
IGLOO2 FPGA and SmartFusion2 SoC FPGA

DS0451 Datasheet



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List of Changes

Datasheet Categories

Safety Critical, Life Support, and High-Reliability Applications Policy

Microsemi Corporate Headquarters

IGLOO2 and SmartFusion2 SoC FPGA AC/DC Electrical Characteristics

1. Introduction

Microsemi's mainstream SmartFusion[®]2 SoC 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 five MB of embedded RAM, up to 16 SERDES lanes, and up to four PCI Express Gen 2 endpoints, as well as integrated hard DDR3 memory controllers with error correction.

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

2. Device Status

For more information on device status, refer to the "Datasheet Categories" section on page 135.

Table 1 • IGLOO2 FPGA and SmartFusion2 SoC FPGA Device Status

| Design Security Device Densities | Status |
|---|---------------|
| 005 | Production |
| 010, 010T | Production |
| 025, 025T | Production |
| 050, 050T | Production |
| 060, 060T | Preliminary |
| 090, 090T | Production |
| 150, 150T | Production |
| Data Security Device Densities | Status |
| 005S | Production |
| 010TS | Production |
| 025TS | Production |
| 050TS | Production |
| 060TS | Preliminary |
| 090TS | Production |
| 150TS | Production |

3. Product Briefs and Pin Descriptions

The product brief and pin descriptions are published separately:

IGLOO2 Product Brief

IGLOO2 Pin Descriptions

SmartFusion2 SoC FPGA Product Brief

SmartFusion2 Pin Descriptions

4. General Specifications

4.1 Operating Conditions

Stresses beyond those listed in [Table 2](#) 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 [Table 2](#) is not implied.

Table 2 • Absolute Maximum Ratings

| Symbol | Parameter | Limits | | Units | Notes |
|-----------------------------|---|--------|------|-------|-------|
| | | Min | Max | | |
| 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} | Storage temperature | -65 | 150 | °C | * |

Table 2 • Absolute Maximum Ratings (continued)

| Symbol | Parameter | Limits | | Units | Notes |
|----------------|----------------------|--------|-----|-------|-------|
| | | Min | Max | | |
| T _J | Junction temperature | -55 | 125 | °C | |

*Note: *For flash programming and retention maximum limits, refer to Table 4 on page 14. For recommended operating conditions, refer to Table 3 on page 13.*

Table 3 • Recommended Operating Conditions

| Symbol | Parameter | Conditions | Min | Typ | Max | Units | Notes |
|-----------------------------|---|-------------|-------|-----|-------|-------|-------|
| T _J | Operating Junction Temperature | Commercial | 0 | 25 | 85 | °C | |
| | | Industrial | -40 | 25 | 100 | °C | |
| | Programming Junction Temperatures | Commercial | 0 | 25 | 85 | °C | |
| | | Industrial | -40 | 25 | 100 | °C | 1 |
| 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 the 005, 010, 025, 050 devices | 2.5 V range | 2.375 | 2.5 | 2.625 | V | |
| | | 3.3 V range | 3.15 | 3.3 | 3.45 | V | |
| VPP | Power supply for charge pumps (for normal operation and programming) for the 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 to PLL5 | 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 | High supply voltage for PLL SERDES[01] | 2.5 V range | 2.375 | 2.5 | 2.625 | V | 2 |
| | | 3.3 V range | 3.15 | 3.3 | 3.45 | V | 2 |
| SERDES_[01]_L[0123]_VDDAPLL | Analog power for SERDES[01] PLL Lane0 to Lane3. This is a +2.5 V SERDES internal PLL supply. | | 2.375 | 2.5 | 2.625 | 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. | | 1.14 | 1.2 | 1.26 | V | |
| SERDES_[01]_VDD | PCIe/PCS power supply | | 1.14 | 1.2 | 1.26 | V | |

Notes:

- Programming at Industrial temperature range is available only with VPP=3.3V.
- Power supply ramps must all be strictly monotonic, without plateaus.

Table 3 • Recommended Operating Conditions (continued)

| Symbol | Parameter | Conditions | Min | Typ | Max | Units | Notes |
|--------|--|-------------|--------------|-------------|--------------|-------|-------|
| 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 | | 3.15 | 3.3 | 3.45 | V | |
| | LVDS differential I/O | | 2.375 | 2.5 | 3.45 | V | |
| | B-LVDS, M-LVDS, Mini-LVDS, RSDS differential I/O | | 2.375 | 2.5 | 2.625 | V | |
| | LVPECL differential I/O | | 3.15 | 3.3 | 3.45 | 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 | |

Notes:

- Programming at Industrial temperature range is available only with VPP=3.3V.
- Power supply ramps must all be strictly monotonic, without plateaus.

Table 4 • FPGA Operating Limits

| Product Grade | Element | Programming Temperature | Operating Temperature | Programming Cycles | Digest Temperature | Digest Cycles | Retention (Biased/Unbiased) | Notes |
|---------------|---------|--|--|--------------------|--|---------------|-----------------------------|-------|
| Commercial | FPGA | Min T _J = 0°C Max T _J = 85°C | Min T _J = 0°C Max T _J = 85°C | 500 | Min T _J = 0°C Max T _J = 85°C | 2000 | 20 years | |
| Industrial | FPGA | Min T _J = -40°C Max T _J = 100°C | Min T _J = -40°C Max T _J = 100°C | 500 | Min T _J = -40°C Max T _J = 100°C | 2000 | 20 years | * |

Note: *Programming at Industrial temperature range is available only with VPP = 3.3 V

Table 5 • Embedded Operating Flash Limits

| Product Grade | Element | Programming Temperature | Maximum Operating Temperature | Programming Cycles | Retention (Biased/Unbiased) |
|---------------|----------------|--|--|---|-----------------------------|
| Commercial | Embedded flash | Min T _J = 0°C Max T _J = 85°C | Min T _J = 0°C Max T _J = 85°C | < 1000 cycles per page, up to two million cycles per eNVM Array | 20 years |
| | | | | < 10000 cycles per page, up to 20 million cycles per eNVM Array | 10 years |
| Industrial | Embedded flash | Min T _J = -40°C Max T _J = 100°C | Min T _J = -40°C Max T _J = 100°C | < 1000 cycles per page, up to two million cycles per eNVM Array | 20 years |
| | | | | < 10000 cycles per page, up to 20 million cycles per eNVM Array | 10 years |

Table 6 • Device Storage Temperature and Retention

| Product Grade | Storage Temperature (Tstg) | Retention |
|---------------|--|-----------|
| Commercial | Min T _J = 0°C Max T _J = 85°C | 20 years |
| Industrial | Min T _J = -40°C Max T _J = 100°C | 20 years |

4.2 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 100mA.

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

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.

4.3 Thermal Characteristics

4.3.1 Introduction

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 causes the chip's junction temperature to be higher than the ambient, case, or board temperatures.

EQ 1 through EQ 3 give the relationship between thermal resistance, temperature gradient, and power.

$$\theta_{JA} = \frac{T_J - T_A}{P} \quad \text{EQ 1}$$

$$\theta_{JB} = \frac{T_J - T_B}{P} \quad \text{EQ 2}$$

$$\theta_{JC} = \frac{T_J - T_C}{P} \quad \text{EQ 3}$$

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 7 • Package Thermal Resistance

| Product M2GL/M2S | θ_{JA} | | | θ_{JB} | θ_{JC} | Units |
|------------------|---------------|---------|---------|---------------|---------------|-------|
| | Still Air | 1.0 m/s | 2.5 m/s | | | |
| 005 | | | | | | |
| FG484 | 19.36 | 15.81 | 14.63 | 9.74 | 5.27 | °C/W |
| VF256 | 41.30 | 38.16 | 35.30 | 28.41 | 3.94 | °C/W |
| VF400 | 20.19 | 16.94 | 15.41 | 8.86 | 4.95 | °C/W |
| TQ144 | 42.80 | 36.80 | 34.50 | 37.20 | 10.80 | °C/W |
| 010 | | | | | | |
| FG484 | 18.22 | 14.83 | 13.62 | 8.83 | 4.92 | °C/W |
| VF256 | 37.36 | 34.26 | 31.45 | 24.84 | 7.89 | °C/W |
| VF400 | 19.40 | 15.75 | 14.22 | 8.11 | 4.22 | °C/W |
| TQ144 | 38.60 | 32.60 | 30.30 | 31.80 | 8.60 | °C/W |
| 025 | | | | | | |
| FG484 | 17.03 | 13.66 | 12.45 | 7.66 | 4.18 | °C/W |
| VF256 | 33.85 | 30.59 | 27.85 | 21.63 | 6.13 | °C/W |
| VF400 | 18.36 | 14.89 | 13.36 | 7.12 | 3.41 | °C/W |
| FCS325 | 29.17 | 24.87 | 23.12 | 14.44 | 2.31 | °C/W |
| 050 | | | | | | |
| FG484 | 15.29 | 12.19 | 10.99 | 6.27 | 3.24 | °C/W |
| FG896 | 14.70 | 12.50 | 10.90 | 7.20 | 4.90 | °C/W |
| VF400 | 17.53 | 14.17 | 12.63 | 6.32 | 2.81 | °C/W |
| FCS325 | 27.38 | 23.18 | 21.41 | 12.47 | 1.59 | °C/W |
| 060 | | | | | | |
| FG484 | 15.40 | 12.06 | 10.85 | 6.14 | 3.15 | °C/W |
| FG676 | 15.49 | 12.21 | 11.06 | 7.07 | 3.87 | °C/W |
| VF400 | 17.45 | 14.01 | 12.47 | 6.22 | 2.69 | °C/W |
| FCS325 | 27.03 | 22.91 | 21.25 | 12.33 | 1.54 | °C/W |
| 090 | | | | | | |
| FG484 | 14.64 | 11.37 | 10.16 | 5.43 | 2.77 | °C/W |
| FG676 | 14.52 | 11.19 | 10.37 | 6.17 | 3.24 | °C/W |
| FCS325 | 26.63 | 22.26 | 20.13 | 14.24 | 2.50 | °C/W |
| 150 | | | | | | |
| FC1152 | 9.08 | 6.81 | 5.87 | 2.56 | 0.38 | °C/W |
| FCS536 | 15.01 | 12.06 | 10.76 | 3.69 | 1.55 | °C/W |
| FCV484 | 16.21 | 13.11 | 11.84 | 6.73 | 0.10 | °C/W |

4.3.2 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 should 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 [EQ 4](#).

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

EQ 4

The absolute maximum junction temperature is 100°C. EQ 5 shows a sample calculation of the absolute maximum power dissipation allowed for the M2GL050T-FG896 package at commercial temperature and in still air, where

$$\theta_{JA} = 14.7^{\circ}\text{C/W (taken from Table 7 on page 16).}$$

$$T_A = 85^{\circ}\text{C}$$

$$\text{Maximum Power Allowed} = \frac{100^{\circ}\text{C} - 85^{\circ}\text{C}}{14.7^{\circ}\text{C/W}} = 1.088 \text{ W}$$

EQ 5

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.

4.3.3 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.

4.3.4 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.

5. Power Consumption

5.1 Quiescent Supply Current

Table 8 • Quiescent Supply Current Characteristics

| Power Supplies/Blocks | Modes and Configurations | | Notes |
|--|--------------------------|-------------------|-------|
| | Non-Flash*Freeze Mode | Flash*Freeze Mode | |
| FPGA Core | On | Off | |
| VDD / SERDES_[01]_VDD | On | On | 1 |
| VPP / VPPNVM | On | On | |
| HPMS_MDDR_PLL_VDDA / FDDR_PLL_VDDA/ CCC_XX[01]_PLL_VDDA / PLL0_PLL1_HPMS_MDDR_VDDA | 0 V | 0 V | |
| SERDES_[01]_PLL_VDDA | 0 V | 0 V | 3 |
| SERDES_[01]_L[0123]_VDDAPLL / VDD_2V5 | On | On | 3 |
| SERDES_[01]_L[0123]_VDDAIIO | On | On | 3 |

Table 8 • Quiescent Supply Current Characteristics (continued)

| | | | |
|-------------------------------------|----------|-------------|------|
| VDDIx | On | On | 2, 4 |
| VREFx | On | On | |
| MSSDDR CLK | 32 kHz | 32 kHz | |
| RAM | On | Sleep state | |
| System Controller | 50 MHz | 50 MHz | |
| 50 MHz Oscillator (enable/disable) | Enable | Disabled | |
| 1 MHz Oscillator (enable/disable) | Disabled | Disabled | |
| Crystal Oscillator (enable/disable) | Disabled | Disabled | |

Notes:

1. SERDES_[01]_VDD Power Supply is shorted to VDD.
2. 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 SmartFusion2 Board Design Guidelines and IGLOO2 Board Design Guidelines application notes.
3. SERDES and DDR blocks to be unused.
4. No Differential (that is to say, LVDS) I/O's or ODT attributes to be used.

Table 9 • SmartFusion2 and IGLOO2 Quiescent Supply Current – Typical Process

| Parameter | Modes | Conditions | 005 | 010 | 025 | 050 | 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) | 5.4 | 6.6 | 8.6 | 11.4 | 15.0 | 21.7 | mA |
| | | Commercial (T _J = 85°C) | 17.4 | 25.0 | 36.4 | 52.3 | 72.8 | 112.2 | mA |
| | | Industrial (T _J = 100°C) | 25.1 | 36.6 | 54.0 | 78.1 | 109.4 | 169.4 | mA |
| IDC2 | Flash*Freeze | Typical (T _J = 25°C) | 1.6 | 2.2 | 2.8 | 3.2 | 4.2 | 5.2 | mA |
| | | Commercial (T _J = 85°C) | 10.8 | 15.2 | 19.6 | 21.8 | 29.0 | 35.6 | mA |
| | | Industrial (T _J = 100°C) | 16.6 | 23.4 | 30.1 | 33.6 | 44.7 | 54.8 | mA |

Table 10 • SmartFusion2 and IGLOO2 Quiescent Supply Current – Worst-Case Process

| Parameter | Modes | Conditions | 005 | 010 | 025 | 050 | 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 | Commercial (T _J = 85°C) | 32.2 | 47.2 | 69.7 | 101.0 | 141.5 | 219.2 | mA |
| | | Industrial (T _J = 100°C) | 47.5 | 70.4 | 104.9 | 152.6 | 214.6 | 333.6 | mA |
| IDC2 | Flash*Freeze | Commercial (T _J = 85°C) | 21.5 | 30.3 | 39.1 | 43.6 | 58.0 | 71.1 | mA |
| | | Industrial (T _J = 100°C) | 33.2 | 46.7 | 60.2 | 67.1 | 89.3 | 109.6 | mA |

5.2. Programming Currents

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

Table 11 • Currents During Program Cycle, 0°C ≤ Tj ≤ 85°C – Typical Process

| Power Supplies | Voltage (V) | 005 | 010 | 025 | 050 | 090 | 150 | Units | Notes |
|-----------------|-------------|-----|-----|-----|-----|-----|-----|-------|-------|
| VDD | 1.26 | 46 | 53 | 55 | 58 | 42 | 52 | mA | |
| VPP | 3.46 | 8 | 11 | 6 | 10 | 12 | 12 | mA | |
| VPPNVM | 3.46 | 1 | 2 | 2 | 3 | 3 | – | mA | * |
| VDDI | 2.62 | 31 | 16 | 17 | 1 | 12 | 81 | mA | |
| | 3.46 | 62 | 31 | 36 | 1 | 17 | 84 | mA | |
| Number of banks | – | 7 | 8 | 8 | 10 | 9 | 19 | – | |

*Note: *VPP and VPPNVM are internally shorted.*

Table 12 • Currents During Verify Cycle, 0°C ≤ Tj ≤ 85°C – Typical Process

| Power Supplies | Voltage (V) | 005 | 010 | 025 | 050 | 090 | 150 | Units | Notes |
|-----------------|-------------|-----|-----|-----|-----|-----|-----|-------|-------|
| VDD | 1.26 | 44 | 53 | 55 | 58 | 41 | 51 | mA | |
| VPP | 3.46 | 6 | 5 | 3 | 15 | 11 | 12 | mA | |
| VPPNVM | 3.46 | 1 | 0 | 0 | 1 | 1 | – | mA | * |
| VDDI | 2.62 | 31 | 16 | 17 | 1 | 11 | 81 | mA | |
| | 3.46 | 61 | 32 | 36 | 1 | 17 | 84 | mA | |
| Number of banks | – | 7 | 8 | 8 | 10 | 9 | 19 | – | |

*Note: *VPP and VPPNVM are internally shorted.*

Table 13 • Inrush Currents at Power up, –40°C ≤ Tj ≤ 100°C – Typical Process

| Power Supplies | Voltage (V) | 005 | 010 | 025 | 050 | 090 | 150 | Units |
|-----------------|-------------|-----|-----|-----|-----|-----|-----|-------|
| VDD | 1.26 | 25 | 32 | 38 | 48 | 77 | 109 | mA |
| VPP | 3.46 | 33 | 49 | 36 | 180 | 36 | 51 | mA |
| VDDI | 2.62 | 134 | 141 | 161 | 187 | 272 | 388 | mA |
| Number of banks | – | 7 | 8 | 8 | 10 | 9 | 19 | – |

6. Average Fabric Temperature and Voltage Derating Factors

Table 14 • Average Temperature and Voltage Derating Factors for Fabric Timing Delays
Normalized to $T_J = 85^\circ\text{C}$, Worst-case VDD = 1.14 V

| Array Voltage VDD (V) | Junction Temperature ($^\circ\text{C}$) | | | | | |
|--------------------------|---|-------------------|--------------------|--------------------|--------------------|---------------------|
| | -40°C | 0°C | 25°C | 70°C | 85°C | 100°C |
| 1.14 | 0.83 | 0.89 | 0.92 | 0.98 | 1.00 | 1.02 |
| 1.2 | 0.75 | 0.80 | 0.83 | 0.89 | 0.91 | 0.93 |
| 1.26 | 0.69 | 0.73 | 0.76 | 0.81 | 0.83 | 0.85 |

7. Timing Model



Figure 1 • Timing Model

Table 15 • Timing Model ParametersWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Index | Parameter | Description | Speed Grade -1 | Units | For More Information |
|-------|-------------|---|----------------|-------|----------------------|
| A | t_{PY} | Propagation delay of DDR3 Receiver | 1.605 | ns | Refer to page 58 |
| B | t_{CLKQ} | Clock-to-Q of the Input Data Register | 0.16 | ns | Refer to page 83 |
| | t_{SUD} | Setup Time of the Input Data Register | 0.357 | ns | Refer to page 83 |
| C | t_{RCKH} | Input High Delay for Global Clock | 1.53 | ns | Refer to page 90 |
| | t_{RCKL} | Input Low Delay for Global Clock | 0.897 | ns | Refer to page 90 |
| D | t_{PY} | Input Propagation Delay of LVDS Receiver | 2.774 | ns | Refer to page 66 |
| E | t_{DP} | Propagation Delay of a three-input AND Gate | 0.198 | ns | Refer to page 87 |
| F | t_{DP} | Propagation Delay of an OR Gate | 0.179 | ns | Refer to page 87 |
| G | t_{DP} | Propagation Delay of an LVDS Transmitter | 2.136 | ns | Refer to page 66 |
| H | t_{DP} | Propagation Delay of a three-input XOR Gate | 0.241 | ns | Refer to page 87 |
| I | t_{DP} | Propagation Delay of LVCMOS 2.5 V Transmitter, Drive strength of 16 mA on the MSIO Bank | 2.412 | ns | Refer to page 35 |
| J | t_{DP} | Propagation Delay of a two-input NAND Gate | 0.179 | ns | Refer to page 87 |
| K | t_{DP} | Propagation Delay of LVCMOS 2.5 V Transmitter, Drive strength of 8 mA on the MSIO Bank | 2.309 | ns | Refer to page 35 |
| L | t_{CLKQ} | Clock-to-Q of the Data Register | 0.108 | ns | Refer to page 89 |
| | t_{SUD} | Setup Time of the Data Register | 0.254 | ns | Refer to page 89 |
| M | t_{DP} | Propagation Delay of a two-input AND Gate | 0.179 | ns | Refer to page 87 |
| N | t_{OCLKQ} | Clock-to-Q of the Output Data Register | 0.263 | ns | Refer to page 80 |
| | t_{OSUD} | Setup Time of the Output Data Register | 0.19 | ns | Refer to page 80 |
| O | t_{DP} | Propagation Delay of SSTL2, Class I Transmitter on the MSIO Bank | 2.055 | ns | Refer to page 52 |
| P | t_{DP} | Propagation Delay of LVCMOS 1.5 V Transmitter, Drive strength of 12 mA, fast slew on the DDRIO Bank | 3.316 | ns | Refer to page 41 |

8. 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 *IGLOO2 FPGA Fabric Architecture User Guide* or the *SmartFusion2 FPGA Fabric Architecture User Guide*.

8.1 Input Buffer and AC Loading



Figure 2 • Input Buffer AC Loading

8.2. Output Buffer and AC Loading



Figure 3 • Output Buffer AC Loading

8.3. 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 Figure 4.



Figure 4 • Tristate Buffer for Enable Path Test Point

8.4 I/O Speeds

Table 16 • Maximum Data Rate Summary Table for Worst-Case Industrial Conditions

| Single-Ended I/O | MSIO | MSIOD | DDRIO | Units |
|--------------------------|------|-------|-------|-------|
| PCI 3.3 V | 630 | – | – | Mbps |
| LVTTL 3.3 V | 600 | – | – | Mbps |
| LVC MOS 3.3 V | 600 | – | – | Mbps |
| LVC MOS 2.5 V | 410 | 420 | 400 | Mbps |
| LVC MOS 1.8 V | 295 | 400 | 400 | Mbps |
| LVC MOS 1.5 V | 160 | 220 | 235 | Mbps |
| LVC MOS 1.2 V | 120 | 160 | 200 | Mbps |
| LPDDR-LVC MOS 1.8 V Mode | – | – | 400 | Mbps |
| Voltage-Referenced I/O | MSIO | MSIOD | DDRIO | Units |
| LPDDR | – | – | 400 | Mbps |
| HSTL1.5 V | – | – | 400 | Mbps |
| SSTL 2.5 V | 510 | 700 | 400 | Mbps |
| Voltage-Referenced I/O | MSIO | MSIOD | DDRIO | Units |
| SSTL 1.8 V | – | – | 667 | Mbps |
| SSTL 1.5 V | – | – | 667 | Mbps |
| Differential I/O | MSIO | MSIOD | DDRIO | Units |
| LVPECL (input only) | 900 | – | – | Mbps |
| LVDS 3.3 V | 535 | 700 | – | Mbps |
| LVDS 2.5 V | 535 | 700 | – | Mbps |
| RS DS | 520 | 700 | – | Mbps |
| BLVDS | 500 | – | – | Mbps |
| MLVDS | 500 | – | – | Mbps |
| Mini-LVDS | 520 | 700 | – | Mbps |

Note: Refer to the individual I/O standards for operating conditions.

Table 17 • Maximum Frequency Summary Table for Worst-Case Industrial Conditions

| Single-Ended I/O | MSIO | MSIOD | DDRIO | Units |
|---------------------------|-------|-------|-------|-------|
| PCI 3.3 V | 315 | – | – | MHz |
| LVTTL 3.3 V | 300 | – | – | MHz |
| LVC MOS 3.3 V | 300 | – | – | MHz |
| LVC MOS 2.5 V | 205 | 210 | 200 | MHz |
| LVC MOS 1.8 V | 147.5 | 200 | 200 | MHz |
| LVC MOS 1.5 V | 80 | 110 | 118 | MHz |
| LVC MOS 1.2 V | 60 | 80 | 100 | MHz |
| LPDDR– LVC MOS 1.8 V mode | – | – | 200 | MHz |

Table 17 • Maximum Frequency Summary Table for Worst-Case Industrial Conditions (continued)

| Voltage-Referenced I/O | MSIO | MSIOD | DDRIO | Units |
|--|-------------|--------------|--------------|--------------|
| LPDDR | – | – | 200 | MHz |
| HSTL1.5 V | – | – | 200 | MHz |
| SSTL 2.5 V | 255 | 350 | 200 | MHz |
| SSTL 1.8 V | – | – | 334 | MHz |
| SSTL 1.5 V | – | – | 334 | MHz |
| Differential I/O | MSIO | MSIOD | DDRIO | Units |
| LVPECL (input only) | 450 | – | – | MHz |
| LVDS 3.3 V | 267.5 | 350 | – | MHz |
| LVDS 2.5 V | 267.5 | 350 | – | MHz |
| RSDS | 260 | 350 | – | MHz |
| BLVDS | 250 | – | – | MHz |
| MLVDS | 250 | – | – | MHz |
| Mini-LVDS | 260 | 350 | – | MHz |
| <i>Note: Refer to the individual I/O standards for operating conditions.</i> | | | | |

8.5 Detailed I/O Characteristics

Table 18 • Input Capacitance

| Symbol | Definition | Minimum | Maximum | Units |
|----------|-------------------|---------|---------|-------|
| C_{IN} | Input capacitance | – | 10 | pF |

Table 19 • I/O Weak Pull-Up/Pull-Down Resistances for DDRIO I/O Bank
Minimum and Maximum Weak Pull-Up/Pull-Down Resistance Values at VOH/VOL Level

| | DDRIO I/O Bank | | | | Notes |
|-------------|-------------------------------------|-------|---------------------------------------|-------|-------|
| | R(WEAK PULL-UP) at VOH (Ω) | | R(WEAK PULL-DOWN) at VOL (Ω) | | |
| VDDI Domain | Min | Max | Min | Max | |
| 2.5 V | 10K | 15.1K | 9.98K | 15.3K | 1, 2 |
| 1.8 V | 10.3K | 16.2K | 10.3K | 16.6K | 1, 2 |
| 1.5 V | 10.6K | 17.2K | 10.6K | 17.9K | 1, 2 |
| 1.2 V | 11.1K | 19.3K | 11.2K | 20.9K | 1, 2 |

Notes:

- $R(\text{WEAK PULL-DOWN}) = (VOL_{\text{spec}}) / I(\text{WEAK PULL-DOWN MAX})$
- $R(\text{WEAK PULL-UP}) = (VDDI_{\text{max}} - VOH_{\text{spec}}) / I(\text{WEAK PULL-UP MIN})$

Table 20 • I/O Weak Pull-Up/Pull-Down Resistances for MSIO I/O Bank
Minimum and Maximum Weak Pull-Up/Pull-Down Resistance Values at VOH/VOL Level

| | MSIO I/O Bank | | | | Notes |
|-------------|-------------------------------------|-------|---------------------------------------|-------|-------|
| | R(WEAK PULL-UP) at VOH (Ω) | | R(WEAK PULL-DOWN) at VOL (Ω) | | |
| VDDI Domain | Min | Max | Min | Max | |
| 3.3 V | 9.9K | 14.5K | 9.98K | 14.9K | – |
| 2.5 V | 10K | 15K | 10.1K | 15.6K | 1, 2 |
| 1.8 V | 10.4K | 16.2K | 10.4K | 17.3K | 1, 2 |
| 1.5 V | 10.7K | 17.3K | 10.8K | 18.9K | 1, 2 |
| 1.2 V | 11.3K | 19.7K | 11.5K | 22.7K | 1, 2 |

Notes:

- $R(\text{WEAK PULL-DOWN}) = (VOL_{\text{spec}}) / I(\text{WEAK PULL-DOWN MAX})$
- $R(\text{WEAK PULL-UP}) = (VDDI_{\text{max}} - VOH_{\text{spec}}) / I(\text{WEAK PULL-UP MIN})$

Table 21 • I/O Weak Pull-Up/Pull-Down Resistances for MSIOD I/O Bank
Minimum and Maximum Weak Pull-Up/Pull-Down Resistance Values at VOH/VOL Level

| | MSIOD I/O Bank | | | | |
|-------------|-------------------------------------|-------|---------------------------------------|-------|-------|
| | R(WEAK PULL-UP) at VOH (Ω) | | R(WEAK PULL-DOWN) at VOL (Ω) | | |
| VDDI Domain | Min | Max | Min | Max | Notes |
| 2.5 V | 9.6K | 14.1K | 9.5K | 13.9K | 1, 2 |
| 1.8 V | 9.7K | 14.7K | 9.7K | 14.5K | 1, 2 |
| 1.5 V | 9.9K | 15.3K | 9.8K | 15K | 1, 2 |
| 1.2 V | 10.3K | 16.7K | 10K | 16.2K | 1, 2 |

Notes:

- $R(\text{WEAK PULL-DOWN}) = (V_{OL\text{spec}}) / I(\text{WEAK PULL-DOWN MAX})$
- $R(\text{WEAK PULL-UP}) = (V_{DDI\text{max}} - V_{OH\text{spec}}) / I(\text{WEAK PULL-UP MIN})$

Table 22 • 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 | $0.05 \times V_{DDI}$ (Worst-case) |
| 2.5 V LVCMOS | $0.05 \times V_{DDI}$ (Worst-case) |
| 1.8 V LVCMOS | $0.1 \times V_{DDI}$ (Worst-case) |
| 1.5 V LVCMOS | 60 mV |
| 1.2 V LVCMOS | 20 mV |

8.6 Single-Ended I/O Standards

8.6.1 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.

8.6.2 3.3 V LVCMOS/LVTTTL

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

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

Table 23 • LVTTTL/LVCMOS 3.3 V DC Voltage Specification (Applicable to MSIO I/O Bank Only)

| Symbol | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|---|----------------------|------------|------------|-----|------|-------|-------|
| LVTTTL/LVCMOS 3.3 V DC Recommended DC Operating Conditions | | | | | | | |
| VDDI | Supply voltage | | 3.15 | 3.3 | 3.45 | V | |
| LVTTTL/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 | |
| IIH (DC) | Input current High | | – | – | 10 | μA | |
| IIL (DC) | Input current Low | | – | – | 10 | μA | |
| Symbol | Parameters | Conditions | Min | Typ | Max | Units | Notes |
| LVCMOS 3.3 V DC Output Voltage Specification | | | | | | | |
| VOH | DC output logic High | | VDDI – 0.4 | – | – | V | * |
| VOL | DC output logic Low | | – | – | 0.4 | V | * |
| LVTTTL 3.3 V DC Output Voltage Specification | | | | | | | |
| VOH | DC output logic High | | 2.4 | – | – | V | |
| VOL | DC output logic Low | | – | – | 0.4 | V | |
| <i>Note: * The VOH/VOL test points selected ensure compliance with LVCMOS 3.3 V JESD8-B requirements.</i> | | | | | | | |

Table 24 • LVTTTL/LVCMOS 3.3 V AC Specifications (Applicable to MSIO I/O Bank Only)

| Symbol | Parameters | Conditions | Min | Typ | Max | Units |
|--|--|--|-----|-----|-----|-------|
| LVTTTL/LVCMOS 3.3 V Maximum Switching Speed | | | | | | |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 600 | Mbps |
| LVTTTL/LVCMOS 3.3 V AC Test Parameters Specifications | | | | | | |
| Vtrip | Measuring/trip point for data path | | – | 1.4 | – | 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 25 • LVTTTL/LVCMOS 3.3 V Transmitter Drive Strength Specifications

| Output Drive Selection | VOH (V) | VOL (V) | IOH (at VOH) mA | IOL (at VOL) mA |
|---|------------|---------|-----------------|-----------------|
| MSIO I/O Bank | | | | |
| 2 mA | VDDI – 0.4 | 0.4 | 2 | 2 |
| 4 mA | VDDI – 0.4 | 0.4 | 4 | 4 |
| 8 mA | VDDI – 0.4 | 0.4 | 8 | 8 |
| 12 mA | VDDI – 0.4 | 0.4 | 12 | 12 |
| 16 mA | VDDI – 0.4 | 0.4 | 16 | 16 |
| 20 mA | VDDI – 0.4 | 0.4 | 20 | 20 |
| <i>Note: For a detailed I/V curve, use the corresponding IBIS models: www.microsemi.com/soc/download/ibis/default.aspx.</i> | | | | |

8.6.2.2 AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, VDDI = 3.0 V

AC Switching Characteristics for Receiver (Input Buffers)**Table 26 • LVTTL/LVCMOS 3.3 V Receiver Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{PY} | | t_{PYS} | | Units |
|--|--------------------------|-------------|-------|-----------|-------|-------|
| | | Speed Grade | | | | |
| | | -1 | Std | -1 | Std | |
| LVTTL/LVCMOS 3.3 V (for MSIO I/O Bank) | None | 2.262 | 2.663 | 2.289 | 2.695 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 27 • LVTTTL/LVCMOS 3.3 V Transmitter Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|---|--------------|-------------|-------|----------|-------|----------|-------|------------|-------|------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVTTTL/LVCMOS 3.3 V (for MSIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 3.192 | 3.755 | 3.47 | 4.083 | 2.969 | 3.494 | 1.856 | 2.183 | 3.337 | 3.926 | ns |
| 4 mA | Slow | 2.331 | 2.742 | 2.673 | 3.145 | 2.526 | 2.973 | 3.034 | 3.569 | 4.451 | 5.236 | ns |
| 8 mA | Slow | 2.135 | 2.511 | 2.33 | 2.741 | 2.297 | 2.703 | 4.532 | 5.331 | 4.825 | 5.676 | ns |
| 12 mA | Slow | 2.052 | 2.414 | 2.107 | 2.479 | 2.162 | 2.544 | 5.75 | 6.764 | 5.445 | 6.406 | ns |
| 16 mA | Slow | 2.062 | 2.425 | 2.072 | 2.438 | 2.145 | 2.525 | 5.993 | 7.05 | 5.625 | 6.618 | ns |
| 20 mA | Slow | 2.148 | 2.527 | 1.999 | 2.353 | 2.088 | 2.458 | 6.262 | 7.367 | 5.876 | 6.913 | ns |
| <i>Note: *Delay increases with drive strength are inherent to built-in slew control circuitry for simultaneous switching output (SSO) management.</i> | | | | | | | | | | | | |

8.6.3 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.

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

Table 28 • LVCMOS 2.5 V DC Voltage Specification

| Symbol | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|--|---|------------|------------|-----|-------|-------|-------|
| LVCMOS 2.5 V DC 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 Banks) | | 1.7 | – | 2.625 | V | |
| VIH (DC) | DC input logic High (for MSIO I/O Bank) | | 1.7 | – | 3.45 | V | |
| VIL (DC) | DC input logic Low | | –0.3 | – | 0.7 | V | |
| IIH (DC) | Input current High | | – | – | 10 | μA | |
| IIL (DC) | Input current Low | | – | – | 10 | μA | |
| LVCMOS 2.5 V DC Output Voltage Specification | | | | | | | |
| VOH | DC output logic High | | VDDI – 0.4 | – | – | V | * |
| VOL | DC output logic Low | | – | – | 0.4 | V | * |
| <i>Note: *The VOH/VOL test points selected ensure compliance with LVCMOS 2.5 V JEDEC8-5A requirements.</i> | | | | | | | |

Table 29 • LVCMOS 2.5 V AC Specifications

| Symbol | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|--|-----|------------------------|-----|-------|
| LVCMOS 2.5 V AC Minimum and Maximum Switching Speed | | | | | | |
| Dmax | Maximum data rate (for DDRIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 400 | Mbps |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 410 | Mbps |
| Dmax | Maximum data rate (for MSIOD I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 420 | Mbps |
| LVCMOS 2.5 V AC Calibrated Impedance Option | | | | | | |
| Rodt_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 | | | | | | |
| Vtrip | Measuring/trip point for data path | | – | 1.2 | – | 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 30 • LVCMOS 2.5 V Transmitter Drive Strength Specifications

| Output Drive Selection | | | VOH (V) | VOL (V) | IOH (at VOH) mA | IOL (at VOL) mA |
|------------------------|----------------|---|------------|---------|-----------------|-----------------|
| MSIO I/O Bank | MSIOD I/O Bank | DDRIO I/O Bank (With Software Default Fixed Code) | Min | Max | | |
| 2 mA | 2 mA | 2 mA | VDDI – 0.4 | 0.4 | 2 | 2 |
| 4 mA | 4 mA | 4 mA | VDDI – 0.4 | 0.4 | 4 | 4 |
| 6 mA | 6 mA | 6 mA | VDDI – 0.4 | 0.4 | 6 | 6 |
| 8 mA | 8 mA | 8 mA | VDDI – 0.4 | 0.4 | 8 | 8 |
| 12 mA | 12 mA | 12 mA | VDDI – 0.4 | 0.4 | 12 | 12 |
| 16 mA | N/A | 16 mA | VDDI – 0.4 | 0.4 | 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: www.microsemi.com/soc/download/ibis/default.aspx.

8.6.3.2 AC Switching CharacteristicsWorst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V, VDDI = 2.375 V**AC Switching Characteristics for Receiver (Input Buffers)****Table 31 • LVCMOS 2.5 V Receiver Characteristics**Worst-Case Commercial Conditions: T_J = 85°C, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t _{py} | | t _{pys} | | Units |
|-----------------------------------|--------------------------|-----------------|-------|------------------|-------|-------|
| | | Speed Grade | | | | |
| | | –1 | Std | –1 | Std | |
| LVCMOS 2.5 V (for DDRIO I/O Bank) | None | 1.823 | 2.145 | 1.932 | 2.274 | ns |
| LVCMOS 2.5 V (for MSIO I/O Bank) | None | 2.486 | 2.925 | 2.495 | 2.935 | ns |
| LVCMOS 2.5 V (for MSIOD I/O Bank) | None | 2.29 | 2.694 | 2.305 | 2.712 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 32 • LVCMOS 2.5 V Transmitter Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|--|--------------|-------------|-------|----------|-------|----------|-------|------------|-------|------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVCMOS 2.5 V (for DDRIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 3.657 | 4.302 | 3.393 | 3.991 | 3.675 | 4.323 | 3.894 | 4.582 | 3.552 | 4.18 | ns |
| | Medium | 3.374 | 3.97 | 3.139 | 3.693 | 3.396 | 3.995 | 3.635 | 4.277 | 3.253 | 3.828 | ns |
| | Medium fast | 3.239 | 3.811 | 3.036 | 3.572 | 3.261 | 3.836 | 3.519 | 4.141 | 3.128 | 3.681 | ns |
| | Fast | 3.224 | 3.793 | 3.029 | 3.563 | 3.246 | 3.818 | 3.512 | 4.132 | 3.119 | 3.67 | ns |
| 4 mA | Slow | 3.095 | 3.641 | 2.705 | 3.182 | 3.088 | 3.633 | 4.738 | 5.575 | 4.348 | 5.116 | ns |
| | Medium | 2.825 | 3.324 | 2.488 | 2.927 | 2.823 | 3.321 | 4.492 | 5.285 | 4.063 | 4.781 | ns |
| | Medium fast | 2.701 | 3.178 | 2.384 | 2.804 | 2.698 | 3.173 | 4.364 | 5.135 | 3.945 | 4.642 | ns |
| | Fast | 2.69 | 3.165 | 2.377 | 2.796 | 2.687 | 3.161 | 4.359 | 5.129 | 3.94 | 4.636 | ns |
| 6 mA | Slow | 2.919 | 3.434 | 2.491 | 2.93 | 2.902 | 3.414 | 5.085 | 5.983 | 4.674 | 5.5 | ns |
| | Medium | 2.65 | 3.118 | 2.279 | 2.681 | 2.642 | 3.108 | 4.845 | 5.701 | 4.375 | 5.148 | ns |
| | Medium fast | 2.529 | 2.975 | 2.176 | 2.56 | 2.521 | 2.965 | 4.724 | 5.558 | 4.259 | 5.011 | ns |
| | Fast | 2.516 | 2.96 | 2.168 | 2.551 | 2.508 | 2.95 | 4.717 | 5.55 | 4.251 | 5.002 | ns |
| 8 mA | Slow | 2.863 | 3.368 | 2.427 | 2.855 | 2.844 | 3.346 | 5.196 | 6.114 | 4.769 | 5.612 | ns |
| | Medium | 2.599 | 3.058 | 2.217 | 2.608 | 2.59 | 3.047 | 4.952 | 5.827 | 4.471 | 5.261 | ns |
| | Medium fast | 2.483 | 2.921 | 2.114 | 2.487 | 2.473 | 2.91 | 4.832 | 5.685 | 4.364 | 5.134 | ns |
| | Fast | 2.467 | 2.902 | 2.106 | 2.478 | 2.457 | 2.89 | 4.826 | 5.678 | 4.348 | 5.116 | ns |
| 12 mA | Slow | 2.747 | 3.232 | 2.296 | 2.701 | 2.724 | 3.204 | 5.39 | 6.342 | 4.938 | 5.81 | ns |
| | Medium | 2.493 | 2.934 | 2.102 | 2.473 | 2.483 | 2.921 | 5.166 | 6.078 | 4.65 | 5.471 | ns |
| | Medium fast | 2.382 | 2.803 | 2.006 | 2.36 | 2.371 | 2.789 | 5.067 | 5.962 | 4.546 | 5.349 | ns |
| | Fast | 2.369 | 2.787 | 1.999 | 2.352 | 2.357 | 2.773 | 5.063 | 5.958 | 4.538 | 5.339 | ns |
| 16 mA | Slow | 2.677 | 3.149 | 2.213 | 2.604 | 2.649 | 3.116 | 5.575 | 6.56 | 5.08 | 5.977 | ns |
| | Medium | 2.432 | 2.862 | 2.028 | 2.386 | 2.421 | 2.848 | 5.372 | 6.32 | 4.801 | 5.649 | ns |
| | Medium fast | 2.324 | 2.734 | 1.937 | 2.278 | 2.311 | 2.718 | 5.297 | 6.233 | 4.7 | 5.531 | ns |
| | Fast | 2.313 | 2.721 | 1.929 | 2.269 | 2.3 | 2.706 | 5.296 | 6.231 | 4.699 | 5.529 | ns |
| LVCMOS 2.5 V (for MSIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 3.48 | 4.095 | 3.855 | 4.534 | 3.785 | 4.453 | 2.12 | 2.494 | 3.45 | 4.059 | ns |
| 4 mA | Slow | 2.583 | 3.039 | 3.042 | 3.579 | 3.138 | 3.691 | 4.143 | 4.874 | 4.687 | 5.513 | ns |
| 6 mA | Slow | 2.392 | 2.815 | 2.669 | 3.139 | 2.82 | 3.317 | 4.909 | 5.775 | 5.083 | 5.98 | ns |
| 8 mA | Slow | 2.309 | 2.717 | 2.565 | 3.017 | 2.74 | 3.223 | 5.812 | 6.837 | 5.523 | 6.497 | ns |
| 12 mA | Slow | 2.333 | 2.745 | 2.437 | 2.867 | 2.626 | 3.089 | 6.131 | 7.213 | 5.712 | 6.72 | ns |
| 16 mA | Slow | 2.412 | 2.838 | 2.335 | 2.747 | 2.533 | 2.979 | 6.54 | 7.694 | 6.007 | 7.067 | ns |

Table 32 • LVCMOS 2.5 V Transmitter Characteristics (continued)
Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|---|--------------|-------------|-------|----------|-------|----------|-------|------------|-------|------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVCMOS 2.5 V (for MSIOD I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 2.206 | 2.596 | 2.678 | 3.15 | 2.64 | 3.106 | 4.935 | 5.805 | 4.74 | 5.576 | ns |
| 4 mA | Slow | 1.835 | 2.159 | 2.242 | 2.637 | 2.256 | 2.654 | 5.413 | 6.368 | 5.15 | 6.059 | ns |
| 6 mA | Slow | 1.709 | 2.01 | 2.132 | 2.508 | 2.167 | 2.549 | 5.813 | 6.838 | 5.499 | 6.469 | ns |
| 8 mA | Slow | 1.63 | 1.918 | 1.958 | 2.303 | 2.012 | 2.367 | 6.226 | 7.324 | 5.816 | 6.842 | ns |
| 12 mA | Slow | 1.648 | 1.939 | 1.86 | 2.187 | 1.921 | 2.259 | 6.519 | 7.669 | 6.027 | 7.09 | ns |
| <i>Note: *Delay increases with drive strength are inherent to built-in slew control circuitry for simultaneous switching output (SSO) management.</i> | | | | | | | | | | | | |

8.6.4 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.

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

Table 33 • LVCMOS 1.8 V DC Voltage Specification

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|---|------------|-----------------------|-----|-----------------------|---------------|
| LVCMOS 1.8 V DC Recommended Operating Conditions | | | | | | |
| VDDI | Supply voltage | | 1.710 | 1.8 | 1.89 | V |
| LVCMOS 1.8 V DC Input Voltage Specification | | | | | | |
| V _{IH} (DC) | DC input logic High (for MSIOD and DDRIO I/O Banks) | | $0.65 \times V_{DDI}$ | – | 1.89 | V |
| V _{IH} (DC) | DC input logic High (for MSIO I/O Bank) | | $0.65 \times V_{DDI}$ | – | 3.45 | V |
| V _{IL} (DC) | DC input logic Low | | –0.3 | – | $0.35 \times V_{DDI}$ | V |
| I _{IH} (DC) | Input current High | | – | – | 10 | μA |
| I _{IL} (DC) | Input current Low | | – | – | 10 | μA |
| LVCMOS 1.8 V DC Output Voltage Specification | | | | | | |
| V _{OH} | DC output logic High | | $V_{DDI} - 0.45$ | – | – | V |
| V _{OL} | DC output logic Low | | – | – | 0.45 | V |

Table 34 • LVCMOS 1.8 V AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|--|--|--|-----|-----|-----|-------|-------|
| LVCMOS 1.8 V Minimum and Maximum AC Switching Speed | | | | | | | |
| D _{max} | Maximum data rate (for DDRIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 400 | Mbps | * |
| D _{max} | Maximum data rate (for MSIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 295 | Mbps | |
| D _{max} | Maximum data rate (for MSIOD I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 400 | Mbps | * |

Table 34 • LVCMOS 1.8 V AC Specifications (continued)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|---|--|------------|-----|------------------------|-----|-------|-------|
| LVCMOS 1.8 V AC Calibrated Impedance Option | | | | | | | |
| 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 | |
| <i>Note: *Maximum Data Rate applies for Drive Strength 8mA and above, All Slews</i> | | | | | | | |

Table 35 • LVCMOS 1.8 V Transmitter Drive Strength Specifications

| Output Drive Selection | | | VOH (V) | | IOH (at VOH) mA | IOL (at VOL) mA | Notes |
|--|----------------|----------------|-------------|------|-----------------|-----------------|-------|
| MSIO I/O Bank | MSIOD I/O Bank | DDRIO I/O Bank | Min | Max | | | |
| 2 mA | 2 mA | 2 mA | VDDI – 0.45 | 0.45 | 2 | 2 | |
| 4 mA | 4 mA | 4 mA | VDDI – 0.45 | 0.45 | 4 | 4 | |
| 6 mA | 6 mA | 6 mA | VDDI – 0.45 | 0.45 | 6 | 6 | |
| 8 mA | 8 mA | 8 mA | VDDI – 0.45 | 0.45 | 8 | 8 | |
| 10 mA | 10 mA | 10 mA | VDDI – 0.45 | 0.45 | 10 | 10 | |
| 12 mA | N/A | 12 mA | VDDI – 0.45 | 0.45 | 12 | 12 | |
| N/A | N/A | 16 mA | VDDI – 0.45 | 0.45 | 16 | 16 | * |
| <i>Note: *16mA Drive Strengths, All Slews, meets LPDDR JEDEC Electrical Compliance</i> | | | | | | | |

8.6.4.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 36 • LVCMOS 1.8 V Receiver Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case V_{DDI}

| | On-Die Termination (ODT) | t_{PY} | | t_{PVS} | | Units |
|--|--------------------------|-------------|-------|-----------|-------|-------|
| | | Speed Grade | | | | |
| | | -1 | Std | -1 | Std | |
| LVCMOS 1.8 V (for DDRIO I/O Bank with FIXED CODES) | None | 1.968 | 2.315 | 2.099 | 2.47 | ns |
| | 50 | 2.898 | 3.411 | 2.883 | 3.393 | ns |
| LVCMOS 1.8 V (for MSIO I/O Bank) | None | 2.898 | 3.411 | 2.883 | 3.393 | ns |
| | 50 | 3.05 | 3.59 | 3.044 | 3.583 | ns |
| | 75 | 2.999 | 3.53 | 2.987 | 3.516 | ns |
| | 150 | 2.947 | 3.469 | 2.933 | 3.452 | ns |
| LVCMOS 1.8 V (for MSIOD I/O Bank) | None | 2.611 | 3.071 | 2.598 | 3.057 | ns |
| | 50 | 2.775 | 3.264 | 2.775 | 3.265 | ns |
| | 75 | 2.72 | 3.2 | 2.712 | 3.19 | ns |
| | 150 | 2.666 | 3.137 | 2.655 | 3.123 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 37 • LVCMOS 1.8 V Transmitter Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case V_{DDI}

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|---|--------------|-------------|-------|----------|-------|----------|-------|------------|-------|------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVCMOS 1.8 V (for DDRIO I/O Bank with Fixed Code) | | | | | | | | | | | | |
| 2 mA | Slow | 4.234 | 4.981 | 3.646 | 4.29 | 4.245 | 4.995 | 4.908 | 5.774 | 4.434 | 5.216 | ns |
| | Medium | 3.824 | 4.498 | 3.282 | 3.861 | 3.834 | 4.511 | 4.625 | 5.441 | 4.116 | 4.843 | ns |
| | Medium fast | 3.627 | 4.267 | 3.111 | 3.66 | 3.637 | 4.279 | 4.481 | 5.272 | 3.984 | 4.687 | ns |
| | Fast | 3.605 | 4.241 | 3.097 | 3.644 | 3.615 | 4.253 | 4.472 | 5.262 | 3.973 | 4.674 | ns |
| 4 mA | Slow | 3.923 | 4.615 | 3.314 | 3.9 | 3.918 | 4.61 | 5.403 | 6.356 | 4.894 | 5.757 | ns |
| | Medium | 3.518 | 4.138 | 2.961 | 3.484 | 3.515 | 4.135 | 5.121 | 6.025 | 4.561 | 5.366 | ns |
| | Medium fast | 3.321 | 3.907 | 2.783 | 3.275 | 3.317 | 3.903 | 4.966 | 5.843 | 4.426 | 5.206 | ns |
| | Fast | 3.301 | 3.883 | 2.77 | 3.259 | 3.296 | 3.878 | 4.957 | 5.831 | 4.417 | 5.196 | ns |
| 6 mA | Slow | 3.71 | 4.364 | 3.104 | 3.652 | 3.702 | 4.355 | 5.62 | 6.612 | 5.08 | 5.977 | ns |
| | Medium | 3.333 | 3.921 | 2.779 | 3.27 | 3.325 | 3.913 | 5.346 | 6.289 | 4.777 | 5.62 | ns |
| | Medium fast | 3.155 | 3.712 | 2.62 | 3.083 | 3.146 | 3.702 | 5.21 | 6.13 | 4.657 | 5.479 | ns |
| | Fast | 3.134 | 3.688 | 2.608 | 3.068 | 3.125 | 3.677 | 5.202 | 6.12 | 4.648 | 5.468 | ns |

Table 37 • LVCMOS 1.8 V Transmitter Characteristics (continued)
Worst-Case Commercial Conditions: T_J = 85°C, VDD = 1.14 V, Worst-Case VDDI

| Output Drive Selection | Slew Control | t _{DP} | | t _{ZL} | | t _{ZH} | | t _{HZ} * | | t _{LZ} * | | Units |
|---|--------------|-----------------|-------|-----------------|-------|-----------------|-------|-------------------|-------|-------------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| 8 mA | Slow | 3.619 | 4.258 | 3.007 | 3.538 | 3.607 | 4.244 | 5.815 | 6.841 | 5.249 | 6.175 | ns |
| | Medium | 3.246 | 3.819 | 2.686 | 3.16 | 3.236 | 3.807 | 5.542 | 6.52 | 4.936 | 5.807 | ns |
| | Medium fast | 3.066 | 3.607 | 2.525 | 2.971 | 3.054 | 3.593 | 5.405 | 6.359 | 4.811 | 5.66 | ns |
| | Fast | 3.046 | 3.584 | 2.513 | 2.957 | 3.034 | 3.57 | 5.401 | 6.353 | 4.803 | 5.651 | ns |
| 10 mA | Slow | 3.498 | 4.115 | 2.878 | 3.386 | 3.481 | 4.096 | 6.046 | 7.113 | 5.444 | 6.404 | ns |
| | Medium | 3.138 | 3.692 | 2.569 | 3.023 | 3.126 | 3.678 | 5.782 | 6.803 | 5.129 | 6.034 | ns |
| | Medium fast | 2.966 | 3.489 | 2.414 | 2.841 | 2.951 | 3.472 | 5.666 | 6.665 | 5.013 | 5.897 | ns |
| | Fast | 2.945 | 3.464 | 2.401 | 2.826 | 2.93 | 3.448 | 5.659 | 6.658 | 5.003 | 5.886 | ns |
| 12 mA | Slow | 3.417 | 4.02 | 2.807 | 3.303 | 3.401 | 4.002 | 6.083 | 7.156 | 5.464 | 6.428 | ns |
| | Medium | 3.076 | 3.618 | 2.519 | 2.964 | 3.063 | 3.604 | 5.828 | 6.856 | 5.176 | 6.089 | ns |
| | Medium fast | 2.913 | 3.427 | 2.376 | 2.795 | 2.898 | 3.41 | 5.725 | 6.736 | 5.072 | 5.966 | ns |
| | Fast | 2.894 | 3.405 | 2.362 | 2.78 | 2.879 | 3.388 | 5.715 | 6.724 | 5.064 | 5.957 | ns |
| 16 mA | Slow | 3.366 | 3.96 | 2.751 | 3.237 | 3.348 | 3.939 | 6.226 | 7.324 | 5.576 | 6.56 | ns |
| | Medium | 3.03 | 3.565 | 2.47 | 2.906 | 3.017 | 3.55 | 5.981 | 7.036 | 5.282 | 6.214 | ns |
| | Medium fast | 2.87 | 3.377 | 2.328 | 2.739 | 2.854 | 3.358 | 5.895 | 6.935 | 5.18 | 6.094 | ns |
| | Fast | 2.853 | 3.357 | 2.314 | 2.723 | 2.837 | 3.338 | 5.889 | 6.929 | 5.177 | 6.09 | ns |
| LVCMOS 1.8 V (for MSIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 3.441 | 4.047 | 4.165 | 4.9 | 4.413 | 5.192 | 4.891 | 5.755 | 5.138 | 6.044 | ns |
| 4 mA | Slow | 3.218 | 3.786 | 3.642 | 4.284 | 3.941 | 4.636 | 5.665 | 6.665 | 5.568 | 6.551 | ns |
| 6 mA | Slow | 3.141 | 3.694 | 3.501 | 4.118 | 3.823 | 4.498 | 6.587 | 7.75 | 6.032 | 7.096 | ns |
| 8 mA | Slow | 3.165 | 3.723 | 3.319 | 3.904 | 3.654 | 4.298 | 6.898 | 8.115 | 6.216 | 7.313 | ns |
| 10 mA | Slow | 3.202 | 3.767 | 3.278 | 3.857 | 3.616 | 4.254 | 7.25 | 8.529 | 6.435 | 7.571 | ns |
| 12 mA | Slow | 3.277 | 3.855 | 3.175 | 3.736 | 3.519 | 4.139 | 7.392 | 8.697 | 6.538 | 7.692 | ns |
| LVCMOS 1.8 V (for MSIOD I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 2.725 | 3.206 | 3.316 | 3.901 | 3.484 | 4.099 | 5.204 | 6.123 | 4.997 | 5.88 | ns |
| 4 mA | Slow | 2.242 | 2.638 | 2.777 | 3.267 | 2.947 | 3.466 | 5.729 | 6.74 | 5.448 | 6.41 | ns |
| 6 mA | Slow | 1.995 | 2.347 | 2.466 | 2.901 | 2.63 | 3.094 | 6.372 | 7.496 | 5.987 | 7.043 | ns |
| 8 mA | Slow | 2.001 | 2.354 | 2.44 | 2.87 | 2.6 | 3.058 | 6.633 | 7.804 | 6.193 | 7.286 | ns |
| 10 mA | Slow | 2.025 | 2.382 | 2.312 | 2.719 | 2.47 | 2.906 | 6.94 | 8.165 | 6.412 | 7.544 | ns |
| <i>Note: *Delay increases with drive strength are inherent to built-in slew control circuitry for simultaneous switching output (SSO) management.</i> | | | | | | | | | | | | |

8.6.5 1.5 V LVCMOS

LVCMOS 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.

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

Table 38 • LVCMOS 1.5 V DC Voltage Specification

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|---|------------|--------------------|-----|--------------------|-------|
| LVCMOS 1.5 V DC Recommended Operating Conditions | | | | | | |
| VDDI | Supply voltage | | 1.425 | 1.5 | 1.575 | V |
| LVCMOS 1.5 V DC Input Voltage Specification | | | | | | |
| VIH (DC) | DC input logic High for (MSIOD and DDRIO I/O Banks) | | $0.65 \times VDDI$ | – | 1.575 | V |
| VIH (DC) | DC input logic High (for MSIO I/O Bank) | | $0.65 \times VDDI$ | – | 3.45 | V |
| VIL (DC) | DC input logic Low | | –0.3 | – | $0.35 \times VDDI$ | V |
| I _{IH} (DC) | Input current High | | – | – | 10 | μA |
| I _{IL} (DC) | Input current Low | | – | – | 10 | μA |
| LVCMOS 1.5 V DC Output Voltage Specification | | | | | | |
| VOH | DC output logic High | | $VDDI \times 0.75$ | – | – | V |
| VOL | DC output logic Low | | – | – | $VDDI \times 0.25$ | V |

Table 39 • LVCMOS 1.5 V AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|--|-----|----------------|-----|-------|
| LVCMOS 1.5 V AC Minimum and Maximum Switching Speed | | | | | | |
| D _{max} | Maximum data rate (for DDRIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 235 | Mbps |
| D _{max} | Maximum data rate (for MSIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 160 | Mbps |
| D _{max} | Maximum data rate (for MSIOD I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 220 | Mbps |
| LVCMOS 1.5 V AC Calibrated Impedance Option | | | | | | |
| R _{odt_cal} | Supported output driver calibrated impedance (for DDRIO I/O Bank) | | – | 75, 60, 50, 40 | – | Ω |
| LVCMOS 1.5 V AC Test Parameters Specifications | | | | | | |
| V _{trip} | Measuring/trip point | | – | 0.75 | – | 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 40 • LVC MOS 1.5 V Transmitter Drive Strength Specifications

| Output Drive Selection | | | VOH (V) | VOL (V) | IOH (at VOH) mA | IOL (at VOL) mA |
|------------------------|----------------|----------------|-------------|-------------|--------------------|--------------------|
| MSIO I/O Bank | MSIOD I/O Bank | DDRIO I/O Bank | Min | Max | | |
| 2 mA | 2 mA | 2 mA | VDDI × 0.75 | VDDI × 0.25 | 2 | 2 |
| 4 mA | 4 mA | 4 mA | VDDI × 0.75 | VDDI × 0.25 | 4 | 4 |
| 6 mA | 6 mA | 6 mA | VDDI × 0.75 | VDDI × 0.25 | 6 | 6 |
| 8 mA | N/A | 8 mA | VDDI × 0.75 | VDDI × 0.25 | 8 | 8 |
| N/A | N/A | 10 mA | VDDI × 0.75 | VDDI × 0.25 | 10 | 10 |
| N/A | N/A | 12 mA | VDDI × 0.75 | VDDI × 0.25 | 12 | 12 |

Note: For a detailed I/V curve, use the corresponding IBIS models: www.microsemi.com/soc/download/ibis/default.aspx.

8.6.5.2 AC Switching CharacteristicsWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, VDDI = 1.425 V**AC Switching Characteristics for Receiver (Input Buffers)****Table 41 • LVC MOS 1.5 V Receiver Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{PY} | | t_{PYS} | | Units |
|---|--------------------------|-------------|-------|-----------|-------|-------|
| | | Speed Grade | | | | |
| | | -1 | Std | -1 | Std | |
| LVC MOS 1.5 V (for DDRIO I/O Bank with FIXED CODES) | None | 2.051 | 2.413 | 2.086 | 2.455 | ns |
| LVC MOS 1.5 V (for MSIO I/O Bank) | None | 3.311 | 3.896 | 3.285 | 3.865 | ns |
| | 50 | 3.654 | 4.299 | 3.623 | 4.263 | ns |
| | 75 | 3.533 | 4.156 | 3.501 | 4.119 | ns |
| | 150 | 3.415 | 4.018 | 3.388 | 3.986 | ns |
| LVC MOS 1.5 V (for MSIOD I/O Bank) | None | 2.959 | 3.481 | 2.93 | 3.447 | ns |
| | 50 | 3.298 | 3.88 | 3.268 | 3.845 | ns |
| | 75 | 3.162 | 3.719 | 3.128 | 3.68 | ns |
| | 150 | 3.053 | 3.592 | 3.021 | 3.554 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 42 • LVC MOS 1.5 V Transmitter Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|------------------------------------|--------------|-------------|-------|----------|-------|----------|-------|------------|-------|------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVC MOS 1.5 V (for DDRIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 5.122 | 6.026 | 4.31 | 5.07 | 5.145 | 6.052 | 5.258 | 6.186 | 4.672 | 5.496 | ns |
| | Medium | 4.58 | 5.389 | 3.86 | 4.54 | 4.6 | 5.411 | 4.977 | 5.855 | 4.357 | 5.126 | ns |
| | Medium fast | 4.323 | 5.086 | 3.629 | 4.269 | 4.341 | 5.107 | 4.804 | 5.652 | 4.228 | 4.974 | ns |
| | Fast | 4.296 | 5.054 | 3.609 | 4.245 | 4.314 | 5.075 | 4.791 | 5.636 | 4.219 | 4.963 | ns |

Table 42 • LVCMOS 1.5 V Transmitter Characteristics (continued)
Worst-Case Commercial Conditions: T_J = 85°C, VDD = 1.14 V, Worst-Case VDDI

| Output Drive Selection | Slew Control | t _{DP} | | t _{ZL} | | t _{ZH} | | t _{HZ} * | | t _{LZ} * | | Units |
|---|--------------|-----------------|-------|-----------------|-------|-----------------|-------|-------------------|-------|-------------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| 4 mA | Slow | 4.449 | 5.235 | 3.707 | 4.361 | 4.443 | 5.227 | 6.058 | 7.127 | 5.458 | 6.421 | ns |
| | Medium | 3.961 | 4.66 | 3.264 | 3.839 | 3.954 | 4.651 | 5.778 | 6.797 | 5.116 | 6.018 | ns |
| | Medium fast | 3.729 | 4.387 | 3.043 | 3.579 | 3.72 | 4.376 | 5.63 | 6.624 | 4.981 | 5.86 | ns |
| | Fast | 3.704 | 4.358 | 3.027 | 3.56 | 3.695 | 4.347 | 5.624 | 6.617 | 4.973 | 5.851 | ns |
| 6 mA | Slow | 4.244 | 4.993 | 3.465 | 4.076 | 4.233 | 4.979 | 6.39 | 7.518 | 5.736 | 6.748 | ns |
| | Medium | 3.774 | 4.44 | 3.05 | 3.587 | 3.762 | 4.426 | 6.114 | 7.193 | 5.397 | 6.35 | ns |
| | Medium fast | 3.544 | 4.17 | 2.839 | 3.339 | 3.529 | 4.152 | 5.978 | 7.033 | 5.27 | 6.2 | ns |
| | Fast | 3.519 | 4.14 | 2.82 | 3.317 | 3.504 | 4.122 | 5.965 | 7.017 | 5.259 | 6.187 | ns |
| 8 mA | Slow | 4.099 | 4.823 | 3.311 | 3.894 | 4.087 | 4.807 | 6.584 | 7.746 | 5.854 | 6.888 | ns |
| | Medium | 3.656 | 4.301 | 2.927 | 3.443 | 3.642 | 4.284 | 6.311 | 7.425 | 5.553 | 6.533 | ns |
| | Medium fast | 3.437 | 4.044 | 2.731 | 3.213 | 3.42 | 4.023 | 6.182 | 7.273 | 5.435 | 6.394 | ns |
| | Fast | 3.41 | 4.012 | 2.715 | 3.193 | 3.393 | 3.991 | 6.178 | 7.269 | 5.425 | 6.383 | ns |
| 10 mA | Slow | 4.029 | 4.74 | 3.238 | 3.809 | 4.015 | 4.723 | 6.732 | 7.921 | 5.965 | 7.018 | ns |
| | Medium | 3.601 | 4.237 | 2.867 | 3.372 | 3.586 | 4.218 | 6.473 | 7.615 | 5.669 | 6.669 | ns |
| | Medium fast | 3.384 | 3.981 | 2.672 | 3.143 | 3.365 | 3.958 | 6.351 | 7.471 | 5.55 | 6.529 | ns |
| | Fast | 3.357 | 3.949 | 2.655 | 3.123 | 3.338 | 3.927 | 6.345 | 7.464 | 5.54 | 6.518 | ns |
| 12 mA | Slow | 3.974 | 4.675 | 3.196 | 3.759 | 3.958 | 4.656 | 6.842 | 8.049 | 6.068 | 7.139 | ns |
| | Medium | 3.55 | 4.176 | 2.827 | 3.326 | 3.534 | 4.157 | 6.584 | 7.746 | 5.751 | 6.766 | ns |
| | Medium fast | 3.345 | 3.935 | 2.638 | 3.103 | 3.325 | 3.911 | 6.488 | 7.633 | 5.641 | 6.637 | ns |
| | Fast | 3.316 | 3.902 | 2.621 | 3.083 | 3.297 | 3.878 | 6.486 | 7.63 | 5.626 | 6.619 | ns |
| LVCMOS 1.5 V (for MSIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 4.423 | 5.203 | 5.397 | 6.35 | 5.686 | 6.69 | 5.609 | 6.599 | 5.561 | 6.542 | ns |
| 4 mA | Slow | 4.05 | 4.765 | 4.503 | 5.298 | 4.92 | 5.788 | 7.358 | 8.657 | 6.525 | 7.677 | ns |
| 6 mA | Slow | 4.081 | 4.801 | 4.259 | 5.012 | 4.699 | 5.528 | 7.659 | 9.011 | 6.709 | 7.893 | ns |
| 8 mA | Slow | 4.234 | 4.98 | 4.068 | 4.786 | 4.521 | 5.319 | 8.218 | 9.668 | 7.05 | 8.294 | ns |
| LVCMOS 1.5 V (for MSIOD I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 2.735 | 3.218 | 3.371 | 3.966 | 3.618 | 4.257 | 6.03 | 7.095 | 5.705 | 6.712 | ns |
| 4 mA | Slow | 2.426 | 2.854 | 2.992 | 3.521 | 3.221 | 3.79 | 6.738 | 7.927 | 6.298 | 7.41 | ns |
| 6 mA | Slow | 2.433 | 2.862 | 2.81 | 3.306 | 3.031 | 3.566 | 7.123 | 8.38 | 6.596 | 7.76 | ns |
| <i>Note: *Delay increases with drive strength are inherent to built-in slew control circuitry for simultaneous switching output (SSO) management.</i> | | | | | | | | | | | | |

8.6.6 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.

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

Table 43 • LVCMOS 1.2 V DC Voltage Specification

| Symbols | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|--|---|------------|--------------------|-----|--------------------|-------|-------|
| LVCMOS 1.2 V DC 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) | | $0.65 \times VDDI$ | – | 1.26 | V | |
| VIH (DC) | DC input logic High (for MSIO I/O Bank) | | $0.65 \times VDDI$ | – | 3.45 | V | |
| VIL (DC) | DC input logic Low | | –0.3 | – | $0.35 \times VDDI$ | V | |
| IIH (DC) | Input current High | | – | – | 10 | μA | |
| IIL (DC) | Input current Low | | – | – | 10 | μA | |
| LVCMOS 1.2 V DC Output Voltage Specification | | | | | | | |
| VOH | DC output logic High | | $VDDI \times 0.75$ | – | – | V | |
| VOL | DC output logic Low | | – | – | $VDDI \times 0.25$ | V | |

Table 44 • LVCMOS 1.2 V AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|--|--|-----|----------------|-----|-------|
| LVCMOS 1.2 V Minimum and Maximum AC Switching Speed | | | | | | |
| Dmax | Maximum data rate (for DDRIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 200 | Mbps |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 120 | Mbps |
| Dmax | Maximum data rate (for MSIOD I/O Bank) | AC loading: 17 pF load, maximum drive/slew | – | – | 160 | Mbps |
| 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 | | – | 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 45 • LVCMOS 1.2 V Transmitter Drive Strength Specifications

| Output Drive Selection | | | VOH (V) | VOL (V) | IOH (at VOH) mA | IOL (at VOL) mA |
|------------------------|----------------|----------------|-------------|-------------|--------------------|--------------------|
| MSIO I/O Bank | MSIOD I/O Bank | DDRIO I/O Bank | Min | Max | | |
| 2 mA | 2 mA | 2 mA | VDDI × 0.75 | VDDI × 0.25 | 2 | 2 |
| 4 mA | 4 mA | 4 mA | VDDI × 0.75 | VDDI × 0.25 | 4 | 4 |
| N/A | N/A | 6 mA | VDDI × 0.75 | VDDI × 0.25 | 6 | 6 |

Note: For a detailed I/V curve, use the corresponding IBIS models: www.microsemi.com/soc/download/ibis/default.aspx.

8.6.6.2 AC Switching CharacteristicsWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, VDDI = 1.14 V**AC Switching Characteristics for Receiver (Input Buffers)****Table 46 • LVCMOS 1.2 V Receiver Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{PY} | | t_{PYS} | | Units |
|---|-----------------------------|-------------|-------|-----------|-------|-------|
| | | Speed Grade | | | | |
| | | -1 | Std | -1 | Std | |
| LVCMOS 1.2 V (for DDRIO I/O Bank with Fixed Code) | None | 2.448 | 2.88 | 2.466 | 2.901 | ns |
| LVCMOS 1.2 V (for MSIO I/O Bank) | None | 4.714 | 5.545 | 4.675 | 5.5 | ns |
| | 50 | 6.668 | 7.845 | 6.579 | 7.74 | ns |
| | 75 | 5.832 | 6.862 | 5.76 | 6.777 | ns |
| | 150 | 5.162 | 6.073 | 5.111 | 6.014 | ns |
| LVCMOS 1.2 V (for MSIOD I/O Bank) | None | 4.154 | 4.887 | 4.114 | 4.84 | ns |
| | 50 | 6.918 | 8.139 | 6.806 | 8.008 | ns |
| | 75 | 5.613 | 6.603 | 5.533 | 6.509 | ns |
| | 150 | 4.716 | 5.549 | 4.657 | 5.479 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 47 • LVCMOS 1.2 V Transmitter Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|---|--------------|-------------|-------|----------|-------|----------|-------|------------|--------|------------|--------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVCMOS 1.2 V (for DDRIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 6.713 | 7.897 | 5.362 | 6.308 | 6.723 | 7.909 | 7.233 | 8.51 | 6.375 | 7.499 | ns |
| | Medium | 5.912 | 6.955 | 4.616 | 5.43 | 5.915 | 6.959 | 6.887 | 8.102 | 6.009 | 7.069 | ns |
| | Medium fast | 5.5 | 6.469 | 4.231 | 4.978 | 5.5 | 6.471 | 6.672 | 7.849 | 5.835 | 6.865 | ns |
| | Fast | 5.462 | 6.426 | 4.194 | 4.935 | 5.463 | 6.427 | 6.646 | 7.819 | 5.828 | 6.857 | ns |
| 4 mA | Slow | 6.109 | 7.186 | 4.708 | 5.539 | 6.098 | 7.174 | 8.005 | 9.418 | 7.033 | 8.274 | ns |
| | Medium | 5.355 | 6.299 | 4.034 | 4.746 | 5.338 | 6.28 | 7.637 | 8.985 | 6.672 | 7.849 | ns |
| | Medium fast | 4.953 | 5.826 | 3.685 | 4.336 | 4.932 | 5.802 | 7.44 | 8.752 | 6.499 | 7.646 | ns |
| | Fast | 4.911 | 5.777 | 3.658 | 4.303 | 4.89 | 5.754 | 7.427 | 8.737 | 6.488 | 7.632 | ns |
| 6 mA | Slow | 5.89 | 6.929 | 4.506 | 5.301 | 5.874 | 6.911 | 8.337 | 9.808 | 7.315 | 8.605 | ns |
| | Medium | 5.176 | 6.089 | 3.862 | 4.543 | 5.155 | 6.065 | 7.986 | 9.394 | 6.943 | 8.168 | ns |
| | Medium fast | 4.792 | 5.637 | 3.523 | 4.145 | 4.765 | 5.606 | 7.808 | 9.186 | 6.775 | 7.97 | ns |
| | Fast | 4.754 | 5.593 | 3.486 | 4.101 | 4.728 | 5.563 | 7.777 | 9.149 | 6.769 | 7.963 | ns |
| LVCMOS 1.2 V (for MSIO I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 6.746 | 7.937 | 7.458 | 8.774 | 8.172 | 9.614 | 9.867 | 11.608 | 8.393 | 9.874 | ns |
| 4 mA | Slow | 7.068 | 8.315 | 6.678 | 7.857 | 7.474 | 8.793 | 10.986 | 12.924 | 9.043 | 10.638 | ns |
| LVCMOS 1.2 V (for MSIOD I/O Bank) | | | | | | | | | | | | |
| 2 mA | Slow | 3.883 | 4.568 | 4.868 | 5.726 | 5.329 | 6.269 | 7.994 | 9.404 | 7.527 | 8.855 | ns |
| 4 mA | Slow | 3.774 | 4.44 | 4.188 | 4.926 | 4.613 | 5.426 | 8.972 | 10.555 | 8.315 | 9.782 | ns |
| <i>Note: *Delay increases with drive strength are inherent to built-in slew control circuitry for simultaneous switching output (SSO) management.</i> | | | | | | | | | | | | |

8.6.7 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.

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

Table 48 • PCI/PCI-X DC Voltage Specification (Applicable to MSIO Bank Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|----------------------|------------|-----------------------|-----|------|-------|
| PCI/PCIX DC Recommended 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 |
| I _{IH} (DC) | Input current High | | – | – | 10 | μA |
| I _{IL} (DC) | Input current Low | | – | – | 10 | μA |
| 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 49 • PCI/PCI-X AC Specifications (Applicable to MSIO Bank Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|---|--------------------------------------|-----|--------------|-----|-------|
| PCI/PCI-X Minimum and Maximum AC Switching Speed | | | | | | |
| D _{max} | Maximum data rate (MSIO I/O Bank) | AC Loading: per JEDEC specifications | – | – | 630 | Mbps |
| PCI/PCI-X AC Test Parameters Specifications | | | | | | |
| V _{trip} | Measuring/trip point for data path (falling edge) | | – | 0.615 × VDDI | – | V |
| V _{trip} | Measuring/trip point for data path (rising edge) | | – | 0.285 × VDDI | – | V |
| R _{tt_test} | Resistance for data test path | | – | 25 | – | Ω |
| 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}) | | – | 10 | – | pF |

8.6.7.2 AC Switching Characteristics

Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V, VDDI = 3.0 V

AC Switching Characteristics for Receiver (Input Buffers)

Table 50 • PCI/PCIX AC Switching Characteristics for Receiver (Input Buffers)

Worst-Case Commercial Conditions: T_J = 85°C, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t _{py} | | t _{pys} | | Units |
|------------------------------|--------------------------|-----------------|-------|------------------|-------|-------|
| | | Speed Grade | | | | |
| | | –1 | Std | –1 | Std | |
| PCI/PCIX (for MSIO I/O Bank) | None | 2.229 | 2.623 | 2.238 | 2.633 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 51 • PCI/PCIX AC switching Characteristics for Transmitter (Output Buffers)**Worst-Case Commercial Conditions: $T_J = 85^{\circ}\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{zL} | | t_{zH} | | t_{HZ} | | t_{LZ} | | Units |
|------------------------------|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| PCI/PCIX (for MSIO I/O Bank) | 2.146 | 2.525 | 2.043 | 2.404 | 2.084 | 2.452 | 6.095 | 7.171 | 5.558 | 6.539 | ns |

8.7 Memory Interface and Voltage Referenced I/O Standards

8.7.1 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.

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

Table 52 • 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 | | VREF + 0.1 | – | 1.575 | V |
| VIL (DC) | DC input logic Low | | –0.3 | – | VREF – 0.1 | V |
| IIH (DC) | Input current High | | – | – | 10 | μA |
| IIL (DC) | Input current Low | | – | – | 10 | μA |
| HSTL DC Output Voltage Specification | | | | | | |
| HSTL Class I | | | | | | |
| VOH | DC output logic High | | VDDI – 0.4 | – | – | V |
| VOL | DC output logic Low | | – | – | 0.4 | V |
| IOH at VOH | Output minimum source DC current (MSIO and DDRIO I/O Banks) | | –8.0 | – | – | mA |
| IOL at VOL | Output minimum sink current (MSIO and DDRIO I/O Banks) | | 8.0 | – | – | mA |
| HSTL Class II (Applicable to DDRIO I/O Bank Only) | | | | | | |
| VOH | DC output logic High | | VDDI – 0.4 | – | – | V |
| VOL | DC output logic Low | | – | – | 0.4 | V |
| IOH at VOH | Output minimum source DC current | | –16.0 | – | – | mA |
| IOL at VOL | Output minimum sink current | | 16.0 | – | – | mA |
| HSTL DC Differential Voltage Specifications | | | | | | |
| VID (DC) | DC input differential voltage | | 0.2 | – | – | V |

Table 53 • HSTL AC Specifications (Applicable to DDRIO Bank Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|--------------------------------------|------|------------|-----|-------|
| HSTL AC Differential Voltage Specifications | | | | | | |
| V _{DIFF} | AC input differential voltage | | 0.4 | – | – | V |
| V _x | AC differential cross point voltage | | 0.68 | – | 0.9 | V |
| HSTL Minimum and Maximum AC Switching Speed | | | | | | |
| D _{max} | Maximum data rate | AC loading: per JEDEC specifications | – | – | 400 | Mbps |
| HSTL Impedance Specification | | | | | | |
| R _{ref} | Supported output driver calibrated impedance (for DDRIO I/O Bank) | Reference resistance = 191 Ω | – | 25.5, 47.8 | – | Ω |
| R _{TT} | Effective impedance value (ODT for DDRIO I/O Bank only) | Reference resistance = 191 Ω | – | 47.8 | – | Ω |
| HSTL AC Test Parameters Specification | | | | | | |
| V _{trip} | Measuring/trip point for data path | | – | 0.75 | – | 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 HSTL15 Class I (t _{DP}) | | – | 50 | – | Ω |
| R _{tt_test} | Reference resistance for data test path for HSTL15 Class II (t _{DP}) | | – | 25 | – | Ω |
| C _{load} | Capacitive loading for data path (t _{DP}) | | – | 5 | – | pF |

8.7.1.2 AC Switching Characteristics

AC Switching Characteristics for Receiver (Input Buffers)

Table 54 • HSTL Receiver CharacteristicsWorst-Case Commercial Conditions: T_J = 85°C, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t _{py} | | Units |
|--|--------------------------|-----------------|-------|-------|
| | | Speed Grade | | |
| | | –1 | Std | |
| HSTL (for DDRIO I/O Bank with Fixed Code) | | | | |
| Pseudo differential | None | 1.605 | 1.888 | ns |
| | 47.8 | 1.614 | 1.898 | ns |
| True differential | None | 1.622 | 1.909 | ns |
| | 47.8 | 1.628 | 1.916 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 55 • HSTL Transmitter Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|---|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| HSTL Class I (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.6 | 3.059 | 2.514 | 2.958 | 2.514 | 2.958 | 2.431 | 2.86 | 2.431 | 2.86 | ns |
| Differential | 2.621 | 3.083 | 2.648 | 3.115 | 2.647 | 3.113 | 2.925 | 3.442 | 2.923 | 3.44 | ns |
| HSTL Class II (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.511 | 2.954 | 2.488 | 2.927 | 2.49 | 2.93 | 2.409 | 2.833 | 2.411 | 2.836 | ns |
| Differential | 2.528 | 2.974 | 2.552 | 3.003 | 2.551 | 3.001 | 2.897 | 3.409 | 2.896 | 3.408 | ns |

8.7.2 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.

8.7.3 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.

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

Table 56 • DDR1/SSTL2 DC Voltage Specification

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|----------------------------------|------------|------------------|-------|------------------|---------------|
| DDR/SSTL2 DC Recommended 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 |
| DDR/SSTL2 DC Input Voltage Specification | | | | | | |
| VIH (DC) | DC input logic High | | $V_{REF} + 0.15$ | – | 2.625 | V |
| VIL (DC) | DC input logic Low | | –0.3 | – | $V_{REF} - 0.15$ | V |
| IIH (DC) | Input current High | | – | – | 10 | μA |
| IIL (DC) | Input current Lo | | – | – | 10 | μA |
| DDR/SSTL2 DC Output Voltage Specification | | | | | | |
| SSTL2 Class I (DDR Reduced Drive) | | | | | | |
| VOH | DC output logic High | | $V_{TT} + 0.608$ | – | – | V |
| VOL | DC output logic Low | | – | – | $V_{TT} - 0.608$ | V |
| IOH at VOH | Output minimum source DC current | | 8.1 | – | – | mA |

Table 56 • DDR1/SSTL2 DC Voltage Specification (continued)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|----------------------------------|------------|------------|-----|------------|-------|
| 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 57 • DDR1/SSTL2 AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|--|--------------------------------------|-------------------------|--------|-------------------------|----------|
| SSTL2 AC Differential Voltage Specification | | | | | | |
| VDIFF (AC) | AC input differential voltage | | 0.7 | - | - | V |
| Vx (AC) | AC differential cross point voltage | | $0.5 \times VDDI - 0.2$ | - | $0.5 \times VDDI + 0.2$ | V |
| SSTL2 Minimum and Maximum AC Switching Speeds | | | | | | |
| Dmax | Maximum data rate (for DDRIO I/O Bank) | AC loading: per JEDEC specifications | - | - | 400 | Mbps |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 17pF load | - | - | 575 | Mbps |
| Dmax | Maximum data rate (for MSIOD I/O Bank) | AC loading: 3 pF / 50 Ω load | - | - | 700 | Mbps |
| | | AC loading: 17pF load | - | - | 510 | Mbps |
| SSTL2 Impedance Specifications | | | | | | |
| - | Supported output driver calibrated impedance (for DDRIO I/O Bank) | Reference resistor = 150 Ω | - | 20, 42 | - | Ω |
| AC Test Parameters Specifications | | | | | | |
| Vtrip | Measuring/trip point for data path | | - | 1.25 | - | 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 SSTL2 Class I (t_{DP}) | | - | 50 | - | Ω |
| Rtt_test | Reference resistance for data test path for SSTL2 Class II (t_{DP}) | | - | 25 | - | Ω |
| Cload | Capacitive loading for data path (t_{DP}) | | - | 5 | - | pF |

8.7.3.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 58 • DDR1/SSTL2 Receiver Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{PY} | | Units |
|-----------------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| SSTL2 (for DDRIO I/O Bank) | | | | |
| Pseudo differential | None | 1.549 | 1.821 | ns |
| True differential | None | 1.589 | 1.87 | ns |
| SSTL2 (for MSIO I/O Bank) | | | | |
| Pseudo differential | None | 2.798 | 3.293 | ns |
| True differential | None | 2.733 | 3.215 | ns |
| SSTL2 (for MSIOD I/O Bank) | | | | |
| Pseudo differential | None | 2.476 | 2.913 | ns |
| True differential | None | 2.475 | 2.911 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 59 • DDR1/SSTL2 Transmitter Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|--|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| SSTL2 Class I (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.26 | 2.66 | 1.99 | 2.341 | 1.985 | 2.335 | 2.135 | 2.512 | 2.13 | 2.505 | ns |
| Differential | 2.26 | 2.658 | 2.202 | 2.591 | 2.201 | 2.589 | 2.393 | 2.815 | 2.392 | 2.814 | ns |
| SSTL2 Class I (for MSIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.055 | 2.417 | 2.037 | 2.396 | 2.03 | 2.388 | 2.068 | 2.433 | 2.061 | 2.425 | ns |
| Differential | 2.192 | 2.58 | 2.434 | 2.864 | 2.425 | 2.852 | 2.164 | 2.545 | 2.156 | 2.536 | ns |
| SSTL2 Class I (for MSIOD I/O Bank) | | | | | | | | | | | |
| Single-ended | 1.512 | 1.779 | 1.462 | 1.72 | 1.462 | 1.72 | 1.676 | 1.972 | 1.676 | 1.971 | ns |
| Differential | 1.676 | 1.971 | 1.774 | 2.087 | 1.766 | 2.077 | 1.854 | 2.181 | 1.845 | 2.171 | ns |
| SSTL2 Class II (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.122 | 2.497 | 1.906 | 2.243 | 1.902 | 2.237 | 2.061 | 2.424 | 2.056 | 2.418 | ns |
| Differential | 2.127 | 2.501 | 2.042 | 2.402 | 2.043 | 2.403 | 2.363 | 2.78 | 2.365 | 2.781 | ns |
| SSTL2 Class I (for MSIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.29 | 2.693 | 1.988 | 2.338 | 1.978 | 2.326 | 1.989 | 2.34 | 1.979 | 2.328 | ns |
| Differential | 2.418 | 2.846 | 2.304 | 2.711 | 2.297 | 2.702 | 2.131 | 2.506 | 2.124 | 2.499 | ns |

8.7.4 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.

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

Table 60 • SSTL18 DC Minimum and Maximum DC Input and Output Levels

| Symbols | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|---|--|--------------|-------|-------|--------------|-------|-------|
| SSTL18 DC 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 | | – | – | 10 | μA | |
| IIL (DC) | Input current Low | | – | – | 10 | μA | |
| 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) | | 6.5 | – | – | mA | |
| IOL at VOL | Output minimum sink current (DDRIO I/O Bank only) | | –6.5 | – | – | mA | |
| SSTL18 Class II (DDR2 Full 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) | | 13.4 | – | – | mA | |
| IOL at VOL | Output minimum sink current (DDRIO I/O Bank only) | | –13.4 | – | – | mA | |
| SSTL18 DC Differential Voltage Specification | | | | | | | |
| VID (DC) | DC input differential voltage | | 0.3 | – | – | V | |
| <i>Note: *To meet JEDEC Electrical Compliance, use DDR2 Full Drive Transmitter.</i> | | | | | | | |

Table 61 • SSTL18 AC Specifications (Applicable to DDRIO Bank Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|-------------------------------------|------------------------------|-------------|------------------------------|-------|
| SSTL18 AC Differential Voltage Specification | | | | | | |
| V _{DIFF} (AC) | AC input differential voltage | | 0.5 | – | – | V |
| V _x (AC) | AC differential cross point voltage | | $0.5 \times V_{DDI} - 0.175$ | – | $0.5 \times V_{DDI} + 0.175$ | V |
| SSTL18 Minimum and Maximum AC Switching Speed | | | | | | |
| D _{max} | Maximum data rate (for DDRIO I/O Bank) | AC loading: per JEDEC specification | – | – | 667 | Mbps |
| SSTL18 Impedance Specifications | | | | | | |
| R _{ref} | Supported output driver calibrated impedance (for DDRIO I/O Bank) | Reference resistor = 150 Ω | – | 20, 42 | – | Ω |
| R _{TT} | Effective impedance value (ODT) | Reference resistor = 150 Ω | – | 50, 75, 150 | – | Ω |
| SSTL18 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 SSTL18 Class I (t _{DP}) | | – | 50 | – | Ω |
| R _{tt_test} | Reference resistance for data test path for SSTL18 Class II (t _{DP}) | | – | 25 | – | Ω |
| C _{load} | Capacitive loading for data path (t _{DP}) | | – | 5 | – | pF |

8.7.4.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.71\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 62 • DDR2/SSTL18 Receiver Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case V_{DDI}

| | On-Die Termination (ODT) | t_{PY} | | Units |
|--|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| SSTL18 (for DDRIO I/O Bank with Fixed Code) | | | | |
| Pseudo differential | None | 1.567 | 1.844 | ns |
| True differential | None | 1.588 | 1.869 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 63 • DDR2/SSTL18 Transmitter Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case V_{DDI}

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|---|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| SSTL18 Class I (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.383 | 2.804 | 2.23 | 2.623 | 2.229 | 2.622 | 2.202 | 2.591 | 2.201 | 2.59 | ns |
| Differential | 2.413 | 2.84 | 2.797 | 3.29 | 2.797 | 3.29 | 2.282 | 2.685 | 2.282 | 2.685 | ns |
| SSTL18 Class II (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.281 | 2.683 | 2.196 | 2.584 | 2.195 | 2.583 | 2.171 | 2.555 | 2.17 | 2.554 | ns |
| Differential | 2.315 | 2.724 | 2.698 | 3.173 | 2.698 | 3.173 | 2.242 | 2.639 | 2.242 | 2.639 | ns |

8.7.5 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.

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

Table 64 • SSTL15 DC Voltage Specification (for DDRIO I/O Bank Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|----------------------------------|------------|-------------------|-------|-------------------|-------|
| SSTL15 DC 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 | | – | – | 10 | μA |
| IIL (DC) | Input current Low | | – | – | 10 | μA |
| SSTL15 DC Output Voltage Specification | | | | | | |
| DDR3/SSTL15 Class I (DDR3 Reduced Drive) | | | | | | |
| VOH | DC output logic High | | $0.8 \times VDDI$ | – | – | V |
| VOL | DC output logic Low | | – | – | $0.2 \times VDDI$ | V |
| IOH at VOH | Output minimum source DC current | | 6.5 | – | – | mA |
| IOL at VOL | Output minimum sink current | | –6.5 | – | – | mA |
| DDR3/SSTL15 Class II (DDR3 Full Drive) | | | | | | |
| VOH | DC output logic High | | $0.8 \times VDDI$ | – | – | V |
| VOL | DC output logic Low | | – | – | $0.2 \times VDDI$ | 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 |
| <i>Note: *To meet JEDEC Electrical Compliance, use DDR3 Full Drive Transmitter.</i> | | | | | | |

Table 65 • SSTL15 AC Specifications (for DDRIO I/O Bank Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|---|--------------------------------------|---------------------------------|---------------------|---------------------------------|-------|
| SSTL15 Differential Voltage Specification | | | | | | |
| V _{DIFF} (AC) | AC input differential voltage | | 0.3 | – | – | V |
| V _x (AC) | AC differential cross point voltage | | $0.5 \times V_{DDI}$ – 0.150 | – | $0.5 \times V_{DDI} +$ 0.150 | V |
| SSTL15 Minimum and Maximum AC Switching Speed (for DDRIO I/O Banks only) | | | | | | |
| D _{max} | Maximum data rate | AC loading: per JEDEC specifications | – | – | 667 | Mbps |
| SSTL15 AC Calibrated Impedance Option | | | | | | |
| R _{ref} | Supported output driver calibrated impedance | Reference resistor = 240 Ω | – | 34, 40 | – | Ω |
| R _{TT} | Effective impedance value (ODT) | Reference resistor = 240 Ω | – | 20, 30, 40, 60, 120 | – | Ω |
| SSTL15 AC Test Parameters Specifications | | | | | | |
| V _{trip} | Measuring/trip point for data path | | – | 0.75 | – | 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 SSTL15 Class I (t _{DP}) | | – | 50 | – | Ω |
| R _{tt_test} | Reference resistance for data test path for SSTL15 Class II (t _{DP}) | | – | 25 | – | Ω |
| C _{load} | Capacitive loading for data path (t _{DP}) | | – | 5 | – | pF |

8.7.5.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 1.425\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 66 • DDR3/SSTL15 Receiver Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{py} | | Units |
|---|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| DDR3/SSTL15 (for DDRIO I/O Bank – with Calibration Only) | | | | |
| Pseudo differential | None | 1.605 | 1.888 | ns |
| | 20 | 1.616 | 1.901 | ns |
| | 30 | 1.613 | 1.897 | ns |
| | 40 | 1.611 | 1.895 | ns |
| | 60 | 1.609 | 1.893 | ns |
| | 120 | 1.607 | 1.89 | ns |
| True differential | None | 1.623 | 1.91 | ns |
| | 20 | 1.637 | 1.926 | ns |
| | 30 | 1.63 | 1.918 | ns |
| | 40 | 1.626 | 1.914 | ns |
| | 60 | 1.622 | 1.91 | ns |
| | 120 | 1.619 | 1.905 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 67 • DDR3/SSTL15 Transmitter Characteristics

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|---|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| DDR3 Reduced Drive/SSTL15 Class I (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.533 | 2.98 | 2.522 | 2.967 | 2.523 | 2.968 | 2.427 | 2.855 | 2.428 | 2.856 | ns |
| Differential | 2.555 | 3.005 | 3.073 | 3.615 | 3.073 | 3.615 | 2.416 | 2.843 | 2.416 | 2.843 | ns |
| DDR3 Full Drive/SSTL15 Class II (for DDRIO I/O Bank) | | | | | | | | | | | |
| Single-ended | 2.53 | 2.977 | 2.514 | 2.958 | 2.516 | 2.96 | 2.422 | 2.849 | 2.425 | 2.852 | ns |
| Differential | 2.552 | 3.002 | 2.591 | 3.048 | 2.59 | 3.047 | 2.882 | 3.391 | 2.881 | 3.39 | ns |

8.7.6 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.

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

Table 68 • LPDDR DC Voltage Specification

| Symbols | Parameters | Conditions | Min | Typ | Max | Units | Notes |
|--|----------------------------------|------------|-------------------|-------|-------------------|-------|-------|
| 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 | | – | – | 10 | μA | |
| IIL (DC) | Input current Low | | – | – | 10 | μA | |
| LPDDR DC Output Voltage Specification 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 DC Output Voltage Specification Full 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 Differential Voltage Specification | | | | | | | |
| VID (DC) | DC input differential voltage | | $0.4 \times VDDI$ | – | – | V | |
| <i>Note: *To meet JEDEC Electrical Compliance, use LPDDR Full Drive Transmitter.</i> | | | | | | | |

Table 69 • LPDDR AC Specifications (for DDRIO I/O Banks Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|--|--------------------------------------|-------------------|--------|-------------------|-------|
| LPDDR AC Differential Voltage Specification | | | | | | |
| VDIFF | AC input differential voltage | | $0.6 \times VDDI$ | – | – | V |
| Vx | AC differential cross point voltage | | $0.4 \times VDDI$ | – | $0.6 \times VDDI$ | V |
| LPDDR AC Specifications | | | | | | |
| Dmax | Maximum data rate | AC loading: per JEDEC specifications | – | – | 400 | Mbps |
| LPDDR AC Calibrated Impedance Option | | | | | | |
| Rref | Supported output driver calibrated impedance | Reference resistor = 150 Ω | – | 20, 42 | – | Ω |

Table 69 • LPDDR AC Specifications (for DDRIO I/O Banks Only) (continued)

| | | | | | | |
|--|--|-----------------------------------|---|-------------|---|----------|
| Rtt | Effective impedance value (ODT) | Reference resistor = 150 Ω | – | 50, 70, 150 | – | Ω |
| LPDDR 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 LPDDR (t_{DP}) | | – | 50 | – | Ω |
| Cload | Capacitive loading for data path (t_{DP}) | | – | 5 | – | Ω |

8.7.6.2 AC Switching Characteristics**Table 70 • LPDDR Receiver Characteristics****Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI**

| | On-Die Termination (ODT) | t_{py} | | Units |
|--|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | –1 | Std | |
| LPDDR (for DDRIO I/O Bank with FIXED CODES) | | | | |
| Pseudo differential | None | 1.568 | 1.845 | ns |
| True differential | None | 1.588 | 1.869 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 71 • LPDDR Transmitter Characteristics****Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI**

| | t_{DP} | | t_{ENZL} | | t_{ENZH} | | t_{ENHZ} | | t_{ENLZ} | | Units |
|---|-------------|-------|------------|-------|------------|-------|------------|-------|------------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | –1 | Std | –1 | Std | –1 | Std | –1 | Std | –1 | Std | |
| LPDDR Reduced Drive for DDRIO I/O Bank | | | | | | | | | | | |
| Single-ended | 2.383 | 2.804 | 2.23 | 2.623 | 2.229 | 2.622 | 2.202 | 2.591 | 2.201 | 2.59 | ns |
| Differential | 2.396 | 2.819 | 2.764 | 3.252 | 2.764 | 3.252 | 2.255 | 2.653 | 2.255 | 2.653 | ns |
| LPDDR Full Drive for DDRIO I/O Bank | | | | | | | | | | | |
| Single-ended | 2.281 | 2.683 | 2.196 | 2.584 | 2.195 | 2.583 | 2.171 | 2.555 | 2.17 | 2.554 | ns |
| Differential | 2.298 | 2.703 | 2.288 | 2.692 | 2.288 | 2.692 | 2.593 | 3.051 | 2.593 | 3.051 | ns |

8.7.6.3. Minimum and Maximum DC/AC Input and Output Levels Specification using LPDDR-LVCMOS 1.8 V Mode

Table 72 • LPDDR-LVCMOS 1.8 V Mode (Minimum and Maximum DC Input and Output Levels)

| 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 | | | | | | |
| V _{IH} (dc) | DC input Logic HIGH (for MSIOD and DDRIO I/O Banks) | | 0.65 × VDDI | – | 1.89 | V |
| V _{IH} (dc) | DC input Logic HIGH (for MSIO I/O Bank) | | 0.65 × VDDI | – | 3.45 | V |
| V _{IL} (dc) | DC input Logic LOW | | –0.3 | – | 0.35 × VDDI | V |
| I _{IH} (dc) | Input current HIGH | | – | – | 10 | uA |
| I _{IL} (dc) | Input current LOW | | – | – | 10 | uA |
| LPDDR-LVCMOS 1.8V Mode DC Output Voltage Specification | | | | | | |
| V _{OH} | DC output Logic HIGH | | VDDI – 0.45 | – | – | V |
| V _{OL} | DC output Logic LOW | | – | – | 0.45 | V |

Table 73 • LPDDR-LVCMOS 1.8 V Minimum and Maximum AC Switching Speeds

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|------------------|--|---|-----|-----|-----|-------|
| D _{max} | Maximum Data Rate (for DDRIO I/O Bank) | AC Loading: 17pF Load, 8mA Drive and Above/All Slew | – | – | 400 | Mbps |

Table 74 • LPDDR-LVCMOS 1.8 V Minimum and Maximum AC Input and Output Levels

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|---|------------|-----|-----------------------|-----|-------|
| LPDDR - LVCMOS 1.8 V Calibrated Impedance Option | | | | | | |
| R _{odt_cal} | Supported Output Driver Calibrated Impedance (for DDRIO I/O Bank) | | – | 75,60,50,3 3,25,20 | – | Ω |
| LPDDR- LVCMOS 1.8V 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 |
| C _{load} | Capacitive Loading for data path (t _{DP}) | | – | 5 | – | pF |

Table 75 • LPDDR-LVCMOS 1.8 V Mode Transmitter Drive Strength Specification

| Output Drive Selection | VOH (V) Min | VOL (V) Max | IOH (at VOH) mA | IOL (at VOL) mA | Notes |
|---|-------------|-------------|-----------------|-----------------|-------|
| DDRIO Bank | | | | | |
| 2mA | VDDI – 0.45 | 0.45 | 2 | 2 | |
| 4mA | VDDI – 0.45 | 0.45 | 4 | 4 | |
| 6mA | VDDI – 0.45 | 0.45 | 6 | 6 | |
| 8mA | VDDI – 0.45 | 0.45 | 8 | 8 | |
| 10mA | VDDI – 0.45 | 0.45 | 10 | 10 | |
| 12mA | VDDI – 0.45 | 0.45 | 12 | 12 | |
| 16mA | VDDI – 0.45 | 0.45 | 16 | 16 | * |
| <i>Note: *16mA Drive Strengths, All Slews, meet LPDDR JEDEC electrical compliance</i> | | | | | |

Table 76 • LPDDR-LVCMOS 1.8V AC Switching Characteristics for Receiver (Input Buffers)

| | ODT (On Die Termination) | Speed Grade | | | | Units |
|--|--------------------------|-------------|-------|-------|------|-------|
| | | –1 | Std | –1 | Std | |
| LPDDR-LVCMOS 1.8 mode (for DDRIO I/O Bank with Fixed Code) | None | 1.968 | 2.315 | 2.099 | 2.47 | ns |

Table 77 • LPDDR-LVCMOS 1.8 V AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

| Output Drive Selection | Slew Control | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ}^* | | t_{LZ}^* | | Units |
|--|--------------|-------------|-------|----------|-------|----------|-------|------------|-------|------------|-------|-------|
| | | Speed Grade | | | | | | | | | | |
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LPDDR-LVCMOS 1.8 V Mode (for DDRIO I/O Bank) | | | | | | | | | | | | |
| 2mA | slow | 4.234 | 4.981 | 3.646 | 4.29 | 4.245 | 4.995 | 4.908 | 5.774 | 4.434 | 5.216 | ns |
| | medium | 3.824 | 4.498 | 3.282 | 3.861 | 3.834 | 4.511 | 4.625 | 5.441 | 4.116 | 4.843 | ns |
| | medium_fast | 3.627 | 4.267 | 3.111 | 3.66 | 3.637 | 4.279 | 4.481 | 5.272 | 3.984 | 4.687 | ns |
| | fast | 3.605 | 4.241 | 3.097 | 3.644 | 3.615 | 4.253 | 4.472 | 5.262 | 3.973 | 4.674 | ns |
| 4mA | slow | 3.923 | 4.615 | 3.314 | 3.9 | 3.918 | 4.61 | 5.403 | 6.356 | 4.894 | 5.757 | ns |
| | medium | 3.518 | 4.138 | 2.961 | 3.484 | 3.515 | 4.135 | 5.121 | 6.025 | 4.561 | 5.366 | ns |
| | medium_fast | 3.321 | 3.907 | 2.783 | 3.275 | 3.317 | 3.903 | 4.966 | 5.843 | 4.426 | 5.206 | ns |
| | fast | 3.301 | 3.883 | 2.77 | 3.259 | 3.296 | 3.878 | 4.957 | 5.831 | 4.417 | 5.196 | ns |
| 6mA | slow | 3.71 | 4.364 | 3.104 | 3.652 | 3.702 | 4.355 | 5.62 | 6.612 | 5.08 | 5.977 | ns |
| | medium | 3.333 | 3.921 | 2.779 | 3.27 | 3.325 | 3.913 | 5.346 | 6.289 | 4.777 | 5.62 | ns |
| | medium_fast | 3.155 | 3.712 | 2.62 | 3.083 | 3.146 | 3.702 | 5.21 | 6.13 | 4.657 | 5.479 | ns |
| | fast | 3.134 | 3.688 | 2.608 | 3.068 | 3.125 | 3.677 | 5.202 | 6.12 | 4.648 | 5.468 | ns |
| 8mA | slow | 3.619 | 4.258 | 3.007 | 3.538 | 3.607 | 4.244 | 5.815 | 6.841 | 5.249 | 6.175 | ns |
| | medium | 3.246 | 3.819 | 2.686 | 3.16 | 3.236 | 3.807 | 5.542 | 6.52 | 4.936 | 5.807 | ns |
| | medium_fast | 3.066 | 3.607 | 2.525 | 2.971 | 3.054 | 3.593 | 5.405 | 6.359 | 4.811 | 5.66 | ns |
| | fast | 3.046 | 3.584 | 2.513 | 2.957 | 3.034 | 3.57 | 5.401 | 6.353 | 4.803 | 5.651 | ns |
| 10mA | slow | 3.498 | 4.115 | 2.878 | 3.386 | 3.481 | 4.096 | 6.046 | 7.113 | 5.444 | 6.404 | ns |
| | medium | 3.138 | 3.692 | 2.569 | 3.023 | 3.126 | 3.678 | 5.782 | 6.803 | 5.129 | 6.034 | ns |
| | medium_fast | 2.966 | 3.489 | 2.414 | 2.841 | 2.951 | 3.472 | 5.666 | 6.665 | 5.013 | 5.897 | ns |
| | fast | 2.945 | 3.464 | 2.401 | 2.826 | 2.93 | 3.448 | 5.659 | 6.658 | 5.003 | 5.886 | ns |
| 12mA | slow | 3.417 | 4.02 | 2.807 | 3.303 | 3.401 | 4.002 | 6.083 | 7.156 | 5.464 | 6.428 | ns |
| | medium | 3.076 | 3.618 | 2.519 | 2.964 | 3.063 | 3.604 | 5.828 | 6.856 | 5.176 | 6.089 | ns |
| | medium_fast | 2.913 | 3.427 | 2.376 | 2.795 | 2.898 | 3.41 | 5.725 | 6.736 | 5.072 | 5.966 | ns |
| | fast | 2.894 | 3.405 | 2.362 | 2.78 | 2.879 | 3.388 | 5.715 | 6.724 | 5.064 | 5.957 | ns |
| 16mA | slow | 3.366 | 3.96 | 2.751 | 3.237 | 3.348 | 3.939 | 6.226 | 7.324 | 5.576 | 6.56 | ns |
| | medium | 3.03 | 3.565 | 2.47 | 2.906 | 3.017 | 3.55 | 5.981 | 7.036 | 5.282 | 6.214 | ns |
| | medium_fast | 2.87 | 3.377 | 2.328 | 2.739 | 2.854 | 3.358 | 5.895 | 6.935 | 5.18 | 6.094 | ns |
| | fast | 2.853 | 3.357 | 2.314 | 2.723 | 2.837 | 3.338 | 5.889 | 6.929 | 5.177 | 6.09 | ns |

*Note: *Delay increases with drive strength are inherent to built-in slew control circuitry for simultaneous switching output (SSO) management).*

8.8. Differential I/O Standards

Configuration of the I/O modules as a differential pair is handled by Microsemi SoC Products Group Libero 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).

8.8.1 LVDS

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

8.8.1.1 Minimum and Maximum Input and Output Levels

Table 78 • 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 |
| IIH (DC) | Input current High | | – | – | 10 | μA |
| IIL (DC) | Input current Low | | – | – | 10 | μA |
| 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 | Input differential voltage | | 100 | 350 | 600 | mV |

Table 79 • LVDS AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|---|-----|-------------|-----|-------|
| LVDS Minimum and Maximum AC Switching Speed | | | | | | |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 12 pF / 100 Ω differential load | – | – | 535 | Mbps |
| Dmax | Maximum data rate (for MSIOD I/O Bank) no pre-emphasis | AC loading: 10 pF / 100 Ω differential load | – | – | 620 | Mbps |
| | | AC loading: 2 pF / 100 Ω differential load | – | – | 700 | Mbps |
| LVDS Impedance Specification | | | | | | |
| Rt | Termination resistance | | – | 100 | – | Ω |
| 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 |

8.8.1.2 LVDS25 AC Switching Characteristics

Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V, VDDI = 2.375 V

AC Switching Characteristics for Receiver (Input Buffers)**Table 80 • LVDS25 Receiver Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{py} | | Units |
|---------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| LVDS (for MSIO I/O Bank) | None | 2.774 | 3.263 | ns |
| | 100 | 2.775 | 3.264 | ns |
| LVDS (for MSIOD I/O Bank) | None | 2.554 | 3.004 | ns |
| | 100 | 2.549 | 2.999 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 81 • LVDS25 Transmitter Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|---------------------------|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVDS (for MSIO I/O Bank) | 2.136 | 2.513 | 2.416 | 2.842 | 2.402 | 2.825 | 2.423 | 2.85 | 2.409 | 2.833 | ns |
| LVDS (for MSIOD I/O Bank) | | | | | | | | | | | |
| No pre-emphasis | 1.61 | 1.893 | 1.749 | 2.058 | 1.735 | 2.041 | 1.897 | 2.231 | 1.866 | 2.195 | ns |
| Min pre-emphasis | 1.527 | 1.796 | 1.757 | 2.067 | 1.744 | 2.052 | 1.905 | 2.241 | 1.876 | 2.207 | ns |
| Med pre-emphasis | 1.496 | 1.76 | 1.765 | 2.077 | 1.751 | 2.06 | 1.914 | 2.252 | 1.884 | 2.216 | ns |

8.8.1.3 LVDS33 AC Switching Characteristics**AC Switching Characteristics for Receiver (Input Buffers)****Table 82 • LVDS33 Receiver Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On Die Termination (ODT) | t_{py} | | Units |
|----------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| LVDS33 (for MSIO I/O Bank) | None | 2.572 | 3.025 | ns |
| | 100 | 2.569 | 3.023 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 83 • LVDS33 Transmitter Characteristics**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|----------------------------|-------------|-------|----------|------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| LVDS33 (for MSIO I/O Bank) | 1.942 | 2.284 | 1.98 | 2.33 | 1.97 | 2.318 | 1.953 | 2.298 | 1.96 | 2.307 | ns |

8.8.2 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.

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

Table 84 • B-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 |
| Bus-LVDS DC Input Voltage Specification | | | | | | |
| VI | DC input voltage | | 0 | – | 2.925 | V |
| I _{IH} (DC) | Input current High | | – | – | 10 | μA |
| I _{IL} (DC) | Input current Low | | – | – | 10 | μA |
| 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 85 • B-LVDS AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|--|-----|-------------|-----|-------|
| Bus-LVDS Minimum and Maximum AC Switching Speed | | | | | | |
| D _{max} | Maximum data rate (for MSIO I/O Bank) | AC loading: 2 pF / 100 Ω differential load | – | – | 500 | Mbps |
| Bus-LVDS Impedance Specifications | | | | | | |
| R _t | Termination resistance | | – | 27 | – | Ω |
| Bus-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 |

8.8.2.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 86 • B-LVDS AC Switching Characteristics for Receiver (Input Buffers)

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{PY} | | Units |
|-------------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| Bus-LVDS (for MSIO I/O Bank) | None | 2.738 | 3.221 | ns |
| | 100 | 2.735 | 3.218 | ns |
| Bus-LVDS (for MSIOD I/O Bank) | None | 2.495 | 2.934 | ns |
| | 100 | 2.495 | 2.935 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 87 • B-LVDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|------------------------------|-------------|-------|----------|-------|----------|------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| Bus-LVDS (for MSIO I/O Bank) | 2.258 | 2.656 | 2.343 | 2.756 | 2.329 | 2.74 | 2.12 | 2.494 | 2.123 | 2.497 | ns |

8.8.3 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.

8.8.3.1 Minimum and Maximum Input and Output Levels

Table 88 • M-LVDS DC Voltage Specification

| Symbols | Parameters | Min | Typ | Max | Units | Notes |
|--|--|-------|-------|-------|-------|-------|
| M-LVDS Recommended DC Operating Conditions | | | | | | |
| VDDI | Supply voltage | 2.375 | 2.5 | 2.625 | V | * |
| M-LVDS DC Input Voltage Specification | | | | | | |
| VI | DC input voltage | 0 | – | 2.925 | V | |
| I _{IH} (DC) | Input current High | – | – | 10 | μA | |
| I _{IL} (DC) | Input current Low | – | – | 10 | μA | |
| M-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 | |
| 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 | |
| <i>Note: *Only M-LVDS TYPE I is supported</i> | | | | | | |

Table 89 • M-LVDS AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|---|-------------------------------|--------------|-------------|-----|----------|
| M-LVDS Minimum and Maximum AC Switching Speed | | | | | | |
| D _{max} | Maximum data rate (for MSIO I/O Bank) | AC loading: differential load | 2 pF / 100 Ω | – | – | 500 Mbps |
| M-LVDS Impedance Specification | | | | | | |
| R _t | Termination resistance | | – | 50 | – | Ω |
| M-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 |

8.8.3.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 90 • M-LVDS AC Switching Characteristics for Receiver (Input Buffers)

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{pY} | | Units |
|-----------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| M-LVDS (for MSIO I/O Bank) | None | 2.738 | 3.221 | ns |
| | 100 | 2.735 | 3.218 | ns |
| M-LVDS (for MSIOD I/O Bank) | None | 2.495 | 2.934 | ns |
| | 100 | 2.495 | 2.935 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 91 • M-LVDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|----------------------------|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-----|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| M-LVDS (for MSIO I/O Bank) | 2.258 | 2.656 | 2.348 | 2.762 | 2.334 | 2.746 | 2.123 | 2.497 | 2.125 | 2.5 | ns |

8.8.4 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.

8.8.4.1 Mini-LVDS Minimum and Maximum Input and Output Levels

Table 92 • 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 93 • Mini-LVDS AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---|--|---|-----|-------------|-----|----------|
| Mini-LVDS Minimum and Maximum AC Switching Speed | | | | | | |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 2 pF / 100 Ω differential load | – | – | 520 | Mbps |
| Dmax | Maximum data rate (for MSIOD I/O Bank) | AC loading: 2 pF / 100 Ω differential load | – | – | 700 | 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 |

8.8.4.2 AC Switching CharacteristicsWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, VDDI = 2.375 V**AC Switching Characteristics for Receiver (Input Buffers)****Table 94 • Mini-LVDS AC Switching Characteristics for Receiver (Input Buffers)**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{py} | | Units |
|--------------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | –1 | Std | |
| Mini-LVDS (for MSIO I/O Bank) | None | 2.855 | 3.359 | ns |
| | 100 | 2.85 | 3.353 | ns |
| Mini-LVDS (for MSIOD I/O Bank) | None | 2.602 | 3.061 | ns |
| | 100 | 2.597 | 3.055 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Table 95 • Mini-LVDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)**Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|---------------------------------------|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | –1 | Std | –1 | Std | –1 | Std | –1 | Std | –1 | Std | |
| Mini-LVDS (for MSIO I/O Bank) | 2.097 | 2.467 | 2.308 | 2.715 | 2.296 | 2.701 | 1.964 | 2.31 | 1.949 | 2.293 | ns |
| Mini-LVDS (for MSIOD I/O Bank) | | | | | | | | | | | |
| No pre-emphasis | 1.614 | 1.899 | 1.562 | 1.837 | 1.553 | 1.826 | 1.593 | 1.874 | 1.578 | 1.856 | ns |
| Min pre-emphasis | 1.604 | 1.887 | 1.745 | 2.053 | 1.731 | 2.036 | 1.892 | 2.225 | 1.861 | 2.189 | ns |
| Med pre-emphasis | 1.521 | 1.79 | 1.753 | 2.062 | 1.737 | 2.043 | 1.9 | 2.235 | 1.868 | 2.197 | ns |
| Max pre-emphasis | 1.492 | 1.754 | 1.762 | 2.073 | 1.745 | 2.052 | 1.91 | 2.247 | 1.876 | 2.206 | ns |

8.8.5 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.

8.8.5.1 Minimum and Maximum Input and Output Levels

Table 96 • 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 | | | | | | |
| VI | 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 |
| VICM | Input common mode voltage | | 0.3 | – | 1.5 | V |
| VID | Input differential voltage | | 100 | – | 600 | mV |

Table 97 • RSDS AC Specifications

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|--|--|---|-----|-------------|-----|----------|
| RSDS Minimum and Maximum AC Switching Speed | | | | | | |
| Dmax | Maximum data rate (for MSIO I/O Bank) | AC loading: 2 pF / 100 Ω differential load | – | – | 520 | Mbps |
| Dmax | Maximum data rate (for MSIOD I/O Bank) | AC loading: 2 pF / 100 Ω differential load | – | – | 700 | 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 |

8.8.5.2. AC Switching Characteristics

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, $V_{DDI} = 2.375\text{ V}$

AC Switching Characteristics for Receiver (Input Buffers)

Table 98 • RSDS AC Switching Characteristics for Receiver (Input Buffers)

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case V_{DDI}

| | On-Die Termination (ODT) | t_{PY} | | Units |
|---------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | -1 | Std | |
| RSDS (for MSIO I/O Bank) | None | 2.855 | 3.359 | ns |
| | 100 | 2.85 | 3.353 | ns |
| RSDS (for MSIOD I/O Bank) | None | 2.602 | 3.061 | ns |
| | 100 | 2.597 | 3.055 | ns |

AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Table 99 • RSDS AC Switching Characteristics for Transmitter (Output and Tristate Buffers)

Worst-Case Commercial Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$, Worst-Case V_{DDI}

| | t_{DP} | | t_{ZL} | | t_{ZH} | | t_{HZ} | | t_{LZ} | | Units |
|---------------------------|-------------|-------|----------|-------|----------|-------|----------|-------|----------|-------|-------|
| | Speed Grade | | | | | | | | | | |
| | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| RSDS (for MSIO I/O Bank) | 2.097 | 2.467 | 2.303 | 2.709 | 2.291 | 2.695 | 1.961 | 2.307 | 1.947 | 2.29 | ns |
| RSDS (for MSIOD I/O Bank) | | | | | | | | | | | |
| No pre-emphasis | 1.614 | 1.899 | 1.559 | 1.834 | 1.55 | 1.823 | 1.59 | 1.87 | 1.575 | 1.852 | ns |
| Min pre-emphasis | 1.604 | 1.887 | 1.742 | 2.05 | 1.728 | 2.032 | 1.889 | 2.222 | 1.858 | 2.185 | ns |
| Med pre-emphasis | 1.521 | 1.79 | 1.753 | 2.062 | 1.737 | 2.043 | 1.9 | 2.235 | 1.868 | 2.197 | ns |
| Max pre-emphasis | 1.492 | 1.754 | 1.762 | 2.073 | 1.745 | 2.052 | 1.91 | 2.247 | 1.876 | 2.206 | ns |

8.8.6 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.

8.8.6.1 Minimum and Maximum Input and Output Levels

Table 100 • 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 101 • LVPECL Minimum and Maximum AC Switching Speeds (Applicable to MSIO I/O Banks Only)

| Symbols | Parameters | Conditions | Min | Typ | Max | Units |
|---------------------------------|---------------------------------------|------------|-----|-----|-----|-------|
| LVPECL AC Specifications | | | | | | |
| Dmax | Maximum data rate (for MSIO I/O Bank) | | – | – | 900 | Mbps |

8.8.6.2 AC Switching Characteristics

Worst Commercial-Case Conditions: $T_j = 85^\circ\text{C}$, VDD = 1.14 V, VDDI = 2.375 V

AC Switching Characteristics for Receiver (Input Buffers)

Table 102 • LVPECL Receiver Characteristics

Worst-Case Commercial Conditions: $T_j = 85^\circ\text{C}$, VDD = 1.14 V, Worst-Case VDDI

| | On-Die Termination (ODT) | t_{py} | | Units |
|----------------------------|--------------------------|-------------|-------|-------|
| | | Speed Grade | | |
| | | –1 | Std | |
| LVPECL (for MSIO I/O Bank) | None | 2.572 | 3.025 | ns |
| | 100 | 2.569 | 3.023 | ns |

8.9 I/O Register Specifications

8.9.1 Input Register



Figure 5 • Timing Model for Input Register



Figure 6 • I/O Register Input Timing Diagram

Table 103 • Input Data Register Propagation Delays
Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Measuring Nodes (from, to)* | Speed Grade | | Units |
|----------------------|---|-----------------------------|-------------|-------|-------|
| | | | -1 | Std | |
| t_{BYP} | Bypass Delay of the Input Register | F, G | 0.353 | 0.415 | ns |
| t_{CLKQ} | Clock-to-Q of the Input Register | E, G | 0.16 | 0.188 | ns |
| t_{SUD} | Data Setup Time for the Input Register | A, E | 0.357 | 0.421 | ns |
| t_{HD} | Data Hold Time for the Input Register | A, E | 0 | 0 | ns |
| t_{SUE} | Enable Setup Time for the Input Register | B, E | 0.46 | 0.542 | ns |
| t_{HE} | Enable Hold Time for the Input Register | B, E | 0 | 0 | ns |
| t_{SUSL} | Synchronous Load Setup Time for the Input Register | D, E | 0.46 | 0.542 | ns |
| t_{HSL} | Synchronous Load Hold Time for the Input Register | D, E | 0 | 0 | ns |
| t_{IALn2Q} | Asynchronous Clear-to-Q of the Input Register ($\text{ADn}=1$) | C, G | 0.625 | 0.735 | ns |
| | Asynchronous Preset-to-Q of the Input Register ($\text{ADn}=0$) | C, G | 0.587 | 0.69 | ns |
| t_{IREMALn} | Asynchronous Load Removal Time for the Input Register | C, E | 0 | 0 | ns |
| t_{RECALn} | Asynchronous Load Recovery Time for the Input Register | C, E | 0.074 | 0.087 | ns |
| t_{WALn} | Asynchronous Load Minimum Pulse Width for the Input Register | C, C | 0.304 | 0.357 | ns |
| t_{CKMPWH} | Clock Minimum Pulse Width High for the Input Register | E, E | 0.075 | 0.088 | ns |
| t_{CKMPWL} | Clock Minimum Pulse Width Low for the Input Register | E, E | 0.159 | 0.187 | ns |

*Note: *For the derating values at specific junction temperature and voltage supply levels, refer to Table 14 on page 20 for derating values.*

8.9.2 Output/Enable Register

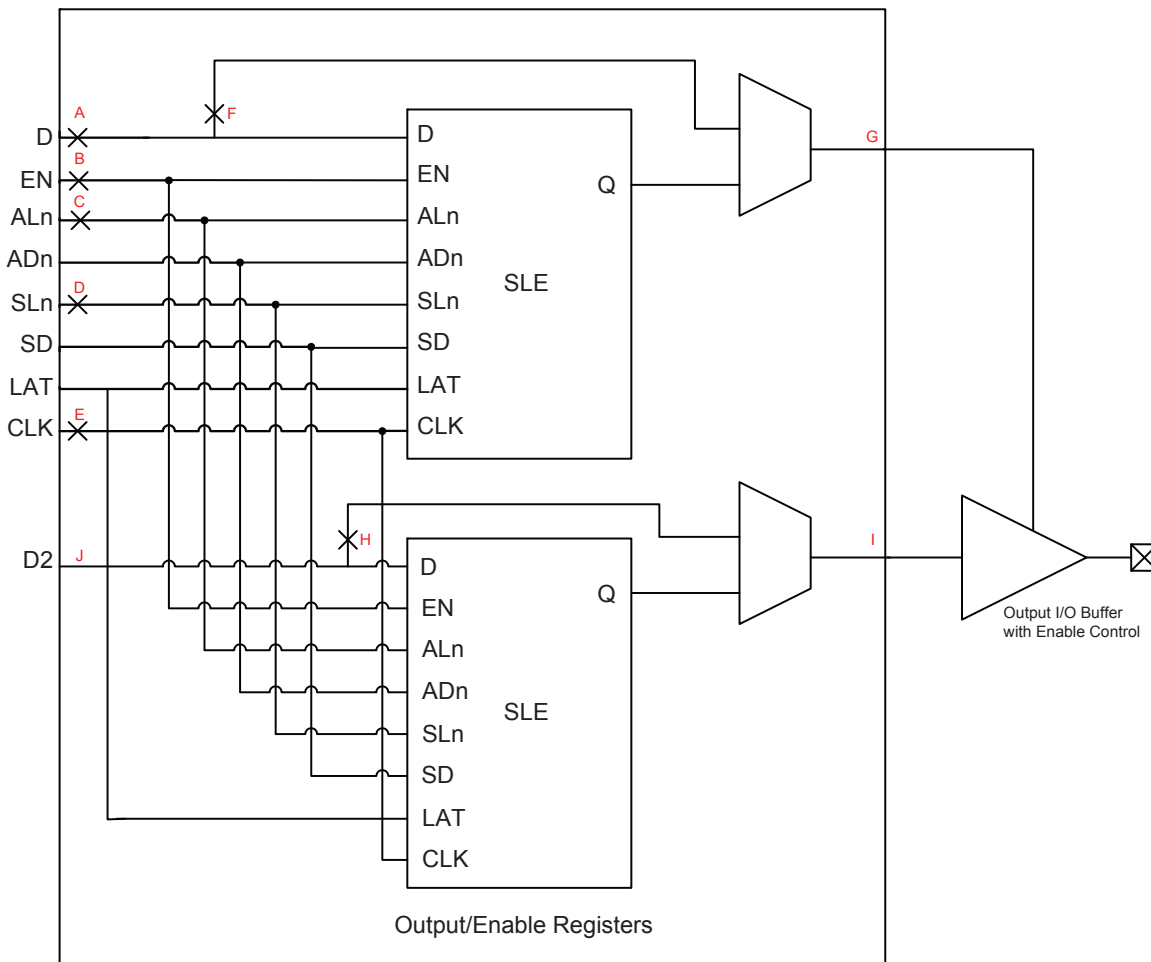


Figure 7 • Timing Model for Output/Enable Register



Figure 8 • I/O Register Output Timing Diagram

Table 104 • Output/Enable Data Register Propagation DelaysWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Measuring Nodes (from, to)* | Speed Grade | | Units |
|---|--|-----------------------------|-------------|-------|-------|
| | | | -1 | Std | |
| t_{OBYP} | Bypass Delay of the Output/Enable Register | F, G or H, I | 0.353 | 0.415 | ns |
| t_{OCLKQ} | Clock-to-Q of the Output/Enable Register | E, G or E, I | 0.263 | 0.309 | ns |
| t_{OSUD} | Data Setup Time for the Output/Enable Register | A, E or J, E | 0.19 | 0.223 | ns |
| t_{OHD} | Data Hold Time for the Output/Enable Register | A, E or J, E | 0 | 0 | ns |
| t_{OSUE} | Enable Setup Time for the Output/Enable Register | B, E | 0.419 | 0.493 | ns |
| t_{OHE} | Enable Hold Time for the Output/Enable Register | B, E | 0 | 0 | ns |
| t_{OSUSL} | Synchronous Load Setup Time for the Output/Enable Register | D, E | 0.196 | 0.231 | ns |
| t_{OHSL} | Synchronous Load Hold Time for the Output/Enable Register | D, E | 0 | 0 | ns |
| t_{OALn2Q} | Asynchronous Clear-to-Q of the Output/Enable Register (ADn = 1) | C, G or C, I | 0.505 | 0.594 | ns |
| | Asynchronous Preset-to-Q of the Output/Enable Register (ADn = 0) | C, G or C, I | 0.528 | 0.621 | ns |
| $t_{OREMALn}$ | Asynchronous Load Removal Time for the Output/Enable Register | C, E | 0 | 0 | ns |
| $t_{ORECALn}$ | Asynchronous Load Recovery Time for the Output/Enable Register | C, E | 0.034 | 0.04 | ns |
| t_{OWALn} | Asynchronous Load Minimum Pulse Width for the Output/Enable Register | C, C | 0.304 | 0.357 | ns |
| $t_{OCKMPWH}$ | Clock Minimum Pulse Width High for the Output/Enable Register | E, E | 0.075 | 0.088 | ns |
| $t_{OCKMPWL}$ | Clock Minimum Pulse Width Low for the Output/Enable Register | E, E | 0.159 | 0.187 | ns |
| <i>Note: *For the derating values at specific junction temperature and voltage supply levels, refer to Table 14 on page 20 for derating values.</i> | | | | | |

8.10. DDR Module Specification

8.10.1 Input DDR Module



Figure 9 • Input DDR Module

8.10.3 Timing Characteristics

Table 105 • Input DDR Propagation Delays

Worst Commercial-Case Conditions: $T_j = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Measuring Nodes (from, to) | Speed Grade | | Units |
|-------------------------|---|-------------------------------|-------------|-------|-------|
| | | | -1 | Std | |
| t_{DDRICKQ1} | Clock-to-Out Out_QR for Input DDR | B,C | 0.16 | 0.188 | ns |
| t_{DDRICKQ2} | Clock-to-Out Out_QF for Input DDR | B,D | 0.166 | 0.195 | ns |
| t_{DDRISUD} | Data Setup for Input DDR | A,B | 0.357 | 0.421 | ns |
| t_{DDRIHD} | Data Hold for Input DDR | A,B | 0 | 0 | ns |
| t_{DDRISUE} | Enable Setup for Input DDR | E,B | 0.46 | 0.542 | ns |
| t_{DDRIHE} | Enable Hold for Input DDR | E,B | 0 | 0 | ns |
| t_{DDRISUSL_n} | Synchronous Load Setup for Input DDR | G,B | 0.46 | 0.542 | ns |
| t_{DDRIHSL_n} | Synchronous Load Hold for Input DDR | G,B | 0 | 0 | ns |
| $t_{\text{DDRIAL2Q1}}$ | Asynchronous Load-to-Out QR for Input DDR | F,C | 0.587 | 0.69 | ns |
| $t_{\text{DDRIAL2Q2}}$ | Asynchronous Load-to-Out QF for Input DDR | F,D | 0.541 | 0.636 | ns |
| $t_{\text{DDRIREMAL}}$ | Asynchronous Load Removal time for Input DDR | F,B | 0 | 0 | ns |
| $t_{\text{DDRIRECAL}}$ | Asynchronous Load Recovery time for Input DDR | F,B | 0.074 | 0.087 | ns |
| t_{DDRIWAL} | Asynchronous Load Minimum Pulse Width for Input DDR | F,F | 0.304 | 0.357 | ns |
| $t_{\text{DDRICKMPWH}}$ | Clock Minimum Pulse Width High for Input DDR | B,B | 0.075 | 0.088 | ns |
| $t_{\text{DDRICKMPWL}}$ | Clock Minimum Pulse Width Low for Input DDR | B,B | 0.159 | 0.187 | ns |

8.10.4 Output DDR Module



Figure 11 • Output DDR Module



Figure 12 • Output DDR Timing Diagram

8.10.5 Timing Characteristics

Table 106 • Output DDR Propagation Delays

Worst Commercial-Case Conditions: $T_j = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Measuring Nodes (from, to) | Speed Grade | | Units |
|-------------------------|--|-------------------------------|-------------|-------|-------|
| | | | -1 | Std | |
| t_{DDROCLKQ} | Clock-to-Out of DDR for Output DDR | E,G | 0.263 | 0.309 | ns |
| t_{DDROSUDF} | Data_F Data Setup for Output DDR | F,E | 0.143 | 0.168 | ns |
| t_{DDROSUDR} | Data_R Data Setup for Output DDR | A,E | 0.19 | 0.223 | ns |
| t_{DDROHDF} | Data_F Data Hold for Output DDR | F,E | 0 | 0 | ns |
| t_{DDROHDR} | Data_R Data Hold for Output DDR | A,E | 0 | 0 | ns |
| t_{DDROSUE} | Enable Setup for Input DDR | B,E | 0.419 | 0.493 | ns |
| t_{DDROHE} | Enable Hold for Input DDR | B,E | 0 | 0 | ns |
| t_{DDROSUSL_n} | Synchronous Load Setup for Input DDR | D,E | 0.196 | 0.231 | ns |
| t_{DDROHSL_n} | Synchronous Load Hold for Input DDR | D,E | 0 | 0 | ns |
| t_{DDROAL2Q} | Asynchronous Load-to-Out for Output DDR | C,G | 0.528 | 0.621 | ns |
| t_{DDROREML} | Asynchronous Load Removal time for Output DDR | C,E | 0 | 0 | ns |
| $t_{\text{DDRORECAL}}$ | Asynchronous Load Recovery time for Output DDR | C,E | 0.034 | 0.04 | ns |
| t_{DDROWAL} | Asynchronous Load Minimum Pulse Width for Output DDR | C,C | 0.304 | 0.357 | ns |
| $t_{\text{DDROCKMPWH}}$ | Clock Minimum Pulse Width High for the Output DDR | E,E | 0.075 | 0.088 | ns |
| $t_{\text{DDROCKMPWL}}$ | Clock Minimum Pulse Width Low for the Output DDR | E,E | 0.159 | 0.187 | ns |

9. Logic Element Specifications

9.1 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 [IGLOO2 Macro Library Guide](#) or the [SmartFusion2 Macro Library Guide](#).

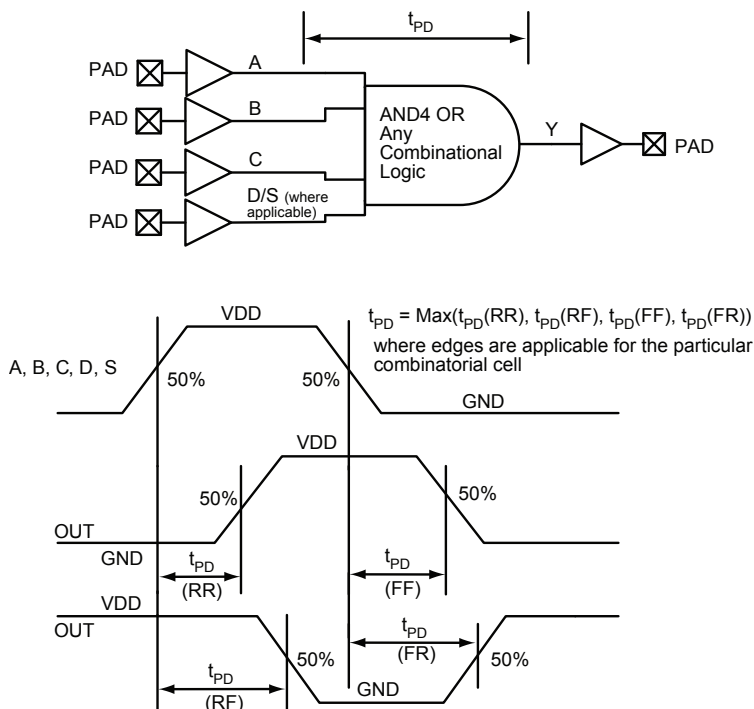


Figure 13 • LUT-4

Timing Characteristics

Table 107 • Combinatorial Cell Propagation Delays
Worst Commercial-Case Conditions: $T_j = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Combinatorial Cell | Equation | Parameter | Speed Grade | | Units |
|--------------------|---------------------------------|-----------|-------------|-------|-------|
| | | | -1 | Std | |
| INV | $Y = !A$ | t_{PD} | 0.102 | 0.12 | ns |
| AND2 | $Y = A \cdot B$ | t_{PD} | 0.179 | 0.211 | ns |
| NAND2 | $Y = !(A \cdot B)$ | t_{PD} | 0.144 | 0.169 | ns |
| OR2 | $Y = A + B$ | t_{PD} | 0.179 | 0.211 | ns |
| NOR2 | $Y = !(A + B)$ | t_{PD} | 0.144 | 0.169 | ns |
| XOR2 | $Y = A \oplus B$ | t_{PD} | 0.179 | 0.211 | ns |
| XOR3 | $Y = A \oplus B \oplus C$ | t_{PD} | 0.241 | 0.283 | ns |
| AND3 | $Y = A \cdot B \cdot C$ | t_{PD} | 0.198 | 0.233 | ns |
| AND4 | $Y = A \cdot B \cdot C \cdot D$ | t_{PD} | 0.371 | 0.436 | ns |

9.2 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 14 • Sequential Module

Figure 15 shows a configuration with SD = 0 (synchronous clear) and ADn = 1 (asynchronous clear) for a flip-flop (LAT = 0).



Figure 15 • Sequential Module Timing Diagram

9.2.1 Timing Characteristics

Table 108 • Register Delays

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | Units |
|--------------|--|-------------|-------|-------|
| | | -1 | Std | |
| t_{CLKQ} | Clock-to-Q of the Core register | 0.108 | 0.127 | ns |
| t_{SUD} | Data Setup Time for the Core register | 0.254 | 0.298 | ns |
| t_{HD} | Data Hold Time for the Core register | 0 | 0 | ns |
| t_{SUE} | Enable Setup Time for the Core register | 0.335 | 0.394 | ns |
| t_{HE} | Enable Hold Time for the Core register | 0 | 0 | ns |
| t_{SUSL} | Synchronous Load Setup Time for the Core register | 0.335 | 0.394 | ns |
| t_{HSL} | Synchronous Load Hold Time for the Core register | 0 | 0 | ns |
| t_{ALn2Q} | Asynchronous Clear-to-Q of the Core register ($AD_n = 1$) | 0.473 | 0.556 | ns |
| | Asynchronous Preset-to-Q of the Core register ($AD_n = 0$) | 0.451 | 0.531 | ns |
| t_{REMAln} | Asynchronous Load Removal Time for the Core register | 0 | 0 | ns |
| t_{RECALn} | Asynchronous Load Recovery Time for the Core register | 0.353 | 0.415 | ns |
| t_{WALn} | Asynchronous Load Minimum Pulse Width for the Core register | 0.304 | 0.357 | ns |
| t_{CKMPWH} | Clock Minimum Pulse Width High for the Core register | 0.075 | 0.088 | ns |
| t_{CKMPWL} | Clock Minimum Pulse Width Low for the Core register | 0.159 | 0.187 | ns |

10. 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 *IGLOO2 FPGA Fabric User Guide* or the *SmartFusion2 FPGA Fabric Architecture User Guide* for the positions of various global routing resources.

Table 109 • 150 Device Global Resource

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKL} | Input Low Delay for Global Clock | 0.83 | 0.911 | 0.831 | 0.913 | ns |
| t_{RCKH} | Input High Delay for Global Clock | 1.457 | 1.588 | 1.715 | 1.869 | ns |
| t_{RCKSW} | Maximum Skew for Global Clock | – | 0.131 | – | 0.154 | ns |

Table 110 • 090 Device Global Resource

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|------------|----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKL} | Input Low Delay for Global Clock | 0.835 | 0.888 | 0.833 | 0.886 | ns |

Table 110 • 090 Device Global Resource (continued)
Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKH} | Input High Delay for Global Clock | 1.405 | 1.489 | 1.654 | 1.752 | ns |
| t_{RCKSW} | Maximum Skew for Global Clock | – | 0.084 | – | 0.098 | ns |

Table 111 • 050 Device Global Resource
Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKL} | Input Low Delay for Global Clock | 0.827 | 0.897 | 0.826 | 0.896 | ns |
| t_{RCKH} | Input High Delay for Global Clock | 1.419 | 1.53 | 1.671 | 1.8 | ns |
| t_{RCKSW} | Maximum Skew for Global Clock | – | 0.111 | – | 0.129 | ns |

Table 112 • 025 Device Global Resource
Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKL} | Input Low Delay for Global Clock | 0.747 | 0.799 | 0.745 | 0.797 | ns |
| t_{RCKH} | Input High Delay for Global Clock | 1.294 | 1.378 | 1.522 | 1.621 | ns |
| t_{RCKSW} | Maximum Skew for Global Clock | – | 0.084 | – | 0.099 | ns |

Table 113 • 010 Device Global Resource
Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKL} | Input Low Delay for Global Clock | 0.626 | 0.669 | 0.627 | 0.668 | ns |
| t_{RCKH} | Input High Delay for Global Clock | 1.112 | 1.182 | 1.308 | 1.393 | ns |
| t_{RCKSW} | Maximum Skew for Global Clock | – | 0.07 | – | 0.085 | ns |

Table 114 • 005 Device Global Resource
Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-----------------------------------|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RCKL} | Input Low Delay for Global Clock | 0.625 | 0.66 | 0.628 | 0.66 | ns |
| t_{RCKH} | Input High Delay for Global Clock | 1.126 | 1.187 | 1.325 | 1.397 | ns |
| t_{RCKSW} | Maximum Skew for Global Clock | – | 0.061 | – | 0.072 | ns |

11. FPGA Fabric SRAM

Refer to the *IGLOO2 FPGA Fabric User Guide* or *SmartFusion2 FPGA Fabric User Guide* for more information.

11.1 FPGA Fabric Large SRAM (LSRAM)

Table 115 • RAM1K18 – Dual-Port Mode for Depth × Width Configuration 1Kx18

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CY} | Clock period | 2.5 | – | 2.941 | – | ns |
| $t_{CLKMPWH}$ | Clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| $t_{CLKMPWL}$ | Clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t_{PLCY} | Pipelined clock period | 2.5 | – | 2.941 | – | ns |
| $t_{PLCLKMPWH}$ | Pipelined clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| $t_{PLCLKMPWL}$ | Pipelined clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t_{CLK2Q} | Read access time with pipeline register | – | 0.334 | – | 0.393 | ns |
| | Read access time without pipeline register | – | 2.273 | – | 2.674 | ns |
| | Access time with feed-through write timing | – | 1.529 | – | 1.799 | ns |
| t_{ADDRSU} | Address setup time | 0.441 | – | 0.519 | – | ns |
| t_{ADDRHD} | Address hold time | 0.274 | – | 0.322 | – | ns |
| t_{DSU} | Data setup time | 0.341 | – | 0.401 | – | ns |
| t_{DHD} | Data hold time | 0.107 | – | 0.126 | – | ns |
| t_{BLKSU} | Block select setup time | 0.207 | – | 0.244 | – | ns |
| t_{BLKHD} | Block select hold time | 0.216 | – | 0.254 | – | ns |
| t_{BLK2Q} | Block select to out disable time (when pipelined register is disabled) | – | 1.529 | – | 1.799 | ns |
| t_{BLKMPW} | Block select minimum pulse width | 0.186 | – | 0.219 | – | ns |
| t_{RDESU} | Read enable setup time | 0.449 | – | 0.528 | – | ns |
| t_{RDEHD} | Read enable hold time | 0.167 | – | 0.197 | – | ns |
| $t_{RDPLESU}$ | Pipelined read enable setup time (A_DOUT_EN, B_DOUT_EN) | 0.248 | – | 0.291 | – | ns |
| $t_{RDPLEHD}$ | Pipelined read enable hold time (A_DOUT_EN, B_DOUT_EN) | 0.102 | – | 0.12 | – | ns |
| t_{R2Q} | Asynchronous reset to output propagation delay | – | 1.506 | – | 1.772 | ns |
| t_{RSTREM} | Asynchronous reset removal time | 0.506 | – | 0.595 | – | ns |
| t_{RSTREC} | Asynchronous reset recovery time | 0.004 | – | 0.005 | – | ns |
| t_{RSTMPW} | Asynchronous reset minimum pulse width | 0.301 | – | 0.354 | – | ns |
| $t_{PLRSTREM}$ | Pipelined register asynchronous reset removal time | –0.279 | – | –0.328 | – | ns |
| $t_{PLRSTREC}$ | Pipelined register asynchronous reset recovery time | 0.327 | – | 0.385 | – | ns |
| $t_{PLRSTMPW}$ | Pipelined register asynchronous reset minimum pulse width | 0.282 | – | 0.332 | – | ns |
| t_{SRSTSU} | Synchronous reset setup time | 0.226 | – | 0.265 | – | ns |
| t_{SRSTHD} | Synchronous reset hold time | 0.036 | – | 0.043 | – | ns |
| t_{WESU} | Write enable setup time | 0.39 | – | 0.458 | – | ns |
| t_{WEHD} | Write enable hold time | 0.242 | – | 0.285 | – | ns |
| f_{MAX} | Maximum frequency | – | 400 | – | 340 | MHz |

Table 116 • RAM1K18 – Dual-Port Mode for Depth × Width Configuration 2Kx9
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Clock period | 2.5 | – | 2.941 | – | ns |
| t _{CLKMPWH} | Clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{CLKMPWL} | Clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{PLCY} | Pipelined clock period | 2.5 | – | 2.941 | – | ns |
| t _{PLCLKMPWH} | Pipelined clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{PLCLKMPWL} | Pipelined clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.334 | – | 0.393 | ns |
| | Read access time without pipeline register | – | 2.273 | – | 2.674 | ns |
| | Access time with feed-through write timing | – | 1.529 | – | 1.799 | ns |
| t _{ADDRSU} | Address setup time | 0.475 | – | 0.559 | – | ns |
| t _{ADDRHD} | Address hold time | 0.274 | – | 0.322 | – | ns |
| t _{DSU} | Data setup time | 0.336 | – | 0.395 | – | ns |
| t _{DHD} | Data hold time | 0.082 | – | 0.096 | – | ns |
| t _{BLKSU} | Block select setup time | 0.207 | – | 0.244 | – | ns |
| t _{BLKHD} | Block select hold time | 0.216 | – | 0.254 | – | ns |
| t _{BLK2Q} | Block select to out disable time (when pipelined register is disabled) | – | 1.529 | – | 1.799 | ns |
| t _{BLKMPW} | Block select minimum pulse width | 0.186 | – | 0.219 | – | ns |
| t _{RDESU} | Read enable setup time | 0.485 | – | 0.57 | – | ns |
| t _{RDEHD} | Read enable hold time | 0.071 | – | 0.083 | – | ns |
| t _{RDPLESU} | Pipelined read enable setup time (A_DOUT_EN, B_DOUT_EN) | 0.248 | – | 0.291 | – | ns |
| t _{RDPLEHD} | Pipelined read enable hold time (A_DOUT_EN, B_DOUT_EN) | 0.102 | – | 0.12 | – | ns |
| t _{R2Q} | Asynchronous reset to output propagation delay | – | 1.514 | – | 1.781 | ns |
| t _{RSTREM} | Asynchronous reset removal time | 0.506 | – | 0.595 | – | ns |
| t _{RSTREC} | Asynchronous reset recovery time | 0.004 | – | 0.005 | – | ns |
| t _{RSTMPW} | Asynchronous reset minimum pulse width | 0.301 | – | 0.354 | – | ns |
| t _{PLRSTREM} | Pipelined register asynchronous reset removal time | –0.279 | – | –0.328 | – | ns |
| t _{PLRSTREC} | Pipelined register asynchronous reset recovery time | 0.327 | – | 0.385 | – | ns |
| t _{PLRSTMPW} | Pipelined register asynchronous reset minimum pulse width | 0.282 | – | 0.332 | – | ns |
| t _{SRSTSU} | Synchronous reset setup time | 0.226 | – | 0.265 | – | ns |
| t _{SRSTHD} | Synchronous reset hold time | 0.036 | – | 0.043 | – | ns |
| t _{WESU} | Write enable setup time | 0.415 | – | 0.488 | – | ns |
| t _{WEHD} | Write enable hold time | 0.048 | – | 0.057 | – | ns |
| f _{MAX} | Maximum frequency | – | 400 | – | 340 | MHz |

Table 117 • RAM1K18 – Dual-Port Mode for Depth × Width Configuration 4Kx4
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Clock period | 2.5 | – | 2.941 | – | ns |
| t _{CLKMPWH} | Clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{CLKMPWL} | Clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{PLCY} | Pipelined clock period | 2.5 | – | 2.941 | – | ns |
| t _{PLCLKMPWH} | Pipelined clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{PLCLKMPWL} | Pipelined clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.323 | – | 0.38 | ns |
| | Read access time without pipeline register | – | 2.273 | – | 2.673 | ns |
| | Access time with feed-through write timing | – | 1.511 | – | 1.778 | ns |
| t _{ADDRSU} | Address setup time | 0.543 | – | 0.638 | – | ns |
| t _{ADDRHD} | Address hold time | 0.274 | – | 0.322 | – | ns |
| t _{DSU} | Data setup time | 0.334 | – | 0.393 | – | ns |
| t _{DHD} | Data hold time | 0.082 | – | 0.096 | – | ns |
| t _{BLKSU} | Block select setup time | 0.207 | – | 0.244 | – | ns |
| t _{BLKHD} | Block select hold time | 0.216 | – | 0.254 | – | ns |
| t _{BLK2Q} | Block select to out disable time (when pipelined register is disabled) | – | 1.511 | – | 1.778 | ns |
| t _{BLKMPW} | Block select minimum pulse width | 0.186 | – | 0.219 | – | ns |
| t _{RDESU} | Read enable setup time | 0.516 | – | 0.607 | – | ns |
| t _{RDEHD} | Read enable hold time | 0.071 | – | 0.083 | – | ns |
| t _{RDPLESU} | Pipelined read enable setup time (A_DOUT_EN, B_DOUT_EN) | 0.248 | – | 0.291 | – | ns |
| t _{RDPLEHD} | Pipelined read enable hold time (A_DOUT_EN, B_DOUT_EN) | 0.102 | – | 0.12 | – | ns |
| t _{R2Q} | Asynchronous reset to output propagation delay | – | 1.507 | – | 1.773 | ns |
| t _{RSTREM} | Asynchronous reset removal time | 0.506 | – | 0.595 | – | ns |
| t _{RSTREC} | Asynchronous reset recovery time | 0.004 | – | 0.005 | – | ns |
| t _{RSTMPW} | Asynchronous reset minimum pulse width | 0.301 | – | 0.354 | – | ns |
| t _{PLRSTREM} | Pipelined register asynchronous reset removal time | –0.279 | – | –0.328 | – | ns |
| t _{PLRSTREC} | Pipelined register asynchronous reset recovery time | 0.327 | – | 0.385 | – | ns |
| t _{PLRSTMPW} | Pipelined register asynchronous reset minimum pulse width | 0.282 | – | 0.332 | – | ns |
| t _{SRSTSU} | Synchronous reset setup time | 0.226 | – | 0.265 | – | ns |
| t _{SRSTHD} | Synchronous reset hold time | 0.036 | – | 0.043 | – | ns |
| t _{WESU} | Write enable setup time | 0.458 | – | 0.539 | – | ns |
| t _{WEHD} | Write enable hold time | 0.048 | – | 0.057 | – | ns |
| f _{MAX} | Maximum frequency | – | 400 | – | 340 | MHz |

Table 118 • RAM1K18 – Dual-Port Mode for Depth × Width Configuration 8Kx2
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Clock period | 2.5 | – | 2.941 | – | ns |
| t _{CLKMPWH} | Clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{CLKMPWL} | Clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{PLCY} | Pipelined clock period | 2.5 | – | 2.941 | – | ns |
| t _{PLCLKMPWH} | Pipelined clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{PLCLKMPWL} | Pipelined clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.32 | – | 0.377 | ns |
| | Read access time without pipeline register | – | 2.272 | – | 2.673 | ns |
| | Access time with feed-through write timing | – | 1.511 | – | 1.778 | ns |
| t _{ADDRSU} | Address setup time | 0.612 | – | 0.72 | – | ns |
| t _{ADDRHD} | Address hold time | 0.274 | – | 0.322 | – | ns |
| t _{DSU} | Data setup time | 0.33 | – | 0.388 | – | ns |
| t _{DHD} | Data hold time | 0.082 | – | 0.096 | – | ns |
| t _{BLKSU} | Block select setup time | 0.207 | – | 0.244 | – | ns |
| t _{BLKHD} | Block select hold time | 0.216 | – | 0.254 | – | ns |
| t _{BLK2Q} | Block select to out disable time (when pipelined register is disabled) | – | 1.511 | – | 1.778 | ns |
| t _{BLKMPW} | Block select minimum pulse width | 0.186 | – | 0.219 | – | ns |
| t _{RDESU} | Read enable setup time | 0.529 | – | 0.622 | – | ns |
| t _{RDEHD} | Read enable hold time | 0.071 | – | 0.083 | – | ns |
| t _{RDPLESU} | Pipelined read enable setup time (A_DOUT_EN, B_DOUT_EN) | 0.248 | – | 0.291 | – | ns |
| t _{RDPLEHD} | Pipelined read enable hold time (A_DOUT_EN, B_DOUT_EN) | 0.102 | – | 0.12 | – | ns |
| t _{R2Q} | Asynchronous reset to output propagation delay | – | 1.528 | – | 1.797 | ns |
| t _{RSTREM} | Asynchronous reset removal time | 0.506 | – | 0.595 | – | ns |
| t _{RSTREC} | Asynchronous reset recovery time | 0.004 | – | 0.005 | – | ns |
| t _{RSTMPW} | Asynchronous reset minimum pulse width | 0.301 | – | 0.354 | – | ns |
| t _{PLRSTREM} | Pipelined register asynchronous reset removal time | –0.279 | – | –0.328 | – | ns |
| t _{PLRSTREC} | Pipelined register asynchronous reset recovery time | 0.327 | – | 0.385 | – | ns |
| t _{PLRSTMPW} | Pipelined register asynchronous reset minimum pulse width | 0.282 | – | 0.332 | – | ns |
| t _{SRSTSU} | Synchronous reset setup time | 0.226 | – | 0.265 | – | ns |
| t _{SRSTHD} | Synchronous reset hold time | 0.036 | – | 0.043 | – | ns |
| t _{WESU} | Write enable setup time | 0.488 | – | 0.574 | – | ns |
| t _{WEHD} | Write enable hold time | 0.048 | – | 0.057 | – | ns |
| f _{MAX} | Maximum frequency | – | 400 | – | 340 | MHz |

Table 119 • RAM1K18 – Dual-Port Mode for Depth × Width Configuration 16Kx1
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Clock period | 2.5 | – | 2.941 | – | ns |
| t _{CLKMPWH} | Clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{CLKMPWL} | Clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{PLCY} | Pipelined clock period | 2.5 | – | 2.941 | – | ns |
| t _{PLCLKMPWH} | Pipelined clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{PLCLKMPWL} | Pipelined clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.32 | – | 0.377 | ns |
| | Read access time without pipeline register | – | 2.269 | – | 2.669 | ns |
| | Access time with feed-through write timing | – | 1.51 | – | 1.777 | ns |
| t _{ADDRSU} | Address setup time | 0.626 | – | 0.737 | – | ns |
| t _{ADDRHD} | Address hold time | 0.274 | – | 0.322 | – | ns |
| t _{DSU} | Data setup time | 0.322 | – | 0.378 | – | ns |
| t _{DHD} | Data hold time | 0.082 | – | 0.096 | – | ns |
| t _{BLKSU} | Block select setup time | 0.207 | – | 0.244 | – | ns |
| t _{BLKHD} | Block select hold time | 0.216 | – | 0.254 | – | ns |
| t _{BLK2Q} | Block select to out disable time (when pipelined register is disabled) | – | 1.51 | – | 1.777 | ns |
| t _{BLKMPW} | Block select minimum pulse width | 0.186 | – | 0.219 | – | ns |
| t _{RDESU} | Read enable setup time | 0.53 | – | 0.624 | – | ns |
| t _{RDEHD} | Read enable hold time | 0.071 | – | 0.083 | – | ns |
| t _{RDPLESU} | Pipelined read enable setup time (A_DOUT_EN, B_DOUT_EN) | 0.248 | – | 0.291 | – | ns |
| t _{RDPLEHD} | Pipelined read enable hold time (A_DOUT_EN, B_DOUT_EN) | 0.102 | – | 0.12 | – | ns |
| t _{R2Q} | Asynchronous reset to output propagation delay | – | 1.547 | – | 1.82 | ns |
| t _{RSTREM} | Asynchronous reset removal time | 0.506 | – | 0.595 | – | ns |
| t _{RSTREC} | Asynchronous reset recovery time | 0.004 | – | 0.005 | – | ns |
| t _{RSTMPW} | Asynchronous reset minimum pulse width | 0.301 | – | 0.354 | – | ns |
| t _{PLRSTREM} | Pipelined register asynchronous reset removal time | –0.279 | – | –0.328 | – | ns |
| t _{PLRSTREC} | Pipelined register asynchronous reset recovery time | 0.327 | – | 0.385 | – | ns |
| t _{PLRSTMPW} | Pipelined register asynchronous reset minimum pulse width | 0.282 | – | 0.332 | – | ns |
| t _{SRSTSU} | Synchronous reset setup time | 0.226 | – | 0.265 | – | ns |
| t _{SRSTHD} | Synchronous reset hold time | 0.036 | – | 0.043 | – | ns |
| t _{WESU} | Write enable setup time | 0.454 | – | 0.534 | – | ns |
| t _{WEHD} | Write enable hold time | 0.048 | – | 0.057 | – | ns |
| f _{MAX} | Maximum frequency | – | 400 | – | 340 | MHz |

Table 120 • RAM1K18 – Two-Port Mode for Depth × Width Configuration 512x36
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Clock period | 2.5 | – | 2.941 | – | ns |
| t _{CLKMPWH} | Clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{CLKMPWL} | Clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{PLCY} | Pipelined clock period | 2.5 | – | 2.941 | – | ns |
| t _{PLCLKMPWH} | Pipelined clock minimum pulse width High | 1.125 | – | 1.323 | – | ns |
| t _{PLCLKMPWL} | Pipelined clock minimum pulse width Low | 1.125 | – | 1.323 | – | ns |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.334 | – | 0.393 | ns |
| | Read access time without pipeline register | – | 2.25 | – | 2.647 | ns |
| t _{ADDRSU} | Address setup time | 0.313 | – | 0.368 | – | ns |
| t _{ADDRHD} | Address hold time | 0.274 | – | 0.322 | – | ns |
| t _{DSU} | Data setup time | 0.337 | – | 0.396 | – | ns |
| t _{DHD} | Data hold time | 0.111 | – | 0.13 | – | ns |
| t _{BLKSU} | Block select setup time | 0.207 | – | 0.244 | – | ns |
| t _{BLKHD} | Block select hold time | 0.201 | – | 0.237 | – | ns |
| t _{BLK2Q} | Block select to out disable time (when pipelined register is disabled) | – | 2.25 | – | 2.647 | ns |
| t _{BLKMPW} | Block select minimum pulse width | 0.186 | – | 0.219 | – | ns |
| t _{RDESU} | Read enable setup time | 0.449 | – | 0.528 | – | ns |
| t _{RDEHD} | Read enable hold time | 0.167 | – | 0.197 | – | ns |
| t _{RDPLESU} | Pipelined read enable setup time (A_DOUT_EN, B_DOUT_EN) | 0.248 | – | 0.291 | – | ns |
| t _{RDPLEHD} | Pipelined read enable hold time (A_DOUT_EN, B_DOUT_EN) | 0.102 | – | 0.12 | – | ns |
| t _{R2Q} | Asynchronous reset to output propagation delay | – | 1.506 | – | 1.772 | ns |
| t _{RSTREM} | Asynchronous reset removal time | 0.506 | – | 0.595 | – | ns |
| t _{RSTREC} | Asynchronous reset recovery time | 0.004 | – | 0.005 | – | ns |
| t _{RSTMPW} | Asynchronous reset minimum pulse width | 0.301 | – | 0.354 | – | ns |
| t _{PLRSTREM} | Pipelined register asynchronous reset removal time | –0.279 | – | –0.328 | – | ns |
| t _{PLRSTREC} | Pipelined register asynchronous reset recovery time | 0.327 | – | 0.385 | – | ns |
| t _{PLRSTMPW} | Pipelined register asynchronous reset minimum pulse width | 0.282 | – | 0.332 | – | ns |
| t _{SRSTSU} | Synchronous reset setup time | 0.226 | – | 0.265 | – | ns |
| t _{SRSTHD} | Synchronous reset hold time | 0.036 | – | 0.043 | – | ns |
| t _{WESU} | Write enable setup time | 0.39 | – | 0.458 | – | ns |
| t _{WEHD} | Write enable hold time | 0.242 | – | 0.285 | – | ns |
| f _{MAX} | Maximum frequency | – | 400 | – | 340 | MHz |

11.2. FPGA Fabric Micro SRAM (uSRAM)

Table 121 • uSRAM (RAM64x18) in 64x18 Mode

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|---|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CY} | Read clock period | 4 | – | 4 | – | ns |
| $t_{CLKMPWH}$ | Read clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{CLKMPWL}$ | Read clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{PLCY} | Read pipeline clock period | 4 | – | 4 | – | ns |
| $t_{PLCLKMPWH}$ | Read pipeline clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{PLCLKMPWL}$ | Read pipeline clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{CLK2Q} | Read access time with pipeline register | – | 0.266 | – | 0.313 | ns |
| | Read access time without pipeline register | – | 1.677 | – | 1.973 | ns |
| t_{ADDRSU} | Read address setup time in synchronous mode | 0.301 | – | 0.354 | – | ns |
| | Read address setup time in asynchronous mode | 1.856 | – | 2.184 | – | ns |
| t_{ADDRHD} | Read address hold time in synchronous mode | 0.091 | – | 0.107 | – | ns |
| | Read address hold time in asynchronous mode | –0.778 | – | –0.915 | – | ns |
| t_{RDENSU} | Read enable setup time | 0.278 | – | 0.327 | – | ns |
| t_{RDENHD} | Read enable hold time | 0.057 | – | 0.067 | – | ns |
| t_{BLKSU} | Read block select setup time | 1.839 | – | 2.163 | – | ns |
| t_{BLKHD} | Read block select hold time | –0.65 | – | –0.765 | – | ns |
| t_{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | – | 2.036 | | 2.396 | ns |
| t_{RSTREM} | Read asynchronous reset removal time (pipelined clock) | –0.023 | – | –0.027 | – | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | – | 0.054 | – | ns |
| t_{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | – | 0.597 | – | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | – | 0.278 | – | ns |
| t_{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | – | 0.839 | | 0.987 | ns |
| t_{SRSTSU} | Read synchronous reset setup time | 0.271 | – | 0.319 | – | ns |
| t_{SRSTHD} | Read synchronous reset hold time | 0.061 | – | 0.071 | – | ns |
| t_{CCY} | Write clock period | 4 | – | 4 | – | ns |
| $t_{CCLKMPWH}$ | Write clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{CCLKMPWL}$ | Write clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t_{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t_{DINCSU} | Write input data setup time | 0.115 | – | 0.135 | – | ns |
| t_{DINCHD} | Write input data hold time | 0.15 | – | 0.177 | – | ns |
| $t_{ADDRCSU}$ | Write address setup time | 0.088 | – | 0.104 | – | ns |
| $t_{ADDRCHD}$ | Write address hold time | 0.128 | – | 0.15 | – | ns |

Table 121 • uSRAM (RAM64x18) in 64x18 Mode (continued)Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|-------------------------|-------------|-----|-------|-----|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |
| t_{WECHD} | Write enable hold time | –0.026 | | –0.03 | – | ns |
| f_{MAX} | Maximum frequency | – | 250 | – | 250 | MHz |

Table 122 • uSRAM (RAM64x16) in 64x16 ModeWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|---|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CY} | Read clock period | 4 | – | 4 | – | ns |
| $t_{CLKMPWH}$ | Read clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{CLKMPWL}$ | Read clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{PLCY} | Read pipeline clock period | 4 | – | 4 | – | ns |
| $t_{PLCLKMPWH}$ | Read pipeline clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{PLCLKMPWL}$ | Read pipeline clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{CLK2Q} | Read access time with pipeline register | – | 0.266 | – | 0.313 | ns |
| | Read access time without pipeline register | – | 1.677 | – | 1.973 | ns |
| t_{ADDRSU} | Read address setup time in synchronous mode | 0.301 | – | 0.354 | – | ns |
| | Read address setup time in asynchronous mode | 1.856 | – | 2.184 | – | ns |
| t_{ADDRHD} | Read address hold time in synchronous mode | 0.091 | – | 0.107 | – | ns |
| | Read address hold time in asynchronous mode | –0.778 | – | –0.915 | – | ns |
| t_{RDENSU} | Read enable setup time | 0.278 | – | 0.327 | – | ns |
| t_{RDENHD} | Read enable hold time | 0.057 | – | 0.067 | – | ns |
| t_{BLKSU} | Read block select setup time | 1.839 | – | 2.163 | – | ns |
| t_{BLKHD} | Read block select hold time | –0.65 | – | –0.765 | – | ns |
| t_{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | – | 2.036 | – | 2.396 | ns |
| t_{RSTREM} | Read asynchronous reset removal time (pipelined clock) | –0.023 | – | –0.027 | – | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | – | 0.054 | – | ns |
| t_{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | – | 0.597 | – | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | – | 0.278 | – | ns |
| t_{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | – | 0.835 | – | 0.983 | ns |
| t_{SRSTSU} | Read synchronous reset setup time | 0.271 | – | 0.319 | – | ns |
| t_{SRSTHD} | Read synchronous reset hold time | 0.061 | – | 0.071 | – | ns |
| t_{CCY} | Write clock period | 4 | – | 4 | – | ns |
| $t_{CCLKMPWH}$ | Write clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |

Table 122 • uSRAM (RAM64x16) in 64x16 Mode (continued)Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------------|-------------------------------------|-------------|-----|-------|-----|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CCLKMPWL} | Write clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t_{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t_{DINCSU} | Write input data setup time | 0.115 | – | 0.135 | – | ns |
| t_{DINCHD} | Write input data hold time | 0.15 | – | 0.177 | – | ns |
| t_{ADDRCSU} | Write address setup time | 0.088 | – | 0.104 | – | ns |
| t_{ADDRCHD} | Write address hold time | 0.128 | – | 0.15 | – | ns |
| t_{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |
| t_{WECHD} | Write enable hold time | –0.026 | – | –0.03 | – | ns |
| f_{MAX} | Maximum frequency | – | 250 | – | 250 | MHz |

Table 123 • uSRAM (RAM128x9) in 128x9 ModeWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|---|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CY} | Read clock period | 4 | – | 4 | – | ns |
| t_{CLKMPWH} | Read clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t_{CLKMPWL} | Read clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{PLCY} | Read pipeline clock period | 4 | – | 4 | – | ns |
| $t_{\text{PLCLKMPWH}}$ | Read pipeline clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{\text{PLCLKMPWL}}$ | Read pipeline clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{CLK2Q} | Read access time with pipeline register | – | 0.266 | – | 0.313 | ns |
| | Read access time without pipeline register | – | 1.677 | – | 1.973 | ns |
| t_{ADDRSU} | Read address setup time in synchronous mode | 0.301 | – | 0.354 | – | ns |
| | Read address setup time in asynchronous mode | 1.856 | – | 2.184 | – | ns |
| t_{ADDRHD} | Read address hold time in synchronous mode | 0.091 | – | 0.107 | – | ns |
| | Read address hold time in asynchronous mode | –0.778 | – | –0.915 | – | ns |
| t_{RDENSU} | Read enable setup time | 0.278 | – | 0.327 | – | ns |
| t_{RDENHD} | Read enable hold time | 0.057 | – | 0.067 | – | ns |
| t_{BLKSU} | Read block select setup time | 1.839 | – | 2.163 | – | ns |
| t_{BLKHD} | Read block select hold time | –0.65 | – | –0.765 | – | ns |
| t_{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | – | 2.036 | – | 2.396 | ns |
| t_{RSTREM} | Read asynchronous reset removal time (pipelined clock) | –0.023 | – | –0.027 | – | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | – | 0.054 | – | ns |

Table 123 • uSRAM (RAM128x9) in 128x9 Mode (continued)Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|----------------|---|-------------|-------|-------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | – | 0.597 | – | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | – | 0.278 | – | ns |
| t_{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | | 0.835 | | 0.982 | ns |
| t_{SRSTSU} | Read synchronous reset setup time | 0.271 | – | 0.319 | – | ns |
| t_{SRSTHD} | Read synchronous reset hold time | 0.061 | – | 0.071 | – | ns |
| t_{CCY} | Write clock period | 4 | – | 4 | – | ns |
| $t_{CCLKMPWH}$ | Write clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{CCLKMPWL}$ | Write clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t_{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t_{DINCSU} | Write input data setup time | 0.115 | – | 0.135 | – | ns |
| t_{DINCHD} | Write input data hold time | 0.15 | – | 0.177 | – | ns |
| $t_{ADDRCSU}$ | Write address setup time | 0.088 | – | 0.104 | – | ns |
| $t_{ADDRCHD}$ | Write address hold time | 0.128 | – | 0.15 | – | ns |
| t_{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |
| t_{WECHD} | Write enable hold time | –0.026 | – | –0.03 | – | ns |
| f_{MAX} | Maximum frequency | – | 250 | – | 250 | MHz |

Table 124 • uSRAM (RAM128x8) in 128x8 ModeWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|--|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CY} | Read clock period | 4 | – | 4 | – | ns |
| $t_{CLKMPWH}$ | Read clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{CLKMPWL}$ | Read clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{PLCY} | Read pipeline clock period | 4 | – | 4 | – | ns |
| $t_{PLCLKMPWH}$ | Read pipeline clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| $t_{PLCLKMPWL}$ | Read pipeline clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t_{CLK2Q} | Read access time with pipeline register | – | 0.266 | – | 0.313 | ns |
| | Read access time without pipeline register | – | 1.677 | – | 1.973 | ns |
| t_{ADDRSU} | Read address setup time in synchronous mode | 0.301 | – | 0.354 | – | ns |
| | Read address setup time in asynchronous mode | 1.856 | – | 2.184 | – | ns |
| t_{ADDRHD} | Read address hold time in synchronous mode | 0.091 | – | 0.107 | – | ns |
| | Read address hold time in asynchronous mode | –0.778 | – | –0.915 | – | ns |
| t_{RDENSU} | Read enable setup time | 0.278 | – | 0.327 | – | ns |

Table 124 • uSRAM (RAM128x8) in 128x8 Mode (continued)
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|-----------------------|---|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{RDENHD} | Read enable hold time | 0.057 | – | 0.067 | – | ns |
| t _{BLKSU} | Read block select setup time | 1.839 | – | 2.163 | – | ns |
| t _{BLKHD} | Read block select hold time | –0.65 | – | –0.765 | – | ns |
| t _{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | | 2.036 | | 2.396 | ns |
| t _{RSTREM} | Read asynchronous reset removal time (pipelined clock) | –0.023 | – | –0.027 | – | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | – | 0.054 | – | ns |
| t _{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | – | 0.597 | – | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | – | 0.278 | – | ns |
| t _{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | – | 0.835 | – | 0.982 | ns |
| t _{SRSTSU} | Read synchronous reset setup time | 0.271 | – | 0.319 | – | ns |
| t _{SRSTHD} | Read synchronous reset hold time | 0.061 | – | 0.071 | – | ns |
| t _{CCY} | Write clock period | 4 | – | 4 | – | ns |
| t _{CCLKMPWH} | Write clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{CCLKMPWL} | Write clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t _{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t _{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t _{DINCSU} | Write input data setup time | 0.115 | – | 0.135 | – | ns |
| t _{DINCHD} | Write input data hold time | 0.15 | – | 0.177 | – | ns |
| t _{ADDRCSU} | Write address setup time | 0.088 | – | 0.104 | – | ns |
| t _{ADDRCHD} | Write address hold time | 0.128 | – | 0.15 | – | ns |
| t _{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |
| t _{WECHD} | Write enable hold time | –0.026 | – | –0.03 | – | ns |
| f _{MAX} | Maximum frequency | – | 250 | – | 250 | MHz |

Table 125 • uSRAM (RAM256x4) in 256x4 Mode
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|--|-------------|-----|-----|-----|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Read clock period | 4 | – | 4 | – | ns |
| t _{CLKMPWH} | Read clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{CLKMPWL} | Read clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t _{PLCY} | Read pipeline clock period | 4 | – | 4 | – | ns |
| t _{PLCLKMPWH} | Read pipeline clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{PLCLKMPWL} | Read pipeline clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |

Table 125 • uSRAM (RAM256x4) in 256x4 Mode (continued)
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|-----------------------|---|-------------|------|-------|------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.27 | | 0.31 | ns |
| | Read access time without pipeline register | – | 1.75 | | 2.06 | ns |
| t _{ADDRSU} | Read address setup time in synchronous mode | 0.301 | – | 0.354 | – | ns |
| | Read address setup time in asynchronous mode | 1.931 | – | 2.272 | – | ns |
| t _{ADDRHD} | Read address hold time in synchronous mode | 0.121 | – | 0.142 | – | ns |
| | Read address hold time in asynchronous mode | –0.65 | – | –0.76 | – | ns |
| t _{RDENSU} | Read enable setup time | 0.278 | – | 0.327 | – | ns |
| t _{RDENHD} | Read enable hold time | 0.057 | – | 0.067 | – | ns |
| t _{BLKSU} | Read block select setup time | 1.839 | – | 2.163 | – | ns |
| t _{BLKHD} | Read block select hold time | –0.65 | | –0.77 | | ns |
| t _{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | – | 2.09 | – | 2.46 | ns |
| t _{RSTREM} | Read asynchronous reset removal time (pipelined clock) | –0.02 | – | –0.03 | – | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | – | 0.054 | – | ns |
| t _{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | – | 0.597 | – | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | – | 0.278 | – | ns |
| t _{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | – | 0.83 | – | 0.98 | ns |
| t _{SRSTSU} | Read synchronous reset setup time | 0.271 | – | 0.319 | – | ns |
| t _{SRSTHD} | Read synchronous reset hold time | 0.061 | – | 0.071 | – | ns |
| t _{CCY} | Write clock period | 4 | – | 4 | – | ns |
| t _{CCLKMPWH} | Write clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{CCLKMPWL} | Write clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t _{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t _{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t _{DINCSU} | Write input data setup time | 0.101 | – | 0.118 | – | ns |
| t _{DINCHD} | Write input data hold time | 0.137 | – | 0.161 | – | ns |
| t _{ADDRCSU} | Write address setup time | 0.088 | – | 0.104 | – | ns |
| t _{ADDRCHD} | Write address hold time | 0.245 | – | 0.288 | – | ns |
| t _{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |
| t _{WECHD} | Write enable hold time | –0.03 | – | –0.03 | – | ns |
| f _{MAX} | Maximum frequency | – | 250 | – | 250 | MHz |

Table 126 • uSRAM (RAM512x2) in 512x2 Mode
Worst Commercial-Case Conditions: T_J = 85°C, VDD = 1.14 V

| Parameter | Description | Speed Grade | | | | Units |
|------------------------|---|-------------|------|-------|------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t _{CY} | Read clock period | 4 | – | 4 | – | ns |
| t _{CLKMPWH} | Read clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{CLKMPWL} | Read clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t _{PLCY} | Read pipeline clock period | 4 | – | 4 | – | ns |
| t _{PLCLKMPWH} | Read pipeline clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{PLCLKMPWL} | Read pipeline clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t _{CLK2Q} | Read access time with pipeline register | – | 0.27 | – | 0.31 | ns |
| | Read access time without pipeline register | – | 1.76 | – | 2.08 | ns |
| t _{ADDRSU} | Read address setup time in synchronous mode | 0.301 | – | 0.354 | – | ns |
| | Read address setup time in asynchronous mode | 1.96 | – | 2.306 | – | ns |
| t _{ADDRHD} | Read address hold time in synchronous mode | 0.137 | – | 0.161 | – | ns |
| | Read address hold time in asynchronous mode | –0.58 | – | –0.68 | – | ns |
| t _{RDENSU} | Read enable setup time | 0.278 | – | 0.327 | – | ns |
| t _{RDENHD} | Read enable hold time | 0.057 | – | 0.067 | – | ns |
| t _{BLKSU} | Read block select setup time | 1.839 | – | 2.163 | – | ns |
| t _{BLKHD} | Read block select hold time | –0.65 | – | –0.77 | – | ns |
| t _{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | – | 2.14 | – | 2.52 | ns |
| t _{RSTREM} | Read asynchronous reset removal time (pipelined clock) | –0.02 | – | –0.03 | – | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | – | 0.054 | – | ns |
| t _{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | – | 0.597 | – | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | – | 0.278 | – | ns |
| t _{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | – | 0.83 | – | 0.98 | ns |
| t _{SRSTSU} | Read synchronous reset setup time | 0.271 | – | 0.319 | – | ns |
| t _{SRSTHD} | Read synchronous reset hold time | 0.061 | – | 0.071 | – | ns |
| t _{CCY} | Write clock period | 4 | – | 4 | – | ns |
| t _{CCLKMPWH} | Write clock minimum pulse width High | 1.8 | – | 1.8 | – | ns |
| t _{CCLKMPWL} | Write clock minimum pulse width Low | 1.8 | – | 1.8 | – | ns |
| t _{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t _{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t _{DINCSU} | Write input data setup time | 0.101 | – | 0.118 | – | ns |
| t _{DINCHD} | Write input data hold time | 0.137 | – | 0.161 | – | ns |
| t _{ADDRCSU} | Write address setup time | 0.088 | – | 0.104 | – | ns |
| t _{ADDRCHD} | Write address hold time | 0.247 | – | 0.29 | – | ns |
| t _{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |

Table 126 • uSRAM (RAM512x2) in 512x2 Mode (continued)Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-------------|------------------------|-------------|-----|-------|-----|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{WECHD} | Write enable hold time | -0.03 | - | -0.03 | - | ns |
| f_{MAX} | Maximum frequency | - | 250 | - | 250 | MHz |

Table 127 • uSRAM (RAM1024x1) in 1024x1 ModeWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|---|-------------|------|-------|------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{CY} | Read clock period | 4 | - | 4 | - | ns |
| $t_{CLKMPWH}$ | Read clock minimum pulse width High | 1.8 | - | 1.8 | - | ns |
| $t_{CLKMPWL}$ | Read clock minimum pulse width Low | 1.8 | - | 1.8 | - | ns |
| t_{PLCY} | Read pipeline clock period | 4 | - | 4 | - | ns |
| $t_{PLCLKMPWH}$ | Read pipeline clock minimum pulse width High | 1.8 | - | 1.8 | - | ns |
| $t_{PLCLKMPWL}$ | Read pipeline clock minimum pulse width Low | 1.8 | - | 1.8 | - | ns |
| t_{CLK2Q} | Read access time with pipeline register | - | 0.27 | - | 0.31 | ns |
| | Read access time without pipeline register | - | 1.78 | - | 2.1 | ns |
| t_{ADDRSU} | Read address setup time in synchronous mode | 0.301 | - | 0.354 | - | ns |
| | Read address setup time in asynchronous mode | 1.978 | - | 2.327 | - | ns |
| t_{ADDRHD} | Read address hold time in synchronous mode | 0.137 | - | 0.161 | - | ns |
| | Read address hold time in asynchronous mode | -0.6 | - | -0.71 | - | ns |
| t_{RDENSU} | Read enable setup time | 0.278 | - | 0.327 | - | ns |
| t_{RDENHD} | Read enable hold time | 0.057 | - | 0.067 | - | ns |
| t_{BLKSU} | Read block select setup time | 1.839 | - | 2.163 | - | ns |
| t_{BLKHD} | Read block select hold time | -0.65 | - | -0.77 | - | ns |
| t_{BLK2Q} | Read block select to out disable time (when pipelined register is disabled) | - | 2.16 | - | 2.54 | ns |
| t_{RSTREM} | Read asynchronous reset removal time (pipelined clock) | -0.02 | - | -0.03 | - | ns |
| | Read asynchronous reset removal time (non-pipelined clock) | 0.046 | - | 0.054 | - | ns |
| t_{RSTREC} | Read asynchronous reset recovery time (pipelined clock) | 0.507 | - | 0.597 | - | ns |
| | Read asynchronous reset recovery time (non-pipelined clock) | 0.236 | - | 0.278 | - | ns |
| t_{R2Q} | Read asynchronous reset to output propagation delay (with pipelined register enabled) | - | 0.83 | - | 0.98 | ns |
| t_{SRSTSU} | Read synchronous reset setup time | 0.271 | - | 0.319 | - | ns |
| t_{SRSTHD} | Read synchronous reset hold time | 0.061 | - | 0.071 | - | ns |
| t_{CCY} | Write clock period | 4 | - | 4 | - | ns |
| $t_{CCLKMPWH}$ | Write clock minimum pulse width High | 1.8 | - | 1.8 | - | ns |
| $t_{CCLKMPWL}$ | Write clock minimum pulse width Low | 1.8 | - | 1.8 | - | ns |

Table 127 • uSRAM (RAM1024x1) in 1024x1 Mode (continued)Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|---------------|-----------------------------|-------------|-----|-------|-----|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{BLKCSU} | Write block setup time | 0.404 | – | 0.476 | – | ns |
| t_{BLKCHD} | Write block hold time | 0.007 | – | 0.008 | – | ns |
| t_{DINCSU} | Write input data setup time | 0.003 | – | 0.004 | – | ns |
| t_{DINCHD} | Write input data hold time | 0.137 | – | 0.161 | – | ns |
| $t_{ADDRCSU}$ | Write address setup time | 0.088 | – | 0.104 | – | ns |
| $t_{ADDRCHD}$ | Write address hold time | 0.247 | – | 0.29 | – | ns |
| t_{WECSU} | Write enable setup time | 0.397 | – | 0.467 | – | ns |
| t_{WECHD} | Write enable hold time | –0.03 | – | –0.03 | – | ns |
| f_{MAX} | Maximum frequency | – | 250 | – | 250 | MHz |

12. Embedded NVM (eNVM) Characteristics

Table 128 • eNVM Read Performance

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

| Symbol | Description | Operating Temperature Range | | | | | | Unit |
|----------------------|-----------------------------|-----------------------------|-----|----------------|-----|-------------|-----|------|
| | | -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 | |
| F _{MAXREAD} | eNVM Maximum Read Frequency | 25 | 25 | 25 | 25 | 25 | 25 | MHz |

Table 129 • eNVM Page Programming

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

| Symbol | Description | Operating Temperature Range | | | | | | Unit |
|----------------------|----------------------------|-----------------------------|-----|----------------|-----|-------------|-----|------|
| | | -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 |

13. Crystal Oscillator

Table 130 describes the electrical characteristics of the crystal oscillator in the IGLOO2 FPGA and SmartFusion2 SoC FPGAs.

Table 130 • Electrical Characteristics of the Crystal Oscillator – High Gain Mode (20 MHz)

| Parameter | Description | Condition | Min | Typ | Max | Units |
|------------|--|-------------------------------------|---------|-------|---------|-------|
| FXTAL | Operating frequency | | – | 20 | – | MHz |
| ACCXTAL | Accuracy | 005, 010, 025, 050, and 090 Devices | – | – | 0.0047 | % |
| | | 150 Devices | – | – | 0.0058 | % |
| 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) | 010, 025, and 050 Devices | – | 200 | 300 | ps |
| | | 150 Devices | – | 250 | 410 | ps |
| | | 005 and 090 Devices | – | 250 | 550 | ps |
| IDYNXTAL | Operating current | 010 and 050 Devices | – | 1.5 | – | mA |
| | | 005, 025, 090, and 150 Devices | – | 1.65 | – | 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) | 005, 010, 025, and 050 Devices | – | – | 0.8 | ms |
| | | 090 and 150 Devices | – | – | 1.0 | ms |

Table 131 • Electrical Characteristics of the Crystal Oscillator – Medium Gain Mode (2 MHz)

| Parameter | Description | Condition | Min | Typ | Max | Units |
|------------|---|-------------------------------------|---------|-------|---------|-------|
| FXTAL | Operating frequency | | – | 2 | – | MHz |
| ACCXTAL | Accuracy | 050 Devices | – | – | 0.00105 | % |
| | | 005, 010, 025, 090, and 150 Devices | – | – | 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 |

Table 131 • Electrical Characteristics of the Crystal Oscillator – Medium Gain Mode (2 MHz) (continued)

| | | | | | | |
|--------|--|---------------------|---|---|-----|----|
| SUXTAL | Startup time (with regard to stable oscillator output) | 010 and 050 Devices | – | – | 4.5 | ms |
| | | 005 and 025 Devices | – | – | 5 | ms |
| | | 090 and 150 Devices | – | – | 7 | ms |

Table 132 • Electrical Characteristics of the Crystal Oscillator – Low Gain Mode (32 kHz)

| Parameter | Description | Condition | Min | Typ | Max | Units |
|------------|--|-------------------------------------|---------|-------|---------|-------|
| FXTAL | Operating frequency | | – | 32 | – | kHz |
| ACCXTAL | Accuracy | 005, 010, 025, 050, and 090 Devices | – | – | 0.004 | % |
| | | 150 Devices | – | – | 0.005 | % |
| CYCXTAL | Output duty cycle | | – | 49–51 | 47–53 | % |
| 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 | 010 and 050 Devices | – | 0.044 | – | mA |
| | | 005, 025, 090, and 150 Devices | – | 0.060 | – | 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) | 005, 025, 050, 090, and 150 Devices | – | – | 115 | ms |
| | | 010 Devices | – | – | 126 | ms |

14. On-Chip Oscillator

Table 133 and Table 134 describe the electrical characteristics of the available on-chip oscillators in the IGLOO2 FPGAs and SmartFusion2 SoC FPGAs.

Table 133 • Electrical Characteristics of the 50 MHz RC Oscillator

| Parameter | Description | Condition | Min | Typ | Max | Units |
|---------------------|------------------------------|-----------------------|-----|-------|-----------|-------|
| F50RC | Operating frequency | | – | 50 | – | MHz |
| ACC50RC | Accuracy | 050 Devices | – | 1 | 4 | % |
| | | 005 and 025 Devices | – | 1 | 5 | % |
| | | 090 Devices | – | 1 | 6.3 | % |
| | | 010 and 150 Devices | – | 1 | 7.1 | % |
| CYC50RC | Output duty cycle | | – | 49–51 | 46.5–53.5 | % |
| JIT50RC | Output jitter (peak to peak) | Period Jitter | | | | |
| | | 005, 010, 050 Devices | – | 200 | 300 | ps |
| | | 150 Devices | – | 200 | 400 | ps |
| | | 025 and 090 Devices | – | 300 | 500 | ps |
| | | Cycle-to-Cycle Jitter | | | | |
| | | 005 and 050 Devices | – | 200 | 300 | ps |
| | | 010 and 150 Devices | – | 320 | 420 | ps |
| 025 and 090 Devices | – | 320 | 850 | ps | | |
| IDYN50RC | Operating current | | – | 6.5 | – | mA |

Table 134 • Electrical Characteristics of the 1 MHz RC Oscillator

| Parameter | Description | Condition | Min | Typ | Max | Units |
|-----------|------------------------------|--------------------------------|-----|-------|-----------|-------|
| F1RC | Operating frequency | | – | 1 | – | MHz |
| ACC1RC | Accuracy | 005, 010, 025, and 050 Devices | – | 1 | 3 | % |
| | | 150 Devices | – | 1 | 4.5 | % |
| | | 090 Devices | – | 1 | 5.6 | % |
| CYC1RC | Output duty cycle | | – | 49–51 | 46.5–53.5 | % |
| JIT1RC | Output jitter (peak to peak) | Period Jitter | | | | |
| | | 005, 010, 025, and 050 Devices | – | 10 | 20 | ns |
| | | 090 and 150 Devices | – | 10 | 28 | ns |
| | | Cycle-to-Cycle Jitter | | | | |
| | | 005, 010, and 050 Devices | – | 10 | 20 | ns |
| | | 025 and 150 Devices | – | 10 | 35 | ns |
| | | 090 Devices | – | 10 | 45 | ns |
| IDYN1RC | Operating current | | – | 0.1 | – | mA |
| SU1RC | Startup time | 050, 090, and 150 Devices | – | – | 17 | μs |
| | | 005, 010, and 025 Devices | – | – | 18 | μs |

15. Clock Conditioning Circuits (CCC)

Table 135 • IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Specification

Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Conditions | Minimum | Typical | Maximum | Units | Notes |
|--|---|---------|---------|---------|---------------|-------|
| 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} | | 0.078 | – | 400 | MHz | 1 |
| PLL VCO frequency | | 500 | – | 1000 | MHz | 2 |
| Delay increments in programmable delay blocks | | – | 75 | 100 | ps | |
| Number of programmable values in each programmable delay block | | – | – | 64 | – | |
| Acquisition time | | – | 70 | 100 | μs | |
| 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 | 050 Devices $F_{out} \leq 400\text{ MHz}$ | 48 | – | 52 | % | |
| | 005, 010, and 025 Devices $F_{out} < 350\text{ MHz}$ | 48 | – | 52 | % | |
| | 005, 010, and 025 Devices $350\text{ MHz} \leq F_{out} \leq 400\text{ MHz}$ | 46 | – | 54 | % | |
| | 090 Devices $F_{out} \leq 100\text{ MHz}$ | 48 | – | 52 | % | |
| | 090 Devices $100\text{ MHz} \leq F_{out} \leq 400\text{ MHz}$ | 44 | – | 52 | % | |
| | 150 Devices $F_{out} \leq 120\text{ MHz}$ | 48 | – | 52 | % | |
| | 150 Devices $120\text{ MHz} \leq F_{out} \leq 400\text{ MHz}$ | 45 | – | 52 | % | |
| Spread Spectrum Characteristics | | | | | | |
| Modulation frequency range | | 25 | 35 | 50 | k | |
| Modulation depth range | | 0 | – | 1.5 | % | |

Table 135 • IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Specification (continued)**Worst-Case Industrial Conditions: T_J = 100°C, VDD = 1.14 V**

| | | | | | | |
|--------------------------|--|---|-----|---|---|--|
| Modulation depth control | | – | 0.5 | – | % | |
|--------------------------|--|---|-----|---|---|--|

Note:

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

Table 136 • IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Jitter SpecificationsWorst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| CCC Output Maximum Peak-to-Peak Period Jitter fOUT_CCC | | | | | | | |
|---|---|---|---------------------|---|----------------------|-------|-------|
| Parameter | Conditions/Package Combinations | | | | | Units | Notes |
| 010, 050 FG896/FG484 Packages | SSO = 0 | $0 < \text{SSO} \leq 2$ | $\text{SSO} \leq 4$ | $\text{SSO} \leq 8$ | $\text{SSO} \leq 16$ | | * |
| 20 MHz to 100 MHz | $\text{Max}(110, \pm 1\% \times (1/f_{\text{OUT_CCC}}))$ | $\text{Max}(150, \pm 1\% \times (1/f_{\text{OUT_CCC}}))$ | | | | ps | |
| 100 MHz to 400 MHz | $\text{Max}(120, \pm 1\% \times (1/f_{\text{OUT_CCC}}))$ | $\text{Max}(150, \pm 1\% \times (1/f_{\text{OUT_CCC}}))$ | | $\text{Max}(170, \pm 1\% \times (1/f_{\text{OUT_CCC}}))$ | | ps | |
| 025 FG484 Package | $0 < \text{SSO} \leq 16$ | | | | | | * |
| 20 MHz to 74 MHz | $\pm 1\% \times (1/f_{\text{OUT_CCC}})$ | | | | | ps | |
| 74 MHz to 400 MHz | 210 | | | | | ps | |
| 005 FG484 Package | $0 < \text{SSO} \leq 16$ | | | | | | * |
| 20 MHz to 53 MHz | $\pm 1\% \times (1/f_{\text{OUT_CCC}})$ | | | | | ps | |
| 53 MHz to 400 MHz | 270 | | | | | ps | |
| 090 FG676 and FC325 Package | $0 < \text{SSO} \leq 16$ | | | | | | * |
| 20 MHz to 100 MHz | $\pm 1\% \times (1/f_{\text{OUT_CCC}})$ | | | | | ps | |
| 100 MHz to 400 MHz | 150 | | | | | ps | |
| 150 FC1152 Package | $0 < \text{SSO} \leq 16$ | | | | | | * |
| 20 MHz to 100 MHz | $\pm 1\% \times (1/f_{\text{OUT_CCC}})$ | | | | | ps | |
| 100 MHz to 400 MHz | 120 | | | | | ps | |
| <i>Note: *SSO Data is based on LVCMOS 2.5 V MSIO and/or MSIOD Bank I/Os</i> | | | | | | | |

16. JTAG

Table 137 • JTAG 1532

| Parameter | Description | Speed Grade | | | | | | | | | | | | Units |
|-----------|-----------------------------|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | -1 | Std | |
| | | 005 | | 010 | | 025 | | 050 | | 090 | | 150 | | |
| tTCK2Q | Clock to Q (data out) | 7.47 | 8.79 | 7.73 | 9.09 | 7.75 | 9.12 | 7.89 | 9.28 | 8.96 | 10.54 | 8.66 | 10.19 | ns |
| tRSTB2Q | Reset to Q (data out) | 7.65 | 9 | 6.43 | 7.56 | 6.13 | 7.21 | 7.40 | 8.70 | 7.75 | 9.12 | 8.79 | 10.34 | ns |
| tDISU | Test Data Input Setup Time | -1.05 | -0.89 | -0.69 | -0.59 | -0.67 | -0.57 | -0.30 | -0.25 | -1.31 | -1.11 | -0.96 | -0.82 | ns |
| tDIHD | Test Data Input Hold Time | 2.38 | 2.8 | 2.38 | 2.8 | 2.42 | 2.85 | 2.09 | 2.45 | 2.68 | 3.15 | 2.57 | 3.02 | ns |
| tTMSSU | Test Mode Select Setup Time | -0.73 | -0.62 | -1.03 | -1.21 | -1.1 | -0.94 | 0.28 | 0.33 | -1.02 | -0.87 | -0.53 | -0.45 | ns |
| tTMDHD | Test Mode Select Hold Time | 1.36 | 1.6 | 1.43 | 1.68 | 1.93 | 2.27 | 0.16 | 0.19 | 1.67 | 1.96 | 1.02 | 1.2 | ns |
| tTRSTREM | ResetB Removal Time | -0.77 | -0.65 | -1.08 | -0.92 | -1.33 | -1.13 | -0.45 | -0.38 | -0.76 | -0.65 | -1.03 | -0.88 | ns |
| tTRSTREC | ResetB Recovery Time | -0.76 | -0.65 | -1.07 | -0.91 | -1.34 | -1.14 | -0.45 | -0.38 | -0.77 | -0.65 | -1.03 | -0.88 | ns |
| FTCKMAX | TCK Maximum frequency | 25 | 21.25 | 25 | 21.25 | 25 | 21.25 | 25.00 | 21.25 | 25 | 21.25 | 25 | 21.25 | MHz |

17. DEVRST_N Characteristics

Table 138 • DEVRST_N Characteristics

Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Symbol | Description | All Devices/Speed Grades | | | Units | Notes |
|--------------|--------------------|--------------------------|-----|-----|-------|-------|
| | | Min | Typ | Max | | |
| TRAMPDEVRSTN | DEVRST_N ramp rate | — | — | 10 | ns | * |

Note: * Slower ramp rates are susceptible to board level noise.

18. System Controller SPI Characteristics

Table 139 • System Controller SPI Characteristics
Worst-Case Industrial Conditions: T_J = 100°C, VDD = 1.14 V

| Symbol | Description | Conditions | All Devices/Speed Grades | | | Units | Notes |
|--------|---|--|--------------------------|-------|-----|-------|-------|
| | | | 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 | SC_SPI_SCK, SC_SPI_SDO, SC_SPI_SS rise time (10%–90%) 1 | IO Configuration: LVTTTL 3.3 V-20mA AC Loading: 35pF Test Conditions: Typical Voltage, 25C | – | 1.239 | – | ns | * |
| sp5 | SC_SPI_SCK, SC_SPI_SDO, SC_SPI_SS fall time (10%–90%) 1 | IO Configuration: LVTTTL 3.3 V-20mA AC Loading: 35pF Test Conditions: Typical Voltage, 25C | – | 1.245 | – | ns | * |
| sp6 | Data from master (SC_SPI_SDO) setup time | | 160 | – | – | ns | |
| sp7 | Data from master (SC_SPI_SDO) hold time | | 160 | – | – | ns | |
| sp8 | SC_SPI_SDI setup time | | 20 | – | – | ns | |
| sp9 | SC_SPI_SDI hold time | | 20 | – | – | ns | |

Note: *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/soc/download/ibis/default.aspx>. Use the supported I/O Configurations for the System Controller SPI in Table 140.

Table 140 • 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 |

19. 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 141 • Mathblocks with all Registers Used

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|-------------------------------------|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{MISU} | Input, control register setup time | 0.149 | – | 0.176 | – | ns |
| t_{MIHD} | Input, control register hold time | 1.68 | – | 1.976 | – | ns |
| $t_{MOC DINSU}$ | CDIN input setup time | 0.185 | – | 0.218 | – | ns |
| $t_{MOC DINHD}$ | CDIN input hold time | 0.08 | – | 0.094 | – | ns |
| $t_{MSRSTENSU}$ | Synchronous reset/enable setup time | –0.419 | – | –0.493 | – | ns |
| $t_{MSRSTENHD}$ | Synchronous reset/enable hold time | 0.011 | – | 0.013 | – | ns |
| $t_{MARSTREM}$ | Asynchronous reset removal time | 0 | – | 0 | – | ns |
| $t_{MARSTREC}$ | Asynchronous reset recovery time | 0.088 | – | 0.104 | – | ns |
| t_{MOCQ} | Output register clock to out delay | – | 0.232 | – | 0.273 | ns |
| t_{MCLKMP} | CLK minimum period | 2.245 | – | 2.641 | – | ns |

Table 142 • Mathblock with Input Bypassed and Output Registers Used

Worst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|-------------------------------------|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{MOSU} | Output register setup time | 2.294 | – | 2.699 | – | ns |
| t_{MOHD} | Output register hold time | 1.68 | – | 1.976 | – | ns |
| $t_{MOC DINSU}$ | CDIN input setup time | 0.115 | – | 0.136 | – | ns |
| $t_{MOC DINHD}$ | CDIN input hold time | –0.444 | – | –0.522 | – | ns |
| $t_{MSRSTENSU}$ | Synchronous reset/enable setup time | –0.419 | – | –0.493 | – | ns |
| $t_{MSRSTENHD}$ | Synchronous reset/enable hold time | 0.011 | – | 0.013 | – | ns |
| $t_{MARSTREM}$ | Asynchronous reset removal time | 0 | – | 0 | – | ns |
| $t_{MARSTREC}$ | Asynchronous reset recovery time | 0.014 | – | 0.017 | – | ns |
| t_{MOCQ} | Output register clock to out delay | – | 0.232 | – | 0.273 | ns |
| t_{MCLKMP} | CLK minimum period | 2.179 | – | 2.563 | – | ns |

Table 143 • Mathblock with Input Register Used and Output in Bypass ModeWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|-----------------|--------------------------------------|-------------|-------|--------|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{MISU} | Input register setup time | 0.149 | – | 0.176 | – | ns |
| t_{MIHD} | Input register hold time | 0.185 | – | 0.218 | – | ns |
| $t_{MSRSTENSU}$ | Synchronous reset/enable setup time | 0.08 | – | 0.094 | – | ns |
| $t_{MSRSTENHD}$ | Synchronous reset/enable hold time | –0.012 | – | –0.014 | – | ns |
| $t_{MARSTREM}$ | Asynchronous reset removal time | –0.005 | – | –0.005 | – | ns |
| $t_{MARSTREC}$ | Asynchronous reset recovery time | 0.088 | – | 0.104 | – | ns |
| t_{MICQ} | Input register clock to output delay | – | 2.52 | – | 2.964 | ns |
| $t_{MCDIN2Q}$ | CDIN to output delay | – | 1.951 | – | 2.295 | ns |

Table 144 • Mathblock with Input and Output in Bypass ModeWorst Commercial-Case Conditions: $T_J = 85^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | | | Units |
|---------------|-----------------------|-------------|-------|-----|-------|-------|
| | | -1 | | Std | | |
| | | Min | Max | Min | Max | |
| t_{MIQ} | Input to output delay | – | 2.568 | – | 3.022 | ns |
| $t_{MCDIN2Q}$ | CDIN to output delay | – | 1.951 | – | 2.295 | ns |

20. Flash*Freeze Timing Characteristics

Table 145 • Flash*Freeze Entry and Exit Times

Worst-Case Industrial Conditions: T_j = 100°C, VDD = 1.14 V

| Symbols | Parameters | Conditions | 005, 010, 025, 090, and 150 | 050 | Units | Notes |
|-----------|--|--|--------------------------------|-----|-------|-------|
| TFF_ENTRY | Entry time | eNVM and MSS/HPMS PLL = ON | 160 | 150 | μs | 1 |
| | | eNVM and MSS/HPMS PLL=OFF | 215 | 200 | μs | 1 |
| TFF_EXIT | Exit time with respect to the MSS PLL Lock | eNVM and MSS/HPMS PLL = ON during F*F | 100 | 100 | μs | 1 |
| | | eNVM=ON and MSS/HPMS PLL =OFF during F*F and MSS/HPMS PLL turned back on at exit | 136 | 120 | μs | 1 |
| | | eNVM and MSS/HPMS PLL=OFF during F*F and both are turned back on at exit | 200 | 200 | μs | 1 |
| | | eNVM=OFF and MSS/HPMS PLL = ON during F*F and eNVM turned back on at exit | 200 | 200 | μs | 1 |
| | Exit time with respect to the Fabric PLL Lock | eNVM and MSS/HPMS PLL = ON during F*F | 1.5 | 1.5 | ms | 1,2 |
| | | eNVM and MSS/HPMS PLL=OFF during F*F and both are turned back on at exit | 1.5 | 1.5 | ms | 1,2 |
| | Exit time with respect to the Fabric buffer output | eNVM and MSS/HPMS PLL = ON during F*F | 21 | 15 | μs | 1 |
| | | eNVM and MSS/HPMS PLL=OFF during F*F and both are turned back on at exit | 65 | 55 | μs | 1 |

Notes:

1. F*F entry and exit times were measured with FCLK = 100MHz
2. PLL Lock Delay set to 1024 cycles (default)

21. DDR Memory Interface Characteristics

Table 146 • DDR Memory Interface Characteristics
 Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

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

22. SFP Transceiver Characteristics

IGLOO2 and SmartFusion2 SERDES complies with small form-factor pluggable (SFP) requirements as specified in SFP INF-80741. [Table 147](#) provides the electrical characteristics.

Table 147 • SFP Transceiver Electrical Characteristics

Worst-Case Industrial Conditions: $T_J = 100^{\circ}\text{C}$, $V_{DD} = 1.14\text{ V}$

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

Notes:

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.

23. PCIe Electrical and Timing AC and DC Characteristics

PCIe® is a high speed, packet-based, point-to-point, low pin count, serial interconnect bus. 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 148 • Transmitter Parameters

Worst-Case Industrial Conditions: $T_J = 100^{\circ}\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Min | Typ | Max | Units |
|---------------|---|-------|-----|--------------|---------------|
| VTX-DIFF-PP | Differential swing PCIe Gen1 and 2 | 0.8 | – | 1.2 | V |
| VTX-CM-AC-P | Output common mode voltage PCIe Gen1 | – | – | 20 | mV |
| VTX-CM-AC-PP | Output common mode voltage PCIe Gen2 | – | – | 100 | mV |
| VTX-RISE-FALL | Rise and fall time (20% to 80%) PCIe Gen1 | 0.125 | – | – | UI |
| | Rise and fall time (20% to 80%) PCIe Gen2 | 0.15 | – | – | UI |
| ZTX-DIFF-DC | Output impedance – differential | 80 | – | 120 | Ω |
| LTX-SKEW | Lane-to-lane TX skew within a SERDES block PCIe Gen1 | – | – | 500 ps+ 2 UI | ps |
| | Lane-to-lane TX skew within a SERDES block PCIe Gen2 | – | – | 500 ps+4 UI | ps |
| RLTX-DIFF | Return loss differential mode PCIe Gen1 | –10 | – | – | dB |
| | Return loss differential mode PCIe Gen2 0.05 GHz to 1.25 GHz | –10 | – | – | dB |
| | 1.25 GHz to 2.5 GHz | –8 | – | – | dB |
| RLTX-CM | Return loss common mode PCIe Gen1 and 2 | –6 | – | – | dB |
| TX-LOCK-RST | Transmit PLL lock time from reset | – | – | 10 | μs |

Table 149 • Receiver Parameters

Worst-Case Industrial Conditions: $T_J = 100^{\circ}\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Min | Typ | Max | Units |
|----------------|--|-------|-------|-------|---------------|
| VRX-DIFF-PP-CC | Input levels PCIe Gen1 | 0.175 | – | 1.2 | V |
| | Input levels PCIe Gen2 | 0.12 | – | 1.2 | V |
| VRX-CM-DC-P | Input common mode range (DC coupled) Note: PCIe standard mandates AC coupling | NA | NA | NA | – |
| VRX-CM-AC-P | Input common mode range (AC coupled) | – | – | 150 | mV |
| VRX-DIFF-PP-CC | Differential input sensitivity PCIe Gen1 | 0.175 | – | – | mV |
| | Differential input sensitivity PCIe Gen2 | 0.12 | – | – | 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 PCIe Gen1 | –10 | – | – | dB |
| | Return loss differential mode PCIe Gen2 0.05 GHz to 1.25 GHz | –10 | – | – | dB |
| | 1.25 GHz to 2.5 GHz | –8 | – | – | dB |
| RLRX-CM | Return loss common mode PCIe Gen1 and 2 | –6 | – | – | dB |

Table 149 • Receiver Parameters (continued)Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| | | | | | |
|----------------------|--|----|---|-----|----|
| | CID limit (set by 8B/10B coding, not the receiver PLL) | – | – | 4 | UI |
| VRX-IDLE-DET-DIFF-PP | Signal detect limit | 65 | – | 175 | mV |

Table 150 • SERDES Reference Clock AC SpecificationsWorst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| 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 151 • 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 |
| HCSL Differential Voltage Specification | | | | | | |
| VICM | Input common mode voltage | | 0.05 | – | 2.4 | V |
| VIDIFF | Input differential voltage | | 100 | – | 1100 | mV |

Table 152 • HCSL Minimum and 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 |

24. SmartFusion2 Specifications

24.1 MSS Clock Frequency

Table 153 • Maximum Frequency for MSS Main Clock
Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Symbol | Description | Speed Grade | | Units |
|--------|--|-------------|-----|-------|
| | | -1 | Std | |
| M3_CLK | Maximum frequency for the MSS Main Clock | 166 | 142 | MHz |

24.2 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. For timing parameter definitions, refer to [Figure 16 on page 125](#).

Table 154 • I²C Characteristics
Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Definition | Conditions | Min | Typ | Max | Units | Notes |
|-----------------|---|---|-----------------------|-------|------|---------------|-------|
| VIL | Input low voltage | Refer to the "Single-Ended I/O Standards" section on page 29 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 29 for more information. I/O standard used for illustration: MSIO bank – LVTTTL 8 mA low drive. | 2 | - | 3.45 | V | |
| VHYS | Hysteresis of Schmitt triggered inputs for $V_{DDI} > 2\text{ V}$ | Refer to Table 22 on page 29 for more information. | $0.05 \times V_{DDI}$ | - | - | V | |
| IIL | Input current high | Refer to the "Single-Ended I/O Standards" section on page 29 for more information. | - | - | 10 | μA | |
| IIH | Input current low | Refer to the "Single-Ended I/O Standards" section on page 29 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 29 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 VIHMin to VILMax | VIHmin to VILMax, $C_{load} = 400\text{ pF}$ | - | 21.04 | - | ns | 1 |
| | | VIHmin to VILMax, $C_{load} = 100\text{ pF}$ | - | 5.556 | - | ns | |

Table 154 • I2C Characteristics (continued)Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Definition | Conditions | Min | Typ | Max | Units | Notes |
|-----------------|--|--|-----|--------|--------|----------|-------|
| t_{OR} | Output rise time from V_{ILMax} to V_{IHMin} | V_{ILMax} to V_{IHMin} , $C_{load} = 400\text{pF}$ | – | 19.887 | – | ns | 1 |
| | | V_{ILMax} to V_{IHMin} , $C_{load} = 100\text{pF}$ | – | 5.218 | – | ns | |
| $R_{pull-up}$ | Output buffer maximum pull-down resistance | | – | – | 50 | Ω | 2, 3 |
| $R_{pull-down}$ | Output buffer maximum pull-up resistance | | – | – | 131.25 | Ω | 2, 4 |
| D_{max} | 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 | |

Notes:

1. These values are provided for MSIO Bank – LVTTTL 8 mA Low Drive at 25°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/soc/download/ibis/default.aspx>.
2. These maximum values are provided for information only. Minimum output buffer resistance values depend on V_{DDI} , 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/soc/download/ibis/default.aspx>.
3. $R(PULL-DOWN-MAX) = (V_{OLspec}) / I_{OLspec}$
4. $R(PULL-UP-MAX) = (V_{DDImax} - V_{OHspec}) / I_{OHspec}$

Table 155 • I2C Switching CharacteristicsWorst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

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

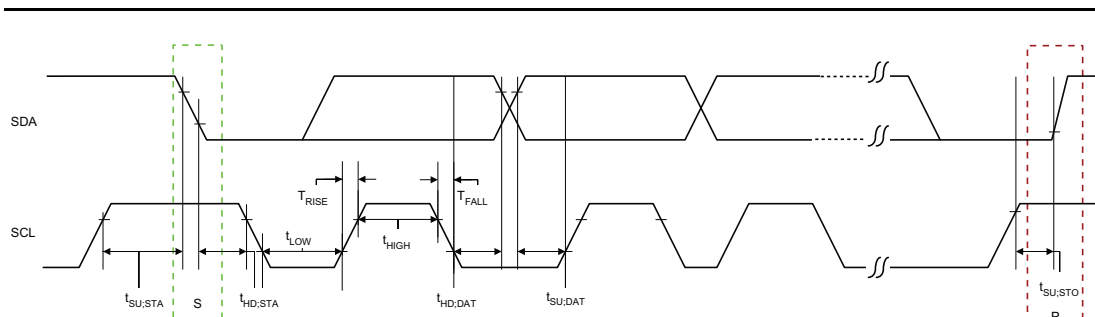


Figure 16 • I²C Timing Parameter Definition

24.3 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. For timing parameter definitions, refer to Figure 17 on page 127.

Table 156 • SPI Characteristics

Worst-Case Industrial Conditions: T_J = 100°C, VDD = 1.14 V

| Symbol | Description | Conditions | All Devices/Speed Grades | | | Unit | Notes |
|--------------------------|--|------------|--------------------------|-----|-----|------|-------|
| | | | Min | Typ | Max | | |
| 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 | |
| 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 | | |

Table 156 • SPI Characteristics (continued)
Worst-Case Industrial Conditions: T_J = 100°C, VDD = 1.14 V

| Symbol | Description | Conditions | All Devices/Speed Grades | | | Unit | Notes |
|---|--|---|-----------------------------|-------|-----|------|-------|
| | | | Min | Typ | Max | | |
| 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 | SPI_[0 1]_CLK, SPI_[0 1]_DO, SPI_[0 1]_SS rise time (10%–90%) | IO Configuration: LVCMOS 2.5 V-8mA AC Loading: 35pF Test Conditions: Typical Voltage, 25°C | – | 2.77 | – | ns | 1 |
| sp5 | SPI_[0 1]_CLK, SPI_[0 1]_DO, SPI_[0 1]_SS fall time (10%–90%) | IO Configuration: LVCMOS 2.5 V-8mA AC Loading: 35pF Test Conditions: Typical Voltage, 25°C | – | 2.906 | – | ns | 1 |
| SPI Master Configuration | | | | | | | |
| sp6m | SPI_[0 1]_DO setup time | | (SPI_x_CLK_period/2) – 3.0 | – | – | ns | 2 |
| sp7m | SPI_[0 1]_DO hold time | | (SPI_x_CLK_period/2) – 2.5 | – | – | ns | 2 |
| sp8m | SPI_[0 1]_DI setup time | | 8 | – | – | ns | 2 |
| sp9m | SPI_[0 1]_DI hold time | | 2.5 | – | – | ns | 2 |
| SPI Slave Configuration | | | | | | | |
| sp6s | SPI_[0 1]_DO setup time | | (SPI_x_CLK_period/2) – 12.0 | – | – | ns | 2 |
| sp7s | SPI_[0 1]_DO hold time | | (SPI_x_CLK_period/2) + 3.0 | – | – | ns | 2 |
| sp8s | SPI_[0 1]_DI setup time | | 2 | – | – | ns | 2 |
| sp9s | SPI_[0 1]_DI hold time | | 3 | – | – | ns | 2 |
| Notes: | | | | | | | |
| 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/soc/download/ibis/default.aspx . | | | | | | | |
| 2. For allowable pclk configurations, refer to the Serial Peripheral Interface Controller section in the <i>SmartFusion2 ARM Cortex-M3 and Microcontroller Subsystem User's Guide</i> . | | | | | | | |



Figure 17 • SPI Timing for a Single Frame Transfer in Motorola Mode (SPH = 1)

25. CAN Controller Characteristics

Table 157 • CAN Controller Characteristics

Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | Units | Notes |
|------------|--|-------------|------|-------|-------|
| | | -1 | Std | | |
| FCANREFCLK | Internally Sourced CAN Reference Clock Frequency | 160 | 136 | MHz | * |
| BAUDCANMAX | Maximum CAN Performance Baud Rate | 1 | 1 | Mbps | |
| BAUDCANMIN | Minimum CAN Performance Baud Rate | 0.05 | 0.05 | Mbps | |

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

26. USB Characteristics

Table 158 • USB Characteristics

Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Parameter | Description | Speed Grade | | Units |
|------------|--|-------------|-------|-------|
| | | -1 | Std | |
| FUSBREFCLK | Internally Sourced USB Reference Clock Frequency | 166 | 142 | MHz |
| TUSBCLK | USB Clock Period | 16.66 | 16.66 | ns |
| TUSBPD | Clock to USB Data Propagation Delay | 9.0 | 9.0 | ns |
| TUSBSU | Setup Time for USB Data | 6.0 | 6.0 | ns |
| TUSBHD | Hold Time for USB Data | 0 | 0 | ns |

27. IGLOO2 Specifications

27.1 HPMS Clock Frequency

Table 159 • Maximum Frequency for HPMS Main Clock
Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Symbol | Description | Speed Grade | | Units |
|----------|---|-------------|-----|-------|
| | | -1 | Std | |
| HPMS_CLK | Maximum Frequency for the HPMS Main Clock | 166 | 142 | MHz |

27.2 IGLOO2 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 18 on page 132](#).

Table 160 • SPI Characteristics
Worst-Case Industrial Conditions: $T_J = 100^\circ\text{C}$, $V_{DD} = 1.14\text{ V}$

| Symbol | Description | Conditions | All Devices/Speed Grades | | | Unit | Notes |
|--------------------------|--|------------|--------------------------|-----|---------------|---------------|-------|
| | | | Min | Typ | Max | | |
| 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 | |
| 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 | | |

Notes:

- 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/soc/download/ibis/default.aspx>.
- For allowable pclk configurations, refer to the Serial Peripheral Interface Controller section in the *SmartFusion2 ARM Cortex-M3 and Microcontroller Subsystem User's Guide*.

Table 160 • SPI Characteristics (continued)
Worst-Case Industrial Conditions: T_J = 100°C, VDD = 1.14 V

| Symbol | Description | Conditions | All Devices/Speed Grades | | | Unit | Notes |
|--|--|---|---|-------|-----|------|-------|
| | | | Min | Typ | Max | | |
| 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 | SPI_[0 1]_CLK, SPI_[0 1]_DO, SPI_[0 1]_SS rise time (10%–90%) | IO Configuration: LVCMOS 2.5 V-8mA AC Loading: 35pF Test Conditions: Typical Voltage, 25°C | – | 2.77 | – | ns | 1 |
| sp5 | SPI_[0 1]_CLK, SPI_[0 1]_DO, SPI_[0 1]_SS fall time (10%–90%) | IO Configuration: LVCMOS 2.5 V-8mA AC Loading: 35pF Test Conditions: Typical Voltage, 25°C | – | 2.906 | – | ns | 1 |
| SPI Master Configuration | | | | | | | |
| sp6m | SPI_[0 1]_DO setup time | | $(\text{SPI}_x\text{CLK_period}/2) - 3.0$ | – | – | ns | 2 |
| sp7m | SPI_[0 1]_DO hold time | | $(\text{SPI}_x\text{CLK_period}/2) - 2.5$ | – | – | ns | 2 |
| sp8m | SPI_[0 1]_DI setup time | | 8 | – | – | ns | 2 |
| sp9m | SPI_[0 1]_DI hold time | | 2.5 | – | – | ns | 2 |
| SPI Slave Configuration | | | | | | | |
| sp6s | SPI_[0 1]_DO setup time | | $(\text{SPI}_x\text{CLK_period}/2) - 12.0$ | – | – | ns | 2 |
| sp7s | SPI_[0 1]_DO hold time | | $(\text{SPI}_x\text{CLK_period}/2) + 3.0$ | – | – | ns | 2 |
| sp8s | SPI_[0 1]_DI setup time | | 2 | – | – | ns | 2 |
| sp9s | SPI_[0 1]_DI hold time | | 3 | – | – | ns | 2 |
| Notes: | | | | | | | |
| <ol style="list-style-type: none"> 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/soc/download/ibis/default.aspx. For allowable pclk configurations, refer to the Serial Peripheral Interface Controller section in the <i>SmartFusion2 ARM Cortex-M3 and Microcontroller Subsystem User's Guide</i>. | | | | | | | |



Figure 18 • SPI Timing for a Single Frame Transfer in Motorola Mode (SPH = 1)

Datasheet Information

List of Changes

The following table shows important changes made in this document for each revision.

| Revision | Changes | Page |
|-------------------------------|--|----------|
| Revision 7 (June 2015) | Updated Table 1: "IGLOO2 FPGA and SmartFusion2 SoC FPGA Device Status" (SAR 68620). | 11 |
| Revision 6 (May 2015) | Updated Table 4: "FPGA Operating Limits" (SAR 65949). | 14 |
| | Updated Table 7: "Package Thermal Resistance" (SAR 62995). | 16 |
| | Updated Table 61: "SSTL18 AC Specifications (Applicable to DDRIO Bank Only)" and Table 65: "SSTL15 AC Specifications (for DDRIO I/O Bank Only)" (SAR 67210). | 54, 57 |
| | Added "Embedded NVM (eNVM) Characteristics" (SAR 52509). | 106 |
| | Updated Table 130: "Electrical Characteristics of the Crystal Oscillator – High Gain Mode (20 MHz)" (SAR 64855). | 107 |
| | Updated Table 135: "IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Specification" (SAR 65958 and SAR 56666). | 110 |
| | Added "DDR Memory Interface Characteristics" (SAR 66223). | 119 |
| | Added "SFP Transceiver Characteristics" (SAR 63105). | 120 |
| | Updated Table 153: "Maximum Frequency for MSS Main Clock" and Table 159: "Maximum Frequency for HPMS Main Clock" (SAR 66314). | 123, 130 |
| Revision 5 (March 2015) | Updated Table 1: "IGLOO2 FPGA and SmartFusion2 SoC FPGA Device Status" | 11 |
| | Updated Table 3: "Recommended Operating Conditions" for T _J symbol information. | 13 |
| | Updated Table 4: "FPGA Operating Limits" (SAR 63109). | 14 |
| | Updated Table 7: "Package Thermal Resistance" | 16 |
| | Updated Table 135: "IGLOO2 and SmartFusion2 SoC FPGAs CCC/PLL Specification" (SAR 62012). | 110 |
| | Added Table 138: "DEVRST_N Characteristics" (SAR 64100). | 114 |
| | Added Table 157: "CAN Controller Characteristics" , Table 158: "USB Characteristics" (SAR 50424). | 128, 129 |
| Revision 4 (November 2014) | Updated Table 1 . Changed the Status of 090 devices to "Production" (SAR 62750). | 11 |
| | Updated Figure 9 . Removed inverter bubble from DDR_IN latch (SAR 61418). | 81 |
| | Updated "PCIe Electrical and Timing AC and DC Characteristics" (SAR 62836). | 121 |
| Revision 3 (October 2014) | Updated Theta B/C columns and FCS325 package in Table 7 (SAR 62002). | 16 |

| Revision | Changes | Page |
|---|---|------------|
| Revision 2 (October 2014) | "IGLOO2 FPGA and SmartFusion2 SoC FPGA Device Status" table was updated (SAR 59056). | 11 |
| | Table 6 temperature and data retention information was updated SAR (61363). | 15 |
| | Storage Operating Table was updated and split into three tables – Table 4-Table 6 (SAR 58725). | 15–19 |
| | Updated Theta B/C columns and FCS325 package in Table 7 (SAR 62002). | 16 |
| | Added 090-FCS325 thermal resistance to Table 7 (SAR 59384). | 16 |
| | TQ144 package was added to Table 7 (SAR 57708). | 16 |
| | Added PLL jitter data for the VF400 package (SAR 53162). | 16 |
| | Added Additional Worst Case IDD to Table 9 and Table 10 (SAR 59077). | 18 |
| | Table 11, Table 12, and Table 13 were added to verify Inrush currents (SAR 56348). | 19 |
| | Table 16 and Table 17 – I/O speeds were replaced. | 26, 26 |
| | Max speed was changed in Table 29 (SAR 57221) and in Table 34 (SAR 57113). | 34, 36 |
| | "Minimum and Maximum DC/AC Input and Output Levels Specification" and Table 33–Table 37 were added. | 36–38 |
| | Added Cloud to Table 49 (SAR 56238). | 46 |
| | Removed "Rs" information in DDR Timing Measurement Table 61, Table 65, and Table 69. | 54, 57, 59 |
| | Updated drive programming for M/B-LVDS outputs (SAR 58154). | 69 |
| | Added an inverter bubble to DDR_IN latch in Figure 9 (SAR 61418). | 81 |
| | QF waveform in the Input DDR Timing Diagram was updated (SAR 59816). | 82 |
| | uSRAM Write Clock minimum values were updated in Table 121–Table 127 (SAR 55236). | 97–104 |
| | Fixed typo in the 32 kHz Crystal (XTAL) oscillator accuracy data section (SAR 59669). | 108 |
| | The "On-Chip Oscillator" section was split, and the "Embedded NVM (eNVM) Characteristics" section was added. Table 130–Table 134 were revised.(SARs 57898 and 59669). | 109 |
| | PLL VCP Frequency and conditions were added to Table 135 (SAR 57416). | 110 |
| | Fixed typo for PLL jitter data in the 100-400 MHz range (SAR 60727). | 110 |
| | Updated FCCC information in Table 135 and Table 136 (SAR 60799). | 110 |
| Device 025 specifications were added to Table 136 (SAR 51625). | 112 | |
| JTAG Table 137 was replaced (SAR 51188). | 113 | |
| Flash*Freeze Table 145 was replaced (SAR 57828). | 118 | |
| Added support for HCSL I/O Standard for SERDES reference clocks in Table 151 and Table 152 (SAR 50748). | 122 | |
| Tir and Tif parameters were added to Table 154 (SAR 52203). | 123 | |
| Speed grade consistency was fixed in tables throughout the datasheet (SAR 50722). | NA | |
| Added jitter attenuation information (SAR 59405). | NA | |
| Revision 1 (May 2014) | The IGLOO2 v2 and the SmartFusion2 v5 datasheets are combined into this single product family datasheet. | N/A |

Datasheet Categories

Categories

In order to provide the latest information to designers, some datasheet parameters are published before data has been fully characterized from silicon devices. The data provided for a given device, as highlighted in [Table 1 on page 11](#) is designated as either "Product Brief," "Advance," "Preliminary," or "Production." The definitions of these categories are as follows:

Product Brief

The product brief is a summarized version of a datasheet (advance or production) and contains general product information. This document gives an overview of specific device and family information.

Advance

This version contains initial estimated information based on simulation, other products, devices, or speed grades. This information can be used as estimates, but not for production.

This label only applies to the DC and Switching Characteristics chapter of the datasheet and will only be used when the data has not been fully characterized.

Preliminary

The datasheet contains information based on simulation and/or initial characterization. The information is believed to be correct, but changes are possible.

Production

This version contains information that is considered to be final.

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Microsemi Corporate Headquarters

One Enterprise, Aliso Viejo, CA 92656 USA. Within the USA: +1 (949) 380-6100

Sales: +1 (949) 380-6136

Fax: +1 (949) 215-4996

Sales.Support@Microsemi.com



Microsemi Corporate Headquarters
One Enterprise, Aliso Viejo,
CA 92656 USA

Within the USA: +1 (800) 713-4113
Outside the USA: +1 (949) 380-6100
Sales: +1 (949) 380-6136
Fax: +1 (949) 215-4996

E-mail: sales.support@microsemi.com

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Как с нами связаться

Телефон: 8 (812) 309 58 32 (многоканальный)

Факс: 8 (812) 320-02-42

Электронная почта: org@eplast1.ru

Адрес: 198099, г. Санкт-Петербург, ул. Калинина, дом 2, корпус 4, литера А.