

XMC4500

Microcontroller Series
for Industrial Applications

XMC4000 Family

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

Data Sheet

V1.6 2023-04

Microcontrollers

Edition 2023-04

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118	Table 64: Added package details: PG-LQFP-100-29 and PG-LQFP-144-26. Deleted package details: PG-LQFP-100-11 and PG-LQFP-144-18.
121, 123	Added package diagrams: PG-LQFP-100-29 and PG-LQFP-144-26.
118	Deleted package diagrams: PG-LQFP-100-11 and PG-LQFP-144-18.

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About this Document

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

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

XMC4000 Family User Documentation

The set of user documentation includes:

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

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

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

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

1 Summary of Features

The XMC4500 devices are members of the XMC4000 Family of microcontrollers based on the ARM Cortex-M4 processor core. The XMC4000 is a family of high performance and energy efficient microcontrollers optimized for Industrial Connectivity, Industrial Control, Power Conversion, Sense & Control.

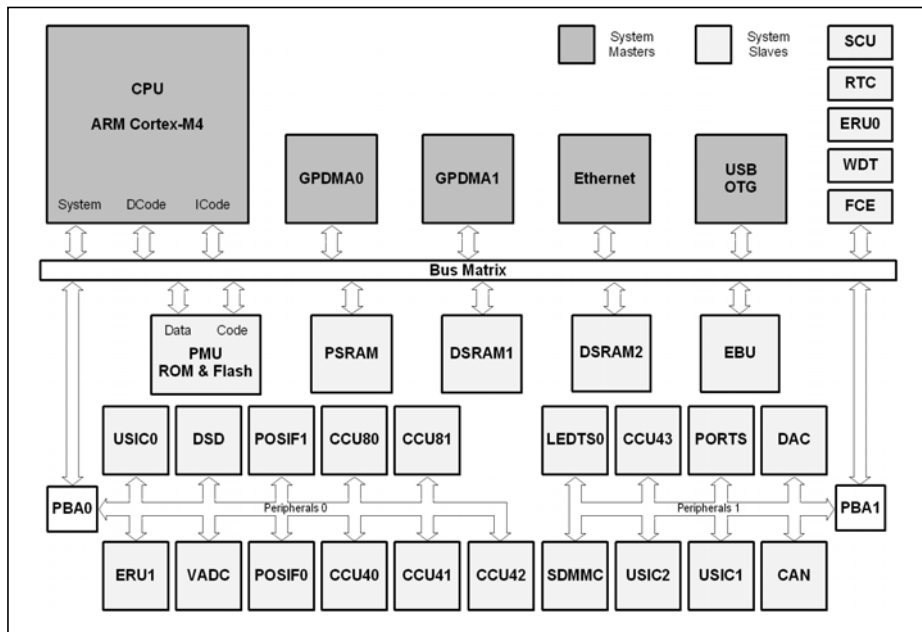


Figure 1 System Block Diagram

CPU Subsystem

- CPU Core
 - High Performance 32-bit ARM Cortex-M4 CPU
 - 16-bit and 32-bit Thumb2 instruction set
 - DSP/MAC instructions
 - System timer (SysTick) for Operating System support
- Floating Point Unit
- Memory Protection Unit
- Nested Vectored Interrupt Controller
- Two General Purpose DMA with up-to 12 channels
- Event Request Unit (ERU) for programmable processing of external and internal service requests
- Flexible CRC Engine (FCE) for multiple bit error detection

On-Chip Memories

- 16 KB on-chip boot ROM
- 64 KB on-chip high-speed program memory
- 64 KB on-chip high speed data memory
- 32 KB on-chip high-speed communication
- 1024 KB on-chip Flash Memory with 4 KB instruction cache

Communication Peripherals

- Ethernet MAC module capable of 10/100 Mbit/s transfer rates
- Universal Serial Bus, USB 2.0 host, Full-Speed OTG, with integrated PHY
- Controller Area Network interface (MultiCAN), Full-CAN/Basic-CAN with 3 nodes, 64 message objects (MO), data rate up to 1MBit/s
- Six Universal Serial Interface Channels (USIC), providing 6 serial channels, usable as UART, double-SPI, quad-SPI, IIC, IIS and LIN interfaces
- LED and Touch-Sense Controller (LEDTS) for Human-Machine interface
- SD and Multi-Media Card interface (SDMMC) for data storage memory cards
- External Bus Interface Unit (EBU) enabling communication with external memories and off-chip peripherals

Analog Frontend Peripherals

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

Industrial Control Peripherals

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

Input/Output Lines

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

On-Chip Debug Support

- Full support for debug features: 8 breakpoints, CoreSight, trace
- Various interfaces: ARM-JTAG, SWD, single wire trace

1.1 Ordering Information

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

- <DDD> the derivatives function set
- <Z> the package variant
 - E: LFBGA
 - F: LQFP
 - Q: VQFN
- <PPP> package pin count
- <T> the temperature range:
 - F: -40°C to 85°C
 - X: -40°C to 105°C
 - K: -40°C to 125°C
- <FFFF> the Flash memory size.

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

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

For simplicity the term **XMC4500** is used for all derivatives throughout this document.

1.2 Device Types

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

Table 1 Synopsis of XMC4500 Device Types

Derivative¹⁾	Package	Flash Kbytes	SRAM Kbytes
XMC4500-E144x1024	PG-LFBGA-144	1024	160
XMC4500-F144x1024	PG-LQFP-144	1024	160
XMC4500-F100x1024	PG-LQFP-100	1024	160
XMC4500-F144x768	PG-LQFP-144	768	160
XMC4500-F100x768	PG-LQFP-100	768	160
XMC4502-F100x768	PG-LQFP-100	768	160
XMC4504-F144x512	PG-LQFP-144	512	128
XMC4504-F100x512	PG-LQFP-100	512	128

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

Summary of Features
1.3 Device Type Features

The following table lists the available features per device type.

Table 2 Features of XMC4500 Device Types

Derivative¹⁾	LEDTS Intf.	SDMMC Intf.	EBU Intf.²⁾	ETH Intf.³⁾	USB Intf.	USIC Chan.	MultiCAN Nodes, MO
XMC4500-E144x1024	1	1	SDM	MR	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F144x1024	1	1	SDM	MR	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F100x1024	1	1	M16	R	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F144x768	1	1	SDM	MR	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4500-F100x768	1	1	M16	R	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4502-F100x768	1	1	M16	-	1	3 x 2	N0, N1, N2 MO[0..63]
XMC4504-F144x512	1	1	SDM	-	-	3 x 2	-
XMC4504-F100x512	1	1	M16	-	-	3 x 2	-

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

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

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

Summary of Features
Table 3 Features of XMC4500 Device Types

Derivative¹⁾	ADC Chan.	DSD Chan.	DAC Chan.	CCU4 Slice	CCU8 Slice	POSIF Intf.
XMC4500-E144x1024	32	4	2	4 x 4	2 x 4	2
XMC4500-F144x1024	32	4	2	4 x 4	2 x 4	2
XMC4500-F100x1024	24	4	2	4 x 4	2 x 4	2
XMC4500-F144x768	32	4	2	4 x 4	2 x 4	2
XMC4500-F100x768	24	4	2	4 x 4	2 x 4	2
XMC4502-F100x768	24	4	2	4 x 4	2 x 4	2
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 ADC Channels¹⁾

Package	VADC G0	VADC G1	VADC G2	VADC G3
PG-LQFP-144 PG-LFBGA-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
SCU_IDCHIP	0004 5004 _H	AC
JTAG IDCODE	101D B083 _H	EES-AA, ES-AA
JTAG IDCODE	101D B083 _H	ES-AB, AB
JTAG IDCODE	401D B083 _H	AC

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

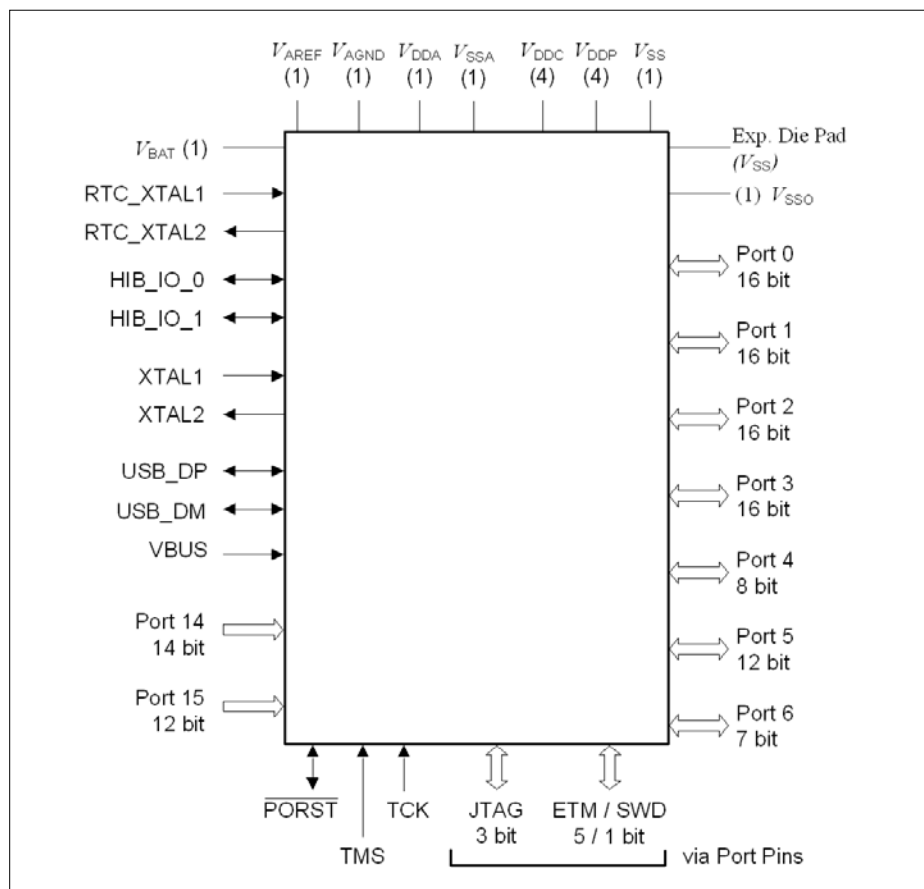


Figure 2 XMC4500 Logic Symbol PG-LQFP-144

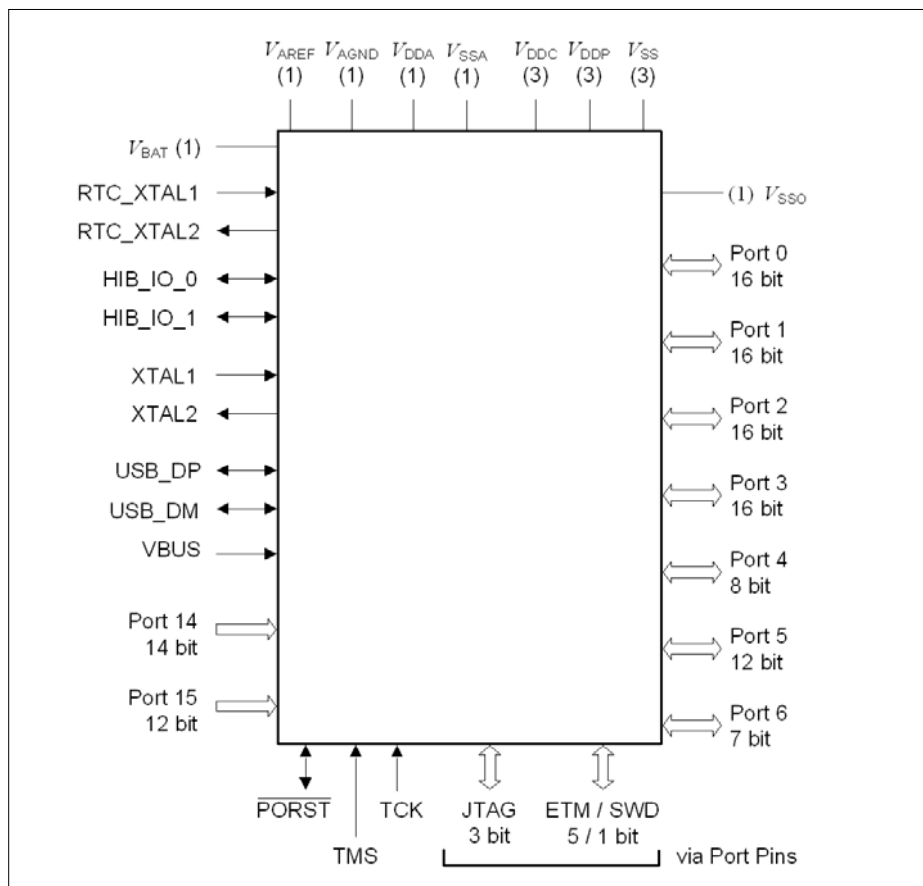


Figure 3 XMC4500 Logic Symbol PG-LFBGA-144

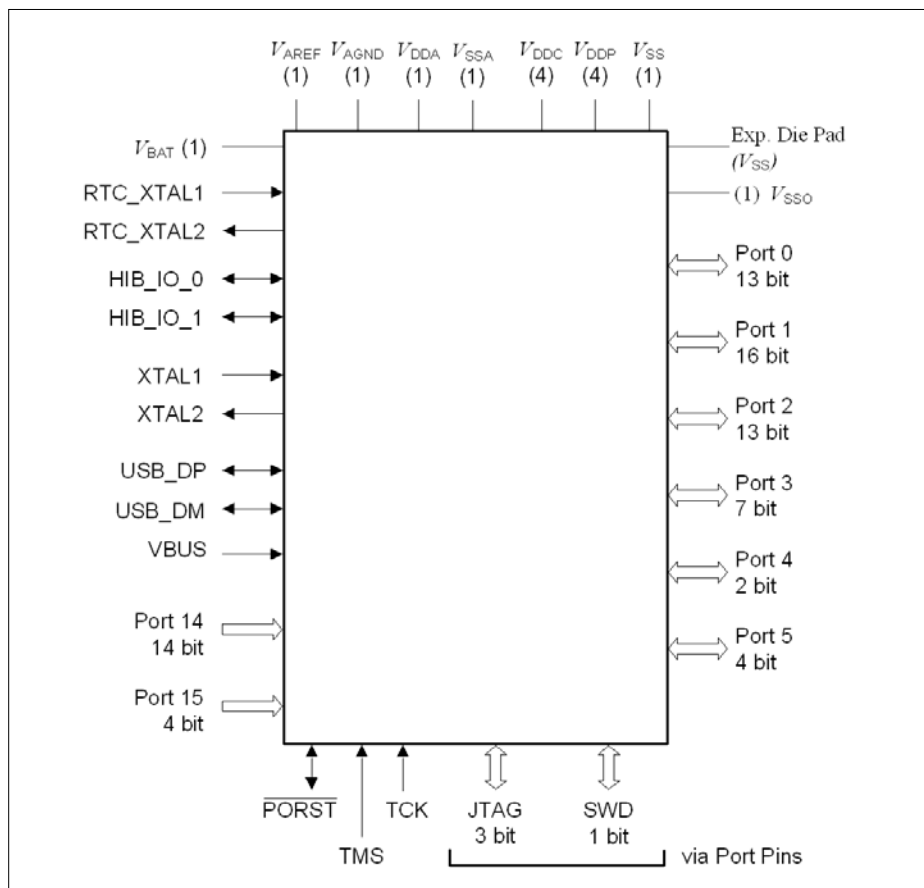


Figure 4 XMC4500 Logic Symbol PG-LQFP-100

2.2 Pin Configuration and Definition

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

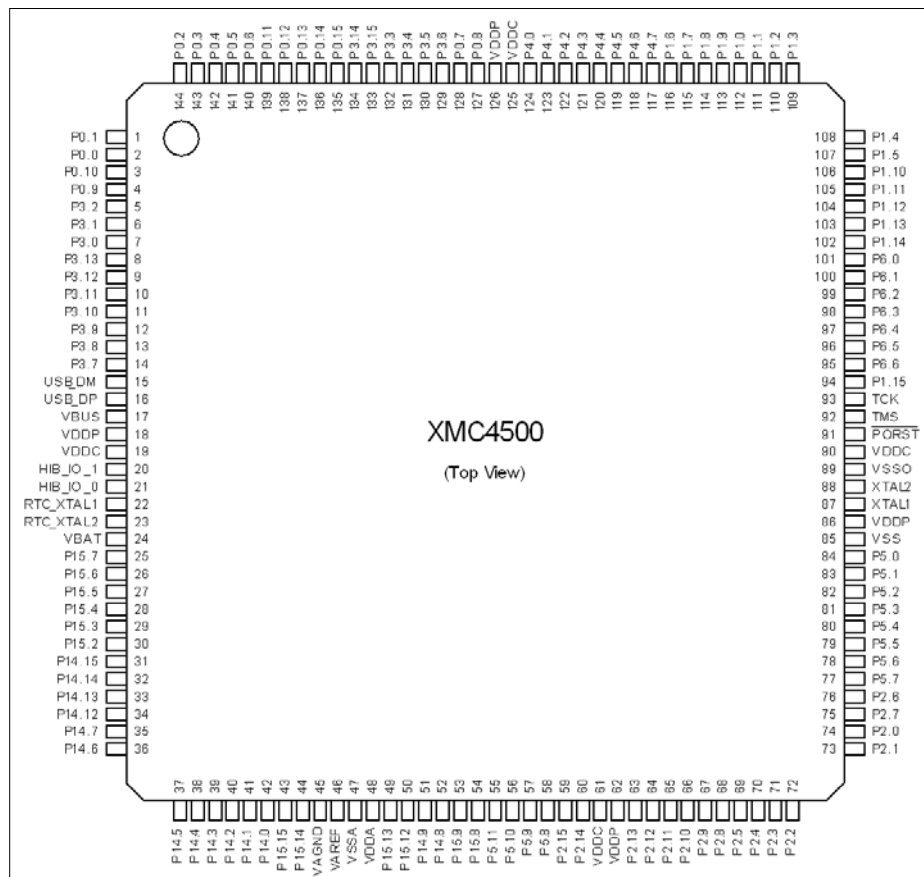


Figure 5 XMC4500 PG-LQFP-144 Pin Configuration (top view)

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	HB_I O_1	HB_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	PORT1	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)

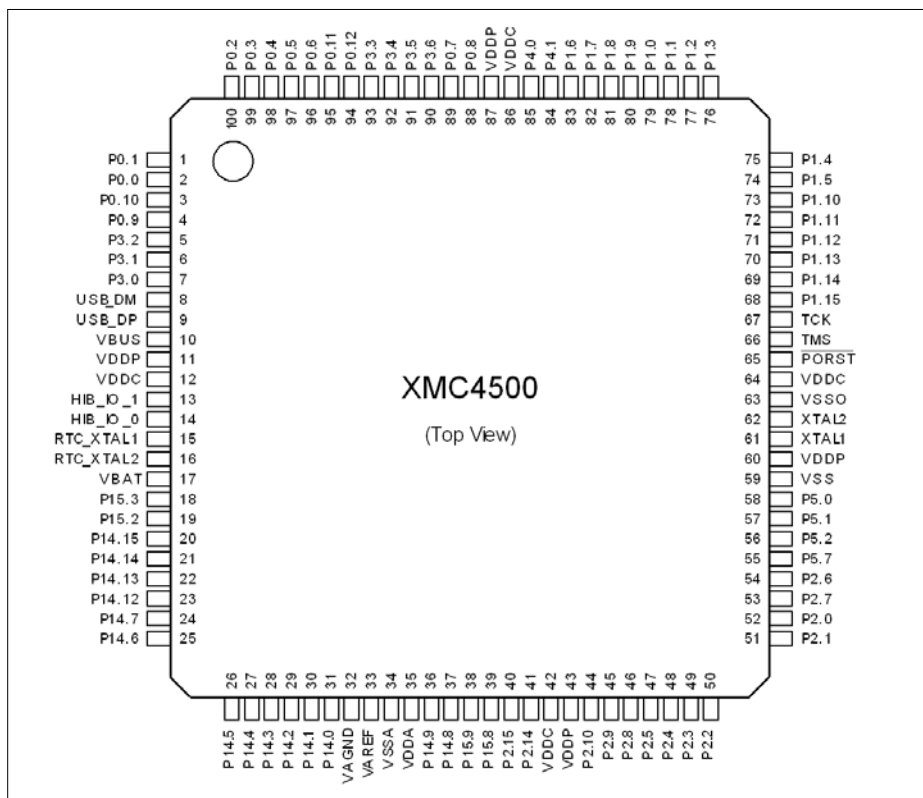


Figure 7 XMC4500 PG-LQFP-100 Pin Configuration (top view)

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. $\overline{\text{PORST}}$) and supply pins.

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

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

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

Table 9 Package Pin Mapping

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P0.0	2	C4	2	A1+	
P0.1	1	C3	1	A1+	
P0.2	144	A3	100	A2	
P0.3	143	A4	99	A2	
P0.4	142	B5	98	A2	
P0.5	141	A5	97	A2	
P0.6	140	A6	96	A2	
P0.7	128	B7	89	A2	After a system reset, via HWSEL this pin selects the DB.TDI function.
P0.8	127	A8	88	A2	After a system reset, via HWSEL this pin selects the $\overline{\text{DB.TRST}}$ function, with a weak pull-down active.
P0.9	4	D4	4	A2	
P0.10	3	B4	3	A1+	

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

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P0.11	139	E5	95	A1+	
P0.12	138	D5	94	A1+	
P0.13	137	C5	-	A1+	
P0.14	136	E6	-	A1+	
P0.15	135	C6	-	A1+	
P1.0	112	D9	79	A1+	
P1.1	111	E9	78	A1+	
P1.2	110	C11	77	A2	
P1.3	109	C12	76	A2	
P1.4	108	C10	75	A1+	
P1.5	107	D10	74	A1+	
P1.6	116	B9	83	A2	
P1.7	115	B10	82	A2	
P1.8	114	A10	81	A2	
P1.9	113	B11	80	A2	
P1.10	106	D12	73	A1+	
P1.11	105	D11	72	A1+	
P1.12	104	E11	71	A2	
P1.13	103	E12	70	A2	
P1.14	102	E10	69	A2	
P1.15	94	G12	68	A2	
P2.0	74	J11	52	A2	
P2.1	73	K12	51	A2	After a system reset, via HWSEL this pin selects the DB.TDO function.
P2.2	72	K11	50	A2	
P2.3	71	L11	49	A2	
P2.4	70	L10	48	A2	
P2.5	69	M10	47	A2	
P2.6	76	J9	54	A1+	
P2.7	75	K9	53	A1+	
P2.8	68	L9	46	A2	
P2.9	67	M9	45	A2	

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

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P2.10	66	L8	44	A2	
P2.11	65	M8	-	A2	
P2.12	64	L7	-	A2	
P2.13	63	M7	-	A2	
P2.14	60	K7	41	A2	
P2.15	59	J6	40	A2	
P3.0	7	C1	7	A2	
P3.1	6	B2	6	A2	
P3.2	5	B3	5	A2	
P3.3	132	F7	93	A1+	
P3.4	131	E7	92	A1+	
P3.5	130	B6	91	A2	
P3.6	129	A7	90	A2	
P3.7	14	E4	-	A1+	
P3.8	13	E3	-	A1+	
P3.9	12	F5	-	A1+	
P3.10	11	F6	-	A1+	
P3.11	10	D3	-	A1+	
P3.12	9	D2	-	A2	
P3.13	8	C2	-	A2	
P3.14	134	D6	-	A1+	
P3.15	133	D7	-	A1+	
P4.0	124	B8	85	A2	
P4.1	123	A9	84	A2	
P4.2	122	E8	-	A1+	
P4.3	121	F8	-	A1+	
P4.4	120	C7	-	A1+	
P4.5	119	D8	-	A1+	
P4.6	118	C8	-	A1+	
P4.7	117	C9	-	A1+	
P5.0	84	H9	58	A1+	
P5.1	83	H8	57	A1+	
P5.2	82	H7	56	A1+	

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

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
P5.3	81	J10	-	A2	
P5.4	80	K10	-	A2	
P5.5	79	J8	-	A2	
P5.6	78	K8	-	A2	
P5.7	77	J7	55	A1+	
P5.8	58	H6	-	A2	
P5.9	57	K6	-	A2	
P5.10	56	H5	-	A1+	
P5.11	55	J5	-	A1+	
P6.0	101	G10	-	A2	
P6.1	100	F9	-	A2	
P6.2	99	H10	-	A2	
P6.3	98	G9	-	A1+	
P6.4	97	F10	-	A2	
P6.5	96	F11	-	A2	
P6.6	95	F12	-	A2	
P14.0	42	L3	31	AN/DIG_IN	
P14.1	41	L2	30	AN/DIG_IN	
P14.2	40	K3	29	AN/DIG_IN	
P14.3	39	J4	28	AN/DIG_IN	
P14.4	38	K1	27	AN/DIG_IN	
P14.5	37	K2	26	AN/DIG_IN	
P14.6	36	J3	25	AN/DIG_IN	
P14.7	35	J2	24	AN/DIG_IN	
P14.8	52	M5	37	AN/DAC/DI G_IN	
P14.9	51	L5	36	AN/DAC/DI G_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	

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

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
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	
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". As output the medium driver mode is active.
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. As output the medium driver mode is active.
TCK	93	G8	67	A1	Weak pull-down active.
TMS	92	G7	66	A1+	Weak pull-up active. As output the strong-soft driver mode is active.
PORST	91	G11	65	special	Weak pull-up permanently active, strong pull-down controlled by EVR.
XTAL1	87	H11	61	clock_IN	
XTAL2	88	H12	62	clock_O	

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

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
RTC_XTAL1	22	F2	15	clock_IN	
RTC_XTAL2	23	F1	16	clock_O	
VBAT	24	G1	17	Power	When VDDP is supplied VBAT has to be supplied as well.
VBUS	17	E2	10	special	
VAREF	46	M3	33	AN_Ref	
VAGND	45	M2	32	AN_Ref	
VDDA	48	L1	35	AN_Power	
VSSA	47	M1	34	AN_Power	
VDDC	19	-	12	Power	
VDDC	61	-	42	Power	
VDDC	90	-	64	Power	
VDDC	125	-	86	Power	
VDDC	-	A2	-	Power	
VDDC	-	B12	-	Power	
VDDC	-	M11	-	Power	
VDDP	18	-	11	Power	
VDDP	62	-	43	Power	
VDDP	86	-	60	Power	
VDDP	126	-	87	Power	
VDDP	-	A11	-	Power	
VDDP	-	B1	-	Power	
VDDP	-	L12	-	Power	
VSS	85	-	59	Power	
VSS	-	A1	-	Power	
VSS	-	A12	-	Power	
VSS	-	M12	-	Power	

General Device Information

Table 9 Package Pin Mapping (cont'd)

Function	LQFP-144	LFBGA-144	LQFP-100	Pad Type	Notes
VSSO	89	J12	63	Power	
VSS	Exp. Pad	-	Exp. Pad	Power	Exposed Die Pad The exposed die pad is connected internally to VSS. For proper operation, it is mandatory to connect the exposed pad directly to the common ground on the board. For thermal aspects, please refer to the Data Sheet. Board layout examples are given in an application note.

2.2.2 Port I/O Functions

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

Table 10 Port I/O Function Description

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

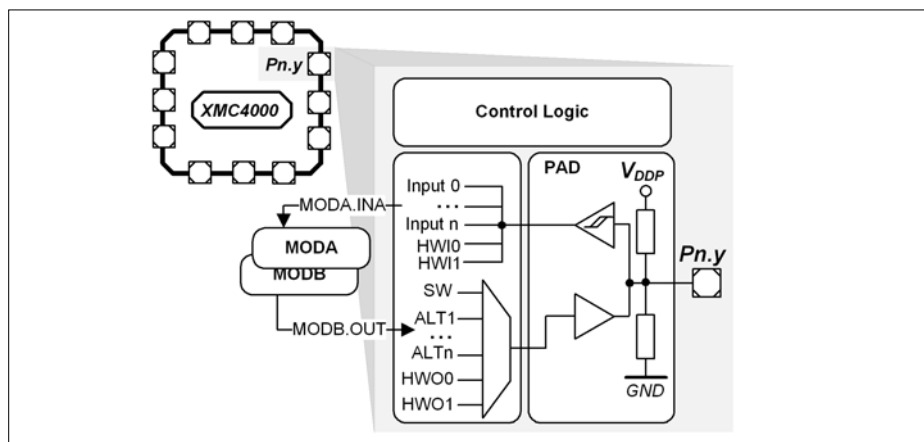


Figure 8 Simplified Port Structure

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

Up to four alternate output functions (ALT1/2/3/4) can be mapped to a single port pin, selected by Pn_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
P0.0		CAN, NC_TX0	CC180, OUT12	LEDTS0, COL2					UIC1, DX0D	ETH0, CLK_RMIB	ERL0, 380				ETH0, CLK_RMIB
P0.1	USB, DRIVE/BIUS	UIC1, DOU70	CC180, OUT11	LEDTS0, COL3						ETH0, CRS_DVB	ERL0, 380				ETH0, RXDV1B
P0.2		UIC1, SEL01	CC180, OUT10		UIC0, DOU73	ERL0, AD9	UIC0, HWI03	ERL0, DO9	ETH0, RXDV0B		ERL0, 383				
P0.3		CC180, OUT20	CC180, OUT20		UIC0, DOU72	ERL0, AD1	UIC0, HWI02	ERL0, DI1	ETH0, RXDV1B		ERL0, 380				
P0.4	ETH0, TX_EN		CC180, OUT19		UIC0, DOU71	ERL0, AD2	UIC0, HWI01	ERL0, DI2	UIC0, DVA0A		ERL0, 383				
P0.5	ETH0, TXD0	UIC0, DOU70	CC180, OUT09		UIC0, DOU70	ERL0, AD3	UIC0, HWI00	ERL0, DI3	UIC0, DX0B		ERL0, 380				
P0.6	ETH0, TXD1	UIC0, SEL00	CC180, OUT10			ERL0, AD7				UIC0, DX2A	ERL0, 382				CC180, IN2B
P0.7	WWDT, SERVICE_OUT	UIC0, SEL00				ERL0, AD6	D8, TD1	ERL0, DI6	UIC0, DX2B	DS0, DIN1A	ERL0, 381				CC180, IN2A
P0.8	SQU, EXCLK	UIC0, SEL00				ERL0, AD7	TRST, TRST	ERL0, DI7	UIC0, DX1B	DS0, DIN0A	ERL0, 381				CC180, IN1B
P0.9		UIC1, SEL00	CC180, OUT12	LEDTS0, COL1	ETH0, NC_TX0	ERL0, AD7	ETH0, DVA0A		UIC1, DX0A	DS0, DIN0A	ERL0, 381				
P0.10	ETH0, MD0	UIC1, SEL00	CC180, OUT10						UIC1, DX1A		ERL0, 380				
P0.11		UIC0, SEL00	CC180, OUT11		SEMMAC, RST	ERL0, BREQ			UIC0, DX1A	UIC0, DX1A	ERL0, 382				
P0.12		UIC1, SEL00	CC180, OUT10			ERL0, HELDA	ERL0, HELDA		UIC1, DX2B	UIC1, DX2B	ERL0, 382				
P0.13		UIC1, SEL00	CC180, OUT10						UIC1, DX1B	UIC1, DX1B	ERL0, 382				
P0.14		UIC0, SEL01	CC180, OUT11		UIC1, DOU73		UIC1, HWI03				CC180, IN2C				
P0.15		UIC0, SEL00	CC180, OUT10		UIC1, DOU72		UIC1, HWI02				CC180, IN2C				
P1.0	DS0, CPWM0	UIC0, SEL00	CC180, OUT10	ERL0, DOU73					UIC0, DX2A		ERL0, 380				CC180, IN3A
P1.1	DS0, CPWM1	UIC0, SEL00	CC180, OUT10	ERL0, DOU72	SEMMAC, SDWC				UIC0, DX1A	POSFQ, IN2A	ERL0, 380				CC180, IN2A
P1.2		UIC0, SEL00	CC180, OUT10	ERL0, DOU71	UIC0, DOU73	ERL0, AD14	UIC0, HWI03	ERL0, DI14	POSFQ, IN1A	POSFQ, IN1A	ERL0, 380				CC180, IN1A
P1.3		UIC0, SEL00	CC180, OUT10	ERL0, DOU70	UIC0, DOU72	ERL0, AD15	UIC0, HWI02	ERL0, DI15	POSFQ, IN0A	POSFQ, IN0A	ERL0, 380				CC180, IN0A
P1.4	WWDT, SERVICE_OUT	CAN, NC_TX0	CC180, OUT10	CC180, OUT10	UIC0, DOU71		UIC0, HWI01		UIC0, DX0B	CAN, NC_TX0D	ERL0, 380				CC180, IN0A

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

Function	Outputs					Inputs						
	ALT1	ALT2	ALT3	ALT4	HW00	HW01	HW10	HW11	Input	Input	Input	Input
P1.5	CAN, N1_TXD	UC03, DOU09	COU80, OUT23	COU81, OUT10	UC03, DOU10	UC03, HW10	UC03, HW10	UC03, DOX0A	CAN, N0_RX0A	ERU0, Z40	ERU1, GA0	CCU41, IN1C
P1.6		UC03, SCKOUT			SDMMC, DATA_OUT	ERU1, AD10	SDMMC, DATA_IN	UC03, DOX0A	DS0, MCLK0A			
P1.7		UC03, DOU10	DS0, MCLK0A		SDMMC, DATA_OUT	ERU1, AD11	SDMMC, DATA_IN	UC03, DOX0A	DS0, MCLK0A			
P1.8		UC03, SCKOUT	DS0, MCLK0A		SDMMC, DATA_OUT	ERU1, AD12	SDMMC, DATA_IN	CAN, N1_RX0C	DS0, MCLK1A			
P1.9		CAN, N1_TXD	UC03, SCKOUT		SDMMC, DATA_OUT	ERU1, AD13	SDMMC, DATA_IN	UC03, DOX0A	DS0, MCLK1A			
P1.10	ETH0, MDC	UC03, SCKOUT	COU81, OUT21				SDMMC, DATA_IN					CCU41, IN2C
P1.11		UC03, SCKOUT	COU81, OUT11		ETH0, MDC	ETH0, MDC	ETH0, MDC					CCU41, IN2C
P1.12	ETH0, TX_EN	CAN, N1_TXD	COU81, OUT10		SDMMC, DATA_OUT	ERU1, AD16	SDMMC, DATA_IN	ERU1, D16				
P1.13	ETH0, TXD0	UC01, SEL0	COU81, OUT20		SDMMC, DATA_OUT	ERU1, AD17	SDMMC, DATA_IN	ERU1, D17				
P1.14	ETH0, TXD1	UC01, SEL0	COU81, OUT10					ERU1, D18				
P1.15	SCI, EXTCLK	DS0, MCLK2	COU81, OUT00					ERU1, D19	DS0, MCLK2B		ERU1, 1A0	
P2.0		COU81, OUT21	DS0, GPPW1N	LEDTS0, COL	ETH0, MDC	ERU1, AD20	ETH0, MDC	ERU1, D20		ERU0, 0B3		CCU40, IN1C
P2.1		COU81, OUT11	DS0, GPPW1P	LEDTS0, COL	DS0, TRACED0	ERU1, AD21	ERU1, D21	ERU1, D21	ETH0, CAL_C0M1A	ERU1, 0B5		CCU40, IN2C
P2.2	VADC, EMU000	COU81, OUT01	COU41, OUT32	LEDTS0, LINE0	LEDTS0, EXTENDED0	ERU1, AD22	LEDTS0, TSIN4A	ERU1, D22	UC01, D0X0A	ERU0, 1B2		CCU41, IN3A
P2.3	VADC, EMU001	UC01, SEL00	COU41, OUT2	LEDTS0, LINE1	EXTENDED1	ERU1, AD23	LEDTS0, TSIN1A	ERU1, D23	UC01, D0X1A	ERU0, 1A2	POSIF1, IN2A	CCU41, IN2A
P2.4	VADC, EMU002	UC01, SCKOUT	COU41, OUT1	LEDTS0, LINE2	EXTENDED2	ERU1, AD24	LEDTS0, TSIN2A	ERU1, D24	UC01, D0X1A	ERU0, 0B2	POSIF1, IN1A	CCU41, IN1A
P2.5	ETH0, TX_EN	UC01, DOU10	COU41, OUT0	LEDTS0, LINE3	EXTENDED3	ERU1, AD25	LEDTS0, TSIN3A	ERU1, D25	UC01, D0X0A	ERU0, 0A2	POSIF1, IN0A	CCU41, IN0A
P2.6	UC03, SEL04	UC03, SCKOUT	COU80, OUT13	LEDTS0, COL	UC03, DOU13		UC03, HW03		CAN, N1_RX0A	ERU0, 1B1		CCU40, IN2C
P2.7	ETH0, MDC	CAN, N1_TXD	COU80, OUT03	LEDTS0, COL					DS0, MCLK0B		ERU1, 1B0	CCU40, IN2C
P2.8	ETH0, TXD0		COU80, OUT32	LEDTS0, LINE4	EXTENDED4	ERU1, AD26	LEDTS0, TSIN4A	ERU1, D26	DAC, TRIGGER6			CCU40, IN2B
P2.9	ETH0, TXD1		COU80, OUT22	LEDTS0, LINE5	EXTENDED5	ERU1, AD27	LEDTS0, TSIN5A	ERU1, D27	DAC, TRIGGER4			CCU41, IN2B
P2.10	VADC, EMU010				DS0, TRACED4	ERU1, AD28		ERU1, D28				
P2.11	ETH0, TXER		COU80, OUT22		DS0, TRACED4	ERU1, AD29		ERU1, D29				

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

Function	Outputs					Inputs									
	ALT1	ALT2	ALT3	ALT4	HW00	HW01	HWI0	HWI1	Input	Input	Input	Input	Input	Input	Input
P2.12	ETH0_TAO2		CGI413_OUT233	ETH0_TX09	DB_ETM_TRACEA TA1	EBU AD30		EBU D30					CGI43_IN3C		
P2.13	ETH0_TAO3			ETH0_TX01	DB_ETM_TRACEA TA0	EBU AD31		EBU D31					CGI43_IN3C		
P2.14	VADC_EMUX11	UI01_DOUT0	CGI480_OUT121		DB_ETM_TRACECLK B02	EBU B02							CGI43_IN3B	CGI43_IN3B	CGI43_IN3B
P2.15	VADC_EMUX12		CGI480_OUT111	LEDTS0_LINE9	LEDTS0_EXTENDED06	EBU B01	LEDTS0_TSINA	ETH0_COA	UI01_DOUT0	UI01_DOUT0	CGI42_IN3B	CGI42_IN3B	CGI42_IN3B	CGI42_IN3B	CGI42_IN3B
P3.0	UCP1_SELO0	UCP1_SCLKOUT	CGI42_OUT175		EBU P02	EBU P02		UCP1_DAB	UCP1_DAB				CGI42_IN3B		
P3.1		UCP1_SELO0			EBU P02_WIR	EBU P02			UCP1_DAB	UCP1_DAB			CGI42_IN3B		
P3.2	USB_DRIVE/USB	CAN_N0_TX00		LEDTS0_COA	EBU CS0	EBU CS0							CGI42_IN3B		
P3.3		UCP1_SELO1	CGI42_OUT173		SDMMC_LED			EBU WAIT	DS0_DIN3B	DS0_DIN3B			CGI42_IN3B		
P3.4	UCP1_MCLKOUT	UCP1_SELO2	CGI42_OUT172	DS0_MCLK3	SDMMC_BUS_POWER			EBU HOLD	DS0_DIN3B	DS0_DIN3B			CGI42_IN3B		
P3.5	UCP1_DOUT0	UCP1_SELO3	CGI42_OUT171	UCP1_DOUT0	SDMMC_CMD_OUT	EBU AD4	SDMMC_CMD_IN	EBU D4	UCP1_DAB	UCP1_DAB			CGI42_IN3B		
P3.6	UCP1_SCLKOUT	UCP1_SELO4	CGI42_OUT170	UCP1_SCLKOUT	SDMMC_CLK_OUT	EBU AD5	SDMMC_CMD_IN	EBU D5	UCP1_DAB	UCP1_DAB			CGI42_IN3B		
P3.7		CAN_N2_TX00	CGI411_OUT173	LEDTS0_LINE0					UCP1_DAB	UCP1_DAB			CGI42_IN3B		
P3.8	UCP1_DOUT0	UCP1_SELO5	CGI411_OUT172	LEDTS0_LINE1					CAN_N2_RX0B	CAN_N2_RX0B			POSIF1_IN3B		
P3.9	UCP1_SCLKOUT	CAN_N1_TX00	CGI411_OUT171	LEDTS0_LINE2									POSIF1_IN3B		
P3.10	UCP1_SELO0	CAN_N2_TX00	CGI411_OUT170	LEDTS0_LINE3	UCP1_DOUT3	UCP1_HWN3							POSIF1_IN3B		
P3.11	UCP1_DOUT0	UCP1_SELO6	CGI42_OUT173	LEDTS0_LINE4	UCP1_DOUT2	UCP1_HWN2		CAN_N1_RX0B					CGI42_IN3B		
P3.12		UCP1_SELO1	CGI42_OUT172	LEDTS0_LINE5	UCP1_DOUT1	UCP1_HWN1		CAN_N2_RX0C	UCP1_DOUT0	UCP1_DOUT0			CGI42_IN3B		
P3.13	UCP1_SCLKOUT	UCP1_DOUT0	CGI42_OUT171	LEDTS0_LINE6	UCP1_DOUT0	UCP1_HWN0		UCP1_DOUT0	UCP1_DOUT0	UCP1_DOUT0			CGI42_IN3B		
P3.14		UCP1_SELO3			UCP1_DOUT1	UCP1_HWN1		UCP1_DOUT1	UCP1_DOUT1	UCP1_DOUT1			CGI42_IN3B		
P3.15		UCP1_DOUT0			UCP1_DOUT0	UCP1_HWN0		UCP1_DOUT0	UCP1_DOUT0	UCP1_DOUT0			CGI42_IN3B		
P4.0			DS0_MCLK1		SDMMC_DATA_OUT	EBU AD8	SDMMC_DATA_IN	EBU D8	UCP1_DAB	UCP1_DAB			UCP1_DOUT0		
P4.1	UCP1_SELO0		DS0_MCLK0	UCP1_SELO0	SDMMC_DATA_OUT	EBU AD9	SDMMC_DATA_IN	EBU D9	UCP1_DAB	UCP1_DAB			UCP1_DOUT0		
P4.2	UCP1_SELO1	UCP1_DOUT0		SCLKOUT					UCP1_DOUT0	UCP1_DOUT0			UCP1_DOUT0		

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

Function	Outputs					Inputs									
	ALT1	ALT2	ALT3	ALT4	HW00	HW01	HWI0	HWI1	Input	Input	Input	Input	Input	Input	Input
P4.3	UC01, SELO2	UC00, SELO6	CC043, OUT3										CC043, IN3A		
P4.4		UC00, SELO4	CC043, OUT2		UC01, DOUT3		UC01, HWI03						CC043, IN3A		
P4.5		UC00, SELO3	CC043, OUT1		UC01, DOUT2		UC01, HWI02						CC043, IN1A		
P4.6		UC00, SELO2	CC043, OUT0		UC01, DOUT1		UC01, HWI01		CAN, NZ_RXD0				CC043, IN0A		
P4.7		CAN, NZ_TXD0			UC01, DOUT0		UC01, HWI00		UC00, DX0C				CC043, IN0C		
P5.0	UC00, DOUT0	PSD, COPPWN	CC081, OUT3		UC00, DOUT0		UC00, HWI00		ETH0, RXD0D	UC00, DX0D			CC081, IN0A	CC081, IN0A	CC081, IN0A
P5.1	UC00, DOUT0	PSD, COPPWP	CC081, OUT2		UC00, DOUT1		UC00, HWI01		ETH0, RXD0B	UC00, DX0B			CC081, IN0B		
P5.2	UC00, SCKOUT		CC081, OUT1						UC00, DATA	ETH0, CARL_DVD			CC081, IN1B		ETH0, RXD1D
P5.3	UC00, SELO0		CC081, OUT2		EBU, ONE	EBU, A20			UC00, D0A	ETH0, RXE0D			CC081, IN2B		
P5.4	UC00, SELO1		CC081, OUT1		EBU, RXS	EBU, A21			UC00, D0A	ETH0, CRSD			CC081, IN3B		
P5.5	UC00, SELO2		CC081, OUT1		EBU, C0S	EBU, A22				ETH0, C0LD					
P5.6	UC00, SELO3		CC081, OUT0		EBU, BFCLOD	EBU, A23			EBU, BFCLOI						
P5.7			CC081, OUT0	LEDTS0, C0SA	UC00, DOUT2		UC00, HWI02								
P5.8	UC00, SCKOUT		CC080, OUT0		EBU, SCKLOD	EBU, C0S2			ETH0, RXD0A	UC00, DX1B					
P5.9	UC00, SELO0		CC080, OUT0	ETH0, TX_EN	EBU, BFCLOD	EBU, C0S3			ETH0, RXD0A	UC00, DX2B					
P5.10	UC00, MCKOUT		CC080, OUT0	LEDTS0, LINE7	LEDTS0, EXTENDED7				ETH0, CLK_TKA						
P5.11	UC00, SELO1		CC080, OUT0						ETH0, CRSA						
P6.0	ETH0, TXD0	UC01, SELO1	CC081, OUT3		DE, ETM_TRACECLK	EBU, A19									
P6.1	ETH0, TXD3	UC01, SELO0	CC081, OUT0	DE, ETM_TRACEA	DE, ETM_TRACEA	EBU, A17			UC01, DX0C						
P6.2	ETH0, TXEN	UC01, SCKOUT	CC043, OUT5	DE, ETM_TRACEA	DE, ETM_TRACEA	EBU, A18			UC01, DX1C						
P6.3			CC043, OUT2						UC01, DX0C	ETH0, RXD0B					
P6.4		UC01, DOUT0	CC043, OUT1		EBU, SCKLOD	EBU, A19			EBU, SCKLOI	ETH0, RXD0B					
P6.5		UC01, MCKOUT	CC043, OUT0	DE, ETM_TRACEA	DE, ETM_TRACEA	EBU, B0C2			ETH0, DSD	ETH0, CLK_RMID					ETH0, CLK_RXD

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

Function	Outputs					Inputs							
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input	Input
PS6			PSD MCLK3		DB ETM_TRACE0 TA0	SR7 BES			PSD MCLKSA	ETH0 CLK_TXB			
PI4.0									VADC G0CH0				
PI4.1									VADC G0CH1				
PI4.2									VADC G0CH2				
PI4.3									VADC G1CH3				
PI4.4									VADC G0CH4	VADC G2CH0			
PI4.5									VADC G0CH5	VADC G2CH1			
PI4.6									VADC G0CH6				GPIOC6
PI4.7									VADC G0CH7				GPIOC7
PI4.8					DAC OUT_0				VADC G1CH0	VADC G2CH2			
PI4.9					DAC OUT_1				VADC G1CH1	VADC G2CH3			
PI4.12									VADC G1CH4				
PI4.13									VADC G1CH6				
PI4.14									VADC G1CH6				GPIOC6
PI4.15									VADC G1CH7				GPIOC7
PI5.2									VADC G2CH2				
PI5.3									VADC G2CH3				
PI5.4									VADC G2CH4				
PI5.5									VADC G2CH5				
PI5.6									VADC G2CH6				
PI5.7									VADC G2CH7				
PI5.8										VADC G3CH0	ETH0 CLK_RMIC		ETH0 CURRAC
PI5.9										VADC G3CH1	ETH0 CRS_DVC		ETH0 RDVC

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

Function	Outputs					Inputs						
	ALT1	ALT2	ALT3	ALT4	HWO0	HWO1	HWI0	HWI1	Input	Input	Input	Input
P15_12										VADC_GSCH4		Input
P15_13										VADC_GSCH5		
P15_14										VADC_GSCH6		
P15_15										VADC_GSCH7		
USB_DP												
USB_DM												
HIB_IO_0	HIBOUT	WWDT_SERVICE_OUT							WAKEUPA			
HIB_IO_1	HIBOUT	WWDT_SERVICE_OUT							WAKEUPB			
TOX							DB17CV_SWCLK					
TMS					DB17MS_STROBE							
PORST												
XTAL1									UPC0_DX0F	UPC1_DX0F	UPC3_DX0F	UPC1_DX0F
XTAL2												
RTC_XTAL1										ERL0_1B1		
RTC_XTAL2												

2.3 Power Connection Scheme

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

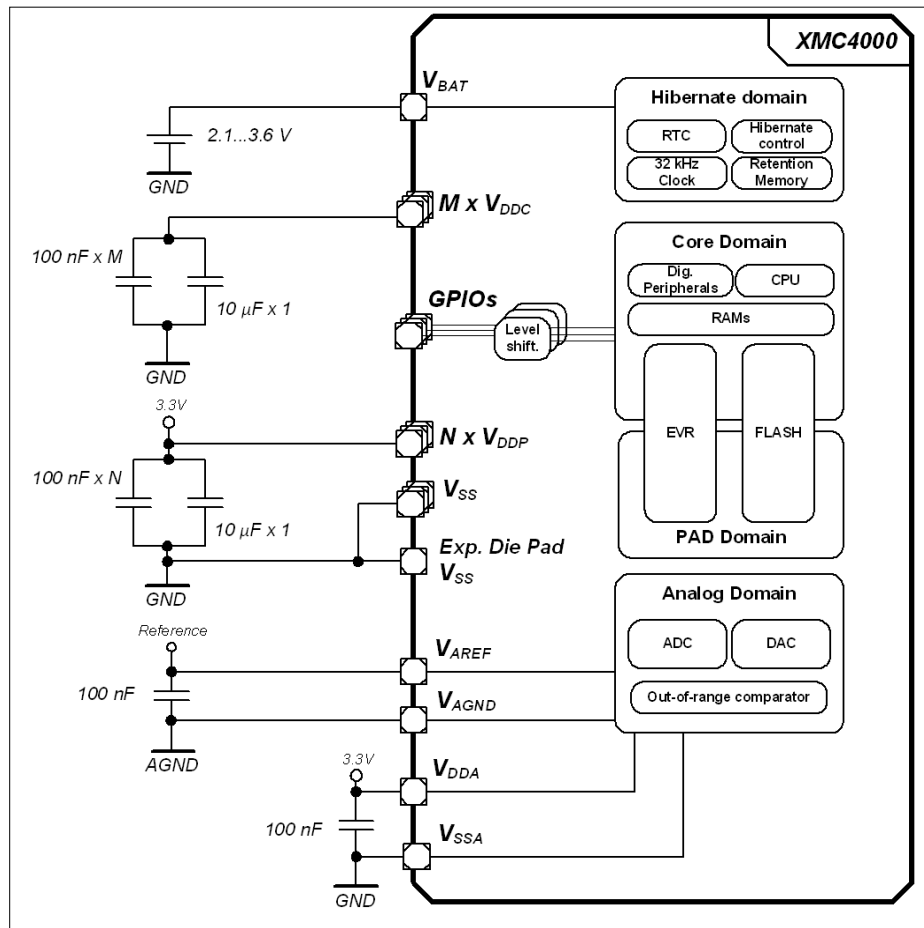


Figure 9 Power Connection Scheme

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

The XMC4500 has a common ground concept, all V_{SS} , V_{SSA} and V_{SSO} pins share the same ground potential. In packages with an exposed die pad it must be connected to the common ground as well.

V_{AGND} is the low potential to the analog reference V_{AREF} . Depending on the application it can share the common ground or have a different potential.

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

3 Electrical Parameters

3.1 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	-1.0	–	$V_{DDP} + 1.0$ or max. 4.3	V	whichever is lower
Voltage on any analog input pin with respect to V_{AGND}	V_{AIN} V_{AREF}	SR	-1.0	–	$V_{DDP} + 1.0$ or max. 4.3	V	whichever is lower
Input current on any pin during overload condition	I_{IN}	SR	-10	–	+10	mA	
Absolute maximum sum of all input circuit currents for one port group during overload condition ¹⁾	ΣI_{IN}	SR	-25	–	+25	mA	
Absolute maximum sum of all input circuit currents during overload condition	ΣI_{IN}	SR	-100	–	+100	mA	

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

Figure 10 explains the input voltage ranges of V_{IN} and V_{AIN} and its dependency to the supply level of V_{DDP} . The input voltage must not exceed 4.3 V, and it must not be more than 1.0 V above V_{DDP} . For the range up to $V_{DDP} + 1.0$ V also see the definition of the overload conditions in [Section 3.1.3](#).

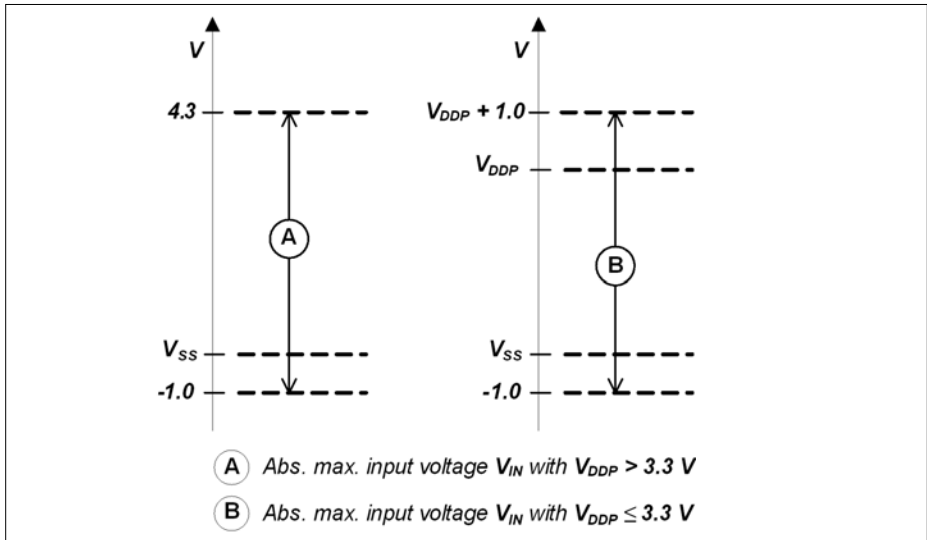


Figure 10 Absolute Maximum Input Voltage Ranges

3.1.3 Pin Reliability in Overload

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

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

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

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

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

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

Table 13 Overload Parameters

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

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

Figure 11 shows the path of the input currents during overload via the ESD protection structures. The diodes against V_{DDP} and ground are a simplified representation of these ESD protection structures.

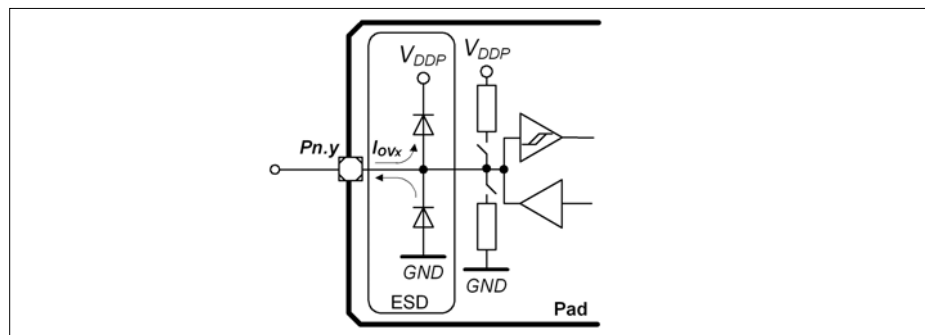


Figure 11 Input Overload Current via ESD structures

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

Electrical Parameters
Table 14 PN-Junction Characterisitcs for positive Overload

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

Table 15 PN-Junction Characterisitcs for negative Overload

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

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

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

3.1.4 Pad Driver and Pad Classes Summary

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

Table 17 Pad Driver and Pad Classes Overview

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

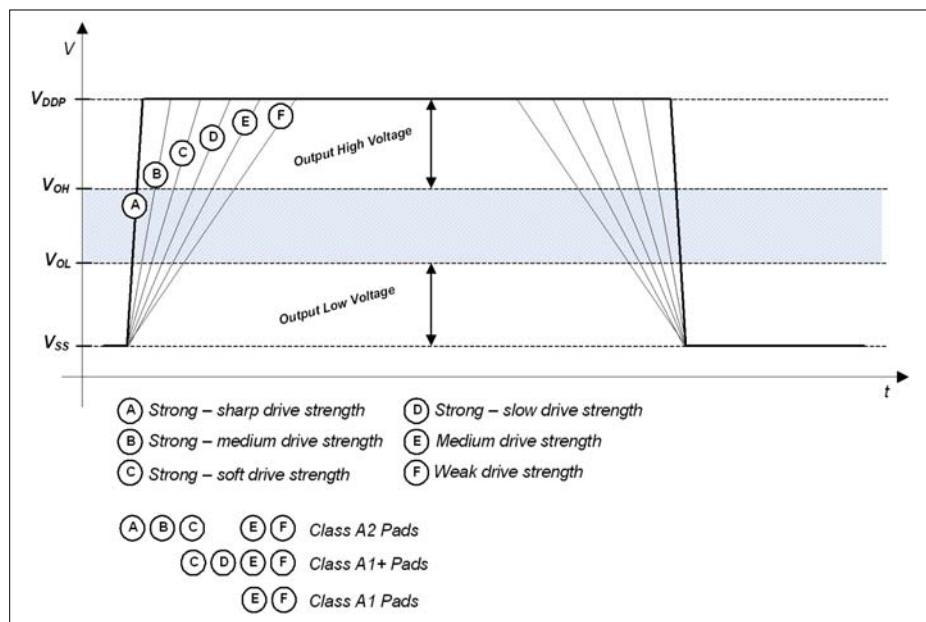


Figure 12 Output Slopes with different Pad Driver Modes

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

3.1.5 Operating Conditions

The following operating conditions must not be exceeded in order to ensure correct operation and reliability of the XMC4500. All parameters specified in the following sections refer to these operating conditions, unless noted otherwise.

Table 18 Operating Conditions Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Ambient Temperature	T_A SR	-40	—	85	°C	Temp. Range F
		-40	—	105	°C	Temp. Range X
		-40	—	125	°C	Temp. Range K
Digital supply voltage	V_{DDP} SR	3.13 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	
Analog supply voltage	V_{DDA} SR	3.0	3.3	3.6 ²⁾	V	
Analog ground voltage for V_{DDA}	V_{SSA} SR	-0.1	0	0.1	V	
Battery Supply Voltage for Hibernate Domain	V_{BAT} SR	1.95 ³⁾	—	3.63	V	When V_{DDP} is supplied V_{BAT} has to be supplied as well.
System Frequency	f_{SYS} SR	—	—	120	MHz	
Short circuit current of digital outputs	I_{SC} SR	-5	—	5	mA	
Absolute sum of short circuit currents per pin group ⁴⁾	ΣI_{SC_PG} SR	—	—	20	mA	
Absolute sum of short circuit currents of the device	ΣI_{SC_D} SR	—	—	100	mA	

1) See also the Supply Monitoring thresholds, [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) To start the hibernate domain it is required that $V_{BAT} \geq 2.1$ V, for a reliable start of the oscillation of RTC_XTAL in crystal mode it is required that $V_{BAT} \geq 3.0$ V.

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

3.2 DC Parameters

3.2.1 Input/Output Pins

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

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

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

Table 19 Standard Pad Parameters

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

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

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

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

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

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

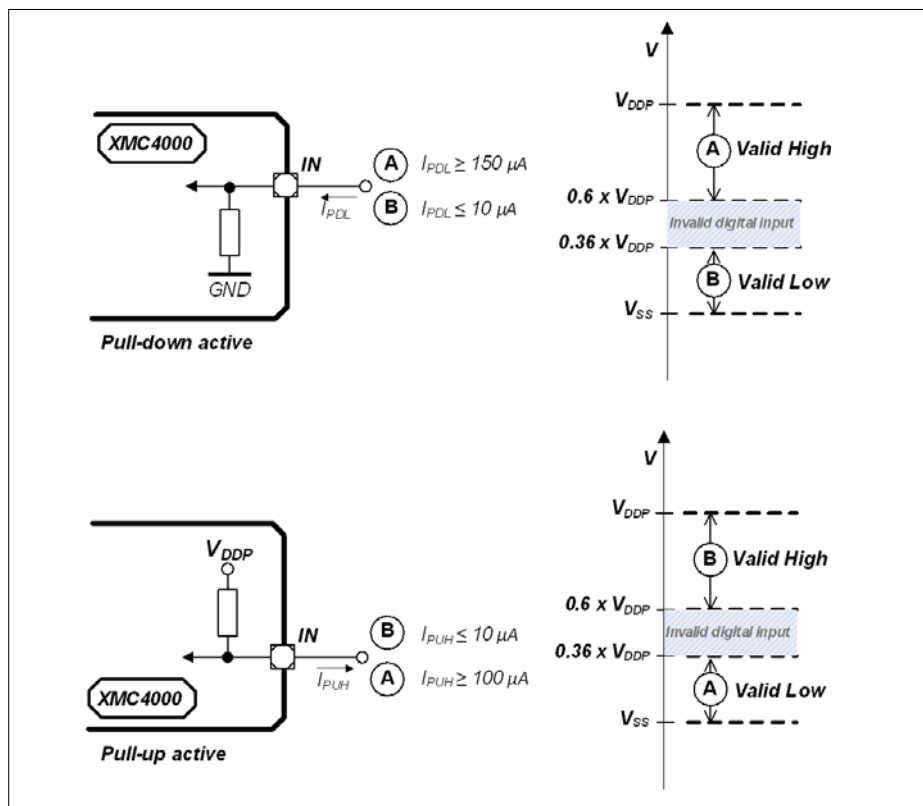


Figure 13 Pull Device Input Characteristics

Figure 13 visualizes the input characteristics with an active internal pull device:

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

Electrical Parameters
Table 20 Standard Pads Class_A1

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

1) POD = Pin Out Driver

Table 21 Standard Pads Class_A1+

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

Electrical Parameters
Table 21 Standard Pads Class_A1+

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

1) POD = Pin Out Driver

Table 22 Standard Pads Class_A2

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

Electrical Parameters
Table 22 Standard Pads Class_A2

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

3.2.2 Analog to Digital Converters (VADC)

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

Table 23 VADC Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Analog reference voltage ⁵⁾	V_{AREF} SR	$V_{AGND} + 1$	–	$V_{DDA} + 0.05^{1)}$	V	
Analog reference ground ⁵⁾	V_{AGND} SR	$V_{SSM} - 0.05$	–	$V_{AREF} - 1$	V	
Analog reference voltage range ²⁾⁵⁾	$V_{AREF} - V_{AGND}$ SR	1	–	$V_{DDA} + 0.1$	V	
Analog input voltage	V_{AIN} SR	V_{AGND}	–	V_{DDA}	V	
Input leakage at analog inputs ³⁾	I_{OZ1} CC	-100	–	200	nA	$0.03 \times V_{DDA} < V_{AIN} < 0.97 \times V_{DDA}$
		-500	–	100	nA	$0 V \leq V_{AIN} \leq 0.03 \times V_{DDA}$
		-100	–	500	nA	$0.97 \times V_{DDA} \leq V_{AIN} \leq V_{DDA}$
Input leakage current at VAREF	I_{OZ2} CC	-1	–	1	μA	$0 V \leq V_{AREF} \leq V_{DDA}$
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 23 VADC Parameters (Operating Conditions apply)

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Total Unadjusted Error	TUE_{CC}	-4	–	4	LSB	12-bit resolution; $V_{DDA} = 3.3\text{ V}$; $V_{AREF} = V_{DDA}$ ⁷⁾
Differential Non-Linearity Error ⁸⁾	$EA_{DNL_{CC}}$	-3	–	3	LSB	
Gain Error ⁸⁾	$EA_{GAIN_{CC}}$	-4	–	4	LSB	
Integral Non-Linearity ⁸⁾	$EA_{INL_{CC}}$	-3	–	3	LSB	
Offset Error ⁸⁾	$EA_{OFF_{CC}}$	-4	–	4	LSB	
RMS Noise ⁹⁾	$EN_{RMS_{CC}}$	–	1	2 ¹⁰⁾¹¹⁾	LSB	
Worst case ADC V_{DDA} power supply current per active converter	$I_{DDAA_{CC}}$	–	1.5	2	mA	during conversion $V_{DDP} = 3.6\text{ V}$, $T_J = 150\text{ °C}$
Charge consumption on V_{AREF} per conversion ⁵⁾	$Q_{CONV_{CC}}$	–	30	–	pC	$0\text{ V} \leq V_{AREF} \leq V_{DDA}$ ¹²⁾
ON resistance of the analog input path	$R_{AIN_{CC}}$	–	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 16](#)).
- 4) The sampling capacity of the conversion C-network is pre-charged to $V_{AREF}/2$ before the sampling moment. Because of the parasitic elements, the voltage measured at AINx can deviate from $V_{AREF}/2$.
- 5) Applies to AINx, when used as alternate reference input.
- 6) This represents an equivalent switched capacitance. This capacitance is not switched to the reference voltage at once. Instead, smaller capacitances are successively switched to the reference voltage.
- 7) For 10-bit conversions, the errors are reduced to 1/4; for 8-bit conversions, the errors are reduced to 1/16. Never less than ± 1 LSB.
- 8) The sum of DNL/INL/GAIN/OFF errors does not exceed the related total unadjusted error TUE.

Electrical Parameters

- 9) This parameter is valid for soldered devices and requires careful analog board design.
- 10) Resulting worst case combined error is arithmetic combination of TUE and EN_{RMS} .
- 11) Value is defined for one sigma Gauss distribution.
- 12) The resulting current for a conversion can be calculated with $I_{AREF} = Q_{CONV} / t_c$.
The fastest 12-bit post-calibrated conversion of $t_c = 550$ ns results in a typical average current of $I_{AREF} = 54.5$ μ A.

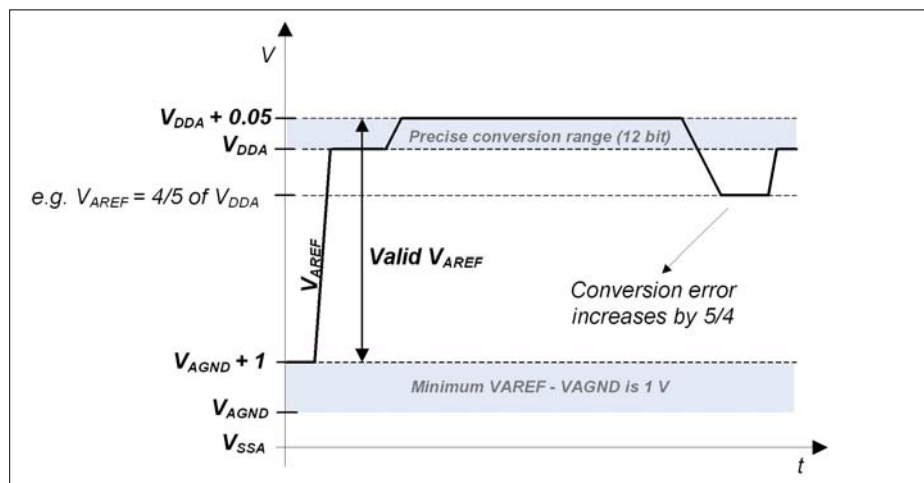


Figure 14 VADC Reference Voltage Range

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

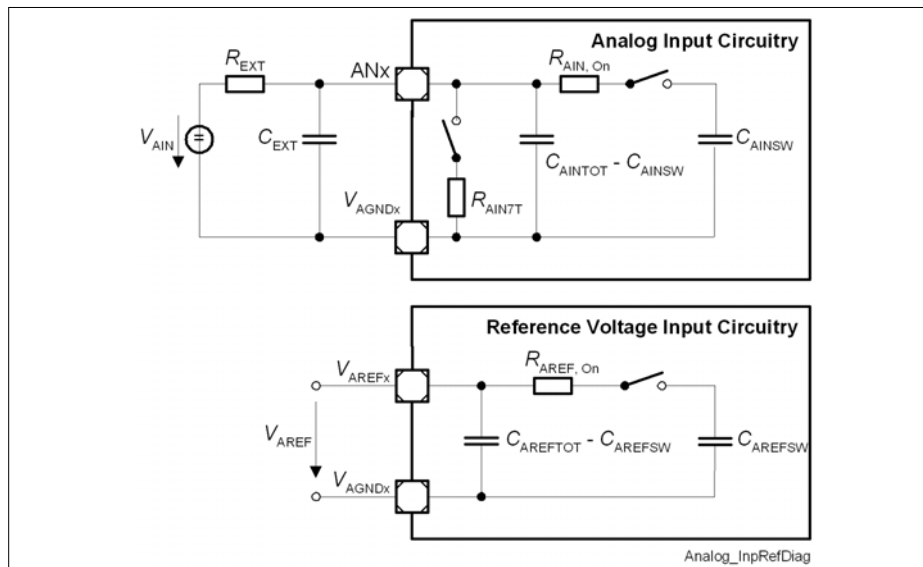


Figure 15 VADC Input Circuits

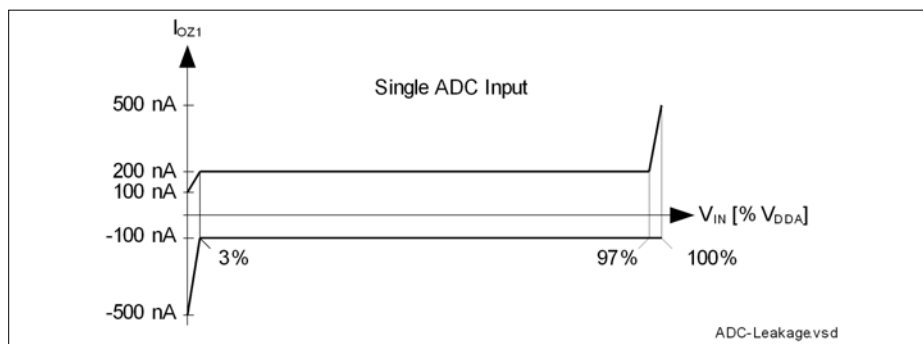


Figure 16 VADC Analog Input Leakage Current

Conversion Time

Table 24 Conversion Time (Operating Conditions apply)

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

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

Conversion Time Examples

System assumptions:

$f_{ADC} = 120 \text{ MHz}$ 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.

Electrical Parameters
Table 25 DAC Parameters (Operating Conditions apply)

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
RMS supply current	I_{DD}	CC	–	2.5	4	mA	per active DAC channel, without load currents of DAC outputs
Resolution	RES	CC	–	12	–	Bit	
Update rate	f_{URATE_A}	CC	–		2	Msam ple/s	data rate, where DAC can follow 64 LSB code jumps to ± 1 LSB accuracy
Update rate	f_{URATE_F}	CC	–		5	Msam ple/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
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	μ s	time from output enabling till code valid ± 16 LSB

Electrical Parameters
Table 25 DAC Parameters (Operating Conditions apply) (cont'd)

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
3dB Bandwidth of Output Buffer	f_{C1}	CC	2.5	5	–	MHz	verified by design
Output sourcing current	I_{OUT_SOURCE}	CC	–	-30	–	mA	
Output sinking current	I_{OUT_SINK}	CC	–	0.6	–	mA	
Output resistance	R_{OUT}	CC	–	50	–	Ohm	
Load resistance	R_L	SR	5	–	–	kOhm	
Load capacitance	C_L	SR	–	–	50	pF	
Signal-to-Noise Ratio	SNR	CC	–	70	–	dB	examination bandwidth < 25 kHz
Total Harmonic Distortion	THD	CC	–	70	–	dB	examination bandwidth < 25 kHz
Power Supply Rejection Ratio	$PSRR$	CC	–	56	–	dB	to V_{DDA} verified by design

Conversion Calculation

Unsigned:

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

Signed:

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

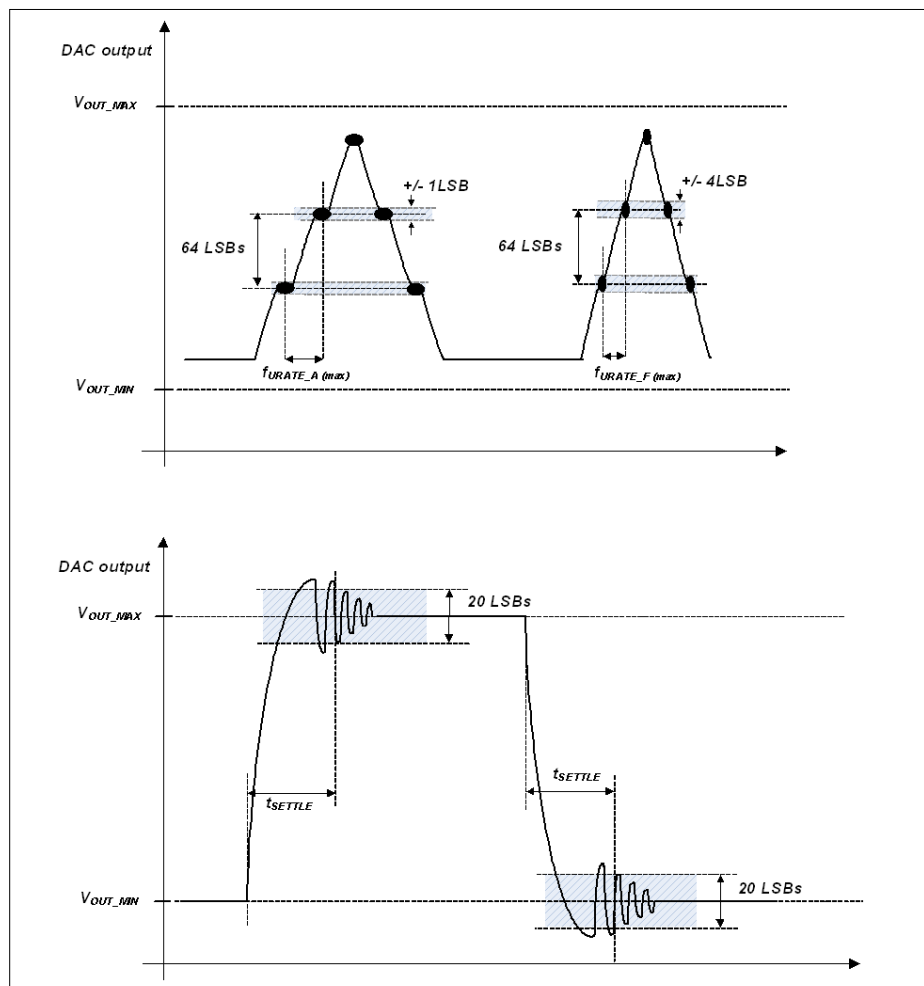


Figure 17 DAC Conversion Examples

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

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

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

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

Table 26 ORC Parameters (Operating Conditions apply)

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
DC Switching Level	V_{ODC}	CC	100	125	200	mV	$V_{AIN} \geq V_{AREF} + V_{ODC}$
Hysteresis	V_{OHYS}	CC	50	–	V_{ODC}	mV	
Detection Delay of a persistent Overvoltage	t_{ODD}	CC	55	–	450	ns	$V_{AIN} \geq V_{AREF} + 200 \text{ mV}$
			45	–	105	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Always detected Overvoltage Pulse	t_{OPDD}	CC	440	–	–	ns	$V_{AIN} \geq V_{AREF} + 200 \text{ mV}$
			90	–	–	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Never detected Overvoltage Pulse	t_{OPDN}	CC	–	–	49	ns	$V_{AIN} \geq V_{AREF} + 200 \text{ mV}$
			–	–	30	ns	$V_{AIN} \geq V_{AREF} + 400 \text{ mV}$
Release Delay	t_{ORD}	CC	65	–	105	ns	$V_{AIN} \leq V_{AREF}$
Enable Delay	t_{OED}	CC	–	100	200	ns	

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

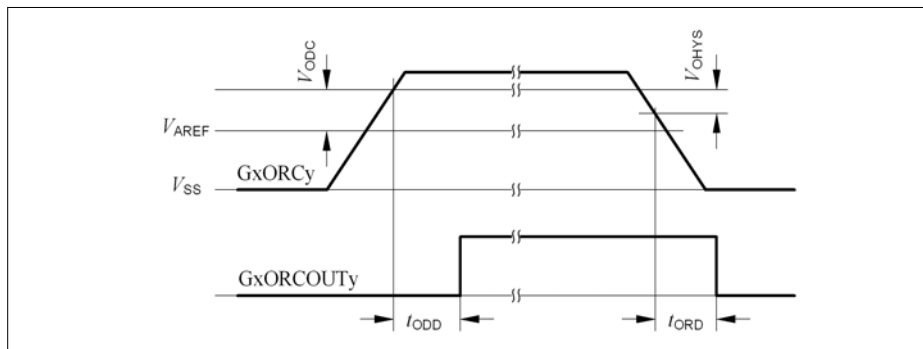


Figure 18 GxORCOUTy Trigger Generation

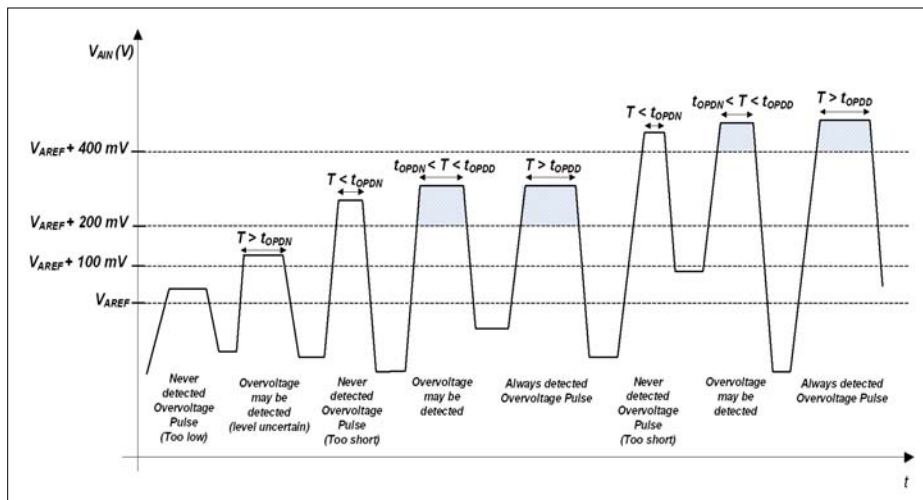


Figure 19 ORC Detection Ranges

3.2.5 Die Temperature Sensor

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

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

Table 27 Die Temperature Sensor Parameters

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

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

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

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

This formula and the values defined in **Table 27** apply with the following calibration values:

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

3.2.6 USB OTG Interface DC Characteristics

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

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

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

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

Electrical Parameters
Table 29 USB OTG Data Line (USB_DP, USB_DM) Parameters (Operating Conditions apply)

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

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

3.2.7 Oscillator Pins

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

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

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

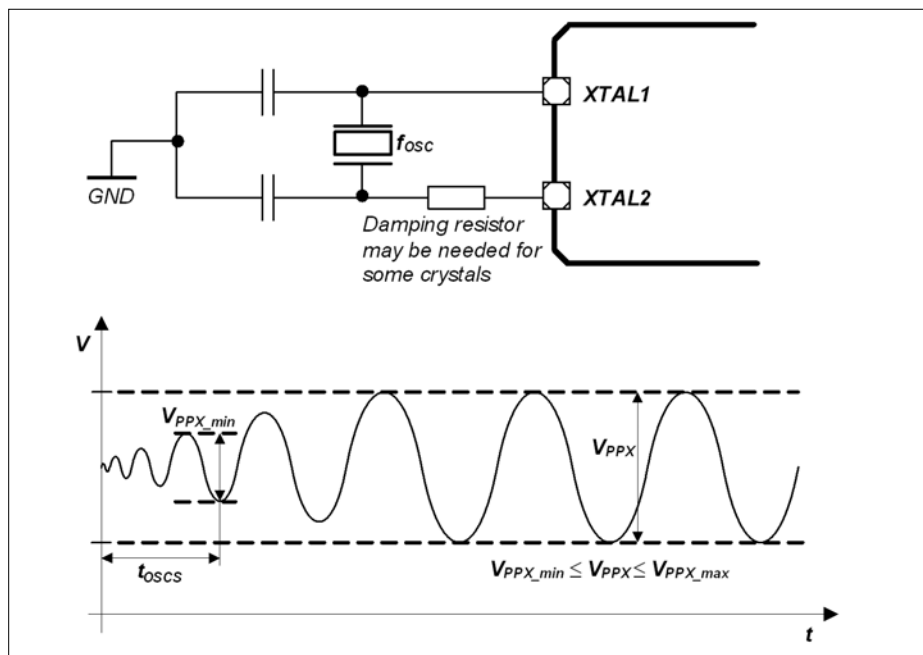


Figure 20 Oscillator in Crystal Mode

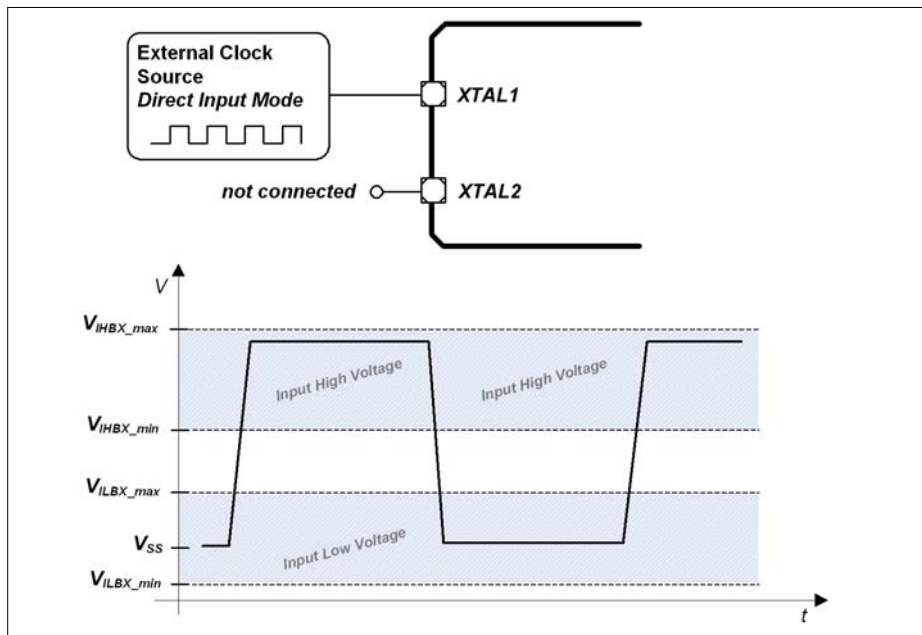


Figure 21 **Oscillator in Direct Input Mode**

Table 30 OSC_XTAL Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input frequency	f_{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 31 RTC_XTAL Parameters

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

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

3.2.8 Power Supply Current

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

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

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

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

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

Table 32 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	–		100 / 100 / 100

Electrical Parameters
Table 32 Power Supply Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Sleep supply current ⁴⁾ Peripherals disabled Frequency: $f_{CPU} / f_{PERIPH} / f_{CCU}$ in MHz	I_{DDPS} CC	–	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	

Electrical Parameters

Table 32 Power Supply Parameters

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_Sl 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 33 Flash Memory Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Erase Time per 256 Kbyte Sector	t_{ERP} CC	–	5	5.5	s	
Erase Time per 64 Kbyte Sector	t_{ERP} CC	–	1.2	1.4	s	
Erase Time per 16 Kbyte Logical Sector	t_{ERP} CC	–	0.3	0.4	s	
Program time per page ¹⁾	t_{PRP} CC	–	5.5	11	ms	
Erase suspend delay	$t_{\text{FL_ErSusp}}$ CC	–	–	15	ms	
Wait time after margin change	$t_{\text{FL_Margin Del}}$ CC	10	–	–	μs	
Wake-up time	t_{WU} CC	–	–	270	μs	
Read access time	t_{a} CC	22	–	–	ns	For operation with $1 / f_{\text{CPU}} < t_{\text{a}}$ 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: $\text{FCON.WSPFLASH} \times (1 / f_{\text{CPU}}) \geq t_{\text{a}}$.

3) Storage and inactive time included.

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

3.3 AC Parameters

3.3.1 Testing Waveforms

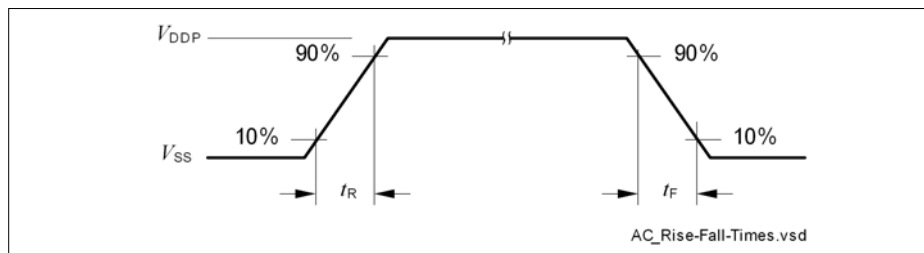


Figure 22 Rise/Fall Time Parameters

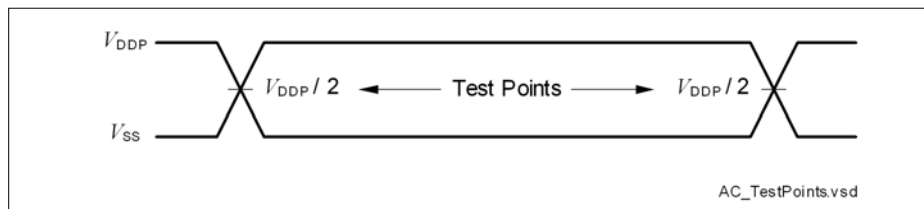


Figure 23 Testing Waveform, Output Delay

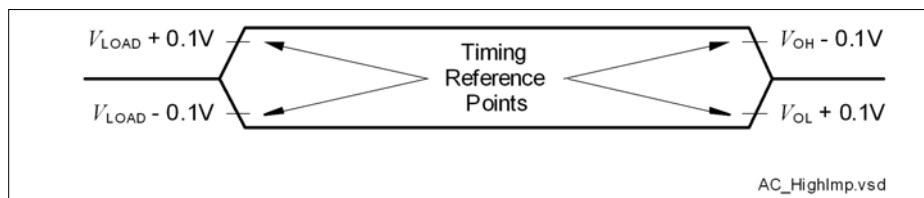


Figure 24 Testing Waveform, Output High Impedance

3.3.2 Power-Up and Supply Monitoring

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

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

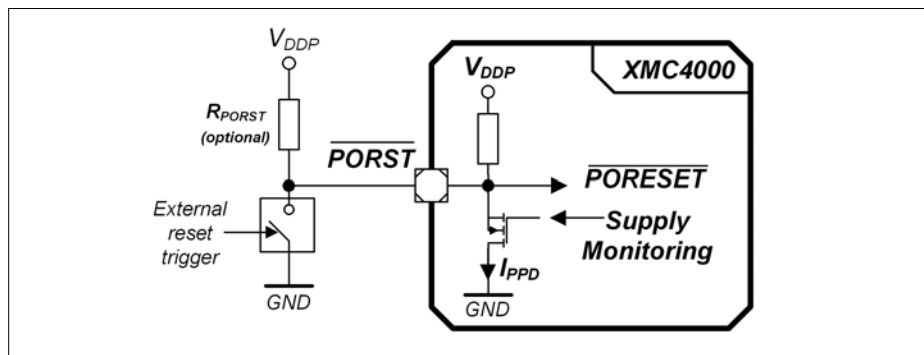


Figure 25 **$\overline{\text{PORST}}$ Circuit**

Table 34 **Supply Monitoring Parameters**

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

1) Minimum threshold for reset assertion.

Electrical Parameters

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

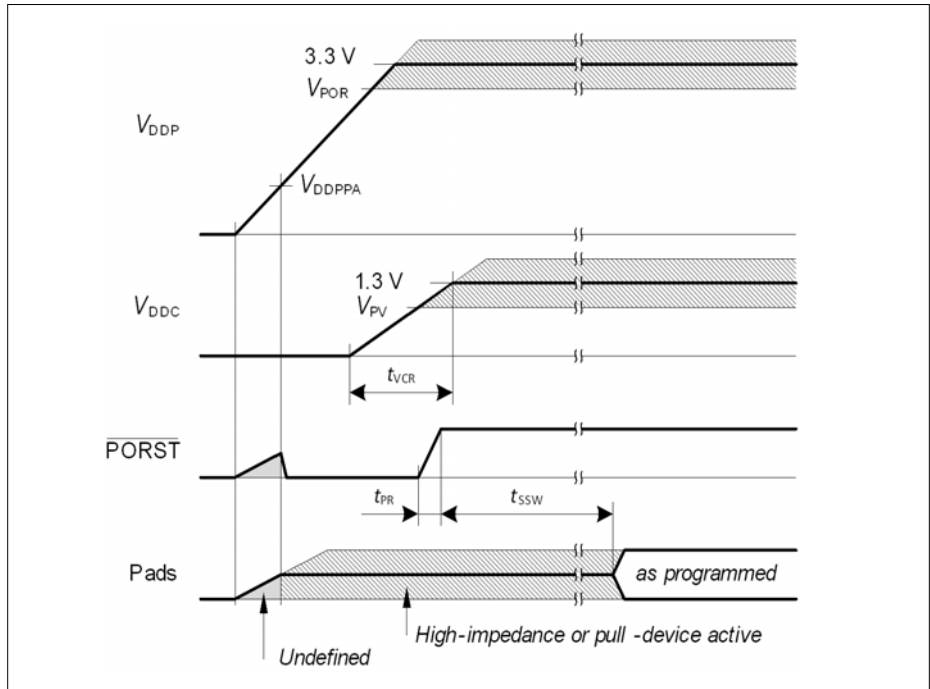


Figure 26 Power-Up Behavior

3.3.3 Power Sequencing

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

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

Table 35 Power Sequencing Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Positive Load Step Current	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 36 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 37 Fast Internal Clock Parameters

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

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

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

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

Electrical Parameters

Slow Internal Clock Source

Table 38 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 39 JTAG Interface Timing Parameters

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

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

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

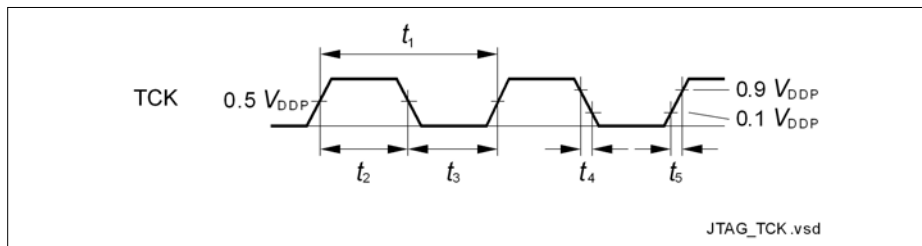


Figure 27 Test Clock Timing (TCK)

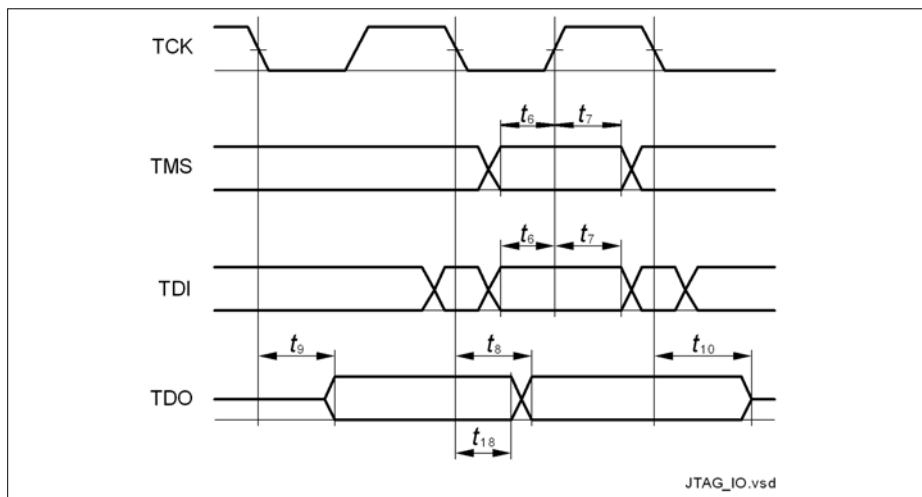


Figure 28 JTAG Timing

3.3.7 Serial Wire Debug Port (SW-DP) Timing

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

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

Note: Operating conditions apply.

Table 40 SWD Interface Timing Parameters (Operating Conditions apply)

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

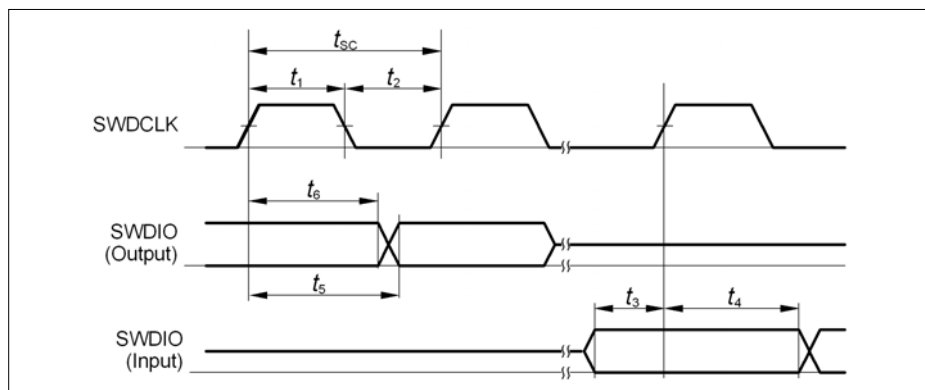


Figure 29 SWD Timing

3.3.8 Embedded Trace Macro Cell (ETM) Timing

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

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

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

Table 41 ETM Interface Timing Parameters

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

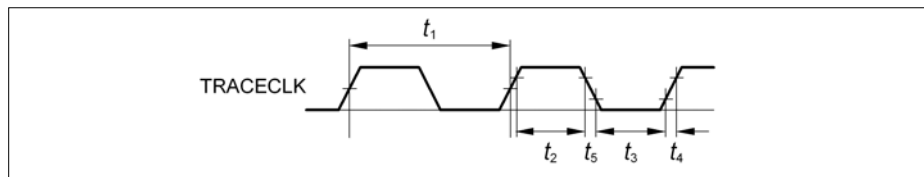


Figure 30 ETM Clock Timing

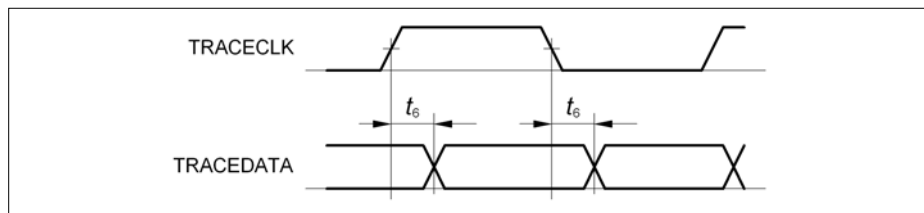


Figure 31 ETM Data Timing

3.3.9 Peripheral Timing

3.3.9.1 Delta-Sigma Demodulator Digital Interface Timing

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

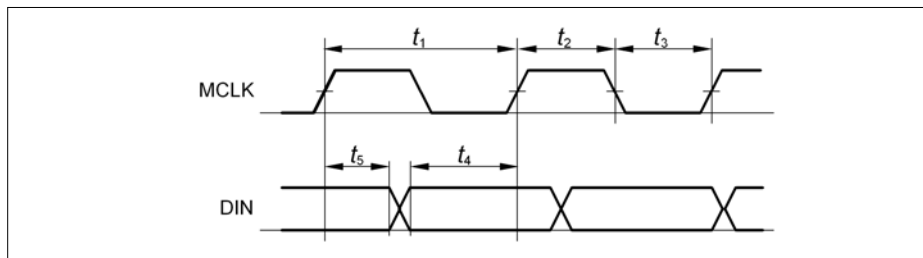
The data timing is relative to the active clock edge. Depending on the operation mode of the connected modulator that can be the rising and falling clock edge.

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

Table 42 DSD Interface Timing Parameters

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

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


Figure 32 DSD Data Timing

3.3.9.2 Synchronous Serial Interface (USIC SSC) Timing

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

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

Table 43 USIC SSC Master Mode Timing

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

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

Table 44 USIC SSC Slave Mode Timing

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

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

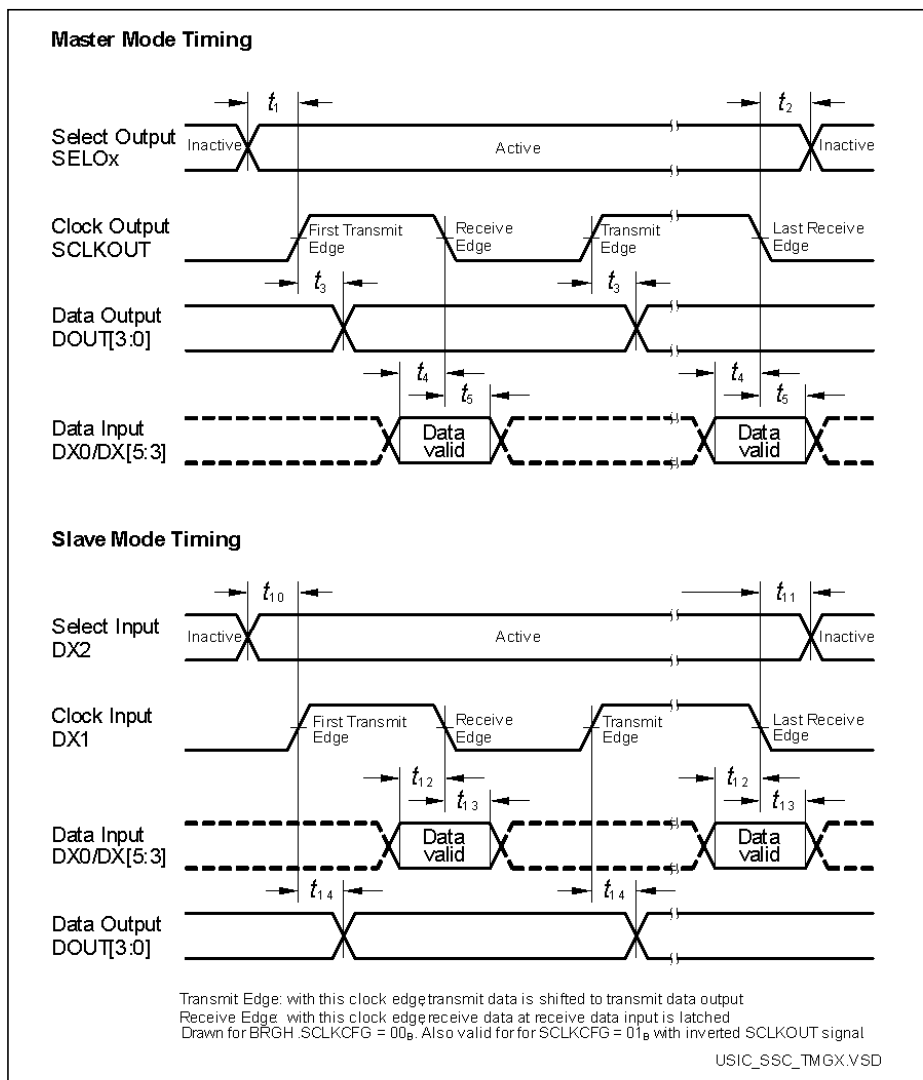


Figure 33 USIC - SSC Master/Slave Mode Timing

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

3.3.9.3 Inter-IC (IIC) Interface Timing

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

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

Table 45 USIC IIC Standard Mode Timing¹⁾

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

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

Table 46 USIC IIC Fast Mode Timing¹⁾

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

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

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

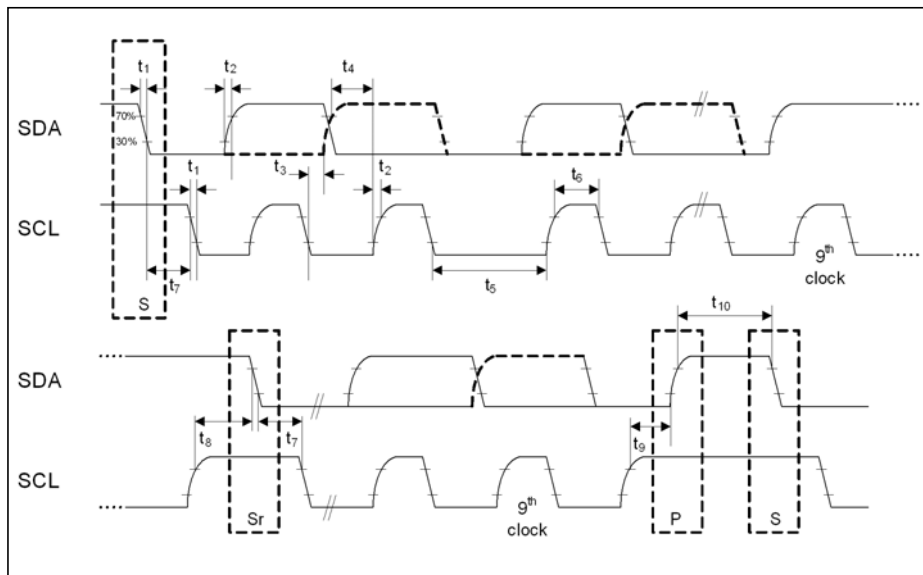


Figure 34 USIC IIC Stand and Fast Mode Timing

3.3.9.4 Inter-IC Sound (IIS) Interface Timing

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

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

Table 47 USIC IIS Master Transmitter Timing

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

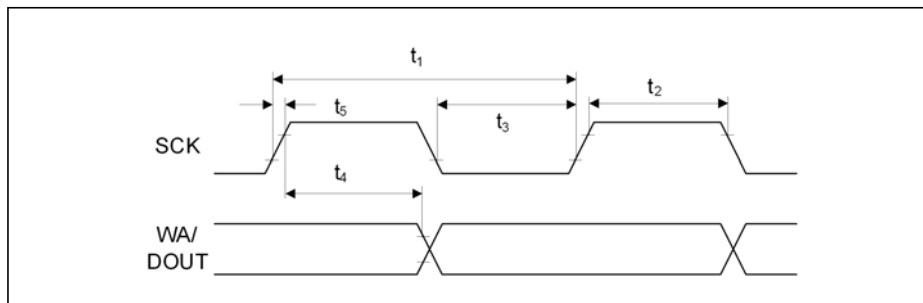


Figure 35 USIC IIS Master Transmitter Timing

Table 48 USIC IIS Slave Receiver Timing

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

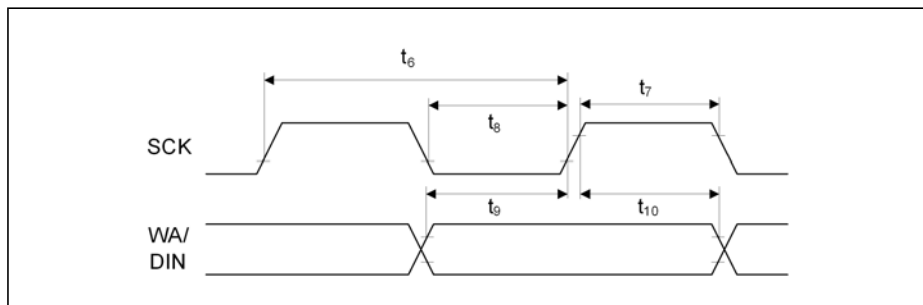


Figure 36 USIC IIS Slave Receiver Timing

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 49 SDMMC Timing for Full-Speed Mode

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

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

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

Electrical Parameters

Table 50 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)

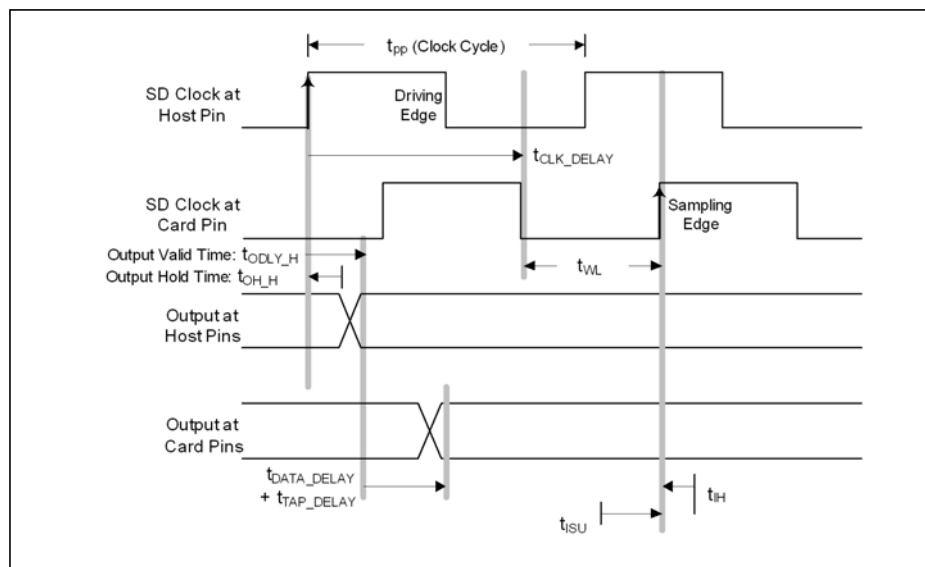


Figure 37 Full-Speed Output Path

Full-Speed Write Meeting Setup (Maximum Delay)

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

No clock delay:

(1)

$$t_{ODLY_F} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ISU} < t_{WL}$$

With clock delay:

(2)

$$t_{ODLY_F} + t_{DATA_DELAY} + t_{TAP_DELAY} + t_{ISU} < t_{WL} + t_{CLK_DELAY}$$

(3)

$$t_{DATA_DELAY} + t_{TAP_DELAY} + t_{WL} < t_{PP} + t_{CLK_DELAY} - t_{ISU} - t_{ODLY_F}$$

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

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

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

Full-Speed Write Meeting Hold (Minimum Delay)

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

(4)

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

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

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

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

Full-Speed Input Path (Read)

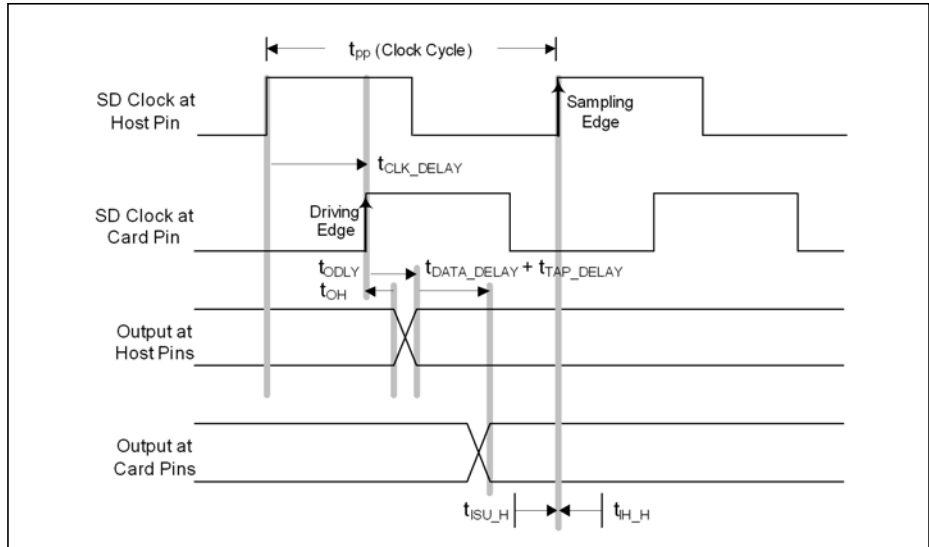


Figure 38 Full-Speed Input Path

Full-Speed Read Meeting Setup (Maximum Delay)

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

(5)

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

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

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

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

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

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

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

(6)

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

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

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

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

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

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

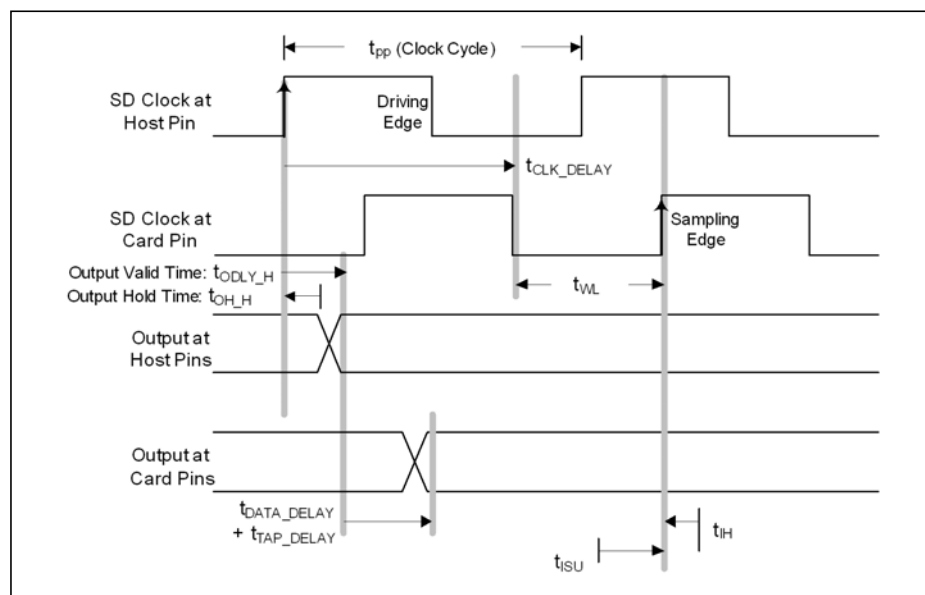
Parameter	Symbol		Values		Unit	Note/ Test Condition
			Min.	Max.		
Clock frequency in high speed transfer mode ($1/t_{\text{pp}}$)	f_{pp}	CC	0	48	MHz	
Clock cycle in high speed transfer mode	t_{pp}	CC	20	—	ns	
Clock low time	t_{WL}	CC	7	—	ns	
Clock high time	t_{WH}	CC	7	—	ns	
Clock rise time	t_{TLH}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

Table 52 SD Card Bus Timing for High-Speed 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 39 High-Speed Output Path

High-Speed Write Meeting Setup (Maximum Delay)

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

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)

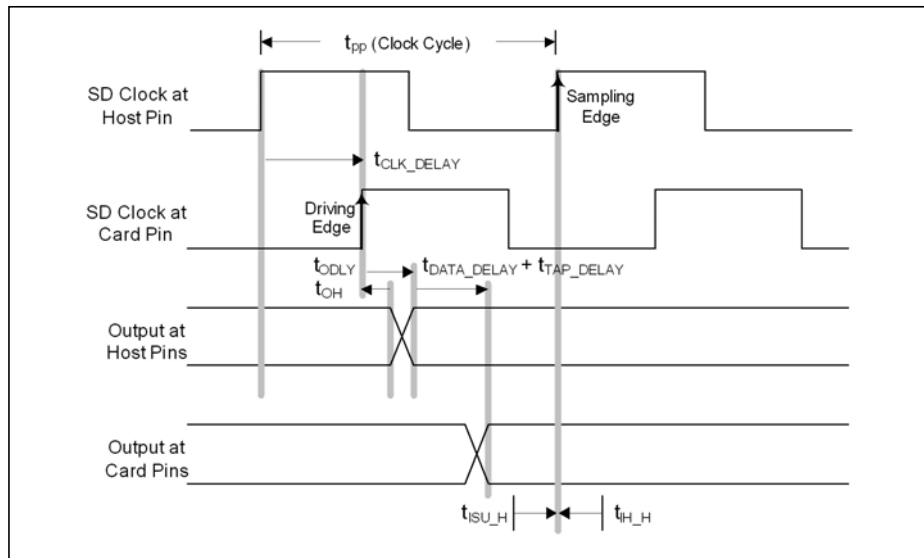


Figure 40 High-Speed Input Path

High-Speed Read Meeting Setup (Maximum Delay)

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

(11)

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

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

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

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

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

Electrical Parameters

High-Speed Read Meeting Hold (Minimum Delay)

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

(12)

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

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

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

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

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

3.3.10 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 53 Common Timing Parameters for all Asynchronous Timings

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

Read Timing
Table 54 Asynchronous Read Timing, Multiplexed and Demultiplexed

Parameter			Symbol	Limit Values		Unit
				Min.	Max.	
A(24:16) output delay	to $\overline{RD}$ 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

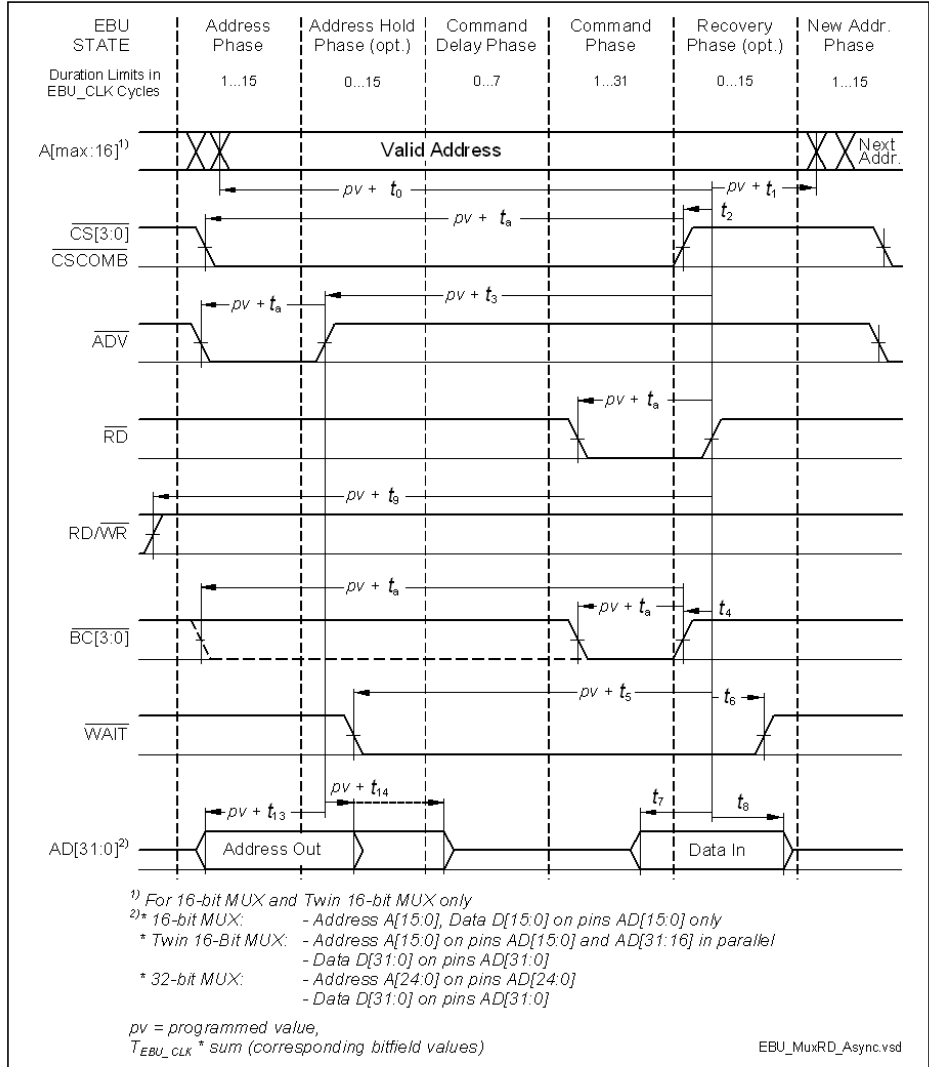


Figure 41 Multiplexed Read Access

Demultiplexed Read Timing

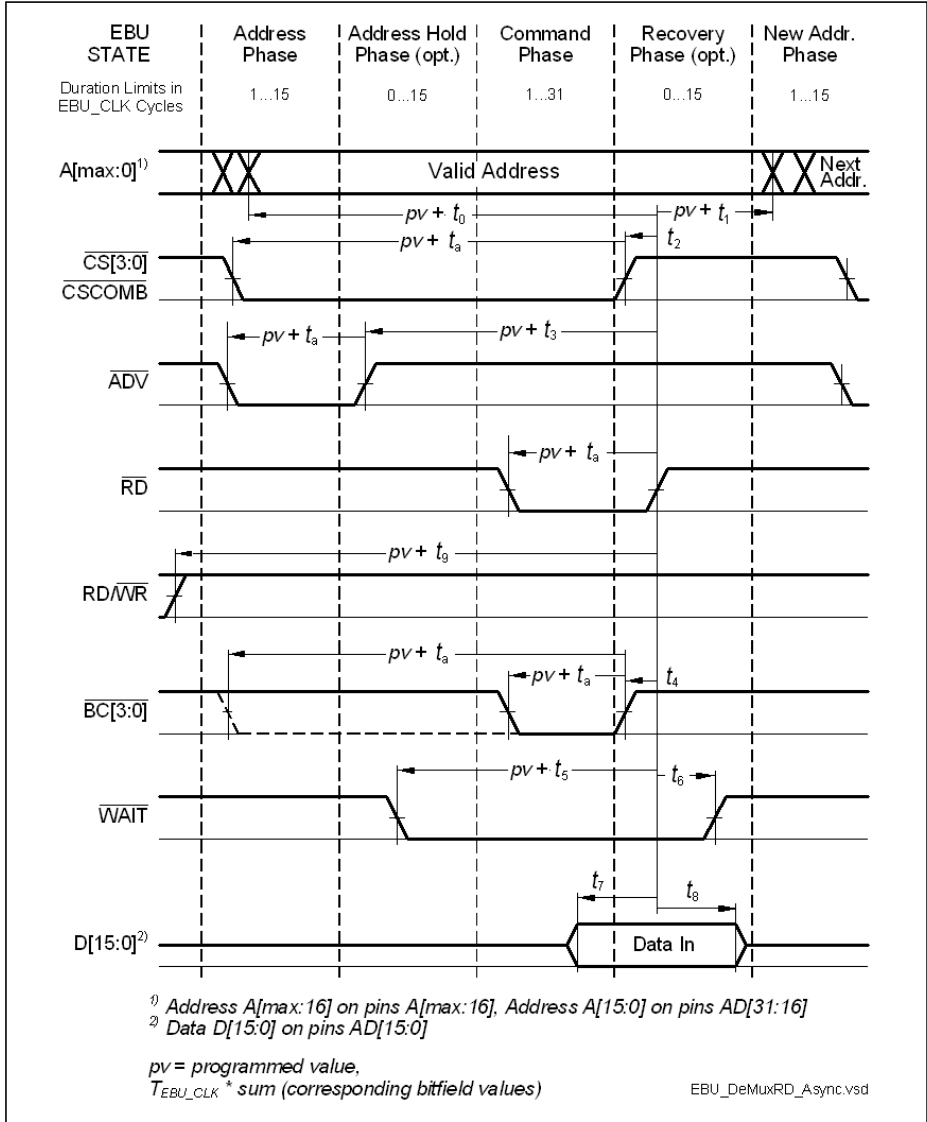


Figure 42 Demultiplexed Read Access

Write Timing
Table 55 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	

Demultiplexed Write Timing

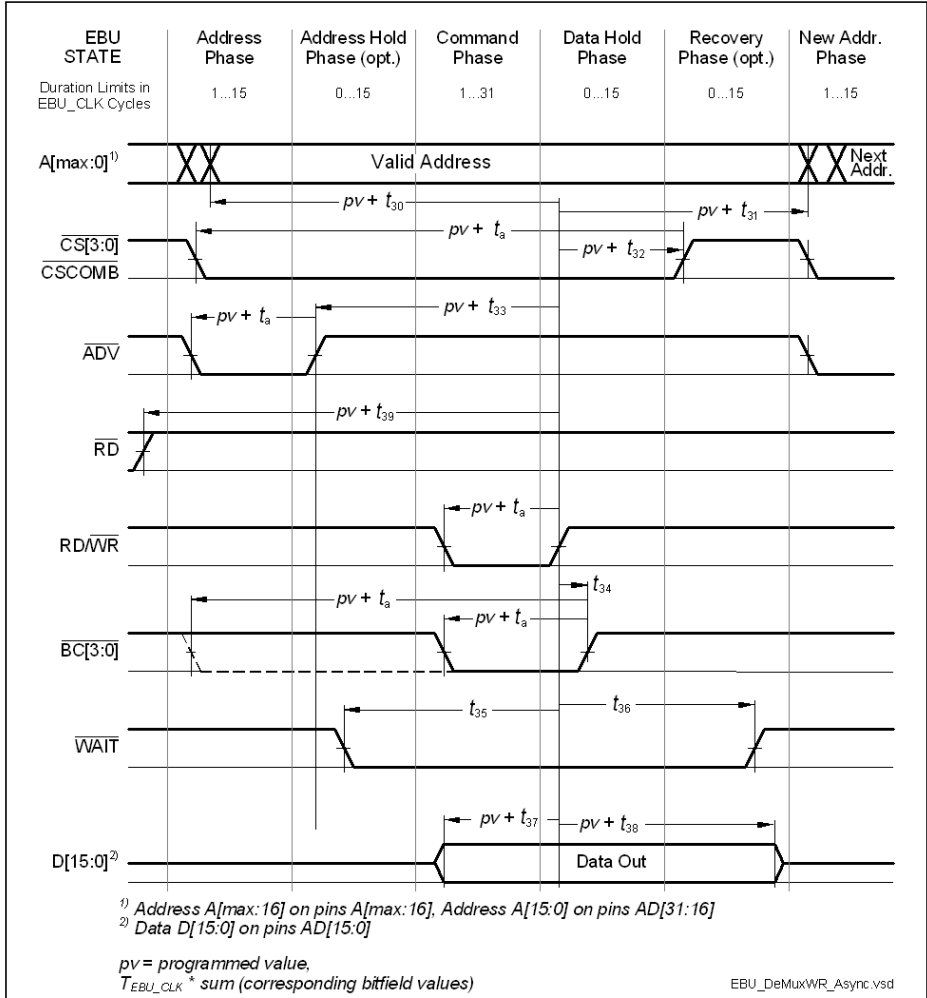


Figure 44 Demultiplexed Write Access

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 $C_L = 16 \text{ pF}$.

Table 56 EBU Burst Mode Read / Write Access Timing Parameters

Parameter	Symbol		Values			Unit	Note / Test Condition
			Min.	Typ.	Max.		
Output delay from BFCLKO rising edge	t_{10}	CC	-2	—	2	ns	—
$\overline{\text{RD}}$ and RD/WR active/inactive after BFCLKO active edge ¹⁾	t_{12}	CC	-2	—	2	ns	—
$\overline{\text{CSx}}$ output delay from BFCLKO active edge ¹⁾	t_{21}	CC	-2.5	—	1.5	ns	—
$\overline{\text{ADV}}$ active/inactive after BFCLKO active edge ²⁾	t_{22}	CC	-2	—	2	ns	—
$\overline{\text{BAA}}$ 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	—
WAIT setup (low or high) to BFCLKI rising edge ³⁾	t_{25}	SR	3	—	—	ns	—
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 $T_{\text{CPU}} = 1 / f_{\text{CPU}}$.

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.

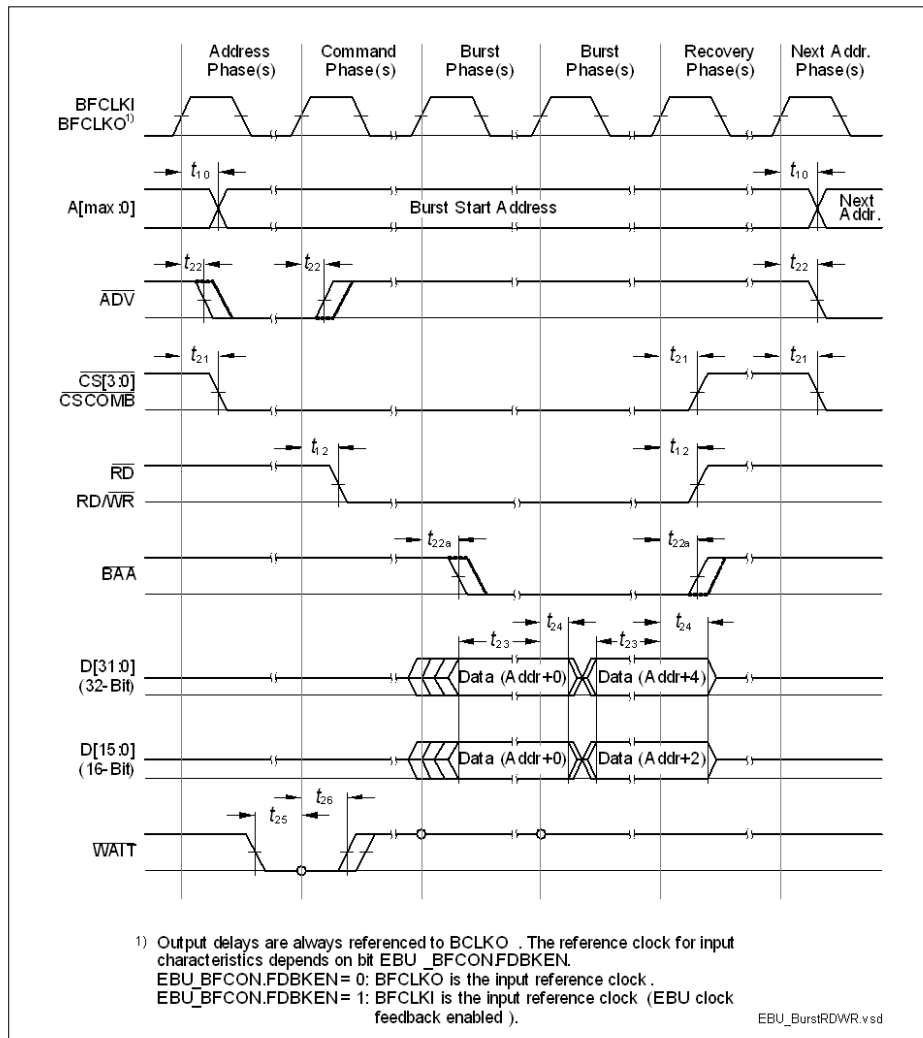


Figure 45 EBU Burst Mode Read / Write Access Timing

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 57 EBU Arbitration Signal Timing Parameters

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

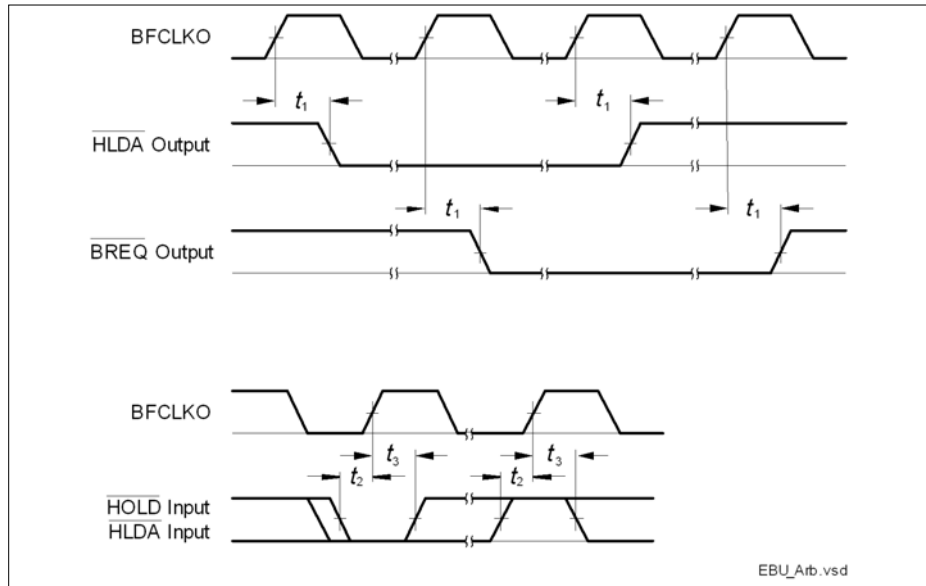


Figure 46 EBU Arbitration Signal Timing

3.3.10.4 EBU SDRAM Access Timing

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

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

Table 58 EBU SDRAM Access SDCLKO Signal Timing Parameters

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

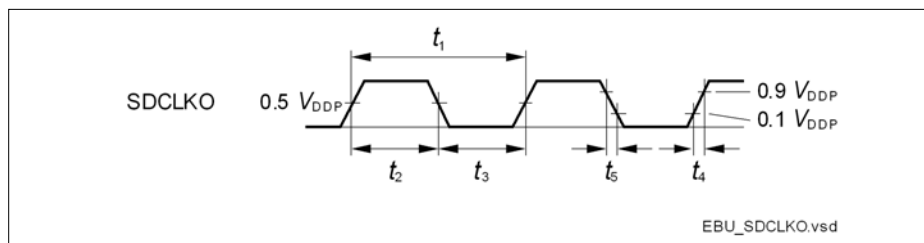


Figure 47 EBU SDRAM Access CLKOUT Timing

Table 59 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	–	
$\text{RD}/\overline{\text{WR}}$ low		CC	t_{14}	–	9	
$\text{RD}/\overline{\text{WR}}$ 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	D(15:0) input setup to SDCLKO low-to-high transition	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.

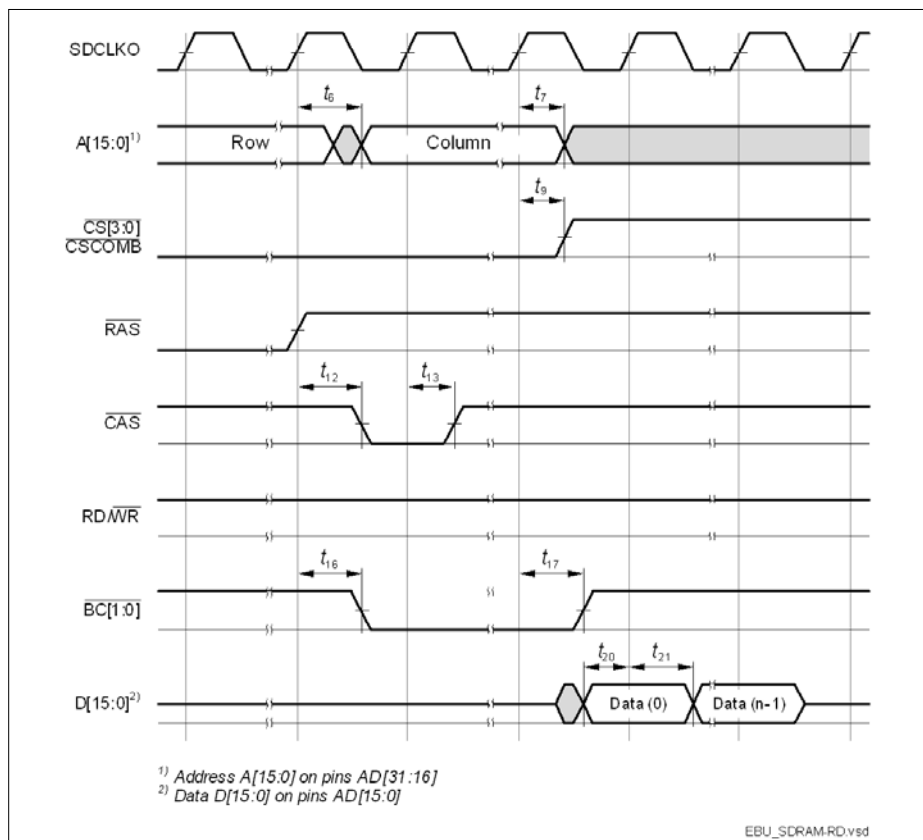


Figure 48 EBU SDRAM Read Access Timing

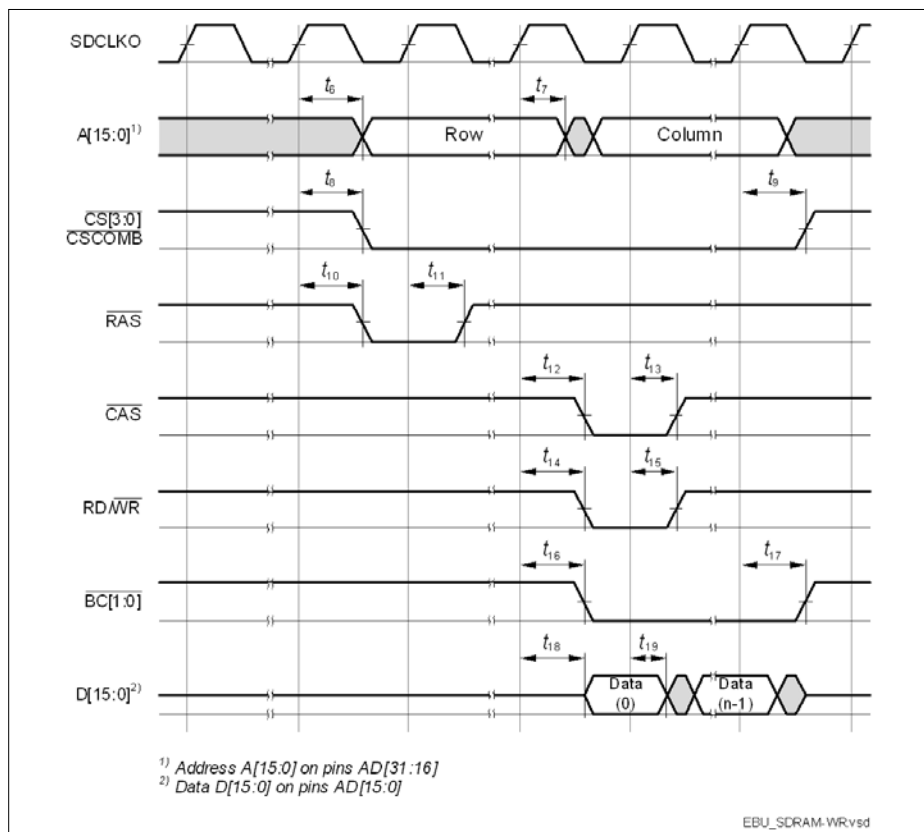


Figure 49 EBU SDRAM Write Access Timing

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 60 USB Timing Parameters (operating conditions apply)

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

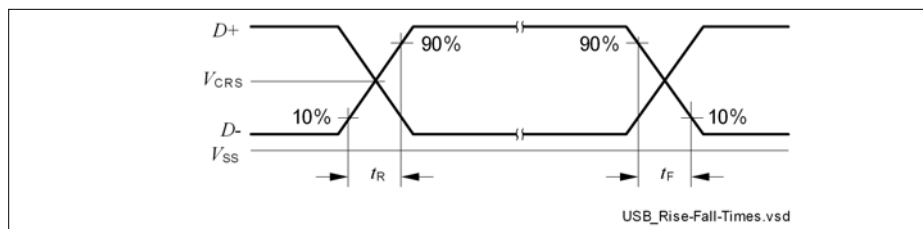


Figure 50 USB Signal Timing

3.3.12 Ethernet Interface (ETH) Characteristics

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

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

3.3.12.1 ETH Measurement Reference Points

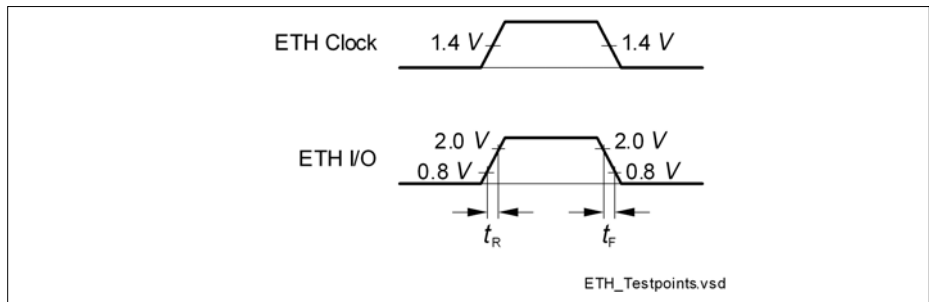


Figure 51 ETH Measurement Reference Points

3.3.12.2 ETH Management Signal Parameters (ETH_MDC, ETH_MDIO)

Table 61 ETH Management Signal Timing Parameters

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

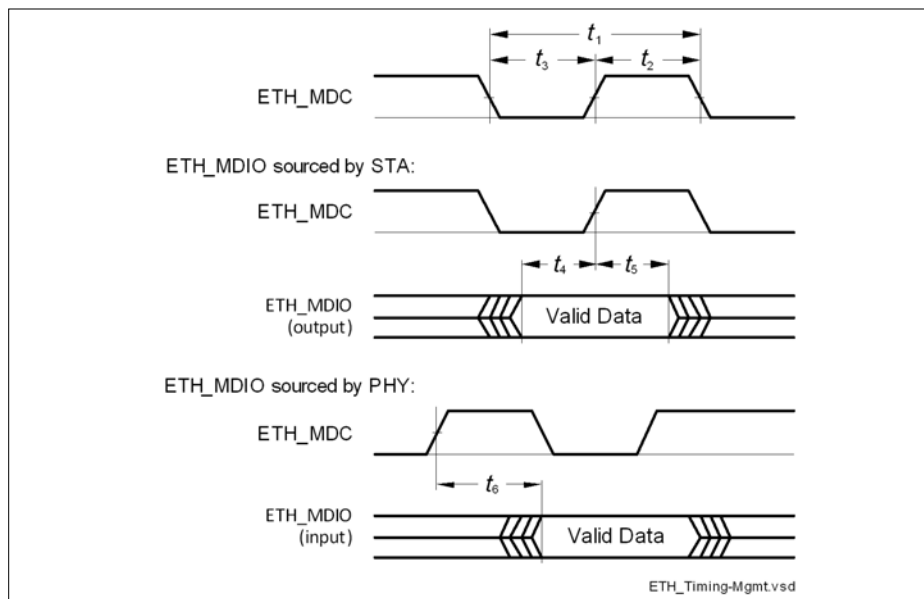


Figure 52 ETH Management Signal Timing

3.3.12.3 ETH MII Parameters

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

Table 62 ETH MII Signal Timing Parameters

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

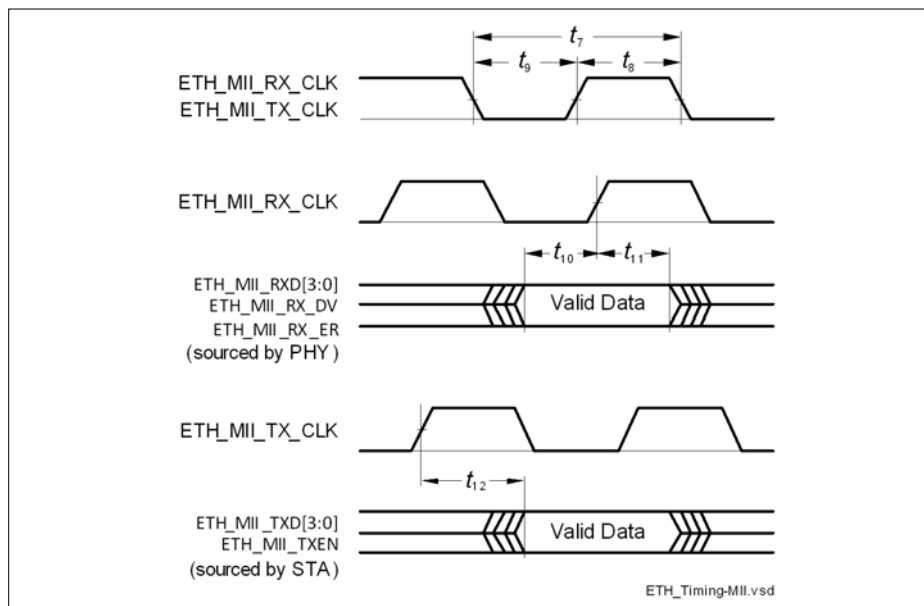


Figure 53 ETH MII Signal Timing

3.3.12.4 ETH RMII Parameters

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

Table 63 ETH RMII Signal Timing Parameters

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

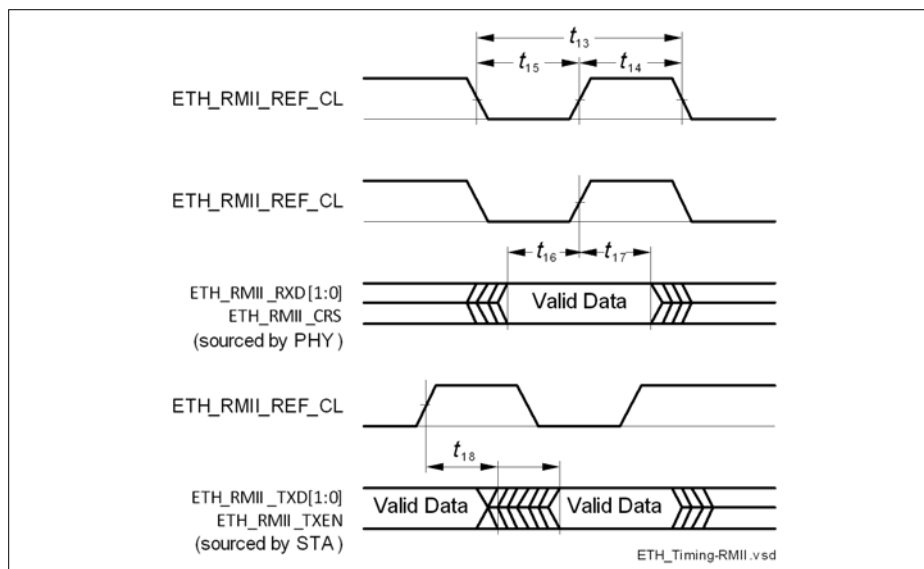


Figure 54 ETH RMII Signal Timing

4 Package and Reliability

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

Table 64 Thermal Characteristics of the Packages

Parameter	Symbol	Limit Values		Unit	Package Types
		Min.	Max.		
Exposed Die Pad Dimensions (including U-Groove where applicable)	Ex × Ey CC	-	6.5 × 6.5	mm	PG-LQFP-144-24
		-	7.0 × 7.0	mm	PG-LQFP-100-25
Exposed Die Pad Dimensions	-	-	7.0 × 7.0	mm	PG-LQFP-100-29
	-	-	6.5 × 6.5	mm	PG-LQFP-144-26
Thermal resistance Junction-Ambient $T_j \leq 150\text{ °C}$	$R_{\Theta JA}$ CC	-	40.5	K/W	PG-LFBGA-144-10
		-	19.5	K/W	PG-LQFP-144-24 ¹⁾
		-	21.0	K/W	PG-LQFP-100-25 ¹⁾
		-	21.0	K/W	PG-LQFP-100-29 ¹⁾
		-	19.5	K/W	PG-LQFP-144-26 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 $R_{\Theta JA}$ ” quantifies these parameters. The power dissipation must be limited so that the average junction temperature does not exceed 150 °C.

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

The internal power consumption is defined as

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

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

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

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

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

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

4.2 Package Outlines

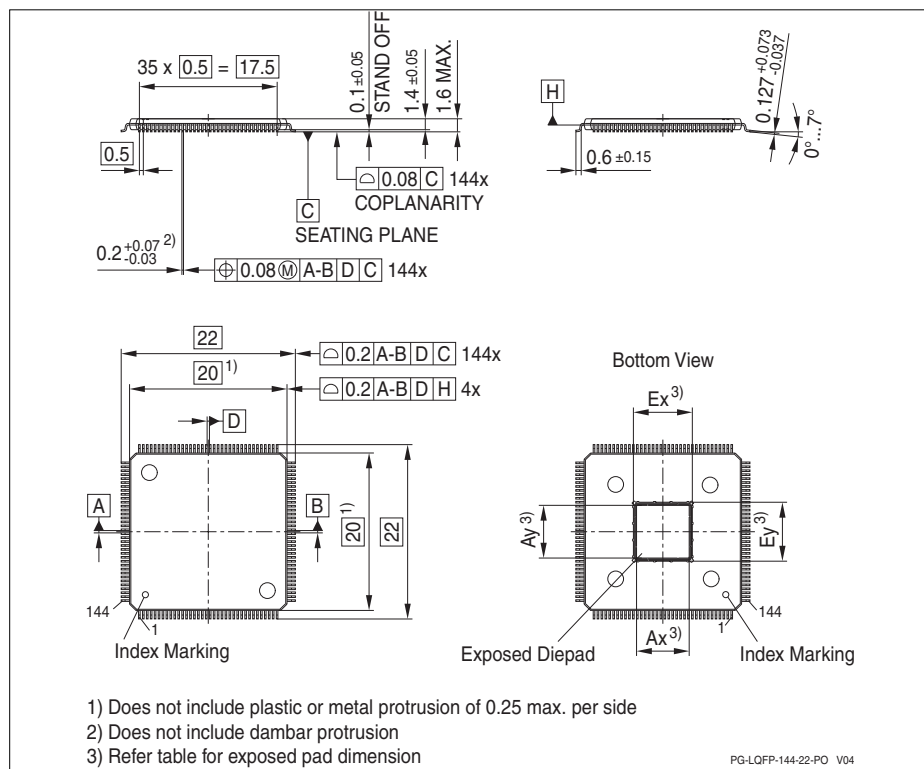


Figure 55 PG-LQFP-144-24 (Plastic Green Low Profile Quad Flat Package)

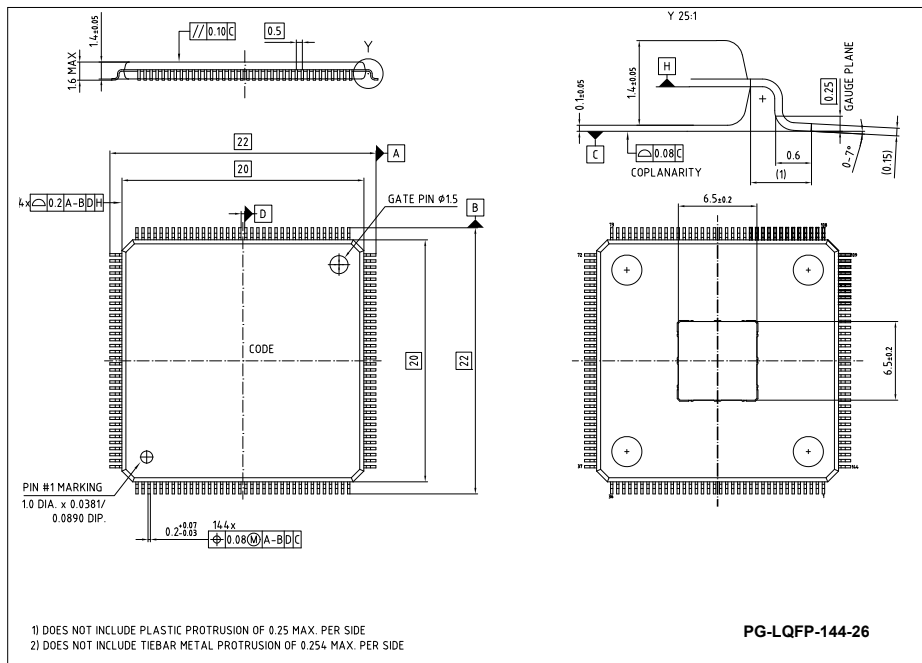


Figure 56 PG-LQFP-144-26 (Plastic Green Low Profile Quad Flat Package)

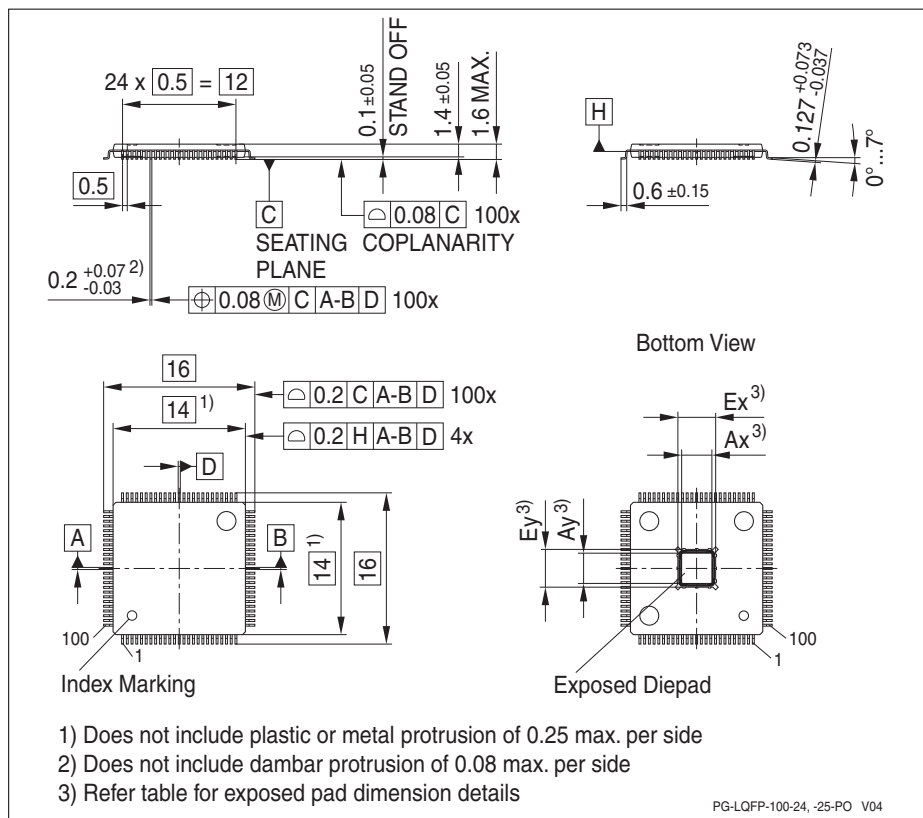


Figure 57 PG-LQFP-100-25 (Plastic Green Low Profile Quad Flat Package)

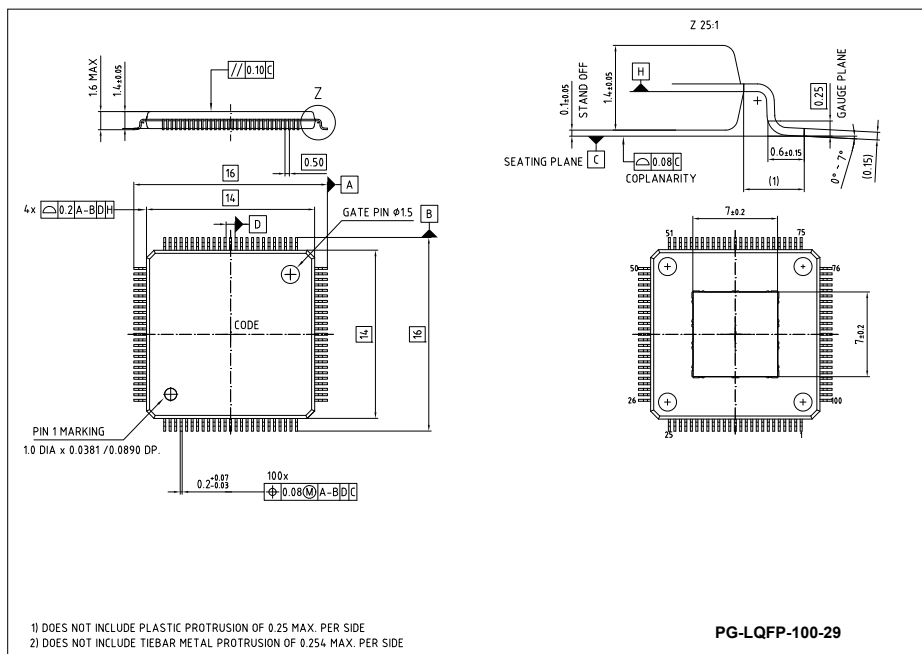


Figure 58 PG-LQFP-100-29 (Plastic Green Low Profile Quad Flat Package)

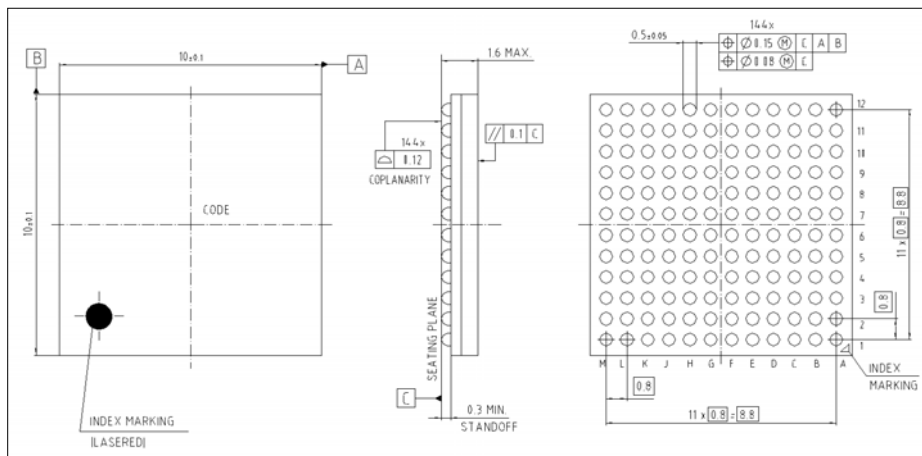


Figure 59 PG-LFBGA-144-10 (Plastic Green Low Profile Fine Pitch Ball Grid Array)

All dimensions in mm.

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

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 65 Quality Parameters

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Operation lifetime	t_{OP} CC	20	–	–	a	$T_J \leq 109^\circ\text{C}$, device permanent on
ESD susceptibility according to Human Body Model (HBM)	V_{HBM} SR	–	–	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-020D
Soldering temperature	T_{SDR} SR	–	–	260	$^\circ\text{C}$	Profile according to JEDEC J-STD-020D

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