

XMC4500

Microcontroller Series
for Industrial Applications

XMC4000 Family

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

Data Sheet

V1.0 2013-01

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Revision History: V1.0 2013-01

Previous Versions:

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V0.8, 2012-11

Page	Subjects
11	Reflect the supported Ethernet interface depending on the package (MII, RMII).
33	Characterization and qualification completed for PG-LQFP-144 and PG-LQFP-100.
56	Changed frequency dependency of the I_{DDP} current from 5 mA per 10 MHz to 6 mA per 10 MHz (see footnote 10).
66	Improved Fast Internal Clock Source parameters.
72	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.

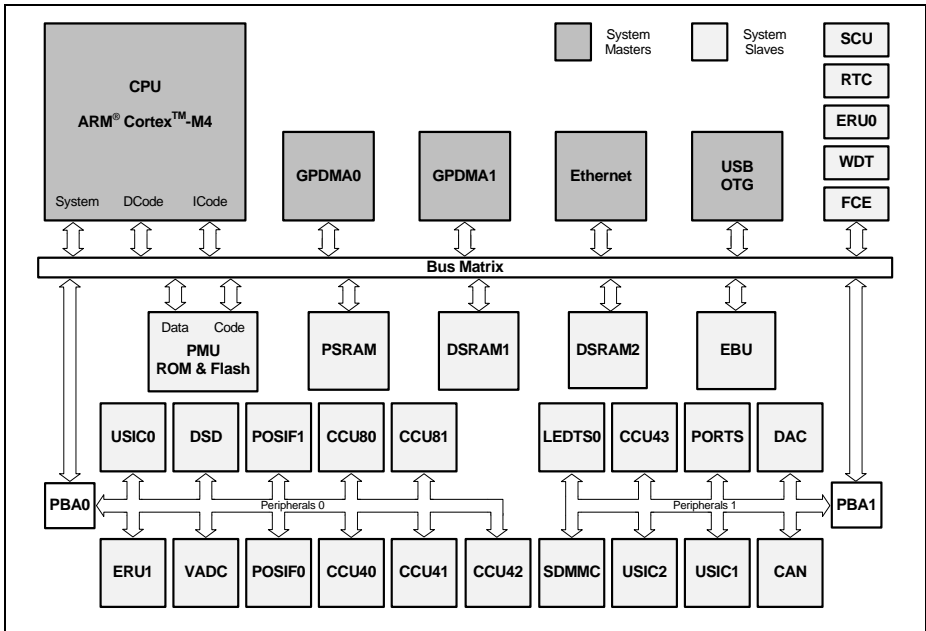


Figure 1 System Block Diagram

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 ¹⁾	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 ¹⁾	LEDTS Intf.	SDMMC Intf.	EBU Intf. ²⁾	ETH Intf. ³⁾	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 ¹⁾	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 _H – 0807 FFFF _H	0C00 0000 _H – 0C07 FFFF _H
768 Kbytes	0800 0000 _H – 080B FFFF _H	0C00 0000 _H – 0C0B FFFF _H
1,024 Kbytes	0800 0000 _H – 080F FFFF _H	0C00 0000 _H – 0C0F FFFF _H

Table 5 SRAM Memory Ranges

Total SRAM Size	Program SRAM	System Data SRAM	Communication Data SRAM
128 Kbytes	1000 0000 _H – 1000 FFFF _H	2000 0000 _H – 2000 FFFF _H	–
160 Kbytes	1000 0000 _H – 1000 FFFF _H	2000 0000 _H – 2000 FFFF _H	3000 0000 _H – 3000 7FFF _H

Table 6 AD Converter Channels¹⁾

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 _H	EES-AA, ES-AA
SCU_IDCHIP	0004 5003 _H	ES-AB, AB
JTAG IDCODE	101D B083 _H	EES-AA, ES-AA
JTAG IDCODE	301D B083 _H	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

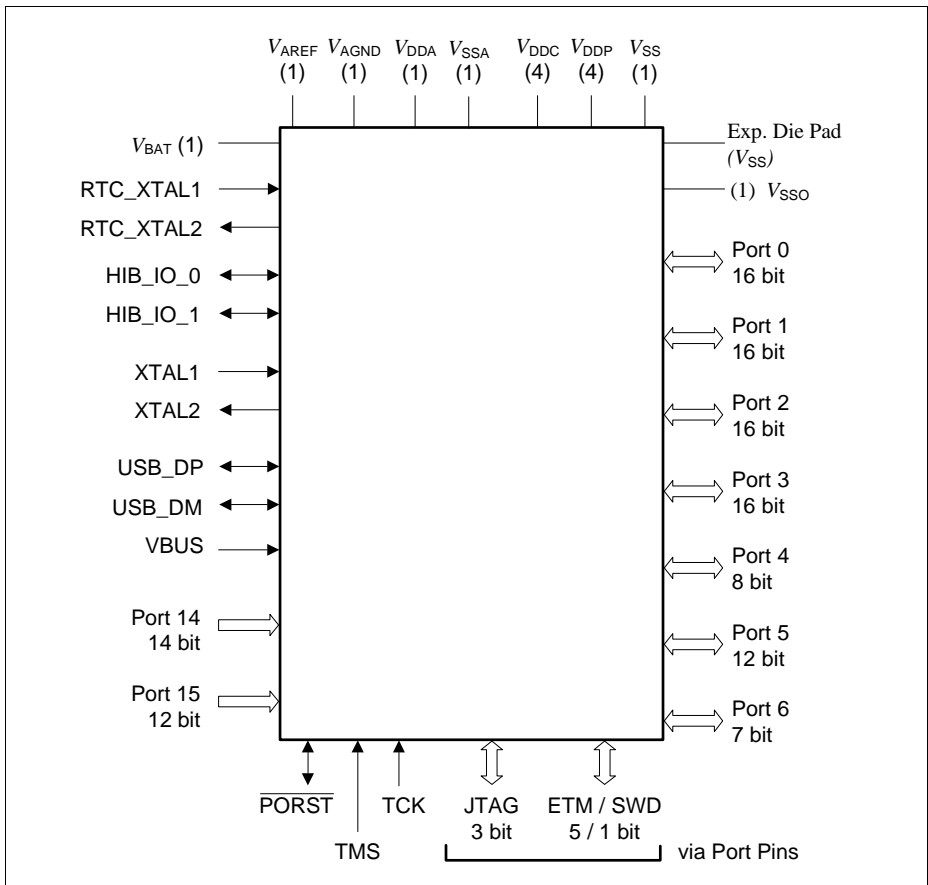


Figure 2 XMC4500 Logic Symbol PG-LQFP-144

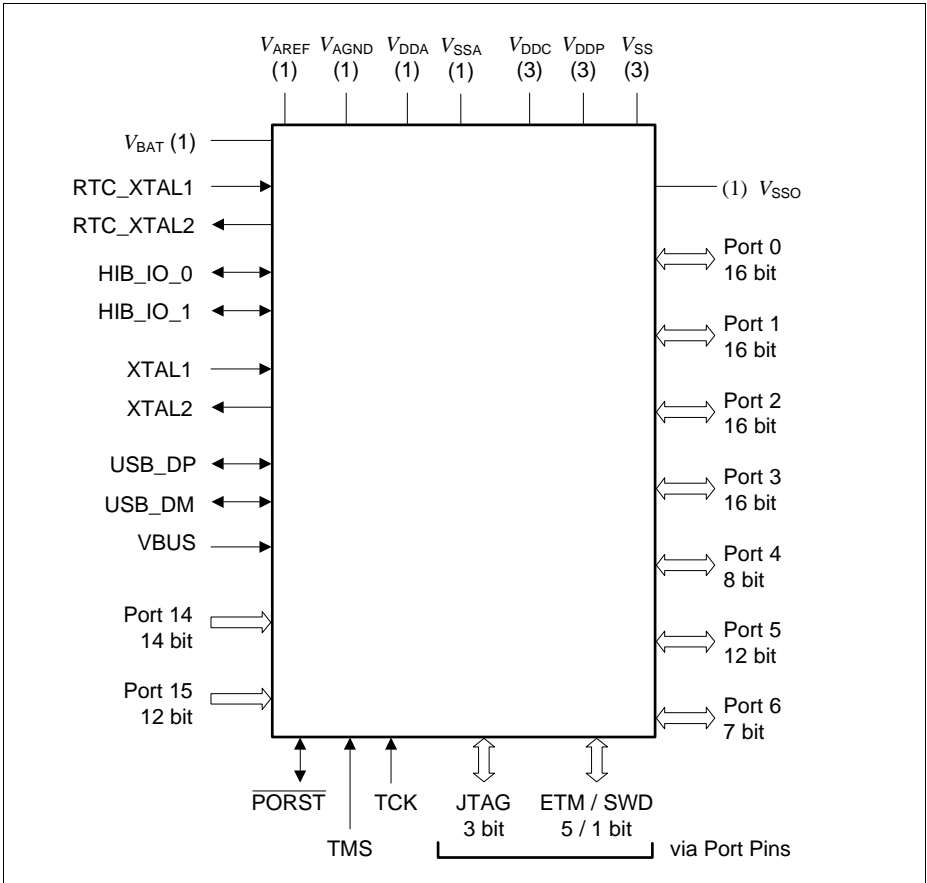


Figure 3 XMC4500 Logic Symbol PG-LFBGA-144

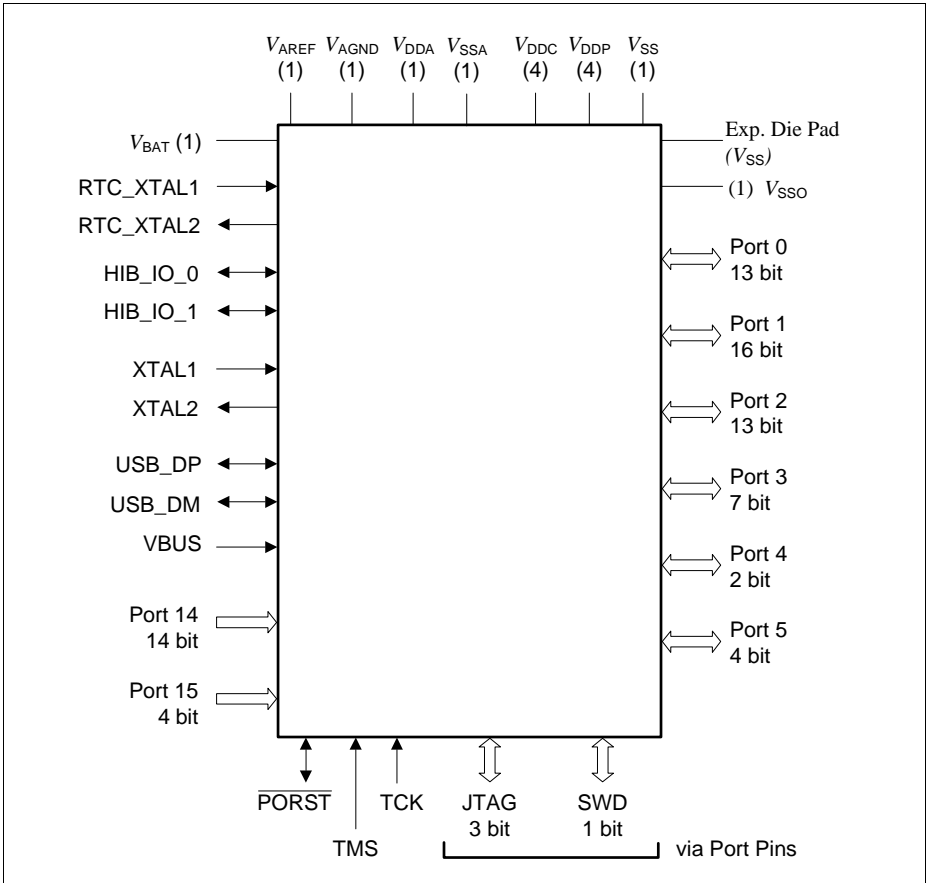


Figure 4 XMC4500 Logic Symbol PG-LQFP-100

2.2 Pin Configuration and Definition

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

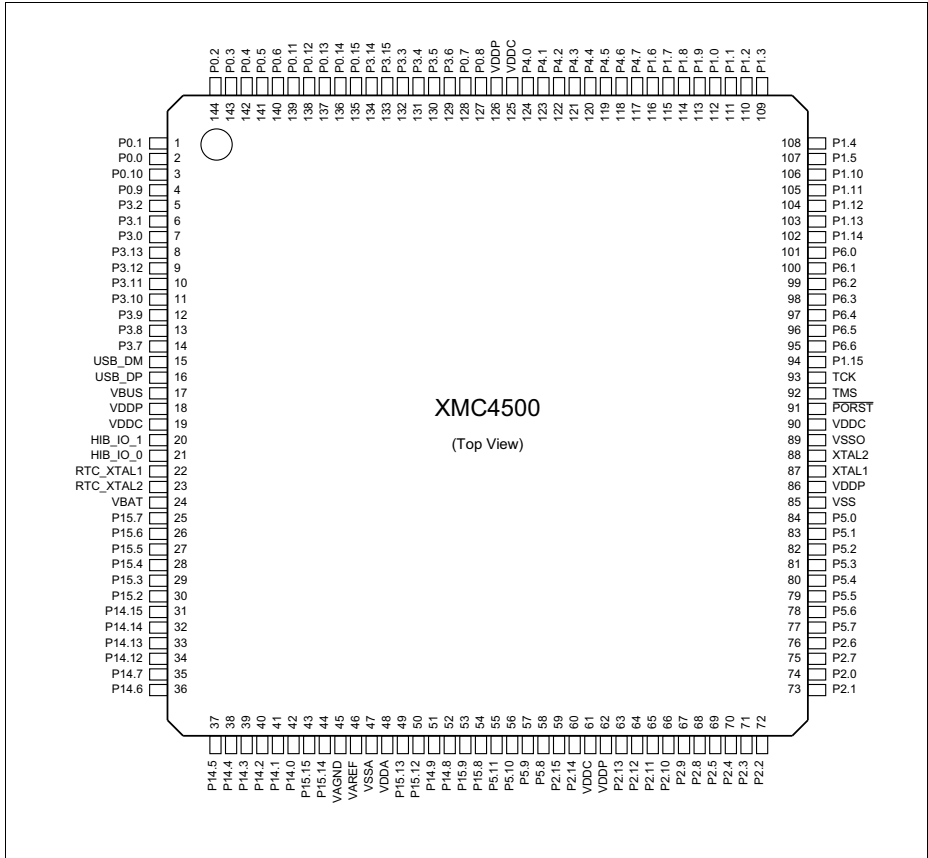


Figure 5 XMC4500 PG-LQFP-144 Pin Configuration (top view)

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)

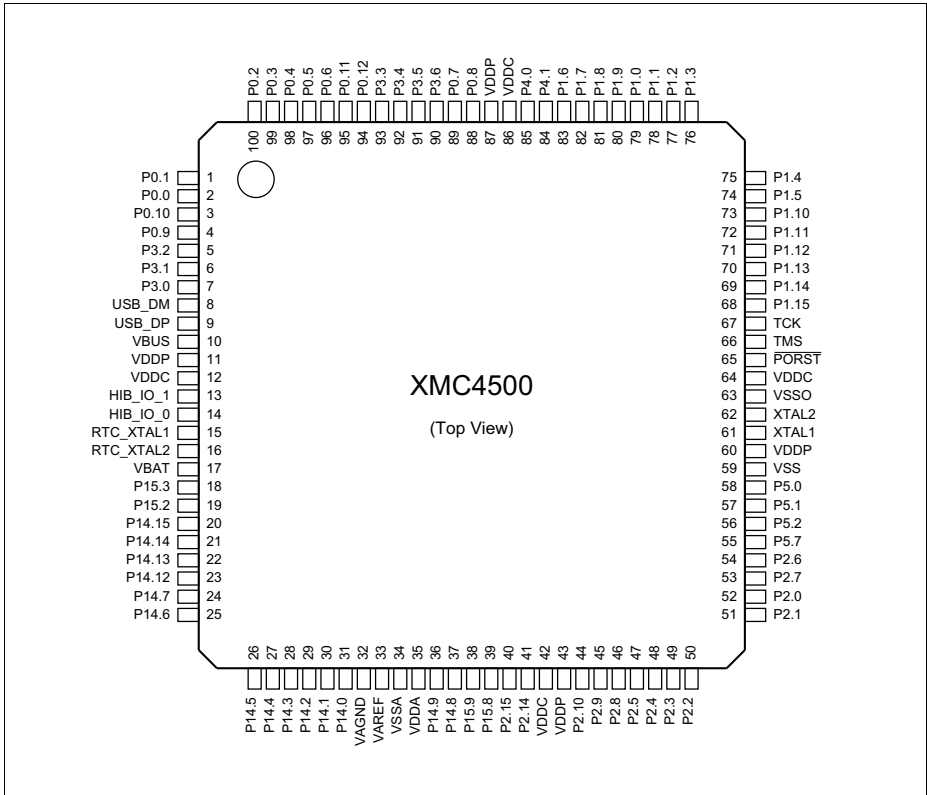


Figure 7 XMC4500 PG-LQFP-100 Pin Configuration (top view)

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.
$\overline{\text{PORST}}$	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>Exposed Die Pad The exposed die pad is connected internally to V_{SS}. 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_IOC.R.PC. The output value is directly driven by the respective module, with the pin characteristics controlled by the port registers (within the limits of the connected pad).

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

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

By Pn_HWSEL it is possible to select between different hardware “masters” (HWO0/HWI0, 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	Input	Input	Input
P0.0		CAN. NO_TXD	CCU80. DOUT21	LEDTS0. COL2					U1C1. DX0D	ETH0. CLK_RMIB	ERU0. 0B0					ETH0. CLKRXB
P0.1	USB. DRIVEVBUS	U1C1. DOUT0	CCU80. OUT11	LEDTS0. COL3						ETH0. CRS_DVB	ERU0. 0A0					ETH0. RXDVB
P0.2		U1C1. SELO1	CCU80. OUT01		U1C0. DOUT3	EBU. AD0	U1C0. HWIN3	EBU. D0	ETH0. RXDOB		ERU0. 3B3					
P0.3			CCU80. OUT20		U1C0. DOUT2	EBU. AD1	U1C0. HWIN2	EBU. D1	ETH0. RXD1B			ERU1. 3B0				
P0.4	ETH0. TX_EN		CCU80. OUT10		U1C0. DOUT1	EBU. AD2	U1C0. HWIN1	EBU. D2		U1C0. DX0A	ERU0. 2B3					
P0.5	ETH0. TXD0	U1C0. DOUT0	CCU80. OUT00		U1C0. DOUT0	EBU. AD3	U1C0. HWIN0	EBU. D3		U1C0. DX0B		ERU1. 3A0				
P0.6	ETH0. TXD1	U1C0. SELO0	CCU80. OUT30			EBU. ADV				U1C0. DX2A	ERU0. 3B2		CCU80. IN2B			
P0.7	WWDT. SERVICE_OUT	U0C0. SELO0			EBU. AD6	DB. TDI	EBU. D6	U0C0. DX2B	DSD. DIN1A	ERU0. 2B1			CCU80. IN1A	CCU80. IN1A	CCU80. IN2A	CCU80. IN3A
P0.8	SCU. EXTCLK	U0C0. SCLKOUT			EBU. AD7	DB. TRST	EBU. D7	U0C0. DX1B	DSD. DIN0A	ERU0. 2A1			CCU80. IN1B			
P0.9		U1C1. SELO0	CCU80. OUT12	LEDTS0. COL0	ETH0. MDO	EBU. DST	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. OUT31		SDMMC. RST	EBU. BREQ			ETH0. RXERB	U1C0. DX1A	ERU0. 3A2					
P0.12		U1C1. SELO0	CCU40. OUT3			EBU. HEDA		EBU. HEDA		U1C1. DX2B	ERU0. 2B2					
P0.13		U1C1. SCLKOUT	CCU40. OUT2							U1C1. DX1B	ERU0. 2A2					
P0.14		U1C0. SELO1	CCU40. OUT1		U1C1. DOUT3		U1C1. HWIN3									CCU42. IN3C
P0.15		U1C0. SELO2	CCU40. OUT0		U1C1. DOUT2		U1C1. HWIN2									CCU42. IN2C
P1.0	DSD. CGPWMM	U0C0. SELO0	CCU40. OUT3	ERU1. PDOUT3				U0C0. DX2A			ERU0. 3B0					CCU40. IN3A
P1.1	DSD. CGPWMP	U0C0. SCLKOUT	CCU40. OUT2	ERU1. PDOUT2		SDMMC. SDWC		U0C0. DX1A	POSIF0. IN2A	ERU0. 3A0						CCU40. IN2A
P1.2			CCU40. OUT1	ERU1. PDOUT1	U0C0. DOUT3	EBU. AD14	U0C0. HWIN3	EBU. D14		POSIF0. IN1A		ERU1. 2B0				CCU40. IN1A
P1.3		U0C0. MCLKOUT	CCU40. OUT0	ERU1. PDOUT0	U0C0. DOUT2	EBU. AD15	U0C0. HWIN2	EBU. D15		POSIF0. IN0A		ERU1. 2A0				CCU40. IN0A
P1.4	WWDT. SERVICE_OUT	CAN. NO_TXD	CCU80. OUT33	CCU81. OUT20	U0C0. DOUT1		U0C0. HWIN1		U0C0. DX0B	CAN. NT_RXDD	ERU0. 2B0					CCU41. IN1C
P1.5	CAN. NT_TXD	U0C0. DOUT0	CCU80. OUT23	CCU81. OUT10	U0C0. DOUT0		U0C0. HWIN0		U0C0. DX0A	CAN. NO_RXDA	ERU0. 2A0	ERU1. 3A0				CCU41. IN1C
																DSD. DN2B

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

Function	Outputs						Inputs								
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	Input	Input	Input
P1.6		U0C0_SCLKOUT			SDMMC_DATA1_OUT	EBU_AD10	SDMMC_DATA1_IN	EBU_D10	DSD_DIN2A						
P1.7		U0C1_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_MCLK0A					
P1.10	ETH0_MDC	U0C0_SCLKOUT	CCU81_OUT21				SDMMC_SDIOB						CCU41_IN0C		
P1.11		U0C0_SELO0	CCU81_OUT11		ETH0_MDO		ETH0_MDIC						CCU41_IN0C		
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_CGPVMMN	LEDS0_COL1	ETH0_MDO	EBU_AD20	ETH0_MDIB	EBU_D20			ERU0_0B3		CCU40_IN1C		
P2.1		CCU81_OUT11	DSD_CGPVMP	LEDS0_COLO	DB_TDO/TRACESWO	EBU_AD21		EBU_D21	ETH0_CLK_RMIA			ERU1_0B0	CCU40_IN0C		ETH0_CLKRXA
P2.2	VADC_EMUX00	CCU81_OUT01	CCU41_OUT3	LEDS0_LINE0	LEDS0_EXTENDED0	EBU_AD22	LEDS0_TSINA	EBU_D22	ETH0_RXDA0A	U0C1_DXA0	ERU0_1B2		CCU41_IN5A		
P2.3	VADC_EMUX01	U0C1_SELO0	CCU41_OUT2	LEDS0_LINE1	LEDS0_EXTENDED1	EBU_AD23	LEDS0_TSINA	EBU_D23	ETH0_RXDA1A	U0C1_DXA2A	ERU0_1A2	POSIF1_IN2A	CCU41_IN2A		
P2.4	VADC_EMUX02	U0C1_SCLKOUT	CCU41_OUT1	LEDS0_LINE2	LEDS0_EXTENDED2	EBU_AD24	LEDS0_TSINA	EBU_D24	ETH0_RXDA1A	U0C1_DXA1A	ERU0_0B2	POSIF1_IN1A	CCU41_IN1A		
P2.5	ETH0_TX_EN	U0C1_DOUT0	CCU41_OUT0	LEDS0_LINE3	LEDS0_EXTENDED3	EBU_AD25	LEDS0_TSINA	EBU_D25	ETH0_CRS_DVA	U0C1_DXB8	ERU0_0A2	POSIF1_IN0A	CCU41_IN0A		ETH0_CRS_DVA
P2.6	U0C0_SELO4	CCU80_OUT13	CCU80_OUT13	LEDS0_COL3	U0C0_DOUT3				DSD_DIN1B	CAN_N1_RXDA	ERU0_1B3		CCU40_IN0C		
P2.7	ETH0_MDC	CAN_N1_TXD	CCU80_OUT03	LEDS0_COL2					DSD_DIN0B			ERU1_1B0	CCU40_IN0C		
P2.8	ETH0_TXD0		CCU80_OUT32	LEDS0_LINE4	LEDS0_EXTENDED4	EBU_AD26	LEDS0_TSINA	EBU_D26	DAC_TRIGGER5				CCU40_IN0B	CCU40_IN2B	CCU40_IN3B
P2.9	ETH0_TXD1		CCU80_OUT22	LEDS0_LINE5	LEDS0_EXTENDED5	EBU_AD27	LEDS0_TSINA	EBU_D27	DAC_TRIGGER4				CCU41_IN0B	CCU41_IN1B	CCU41_IN2B
P2.10	VADC_EMUX10				DB_ETM_TRACEDATA_9	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	Input	Input	Input	
P2.13	ETH0_TXD3			ETH0_TXD1	DB_ETM_TRACEDATA0	EBU_AD31		EBU_D31					CCU43_IN2C			
P2.14	VADC_EMUX11	U1C0_DOUT0	CCU80_OUT21		DB_ETM_TRACECLK	EBU_B0C				U1C0_DX0D			CCU43_IN0B	CCU43_IN1B	CCU43_IN2B	CCU43_IN3B
P2.15	VADC_EMUX12		CCU80_OUT11	LEDT50_LINE6	LEDT50_EXTENDED6	EBU_BCT	LEDT50_TSINA		ETH0_COLA	U1C0_DX0C			CCU42_IN0B	CCU42_IN1B	CCU42_IN2B	CCU42_IN3B
P3.0	U2C1_SEL00	U1C1_SCLKOUT	CCU42_OUT0			EBU_RD				U1C1_DX1B			CCU80_IN2C	CCU81_IN0C		
P3.1		U1C1_SEL00				EBU_RDV EBU_WR				U1C1_DX2B		ERU0_0B1	CCU80_IN1C			
P3.2	USB_DRIVEVBUS	CAN_NO_TXD		LEDT50_COLA		EBU_CS0						ERU0_GA1	CCU80_IN0C			
P3.3		U1C1_SEL01	CCU42_OUT3		SDMMC_LED			EBU_WAIT			DSD_DIN3B		CCU42_IN2A	CCU80_IN0B		
P3.4	U2C1_MCLKOUT	U1C1_SEL02	CCU42_OUT2	DSD_MCLK3	SDMMC_BUS_POWER			EBU_HOLD		U2C1_DX0B	DSD_MCLK3B		CCU42_IN2A	CCU80_IN0B		
P3.5	U2C1_DOUT0	U1C1_SEL03	CCU42_OUT1	U0C1_DOUT0	SDMMC_CMD_OUT	EBU_AD4	SDMMC_CMD_IN	EBU_D4		U2C1_DX0A		ERU0_0B1	CCU42_IN1A			
P3.6	U2C1_SCLKOUT	U1C1_SEL04	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	LEDT50_LINE0						U2C0_DX0C						
P3.8	U2C0_DOUT0	U0C1_SEL03	CCU41_OUT2	LEDT50_LINE1						CAN_NZ_RXDB			POSIF1_IN2B			
P3.9	U2C0_SCLKOUT	CAN_N1_TXD	CCU41_OUT1	LEDT50_LINE2									POSIF1_IN1B			
P3.10	U2C0_SEL00	CAN_NO_TXD	CCU41_OUT0	LEDT50_LINE3	U0C1_DOUT3		U0C1_HWI3						POSIF1_IN0B			
P3.11	U2C1_DOUT0	U1C1_SEL02	CCU42_OUT3	LEDT50_LINE4	U0C1_DOUT2		U0C1_HWI2			CAN_N1_RXDB				CCU81_IN3C		
P3.12		U1C1_SEL01	CCU42_OUT2	LEDT50_LINE5	U0C1_DOUT1		U0C1_HWI1			CAN_NO_RXDC	U2C1_DX0D			CCU81_IN2C		
P3.13	U2C1_SCLKOUT	U1C1_DOUT0	CCU42_OUT1	LEDT50_LINE6	U0C1_DOUT0		U0C1_HWI0			U0C1_DX0D			CCU80_IN3C	U0C1_IN1C		
P3.14		U1C0_SEL03			U1C1_DOUT1		U1C1_HWI1			U1C1_DX0B			CCU42_IN1C			
P3.15		U1C1_DOUT0			U1C1_DOUT0		U1C1_HWI0			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_SEL00	U1C1_MCLKOUT	DSD_MCLK0	U0C1_SEL00	SDMMC_DATA3_OUT	EBU_AD9	SDMMC_DATA3_IN	EBU_D9		U2C1_DX2B	DSD_MCLK0B		U2C1_DX2A			
P4.2	U2C1_SEL01	U1C1_DOUT0		U2C1_SCLKOUT						U1C1_DX0C			U2C1_DX1A	CCU43_IN1C		
P4.3	U2C1_SEL02	U0C0_SEL05	CCU43OUT3											CCU43_IN3A		
P4.4		U0C0_SEL04	CCU43OUT2		U2C1_DOUT3		U2C1_HWI3							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	Input	Input	Input
P4.5		U0C0. SELO3	CCU43OUT1		U2C1. DOUT2		U2C1. HWIN2						CCU43. IN1A		
P4.6		U0C0. SELO2	CCU43OUT0		U2C1. DOUT1		U2C1. HWIN1		CAN. N2_RXDC				CCU43. IN0A		
P4.7		CAN. N2_TXD			U2C1. DOUT0		U2C1. HWIN0		U2C0. DX0C				CCU43. IN0C		
P5.0	U2C0. DOUT0	DSD. CGPWMIN	CCU81. OUT33		U2C0. DOUT0		U2C0. HWIN0		U2C0. DX0B	ETH0. RXD0D	U0C0. DX0D		CCU81. IN0A	CCU81. IN1A	CCU81. IN2A
P5.1	U0C0. DOUT0	DSD. CGPWMP	CCU81. OUT32		U2C0. DOUT1		U2C0. HWIN1		U2C0. DX0A	ETH0. RXD1D			CCU81. IN0B		
P5.2	U2C0. SCLKOUT		CCU81. OUT23						U2C0. DX1A	ETH0. CRS_DVD			CCU81. IN1B		ETH0. RXD0VD
P5.3	U2C0. SELO0		CCU81. OUT22		EBU. CKE	EBU. A20			U2C0. DX2A	ETH0. RXERD			CCU81. IN2B		
P5.4	U2C0. SELO1		CCU81. OUT13		EBU. RAS	EBU. A21				ETH0. CRSD			CCU81. IN3B		
P5.5	U2C0. SELO2		CCU81. OUT12		EBU. CAS	EBU. A22				ETH0. COLD					
P5.6	U2C0. SELO3		CCU81. OUT03		EBU. BFCLKO	EBU. A23				EBU. BFCLKI					
P5.7			CCU81. OUT02	LEDS0. COLA	U2C0. DOUT2		U2C0. HWIN2								
P5.8		U1C0. SCLKOUT	CCU80. OUT01		EBU. SDCLKO	EBU. CS2				ETH0. RXD2A	U1C0. DX1B				
P5.9		U1C0. SELO0	CCU80. OUT20	ETH0. TX_EN	EBU. BFCLKO	EBU. CS3				ETH0. RXD3A	U1C0. DX2B				
P5.10		U1C0. MCLKOUT	CCU80. OUT10	LEDS0. LINE7	LEDS0. EXTENDED7		LEDS0. TSIN7A				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. SDCLKO	EBU. A19			EBU. SDCLKI	ETH0. RXD2B					
P6.5		U0C1. MCLKOUT	CCU43OUT0		DB. ETM_TRACEDATA 1	EBU. BC2				DSD. DIN3A	ETH0. CLK_RMID				ETH0. CLKRXD
P6.6		DSD. MCLK3			DB. ETM_TRACEDATA 0	EBU. BC3				DSD. MCLK3A	ETH0. CLK_TXB				
P14.0										VADC. GOCH0					

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

Function	Outputs						Inputs									
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	Input	Input	Input	Input
P14.1									VADC_G0CH1							
P14.2									VADC_G0CH2	VADC_G1CH2						
P14.3									VADC_G0CH3	VADC_G1CH3				DI/N_NO_RXDB		
P14.4									VADC_G0CH4		VADC_G2CH0					
P14.5									VADC_G0CH5		VADC_G2CH1			POSIF0_INB		
P14.6									VADC_G0CH6					POSIF0_INB		G0ORC6
P14.7									VADC_G0CH7					POSIF0_INB		G0ORC7
P14.8					DAC_OUT_0					VADC_G1CH0		VADC_G3CH2		ETH0_RXDOC		
P14.9					DAC_OUT_1					VADC_G1CH1		VADC_G3CH3		ETH0_RXD1C		
P14.12										VADC_G1CH4						
P14.13										VADC_G1CH5						
P14.14										VADC_G1CH6						G1ORC6
P14.15										VADC_G1CH7						G1ORC7
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			ETH0_CLKRXC
P15.9											VADC_G3CH1		ETH0_CRS_DVC			ETH0_RXDVC
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	Input	Input	Input
USB_DP																
USB_DM																
HIB_IO_0	HIBOUT	WWDI. SERVICE_OUT								WAKEUPA						
HIB_IO_1	HIBOUT	WWDI. SERVICE_OUT								WAKEUPB						
TCK																
TMS					DB.TMS/ SWDIO											
PORST																
XTAL1										U0C0. DX0F	U0C1. DX0F	U1C0. DX0F	U1C1. DX0F	U2C0. DX0F	U2C1. DX0F	
XTAL2																
RTC_XTAL1												ERUD. FB1				
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 ¹⁾	ΣI_{IN}	SR	-25	–	+25	mA	
Absolute maximum sum of all input circuit currents during overload condition	ΣI_{IN}	SR	-100	–	+100	mA	

1) The port groups are defined in [Table 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 ¹⁾	I_{OVG} SR	–	–	20	mA	$\Sigma I_{OVx} $, for all $I_{OVx} < 0$ mA
		–	–	20	mA	$\Sigma I_{OVx} $, for all $I_{OVx} > 0$ mA
Absolute sum of all input circuit currents during overload condition	I_{OVS} SR	–	–	80	mA	ΣI_{OVG}

1) The port groups are defined in **Table 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	A1 (e.g. GPIO)	6 MHz	100 pF	No
			A1+ (e.g. serial I/Os)	25 MHz	50 pF	Series termination recommended
			A2 (e.g. ext. Bus)	80 MHz	15 pF	Series termination recommended

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 ¹⁾	3.3	3.63 ²⁾	V	
Core Supply Voltage	V_{DDC} CC	– ¹⁾	1.3	–	V	Generated internally
Digital ground voltage	V_{SS} SR	0	–	–	V	
ADC analog supply voltage	V_{DDA} SR	3.0	3.3	3.6 ²⁾	V	
Analog ground voltage for V_{DDA}	V_{SSA} SR	-0.1	0	0.1	V	
Battery Supply Voltage for Hibernate Domain	V_{BAT} SR	1.95	–	3.63	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 ³⁾	ΣI_{SC_PG} SR	–	–	20	mA	
Absolute sum of short circuit currents of the device	ΣI_{SC_D} SR	–	–	100	mA	

1) See also the Supply Monitoring thresholds, [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 μ 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	–	μA	¹⁾ $V_i \geq 0.6 \times V_{DDP}$
		–	10	μA	²⁾ $V_i \leq 0.36 \times V_{DDP}$
Pull-Up current	$ I_{PUH} $ CC	–	10	μA	²⁾ $V_i \geq 0.6 \times V_{DDP}$
		100	–	μA	¹⁾ $V_i \leq 0.36 \times V_{DDP}$
Input Hysteresis for pads of all A classes ³⁾	HYS_A CC	$0.1 \times V_{DDP}$	–	V	
$\overline{\text{PORST}}$ spike filter always blocked pulse duration	t_{SF1} CC	–	10	ns	
$\overline{\text{PORST}}$ spike filter pass-through pulse duration	t_{SF2} CC	100	–	ns	
$\overline{\text{PORST}}$ pull-down current	t_{SF2} CC	13	–	mA	$V_i = 1 \text{ V}$

- 1) Current required to override the pull device with the opposite logic level (“force current”).
With active pull device, at load currents between force and keep current the input state is undefined.
- 2) Load current at which the pull device still maintains the valid logic level (“keep current”).
With active pull device, at load currents between force and keep current the input state is undefined.
- 3) Hysteresis is implemented to avoid metastable states and switching due to internal ground bounce. It can not be guaranteed that it suppresses switching due to external system noise.

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 ¹⁾ = 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 ¹⁾ = 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 ¹⁾ = weak
		–	0.4	V	$I_{OL} \leq 2\ \text{mA}$; POD ¹⁾ = medium
Fall time	t_{FA1} CC	–	150	ns	$C_L = 20\ \text{pF}$; POD ¹⁾ = weak
		–	50	ns	$C_L = 50\ \text{pF}$; POD ¹⁾ = medium
Rise time	t_{RA1} CC	–	150	ns	$C_L = 20\ \text{pF}$; POD ¹⁾ = weak
		–	50	ns	$C_L = 50\ \text{pF}$; POD ¹⁾ = 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	μA	$0\text{ V} \leq V_i \leq V_{DDP}$
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 ¹⁾ = weak	V_{OHA1+} CC	$V_{DDP} - 0.4$	–	V	$I_{OH} \geq -400 \mu A$	
		2.4	–	V	$I_{OH} \geq -500 \mu A$	
Output high voltage, POD ¹⁾ = medium		$V_{DDP} - 0.4$	–	V	$I_{OH} \geq -1.4 mA$	
		2.4	–	V	$I_{OH} \geq -2 mA$	
Output high voltage, POD ¹⁾ = strong		$V_{DDP} - 0.4$	–	V	$I_{OH} \geq -1.4 mA$	
		2.4	–	V	$I_{OH} \geq -2 mA$	
Output low voltage		V_{OLA1+} CC	–	0.4	V	$I_{OL} \leq 500 \mu A$; POD ¹⁾ = weak
			–	0.4	V	$I_{OL} \leq 2 mA$; POD ¹⁾ = medium
	–		0.4	V	$I_{OL} \leq 2 mA$; POD ¹⁾ = strong	
Fall time	t_{FA1+} CC	–	150	ns	$C_L = 20 pF$; POD ¹⁾ = weak	
		–	50	ns	$C_L = 50 pF$; POD ¹⁾ = medium	
		–	28	ns	$C_L = 50 pF$; POD ¹⁾ = strong; edge = slow	
		–	16	ns	$C_L = 50 pF$; POD ¹⁾ = strong; edge = soft;	
Rise time	t_{RA1+} CC	–	150	ns	$C_L = 20 pF$; POD ¹⁾ = weak	
		–	50	ns	$C_L = 50 pF$; POD ¹⁾ = medium	
		–	28	ns	$C_L = 50 pF$; POD ¹⁾ = strong; edge = slow	
		–	16	ns	$C_L = 50 pF$; POD ¹⁾ = strong; edge = soft	

1) POD = Pin Out Driver

Table 20 Standard_Pads Class_A2

Parameter	Symbol	Values		Unit	Note / Test Condition
		Min.	Max.		
Input Leakage current	I_{OZA2} CC	-6	6	μA	$0\text{ V} \leq V_i < 0.5 \cdot V_{DDP} - 1\text{ V};$ $0.5 \cdot V_{DDP} + 1\text{ V} < V_i \leq V_{DDP}$
		-3	3	μA	$0.5 \cdot V_{DDP} - 1\text{ V} < V_i < 0.5 \cdot V_{DDP} + 1\text{ V}$
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 ⁵⁾	V_{AREF} SR	$V_{AGND} + 1$	–	$V_{DDA} + 0.05^{1)}$	V	
Analog reference ground ⁵⁾	V_{AGND} SR	$V_{SSM} - 0.05$	–	$V_{AREF} - 1$	V	
Analog reference voltage range ²⁾⁵⁾	$V_{AREF} - V_{AGND}$ SR	1	–	$V_{DDA} + 0.1$	V	
Analog input voltage	V_{AIN} SR	V_{AGND}	–	V_{DDA}	V	
Input leakage at analog inputs ³⁾	I_{OZ1} CC	-100	–	200	nA	$0.03 \times V_{DDA} < V_i < 0.97 \times V_{DDA}$
		-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	μA	$0 V \leq V_{AREF} \leq V_{DDA}$
Input leakage current at VAGND	I_{OZ3} CC	-1	–	1	μA	$0 V \leq V_{AGND} \leq V_{DDA}$
Internal ADC clock	f_{ADCI} CC	2	–	30	MHz	$V_{DDA} = 3.3 V$
Switched capacitance at the analog voltage inputs ⁴⁾	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 ⁵⁾⁶⁾	C_{AREFSW} CC	–	15	30	pF	
Total capacitance of the voltage reference inputs ⁵⁾	$C_{AREFTOT}$ CC	–	20	40	pF	

Electrical Parameters
Table 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;
Differential Non-Linearity Error ⁸⁾	$EA_{DNL_{CC}}$	-3	–	3	LSB	$V_{DDA} = 3.3 V$; $V_{AREF} = V_{DDA}$ ⁷⁾
Gain Error ⁸⁾	$EA_{GAIN_{CC}}$	-4	–	4	LSB	
Integral Non-Linearity ⁸⁾	$EA_{INL_{CC}}$	-3	–	3	LSB	
Offset Error ⁸⁾	$EA_{OFF_{CC}}$	-4	–	4	LSB	
Worst case ADC V_{DDA} power supply current per active converter	$I_{DDAA_{CC}}$	–	1.5	2	mA	during conversion $V_{DDP} = 3.6 V$, $T_J = 150\text{ }^{\circ}C$
Charge consumption on V_{AREF} per conversion ⁵⁾	$Q_{CONV_{CC}}$	–	30	–	pC	$0 V \leq V_{AREF} \leq V_{DDA}$ ⁹⁾
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 ± 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 $t_c = 550$ ns results in a typical average current of $I_{AREF} = 54.5\text{ }\mu A$.

Electrical Parameters

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

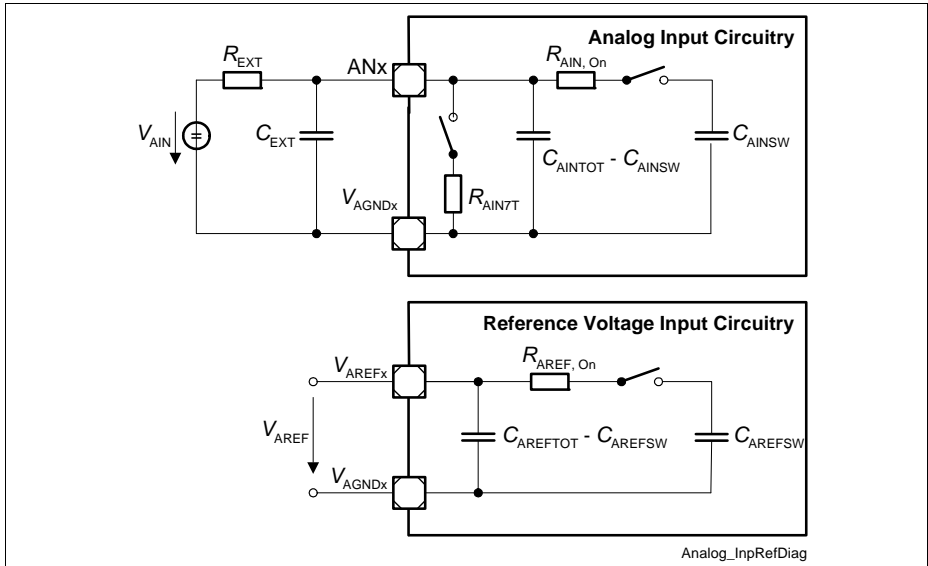


Figure 8 VADC Input Circuits

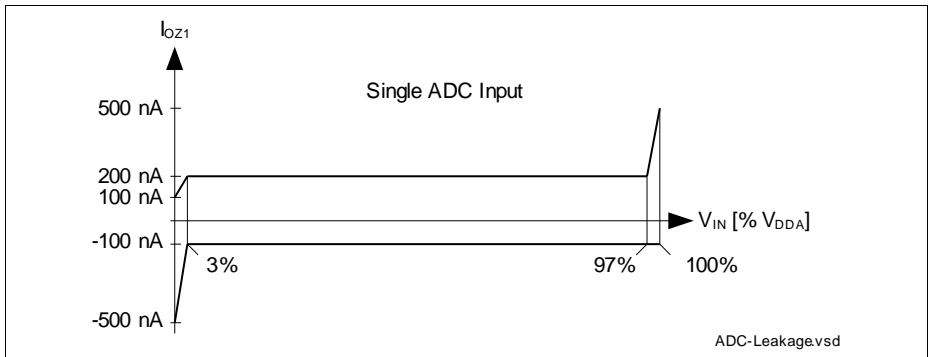


Figure 9 VADC Analog Input Leakage Current

Conversion Time

Table 22 Conversion Time (Operating Conditions apply)

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

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

Conversion Time Examples

System assumptions:

$f_{ADC} = 120 \text{ MHz}$ 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 ± 1 LSB accuracy
Update rate	f_{URATE_F} CC	–		5	Msample/s	data rate, where DAC can follow 64 LSB code jumps to ± 4 LSB accuracy
Settling time	t_{SETTLE} CC	–	1	2	μ s	at full scale jump, output voltage reaches target value ± 20 LSB
Slew rate	SR CC	2	5	–	V/ μ s	
Minimum output voltage	V_{OUT_MIN} CC	–	0.3	–	V	code value unsigned: 000 _H ; signed: 800 _H
Maximum output voltage	V_{OUT_MAX} CC	–	2.5	–	V	code value unsigned: FFF _H ; signed: 7FF _H
Integral non-linearity	INL CC	-4	± 2.5	4	LSB	$R_L \geq 5$ kOhm, $C_L \leq 50$ pF
Differential non-linearity	DNL CC	-2	± 1	2	LSB	$R_L \geq 5$ kOhm, $C_L \leq 50$ pF

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 reference¹⁾ (V_{AREF}) on selected input pins (GxORCy) and generates a service request trigger (GxORCOUTy).

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

The parameters in **Table 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.

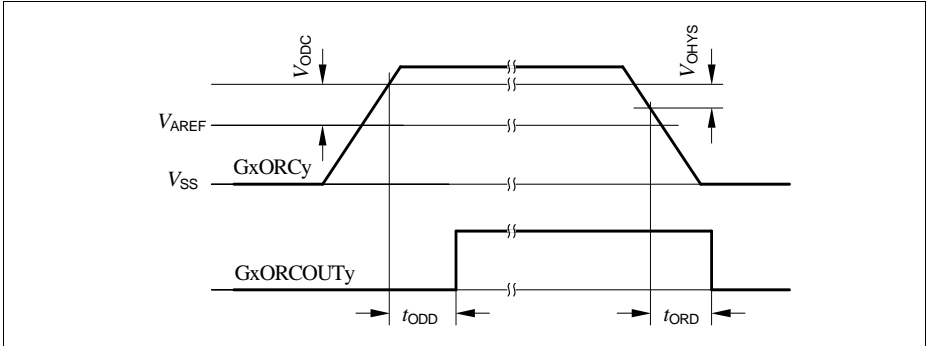


Figure 10 GxORCOUTy Trigger Generation

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)	ΔT_{LE} CC	–	±1	–	°C	per $\Delta T_J \leq 30$ °C
Offset Error	ΔT_{OE} CC	–	±6	–	°C	$\Delta T_{OE} = T_J - T_{DTS}$
Measurement time	t_M CC	–	–	100	µs	
Start-up time after reset inactive	t_{TSST} 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_H (PRELIMINARY)
- DTSCON.REFTRIM = 4_H (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	μ 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) ¹⁾	V_{IHZ} SR	2.7	–	3.6	V	
Differential input sensitivity	V_{DIS} CC	0.2	–	–	V	
Differential common mode range	V_{CM} CC	0.8	–	2.5	V	
Output low voltage	V_{OL} CC	0.0	–	0.3	V	1.5 kOhm pull-up to 3.6 V
Output high voltage	V_{OH} CC	2.8	–	3.6	V	15 kOhm pull-down to 0 V
DP pull-up resistor (idle bus)	R_{PUI} CC	900	–	1 575	Ohm	
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_{OSC} SR	4	–	40	MHz	Direct Input Mode selected
		4	–	25	MHz	External Crystal Mode selected
Oscillator start-up time ¹⁾²⁾	t_{OSCS} CC	–	–	10	ms	
Input voltage at XTAL1	V_{IX} SR	-0.5	–	$V_{\text{DDP}} + 0.5$	V	
Input amplitude (peak-to-peak) at XTAL1 ²⁾³⁾	V_{PPX} SR	$0.4 \times V_{\text{DDP}}$	–	$V_{\text{DDP}} + 1.0$	V	
Input high voltage at XTAL1 ⁴⁾	V_{IHBX} SR	1.0	–	$V_{\text{DDP}} + 0.5$	V	
Input low voltage at XTAL1 ⁴⁾	V_{ILBX} SR	-0.5	–	0.4	V	
Input leakage current at XTAL1	I_{ILX1} CC	-100	–	100	nA	Oscillator power down $0 \text{ V} \leq V_{\text{IX}} \leq V_{\text{DDP}}$

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

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

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

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

Table 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 ¹⁾²⁾³⁾	t_{OSCS} CC	–	–	5	s	
Input voltage at RTC_XTAL1	V_{IX} SR	-0.3	–	$V_{BAT} + 0.3$	V	
Input amplitude (peak-to-peak) at RTC_XTAL1 ²⁾⁴⁾	V_{PPX} CC	$0.2 \times V_{BAT}$	–	$V_{BAT} + 0.6$	V	
Input high voltage at RTC_XTAL1 ⁵⁾	V_{IHBX} SR	$0.6 \times V_{BAT}$	–	$V_{BAT} + 0.3$	V	
Input low voltage at RTC_XTAL1 ⁵⁾	V_{ILBX} SR	-0.3	–	$0.36 \times V_{BAT}$	V	
Input Hysteresis for RTC_XTAL1 ⁵⁾⁶⁾	V_{HYSX} CC	$0.1 \times V_{BAT}$	–	–	V	$3.0 \text{ V} \leq V_{BAT} < 3.6 \text{ V}$
		$0.03 \times V_{BAT}$	–	–	V	$V_{BAT} < 3.0 \text{ V}$
Input leakage current at RTC_XTAL1	I_{ILX1} CC	-100	–	100	nA	Oscillator power down $0 \text{ V} \leq V_{IX} \leq V_{BAT}$

- 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 $0.2 \times V_{BAT}$.
- 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 ⁽¹⁾⁽¹⁰⁾ 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 ⁽²⁾ 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 ⁽³⁾ 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 ⁴⁾ 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 ⁵⁾ Flash in Sleep mode Frequency: $f_{CPU}/f_{PERIPH}/f_{CCU}$ in MHz $f_{CPU}/f_{PERIPH}/f_{CCU}$ in kHz	I_{DDPD} CC	-	20	-	mA	24 / 24 / 24
		-	12	-		4 / 4 / 4
		-	10	-		1 / 1 / 1
		-	6	-		100 / 100 / 100 ⁶⁾
Hibernate supply current RTC on ⁷⁾	I_{DDPH} CC	-	10	-	μ 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 ⁸⁾	I_{DDPH} CC	-	9.2	-	μ 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 ⁹⁾	I_{DDPA} CC	-	-	180 ¹⁰⁾	mA	$V_{DDP} = 3.6$ V, $T_J = 150$ °C
V_{DDA} power supply current	I_{DDA} CC	-	-	- ¹¹⁾	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 Section 3.2.9
Wake-up time from Hibernate mode		–	–	–	ms	Wake-up via power-on reset event, see Section 3.3.2

- 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 ¹⁾	t_{PRP} CC	–	5.5	11	ms	
Erase suspend delay	t_{FL_ErSusp} CC	–	–	15	ms	
Wait time after margin change	$t_{FL_MarginDel}$ CC	10	–	–	μs	
Wake-up time	t_{WU} CC	–	–	270	μs	
Read access time	t_a CC	22	–	–	ns	For operation with $1/f_{CPU} < t_a$ wait states must be configured ²⁾
Data Retention Time, Physical Sector ³⁾⁴⁾	t_{RET} CC	20	–	–	years	Max. 1000 erase/program cycles
Data Retention Time, Logical Sector ³⁾⁴⁾	t_{RETL} CC	20	–	–	years	Max. 100 erase/program cycles
Data Retention Time, User Configuration Block (UCB) ³⁾⁴⁾	t_{RTU} CC	20	–	–	years	Max. 4 erase/program cycles per UCB

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

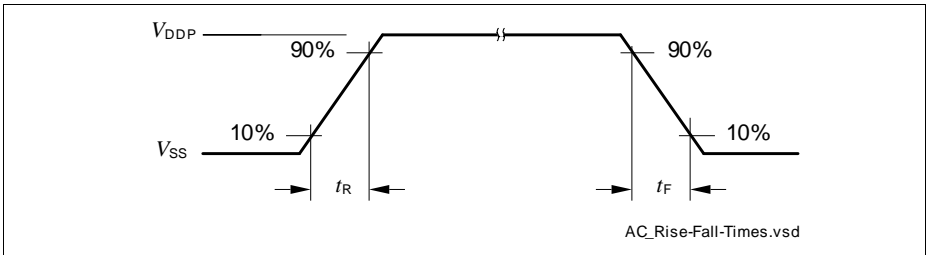


Figure 11 Rise/Fall Time Parameters

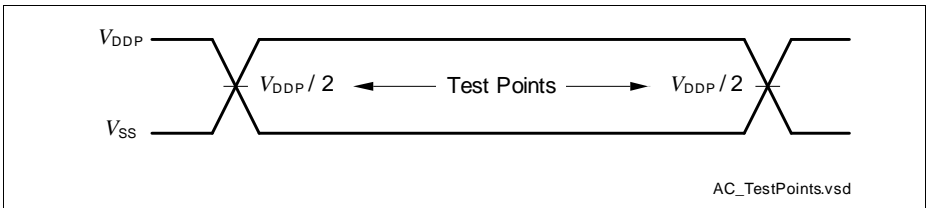


Figure 12 Testing Waveform, Output Delay

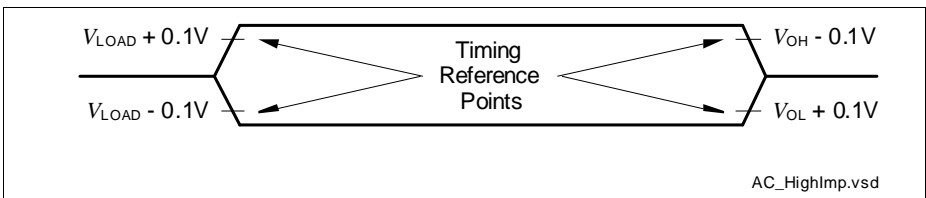


Figure 13 Testing Waveform, Output High Impedance

3.3.2 Power-Up and Supply Monitoring

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

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

Table 32 Supply Monitoring Parameters

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

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

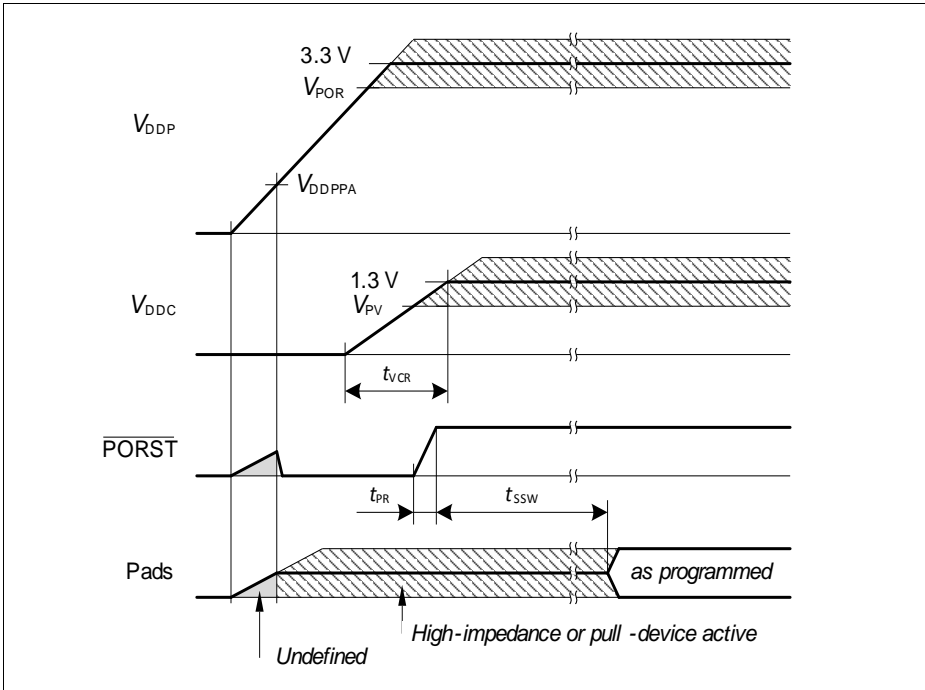


Figure 14 Power-Up Behavior

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	ΔI_{PLS} SR	-	-	50	mA	Load increase on V_{DDP} $\Delta t \leq 10$ ns
Negative Load Step Current	ΔI_{NLS} SR	-	-	150	mA	Load decrease on V_{DDP} $\Delta t \leq 10$ ns
V_{DDC} Voltage Over- / Undershoot from Load Step	ΔV_{LS} CC	-	-	± 100	mV	For maximum positive or negative load step
Positive Load Step Settling Time	t_{PLSS} SR	50	-	-	μ s	
Negative Load Step Settling Time	t_{NLSS} SR	100	-	-	μ s	
External Buffer Capacitor on V_{DDC}	C_{EXT} SR	-	10	-	μ 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 ¹⁾	D_{DC} CC	46	50	54	%	Low pulse to total period, assuming an ideal input clock source
PLL base frequency	$f_{PLLBASE}$ CC	30	–	140	MHz	
VCO input frequency	f_{REF} CC	4	–	16	MHz	
VCO frequency range	f_{VCO} CC	260	–	520	MHz	
PLL lock-in time	t_L CC	–	–	400	μs	

1) 50% for even K2 divider values, 50±(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_{OFINC} CC	–	36.5	–	MHz	not calibrated
		–	24	–	MHz	calibrated
Accuracy	Δf_{OFI} CC	-0.5	–	0.5	%	automatic calibration ¹⁾²⁾
		-15	–	15	%	factory calibration, $V_{\text{DDP}} = 3.3 \text{ V}$
		-25	–	25	%	no calibration, $V_{\text{DDP}} = 3.3 \text{ V}$
		-7	–	7	%	Variation over voltage range ³⁾ $3.13 \text{ V} \leq V_{\text{DDP}} \leq 3.63 \text{ V}$
Start-up time	t_{OFIS} CC	–	50	–	μs	

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

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

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

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	Δf_{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	–	μs	

3.3.6 JTAG Interface Timing

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

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

Note: Operating conditions apply.

Table 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 ¹⁾ (propagation delay)	t_8 CC	–	–	13	ns	$C_L = 50$ pF
		3	–	–	ns	$C_L = 20$ pF
TDO hold after TCK falling edge ¹⁾	t_{18} CC	2	–	–	ns	
TDO high imped. to valid from TCK falling edge ¹⁾²⁾	t_9 CC	–	–	14	ns	$C_L = 50$ pF
TDO valid to high imped. from TCK falling edge ¹⁾	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.

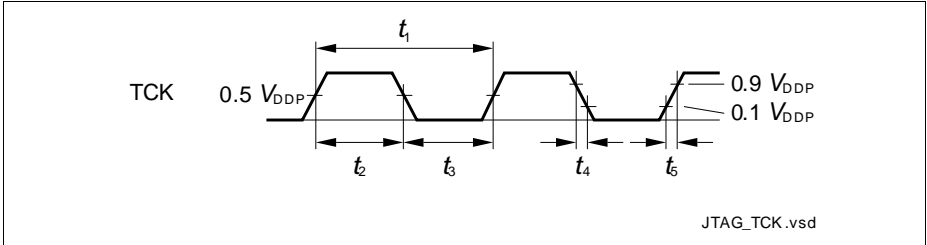


Figure 15 Test Clock Timing (TCK)

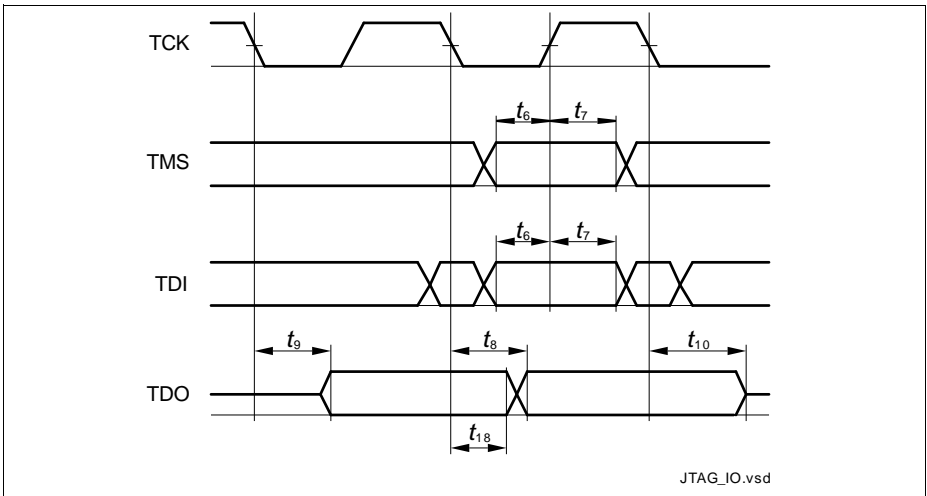


Figure 16 JTAG Timing

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	SR	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	

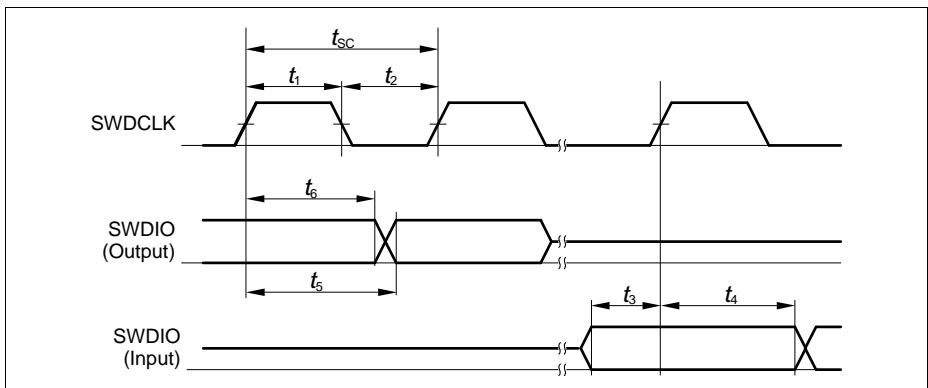


Figure 17 SWD Timing

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	–

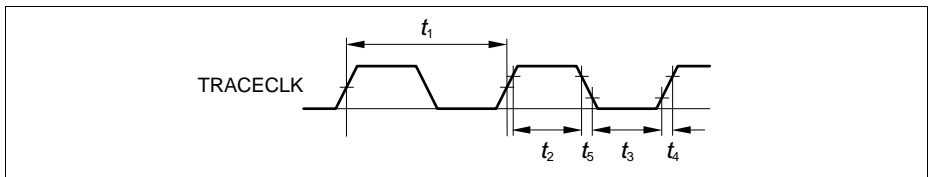


Figure 18 ETM Clock Timing

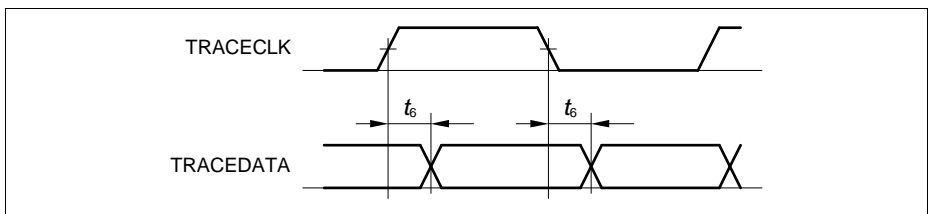


Figure 19 ETM Data Timing

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 ¹⁾	t_{10}	SR	3	–	–	ns	
Select input DX2 hold after last clock input DX1 receive edge ¹⁾	t_{11}	SR	4	–	–	ns	
Receive data input DX0/DX[5:3] setup time to shift clock receive edge ¹⁾	t_{12}	SR	6	–	–	ns	
Data input DX0/DX[5:3] hold time from clock input DX1 receive edge ¹⁾	t_{13}	SR	4	–	–	ns	
Data output DOUT[3:0] valid time	t_{14}	CC	0	–	24	ns	

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

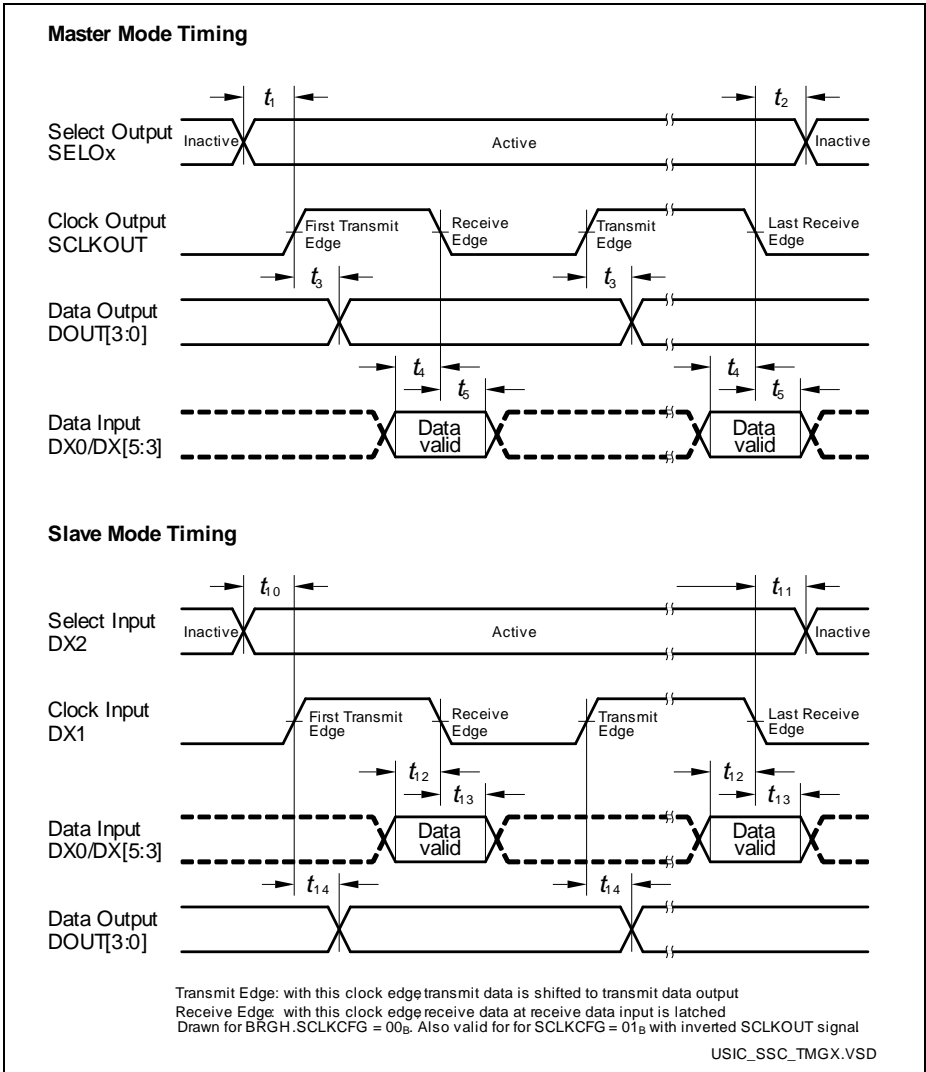


Figure 20 USIC - SSC Master/Slave Mode Timing

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 Timing¹⁾

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

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

Table 43 USIC IIC Fast Mode Timing¹⁾

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

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

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

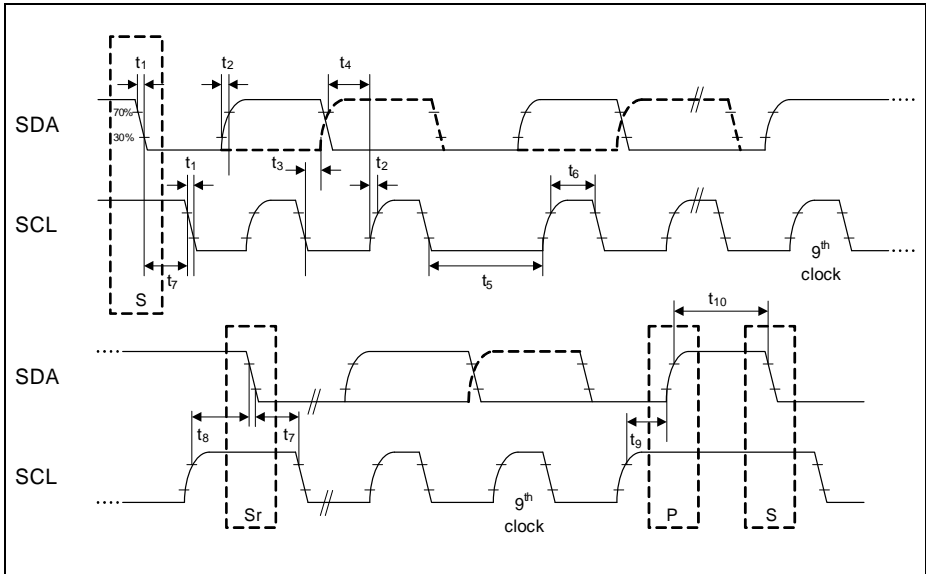


Figure 21 USIC IIC Stand and Fast Mode Timing

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	

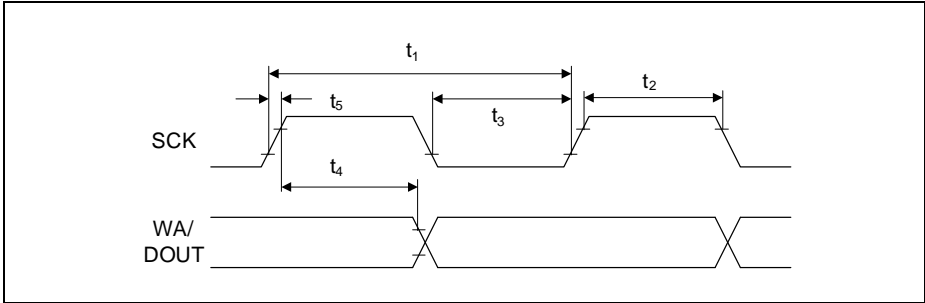


Figure 22 USIC IIS Master Transmitter Timing

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	

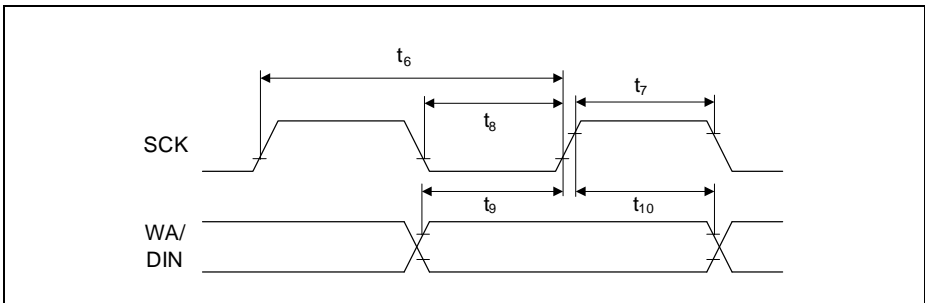


Figure 23 USIC IIS Slave Receiver Timing

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 Mode¹⁾

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

Table 47 SD Card Bus Timing for Full-Speed Mode¹⁾ (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)

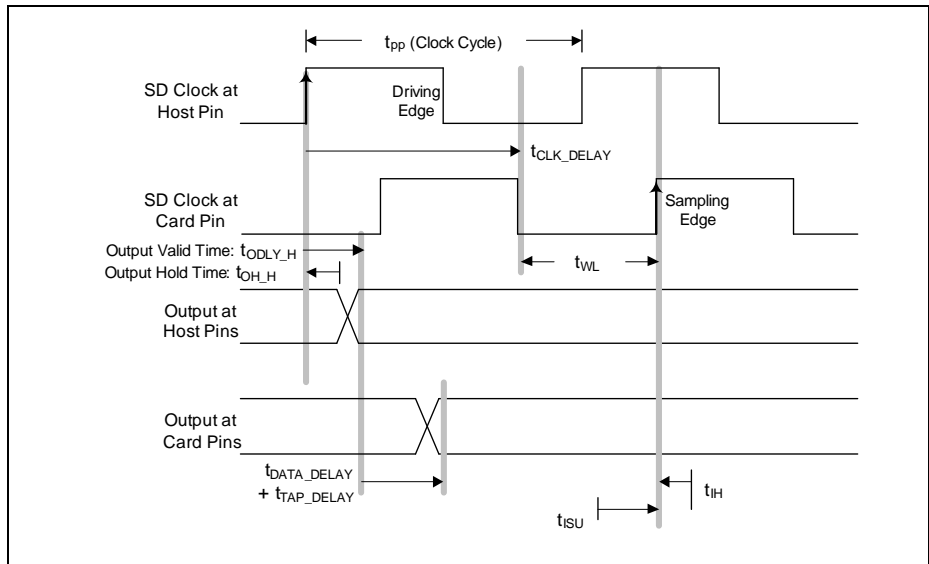


Figure 24 Full-Speed Output Path

Full-Speed Write Meeting Setup (Maximum Delay)

The following equations show how to calculate the allowed skew range 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:

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

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

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

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

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

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

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

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

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

Full-Speed Input Path (Read)

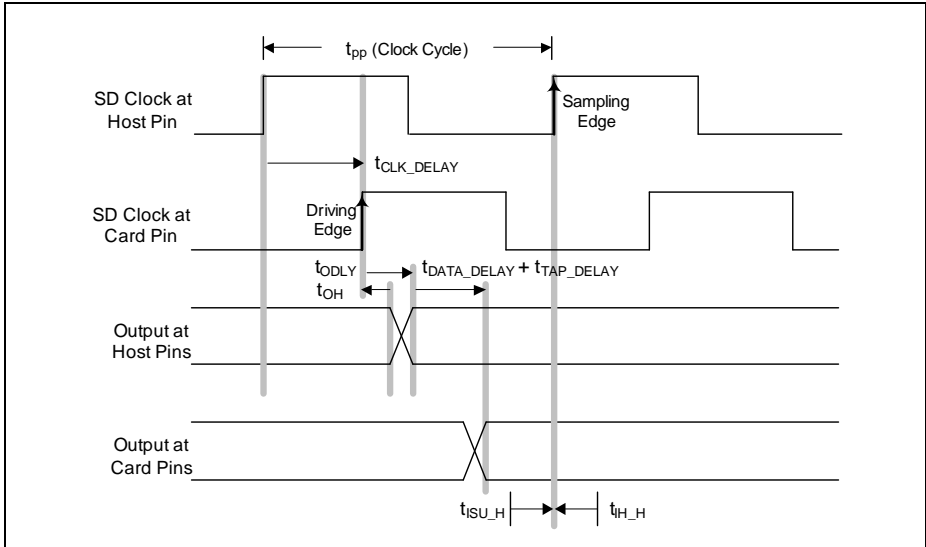


Figure 25 Full-Speed Input Path

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.

Full-Speed Read Meeting Hold (Minimum Delay)

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

(6)

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

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

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

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

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

AC Timing Specifications (High-Speed Mode)

Table 48 SDMMC Timing for High-Speed Mode

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

Table 49 SD Card Bus Timing for High-Speed Mode¹⁾

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

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

High-Speed Output Path (Write)

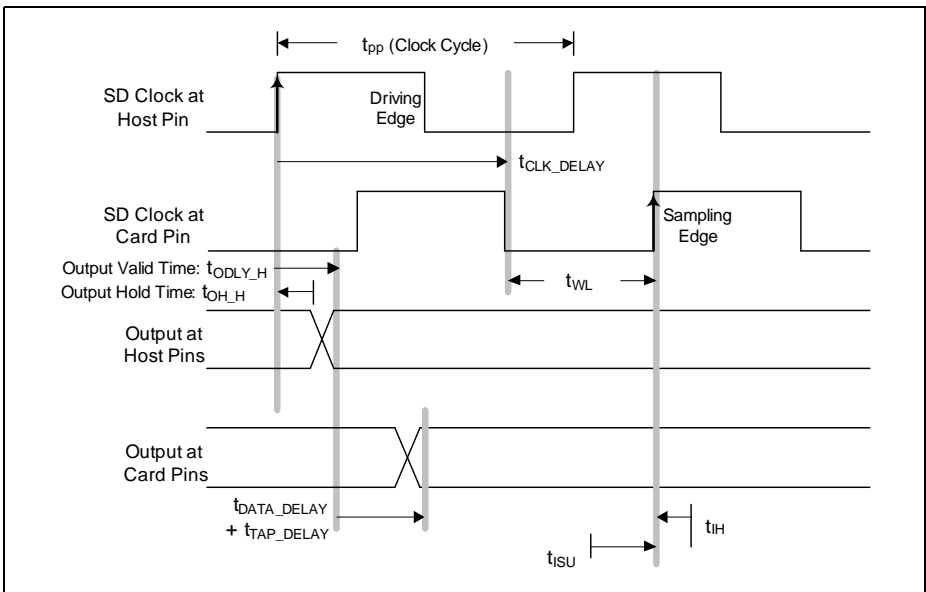


Figure 26 High-Speed Output Path

High-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.

Electrical Parameters

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)

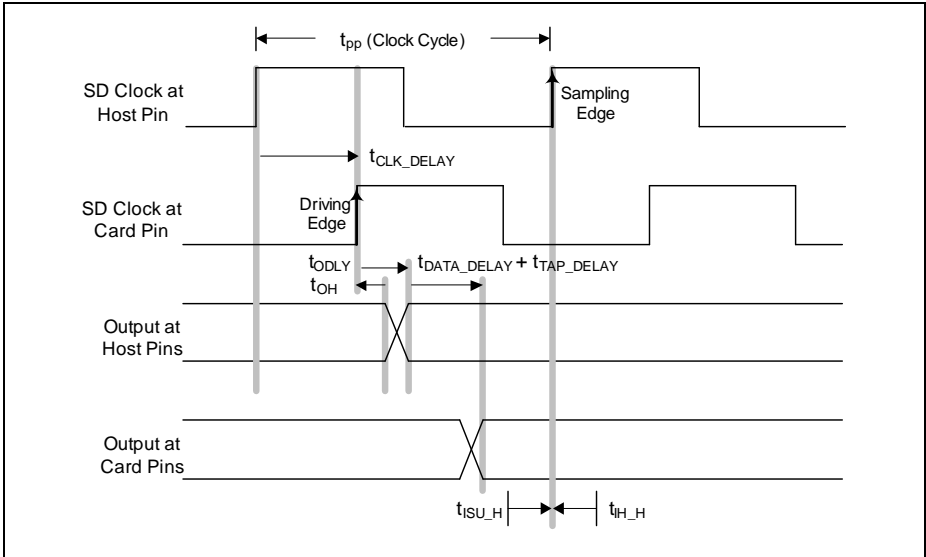


Figure 27 High-Speed Input Path

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

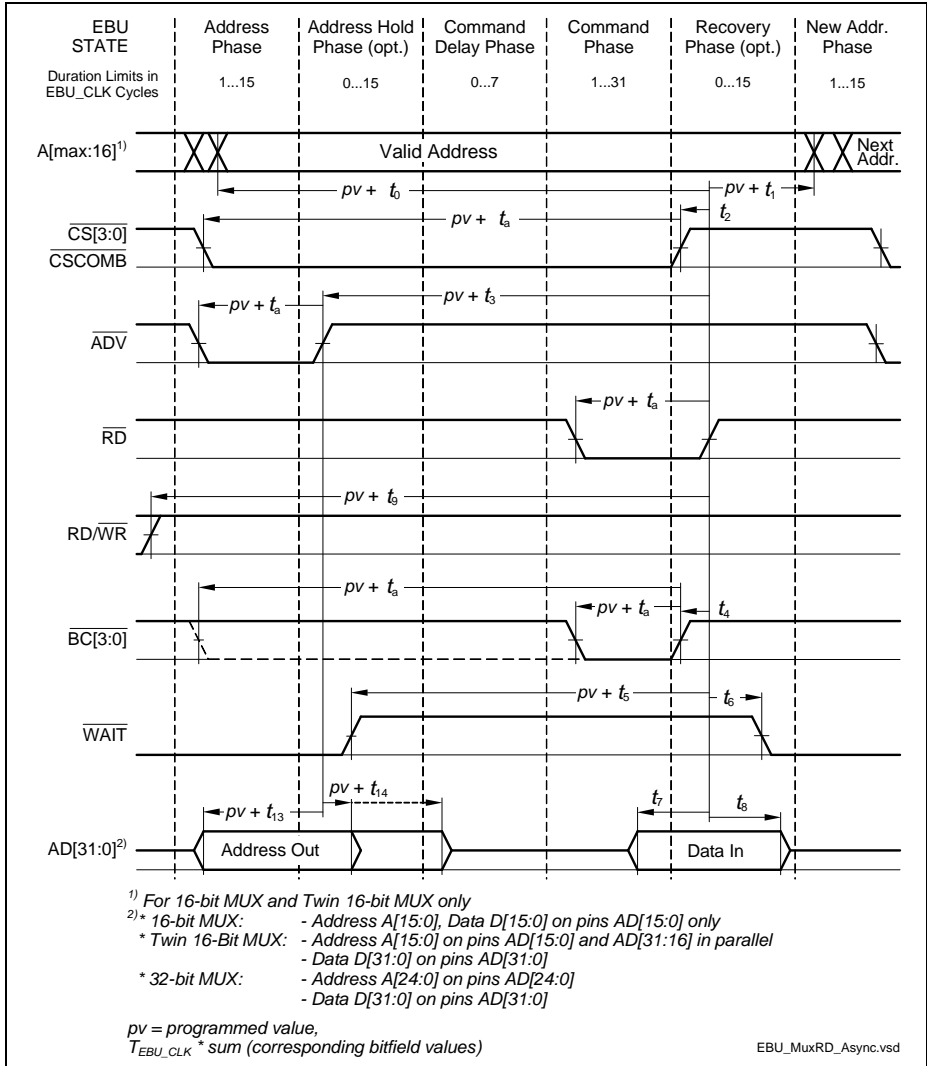


Figure 28 Multiplexed Read Access

Demultiplexed Read Timing

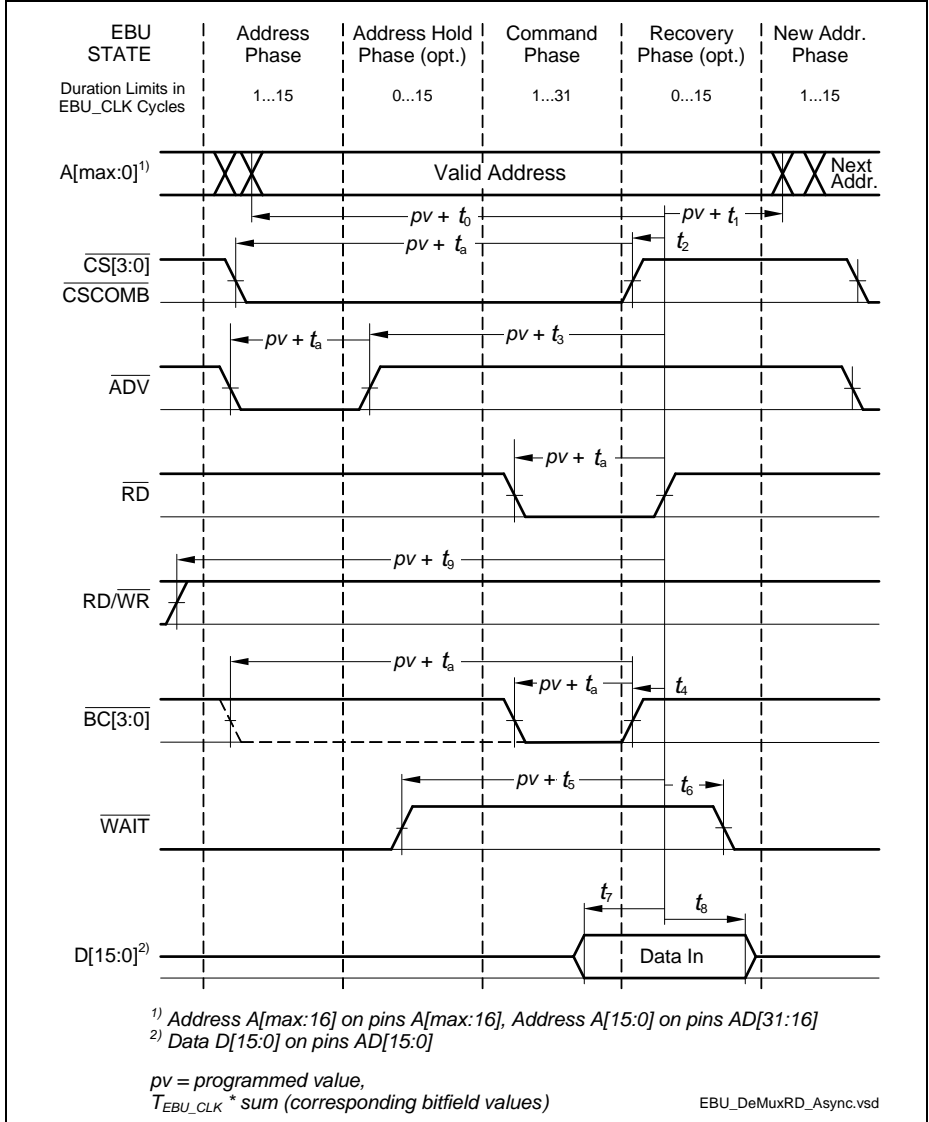


Figure 29 Demultiplexed Read Access

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

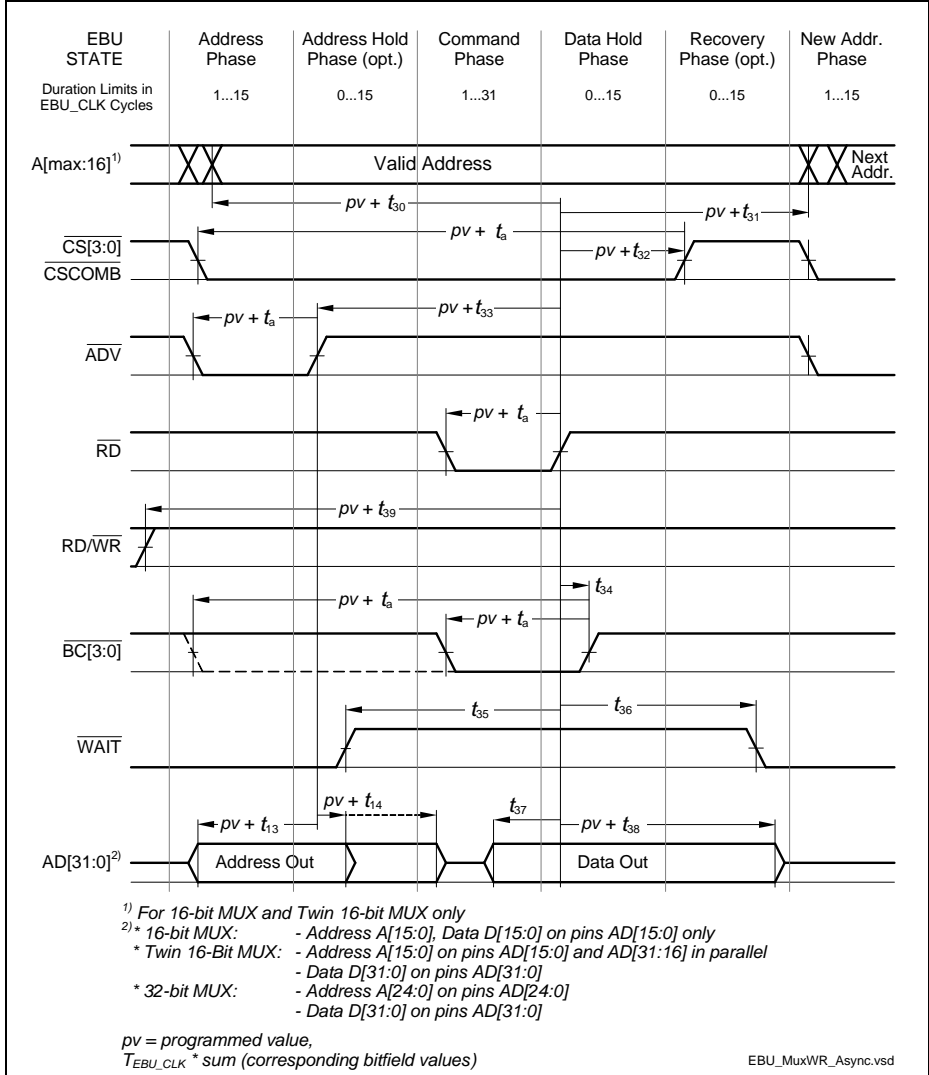


Figure 30 Multiplexed Write Access

Demultiplexed Write Timing

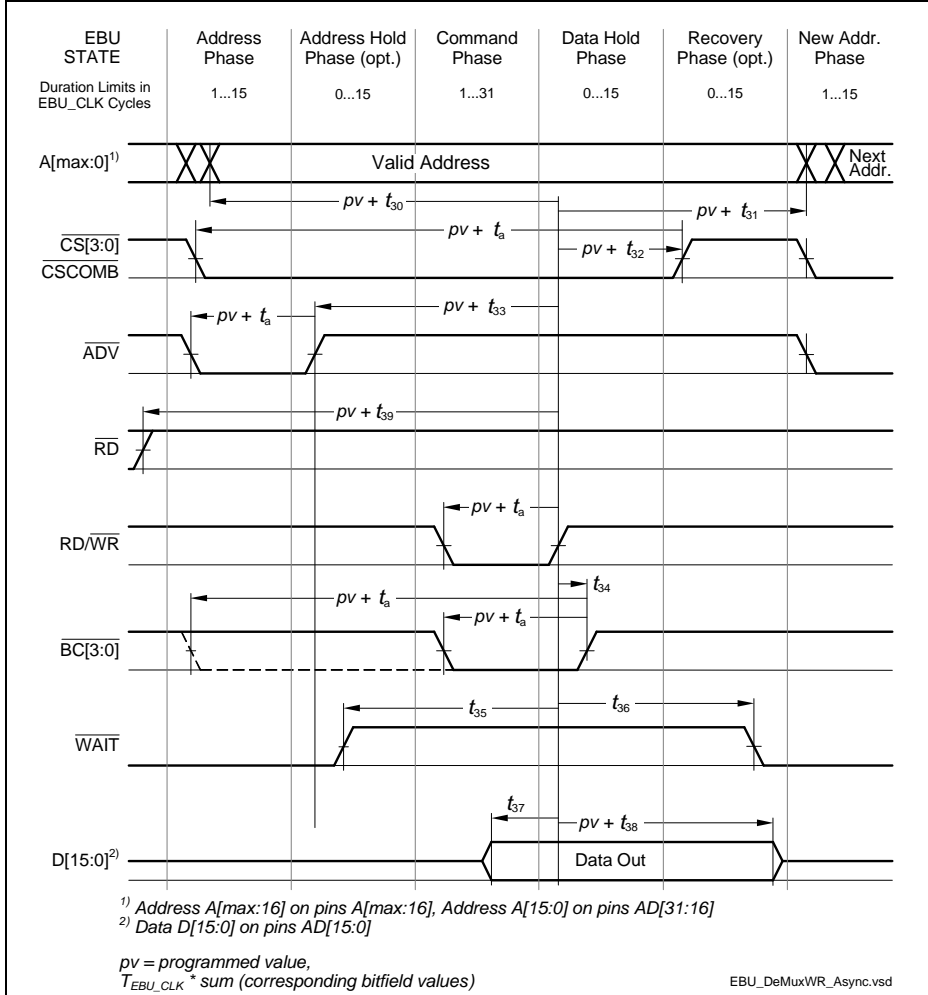


Figure 31 Demultiplexed Write Access

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	CC	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 ¹⁾	t_{12}	CC	-2	–	2	ns	–
\overline{CSx} output delay from BFCLKO active edge ¹⁾	t_{21}	CC	-2.5	–	1.5	ns	–
\overline{ADV} active/inactive after BFCLKO active edge ²⁾	t_{22}	CC	-2	–	2	ns	–
\overline{BAA} active/inactive after BFCLKO active edge ²⁾	t_{22a}	CC	-2.5	–	1.5	ns	–
Data setup to BFCLKI rising edge ³⁾	t_{23}	SR	3	–	–	ns	–
Data hold from BFCLKI rising edge ³⁾	t_{24}	SR	0	–	–	ns	–
\overline{WAIT} setup (low or high) to BFCLKI rising edge ³⁾	t_{25}	SR	3	–	–	ns	–
\overline{WAIT} hold (low or high) from BFCLKI rising edge ³⁾	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_B.

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_B, 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.

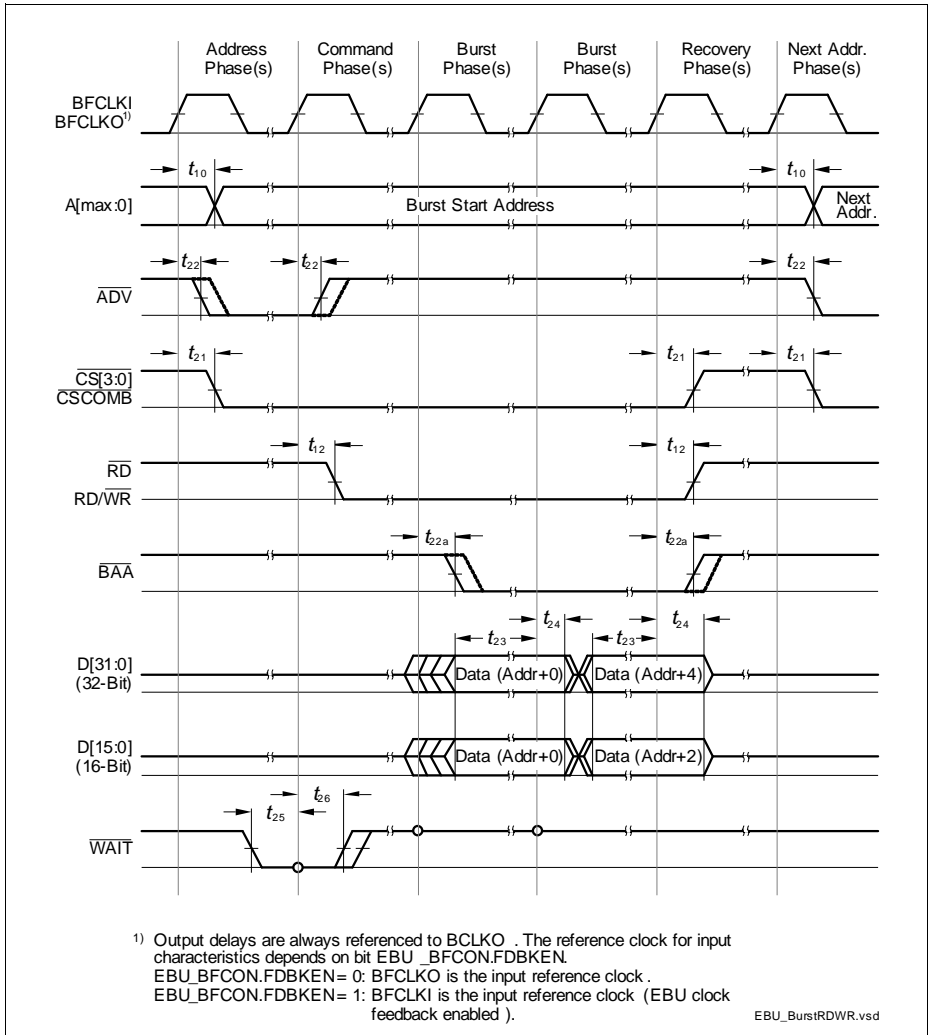


Figure 32 EBU Burst Mode Read / Write Access Timing

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	–

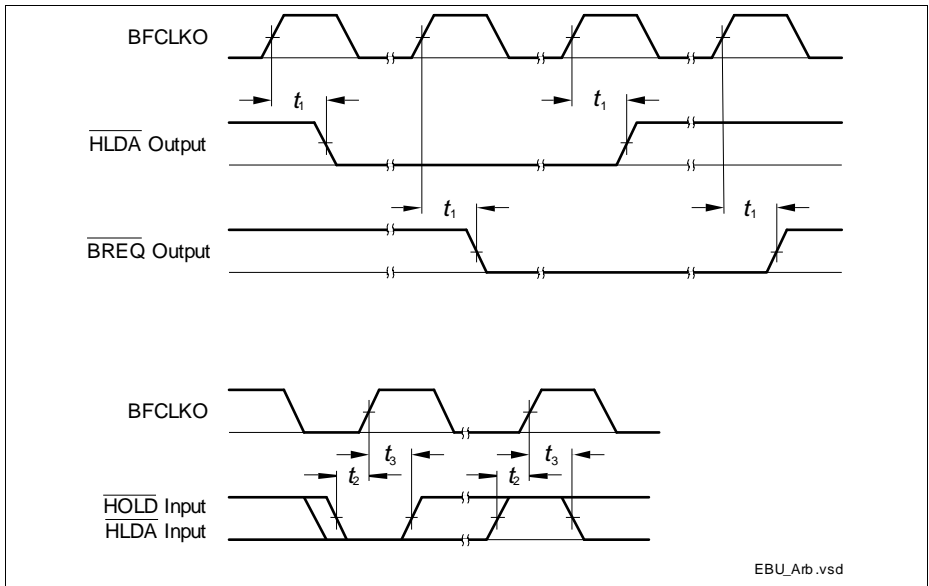


Figure 33 EBU Arbitration Signal Timing

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	–

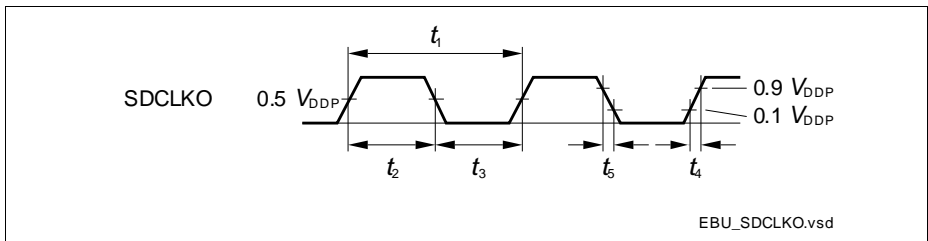


Figure 34 EBU SDRAM Access CLKOUT Timing

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 ¹⁾		CC t_{22}	–	7	
CKE output hold ¹⁾		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.

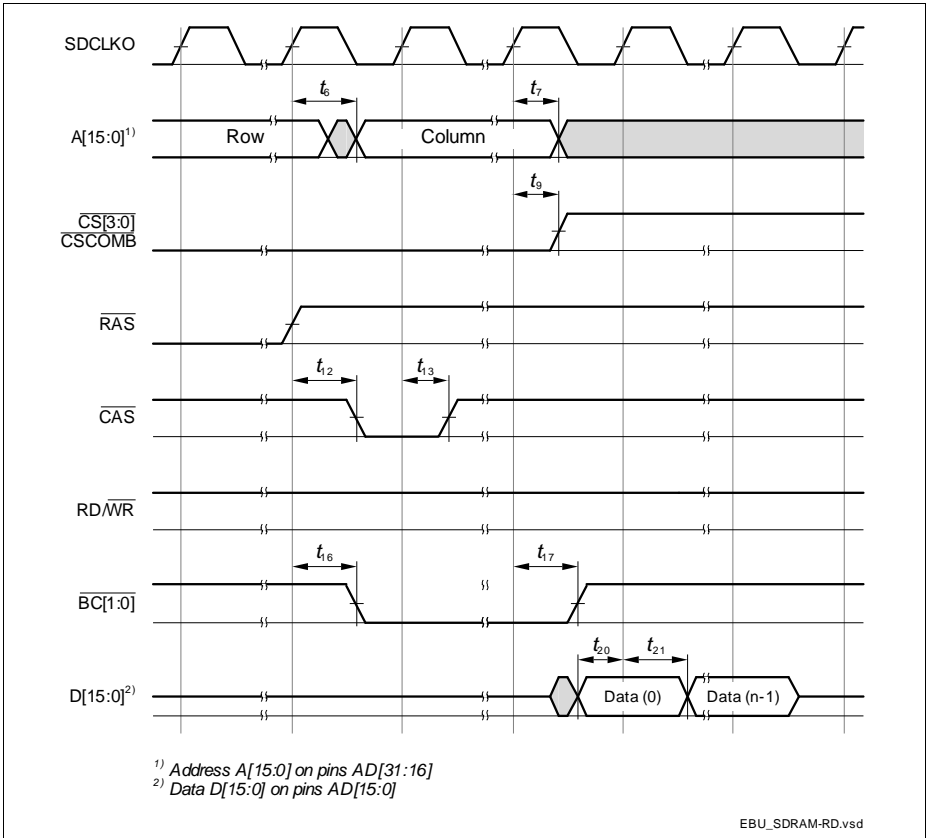


Figure 35 EBU SDRAM Read Access Timing

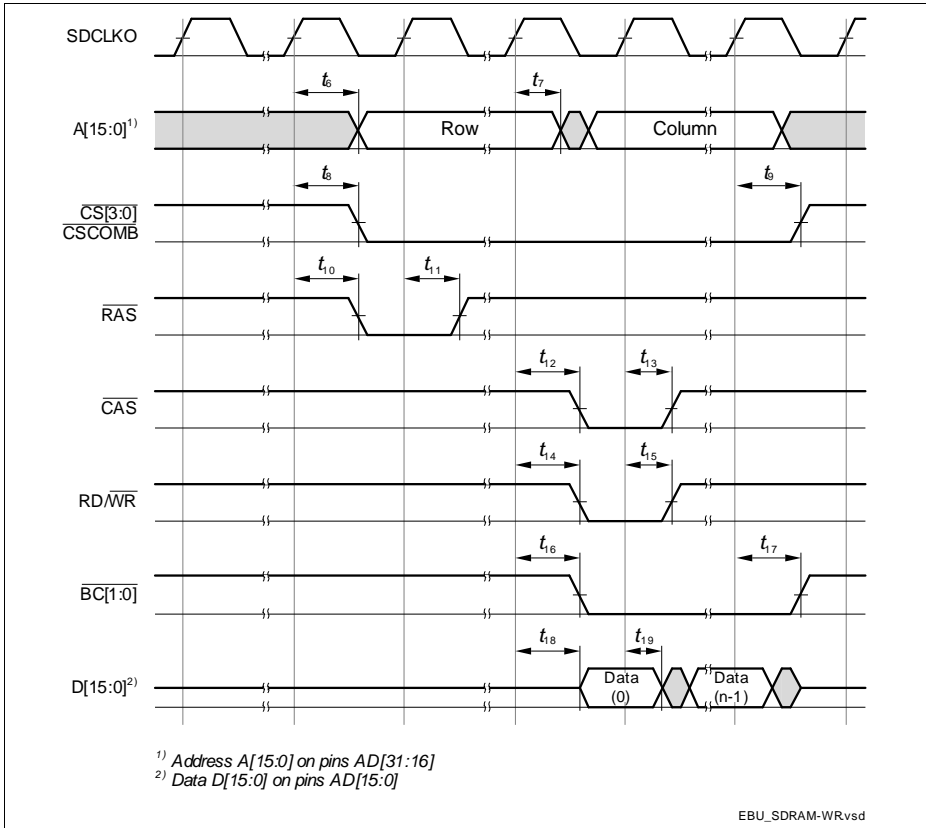


Figure 36 EBU SDRAM Write Access Timing

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	$C_L = 50 \text{ pF}$

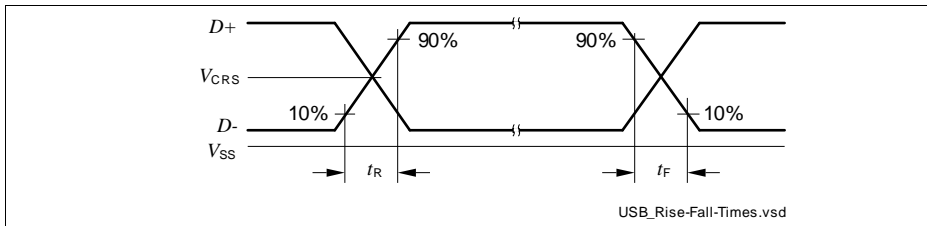


Figure 37 USB Signal Timing

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

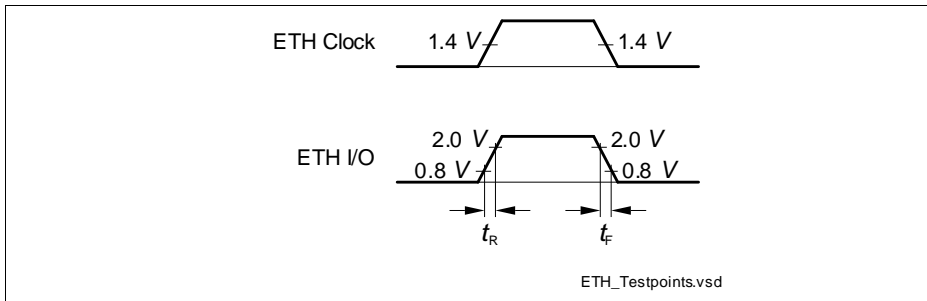


Figure 38 ETH Measurement Reference Points

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	

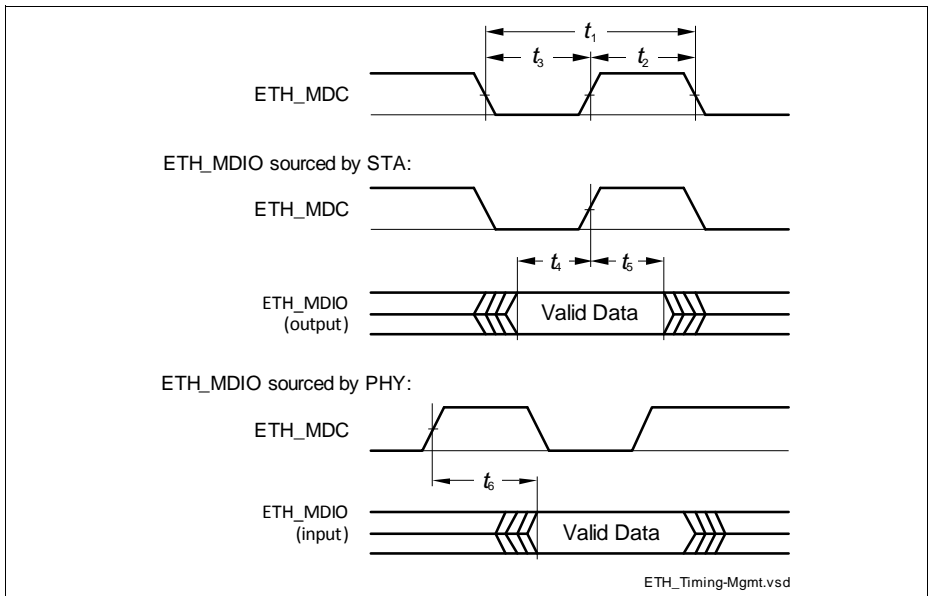


Figure 39 ETH Management Signal Timing

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	SR	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	

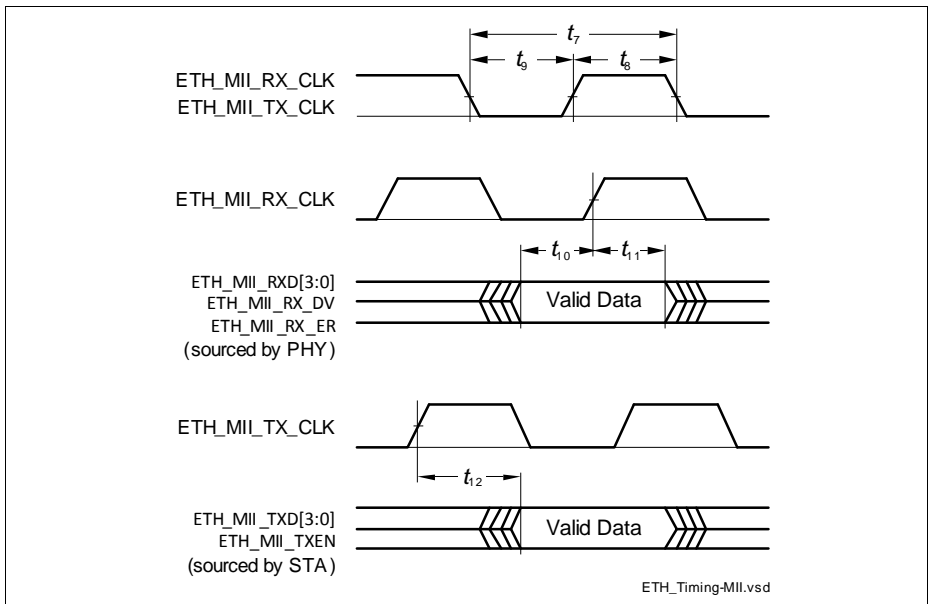


Figure 40 ETH MII Signal Timing

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_CRS setup time	t_{16}	SR	4	–	–	ns	
ETH_RMII_RXD[1:0], ETH_RMII_CRS hold time	t_{17}	SR	2	–	–	ns	
ETH_RMII_TXD[1:0], ETH_RMII_TXEN data valid	t_{18}	CC	4	–	15	ns	

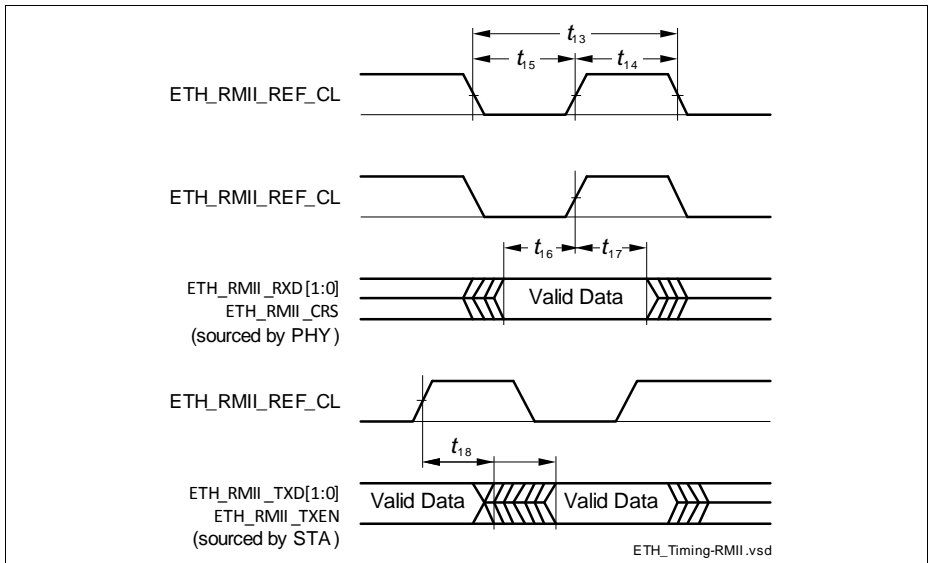


Figure 41 ETH RMII Signal Timing

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 _{θJA} CC	-	40.5	K/W	PG-LFBGA-144-10
		-	22.4	K/W	PG-LQFP-144-18 ¹⁾
		-	23.0	K/W	PG-LQFP-100-11 ¹⁾

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

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

4.1.1 Thermal Considerations

When operating the 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_{θJA}" 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

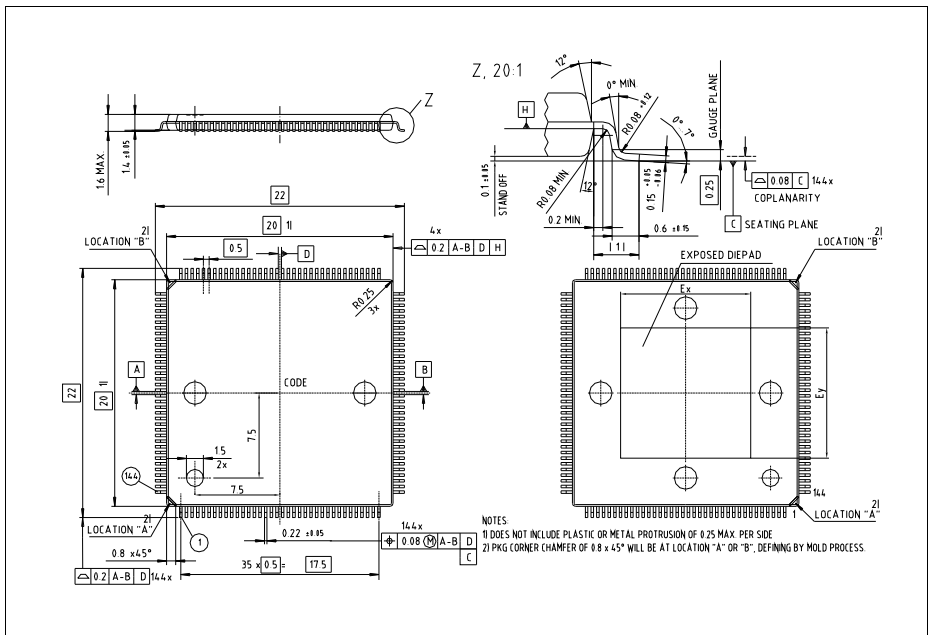


Figure 42 PG-LQFP-144-18 (Plastic Green Low Profile Quad Flat Package)

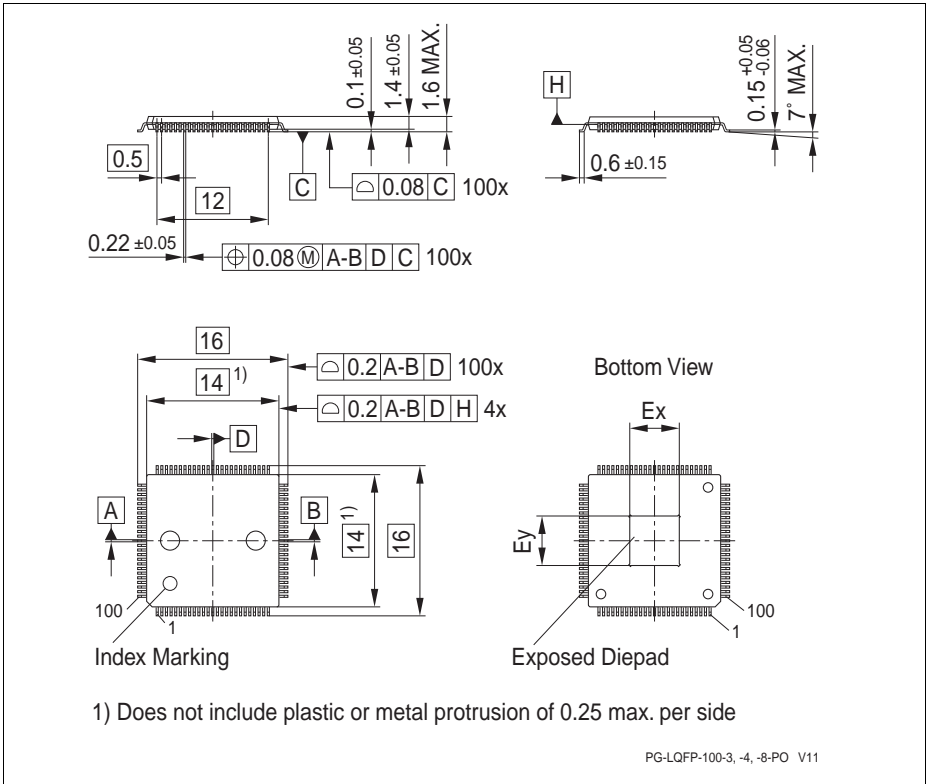


Figure 43 PG-LQFP-100-11 (Plastic Green Low Profile Quad Flat Package)

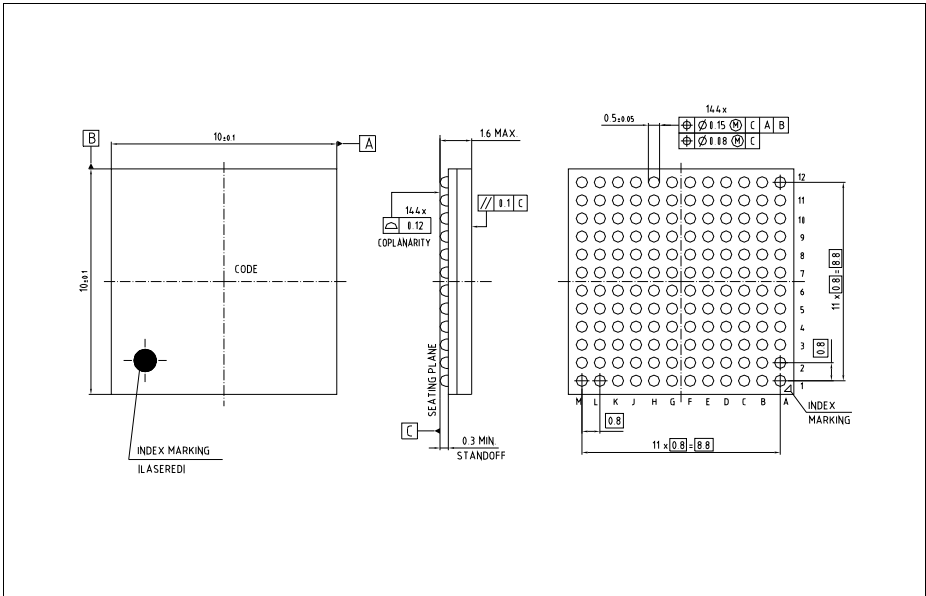


Figure 44 PG-LFBGA-144-10 (Plastic Green Low Profile Fine Pitch Ball Grid Array)

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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