \times V_{DDP}$	V	
Output high voltage, POD = weak	$V_{OHA2}$ CC	$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -400 \mu A$
		2.4	-	V	$I_{OH} \geq -500 \mu A$
Output high voltage, POD = medium		$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -1.4 \text{ mA}$
		2.4	-	V	$I_{OH} \geq -2 \text{ mA}$
Output high voltage, POD = strong		$V_{DDP} - 0.4$	-	V	$I_{OH} \geq -1.4 \text{ mA}$
		2.4	-	V	$I_{OH} \geq -2 \text{ mA}$
Output low voltage, POD = weak	$V_{OLA2}$ CC	-	0.4	V	$I_{OL} \leq 500 \mu A$
Output low voltage, POD = medium		-	0.4	V	$I_{OL} \leq 2 \text{ mA}$
Output low voltage, POD = strong		-	0.4	V	$I_{OL} \leq 2 \text{ mA}$
Fall time	$t_{FA2}$ CC	-	150	ns	$C_L = 20 \text{ pF};$ POD = weak
		-	50	ns	$C_L = 50 \text{ pF};$ POD = medium
		-	3.7	ns	$C_L = 50 \text{ pF};$ POD = strong; edge = sharp
		-	7	ns	$C_L = 50 \text{ pF};$ POD = strong; edge = medium
		-	16	ns	$C_L = 50 \text{ pF};$ POD = strong; edge = soft
Rise time	$t_{RA2}$ CC	-	150	ns	$C_L = 20 \text{ pF};$ POD = weak
		-	50	ns	$C_L = 50 \text{ pF};$ POD = medium
		-	3.7	ns	$C_L = 50 \text{ pF};$ POD = strong; edge = sharp

(table continues...)

### 3 Electrical Parameters

**Table 22** (continued) Standard Pads Class\_A2

Parameter	Symbol	Values		Unit	Note/Test Condition
		Min.	Max.		
		–	7.0	ns	$C_L = 50 \text{ pF}$ ; POD = strong; edge = medium
		–	16		$C_L = 50 \text{ pF}$ ; POD = strong; edge = soft

### 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 23** VADC Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Analog reference voltage <sup>1)</sup>	$V_{AREF}$ SR	$V_{AGND} + 1$	–	$V_{DDA} + 0.05$ <sup>2)</sup>	V	
Analog reference ground <sup>1)</sup>	$V_{AGND}$ SR	$V_{SSM} - 0.05$	–	$V_{AREF} - 1$	V	
Analog reference voltage range <sup>1) 3)</sup>	$V_{AREF} - V_{AGND}$ SR	1	–	$V_{DDA} + 0.1$	V	
Analog input voltage	$V_{AIN}$ SR	$V_{AGND}$	–	$V_{DDA}$	V	
Input leakage at analog inputs <sup>4)</sup>	$I_{OZ1}$ 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 $V_{AREF}$	$I_{OZ2}$ CC	-1	–	1	$\mu\text{A}$	$0 \text{ V} \leq V_{AREF} \leq V_{DDA}$
Input leakage current at $V_{AGND}$	$I_{OZ3}$ CC	-1	–	1	$\mu\text{A}$	$0 \text{ V} \leq V_{AGND} \leq V_{DDA}$
Internal ADC clock	$f_{ADCI}$ CC	2	–	30	MHz	$V_{DDA} = 3.3 \text{ V}$
Switched capacitance at the analog voltage inputs <sup>5)</sup>	$C_{AINSW}$ CC	–	7	20	pF	
Total capacitance of an analog input	$C_{AINTOT}$ CC	–	25	30	pF	
Switched capacitance at the positive reference voltage input <sup>1) 6)</sup>	$C_{AREFSW}$ CC	–	15	30	pF	

(table continues...)

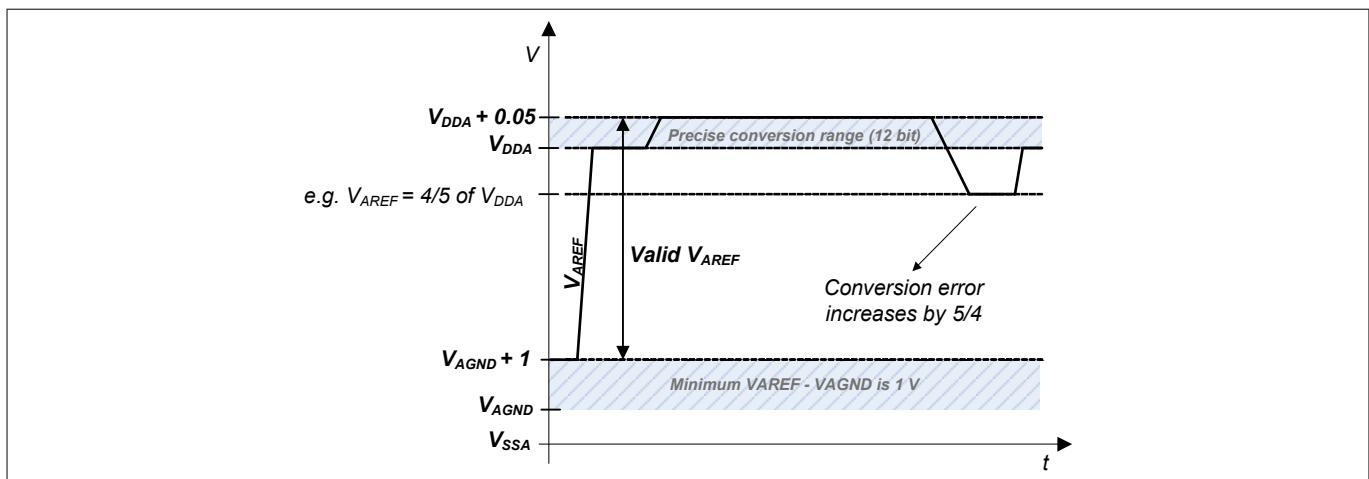
### 3 Electrical Parameters

**Table 23 (continued) VADC Parameters (Operating Conditions apply)**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>			<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Typ.</b>	<b>Max.</b>		
Total capacitance of the voltage reference inputs <sup>1)</sup>	$C_{AREFTOT}$ CC	-	20	40	pF	
Total Unadjusted Error	$TUE$ CC	-4	-	4	LSB	12-bit resolution;
Differential Non-Linearity Error <sup>8)</sup>	$EA_{DNL}$ CC	-3	-	3	LSB	$V_{DDA} = 3.3 \text{ V}$ ; $V_{AREF} = V_{DDA}$ <sup>7)</sup>
Gain Error <sup>8)</sup>	$EA_{GAIN}$ CC	-4	-	4	LSB	
Integral Non-Linearity <sup>8)</sup>	$EA_{INLCC}$	-3	-	3	LSB	
Offset Error <sup>8)</sup>	$EA_{OFF}$ CC	-4	-	4	LSB	
RMS Noise <sup>9)</sup>	$EN_{RMS}$ CC	-	1	<sup>2)</sup> <sup>10)</sup> <sup>11)</sup>	LSB	
Worst case ADC $V_{DDA}$ power supply current per active converter	$I_{DDAA}$ CC	-	1.5	2	mA	during conversion $V_{DDP} = 3.6 \text{ V}$ , $T_J = 150^\circ\text{C}$
Charge consumption on $V_{AREF}$ per conversion <sup>1)</sup>	$Q_{CONV}$ CC	-	30	-	pC	$0 \text{ V} \leq V_{AREF} \leq V_{DDA}$ <sup>12)</sup>
ON resistance of the analog input path	$R_{AIN}$ CC	-	700	1700	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	1700	Ohm	

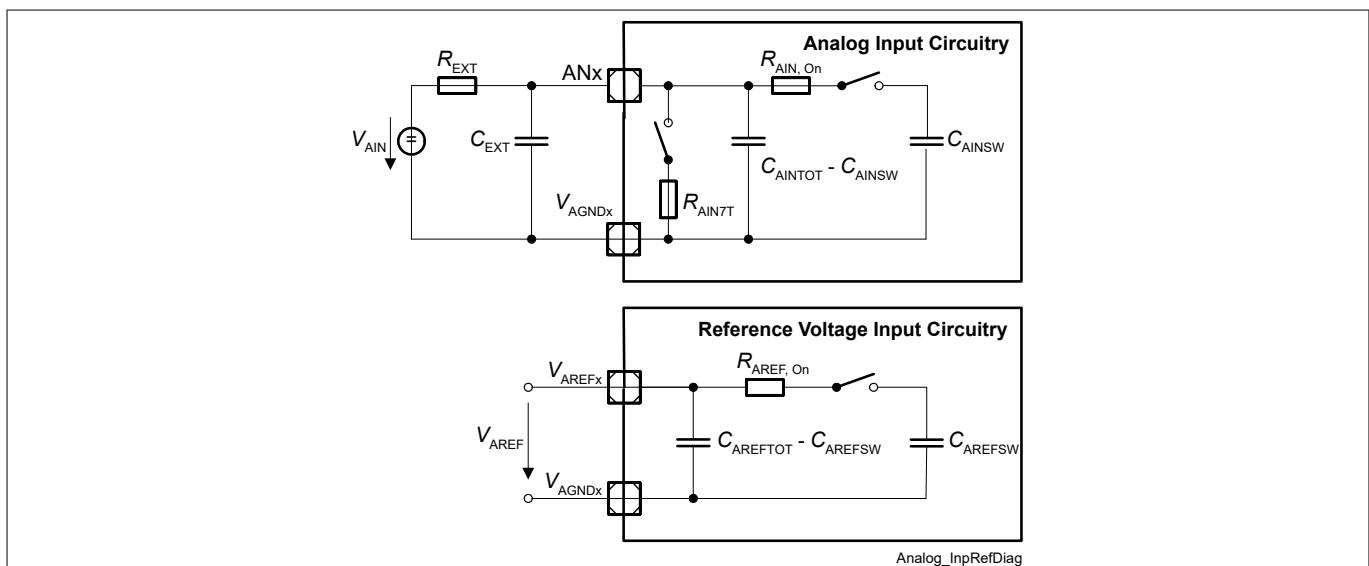
- 1) Applies to AINx, when used as alternate reference input.
- 2) A running conversion may become imprecise in case the normal conditions are violated (voltage overshoot).
- 3) If the analog reference voltage is below VDDA, then the ADC converter errors increase. If the reference voltage is reduced by the factor k ( $k < 1$ ), TUE, DNL, INL, Gain, and Offset errors increase also by the factor 1/k.
- 4) 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 16).
- 5) 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  $V_{AREF}/2$ .
- 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  $\pm 1 \text{ LSB}$ .
- 8) The sum of DNL/INL/GAIN/OFF errors does not exceed the related total unadjusted error TUE.
- 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  $t_c = 550 \text{ ns}$  results in a typical average current of  $I_{AREF} = 54.5 \mu\text{A}$ .

### 3 Electrical Parameters

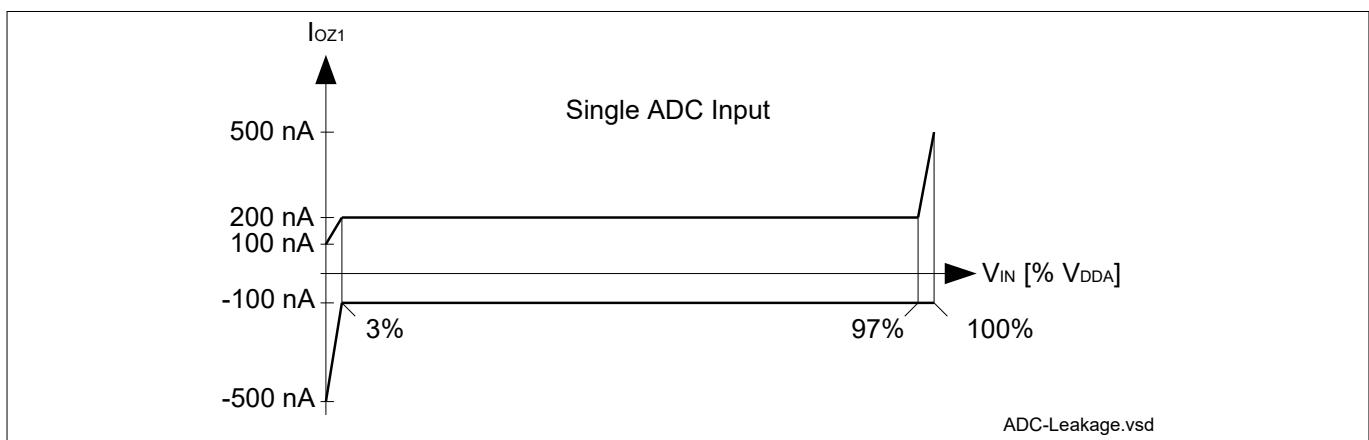


**Figure 14** VADC Reference Voltage Range

The power-up calibration of the VADC requires a maximum number of 4352  $f_{\text{ADCI}}$  cycles.



**Figure 15** VADC Input Circuits



**Figure 16** VADC Analog Input Leakage Current

### 3 Electrical Parameters

#### Conversion Time

**Table 24 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:

$f_{ADC} = 120$  MHz that is  $t_{ADC} = 8.33$  ns,  $DIVA = 3$ ,  $f_{ADCI} = 30$  MHz that is  $t_{ADCI} = 33.3$  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):

$$t_{CN12C} = (2 + 12 + 2) \times t_{ADCI} + 2 \times t_{ADC} = 16 \times 33.3 \text{ ns} + 2 \times 8.33 \text{ ns} = 550 \text{ ns}$$

12-bit uncalibrated conversion:

$$t_{CN12} = (2 + 12) \times t_{ADCI} + 2 \times t_{ADC} = 14 \times 33.3 \text{ ns} + 2 \times 8.33 \text{ ns} = 483 \text{ ns}$$

10-bit uncalibrated conversion:

$$t_{CN10} = (2 + 10) \times t_{ADCI} + 2 \times t_{ADC} = 12 \times 33.3 \text{ ns} + 2 \times 8.33 \text{ ns} = 417 \text{ ns}$$

8-bit uncalibrated:

$$t_{CN8} = (2 + 8) \times t_{ADCI} + 2 \times t_{ADC} = 10 \times 33.3 \text{ ns} + 2 \times 8.33 \text{ ns} = 350 \text{ ns}$$

#### 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 25 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	Msamp le/s	data rate, where DAC can follow 64 LSB code jumps to $\pm 1$ LSB accuracy

(table continues...)

### 3 Electrical Parameters

**Table 25 (continued) DAC Parameters (Operating Conditions apply)**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>			<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Typ.</b>	<b>Max.</b>		
Update rate	$f_{URATE\_F}$ CC	-		5	Msamples/s	data rate, where DAC can follow 64 LSB code jumps to $\pm 4$ LSB accuracy
Settling time	$t_{SETTLE}$ CC	-	1	2	$\mu s$	at full scale jump, output voltage reaches target value $\pm 20$ LSB
Slew rate	SR CC	2	5	-	V/ $\mu s$	
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	-4	$\pm 2.5$	4	LSB	$R_L \geq 5$ kOhm, $C_L \leq 50$ pF
Differential non-linearity	$DNL$ CC	-2	$\pm 1$	2	LSB	$R_L \geq 5$ kOhm, $C_L \leq 50$ pF
Offset error	$ED_{OFF}$ CC		$\pm 20$		mV	
Gain error	$ED_{G\_IN}$ CC	-6.5	-1.5	3	%	
Startup time	$t_{STARTUP}$ CC	-	15	30	$\mu s$	time from output enabling till code valid $\pm 16$ 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

### 3 Electrical Parameters

#### Conversion Calculation

Unsigned:

$$\text{DACxDATA} = 4095 \times (V_{\text{OUT}} - V_{\text{OUT\_MIN}}) / (V_{\text{OUT\_MAX}} - V_{\text{OUT\_MIN}})$$

Signed:

$$\text{DACxDATA} = 4095 \times (V_{\text{OUT}} - V_{\text{OUT\_MIN}}) / (V_{\text{OUT\_MAX}} - V_{\text{OUT\_MIN}}) - 2048$$

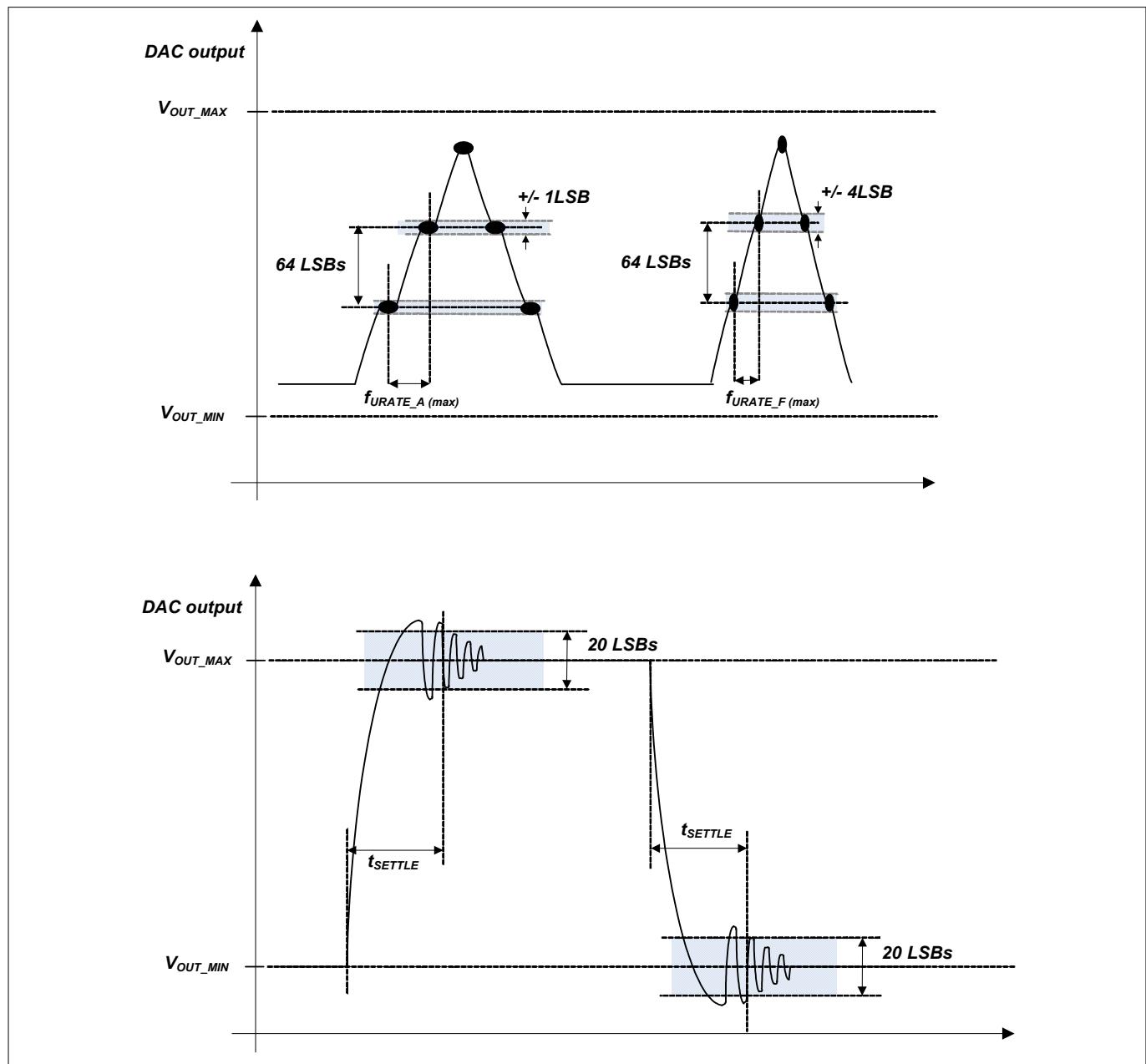


Figure 17 DAC Conversion Examples

### 3 Electrical Parameters

#### 3.2.4 Out-of-Range Comparator (ORC)

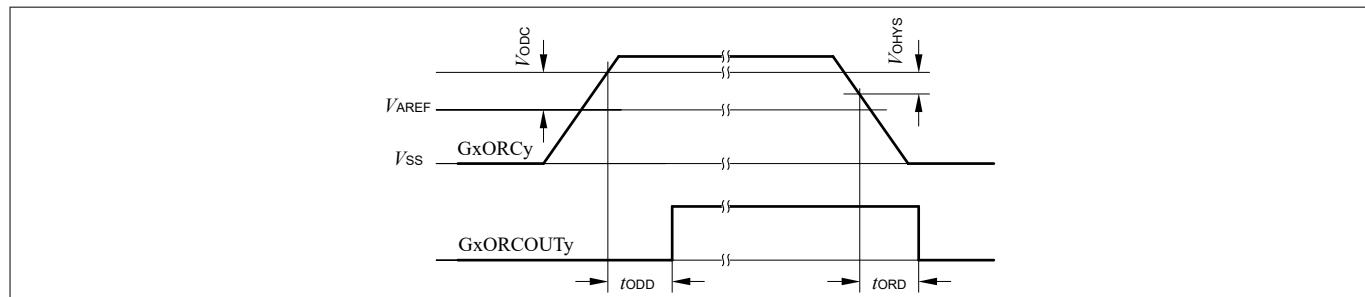
The Out-of-Range Comparator (ORC) triggers on analog input voltages ( $V_{AIN}$ ) above the analog reference<sup>1</sup> ( $V_{AREF}$ ) on selected input pins (GxORC<sub>y</sub>) and generates a service request trigger (GxORCOUT<sub>y</sub>).

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

The parameters in [Table 26](#) apply for the maximum reference voltage  $V_{AREF} = V_{DDA} + 50 \text{ mV}$ .

**Table 26 ORC Parameters (Operating Conditions apply)**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
DC Switching Level	$V_{ODC}$ CC	100	125	200	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	55	-	450	ns	$V_{AIN} \geq V_{AREF} + 200 \text{ mV}$
		45	-	105	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Always detected Overvoltage Pulse	$t_{OPDD}$ CC	440	-	-	ns	$V_{AIN} \geq V_{AREF} + 200 \text{ mV}$
		90	-	-	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Never detected Overvoltage Pulse	$t_{OPDN}$ CC	-	-	49	ns	$V_{AIN} \geq V_{AREF} + 200 \text{ mV}$
		-	-	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	



**Figure 18 GxORCOUT<sub>y</sub> Trigger Generation**

<sup>1</sup> Always the standard VADC reference, alternate references do not apply to the ORC.

### 3 Electrical Parameters

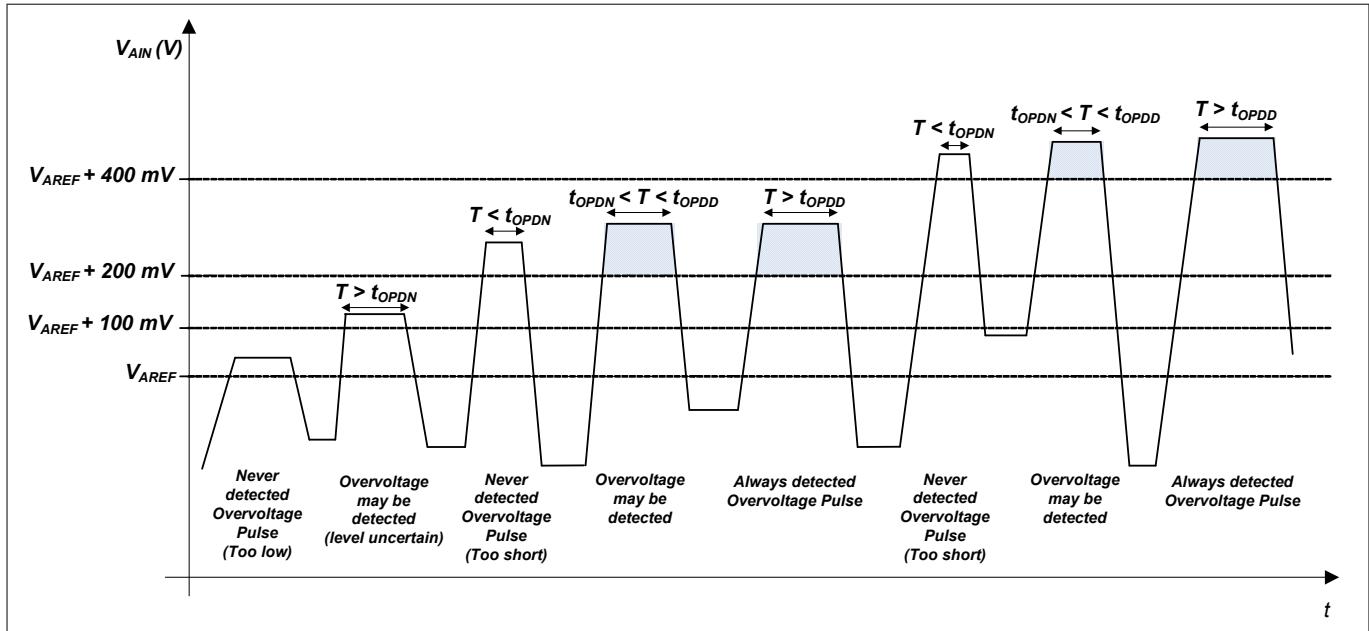


Figure 19      ORC Detection Ranges

#### 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 27      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)	$\Delta T_{LE}$ CC	-	$\pm 1$	-	°C	per $\Delta T_J \leq 30^\circ\text{C}$
Offset Error	$\Delta T_{OE}$ CC	-	$\pm 6$	-	°C	$\Delta T_{OE} = T_J - T_{DTS}$ $V_{DDP} \leq 3.3 \text{ V}^1)$
Measurement time	$t_M$ CC	-	-	100	μs	
Start-up time after reset inactive	$t_{TSST}$ SR	-	-	10	μs	

1) At  $V_{DDP\_max} = 3.63 \text{ V}$  the typical offset error increases by an additional  $\Delta T_{OE} = \pm 1^\circ\text{C}$ .

### 3 Electrical Parameters

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

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

This formula and the values defined in [Table 27](#) apply with the following calibration values:

- DTSCON.BGTRIM = 8<sub>H</sub>
- DTSCON.REFTRIM = 4<sub>H</sub>

### 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 28** **USB OTG VBUS and ID Parameters (Operating Conditions apply)**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
VBUS input voltage range	$V_{\text{IN}}$ 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	$R_{\text{VBUS\_IN}}$ CC	40	–	100	kOhm	
B-device VBUS pull-up resistor	$R_{\text{VBUS\_PU}}$ CC	281	–	–	Ohm	Pull-up voltage = 3.0 V
B-device VBUS pull-down resistor	$R_{\text{VBUS\_PD}}$ CC	656	–	–	Ohm	
USB.ID pull-up resistor	$R_{\text{UID\_PU}}$ CC	14	–	25	kOhm	
VBUS input current	$I_{\text{VBUS\_IN}}$ CC	–	–	150	$\mu\text{A}$	$0 \text{ V} \leq V_{\text{IN}} \leq 5.25 \text{ V};$ $T_{\text{AVG}} = 1 \text{ ms}$

### 3 Electrical Parameters

**Table 29 USB OTG Data Line (USB\_DP, USB\_DM) Parameters (Operating Conditions apply)**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>			<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Typ.</b>	<b>Max.</b>		
Input low voltage	$V_{IL}$ SR	–	–	0.8	V	
Input high voltage (driven)	$V_{IH}$ SR	2.0	–	–	V	
Input high voltage (floating) <sup>1)</sup>	$V_{HZ}$ 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	–	1575	Ohm	
DP pull-up resistor (upstream port receiving)	$R_{PUA}$ CC	1425	–	3090	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.

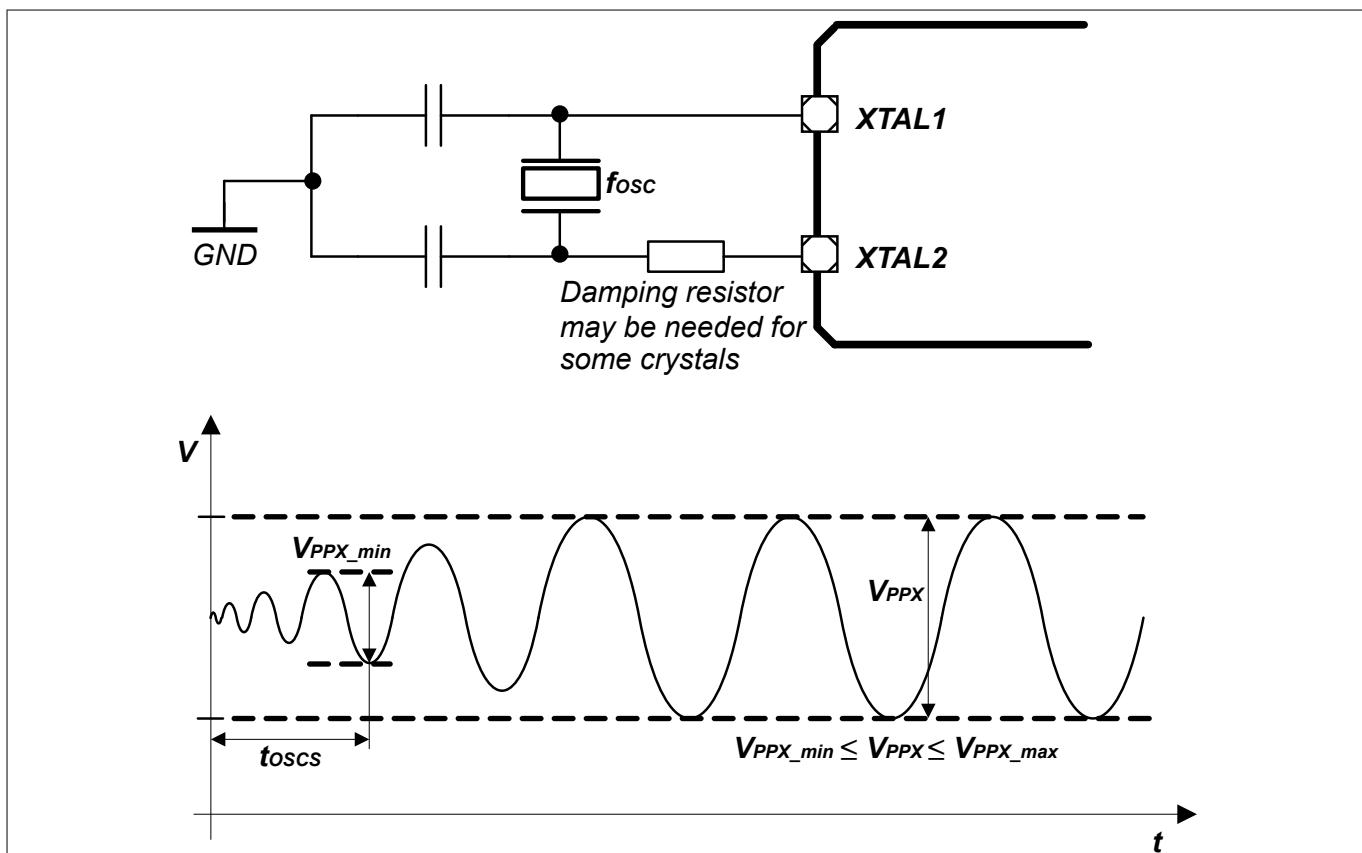
### 3 Electrical Parameters

#### 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.

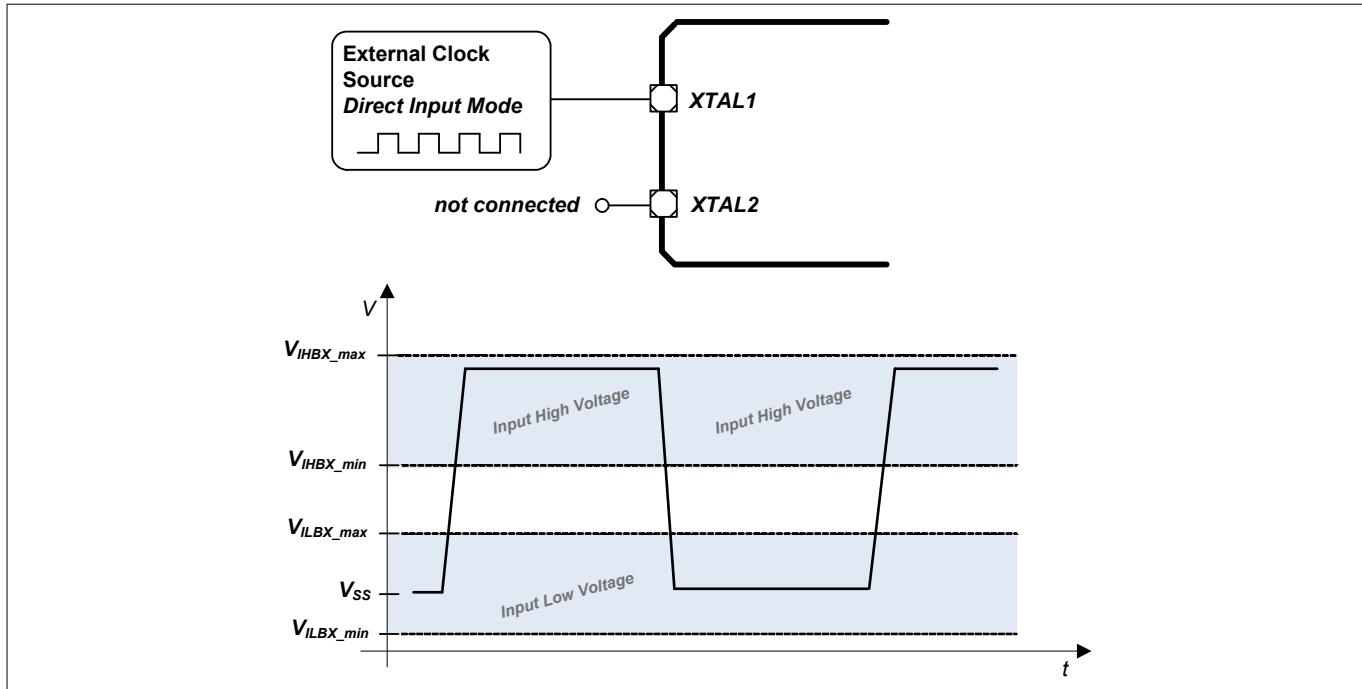
**Note:** These parameters are not subject to production test, but verified by design and/or characterization.

The oscillator pins can be operated with an external crystal (see [Figure 20](#)) or in direct input mode (see [Figure 21](#)).



**Figure 20**      **Oscillator in Crystal Mode**

### 3 Electrical Parameters



**Figure 21**      **Oscillator in Direct Input Mode**

**Table 30**      **OSC\_XTAL Parameters**

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

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

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.

### 3 Electrical Parameters

**Table 31 RTC\_XTAL Parameters**

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

- 1)  $t_{\text{oscS}}$  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.
- 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) 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.
- 4) If the shaper unit is enabled and not bypassed.
- 5) If the shaper unit is bypassed, dedicated DC-thresholds have to be met.
- 6) 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 Electrical Parameters

#### 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:

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

**Table 32 Power Supply Parameters**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Active supply current <sup>1)2)</sup> Peripherals enabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	$I_{DDPA \text{ CC}}$	-	122	-	mA	120/120/120
		-	110	-		120/60/60
		-	85	-		60/60/120
		-	65	-		24/24/24
		-	52	-		1/1/1
Active supply current Code execution from RAM Flash in Sleep mode	$I_{DDPA \text{ CC}}$	-	98	-	mA	120/120/120
		-	80	-		120/60/60
		-	-	-		-
Active supply current <sup>3)</sup> Peripherals disabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	$I_{DDPA \text{ CC}}$	-	115	-	mA	120/120/120
		-	105	-		120/60/60
		-	80	-		60/60/120
		-	63	-		24/24/24
		-	50	-		1/1/1
Sleep supply current <sup>4)</sup> Peripherals enabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	$I_{DDPS \text{ CC}}$	-	115	-	mA	120/120/120
		-	105	-		120/60/60
		-	83	-		60/60/120
		-	60	-		24/24/24
		-	48	-		1/1/1
		-	46	-		100/100/100
Sleep supply current <sup>5)</sup> Peripherals disabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in kHz	$I_{DDPS \text{ CC}}$	-	110	-	mA	120/120/120
		-	100	-		120/60/60
		-	77	-		60/60/120
		-	59	-		24/24/24
		-	48	-		1/1/1
		-	46	-		100/100/100
Deep Sleep supply current <sup>6)</sup>	$I_{DDPD \text{ CC}}$	-	20	-	mA	24/24/24

(table continues...)

### 3 Electrical Parameters

**Table 32 (continued) Power Supply Parameters**

<b>Parameter</b>	<b>Symbol</b>	<b>Values</b>			<b>Unit</b>	<b>Note/Test Condition</b>
		<b>Min.</b>	<b>Typ.</b>	<b>Max.</b>		
Flash in Sleep mode	$f_{\text{CPU}} / f_{\text{PERIPH}} / f_{\text{CCU}}$ in MHz	–	12	–		4/4/4
Frequency: $f_{\text{CPU}} / f_{\text{PERIPH}} / f_{\text{CCU}}$ in kHz		–	10	–		1/1/1
$f_{\text{CPU}} / f_{\text{PERIPH}} / f_{\text{CCU}}$ in kHz		–	6	–		100/100/100 <sup>7)</sup>
Hibernate supply current RTC on <sup>8)</sup>	$I_{\text{DDPH CC}}$	–	10	–	$\mu\text{A}$	$V_{\text{BAT}} = 3.3 \text{ V}$
		–	7.5	–		$V_{\text{BAT}} = 2.4 \text{ V}$
		–	6.2	–		$V_{\text{BAT}} = 2.0 \text{ V}$
Hibernate supply current RTC off <sup>9)</sup>	$I_{\text{DDPH CC}}$	–	9.2	–	$\mu\text{A}$	$V_{\text{BAT}} = 3.3 \text{ V}$
		–	6.7	–		$V_{\text{BAT}} = 2.4 \text{ V}$
		–	5.6	–		$V_{\text{BAT}} = 2.0 \text{ V}$
Worst case active supply current <sup>2)</sup>	$I_{\text{DDPA CC}}$	–	–	180 <sup>10)</sup>	$\text{mA}$	$V_{\text{DDP}} = 3.6 \text{ V}, T_J = 150^\circ\text{C}$
$V_{\text{DDA}}$ power supply current	$I_{\text{DDA CC}}$	–	–	– <sup>11)</sup>	$\text{mA}$	
$I_{\text{DDP}}$ current at PORST Low	$I_{\text{DDP\_PORST CC}}$	–	–	16	$\text{mA}$	$V_{\text{DDP}} = 3.6 \text{ V}, T_J = 150^\circ\text{C}$
Power Dissipation	$P_{\text{DISS CC}}$	–	–	1	$\text{W}$	$V_{\text{DDP}} = 3.6 \text{ V}, T_J = 150^\circ\text{C}$
Wake-up time from Sleep to Active mode	$t_{\text{SSA CC}}$	–	6	–	cycles	
Wake-up time from Deep Sleep to Active mode		–	–	–	ms	Defined by the wake-up of the Flash module, see <a href="#">Section 3.2.9</a>
Wake-up time from Hibernate mode		–	–	–	ms	Wake-up via power-on reset event, see <a href="#">Section 3.3.2</a>

1) CPU executing code from Flash, all peripherals idle.

2) Test Power Loop:  $f_{\text{SYS}} = 120 \text{ MHz}$ , CPU executing benchmark code from Flash, all CCUs in 100 kHz timer mode, all ADC groups in continuous conversion mode, USICs as SPI in internal loop-back mode, CAN in 500 kHz 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.

3) CPU executing code from Flash.

4) CPU in sleep, all peripherals idle, Flash in Active mode.

5) CPU in sleep, Flash in Active mode.

6) CPU in sleep, peripherals disabled, after wake-up code execution from RAM.

7) To wake-up the Flash from its Sleep mode,  $f_{\text{CPU}} \geq 1 \text{ MHz}$  is required.

8) OSC\_ULP operating with external crystal on RTC\_XTAL.

9) OSC\_ULP off, Hibernate domain operating with OSC\_SI clock.

10)  $I_{\text{DDP}}$  decreases typically by approximately 6 mA when  $f_{\text{SYS}}$  decreases by 10 MHz, at constant  $T_J$ .

11) Sum of currents of all active converters (ADC and DAC).

### 3 Electrical Parameters

#### 3.2.9 Flash Memory Parameters

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

**Table 33 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 <sup>1)</sup>	$t_{PRP\ CC}$	-	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 <sup>2)</sup>
Data Retention Time, Physical Sector <sup>3) 4)</sup>	$t_{RET\ CC}$	20	-	-	years	Max. 1000 erase/program cycles
Data Retention Time, Logical Sector <sup>3) 4)</sup>	$t_{RETL\ CC}$	20	-	-	years	Max. 100 erase/program cycles
Data Retention Time, User Configuration Block (UCB) <sup>3) 4)</sup>	$t_{RTU\ CC}$	20	-	-	years	Max. 4 erase/program cycles per UCB

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:  $FCON.WSPFLASH \times (1/f_{CPU}) \geq t_a$ .

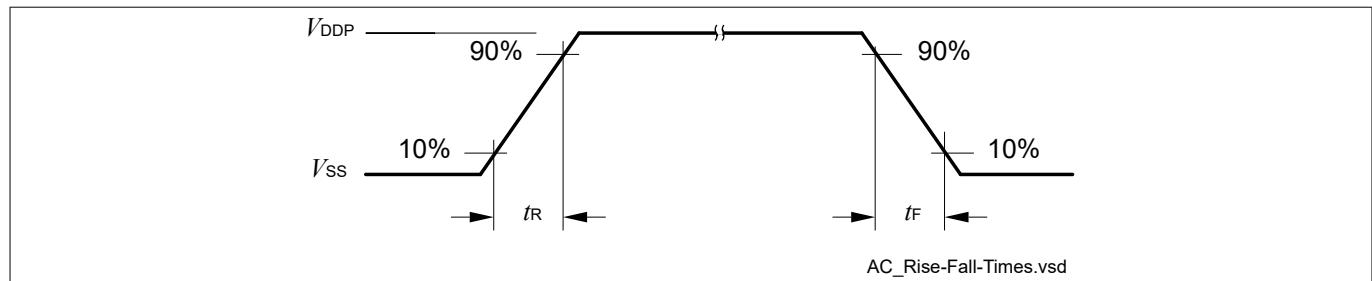
3) Storage and inactive time included.

4) Values given are valid for an average weighted junction temperature of  $T_J = 110^\circ\text{C}$ .

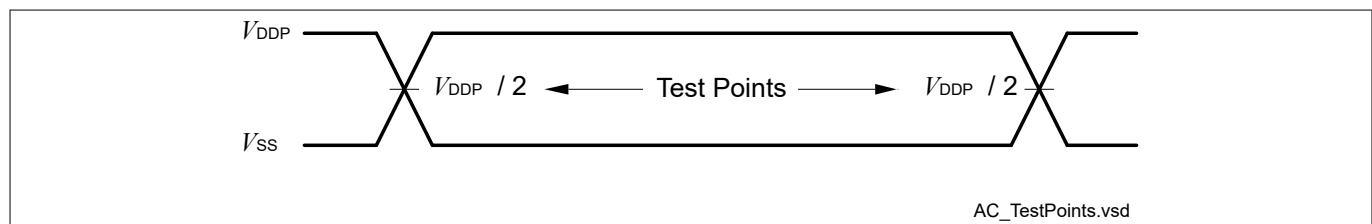
### 3 Electrical Parameters

#### 3.3 AC Parameters

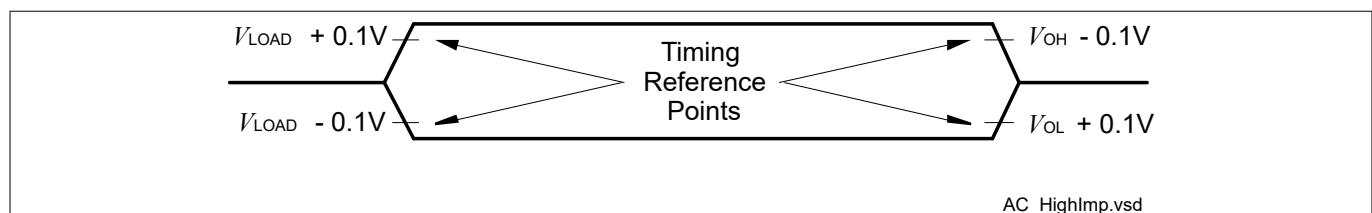
##### 3.3.1 Testing Waveforms



**Figure 22** Rise/Fall Time Parameters



**Figure 23** Testing Waveform, Output Delay



**Figure 24** Testing Waveform, Output High Impedance

### 3 Electrical Parameters

#### 3.3.2 Power-Up and Supply Monitoring

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.

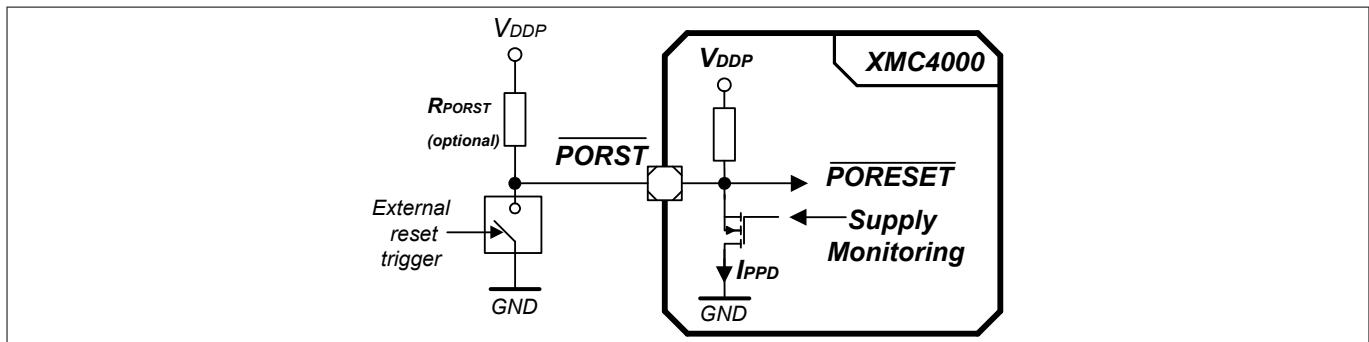


Figure 25 PORST Circuit

Table 34 Supply Monitoring Parameters

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Digital supply voltage reset threshold	$V_{POR\ CC}$	2.79 <sup>1)</sup>	–	3.05 <sup>2)</sup>	V	<sup>3)</sup>
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	
PORST rise time	$t_{PR\ SR}$	–	–	2	$\mu s$	<sup>4)</sup>
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	–	$\mu s$	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.

2) Maximum threshold for reset deassertion.

3) The  $V_{DDP}$  monitoring has a typical hysteresis of  $V_{PORHYS} = 180$  mV.

4) If  $t_{PR}$  is not met, low spikes on PORST may be seen during start up (e.g. reset pulses generated by the supply monitoring due to a slow ramping  $V_{DDP}$ ).

### 3 Electrical Parameters

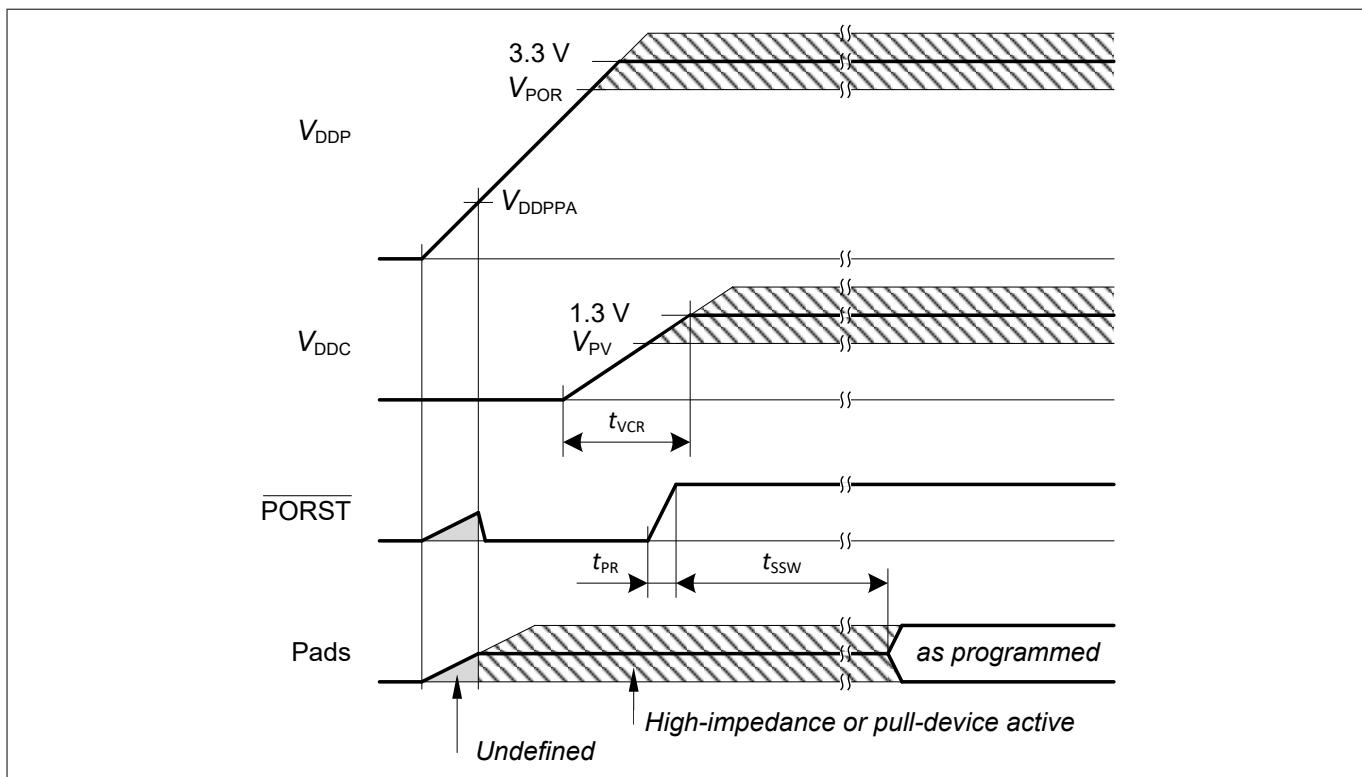


Figure 26 Power-Up Behavior

#### 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 35 Power Sequencing Parameters

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

### 3 Electrical Parameters

#### Positive Load Step Examples

System assumptions:

$f_{CPU} = f_{SYS}$ , target frequency  $f_{CPU} = 120$  MHz, main PLL  $f_{VCO} = 480$  MHz, stepping done by K2 divider,  $t_{PLSS}$  between individual steps:

24 MHz - 48 MHz - 68 MHz - 96 MHz - 120 MHz (K2 steps 20 - 10 - 7 - 5 - 4)

24 MHz - 68 MHz - 96 MHz - 120 MHz (K2 steps 20 - 7 - 5 - 4)

24 MHz - 68 MHz - 120 MHz (K2 steps 20 - 7 - 4)

#### 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 36 PLL Parameters**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Accumulated Jitter	$D_P$ CC	–	–	$\pm 5$	ns	accumulated over 300 cycles $f_{SYS} = 120$ MHz
Duty Cycle <sup>1)</sup>	$D_{DC}$ 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	$\mu s$	

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

### 3 Electrical Parameters

#### 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 37** 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	$\Delta f_{OFI}$ CC	-0.5	-	0.5	%	automatic calibration <sup>1) 2)</sup>
		-15	-	15	%	factory calibration, $V_{DDP} = 3.3\text{ V}$
		-25	-	25	%	no calibration, $V_{DDP} = 3.3\text{ V}$
		-7	-	7	%	Variation over voltage range <sup>3)</sup> $3.13\text{ V} \leq V_{DDP} \leq 3.63\text{ V}$
Start-up time	$t_{OFIS}$ CC	-	50	-	$\mu\text{s}$	

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.

##### Slow Internal Clock Source

**Table 38** Slow Internal Clock Parameters

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

### 3 Electrical Parameters

#### 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.

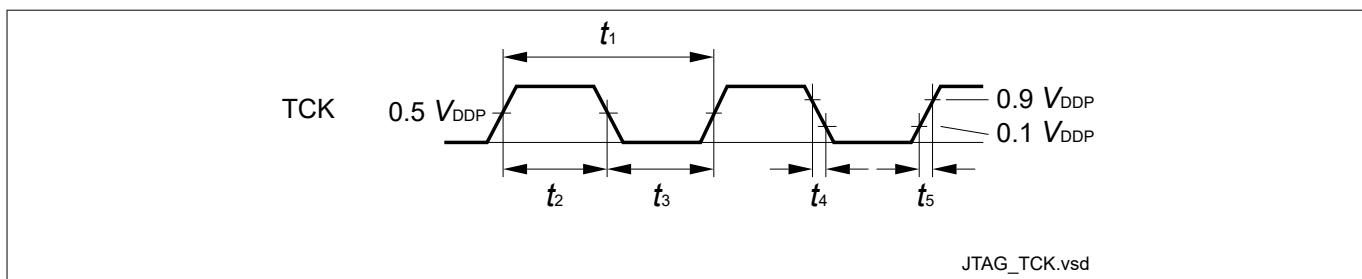
**Note:** Operating conditions apply.

**Table 39 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 <sup>1)</sup> (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 <sup>1)</sup>	$t_{18}$ CC	2	–	–	ns	
TDO high imped. to valid from TCK falling edge <sup>1) 2)</sup>	$t_9$ CC	–	–	14	ns	$C_L = 50 \text{ pF}$
TDO valid to high imped. from TCK falling edge <sup>1)</sup>	$t_{10}$ CC	–	–	13.5	ns	$C_L = 50 \text{ pF}$

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

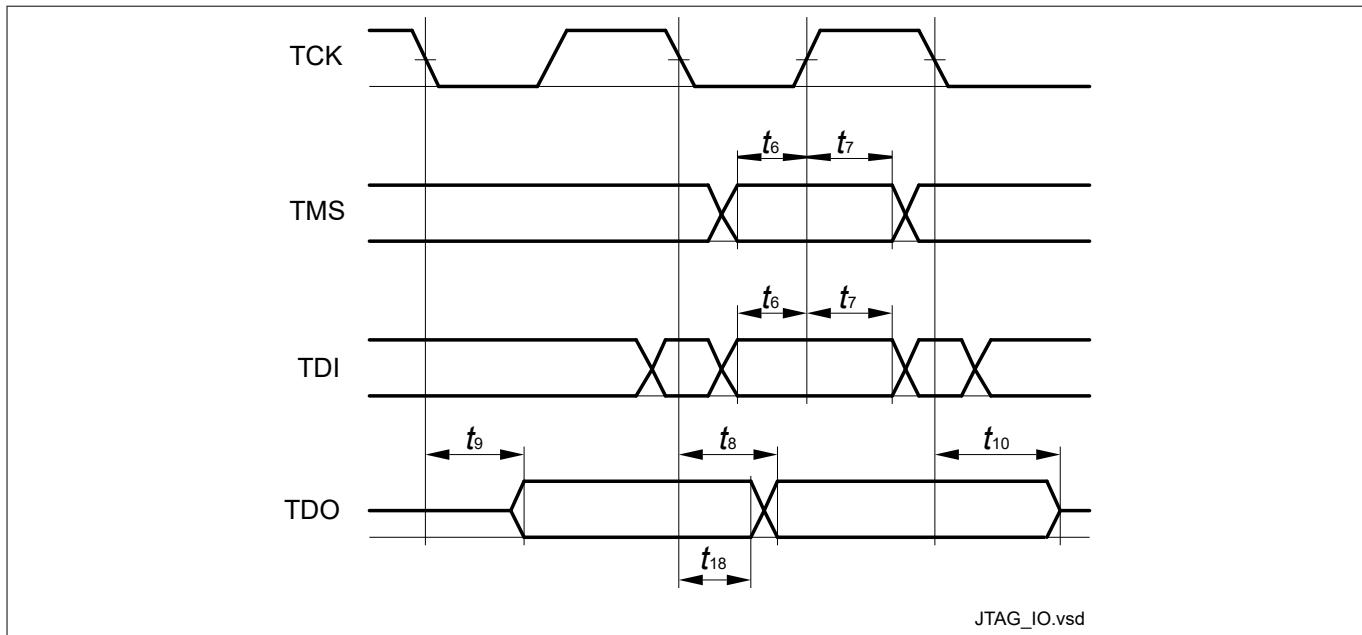
2) The setup time for TDO is given implicitly by the TCK cycle time.



**Figure 27**

**Test Clock Timing (TCK)**

### 3 Electrical Parameters



**Figure 28**      **JTAG Timing**

#### 3.3.7      Serial Wire Debug Port (SW-DP) Timing

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

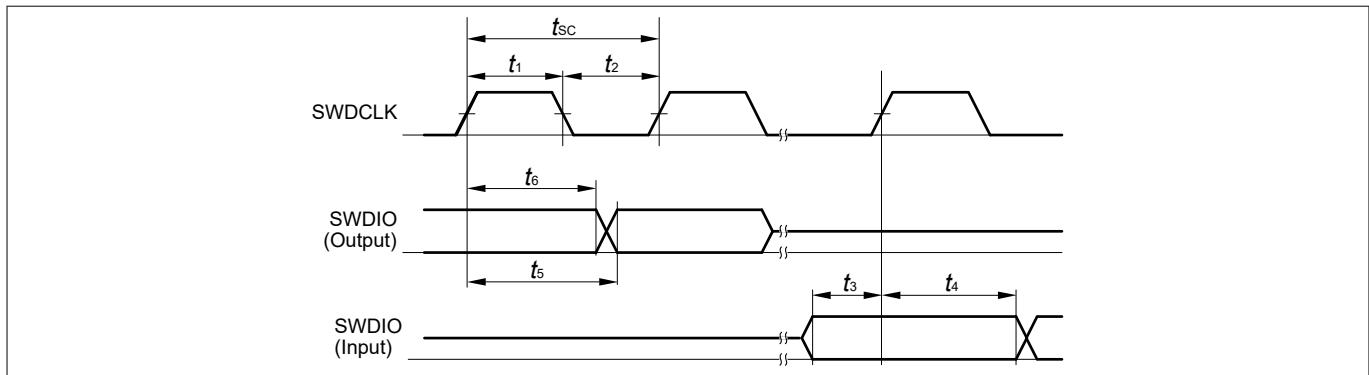
**Note:** These parameters are not subject to production test, but verified by design and/or characterization.

**Note:** Operating conditions apply.

**Table 40**      **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	

### 3 Electrical Parameters



**Figure 29** SWD Timing

#### 3.3.8 Embedded Trace Macro Cell (ETM) Timing

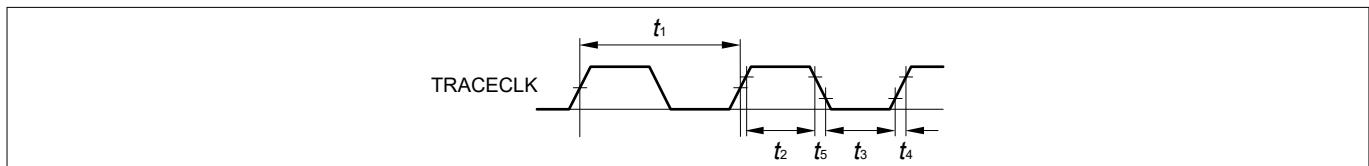
The data timing refers to the active clock edge. The XMC4500 ETM uses the half-rate clocking mode. In this mode both, the rising and falling clock edges are active clock edges.

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

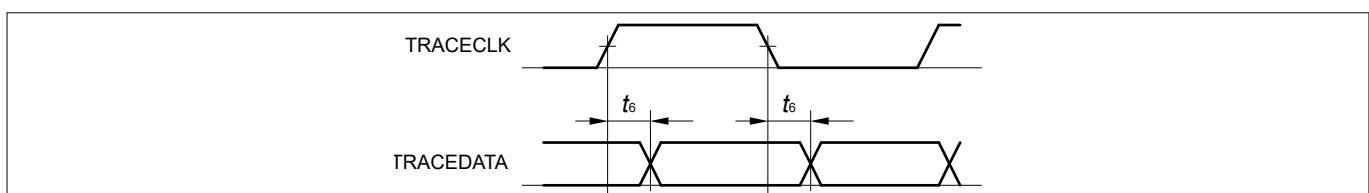
**Note:** Operating conditions apply, with  $C_L \leq 15 \text{ pF}$ .

**Table 41** ETM Interface Timing Parameters

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
TRACECLK period	$t_1$ CC	16.7	–	–	ns	–
TRACECLK high time	$t_2$ CC	2	–	–	ns	–
TRACECLK low time	$t_3$ CC	2	–	–	ns	–
TRACECLK and TRACEDATA rise time	$t_4$ CC	–	–	3	ns	–
TRACECLK and TRACEDATA fall time	$t_5$ CC	–	–	3	ns	–
TRACEDATA output valid time	$t_6$ CC	-2	–	3	ns	–



**Figure 30** ETM Clock Timing



**Figure 31** ETM Data Timing

### 3 Electrical Parameters

#### 3.3.9 Peripheral Timing

##### 3.3.9.1 Delta-Sigma Demodulator Digital Interface Timing

The following parameters are applicable for the digital interface of the Delta-Sigma Demodulator (DSD).

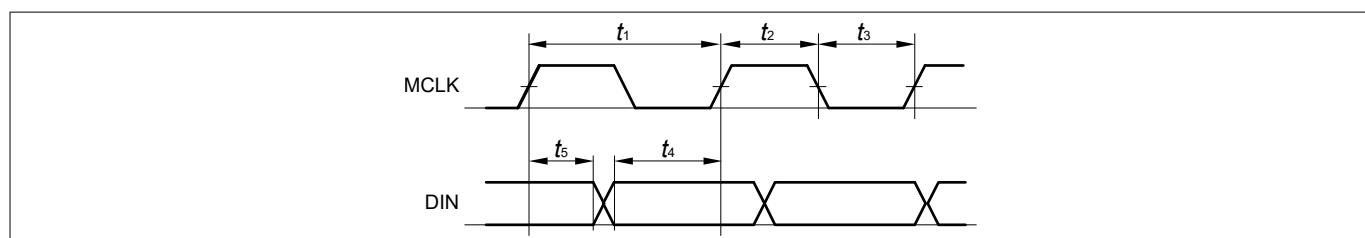
The data timing is relative to the active clock edge. Depending on the operation mode of the connected modulator that can be the rising and falling clock edge.

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

**Table 42 DSD Interface Timing Parameters**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
MCLK period in master mode	$t_1$ CC	33.3	–	–	ns	$t_1 \geq 4 \times t_{\text{PERIPH}}$ <sup>1)</sup>
MCLK high time in master mode	$t_2$ CC	9	–	–	ns	$t_2 > t_{\text{PERIPH}}$ <sup>1)</sup>
MCLK low time in master mode	$t_3$ CC	9	–	–	ns	$t_3 > t_{\text{PERIPH}}$ <sup>1)</sup>
MCLK period in slave mode	$t_1$ SR	33.3	–	–	ns	$t_1 \geq 4 \times t_{\text{PERIPH}}$ <sup>1)</sup>
MCLK high time in slave mode	$t_2$ SR	$t_{\text{PERIPH}}$	–	–	ns	<sup>1)</sup>
MCLK low time in slave mode	$t_3$ SR	$t_{\text{PERIPH}}$	–	–	ns	<sup>1)</sup>
DIN input setup time to the active clock edge	$t_4$ SR	$t_{\text{PERIPH}} + \frac{4}{4}$	–	–	ns	<sup>1)</sup>
DIN input hold time from the active clock edge	$t_5$ SR	$t_{\text{PERIPH}} + \frac{3}{3}$	–	–	ns	<sup>1)</sup>

1)  $t_{\text{PERIPH}} = 1/f_{\text{PERIPH}}$



**Figure 32 DSD Data Timing**

### 3 Electrical Parameters

#### 3.3.9.2 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**

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

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

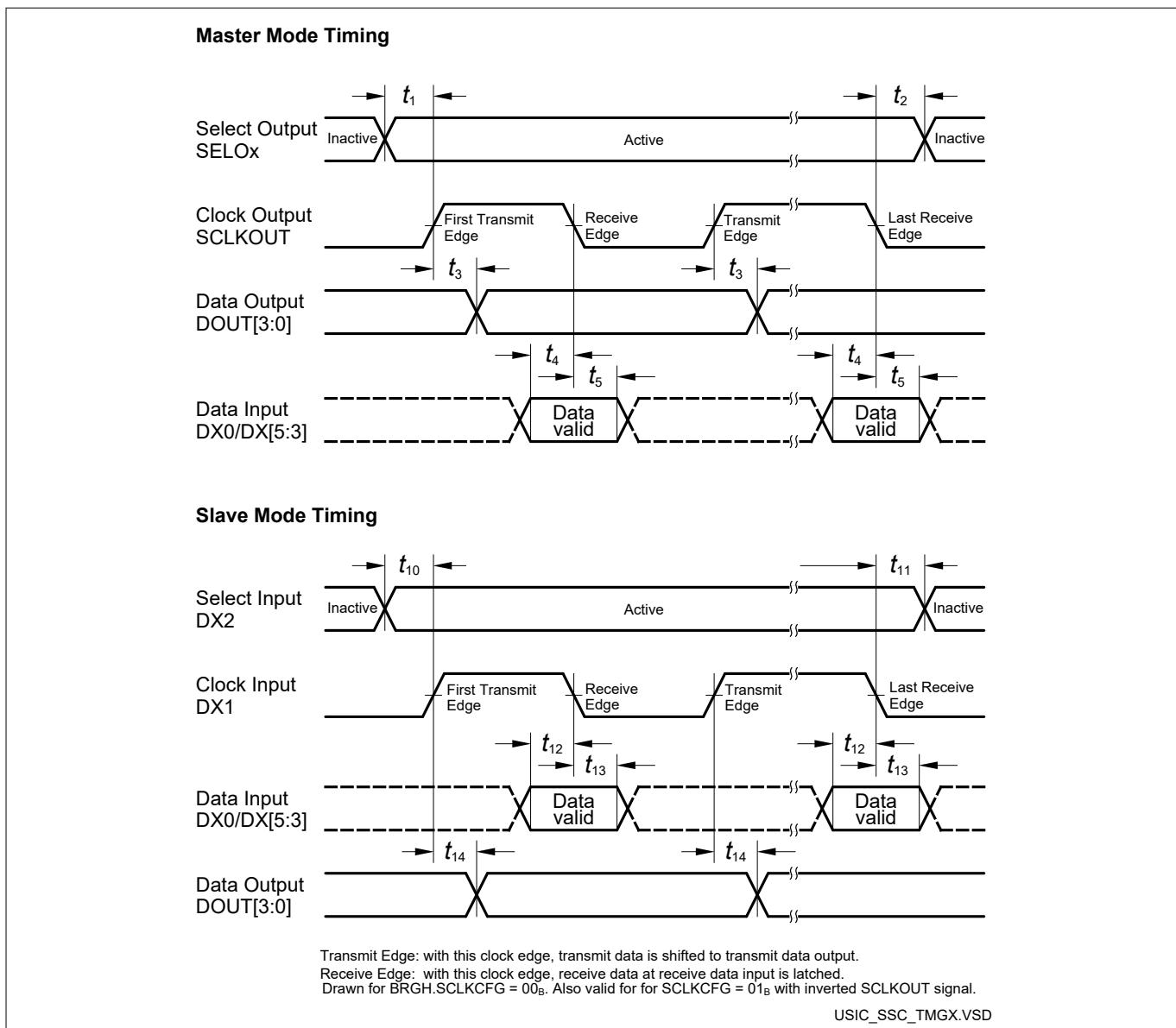
### 3 Electrical Parameters

**Table 44 USIC SSC Slave Mode Timing**

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

### 3 Electrical Parameters



**Figure 33** 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 Electrical Parameters

#### 3.3.9.3 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 Timing<sup>1)</sup>**

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 Timing<sup>1)</sup>**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Fall time of both SDA and SCL	$t_1$ CC/SR	$20 + 0.1 * C_b$ <sup>2)</sup>	–	300	ns	
Rise time of both SDA and SCL	$t_2$ CC/SR	$20 + 0.1 * C_b$ <sup>2)</sup>	–	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	

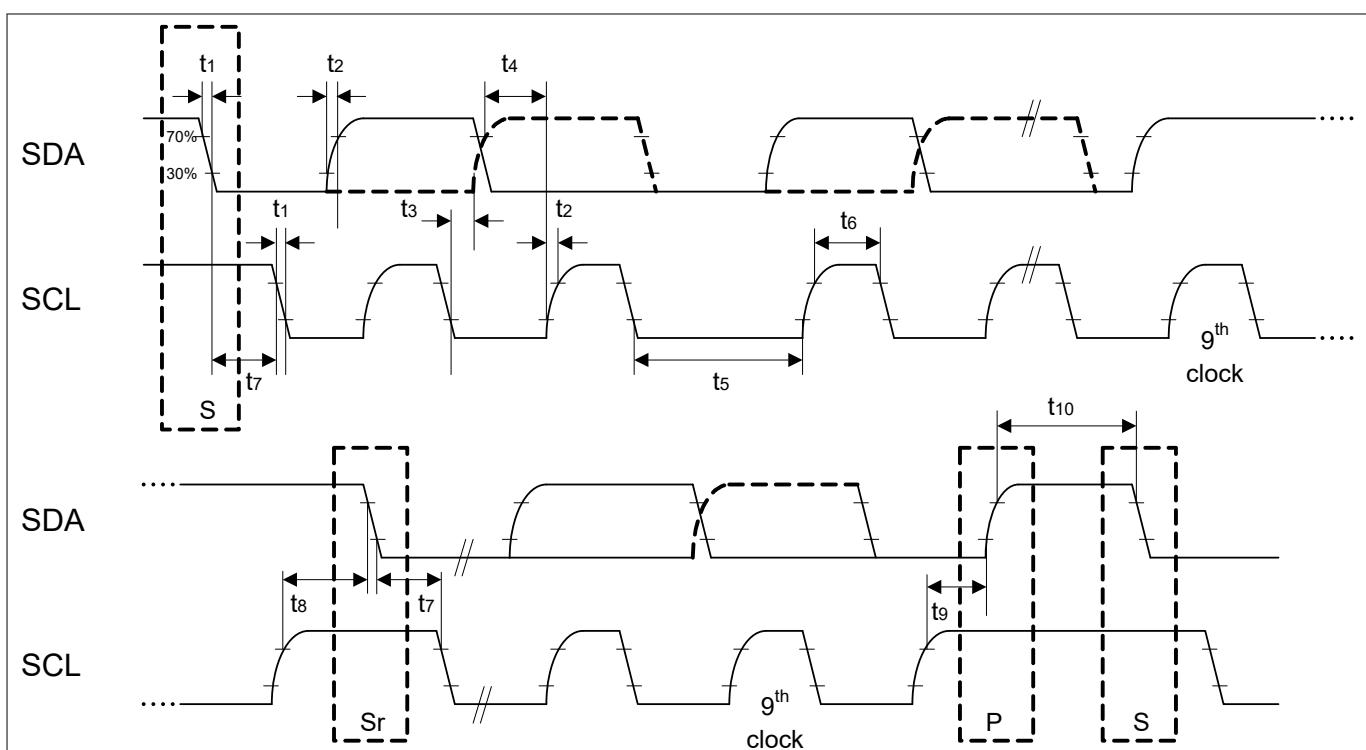
(table continues...)

### 3 Electrical Parameters

**Table 46** (continued) USIC IIC Fast Mode Timing<sup>1)</sup>

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
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 34** USIC IIC Stand and Fast Mode Timing

### 3 Electrical Parameters

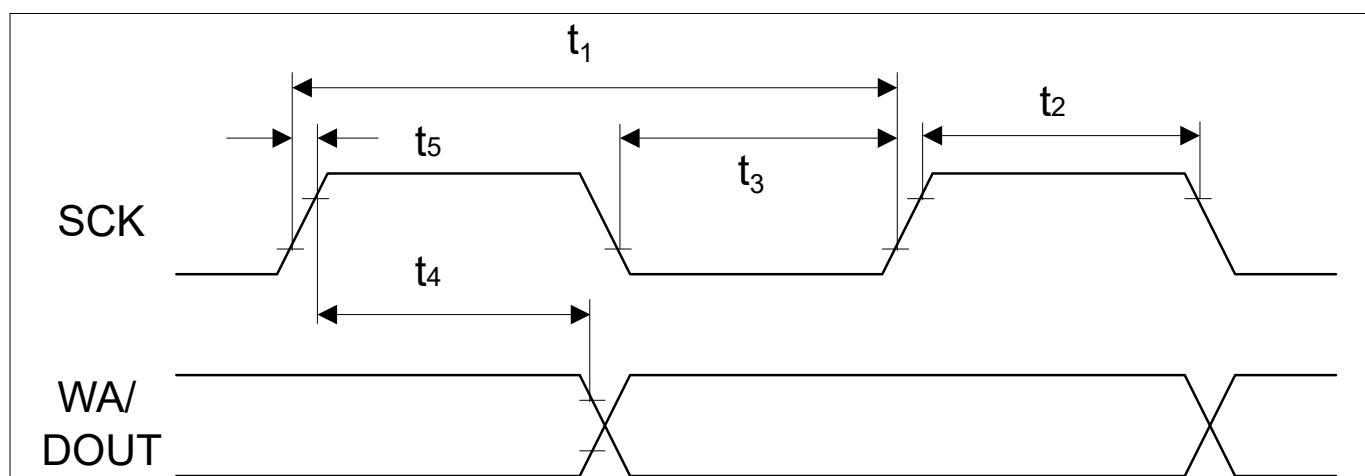
#### 3.3.9.4 Inter-IC Sound (IIS) Interface Timing

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

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

**Table 47** USIC IIS Master Transmitter Timing

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Clock period	$t_1$ CC	33.3	–	–	ns	
Clock high time	$t_2$ CC	$0.35 \times t_{1\min}$	–	–	ns	
Clock low time	$t_3$ CC	$0.35 \times t_{1\min}$	–	–	ns	
Hold time	$t_4$ CC	0	–	–	ns	
Clock rise time	$t_5$ CC	–	–	$0.15 \times t_{1\min}$	ns	

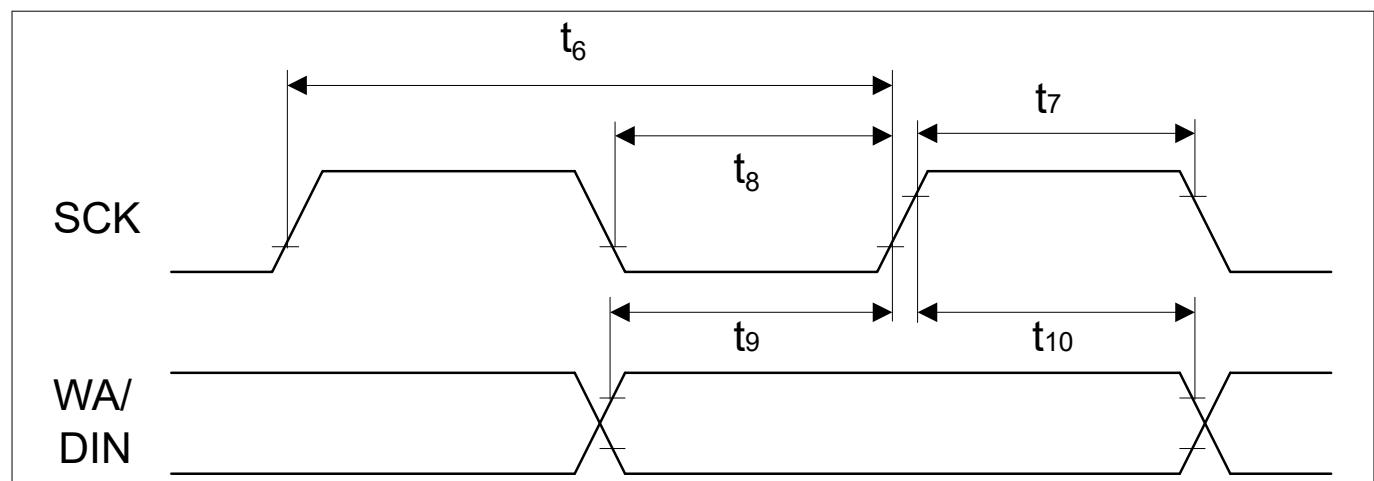


**Figure 35** USIC IIS Master Transmitter Timing

**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	$0.35 \times t_{6\min}$	–	–	ns	
Clock low time	$t_8$ SR	$0.35 \times t_{6\min}$	–	–	ns	
Set-up time	$t_9$ SR	$0.2 \times t_{6\min}$	–	–	ns	
Hold time	$t_{10}$ SR	0	–	–	ns	

### 3 Electrical Parameters



**Figure 36**

**USIC IIS Slave Receiver Timing**

### 3 Electrical Parameters

#### 3.3.9.5 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  $C_L = 40 \text{ pF}$ .

#### 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 ( $1/t_{pp}$ )	$f_{pp} \text{ CC}$	0	24	MHz	
Clock cycle in full speed transfer mode	$t_{pp} \text{ CC}$	40	–	ns	
Clock low time	$t_{WL} \text{ CC}$	10	–	ns	
Clock high time	$t_{WH} \text{ CC}$	10	–	ns	
Clock rise time	$t_{TLH} \text{ CC}$	–	10	ns	
Clock fall time	$t_{THL} \text{ CC}$	–	10	ns	
Inputs setup to clock rising edge	$t_{ISU\_F} \text{ SR}$	2	–	ns	
Inputs hold after clock rising edge	$t_{IH\_F} \text{ SR}$	2	–	ns	
Outputs valid time in full speed mode	$t_{ODLY\_F} \text{ CC}$	–	10	ns	
Outputs hold time in full speed mode	$t_{OH\_F} \text{ CC}$	0	–	ns	

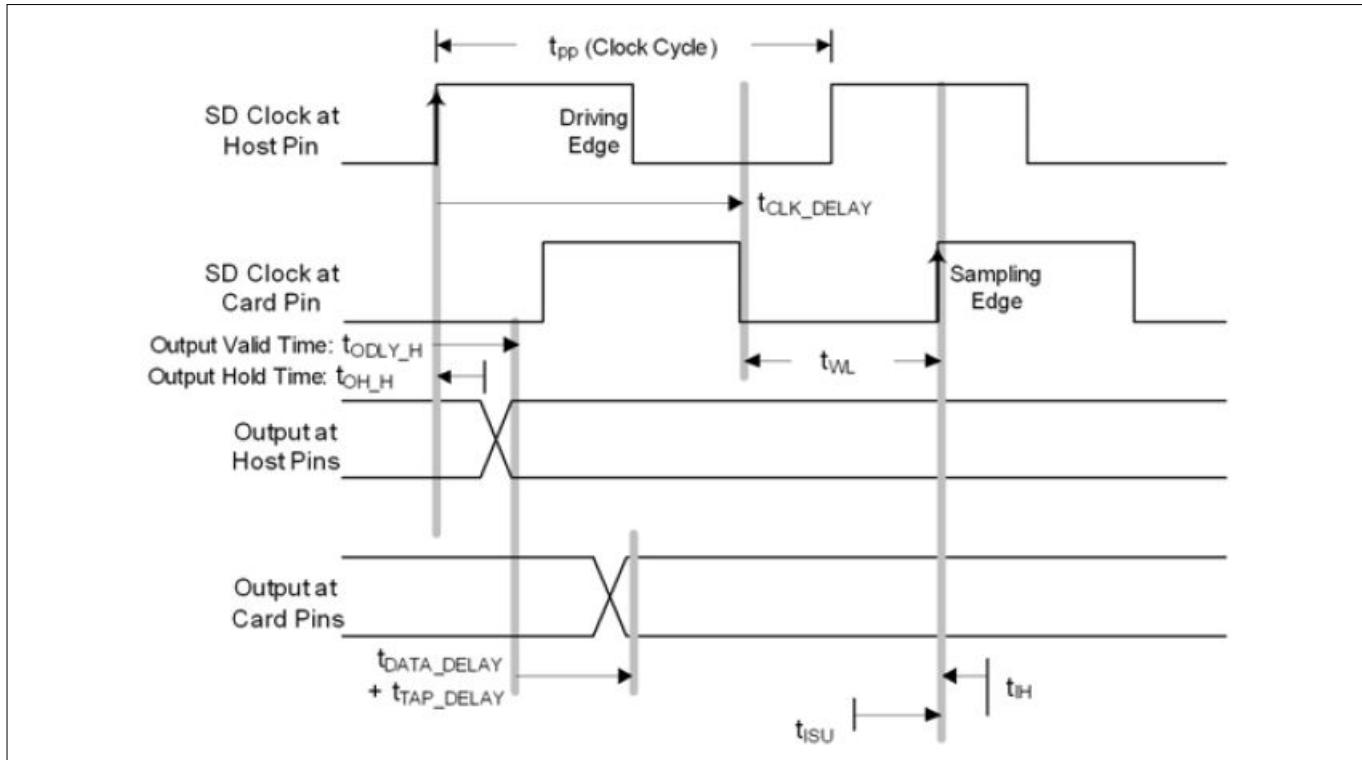
**Table 50 SD Card Bus Timing for Full-Speed Mode<sup>1)</sup>**

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.

### 3 Electrical Parameters

#### Full-Speed Output Path (Write)



**Figure 37**      **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:

$$t_{ODLY\_F} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ISU} < t_{WL} + t_{CLK\_DELAY} \quad (2)$$

$$\begin{aligned} t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{WL} &< t_{PP} + t_{CLK\_DELAY} - t_{ISU} - t_{ODLY\_F} \\ t_{DATA\_DELAY} + t_{TAP\_DELAY} + 20 &< 40 + t_{CLK\_DELAY} - 5 - 10 \\ t_{DATA\_DELAY} &< 5 + t_{CLK\_DELAY} - t_{TAP\_DELAY} \end{aligned} \quad (3)$$

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

### 3 Electrical Parameters

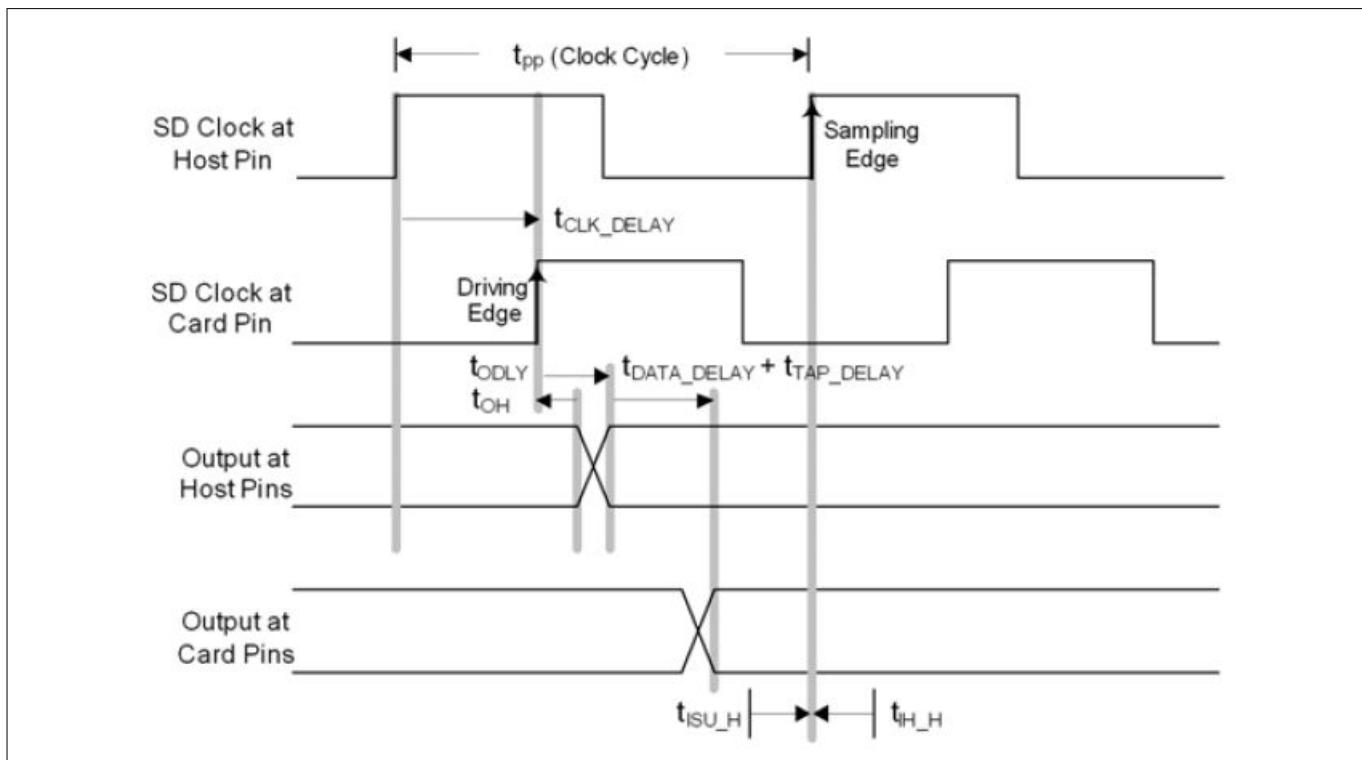
#### Full-Speed Write Meeting Hold (Minimum Delay)

The following equations show how to calculate the allowed skew range between the SD\_CLK and SD\_DAT/CMD signals on the PCB.

$$\begin{aligned} t_{\text{CLK\_DELAY}} &< t_{\text{WL}} + t_{\text{OH\_F}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} - t_{\text{IH}} \\ t_{\text{CLK\_DELAY}} &< 20 + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} - 5 \\ t_{\text{DATA\_DELAY}} &< 15 + t_{\text{CLK\_DELAY}} + t_{\text{TAP\_DELAY}} \end{aligned} \quad (4)$$

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

#### Full-Speed Input Path (Read)



**Figure 38**      **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.

$$\begin{aligned} t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} + t_{\text{ODLY}} + t_{\text{ISU\_F}} &< 0.5 \times t_{\text{pp}} \\ t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &< 0.5 \times t_{\text{pp}} - t_{\text{ODLY}} - t_{\text{ISU\_F}} - t_{\text{TAP\_DELAY}} \\ t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &< 20 - 14 - 2 - t_{\text{TAP\_DELAY}} \\ t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &< 4 - t_{\text{TAP\_DELAY}} \end{aligned} \quad (5)$$

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

### 3 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.

$$\begin{aligned} t_{\text{CLK\_DELAY}} + t_{\text{OH}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} &> t_{\text{IH\_F}} \\ t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &> t_{\text{IH\_F}} - t_{\text{OH}} - t_{\text{TAP\_DELAY}} \\ t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &> 2 - t_{\text{TAP\_DELAY}} \end{aligned} \quad (6)$$

The data + clock delay must be greater than 2 ns if  $t_{\text{TAP\_DELAY}}$  is not used.

If the  $t_{\text{TAP\_DELAY}}$  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 ( $1/t_{\text{pp}}$ )	$f_{\text{pp}}$ CC	0	48	MHz	
Clock cycle in high speed transfer mode	$t_{\text{pp}}$ CC	20	–	ns	
Clock low time	$t_{\text{WL}}$ CC	7	–	ns	
Clock high time	$t_{\text{WH}}$ CC	7	–	ns	
Clock rise time	$t_{\text{TLH}}$ CC	–	3	ns	
Clock fall time	$t_{\text{THL}}$ CC	–	3	ns	
Inputs setup to clock rising edge	$t_{\text{ISU\_H}}$ SR	2	–	ns	
Inputs hold after clock rising edge	$t_{\text{IH\_H}}$ SR	2	–	ns	
Outputs valid time in high speed mode	$t_{\text{ODLY\_H}}$ CC	–	14	ns	
Outputs hold time in high speed mode	$t_{\text{OH\_H}}$ CC	2	–	ns	

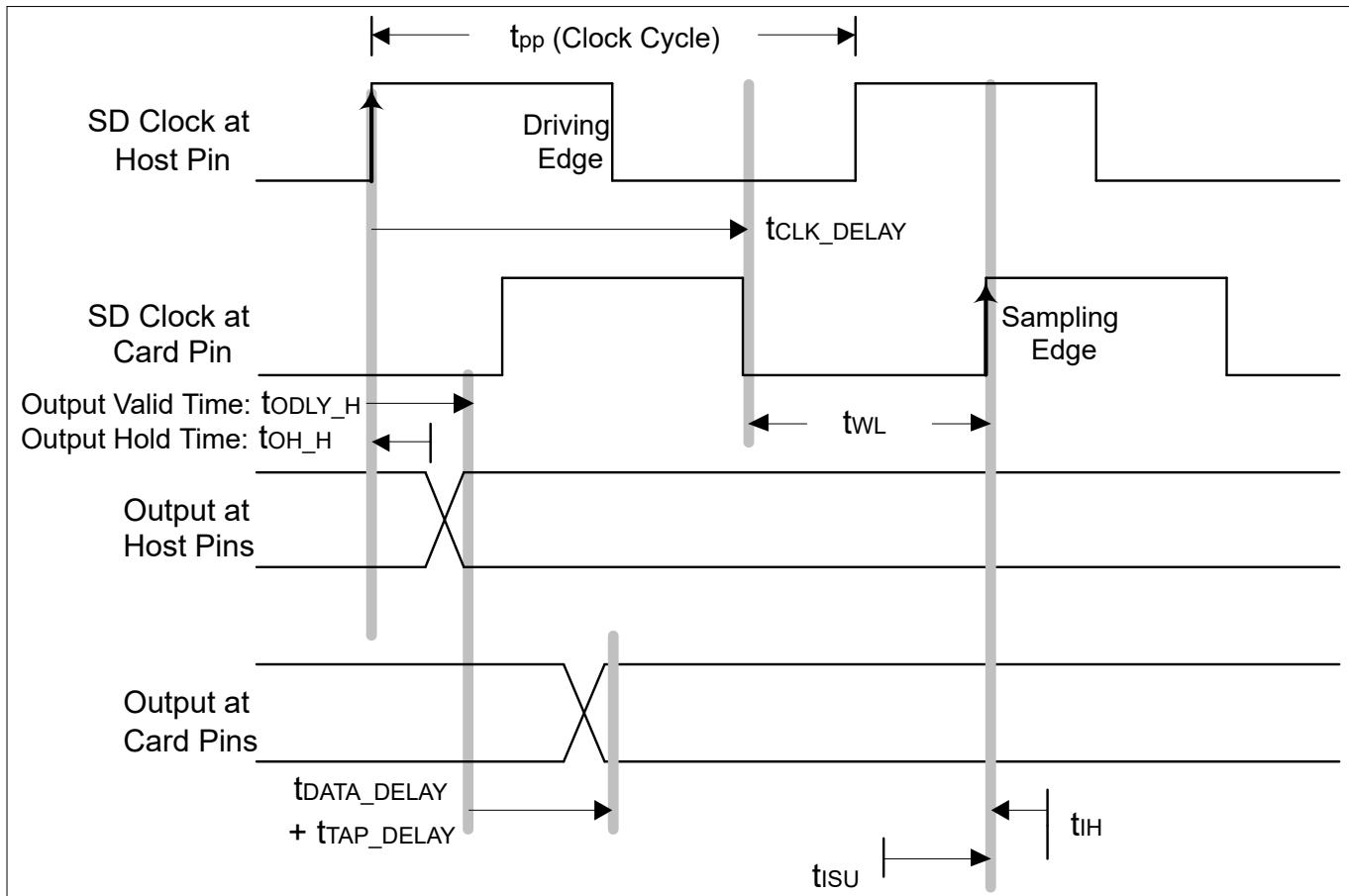
**Table 52 SD Card Bus Timing for High-Speed Mode<sup>1)</sup>**

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

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

### 3 Electrical Parameters

#### High-Speed Output Path (Write)



**Figure 39**      **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:

$$t_{ODLY\_H} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ISU} < t_{WL} + t_{CLK\_DELAY} \quad (8)$$

$$\begin{aligned} t_{DATA\_DELAY} + t_{TAP\_DELAY} - t_{CLK\_DELAY} &< t_{WL} - t_{ISU} - t_{ODLY\_H} \\ t_{DATA\_DELAY} - t_{CLK\_DELAY} &< t_{WL} - t_{ISU} - t_{ODLY\_H} - t_{TAP\_DELAY} \\ t_{DATA\_DELAY} - t_{CLK\_DELAY} &< 10 - 6 - 14 - t_{TAP\_DELAY} \\ t_{DATA\_DELAY} - t_{CLK\_DELAY} &< -10 - t_{TAP\_DELAY} \end{aligned} \quad (9)$$

The data delay is less than the clock delay by at least 10 ns in the ideal case where t<sub>WL</sub>= 10 ns.

### 3 Electrical Parameters

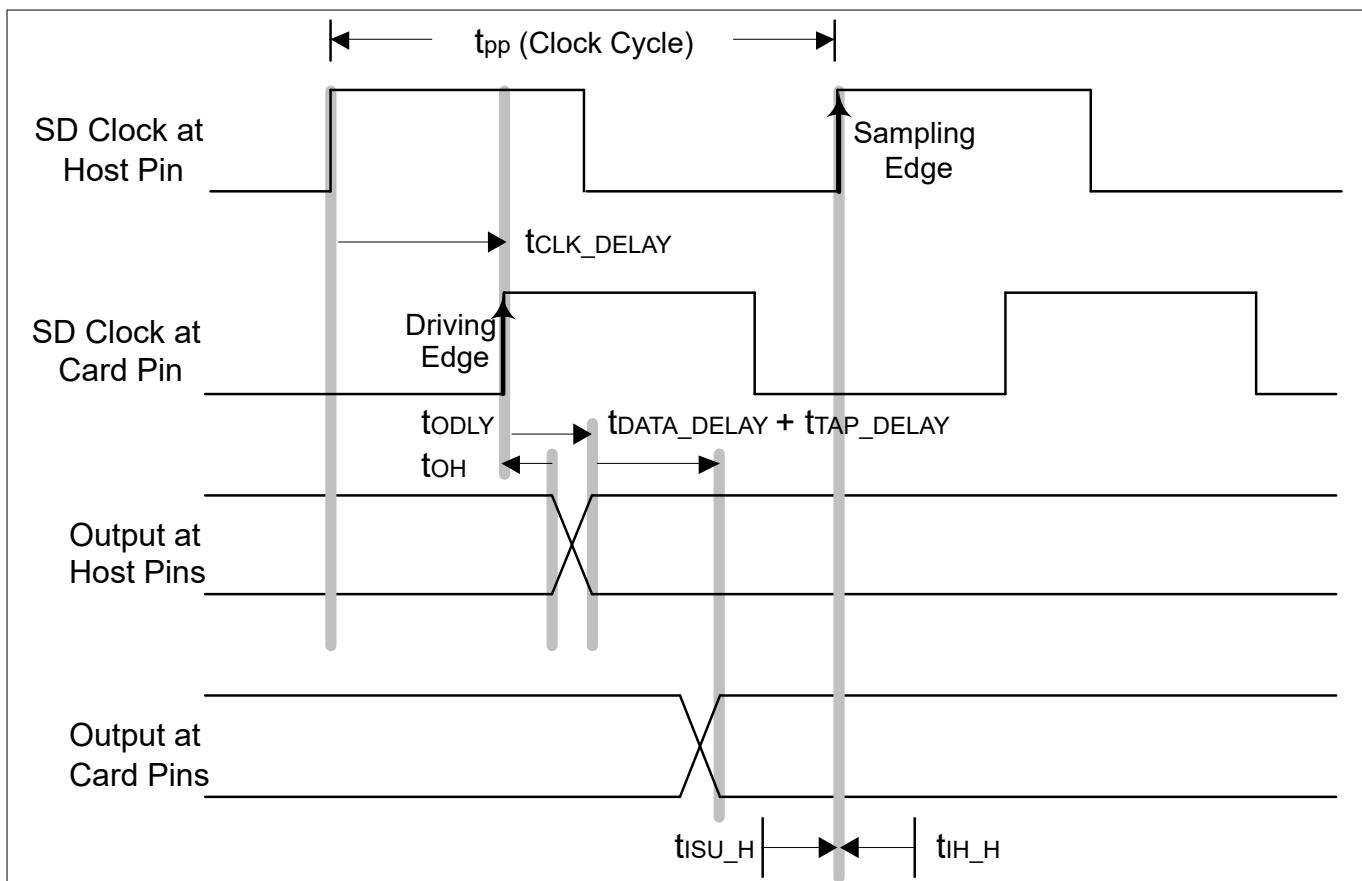
#### High-Speed Write Meeting Hold (Minimum Delay)

The following equations show how to calculate the allowed skew range between the SD\_CLK and SD\_DAT/CMD signals on the PCB.

$$\begin{aligned}
 t_{\text{CLK\_DELAY}} &< t_{\text{WL}} + t_{\text{OH\_H}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} - t_{\text{IH}} \\
 t_{\text{CLK\_DELAY}} - t_{\text{DATA\_DELAY}} &< t_{\text{WL}} + t_{\text{OH\_H}} + t_{\text{TAP\_DELAY}} - t_{\text{IH}} \\
 t_{\text{CLK\_DELAY}} - t_{\text{DATA\_DELAY}} &< 10 + 2 + t_{\text{TAP\_DELAY}} - 2 \\
 t_{\text{CLK\_DELAY}} - t_{\text{DATA\_DELAY}} &< 10 + t_{\text{TAP\_DELAY}}
 \end{aligned} \tag{10}$$

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

#### High-Speed Input Path (Read)



**Figure 40**      **High-Speed Input Path**

### 3 Electrical Parameters

#### 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.

$$\begin{aligned}
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} + t_{\text{ODLY}} + t_{\text{ISU\_H}} &< t_{\text{pp}} \\
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &< t_{\text{pp}} - t_{\text{ODLY}} - t_{\text{ISU\_H}} - t_{\text{TAP\_DELAY}} \\
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &< 20 - 14 - 2 - t_{\text{TAP\_DELAY}} \\
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &< 4 - t_{\text{TAP\_DELAY}}
 \end{aligned} \tag{11}$$

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

#### 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.

$$\begin{aligned}
 t_{\text{CLK\_DELAY}} + t_{\text{OH}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} &> t_{\text{IH\_H}} \\
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &> t_{\text{IH\_H}} - t_{\text{OH}} - t_{\text{TAP\_DELAY}} \\
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &> 2 - 2.5 - t_{\text{TAP\_DELAY}} \\
 t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} &> -0.5 - t_{\text{TAP\_DELAY}}
 \end{aligned} \tag{12}$$

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

### 3 Electrical Parameters

#### 3.3.10 EBU Timing

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

**Note:** Operating Conditions apply, with Class A2 pins and  $C_L = 16 \text{ pF}$ .

#### 3.3.10.1 EBU Asynchronous Timing

**Note:** For each timing, the accumulated PLL jitter must be added separately.

**Table 53 Common Timing Parameters for all Asynchronous Timings**

Parameter	Symbol	Limit Values		Unit	Edge Setting	
		Min.	Max.			
Pulse width deviation from the ideal programmed width due to the A2 pad asymmetry, strong driver mode, rise delay - fall delay. $C_L = 16 \text{ pF}$ .	CC	$t_a$	-1	1.5	ns	
			-2	1		
AD(24:16) output delay	to $\overline{\text{ADV}}$ rising edge, multiplexed read/write	CC	$t_{13}$	-5.5	2	-
			$t_{14}$	-5.5	2	

#### Read Timing

**Table 54 Asynchronous Read Timing, Multiplexed and Demultiplexed**

Parameter	Symbol	Limit Values		Unit		
		Min.	Max.			
A(24:16) output delay	to $\overline{\text{RD}}$ rising edge, deviation from the ideal programmed value.	CC	$t_0$	-2.5	2.5	ns
A(24:16) output delay		CC	$t_1$	-2.5	2.5	
$\overline{\text{CS}}$ rising edge		CC	$t_2$	-2	2.5	
$\overline{\text{ADV}}$ rising edge		CC	$t_3$	-1.5	4.5	
$\overline{\text{BC}}$ rising edge		CC	$t_4$	-2.5	2.5	
WAIT input setup		SR	$t_5$	12	-	
WAIT input hold		SR	$t_6$	0	-	
Data input setup		SR	$t_7$	12	-	
Data input hold		SR	$t_8$	0	-	
RD/ $\overline{\text{WR}}$ output delay		CC	$t_9$	-2.5	1.5	

### 3 Electrical Parameters

#### Multiplexed Read Timing

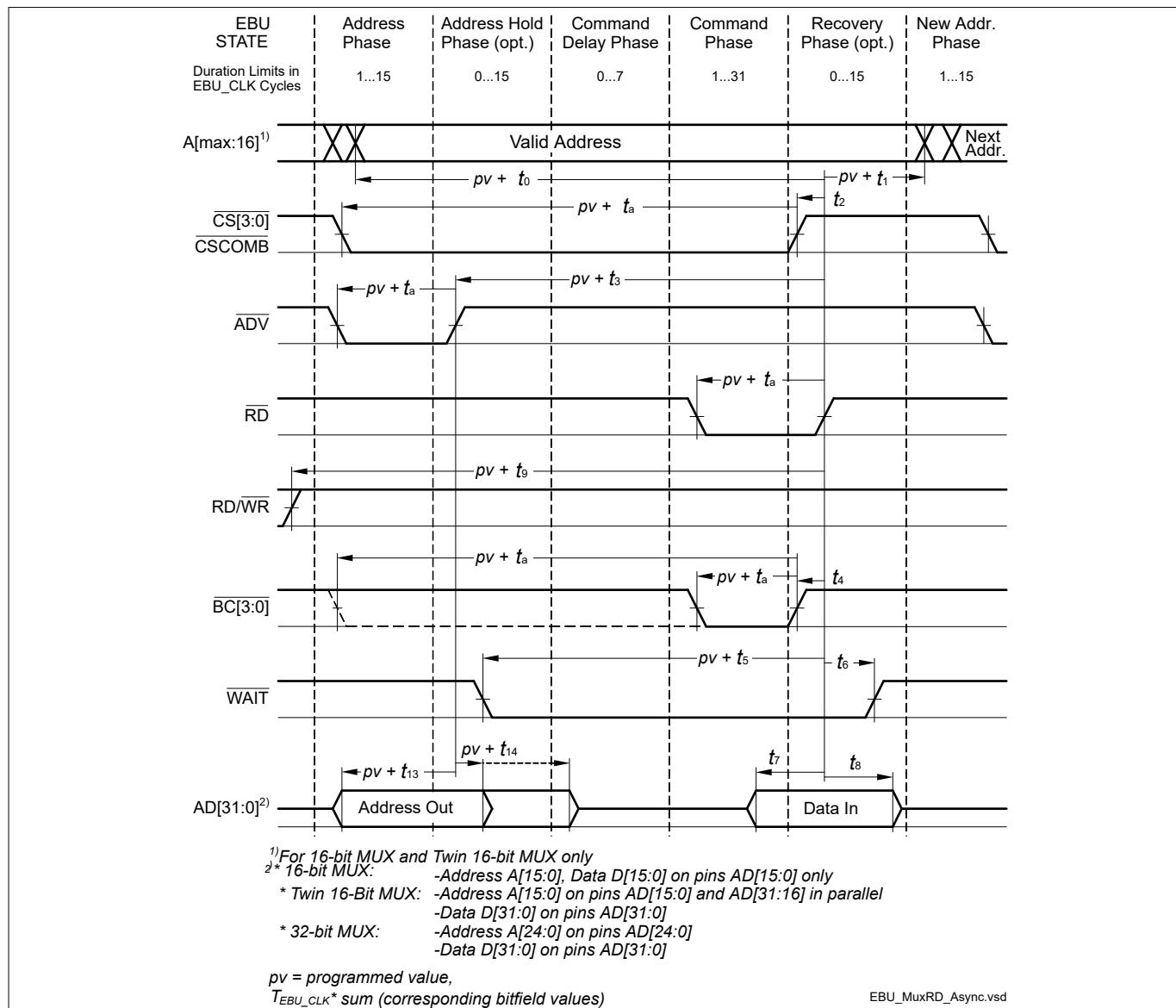


Figure 41

Multiplexed Read Access

### 3 Electrical Parameters

#### Demultiplexed Read Timing

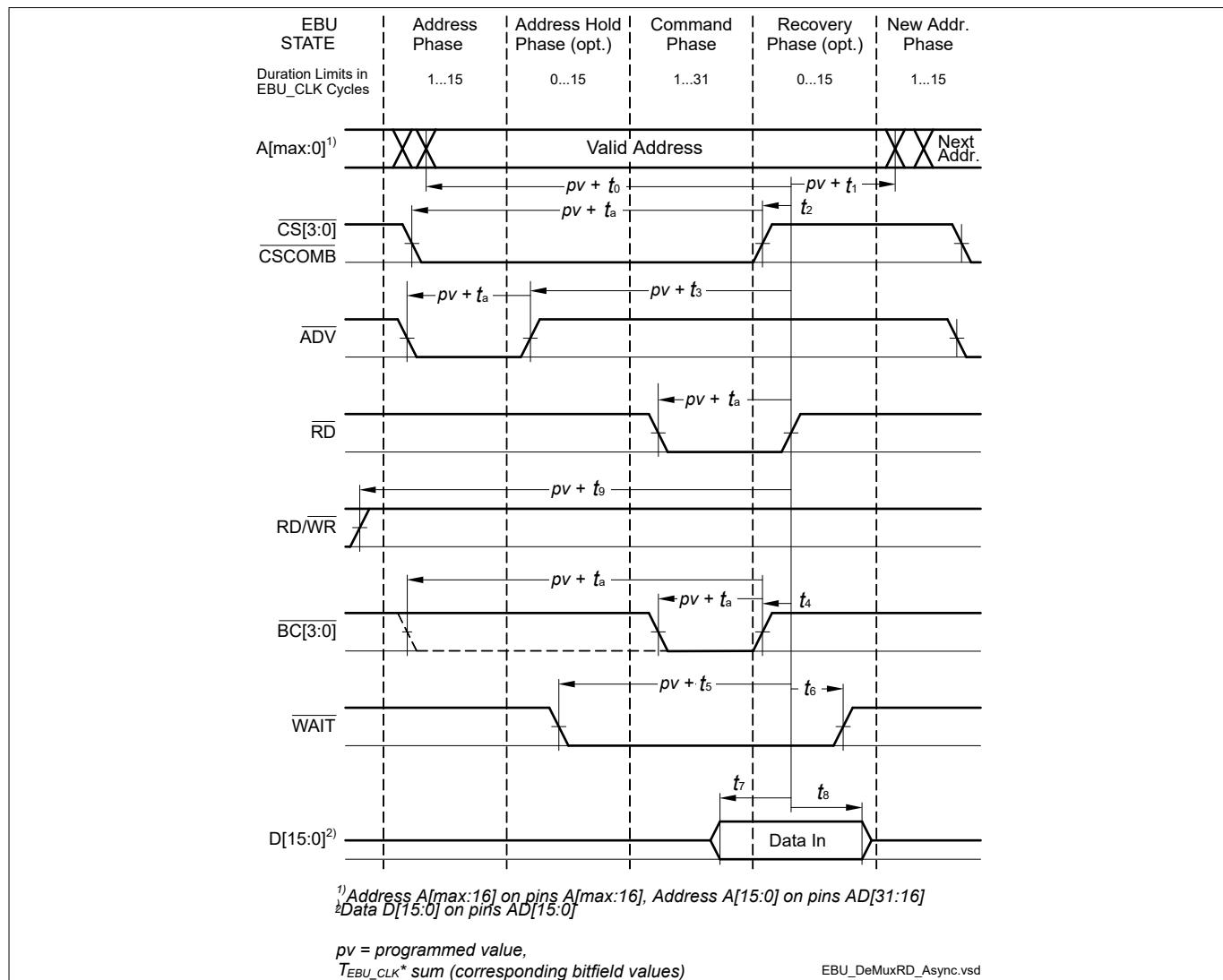


Figure 42

Demultiplexed Read Access

### 3 Electrical Parameters

#### Write Timing

**Table 55 Asynchronous Write Timing, Multiplexed and Demultiplexed**

<b>Parameter</b>		<b>Symbol</b>	<b>Limit Values</b>		<b>Unit</b>
			<b>Min.</b>	<b>Max.</b>	
A(24:0) output delay	to RD/ WR rising edge, deviation from the ideal programmed value.	CC	$t_{30}$	-2.5	2.5
A(24:0) output delay		CC	$t_{31}$	-2.5	2.5
CS rising edge		CC	$t_{32}$	-2	2
ADV rising edge		CC	$t_{33}$	-2	4.5
BC rising edge		CC	$t_{34}$	-2.5	2
WAIT input setup		SR	$t_{35}$	12	-
WAIT input hold		SR	$t_{36}$	0	-
Data output delay		CC	$t_{37}$	-5.5	2
Data output delay		CC	$t_{38}$	-5.5	2
RD/ WR output delay		CC	$t_{39}$	-2.5	1.5

### 3 Electrical Parameters

#### Multiplexed Write Timing

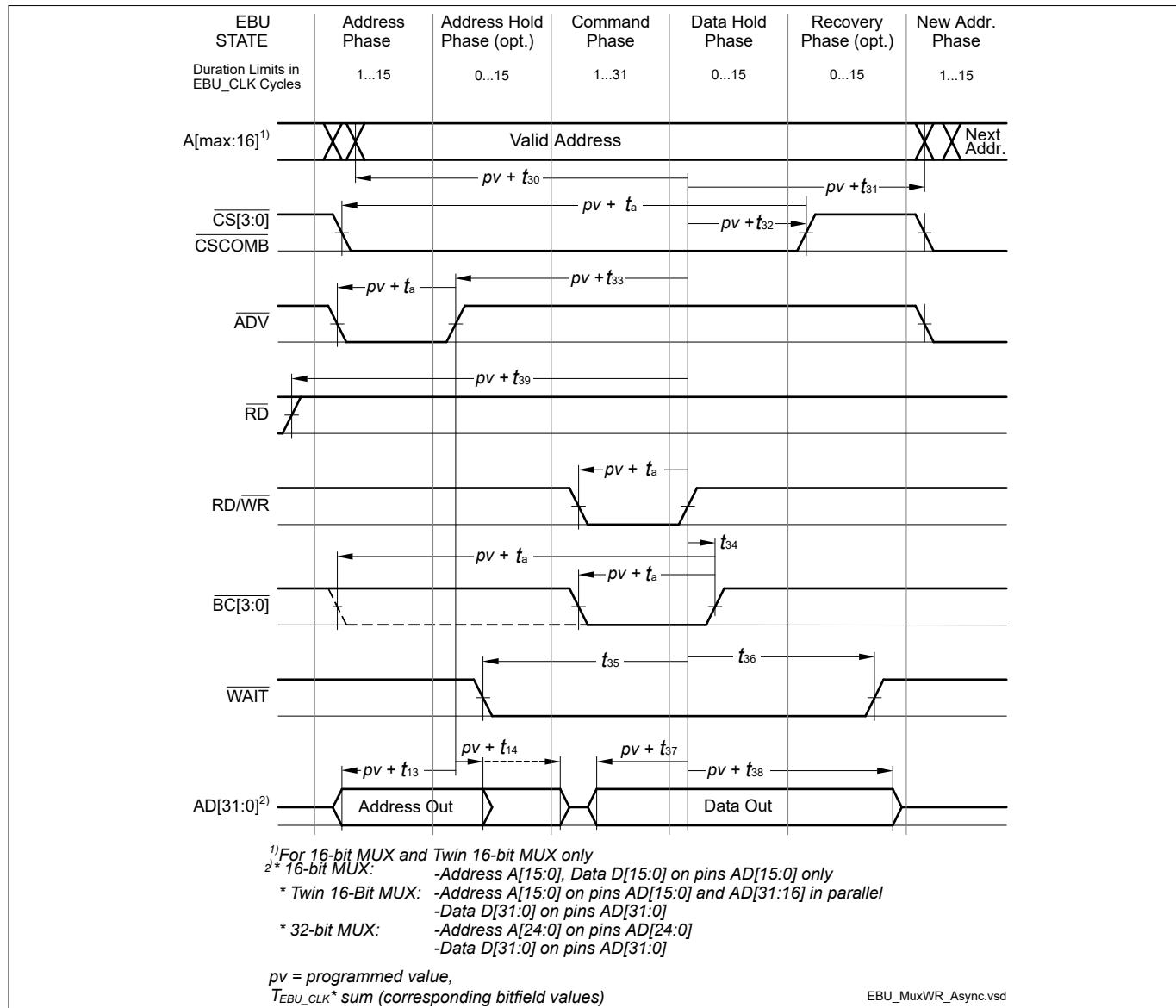
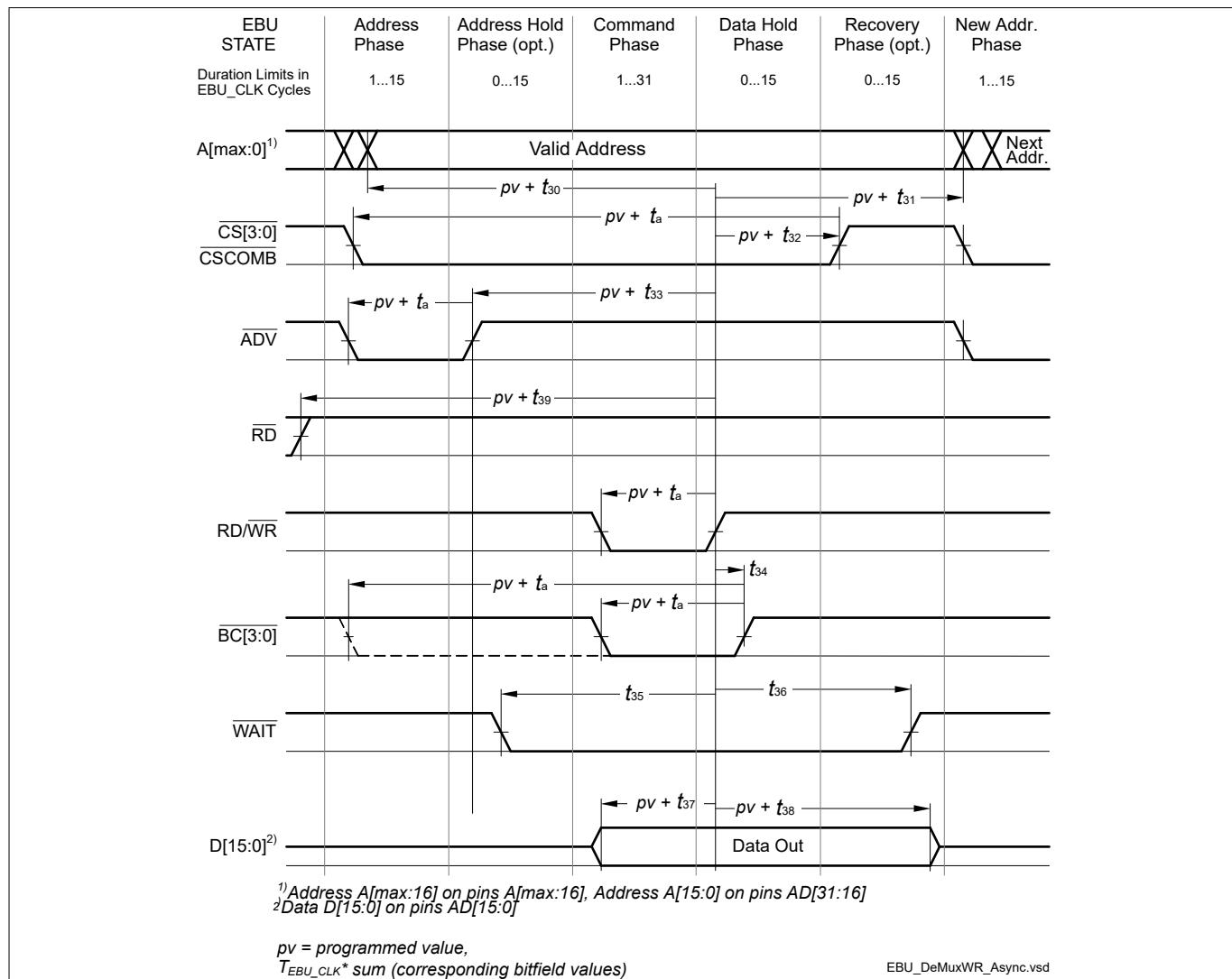


Figure 43

Multiplexed Write Access

### 3 Electrical Parameters

#### Demultiplexed Write Timing



**Figure 44**

**Demultiplexed Write Access**

### 3 Electrical Parameters

#### 3.3.10.2 EBU Burst Mode Access Timing

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

**Note:** Operating Conditions apply, with Class A2 pins and  $C_L = 16 \text{ pF}$ .

**Table 56 EBU Burst Mode Read/Write Access Timing Parameters**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Output delay from BFCLKO rising edge	$t_{10}$ CC	-2	–	2	ns	–
$\overline{\text{RD}}$ and RD/ $\overline{\text{WR}}$ active/inactive after BFCLKO active edge <sup>1)</sup>	$t_{12}$ CC	-2	–	2	ns	–
$\overline{\text{CSx}}$ output delay from BFCLKO active edge <sup>1)</sup>	$t_{21}$ CC	-2.5	–	1.5	ns	–
$\overline{\text{ADV}}$ active/inactive after BFCLKO active edge <sup>2)</sup>	$t_{22}$ CC	-2	–	2	ns	–
$\overline{\text{BAA}}$ active/inactive after BFCLKO active edge <sup>2)</sup>	$t_{22a}$ CC	-2.5	–	1.5	ns	–
Data setup to BFCLKI rising edge <sup>3)</sup>	$t_{23}$ SR	3	–	–	ns	–
Data hold from BFCLKI rising edge <sup>3)</sup>	$t_{24}$ SR	0	–	–	ns	–
WAIT setup (low or high) to BFCLKI rising edge <sup>3)</sup>	$t_{25}$ SR	3	–	–	ns	–
WAIT hold (low or high) from BFCLKI rising edge <sup>3)</sup>	$t_{26}$ SR	0	–	–	ns	–

1) An active edge can be a rising or falling edge, depending on the settings of bits BFCON.EBSE/ECSE and the clock divider ratio.

Negative minimum values for these parameters mean that the last data read during a burst may be corrupted. However, with clock feedback enabled, this value is an oversampling not required for the internal bus transaction, and will be discarded.

2) This parameter is valid for BUSCONx.EBSE = 1 and BUSAPx.EXTCLK = 00<sub>B</sub>.

For BUSCONx.EBSE = 1 and other values of BUSAPx.EXTCLK, ADV and BAA will be delayed by 1/2 of the internal bus clock period  $T_{\text{CPU}} = 1/f_{\text{CPU}}$ .

For BUSCONx. EBSE = 0 and BUSAPx.EXTCLK = 11<sub>B</sub>, add 2 internal bus clock periods.

For BUSCONx. EBSE = 0 and other values of BUSAPx.EXTCLK, add 1 internal bus clock period.

3) If the clock feedback is not enabled, the input signals are latched using the internal clock in the same way as for asynchronous access. Thus,  $t_5$ ,  $t_6$ ,  $t_7$  and  $t_8$  from the asynchronous timing apply.

## 3 Electrical Parameters

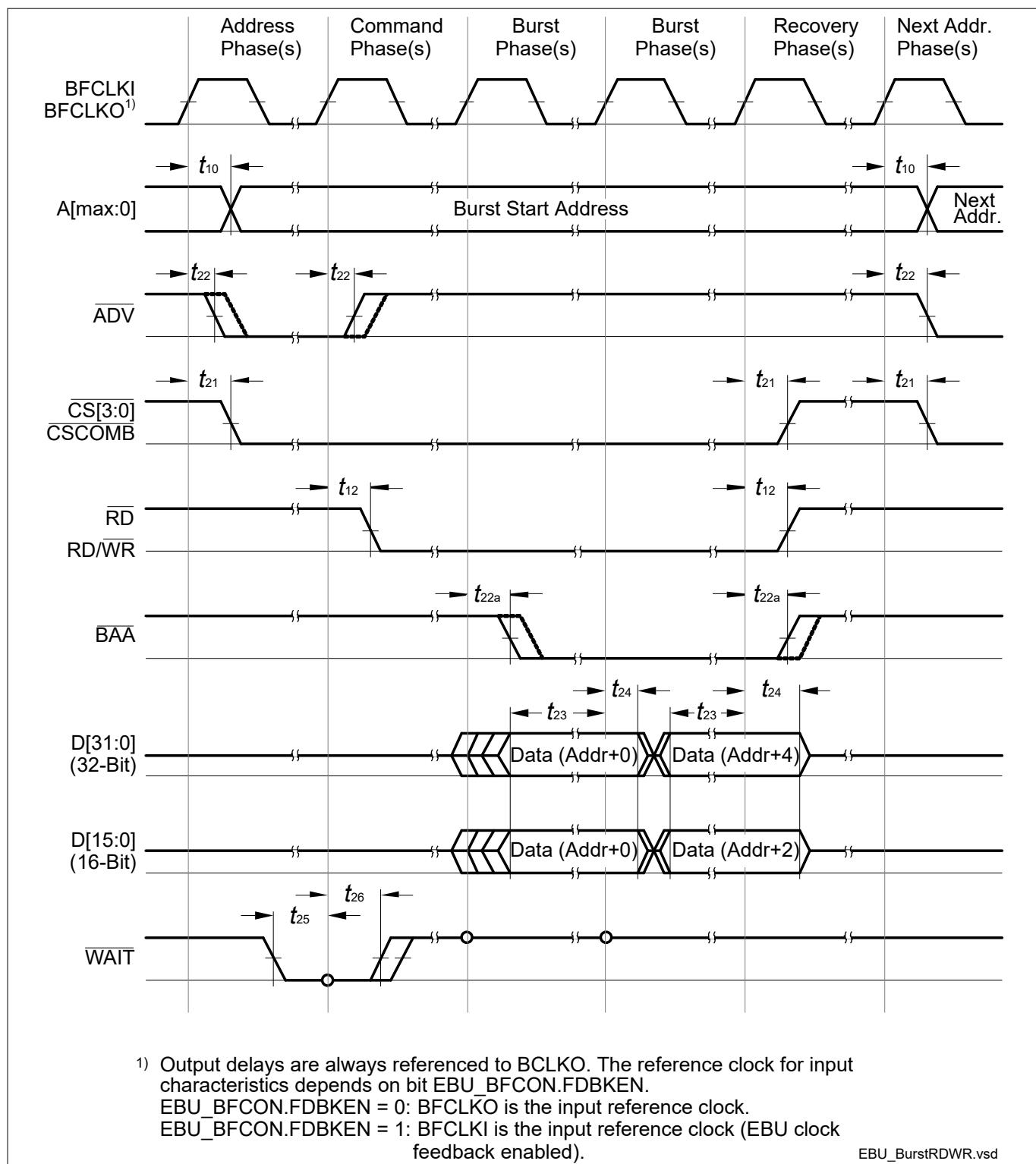


Figure 45

EBU Burst Mode Read/Write Access Timing

### 3 Electrical Parameters

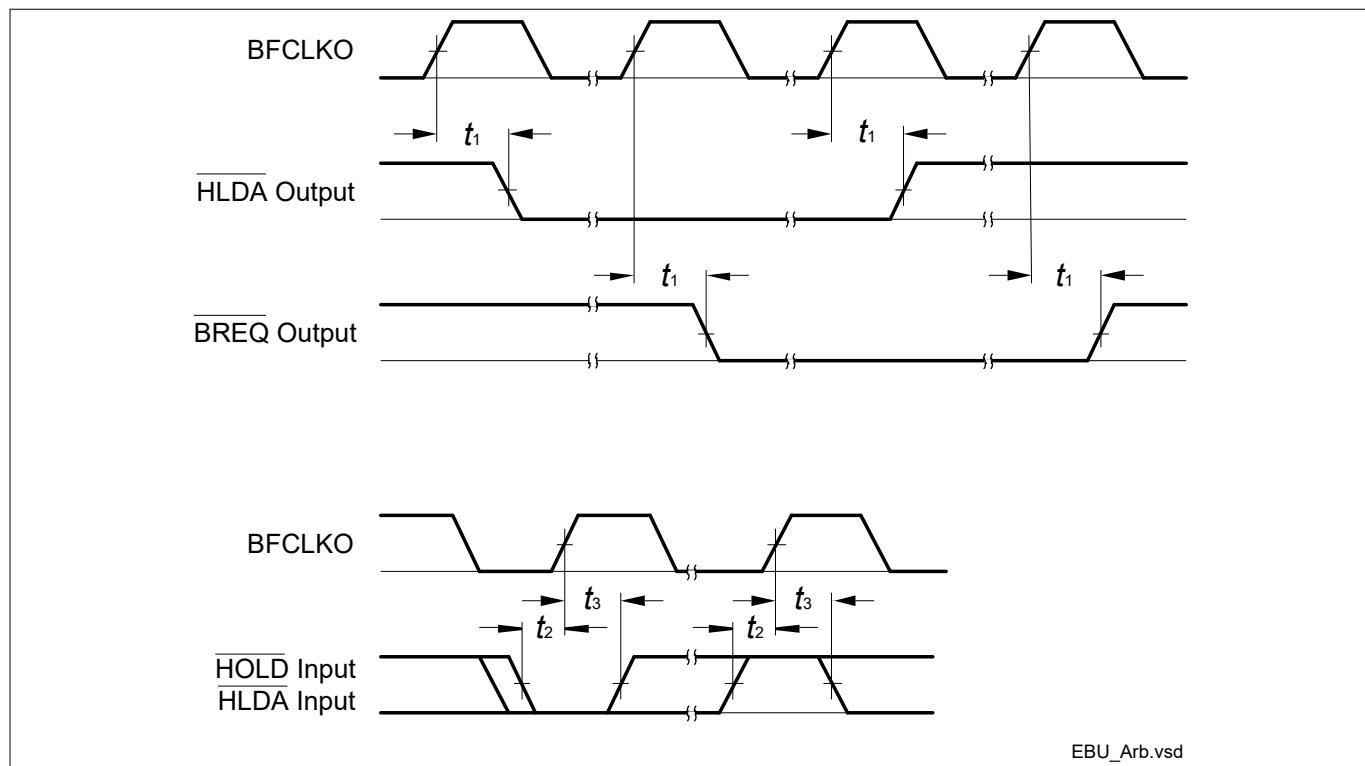
#### 3.3.10.3 EBU Arbitration Signal Timing

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

**Note:** Operating Conditions apply.

**Table 57 EBU Arbitration Signal Timing Parameters**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Output delay from BFCLKO rising edge	$t_1$ CC	—	—	16	ns	$C_L = 50 \text{ pF}$
Data setup to BFCLKO falling edge	$t_2$ SR	11	—	—	ns	—
Data hold from BFCLKO falling edge	$t_3$ SR	2	—	—	ns	—



**Figure 46 EBU Arbitration Signal Timing**

### 3 Electrical Parameters

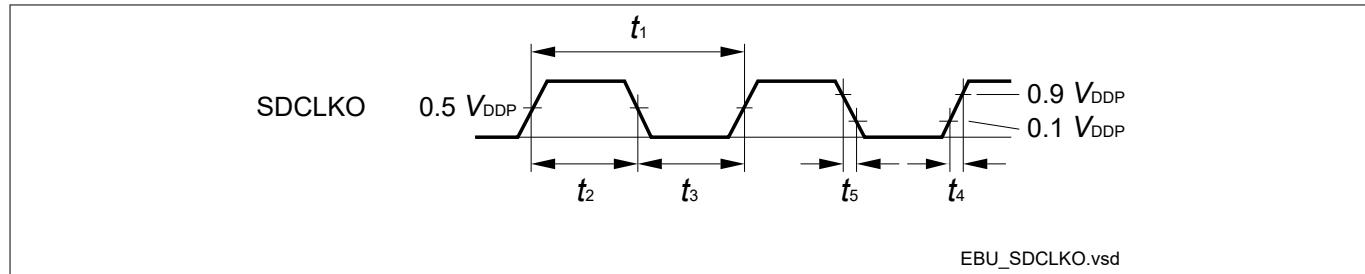
#### 3.3.10.4 EBU SDRAM Access Timing

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

**Note:** Operating Conditions apply, with Class A2 pins and  $C_L = 16 \text{ pF}$ .

**Table 58 EBU SDRAM Access SDCLKO Signal Timing Parameters**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
SDCLKO period	$t_1$ CC	12.5	–	–	ns	–
SDCLKO high time	$t_2$ SR	5.5	–	–	ns	–
SDCLKO low time	$t_3$ SR	3.75	–	–	ns	–
SDCLKO rise time	$t_4$ SR	–	–	3.0	ns	–
SDCLKO fall time	$t_5$ SR	–	–	3.0	ns	–



**Figure 47 EBU SDRAM Access CLKOUT Timing**

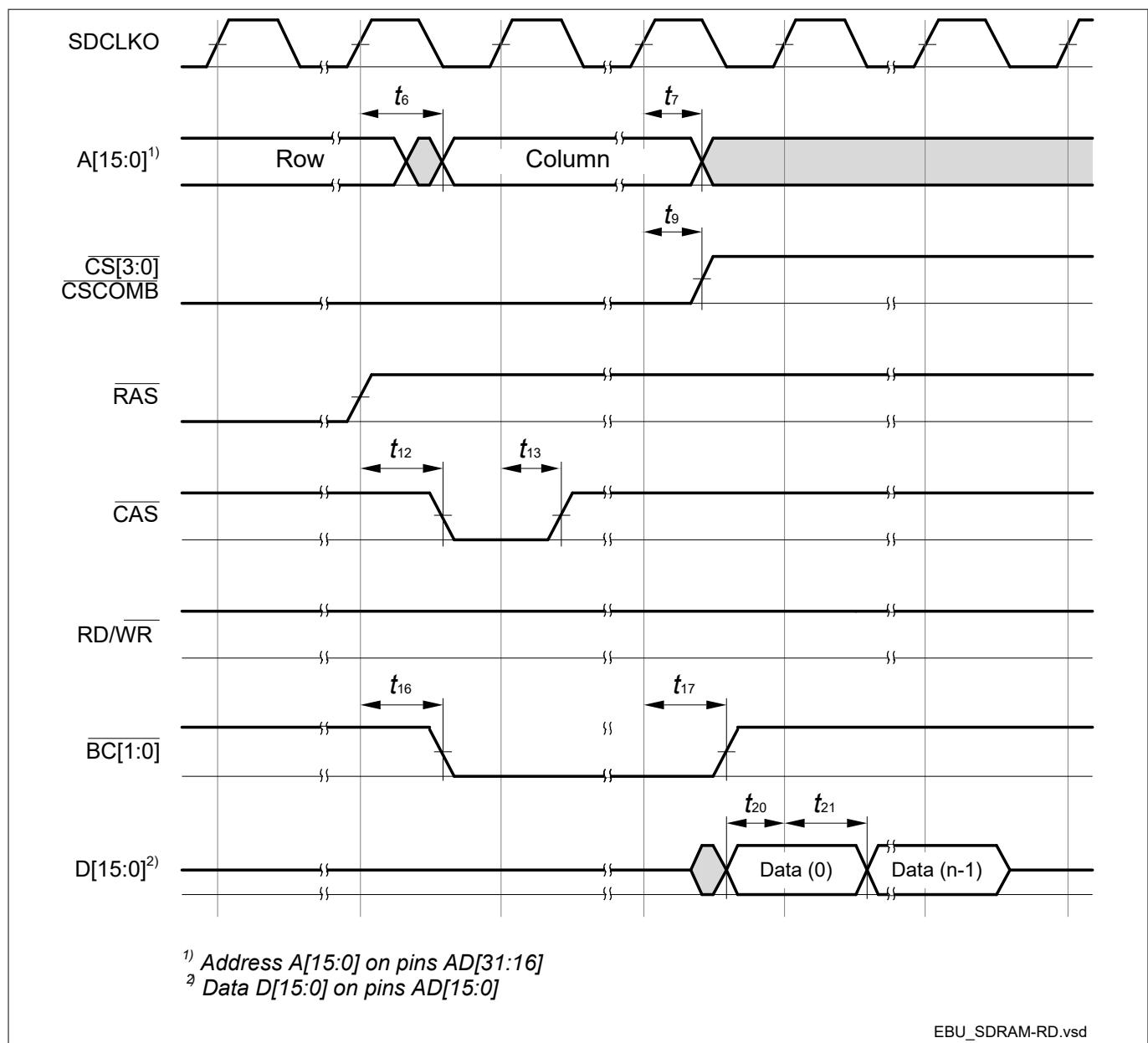
### 3 Electrical Parameters

**Table 59 EBU SDRAM Access Signal Timing Parameters**

Parameter		Symbol	Limit Values		Unit
			Min.	Max.	
A(15:0) output valid	from SDCLK0 low-to-high transition	CC	$t_6$	-	9
A(15:0) output hold		CC	$t_7$	3	-
CS(3:0) low		CC	$t_8$	-	9
CS(3:0) high		CC	$t_9$	3	-
RAS low		CC	$t_{10}$	-	9
RAS high		SR	$t_{11}$	3	-
CAS low		SR	$t_{12}$	-	9
CAS high		CC	$t_{13}$	3	-
RD/ WR low		CC	$t_{14}$	-	9
RD/ WR high		CC	$t_{15}$	3	-
BC(3:0) low		CC	$t_{16}$	-	9
BC(3:0) high		CC	$t_{17}$	3	-
D(15:0) output valid		CC	$t_{18}$	-	9
D(15:0) output hold		CC	$t_{19}$	3	-
CKE output valid <sup>1)</sup>		CC	$t_{22}$	-	7
CKE output hold <sup>1)</sup>		CC	$t_{23}$	2	-
D(15:0) input hold		SR	$t_{21}$	3	-
D(15:0) input setup to SDCLK0 low-to-high transition		SR	$t_{20}$	4	-

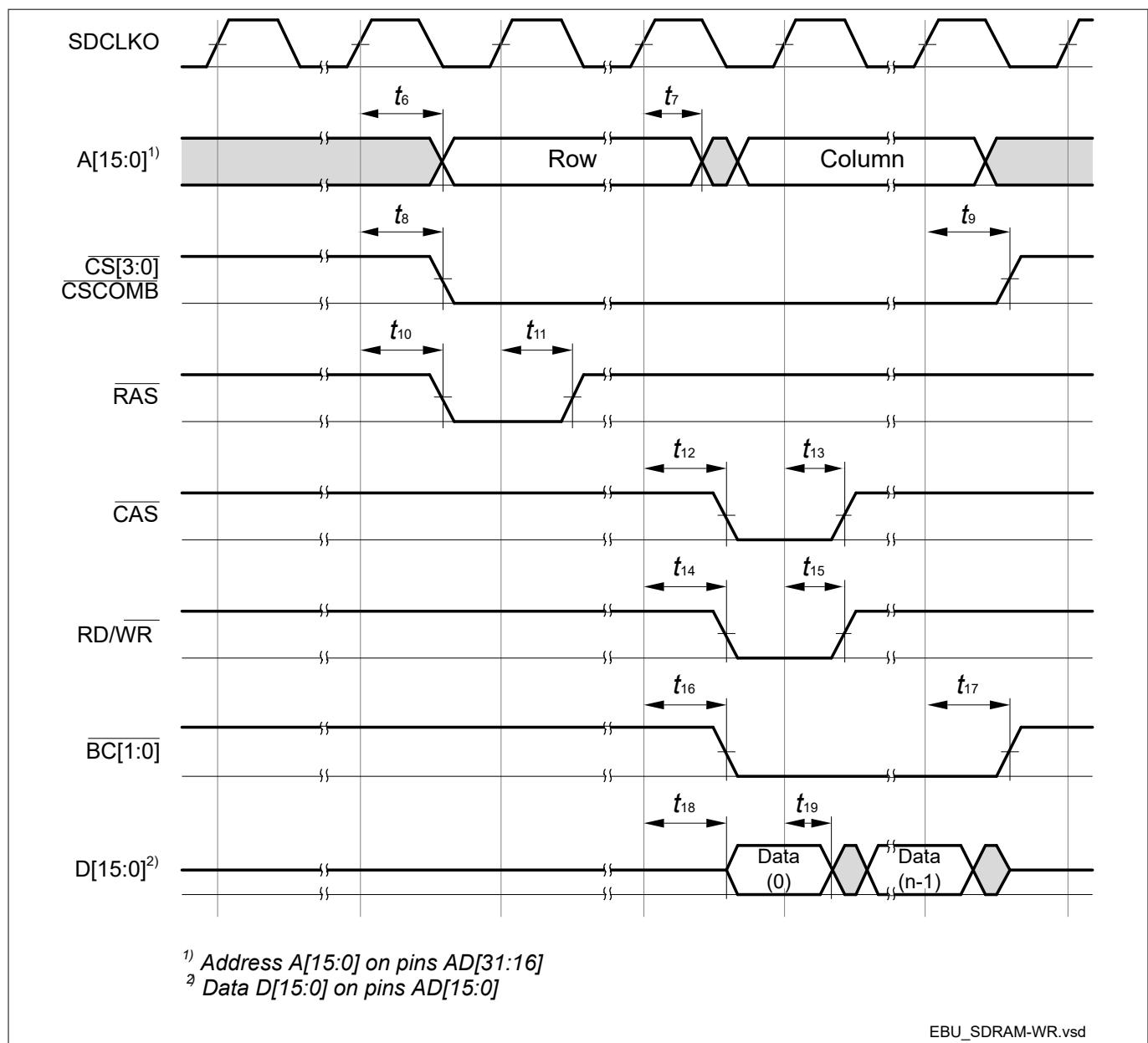
1) Not depicted in the read and write access timing figures below.

### 3 Electrical Parameters



**Figure 48**      **EBU SDRAM Read Access Timing**

### 3 Electrical Parameters



**Figure 49**      **EBU SDRAM Write Access Timing**

### 3 Electrical Parameters

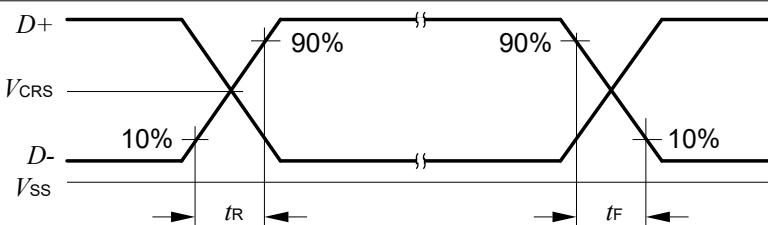
#### 3.3.11 USB Interface Characteristics

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 60** USB Timing Parameters (operating conditions apply)

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



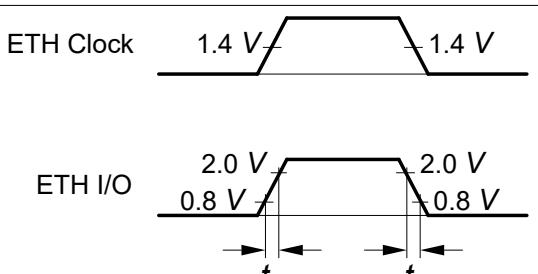
**Figure 50** USB Signal Timing

#### 3.3.12 Ethernet Interface (ETH) Characteristics

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

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

#### 3.3.12.1 ETH Measurement Reference Points



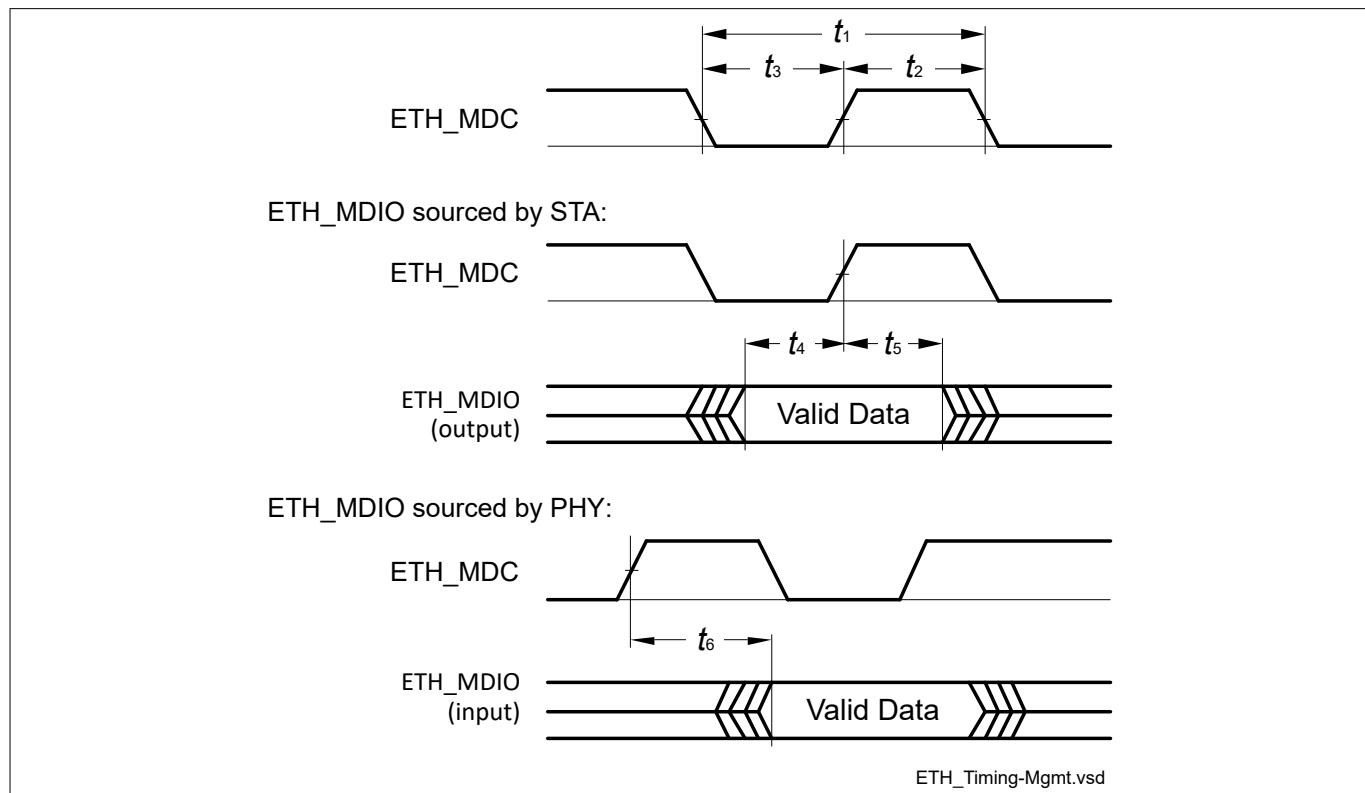
**Figure 51** ETH Measurement Reference Points

### 3 Electrical Parameters

#### 3.3.12.2 ETH Management Signal Parameters (ETH\_MDC, ETH\_MDIO)

**Table 61** 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 52** ETH Management Signal Timing

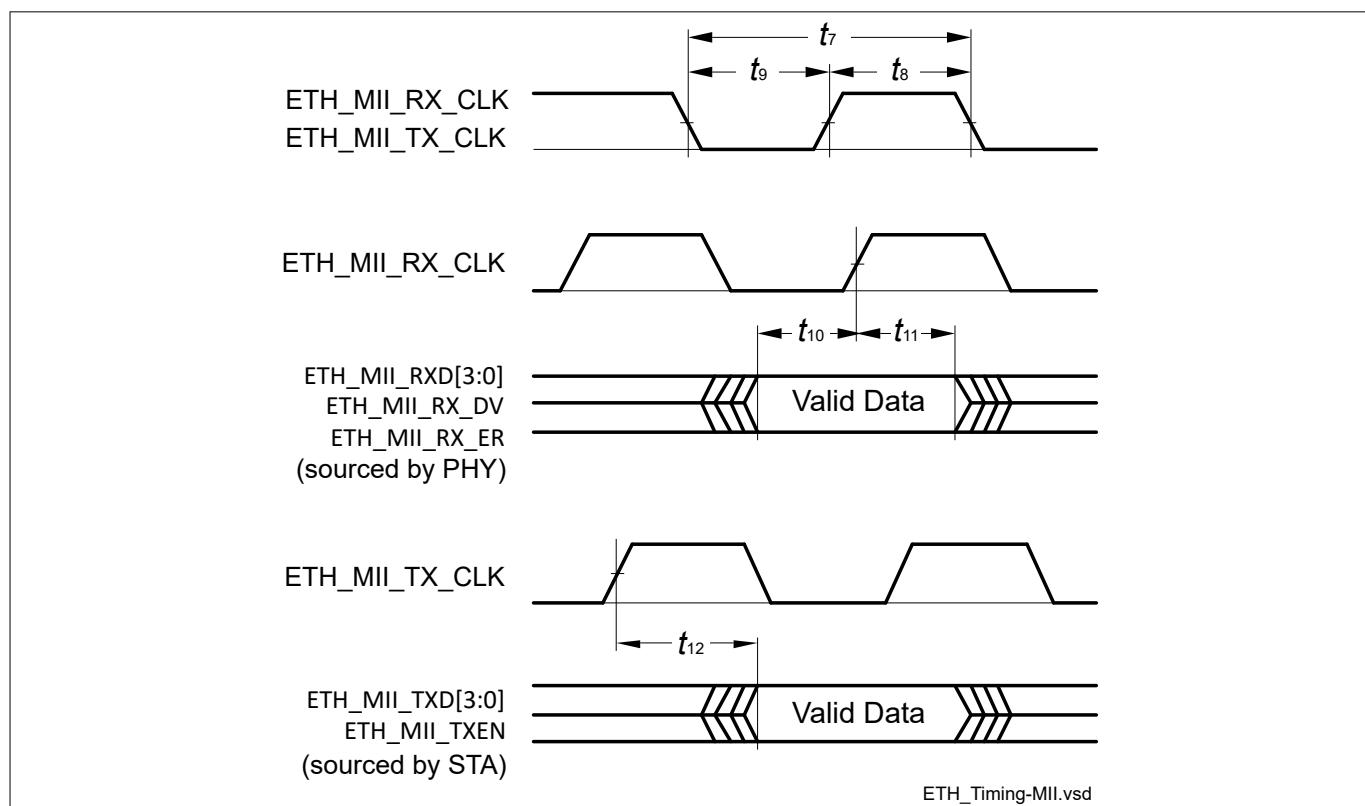
### 3 Electrical Parameters

#### 3.3.12.3 ETH MII Parameters

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

**Table 62** ETH MII Signal Timing Parameters

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Clock period, 10 Mbps	$t_7$ SR	400	–	–	ns	$C_L = 25 \text{ pF}$
Clock high time, 10 Mbps	$t_8$ SR	140	–	260	ns	
Clock low time, 10 Mbps	$t_9$ SR	140	–	260	ns	
Clock period, 100 Mbps	$t_7$ SR	40	–	–	ns	
Clock high time, 100 Mbps	$t_8$ SR	14	–	26	ns	
Clock low time, 100 Mbps	$t_9$ SR	14	–	26	ns	
Input setup time	$t_{10}$ SR	10	–	–	ns	
Input hold time	$t_{11}$ SR	10	–	–	ns	
Output valid time	$t_{12}$ CC	0	–	25	ns	



**Figure 53** ETH MII Signal Timing

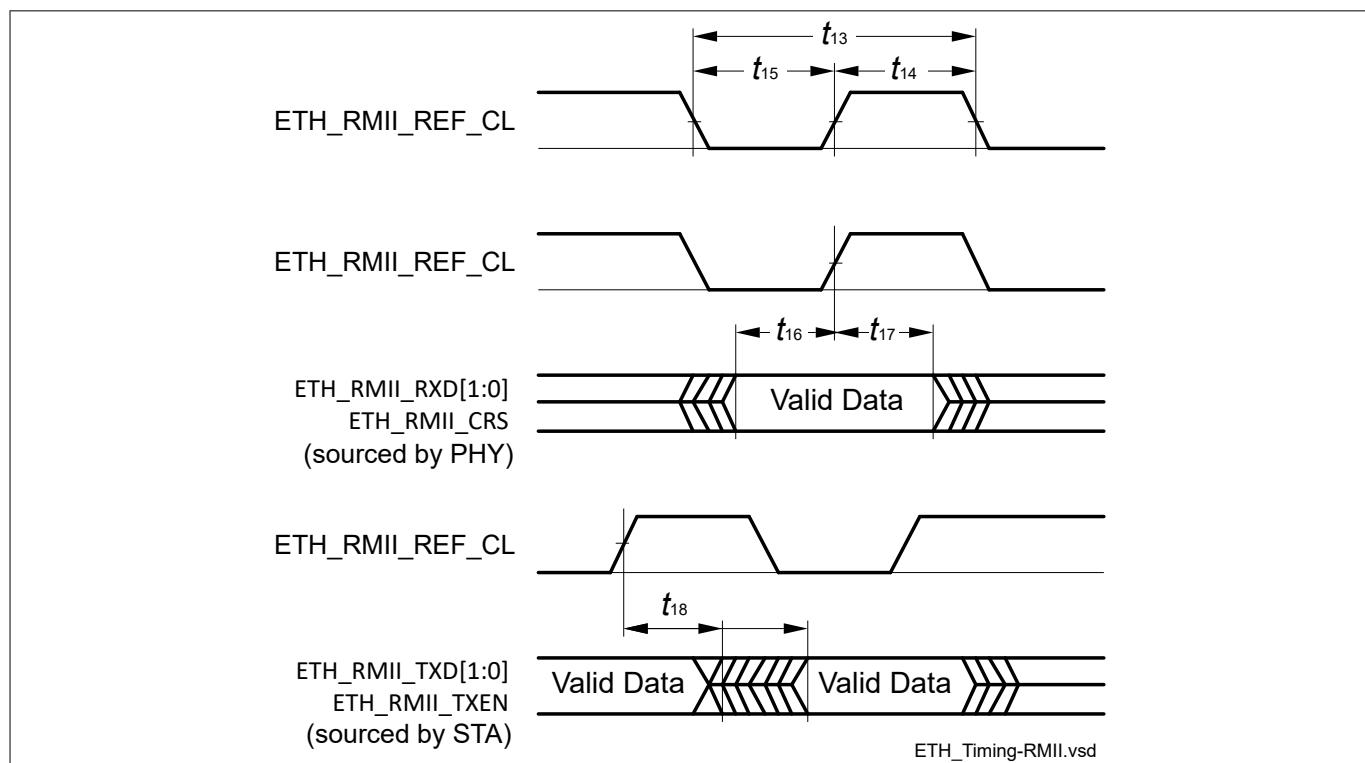
### 3 Electrical Parameters

#### 3.3.12.4 ETH RMII Parameters

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

**Table 63**      **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	$C_L = 25 \text{ pF}; 50 \text{ ppm}$
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 54**

**ETH RMII Signal Timing**

## 4 Package and Reliability

### 4.1 Package and Reliability

The XMC4500 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.

#### 4.1.1 Package Parameters

Table 64 provides the thermal characteristics of the packages used in XMC4500.

**Table 64 Thermal Characteristics of the Packages**

Parameter	Symbol	Limit Values		Unit	Package Types
		Min.	Max.		
Exposed Die Pad dimensions (including U-Groove where applicable)	Ex × Ey CC	-	6.5 × 6.5	mm	PG-LQFP-144-24
		-	7.0 × 7.0	mm	PG-LQFP-100-25
Exposed Die Pad dimensions	-	-	7.0 × 7.0	mm	PG-LQFP-100-29
		-	6.5 × 6.5	mm	PG-LQFP-144-26
Thermal resistance Junction-Ambient $T_J \leq 150^\circ\text{C}$	$R_{\Theta JA}$ CC	-	40.5	K/W	PG-LFBGA-144-10
		-	19.5	K/W	PG-LQFP-144-24 <sup>1)</sup>
		-	21.0	K/W	PG-LQFP-100-25 <sup>1)</sup>
		-	21.0	K/W	PG-LQFP-100-29 <sup>1)</sup>
		-	19.5	K/W	PG-LQFP-144-26 <sup>1)</sup>

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 Package and Reliability

### 4.1.1 Thermal Considerations

When operating the XMC4500 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 Package and Reliability

### 4.2 Package Outlines

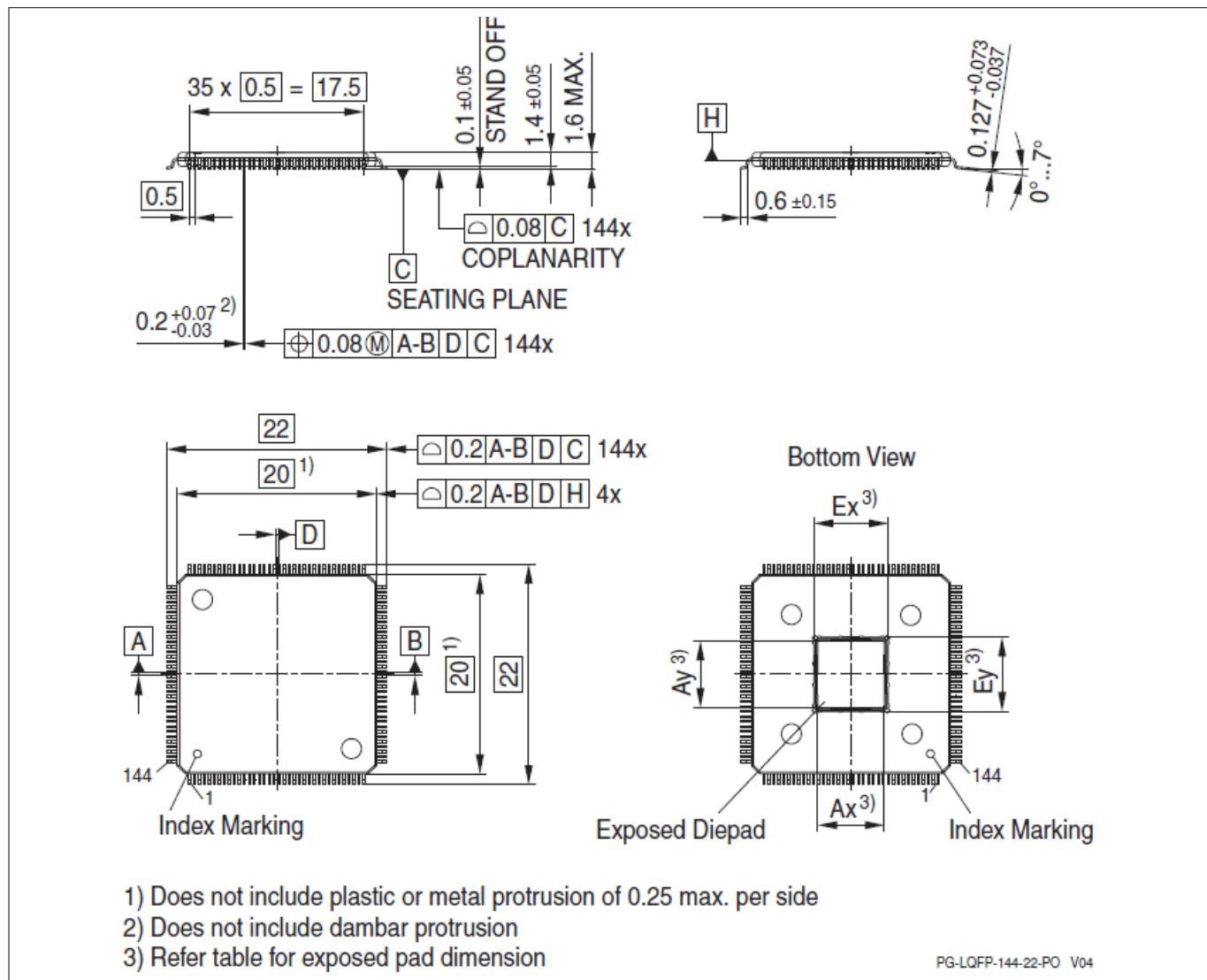
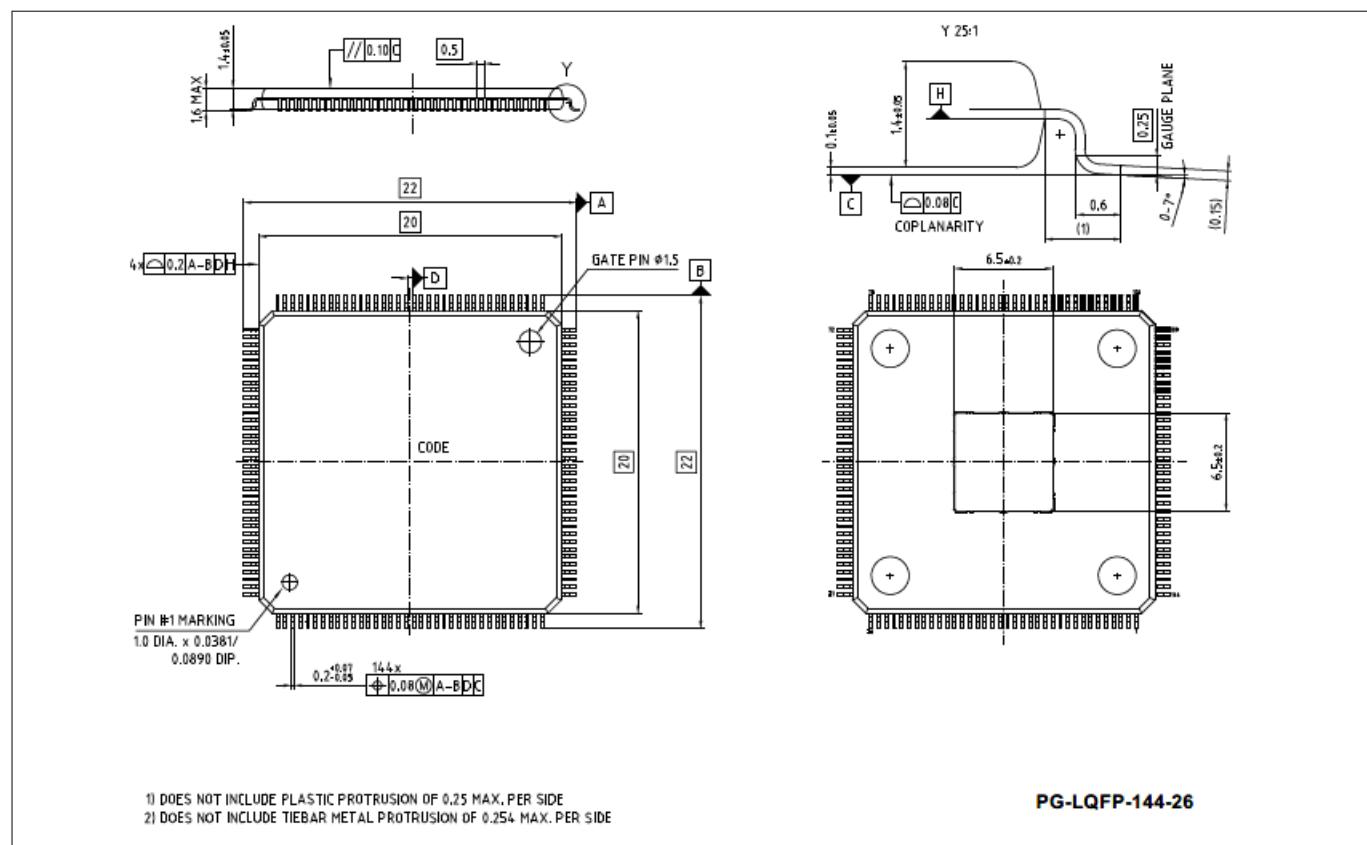


Figure 55

PG-LQFP-144-24 (Plastic Green Low Profile Quad Flat Package)

#### 4 Package and Reliability



**Figure 56**

**PG-LQFP-144-26 (Plastic Green Low Profile Quad Flat Package)**

## 4 Package and Reliability

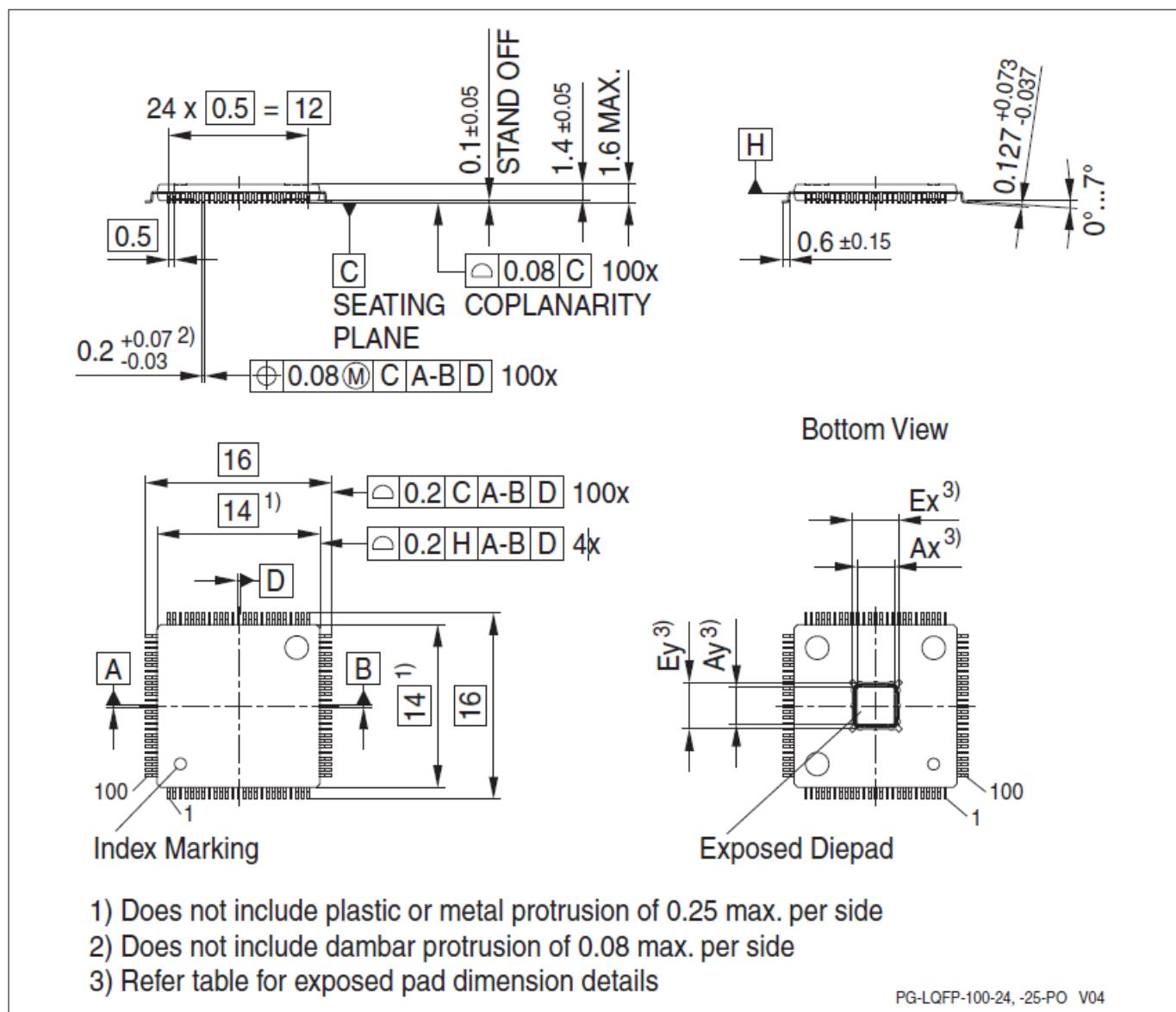


Figure 57

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

#### 4 Package and Reliability

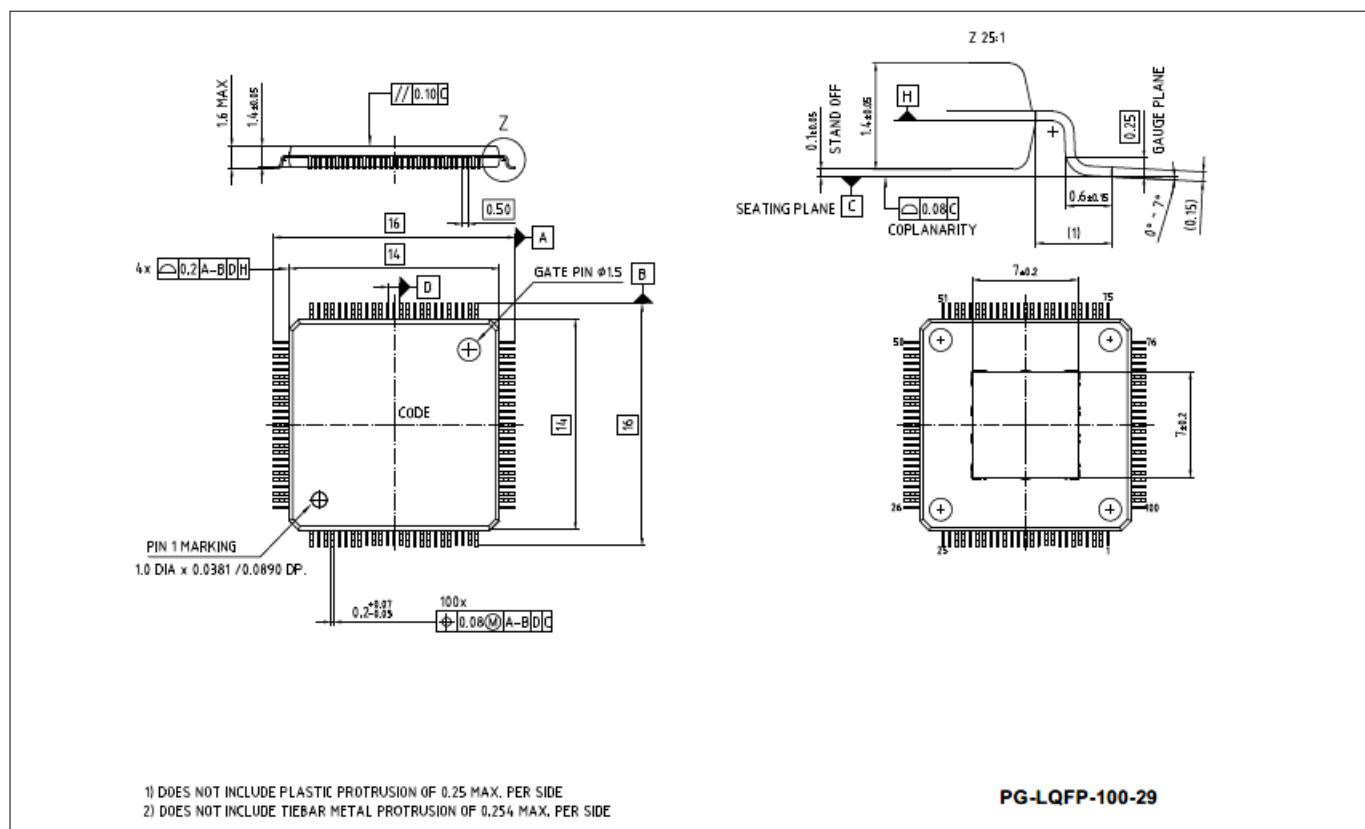


Figure 58

PG-LQFP-100-29 (Plastic Green Low Profile Quad Flat Package)

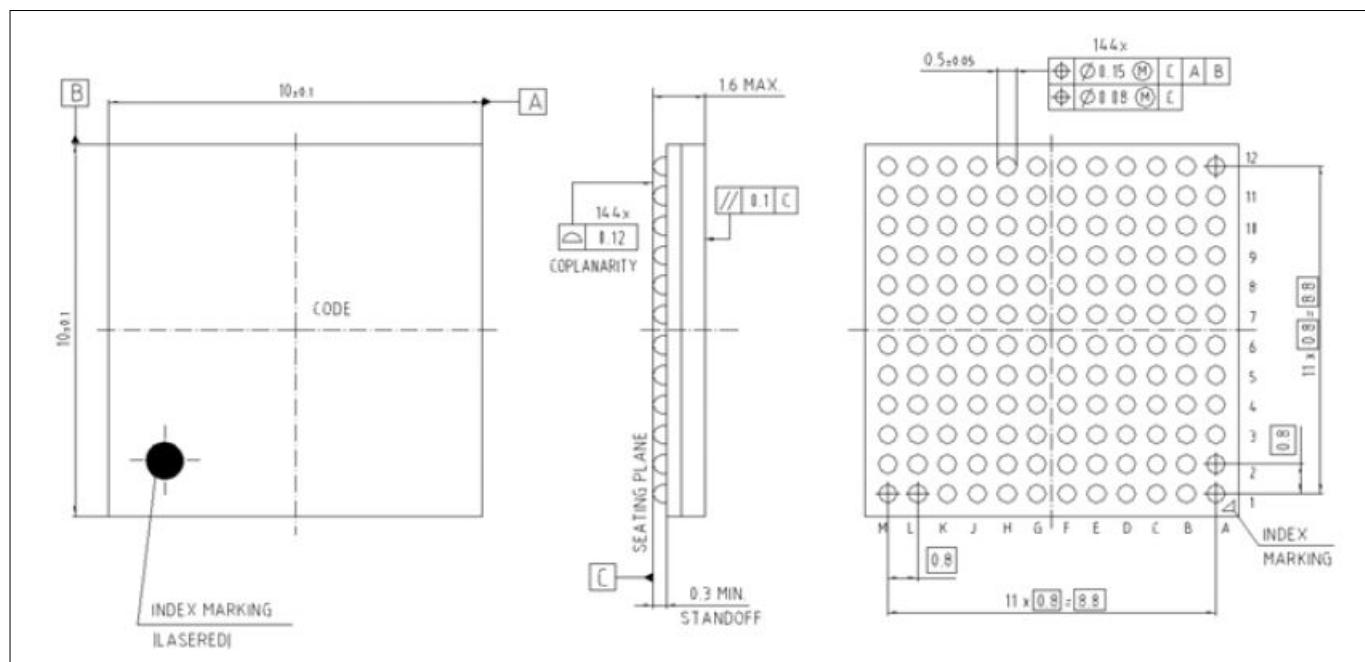


Figure 59

PG-LFBGA-144-10 (Plastic Green Low Profile Fine Pitch Ball Grid Array)

All dimensions in mm.

You can find complete information about Infineon packages, packing and marking in our Infineon Internet Page "Packages": <http://www.infineon.com/packages>.

## 5 Quality Declarations

### 5 Quality Declarations

The qualification of the XMC4500 is executed according to the JEDEC standard JESD47H.

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

**Table 65 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	–	–	2000	V	EIA/JESD22-A114-B
ESD susceptibility according to Charged Device Model (CDM)	$V_{CDM}$ SR	–	–	500	V	Conforming to JESD22-C101-C
Moisture sensitivity level	MSL CC	–	–	3	–	JEDEC J-STD-020D
Soldering temperature	$T_{SDR}$ SR	–	–	260	°C	Profile according to JEDEC J-STD-020D

**Revision history**

## Revision history

<b>Document revision</b>	<b>Date</b>	<b>Description of changes</b>
V1.6	2023-04-01	<a href="#">Table 64</a> : Added package details: PG-LQFP-100-29 and PG-LQFP-144-26. Deleted package details: PG-LQFP-100-11 and PG-LQFP-144-18. Added package diagrams: PG-LQFP-100-29 and PG-LQFP-144-26. Deleted package diagrams: PG-LQFP-100-11 and PG-LQFP-144-18.
V1.7	2024-12-02	Template update; no content update

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