

# XMC4500

Microcontroller Series  
for Industrial Applications

XMC4000 Family

ARM<sup>®</sup> Cortex<sup>™</sup>-M4  
32-bit processor core

Data Sheet

V1.0 2013-01

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## XMC4500 Data Sheet

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### Revision History: V1.0 2013-01

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V0.9, 2012-12

V0.8, 2012-11

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Page	Subjects
<b>11</b>	Reflect the supported Ethernet interface depending on the package (MII, RMII).
<b>33</b>	Characterization and qualification completed for PG-LQFP-144 and PG-LQFP-100.
<b>56</b>	Changed frequency dependency of the $I_{DDP}$ current from 5 mA per 10 MHz to 6 mA per 10 MHz (see footnote 10).
<b>66</b>	Improved Fast Internal Clock Source parameters.
<b>72</b>	DSD timing parameters will be added in a future revision of the Data Sheet.

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## **About this Document**

This Data Sheet is addressed to embedded hardware and software developers. It provides the reader with detailed descriptions about the ordering designations, available features, electrical and physical characteristics of the 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.
- **Data Sheets**
  - list the complete ordering designations, available features and electrical characteristics of derivative devices.
- **Errata Sheets**
  - list deviations from the specifications given in the related Reference Manual or Data Sheets. Errata Sheets are provided for the superset of devices.

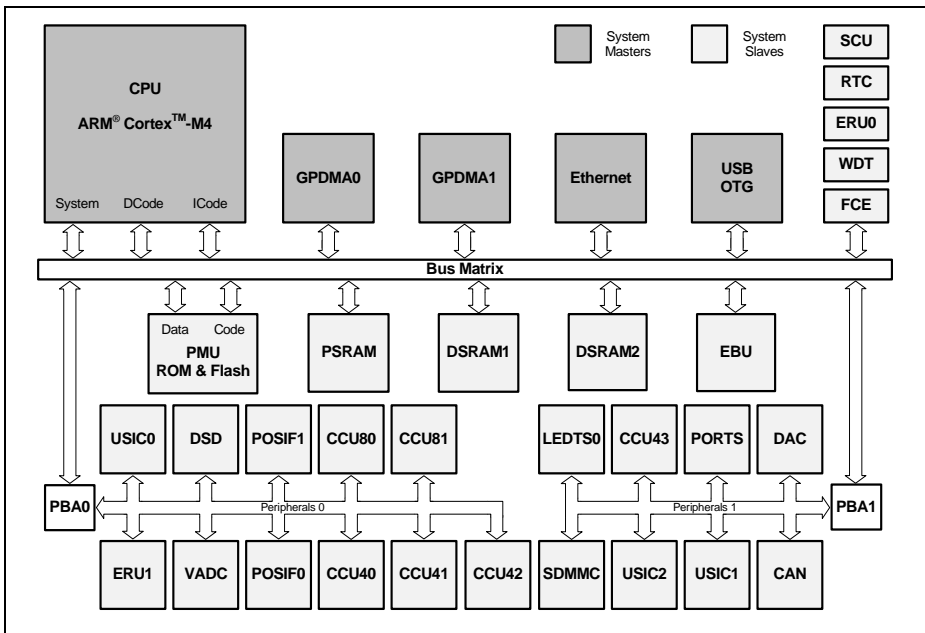
***Attention: Please consult all parts of the documentation set to attain consolidated knowledge about your device.***

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

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

## 1 Summary of Features

The 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



**Summary of Features**

- 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

**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, 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

## **1.1 Ordering Information**

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

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

For ordering codes for the 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-E144F1024	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.

## 1.3 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 Nod./Msg.
XMC4500-E144F1024	1	1	SDM	MR	1	3 x 2	3 / 64
XMC4500-F144x1024	1	1	SDM	MR	1	3 x 2	3 / 64
XMC4500-F100x1024	1	1	M16	R	1	3 x 2	3 / 64
XMC4500-F144x768	1	1	SDM	MR	1	3 x 2	3 / 64
XMC4500-F100x768	1	1	M16	R	1	3 x 2	3 / 64
XMC4502-F100x768	1	1	M16	-	1	3 x 2	3 / 64
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=MII, 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-E144F1024	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
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 AD Converter 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-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.

## 1.5 Identification Registers

The identification registers allow software to identify the marking.

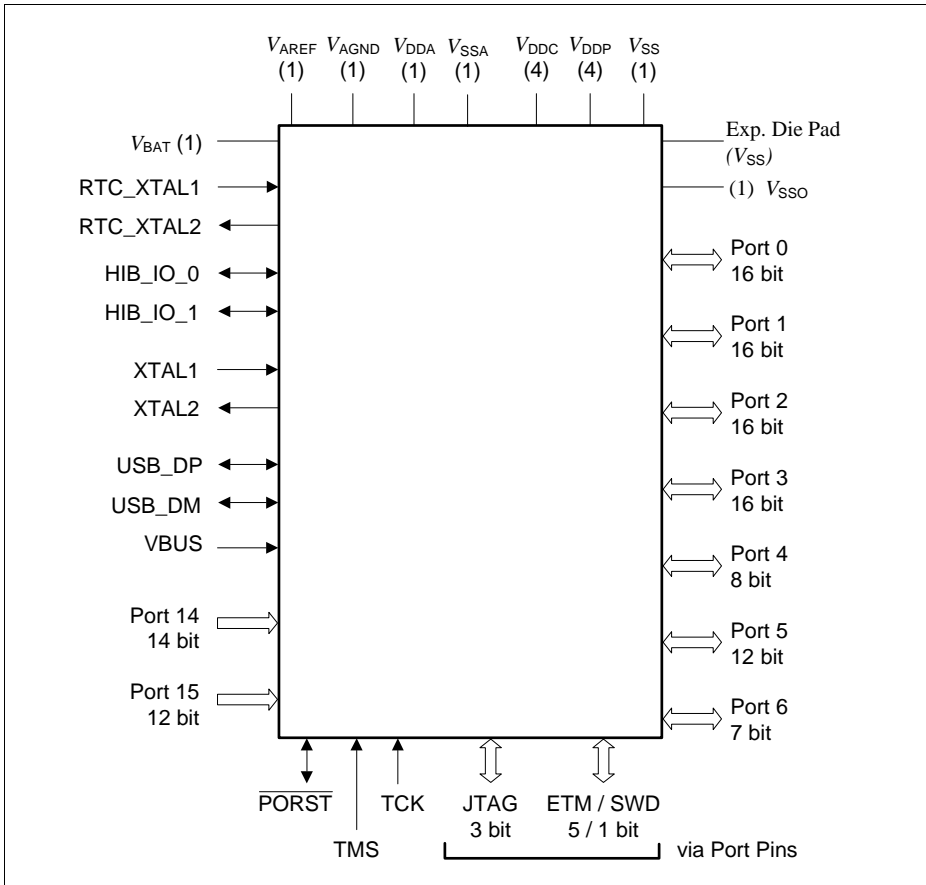
**Table 7 XMC4500 Identification Registers**

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
JTAG IDCODE	101D B083 <sub>H</sub>	EES-AA, ES-AA
JTAG IDCODE	301D B083 <sub>H</sub>	ES-AB, AB

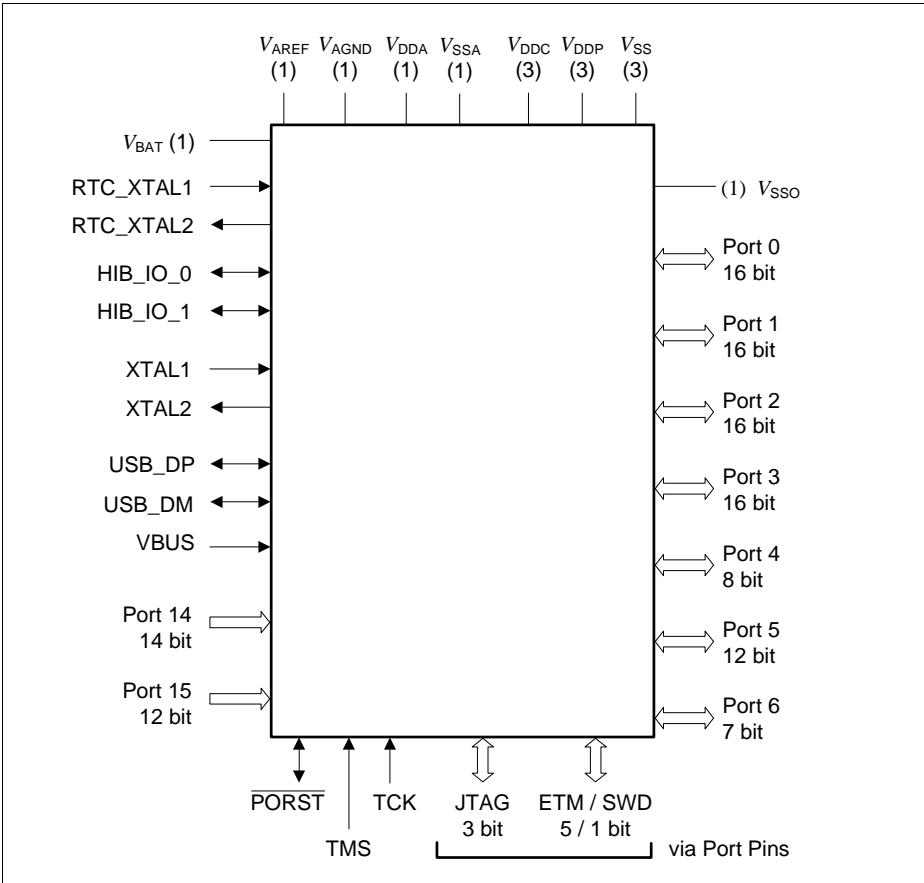
## 2 General Device Information

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

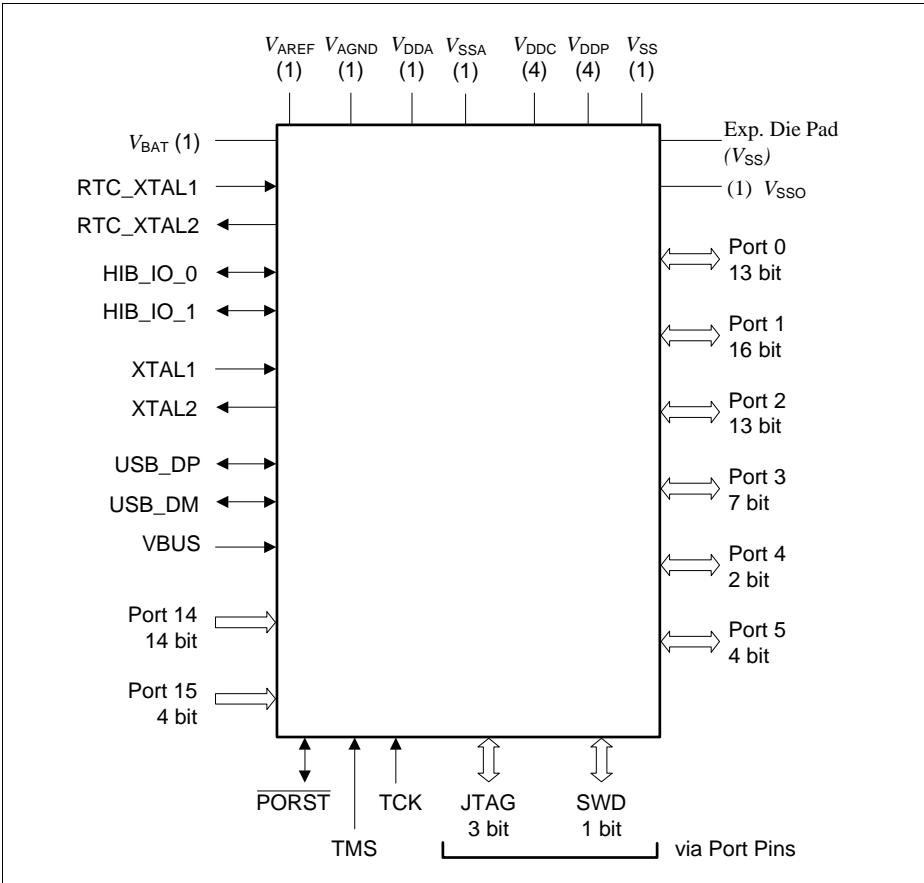
### 2.1 Logic Symbols



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



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

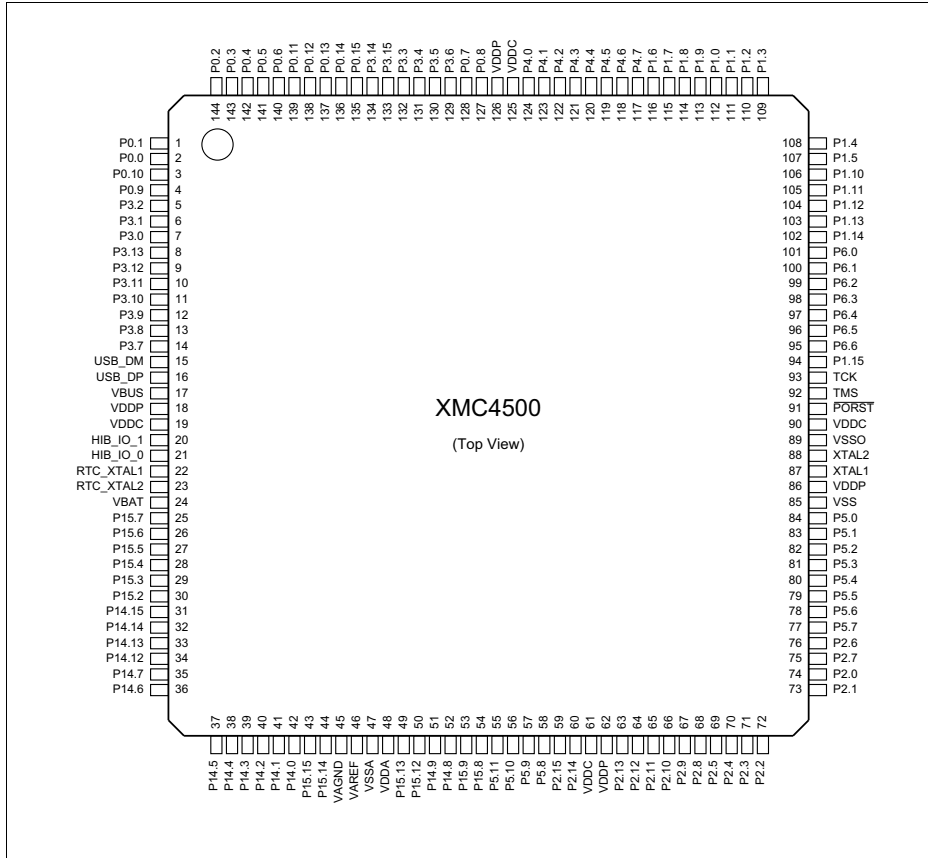


**Figure 4 XMC4500 Logic Symbol PG-LQFP-100**



## 2.2 Pin Configuration and Definition

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



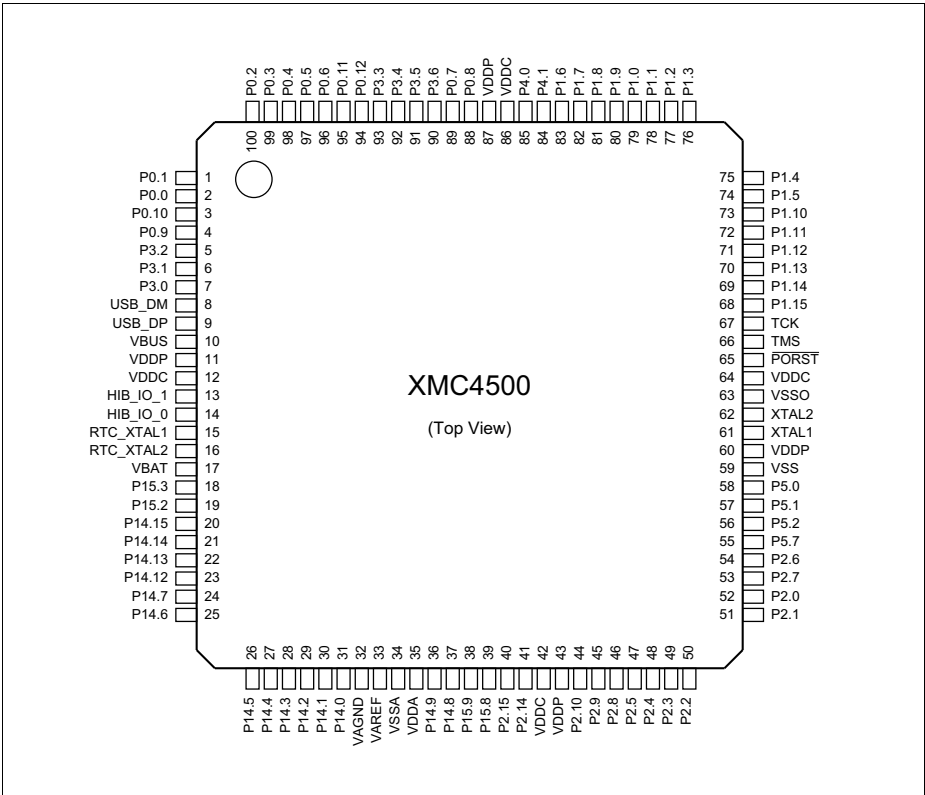
**Figure 5 XMC4500 PG-LQFP-144 Pin Configuration (top view)**

**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_D M	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_D P	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 TAL2	RTC_X TAL1	HIB_I O_1	HIB_I O_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	$\overline{\text{PORST}}$	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
	1	2	3	4	5	6	7	8	9	10	11	12	

XMC4500 - (top view)

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



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

## 2.2.1 Package Pin Summary

The following general scheme is used to describe each pin:

**Table 8 Package Pin Mapping Description**

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

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

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

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

In the “Notes”, special information to the respective pin/function is given, i.e. deviations from the default configuration after reset.

**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, this pin selects HW0.
P0.8	127	A8	88	A2	After a system reset, this pin selects HW0 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+	
P0.13	137	C5	-	A1+	

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

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
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, this pin selects HW0.
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	
P2.12	64	L7	-	A2	
P2.13	63	M7	-	A2	

**General Device Information**

**Table 9 Package Pin Mapping (cont'd)**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
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	
P5.5	79	J8	-	A2	
P5.6	78	K8	-	A2	

**General Device Information**

**Table 9 Package Pin Mapping (cont'd)**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
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	

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

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	At the first power-up and with every reset of the hibernate domain this pin is configured as open-drain output and drives "0".
HIB_IO_1	20	F3	13	A1 special	At the first power-up and with every reset of the hibernate domain this pin is configured as input with no pull device active.
TCK	93	G8	67	A1	Weak pull-down active.
TMS	92	G7	66	A1+	Weak pull-up active.
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 $V_{DDP}$ is supplied $V_{BAT}$ 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	



**General Device Information**

**Table 9 Package Pin Mapping (cont'd)**

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
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	
VSS	-	M12	-	Power	
VSSO	89	J12	63	Power	
VSS	Exp. Pad	-	Exp. Pad	Power	<p><b>Exposed Die Pad</b> The exposed die pad is connected internally to <math>V_{SS}</math>. For proper operation, it is mandatory to connect the exposed pad to the board ground. For thermal aspects, please refer to the Package and Reliability parameters in the Data Sheet. Board layout examples are given in an application note.</p>

### 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

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.

## 2.2.2.1 Port I/O Function Table

**Table 11 Port I/O Functions**

Function	Outputs						Inputs						
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	Input
P0.0		CAN, No. TXD	CCU80, OUT21	LEDTS0, COL2					U1C1, DX0D	ETH0, CLK_RMIB	ERU0, 0B0		
P0.1	USB, DRIVEVBUS	U1C1, DOU0	CCU80, OUT11	LEDTS0, COL3						ETH0, CAS_DVB	ERU0, 0A0		
P0.2		U1C1, SEL01	CCU80, OUT01		U1C0, DOU03	EBU, AD0	U1C0, HWIN3	EBU, D0	ETH0, RX0DB		ERU0, 3B3		
P0.3			CCU80, OUT20		U1C0, DOU02	EBU, AD1	U1C0, HWIN2	EBU, D1	ETH0, RXD1B			ERU1, 3B0	
P0.4	ETH0, TX_EN		CCU80, OUT10		U1C0, DOU01	EBU, AD2	U1C0, HWIN1	EBU, D2		U1C0, DX0A	ERU0, 2B3		
P0.5	ETH0, TXD0	U1C0, DOU0	CCU80, OUT00		U1C0, DOU00	EBU, AD3	U1C0, HWIN0	EBU, D3		U1C0, DX0B		ERU1, 3A0	
P0.6	ETH0, TXD1	U1C0, SEL00	CCU80, OUT30			EBU, ADV				U1C0, DX2A	ERU0, 3B2		CCU80, IN2B
P0.7	WWDT, SERVICE_OUT	U0C0, SEL00				EBU, AD6	DB, TDI	EBU, D6	U0C0, DX2B	DSD, DIN1A	ERU0, 2B1		CCU80, INDA
P0.8	SCL, EXTCLK	U0C0, SCLKOUT				EBU, AD7	CS, TRST	EBU, D7	U0C0, DX1B	DSD, DIN0A	ERU0, 2A1		CCU80, IN1B
P0.9		U1C1, SEL00	CCU80, OUT12	LEDTS0, COL0	ETH0, MDO	EBU, CS1	ETH0, MDIA		U1C1, DX2A	USB, ID	ERU0, 1B0		
P0.10	ETH0, MDC	U1C1, SCLKOUT	CCU80, OUT02	LEDTS0, COL1					U1C1, DX1A		ERU0, 1A0		
P0.11		U1C0, SCLKOUT	CCU80, OUT01		SDMMC, RST	EBU, BREG			ETH0, RXERB	U1C0, DX1A	ERU0, 3A2		
P0.12		U1C1, SEL00	CCU40, OUT3			EBU, FLDIA		EBU, FLDIR		U1C1, DX2B	ERU0, 2B2		
P0.13		U1C1, SCLKOUT	CCU40, OUT2							U1C1, DX1B	ERU0, 2A2		
P0.14		U1C0, SEL01	CCU40, OUT1		U1C1, DOU03		U1C1, HWIN3						CCU42, IN3C
P0.15		U1C0, SEL02	CCU40, OUT0		U1C1, DOU02		U1C1, HWIN2						CCU42, IN2C
P1.0	DSD, CGPWMMN	U0C0, SEL00	CCU40, OUT3		ERU1, PDOU03				U0C0, DX2A		ERU0, 3B0		CCU40, IN3A
P1.1	DSD, CGPWMP	U0C0, SCLKOUT	CCU40, OUT2		ERU1, PDOU02		SDMMC, SDWC		U0C0, DX1A	POSIF0, IN2A	ERU0, 3A0		CCU40, IN2A
P1.2			CCU40, OUT1		ERU1, PDOU01	U0C0, DOU03	EBU, AD14	U0C0, HWIN3	EBU, D14	POSIF0, IN1A			ERU1, 2B0
P1.3		U0C0, MCLKOUT	CCU40, OUT0		ERU1, PDOU00	U0C0, DOU02	EBU, AD15	U0C0, HWIN2	EBU, D15	POSIF0, IN0A			ERU1, 2A0
P1.4	WWDT, SERVICE_OUT	CAN, No. TXD	CCU80, OUT33	CCU81, OUT20	U0C0, DOU01		U0C0, HWIN1		U0C0, DX0B	CAN, NI_RXDD	ERU0, 2B0		CCU41, IN0C
P1.5	CAN, NI_TXD	U0C0, DOU0	CCU80, OUT23	CCU81, OUT10	U0C0, DOU00		U0C0, HWIN0		U0C0, DX0A	CAN, NI_RXDA	ERU0, 2A0	ERU1, 0A0	CCU41, IN1C

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

Function	Outputs							Inputs					
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	
P1.6		U0C0. SCLKOUT			SDMMC. DATA1_OUT	EBU. AD10	SDMMC. DATA1_IN	EBU. D10	DSD. DIN2A				
P1.7		U0C0. DOUT0	DSD. MCLK2		SDMMC. DATA2_OUT	EBU. AD11	SDMMC. DATA2_IN	EBU. D11		DSD. MCLK2A			
P1.8		U0C0. SELO1	DSD. MCLK1		SDMMC. DATA4_OUT	EBU. AD12	SDMMC. DATA4_IN	EBU. D12	CAN. N2_RXDA	DSD. MCLK1A			
P1.9		CAN. N2_TXD			SDMMC. DATA5_OUT	EBU. AD13	SDMMC. DATA5_IN	EBU. D13		DSD. MCLK6A			
P1.10	ETH0. MDC	U0C0. SCLKOUT	CCU81. OUT21				SDMMC. SDCC						CCU41. IN2C
P1.11		U0C0. SELO0	CCU81. OUT11		ETH0. MDO			ETH0. MDIC					CCU41. IN3C
P1.12	ETH0. TX_EN	CAN. N1_TXD	CCU81. OUT01		SDMMC. DATA6_OUT	EBU. AD16	SDMMC. DATA6_IN	EBU. D16					
P1.13	ETH0. TXD0	U0C1. SELO3	CCU81. OUT20		SDMMC. DATA7_OUT	EBU. AD17	SDMMC. DATA7_IN	EBU. D17	CAN. N1_RXDC				
P1.14	ETH0. TXD1	U0C1. SELO2	CCU81. OUT10			EBU. AD18		EBU. D18					
P1.15	SCU. EXTCLK	DSD. MCLK2	CCU81. OUT00			EBU. AD19		EBU. D19		DSD. MCLK2B		ERU1. 1A0	
P2.0		CCU81. OUT21	DSD. CGPWMMN	LEDTS0. COL1	ETH0. MDG	EBU. AD20	ETH0. MDIB	EBU. D20			ERU0. 0B3		CCU40. IN1C
P2.1		CCU81. OUT11	DSD. CGPWMP	LEDTS0. COL0	DB_TDO/ TRACESWO	EBU. AD21		EBU. D21	ETH0. CLK_RMIIA			ERU1. 0B0	CCU40. IN0C
P2.2	VADC. EMUX00	CCU81. OUT01	CCU41. OUT3	LEDTS0. LINE0	LEDTS0. EXTENDED0	EBU. AD22	LEDTS0. TSINA	EBU. D22	ETH0. RXDDA	U0C1. DX0A	ERU0. 1B2		CCU41. IN3A
P2.3	VADC. EMUX01	U0C1. SELO0	CCU41. OUT2	LEDTS0. LINE1	LEDTS0. EXTENDED1	EBU. AD23	LEDTS0. TSIN1A	EBU. D23	ETH0. RXD1A	U0C1. DX2A	ERU0. 1A2	POSIF1. IN2A	CCU41. IN2A
P2.4	VADC. EMUX02	U0C1. SCLKOUT	CCU41. OUT1	LEDTS0. LINE2	LEDTS0. EXTENDED2	EBU. AD24	LEDTS0. TSIN2A	EBU. D24	ETH0. RXERA	U0C1. DX1A	ERU0. 0B2	POSIF1. IN1A	CCU41. IN1A
P2.5	ETH0. TX_EN	U0C1. DOUT0	CCU41. OUT0	LEDTS0. LINE3	LEDTS0. EXTENDED3	EBU. AD25	LEDTS0. TSIN3A	EBU. D25	ETH0. CRS_DVA	U0C1. DX0B	ERU0. 0A2	POSIF1. IN0A	CCU41. IN0A
P2.6	U0C0. SELO4		CCU80. OUT13	LEDTS0. COL3	U0C0. DOUT3				DSD. DIN1B	CAN. N1_RXDA	ERU0. 1B3		CCU40. IN3C
P2.7	ETH0. MDC	CAN. N1_TXD	CCU80. OUT03	LEDTS0. COL2					DSD. DIN1B			ERU1. 1B0	CCU40. IN0C
P2.8	ETH0. TXD0		CCU80. OUT32	LEDTS0. LINE4	LEDTS0. EXTENDED4	EBU. AD26	LEDTS0. TSIN4A	EBU. D26	DIAC. TRIGGER5				CCU40. IN0B
P2.9	ETH0. TXD1		CCU80. OUT22	LEDTS0. LINE5	LEDTS0. EXTENDED5	EBU. AD27	LEDTS0. TSIN5A	EBU. D27	DIAC. TRIGGER4				CCU41. IN0B
P2.10	VADC. EMUX10				DB. ETM_TRACEDATA 3	EBU. AD28		EBU. D28					
P2.11	ETH0. TXER		CCU80. OUT22		DB. ETM_TRACEDATA 2	EBU. AD29		EBU. D29					
P2.12	ETH0. TXD2		CCU81. OUT33	ETH0. TXD0	DB. ETM_TRACEDATA 1	EBU. AD30		EBU. D30					CCU43. IN0C

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

Function	Outputs							Inputs					
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	
P2.13	ETH0. TXD3			ETH0. TXD1	DB. ETM_TRACEDATA 0	EBU. AD31		EBU. D31					CCU43. IN2C
P2.14	VADC. EMUX11	U1C0. DOU70	CCU80. OUT21		DB. ETM_TRACECLK	EBU. BC0				U1C0. DX0D			CCU43. INB3
P2.15	VADC. EMUX12		CCU80. OUT11	LEDTS0. LINE6	LEDTS0. EXTENDED6	EBU. BC1	LEDTS0. TSIN6A	ETH0. COLA		U1C0. DX0C			CCU42. INB3
P3.0	U2C1. SELO0	U0C1. SCLKOUT	CCU42. OUT0			EBU. RD			U0C1. DX1B				CCU80. IN2C
P3.1		U0C1. SELO0				EBU.RD/ EBU.WR			U0C1. DX2B		ERU0. 0B1		CCU80. IN1C
P3.2	USB. DRIVEVBUS	CAN. NO_TXD		LEDTS0. COLA		EBU. CS0					ERU0. 0A1		CCU80. IN0C
P3.3		U1C1. SELO1	CCU42. OUT3		SDMMC. LED			EBU. WAIT			DSD. DIN3B		CCU42. IN3A
P3.4	U2C1. MCLKOUT	U1C1. SELO2	CCU42. OUT2	DSD. MCLK3	SDMMC. BUS_POWER			EBU. HOLD	U2C1. DX0B		DSD. MCLK3B		CCU42. IN2A
P3.5	U2C1. DOU0	U1C1. SELO3	CCU42. OUT1	U0C1. DOU0	SDMMC. CMD_OUT	ERU AD4	SDMMC. CMD_IN	EBU. D4	U2C1. DX0A		ERU0. 3B1		CCU42. IN1A
P3.6	U2C1. SCLKOUT	U1C1. SELO4	CCU42. OUT0	U0C1. SCLKOUT	SDMMC. CLK_OUT	EBU. AD5	SDMMC. CLK_IN	EBU. D5	U2C1. DX1B		ERU0. 3A1		CCU42. IN0A
P3.7		CAN. NZ_TXD	CCU41. OUT3	LEDTS0. LINE6					U2C0. DX0C				
P3.8	U2C0. DOU0	U0C1. SELO3	CCU41. OUT2	LEDTS0. LINE1					CAN. NZ_RXDB				POSBF1. INB3
P3.9	U2C0. SCLKOUT	CAN. N1_TXD	CCU41. OUT1	LEDTS0. LINE2									POSBF1. IN1B
P3.10	U2C0. SELO0	CAN. NO_TXD	CCU41. OUT0	LEDTS0. LINE3	U0C1. DOU3			U0C1. HWIN3					POSBF1. INB3
P3.11	U2C1. DOU0	U0C1. SELO2	CCU42. OUT3	LEDTS0. LINE4	U0C1. DOU2			U0C1. HWIN2		CAN. N1_RXDB			
P3.12		U0C1. SELO1	CCU42. OUT2	LEDTS0. LINE5	U0C1. DOU1			U0C1. HWIN1		CAN. NO_RXDC	U2C1. DX0D		
P3.13	U2C1. SCLKOUT	U0C1. DOU0	CCU42. OUT1	LEDTS0. LINE6	U0C1. DOU0			U0C1. HWING		U0C1. DX0D			CCU80. IN3C
P3.14		U1C0. SELO3			U1C1. DOU1			U1C1. HWIN1			U1C1. DX0B		CCU42. IN1C
P3.15		U1C1. DOU0			U1C1. DOU0			U1C1. HWING			U1C1. DX0A		CCU42. IN0C
P4.0			DSD. MCLK1		SDMMC. DATA0_OUT	EBU. AD8	SDMMC. DATA0_IN	EBU. D8	U1C1. DX1C	DSD. MCLK1B	U0C1. DX0E		U2C1. DX0C
P4.1	U2C1. SELO0	U1C1. MCLKOUT	DSD. MCLK0	U0C1. SELO0	SDMMC. DATA0_OUT	EBU. AD9	SDMMC. DATA0_IN	EBU. D9	U2C1. DX2B	DSD. MCLK0B		U2C1. DX2A	
P4.2	U2C1. SELO1	U1C1. DOU0		U2C1. SCLKOUT					U1C1. DX0C			U2C1. DX1A	CCU43. IN1C
P4.3	U2C1. SELO2	U0C0. SEL06	CCU43OUT3										CCU43. IN3A
P4.4		U0C0. SEL04	CCU43OUT2		U2C1. DOU3			U2C1. HWIN3					CCU43. IN2A

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

Function	Outputs						Inputs					
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input
P4.5		U0C0. SELO3	CCU43OUT1		U2C1. DOUT2		U2C1. HWI2					CCU43. IN1A
P4.6		U0C0. SELO2	CCU43OUT0		U2C1. DOUT1		U2C1. HWI1		CAN. N2_RXDC			CCU43. IN0A
P4.7		CAN. N2_TXD			U2C1. DOUT0		U2C1. HWI0		U0C0. DX0C			CCU43. IN0C
P5.0	U2C0. DOUT0	DSD. CGPWMM	CCU81. OUT33		U2C0. DOUT0		U2C0. HWI0		U2C0. RX0B	ETH0. RX0D0	U0C0. DX0D	CCU81. IN0A
P5.1	U0C0. DOUT0	DSD. CGPWMP	CCU81. OUT32		U2C0. DOUT1		U2C0. HWI1		U2C0. DX0A	ETH0. RXD1D		CCU81. IN0B
P5.2	U2C0. SCLKOUT		CCU81. OUT23					U2C0. DX1A	ETH0. CRS_DIVD			CCU81. IN1B
P5.3	U2C0. SELO0		CCU81. OUT22		EBU. CKE	EBU. A20			U2C0. DX2A	ETH0. RXERD		CCU81. IN2B
P5.4	U2C0. SELO1		CCU81. OUT13		EBU. R2S	EBU. A61				ETH0. CRSD		CCU81. IN0B
P5.5	U2C0. SELO2		CCU81. OUT12		EBU. GAS	EBU. A22				ETH0. COLD		
P5.6	U2C0. SELO3		CCU81. OUT03		EBU. BFCLK0	EBU. A23			EBU. BFCLK1			
P5.7			CCU81. OUT02	LEDT50. COLA	U2C0. DOUT2		U2C0. HWI2					
P5.8		U1C0. SCLKOUT	CCU80. OUT01		EBU. SDCLK0	EBU. CS2			ETH0. RXD2A	U1C0. DX1B		
P5.9		U1C0. SELO0	CCU80. OUT20	ETH0. TX_EN	EBU. BFCLK0	EBU. CS3			ETH0. RXD3A	U1C0. DX2B		
P5.10		U1C0. MCLKOUT	CCU80. OUT10	LEDT50. LINE7	LEDT50. EXTENDED7		LEDT50. TSINTA		ETH0. CLK_TXA			
P5.11		U1C0. SELO1	CCU80. OUT00						ETH0. CRSA			
P6.0	ETH0. TXD2	U0C1. SELO1	CCU81. OUT31		DB. ETM_TRACECLK	EBU. A16						
P6.1	ETH0. TXD3	U0C1. SELO0	CCU81. OUT30		DB. ETM_TRACEDATA 3	EBU. A17			U0C1. DX2C			
P6.2	ETH0. TXER	U0C1. SCLKOUT	CCU43OUT3		DB. ETM_TRACEDATA 2	EBU. A18			U0C1. DX1C			
P6.3			CCU43OUT2						U0C1. DX0C	ETH0. RXD3B		
P6.4		U0C1. DOUT0	CCU43OUT1		EBU. SDCLK0	EBU. A19			EBU. SDCLK1	ETH0. RXD2B		
P6.5		U0C1. MCLKOUT	CCU43OUT0		DB. ETM_TRACEDATA 1	EBU. BC2			DSD. DIN3A	ETH0. CLK_RMII0		
P6.6		DSD. MCLK3			DB. ETM_TRACEDATA 0	EBU. BC3			DSD. MCLK3A	ETH0. CLK_TXB		
P14.0									VADC. G0CH0			

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

Function	Outputs						Inputs							
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	Input	
P14.1									VADC, G0CH1					
P14.2									VADC, G0CH2	VADC, G1CH2				
P14.3									VADC, G0CH3	VADC, G1CH3				CAN, NO_RXDB
P14.4									VADC, G0CH4		VADC, G2CH0			
P14.5									VADC, G0CH5		VADC, G2CH1			POSIF0, IN2B
P14.6									VADC, G0CH6					POSIF0, IN1B
P14.7									VADC, G0CH7					POSIF0, IN0B
P14.8					DAC, OUT_0					VADC, G1CH0		VADC, G3CH2		ETH0, RXD0C
P14.9					DAC, OUT_1					VADC, G1CH1		VADC, G3CH3		ETH0, RXD1C
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			
P15.6											VADC, G2CH6			
P15.7											VADC, G2CH7			
P15.8												VADC, G3CH0		ETH0, CLK_RMII
P15.9												VADC, G3CH1		ETH0, CRS_DVC
P15.12												VADC, G3CH4		
P15.13												VADC, G3CH5		
P15.14												VADC, G3CH6		
P15.15												VADC, G3CH7		

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

Function	Outputs						Inputs						
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	Input
USB_DP													
USB_DM													
HIB_IO_0	HIBOUT	WWDT. SERVICE_OUT							WAKEUPA				
HIB_IO_1	HIBOUT	WWDT. SERVICE_OUT							WAKEUPB				
TCK							DB.TCK/ SWCLK						
TMS					DB.TMS/ SWDIO								
PORST													
XTAL1								UI0C0. DX0F	UIC1. DX0F	UI1C0. DX0F	UI1C1. DX0F	UI2C0. DX0F	
XTAL2													
RTC_XTAL1										ERU0. 1B1			
RTC_XTAL2													



## 3 Electrical Parameters

**Attention:** *All parameters in this chapter are valid for the XMC4500 in the PG-LQFP-144 and PG-LQFP-100 package. For other packages of the XMC4500 the values are still preliminary and may change based on characterization results.*

### 3.1 General Parameters

#### 3.1.1 Parameter Interpretation

The parameters listed in this section partly represent the characteristics of the 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 **C**ontroller **C**haracteristics, which are a distinctive feature of the XMC4500 and must be regarded for system design.
- **SR**  
Such parameters indicate **S**ystem **R**equirements, which must be provided by the application system in which the 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	-0.5	–	$V_{DDP} + 0.5$ or max. 4.3	V	whichever is lower
Voltage on any analog input pin with respect to $V_{AGND}$	$V_{AIN}$ $V_{AREF}$	SR	-0.5	–	$V_{DDP} + 0.5$ 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 [Table 14](#).

### 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.*

**Table 13 Overload Parameters**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input current on analog port pins (P14, P15) during overload condition	$I_{OVA}$ SR	-3	–	3	mA	
Input current on any digital port pin during overload condition	$I_{OVD}$ 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	$\Sigma I_{OVx} $ , for all $I_{OVx} < 0$ mA
		–	–	20	mA	$\Sigma I_{OVx} $ , for all $I_{OVx} > 0$ mA
Absolute sum of all input circuit currents during overload condition	$I_{OVS}$ SR	–	–	80	mA	$\Sigma I_{OVG}$

1) The port groups are defined in **Table 14**.

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

**Table 14 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 its basic characteristics. More details (mainly DC parameters) are defined in the [Section 3.2.1](#).

**Table 15 Pad Driver and Pad Classes Overview**

Class	Power Supply	Type	Sub-Class	Speed Grade	Load	Termination
A	3.3 V	LVTTTL 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

### 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 16 Operating Conditions Parameters**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Ambient Temperature	$T_A$ SR	-40	–	85	°C	Temp. Range F
		-40	–	125	°C	Temp. Range K
Digital supply voltage	$V_{DDP}$ SR	3.13 <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	
ADC 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	–	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>3)</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) The port groups are defined in [Table 14](#).

## 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.

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

**Table 17 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	–	$\mu$ A	<sup>1)</sup> $V_i \geq 0.6 \times V_{DDP}$
		–	10	$\mu$ A	<sup>2)</sup> $V_i \leq 0.36 \times V_{DDP}$
Pull-Up current	$ I_{PUH} $ CC	–	10	$\mu$ A	<sup>2)</sup> $V_i \geq 0.6 \times V_{DDP}$
		100	–	$\mu$ A	<sup>1)</sup> $V_i \leq 0.36 \times V_{DDP}$
Input Hysteresis for pads of all A classes <sup>3)</sup>	$HYS_A$ CC	$0.1 \times V_{DDP}$	–	V	
$\overline{PORST}$ spike filter always blocked pulse duration	$t_{SF1}$ CC	–	10	ns	
$\overline{PORST}$ spike filter pass-through pulse duration	$t_{SF2}$ CC	100	–	ns	
$\overline{PORST}$ pull-down current	$t_{SF2}$ CC	13	–	mA	$V_i = 1$ 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.

**Table 18 Standard\_Pads Class\_A1**

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input leakage current	$I_{OZA1}$ CC	-500	500	nA	$0\text{ V} \leq V_i \leq V_{DDP}$
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	$I_{OH} \geq -400\ \mu\text{A}$
		2.4	–	V	$I_{OH} \geq -500\ \mu\text{A}$
Output high voltage, POD <sup>1)</sup> = medium		$V_{DDP} - 0.4$	–	V	$I_{OH} \geq -1.4\ \text{mA}$
		2.4	–	V	$I_{OH} \geq -2\ \text{mA}$
Output low voltage	$V_{OLA1}$ CC	–	0.4	V	$I_{OL} \leq 500\ \mu\text{A};$ POD <sup>1)</sup> = weak
		–	0.4	V	$I_{OL} \leq 2\ \text{mA};$ POD <sup>1)</sup> = medium
Fall time	$t_{FA1}$ 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
Rise time	$t_{RA1}$ 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

1) POD = Pin Out Driver

**Table 19 Standard\_Pads Class\_A1+**

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

**Electrical Parameters**

**Table 19 Standard\_Pads Class\_A1+ (cont'd)**

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

1) POD = Pin Out Driver



**Table 20 Standard\_Pads Class\_A2**

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input Leakage current	$I_{OZA2}$ CC	-6	6	$\mu\text{A}$	$0\text{ V} \leq V_i < 0.5 \cdot V_{DDP} - 1\text{ V};$ $0.5 \cdot V_{DDP} + 1\text{ V} < V_i \leq V_{DDP}$
		-3	3	$\mu\text{A}$	$0.5 \cdot V_{DDP} - 1\text{ V} < V_i < 0.5 \cdot V_{DDP} + 1\text{ V}$
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	$I_{OH} \geq -400\ \mu\text{A}$
		2.4	-	V	$I_{OH} \geq -500\ \mu\text{A}$
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	$I_{OL} \leq 500\ \mu\text{A}$
Output low voltage, POD = medium		-	0.4	V	$I_{OL} \leq 2\ \text{mA}$
Output low voltage, POD = strong		-	0.4	V	$I_{OL} \leq 2\ \text{mA}$

**Electrical Parameters**

**Table 20 Standard\_Pads Class\_A2 (cont'd)**

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

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

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

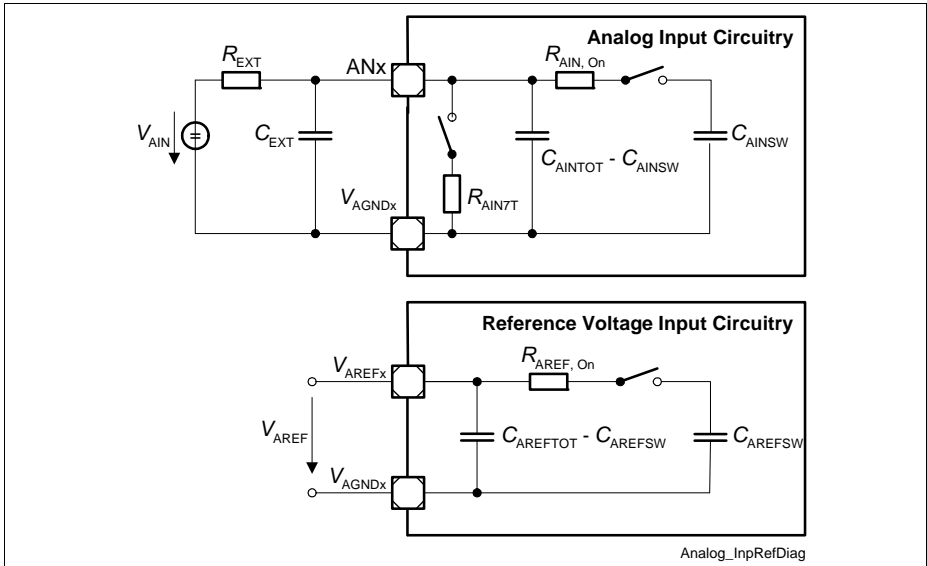
**Electrical Parameters**
**Table 21 VADC Parameters (Operating Conditions apply) (cont'd)**

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

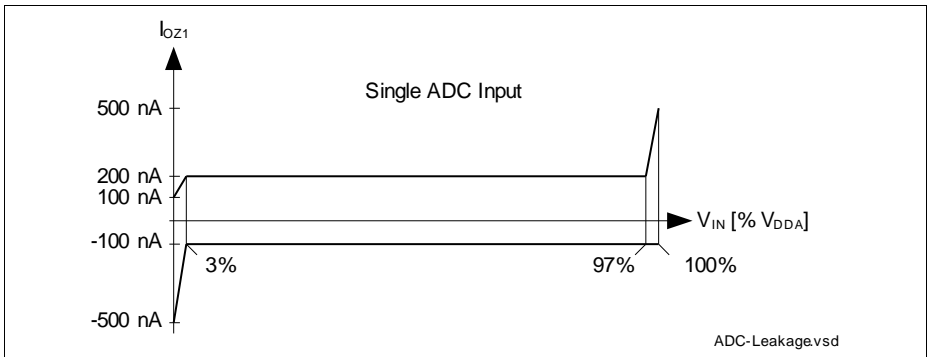
- 1) A running conversion may become imprecise in case the normal conditions are violated (voltage overshoot).
- 2) If the analog reference voltage is below  $V_{DDA}$ , then the ADC converter errors increase. If the reference voltage is reduced by the factor  $k$  ( $k < 1$ ), TUE, DNL, INL, Gain, and Offset errors increase also by the factor  $1/k$ .
- 3) The leakage current definition is a continuous function, as shown in figure ADCx Analog Inputs Leakage. The numerical values defined determine the characteristic points of the given continuous linear approximation - they do not define step function (see [Figure 9](#)).
- 4) The sampling capacity of the conversion C-network is pre-charged to  $V_{AREF}/2$  before the sampling moment. Because of the parasitic elements, the voltage measured at AINx can deviate from  $V_{AREF}/2$ .
- 5) Applies to AINx, when used as alternate reference input.
- 6) This represents an equivalent switched capacitance. This capacitance is not switched to the reference voltage at once. Instead, smaller capacitances are successively switched to the reference voltage.
- 7) For 10-bit conversions, the errors are reduced to 1/4; for 8-bit conversions, the errors are reduced to 1/16. Never less than  $\pm 1$  LSB.
- 8) The sum of DNL/INL/GAIN/OFF errors does not exceed the related total unadjusted error TUE.
- 9) 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  $I_{AREF} = 54.5\text{ }\mu\text{A}$ .

**Electrical Parameters**

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



**Figure 8 VADC Input Circuits**



**Figure 9 VADC Analog Input Leakage Current**

**Conversion Time**

**Table 22 Conversion Time** (Operating Conditions apply)

Parameter	Symbol	Values	Unit	Note
Conversion time	$t_C$ CC	$2 \times T_{ADC} + (2 + N + STC + PC + DM) \times T_{ADCI}$	$\mu\text{s}$	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:

$$f_{ADC} = 120 \text{ MHz i.e. } t_{ADC} = 8.33 \text{ ns, DIVA} = 3, f_{ADCI} = 30 \text{ MHz i.e. } t_{ADCI} = 33.3 \text{ ns}$$

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

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

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

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 23 DAC Parameters (Operating Conditions apply)**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
RMS supply current	$I_{DD}$ CC	–	2.5	4	mA	per active DAC channel, without load currents of DAC outputs
Resolution	$RES$ CC	–	12	–	Bit	
Update rate	$f_{URATE\_A}$ CC	–		2	Msample/s	data rate, where DAC can follow 64 LSB code jumps to $\pm 1$ LSB accuracy
Update rate	$f_{URATE\_F}$ CC	–		5	Msample/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 <sub>H</sub> ; signed: 800 <sub>H</sub>
Maximum output voltage	$V_{OUT\_MAX}$ CC	–	2.5	–	V	code value unsigned: FFF <sub>H</sub> ; signed: 7FF <sub>H</sub>
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

**Electrical Parameters**
**Table 23 DAC Parameters (Operating Conditions apply) (cont'd)**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Offset error	$ED_{OFF}$ CC		±20		mV	
Gain error	$ED_{G\_IN}$ CC	-6.5	-1.5	3	%	
Startup time	$t_{STARTUP}$ CC	–	15	30	µs	time from output enabling till code valid ±16 LSB
3dB Bandwidth of Output Buffer	$f_{C1}$ CC	2.5	5	–	MHz	verified by design
Output sourcing current	$I_{OUT\_SOURCE}$ CC	–	-30	–	mA	
Output sinking current	$I_{OUT\_SINK}$ CC	–	0.6	–	mA	
Output resistance	$R_{OUT}$ CC	–	50	–	Ohm	
Load resistance	$R_L$ SR	5	–	–	kOhm	
Load capacitance	$C_L$ SR	–	–	50	pF	
Signal-to-Noise Ratio	SNR CC	–	70	–	dB	examination bandwidth < 25 kHz
Total Harmonic Distortion	THD CC	–	70	–	dB	examination bandwidth < 25 kHz
Power Supply Rejection Ratio	PSRR CC	–	56	–	dB	to $V_{DDA}$ verified by design

**Conversion Calculation**

Unsigned:

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

Signed:

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



### 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 (GxORCy) and generates a service request trigger (GxORCOUTy).

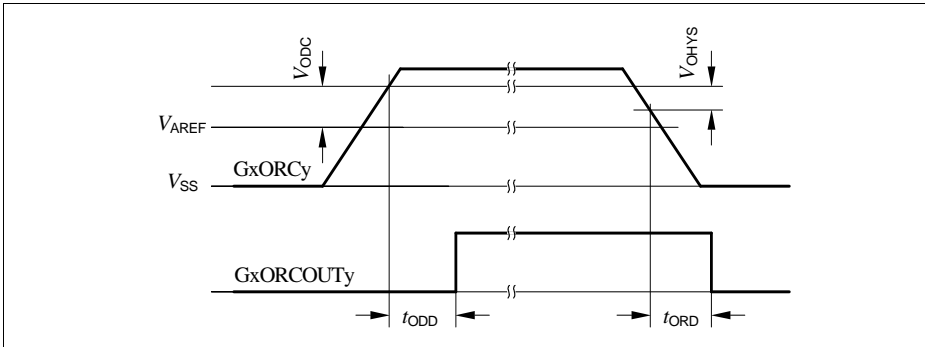
*Note: These parameters are not subject to production test, but verified by design and/or characterization.*

The parameters in **Table 24** apply for the maximum reference voltage  $V_{AREF} = V_{DDA} + 50 \text{ mV}$ .

**Table 24 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	

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



**Figure 10 GxORCOUTy Trigger Generation**

### 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 25 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	–	±1	–	°C	per $\Delta T_J \leq 30$ °C
Offset Error	$\Delta T_{OE}$ CC	–	±6	–	°C	$\Delta T_{OE} = T_J - T_{DTS}$
Measurement time	$t_M$ CC	–	–	100	µs	
Start-up time after reset inactive	$t_{TSSST}$ SR	–	–	10	µs	

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

$$\text{Temperature } T_{DTS} = (\text{RESULT} - 596) / 2.03 \text{ [°C]} \quad (\text{PRELIMINARY})$$

This formula and the values defined in [Table 25](#) apply with the following calibration values:

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

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

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

**Table 27 USB OTG Data Line (USB\_DP, USB\_DN) Parameters** (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input low voltage	$V_{IL}$ SR	–	–	0.8	V	
Input high voltage (driven)	$V_{IH}$ SR	2.0	–	–	V	
Input high voltage (floating) <sup>1)</sup>	$V_{IHZ}$ SR	2.7	–	3.6	V	
Differential input sensitivity	$V_{DIS}$ CC	0.2	–	–	V	
Differential common mode range	$V_{CM}$ CC	0.8	–	2.5	V	
Output low voltage	$V_{OL}$ CC	0.0	–	0.3	V	1.5 kOhm pull-up to 3.6 V
Output high voltage	$V_{OH}$ CC	2.8	–	3.6	V	15 kOhm pull-down to 0 V
DP pull-up resistor (idle bus)	$R_{PUI}$ CC	900	–	1 575	Ohm	
DN pull-up resistor (upstream port receiving)	$R_{PUA}$ CC	1 425	–	3 090	Ohm	
DP, DN pull-down resistor	$R_{PD}$ CC	14.25	–	24.8	kOhm	
Input impedance DP, DN	$Z_{INP}$ CC	300	–	–	kOhm	$0 V \leq V_{IN} \leq V_{DDP}$
Driver output resistance DP, DN	$Z_{DRV}$ 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\_DN and at B-connector with 15 kOhm  $\pm$  5% to ground connected to USB\_DP and USB\_DN.

### 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.*

**Table 28 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	$V_{\text{IX}}$ SR	-0.5	–	$V_{\text{DDP}} + 0.5$	V	
Input amplitude (peak-to-peak) at XTAL1 <sup>2)3)</sup>	$V_{\text{PPX}}$ SR	$0.4 \times V_{\text{DDP}}$	–	$V_{\text{DDP}} + 1.0$	V	
Input high voltage at XTAL1 <sup>4)</sup>	$V_{\text{IHBX}}$ SR	1.0	–	$V_{\text{DDP}} + 0.5$	V	
Input low voltage at XTAL1 <sup>4)</sup>	$V_{\text{ILBX}}$ SR	-0.5	–	0.4	V	
Input leakage current at XTAL1	$I_{\text{ILX1}}$ CC	-100	–	100	nA	Oscillator power down $0 \text{ V} \leq V_{\text{IX}} \leq V_{\text{DDP}}$

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  $0.4 \times V_{\text{DDP}}$ .

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

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

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

**Table 29 RTC\_XTAL Parameters**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input frequency	$f_{OSC}$ SR	–	32.768	–	kHz	
Oscillator start-up time <sup>1)2)3)</sup>	$t_{OSCS}$ CC	–	–	5	s	
Input voltage at RTC_XTAL1	$V_{IX}$ SR	-0.3	–	$V_{BAT} + 0.3$	V	
Input amplitude (peak-to-peak) at RTC_XTAL1 <sup>2)4)</sup>	$V_{PPX}$ CC	$0.2 \times V_{BAT}$	–	$V_{BAT} + 0.6$	V	
Input high voltage at RTC_XTAL1 <sup>5)</sup>	$V_{IHBX}$ SR	$0.6 \times V_{BAT}$	–	$V_{BAT} + 0.3$	V	
Input low voltage at RTC_XTAL1 <sup>5)</sup>	$V_{ILBX}$ SR	-0.3	–	$0.36 \times V_{BAT}$	V	
Input Hysteresis for RTC_XTAL1 <sup>5)6)</sup>	$V_{HYSX}$ CC	$0.1 \times V_{BAT}$		–	V	$3.0 \text{ V} \leq V_{BAT} < 3.6 \text{ V}$
		$0.03 \times V_{BAT}$		–	V	$V_{BAT} < 3.0 \text{ V}$
Input leakage current at RTC_XTAL1	$I_{ILX1}$ CC	-100	–	100	nA	Oscillator power down $0 \text{ V} \leq V_{IX} \leq V_{BAT}$

- 1)  $t_{OSCS}$  is defined from the moment the oscillator is enabled by the user with SCU\_OSCULCTRL.MODE until the oscillations reach an amplitude at RTC\_XTAL1 of  $0.2 * V_{BAT}$ .
- 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.

### 3.2.8 Power Supply Current

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

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

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

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

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

**Table 30 Power Supply Parameters**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Active supply current <sup>(1)(10)</sup> Peripherals enabled Frequency: $f_{CPU}/f_{PERIPH}/f_{CCU}$ in MHz	$I_{DDPA}$ 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	$I_{DDPA}$ CC	–	98	–	mA	120 / 120 / 120
		–	80	–		120 / 60 / 60
Active supply current <sup>(2)</sup> Peripherals disabled Frequency: $f_{CPU}/f_{PERIPH}/f_{CCU}$ in MHz	$I_{DDPA}$ 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>(3)</sup> Peripherals enabled Frequency: $f_{CPU}/f_{PERIPH}/f_{CCU}$ in MHz	$I_{DDPS}$ CC	–	115	–	mA	120 / 120 / 120
		–	105	–		120 / 60 / 60
		–	83	–		60 / 60 / 120
		–	60	–		24 / 24 / 24
		–	48	–		1 / 1 / 1
		$f_{CPU}/f_{PERIPH}/f_{CCU}$ in kHz	–	46		–



**Electrical Parameters**
**Table 30 Power Supply Parameters (cont'd)**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Sleep supply current <sup>4)</sup> Peripherals disabled Frequency: $f_{CPU}/f_{PERIPH}/f_{CCU}$ in MHz	$I_{DDPS}$ 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
$f_{CPU}/f_{PERIPH}/f_{CCU}$ in kHz						
Deep Sleep supply current <sup>5)</sup> Flash in Sleep mode Frequency: $f_{CPU}/f_{PERIPH}/f_{CCU}$ in MHz $f_{CPU}/f_{PERIPH}/f_{CCU}$ in kHz	$I_{DDPD}$ CC	-	20	-	mA	24 / 24 / 24
		-	12	-		4 / 4 / 4
		-	10	-		1 / 1 / 1
		-	6	-		100 / 100 / 100 <sup>6)</sup>
Hibernate supply current RTC on <sup>7)</sup>	$I_{DDPH}$ CC	-	10	-	$\mu$ A	$V_{BAT} = 3.3$ V
		-	7.5	-		$V_{BAT} = 2.4$ V
		-	6.2	-		$V_{BAT} = 2.0$ V
Hibernate supply current RTC off <sup>8)</sup>	$I_{DDPH}$ CC	-	9.2	-	$\mu$ A	$V_{BAT} = 3.3$ V
		-	6.7	-		$V_{BAT} = 2.4$ V
		-	5.6	-		$V_{BAT} = 2.0$ V
Worst case active supply current <sup>9)</sup>	$I_{DDPA}$ CC	-	-	180 <sup>10)</sup>	mA	$V_{DDP} = 3.6$ V, $T_J = 150$ °C
$V_{DDA}$ power supply current	$I_{DDA}$ CC	-	-	- <sup>11)</sup>	mA	
$I_{DDP}$ current at $\overline{PORST}$ Low	$I_{DDP\_PORST}$ CC	-	-	16	mA	$V_{DDP} = 3.6$ V, $T_J = 150$ °C
Power Dissipation	$P_{DISS}$ CC	-	-	1	W	$V_{DDP} = 3.6$ V, $T_J = 150$ °C
Wake-up time from Sleep to Active mode	$t_{SSA}$ CC	-	6	-	cycles	

**Table 30 Power Supply Parameters (cont'd)**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
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) CPU executing code from Flash.
- 3) CPU in sleep, all peripherals idle, Flash in Active mode.
- 4) CPU in sleep, Flash in Active mode.
- 5) CPU in sleep, peripherals disabled, after wake-up code execution from RAM.
- 6) To wake-up the Flash from its Sleep mode,  $f_{CPU} \geq 1$  MHz is required.
- 7) OSC\_ULP operating with external crystal on RTC\_XTAL
- 8) OSC\_ULP off, Hibernate domain operating with OSC\_SI clock
- 9) Test Power Loop:  $f_{SYS} = 120$  MHz, CPU executing benchmark code from Flash, all CCUs in 100kHz timer mode, all ADC groups in continuous conversion mode, USICs as SPI in internal loop-back mode, CAN in 500kHz internal loop-back mode, interrupt triggered DMA block transfers to parity protected RAMs and FCE, DTS measurements and FPU calculations.  
The power consumption of each customer application will most probably be lower than this value, but must be evaluated separately.
- 10)  $I_{DDP}$  decreases typically by approximately 6 mA when  $f_{SYS}$  decreases by 10 MHz, at constant  $T_j$
- 11) Sum of currents of all active converters (ADC and DAC)

### 3.2.9 Flash Memory Parameters

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

**Table 31 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:  $FCON.WSPFLASH \times (1/f_{CPU}) \geq t_a$ .

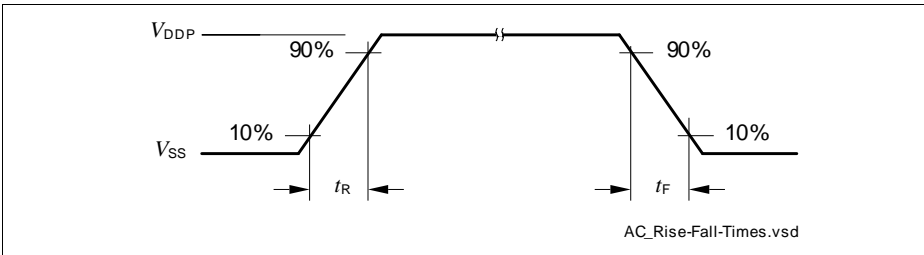
3) Storage and inactive time included.

**Electrical Parameters**

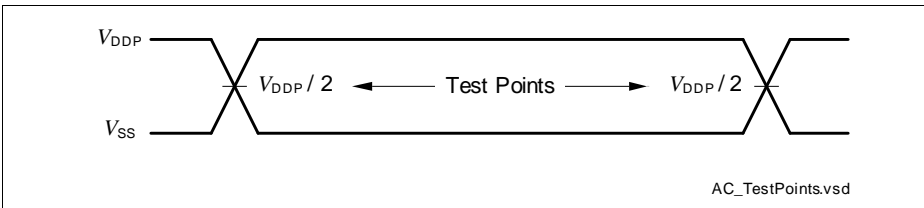
- 4) Values given are valid for an average weighted junction temperature of  $T_j = 110^{\circ}\text{C}$ . Further lifetime dependency values are give in the Quality Declarations.

### 3.3 AC Parameters

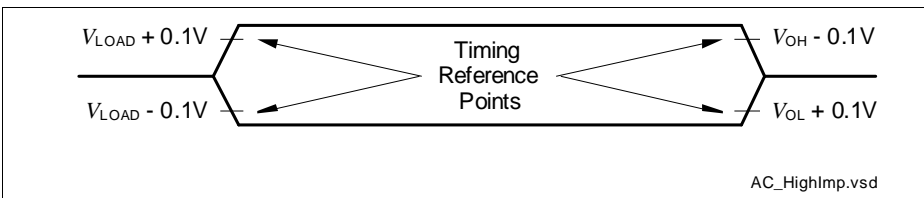
#### 3.3.1 Testing Waveforms



**Figure 11 Rise/Fall Time Parameters**



**Figure 12 Testing Waveform, Output Delay**



**Figure 13 Testing Waveform, Output High Impedance**

### 3.3.2 Power-Up and Supply Monitoring

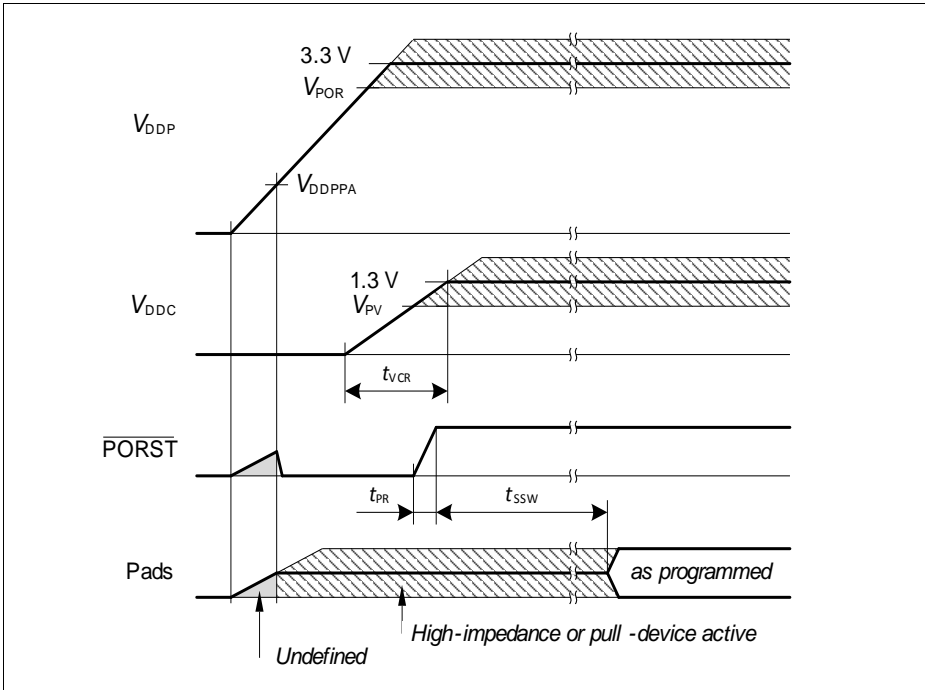
$\overline{\text{PORST}}$  is always asserted when  $V_{\text{DDP}}$  and/or  $V_{\text{DDC}}$  violate the respective thresholds.

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

**Table 32 Supply Monitoring Parameters**

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

- 1) Minimum threshold for reset assertion.
- 2) Maximum threshold for reset deassertion.
- 3) The  $V_{\text{DDP}}$  monitoring has a typical hysteresis of  $V_{\text{PORHYS}} = 180 \text{ mV}$ .



**Figure 14 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 33 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

### 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 34 PLL Parameters**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Accumulated Jitter	$D_P$ CC	–	–	±5	ns	accumulated over 300 cycles $f_{SYS} = 120$ 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	µs	

1) 50% for even K2 divider values, 50±(10/K2) for odd K2 divider values.

### 3.3.5 Internal Clock Source Characteristics

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

#### Fast Internal Clock Source

**Table 35 Fast Internal Clock Parameters**

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

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

**Slow Internal Clock Source**
**Table 36 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	%	$V_{BAT} = \text{const.}$ $0\text{ }^{\circ}\text{C} \leq T_A \leq 85\text{ }^{\circ}\text{C}$
		-5	–	5	%	$V_{BAT} = \text{const.}$ $T_A < 0\text{ }^{\circ}\text{C}$ or $T_A > 85\text{ }^{\circ}\text{C}$
		-5	–	5	%	$2.4\text{ V} \leq V_{BAT}$ , $T_A = 25\text{ }^{\circ}\text{C}$
		-10	–	10	%	$1.95\text{ V} \leq V_{BAT} < 2.4\text{ V}$ , $T_A = 25\text{ }^{\circ}\text{C}$
Start-up time	$t_{OSIS}$ CC	–	50	–	$\mu\text{s}$	

### 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.*

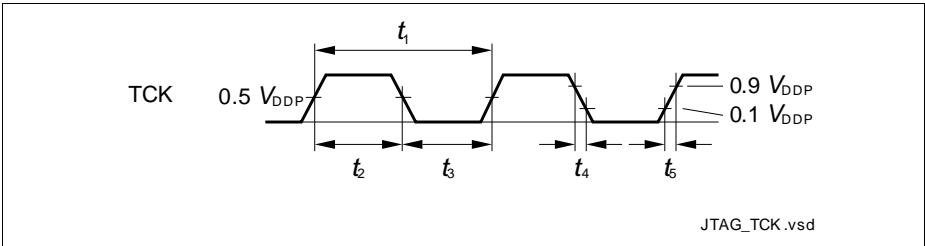
*Note: Operating conditions apply.*

**Table 37 JTAG Interface Timing Parameters**

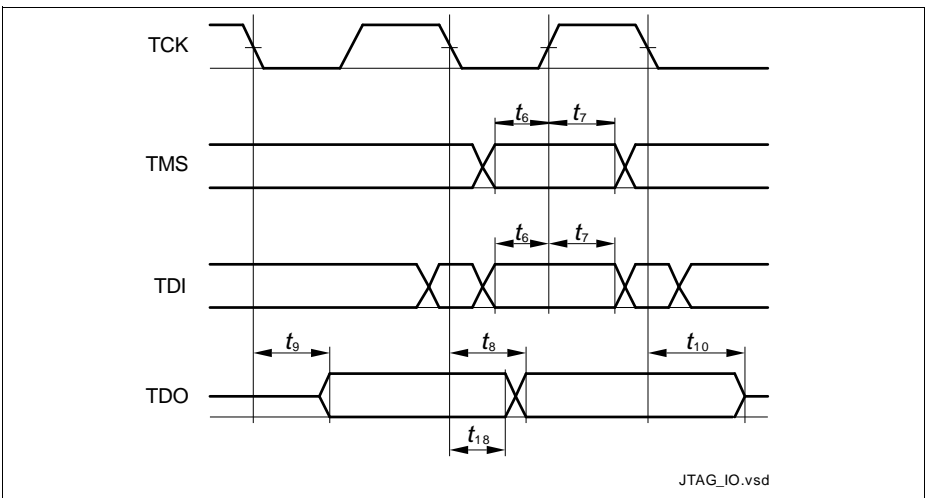
Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
TCK clock period	$t_1$ SR	25	–	–	ns	
TCK high time	$t_2$ SR	10	–	–	ns	
TCK low time	$t_3$ SR	10	–	–	ns	
TCK clock rise time	$t_4$ SR	–	–	4	ns	
TCK clock fall time	$t_5$ SR	–	–	4	ns	
TDI/TMS setup to TCK rising edge	$t_6$ SR	6	–	–	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	$C_L = 50$ pF
		3	–	–	ns	$C_L = 20$ 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	$C_L = 50$ pF
TDO valid to high imped. from TCK falling edge <sup>1)</sup>	$t_{10}$ CC	–	–	13.5	ns	$C_L = 50$ 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 15 Test Clock Timing (TCK)**



**Figure 16 JTAG Timing**

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

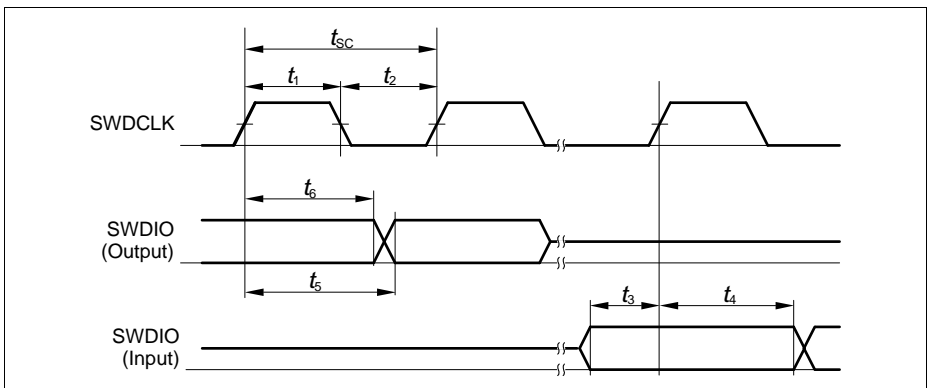
The following parameters are applicable for communication through the SW-DP interface.

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

*Note: Operating conditions apply.*

**Table 38 SWD Interface Timing Parameters (Operating Conditions apply)**

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



**Figure 17 SWD Timing**

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

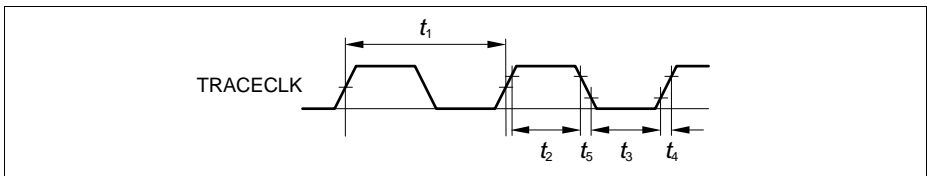
The data timing refers to the active clock edge. The XMC4500 ETM uses the half-rate clocking mode. In this mode both, the rising and falling clock edges are active clock edges.

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

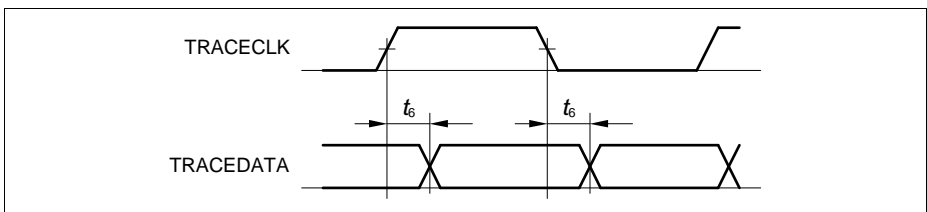
*Note: Operating conditions apply, with  $C_L \leq 15$  pF.*

**Table 39 ETM Interface Timing Parameters**

Parameter	Symbol	CC	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 18 ETM Clock Timing**



**Figure 19 ETM Data Timing**

### 3.3.9 Peripheral Timing

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

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: The timing parameters for this interface will be added in a future revision of the Data Sheet.*

#### 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 40 USIC SSC Master Mode Timing**

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

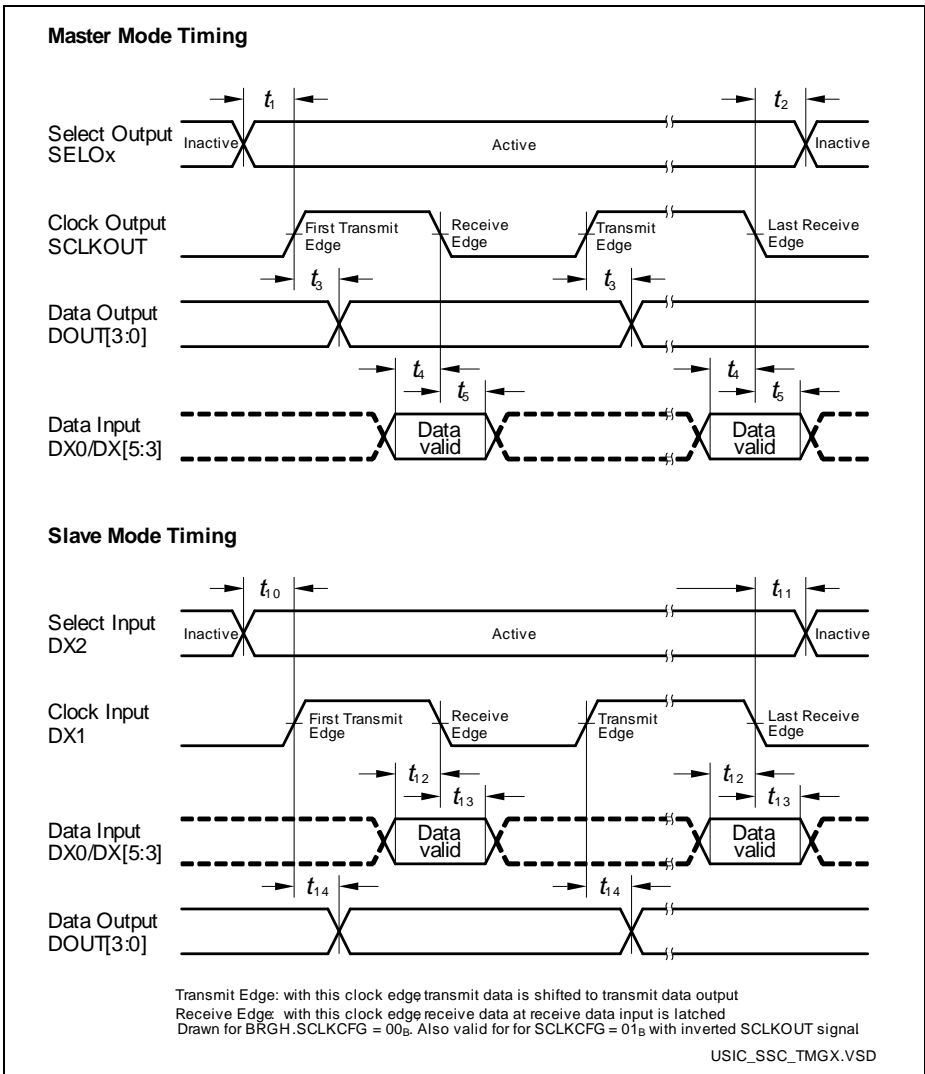
1)  $t_{PB} = 1 / f_{PB}$



**Table 41 USIC SSC Slave Mode Timing**

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
DX1 slave clock period	$t_{CLK}$	SR	66.6	–	–	ns	
Select input DX2 setup to first clock input DX1 transmit edge <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).



**Figure 20 USIC - SSC Master/Slave Mode Timing**

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

### 3.3.9.3 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 42 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	

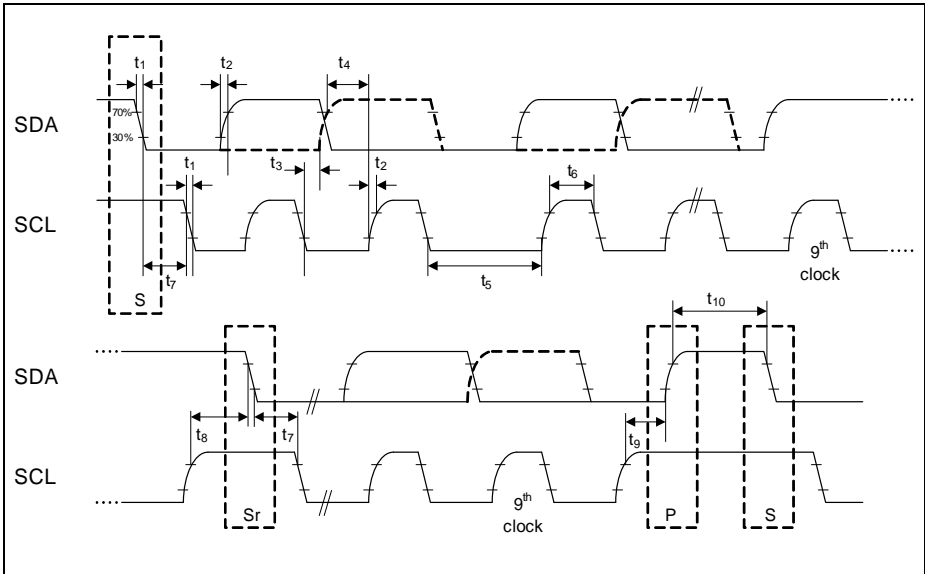
1) Due to the wired-AND configuration of an IIC bus system, the port drivers of the SCL and SDA signal lines need to operate in open-drain mode. The high level on these lines must be held by an external pull-up device, approximately 10 kOhm for operation at 100 kbit/s, approximately 2 kOhm for operation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

**Table 43 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 <sub>b</sub> <sup>2)</sup>	-	300	ns	
Rise time of both SDA and SCL	$t_2$ CC/SR	20 + 0.1 * C <sub>b</sub> <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	
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 <sub>b</sub> 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<sub>b</sub> refers to the total capacitance of one bus line in pF.



**Figure 21 USIC IIC Stand and Fast Mode Timing**

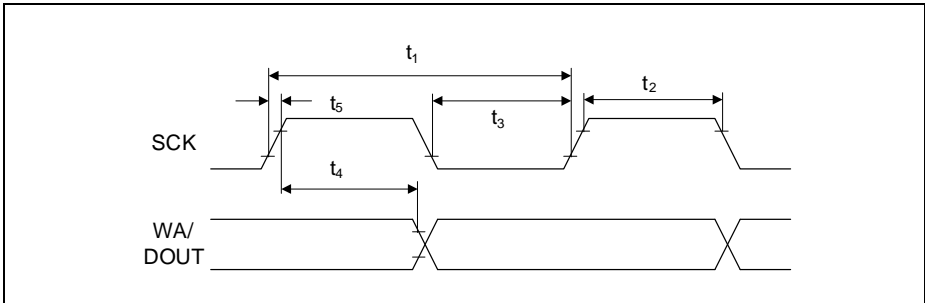
### 3.3.9.4 Inter-IC Sound (IIS) Interface Timing

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 44 USIC IIS Master Transmitter Timing**

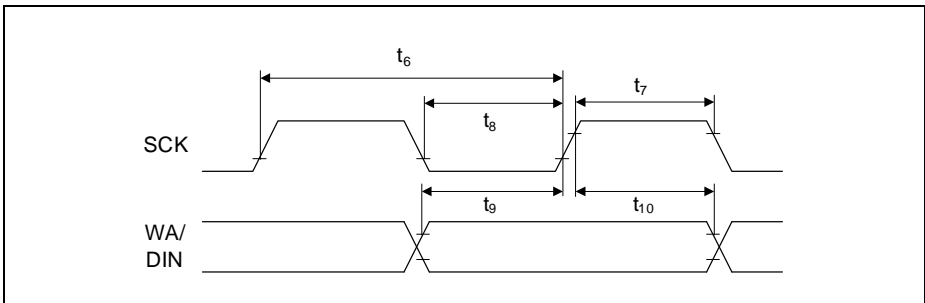
Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Clock period	$t_1$ CC	33.3	–	–	ns	
Clock HIGH	$t_2$ CC	0.35 x $t_{1min}$	–	–	ns	
Clock Low	$t_3$ CC	0.35 x $t_{1min}$	–	–	ns	
Hold time	$t_4$ CC	0	–	–	ns	
Clock rise time	$t_5$ CC	–	–	0.15 x $t_{1min}$	ns	



**Figure 22 USIC IIS Master Transmitter Timing**

**Table 45 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	$t_7$ SR	$0.35 \times t_{6min}$	—	—	ns	
Clock Low	$t_8$ SR	$0.35 \times t_{6min}$	—	—	ns	
Set-up time	$t_9$ SR	$0.2 \times t_{6min}$	—	—	ns	
Hold time	$t_{10}$ SR	0	—	—	ns	



**Figure 23 USIC IIS Slave Receiver Timing**

### 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  $C_L = 40$  pF.*

#### AC Timing Specifications (Full-Speed Mode)

**Table 46 SDMMC Timing for Full-Speed Mode**

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

**Table 47 SD Card Bus Timing for Full-Speed Mode<sup>1)</sup>**

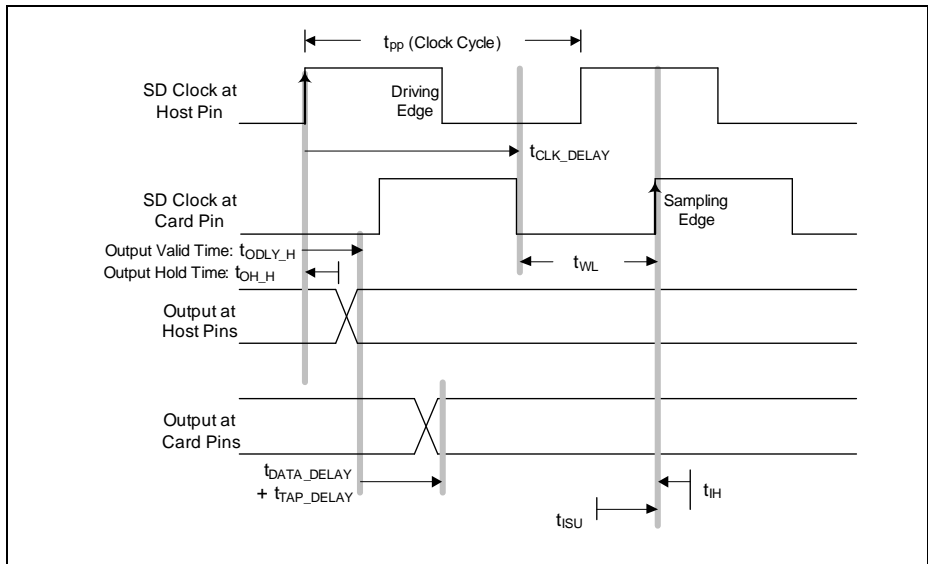
Parameter	Symbol	Values		Unit	Note/ Test Condition
		Min.	Max.		
SD card input setup time	$t_{ISU}$	5	–	ns	
SD card input hold time	$t_{IH}$	5	–	ns	

**Table 47 SD Card Bus Timing for Full-Speed Mode<sup>1)</sup> (cont'd)**

Parameter	Symbol	Values		Unit	Note/ Test Condition
		Min.	Max.		
SD card output valid time	$t_{ODLY}$	–	14	ns	
SD card output hold time	$t_{OH}$	0	–	ns	

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

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



**Figure 24 Full-Speed Output Path**

**Full-Speed Write Meeting Setup (Maximum Delay)**

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

No clock delay:

(1)

$$t_{ODLY\_F} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ISU} < t_{WL}$$



With clock delay:

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

$$t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{WL} < t_{PP} + t_{CLK\_DELAY} - t_{ISU} - t_{ODLY\_F} \quad (3)$$

$$t_{DATA\_DELAY} + t_{TAP\_DELAY} + 20 < 40 + t_{CLK\_DELAY} - 5 - 10$$

$$t_{DATA\_DELAY} < 5 + t_{CLK\_DELAY} - t_{TAP\_DELAY}$$

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

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

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

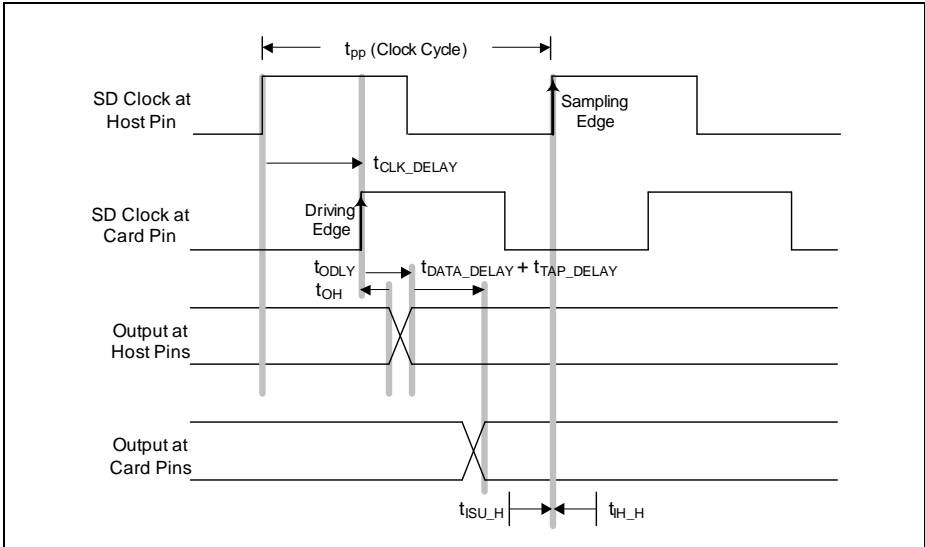
$$t_{CLK\_DELAY} < t_{WL} + t_{OH\_F} + t_{DATA\_DELAY} + t_{TAP\_DELAY} - t_{IH} \quad (4)$$

$$t_{CLK\_DELAY} < 20 + t_{DATA\_DELAY} + t_{TAP\_DELAY} - 5$$

$$t_{DATA\_DELAY} < 15 + t_{CLK\_DELAY} + t_{TAP\_DELAY}$$

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

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



**Figure 25 Full-Speed Input Path**

**Full-Speed Read Meeting Setup (Maximum Delay)**

The following equations show how to calculate the allowed combined propagation delay range of the SD\_CLK and SD\_DAT/CMD signals on the PCB.

(5)

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ODLY} + t_{ISU\_F} < 0,5 \times t_{pp}$$

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} < 0,5 \times t_{pp} - t_{ODLY} - t_{ISU\_F} - t_{TAP\_DELAY}$$

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} < 20 - 14 - 2 - t_{TAP\_DELAY}$$

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} < 4 - t_{TAP\_DELAY}$$

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

**Electrical Parameters**

**Full-Speed Read Meeting Hold (Minimum Delay)**

The following equations show how to calculate the allowed combined propagation delay range of the SD\_CLK and SD\_DAT/CMD signals on the PCB.

(6)

$$t_{\text{CLK\_DELAY}} + t_{\text{OH}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} > t_{\text{IH\_F}}$$

$$t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} > t_{\text{IH\_F}} - t_{\text{OH}} - t_{\text{TAP\_DELAY}}$$

$$t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} > 2 - t_{\text{TAP\_DELAY}}$$

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 48 SDMMC Timing for High-Speed Mode**

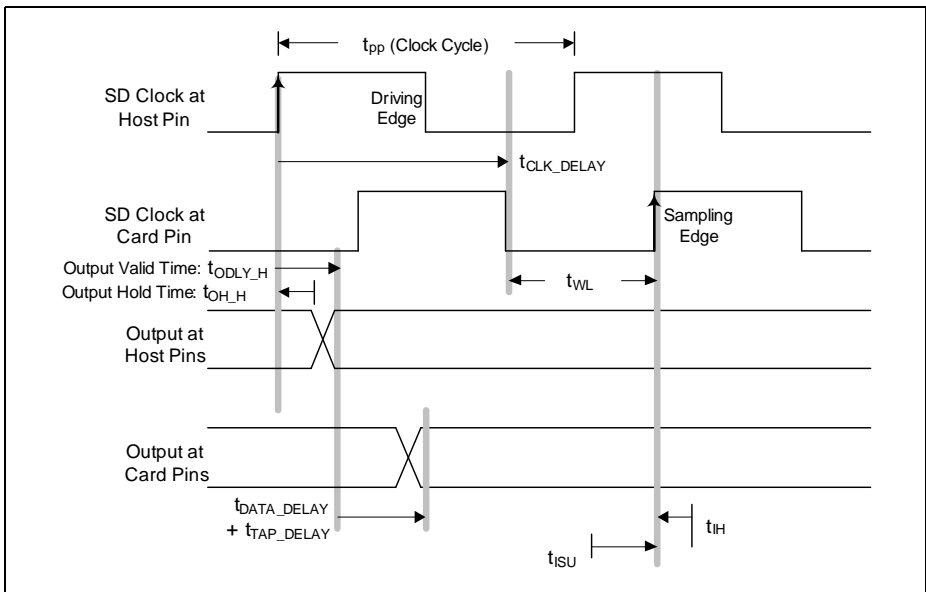
Parameter	Symbol	Values	Unit		Note/ Test Condition
			Min.	Max.	
Clock frequency in high speed transfer mode ( $1/t_{\text{pp}}$ )	$f_{\text{pp}}$ CC	0	48	MHz	
Clock cycle in high speed transfer mode	$t_{\text{pp}}$ CC	20	–	ns	
Clock low time	$t_{\text{WL}}$ CC	7	–	ns	
Clock high time	$t_{\text{WH}}$ 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 49 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	$t_{ISU}$	6	–	ns	
SD card input hold time	$t_{IH}$	2	–	ns	
SD card output valid time	$t_{ODLY}$	–	14	ns	
SD card output hold time	$t_{OH}$	2.5	–	ns	

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

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



**Figure 26 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:

(7)

$$t_{ODLY\_H} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ISU} < t_{WL}$$

With clock delay:

(8)

$$t_{ODLY\_H} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ISU} < t_{WL} + t_{CLK\_DELAY}$$

(9)

$$t_{DATA\_DELAY} + t_{TAP\_DELAY} - t_{CLK\_DELAY} < t_{WL} - t_{ISU} - t_{ODLY\_H}$$

$$t_{DATA\_DELAY} - t_{CLK\_DELAY} < t_{WL} - t_{ISU} - t_{ODLY\_H} - t_{TAP\_DELAY}$$

$$t_{DATA\_DELAY} - t_{CLK\_DELAY} < 10 - 6 - 14 - t_{TAP\_DELAY}$$

$$t_{DATA\_DELAY} - t_{CLK\_DELAY} < -10 - t_{TAP\_DELAY}$$

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

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

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

(10)

$$t_{CLK\_DELAY} < t_{WL} + t_{OH\_H} + t_{DATA\_DELAY} + t_{TAP\_DELAY} - t_{IH}$$

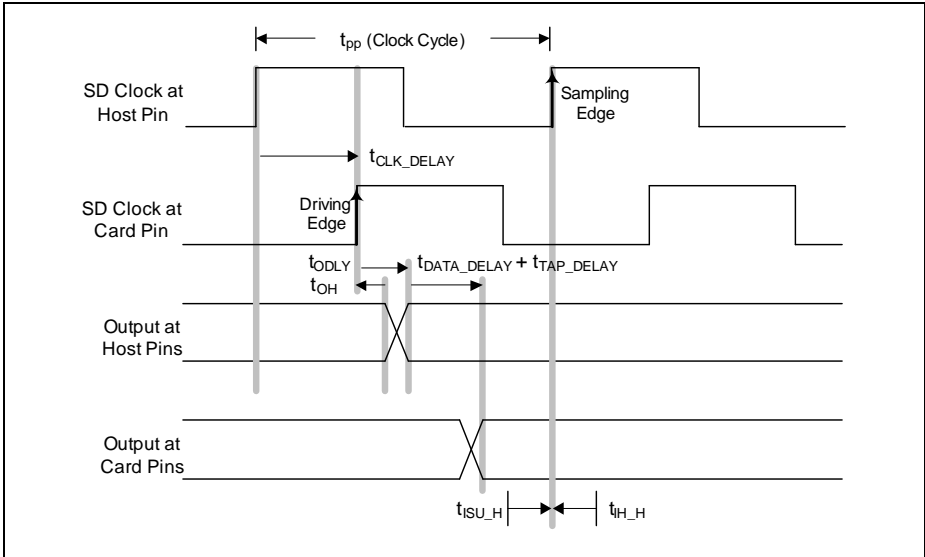
$$t_{CLK\_DELAY} - t_{DATA\_DELAY} < t_{WL} + t_{OH\_H} + t_{TAP\_DELAY} - t_{IH}$$

$$t_{CLK\_DELAY} - t_{DATA\_DELAY} < 10 + 2 + t_{TAP\_DELAY} - 2$$

$$t_{CLK\_DELAY} - t_{DATA\_DELAY} < 10 + t_{TAP\_DELAY}$$

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

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



**Figure 27 High-Speed Input Path**

**High-Speed Read Meeting Setup (Maximum Delay)**

The following equations show how to calculate the allowed combined propagation delay range of the SD\_CLK and SD\_DAT/CMD signals on the PCB.

(11)

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} + t_{TAP\_DELAY} + t_{ODLY} + t_{ISU\_H} < t_{pp}$$

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} < t_{pp} - t_{ODLY} - t_{ISU\_H} - t_{TAP\_DELAY}$$

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} < 20 - 14 - 2 - t_{TAP\_DELAY}$$

$$t_{CLK\_DELAY} + t_{DATA\_DELAY} < 4 - t_{TAP\_DELAY}$$

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

**High-Speed Read Meeting Hold (Minimum Delay)**

The following equations show how to calculate the allowed combined propagation delay range of the SD\_CLK and SD\_DAT/CMD signals on the PCB.

(12)

$$t_{\text{CLK\_DELAY}} + t_{\text{OH}} + t_{\text{DATA\_DELAY}} + t_{\text{TAP\_DELAY}} > t_{\text{IH\_H}}$$

$$t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} > t_{\text{IH\_H}} - t_{\text{OH}} - t_{\text{TAP\_DELAY}}$$

$$t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} > 2 - 2,5 - t_{\text{TAP\_DELAY}}$$

$$t_{\text{CLK\_DELAY}} + t_{\text{DATA\_DELAY}} > -0,5 - t_{\text{TAP\_DELAY}}$$

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

### 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  $C_L = 16$  pF.*

#### 3.3.10.1 EBU Asynchronous Timing

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

**Table 50 Common Timing Parameters for all Asynchronous Timings**

Parameter		Sym bol	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. $C_L = 16$ pF.	CC	$t_a$	-1	1.5	ns	sharp
			-2	1		medium
AD(24:16) output delay	to ADV rising	CC	$t_{13}$	-5.5	2	–
AD(24:16) output delay	edge, multiplexed read / write	CC	$t_{14}$	-5.5	2	–

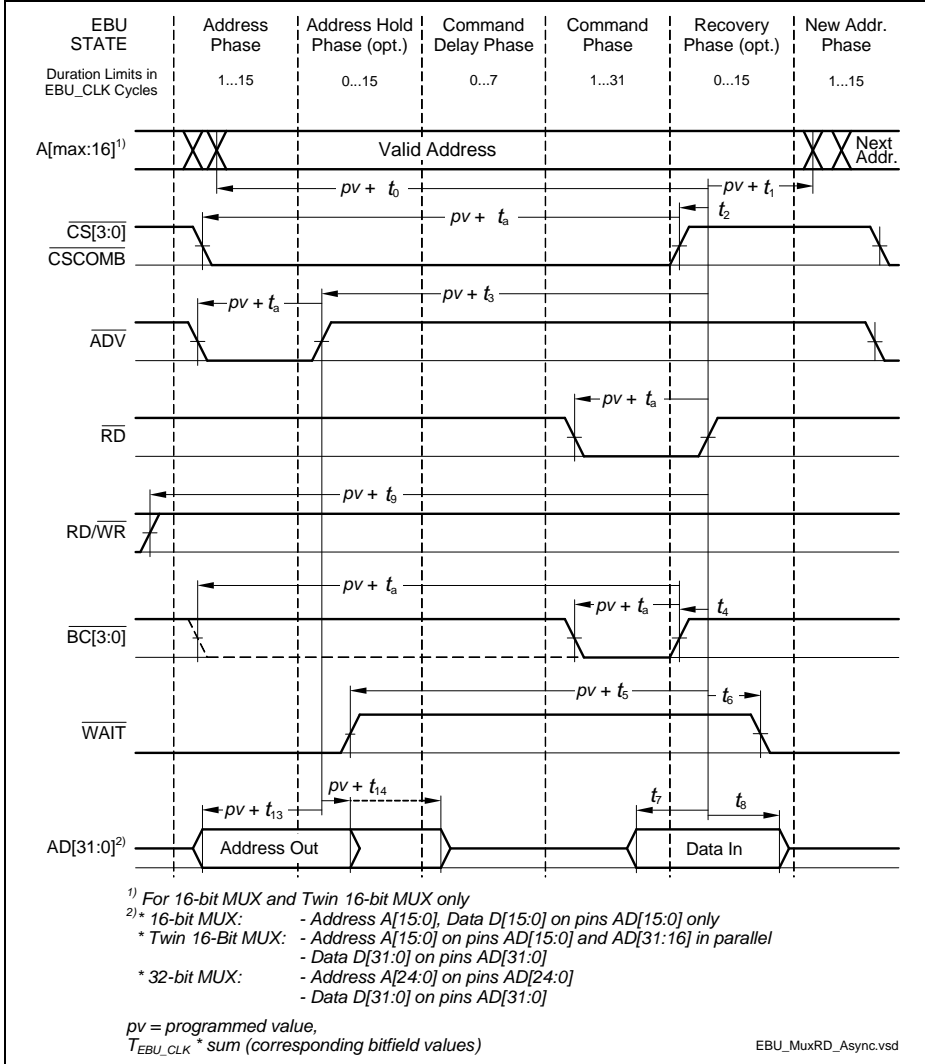


**Read Timing**

**Table 51 Asynchronous Read Timing, Multiplexed and Demultiplexed**

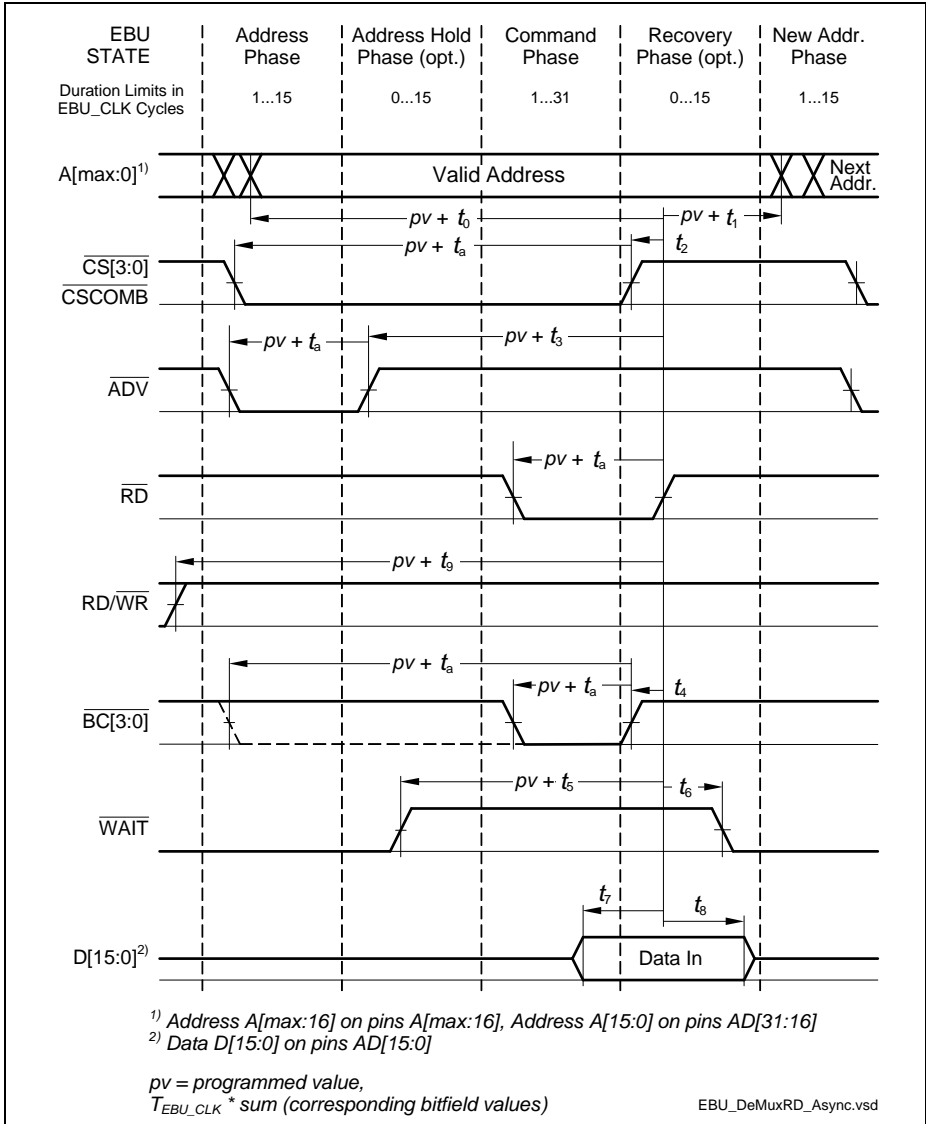
Parameter		Symbol	Limit Values		Unit	
			Min.	Max.		
A(24:16) output delay	to $\overline{RD}$ rising edge, deviation from the ideal programmed value.	CC	$t_0$	-2.5	2.5	ns
A(24:16) output delay		CC	$t_1$	-2.5	2.5	
$\overline{CS}$ rising edge		CC	$t_2$	-2	2.5	
$\overline{ADV}$ rising edge		CC	$t_3$	-1.5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

**Multiplexed Read Timing**



**Figure 28 Multiplexed Read Access**

Demultiplexed Read Timing



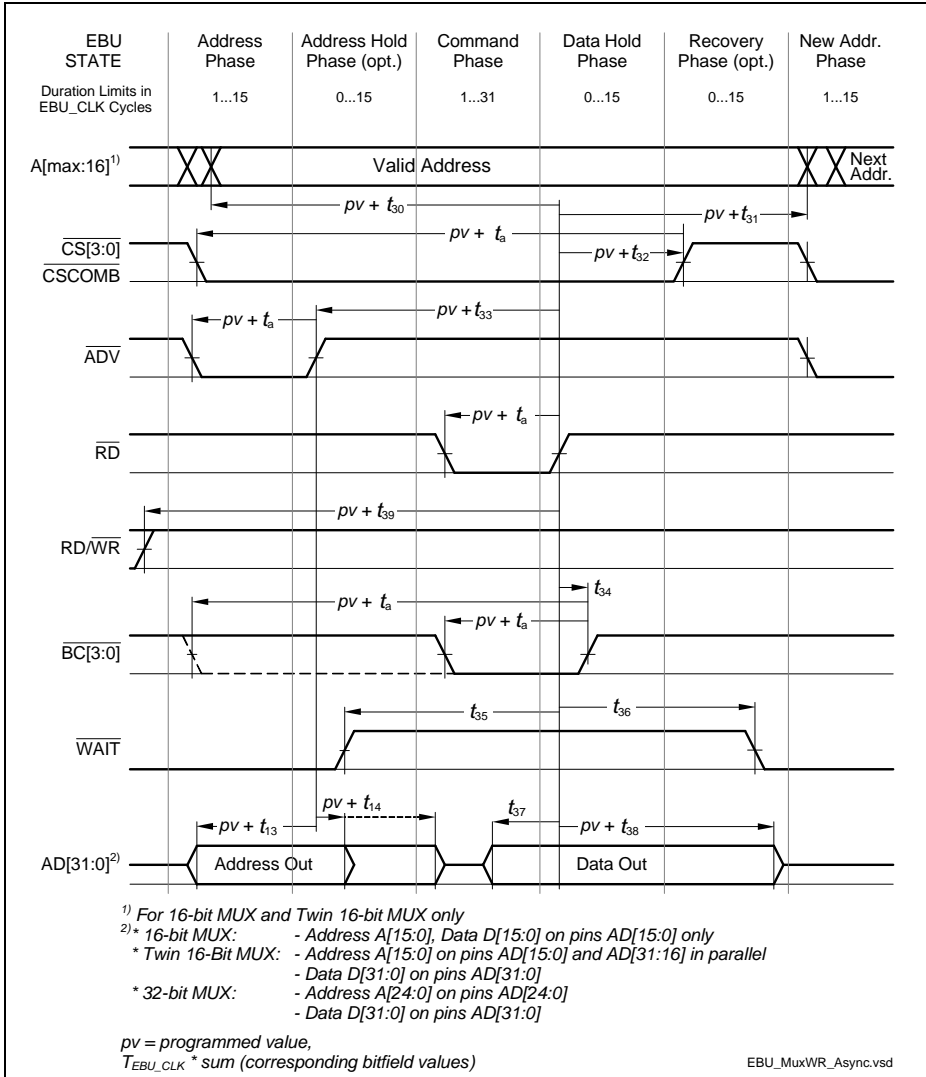
**Figure 29 Demultiplexed Read Access**

**Write Timing**

**Table 52 Asynchronous Write Timing, Multiplexed and Demultiplexed**

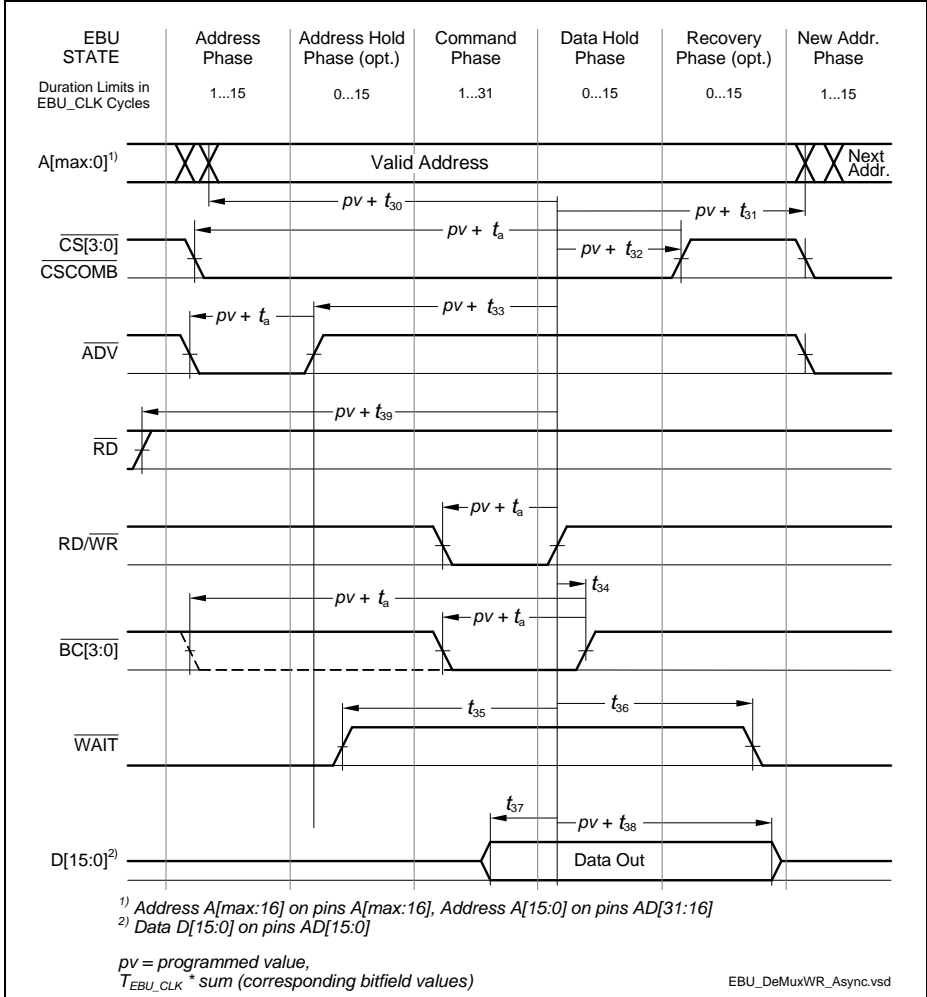
Parameter		Symbol	Limit Values		Unit	
			Min.	Max.		
A(24:0) output delay	to RD/ $\overline{\text{WR}}$ rising edge, deviation from the ideal programmed value.	CC	$t_{30}$	-2.5	2.5	ns
A(24:0) output delay		CC	$t_{31}$	-2.5	2.5	
$\overline{\text{CS}}$ rising edge		CC	$t_{32}$	-2	2	
$\overline{\text{ADV}}$ rising edge		CC	$t_{33}$	-2	4.5	
$\overline{\text{BC}}$ rising edge		CC	$t_{34}$	-2.5	2	
$\overline{\text{WAIT}}$ input setup		SR	$t_{35}$	12	–	
$\overline{\text{WAIT}}$ 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 / $\overline{\text{WR}}$ output delay		CC	$t_{39}$	-2.5	1.5	

Multiplexed Write Timing



**Figure 30 Multiplexed Write Access**

Demultiplexed Write Timing



**Figure 31 Demultiplexed Write Access**

### 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  $C_L = 16$  pF.*

**Table 53 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	–
$\overline{RD}$ and $\overline{RD}/\overline{WR}$ active/inactive after BFCLKO active edge <sup>1)</sup>	$t_{12}$	CC	-2	–	2	ns	–
$\overline{CSx}$ output delay from BFCLKO active edge <sup>1)</sup>	$t_{21}$	CC	-2.5	–	1.5	ns	–
$\overline{ADV}$ active/inactive after BFCLKO active edge <sup>2)</sup>	$t_{22}$	CC	-2	–	2	ns	–
$\overline{BAA}$ 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	–
$\overline{WAIT}$ setup (low or high) to BFCLKI rising edge <sup>3)</sup>	$t_{25}$	SR	3	–	–	ns	–
$\overline{WAIT}$ 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>.

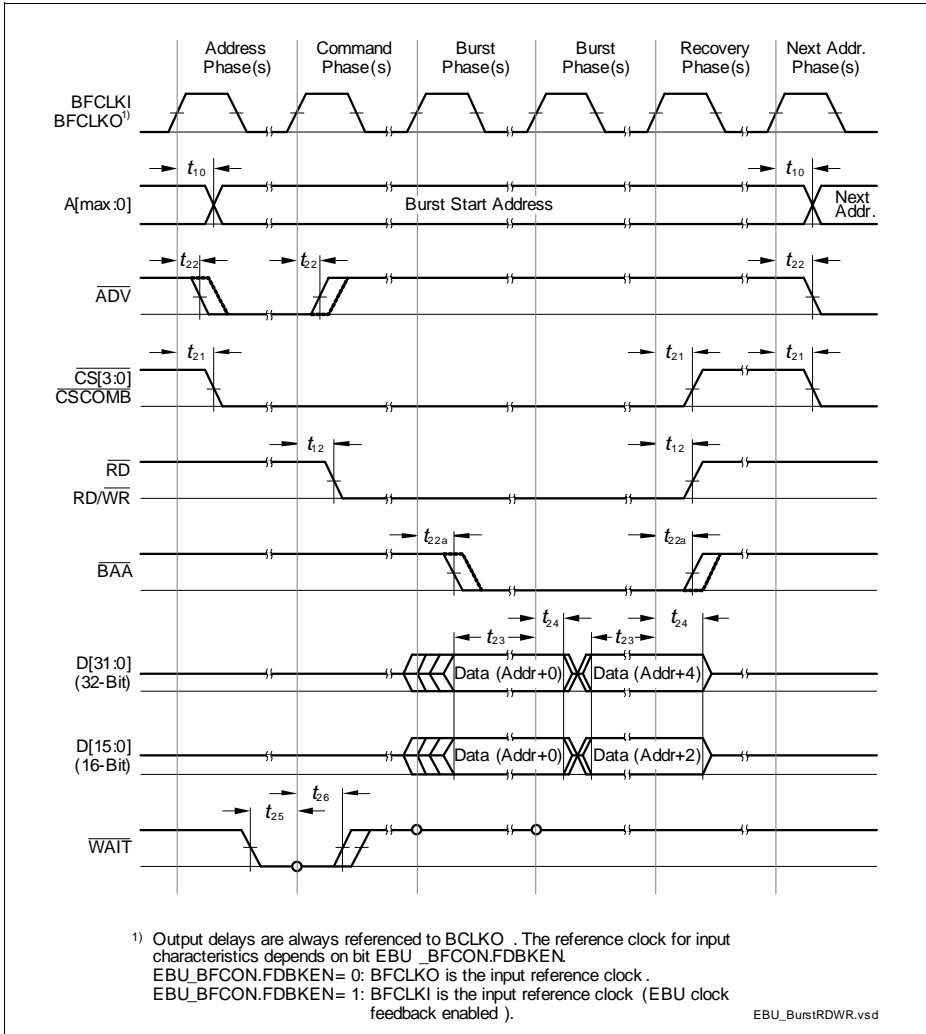
For BUSCONx.EBSE = 1 and other values of BUSAPx.EXTCLK, ADV and BAA will be delayed by 1/2 of the internal bus clock period  $T_{CPU} = 1 / f_{CPU}$ .

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.

**Electrical Parameters**

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.



**Figure 32 EBU Burst Mode Read / Write Access Timing**



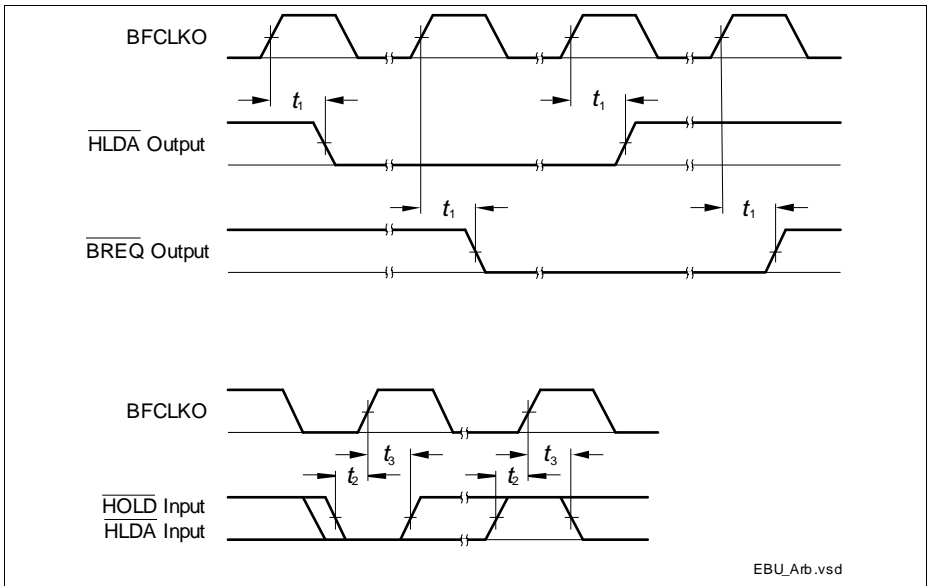
### 3.3.10.3 EBU Arbitration Signal Timing

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

*Note: Operating Conditions apply.*

**Table 54 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	$C_L = 50$ pF
Data setup to BFCLKO falling edge	$t_2$ SR	11	–	–	ns	–
Data hold from BFCLKO falling edge	$t_3$ SR	2	–	–	ns	–



**Figure 33 EBU Arbitration Signal Timing**

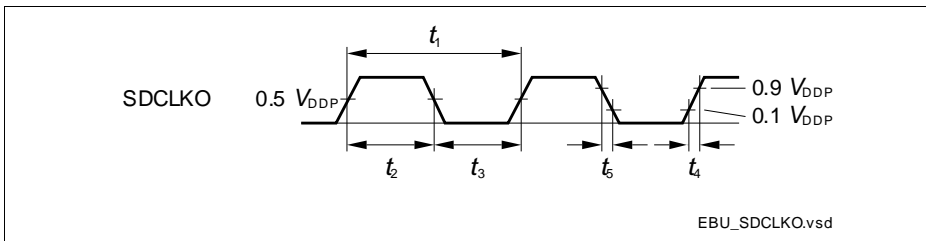
### 3.3.10.4 EBU SDRAM Access Timing

*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  $C_L = 16$  pF.*

**Table 55 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	–

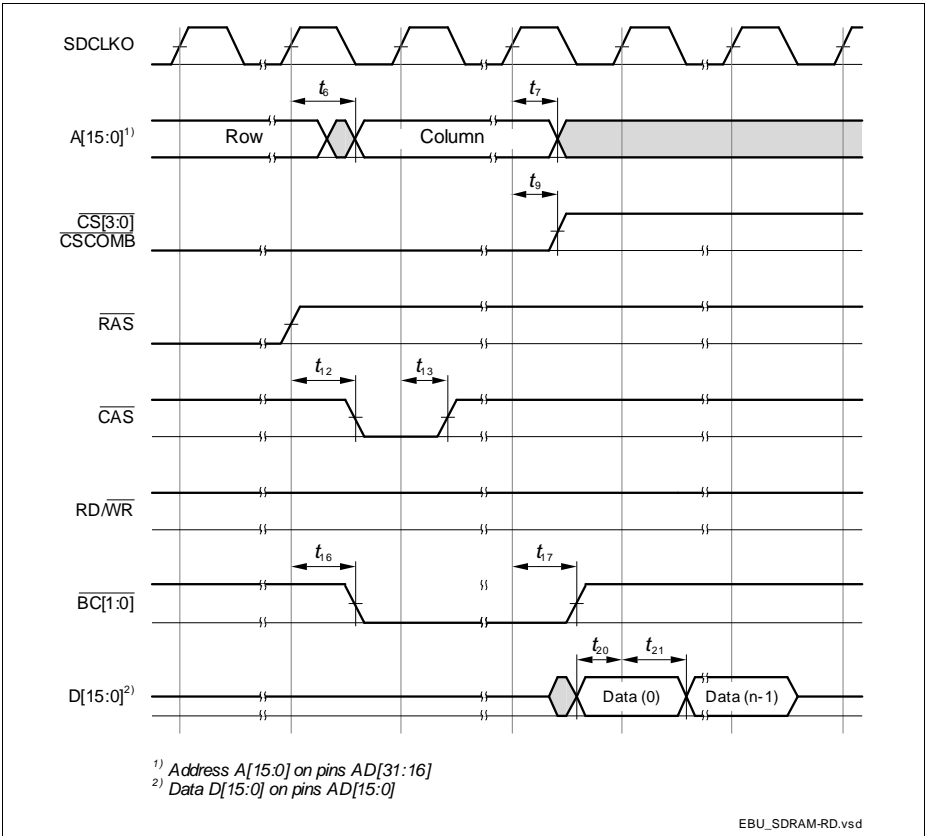


**Figure 34 EBU SDRAM Access CLKOUT Timing**

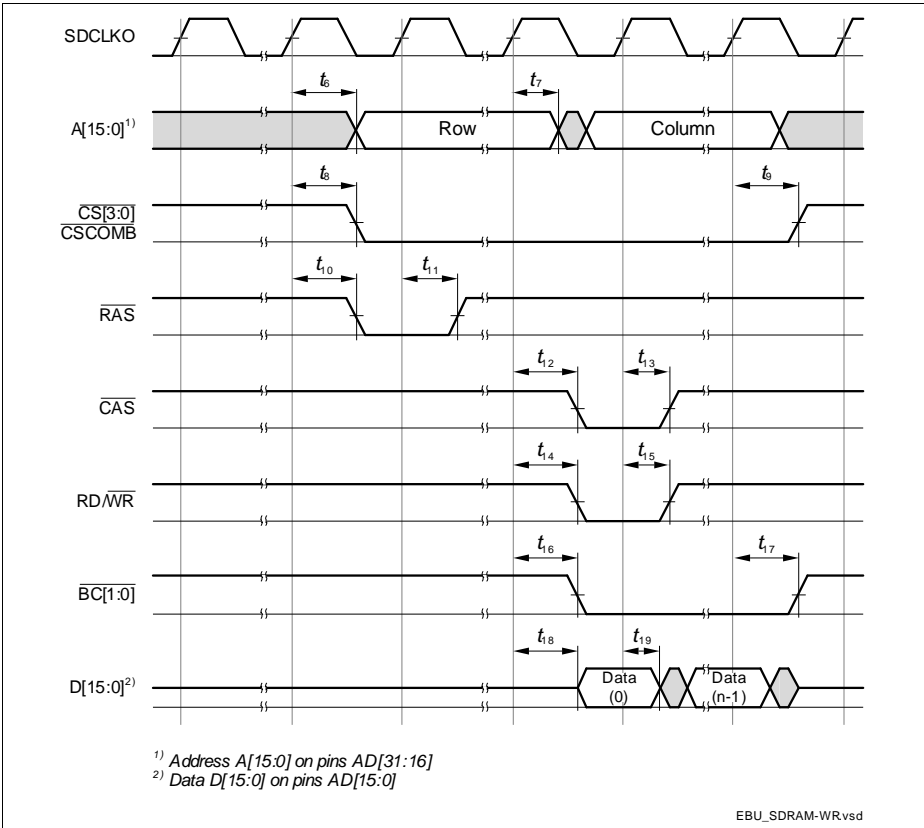
**Table 56 EBU SDRAM Access Signal Timing Parameters**

Parameter		Symbol	Limit Values		Unit	
			Min.	Max.		
A(15:0) output valid	from SDCLKO low-to-high transition	CC	$t_6$	–	9	ns
A(15:0) output hold		CC	$t_7$	3	–	
$\overline{\text{CS}}(3:0)$ low		CC	$t_8$	–	9	
$\overline{\text{CS}}(3:0)$ high		CC	$t_9$	3	–	
$\overline{\text{RAS}}$ low		CC	$t_{10}$	–	9	
$\overline{\text{RAS}}$ high		SR	$t_{11}$	3	–	
$\overline{\text{CAS}}$ low		SR	$t_{12}$	–	9	
$\overline{\text{CAS}}$ high		CC	$t_{13}$	3	–	
$\overline{\text{RD}}/\overline{\text{WR}}$ low		CC	$t_{14}$	–	9	
$\overline{\text{RD}}/\overline{\text{WR}}$ high		CC	$t_{15}$	3	–	
$\overline{\text{BC}}(3:0)$ low		CC	$t_{16}$	–	9	
$\overline{\text{BC}}(3:0)$ 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 SDCLKO low-to-high transition	SR	$t_{20}$	4	–		

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



**Figure 35 EBU SDRAM Read Access Timing**



**Figure 36 EBU SDRAM Write Access Timing**

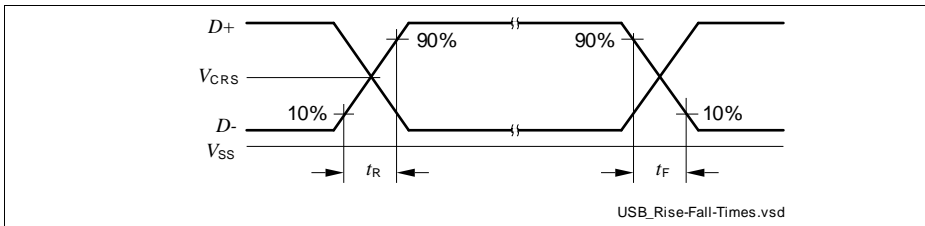
### 3.3.11 USB Interface Characteristics

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 57 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	$C_L = 50 \text{ pF}$



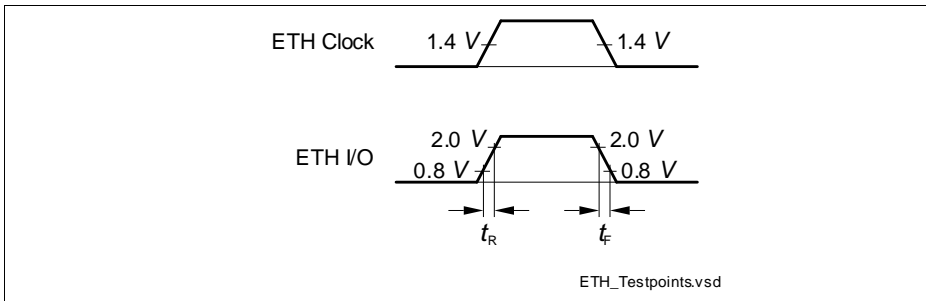
**Figure 37 USB Signal Timing**

### 3.3.12 Ethernet Interface (ETH) Characteristics

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

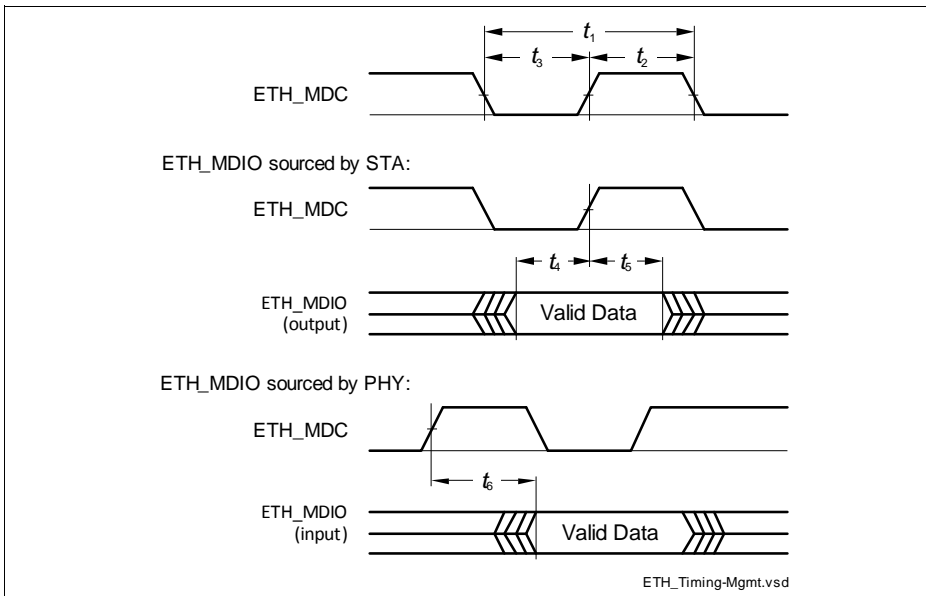


**Figure 38** ETH Measurement Reference Points

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

**Table 58 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 39 ETH Management Signal Timing**

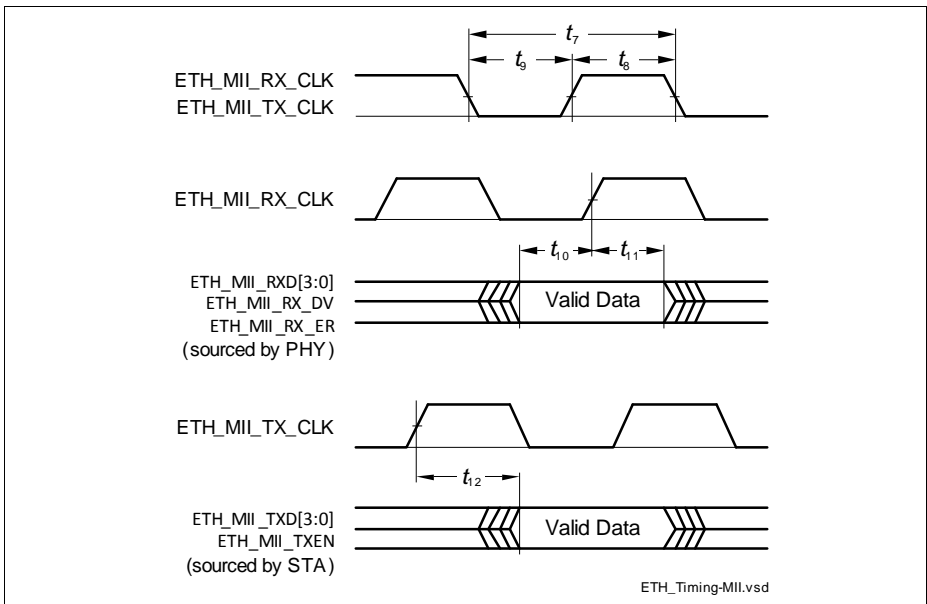


### 3.3.12.3 ETH MII Parameters

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

**Table 59 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	



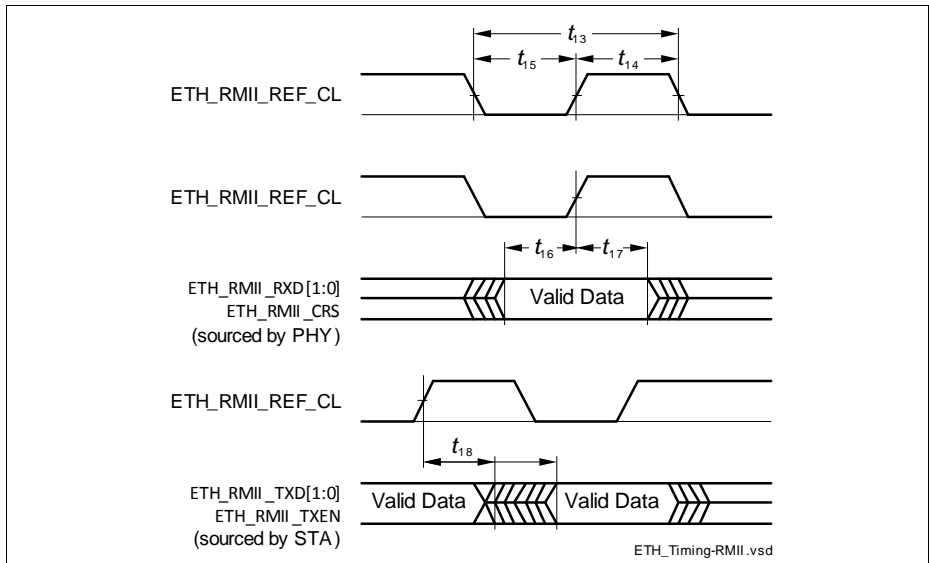
**Figure 40 ETH MII Signal Timing**

### 3.3.12.4 ETH RMII Parameters

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

**Table 60 ETH RMII Signal Timing Parameters**

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



**Figure 41 ETH RMII Signal Timing**

## 4 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 Package Parameters

**Table 61** provides the thermal characteristics of the packages used in XMC4500.

**Table 61 Thermal Characteristics of the Packages**

Parameter	Symbol	Limit Values		Unit	Package Types
		Min.	Max.		
Exposed Die Pad Dimensions	Ex × Ey CC	-	6.5 × 6.5	mm	PG-LQFP-144-18
		-	7.0 × 7.0	mm	PG-LQFP-100-11
Thermal resistance Junction-Ambient	R <sub>θJA</sub> CC	-	40.5	K/W	PG-LFBGA-144-10
		-	22.4	K/W	PG-LQFP-144-18 <sup>1)</sup>
		-	23.0	K/W	PG-LQFP-100-11 <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<sub>SS</sub>, independent of EMC and thermal requirements.*

#### 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<sub>θJA</sub>” 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

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

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

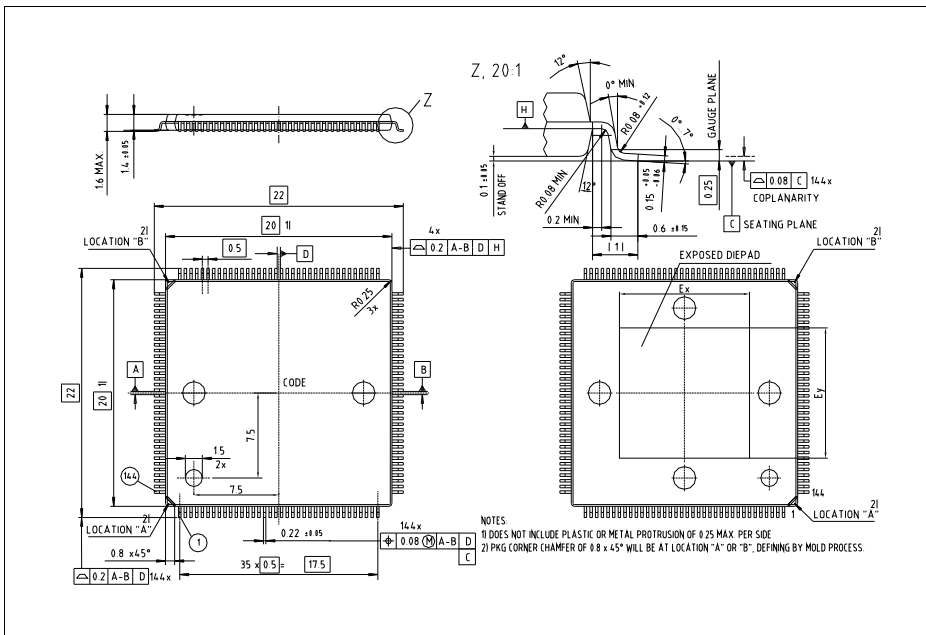
$$P_{IOSTAT} = \Sigma((V_{DDP} - V_{OH}) \times I_{OH}) + \Sigma(V_{OL} \times I_{OL})$$

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

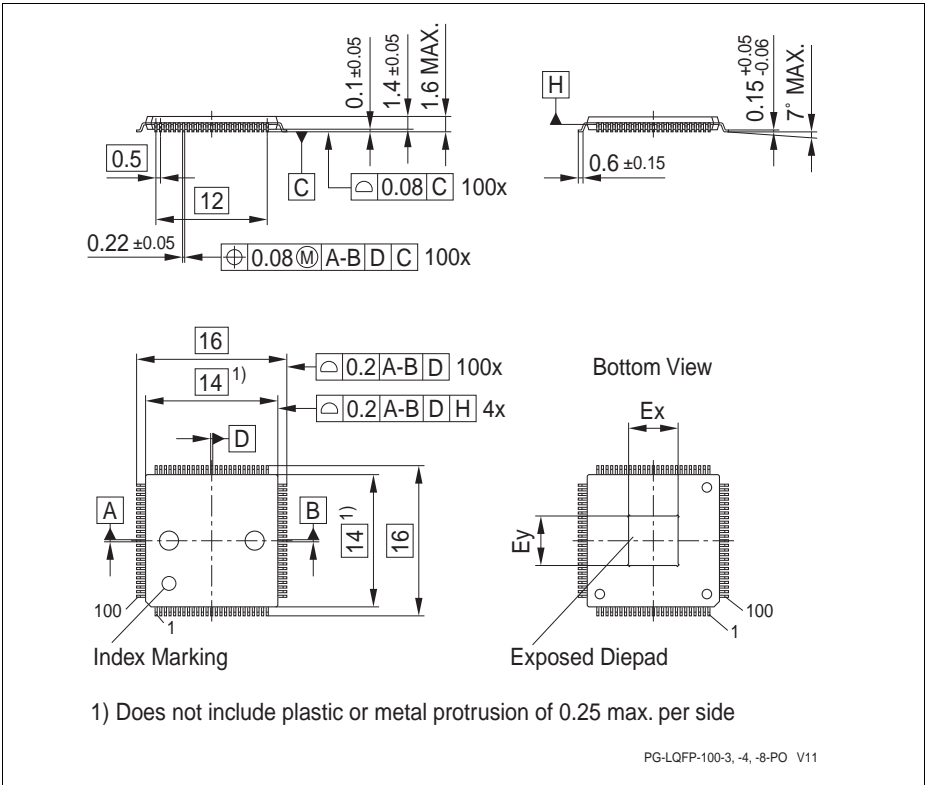
If the total power dissipation for a given system configuration exceeds the defined limit, countermeasures must be taken to ensure proper system operation:

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

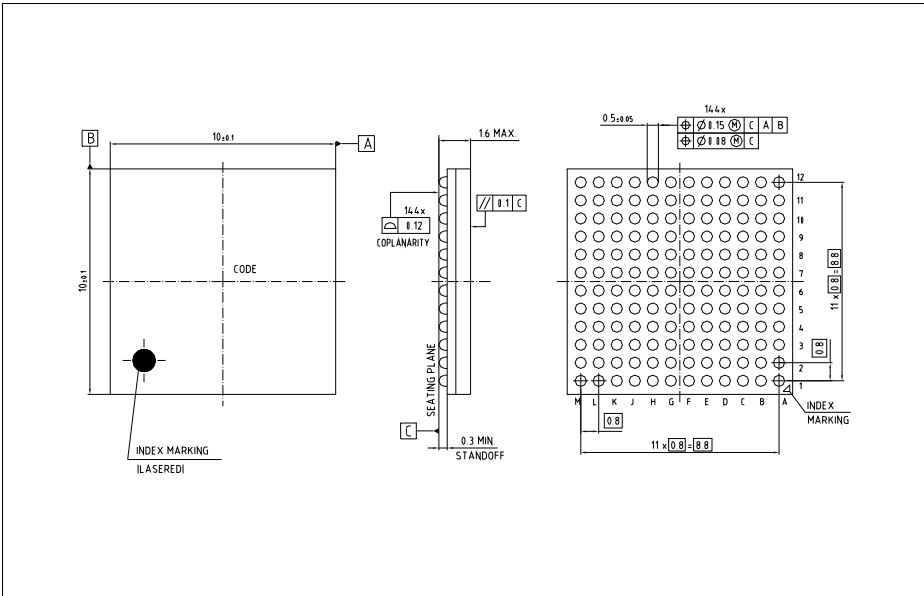
## 4.2 Package Outlines



**Figure 42 PG-LQFP-144-18 (Plastic Green Low Profile Quad Flat Package)**



**Figure 43 PG-LQFP-100-11 (Plastic Green Low Profile Quad Flat Package)**



**Figure 44 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>

### 4.3 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 62 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	–	–	2 000	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-020C

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[FF150R12MS4GBOSA1](#) [SPW21N50C3](#) [IRFS31N20D](#) [XMC1100T038X0064AAXUMA1](#) [BUZ30AHXKSA1](#) [FZ400R17KE3HOSA1](#)  
[IRF2807](#) [SPA07N60CFD](#) [SPP04N50C3XKSA1](#) [IRL2910](#) [IRFS52N15DHR](#) [BGA231N7E6327XTSA2](#) [IRGP20B60PD](#) [TDA21310XUSA1](#)  
[IRF7832](#) [IRF7422D2](#) [IRF7301](#) [IRFR3518](#) [TLE4296G V30](#) [IRFZ24N](#) [IDD05SG60C](#) [IRFP260N](#) [IRF7316](#) [IFX25001TCV10ATMA1](#)  
[IRFR3704](#) [IRLIZ44N](#) [BTT6030-2EKA](#) [BSP299 H6327](#) [IFX2931GV33XUMA1](#) [XMC1301T016X0016AAXUMA1](#) [IPU60R2K0C6BKMA1](#)  
[IPP80N06S4L-07](#) [BSR302N L6327](#) [IPU60R1K4C6](#) [IRF7805](#) [IRLR8103V](#) [BSL802SNH6327XTSA1](#) [IRFR3910](#) [IRFS59N10D](#)  
[IRFS59N10DTRR](#) [EVALM113023645ATOBO1](#) [EVALM11302TOBO1](#) [FD1000R33HE3-K](#)