



**THE DATASHEET OF
M2S050T-1FGG484M**



DS0120
Datasheet
Military Grade IGLOO2 FPGA and SmartFusion2 SoC
FPGA



a  **MICROCHIP** company

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1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the current publication.

1.1 Revision 7.0

The following information was updated in revision 7.0 of this document.

- Information about FPGA Programming Temperature, Operating Temperature, and Retention (Biased/Unbiased) Operating Limits was updated. See [Table 4](#), page 6.
- Information about Embedded Flash Programming Temperature and Maximum Operating Temperature Operating Limits was updated. See [Table 5](#), page 7
- Information about Device Storage Temperature and Retention was updated. See [Table 6](#), page 7.

1.2 Revision 6.0

The following information was updated in revision 6.0 of this document.

- Information about VOH and VOL were updated. See [Table 28](#), page 23.
- Information about DEVRSTN ramp time was updated. See [Table 149](#), page 98.
- Information about System Controller SPI characteristics for sp6 and sp7 were updated. See [Table 152](#), page 100.

The following information was added in revision 6.0 of this document.

- A note about VID was added to LVDS differential voltage specification. See [Table 84](#), page 51.

1.3 Revision 5.0

The following information was updated in revision 5.0 of this document.

- VOH (V) in LVCMOS 2.5 V transmitter drive strength specifications. See [Table 31](#), page 24.
- SPI timing. See [Table 176](#), page 111 and [Table 178](#), page 114.
- I/O Weak Pull-Up/Down resistances. See [Table 20](#), page 20.
- Speed grade -1 was updated for Register Delays, Combinatorial Cell Propagation Delays, Input Data Register Propagation Delays, Output/Enable Data Register Propagation Delays, Input DDR Propagation Delays, and Output DDR Propagation Delays. See [Table 109](#), page 61, [Table 110](#), page 63, [Table 111](#), page 65, [Table 112](#), page 67, [Table 113](#), page 68, and [Table 114](#), page 70.
- High temperature data retention. See [Table 7](#), page 7 and [Figure 1](#), page 7.
- Absolute maximum temperature (T_J) was changed to 145 °C. See [Table 2](#), page 4.
- VTX-DIFF-PP, VTX-CM-AC-P, VTX-RISE-FALL, LTX-SKEW in transmitter parameters table and VRX-IN-PP-CC, RLRX-DIFF, RLRX-CM in Receiver Parameters table. See [Table 164](#), page 106 and [Table 165](#), page 107.
- CID limit was corrected. See [Table 165](#), page 107.
- Input capacitance and leakage current. See [Table 19](#), page 19.
- DEVRESET_N minimum and maximum values. See [Table 149](#), page 98.

The following information was added in revision 5.0 of this document.

- MMUART. See [Table 170](#), page 108.
- FMAXPDEVRST_N was added to DEVRST_N Characteristics table. See [Table 149](#), page 98.
- SerDes Protocol Compliance. See [Table 169](#), page 108.
- F*F timing data corresponding to FCLK = 3 MHz for all dies. See [Table 158](#), page 103
- SPI Clock Fmax. See [Table 152](#), page 100.
- 060 device was added to VPP (Recommended Operating Conditions). See [Table 3](#), page 5.
- SerDes TX-AMP range was added in transmitter parameters table. See [Table 164](#), page 106.
- Digest cycle per programming cycle was added to FPGA operating limits table. See [Table 4](#), page 6.
- A note was added about CID limit. See [Table 165](#), page 107.
- Output duty cycle for 060 device. See [Table 144](#), page 94.
- 060 device was added to JTAG table. See [Table 146](#), page 95.

- Cryptographic Block Characteristics. See [Table 163](#), page 106.
- Non-deterministic Random Bit Generator (NRBG) Characteristics. See [Table 162](#), page 105.
- SRAM PUF. See [Table 161](#), page 104.
- PLL Acquisition time. See [Table 144](#), page 94.
- I_{IL} and I_{IH} was added to input capacitance table. See [Table 19](#), page 19.
- Input T_{RAMPIN} specification was added to input capacitance table. See [Table 19](#), page 19.
- Power-Up to Functional Time, page 96 and DEV_{RST_N} to Functional Time, page 98.
- Programming Time, page 88 was added.

1.4 Revision 4.0

Updated [Table 10](#), page 11, [Table 11](#), page 11, and [Table 145](#), page 95.

1.5 Revision 3.0

Updated [Table 1](#), page 3.

1.6 Revision 2.0

The following is a summary of the changes in revision 2.0 of this document.

- Updated [Table 1](#), page 3, [Table 3](#), page 5, [Table 4](#), page 6, [Table 8](#), page 9, [Table 66](#), page 42, [Table 70](#), page 44, [Table 144](#), page 94, [Table 146](#), page 95, and [Table 177](#), page 114.
- Added [Embedded NVM \(eNVM\) Characteristics](#), page 91, [\$DEV_{RST_N}\$ Characteristics](#), page 98, [DDR Memory Interface Characteristics](#), page 103, [SFP Transceiver Characteristics](#), page 104, [CAN Controller Characteristics](#), page 109, and [USB Characteristics](#), page 109.

1.7 Revision 1.0

Revision 1.0 was the first publication of this document.

2 IGLOO2 and SmartFusion2 SoC FPGA Military Grade AC/DC Electrical Characteristics

Microsemi military-grade SmartFusion[®]2 SoC FPGA and IGLOO[®]2 FPGA families integrate an industry standard 4-input lookup table-based (LUT) FPGA fabric with integrated mathblocks, multiple embedded memory blocks, and high-performance SERDES communications interfaces on a single chip. Both families benefit from low power flash technology and are the most secure and reliable FPGAs in the industry. These next generation devices offer up to 150K Logic Elements, up to 5 MB of embedded RAM, up to 16 SERDES lanes, and up to four PCI Express Gen 1 endpoints, as well as integrated hard DDR3 memory controllers with error correction.

SmartFusion2 military grade devices integrate an entire low power real time Microcontroller Subsystem with a rich set of Industry standard peripherals including Ethernet, USB, and CAN, while the IGLOO2 military devices integrate a high-performance memory subsystem with on-chip flash, 32 kB embedded SRAM, and multiple DMA controllers.

2.1 Device Status

Table 1 • IGLOO2 FPGA and SmartFusion2 SoC FPGA Device Status

Design Security Device Densities	Status
010T	Production
025T	Production
050T	Production
060T	Production
090T	Production
150T	Production
Data Security Device Densities	Status
010TS	Production
025TS	Production
050TS	Production
060TS	Production
090TS	Production
150TS	Production

2.2 Product Briefs and Pin Descriptions

The product brief and pin descriptions are published separately:

- *PB0121: IGLOO2 Product Brief*
- *DS0124: IGLOO2 Pin Descriptions*
- *PB0115: SmartFusion2 SoC FPGA Product Brief*
- *DS0115: SmartFusion2 Pin Descriptions*

2.3 General Specifications

2.3.1 Operating Conditions

Stresses beyond those listed in the following table may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Absolute maximum ratings are stress ratings only; functional operation of the device at these or any other conditions beyond those listed under the recommended operating conditions specified in the following table is not implied.

Table 2 • Absolute Maximum Ratings

Symbol	Parameter	Limits		
		Min	Max	Units
VDD	DC core supply voltage. Must always power this pin.	-0.3	1.32	V
VPP	Power supply for charge pumps (for normal operation and programming). Must always power this pin.	-0.3	3.63	V
MSS_MDDR_PLL_VDDA	Analog power pad for MDDR PLL	-0.3	3.63	V
HPMS_MDDR_PLL_VDDA	Analog power pad for MDDR PLL	-0.3	3.63	V
FDDR_PLL_VDDA	Analog power pad for FDDR PLL	-0.3	3.63	V
PLL0_PLL1_MSS_MDDR_VDDA	Analog power pad for MDDR PLL	-0.3	3.63	V
PLL0_PLL1_HPMS_MDDR_VDDA	Analog power pad for MDDR PLL	-0.3	3.63	V
CCC_XX[01]_PLL_VDDA	Analog power pad for PLL0-5	-0.3	3.63	V
SERDES_[01]_PLL_VDDA	High supply voltage for PLL SERDES[01]	-0.3	3.63	V
SERDES_[01]_L[0123]_VDDAPLL	Analog power for SERDES[01] PLL lane0 to lane3. This is a +2.5 V SERDES internal PLL supply.	-0.3	2.75	V
SERDES_[01]_L[0123]_VDDAIO	TX/RX analog I/O voltage. Low voltage power for the lanes of SERDESIF0. This is a +1.2 V SERDES PMA supply.	-0.3	1.32	V
SERDES_[01]_VDD	PCIe®/PCS power supply	-0.3	1.32	V
VDDix	DC FPGA I/O buffer supply voltage for MSIO I/O Bank	-0.3	3.63	V
	DC FPGA I/O buffer supply voltage for MSIOD/DDRIO I/O Banks	-0.3	2.75	V
VI	I/O Input voltage for MSIO I/O Bank	-0.3	3.63	V
	I/O Input voltage for MSIOD/DDRIO I/O Bank	-0.3	2.75	V
VPPNVM	Analog sense circuit supply of embedded nonvolatile memory (eNVM). Must be shorted to VPP.	-0.3	3.63	V
T _{STG} ¹	Storage temperature	-65	150	°C
T _J	Junction temperature		145	°C

1. For flash programming and retention maximum limits, refer to [Table 4](#), page 6. For recommended operating conditions, see [Table 3](#), page 5.

Table 3 • Recommended Operating Conditions¹

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Tj	Operating Junction Temperature	Military	- 55	25	125	°C
			0	25	85	°C
			- 40	25	100	°C
VDD	DC core supply voltage. Must always power this pin.		1.14	1.2	1.26	V
VPP	Power Supply for Charge Pumps (for Normal Operation and Programming) for 010, 025, 050, and 060 Devices	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
	Power Supply for Charge Pumps (for Normal Operation and Programming) for 090, and 150 devices	3.3 V Range	3.15	3.3	3.45	V
MSS_MDDR_PLL_VDDA	Analog power pad for MDDR PLL	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
HPMS_MDDR_PLL_VDDA	Analog power pad for MDDR PLL	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
FDDR_PLL_VDDA	Analog power pad for FDDR PLL	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
PLL0_PLL1_MSS_MDDR_VDDA	Analog power pad for MDDR PLL	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
PLL0_PLL1_HPMS_MDDR_VDDA	Analog power pad for MDDR PLL	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
CCC_XX[01]_PLL_VDDA	Analog power pad for PLL0-5	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
SERDES_[01]_PLL_VDDA ³	High supply voltage for PLL SERDES[01]	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V
SERDES_[01]_L[0123]_VDDAPLL	Analog power for SERDES[01] PLL lanes 0-3. It is a +2.5 V SERDES internal PLL supply.		2.375	2.5	2.625	V

Table 3 • Recommended Operating Conditions¹ (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
SERDES_[01]_L[0123]_VDDAIO	TX/RX analog I/O voltage. Low voltage power for the lanes of SERDESIF0. It is a +1.2 V SERDES PMA supply.		1.14	1.2	1.26	V
SERDES_[01]_VDD ⁴	PCIe/PCS Power supply		1.14	1.2	1.26	V
VDDix	1.2 V DC supply voltage		1.14	1.2	1.26	V
	1.5 V DC supply voltage		1.425	1.5	1.575	V
	1.8 V DC supply voltage		1.71	1.8	1.89	V
	2.5 V DC supply voltage		2.375	2.5	2.625	V
	3.3 V DC supply voltage (MSIO only)		3.15	3.3	3.45	V
	LVDS differential I/O		2.375	2.5	3.45	V
	BLVDS, MLVDS, Mini-LVDS, RSDS differential I/O		2.375	2.5	2.625	V
VREFx	Reference Voltage Supply for FDDR (Bank0) and MDDR(Bank5)		0.49 × VDDix	0.5 × VDDix	0.51 × VDDix	V
VPPNVM	Analog sense circuit supply of embedded nonvolatile memory (eNVM). Must be shorted to VPP	2.5 V Range	2.375	2.5	2.625	V
		3.3 V Range	3.15	3.3	3.45	V

1. PLL supply voltages should be either 2.5 V or 3.3 V. Mixed voltages are not allowed.
2. Programming at this temperature range is available only with VPP in 3.3 V range.
3. Power supply ramps must all be strictly monotonic, without plateaus.
4. The SERDES_[01]_VDD supply must be connected to VDD.

Table 4 • FPGA Operating Limits

Product Grade	Element	Programming Temperature	Operating Temperature	Programming Cycles	Digest Temperature	Digest Cycles	Retention (Biased/Unbiased)
Military ¹	FPGA	Min T _J = -40 °C Max T _J = 100 °C	Min T _J = -55 °C Max T _J = 125 °C	500	Min T _J = -40 °C Max T _J = 100 °C	2000	20 years
		Min T _J = -40 °C Max T _J = 100 °C	Min T _J = -55 °C Max T _J = 125 °C	500	Min T _J = -55 °C Max T _J = 125 °C	2000	10 years

1. Programming at these temperature ranges is available only with VPP = 3.3 V.

Table 5 • Embedded Flash Limits

Product Grade	Element	Programming Temperature	Maximum Operating Temperature	Programming Cycles	Retention (Biased/Unbiased)
Military	Embedded flash	Min $T_J = -55\text{ }^\circ\text{C}$ Max $T_J = 125\text{ }^\circ\text{C}$	Min $T_J = -55\text{ }^\circ\text{C}$ Max $T_J = 125\text{ }^\circ\text{C}$	< 10,000 cycles per pages, up to one million cycles per eNVM array	10 years
		Min $T_J = -55\text{ }^\circ\text{C}$ Max $T_J = 100\text{ }^\circ\text{C}$	Min $T_J = -55\text{ }^\circ\text{C}$ Max $T_J = 100\text{ }^\circ\text{C}$	< 10,000 cycles per pages, up to one million cycles per eNVM array	20 years

Table 6 • Device Storage Temperature and Retention

Product Grade	Storage Temperature (T_{stg})	Retention
Military	Min $T_J = -55\text{ }^\circ\text{C}$ Max $T_J = 125\text{ }^\circ\text{C}$	10 years
	Min $T_J = -55\text{ }^\circ\text{C}$ Max $T_J = 100\text{ }^\circ\text{C}$	20 years

Figure 1 • High Temperature Data Retention (HTR)

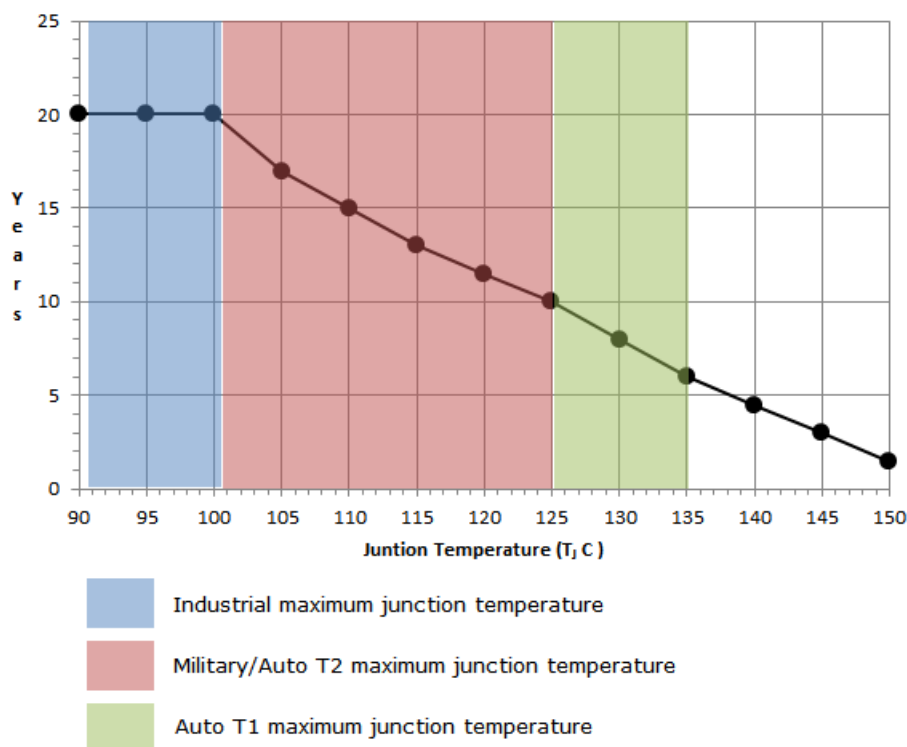


Table 7 • High Temperature Data Retention (HTR)

T_J (°C)	HTR Lifetime ^{1, 2} (years)
90	20.0
95	20.0

Table 7 • High Temperature Data Retention (HTR)

T _J (°C)	HTR Lifetime ^{1, 2} (years)
100	20.0
105	17.0
110	15.0
115	13.0
120	11.5
125	10.0
130	8.0
135	6.0
140	4.5
145	3.0
150	1.5

1. HTR lifetime is the period during which a verify failure is not expected due to flash leakage.
2. The IGLOO2 and SmartFusion2 Military Grade maximum operational junction temperature specification is 125 °C.

2.3.2 Overshoot/Undershoot Limits

For AC signals, the input signal may undershoot during transitions to –1.0 V for no longer than 10% or the period. The current during the transition must not exceed 100 mA.

For AC signals, the input signal may overshoot during transitions to V_{CCI} + 1.0 V for no longer than 10% of the period. The current during the transition must not exceed 100 mA.

Note: The above specification does not apply to the PCI standard. The IGLOO2 and SmartFusion2 PCI I/Os are compliant to the PCI standard including the PCI overshoot/undershoot specifications.

2.3.3 Thermal Characteristics

The temperature variable in the Microsemi SoC Products Group Designer software refers to the junction temperature, not the ambient, case, or board temperatures. This is an important distinction because dynamic and static power consumption will cause the chip's junction temperature to be higher than the ambient, case, or board temperatures.

The following equations give the relationship between thermal resistance, temperature gradient, and power.

$$\theta_{JA} = \frac{T_J - T_A}{P}$$

$$\theta_{JB} = \frac{T_J - T_B}{P}$$

$$\theta_{JC} = \frac{T_J - T_C}{P}$$

where,

θ_{JA} = Junction-to-air thermal resistance

θ_{JB} = Junction-to-board thermal resistance

θ_{JC} = Junction-to-case thermal resistance

T_J = Junction temperature
 T_A = Ambient temperature
 T_B = Board temperature (measured 1.0 mm away from the package edge)
 T_C = Case temperature
 P = Total power dissipated by the device

Table 8 • Package Thermal Resistance

Product	θ_{JA}			θ_{JB}	θ_{JC}	Units
	Still Air	1.0 m/s	2.5 m/s			
010						
FG484	18.22	14.83	13.62	8.83	4.92	°C/W
025						
FG484	17.03	13.66	12.45	7.66	4.18	°C/W
050						
FG484	15.29	12.19	10.99	6.27	3.24	°C/W
060						
FG484	15.40	12.06	10.85	6.14	3.15	°C/W
090						
FG484	14.64	11.37	10.16	5.43	2.77	°C/W
150						
FC1152	9.08	6.81	5.87	2.56	0.38	°C/W

2.3.3.1 Theta-JA

Junction-to-ambient thermal resistance (θ_{JA}) is determined under standard conditions specified by JEDEC (JESD-51), but it has little relevance in actual performance of the product. It must be used with caution, but it is useful for comparing the thermal performance of one package to another.

The maximum power dissipation allowed is calculated using the following equation.

$$\text{Maximum Power Allowed} = \frac{T_{J(\text{MAX})} - T_{A(\text{MAX})}}{\theta_{JA}}$$

The absolute maximum junction temperature is 100°C. The following equation shows a sample calculation of the absolute maximum power dissipation allowed for the M2GL050-FG484 package at military temperature and in still air, where:

$\theta_{JA} = 15.29$ °C/W (taken from [Table 8](#), page 9).

$T_A = 85$ °C

$$\text{Maximum Power Allowed} = \frac{100^\circ\text{C} - 85^\circ\text{C}}{15.29^\circ\text{C/W}} = 0.981 \text{ W}$$

The power consumption of a device can be calculated using the Microsemi SoC Products Group power calculator. The device's power consumption must be lower than the calculated maximum power dissipation by the package.

If the power consumption is higher than the device's maximum allowable power dissipation, a heat sink can be attached on top of the case, or the airflow inside the system must be increased.

2.3.3.2 Theta-JB

Junction-to-board thermal resistance (θ_{JB}) measures the ability of the package to dissipate heat from the surface of the chip to the PCB. As defined by the JEDEC (JESD-51) standard, the thermal resistance from junction to board uses an isothermal ring cold plate zone concept. The ring cold plate is simply a means to generate an isothermal boundary condition at the perimeter. The cold plate is mounted on a JEDEC standard board with a minimum distance of 5.0 mm away from the package edge.

2.3.3.3 Theta-JC

Junction-to-case thermal resistance (θ_{JC}) measures the ability of a device to dissipate heat from the surface of the chip to the top or bottom surface of the package. It is applicable for packages used with external heat sinks. Constant temperature is applied to the surface in consideration and acts as a boundary condition.

This only applies to situations where all or nearly all of the heat is dissipated through the surface in consideration.

2.4 Power Consumption

2.4.1 Quiescent Supply Current

Table 9 • Quiescent Supply Current Characteristics

Power Supplies/Blocks	Modes and Configurations	
	Non-Flash*Freeze Mode	Flash*Freeze Mode
FPGA Core	On	Off
VDD / SERDES_[01]_VDD ¹	On	On
VPP / VPPNVM	On	On
MDDR_PLL_VDDA CCC_XX[01]_PLL_VDDA PLL0_PLL1_MDDR_VDDA FDDR_PLL_VDDA	0 V	0 V
SERDES_[01]_PLL_VDDA ²	0 V	0 V
SERDES_[01]_L[0123]_VDDAPLL / VDD_2V5 ²	On	On
SERDES_[01]_L[0123]_VDDAIIO ²	On	On
VDDIx ^{3 4}	On	On
VREFx	On	On
MSSDDR CLK	32 kHz	32 kHz
RAM	On	Sleep state
HPMS Controller	50 MHz	50 MHz
50 MHz Oscillator (enable/disable)	Enabled	Disabled
1 MHz Oscillator (enable/disable)	Disabled	Disabled
Crystal Oscillator (enable/disable)	Disabled	Disabled

- SERDES_[01]_VDD Power Supply is shorted to VDD.
- SERDES and DDR blocks to be unused.
- VDDIx has been set to ON for test conditions as described. Banks on the east side should always be powered with the appropriate VDDI Bank supplies. For details on bank power supplies, refer to the "Recommendation for Unused Bank Supplies" table in the *AC393: SmartFusion2 and IGLOO2 Board Design Guidelines Application Note*.
- No differential (that is to say, LVDS) I/O's or ODT attributes to be used.

Table 10 • SmartFusion2 and IGLOO2 Quiescent Supply Current—Typical Process

Parameter	Modes	Conditions	010	025	050	060	090	150	Units
			VDD =1.2 V	VDD =1.2 V	VDD =1.2 V	VDD =1.2 V	VDD =1.2 V	VDD =1.2 V	
IDC1	Non-Flash*Freeze	Typical (T _J = 25 °C)	6.9	8.9	13.1	15.3	15.4	27.5	mA
		Military (T _J = 125 °C)	73.0	106.4	180.9	215.4	217.5	390.5	mA
IDC2	Flash*Freeze	Typical (T _J = 25 °C)	2.6	3.7	5.1	5.0	5.1	8.9	mA
		Military (T _J = 125 °C)	55.6	74.2	98.5	98.5	99.5	161.0	mA

Table 11 • SmartFusion2 and IGLOO2 Quiescent Supply Current—Worst-Case Process

Parameter	Modes	Conditions	010	025	050	060	090	150	Units
			VDD =1.26 V	VDD =1.26 V	VDD =1.26 V	VDD =1.26 V	VDD =1.26 V	VDD =1.26 V	
IDC1	Non-Flash*Freeze	Military (T _J = 125 °C)	151.5	227.4	358.9	438.8	443.1	660.4	mA
IDC2	Flash*Freeze	Military (T _J = 125 °C)	127.2	144.2	174.6	193.1	195.0	236.3	mA

2.4.2 Programming Currents

The tables below represent programming, verify and Inrush currents for SmartFusion2 SoC and IGLOO2 FPGA devices.

Table 12 • Currents During Program Cycle, 0 °C ≤ T_J ≤ 85 °C, Typical Process

Power Supplies	Voltage (V)	010	025	050	060	090	150	Units
VDD	1.26	53	55	58	30	42	52	mA
VPP ¹	3.46	11	6	10	9	12	12	mA
VPPNVM ¹	3.46	2	2	3	3	3		mA
VDDI	2.62 ²	16	17	1	12	12	81	mA
	3.46 ²	31	36	1	12	17	84	mA
Number of banks		8	8	10	10	9	19	

1. VPP and VPPNVM are internally shorted for the 150 device.

2. The current for 050 device represents JTAG I/O bank only.

Table 13 • Currents During Verify Cycle, 0 °C ≤ T_J ≤ 85 °C, Typical Process

Power Supplies	Voltage (V)	010	025	050	060	090	150	Units
VDD	1.26	53	55	58	33	41	51	mA
VPP ¹	3.46	5	3	15	8	11	12	mA
VPPNVM ¹	3.46	0	0	1	0	1		mA

Table 13 • Currents During Verify Cycle, 0 °C ≤ T_J ≤ 85 °C, Typical Process (continued)

VDDI	2.62 ²	16	17	1	12	11	81	mA
	3.46 ²	32	36	1	12	17	84	mA
Number of banks		8	8	10	10	9	19	

1. VPP and VPPNVM are internally shorted for the 150 device.
2. The current for 050 device represents JTAG I/O bank only.

Table 14 • Inrush Currents at Power up, -55 °C ≤ T_J ≤ 125 °C, Typical Process

Power Supplies	Voltage (V)	010	025	050	060	090	150	Units
VDD	1.26	53	78	57	54	98	140	mA
VPP	3.46	57	50	180	14	36	51	mA
VDDI	2.62	141	161	187	106	283	404	mA
Number of banks		8	8	10	10	9	19	

2.5 Average Fabric Temperature and Voltage Derating Factors

Table 15 • Average Temperature and Voltage Derating Factors for Fabric Timing Delays (Normalized to T_J = 125 °C, Worst-Case VDD = 1.14 V)

Core Voltage VDD (V)	Junction Temperature (°C)							
	-55 °C	-40 °C	0 °C	25 °C	70 °C	85 °C	100 °C	125 °C
1.14	0.91	0.91	0.93	0.94	0.96	0.97	0.98	1.00
1.2	0.82	0.83	0.84	0.85	0.87	0.87	0.88	0.90
1.26	0.75	0.75	0.77	0.77	0.79	0.80	0.81	0.75

Table 16 • Timing Model Parameters (continued)

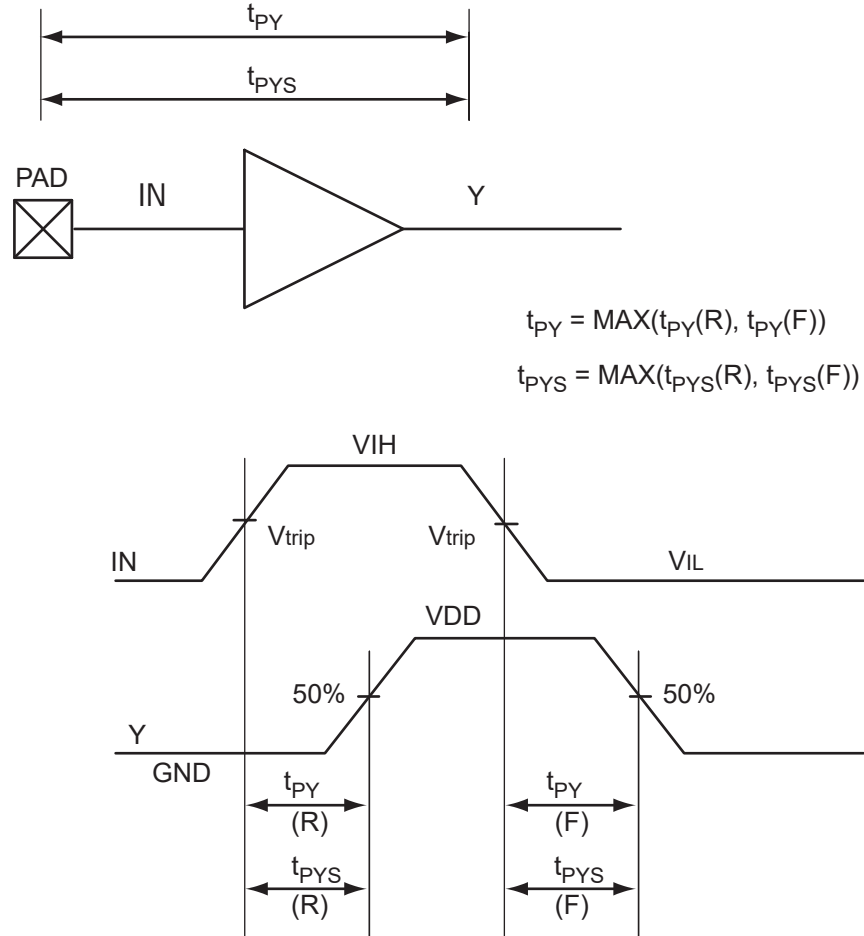
Index	Parameter	Description	Speed Grade –1 (ns)	Notes
C	t_{RCKH}	Input High Delay for Global Clock	1.55	Refer to page 70 for more information
	t_{RCKL}	Input Low Delay for Global Clock	0.861	Refer to page 70 for more information
D	t_{PY}	Input Propagation Delay of LVDS Receiver	3.061	Refer to page 52 for more information
E	t_{DP}	Propagation Delay of a three input AND Gate	0.217	Refer to page 68 for more information
F	t_{DP}	Propagation Delay of a OR Gate	0.17	Refer to page 68 for more information
G	t_{DP}	Propagation Delay of a LVDS Transmitter	2.299	Refer to page 52 for more information
H	t_{DP}	Propagation Delay of a three input XOR Gate	0.236	Refer to page 68 for more information
I	t_{DP}	Propagation Delay of LVCMOS 2.5 V Transmitter, Drive strength of 16 mA on the MSIO Bank	2.717	Refer to page 24 for more information
J	t_{DP}	Propagation Delay of a two input NAND Gate	0.17	Refer to page 68 for more information
K	t_{DP}	Propagation Delay of LVCMOS 2.5 V Transmitter, Drive strength of 8mA on the MSIO Bank	2.594	Refer to page 24 for more information
L	t_{CLKQ}	Clock-to-Q of the Data Register	0.112	Refer to page 61 for more information
	t_{SUD}	Setup Time of the Data Register	0.262	Refer to page 61 for more information
M	t_{DP}	Propagation Delay of a two input AND gate	0.17	Refer to page 68 for more information
N	t_{OCLKQ}	Clock-to-Q of the Output Data Register	0.272	Refer to page 63 for more information
	t_{OSUD}	Setup Time of the Output Data Register	0.196	Refer to page 63 for more information
O	t_{DP}	Propagation Delay of SSTL2, Class I Transmitter on the MSIO Bank	2.283	Refer to page 41 for more information
P	t_{DP}	Propagation Delay of LVCMOS 1.5 V Transmitter, Drive strength of 12 mA, fast slew on the DDRIO Bank	3.703	Refer to page 31 for more information

2.7 User I/O Characteristics

There are three types of I/Os supported in the IGLOO2 FPGA and SmartFusion2 SoC FPGA families: MSIO, MSIOD, and DDRIO I/O banks. The I/O standards supported by the different I/O banks is described in the "I/Os" section of the *UG0445: IGLOO2 FPGA and SmartFusion2 SoC FPGA Fabric User Guide*.

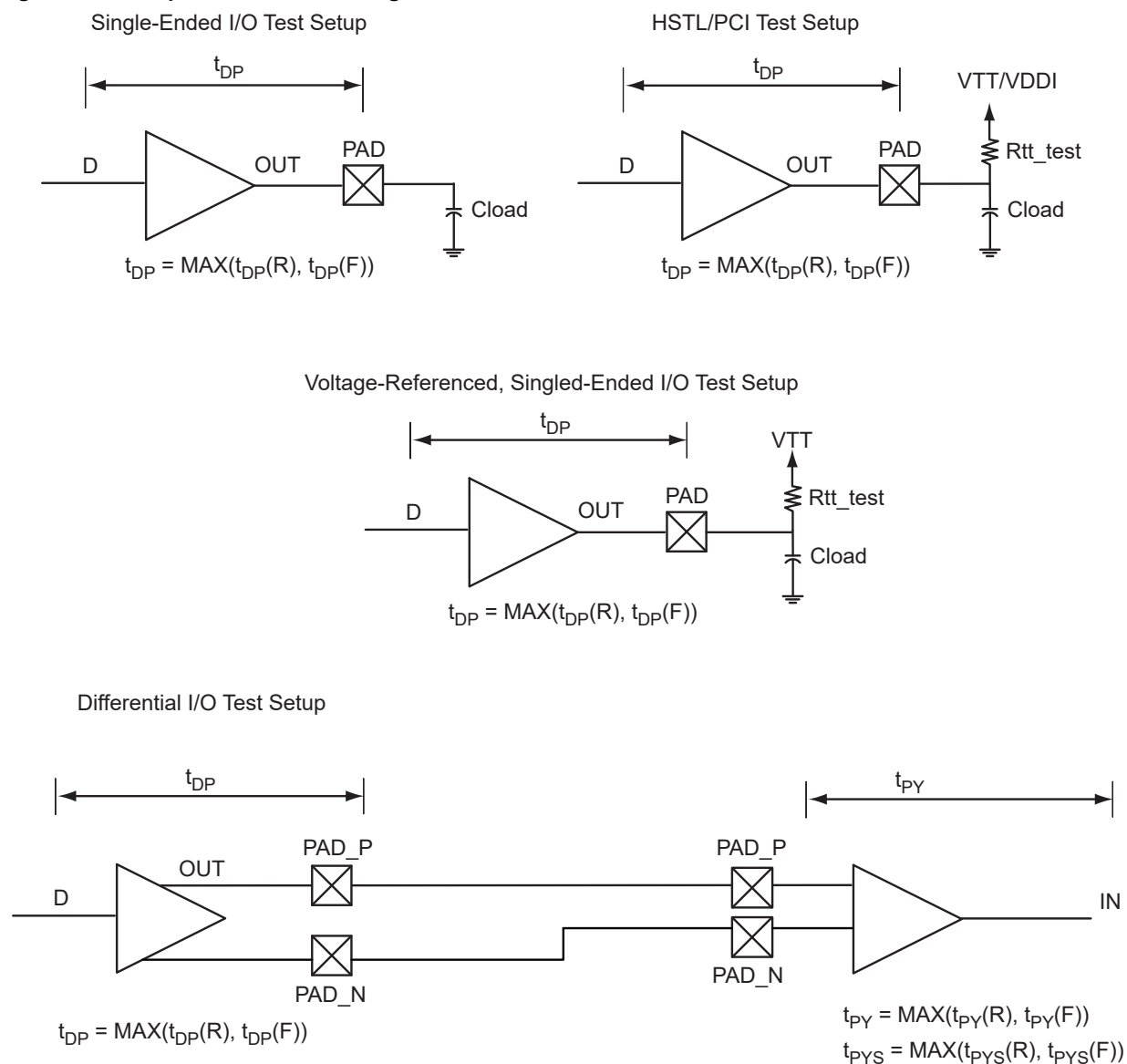
2.7.1 Input Buffer and AC Loading

Figure 3 • Input Buffer AC Loading



2.7.2 Output Buffer and AC Loading

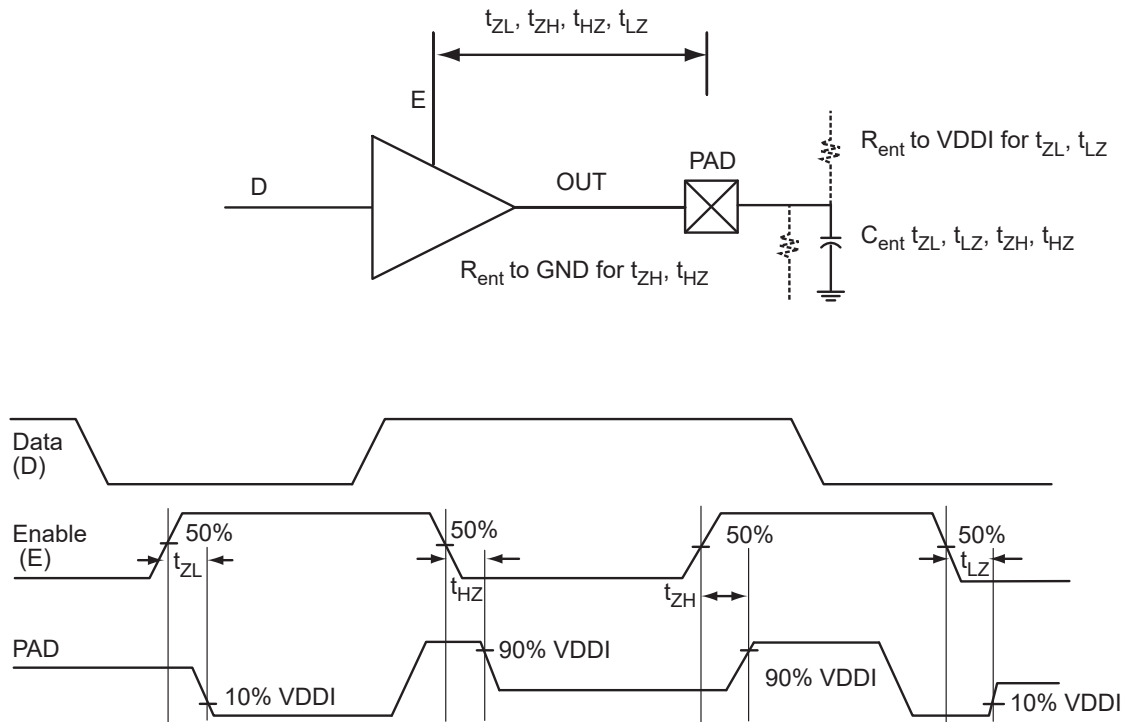
Figure 4 • Output Buffer AC Loading



2.7.3 Tristate Buffer and AC Loading

The tristate path for enable path loadings is described in the respective specifications. The methodology of characterization is illustrated by the enable path test point shown in the following figure.

Figure 5 • Tristate Buffer for Enable Path Test Point



2.7.4 I/O Speeds

Table 17 • Maximum Data Rate Summary for Worst-Case Military Conditions

Single-Ended I/O	MSIO	MSIOD	DDRIO	Units
PCI 3.3 V	560			Mbps
LVTTL 3.3 V	540			Mbps
LVC MOS 3.3 V	540			Mbps
LVC MOS 2.5 V	360	370	360	Mbps
LVC MOS 1.8 V	260	360	360	Mbps
LVC MOS 1.5 V	140	190	210	Mbps
LVC MOS 1.2 V	100	140	180	Mbps
LPDDR – LVC MOS 1.8 V Mode			360	Mbps
Voltage-Referenced I/O	MSIO	MSIOD	DDRIO	Units
LPDDR			360	Mbps
HSTL1.5 V			360	Mbps
SSTL 2.5 V	450	480	360	Mbps
SSTL 1.8 V			600	Mbps
SSTL 1.5 V			600	Mbps
Differential I/O	MSIO	MSIOD	DDRIO	Units
LVPECL (input only)	810			Mbps
LVDS 3.3 V	480	480		Mbps
LVDS 2.5 V	480	480		Mbps
RSDS	460	480		Mbps
BLVDS	450			Mbps
MLVDS	450			Mbps
Mini-LVDS	460	480		Mbps

Table 18 • Maximum Frequency Summary for Worst-Case Military Conditions

Single-Ended I/O	MSIO	MSIOD	DDRIO	Units
PCI 3.3 V	280			MHz
LVTTL 3.3 V	270			MHz
LVC MOS 3.3 V	270			MHz
LVC MOS 2.5 V	180	185	180	MHz
LVC MOS 1.8 V	130	180	180	MHz
LVC MOS 1.5 V	70	95	105	MHz
LVC MOS 1.2 V	50	70	90	MHz
LPDDR - LVC MOS 1.8 V mode			180	MHz

Table 18 • Maximum Frequency Summary for Worst-Case Military Conditions (continued)

Voltage-Referenced I/O	MSIO	MSIOD	DDRIO	Units
LPDDR			180	MHz
HSTL1.5 V			180	MHz
SSTL 2.5 V	225	240	180	MHz
SSTL 1.8 V			300	MHz
SSTL 1.5 V			300	MHz
Differential I/O	MSIO	MSIOD	DDRIO	Units
LVPECL (input only)	405			MHz
LVDS 3.3 V	240	240		MHz
LVDS 2.5 V	240	240		MHz
RSDS	230	240		MHz
BLVDS	225			MHz
MLVDS	225			MHz
Mini-LVDS	230	240		MHz

2.7.5 Detailed I/O Characteristics

Table 19 • Input Capacitance

Symbol	Definition	Condition	Min	Max	Units
CIN	Input Capacitance			10	pF
IIL (DC)	Input current LOW (applicable to HSTL/SSTL inputs only) ¹	VDDI = 2.5 V		400	μA
		VDDI = 1.8 V		500	μA
		VDDI = 1.5 V		600	μA
		Input current LOW (applicable to all other digital inputs)			10
IIH (DC)	Input current HIGH (applicable to HSTL/SSTL inputs only) ¹	VDDI = 2.5 V		400	μA
		VDDI = 1.8 V		500	μA
		VDDI = 1.5 V		600	μA
		Input current HIGH (applicable to all other digital inputs)			10
T _{RAMPIN}	Input ramp time (applicable to all digital inputs) ²			50	ns

1. Applicable when an I/O pair is programmed with an HSTL or SSTL I/O type on the IOP pad and an un-terminated I/O type (such as LVCMOS) on the ION pad.
2. The voltage ramp must be monotonic.

Table 20 • I/O Weak Pull-Up/Pull-Down Resistance Values for DDRIO, MSIO, and MSIOD Banks
 Minimum and Maximum Weak Pull-Up/Pull-Down Resistance Values at VOH/VOL Level

VDDI Domain	DDRIO I/O Bank				MSIO I/O Bank				MSIOD I/O Bank			
	$R_{(WEAK)}$ PULL-UP) at VOH (Ω)		$R_{(WEAK)}$ PULL-DOWN) at VOL (Ω)		$R_{(WEAK)}$ PULL-UP) at VOH (Ω)		$R_{(WEAK)}$ PULL-DOWN) at VOL (Ω)		$R_{(WEAK)}$ PULL-UP) at VOH (Ω)		$R_{(WEAK)}$ PULL-DOWN) at VOL (Ω)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
3.3 V	N/A	N/A	N/A	N/A	9.9 k	17.1 k	9.98 k	17.5 k	N/A	N/A	N/A	N/A
2.5 V ^{1 2}	10 k	17.8 k	9.98 k	18 k	10 k	17.6 k	10.1 k	18.4 k	9.6 k	16.6 k	9.5 k	16.4 k
1.8 V ^{1 2}	10.3 k	19.1 k	10.3 k	19.5 k	10.4 k	19.1 k	10.4 k	20.4 k	9.7 k	17.3 k	9.7 k	17.1 k
1.5 V ^{1 2}	10.6 k	20.2k	10.6 k	21.1 k	10.7 k	20.4 k	10.8 k	22.2 k	9.9 k	18 k	9.8 k	17.6 k
1.2 V ^{1 2}	11.1 k	22.7 k	11.2 k	24.6 k	11.3 k	23.2 k	11.5 k	26.7 k	10.3 k	19.6 k	10 k	19.1 k

1. $R_{(WEAK)}$ PULL-DOWN) = (VOLspec)/I(WEAK PULL-DOWN MAX)
2. $R_{(WEAK)}$ PULL-UP) = (VDDImax - VOHspec)/I(WEAK PULL-UP MIN)

Table 21 • Schmitt Trigger Input Hysteresis
 Hysteresis Voltage Value for Schmitt Trigger Mode Input Buffers

Input Buffer Configuration	Hysteresis Value (Typical, unless otherwise noted)
3.3 V LVTTTL / LVCMOS / PCI / PCI-X	0.05 × VDDI (Worst-case)
2.5 V LVCMOS	0.05 × VDDI (Worst-case)
1.8 V LVCMOS	0.1 × VDDI (Worst-case)
1.5 V LVCMOS	60 mV
1.2 V LVCMOS	20 mV

2.7.6 Single-Ended I/O Standards

2.7.6.1 Low Voltage Complementary Metal Oxide Semiconductor (LVCMOS)

LVCMOS is a widely used switching standard implemented in CMOS transistors. This standard is defined by JEDEC (JESD 8-5). The LVCMOS standards supported in IGLOO2 FPGAs and SmartFusion2 SoC FPGAs are: LVCMOS12, LVCMOS15, LVCMOS18, LVCMOS25, and LVCMOS33.

2.7.6.2 3.3 V LVCMOS/LVTTL

LVCMOS 3.3 V or Low-Voltage Transistor-Transistor Logic (LVTTL) is a general standard for 3.3 V applications.

2.7.6.2.1 Minimum and Maximum AC/DC Input and Output Levels Specification

Table 22 • LVTTL/LVCMOS 3.3 V DC Voltage Specification (Applicable to MSIO I/O Bank Only)

Symbol	Parameters	Conditions	Min	Typ	Max	Units
LVTTL/LVCMOS 3.3 V Recommended DC Operating Conditions						
VDDI	Supply voltage		3.15	3.3	3.45	V
LVTTL/LVCMOS 3.3 V DC Input Voltage Specification						
VIH (DC)	DC input logic High		2.0		3.45	V
VIL (DC)	DC input logic Low		-0.3		0.8	V
I _{IH} (DC)	Input current High				See Table 19, page 19	
I _{IL} (DC)	Input current Low				See Table 19, page 19	
LVCMOS 3.3 V DC Output Voltage Specification						
VOH ¹	DC output logic High		2.4			V
VOL ¹	DC output logic Low				0.4	V
LVTTL 3.3 V DC Output Voltage Specification						
VOH	DC output logic High		2.4			V
VOL	DC output logic Low				0.4	V

1. The VOH/VOL test points selected ensure compliance with LVCMOS 3.3 V JESD8-B requirements.

Table 23 • LVTTL/LVCMOS 3.3 V Maximum Switching Speeds (Applicable to MSIO I/O Bank Only)

Symbol	Parameters	Conditions	Min	Typ	Max	Units
LVTTL/LVCMOS 3.3 V Maximum Switching Speed						
D _{max}	Maximum data rate (for MSIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			540	Mbps

Table 24 • LVTTL/LVCMOS 3.3 V AC Test Parameter Specifications (Applicable to MSIO Bank Only)

LVTTL/LVCMOS 3.3 V AC Test Parameter Specifications						
Symbol	Parameters	Conditions	Min	Typ	Max	Units
V _{trip}	Measuring/trip point for data path			1.4		V
R _{ent}	Resistance for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
C _{ent}	Capacitive loading for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF
C _{load}	Capacitive loading for data path (t _{DP})			5		pF

Table 25 • LVTTTL/LVCMOS 3.3 V Transmitter Drive Strength Specifications (Applicable to MSIO Bank Only)

Output Drive Selection	VOH (V)	VOL (V)	IOH (at VOH) mA	IOL (at VOL) mA
2 mA	2.4	0.4	2	2
4 mA	2.4	0.4	4	4
8 mA	2.4	0.4	8	8
12 mA	2.4	0.4	12	12
16 mA	2.4	0.4	16	16
20 mA	2.4	0.4	18	18

Note: Software Configurator GUI displays the Commercial/Industrial numeric values. The actual drive capability at temperature is defined in the preceding table.

2.7.6.2.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 26 • LVTTTL/LVCMOS 3.3 V Receiver Characteristics for MSIO I/O Banks (Input Buffers)
Worst-case Military conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 3.15\text{ V}$

	On-Die Termination (ODT)	Speed Grade -1 (ns)	
		t_{PY}	t_{PYS}
LVTTTL/LVCMOS 3.3 V (for MSIO I/O Bank)	None	2.416	2.443

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 27 • LVTTTL/LVCMOS 3.3 V Transmitter Characteristics for MSIO I/O Bank (Output and Tristate Buffers)

Worst-case Military conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 3.15\text{ V}$

Output Drive Selection	Slew Control	Speed Grade -1 (ns)				
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}
2 mA	slow	3.515	3.826	3.242	2.024	3.636
4 mA	slow	2.565	2.948	2.774	3.339	4.896
8 mA	slow	2.349	2.568	2.528	5.013	5.329
12 mA	slow	2.261	2.324	2.386	6.389	6.05
16 mA	slow	2.274	2.287	2.369	6.671	6.256
20 mA	slow	2.372	2.206	2.306	6.976	6.541

2.7.6.3 2.5 V LVCMOS

LVCMOS 2.5 V is a general standard for 2.5 V applications and is supported in IGLOO2 FPGA and SmartFusion2 SoC FPGAs in compliance to the JEDEC specification JESD8-5A.

2.7.6.3.1 Minimum and Maximum AC/DC Input and Output Levels Specification

Table 28 • LVCMOS 2.5 V DC Voltage Specification

Symbol	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 2.5 V Recommended DC Operating Conditions						
VDDI	Supply voltage		2.375	2.5	2.625	V
LVCMOS 2.5 V DC Input Voltage Specification						
VIH (DC)	DC input logic High (for MSIOD and DDRIO I/O Bank)		1.7		2.625	V
VIH (DC)	DC input logic High (for MSIO I/O Bank)		1.7		2.75	V
VIL (DC)	DC input logic Low		-0.3		0.7	V
I _{IH} (DC)	Input current High				See Table 19, page 19	
I _{IL} (DC)	Input current Low				See Table 19, page 19	
LVCMOS 2.5 V DC Output Voltage Specification						
VOH	DC output logic High ¹		VDDI-0.4			V
VOL	DC output logic Low ¹				0.4	V

1. The VOH/VOL test points selected ensure compliance with LVCMOS 2.5 V JEDEC8-5A requirements.

Table 29 • LVCMOS 2.5 V Maximum AC Switching Speeds

Symbol	Parameters	Conditions	Min	Typ	Max	Units
D _{max}	Maximum data rate (for DDRIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			360	Mbps
D _{max}	Maximum data rate (for MSIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			360	Mbps
D _{max}	Maximum data rate (for MSIOD I/O Bank)	AC loading: 17 pF load, maximum drive/slew			370	Mbps

Table 30 • LVCMOS 2.5 V AC Test Parameters and Driver Impedance Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 2.5 V Calibrated Impedance Option						
R _{odt_cal}	Supported output driver calibrated impedance (for DDRIO I/O Bank)			75, 60, 50, 33, 25, 20		Ω
LVCMOS 2.5 V AC Test Parameters Specifications						
V _{trip}	Measuring/trip point for data path			1.2		V
R _{ent}	Resistance for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
C _{ent}	Capacitive loading for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF
C _{load}	Capacitive loading for data path (t _{DP})			5		pF

Table 31 • LVCMOS 2.5 V Transmitter Drive Strength Specifications

Output Drive Selection						
MSIO I/O Bank	MSIOD I/O Bank	DDRIO I/O Bank (With Software Default Fixed Code)	VOH (V) Min	VOL (V) Max	IOH (at VOH) mA	IOL (at VOL) mA
2 mA	2 mA	2 mA	VDDI-0.4	0.7	2	2
4 mA	4 mA	4 mA	VDDI-0.4	0.7	4	4
6 mA	6 mA	6 mA	VDDI-0.4	0.7	6	6
8 mA	8 mA	8 mA	VDDI-0.4	0.7	8	8
12 mA	12 mA	12 mA	VDDI-0.4	0.7	12	12
16 mA	N/A	16 mA	VDDI-0.4	0.7	16	16

Note: For board design considerations, output slew rates extraction, detailed output buffer resistances and I/V Curve use the corresponding IBIS models located at:
<http://www.microsemi.com/products/fpga-soc/design-resources/ibis-models>.

2.7.6.3.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 32 • LVCMOS 2.5 V AC Switching Characteristics for Receiver (Input Buffers)

Worst-case Military conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	On-Die Termination (ODT)	Speed Grade -1		
		t_{PY}	t_{PYS}	Units
LVCMOS 2.5 V (for DDRIO I/O Bank)	None	1.903	2.021	ns
LVCMOS 2.5 V (for MSIO I/O Bank)	None	2.689	2.698	ns
LVCMOS 2.5 V (for MSIOD I/O Bank)	None	2.447	2.46	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 33 • LVCMOS 2.5 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Worst-case Military conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

Output Drive Selection	Slew Control	Speed Grade -1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
LVCMOS 2.5 V (for DDRIO I/O Bank with Fixed Code)							
2 mA	slow	3.967	3.664	3.986	4.172	3.811	ns
	medium	3.625	3.38	3.647	3.882	3.458	ns
	medium_fast	3.485	3.259	3.507	3.747	3.327	ns
	fast	3.458	3.253	3.48	3.74	3.31	ns
4 mA	slow	3.371	2.942	3.362	5.148	4.71	ns
	medium	3.063	2.701	3.059	4.874	4.381	ns
	medium_fast	2.925	2.566	2.92	4.686	4.248	ns
	fast	2.91	2.559	2.905	4.683	4.238	ns

Table 33 • LVCMOS 2.5 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-case Military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$ (continued)

Output Drive Selection	Slew Control	Speed Grade –1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
6 mA	slow	3.189	2.716	3.169	5.56	5.092	ns
	medium	2.886	2.473	2.876	5.273	4.752	ns
	medium_fast	2.749	2.355	2.738	5.127	4.167	ns
	fast	2.731	2.345	2.72	5.115	4.6	ns
8 mA	slow	3.132	2.646	3.109	5.686	5.207	ns
	medium	2.832	2.407	2.82	5.402	4.864	ns
	medium_fast	2.698	2.292	2.685	5.262	4.732	ns
	fast	2.684	2.282	2.671	5.252	4.724	ns
12 mA	slow	3.013	2.504	2.984	5.918	5.416	ns
	medium	2.72	2.284	2.707	5.657	5.074	ns
	medium_fast	2.592	2.176	2.578	5.537	4.949	ns
	fast	2.58	2.166	2.566	5.529	4.946	ns
16 mA	slow	2.936	2.415	2.902	6.136	5.577	ns
	medium	2.66	2.206	2.645	5.901	5.261	ns
	medium_fast	2.536	2.102	2.519	5.815	5.142	ns
	fast	2.523	2.093	2.506	5.81	5.137	ns
LVCMOS 2.5 V (for MSIO I/O Bank)							
2 mA	slow	3.933	4.352	4.22	2.358	3.838	ns
4 mA	slow	2.905	3.423	3.508	4.681	5.262	ns
6 mA	slow	2.687	2.995	3.155	5.561	5.73	ns
8 mA	slow	2.594	2.877	3.07	6.602	6.248	ns
12 mA	slow	2.623	2.732	2.944	6.974	6.478	ns
16 mA	slow	2.717	2.617	2.84	7.455	6.824	ns
LVCMOS 2.5 V (for MSIOD I/O Bank)							
2 mA	slow	2.403	2.922	2.89	5.397	5.202	ns
4 mA	slow	1.998	2.446	2.468	5.936	5.665	ns
6 mA	slow	1.861	2.329	2.375	6.391	6.068	ns
8 mA	slow	1.781	2.145	2.208	6.884	6.44	ns
12 mA	slow	1.804	2.039	2.108	7.23	6.685	ns

2.7.6.4 1.8 V LVCMOS

LVCMOS 1.8 is a general standard for 1.8 V applications and is supported in IGLOO2 FPGAs and SmartFusion2 SoC FPGAs in compliance to the JEDEC specification JESD8-7A.

2.7.6.4.1 Minimum and Maximum AC/DC Input and Output Levels

Table 34 • LVCMOS 1.8 V DC Voltage Specification

Symbols	Parameters	Min	Typ	Max	Units
Recommended DC Operating Conditions					
VDDI	Supply Voltage	1.710	1.8	1.89	V
LVCMOS 1.8 V DC Input Voltage Specification					
VIH(DC)	DC input Logic HIGH (for MSIOD and DDRIO I/O Banks)	$0.65 \times VDDI$		1.89	V
VIH(DC)	DC input Logic HIGH (for MSIO I/O Bank)	$0.65 \times VDDI$		2.75	V
VIL(DC)	DC input Logic LOW	-0.3		$0.35 \times VDDI$	V
I _{IH} (DC)	Input Current HIGH			See Table 19, page 19	
I _{IL} (DC)	Input Current LOW			See Table 19, page 19	
LVCMOS 1.8 V DC Output Voltage Specification					
VOH	DC output Logic HIGH	$VDDI - 0.45$			V
VOL	DC output Logic LOW			0.45	V

Table 35 • LVCMOS 1.8 V Maximum AC Switching Speeds

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 18 V Maximum AC Switching Speed						
D _{max}	Maximum data rate (for DDRIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			360	Mbps
D _{max}	Maximum data rate (for MSIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			260	Mbps
D _{max}	Maximum data rate (for MSIOD I/O Bank)	AC loading: 17 pF load, maximum drive/slew			360	Mbps

Table 36 • LVCMOS 1.8 V Transmitter Drive Strength Specifications

Output Drive Selection		VOH (V)		VOL (V)		IOL (at VOL)	
MSIO I/O Bank	MSIOD I/O Bank	Min	Max	Min	Max	IOH (at VOH) mA	mA
2 mA	2 mA	$VDDI - 0.45$	0.45			2	2
4 mA	4 mA	$VDDI - 0.45$	0.45			4	4
6 mA	6 mA	$VDDI - 0.45$	0.45			6	6
8 mA	8 mA	$VDDI - 0.45$	0.45			8	8
10 mA	10 mA	$VDDI - 0.45$	0.45			10	10
12 mA	N/A	$VDDI - 0.45$	0.45			12	12

Note: Maximum data rate applies for drive strength 8 mA and above, all slews.

Table 37 • LVCMOS 1.8 V Transmitter Drive Strength Specifications

Output Drive Selection	VOH (V)		VOL (V)	
	Min	Max	IOH (at VOH) mA	IOL (at VOL) mA
2 mA	VDDI – 0.45	0.45	2	2
4 mA	VDDI – 0.45	0.45	4	4
6 mA ²	VDDI – 0.45	0.45	6	6
8 mA ²	VDDI – 0.45	0.45	6	6
10 mA	VDDI – 0.45	0.45	8	8
12 mA	VDDI – 0.45	0.45	10	10
16 mA	VDDI – 0.45	0.45	12	12

1. Software Configurator GUI will display the Commercial/Industrial numeric values. The actual drive capability at temperature is defined by Table 37, page 27.
2. DDRIO has two 6 mA drive strength settings. The setting that corresponds to Output Drive Selection value of 8 mA has a shorter propagation delay.

Table 38 • LVCMOS 1.8 V AC Test Parameters and Driver Impedance Specifications

LVCMOS 1.8 V AC Calibrated Impedance Option					
Symbols	Parameters	Min	Typ	Max	Units
Rodt_cal	Supported output driver calibrated impedance (for DDRIO I/O Bank)		75, 60, 50, 33, 25, 20		Ω

LVCMOS 1.8 V AC Test Parameters Specifications					
Vtrip	Measuring/trip point for data path		0.9		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})		2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})		5		pF
Cload	Capacitive loading for data path (t_{DP})		5		pF

2.7.6.4.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 39 • LVCMOS 1.8 V AC Switching Characteristics for Receiver (Input Buffers)

 Worst-case Military conditions: $T_J = 125\text{ °C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$

	ODT (On Die Termination)	Speed Grade –1		Units
		t_{PY}	t_{PYS}	
LVCMOS 1.8 V (for DDRIO I/O Bank with Fixed Codes)	None	2.071	2.213	ns
	None	3.185	3.171	ns
	50	3.394	3.397	ns
	75	3.322	3.316	ns
LVCMS 1.8 V (for MSIO I/O Bank)	150	3.252	3.239	ns

Table 39 • LVC MOS 1.8 V AC Switching Characteristics for Receiver (Input Buffers)
 Worst-case Military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$ (continued)

	ODT (On Die Termination)	Speed Grade -1		Units
		t_{PY}	t_{PYS}	
LVC MOS 1.8 V (for MSIOD I/O Bank)	None	2.827	2.813	ns
	50	3.043	3.053	ns
	75	2.968	2.963	ns
	150	2.898	2.886	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 40 • LVC MOS 1.8 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-case Military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$

Output Drive Selection	Slew Control	Speed Grade -1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
LVC MOS 1.8 V (for DDRIO I/O Bank with Fixed Codes)							
2 mA	slow	4.681	4.017	4.69	5.388	4.852	ns
	medium	4.211	3.599	4.219	5.058	4.488	ns
	medium_fast	3.978	3.392	3.986	4.874	4.327	ns
	fast	3.953	3.373	3.961	4.858	4.316	ns
4 mA	slow	4.355	3.657	4.346	5.967	5.399	ns
	medium	3.886	3.246	3.879	5.628	5.01	ns
	medium_fast	3.656	3.05	3.647	5.461	4.845	ns
	fast	3.635	3.033	3.626	5.447	4.838	ns
6 mA	slow	4.105	3.422	4.092	6.221	5.599	ns
	medium	3.68	3.05	3.668	5.9	5.257	ns
	medium_fast	3.477	2.867	3.463	5.739	5.118	ns
	fast	3.451	2.849	3.437	5.72	5.104	ns
8 mA	slow	4.015	3.32	3.998	6.458	5.808	ns
	medium	3.59	2.947	3.574	6.129	5.449	ns
	medium_fast	3.383	2.761	3.366	5.963	5.304	ns
	fast	3.357	2.746	3.34	5.954	5.289	ns
10 mA	slow	3.888	3.18	3.864	6.739	6.045	ns
	medium	3.485	2.822	3.467	6.422	5.7	ns
	medium_fast	3.281	2.642	3.26	6.277	5.553	ns
	fast	3.258	2.627	3.238	6.27	5.546	ns
12 mA	slow	3.795	3.096	3.773	6.773	6.067	ns
	medium	3.408	2.764	3.389	6.47	5.743	ns
	medium_fast	3.215	2.599	3.194	6.346	5.61	ns
	fast	3.196	2.584	3.175	6.335	5.604	ns
16 mA	slow	3.744	3.035	3.719	6.944	6.207	ns
	medium	3.358	2.712	3.339	6.657	5.868	ns
	medium_fast	3.175	2.546	3.153	6.547	5.751	ns
	fast	3.156	2.531	3.133	6.541	5.747	ns

Table 40 • LVC MOS 1.8 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-case Military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$ (continued)

Output Drive Selection	Slew Control	Speed Grade -1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
LVC MOS 1.8 V (for MSIO I/O Bank)							
2 mA	slow	3.957	4.784	5.023	5.643	5.866	ns
4 mA	slow	3.668	4.162	4.485	6.543	6.382	ns
6 mA	slow	3.586	3.994	4.358	7.622	6.941	ns
8 mA	slow	3.616	3.782	4.162	7.988	7.161	ns
10 mA	slow	3.662	3.732	4.121	8.396	7.423	ns
12 mA	slow	3.75	3.615	4.006	8.576	7.543	ns
LVC MOS 1.8 V (for MSIOD I/O Bank)							
2 mA	slow	3.048	3.692	3.898	5.818	5.609	ns
4 mA	slow	2.5	3.088	3.288	6.421	6.121	ns
6 mA	slow	2.225	2.747	2.937	7.18	6.753	ns
8 mA	slow	2.233	2.72	2.904	7.49	6.992	ns
10 mA	slow	2.263	2.577	2.759	7.851	7.253	ns

2.7.6.5 1.5 V LVC MOS

LVC MOS 1.5 is a general standard for 1.5 V applications and is supported in IGLOO2 FPGAs and SmartFusion2 SoC FPGAs in compliance to the JEDEC specification JESD8-11A.

2.7.6.5.1 Minimum and Maximum AC/DC Input and Output Levels Specification

Table 41 • LVC MOS 1.5 V Minimum and Maximum DC Input and Output Levels

Symbols	Parameters	Min	Typ	Max	Units
LVC MOS 1.5 V Recommended DC Operating Conditions					
VDDI	Supply voltage	1.425	1.5	1.575	V
LVC MOS 1.5 V DC Input Voltage Specification					
V _{IH} (DC)	DC input logic High for (MSIOD and DDRIO I/O banks)	$0.65 \times V_{DDI}$		1.575	V
V _{IH} (DC)	DC input logic High (for MSIO I/O Bank)	$0.65 \times V_{DDI}$		2.75	V
V _{IL} (DC)	DC input logic Low	-0.3		$0.35 \times V_{DDI}$	V
I _{IH} (DC)	Input current High			See Table 19, page 19	
I _{IL} (DC)	Input current Low			See Table 19, page 19	
LVC MOS 1.5 V DC Output Voltage Specification					
V _{OH}	DC output logic High	$V_{DDI} \times 0.75$			V
V _{OL}	DC output logic Low			$V_{DDI} \times 0.25$	V

Table 42 • LVCMOS 1.5 V Maximum AC Switching Speeds

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 1.5 V Maximum AC Switching Speed						
Dmax	Maximum data rate (for DDRIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			210	Mbps
Dmax	Maximum data rate (for MSIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			140	Mbps
Dmax	Maximum data rate (for MSIOD I/O Bank)	AC loading: 17 pF load, maximum drive/slew			190	Mbps

Table 43 • LVCMOS 1.5 V AC Test Parameters and Driver Impedance Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 1.5 V AC Calibrated Impedance Option						
Rodt_cal	Supported output driver calibrated impedance (for DDRIO I/O Bank)			75, 60, 50, 40		Ω
LVCMOS 1.5 V AC Test Parameters Specifications						
Vtrip	Measuring/trip point for data path			0.75		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF
Cload	Capacitive loading for data path (t_{DP})			5		pF

Table 44 • LVCMOS 1.5 V Transmitter Drive Strength Specifications

Output Drive Selection			VOH (V)		VOL (V)	
MSIO I/O Bank	MSIOD I/O Bank	DDRIO I/O Bank (with Fixed Code)	Min	Max	IOH (at VOH) mA	IOL (at VOL) mA
2 mA	2 mA	2 mA	$VDDI \times 0.75$	$VDDI \times 0.25$	2	2
4 mA	4 mA	4 mA	$VDDI \times 0.75$	$VDDI \times 0.25$	4	4
6 mA	6 mA	6 mA	$VDDI \times 0.75$	$VDDI \times 0.25$	6	6
8 mA	N/A	8 mA	$VDDI \times 0.75$	$VDDI \times 0.25$	8	8
N/A	N/A	10 mA	$VDDI \times 0.75$	$VDDI \times 0.25$	10	10
N/A	N/A	12 mA	$VDDI \times 0.75$	$VDDI \times 0.25$	12	12

2.7.6.5.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 45 • LVCMOS 1.5 V AC Switching Characteristics for Receiver (Input Buffers)
 Worst-Case Military Conditions: $T_J=125\text{ }^\circ\text{C}$, $V_{DD}=1.14\text{ V}$, $V_{DDI}=1.425\text{ V}$

		Speed Grade –1		
	ODT (On Die Termination)	t_{pY}	t_{pYS}	Units
LVCMOS 1.5 V (for DDRIO I/O Bank with Fixed Codes)	none	2.19	2.216	ns
	none	3.679	3.652	ns
	50	4.151	4.126	ns
	75	3.984	3.953	ns
LVCMOS 1.5 V (for MSIO I/O Bank)	150	3.823	3.791	ns
	none	3.262	3.229	ns
	50	3.76	3.739	ns
	75	3.555	3.52	ns
LVCMOS 1.5 V (for MSIOD I/O Bank)	150	3.395	3.359	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 46 • LVCMOS 1.5 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: $T_J=125\text{ }^\circ\text{C}$, $V_{DD}=1.14\text{ V}$, $V_{DDI}=1.425\text{ V}$

		Speed Grade –1					
Output Drive Selection	Slew Control	t_{DP}	t_{zL}	t_{zH}	t_{HZ}	t_{LZ}	Units
LVCMOS 1.5 V (for DDRIO I/O Bank with Fixed Codes)							
2 mA	slow	5.712	4.796	5.735	5.814	5.138	ns
	medium	5.094	4.274	5.114	5.484	4.779	ns
	medium_fast	4.793	4.013	4.81	5.288	4.625	ns
	fast	4.762	3.98	4.78	5.261	4.615	ns
4 mA	slow	4.966	4.133	4.956	6.763	6.05	ns
	medium	4.412	3.62	4.401	6.433	5.664	ns
	medium_fast	4.145	3.358	4.131	6.249	5.507	ns
	fast	4.116	3.338	4.103	6.238	5.498	ns
6 mA	slow	4.744	3.869	4.728	7.173	6.383	ns
	medium	4.212	3.382	4.195	6.837	6.004	ns
	medium_fast	3.951	3.135	3.93	6.668	5.861	ns
	fast	3.919	3.11	3.899	6.644	5.845	ns
8 mA	slow	4.603	3.691	4.585	7.397	6.553	ns
	medium	4.081	3.242	4.062	7.064	6.189	ns
	medium_fast	3.827	3.015	3.804	6.912	6.051	ns
	fast	3.804	2.994	3.781	6.903	6.051	ns

Table 46 • LVCMOS 1.5 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: $T_J=125\text{ }^\circ\text{C}$, $V_{DD}=1.14\text{ V}$, $V_{DDI}=1.425\text{ V}$ (continued)

Output Drive Selection	Slew Control	Speed Grade –1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
10 mA	slow	4.519	3.612	4.499	7.578	6.676	ns
	medium	4.026	3.177	4.005	7.264	6.335	ns
	medium_fast	3.775	2.948	3.75	7.11	6.198	ns
	fast	3.747	2.929	3.721	7.103	6.19	ns
12 mA	slow	4.456	3.562	4.433	7.704	6.795	ns
	medium	3.965	3.13	3.943	7.388	6.425	ns
	medium_fast	3.731	2.912	3.704	7.278	6.303	ns
	fast	3.703	2.893	3.676	7.275	6.294	ns
LVCMOS 1.5 V (for MSIO I/O Bank)							
2 mA	slow	5.118	6.263	6.53	6.524	6.388	ns
4 mA	slow	4.657	5.178	5.65	8.57	7.55	ns
6 mA	slow	4.693	4.89	5.389	8.928	7.766	ns
8 mA	slow	4.876	4.663	5.183	9.59	8.173	ns
LVCMOS 1.5 V (for MSIOD I/O Bank)							
2 mA	slow	3.085	3.795	4.086	6.838	6.477	ns
4 mA	slow	2.731	3.365	3.631	7.663	7.165	ns
6 mA	slow	2.742	3.162	3.417	8.126	7.52	ns

2.7.6.6 1.2 V LVCMOS

LVCMOS 1.2 is a general standard for 1.2 V applications and is supported in IGLOO2 FPGAs and SmartFusion2 SoC FPGAs in compliance to the JEDEC specification JESD8-12A.

2.7.6.6.1 Minimum and Maximum Input and Output Levels Specification

Table 47 • LVCMOS 1.2 V Minimum and Maximum DC Input and Output Levels

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 1.2 V Recommended DC Operating Conditions						
VDDI	Supply voltage		1.140	1.2	1.26	V
LVCMOS 1.2 V DC Input Voltage Specification						
VIH (DC)	DC input logic High (for MSIOD and DDRIO I/O Banks)		$0.65 \times V_{DDI}$		1.26	V
VIH (DC)	DC input logic High (for MSIO I/O Bank)		$0.65 \times V_{DDI}$		2.75	V
VIL (DC)	DC input logic Low		-0.3		$0.35 \times V_{DDI}$	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
LVCMOS 1.2 V DC Output Voltage Specification						
VOH	DC output logic High		$V_{DDI} \times 0.75$			V
VOL	DC output logic Low				$V_{DDI} \times 0.25$	V

Table 48 • LVCMOS 1.2 V Maximum AC Switching Speeds

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 1.2 V Maximum AC Switching Speed						
Dmax	Maximum data rate (for DDRIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			180	Mbps
Dmax	Maximum data rate (for MSIO I/O Bank)	AC loading: 17 pF load, maximum drive/slew			100	Mbps
Dmax	Maximum data rate (for MSIOD I/O Bank)	AC loading: 17 pF load, maximum drive/slew			140	Mbps

Table 49 • LVCMOS 1.2 V AC Calibrated Impedance and Test Parameters Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVCMOS 1.2 V AC Calibrated Impedance Option						
Rodt_cal	Supported output driver calibrated impedance (for DDRIO I/O Bank)			75, 60, 50, 40		Ω
LVCMOS 1.2 V AC Test Parameters Specifications						
Vtrip	Measuring/trip point for data path			0.6		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF
Cload	Capacitive loading for data path (t_{DP})			5		pF

Table 50 • LVCMOS 1.2 V Transmitter Drive Strength Specifications

Output Drive Selection			VOH (V)		VOL (V)	
MSIO I/O Bank	MSIOD I/O Bank	DDRIO I/O Bank (with Fixed Code)	Min	Max	IOH (at VOH) mA	IOL (at VOL) mA
2 mA	2 mA	2 mA	VDDI \times 0.75	VDDI \times 0.25	2	2
4 mA	4 mA	4 mA	VDDI \times 0.75	VDDI \times 0.25	4	4
N/A	N/A	6 mA	VDDI \times 0.75	VDDI \times 0.25	6	6

2.7.6.6.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 51 • LVCMOS 1.2 V AC Switching Characteristics for Receiver (Input Buffers)

 Worst-Case Military Conditions: $T_J=125^\circ\text{C}$, VDD=1.14 V, VDDI= 1.14 V

	ODT (On Die Termination)	Speed Grade -1		Units
		t_{PY}	t_{PYS}	
LVCMOS 1.2 V (for DDRIO I/O Bank with Fixed Codes)	none	2.539	2.556	ns
	none	4.888	4.845	ns
	50	6.683	6.605	ns
	75	5.923	5.847	ns
LVCMOS 1.2 V (for MSIO I/O Bank)	150	5.29	5.235	ns

Table 51 • LVCMOS 1.2 V AC Switching Characteristics for Receiver (Input Buffers)Worst-Case Military Conditions: $T_J=125\text{ }^\circ\text{C}$, $V_{DD}=1.14\text{ V}$, $V_{DDI}=1.14\text{ V}$ (continued)

	none	4.281	4.235	ns
	50	6.806	6.721	ns
	75	5.643	5.564	ns
LVCMOS 1.2 V (for MSIOD I/O Bank)	150	4.813	4.753	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 52 • LVCMOS 1.2 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Worst-Case Military Conditions: $T_J=125\text{ }^\circ\text{C}$, $V_{DD}=1.14\text{ V}$, $V_{DDI}=1.14\text{ V}$

Output Drive Selection	Slew Control	Speed Grade -1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
LVCMOS 1.2 V (for DDRIO I/O Bank with Fixed Code)							
2 mA	slow	6.938	5.599	6.948	7.568	6.612	ns
	medium	6.11	4.814	6.114	7.201	6.234	ns
	medium_fast	5.675	4.409	5.676	6.971	6.048	ns
	fast	5.633	4.379	5.634	6.958	6.037	ns
4 mA	slow	6.328	4.892	6.316	8.339	7.306	ns
	medium	5.538	4.192	5.521	7.961	6.923	ns
	medium_fast	5.119	3.832	5.097	7.76	6.741	ns
	fast	5.072	3.085	5.051	7.752	6.725	ns
6 mA	slow	6.092	4.681	6.075	8.685	7.589	ns
	medium	5.342	4.016	5.32	8.33	7.19	ns
	medium_fast	4.949	3.66	4.922	8.139	7.022	ns
	fast	4.903	3.622	4.876	8.107	7.006	ns
LVCMOS 1.2 V (for MSIO I/O Bank)							
2 mA	slow	7.051	7.856	8.541	10.387	8.768	ns
4 mA	slow	7.385	7.027	7.815	11.547	9.444	ns
LVCMOS 1.2 V (for MSIOD I/O Bank)							
2 mA	slow	4.048	5.123	5.552	8.401	7.824	ns
4 mA	slow	3.941	4.406	4.814	9.422	8.656	ns

2.7.6.7 3.3 V PCI/PCIX

Peripheral Component Interface (PCI) for 3.3 V standards specify support for 33 MHz and 66 MHz PCI bus applications.

2.7.6.7.1 Minimum and Maximum Input and Output Levels Specification

Table 53 • PCI/PCI-X DC Voltage Specification (Applicable to MSIO Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
PCI/PCIX Recommended DC Operating Conditions						
VDDI	Supply voltage		3.15	3.3	3.45	V
PCI/PCIX DC Input Voltage Specification						
VI	DC input voltage		0		3.45	V
IIH(DC)	Input current High				See Table 19, page 19	
IIL(DC)	Input current Low				See Table 19, page 19	
PCI/PCIX DC Output Voltage Specification						
VOH	DC output logic High		Per PCI Specification			V
VOL	DC output logic Low		Per PCI Specification			V

Table 54 • PCI/PCI-X AC Specifications (Applicable to MSIO Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
PCI/PCI-X AC Specifications						
Dmax	Maximum data rate (MSIO I/O Bank)	AC Loading: per JEDEC specifications			560	Mbps
PCI/PCI-X AC Test Parameters Specifications						
Vtrip	Measuring/trip point for data path (falling edge)			0.615 × VDDI		V
Vtrip	Measuring/trip point for data path (rising edge)			0.285 × VDDI		V
Rtt_test	Resistance for data test path			25		Ω
Rent	Resistance for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF
Cload	Capacitive loading for data path (t _{DP})			10		pF

2.7.6.7.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 55 • PCI/PCIX AC Switching Characteristics for Receiver (Input Buffers)

Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V, VDDI = 3.15 V

	ODT (On Die Termination)	Speed Grade –1		Units
		t _{py}	t _{pys}	
PCI/PCIX (for MSIO I/O Bank)	None	2.379	2.387	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 56 • PCI/PCIX AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 3.15\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
PCI/PCIX (for MSIO I/O Bank)	2.394	2.274	2.316	6.876	6.242	ns

2.7.7 Memory Interface and Voltage Referenced I/O Standards

2.7.7.1 High-Speed Transceiver Logic (HSTL)

The High-Speed Transceiver Logic (HSTL) standard is a general purpose high-speed bus standard sponsored by IBM (EIA/JESD8-6). IGLOO2 FPGA and SmartFusion2 SoC FPGA devices support two classes of the 1.5 V HSTL. These differential versions of the standard require a differential amplifier input buffer and a push-pull output buffer.

2.7.7.1.1 Minimum and Maximum Input and Output Levels Specification

Table 57 • HSTL DC Voltage Specification (Applicable to DDRIO I/O Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
HSTL Recommended DC Operating Conditions						
VDDI	Supply voltage		1.425	1.5	1.575	V
VTT	Termination voltage		0.698	0.750	0.803	V
VREF	Input reference voltage		0.698	0.750	0.803	V
HSTL DC Input Voltage Specification						
VIH (DC)	DC input logic High		$V_{REF} + 0.1$		1.575	V
VIL (DC)	DC input logic Low		-0.3		$V_{REF} - 0.1$	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
HSTL DC Output Voltage Specification						
HSTL Class I						
VOH	DC output logic High		$V_{DDI} - 0.4$			V
VOL	DC output logic Low				0.4	V
IOH at VOH	Output minimum source DC current		-7.0			mA
IOL at VOL	Output minimum sink current		7.0			mA
HSTL Class II						
VOH	DC output logic High		$V_{DDI} - 0.4$			V
VOL	DC output logic Low				0.4	V
IOH at VOH	Output minimum source DC current		-15.0			mA

Table 57 • HSTL DC Voltage Specification (Applicable to DDRIO I/O Bank Only) (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
IOL at VOL	Output minimum sink current		15.0			mA
HSTL DC Differential Voltage Specifications						
VID (DC)	DC input differential voltage		0.2			V

Table 58 • HSTL AC Specifications (Applicable to DDRIO Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
HSTL AC Differential Voltage Specifications						
VDIFF	AC input differential voltage		0.4			V
Vx	AC differential cross point voltage		0.68		0.9	V
HSTL Maximum AC Switching Speed						
Dmax	Maximum data rate	AC loading: per JEDEC specifications			360	Mbps
HSTL Impedance Specification						
Rref	Supported output driver calibrated impedance (for DDRIO I/O Bank)	Reference resistance = 191 Ω		25.5, 47.8		Ω
RTT	Effective impedance value (ODT for DDRIO I/O Bank only)	Reference resistance = 191 Ω		47.8		Ω
HSTL AC Test Parameters Specification						
Vtrip	Measuring/trip point for data path			0.75		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF
Rtt_test	Reference resistance for data test path for HSTL15 Class I (t_{DP})			50		Ω
Rtt_test	Reference resistance for data test path for HSTL15 Class II (t_{DP})			25		Ω
Cload	Capacitive loading for data path (t_{DP})			5		pF

2.7.7.1.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 59 • HSTL15 AC Switching Characteristics for Receiver (Input Buffers)
 Worst-Case Military Conditions: $T_j = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.425\text{ V}$

		t_{PY}	
		ODT (On Die Termination)	Speed Grade -1 Units
HSTL (for DDRIO I/O Bank with Fixed Code)			
Pseudo-Differential	None		1.673 ns
True-Differential	None		1.693 ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 60 • HSTL 15 AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.425\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
HSTL Class I (for DDRIO I/O Bank)						
Single Ended	2.922	2.91	2.904	3.225	3.218	ns
Differential	2.907	2.757	2.755	2.662	2.66	ns
HSTL Class II (for DDRIO I/O Bank)						
Single Ended	2.817	2.735	2.735	2.644	2.644	ns
Differential	2.827	2.81	2.803	3.205	3.197	ns

2.7.7.2 Stub-Series Terminated Logic

Stub-Series Terminated Logic (SSTL) for 2.5 V (SSTL2), 1.8 V (SSTL18), and 1.5 V (SSTL15) is supported in IGLOO2 and SmartFusion2 SoC FPGAs. SSTL2 is defined by JEDEC standard JESD8-9B and SSTL18 is defined by JEDEC standard JESD8-15. IGLOO2 SSTL I/O configurations are designed to meet double data rate standards DDR/2/3 for general purpose memory buses. Double data rate standards are designed to meet their JEDEC specifications as defined by JEDEC standard JESD79F for DDR, JEDEC standard JESD79-2F for DDR, JEDEC standard JESD79-3D for DDR3, and JEDEC standard JESD209A for LPDDR.

2.7.7.3 Stub-Series Terminated Logic 2.5 V (SSTL2)

SSTL2 Class I and Class II are supported in IGLOO2 and SmartFusion2 SoC FPGAs and also comply with reduced and full drive of double data rate (DDR) standards. IGLOO2 and SmartFusion2 SoC FPGA I/Os supports both standards for single-ended signaling and differential signaling for SSTL2. This standard requires a differential amplifier input buffer and a push-pull output buffer.

2.7.7.3.1 Minimum and Maximum DC Input and Output Levels Specification

Table 61 • DDR1/SSTL2 Minimum and Maximum DC Input and Output Levels

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		2.375	2.5	2.625	V
VTT	Termination voltage		1.164	1.250	1.339	V
VREF	Input reference voltage		1.164	1.250	1.339	V
SSTL2 DC Input Voltage Specification						
VIH (DC)	DC input logic High		VREF + 0.15		2.625	V
VIL (DC)	DC input logic Low		-0.3		VREF - 0.15	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
SSTL2 DC Output Voltage Specification						
SSTL2 Class I (DDR Reduced Drive)						
VOH	DC output logic High		VTT + 0.608			V
VOL	DC output logic Low				VTT - 0.608	V
IOH at VOH	Output minimum source DC current		8.1			mA
IOL at VOL	Output minimum sink current		-8.1			mA
SSTL2 Class II (DDR Full Drive) – Applicable to MSIO and DDRIO I/O Banks Only						
VOH	DC output logic High		VTT + 0.81			V
VOL	DC output logic Low				VTT - 0.81	V
IOH at VOH	Output minimum source DC current		16.2			mA
IOL at VOL	Output minimum sink current		-16.2			mA
SSTL2 DC Differential Voltage Specification						
VID (DC)	DC input differential voltage		0.3			V

Table 62 • DDR1/SSTL2 AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
SSTL2 Maximum AC Switching Speeds						
Dmax	Maximum data rate (for DDRIO I/O Bank)	AC loading: per JEDEC specifications			360	Mbps
Dmax	Maximum data rate (for MSIO I/O Bank)	AC loading: 17 pF load			450	Mbps
Dmax	Maximum data rate (for MSIOD I/O Bank)	AC loading: 17 pF load			480	Mbps

Table 62 • DDR1/SSTL2 AC Specifications (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
SSTL2 AC Differential Voltage Specifications						
V _{DIFF}	AC Input Differential Voltage		0.7			V
V _x	AC Differential Cross Point Voltage		$0.5 \times V_{DDI} - 0.2$		$0.5 \times V_{DDI} + 0.2$	V
SSTL2 Impedance Specifications						
	Supported output driver calibrated impedance (for DDRIO I/O Bank)	Reference resistor = 150 Ω		20, 42		Ω
SSTL2 AC Test Parameters Specifications						
V _{trip}	Measuring/trip point for data path			1.25		V
R _{ent}	Resistance for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
C _{ent}	Capacitive loading for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF
R _{tt_test}	Reference resistance for data test path for SSTL2 Class I (t _{DP})			50		Ω
R _{tt_test}	Reference resistance for data test path for SSTL2 Class II (t _{DP})			25		Ω
C _{load}	Capacitive loading for data path (t _{DP})			5		pF

2.7.7.3.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 63 • DDR1/SSTL2 AC Switching Characteristics for Receiver (Input Buffers)
 Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V, VDDI = 2.375 V

	ODT (On Die Termination)	Speed Grade -1	
		t _{py}	Units
SSTL2 (DDRIO I/O Bank)			
Pseudo-Differential	None	1.613	ns
True-Differential	None	1.647	ns
SSTL2 (MSIO I/O Bank)			
Pseudo-Differential	None	3.083	ns
True-Differential	None	3.028	ns
SSTL2 (MSIOD I/O Bank)			
Pseudo-Differential	None	2.721	ns
True-Differential	None	2.71	ns

Table 64 • DDR1/SSTL2 AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
SSTL2 Class I						
DDRIO I/O Bank						
Single Ended	2.457	2.145	2.137	2.302	2.293	ns
Differential	2.454	2.38	2.375	2.589	2.584	ns
MSIO I/O Bank						
Single Ended	2.283	2.255	2.243	2.286	2.273	ns
Differential	2.434	2.702	2.691	2.39	2.381	ns
MSIOD I/O Bank						
Single Ended	1.646	1.59	1.589	1.82	1.818	ns
Differential	1.774	1.93	1.926	2.012	2.007	ns
SSTL2 Class II						
DDRIO I/O Bank						
Single Ended	2.317	2.06	2.053	2.229	2.221	ns
Differential	2.32	2.213	2.21	2.57	2.565	ns
MSIO I/O Bank						
Single Ended	2.563	2.208	2.19	2.205	2.187	ns
Differential	2.703	2.566	2.555	2.363	2.353	ns

2.7.7.4 Stub-Series Terminated Logic 1.8 V (SSTL18)

SSTL18 Class I and Class II are supported in IGLOO2 and SmartFusion2 SoC FPGAs, and also comply with the reduced and full drive double data rate (DDR2) standard. IGLOO2 and SmartFusion2 SoC FPGA I/Os support both standards for single-ended signaling and differential signaling for SSTL18. This standard requires a differential amplifier input buffer and a push-pull output buffer.

2.7.7.4.1 Minimum and Maximum Input and Output Levels Specification

Table 65 • DDR2/SSTL18 AC/DC Minimum and Maximum Input and Output Levels Specification

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		1.71	1.8	1.89	V
VTT	Termination voltage		0.838	0.900	0.964	V
VREF	Input reference voltage		0.838	0.900	0.964	V
SSTL18 DC Input Voltage Specification						
VIH (DC)	DC input logic High		VREF + 0.125		1.89	V
VIL (DC)	DC input logic Low		-0.3		VREF - 0.125	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
SSTL18 DC Output Voltage Specification						
SSTL18 Class I (DDR2 Reduced Drive)						
VOH	DC output logic High		VTT + 0.603			V
VOL	DC output logic Low				VTT - 0.603	V
IOH at VOH	Output minimum source DC current (DDRIO I/O Bank only)		6.0			mA
IOL at VOL	Output minimum sink current (DDRIO I/O Bank only)		-6.0			mA
SSTL18 Class II (DDR2 Full Drive)¹						
VOH	DC output logic High		VTT + 0.603			V
VOL	DC output logic Low				VTT - 0.603	V
IOH at VOH	Output minimum source DC current (DDRIO I/O Bank only)		12.0			mA
IOL at VOL	Output minimum sink current (DDRIO I/O Bank only)		-12.0			mA
SSTL18 DC Differential Voltage Specification						
VID (DC)	DC input differential voltage		0.3			V

1. To meet JEDEC Electrical Compliance, use DDR2 Full Drive Transmitter.

Table 66 • DDR2/SSTL18 AC Specifications (Applicable to DDRIO Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
SSTL18 AC Differential Voltage Specification						
VDIFF (AC)	AC input differential voltage		0.5			V
Vx (AC)	AC differential cross point voltage		$0.5 \times VDDI - 0.175$		$0.5 \times VDDI + 0.175$	V
SSTL18 Maximum AC Switching Speed						
Dmax	Maximum data rate (for DDRIO I/O Bank)	AC loading: per JEDEC specification			600	Mbps

Table 66 • DDR2/SSTL18 AC Specifications (Applicable to DDRIO Bank Only) (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
SSTL18 Impedance Specifications						
Rref	Supported output driver calibrated impedance (for DDRIO I/O Bank)	Reference resistor = 150 Ω		20, 42		Ω
RTT	Effective impedance value (ODT)	Reference resistor = 150 Ω		50, 75, 150		Ω
SSTL18 AC Test Parameters Specifications						
Vtrip	Measuring/trip point for data path			0.9		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF
Rtt_test	Reference resistance for data test path for SSTL18 Class I (t_{DP})			50		Ω
Rtt_test	Reference resistance for data test path for SSTL18 Class II (t_{DP})			25		Ω
Cload	Capacitive loading for data path (t_{DP})			5		pF

2.7.7.4.2 AC Switching Characteristics**AC Switching Characteristics for Receiver (Input Buffers)****Table 67 • DDR2/SSTL18 AC Switching Characteristics for Receiver (Input Buffers)**Worst-Case Military Conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$

	On-Die Termination (ODT)	Speed Grade –1	
		t_{PY}	Units
SSTL18 (for DDRIO I/O Bank with Fixed Codes)			
Pseudo differential	None	1.633	ns
True differential	None	1.65	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 68 • DDR2/SSTL18 AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Worst-Case Military Conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
SSTL18 Class I (for DDRIO I/O Bank)						
Single Ended	2.67	3.078	3.072	2.489	2.484	ns
Differential	2.645	2.431	2.434	2.396	2.398	ns
SSTL18 Class II (for DDRIO I/O Bank)						
Single Ended	2.564	2.973	2.965	2.45	2.444	ns
Differential	2.532	2.401	2.398	2.368	2.365	ns

2.7.7.5 Stub-Series Terminated Logic 1.5 V (SSTL15)

SSTL15 Class I and Class II are supported in IGLOO2 FPGAs and SmartFusion2 SoC FPGAs, and also comply with the reduced and full drive double data rate (DDR3) standard. IGLOO2 FPGA and SmartFusion2 SoC FPGA I/Os supports both standards for single-ended signaling and differential signaling for SSTL18. This standard requires a differential amplifier input buffer and a push-pull output buffer.

2.7.7.5.1 Minimum and Maximum AC/DC Input and Output Levels Specification

Table 69 • DDR3 SSTL15 DC Voltage Specification (for DDRIO I/O Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		1.425	1.5	1.575	V
VTT	Termination voltage		0.698	0.750	0.803	V
VREF	Input reference voltage		0.698	0.750	0.803	V
SSTL15 DC Input Voltage Specification						
VIH(DC)	DC input logic High		VREF + 0.1		1.575	V
VIL(DC)	DC input logic Low		-0.3		VREF - 0.1	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
SSTL15 DC Output Voltage Specification						
DDR3/SSTL15 Class I (DDR3 Reduced Drive)						
VOH	DC output logic High		0.8 x VDDI			V
VOL	DC output logic Low				0.2 x VDDI	V
IOH at VOH	Output minimum source DC current		6.5			mA
IOL at VOL	Output minimum sink current		-6.5			mA
SSTL15 Class II (DDR3 Full Drive)						
VOH	DC output logic High		0.8 x VDDI			V
VOL	DC output logic Low				0.2 x VDDI	V
IOH at VOH	Output minimum source DC current		7.6			mA
IOL at VOL	Output minimum sink current		-7.6			mA
SSTL15 Differential Voltage Specification						
VID	DC input differential voltage		0.2			V

Note: To meet JEDEC Electrical Compliance, use DDR3 Full Drive Transmitter.

Table 70 • DDR3/SSTL15 AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
SSTL15 AC Differential Voltage Specification						
VDIFF	AC input differential voltage		0.3			V
Vx	AC differential cross point voltage		0.5 x VDDI - 0.150		0.5 x VDDI + 0.150	V

Table 70 • DDR3/SSTL15 AC Specifications (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
SSTL15 Maximum AC Switching Speed (for DDRIO I/O Banks Only)						
Dmax	Maximum data rate	AC loading: per JEDEC specifications			600	Mbps
SSTL15 AC Calibrated Impedance Option						
Rref	Supported output driver calibrated impedance	Reference resistor = 240 Ω		34, 40		Ω
RTT	Effective impedance value (ODT)	Reference resistor = 240 Ω		20, 30, 40, 60, 120		Ω
SSTL15 AC Test Parameters Specifications						
Vtrip	Measuring/trip point for data path			0.75		V
Rent	Resistance for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF
Rtt_test	Reference resistance for data test path for SSTL15 Class I (t _{DP})			50		Ω
Rtt_test	Reference resistance for data test path for SSTL15 Class II (t _{DP})			25		Ω
Cload	Capacitive loading for data path (t _{DP})			5		pF

2.7.7.5.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 71 • DDR3/SSTL15 AC Switching Characteristics for Receiver (Input Buffers)
 Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V, VDDI = 1.425 V

		Speed Grade –1	
	ODT (On Die Termination)	t _{PY}	Units
DDR3/SSTL15 (for DDRIO I/O Bank) – Calibration Mode Only			
Pseudo-Differential	None	1.672	ns
True-Differential	None	1.694	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 72 • DDR3/SSTL15 AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V, VDDI = 1.425 V

		Speed Grade –1				
	t _{DP}	t _{ZL}	t _{ZH}	t _{HZ}	t _{LZ}	Units
DDR3 Reduced Drive/SSTL15 Class I (for DDRIO I/O Bank)						
Single Ended	2.832	2.766	2.767	2.658	2.659	ns
Differential	2.848	3.401	3.393	3.173	3.166	ns
DDR3 Full Drive/SSTL15 Class II (for DDRIO I/O Bank)						
Single Ended	2.832	2.76	2.759	2.655	2.655	ns
Differential	2.845	3.397	3.387	3.179	3.171	ns

2.7.7.6 Low Power Double Data Rate (LPDDR)

LPDDR reduced and full drive low power double data rate standards are supported in IGLOO2 FPGA and SmartFusion2 SoC FPGA I/Os. This standard requires a differential amplifier input buffer and a push-pull output buffer. This I/O standard is supported in DDRIO I/O Bank only.

2.7.7.6.1 Minimum and Maximum AC/DC Input and Output Levels Specification

Table 73 • LPDDR AC/DC Specifications (for DDRIO IO Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		1.71	1.8	1.89	V
VTT	Termination voltage		0.838	0.900	0.964	V
VREF	Input reference voltage		0.838	0.900	0.964	V
LPDDR DC Input Voltage Specification						
VIH (DC)	DC input logic High		$0.7 \times VDDI$		1.89	V
VIL (DC)	DC input logic Low		-0.3		$0.3 \times VDDI$	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
LPDDR DC Output Voltage Specification						
LPDDR Reduced Drive						
VOH	DC output logic High		$0.9 \times VDDI$			V
VOL	DC output logic Low				$0.1 \times VDDI$	V
IOH at VOH	Output minimum source DC current		0.1			mA
IOL at VOL	Output minimum sink current		-0.1			mA
LPDDR Full Drive¹						
VOH	DC output logic High		$0.9 \times VDDI$			V
VOL	DC output logic Low				$0.1 \times VDDI$	V
IOH at VOH	Output minimum source DC current		0.1			mA
IOL at VOL	Output minimum sink current		-0.1			mA
LPDDR DC Differential Voltage Specification						
VID (DC)	DC input differential voltage		$0.4 \times VDDI$			V

1. To meet JEDEC Electrical Compliance, use LPDDR Full Drive Transmitter.

Table 74 • LPDDR Maximum AC Switching Speeds (for DDRIO I/O Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Dmax	Maximum data rate	AC loading: per JEDEC specifications			360	Mbps

Table 75 • LPDDR AC Specifications (for DDRIO IO Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LPDDR AC Differential Voltage Specification						
V _{DIFF} (AC)	AC Input differential voltage		0.6 × V _{DDI}	–		V
V _x (AC)	AC Differential Cross Point Voltage		0.4 × V _{DDI}	–	0.6 × V _{DDI}	V
LPDDR Impedance Specifications						
R _{ref}	Supported Output Driver Calibrated Impedance	Reference Resistor = 150 Ω		20,42		Ω
R _{TT}	Effective impedance Value - ODT	Reference Resistor = 150 Ω		50, 75, 150		Ω
LPDDR AC Test Parameters Specifications						
V _{trip}	Measuring/Trip Point for Data Path			0.9		V
R _{ent}	Resistance for Enable Path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
C _{ent}	Capacitive Loading for Enable Path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF
R _{tt_test}	Reference resistance for Data Test Path for LPDDR (t _{DP})			50		Ω
C _{load}	Capacitive Loading for Data Path (t _{DP})			5		pF

2.7.7.6.2 AC Switching Characteristics

Table 76 • LPDDR AC Switching Characteristics for Receiver (Input Buffers)

 Worst-Case Military Conditions: T_J=125 °C, V_{DD}=1.14 V, V_{DDI}= 1.71 V

				Speed Grade –1	
		ODT (On Die Termination)	t _{py}	Units	
LPDDR (for DDRIO I/O Bank with Fixed Codes)					
Pseudo-Differential		None	1.633	ns	
True-Differential		None	1.65	ns	

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 77 • LPDDR AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

 Worst-Case Military Conditions: T_J=125 °C, V_{DD}=1.14 V, V_{DDI}= 1.71 V

							Speed Grade –1				
		t _{DP}	t _{ZL}	t _{ZH}	t _{HZ}	t _{LZ}	Units				
LPDDR Reduced Drive (for DDRIO I/O Bank)											
Single Ended		2.645	2.431	2.434	2.396	2.398	ns				
Differential		2.652	3.044	3.038	2.46	2.455	ns				
LPDDR Full Drive (for DDRIO I/O Bank)											
Single Ended		2.532	2.401	2.398	2.368	2.365	ns				
Differential		2.546	2.509	2.503	2.852	2.845	ns				

2.7.7.6.3 Minimum and Maximum AC/DC Input and Output Levels Specification Using LPDDR-LVCMOS 1.8 V Mode

Table 78 • LPDDR-LVCMOS 1.8 V Mode, Minimum and Maximum DC Input and Output Levels (Applicable to DDRIO I/O Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LPDDR-LVCMOS 1.8 V Recommended DC Operating Conditions						
VDDI	Supply Voltage		1.710	1.8	1.89	V
LPDDR-LVCMOS 1.8 V Mode DC Input Voltage Specification						
VIH(DC)	DC input Logic HIGH for (MSIOD and DDRIO I/O Banks)		0.65 x VDDI		1.89	V
VIH(DC)	DC input Logic HIGH (for MSIO I/O Bank)		0.65 x VDDI		3.45	V
VIL(DC)	DC input Logic LOW		-0.3		0.35 x VDDI	V
IIH(DC)	Input current HIGH				See Table 19, page 19	
IIL(DC)	Input current LOW				See Table 19, page 19	
LPDDR-LVCMOS 1.8 V Mode DC Output Voltage Specification						
VOH	DC output Logic HIGH		VDDI - 0.45			V
VOL	DC output Logic LOW				0.45	V

Table 79 • LPDDR-LVCMOS 1.8 V Maximum AC Switching Speeds (Applicable to DDRIO I/O Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Dmax	Maximum Data Rate (for DDRIO I/O Bank)	AC Loading: 17 pF Load, 8 mA Drive and Above/All Slew			360	Mbps

Table 80 • LPDDR-LVCMOS 1.8 V AC Test Parameters and Driver Impedance Specifications (Applicable to DDRIO I/O Bank Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LPDDR - LVCMOS 1.8 V Calibrated Impedance Option						
Rodt_cal	Supported Output Driver Calibrated Impedance (for DDRIO I/O Bank)			75, 60, 50, 33, 25, 20		Ω
LPDDR- LVCMOS 1.8 V AC Test Parameters Specifications						
Vtrip	Measuring/Trip Point for Data Path			0.9		V
Rent	Resistance for Enable Path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive Loading for Enable Path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF
Cload	Capacitive Loading for Data Path (t_{DP})			5		pF

Table 81 • LPDDR-LVCMOS 1.8 V Mode Transmitter Drive Strength Specification (Applicable to DDRIO I/O Bank Only)

Output Drive Selection	VOH (V) Min	VOL (V) Max	IOH (at VOH) mA	IOL (at VOL) mA	Notes
2 mA	VDDI – 0.45	0.45	2	2	–
4 mA	VDDI – 0.45	0.45	4	4	–
6 mA	VDDI – 0.45	0.45	6	6	–
8 mA	VDDI – 0.45	0.45	8	8	–
10 mA	VDDI – 0.45	0.45	10	10	–
12 mA	VDDI – 0.45	0.45	12	12	–
16 mA ¹	VDDI – 0.45	0.45	16	16	*

1. 16 mA Drive Strengths, All Slews, meet LPDDR JEDEC electrical compliance.

2.7.7.6.4 AC Switching Characteristics

Table 82 • LPDDR - LVCMOS 1.8 V AC Switching Characteristics for Receiver (Input Buffers)
 Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V, VDDI = 1.71 V

	ODT (On Die Termination)	Speed Grade –1		Units
		t _{PY}	t _{PYS}	
LPDDR-LVCMOS 1.8 mode (for DDRIO I/O Bank with Fixed Codes)	None	2.071	2.213	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 83 • LPDDR - LVCMOS 1.8 V AC Switching Characteristics for Transmitter DDRIO I/O Bank (Output and Tristate Buffers)
 Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V, VDDI = 1.71 V

Output Drive Selection	Slew Control	Speed Grade –1					Units
		t _{DP}	t _{ZL}	t _{ZH}	t _{HZ}	t _{LZ}	
2 mA	slow	4.681	4.017	4.69	5.388	4.852	ns
	medium	4.211	3.599	4.219	5.058	4.488	ns
	medium_fast	3.978	3.392	3.986	4.874	4.327	ns
	fast	3.953	3.373	3.961	4.858	4.316	ns
4 mA	slow	4.355	3.657	4.346	5.967	5.399	ns
	medium	3.886	3.246	3.879	5.628	5.01	ns
	medium_fast	3.656	3.05	3.647	5.461	4.845	ns
	fast	3.635	3.033	3.626	5.447	4.838	ns
6 mA	slow	4.105	3.422	4.092	6.221	5.599	ns
	medium	3.68	3.05	3.668	5.9	5.257	ns
	medium_fast	3.477	2.867	3.463	5.739	5.118	ns
	fast	3.451	2.849	3.437	5.72	5.104	ns

Table 83 • LPDDR - LVCMOS 1.8 V AC Switching Characteristics for Transmitter DDRIO I/O Bank (Output and Tristate Buffers) (continued)

 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$ (continued)

Output Drive Selection	Slew Control	Speed Grade –1					Units
		t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
8 mA	slow	4.015	3.32	3.998	6.458	5.808	ns
	medium	3.59	2.947	3.574	6.129	5.449	ns
	medium_fast	3.383	2.761	3.366	5.963	5.304	ns
	fast	3.357	2.746	3.34	5.954	5.289	ns
10 mA	slow	3.888	3.18	3.864	6.739	6.045	ns
	medium	3.485	2.822	3.467	6.422	5.7	ns
	medium_fast	3.281	2.642	3.26	6.277	5.553	ns
	fast	3.258	2.627	3.238	6.27	5.546	ns
12 mA	slow	3.795	3.096	3.773	6.773	6.067	ns
	medium	3.408	2.764	3.389	6.47	5.743	ns
	medium_fast	3.215	2.599	3.194	6.346	5.61	ns
	fast	3.196	2.584	3.175	6.335	5.604	ns
16 mA	slow	3.744	3.035	3.719	6.944	6.207	ns
	medium	3.358	2.712	3.339	6.657	5.868	ns
	medium_fast	3.175	2.546	3.153	6.547	5.751	ns
	fast	3.156	2.531	3.133	6.541	5.747	ns

2.7.8 Differential I/O Standards

Configuration of the I/O modules as a differential pair is handled by Microsemi SoC Products Group Libero[®] SoC software when the user instantiates a differential I/O macro in the design. Differential I/Os can also be used in conjunction with the embedded Input register (InReg), Output register (OutReg), Enable register (EnReg), and Double Data Rate registers (DDR).

2.7.8.1 LVDS

Low-Voltage Differential Signaling (ANSI/TIA/EIA-644) is a high-speed, differential I/O standard.

2.7.8.1.1 Minimum and Maximum Input and Output Levels

Table 84 • LVDS DC Voltage Specification

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVDS Recommended DC Operating Conditions						
VDDI	Supply voltage	2.5 V range	2.375	2.5	2.625	V
VDDI	Supply voltage	3.3 V range	3.15	3.3	3.45	V
LVDS DC Input Voltage Specification						
VI	DC Input voltage	2.5 V range	0		2.925	V
VI	DC input voltage	3.3 V range	0		3.45	V
I _{IH} (DC)	Input current High				See Table 19, page 19	
I _{IL} (DC)	Input current Low				See Table 19, page 19	
LVDS DC Output Voltage Specification						
VOH	DC output logic High		1.25	1.425	1.6	V
VOL	DC output logic Low		0.9	1.075	1.25	V
LVDS Differential Voltage Specification						
VOD	Differential output voltage swing		250	350	450	mV
VOCM	Output common mode voltage		1.125	1.25	1.375	V
VICM	Input common mode voltage		0.05	1.25	2.35	V
VID ¹	Input differential voltage		100	350	600	mV

1. when VID is < 300 mV, the input signal is delayed by up to an additional 450 ps for LVDS25 and 280 ps for LVDS33. This delay is not accounted in the timing model. Clock insertion delays, propagation delays, and I/O to FF delays are marginally affected. Adding a parallel termination resistor of 200 Ω +/- 5% across the receiver pins can mitigate this additional delay when VID is < 300 mV.

Table 85 • LVDS AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVDS Maximum AC Switching Speed						
D _{max}	Maximum data rate (for MSIO I/O Bank)	AC loading: 12 pF / 100 Ω differential load			480	Mbps
D _{max}	Maximum data rate (for MSIOD I/O Bank)	AC loading: 10 pF / 100 Ω differential load			480	Mbps
LVDS Impedance Specification						
R _t	Termination resistance			100		Ω
LVDS AC Test Parameters Specifications						
V _{trip}	Measuring/trip point for data path			Cross point		V
R _{ent}	Resistance for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			2k		Ω
C _{ent}	Capacitive loading for enable path (t _{ZH} , t _{ZL} , t _{HZ} , t _{LZ})			5		pF

2.7.8.1.2 LVDS25 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 86 • LVDS25 Receiver Characteristics

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	On-Die Termination (ODT)	Speed Grade –1	
		t_{pY}	Units
LVDS (for MSIO I/O Bank)	None	3.061	ns
	100	3.057	ns
LVDS (for MSIOD I/O Bank)	None	2.792	ns
	100	2.787	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 87 • LVDS25 Transmitter Characteristics

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
LVDS (for MSIO I/O Bank)	2.299	2.602	2.589	2.305	2.32	ns
LVDS (for MSIOD I/O Bank)						
No pre-emphasis	1.656	1.845	1.838	1.992	1.969	ns
Min pre-emphasis	1.583	1.868	1.866	2.018	1.998	ns
Med pre-emphasis	1.559	1.893	1.886	2.045	2.021	ns

2.7.8.1.3 LVDS33 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 88 • LVDS33 Receiver Characteristics

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 3.15\text{ V}$

	On Die Termination (ODT)	Speed Grade –1	
		t_{pY}	Units
LVDS33 (for MSIO I/O Bank)	None	2.763	ns
	100	2.76	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 89 • LVDS33 Transmitter Characteristics

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 3.15\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
LVDS33 (for MSIO I/O Bank)	2.069	2.112	2.106	2.078	2.09	ns

2.7.8.2 B-LVDS

Bus LVDS (B-LVDS) specifications extend the existing LVDS standard to high-performance multipoint bus applications. Multidrop and multipoint bus configurations may contain any combination of drivers, receivers, and transceivers.

2.7.8.2.1 Minimum and Maximum AC/DC Input and Output Levels Specification

Table 90 • B-LVDS DC Voltage Specification

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Bus-LVDS Recommended DC Operating Conditions						
VDDI	Supply voltage		2.375	2.5	2.625	V
Bus-LVDS DC Input Voltage Specification						
VI	DC input voltage		0		2.925	V
IIH (DC)	Input current High				See Table 19, page 19	
IIL (DC)	Input current Low				See Table 19, page 19	
Bus-LVDS DC Output Voltage Specification (for MSIO I/O Bank only)						
VOH	DC output logic High		1.25	1.425	1.6	V
VOL	DC output logic Low		0.9	1.075	1.25	V
Bus-LVDS Differential Voltage Specification						
VOD	Differential output voltage swing (for MSIO I/O Bank only)		65		460	mV
VOCM	Output common mode voltage (for MSIO I/O Bank only)		1.1		1.5	V
VICM	Input common mode voltage		0.05		2.4	V
VID	Input differential voltage		0.1		VDDI	V

Table 91 • B-LVDS AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Bus-LVDS Maximum AC Switching Speed						
Dmax	Maximum data rate (for MSIO I/O Bank)	AC loading: 2 pF / 100 Ω differential load			450	Mbps
Bus-LVDS Impedance Specifications						
Rt	Termination resistance			27		Ω
Bus-LVDS AC Test Parameters Specifications						
Vtrip	Measuring/trip point for data path			Cross point		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF

2.7.8.2.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 92 • B-LVDS AC Switching Characteristics for Receiver (Input Buffers)
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	On-Die Termination (ODT)	Speed Grade –1	
		t_{pY}	Units
Bus-LVDS (for MSIO I/O Bank)	None	3.011	ns
	100	3.006	ns
Bus-LVDS (for MSIOD I/O Bank)	None	2.722	ns
	100	2.725	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 93 • B-LVDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
Bus-LVDS (for MSIO I/O Bank)	2.78	2.632	2.617	2.448	2.436	ns

2.7.8.3 M-LVDS

M-LVDS specifications extend the existing LVDS standard to high-performance multipoint bus applications. Multidrop and multipoint bus configurations may contain any combination of drivers, receivers, and transceivers.

2.7.8.3.1 Minimum and Maximum Input and Output Levels

Table 94 • M-LVDS DC Voltage Specification

Symbols	Parameters	Conditions	Min	Typ	Max	Units
M-LVDS Recommended DC Operating Conditions						
V _{DDI}	Supply voltage ¹		2.375	2.5	2.625	V
M-LVDS DC Input Voltage Specification						
V _I	DC input voltage		0		2.925	V
I _{IH} (DC)	Input current High				See Table 19, page 19	
I _{IL} (DC)	Input current Low				See Table 19, page 19	
M-LVDS DC Output Voltage Specification (for MSIO I/O Bank Only)						
V _{OH}	DC output logic High		1.25	1.425	1.6	V
V _{OL}	DC output logic Low		0.9	1.075	1.25	V

Table 94 • M-LVDS DC Voltage Specification (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
M-LVDS Differential Voltage Specification						
VOD	Differential output voltage Swing (for MSIO I/O Bank only)		300		650	mV
VOCM	Output common mode voltage (for MSIO I/O Bank only)		0.3		2.1	V
VICM	Input common mode voltage		0.3		1.2	V
VID	Input differential voltage		50		2400	mV

1. Only M-LVDS TYPE I is supported.

Table 95 • M-LVDS AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
M-LVDS Maximum AC Switching Speeds						
Dmax	Maximum data rate (for MSIO I/O Bank)	AC loading: 2 pF / 100 Ω differential load			450	Mbps
M-LVDS Impedance Specification						
Rt	Termination resistance			50		Ω
M-LVDS AC Test Parameters Specifications						
VTrip	Measuring/trip point for data path			Cross point		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF

2.7.8.3.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 96 • M-LVDS AC Switching Characteristics for Receiver (Input Buffers)
 Worst-case Military conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	On-Die Termination (ODT)	Speed Grade -1	
		t_{PY}	Units
M-LVDS (for MSIO I/O Bank)	None	3.011	ns
	100	3.006	ns
M-LVDS (for MSIOD I/O Bank)	None	2.722	ns
	100	2.725	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 97 • M-LVDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-case Military conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	Speed Grade -1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
M-LVDS (for MSIO I/O Bank)	2.78	2.632	2.616	2.447	2.436	ns

2.7.8.4 Mini-LVDS

Mini-LVDS is an unidirectional interface from the timing controller to the column drivers and is designed to the Texas Instruments Standard SLDA007A.

2.7.8.4.1 Mini-LVDS Minimum and Maximum Input and Output Levels

Table 98 • Mini-LVDS DC Voltage Specification

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		2.375	2.5	2.625	V
Mini-LVDS DC Input Voltage Specification						
VI	DC Input voltage		0		2.925	V
Mini-LVDS DC Output Voltage Specification						
VOH	DC output logic High		1.25	1.425	1.6	V
VOL	DC output logic Low		0.9	1.075	1.25	V
Mini-LVDS Differential Voltage Specification						
VOD	Differential output voltage swing		300		600	mV
VOCM	Output common mode voltage		1		1.4	V
VICM	Input common mode voltage		0.3		1.2	V
VID	Input differential voltage		100		600	mV

Table 99 • Mini-LVDS AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Mini-LVDS Maximum AC Switching Speed						
Dmax	Maximum data rate (MSIO I/O Bank)	AC loading: 2 pF / 100 Ω differential load			460	Mbps
Dmax	Maximum data rate (MSIOD I/O Bank)	AC loading: 10 pF / 100 Ω differential load			480	Mbps
Mini-LVDS Impedance Specification						
Rt	Termination resistance			100		Ω
Mini-LVDS AC Test Parameters Specifications						
VTrip	Measuring/trip point for data path			Cross point		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF

2.7.8.4.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 100 • Mini-LVDS AC Switching Characteristics for Receiver (Input Buffers)
 Worst-case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	On-Die Termination (ODT)	Speed Grade –1	
		t_{PY}	Units
Mini-LVDS (for MSIO I/O Bank)	None	3.112	ns
	100	2.995	ns
Mini-LVDS (for MSIOD I/O Bank)	None	2.612	ns
	100	2.612	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 101 • Mini-LVDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)
 Worst-case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
Mini-LVDS (for MSIO I/O Bank)	2.3	2.602	2.59	2.306	2.32	ns
Mini-LVDS (for MSIOD I/O Bank)						
No pre-emphasis	1.652	1.84	1.833	1.988	1.965	ns
Min pre-emphasis	1.652	1.84	1.833	1.988	1.965	ns
Med pre-emphasis	1.577	1.868	1.86	2.02	1.994	ns
Max pre-emphasis	1.555	1.894	1.883	2.048	2.019	ns

2.7.8.5 RSDS

Reduced Swing Differential Signaling (RSDS) is similar to an LVDS high-speed interface using differential signaling. RSDS has a similar implementation to LVDS devices and is only intended for point-to-point applications.

2.7.8.5.1 Minimum and Maximum Input and Output Levels

Table 102 • RSDS DC Voltage Specification

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		2.375	2.5	2.625	V
RSDS DC Input Voltage Specification						
V_I	DC input voltage		0		2.925	V
RSDS DC Output Voltage Specification						
VOH	DC output logic High		1.25	1.425	1.6	V
VOL	DC output logic Low		0.9	1.075	1.25	V
RSDS Differential Voltage Specification						
VOD	Differential output voltage swing		100		600	mV
VOCM	Output common mode voltage		0.5		1.5	V

Table 102 • RSDS DC Voltage Specification (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
VICM	Input common mode voltage		0.3		1.5	V
VID	Input differential voltage		100		600	mV

Table 103 • RSDS AC Specifications

Symbols	Parameters	Conditions	Min	Typ	Max	Units
RSDS Maximum AC Switching Speed						
Dmax	Maximum data rate (for MSIO I/O Bank)	AC loading: 2 pF / 100 Ω differential load			460	Mbps
Dmax	Maximum data rate (for MSIOD I/O Bank)	AC loading: 10 pF / 100 Ω differential load			480	Mbps
RSDS Impedance Specification						
Rt	Termination resistance			100		Ω
RSDS AC Test Parameters Specifications						
VTrip	Measuring/trip point for data path			Cross point		V
Rent	Resistance for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			2k		Ω
Cent	Capacitive loading for enable path (t_{ZH} , t_{ZL} , t_{HZ} , t_{LZ})			5		pF

2.7.8.5.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 104 • RSDS AC Switching Characteristics for Receiver (Input Buffers)Worst-case Military conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	On-Die Termination (ODT)	Speed Grade -1	
		t_{pY}	Units
RSDS (for MSIO I/O Bank)	None	3.112	ns
	100	3.108	ns
RSDS (for MSIOD I/O Bank)	None	2.832	ns
	100	2.821	ns

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 105 • RSDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)Worst-case Military conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

	Speed Grade -1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
RSDS (for MSIO I/O Bank)	2.256	2.484	2.472	2.111	2.096	ns
RSDS (for MSIOD I/O Bank)						
No pre-emphasis	1.661	1.648	1.645	1.675	1.665	ns
Min pre-emphasis	1.651	1.84	1.833	1.988	1.964	ns

Table 105 • RSDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)Worst-case Military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$ (continued)

	Speed Grade –1					Units
	t_{DP}	t_{ZL}	t_{ZH}	t_{HZ}	t_{LZ}	
Med pre-emphasis	1.577	1.868	1.859	2.019	1.993	ns
Max pre-emphasis	1.555	1.894	1.883	2.047	2.018	ns

2.7.8.6 LVPECL

Low-Voltage Positive Emitter-Coupled Logic (LVPECL) is another differential I/O standard. It requires that one data bit be carried through two signal lines. Similar to LVDS, two pins are needed. It also requires external resistor termination. IGLOO2 and SmartFusion2 SoC FPGAs support only LVPECL receivers and do not support LVPECL transmitters.

2.7.8.6.1 Minimum and Maximum Input and Output Levels

Table 106 • LVPECL DC Voltage Specification (Applicable to MSIO I/O Banks Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply voltage		3.15	3.3	3.45	V
LVPECL DC Input Voltage Specification						
VI	DC input voltage		0		3.45	V
LVPECL Differential Voltage Specification						
VICM	Input common mode voltage		0.3		2.8	V
VIDIFF	Input differential voltage		100	300	1,000	mV

Table 107 • LVPECL Maximum AC Switching Speeds (Applicable to MSIO I/O Banks Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
LVPECL AC Specifications						
Fmax	Maximum data rate (for MSIO I/O Bank)				810	Mbps

2.7.8.6.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 108 • LVPECL Receiver CharacteristicsWorst-case Military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 3.15\text{ V}$

	On-Die Termination (ODT)	t_{py}	Units
		Speed Grade –1	
LVPECL (for MSIO I/O Bank)	None	2.71	ns
	100	2.71	ns

2.7.9 I/O Register Specifications

2.7.9.1 Input Register

Figure 6 • Timing Model for Input Register

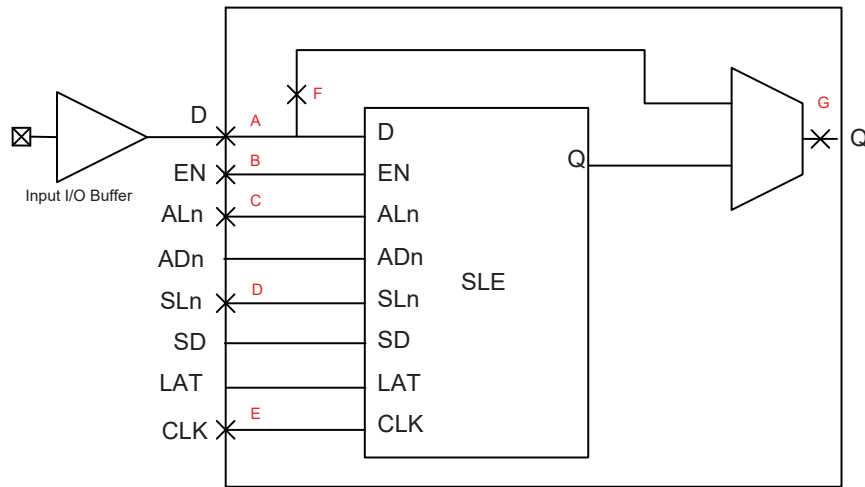


Figure 7 • I/O Register Input Timing Diagram

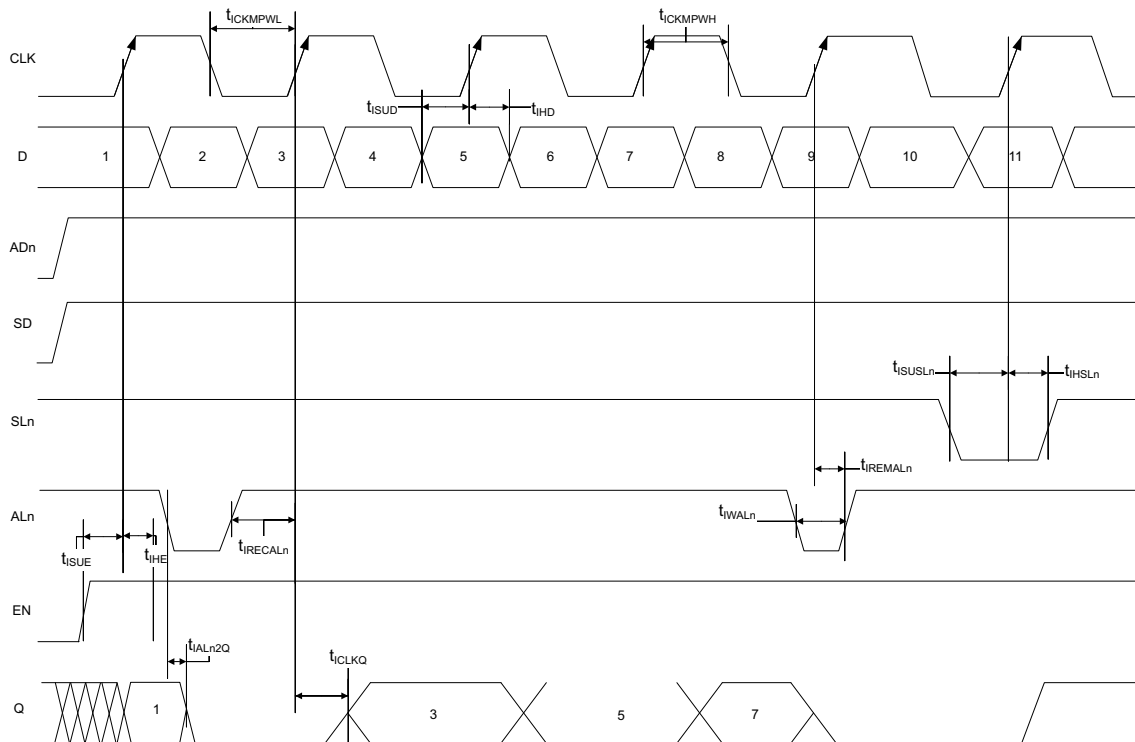


Table 109 • Input Data Register Propagation Delays
Worst-Case Military Conditions: T_J = 125 °C, VDD = 1.14 V

Parameter	Description	Measuring Nodes (from, to)*	Speed Grade –1	Units
t _{BYP}	Bypass Delay of the Input Register	F,G	See SmartTime ¹	ns
t _{CLKQ}	Clock-to-Q of the Input Register	E,G	0.13	ns
t _{ISUD}	Data Setup Time for the Input Register	A,E	See SmartTime ¹	ns
t _{IHD}	Data Hold Time for the Input Register	A,E	See SmartTime ¹	ns
t _{ISUE}	Enable Setup Time for the Input Register	B,E	0.821	ns
t _{IHE}	Enable Hold Time for the Input Register	B,E	0.016	ns
t _{ISUSL}	Synchronous Load Setup Time for the Input Register	D,E	1.726	ns
t _{IHSL}	Synchronous Load Hold Time for the Input Register	D,E	0.062	ns
t _{IAln2Q}	Asynchronous Clear-to-Q of the Input Register (ADn=1)	C,G	0.502	ns
	Asynchronous Preset-to-Q of the Input Register (ADn=0)	C,G	0.459	ns
t _{IREMALn}	Asynchronous Load Removal Time for the Input Register	C,E	0.127	ns
t _{IRECALn}	Asynchronous Load Recovery Time for the Input Register	C,E	0.213	ns
t _{IWALn}	Asynchronous Load Minimum Pulse Width for the Input Register	C,C	0.444	ns
t _{ICKMPWH}	Clock Minimum Pulse Width High for the Input Register	E,E	0.101	ns
t _{ICKMPWL}	Clock Minimum Pulse Width Low for the Input Register	E,E	0.223	ns

1. Delay depends on the die and I/O location. Use the SmartTime tool in Libero for accurate timing data.

2.7.9.2 Output/Enable Register

Figure 8 • Timing Model for Output/Enable Register

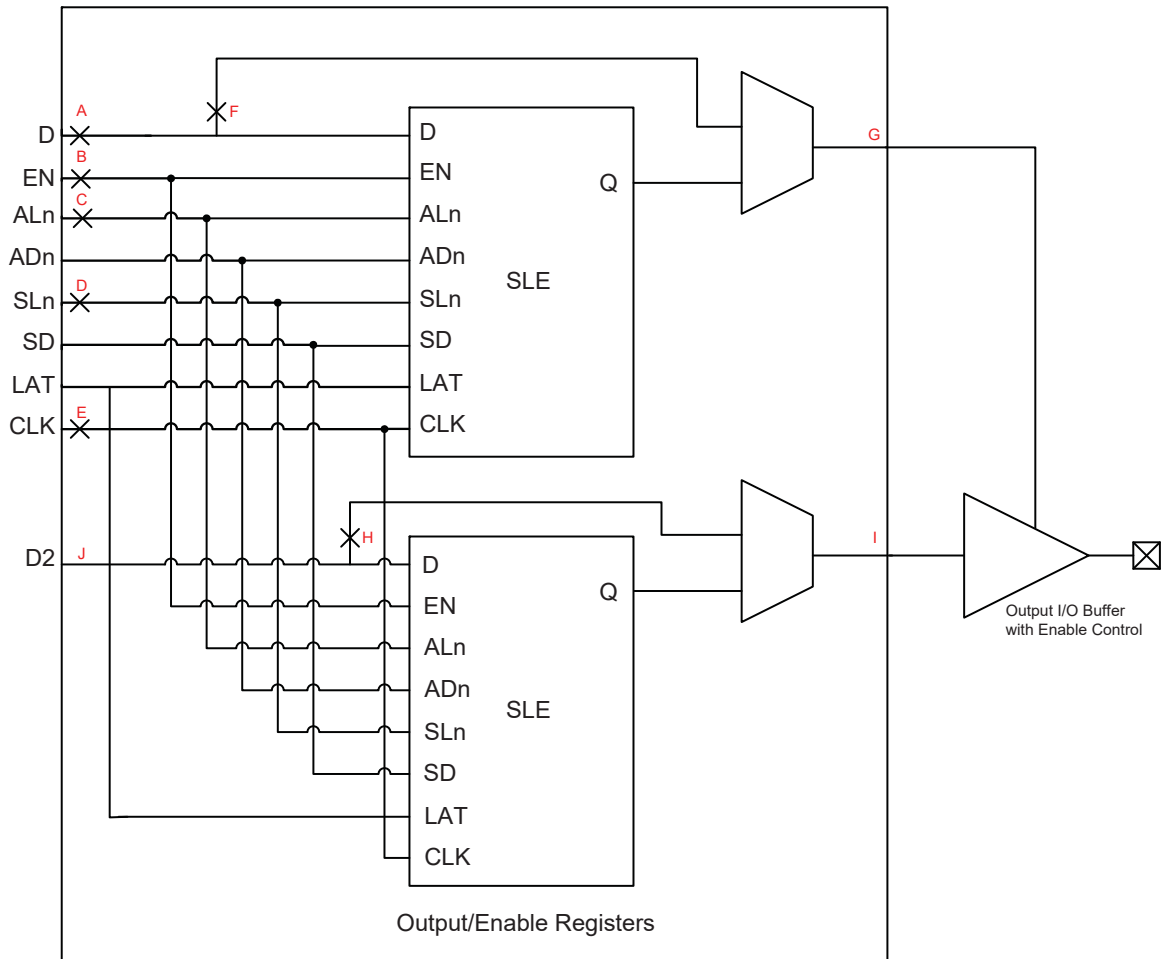
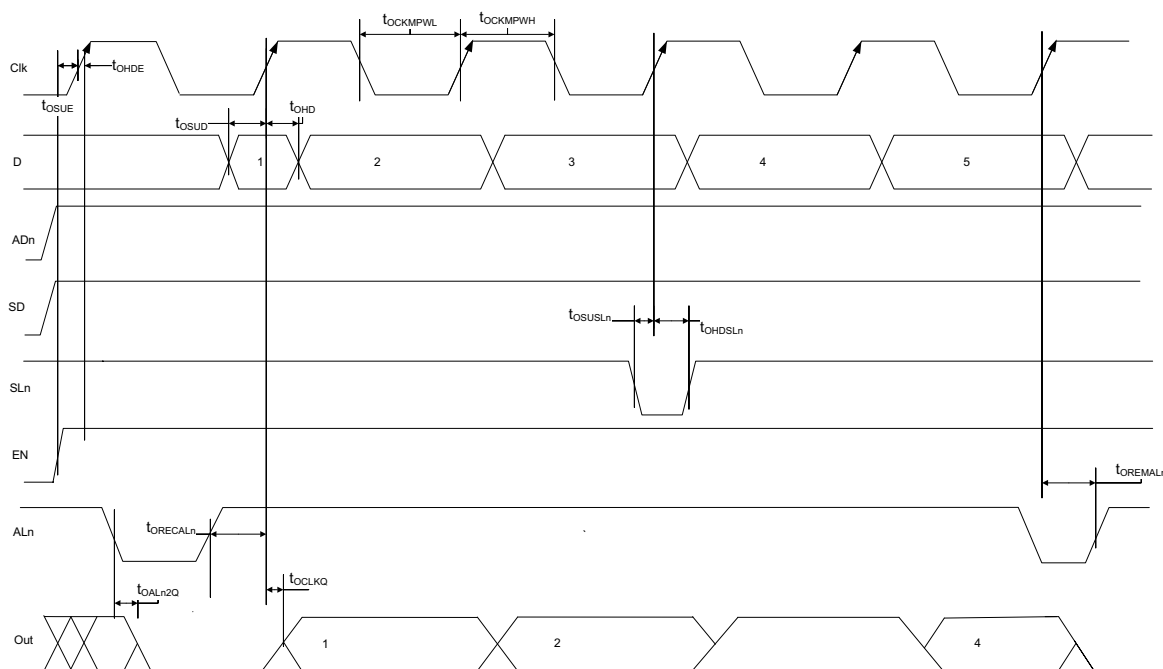


Figure 9 • I/O Register Output Timing Diagram

Table 110 • Output/Enable Data Register Propagation Delays
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Measuring Nodes (from, to)	Speed Grade -1	Units
tOBYP	Bypass Delay of the Output/Enable Register	F,G or H,I	0.342	ns
tOCLKQ	Clock-to-Q of the Output/Enable Register	E,G or E,I	0.254	ns
tOSUD	Data Setup Time for the Output/Enable Register	A,E or J,E	0.268	ns
tOHD	Data Hold Time for the Output/Enable Register	A,E or J,E	0.037	ns
tOSUE	Enable Setup Time for the Output/Enable Register	B,E	0.821	ns
tOHE	Enable Hold Time for the Output/Enable Register	B,E	0.029	ns
tOSUSL	Synchronous Load Setup Time for the Output/Enable Register	D,E	1.824	ns
tOHSL	Synchronous Load Hold Time for the Output/Enable Register	D,E	0.062	ns
tOALn2Q	Asynchronous Clear-to-Q of the Output/Enable Register ($ADn=1$)	C,G or C,I	0.558	ns
	Asynchronous Preset-to-Q of the Output/Enable Register ($ADn=0$)	C,G or C,I	0.526	ns
tOREMALn	Asynchronous Load Removal Time for the Output/Enable Register	C,E	0.134	ns
tORECALn	Asynchronous Load Recovery Time for the Output/Enable Register	C,E	0.236	ns
tOWALn	Asynchronous Load Minimum Pulse Width for the Output/Enable Register	C,C	0.444	ns

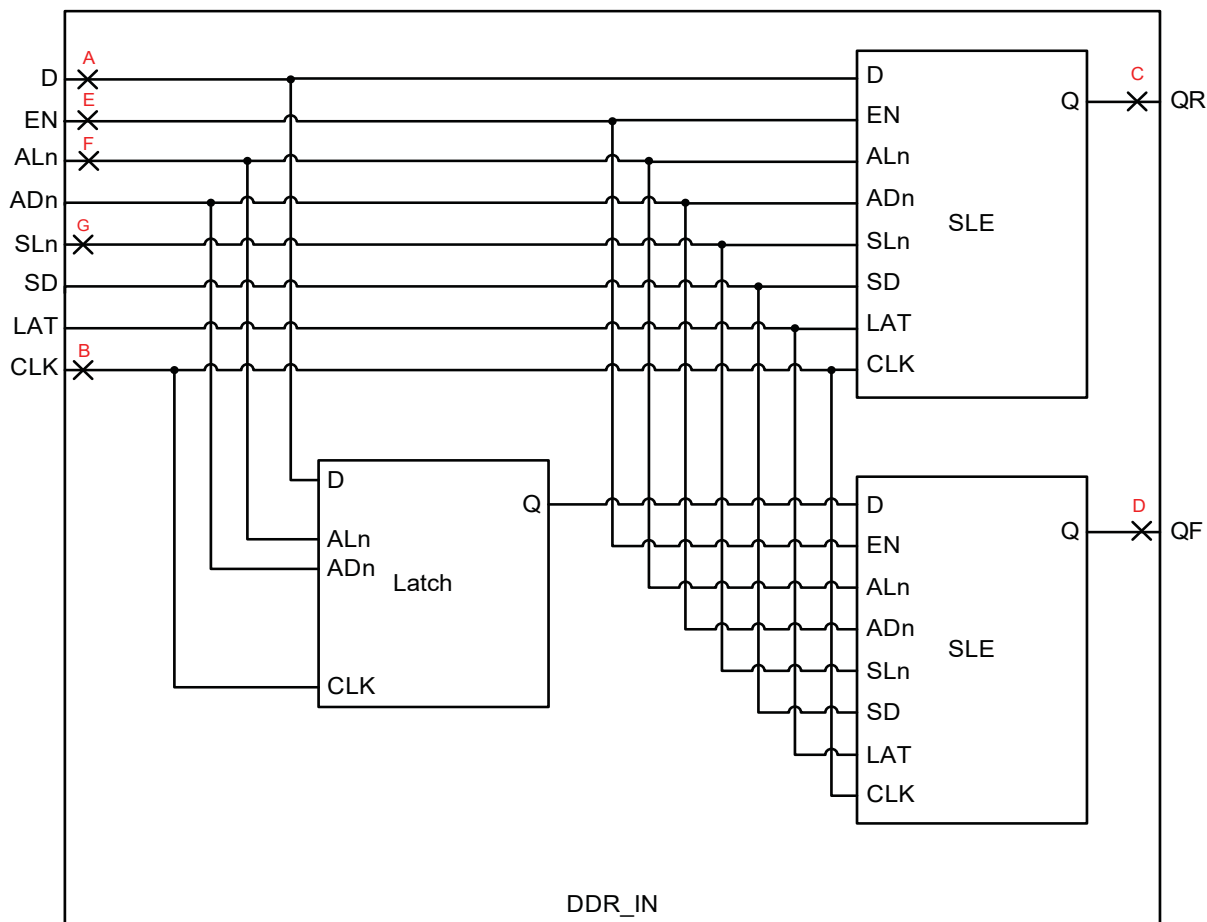
Table 110 • Output/Enable Data Register Propagation Delays
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Measuring Nodes (from, to)	Speed Grade -1	Units
tOCKMPWH	Clock Minimum Pulse Width High for the Output/Enable Register	E,E	0.101	ns
tOCKMPWL	Clock Minimum Pulse Width Low for the Output/Enable Register	E,E	0.223	ns

2.7.10 DDR Module Specification

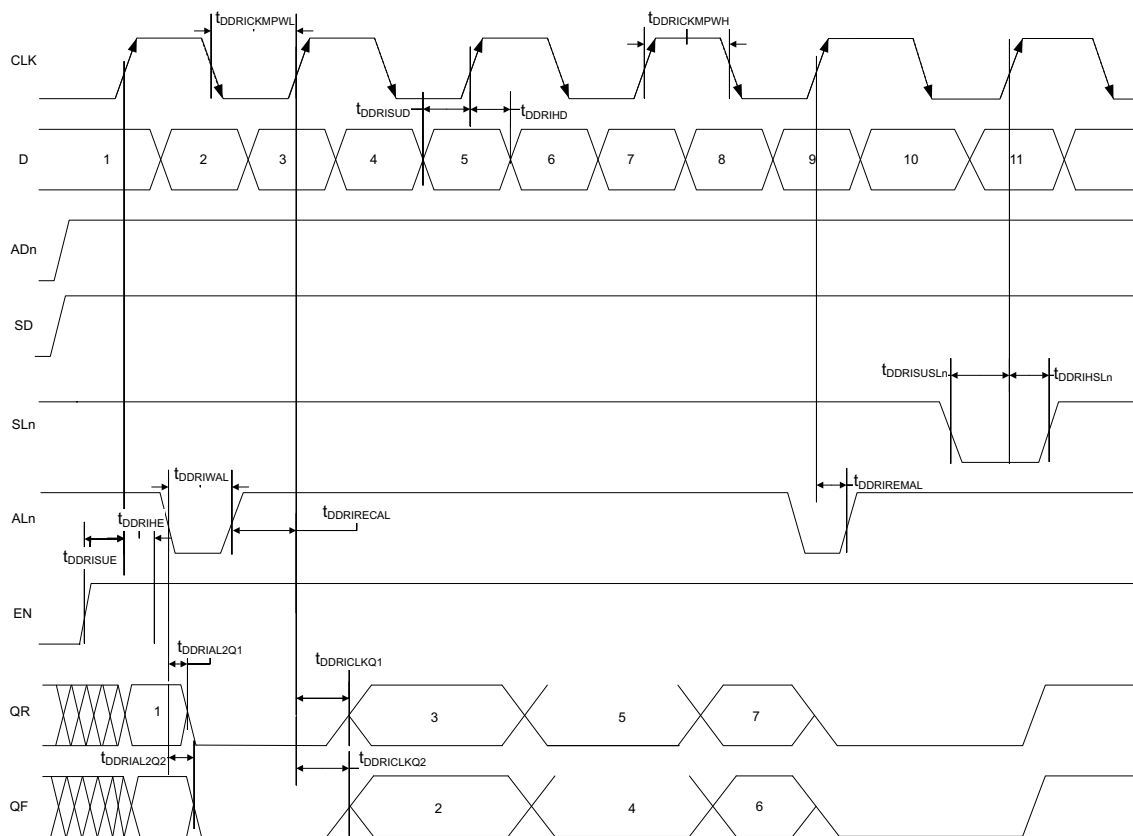
2.7.10.1 Input DDR Module

Figure 10 • Input DDR Module



2.7.10.2 Input DDR Timing Diagram

Figure 11 • Input DDR Timing Diagram



2.7.10.3 Timing Characteristics

Table 111 • Input DDR Propagation Delays
Worst-Case Military Conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Measuring Nodes (from, to)	Speed Grade -1	Units
$t_{DDRICKQ1}$	Clock-to-Out Out_QR for Input DDR	B,C	0.13	ns
$t_{DDRICKQ2}$	Clock-to-Out Out_QF for Input DDR	B,D	0.131	ns
$t_{DDRISUD}$	Data Setup for Input DDR	A,B	See SmartTime ¹	ns
t_{DDRHD}	Data Hold for Input DDR	A,B	See SmartTime ¹	ns
$t_{DDRISUE}$	Enable Setup for Input DDR	E,B	0.821	ns
$t_{DDRRIHE}$	Enable Hold for Input DDR	E,B	0.016	ns
$t_{DDRISUSLn}$	Synchronous Load Setup for Input DDR	G,B	1.726	ns
$t_{DDRISLIn}$	Synchronous Load Hold for Input DDR	G,B	0.062	ns
$t_{DDRIAL2Q1}$	Asynchronous Load-to-Out QR for Input DDR	F,C	0.459	ns
$t_{DDRIAL2Q2}$	Asynchronous Load-to-Out QF for Input DDR	F,D	0.416	ns
$t_{DDRIREMAL}$	Asynchronous Load Removal time for Input DDR	F,B	0.127	ns

Table 111 • Input DDR Propagation Delays
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Measuring Nodes (from, to)	Speed Grade -1	Units
tDDRIRECAL	Asynchronous Load Recovery time for Input DDR	F,B	0.213	ns
tDDRIVAL	Asynchronous Load Minimum Pulse Width for Input DDR	F,F	0.444	ns
tDDRICKMPWH	Clock Minimum Pulse Width High for Input DDR	B,B	0.101	ns
tDDRICKMPWL	Clock Minimum Pulse Width Low for Input DDR	B,B	0.223	ns

1. Delay depends on the die and I/O location. Use the SmartTime tool in Libero for accurate timing data.

2.7.10.4 Output DDR Module

Figure 12 • Output DDR Module

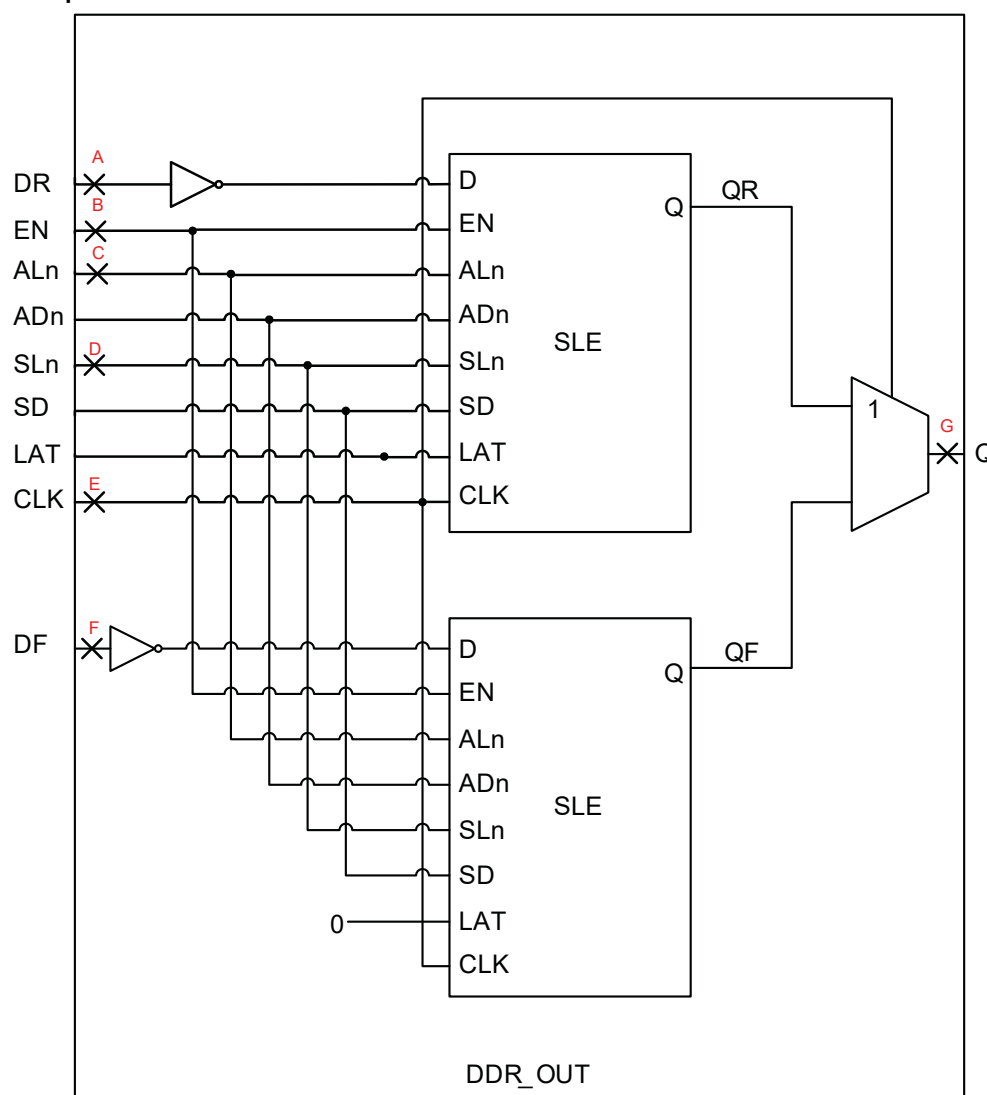


Table 112 • Output DDR Propagation Delays
Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

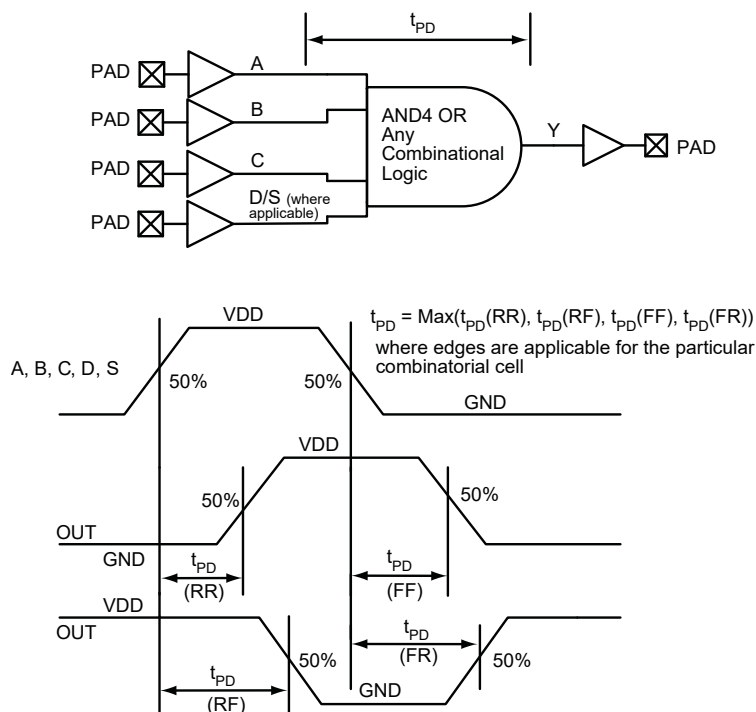
Parameter	Description	Measuring Nodes (from, to)	Speed Grade -1	Units
tDDROWAL	Asynchronous Load Minimum Pulse Width for Output DDR	C,C	0.377	ns
tDDROCKMPWH	Clock Minimum Pulse Width High for the Output DDR	E,E	0.101	ns
tDDROCKMPWL	Clock Minimum Pulse Width Low for the Output DDR	E,E	0.223	ns

2.8 Logic Element Specifications

2.8.1 4-input LUT (LUT-4)

The IGLOO2 and SmartFusion2 SoC FPGAs offer a fully permutable 4-input LUT. In this section, timing characteristics are presented for a sample of the library. For more details, refer to the [SmartFusion2 and IGLOO2 Macro Library Guide](#).

Figure 14 • LUT-4



2.8.1.1 Timing Characteristics

Table 113 • Combinatorial Cell Propagation Delays
Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Combinatorial Cell	Equation	Parameter	Speed Grade -1	Units
INV	$Y = !A$	t_{PD}	0.104	ns
AND2	$Y = A \cdot B$	t_{PD}	0.17	ns
NAND2	$Y = !(A \cdot B)$	t_{PD}	0.152	ns

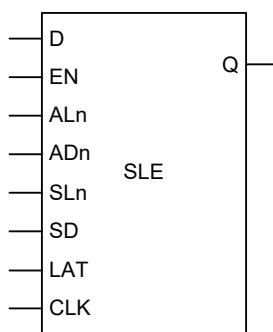
Table 113 • Combinatorial Cell Propagation Delays
Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

OR2	$Y = A + B$	t_{PD}	0.17	ns
NOR2	$Y = \!(A + B)$	t_{PD}	0.152	ns
XOR2	$Y = A \oplus B$	t_{PD}	0.17	ns
XOR3	$Y = A \oplus B \oplus C$	t_{PD}	0.233	ns
AND3	$Y = A \cdot B \cdot C$	t_{PD}	0.217	ns
AND4	$Y = A \cdot B \cdot C \cdot D$	t_{PD}	0.298	ns

2.8.2 Sequential Module

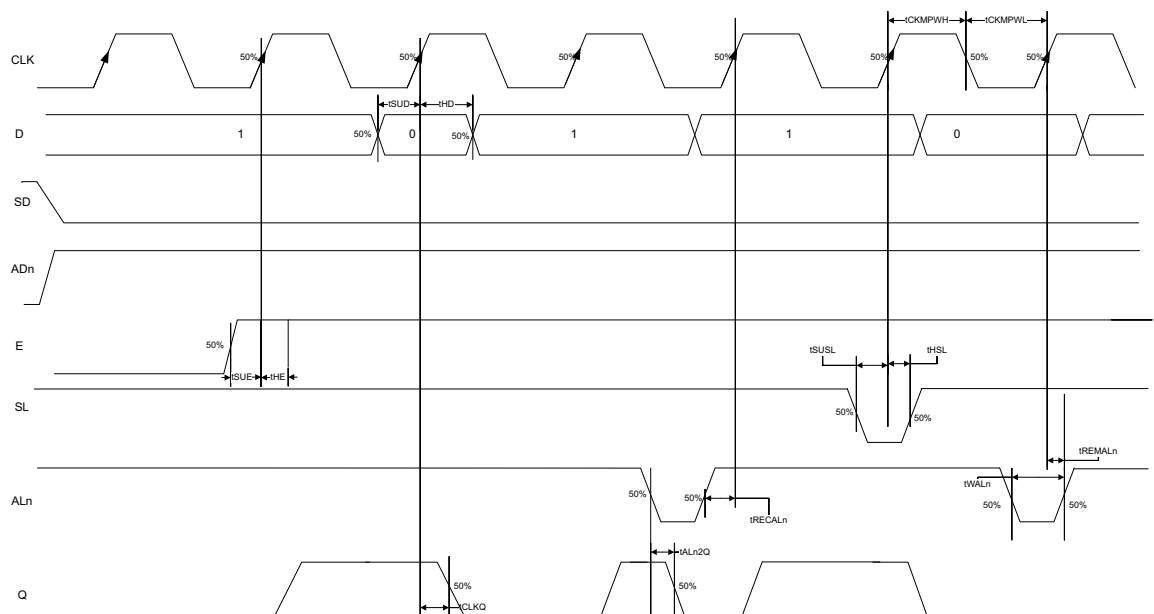
IGLOO2 and SmartFusion2 SoC FPGAs offer a separate flip-flop which can be used independently from the LUT. The flip-flop can be configured as a register or a latch and has a data input and optional enable, synchronous load (clear or preset), and asynchronous load (clear or preset).

Figure 15 • Sequential Module



The following figure shows a configuration with $SD = 0$ (synchronous clear) and $ADn = 1$ (asynchronous clear) for a flip-flop ($LAT = 0$).

Figure 16 • Sequential Module Timing Diagram



2.8.2.1 Timing Characteristics

Table 114 • Register Delays

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1	
		Min	Max
tCLKQ	Clock-to-Q of the Core Register	0.114	ns
tSUD	Data Setup Time for the Core Register	0.262	ns
tHD	Data Hold Time for the Core Register	0	ns
tSUE	Enable Setup Time for the Core Register	0.318	ns
tHE	Enable Hold Time for the Core Register	0	ns
tSUSL	Synchronous Load Setup Time for the Core Register	0.565	ns
tHSL	Synchronous Load Hold Time for the Core Register	0	ns
tALn2Q	Asynchronous Clear-to-Q of the Core Register (ADn=1)	0.495	ns
	Asynchronous Preset-to-Q of the Core Register (ADn=0)	0.47	ns
tREMAIn	Asynchronous Load Removal Time for the Core Register	0	ns
tRECAIn	Asynchronous Load Recovery Time for the Core Register	0.366	ns
tWALn	Asynchronous Load Minimum Pulse Width for the Core Register	0.266	ns
tCKMPWH	Clock Minimum Pulse Width High for the Core Register	0.065	ns
tCKMPWL	Clock Minimum Pulse Width Low for the Core Register	0.139	ns

2.9 Global Resource Characteristics

The IGLOO2 and SmartFusion2 SoC FPGA devices offer a powerful, low skew global routing network which provides an effective clock distribution throughout the FPGA fabric. Refer to the [UG0445: IGLOO2 FPGA and SmartFusion2 SoC FPGA Fabric User Guide](#) for the positions of various global routing resources.

Table 115 • M2S150T Device Global Resource

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tRCKL	Input Low Delay for Global Clock	0.788	0.868	ns
tRCKH	Input High Delay for Global Clock	1.46	1.594	ns
tRCKSW	Maximum Skew for Global Clock	–	0.134	ns

Table 116 • M2S090T Device Global Resource

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tRCKL	Input Low Delay for Global Clock	0.793	0.847	ns
tRCKH	Input High Delay for Global Clock	1.412	1.498	ns
tRCKSW	Maximum Skew for Global Clock	–	0.086	ns

Table 117 • M2S050T Device Global Resource
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tRCKL	Input Low Delay for Global Clock	0.793	0.861	ns
tRCKH	Input High Delay for Global Clock	1.436	1.55	ns
tRCKSW	Maximum Skew for Global Clock		0.114	ns

Table 118 • M2S025T Device Global Resource
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tRCKL	Input Low Delay for Global Clock	0.713	0.762	ns
tRCKH	Input High Delay for Global Clock	1.306	1.391	ns
tRCKSW	Maximum Skew for Global Clock		0.085	ns

Table 119 • M2S010T Device Global Resource
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tRCKL	Input Low Delay for Global Clock	0.598	0.639	ns
tRCKH	Input High Delay for Global Clock	1.116	1.192	ns
tRCKSW	Maximum Skew for Global Clock		0.076	ns

2.10 FPGA Fabric SRAM

Refer to the *UG0445: IGLOO2 FPGA and SmartFusion2 SoC FPGA Fabric User Guide* for more information.

2.10.1 FPGA Fabric Large SRAM (LSRAM)

Table 120 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 1Kx18
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
t _{cy}	Clock Period	3.333		ns
t _{clkmpwh}	Clock Minimum Pulse Width High	1.5		ns
t _{clkmpwl}	Clock Minimum pulse Width Low	1.5		ns
t _{plcy}	Pipelined Clock Period	3.333		ns
t _{plclkmpwh}	Pipelined Clock Minimum Pulse Width High	1.5		ns
t _{plclkmpwl}	Pipelined Clock Minimum pulse Width Low	1.5		ns
t _{clk2q}	Read Access Time with Pipeline Register		0.346	ns
	Read Access Time without Pipeline Register		2.346	ns
	Access Time with Feed-Through Write Timing		1.578	ns
t _{addr_{su}}	Address Setup Time	0.455		ns
t _{addr_{hd}}	Address Hold Time	0.282		ns
t _{dsu}	Data Setup Time	0.352		ns
t _{dhd}	Data Hold Time	0.11		ns
t _{blksu}	Block Select Setup Time	0.214		ns
t _{blkhd}	Block Select Hold Time	0.223		ns
t _{blk2q}	Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		1.578	ns
t _{blkmpw}	Block Select Minimum Pulse Width	0.218		ns
t _{rdsu}	Read Enable Setup Time	0.463		ns
t _{rdehd}	Read Enable Hold Time	0.173		ns
t _{rdplesu}	Pipelined Read Enable Setup Time (A_DOUT_EN, B_DOUT_EN)	0.256		ns
t _{rdplehd}	Pipelined Read Enable Hold Time (A_DOUT_EN, B_DOUT_EN)	0.106		ns
t _{r2q}	Asynchronous Reset to Output Propagation Delay		1.561	ns
t _{rstrem}	Asynchronous Reset Removal Time	0.522		ns
t _{rstrec}	Asynchronous Reset Recovery Time	0.005		ns
t _{rstmpw}	Asynchronous Reset Minimum Pulse Width	0.352		ns
t _{plrstrem}	Pipelined Register Asynchronous Reset Removal Time	-0.288		ns
t _{plrstrec}	Pipelined Register Asynchronous Reset Recovery Time	0.338		ns
t _{plrstmpw}	Pipelined Register Asynchronous Reset Minimum Pulse Width	0.33		ns
t _{srtsu}	Synchronous Reset Setup Time	0.233		ns
t _{srsth}	Synchronous Reset Hold Time	0.037		ns
t _{wesu}	Write Enable Setup Time	0.402		ns

Table 120 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 1Kx18
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
twehd	Write Enable Hold Time	0.25		ns
Fmax	Maximum Frequency		300	MHz

Table 121 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 2Kx9
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
t _{cy}	Clock Period	3.333		ns
t _{clkmpwh}	Clock Minimum Pulse Width High	1.5		ns
t _{clkmpwl}	Clock Minimum pulse Width Low	1.5		ns
t _{plcy}	Pipelined Clock Period	3.333		ns
t _{plclkmpwh}	Pipelined Clock Minimum Pulse Width High	1.5		ns
t _{plclkmpwl}	Pipelined Clock Minimum pulse Width Low	1.5		ns
t _{clk2q}	Read Access Time with Pipeline Register		0.346	ns
	Read Access Time without Pipeline Register		2.346	ns
	Access Time with Feed-Through Write Timing		1.578	ns
t _{addr_{su}}	Address Setup Time	0.49		ns
t _{addr_{hd}}	Address Hold Time	0.282		ns
t _{dsu}	Data Setup Time	0.346		ns
t _{dhd}	Data Hold Time	0.084		ns
t _{blksu}	Block Select Setup Time	0.214		ns
t _{blkhd}	Block Select Hold Time	0.223		ns
t _{blk2q}	Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		1.578	ns
t _{blkmpw}	Block Select Minimum Pulse Width	0.218		ns
t _{rdesu}	Read Enable Setup Time	0.5		ns
t _{rdehd}	Read Enable Hold Time	0.073		ns
t _{rdplesu}	Pipelined Read Enable Setup Time (A_DOUT_EN, B_DOUT_EN)	0.256		ns
t _{rdplehd}	Pipelined Read Enable Hold Time (A_DOUT_EN, B_DOUT_EN)	0.106		ns
t _{r2q}	Asynchronous Reset to Output Propagation Delay		1.569	ns
t _{rstrem}	Asynchronous Reset Removal Time	0.522		ns
t _{rstrec}	Asynchronous Reset Recovery Time	0.005		ns
t _{rstmpw}	Asynchronous Reset Minimum Pulse Width	0.352		ns
t _{plrstrem}	Pipelined Register Asynchronous Reset Removal Time	-0.288		ns
t _{plrstrec}	Pipelined Register Asynchronous Reset Recovery Time	0.338		ns
t _{plrstmpw}	Pipelined Register Asynchronous Reset Minimum Pulse Width	0.33		ns

Table 121 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 2Kx9
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tsrstsu	Synchronous Reset Setup Time	0.233		ns
tsrsthd	Synchronous Reset Hold Time	0.037		ns
twesu	Write Enable Setup Time	0.428		ns
twehd	Write Enable Hold Time	0.05		ns
Fmax	Maximum Frequency		300	MHz

Table 122 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 4Kx4
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tcy	Clock Period	3.333		ns
tclkmpwh	Clock Minimum Pulse Width High	1.5		ns
tclkmpwl	Clock Minimum pulse Width Low	1.5		ns
tplcy	Pipelined Clock Period	3.333		ns
tplclkmpwh	Pipelined Clock Minimum Pulse Width High	1.5		ns
tplclkmpwl	Pipelined Clock Minimum pulse Width Low	1.5		ns
tclk2q	Read Access Time with Pipeline Register		0.334	ns
	Read Access Time without Pipeline Register		2.346	ns
	Access Time with Feed-Through Write Timing		1.56	ns
taddrsu	Address Setup Time	0.56		ns
taddrhd	Address Hold Time	0.282		ns
tdsu	Data Setup Time	0.345		ns
tdhd	Data Hold Time	0.084		ns
tblk2q	Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		1.56	ns
tblkmpw	Block Select Minimum Pulse Width	0.218		ns
trdesu	Read Enable Setup Time	0.532		ns
trdehd	Read Enable Hold Time	0.073		ns
trdplestu	Pipelined Read Enable Setup Time (A_DOUT_EN, B_DOUT_EN)	0.256		ns
trdplehd	Pipelined Read Enable Hold Time (A_DOUT_EN, B_DOUT_EN)	0.106		ns
tr2q	Asynchronous Reset to Output Propagation Delay		1.562	ns
trstrem	Asynchronous Reset Removal Time	0.522		ns
trstrec	Asynchronous Reset Recovery Time	0.005		ns
trstmpw	Asynchronous Reset Minimum Pulse Width	0.352		ns

Table 122 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 4Kx4
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tplrstrem	Pipelined Register Asynchronous Reset Removal Time	–0.288		ns
tplrstrec	Pipelined Register Asynchronous Reset Recovery Time	0.338		ns
tplrstmpw	Pipelined Register Asynchronous Reset Minimum Pulse Width	0.33		ns
tsrstsu	Synchronous Reset Setup Time	0.233		ns
tsrsthd	Synchronous Reset Hold Time	0.037		ns
twesu	Write Enable Setup Time	0.473		ns
twehd	Write Enable Hold Time	0.05		ns
Fmax	Maximum Frequency		300	MHz

Table 123 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 8Kx2
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tcy	Clock Period	3.333		ns
tclkmpwh	Clock Minimum Pulse Width High	1.5		ns
tclkmpwl	Clock Minimum pulse Width Low	1.5		ns
tplcy	Pipelined Clock Period	3.333		ns
tplclkmpwh	Pipelined Clock Minimum Pulse Width High	1.5		ns
tplclkmpwl	Pipelined Clock Minimum pulse Width Low	1.5		ns
tclk2q	Read Access Time with Pipeline Register		0.332	ns
	Read Access Time without Pipeline Register		2.346	ns
	Access Time with Feed-Through Write Timing		1.56	ns
taddrsu	Address Setup Time	0.631		ns
taddrhd	Address Hold Time	0.282		ns
tdsu	Data Setup Time	0.34		ns
tdhd	Data Hold Time	0.084		ns
tblksu	Block Select Setup Time	0.214		ns
tblkhd	Block Select Hold Time	0.223		ns
tblk2q	Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		1.56	ns
tblkmpw	Block Select Minimum Pulse Width	0.218		ns
trdesu	Read Enable Setup Time	0.546		ns
trdehd	Read Enable Hold Time	0.073		ns
trdpleSU	Pipelined Read Enable Setup Time (A_DOUT_EN, B_DOUT_EN)	0.256		ns
trdplehd	Pipelined Read Enable Hold Time (A_DOUT_EN, B_DOUT_EN)	0.106		ns
tr2q	Asynchronous Reset to Output Propagation Delay		1.583	ns

Table 123 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 8Kx2
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		
		Min	Max	Units
trstrem	Asynchronous Reset Removal Time	0.522		ns
trstrec	Asynchronous Reset Recovery Time	0.005		ns
trstmpw	Asynchronous Reset Minimum Pulse Width	0.352		ns
tplrstrem	Pipelined Register Asynchronous Reset Removal Time	–0.288		ns
tplrstrec	Pipelined Register Asynchronous Reset Recovery Time	0.338		ns
tplrstmpw	Pipelined Register Asynchronous Reset Minimum Pulse Width	0.33		ns
tsrstsu	Synchronous Reset Setup Time	0.233		ns
tsrsthd	Synchronous Reset Hold Time	0.037		ns
twesu	Write Enable Setup Time	0.504		ns
twehd	Write Enable Hold Time	0.05		ns
Fmax	Maximum Frequency		300	MHz

Table 124 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 16Kx1
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tcy	Clock Period	3.333		ns
tclkmpwh	Clock Minimum Pulse Width High	1.5		ns
tclkmpwl	Clock Minimum pulse Width Low	1.5		ns
tpcy	Pipelined Clock Period	3.333		ns
tpclckmpwh	Pipelined Clock Minimum Pulse Width High	1.5		ns
tpclckmpwl	Pipelined Clock Minimum pulse Width Low	1.5		ns
tclk2q	Read Access Time with Pipeline Register		0.332	ns
	Read Access Time without Pipeline Register		2.342	ns
	Access Time with Feed-Through Write Timing		1.559	ns
taddrsu	Address Setup Time	0.646		ns
taddrhd	Address Hold Time	0.282		ns
tdsu	Data Setup Time	0.332		ns
tdhd	Data Hold Time	0.084		ns
tblkstu	Block Select Setup Time	0.214		ns
tblkhd	Block Select Hold Time	0.223		ns
tblk2q	Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		1.559	ns
tblkmpw	Block Select Minimum Pulse Width	0.218		ns
trdesu	Read Enable Setup Time	0.547		ns
trdehd	Read Enable Hold Time	0.073		ns
trdplestu	Pipelined Read Enable Setup Time (A_DOUT_EN, B_DOUT_EN)	0.256		ns

Table 124 • RAM1K18—Dual-Port Mode for Depth × Width Configuration 16Kx1
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
trdplehd	Pipelined Read Enable Hold Time (A_DOUT_EN, B_DOUT_EN)	0.106		ns
tr2q	Asynchronous Reset to Output Propagation Delay		1.603	ns
trstrem	Asynchronous Reset Removal Time	0.522		ns
trstrec	Asynchronous Reset Recovery Time	0.005		ns
trstmpw	Asynchronous Reset Minimum Pulse Width	0.352		ns
tplrstrem	Pipelined Register Asynchronous Reset Removal Time	–0.288		ns
tplrstrec	Pipelined Register Asynchronous Reset Recovery Time	0.338		ns
tplrstmpw	Pipelined Register Asynchronous Reset Minimum Pulse Width	0.33		ns
tsrstsu	Synchronous Reset Setup Time	0.233		ns
tsrsthd	Synchronous Reset Hold Time	0.037		ns
twesu	Write Enable Setup Time	0.468		ns
twehd	Write Enable Hold Time	0.05		ns
Fmax	Maximum Frequency		300	MHz

Table 125 • RAM1K18—Two-Port Mode for Depth × Width Configuration 512x36
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tcy	Clock Period	3.333		ns
tclkmpwh	Clock Minimum Pulse Width High	1.5		ns
tclkmpwl	Clock Minimum pulse Width Low	1.5		ns
tplcy	Pipelined Clock Period	3.333		ns
tplclkmpwh	Pipelined Clock Minimum Pulse Width High	1.5		ns
tplclkmpwl	Pipelined Clock Minimum pulse Width Low	1.5		ns
tclk2q	Read Access Time with Pipeline Register		0.346	ns
	Read Access Time without Pipeline Register		2.322	ns
taddrsu	Address Setup Time	0.323		ns
taddrhd	Address Hold Time	0.282		ns
tdsu	Data Setup Time	0.348		ns
tdhd	Data Hold Time	0.114		ns
tblkstu	Block Select Setup Time	0.214		ns
tblkhd	Block Select Hold Time	0.208		ns
tblk2q	Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.322	ns
tblkmpw	Block Select Minimum Pulse Width	0.218		ns
trdesu	Read Enable Setup Time	0.463		ns
trdehd	Read Enable Hold Time	0.173		ns

Table 125 • RAM1K18—Two-Port Mode for Depth × Width Configuration 512x36
Worst-Case Military Conditions: T_j = 125 °C, VDD = 1.14 V (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
trdple _{su}	Pipelined Read Enable Setup Time (A_DOUT_EN, B_DOUT_EN)	0.256		ns
trdple _{hd}	Pipelined Read Enable Hold Time (A_DOUT_EN, B_DOUT_EN)	0.106		ns
tr2q	Asynchronous Reset to Output Propagation Delay		1.561	ns
trstrem	Asynchronous Reset Removal Time	0.522		ns
trstrec	Asynchronous Reset Recovery Time	0.005		ns
trstmpw	Asynchronous Reset Minimum Pulse Width	0.352		ns
tplrstrem	Pipelined Register Asynchronous Reset Removal Time	–0.288		ns
tplrstrec	Pipelined Register Asynchronous Reset Recovery Time	0.338		ns
tplrstmpw	Pipelined Register Asynchronous Reset Minimum Pulse Width	0.33		ns
tsrst _{su}	Synchronous Reset Setup Time	0.233		ns
tsrst _{hd}	Synchronous Reset Hold Time	0.037		ns
twesu	Write Enable Setup Time	0.402		ns
twehd	Write Enable Hold Time	0.25		ns
F _{max}	Maximum Frequency		300	MHz

2.10.2 FPGA Fabric Micro SRAM (μ SRAM)

Table 126 • μ SRAM (RAM64x18) in 64x18 Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
t _{cy}	Read Clock Period	4		ns
t _{clkmpwh}	Read Clock Minimum Pulse Width High	1.8		ns
t _{clkmpwl}	Read Clock Minimum pulse Width Low	1.8		ns
t _{plcy}	Read Pipe-line clock period	4		ns
t _{plclkmpwh}	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
t _{plclkmpwl}	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
t _{clk2q}	Read Access Time with Pipeline Register		0.276	ns
	Read Access Time without Pipeline Register		1.738	ns
t _{addr_{su}}	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	1.916		ns
t _{addr_{hd}}	Read Address Hold Time in Synchronous Mode	0.094		ns
	Read Address Hold Time in Asynchronous Mode	–0.803		ns
t _{rdensu}	Read Enable Setup Time	0.287		ns
t _{rdenhd}	Read Enable Hold Time	0.059		ns
t _{blk_{su}}	Read Block Select Setup Time	1.898		ns
t _{blk_{hd}}	Read Block Select Hold Time	–0.671		ns
t _{blk2q}	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.102	ns
t _{rstrem}	Read Asynchronous Reset Removal Time (Pipelined Clock)	–0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns
t _{rstrec}	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
t _{r2q}	Read Asynchronous Reset to Output Propagation Delay (with Pipe-Line Register Enabled)		0.869	ns
t _{rst_{su}}	Read Synchronous Reset Setup Time	0.279		ns
t _{rst_{hd}}	Read Synchronous Reset Hold Time	0.062		ns
t _{ccy}	Write Clock Period	4		ns
t _{cclkmpwh}	Write Clock Minimum Pulse Width High	1.8		ns
t _{cclkmpwl}	Write Clock Minimum Pulse Width Low	1.8		ns
t _{blk_{csu}}	Write Block Setup Time	0.417		ns
t _{blk_{chd}}	Write Block Hold Time	0.007		ns
t _{din_{csu}}	Write Input Data setup Time	0.119		ns
t _{din_{chd}}	Write Input Data hold Time	0.155		ns
t _{addr_{csu}}	Write Address Setup Time	0.091		ns

Table 126 • μ SRAM (RAM64x18) in 64x18 Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		
		Min	Max	Units
taddrchd	Write Address Hold Time	0.132		ns
twecsu	Write Enable Setup Time	0.41		ns
twechd	Write Enable Hold Time	–0.027		ns
fmax	Maximum Frequency		250	MHz

Table 127 • μ SRAM (RAM64x16) in 64x16 Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tcy	Read Clock Period	4		ns
tclkmpwh	Read Clock Minimum Pulse Width High	1.8		ns
tclkmpwl	Read Clock Minimum pulse Width Low	1.8		ns
tplcy	Read Pipe-line clock period	4		ns
tplckmpwh	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
tplckmpwl	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
tclk2q	Read Access Time with Pipeline Register		0.276	ns
	Read Access Time without Pipeline Register		1.738	ns
taddrsu	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	1.916		ns
taddrhd	Read Address Hold Time in Synchronous Mode	0.094		ns
	Read Address Hold Time in Asynchronous Mode	–0.803		ns
trdensu	Read Enable Setup Time	0.287		ns
trdenhd	Read Enable Hold Time	0.059		ns
tblksu	Read Block Select Setup Time	1.898		ns
tblkhd	Read Block Select Hold Time	–0.671		ns
tblk2q	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.102	ns
trstrem	Read Asynchronous Reset Removal Time (Pipelined Clock)	–0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns
trstrec	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
tr2q	Read Asynchronous Reset to Output Propagation Delay (With Pipe-Line Register Enabled)		0.866	ns
tsrstsu	Read Synchronous Reset Setup Time	0.279		ns
tsrsthd	Read Synchronous Reset Hold Time	0.062		ns

Table 127 • μ SRAM (RAM64x16) in 64x16 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tccy	Write Clock Period	4		ns
tclkmpwh	Write Clock Minimum Pulse Width High	1.8		ns
tclkmpwl	Write Clock Minimum Pulse Width Low	1.8		ns
tblksu	Write Block Setup Time	0.417		ns
tblkchd	Write Block Hold Time	0.007		ns
tdincsu	Write Input Data setup Time	0.119		ns
tdinchd	Write Input Data hold Time	0.155		ns
taddrcsu	Write Address Setup Time	0.091		ns
taddrchd	Write Address Hold Time	0.132		ns
twecsu	Write Enable Setup Time	0.41		ns
twechd	Write Enable Hold Time	–0.027		ns
fmax	Maximum Frequency		250	MHz

Table 128 • μ SRAM (RAM128x9) in 128x9 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		
		Min	Max	Units
tcy	Read Clock Period	4		ns
tclkmpwh	Read Clock Minimum Pulse Width High	1.8		ns
tclkmpwl	Read Clock Minimum pulse Width Low	1.8		ns
tpcy	Read Pipe-line clock period	4		ns
tplclkmpwh	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
tplclkmpwl	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
tclk2q	Read Access Time with Pipeline Register		0.276	ns
	Read Access Time without Pipeline Register		1.776	ns
taddrsu	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	1.959		ns
taddrhd	Read Address Hold Time in Synchronous Mode	0.125		ns
	Read Address Hold Time in Asynchronous Mode	–0.704		ns
trdensu	Read Enable Setup Time	0.287		ns
trdenhd	Read Enable Hold Time	0.059		ns
tblksu	Read Block Select Setup Time	1.898		ns
tblkhd	Read Block Select Hold Time	–0.671		ns
tblk2q	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.14	ns

Table 128 • μ SRAM (RAM128x9) in 128x9 Mode
 Worst-Case Military Conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
trstrem	Read Asynchronous Reset Removal Time (Pipelined Clock)	–0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns
trstrec	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
tr2q	Read Asynchronous Reset to Output Propagation Delay (with Pipe-Line Register Enabled)		0.865	ns
tsrstu	Read Synchronous Reset Setup Time	0.279		ns
tsrsth	Read Synchronous Reset Hold Time	0.062		ns
tccy	Write Clock Period	4		ns
tcclkmpwh	Write Clock Minimum Pulse Width High	1.8		ns
tcclkmpwl	Write Clock Minimum Pulse Width Low	1.8		ns
tblkcsu	Write Block Setup Time	0.417		ns
tblkch	Write Block Hold Time	0.007		ns
tdincsu	Write Input Data setup Time	0.104		ns
tdinch	Write Input Data hold Time	0.142		ns
taddrcsu	Write Address Setup Time	0.091		ns
taddrch	Write Address Hold Time	0.24		ns
twecsu	Write Enable Setup Time	0.41		ns
twech	Write Enable Hold Time	–0.027		ns
fmax	Maximum Frequency		250	MHz

Table 129 • μ SRAM (RAM128x8) in 128x8 Mode
 Worst-Case Military Conditions: $T_J = 125^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tcy	Read Clock Period	4		ns
tcclkmpwh	Read Clock Minimum Pulse Width High	1.8		ns
tcclkmpwl	Read Clock Minimum pulse Width Low	1.8		ns
tpcy	Read Pipe-line clock period	4		ns
tpclclkmpwh	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
tpclclkmpwl	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
tclk2q	Read Access Time with Pipeline Register		0.276	ns
	Read Access Time without Pipeline Register		1.776	ns
taddrsu	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	1.959		ns

Table 129 • μ SRAM (RAM128x8) in 128x8 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
taddrhd	Read Address Hold Time in Synchronous Mode	0.125		ns
	Read Address Hold Time in Asynchronous Mode	–0.704		ns
trdensu	Read Enable Setup Time	0.287		ns
trdenhd	Read Enable Hold Time	0.059		ns
tblksu	Read Block Select Setup Time	1.898		ns
tblkhd	Read Block Select Hold Time	–0.671		ns
tblk2q	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.14	ns
trstrem	Read Asynchronous Reset Removal Time (Pipelined Clock)	–0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns
trstrec	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
tr2q	Read Asynchronous Reset to Output Propagation Delay (With Pipe-Line Register Enabled)		0.865	ns
tsrstsu	Read Synchronous Reset Setup Time	0.279		ns
tsrsthd	Read Synchronous Reset Hold Time	0.062		ns
tccy	Write Clock Period	4		ns
tcclkmpwh	Write Clock Minimum Pulse Width High	1.8		ns
tcclkmpwl	Write Clock Minimum Pulse Width Low	1.8		ns
tblksu	Write Block Setup Time	0.417		ns
tblkhd	Write Block Hold Time	0.007		ns
tdincsu	Write Input Data setup Time	0.104		ns
tdinchd	Write Input Data hold Time	0.142		ns
taddrcsu	Write Address Setup Time	0.091		ns
taddrchd	Write Address Hold Time	0.24		ns
twecsu	Write Enable Setup Time	0.41		ns
twechd	Write Enable Hold Time	–0.027		ns
fmax	Maximum Frequency		250	MHz

Table 130 • μ SRAM (RAM256x4) in 256x4 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
t _{cy}	Read Clock Period	4		ns
t _{clkmpwh}	Read Clock Minimum Pulse Width High	1.8		ns
t _{clkmpwl}	Read Clock Minimum pulse Width Low	1.8		ns
t _{p_lcy}	Read Pipe-line clock period	4		ns
t _{plclkmpwh}	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
t _{plclkmpwl}	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
t _{clk2q}	Read Access Time with Pipeline Register		0.276	ns
	Read Access Time without Pipeline Register		1.812	ns
t _{addr_s}	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	1.993		ns
t _{addr_h}	Read Address Hold Time in Synchronous Mode	0.125		ns
	Read Address Hold Time in Asynchronous Mode	–0.669		ns
t _{rdensu}	Read Enable Setup Time	0.287		ns
t _{rdenhd}	Read Enable Hold Time	0.059		ns
t _{blk_s}	Read Block Select Setup Time	1.898		ns
t _{blk_h}	Read Block Select Hold Time	–0.671		ns
t _{blk2q}	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.166	ns
t _{rstrem}	Read Asynchronous Reset Removal Time (Pipelined Clock)	–0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns
t _{rstrec}	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
t _{r2q}	Read Asynchronous Reset to Output Propagation Delay (With Pipe-Line Register Enabled)		0.863	ns
t _{srsts_s}	Read Synchronous Reset Setup Time	0.279		ns
t _{srsth_d}	Read Synchronous Reset Hold Time	0.062		ns
t _{ccy}	Write Clock Period	4		ns
t _{cclkmpwh}	Write Clock Minimum Pulse Width High	1.8		ns
t _{cclkmpwl}	Write Clock Minimum Pulse Width Low	1.8		ns
t _{blk_s}	Write Block Setup Time	0.417		ns
t _{blk_h}	Write Block Hold Time	0.007		ns
t _{din_s}	Write Input Data setup Time	0.104		ns
t _{din_h}	Write Input Data hold Time	0.142		ns
t _{addr_s}	Write Address Setup Time	0.091		ns
t _{addr_h}	Write Address Hold Time	0.253		ns
t _{wec_s}	Write Enable Setup Time	0.41		ns

Table 130 • μ SRAM (RAM256x4) in 256x4 Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
twechd	Write Enable Hold Time	-0.027		ns
fmax	Maximum Frequency		250	MHz

Table 131 • μ SRAM (RAM512x2) in 512x2 Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tcy	Read Clock Period	4		ns
tclkmpwh	Read Clock Minimum Pulse Width High	1.8		ns
tclkmpwl	Read Clock Minimum pulse Width Low	1.8		ns
tpcy	Read Pipe-line clock period	4		ns
tpclkmpwh	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
tpclkmpwl	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
tclk2q	Read Access Time with Pipeline Register		0.276	ns
	Read Access Time without Pipeline Register		1.824	ns
taddrsu	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	2.023		ns
taddrhd	Read Address Hold Time in Synchronous Mode	0.141		ns
	Read Address Hold Time in Asynchronous Mode	-0.599		ns
trdensu	Read Enable Setup Time	0.287		ns
trdenhd	Read Enable Hold Time	0.059		ns
tblksu	Read Block Select Setup Time	1.898		ns
tblkhd	Read Block Select Hold Time	-0.671		ns
tblk2q	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.219	ns
trstrem	Read Asynchronous Reset Removal Time (Pipelined Clock)	-0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns
trstrec	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
tr2q	Read Asynchronous Reset to Output Propagation Delay (With Pipe-Line Register Enabled)		0.862	ns
tsrstsu	Read Synchronous Reset Setup Time	0.279		ns
tsrsthd	Read Synchronous Reset Hold Time	0.062		ns
tccy	Write Clock Period	4		ns
tcclkmpwh	Write Clock Minimum Pulse Width High	1.8		ns

Table 131 • μ SRAM (RAM512x2) in 512x2 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tclkmpwl	Write Clock Minimum Pulse Width Low	1.8		ns
tblkcsu	Write Block Setup Time	0.417		ns
tblkchd	Write Block Hold Time	0.007		ns
tdincsu	Write Input Data setup Time	0.104		ns
tdinchd	Write Input Data hold Time	0.142		ns
taddrcsu	Write Address Setup Time	0.091		ns
taddrchd	Write Address Hold Time	0.255		ns
twecsu	Write Enable Setup Time	0.41		ns
twechd	Write Enable Hold Time	–0.027		ns
fmax	Maximum Frequency		250	MHz

Table 132 • μ SRAM (RAM1024x1) in 1024x1 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1		Units
		Min	Max	
tcy	Read Clock Period	4		ns
tclkmpwh	Read Clock Minimum Pulse Width High	1.8		ns
tclkmpwl	Read Clock Minimum pulse Width Low	1.8		ns
tplcy	Read Pipe-line clock period	4		ns
tplclkmpwh	Read Pipe-line clock Minimum Pulse Width High	1.8		ns
tplclkmpwl	Read Pipe-line clock Minimum Pulse Width Low	1.8		ns
tclk2q	Read Access Time with Pipeline Register		0.274	ns
	Read Access Time without Pipeline Register		1.839	ns
taddrsu	Read Address Setup Time in Synchronous Mode	0.311		ns
	Read Address Setup Time in Asynchronous Mode	2.041		ns
taddrhd	Read Address Hold Time in Synchronous Mode	0.141		ns
	Read Address Hold Time in Asynchronous Mode	–0.623		ns
trdensu	Read Enable Setup Time	0.287		ns
trdenhd	Read Enable Hold Time	0.059		ns
tblkcu	Read Block Select Setup Time	1.898		ns
tblkhd	Read Block Select Hold Time	–0.671		ns
tblk2q	Read Block Select to Out Disable Time (when Pipe-Lined Registered is Disabled)		2.236	ns
trstrem	Read Asynchronous Reset Removal Time (Pipelined Clock)	–0.15		ns
	Read Asynchronous Reset Removal Time (Non-Pipelined Clock)	0.047		ns

Table 132 • μ SRAM (RAM1024x1) in 1024x1 Mode
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Parameter	Description	Speed Grade -1		Units
		Min	Max	
trstrec	Read Asynchronous Reset Recovery Time (Pipelined Clock)	0.524		ns
	Read Asynchronous Reset Recovery Time (Non-Pipelined Clock)	0.244		ns
tr2q	Read Asynchronous Reset to Output Propagation Delay (With Pipe-Line Register Enabled)		0.862	ns
tsrstsu	Read Synchronous Reset Setup Time	0.279		ns
tsrsthd	Read Synchronous Reset Hold Time	0.062		ns
tccy	Write Clock Period	4		ns
tcclmpwh	Write Clock Minimum Pulse Width High	1.8		ns
tcclmpwl	Write Clock Minimum Pulse Width Low	1.8		ns
tblkcsu	Write Block Setup Time	0.417		ns
tblkchd	Write Block Hold Time	0.007		ns
tdincsu	Write Input Data setup Time	0.003		ns
tdinchd	Write Input Data hold Time	0.142		ns
taddrcsu	Write Address Setup Time	0.091		ns
taddrchd	Write Address Hold Time	0.255		ns
twecsu	Write Enable Setup Time	0.41		ns
twechd	Write Enable Hold Time	-0.027		ns
fmax	Maximum Frequency		250	MHz

2.11 Programming Time

External SPI flash part # AT25DF641-s3H was used during these measurements. Typical Conditions: T_J = 25 °C, VDD = 1.2 V.

Table 133 • Programming Time of JTAG, 2 Step IAP, and MSS/Cortex-M3 ISP—Typical Conditions

	Device	Image size Bytes	JTAG		2 Step IAP			MSS/Cortex-M3 ISP (SmartFusion2 Only)			Units
			Program	Verify	Authenti cate	Program	Verify	Authenti cate	Program	Verify	
Fabric Only	M2S010/M2GL010	568,784	28	18	7	23	12	10	26	14	sec
	M2S025/M2GL025	1,223,504	51	26	14	33	23	21	39	29	sec
	M2S050/M2GL050	2,424,832	66	54	29	52	40	39	60	50	sec
	M2S060/M2GL060	2,418,896	77	54	39	61	50	44	65	54	sec
	M2S090/M2GL090	3,645,968	113	126	60	84	73	66	90	79	sec
	M2S150/M2GL150	6,139,184	155	193	100	132	120	108	140	128	sec
eNVM Only	M2S010/M2GL010	274,816	78	9	4	76	11	4	82	7	sec
	M2S025/M2GL025	274,816	78	9	4	78	10	4	82	8	sec
	M2S050/M2GL050	278,528	84	8	3	85	9	4	80	8	sec
	M2S060/M2GL060	268,480	76	8	5	76	22	6	80	8	sec
	M2S090/M2GL090	544,496	154	15	10	152	43	10	157	15	sec
	M2S150/M2GL150	544,496	155	15	10	153	44	10	158	15	sec
Fabric + eNVM	M2S010/M2GL010	842,688	107	20	11	100	21	15	107	21	sec
	M2S025/M2GL025	1,497,408	120	35	19	113	32	26	121	35	sec
	M2S050/M2GL050	2,695,168	162	59	32	136	48	43	141	55	sec
	M2S060/M2GL060	2,686,464	158	70	43	137	70	48	143	60	sec
	M2S090/M2GL090	4,190,208	266	147	68	236	115	75	244	91	sec
	M2S150/M2GL150	6,682,768	316	231	109	286	162	117	296	141	sec

Table 134 • Programming Time of Auto Programming, Auto Update, and Programming Recovery—Typical Conditions

	Device	Image Size (Bytes)	Auto Programming	Auto Update	Programming Recovery	Units
			SPI CLK = 100 kHz	SPI CLK = 25 MHz	SPI CLK = 12.5 MHz	
			Program	Program	Program	
Fabric Only	M2S010/M2GL010	568,784	77	35	35	sec
	M2S025/M2GL025	1,223,504	150	42	41	sec
	M2S050/M2GL050	2,424,832	33 ¹	Not supported	Not supported	sec
	M2S060/M2GL060	2,418,896	291	83	82	sec
	M2S090/M2GL090	3,645,968	427	109	108	sec
	M2S150/M2GL150	6,139,184	708	157	160	sec
eNVM Only	M2S010/M2GL010	274,816	86	87	87	sec
	M2S025/M2GL025	274,816	87	85	86	sec
	M2S050/M2GL050	278,528	85	Not supported	Not supported	sec
	M2S060/M2GL060	268,480	78	86	86	sec
	M2S090/M2GL090	544,496	154	162	162	sec
	M2S150/M2GL150	544,496	161	161	161	sec
Fabric + eNVM	M2S010/M2GL010	842,688	161	113	113	sec
	M2S025/M2GL025	1,497,408	229	120	121	sec
	M2S050/M2GL050	2,695,168	112	Not supported	Not supported	sec
	M2S060/M2GL060	2,686,464	368	161	158	sec
	M2S090/M2GL090	4,190,208	582	261	260	sec
	M2S150/M2GL150	6,682,768	867	309	310	sec

1. Auto programming in the 050 device is done using SC_SPI, and SPI CLK is set to 6.25 MHz.

Worst-case conditions: $T_J = 100\text{ }^{\circ}\text{C}$, $V_{DD} = 1.14\text{ V}$.**Table 135 • Programming Time of JTAG, 2 Step IAP, and MSS/Cortex-M3 ISP—Worst-Case Conditions**

	Device	Image size Bytes	JTAG		2 Step IAP			MSS/Cortex-M3 ISP (SmartFusion2 Only)			Units
			Program	Verify	Authenti cate	Program	Verify	Authenti cate	Program	Verify	
Fabric Only	M2S010/M2GL010	568,784	50	18	7	45	12	10	48	14	sec
	M2S025/M2GL025	1,223,504	73	26	14	55	23	21	61	29	sec
	M2S050/M2GL050	2,424,832	88	54	29	74	40	39	82	50	sec
	M2S060/M2GL060	2,418,896	99	54	39	83	50	44	87	54	sec
	M2S090/M2GL090	3,645,968	135	126	60	106	73	66	112	79	sec
	M2S150/M2GL150	6,139,184	177	193	100	154	120	108	162	128	sec
eNVM Only	M2S010/M2GL010	274,816	100	9	4	98	11	4	104	7	sec
	M2S025/M2GL025	274,816	100	9	4	100	10	4	104	8	sec
	M2S050/M2GL050	278,528	106	8	3	107	9	4	102	8	sec
	M2S060/M2GL060	268,480	98	8	5	98	22	6	102	8	sec
	M2S090/M2GL090	544,496	176	15	10	174	43	10	179	15	sec
	M2S150/M2GL150	544,496	177	15	10	175	44	10	180	15	sec
Fabric + eNVM	M2S010/M2GL010	842,688	129	20	11	122	21	15	129	21	sec
	M2S025/M2GL025	1,497,408	142	35	19	135	32	26	143	35	sec
	M2S050/M2GL050	2,695,168	184	59	32	158	48	43	163	55	sec
	M2S060/M2GL060	2,686,464	180	70	43	159	70	48	165	60	sec
	M2S090/M2GL090	4,190,208	288	147	68	258	115	75	266	91	sec
	M2S150/M2GL150	6,682,768	338	231	109	308	162	117	318	141	sec

Table 136 • Programming Time of Auto Programming, Auto Update, and Programming Recovery—Worst-Case Conditions

	Device	Image Size (Bytes)	Auto Programming	Auto Update	Programming Recovery	Units
			SPI CLK = 100 kHz	SPI CLK = 25 MHz	SPI CLK = 12.5 MHz	
			Program	Program	Program	
Fabric Only	M2S010/M2GL010	568,784	99	57	57	sec
	M2S025/M2GL025	1,223,504	150	64	63	sec
	M2S050/M2GL050	2,424,832	55 ¹	Not supported	Not supported	sec
	M2S060/M2GL060	2,418,896	313	105	104	sec
	M2S090/M2GL090	3,645,968	449	131	130	sec
	M2S150/M2GL150	6,139,184	730	179	183	sec
eNVM Only	M2S010/M2GL010	274,816	108	109	109	sec
	M2S025/M2GL025	274,816	109	107	108	sec
	M2S050/M2GL050	278,528	107	Not supported	Not supported	sec
	M2S060/M2GL060	268,480	100	108	108	sec
	M2S090/M2GL090	544,496	176	184	184	sec
	M2S150/M2GL150	544,496	183	183	183	sec
Fabric + eNVM	M2S010/M2GL010	842,688	183	135	135	sec
	M2S025/M2GL025	1,497,408	251	142	143	sec
	M2S050/M2GL050	2,695,168	134	Not supported	Not supported	sec
	M2S060/M2GL060	2,686,464	390	183	180	sec
	M2S090/M2GL090	4,190,208	604	283	282	sec
	M2S150/M2GL150	6,682,768	889	331	332	sec

1. Auto programming in the 050 device is done using SC_SPI, and SPI CLK is set to 6.25 MHz.

2.12 Embedded NVM (eNVM) Characteristics

Table 137 • eNVM Read Performance

Worst-Case Conditions: VDD = 1.14 V, VPPNVM = VPP = 2.375 V

Symbol	Description	Operating Temperature Range							Units
T _j	Junction Temperature Range	–55 °C to 125 °C	–40 °C to 100 °C	0 °C to 85 °C					°C
Speed grade		–1	Std	–1	Std	–1	Std		
F _{MAXREAD}	eNVM Maximum Read Frequency	25	25	25	25	25	25	25	MHz

Table 138 • eNVM Page Programming**Worst-Case Conditions: VDD = 1.14 V, VPPNVM = VPP = 2.375 V**

Symbol	Description	Operating Temperature Range						Units
		–55 °C to 125 °C	–40 °C to 100 °C	0 °C to 85 °C				
T _j	Junction Temperature Range	–55 °C to 125 °C	–40 °C to 100 °C	0 °C to 85 °C				°C
Speed grade		–1	Std	–1	Std	–1	Std	
t _{PAGEPGM}	eNVM Page Programming Time	40	40	40	40	40	40	ms

2.13 Crystal Oscillator

Table 139, page 92 describes the electrical characteristics of the crystal oscillator in the IGLOO2 FPGA and SmartFusion2 SoC FPGAs.

Table 139 • Electrical Characteristics of the Crystal Oscillator—High Gain Mode (20 MHz)**Worst-Case Military Conditions: T_j = 125 °C, VDD = 1.14 V**

Parameter	Description	Min	Typ	Max	Units
FXTAL	Operating frequency		20		MHz
ACCXTAL	Accuracy			0.006	%
CYCXTAL	Output duty cycle		49–51	47–53	%
JITPERXTAL	Output Period Jitter (peak to peak)		200	300	ps
JITCYCXTAL	Output Cycle to Cycle Jitter (peak to peak)		200	550	ps
IDYNXTAL	Operating current		1.5		mA
VIHXTAL	Input logic level High	0.9 × VPP			V
VILXTAL	Input logic level Low			0.1 × VPP	V
SUXTAL	Startup time (with regard to stable oscillator output)			1	ms

Table 140 • Electrical Characteristics of the Crystal Oscillator—Medium Gain Mode (2 MHz)**Worst-Case Military Conditions: T_j = 125 °C, VDD = 1.14 V**

Parameter	Description	Min	Typ	Max	Units
FXTAL	Operating frequency		2		MHz
ACCXTAL	Accuracy			0.003	%
CYCXTAL	Output duty cycle		49–51	47–53	%
JITPERXTAL	Output Period Jitter (peak to peak)		1	5	ns
JITCYCXTAL	Output Cycle to Cycle Jitter (peak to peak)		1	5	ns
IDYNXTAL	Operating current		0.3		mA
VIHXTAL	Input logic level High	0.9 × VPP			V
VILXTAL	Input logic level Low			0.1 × VPP	V
SUXTAL	Startup time (with regard to stable oscillator output)			4.5	ms

Table 141 • Electrical Characteristics of the Crystal Oscillator—Low Gain Mode (32 kHz)
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Min	Typ	Max	Units
FXTAL	Operating frequency		32		kHz
ACCXTAL	Accuracy			0.006	%
CYCXTAL	Output duty cycle		49–51	45.5–54.5	%
JITPERXTAL	Output Period Jitter (peak to peak)		150	300	ns
JITCYCXTAL	Output Cycle to Cycle Jitter (peak to peak)		150	300	ns
IDYNXTAL	Operating current		0.044		mA
VIHXTAL	Input logic level High	$0.9 \times V_{PP}$			V
VILXTAL	Input logic level Low			$0.1 \times V_{PP}$	V
SUXTAL	Startup time (with regard to stable oscillator output)			120	ms

2.14 On-Chip Oscillator

Table 142, page 93 and Table 143, page 93 describe the electrical characteristics of the available on-chip oscillators in the IGLOO2 FPGAs and SmartFusion2 SoC FPGAs.

Table 142 • Electrical Characteristics of the 50 MHz RC Oscillator
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Condition	Min	Typ	Max	Units
F50RC	Operating frequency			50		MHz
ACC50RC	Accuracy			1	8	%
CYC50RC	Output duty cycle			49–51	46–54	%
JIT50RC	Output jitter (peak to peak)	Period Jitter		200	500	ps
		Cycle-to-Cycle Jitter		320	900	ps
IDYN50RC	Operating current			8.5		mA

Table 143 • Electrical Characteristics of the 1 MHz RC Oscillator
 Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Condition	Min	Typ	Max	Units
F1RC	Operating frequency			1		MHz
ACC1RC	Accuracy			1	6	%
CYC1RC	Output duty cycle			49–51	46.5–53.5	%
JIT1RC	Output jitter (peak to peak)	Period Jitter		10	36	ps
		Cycle-to-Cycle Jitter		10	50	ps
IDYN1RC	Operating current			0.1		mA
SU1RC	Startup time				20	μs

2.15 Clock Conditioning Circuits (CCC)

Table 144 • IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Specification
 Military Worst-Case Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Conditions	Min	Typ	Max	Units
Clock conditioning circuitry input frequency f_{IN_CCC}	All CCC	1		200	MHz
	32 kHz Capable CCC	0.032		200	MHz
Clock conditioning circuitry output frequency $f_{OUT_CCC}^1$		0.078		400	MHz
PLL VCO frequency ²		500		1000	MHz
Delay increments in programmable delay blocks			75	100	ps
Number of programmable values in each programmable delay block				64	
Acquisition time	$f_{IN} \geq 1\text{ MHz}$		70	100	μs
	$f_{IN} = 32\text{ kHz}$		1	16	ms
Input Duty Cycle (Reference Clock)	Internal Feedback				
	$1\text{ MHz} \leq f_{IN_CCC} \leq 25\text{ MHz}$	10		90	%
	$25\text{ MHz} \leq f_{IN_CCC} \leq 100\text{ MHz}$	25		75	%
	$100\text{ MHz} \leq f_{IN_CCC} \leq 150\text{ MHz}$	35		65	%
	$150\text{ MHz} \leq f_{IN_CCC} \leq 200\text{ MHz}$	45		55	%
	External Feedback (CCC, FPGA, Off-chip)				
	$1\text{ MHz} \leq f_{IN_CCC} \leq 25\text{ MHz}$	25		75	%
	$25\text{ MHz} \leq f_{IN_CCC} \leq 35\text{ MHz}$	35		65	%
	$35\text{ MHz} \leq f_{IN_CCC} \leq 50\text{ MHz}$	45		55	%
Output duty cycle	010, 025, and 050 Devices	46		52	%
	060, 090, and 150 Devices	44		52	%
Spread Spectrum Characteristics					
Modulation frequency range		25	35	50	kHz
Modulation depth range		0		1.5	%
Modulation depth control			0.5		%

1. The minimum output clock frequency is limited by the PLL. For more information refer to the [UG0449: SmartFusion2 and IGLOO2 Clocking Resources User Guide](#).
2. The PLL is used in conjunction with the Clock Conditioning Circuitry. Performance will be limited by the CCC output frequency.

Table 145 • IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Jitter Specifications
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Conditions/Package Combinations				Units	
CCC Output Peak-to-Peak Period Jitter f_{OUT_CCC}						
010, 050 FG484 Packages ¹	SSO = 0	0 < SSO ≤ 2	SSO ≤ 4	SSO ≤ 8	SSO ≤ 16	
20 MHz to 100 MHz	Max(110, ± 1% x (1/ f_{OUT_CCC}))		Max(150, ± 1% x (1/ f_{OUT_CCC}))		ps	
100 MHz to 400 MHz	120	150		170	ps	
025 FG484 Package ¹	0 < SSO ≤ 16					
20 MHz to 74 MHz	± 1% x (1/ f_{OUT_CCC})				ps	
74 MHz to 400 MHz	210				ps	
090 FG484 and 150 FC1152 Packages ¹	0 < SSO ≤ 16					
20 MHz to 100 MHz	± 1% x (1/ f_{OUT_CCC})				ps	
100 MHz to 400 MHz	150				ps	

1. SSO Data is based on LVCMOS 2.5 V MSIO and/or MSIOD Bank I/Os.

2.16 JTAG

Table 146 • JTAG 1532
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Speed Grade –1						Units
		010	025	050	060	090	150	
tTCK2Q	Clock to Q (data out)	7.91	7.95	8.15	8.54	9.21	8.85	ns
tRSTB2Q	Reset to Q (data out)	6.54	6.27	7.54	8.70	7.94	8.99	ns
tDISU	Test Data Input Setup Time	–0.70	–0.70	–0.31	–1.20	–1.33	–1.02	ns
tDIHD	Test Data Input Hold Time	2.38	2.47	2.13	2.55	2.71	2.59	ns
tTMSSU	Test Mode Select Setup Time	–0.86	–1.13	0.26	–0.99	–1.03	–0.56	ns
tTMDHD	Test Mode Select Hold Time	1.48	1.98	0.21	1.71	1.69	1.05	ns
tTRSTREM	ResetB Removal Time	–1.1	–1.38	–0.49	–1.24	–0.8	–1.07	ns
tTRSTREC	ResetB Recovery Time	–1.1	–1.38	–0.47	–1.23	–0.8	–1.07	ns
FTCKMAX	TCK Maximum frequency	25	25	25	25	25	25	MHz

2.17 Power-Up to Functional Time

Worst-Case Industrial Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$.

Figure 17 • Power-Up to Functional Timing Diagram when MSS/HPMS is Used

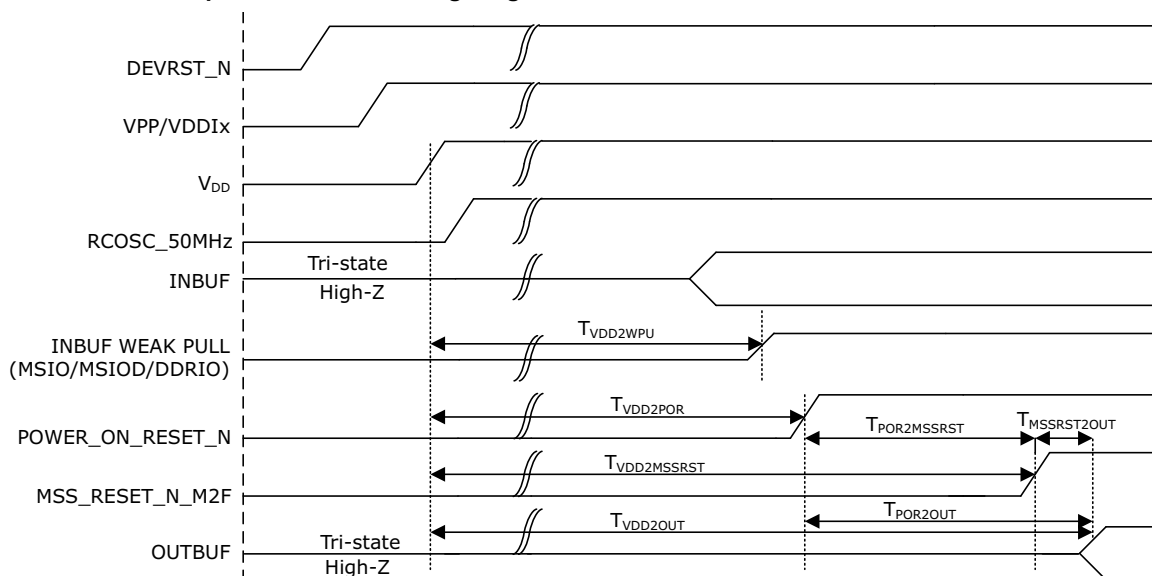


Table 147 • Maximum Power-Up to Functional Time when MSS/HPMS is Used (μs)

Parameter	From	To	Description	010	025	050	060	090	150
$T_{POR2OUT}$	POWER_ON_RESET_N	Output available at I/O	Fabric to output	500	531	483	474	524	647
$T_{POR2MSSRST}$	POWER_ON_RESET_N	MSS_RESET_N_M2F	Fabric to MSS	497	528	480	468	518	641
$T_{MSSRST2OUT}$	MSS_RESET_N_M2F / HMPRES_ET_N_M2F	Output available at I/O	MSS to output	3.6	3.6	3.4	4.9	4.8	4.8
$T_{VDD2OUT}$	VDD	Output available at I/O	VDD at its minimum threshold level to output	2975	3012	2959	2869	2992	3225
$T_{VDD2POR}$	VDD	POWER_ON_RESET_N	VDD at its minimum threshold level to Fabric	2487	2496	2486	2406	2563	2602
$T_{VDD2MSSRST}$	VDD	MSS_RESET_N_M2F	VDD at its minimum threshold level to MSS	2972	3008	2956	2864	2987	3220
$T_{VDD2WPU}$	VDD	DDRIO Inbuf Weak Pull	VDD to Inbuf Weak Pull	2487	2509	2475	2507	2519	2617
	VDD	MSIO Inbuf Weak Pull	VDD to Inbuf Weak Pull	2491	2510	2478	2517	2525	2620
	VDD	MSIOD Inbuf Weak Pull	VDD to Inbuf Weak Pull	2468	2493	2458	2486	2499	2595

Figure 18 • Power-Up to Functional Timing Diagram when MSS/HPMS is not Used

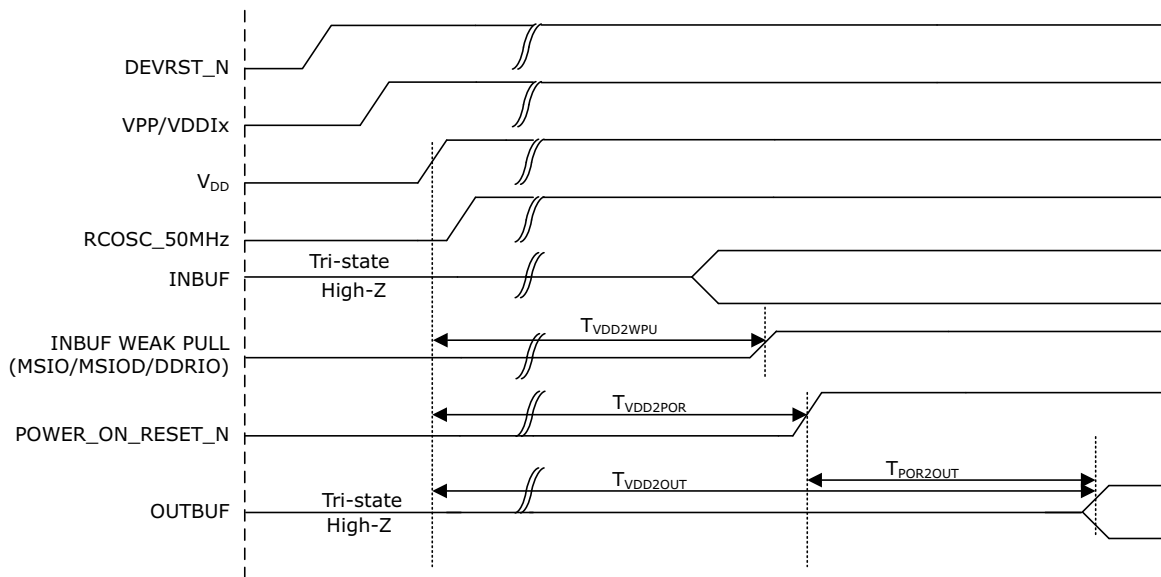


Table 148 • Maximum Power-Up to Functional Time when MSS/HPMS is Not Used (μ s)

Parameter	From	To	Description	010	025	050	060	090	150
$T_{POR2OUT}$	POWER_ON_RESET_N	Output available at I/O	Fabric to output	114	114	113	114	114	114
$T_{VDD2OUT}$	VDD	Output available at I/O	VDD at its minimum threshold level to output	2600	2607	2558	2591	2600	2699
$T_{VDD2POR}$	VDD	POWER_ON_RESET_N	VDD at its minimum threshold level to Fabric	2486	2493	2445	2477	2486	2585
$T_{VDD2WPU}$	VDD	DDRIO Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	2487	2509	2475	2507	2519	2617
	VDD	MSIO Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	2491	2510	2478	2517	2525	2620
	VDD	MSIOD Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	2468	2493	2458	2486	2499	2595

2.18 DEVRST_N Characteristics

Table 149 • DEVRST_N Characteristics
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Symbol	Description	All Devices/Speed Grades			Units
		Min	Typ	Max	
TRAMPDEVRST_N	DEVRSTN ramp time			1	μs
FMAXPDEVRST_N	DEVRSTN cycling rate			100	kHZ

2.19 DEVRST_N to Functional Time

Worst-case industrial conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$.

Figure 19 • DEVRST_N to Functional Timing Diagram when MSS/HPMS is Used

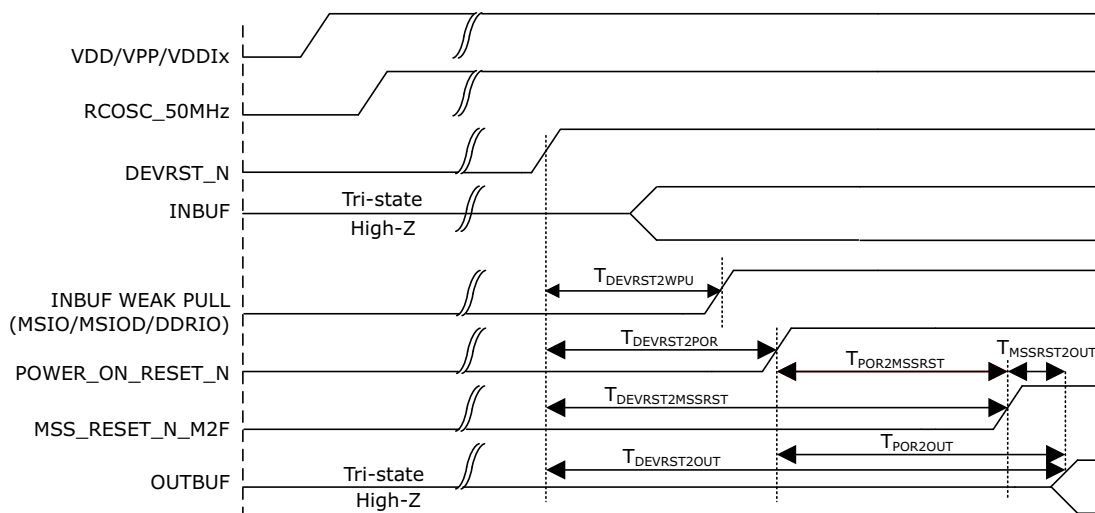
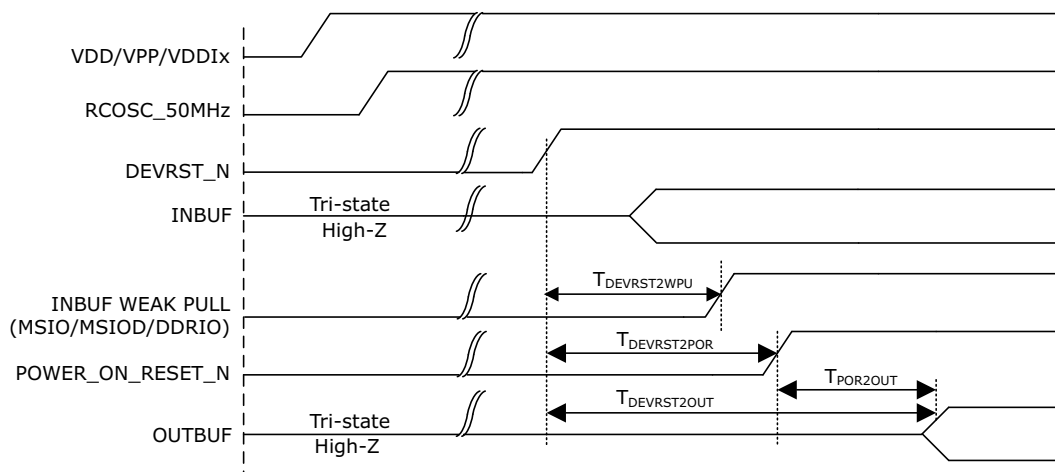


Table 150 • Maximum DEVRST_N to Functional Time when MSS/HPMS is Used (μs)

Parameter	From	To	Description	010	025	050	060	090	150
$T_{POR2OUT}$	POWER_ON_RESET_N	Output available at I/O	Fabric to output	501	527	521	422	419	694
$T_{POR2MSSRST}$	POWER_ON_RESET_N	MSS_RESET_N_M2F	Fabric to MSS	497	524	518	417	414	689
$T_{MSSRST2OUT}$	MSS_RESET_N_M2F / HMP5_RESE_T_N_M2F	Output available at I/O	MSS to output	3.5	3.5	3.3	4.8	4.8	4.8
$T_{DEVRST2OUT}$	DEVRST_N	Output available at I/O	VDD at its minimum threshold level to output	768	715	691	641	635	871

Table 150 • Maximum DEVRST_N to Functional Time when MSS/HPMS is Used (μs) (continued)

Parameter	From	To	Description	010	025	050	060	090	150
$T_{\text{DEVRST2POR}}$	DEVRST_N	POWER_ON_RESET_N	VDD at its minimum threshold level to Fabric	289	216	213	237	234	219
$T_{\text{DEVRST2MSSRST}}$	DEVRST_N	MSS_RESET_N_M2F	VDD at its minimum threshold level to MSS	765	712	688	636	630	866
$T_{\text{DEVRST2WPU}}$	DEVRST_N	DDRIO Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	202	197	193	216	215	215
	DEVRST_N	MSIO Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	202	197	193	216	215	215
	DEVRST_N	MSIOD Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	202	197	193	216	215	215

Figure 20 • DEVRST_N to Functional Timing Diagram when MSS/HPMS is not Used

Table 151 • Maximum DEVRST_N to Functional Time when MSS/HPMS is Not Used (μs)

Parameter	From	To	Description	010	025	050	060	090	150
T_{POR2OUT}	POWER_ON_RESET_N	Output available at I/O	Fabric to output	116	113	113	115	115	114
$T_{\text{DEVRST2OUT}}$	DEVRST_N	Output available at I/O	VDD at its minimum threshold level to output	353	314	307	343	341	341
$T_{\text{DEVRST2POR}}$	DEVRST_N	POWER_ON_RESET_N	VDD at its minimum threshold level to Fabric	238	201	195	230	229	227

Table 151 • Maximum DEVRST_N to Functional Time when MSS/HPMS is Not Used (μ s) (continued)

Parameter	From	To	Description	010	025	050	060	090	150
T _{DEVRST2WPU}	DEVRST_N	DDRIO Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	202	197	193	216	215	215
	DEVRST_N	MSIO Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	202	197	193	216	215	215
	DEVRST_N	MSIOD Inbuf Weak Pull	DEVRST_N to Inbuf Weak Pull	202	197	193	216	215	215

2.20 System Controller SPI Characteristics

Table 152 • System Controller SPI CharacteristicsWorst-Case Military Conditions: T_j = 125 °C, VDD = 1.14 V

Symbol	Description	Conditions	All Devices/Speed Grades			Units
			Min	Typ	Max	
sp1	SC_SPI_SCK minimum period		20			ns
sp2	SC_SPI_SCK minimum pulse width high		10			ns
sp3	SC_SPI_SCK minimum pulse width low		10			ns
sp4 ¹	SC_SPI_SCK, SC_SPI_SS rise time (10%-90%) 1	I/O Configuration: LVTTTL 3.3 V- 20 mA AC Loading: 35 pF Test Conditions: Typical Voltage, 25 °C		1.239		ns
sp5 ¹	SC_SPI_SCK, SC_SPI_SS fall time (10%-90%) 1	I/O Configuration: LVTTTL 3.3 V- 20 mA AC Loading: 35 pF Test Conditions: Typical Voltage, 25 °C		1.245		ns
sp6	SC_SPI_SDO setup time		160			ns
sp7	SC_SPI_SDO hold time		160			ns
sp8	SC_SPI_SDI setup time		20			ns
sp9	SC_SPI_SDI hold time		20			ns

1. For specific Rise/Fall Times, board design considerations and detailed output buffer resistances, use the corresponding IBIS models located on the Microsemi SoC Products Group website: <http://www.microsemi.com/products/fpga-soc/design-resources/ibis-models>. Use the supported I/O Configurations for the System Controller SPI in Table 153, page 100.

Table 153 • Supported I/O Configurations for System Controller SPI (for MSIO Bank Only)

Voltage Supply	I/O Drive Configuration	Units
3.3 V	20	mA
2.5 V	16	mA
1.8 V	12	mA
1.5 V	8	mA
1.2 V	4	mA

2.21 Mathblock Timing Characteristics

The fundamental building block in any digital signal processing algorithm is the multiply-accumulate function. Each IGLOO2 and SmartFusion2 SoC mathblock supports 18x18 signed multiplication, dot product, and built-in addition, subtraction, and accumulation units to combine multiplication results efficiently.

Table 154 • Mathblocks With All Registers Used (Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$)

Mathblock With All Registers Used		Speed Grade –1		
Parameter	Description	Min	Max	Units
TMISU	Input, Control Register Setup time	0.149		ns
TMIHD	Input, Control Register Hold time	0.08		ns
TMOCDINSU	CDIN Input Setup time	1.68		ns
TMOCDINH	CDIN Input Hold time	–0.419		ns
TMSRSTENSU	Synchronous Reset/Enable Setup time	0.185		ns
TMSRSTENHD	Synchronous Reset/Enable Hold time	0.011		ns
TMARSTREM	Asynchronous Reset Removal time	0		ns
TMARSTREC	Asynchronous Reset Recovery time	0.088		ns
TMOCQ	Output Register Clock to Out delay		0.232	ns
TMCLKMP	CLK Minimum period	2.245		ns

**Table 155 • Mathblock With Input Bypassed and Output Registers Used
Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$**

Mathblock With Input Bypassed and Output Registers Used		Speed Grade –1		
Parameter	Description	Min	Max	Units
TMOSU	Output Register Setup time	2.294		ns
TMOHD	Output Register Hold time	–0.444		ns
TMOCDINSU	CDIN Input Setup time	1.68		ns
TMOCDINH	CDIN Input Hold time	–0.419		ns
TMSRSTENSU	Synchronous Reset/Enable Setup time	0.115		ns
TMSRSTENHD	Synchronous Reset/Enable Hold time	0.011		ns
TMARSTREM	Asynchronous Reset Removal time	0		ns
TMARSTREC	Asynchronous Reset Recovery time	0.014		ns
TMOCQ	Output Register Clock to Out delay		0.232	ns
TMCLKMP	CLK Minimum period	2.179		ns

Table 156 • Mathblock With Input Register Used and Output in Bypass Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Mathblock With Input Register Used and Output in Bypass Mode		Speed Grade –1		
Parameter	Description	Min	Max	Units
TMISU	Input Register Setup time	0.149		ns
TMIHD	Input Register Hold time	0.08		ns
TMSRSTENSU	Synchronous Reset/Enable Setup time	0.185		ns
TMSRSTENHD	Synchronous Reset/Enable Hold time	–0.012		ns
TMARSTREM	Asynchronous Reset Removal time	–0.005		ns
TMARSTREC	Asynchronous Reset Recovery time	0.088		ns
TMICQ	Input Register Clock to Output delay		2.52	ns
TMCDIN2Q	CDIN to Output delay		1.951	ns

Table 157 • Mathblock With Input and Output in Bypass Mode
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Mathblock With Input and Output in Bypass Mode		Speed Grade –1		
Parameter	Description	Min	Max	Units
TMIQ	Input to Output delay		2.568	ns
TMCDIN2Q	CDIN to Output delay		1.951	ns

2.22 Flash*Freeze Timing Characteristics

Table 158 • Flash*Freeze Entry and Exit Times
 Military Worst-Case conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Symbols	Parameters	Conditions	Entry/Exit Timing		Units
			FCLK=100 MHz	FCLK=3 MHz	
TFF_ENTRY	Entry time	eNVM and MSS/HPMS PLL = ON	160	320	μs
		eNVM and MSS/HPMS PLL = OFF	215	430	μs
TFF_EXIT	Exit time with respect to MSS PLL Lock	eNVM and MSS/HPMS PLL = ON during Flash*Freeze	100	140	μs
		eNVM = ON and MSS/HPMS PLL = OFF during Flash*Freeze and MSS/HPMS PLL turned back on at exit	136	190	μs
		eNVM and MSS PLL=OFF during Flash*Freeze and both are turned back on at exit	200	285	μs
		eNVM = OFF and MSS PLL = ON during Flash*Freeze and eNVM turned back on at exit	200	285	μs
	Exit time with respect to Fabric PLL Lock ¹	eNVM and MSS/HPMS PLL = ON during Flash*Freeze	1.5	1.5	ms
		eNVM and MSS PLL=OFF during Flash*Freeze and both are turned back on at exit	1.5	1.5	ms
	Exit time with respect to Fabric buffer output	eNVM and MSS/HPMS PLL = ON during Flash*Freeze	21	21	μs
		eNVM and MSS PLL=OFF during Flash*Freeze and both are turned back on at exit	65	65	μs

1. PLL lock delay set to 1024 cycles (default).

2.23 DDR Memory Interface Characteristics

Table 159 • DDR Memory Interface Characteristics
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Standard	Supported Data Rate			Unit
	Min	Typ	Max	
DDR3			667	Mbps
DDR2			667	Mbps
LPDDR	50		400	Mbps

2.24 SFP Transceiver Characteristics

IGLOO2 and SmartFusion2 SERDES complies with small form-factor pluggable (SFP) requirements as specified in SFP INF-80741. The following table provides the electrical characteristics.

Table 160 • SFP Transceiver Electrical Characteristics
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Pin	Direction	Differential Peak-Peak Voltage			Unit
		Min	Typ	Max	
RD+/- ¹	Output	1600	–	2400	mV
TD+/- ²	Input	350	–	2400	mV

1. Based on default SERDES transmitter settings for PCIe Gen1. Lower amplitudes are available through programming changes to TX_AMP setting.
2. Based on Input Voltage Common-Mode (VICM) = 0 V. Requires AC Coupling.

2.25 SRAM PUF

Worst-case military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$.

For more information about SRAM physical unclonable functions (PUF) services, see [AC434: Using SRAM PUF System Service in SmartFusion2 Application Note](#).

Table 161 • SRAM PUF

Service	PUF OFF		PUFF ON		Units
	Typ	Max	Typ	Max	
Create activation code	709.1	770.8	796.0	865.3	ms
Delete activation code	1329.3	1444.9	1303.0	1416.3	ms
Create intrinsic keycode	656.6	713.7	643.6	699.5	ms
Create extrinsic keycode	656.6	713.7	643.6	699.5	ms
Get number of keys	1.3	1.5	1.3	1.4	ms
Export (KC0, KC1)	998.0	1084.8	978.2	1063.3	ms
Export 2 keycodes	2020.2	2195.9	1980.2	2152.4	ms
Export 4 keycodes	3065.7	3332.2	3005.0	3266.3	ms
Export 8 keycodes	5101.0	5544.6	5000.0	5434.8	ms
Export 16 keycodes	9212.1	10013.2	9029.7	9814.9	ms
Import (KC0, KC1)	39.7	43.1	38.9	42.3	ms
Import 2 keycodes	50.1	54.5	49.1	53.4	ms
Import 4 keycodes	60.6	65.9	59.4	64.6	ms
Import 8 keycodes	80.9	87.9	79.3	86.2	ms
Import 16 keycodes	123.8	134.6	121.4	131.9	ms
Delete keycode	552.5	600.6	541.6	588.7	ms
Fetch key	31.4	34.1	11.5	12.5	ms
Fetch ECC key	20.0	21.7	1.9	2.1	ms
Get seed	2.0	2.2	0.9	1.0	ms

2.26 Non-Deterministic Random Bit Generator (NRBG) Characteristics

The following table lists the NRBG characteristics of military-grade SmartFusion2 and IGLOO2 devices. For detailed information about NRBG, see [AC407: Using NRBG Services in SmartFusion2 and IGLOO2 Devices Application Note](#).

Table 162 • NRBG Characteristics

Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Service	Conditions		Timing	Units
	Prediction Resistance	Additional Input		
Instantiate	OFF	X	85	ms
Generate (after instantiate) ¹	OFF	0	4.5 ms + (7 μ s/byte \times No. of bytes)	
	OFF	64	6.0 ms + (7 μ s/byte \times No. of bytes)	
	OFF	128	7.0 ms + (7 μ s/byte \times No. of bytes)	
	ON	X	47	ms
Generate (subsequent) ¹	OFF	0	0.5 ms + (7 μ s/byte \times No. of bytes)	
	OFF	64	2.0 ms + (7 μ s/byte \times No. of bytes)	
	OFF	128	3.0 ms + (7 μ s/byte \times No. of bytes)	
	ON	X	43	ms
Reseed			40	ms
Uninstantiate			0.16	ms
Reset			0.10	ms
Self test	First time after power-up		20	ms
	Subsequent		6	ms

1. If PUF is OFF, *Generate* incurs an additional PUF delay time for consecutive service calls.

2.27 Cryptographic Block Characteristics

The following table lists the cryptographic block characteristics of military-grade SmartFusion2 and IGLOO2 devices. For detailed information about cryptographic blocks, see the following documents:

- [AC410: Using AES System Services in SmartFusion2 and IGLOO2 Devices Application Note](#)
- [AC432: Using SHA-256 System Services in SmartFusion2 and IGLOO2 Devices Application Note](#)

Table 163 • Cryptographic Block Characteristics
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Service	Conditions	Timing	Units
Any service	First certificate check penalty at boot	11.5	ms
AES128/256 (encoding/decoding) ¹	Up to 100 blocks	200	kbps
	100 blocks up to 64k blocks	650	kbps
SHA256	512 bits	530	kbps
	1024 bits	770	kbps
	2048 bits	940	kbps
	24 kbits	1130	kbps
HMAC	512 bytes	810	kbps
	1024 bytes	880	kbps
	2048 bytes	920	kbps
	24 kbytes	970	kbps
KeyTree		1.6	ms
Challenge-response	PUF = OFF	23	ms
	PUF = ON	6.6	ms
ECC point multiplication		590	ms
ECC point addition		8	ms

1. Applicable when using Cypher Block Chaining (CBC) mode.

2.28 SerDes Electrical and Timing AC and DC Characteristics

The IGLOO2 and SmartFusion2 SoC FPGAs has up to four hard high-speed serial interface blocks. Each SERDES block contains a PCIe system block. The PCIe system is connected to the SERDES block.

Table 164 • Transmitter Parameters
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Min	Typ	Max	Units
VTX-DIFF-PP	Differential swing (2.5 Gbps)	0.8		1.2	V
VTX-CM-AC-P	Output common mode voltage (2.5 Gbps)			20	mV
VTX-RISE-FALL	Rise and fall time (20% to 80%, 2.5 Gbps)	0.125			UI
ZTX-DIFF-DC	Output impedance – differential	80		120	Ω
LTX-SKEW	Lane-to-lane TX skew within a SERDES block (2.5 Gbps)			500 ps + 2 UI	ps
RLTX-DIFF	Return loss differential mode (2.5 Gbps)	-10			dB
RLTX-CM	Return loss common mode (2.5 Gbps)	-6			dB

Table 164 • Transmitter Parameters (continued)Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

TX-LOCK-RST	Transmit PLL lock time from reset		10	μs
VTX-AMP	100 mV setting	90	150	mV
	400 mV setting	320	480	mV
	800 mV setting	660	940	mV
	1200 mV setting	950	1400	mV

Table 165 • Receiver ParametersWorst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Min	Typ	Max	Units
VRX-IN-PP-CC	Differential input peak-to-peak sensitivity (2.5 Gbps)	0.238		1.2	V
	Differential input peak-to-peak sensitivity (2.5 Gbps, deemphasized)	0.219		1.2	V
VRX-CM-AC-P	Input common mode range (AC coupled)			150	mV
ZRX-DIFF-DC	Differential input termination	80	100	120	Ω
REXT	External calibration resistor	1,188	1,200	1,212	Ω
CDR-LOCK-RST	CDR relock time from reset			15	μs
RLRX-DIFF	Return loss differential mode (2.5 Gbps)	-10			dB
RLRX-CM	Return loss common mode (2.5 Gbps)	-6			dB
RX-CID ¹	CID limit (set by 8B/10B coding, not the receiver PLL)			200	UI
VRX-IDLE-DET-DIFF-PP	Signal detect limit	65		175	mV

1. AC-coupled, BER = e^{-12} .**Table 166 • SERDES Reference Clock AC Specifications**Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, Worst-Case $V_{DD} = 1.14\text{ V}$

Symbols	Description	Min	Typ	Max	Units
FREFCLK	Reference Clock Frequency	100		160	MHz
TRISE	Reference Clock Rise Time	0.6		4	V/ns
TFALL	Reference Clock Fall Time	0.6		4	V/ns
TCYC	Reference Clock Duty Cycle	40		60	%
Mmrefclk	Reference Clock Mismatch	-300		300	ppm
SSCref	Reference Spread Spectrum Clock	0		5000	ppm

Table 167 • HCSL Minimum and Maximum DC Input Levels (Applicable to SERDES REFCLK Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
Recommended DC Operating Conditions						
VDDI	Supply Voltage		2.375	2.5	2.625	V
HCSL DC Input Voltage Specification						
VI	DC Input voltage		0		2.625	V

Table 167 • HCSL Minimum and Maximum DC Input Levels (Applicable to SERDES REFCLK Only) (continued)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
HCSL Differential Voltage Specification						
VICM	Input common mode voltage		0.05		2.4	V
VIDIFF	Input differential voltage		100		1100	mV

Table 168 • HCSL Maximum AC Switching Speeds (Applicable to SERDES REFCLK Only)

Symbols	Parameters	Conditions	Min	Typ	Max	Units
HCSL AC Specifications						
Fmax	Maximum Data Rate (for MSIO IO Bank)				350	Mbps
HCSL Impedance Specifications						
Rt	Termination Resistance			100		Ω

2.29 SERDES Protocol Compliance

Table 169 • SERDES Protocol Compliance

Protocol	Maximum Data Rate	-1 Speed Grade
PCIe Gen 1	2.5 Gbps	Yes
XAUI	3.125 Gbps	Yes
Generic EPCS	2.5 Gbps	Yes

2.30 MMUART Characteristics

Worst-case military conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$.

Table 170 • MMUART Characteristics

Parameter	Descriptions	-1 Speed Grade	Units
FMMUART_REF_CLK	Internally sourced MMUART reference clock frequency	133	MHz
BAUDMMUARTTx	Maximum transmit baud rate	8.3125	Mbps
BAUDMMUARTRx	Maximum receive baud rate	8.3125	Mbps

2.31 CAN Controller Characteristics

Table 171 • CAN Controller Characteristics

Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Min	Typ	Max	Units
FCANREFCLK ¹	Internally Sourced CAN Reference Clock Frequency			128	MHz
BAUDCAN	CAN Performance Baud Rate	0.05		1	Mbps

1. PCLK to CAN controller must be a multiple of 8 MHz.

2.32 USB Characteristics

Table 172 • USB Characteristics

Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Description	Min	Typ	Max	Units
FUSBREFCLK	Internally Sourced USB Reference Clock Frequency			133	MHz
TUSBCLK	USB Clock Period			16.66	ns
TUSBPD	Clock to USB Data Propagation Delay			9.0	ns
TUSBSU	Setup Time for USB Data			6.0	ns
TUSBHD	Hold Time for USB Data	0			ns

2.33 SmartFusion2 Specifications

2.33.1 MSS Clock Frequency

Table 173 • Maximum Frequency for MSS Main Clock

Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Symbol	Description	Speed Grade –1	Units
M3_CLK	Maximum frequency for the MSS Main Clock (FCLK)	133	MHz

2.33.2 SmartFusion2 Inter-Integrated Circuit (I²C) Characteristics

This section describes the DC and switching of the I²C interface. Unless otherwise noted, all output characteristics given are for a 100 pF load on the pins.

Table 174 • I²C Characteristics

Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Definition	Conditions	Min	Typ	Max	Units
VIL	Input low voltage	Refer to the "Single-Ended I/O Standards" section on page 20 for more information. I/O standard used for illustration: MSIO bank– LVTTTL 8 mA low drive.	–0.3		0.8	V
VIH	Input high voltage	Refer to the "Single-Ended I/O Standards" section on page 20 for more information. I/O standard used for illustration: MSIO bank – LVTTTL 8 mA low drive.	2		3.45	V

Table 174 • I2C Characteristics**Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)**

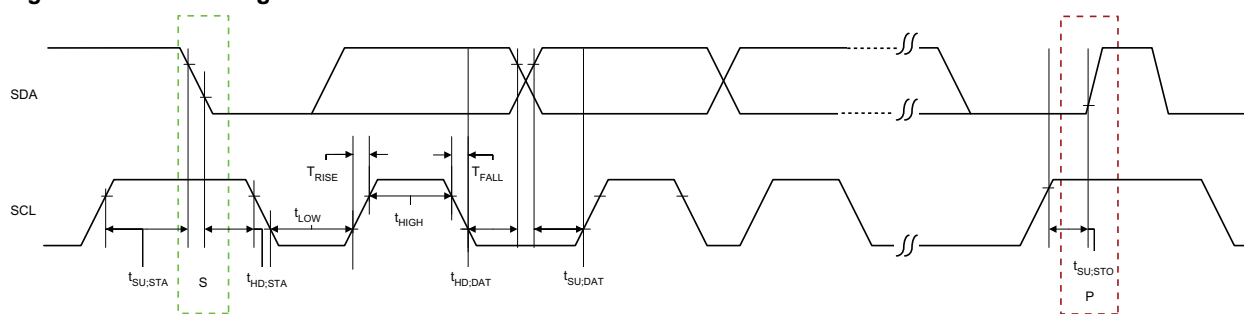
Parameter	Definition	Conditions	Min	Typ	Max	Units
VHYS	Hysteresis of Schmitt triggered inputs for $V_{DDI} > 2\text{ V}$	Refer to Table 21 on page 20 for more information.	0.05 x V_{DDI}			V
IIL	Input current high	Refer to the "Single-Ended I/O Standards" section on page 20 for more information.			10	μA
IIL	Input current low	Refer to the "Single-Ended I/O Standards" section on page 20 for more information.			10	μA
Tir	Input rise time	Standard Mode			1000	ns
		Fast Mode			300	ns
Tif	Input fall time	Standard Mode			300	ns
		Fast Mode			300	ns
VOL	Maximum output voltage low (open drain) at 3 mA sink current for $V_{DDI} > 2\text{ V}$	Refer to the "Single-Ended I/O Standards" section on page 20 for more information. I/O standard used for illustration: MSIO bank – LVTTTL 8 mA low drive.			0.4	V
Cin	Pin capacitance	$V_{IN} = 0$, $f = 1.0\text{ MHz}$			10	pF
t_{OF}	Output fall time from V_{IHMin} to V_{ILMax}	V_{IHmin} to V_{ILMax} , $C_{load} = 400\text{ pF}^1$		21.04		ns
		V_{IHmin} to V_{ILMax} , $C_{load} = 100\text{ pF}$		5.556		ns
t_{OR}	Output rise time from V_{ILMax} to V_{IHMin}	V_{ILMax} to V_{IHmin} , $C_{load} = 400\text{ pF}^1$		19.887		ns
		V_{ILMax} to V_{IHmin} , $C_{load} = 100\text{ pF}$		5.218		ns
$R_{pull-up}^{2,3}$	Output buffer maximum pull-down resistance				50	Ω
$R_{pull-down}^{2,4}$	Output buffer maximum pull-up resistance				131.25	Ω
Dmax	Maximum data rate	Fast mode			400	Kbps
		Standard mode			100	Kbps
t_{FILT}	Pulse width of spikes which must be suppressed by the input filter	Fast mode		50		ns

1. These values are provided for MSIO Bank - LVTTTL 8 mA Low Drive at $25\text{ }^\circ\text{C}$, typical conditions. For Board Design considerations and detailed output buffer resistances, use the corresponding IBIS models located on the SoC Products Group website: <http://www.microsemi.com/products/fpga-soc/design-resources/ibis-models>.
2. These maximum values are provided for information only. Minimum output buffer resistance values depend on V_{DDIX} , drive strength selection, temperature, and process. For board design considerations and detailed output buffer resistances, use the corresponding IBIS models located on the SoC Products Group website: <http://www.microsemi.com/products/fpga-soc/design-resources/ibis-models>.
3. $R(\text{PULL-DOWN-MAX}) = (V_{OLspec}) / I_{OLspec}$.
4. $R(\text{PULL-UP-MAX}) = (V_{DDImax} - V_{OHspec}) / I_{OHspec}$.

Table 175 • I2C Switching Characteristics
Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Parameter	Definition	Conditions	Speed Grade -1		Units
			Min	Max	
t_{LOW}	Low period of I2C_x_SCL		1		clk cycles
t_{HIGH}	High period of I2C_x_SCL		1		clk cycles
$t_{HD;STA}$	START hold time		1		clk cycles
$t_{SU;STA}$	START setup time		1		clk cycles
$t_{HD;DAT}$	DATA hold time		1		clk cycles
$t_{SU;DAT}$	DATA setup time		1		clk cycles
$t_{SU;STO}$	STOP setup time		1		clk cycles

Figure 21 • I2C Timing Parameter Definition



2.33.3 Serial Peripheral Interface (SPI) Characteristics

This section describes the DC and switching of the SPI interface. Unless otherwise noted, all output characteristics given are for a 35 pF load on the pins and all sequential timing characteristics are related to SPI_x_CLK.

Table 176 • SPI Characteristics
Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Symbol	Description	Conditions	All Devices/Speed Grades		
			Min	Typ	Max Unit
SPIFMAX	Maximum operating frequency of SPI interface			20	MHz
sp1	SPI_[0 1]_CLK minimum period				
	SPI_[0 1]_CLK = PCLK/2		12		ns
	SPI_[0 1]_CLK = PCLK/4		24.1		ns
	SPI_[0 1]_CLK = PCLK/8		48.2		ns
	SPI_[0 1]_CLK = PCLK/16		0.1		μs
	SPI_[0 1]_CLK = PCLK/32		0.19		μs
	SPI_[0 1]_CLK = PCLK/64		0.39		μs
	SPI_[0 1]_CLK = PCLK/128		0.77		μs

Table 176 • SPI Characteristics
Worst-Case Military Conditions: T_j = 125 °C, VDD = 1.14 V (continued)

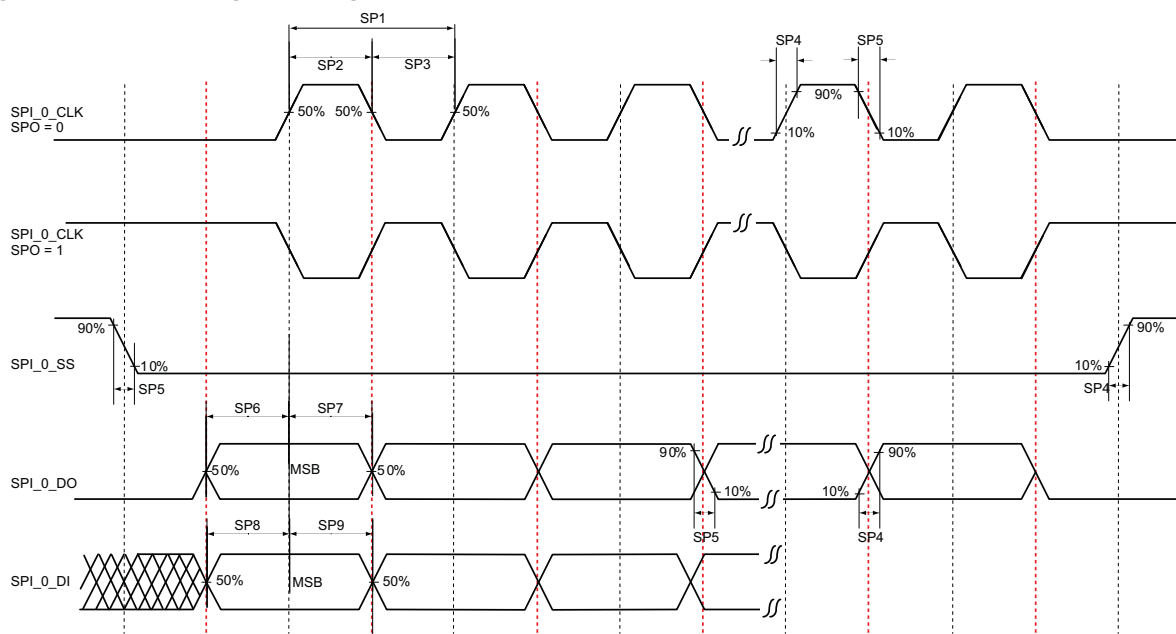
Symbol	Description	Conditions	All Devices/Speed Grades			Unit
			Min	Typ	Max	
sp2	SPI_[0 1]_CLK minimum pulse width high					
	SPI_[0 1]_CLK = PCLK/2		6			ns
	SPI_[0 1]_CLK = PCLK/4		12.05			ns
	SPI_[0 1]_CLK = PCLK/8		24.1			ns
	SPI_[0 1]_CLK = PCLK/16		0.05			µs
	SPI_[0 1]_CLK = PCLK/32		0.095			µs
	SPI_[0 1]_CLK = PCLK/64		0.195			µs
	SPI_[0 1]_CLK = PCLK/128		0.385			µs
sp3	SPI_[0 1]_CLK minimum pulse width low					
	SPI_[0 1]_CLK = PCLK/2		6			ns
	SPI_[0 1]_CLK = PCLK/4		12.05			ns
	SPI_[0 1]_CLK = PCLK/8		24.1			ns
	SPI_[0 1]_CLK = PCLK/16		0.05			µs
	SPI_[0 1]_CLK = PCLK/32		0.095			µs
	SPI_[0 1]_CLK = PCLK/64		0.195			µs
	SPI_[0 1]_CLK = PCLK/128		0.385			µs
sp4 ¹	SPI_[0 1]_CLK, SPI_[0 1]_DO, SPI_[0 1]_SS rise time (10%–90%)	IO Configuration: LVCMOS 2.5 V - 8 mA AC Loading: 35 pF Test Conditions: Typical Voltage, 25 °C		2.77		ns
sp5 ¹	SPI_[0 1]_CLK, SPI_[0 1]_DO, SPI_[0 1]_SS fall time (10%–90%)	IO Configuration: LVCMOS 2.5 V - 8 mA AC Loading: 35 pF Test Conditions: Typical Voltage, 25 °C		2.906		ns
SPI Master Configuration (Applicable to 010, 025, and 050 Devices)						
sp6m ²	SPI_[0 1]_DO setup time		(SPI_x_CLK_period/2) – 8.0			ns
sp7m ²	SPI_[0 1]_DO hold time		(SPI_x_CLK_period/2) – 2.5			ns
sp8m ²	SPI_[0 1]_DI setup time		12			ns
sp9m ²	SPI_[0 1]_DI hold time		2.5			ns
SPI Slave Configuration (Applicable to 010, 025, and 050 Devices)						
sp6s ²	SPI_[0 1]_DO setup time		(SPI_x_CLK_period/2) – 17.0			ns
sp7s ²	SPI_[0 1]_DO hold time		(SPI_x_CLK_period/2) + 3.0			ns
sp8s ²	SPI_[0 1]_DI setup time		2			ns
sp9s ²	SPI_[0 1]_DI hold time		7			ns
SPI Master Configuration (Applicable to 060, 090, and 150 Devices)						
sp6m ²	SPI_[0 1]_DO setup time		(SPI_x_CLK_period/2) – 7.0			ns

Table 176 • SPI Characteristics
Worst-Case Military Conditions: $T_j = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)

Symbol	Description	Conditions	All Devices/Speed Grades			Unit
			Min	Typ	Max	
sp7m ²	SPI_[0 1]_DO hold time		$(\text{SPI_x_CLK_period}/2) - 9.5$			ns
sp8m ²	SPI_[0 1]_DI setup time		15			ns
sp9m ²	SPI_[0 1]_DI hold time		-2.5			ns
SPI Slave Configuration (Applicable to 060, 090, and 150 Devices)						
sp6s ²	SPI_[0 1]_DO setup time		$(\text{SPI_x_CLK_period}/2) - 16.0$			ns
sp7s ²	SPI_[0 1]_DO hold time		$(\text{SPI_x_CLK_period}/2) - 3.5$			ns
sp8s ²	SPI_[0 1]_DI setup time		3			ns
sp9s ²	SPI_[0 1]_DI hold time		2.5			ns

- For specific Rise/Fall Times board design considerations and detailed output buffer resistances, use the corresponding IBIS models located on the Microsemi SoC Products Group website:
<http://www.microsemi.com/products/fpga-soc/design-resources/ibis-models>.
- For allowable pclk configurations, refer to the Serial Peripheral Interface Controller section in the *UG0331: SmartFusion2 Microcontroller Subsystem User Guide*.

Figure 22 • SPI Timing for a Single Frame Transfer in Motorola Mode (SPH = 1)



2.34 IGLOO2 Specifications

2.34.1 HPMS Clock Frequency

Table 177 • Maximum Frequency for HPMS Main Clock
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

Symbol	Description	Speed Grade –1	Units
HPMS_CLK	Maximum Frequency for the HPMS Main Clock (FCLK)	133	MHz

2.34.2 Serial Peripheral Interface (SPI) Characteristics

This section describes the DC and switching of the SPI interface. Unless otherwise noted, all output characteristics given are for a 35 pF load on the pins and all sequential timing characteristics are related to SPI_0_CLK. For timing parameter definitions, refer to [Figure 23](#), page 116.

Table 178 • SPI Characteristics
 Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

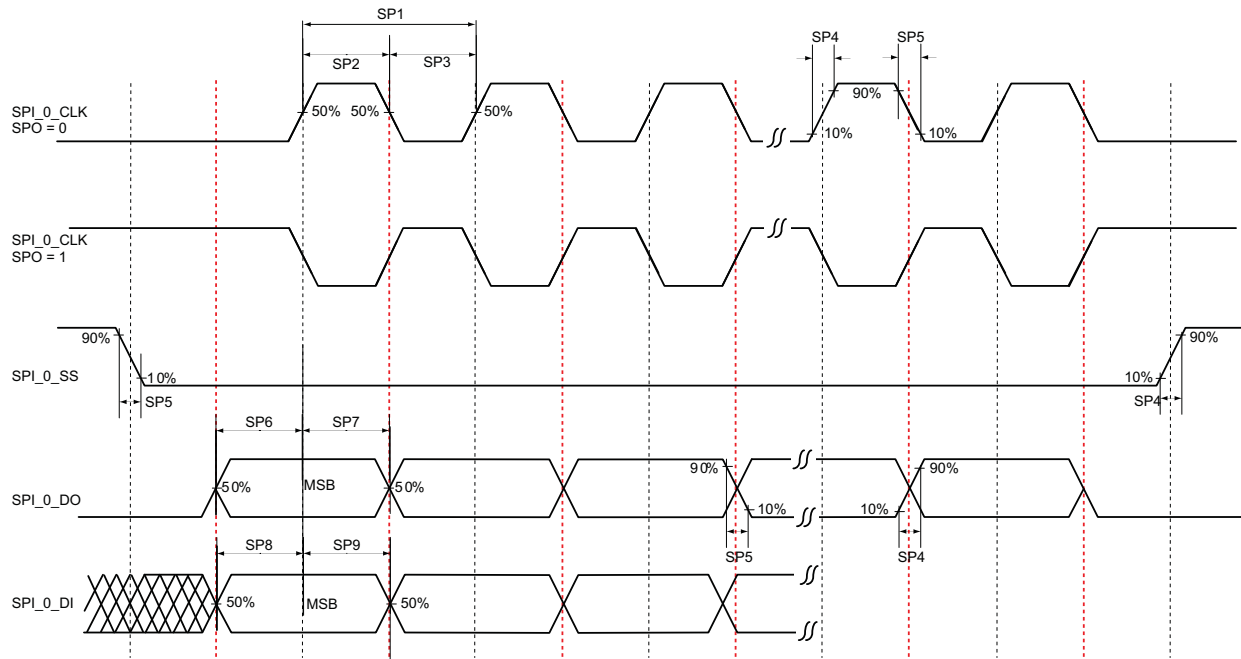
Symbol	Description	Conditions	All Devices/Speed Grades		
			Min	Typ	Max Unit
sp1	SPI_0_CLK minimum period				
	SPI_0_CLK = PCLK/2		12		ns
	SPI_0_CLK = PCLK/4		24.1		ns
	SPI_0_CLK = PCLK/8		48.2		ns
	SPI_0_CLK = PCLK/16		0.1		μs
	SPI_0_CLK = PCLK/32		0.19		μs
	SPI_0_CLK = PCLK/64		0.39		μs
	SPI_0_CLK = PCLK/128		0.77		μs
sp2	SPI_0_CLK minimum pulse width high				
	SPI_0_CLK = PCLK/2		6		ns
	SPI_0_CLK = PCLK/4		12.05		ns
	SPI_0_CLK = PCLK/8		24.1		ns
	SPI_0_CLK = PCLK/16		0.05		μs
	SPI_0_CLK = PCLK/32		0.095		μs
	SPI_0_CLK = PCLK/64		0.195		μs
	SPI_0_CLK = PCLK/128		0.385		μs
sp3	SPI_0_CLK minimum pulse width low				
	SPI_0_CLK = PCLK/2		6		ns
	SPI_0_CLK = PCLK/4		12.05		ns
	SPI_0_CLK = PCLK/8		24.1		ns
	SPI_0_CLK = PCLK/16		0.05		μs
	SPI_0_CLK = PCLK/32		0.095		μs
	SPI_0_CLK = PCLK/64		0.195		μs
	SPI_0_CLK = PCLK/128		0.385		μs

Table 178 • SPI Characteristics**Worst-Case Military Conditions: $T_J = 125\text{ }^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$ (continued)**

Symbol	Description	Conditions	All Devices/Speed Grades			
			Min	Typ	Max	Unit
sp4 ¹	SPI_0_CLK, SPI_0_DO, SPI_0_SS rise time (10%- 90%)	I/O Configuration: LVCMOS 2.5 V- 8 mA AC Loading: 35 pF Test Conditions: Typical Voltage, 25 °C		2.77		ns
sp5 ¹	SPI_0_CLK, SPI_0_DO, SPI_0_SS fall time (10%- 90%)	I/O Configuration: LVCMOS 2.5 V- 8 mA AC Loading: 35 pF Test Conditions: Typical Voltage, 25 °C		2.906		ns
SPI Master Configuration						
sp6m ²	SPI_0_DO setup time		(SPI_x_CLK_period/2) – 3.0			ns
sp7m ²	SPI_0_DO hold time		(SPI_x_CLK_period/2) – 2.5			ns
sp8m ²	SPI_0_DI setup time		8			ns
sp9m ²	SPI_0_DI hold time		2.5			ns
SPI Slave Configuration						
sp6s ²	SPI_0_DO setup time		(SPI_x_CLK_period/2) – 12.0			ns
sp7s ²	SPI_0_DO hold time		(SPI_x_CLK_period/2) + 3.0			ns
sp8s ²	SPI_0_DI setup time		2			ns
sp9s ²	SPI_0_DI hold time		3			ns

- For specific Rise/Fall Times board design considerations and detailed output buffer resistances, use the corresponding IBIS models located on the Microsemi SoC Products Group website:
<http://www.microsemi.com/products/fpga-soc/design-resources/ibis-models>.
- For allowable pclk configurations, refer to the Serial Peripheral Interface Controller section in the *UG0331: SmartFusion2 Microcontroller Subsystem User Guide*.

Figure 23 • SPI Timing for a Single Frame Transfer in Motorola Mode (SPH = 1)





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