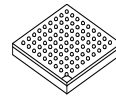
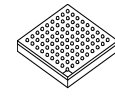




## MCF5441x



MAPBGA-256  
17mm x 17mm



MAPBGA-196  
12 mm x 12 mm

### MCF5441x ColdFire Microprocessor Data Sheet

- Version 4 ColdFire Core with EMAC and MMU
- Up to 385 Dhrystone 2.1 MIPS @ 250 MHz
- 8 KB instruction cache and 8 KB data cache
- 64 KB internal SRAM dual-ported to processor local bus and other crossbar switch masters
- System boot from NOR, NAND, SPI flash, EEPROM, or FRAM
- Crossbar switch technology (XBS) for concurrent access to peripherals or RAM from multiple bus masters
- 64-channel DMA controller
- SDRAM controller supporting full-speed operation from a single x8 DDR2 component up to 250 MHz
- 32-bit FlexBus external memory interface for RAM, ROM, MRAM, and programmable logic
- USB 2.0 host controller
- USB 2.0 host/device/On-the-Go controller
- 8-bit single data rate ULPI port usable by the dedicated USB host module or the USB host/device/OTG module
- Dual 10/100 Ethernet MACs with hardware CRC checking/generation, IEEE 1588-2002 support, and optional Ethernet switch
- CPU direct-attached hardware accelerator for DES, 3DES, AES, MD5, SHA-1, and SHA-256 algorithms
- Random number generator
- Enhanced Secure Digital host controller for SD, SDHC, SDIO, MMC, and MMCplus cards
- Two ISO7816 smart card interfaces
- Two FlexCAN modules
- Six I<sup>2</sup>C bus interfaces with DMA support in master mode
- Two synchronous serial interfaces
- Four 32-bit timers with DMA support
- Four programmable interrupt timers
- 8-channel, 16-bit motor control PWM timer
- Dual 12-bit ADCs with shared input channels and multiple conversion trigger sources
- Dual 12-bit DACs with DMA support
- 1-wire module with DMA support
- NAND flash controller
- Real-time clock with 32-kHz oscillator, 2 KB standby SRAM, and battery backup supply input
- Up to four DMA-supported serial peripheral interfaces (DSPI)
- Up to ten UARTs with single-wire mode support
- Up to five external IRQ interrupts and 2 external DMA request/acknowledge pairs
- Up to 16 processor local bus Rapid GPIO pins
- Up to 87 standard GPIO pins

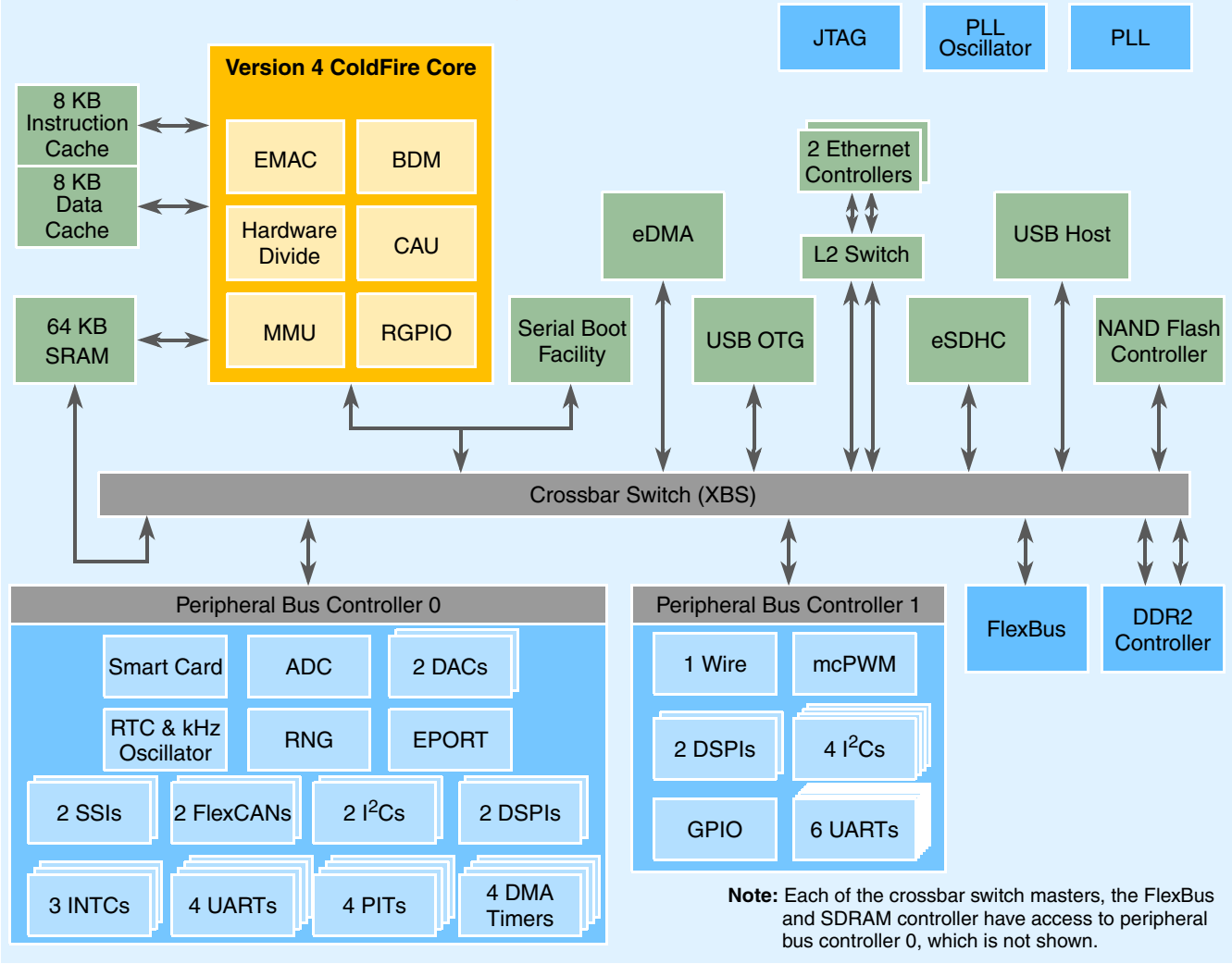
This document contains information on a new product. Specifications and information herein are subject to change without notice.

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# MCF5441x



- ADC** – Analog-to-digital converter
- BDM** – Background debug module
- CAU** – Cryptography acceleration unit
- DAC** – Digital-to-analog
- DSPI** – DMA serial peripheral interface
- eDMA** – Enhanced direct memory access module
- eSDHC** – Enhanced Secure Digital host controller
- EMAC** – Enhanced multiply-accumulate unit
- EPORT** – Edge port module
- GPIO** – General purpose input/output module
- I<sup>2</sup>C** – Inter-Integrated Circuit

- INTC** – Interrupt controller
- JTAG** – Joint Test Action Group interface
- mcPWM** – Motor control pulse width modulator
- PIT** – Programmable interrupt timers
- PLL** – Phase locked loop module
- RGPIO** – Rapid GPIO
- RNG** – Random number generator
- RTC** – Real time clock
- SSI** – Synchronous serial interface
- USB OTG** – Universal Serial Bus On-the-Go controller

# 1 MCF5441x family comparison

Table 1. MCF5441x family configurations

| Module   | MCF54410      | MCF54415  | MCF54416  | MCF54417  | MCF54418  |
|--|---------------|-----------|-----------|-----------|-----------|
| Version 4 ColdFire core with EMAC (enhanced multiply-accumulate unit) and MMU (memory management unit) | •             | •         | •         | •         | •         |
| Cryptography acceleration unit (CAU)   | —             | —         | •         | —         | •         |
| Core (system) and SDRAM clock  | up to 250 MHz |           |           |           |           |
| Peripheral clock<br>(Core clock ÷ 2)   | up to 125 MHz |           |           |           |           |
| External bus (FlexBus) clock   | up to 100 MHz |           |           |           |           |
| Performance (Dhrystone 2.1 MIPS)   | up to 385     |           |           |           |           |
| Static RAM (SRAM)  | 64 KB         |           |           |           |           |
| Independent data/instruction cache   | 8 KB each     |           |           |           |           |
| USB 2.0 Host controller  | —             | •         | •         | •         | •         |
| USB 2.0 Host/Device/On-the-Go controller   | •             | •         | •         | •         | •         |
| UTMI+ Low Pin Interface (ULPI) for external high-speed USB PHY   | —             | •         | •         | •         | •         |
| 10/100 Mbps Ethernet controller with IEEE 1588 support   | 1             | 2         | 2         | 2         | 2         |
| Level 2 IEEE 1588-compliant 3-port Ethernet switch   | —             | —         | —         | •         | •         |
| Enhanced Secure Digital host controller (eSDHC)  | •             | •         | •         | •         | •         |
| Smart card/Subscriber Identity Module (SIM)  | —             | 2 ports   | 2 ports   | 2 ports   | 2 ports   |
| UARTs  | 6             | 10        | 10        | 10        | 10        |
| DSPI   | 3             | 4         | 4         | 4         | 4         |
| CAN 2.0B controllers   | 1             | 2         | 2         | 2         | 2         |
| I <sup>2</sup> C   | 4             | 6         | 6         | 6         | 6         |
| Synchronous serial interface (SSI)   | 1             | 2         | 2         | 2         | 2         |
| 12-bit ADC   | —             | •         | •         | •         | •         |
| 12-bit DAC   | —             | 2         | 2         | 2         | 2         |
| 32-bit DMA timers  | 4             | 4         | 4         | 4         | 4         |
| Periodic interrupt timers (PIT)  | 4             | 4         | 4         | 4         | 4         |
| Motor control PWM timer (mcPWM)  | —             | 8 channel | 8 channel | 8 channel | 8 channel |
| 64-channel DMA controller  | •             | •         | •         | •         | •         |
| Real-time clock with 2 KB standby RAM and battery back-up input  | •             | •         | •         | •         | •         |
| DDR2 SDRAM controller  | •             | •         | •         | •         | •         |
| FlexBus external memory controller   | •             | •         | •         | •         | •         |

**Table 1. MCF5441x family configurations (continued)**

| Module   | MCF54410      | MCF54415      | MCF54416 | MCF54417 | MCF54418 |
|--|---------------|---------------|----------|----------|----------|
| NAND flash controller                            | •             | •             | •        | •        | •        |
| 1-Wire <sup>®</sup> interface                    | •             | •             | •        | •        | •        |
| Serial boot facility                             | •             | •             | •        | •        | •        |
| Watchdog timer                                   | •             | •             | •        | •        | •        |
| Interrupt controllers (INTC)                     | 3             | 3             | 3        | 3        | 3        |
| Edge port module (EPORT)                         | 3 IRQs        | 5 IRQs        | 5 IRQs   | 5 IRQs   | 5 IRQs   |
| Rapid GPIO pins                                  | 9             | 16            | 16       | 16       | 16       |
| General-purpose I/O (GPIO) pins                  | 48            | 87            | 87       | 87       | 87       |
| JTAG - IEEE <sup>®</sup> 1149.1 Test Access Port | •             | •             | •        | •        | •        |
| Package  | 196<br>MAPBGA | 256<br>MAPBGA |          |          |          |

## 1.1 Ordering information

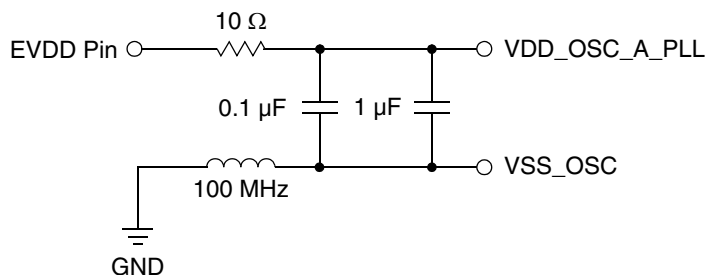
**Table 2. Orderable part numbers**

| Freescall Part Number | Description             | Package    | Speed   | Temperature  |
|-----------------------|-------------------------|------------|---------|--------------|
| MCF54410CMF250        | MCF54410 Microprocessor | 196 MAPBGA | 250 MHz | -40 to +85°C |
| MCF54415CMJ250        | MCF54415 Microprocessor | 256 MAPBGA |         |              |
| MCF54416CMJ250        | MCF54416 Microprocessor |            |         |              |
| MCF54417CMJ250        | MCF54417 Microprocessor |            |         |              |
| MCF54418CMJ250        | MCF54418 Microprocessor |            |         |              |

## 2 Hardware design considerations

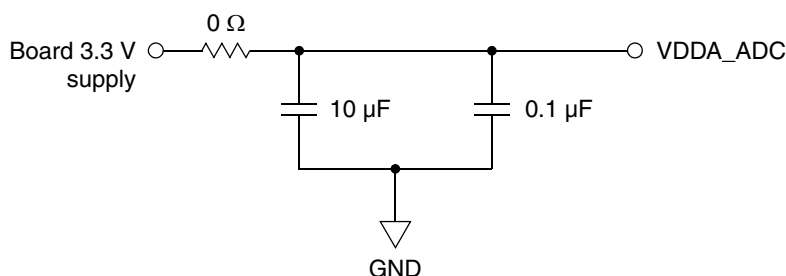
### 2.1 Power filtering

To further enhance noise isolation, an external filter is strongly recommended for the analog  $V_{DD}$  pins (VDDA\_PLL and VDDA\_DAC\_ADC). The filter shown in [Figure 1](#) should be connected between the board 3.3 V (nominal) supply and the analog pins. The resistor and capacitors should be placed as close to the dedicated analog  $V_{DD}$  pin as possible. The 10  $\Omega$  resistor in the given filter is required.



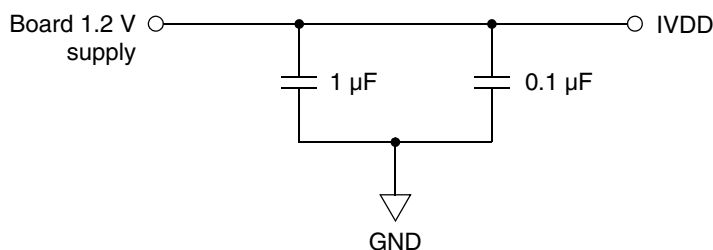
**Figure 1. Oscillator/PLL/DAC power filter**

Figure 2 shows an example for isolating the ADC power supply from the I/O supply (EVDD) and ground. Note that in this power supply the 10 Ω resistor is replaced by a 0 Ω resistor. This will reduce the IR drop into the ADC, limiting additional gain error.



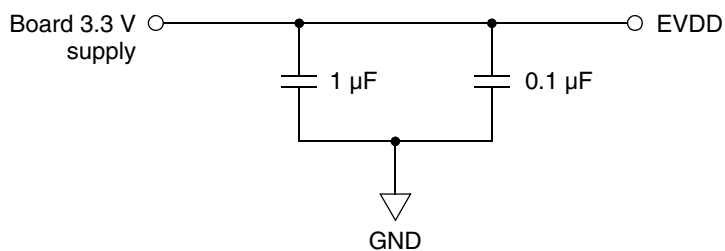
**Figure 2. ADC power filter**

Figure 3 shows an example for bypassing the internal core digital power supply for the MPU. This bypass should be applied to as many IVDD signals as routing allows. Each one should be placed as close to the ball as possible.



**Figure 3. IVDD power filter**

Figure 4 shows an example for bypassing the external pad ring digital power supply for the MPU. This bypass should be applied to as many EVDD signals as routing allows. Each one should be placed as close to the ball as possible.



**Figure 4. EVDD power filter**

Figure 5 shows an example for bypassing the FlexBus power supply for the MPU. This bypass should be applied to as many FB\_VDD signals as routing allows. Each one should be placed as close to the ball as possible.

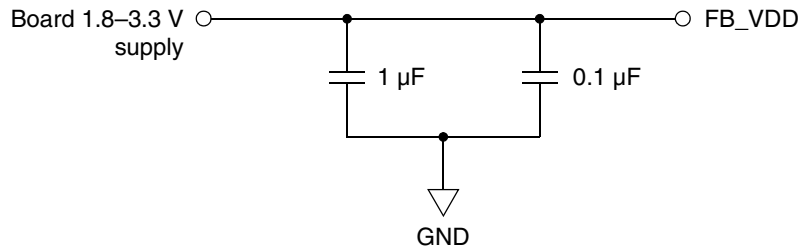
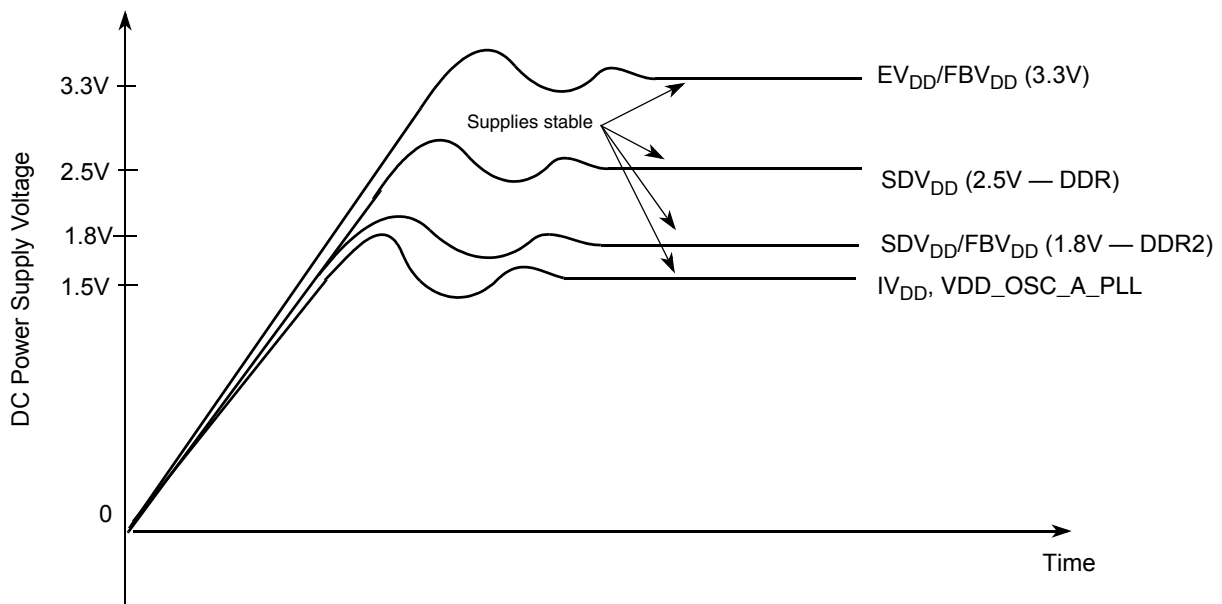


Figure 5. FB\_VDD power filter

## 2.2 Supply voltage sequencing

Figure 6 shows requirements in the sequencing of the I/O V<sub>DD</sub> (EV<sub>DD</sub>), FlexBus V<sub>DD</sub> (FBV<sub>DD</sub>), SDRAM V<sub>DD</sub> (SDV<sub>DD</sub>), PLL V<sub>DD</sub> (VDD\_OSC\_A\_PLL), and internal logic/core V<sub>DD</sub> (IV<sub>DD</sub>).



Notes:

- <sup>1</sup> Input voltage must not be greater than the supply voltage (EV<sub>DD</sub>, FBV<sub>DD</sub>, SDV<sub>DD</sub>, IV<sub>DD</sub>, or PV<sub>DD</sub>) by more than 0.5V at any time, including during power-up.
- <sup>2</sup> Use 25 V/millisecond or slower rise time for all supplies.

Figure 6. Supply voltage sequencing and separation cautions

The relationships between FBV<sub>DD</sub>, SDV<sub>DD</sub> and EV<sub>DD</sub> are non-critical during power-up and power-down sequences. FBV<sub>DD</sub> (1.8 – 3.3V), SDV<sub>DD</sub> (2.5V or 1.8V) and EV<sub>DD</sub> are specified relative to IV<sub>DD</sub>.

### NOTE

All I/O VDD pins must be powered on when the device is functioning, except when in standby mode.

In standby mode, all I/O VDD pins, except VSTBY\_RTC (battery), can be switched off.

## 2.2.1 Power-up sequence

If  $EV_{DD}/FBV_{DD}/SDV_{DD}$  are powered up with the  $IV_{DD}$  at 0 V, the sense circuits in the I/O pads cause all pad output drivers connected to the  $EV_{DD}/FBV_{DD}/SDV_{DD}$  to be in a high impedance state. There is no limit on how long after  $EV_{DD}/FBV_{DD}/SDV_{DD}$  powers up before  $IV_{DD}$  must power up.  $IV_{DD}$  should not lead the  $EV_{DD}$ ,  $FBV_{DD}$ , or  $SDV_{DD}$  by more than 0.4 V during power ramp-up, or there will be high current in the internal ESD protection diodes. The rise times on the power supplies should be slower than 25 V/millisecond to avoid turning on the internal ESD protection clamp diodes.

## 2.2.2 Power-down sequence

If  $IV_{DD}/PV_{DD}$  are powered down first, sense circuits in the I/O pads cause all output drivers to be in a high impedance state. There is no limit on how long after  $IV_{DD}$  and  $PV_{DD}$  power down before  $EV_{DD}$ ,  $FBV_{DD}$ , or  $SDV_{DD}$  must power down.  $IV_{DD}$  should not lag  $EV_{DD}$ ,  $FBV_{DD}$ , or  $SDV_{DD}$  going low by more than 0.4 V during power down or there will be undesired high current in the ESD protection diodes. There are no requirements for the fall times of the power supplies.

The recommended power down sequence is as follows:

1. Drop  $IV_{DD}/PV_{DD}$  to 0 V.
2. Drop  $EV_{DD}/FBV_{DD}/SDV_{DD}$  supplies.

## 2.3 Power consumption specifications

Table 3. Estimated power consumption specifications

| Characteristic   | Symbol        | Typical | Unit |
|--|---------------|---------|------|
| Core operating supply current (nominal 1.2 V) <sup>1</sup> | IVDD          |         | mA   |
| Run mode   |               | 127     |      |
| Wait mode  |               | 33      |      |
| Doze mode  |               | 32      |      |
| Stop00 mode  |               | 9.3     |      |
| Stop01 mode  |               | 9.2     |      |
| Stop02 mode  |               | 3.6     |      |
| Stop03 mode  |               | 3.4     |      |
| FlexBus operating supply current                           | FBVDD         |         | mA   |
| Run mode (application dependent)                           |               | 80      |      |
| Wait mode  |               | 49      |      |
| Doze mode  |               | 42      |      |
| Stop00 mode  |               | 40      |      |
| Stop01, Stop02, Stop03 mode                                |               | 28      |      |
| SDRAM operating supply current (DDR2 at 1.8 V)             | SDVDD         |         | mA   |
| Isys(DQ) [ $\times 8$ , $2\times DQS$ ]                    |               | 3       |      |
| Isys(WR) [ $\times 8$ , $2\times DQS$ ]                    |               | 15      |      |
| Isys(RD) [ $\times 8$ , $2\times DQS$ ]                    |               | 15      |      |
| SDRAM input reference current                              | SDVREF        |         | mA   |
| Isys(REF)  |               | 1.3     |      |
| SDRAM termination current                                  | SDVTT         |         | mA   |
| Isys(termRD)   |               | 41      |      |
| Total SDIDD MPU side <sup>2</sup>                          |               | 75      |      |
| Oscillator/PLL operating supply current (nominal 3.3 V)    | VDD_OSC_A_PLL |         | mA   |
| Run, Wait, Doze, Stop00, Stop01 mode                       |               | 10      |      |
| Stop02 mode  |               | 6       |      |
| Stop03 mode  |               | 1       |      |



**Table 3. Estimated power consumption specifications (continued)**

| Characteristic   | Symbol                | Typical        | Unit |
|--|-----------------------|----------------|------|
| External I/O pad operating supply current (nominal 3.3 V)                      | EVDD                  | — <sup>3</sup> | mA   |
| USB operating supply current (nominal 3.3 V)                                   | VDD_USBO,<br>VDD_USBH | 30             | mA   |
| ADC operating supply current (nominal 3.3 V)<br>Speed mode 00<br>Speed mode 01 | VDDA_ADC              | 14<br>22       | mA   |
| DAC operating supply current (nominal 3.3 V)                                   | VDDA_DAC_ADC          | 11             | mA   |
| RTC standby supply current<br>ISTBY  | VSTBY_RTC             | 17             | μA   |

<sup>1</sup> Current measured at maximum system clock frequency, all modules active, and default drive strength with matching load.

<sup>2</sup> DDR2 interface power is estimated from the Micron DDR2 data sheet. The numbers given in this table do not include the actual power consumption of the memory itself. The current drawn by the memory needs to be added to the values in this table and may be several hundred mA.

<sup>3</sup> EVDD values depend on the application, with the restrictions that any single pin cannot exceed 25 mA and that the total power does not exceed the thermal characteristics.

## 3 Pin assignments and reset states

### 3.1 Signal multiplexing

The following table lists all the MCF5441x pins grouped by function. The Dir column is the direction for the primary function of the pin only. Refer to the following sections for package diagrams. For a more detailed discussion of the MCF5441x signals, consult the *MCF5441x Reference Manual* (MCF54418RM).

#### NOTE

In this table and throughout this document a single signal within a group is designated without square brackets (i.e., FB\_AD23), while designations for multiple signals within a group use brackets (i.e., FB\_AD[23:21]) and is meant to include all signals within the two bracketed numbers when these numbers are separated by a colon.

#### NOTE

The primary functionality of a pin is not necessarily its default functionality. Most pins that are muxed with GPIO default to their GPIO functionality. See the following table for a list of the exceptions.

**Table 4. Special-case default signal functionality**

| Pin  | Default signal  |
|--|---|
| FB_CLK, $\overline{\text{FB\_OE}}$ , $\overline{\text{FB\_R/W}}$ ,<br>$\overline{\text{FB\_BE/BWE}}[1:0]$ ,<br>$\overline{\text{FB\_CS}}[5:4]$ | $\overline{\text{FB\_CLK}}$ , $\overline{\text{FB\_OE}}$ , $\overline{\text{FB\_R/W}}$ ,<br>$\overline{\text{FB\_BE/BWE}}[1:0]$ , $\overline{\text{FB\_CS}}[5:4]$ |
| FB_ALE   | FB_ALE or $\overline{\text{FB\_TS}}$<br>(depending on RCON[3])  |
| $\overline{\text{FB\_BE/BWE}}3$  | Boot from NFC, NF_ALE.<br>Otherwise, $\overline{\text{FB\_BE/BWE}}3$ .  |
| $\overline{\text{FB\_BE/BWE}}2$  | Boot from NFC, NF_CLE.<br>Otherwise, $\overline{\text{FB\_BE/BWE}}2$ .  |
| FB_CS1   | Boot from NFC, NFC_CE.<br>Otherwise, GPIO.  |
| FB_CS0   | Boot from FlexBus, FB_CS0.<br>Otherwise, GPIO.  |
| $\overline{\text{FB\_TA}}$   | Boot from NFC, $\overline{\text{NFC\_R/B}}$ .<br>Otherwise, $\overline{\text{FB\_TA}}$ .  |
| ALLPST, PST[3:0],<br>DDATA[3:0]  | ALLPST, PST[3:0], DDATA[3:0]  |

**NOTE**

While most modules and functionalities between the 196 and 256 MAPBGA package are the same, the following modules have been removed from 196 MAPBGA for pin space:

UART2, UART6, UART9, PWM, SSI1, SIM1, USB HOST, IRQ6, IRQ3, IRQ2, FLEXCAN1, I2C1, ADC, DAC.

Other modifications to the 196 MAPBGA package are:

- SDRAMC — One address line, SD\_A14, is removed.
- SDHC — Number of data lines for eSDHC have been reduced to 4 instead of 8.
- MAC — Only MAC0\_RMII mode is implemented.

**Table 5. MCF5441x Signal information and muxing**

| Signal name                | GPIO | Alternate 1 | Alternate 2 | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA | 256 MAPBGA |
|----------------------------|------|-------------|-------------|---|------------------------|----------------|-----------------------|------------|------------|
| <b>Reset</b>               |      |             |             |   |                        |                |                       |            |            |
| RESET                      | —    | —           | —           | U                                       | I                      | EVDD           | ssr                   | K14        | K15        |
| $\overline{\text{RSTOUT}}$ | —    | —           | —           | —                                       | O                      | EVDD           | msr                   | P12        | L16        |
| <b>Clock</b>               |      |             |             |   |                        |                |                       |            |            |
| EXTAL/<br>RMII_REF_CLK     | —    | —           | —           | —                                       | I <sup>4</sup>         | EVDD           | ae                    | G14        | G16        |

Table 5. MCF5441x Signal information and muxing (continued)

| Signal name  | GPIO    | Alternate 1   | Alternate 2                     | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA                            | 256 MAPBGA                           |
|--|---------|---|---------------------------------|---|------------------------|----------------|-----------------------|---------------------------------------|--------------------------------------|
| XTAL   | —       | —   | —                               | —                                       | O                      | EVDD           | ae                    | H14                                   | H16                                  |
| <b>Mode selection</b>  |         |   |                                 |   |                        |                |                       |                                       |                                      |
| BOOTMOD[1:0]   | —       | —   | —                               | —                                       | I                      | EVDD           | msr                   | G5,H5                                 | K5, L5                               |
| <b>FlexBus</b>   |         |   |                                 |   |                        |                |                       |                                       |                                      |
| FB_AD[31:24]/<br>NFC_IO[15:8] <sup>5</sup>                   | —       | —   | —                               | —                                       | I/O                    | FBVDD          | fsr                   | A10, A9,<br>B9, C9, A8,<br>B8, C8, A7 | B9, C8, A9,<br>B8, D8, A8,<br>D7, B7 |
| FB_AD[23:16]/<br>NFC_IO[7:0] <sup>5</sup>                    | —       | —   | —                               | —                                       | I/O                    | FBVDD          | fsr                   | B7, C7, C6,<br>B6, A6, A5,<br>B5, A4  | C7, A7, D6,<br>A6, B6, D5,<br>C6, A5 |
| FB_AD[15:10]   | —       | —   | —                               | — <sup>6</sup>                          | I/O                    | FBVDD          | fsr                   | C5, A3, B4,<br>C4, B3, A2             | B5, A4, A3,<br>D4, B4, C5            |
| FB_AD[9:8]   | —       | —   | —                               | U <sup>7</sup>                          | I/O                    | FBVDD          | fsr                   | B2, C3                                | C4, B3                               |
| FB_AD[7:0]   | —       | —   | —                               | —                                       | I/O                    | FBVDD          | fsr                   | D4, B1, C2,<br>D3, C1, D2,<br>E3, D1  | C3, E4, D3,<br>E3, A2, B2,<br>C2, F3 |
| FB_ALE   | PA7     | $\overline{\text{FB\_TS}}$                                    | —                               | —                                       | O                      | FBVDD          | fsr                   | E2                                    | D2                                   |
| $\overline{\text{FB\_OE}}$ /<br>$\overline{\text{NFC\_RE}}$  | PA6     | $\overline{\text{FB\_TBST}}$ /<br>$\overline{\text{NFC\_RE}}$ | —                               | —                                       | O                      | FBVDD          | fsr                   | H1                                    | F1                                   |
| $\overline{\text{FB\_R/W}}$ /<br>$\overline{\text{NFC\_WE}}$ | PA5     | —   | —                               | —                                       | O                      | FBVDD          | fsr                   | H2                                    | G2                                   |
| $\overline{\text{FB\_TA}}$                                   | PA4     | —   | NFC_R $\overline{\text{B}}$     | U <sup>8</sup>                          | O                      | FBVDD          | fsr                   | H3                                    | H3                                   |
| $\overline{\text{FB\_BE/BWE3}}$                              | PA3     | $\overline{\text{FB\_CS3}}$                                   | FB_A1/<br>NFC_ALE <sup>9</sup>  | —                                       | O                      | FBVDD          | fsr                   | F3                                    | C1                                   |
| $\overline{\text{FB\_BE/BWE2}}$                              | PA2     | $\overline{\text{FB\_CS2}}$                                   | FB_A0/<br>NFC_CLE <sup>10</sup> | —                                       | O                      | FBVDD          | fsr                   | E1                                    | E2                                   |
| $\overline{\text{FB\_BE/BWE}}$ [1:0]                         | PA[1:0] | FB_TSI $\overline{\text{Z}}$ [1:0]                            | —                               | —                                       | O                      | FBVDD          | fsr                   | F2, F1                                | D1, F4                               |
| FB_CLK   | PB7     | —   | —                               | —                                       | O                      | FBVDD          | fsr                   | G1                                    | G1                                   |
| $\overline{\text{FB\_CS5}}$                                  | PB6     | $\overline{\text{DACK1}}$                                     | —                               | —                                       | O                      | FBVDD          | fsr                   | —                                     | F2                                   |
| $\overline{\text{FB\_CS4}}$                                  | PB5     | $\overline{\text{DREQ1}}$                                     | —                               | —                                       | O                      | FBVDD          | fsr                   | —                                     | B1                                   |
| $\overline{\text{FB\_CS1}}$                                  | PB4     | —   | NFC_C $\overline{\text{E}}$     | —                                       | O                      | FBVDD          | fsr                   | G3                                    | E1                                   |
| $\overline{\text{FB\_CS0}}$                                  | PB3     | —   | —                               | —                                       | O                      | FBVDD          | fsr                   | G2                                    | G3                                   |
| <b>I<sup>2</sup>C 0</b>                                      |         |   |                                 |   |                        |                |                       |                                       |                                      |
| I2C0_SCL   | PB2     | UART8_TXD   | CAN0_TX                         | —                                       | I/O                    | EVDD           | ssr                   | H12                                   | G15                                  |
| I2C0_SDA   | PB1     | UART8_RXD   | CAN0_RX                         | —                                       | I/O                    | EVDD           | ssr                   | G12                                   | G14                                  |

Table 5. MCF5441x Signal information and muxing (continued)

| Signal name                 | GPIO | Alternate 1 | Alternate 2 | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA   | 256 MAPBGA   |
|-----------------------------|------|-------------|-------------|---|------------------------|----------------|-----------------------|--|--|
| <b>FlexCAN 1</b>            |      |             |             |   |                        |                |                       |  |  |
| CAN1_TX                     | PB0  | UART9_TXD   | I2C1_SCL    | —                                       | I/O                    | EVDD           | ssr                   | —  | D14  |
| CAN1_RX                     | PC7  | UART9_RXD   | I2C1_SDA    | —                                       | I/O                    | EVDD           | ssr                   | —  | D15  |
| <b>SDRAM controller</b>     |      |             |             |   |                        |                |                       |  |  |
| SD_A14                      | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | —  | P6   |
| SD_A[13:0]                  | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | P3, M1, M3,<br>L2, L1, N4,<br>M2, P2, L3,<br>L4, N1, N2,<br>K1, N3 | R4, R1, R3,<br>N4, P3, T4,<br>R2, T2, N3,<br>P5, P4, N5,<br>P2, T3 |
| SD_BA[2:0]                  | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | M6, J4, P4   | P7, N6, R5   |
| $\overline{\text{SD\_CAS}}$ | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | K4   | N8   |
| SD_CKE                      | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | N6   | R7   |
| SD_CLK                      | —    | —           | —           | —                                       | O                      | SDVDD          | st_ck                 | P6   | T5   |
| $\overline{\text{SD\_CLK}}$ | —    | —           | —           | —                                       | O                      | SDVDD          | st_ck                 | P7   | T6   |
| $\overline{\text{SD\_CS}}$  | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | M5   | N7   |
| SD_D[7:0]                   | —    | —           | —           | —                                       | I/O                    | SDVDD          | st_odt                | P11, M10,<br>N10, M9,<br>P10, M8,<br>N8, M7                        | T12, R11,<br>T11, R10,<br>N9, T10,<br>P9, R9                       |
| SD_DM                       | —    | —           | —           | —                                       | O                      | SDVDD          | st_odt                | N7   | T7   |
| SD_DQS                      | —    | —           | —           | —                                       | I/O                    | SDVDD          | st_dqs                | P8   | T8   |
| $\overline{\text{SD\_DQS}}$ | —    | —           | —           | —                                       | I/O                    | SDVDD          | st_dqs                | P9   | T9   |
| SD_ODT                      | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | P5   | P8   |
| $\overline{\text{SD\_RAS}}$ | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | M4   | R6   |
| $\overline{\text{SD\_WE}}$  | —    | —           | —           | —                                       | O                      | SDVDD          | st_dec<br>ap          | N5   | R8   |
| SD_VREF                     | —    | —           | —           | —                                       | —                      | SDVDD          | st_vref               | N9   | P10  |
| SD_VTT                      | —    | —           | —           | —                                       | —                      | SDVDD          | st_vtt                | L8   | N10  |

Table 5. MCF5441x Signal information and muxing (continued)

| Signal name                               | GPIO | Alternate 1               | Alternate 2             | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA | 256 MAPBGA |
|---|------|---------------------------|-------------------------|---|------------------------|----------------|-----------------------|------------|------------|
| <b>External interrupts port</b>           |      |                           |                         |   |                        |                |                       |            |            |
| $\overline{\text{IRQ7}}$                  | PC6  | —                         | —                       | —                                       | I                      | EVDD           | ssr                   | G10        | F12        |
| $\overline{\text{IRQ6}}$                  | PC5  | —                         | USB_CLKIN <sup>11</sup> | —                                       | I                      | EVDD           | ssr                   | —          | N1         |
| $\overline{\text{IRQ4}}$                  | PC4  | $\overline{\text{DREQ0}}$ | —                       | —                                       | I                      | EVDD           | ssr                   | E11        | F14        |
| $\overline{\text{IRQ3}}$                  | PC3  | DSP10_PCS3                | USBH_VBUS_EN            | —                                       | I                      | EVDD           | ssr                   | —          | M1         |
| $\overline{\text{IRQ2}}$                  | PC2  | DSP10_PCS2                | USBH_VBUS_OC            | — <sup>12</sup>                         | I                      | EVDD           | ssr                   | —          | M2         |
| $\overline{\text{IRQ1}}$                  | PC1  | —                         | —                       | —                                       | I                      | EVDD           | ssr                   | E13        | F13        |
| <b>USB On-the-Go</b>                      |      |                           |                         |   |                        |                |                       |            |            |
| USBO_DM                                   | —    | —                         | —                       | —                                       | I/O                    | VDD_USB0       | ae                    | B13        | A14        |
| USBO_DP                                   | —    | —                         | —                       | —                                       | I/O                    | VDD_USB0       | ae                    | A13        | B14        |
| <b>USB host</b>                           |      |                           |                         |   |                        |                |                       |            |            |
| USBH_DM                                   | —    | —                         | —                       | —                                       | I/O                    | VDD_USBH       | ae                    | —          | A15        |
| USBH_DP                                   | —    | —                         | —                       | —                                       | I/O                    | VDD_USBH       | ae                    | —          | B15        |
| <b>ADC</b>                                |      |                           |                         |   |                        |                |                       |            |            |
| ADC_IN7/<br>DAC1_OUT                      | —    | —                         | —                       | —                                       | I                      | VDDA_DAC_ADC   | ae                    | —          | K3         |
| ADC_IN[6:4]                               | —    | —                         | —                       | —                                       | I                      | VDDA_ADC       | ae                    | —          | H2, J3, G4 |
| ADC_IN3/<br>DAC0_OUT                      | —    | —                         | —                       | —                                       | I                      | VDDA_DAC_ADC   | ae                    | —          | K4         |
| ADC_IN[2:0]                               | —    | —                         | —                       | —                                       | I                      | VDDA_ADC       | ae                    | —          | J2, J1, H1 |
| <b>Real time clock</b>                    |      |                           |                         |   |                        |                |                       |            |            |
| RTC_EXTAL                                 | —    | —                         | —                       | —                                       | I <sup>4</sup>         | VSTBY          | ae                    | B14        | B16        |
| RTC_XTAL                                  | —    | —                         | —                       | —                                       | O                      | VSTBY          | ae                    | C14        | C16        |
| <b>DSP10/SBF<sup>13</sup></b>             |      |                           |                         |   |                        |                |                       |            |            |
| DSP10_PCS1/<br>$\overline{\text{SBF_CS}}$ | PC0  | —                         | —                       | —                                       | I/O                    | EVDD           | msr                   | K3         | L1         |

Table 5. MCF5441x Signal information and muxing (continued)

| Signal name                 | GPIO        | Alternate 1        | Alternate 2                             | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA | 256 MAPBGA |
|-----------------------------|-------------|--------------------|---|---|------------------------|----------------|-----------------------|------------|------------|
| DSPIO_PCS0/ $\overline{SS}$ | PD7         | I2C3_SDA           | SDHC_DAT3                               | —                                       | I/O                    | EVDD           | msr                   | J1         | K2         |
| DSPIO_SCK/<br>SBF_CK        | PD6         | I2C3_SCL           | SDHC_CLK                                | —                                       | I/O                    | EVDD           | msr                   | J3         | L2         |
| DSPIO_SIN/<br>SBF_DI        | PD5         | UART3_RXD          | SDHC_CMD                                | U <sup>14</sup>                         | I                      | EVDD           | msr                   | K2         | L3         |
| DSPIO_SOUT/<br>SBF_DO       | PD4         | UART3_TXD          | SDHC_DAT0                               | —                                       | O                      | EVDD           | msr                   | J2         | K1         |
| <b>One wire</b>             |             |                    |   |   |                        |                |                       |            |            |
| OW_DAT                      | RGPIO0/PD3  | $\overline{DACK0}$ | —                                       | —                                       | I/O                    | EVDD           | ssr                   | M11        | N11        |
| <b>DMA timers</b>           |             |                    |   |   |                        |                |                       |            |            |
| T3IN/PWM_EXTA3              | RGPIO1/PD2  | T3OUT              | USBO_VBUS_EN/<br>ULPI_DIR <sup>15</sup> | —                                       | I                      | EVDD           | msr                   | G13        | G13        |
| T2IN/PWM_EXTA2              | RGPIO2/PD1  | T2OUT              | SDHC_DAT2                               | —                                       | I                      | EVDD           | msr                   | J12        | H14        |
| T1IN/PWM_EXTA1              | RGPIO3/PD0  | T1OUT              | SDHC_DAT1                               | —                                       | I                      | EVDD           | msr                   | H13        | H13        |
| T0IN/PWM_EXTA0              | RGPIO4/PE7  | T0OUT              | USBO_VBUS_OC/<br>ULPI_NXT <sup>16</sup> | — <sup>17</sup>                         | I                      | EVDD           | msr                   | J13        | H15        |
| <b>UART 2</b>               |             |                    |   |   |                        |                |                       |            |            |
| $\overline{UART2\_CTS}$     | RGPIO14/PE6 | UART6_TXD          | SSI1_BCLK                               | —                                       | I                      | EVDD           | msr                   | —          | M4         |
| $\overline{UART2\_RTS}$     | RGPIO15/PE5 | UART6_RXD          | SSI1_FS                                 | —                                       | O                      | EVDD           | msr                   | —          | M3         |
| UART2_RXD                   | PE4         | PWM_A3             | SSI1_RXD                                | —                                       | I                      | EVDD           | msr                   | —          | P1         |
| UART2_TXD                   | PE3         | PWM_B3             | SSI1_TXD                                | —                                       | I/O <sup>18</sup>      | EVDD           | msr                   | —          | N2         |
| <b>UART 1</b>               |             |                    |   |   |                        |                |                       |            |            |
| $\overline{UART1\_CTS}$     | RGPIO7/PE2  | UART5_TXD          | DSPI3_SCK                               | —                                       | I                      | EVDD           | msr                   | D12        | C10        |
| $\overline{UART1\_RTS}$     | RGPIO8/PE1  | UART5_RXD          | DSPI3_PCS0                              | —                                       | O                      | EVDD           | msr                   | D11        | D10        |
| UART1_RXD                   | PE0         | I2C5_SDA           | DSPI3_SIN                               | —                                       | I                      | EVDD           | msr                   | B10        | C9         |
| UART1_TXD                   | PF7         | I2C5_SCL           | DSPI3_SOUT                              | —                                       | I/O <sup>18</sup>      | EVDD           | msr                   | C10        | D9         |
| <b>UART 0</b>               |             |                    |   |   |                        |                |                       |            |            |
| $\overline{UART0\_CTS}$     | RGPIO5/PF6  | UART4_TXD          | DSPI2_SCK                               | —                                       | I                      | EVDD           | msr                   | E12        | E13        |
| $\overline{UART0\_RTS}$     | RGPIO6/PF5  | UART4_RXD          | DSPI2_PCS0                              | —                                       | O                      | EVDD           | msr                   | C12        | B11        |
| UART0_RXD                   | PF4         | I2C4_SDA           | DSPI2_SIN                               | —                                       | I                      | EVDD           | msr                   | C11        | B10        |
| UART0_TXD                   | PF3         | I2C4_SCL           | DSPI2_SOUT                              | —                                       | I/O <sup>18</sup>      | EVDD           | msr                   | B11        | D11        |

Table 5. MCF5441x Signal information and muxing (continued)

| Signal name  | GPIO        | Alternate 1                  | Alternate 2    | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA | 256 MAPBGA |
|--|-------------|------------------------------|----------------|---|------------------------|----------------|-----------------------|------------|------------|
| <b>Enhanced secure digital host controller</b>     |             |                              |                |   |                        |                |                       |            |            |
| SDHC_DAT3  | PF2         | PWM_A1                       | DSPI1_PCS0     | —                                       | I/O                    | EVDD           | msr                   | —          | B13        |
| SDHC_DAT2  | PF1         | PWM_B1                       | DSPI1_PCS2     | —                                       | I/O                    | EVDD           | msr                   | —          | E14        |
| SDHC_DAT1  | PF0         | PWM_A2                       | DSPI1_PCS1     | —                                       | I/O                    | EVDD           | msr                   | —          | D12        |
| SDHC_DAT0  | PG7         | PWM_B2                       | DSPI1_SOUT     | —                                       | I/O                    | EVDD           | msr                   | —          | B12        |
| SDHC_CMD   | PG6         | PWM_B0                       | DSPI1_SIN      | —                                       | I/O                    | EVDD           | msr                   | —          | C11        |
| SDHC_CLK   | PG5         | PWM_A0                       | DSPI1_SCK      | —                                       | O                      | EVDD           | msr                   | —          | A10        |
| <b>Smart card interface 0</b>                      |             |                              |                |   |                        |                |                       |            |            |
| SIM0_DATA  | RGPIO13/PG4 | PWM_FAULT2                   | SDHC_DAT7      | —                                       | I/O                    | EVDD           | msr                   | —          | E12        |
| SIM0_VEN   | RGPIO12/PG3 | PWM_FAULT0                   | —              | —                                       | O                      | EVDD           | msr                   | —          | D13        |
| SIM0_RST   | RGPIO11/PG2 | PWM_FORCE                    | SDHC_DAT6      | —                                       | O                      | EVDD           | msr                   | —          | C15        |
| SIM0_PD  | RGPIO10/PG1 | PWM_SYNC                     | SDHC_DAT5      | —                                       | I                      | EVDD           | msr                   | —          | C14        |
| SIM0_CLK   | RGPIO9/PG0  | PWM_FAULT1                   | SDHC_DAT4      | —                                       | O                      | EVDD           | msr                   | —          | A11        |
| <b>Synchronous serial interface 0<sup>19</sup></b> |             |                              |                |   |                        |                |                       |            |            |
| SSI0_RXD   | PH7         | I2C2_SDA                     | SIM1_VEN       | —                                       | I                      | EVDD           | msr                   | B12        | C12        |
| SSI0_TXD   | PH6         | I2C2_SCL                     | SIM1_DATA      | —                                       | O                      | EVDD           | msr                   | A11        | C13        |
| SSI0_FS  | PH5         | UART7_TXD                    | SIM1_RST       | —                                       | I/O                    | EVDD           | msr                   | C13        | E15        |
| SSI0_MCLK  | PH4         | SSI_CLKIN                    | SIM1_CLK       | —                                       | O                      | EVDD           | msr                   | A12        | A12        |
| SSI0_BCLK  | PH3         | UART7_RXD                    | SIM1_PD        | —                                       | I/O                    | EVDD           | msr                   | D13        | A13        |
| <b>Ethernet subsystem</b>                          |             |                              |                |   |                        |                |                       |            |            |
| MII0_MDC   | PI1         | RMII0_MDC <sup>20</sup>      | —              | —                                       | O                      | EVDD           | fsr                   | N14        | P16        |
| MII0_MDIO  | PI0         | RMII0_MDIO <sup>20</sup>     | —              | —                                       | I/O                    | EVDD           | fsr                   | M14        | N16        |
| MII0_RXDV  | PJ7         | RMII0_CRSDV <sup>20</sup>    | —              | —                                       | I                      | EVDD           | fsr                   | M13        | P14        |
| MII0_RXD[1:0]                                      | PJ[6:5]     | RMII0_RXD[1:0] <sup>20</sup> | —              | —                                       | I                      | EVDD           | fsr                   | P13, N13   | R15, T15   |
| MII0_RXER  | PJ4         | RMII0_RXER <sup>20</sup>     | —              | —                                       | I                      | EVDD           | fsr                   | M12        | N14        |
| MII0_TXD[1:0]                                      | PJ[3:2]     | RMII0_TXD[1:0] <sup>20</sup> | —              | —                                       | O                      | EVDD           | fsr                   | L12, L11   | R13, P13   |
| MII0_TXEN  | PJ1         | RMII0_TXEN <sup>20</sup>     | —              | D <sup>21</sup>                         | O                      | EVDD           | fsr                   | N12        | P12        |
| MII0_COL   | PJ0         | RMII1_MDC                    | ULPI_STP       | —                                       | I                      | EVDD           | fsr                   | —          | R12        |
| MII0_TXER  | PK7         | RMII1_MDIO                   | ULPI_DATA4     | —                                       | O                      | EVDD           | fsr                   | —          | R14        |
| MII0_CRSDV   | PK6         | RMII1_CRSDV                  | ULPI_DATA5     | —                                       | I                      | EVDD           | fsr                   | —          | P11        |
| MII0_RXD[3:2]                                      | PK[5:4]     | RMII1_RXD[1:0]               | ULPI_DATA[1:0] | —                                       | I                      | EVDD           | fsr                   | —          | P15, N13   |

Table 5. MCF5441x Signal information and muxing (continued)

| Signal name                                   | GPIO    | Alternate 1                            | Alternate 2    | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA                           | 256 MAPBGA                |
|---|---------|--|----------------|---|------------------------|----------------|-----------------------|--------------------------------------|---------------------------|
| MII0_RXCLK                                    | PK3     | RMII1_RXER                             | ULPI_DATA6     | —                                       | I                      | EVDD           | fsr                   | —                                    | M14                       |
| MII0_TXD[3:2]                                 | PK[2:1] | RMII1_TXD[1:0]                         | ULPI_DATA[3:2] | —                                       | O                      | EVDD           | fsr                   | —                                    | T13, N12                  |
| MII0_TXCLK                                    | PK0     | RMII1_TXEN                             | ULPI_DATA7     | D <sup>21</sup>                         | I                      | EVDD           | fsr                   | —                                    | T14                       |
| <b>BDM/JTAG</b>                               |         |  |                |   |                        |                |                       |                                      |                           |
| ALLPST <sup>22</sup>                          | PH2     | —                                      | —              | —                                       | O                      | EVDD           | fsr                   | K12                                  | —                         |
| DDATA[3:2]                                    | PH[1:0] | —                                      | —              | —                                       | O                      | EVDD           | fsr                   | —                                    | L15, M13                  |
| DDATA[1:0]                                    | PI[7:6] | —                                      | —              | —                                       | O                      | EVDD           | fsr                   | —                                    | M15, L14                  |
| PST[3:0]                                      | PI[5:2] | —                                      | —              | —                                       | O                      | EVDD           | fsr                   | —                                    | J13, J16,<br>J15, J14     |
| JTAG_EN                                       | —       | —                                      | —              | D                                       | I                      | EVDD           | msr                   | N11                                  | N15                       |
| PSTCLK  | —       | TCLK <sup>23</sup>                     | —              | —                                       | I                      | EVDD           | fsr                   | L14                                  | M16                       |
| DSI   | —       | TDI <sup>23</sup>                      | —              | U                                       | I                      | EVDD           | msr                   | L10                                  | L13                       |
| DSO   | —       | TDO <sup>23</sup>                      | —              | —                                       | O                      | EVDD           | msr                   | L13                                  | K14                       |
| $\overline{\text{BKPT}}$                      | —       | TMS <sup>23</sup>                      | —              | U                                       | I                      | EVDD           | msr                   | K13                                  | K16                       |
| DSCLK   | —       | $\overline{\text{TRST}}$ <sup>23</sup> | —              | U                                       | I                      | EVDD           | msr                   | L9                                   | K13                       |
| <b>Test</b><br>(this signal must be grounded) |         |  |                |   |                        |                |                       |                                      |                           |
| TEST  | —       | —                                      | —              | D                                       | I                      | EVDD           | ssr                   | K10                                  | R16                       |
| <b>Power supplies</b>                         |         |  |                |   |                        |                |                       |                                      |                           |
| IVDD  | —       | —                                      | —              | —                                       | —                      | —              | —                     | D9, D10,<br>E9, E10, F9,<br>F10, F12 | E9–E11,<br>F9–F11         |
| EVDD  | —       | —                                      | —              | —                                       | —                      | —              | —                     | F4–F7, G6,<br>G7, H6, H7,<br>J5, J6  | H8, J7–J10,<br>K6–K11, L6 |
| FB_VDD  | —       | —                                      | —              | —                                       | —                      | —              | —                     | D5–D7,<br>E4–E7                      | E5–E7, F5,<br>F6, G5      |
| SD_VDD  | —       | —                                      | —              | —                                       | —                      | —              | —                     | K7–K9,<br>L5–L7                      | M7–M12                    |
| VDD_OSC_A_PLL                                 | —       | —                                      | —              | —                                       | —                      | —              | vddint                | F14                                  | F15                       |
| VSS_OSC_A_PLL                                 | —       | —                                      | —              | —                                       | —                      | —              | vddint                | F13                                  | F16                       |
| VDD_USBO                                      | —       | —                                      | —              | —                                       | —                      | —              | vdde                  | F11                                  | G12                       |
| VDD_USBH                                      | —       | —                                      | —              | —                                       | —                      | —              | vdde                  | —                                    | H12                       |
| VDDA_ADC                                      | —       | —                                      | —              | —                                       | —                      | —              | —                     | —                                    | H4                        |



**Table 5. MCF5441x Signal information and muxing (continued)**

| Signal name         | GPIO | Alternate 1 | Alternate 2 | Pullup (U) <sup>1</sup><br>Pulldown (D) | Direction <sup>2</sup> | Voltage domain | Pad type <sup>3</sup> | 196 MAPBGA  | 256 MAPBGA   |
|---------------------|------|-------------|-------------|---|------------------------|----------------|-----------------------|---|--|
| VSSA_ADC            | —    | —           | —           | —                                       | —                      | —              | vssint                | —   | H5   |
| VDDA_DAC_ADC        | —    | —           | —           | —                                       | —                      | —              | vddint                | —   | J4   |
| VSSA_DAC_ADC        | —    | —           | —           | —                                       | —                      | —              | vssint                | —   | J5   |
| VSTBY <sup>24</sup> | —    | —           | —           | —                                       | —                      | —              | vddint                | E14   | E16  |
| VSS                 | —    | —           | —           | —                                       | —                      | —              | —                     | A1, A14,<br>D8, D14,<br>E8, F8, G4,<br>G8, G9,<br>G11, H4,<br>H8–11,<br>J7–11, J14,<br>K5, K6,<br>K11, P1,<br>P14 | A1, A16,<br>D16, E8,<br>F7, F8,<br>G6–G11,<br>H6, H7,<br>H9–H11,<br>J6, J11,<br>J12, K12,<br>L4, L7–L12,<br>M5, M6, T1,<br>T16 |

- <sup>1</sup> All pins available with GPIO contain a configurable pull-up/down. This column indicates the pull devices that are enabled automatically at reset. Pull-ups are generally only enabled on pins with their primary function, except as noted.
- <sup>2</sup> Refers to pin's primary function.
- <sup>3</sup> For details on the available slew rates of the various pad types see section "Output Pad Loading and Slew Rate" of the *MCF5441x Data Sheet* or section "Slew Rate Control Registers (SRCR\_x)" in chapter "Pin-Multiplexing and Control" of the *MCF5441x Reference Manual*.
- <sup>4</sup> Enabled as input only in oscillator bypass mode (internal crystal oscillator is disabled).
- <sup>5</sup> These pins are time-division multiplexed between the FlexBus and NFC. An arbitration mechanism determines which module drives these pins at any point in time.
- <sup>6</sup> An internal pulldown circuit is enabled during system reset for FB\_AD[10].
- <sup>7</sup> An internal pullup circuit is enabled when the system is in reset state.
- <sup>8</sup> Configurable pull that is enabled and pulled up after reset.
- <sup>9</sup> When configured for FB\_A1, this pin is time-division multiplexed between the FlexBus and NFC. An arbitration mechanism determines which module drives the pin at any point in time. When not configured as FB\_A1, NFC\_ALE cannot be used.
- <sup>10</sup> When configured for FB\_A0, this pin is time-division multiplexed between the FlexBus and NFC. An arbitration mechanism determines which module drives the pin at any point in time. When not configured as FB\_A0, NFC\_CLE cannot be used.
- <sup>11</sup> Since USB\_CLKIN is a clock signal, it must be dedicated to the USB system. Do not implement this pin as dual-use.
- <sup>12</sup> When Alternate 2 is selected, then internal pullup/pulldown control will come from the MISCCR[3] register of CIM.
- <sup>13</sup> When booting from serial boot flash, the SBF function is enabled automatically. After the SBF function completes its reset sequence, the signals are returned to GPIO functionality.
- <sup>14</sup> Automatic pull-up when SBF controls the pin during reset only. Configurable pull when UART, DSPI, or SDHC control the pin.
- <sup>15</sup> If ULPI is enabled, ULPI\_DIR is available as the Alternate 2 function. If ULPI is disabled, USBO\_VBUS\_EN is available.
- <sup>16</sup> If ULPI is enabled, ULPI\_NEXT is available as the Alternate 2 function. If ULPI is disabled, USBO\_VBUS\_OC is available.
- <sup>17</sup> When Alternate 2 is selected, then internal pullup/pulldown control will come from the MISCCR[2] register of CIM.
- <sup>18</sup> UARTx\_TXD pad can act as RXD(input) pad when UART One Wire mode is enabled.
- <sup>19</sup> The SIM1 signals are available with 256 MAPBGA but are not available with 196 MAPBGA.
- <sup>20</sup> These RMII functions are selected by the mode chosen by the MAC-NET, not by the pin-multiplexing and control (GPIO) module.

## Pin assignments and reset states

- <sup>21</sup> Configurable pull that is enabled and pulled down after reset.
- <sup>22</sup> The ALLPST signal is available only on the 196 MAPBGA package and allows limited debug trace functionality compared to the 256 MAPBGA package.
- <sup>23</sup> If JTAG\_EN is asserted, these pins default to Alternate 1 (JTAG) functionality. The GPIO module is not responsible for assigning these pins.
- <sup>24</sup> VSTBY is for optional standby lithium battery. If not used, connect to EVDD.

## 3.2 Pinout—196 MAPBGA

The pinout for the MCF54410 package is shown below.

|   | 1          | 2          | 3          | 4        | 5         | 6       | 7        | 8       | 9        | 10      | 11         | 12         | 13           | 14           |   |
|---|------------|------------|------------|----------|-----------|---------|----------|---------|----------|---------|------------|------------|--------------|--------------|---|
| A | GND        | FB_AD10    | FB_AD14    | FB_AD16  | FB_AD18   | FB_AD19 | FB_AD24  | FB_AD27 | FB_AD30  | FB_AD31 | SSIO_TXD   | SSIO_MCLK  | USB_DPLS     | GND          | A |
| B | FB_AD6     | FB_AD9     | FB_AD11    | FB_AD13  | FB_AD17   | FB_AD20 | FB_AD23  | FB_AD26 | FB_AD29  | U1_RXD  | U0_TXD     | SSIO_RXD   | USB_DMNS     | RTC_EXTAL    | B |
| C | FB_AD3     | FB_AD5     | FB_AD8     | FB_AD12  | FB_AD15   | FB_AD21 | FB_AD22  | FB_AD25 | FB_AD28  | U1_TXD  | U0_RXD     | U0RTS_B    | SSIO_FS      | RTC_XTAL     | C |
| D | FB_AD0     | FB_AD2     | FB_AD4     | FB_AD7   | FBVDD     | FBVDD   | FBVDD    | GND     | CVDD     | CVDD    | U1RTS_B    | U1CTS_B    | SSIO_BCLK    | GND          | D |
| E | FB_BE2_B   | FB_ALE     | FB_AD1     | FBVDD    | FBVDD     | FBVDD   | FBVDD    | GND     | CVDD     | CVDD    | IRQ4_B     | U0CTS_B    | IRQ1_B       | VSTBY        | E |
| F | FB_BE0_B   | FB_BE1_B   | FB_BE3_B   | EVDD     | EVDD      | EVDD    | EVDD     | GND     | CVDD     | CVDD    | VDD_USBO   | CVDD       | VSS_OSC_A_PL | VDD_OSC_A_PL | F |
| G | FB_CLK     | FB_CS0_B   | FB_CS1_B   | GND      | BOOT_MOD1 | EVDD    | EVDD     | GND     | GND      | IRQ7_B  | GND        | I2C0_SDA   | T3IN         | EXTAL        | G |
| H | FB_OE_B    | FB_RW_B    | FB_TA_B    | GND      | BOOT_MOD0 | EVDD    | EVDD     | GND     | GND      | GND     | GND        | I2C0_SCL   | T1IN         | XTAL         | H |
| J | DSPIO_PCS0 | DSPIO_SOUT | DSPIO_SCK  | SD_BA1   | EVDD      | EVDD    | GND      | GND     | GND      | GND     | GND        | T2IN       | T0IN         | GND          | J |
| K | SD_A1      | DSPIO_SIN  | DSPIO_PCS1 | SD_CAS_B | GND       | GND     | SDVDD    | SDVDD   | SDVDD    | TEST    | GND        | ALLPST     | TMS          | RSTIN_B      | K |
| L | SD_A9      | SD_A10     | SD_A5      | SD_A4    | SDVDD     | SDVDD   | SDVDD    | SD_VTT  | TRST_B   | TDI     | RM110_TXD0 | RM110_TXD1 | TDO          | TCLK         | L |
| M | SD_A12     | SD_A7      | SD_A11     | SD_RAS_B | SD_CS_B   | SD_BA2  | SD_D0    | SD_D2   | SD_D4    | SD_D6   | OWIO       | RMII0_RXER | RMII0_CRSDV  | RMII0_MDIO   | M |
| N | SD_A3      | SD_A2      | SD_A0      | SD_A8    | SD_WE_B   | SD_CKE  | SD_DQM   | SD_D1   | SD_VREF  | SD_D5   | JTAG_EN    | RMII0_TXEN | RMII0_RXD0   | RMII0_MDC    | N |
| P | GND        | SD_A6      | SD_A13     | SD_BA0   | SD_ODT    | SD_CLK  | SD_CLK_B | SD_DQS  | SD_DQS_B | SD_D3   | SD_D7      | RSTOUT_B   | RMII0_RXD1   | GND          | P |

Figure 7. MCF54410 Pinout (196 MAPBGA)

### 3.3 Pinout—256 MAPBGA

The pinout for the MCF54415, MCF54416, MCF54417, and MCF54418 packages are shown below.

|   | 1          | 2          | 3         | 4            | 5            | 6       | 7       | 8       | 9         | 10        | 11        | 12        | 13        | 14         | 15            | 16            |   |
|---|------------|------------|-----------|--------------|--------------|---------|---------|---------|-----------|-----------|-----------|-----------|-----------|------------|---------------|---------------|---|
| A | VSS        | FB_AD3     | FB_AD13   | FB_AD14      | FB_AD16      | FB_AD20 | FB_AD22 | FB_AD26 | FB_AD29   | SDHC_CLK  | SIM0_CLK  | SSIO_MCLK | SSIO_BCLK | USBO_DM    | USBH_DM       | VSS           | A |
| B | FB_CS4     | FB_AD2     | FB_AD8    | FB_AD11      | FB_AD15      | FB_AD19 | FB_AD24 | FB_AD28 | FB_AD31   | UART0_RXD | UART0_RTS | SDHC_DAT0 | SDHC_DAT3 | USBO_DP    | USBH_DP       | RTC_EXTAL     | B |
| C | FB_BE/BWE3 | FB_AD1     | FB_AD7    | FB_AD9       | FB_AD10      | FB_AD17 | FB_AD23 | FB_AD30 | UART1_RXD | UART1_CTS | SDHC_CMD  | SSIO_RXD  | SSIO_TXD  | SIM0_PD    | SIM0_RST      | RTC_XTAL      | C |
| D | FB_BE/BWE1 | FB_ALE     | FB_AD5    | FB_AD12      | FB_AD18      | FB_AD21 | FB_AD25 | FB_AD27 | UART1_TXD | UART1_RTS | UART0_TXD | SDHC_DAT1 | SIM0_VEN  | CAN1_TX    | CAN1_RX       | VSS           | D |
| E | FB_CS1     | FB_BE/BWE2 | FB_AD4    | FB_AD6       | FB_VDD       | FB_VDD  | FB_VDD  | VSS     | IVDD      | IVDD      | IVDD      | SIM0_XMT  | UART0_CTS | SDHC_DAT2  | SSIO_FS       | VSTBY_RTC     | E |
| F | FB_OE      | FB_CS5     | FB_AD0    | FB_BE/BWE0   | FB_VDD       | FB_VDD  | VSS     | VSS     | IVDD      | IVDD      | IVDD      | IRQ7      | IRQ1      | IRQ4       | VDD_OSC_A_PLL | VSS_OSC_A_PLL | F |
| G | FB_CLK     | FB_R/W     | FB_CS0    | ADC_IN4      | FB_VDD       | VSS     | VSS     | VSS     | VSS       | VSS       | VSS       | VDD_USBO  | T3IN      | I2C0_SDA   | I2C0_SCL      | EXTAL         | G |
| H | ADC_IN0    | ADC_IN6    | FB_TA     | AVDD_ADC     | AVSS_ADC     | VSS     | VSS     | EVDD    | VSS       | VSS       | VSS       | VDD_USBH  | T1IN      | T2IN       | T0IN          | XTAL          | H |
| J | ADC_IN1    | ADC_IN2    | ADC_IN5   | VDDA_DAC_ADC | VSSA_DAC_ADC | VSS     | EVDD    | EVDD    | EVDD      | EVDD      | VSS       | VSS       | PST3      | PST0       | PST1          | PST2          | J |
| K | DSP10_SOUT | DSP10_PCS0 | ADC_IN7   | ADC_IN3      | BOOT_MOD1    | EVDD    | EVDD    | EVDD    | EVDD      | EVDD      | EVDD      | VSS       | TRST      | TDO        | RESET         | TMS           | K |
| L | DSP10_PCS1 | DSP10_SCK  | DSP10_SIN | VSS          | BOOT_MOD0    | EVDD    | VSS     | VSS     | VSS       | VSS       | VSS       | VSS       | TDI       | DDATA0     | DDATA3        | RST_OUT       | L |
| M | IRQ3       | IRQ2       | UART2_RTS | UART2_CTS    | VSS          | VSS     | SD_VDD  | SD_VDD  | SD_VDD    | SD_VDD    | SD_VDD    | SD_VDD    | DDATA2    | MII0_RXCLK | DDATA1        | TCLK          | M |
| N | IRQ6       | UART2_TXD  | SD_A5     | SD_A10       | SD_A2        | SD_BA1  | SD_CS   | SD_CAS  | SD_D3     | SD_VTT    | OW_IO     | MII0_TXD2 | MII0_RXD2 | MII0_RXER  | JTAG_EN       | MII0_MDIO     | N |
| P | UART2_RXD  | SD_A1      | SD_A9     | SD_A3        | SD_A4        | SD_A14  | SD_BA2  | SD_ODT  | SD_D1     | SD_VREF   | MII0_CRS  | MII0_TXEN | MII0_TXD0 | MII0_RXDV  | MII0_RXD3     | MII0_MDC      | P |
| R | SD_A12     | SD_A7      | SD_A11    | SD_A13       | SD_BA0       | SD_RAS  | SD_CKE  | SD_WE   | SD_D0     | SD_D4     | SD_D6     | MII0_COL  | MII0_TXD1 | MII0_TXER  | MII0_RXD1     | TEST          | R |
| T | VSS        | SD_A6      | SD_A0     | SD_A8        | SD_CLK       | SD_CLK  | SD_DM   | SD_DQS  | SD_DQS    | SD_D2     | SD_D5     | SD_D7     | MII0_TXD3 | MII0_TXCLK | MII0_RXD0     | VSS           | T |

Figure 8. MCF54415, MCF54416, MCF54417, and MCF54418 Pinout (256 MAPBGA)

## 4 Electrical characteristics

This document contains electrical specification tables and reference timing diagrams for the MCF5441x microprocessor. This section contains detailed information on AC/DC electrical characteristics and AC timing specifications.

### NOTE

The specifications for this device in any other document are superseded by the specifications in this document.

### 4.1 Absolute maximum ratings

Table 6. Absolute maximum ratings<sup>1, 2</sup>

| Rating   | Symbol                   | Pin name      | Value        | Units |
|--|--------------------------|---------------|--------------|-------|
| External I/O pad supply voltage  | $EV_{DD}$                | EVDD          | -0.3 to +4.0 | V     |
| Internal logic supply voltage  | $IV_{DD}$                | IVDD          | -0.5 to +2.0 | V     |
| FlexBus I/O pad supply voltage   | $FBV_{DD}$               | FB_VDD        | -0.3 to +4.0 | V     |
| SDRAM I/O pad supply voltage   | $SDV_{DD}$               | SD_VDD        | -0.3 to +4.0 | V     |
| PLL supply voltage   | $PV_{DD}$                | VDD_OSC_A_PLL | -0.3 to +4.0 | V     |
| USB OTG supply voltage   | $USBV_{DD}$              | VDD_USBO      | -0.3 to +4.0 | V     |
| USB host supply voltage  | $USBV_{DD}$              | VDD_USBH      | -0.3 to +4.0 | V     |
| ADC supply voltage   | $AV_{DD}$                | VDDA_ADC      | -0.3 to +4.0 | V     |
| DAC and ADC supply voltage   | —                        | VDDA_DAC_ADC  | -0.3 to +4.0 | V     |
| RTC standby supply voltage   | $RTCV_{STBY}$            | VSTBY_RTC     | -0.3 to +4.0 | V     |
| Digital input voltage <sup>3</sup>   | $V_{IN}$                 | —             | -0.3 to +3.6 | V     |
| Instantaneous maximum current<br>Single pin limit (applies to all pins) <sup>3, 4, 5</sup> | $I_{DD}$                 | —             | 25           | mA    |
| Operating temperature range (packaged)   | $T_A$<br>( $T_L - T_H$ ) | —             | -40 to +85   | °C    |
| Storage temperature range  | $T_{stg}$                | —             | -55 to +150  | °C    |

<sup>1</sup> Functional operating conditions are given in Table 11. Absolute maximum ratings are stress ratings only, and functional operation at the maximum is not guaranteed. Continued operation at these levels may affect device reliability or cause permanent damage to the device.

<sup>2</sup> This device contains circuitry protecting against damage due to high static voltage or electrical fields. However, it is advised that normal precautions be taken to avoid application of any voltages higher than maximum-rated voltages to this high-impedance circuit. Immunity to static and electrical fields is enhanced if unused inputs are tied to an appropriate logic voltage level (e.g.,  $V_{SS}$  or  $EV_{DD}$ ).

<sup>3</sup> Input must be current limited to the value specified. To determine the value of the required current-limiting resistor, calculate resistance values for positive and negative clamp voltages, and then use the larger of the two values.

<sup>4</sup> All functional non-supply pins are internally clamped to  $V_{SS}$  and  $EV_{DD}$ .

<sup>5</sup> Power supply must maintain regulation within operating  $EV_{DD}$ ,  $FBV_{DD}$ , and  $SDV_{DD}$  range during instantaneous and operating maximum current conditions. If positive injection current ( $V_{in} > EV_{DD}$ ,  $FBV_{DD}$ , or  $SDV_{DD}$ ) is greater than  $I_{DD}$ , the injection current may flow out of  $EV_{DD}$ ,  $FBV_{DD}$ , or  $SDV_{DD}$  and could result in external power supply going out of regulation. Ensure the external  $EV_{DD}$ ,  $FBV_{DD}$ , or  $SDV_{DD}$  load shunts current greater than maximum injection current. This is the greatest risk when the MPU is not consuming power (for example, no clock).

## 4.2 Thermal characteristics

Table 7. Thermal characteristics

| Characteristic   |  | Symbol         | 196 MAPBGA | 256 MAPBGA | Unit |
|--|--|----------------|------------|------------|------|
| Junction to ambient, natural convection <sup>1</sup>           | Single layer board (1s) <sup>2</sup>   | $\theta_{JA}$  | 58         | —          |      |
|  | Four layer board (2s2p) <sup>2,3</sup> | $\theta_{JA}$  | 35         | 32         | °C/W |
| Junction to ambient (@200 ft/min) <sup>1, 3</sup>              | Single layer board (1s)                | $\theta_{JMA}$ | 48         | —          |      |
|  | Four layer board (2s2p)                | $\theta_{JMA}$ | 32         | 29         | °C/W |
| Junction to board <sup>4</sup>                                 |  | $\theta_{JB}$  | 22         | 22         | °C/W |
| Junction to case <sup>5</sup>                                  |  | $\theta_{JC}$  | 14         | 12         | °C/W |
| Junction to top of package, natural convection <sup>1, 6</sup> |  | $\Psi_{jt}$    | 3          | 2          | °C/W |
| Maximum operating junction temperature                         |  | $T_j$          | 105        | 105        | °C   |

<sup>1</sup>  $\theta_{JA}$  and  $\Psi_{jt}$  parameters are simulated in conformance with EIA/JESD Standard 51-2 for natural convection. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.

<sup>2</sup> Per JEDEC JESD51-2 with the single layer board horizontal. Board meets JESD51-9 specification.

<sup>3</sup> Per JEDEC JESD51-6 with the board horizontal.

<sup>4</sup> Thermal resistance between the die and the printed circuit board in conformance with JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.

<sup>5</sup> Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).

<sup>6</sup> Thermal characterization parameter indicating the temperature difference between package top and the junction temperature per JEDEC JESD51-2. When Greek letters are not available, the thermal characterization parameter is written in conformance with Psi-JT.

The average chip-junction temperature ( $T_j$ ) in °C can be obtained from:

$$T_j = T_A + (P_D \times \theta_{JMA}) \tag{Eqn. 1}$$

Where:

- $T_A$  = Ambient Temperature, °C
- $\theta_{JMA}$  = Package Thermal Resistance, Junction-to-Ambient, °C/W
- $P_D$  =  $P_{INT} + P_{I/O}$
- $P_{INT}$  =  $I_{DD} \times IV_{DD}$ , Watts - Chip Internal Power
- $P_{I/O}$  = Power Dissipation on Input and Output Pins – User Determined

For most applications  $P_{I/O} < P_{INT}$  and can be ignored. An approximate relationship between  $P_D$  and  $T_j$  (if  $P_{I/O}$  is neglected) is:

$$P_D = \frac{K}{(T_j + 273^\circ C)} \tag{Eqn. 2}$$

Solving equations 1 and 2 for K gives:

$$K = P_D \times (T_A \times 273^\circ C) + Q_{JMA} \times P_D^2 \quad \text{Eqn. 3}$$

where K is a constant pertaining to the particular part. K can be determined from Equation 3 by measuring  $P_D$  (at equilibrium) for a known  $T_A$ . Using this value of K, the values of  $P_D$  and  $T_J$  can be obtained by solving Equation 1 and Equation 2 iteratively for any value of  $T_A$ .

### 4.3 ESD protection

**Table 8. ESD protection characteristics<sup>1, 2</sup>**

| Characteristics                 | Symbol | Value | Units |
|---------------------------------|--------|-------|-------|
| ESD Target for Human Body Model | HBM    | 2000  | V     |

<sup>1</sup> All ESD testing is in conformity with JESD22 Stress Test Qualification.

<sup>2</sup> A device is defined as a failure if after exposure to ESD pulses the device no longer meets the device specification requirements. Complete DC parametric and functional testing is performed per applicable specification at room temperature followed by hot temperature, unless specified otherwise in the device specifications provided in this document.

### 4.4 Static latch-up (LU)

Two complementary static tests are required on six parts to assess the latch-up performance:

- A supply over voltage is applied to each power supply pin.
- A current injection is applied to each input, output, and configurable I/O pin.

These tests are compliant with the EIA/JESD 78 IC latch-up standard.

**Table 9. Latch-up results**

| No. | Symbol | Parameter             | Conditions                                | Class      |
|-----|--------|-----------------------|---|------------|
| 1   | LU CC  | Static latch-up class | $T_A = 125^\circ C$ conforming to JESD 78 | II level A |

### 4.5 DC electrical specifications

**Table 10. Power supply specifications**

| Characteristic                                    | Symbol      | Pin Name      | Min                    | Max                    | Units |
|---|-------------|---------------|------------------------|------------------------|-------|
| Internal logic supply voltage, nominal 1.2 V      | $IV_{DD}$   | IVDD          | 1.14                   | 1.32                   | V     |
| FlexBus supply voltage<br>Nominal 1.8–3.3 V       | $FBV_{DD}$  | FB_VDD        | 1.71                   | 3.63                   | V     |
| SDRAM supply voltage<br>DDR2 @ 1.8 V              | $SDV_{DD}$  | SD_VDD        | 1.71                   | 1.98                   | V     |
| SDRAM input reference voltage                     | $SDV_{REF}$ | SD_VREF       | $0.49 \times SDV_{DD}$ | $0.51 \times SDV_{DD}$ | V     |
| SDRAM termination supply voltage                  | $SDV_{TT}$  | SD_VTT        | $SDV_{REF} - 0.04$     | $SDV_{REF} + 0.04$     | V     |
| PLL analog operation voltage range, nominal 3.3 V | $PV_{DD}$   | VDD_OSC_A_PLL | 3.135                  | 3.63                   | V     |

**Table 10. Power supply specifications (continued)**

| Characteristic                                 | Symbol        | Pin Name             | Min   | Max              | Units |
|--|---------------|----------------------|-------|------------------|-------|
| External I/O pad supply voltage, nominal 3.3 V | $EV_{DD}$     | EVDD                 | 3.135 | 3.63             | V     |
| USB supply voltage, nominal 3.3 V              | $USBV_{DD}$   | VDD_USBO<br>VDD_USBH | 3.135 | 3.63             | V     |
| ADC supply voltage                             | $AV_{DD}$     | VDDA_ADC             | 3.135 | 3.63             | V     |
| DAC supply voltage                             | —             | VDDA_DAC_<br>ADC     | 3.135 | 3.63             | V     |
| RTC standby supply voltage                     | $RTCV_{STBY}$ | VSTBY_RTC            | 1.6   | $EV_{DD} - 0.2V$ | V     |

**Table 11. I/O electrical specifications**

| Characteristic   | Symbol     | Min                    | Max                    | Units   |
|--|------------|------------------------|------------------------|---------|
| CMOS input high voltage  | $EV_{IH}$  | $0.65 \times EV_{DD}$  | $EV_{DD} + 0.3$        | V       |
| CMOS input low voltage   | $EV_{IL}$  | $V_{SS} - 0.3$         | $0.35 \times EV_{DD}$  | V       |
| CMOS output high voltage<br>$I_{OH} = -2.0$ mA                                 | $EV_{OH}$  | $0.8 \times EV_{DD}$   | —                      | V       |
| CMOS output low voltage<br>$I_{OL} = 2.0$ mA                                   | $EV_{OL}$  | —                      | $0.2 \times EV_{DD}$   | V       |
| SDRAM input high voltage<br>DDR2 @ 1.8V  | $SDV_{IH}$ | $SDV_{REF} + 0.125$    | $SDV_{DD} + 0.3$       | V       |
| SDRAM input low voltage<br>DDR2 @ 1.8V   | $SDV_{IL}$ | -0.3                   | $SDV_{REF} - 0.125$    | V       |
| SDRAM output high voltage<br>DDR2@ 1.8V $I_{OH} = -13.4$ mA                    | $SDV_{OH}$ | $SDV_{DD} \times 0.9$  | —                      | V       |
| SDRAM output low voltage<br>DDR2@ 1.8V $I_{OH} = 13.4$ mA                      | $SDV_{OL}$ | —                      | $SDV_{DD} \times 0.1$  | V       |
| FlexBus input high voltage<br>@ 1.8V–3.3V                                      | $FBV_{IH}$ | $0.51 \times FBV_{DD}$ | $FBV_{DD} + 0.3$       | V       |
| FlexBus input low voltage<br>@ 1.8V–3.3V                                       | $FBV_{IL}$ | $V_{SS} - 0.3$         | $0.42 \times FBV_{DD}$ | V       |
| FlexBus output high voltage<br>@ 1.8V–3.3V<br>$I_{OH} = -5.0$ mA for all modes | $FBV_{OH}$ | $0.8 \times FBV_{DD}$  | —                      | V       |
| FlexBus output low voltage<br>@ 1.8V–3.3V<br>$I_{OL} = 5.0$ mA for all modes   | $FBV_{OL}$ | —                      | $0.2 \times FBV_{DD}$  | V       |
| Input Leakage Current<br>$V_{in} = V_{DD}$ or $V_{SS}$ , Input-only pins       | $I_{in}$   | -2.5                   | 2.5                    | $\mu A$ |



**Table 11. I/O electrical specifications (continued)**

| Characteristic   | Symbol    | Min    | Max       | Units         |
|--|-----------|--------|-----------|---------------|
| Weak internal pull-up/pull-down device current <sup>1</sup>                                  | $I_{APU}$ | 10     | 315       | $\mu\text{A}$ |
| Selectable weak internal pull-up/pull-down device current <sup>1</sup>                       | $I_{APU}$ | 25     | 150       | $\mu\text{A}$ |
| Input capacitance <sup>2</sup><br>All input-only pins<br>All input/output (three-state) pins | $C_{in}$  | —<br>— | 7<br>7    | pF            |
| Output loading for CMOS pads ( $EV_{DD}$ and $FBV_{DD}$ domains)<br>Low drive<br>High drive  | $C_L$     |        | 50<br>200 | pF            |
| Output loading for SDRAMC pads ( $SDV_{DD}$ domain)<br>Low drive<br>High drive               | $C_L$     |        | 5<br>50   | pF            |

<sup>1</sup> Refer to the signals section for pins having weak internal pull-up devices.

<sup>2</sup> This parameter is characterized before qualification rather than 100% tested.

## 4.6 Output pad loading and slew rate

The output pins on the MCF5441x devices have programmable slew rates. [Table 12](#) lists the rise/fall time for pins based on the type of pad used for the signal, the value programmed into the appropriate field of the slew rate control registers, and capacitive loading. Refer to [Table 5](#) for a list of the external signals to pad connections.

### NOTE

To allow the I/O interfaces to run at their maximum frequency, set their respective slew rate select values to 11.

**Table 12. Output pad slew rates**

| Pad type <sup>1</sup> | Slew rate select field value | Drive load (pF) | Rise/fall time (ns) |
|-----------------------|------------------------------|-----------------|---------------------|
| ssr                   | 11                           | 50              | 2.2                 |
|                       |                              | 200             | 6                   |
|                       | 10                           | 50              | 22                  |
|                       |                              | 200             | 28                  |
|                       | 01                           | 50              | 42                  |
|                       |                              | 200             | 50                  |
|                       | 00                           | 50              | 210                 |
|                       |                              | 200             | 220                 |

**Table 12. Output pad slew rates (continued)**

| Pad type <sup>1</sup> | Slew rate select field value | Drive load (pF) | Rise/fall time (ns) |
|-----------------------|------------------------------|-----------------|---------------------|
| msr                   | 11                           | 50              | 1.2                 |
|                       |                              | 200             | 6                   |
|                       | 10                           | 50              | 9                   |
|                       |                              | 200             | 14                  |
|                       | 01                           | 50              | 17                  |
|                       |                              | 200             | 23                  |
| 00                    | 50                           | 110             |                     |
|                       | 200                          | 120             |                     |
| fsr                   | 11                           | 50              | 1.1                 |
|                       |                              | 200             | 2.6                 |
|                       | 10                           | 50              | 2.4                 |
|                       |                              | 200             | 5                   |
|                       | 01                           | 50              | 5                   |
|                       |                              | 200             | 8                   |
|                       | 00                           | 50              | 16                  |
|                       |                              | 200             | 21                  |

<sup>1</sup> The ae pads are used for USB communication and are governed by usb.org specifications. They are not included in this table.

## 4.7 DDR pad drive strengths

The DDR pins on the MCF5441x devices have programmable drive strengths. [Table 13](#) lists the drive strengths for pins based on the value programmed into the appropriate field of the drive strength control register. Refer to [Table 5](#) for a list of the external signals to pad connections.

### NOTE

For a single device drive, this setting should be 00 to enable Half Strength mode. High strength is intended for multiple device drives (DIMM).

**Table 13. DDR pad drive strengths**

| Pad type | Drive strength select field value | Drive strength          |
|----------|-----------------------------------|-------------------------|
| st       | 00                                | Half strength 1.8V DDR2 |
|          | 01                                | Full strength 1.8V DDR2 |
|          | 10                                | Reserved                |
|          | 11                                | Reserved                |

## 4.8 Oscillator and PLL electrical characteristics

Reference Figure 9 for crystal circuits.

Table 14. PLL electrical characteristics

| Num | Characteristic  | Symbol             | Min             | Max   | Unit          |
|-----|---|--------------------|-----------------|---|---------------|
| 1   | PLL Reference Frequency Range <sup>1</sup><br>Crystal reference<br>External reference   | $f_{ref\_crystal}$ | 14 <sup>1</sup> | 50 <sup>1</sup>   | MHz           |
|     |   | $f_{ref\_ext}$     | 14 <sup>1</sup> | 50 <sup>1</sup>   | MHz           |
| 2   | Core frequency<br>FB_CLK frequency <sup>2</sup> (MISCCR2[FBHALF] = 0)   | $f_{sys}$          | 120             | 250   | MHz           |
|     |   | $f_{sys/2}$        | 60              | 100   | MHz           |
| 3   | VCO frequency   | $f_{vco}$          | 240             | 500   | MHz           |
| 4   | DCC frequency <sup>3</sup>  | $f_{DCC}$          | 300             | 500   | MHz           |
| 5   | Crystal start-up time <sup>4, 5</sup>   | $t_{cst}$          | —               | 10  | ms            |
| 6   | EXTAL input high voltage<br>External and limp modes   | $V_{IHEXT}$        | $EV_{IH}$       | EVDD  | V             |
| 7   | EXTAL input low voltage<br>External and limp modes  | $V_{ILEXT}$        | 0               | $EV_{IL}$   | V             |
| 8   | PLL lock time <sup>4, 6</sup>   | $t_{pll}$          | —               | 50  | ms            |
| 9   | Duty cycle of reference <sup>4</sup>  | $t_{dc}$           | -45%            | +45%  | %             |
| 10  | Crystal capacitive load   | $C_L$              | —               | From crystal spec   | pF            |
| 11  | Feedback resistor   | $R_F$              | 10              | —   | MΩ            |
| 12  | Series resistor   | $R_S$              | 0               | 200   | Ω             |
| 13  | Discrete load capacitance for XTAL  | $C_{L\_XTAL}$      | —               | $2 \times C_L - C_{S\_XTAL} - C_{PCB\_XTAL}$ <sup>7</sup>   | pF            |
| 14  | Discrete load capacitance for EXTAL   | $C_{L\_EXTAL}$     | —               | $2 \times C_L - C_{S\_EXTAL} - C_{PCB\_EXTAL}$ <sup>7</sup> | pF            |
| 15  | FB_CLK period jitter, <sup>4, 5, 7, 8</sup> Measured at $f_{SYS}$ Max<br>Peak-to-peak jitter (clock edge to clock edge)<br>Long term jitter | $C_{jitter}$       | —               | 10  | % $f_{sys/3}$ |
|     |   |                    | —               | 0.1   | % $f_{sys/3}$ |

<sup>1</sup> These reference value ranges are for after a PLL predivider (PREDIV), which can be programmed to 1, 2, 4, 8, or 16. The PREDIV value can be set while booting from serial flash. In parallel reset configuration, the PREDIV value is set to one. In this mode, if the input frequency results in an out of range reference frequency, boot the processor in limp mode, set the proper PREDIV and multiplier settings, and switch to PLL mode.

<sup>2</sup> All internal registers retain data at 0 Hz.

<sup>3</sup> Required only for DDR2 memory.

<sup>4</sup> This parameter is guaranteed by characterization before qualification rather than 100% tested.

<sup>5</sup> Proper PC board layout procedures must be followed to achieve specifications.

<sup>6</sup> This specification is the PLL lock time only and does not include oscillator start-up time.

<sup>7</sup>  $C_{PCB\_EXTAL}$  and  $C_{PCB\_XTAL}$  are the measured PCB stray capacitances on EXTAL and XTAL, respectively.

<sup>8</sup> Jitter is the average deviation from the programmed frequency measured over the specified interval at maximum  $f_{sys}$ . Measurements are made with the device powered by filtered supplies and clocked by a stable external clock signal. Noise injected into the PLL circuitry via PLL  $V_{DD}$ ,  $EV_{DD}$ , and  $V_{SS}$  and variation in crystal oscillator frequency increase the  $C_{jitter}$  percentage for a given interval.

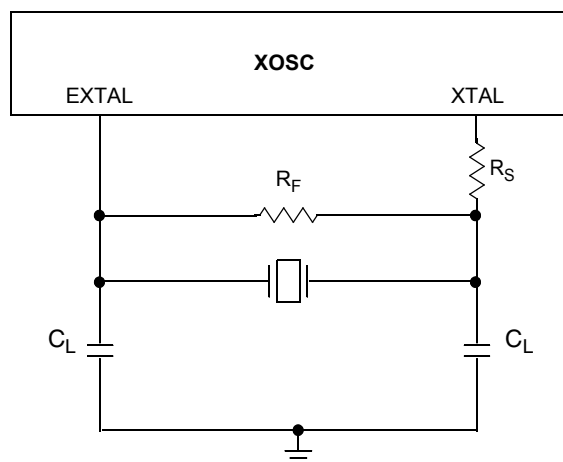


Figure 9. Typical crystal circuit

## 4.9 Reset timing specifications

Table 15 lists specifications for the reset timing parameters shown in Figure 10.

Table 15. Reset and configuration override timing

| Num             | Characteristic  | Min | Max | Unit          |
|-----------------|---|-----|-----|---------------|
| R1 <sup>1</sup> | $\overline{\text{RESET}}$ valid to FB_CLK (setup)                                     | 9   | —   | ns            |
| R2              | FB_CLK to $\overline{\text{RESET}}$ invalid (hold)                                    | 1.5 | —   | ns            |
| R3              | $\overline{\text{RESET}}$ valid time <sup>2</sup>                                     | 5   | —   | FB_CLK cycles |
| R4              | FB_CLK to $\overline{\text{RSTOUT}}$ valid  | —   | 10  | ns            |
| R5              | $\overline{\text{RSTOUT}}$ valid to Configuration Override inputs valid               | 0   | —   | ns            |
| R6              | Configuration Override inputs valid to $\overline{\text{RSTOUT}}$ invalid (setup)     | 20  | —   | FB_CLK cycles |
| R7              | Configuration Override inputs invalid after $\overline{\text{RSTOUT}}$ invalid (hold) | 0   | —   | ns            |
| R8              | $\overline{\text{RSTOUT}}$ invalid to Configuration Override inputs High Impedance    | —   | 1   | FB_CLK cycles |
| R9              | Minimum RSTOUT pulse width  | 512 | —   | FB_CLK cycles |

<sup>1</sup>  $\overline{\text{RESET}}$  and configuration override data lines are synchronized internally. Setup and hold times must be met only if recognition on a particular clock is required.

<sup>2</sup> During low power STOP, the synchronizers for the  $\overline{\text{RESET}}$  input are bypassed and  $\overline{\text{RESET}}$  is asserted asynchronously to the system. Thus,  $\overline{\text{RESET}}$  must be held a minimum of 100 ns.

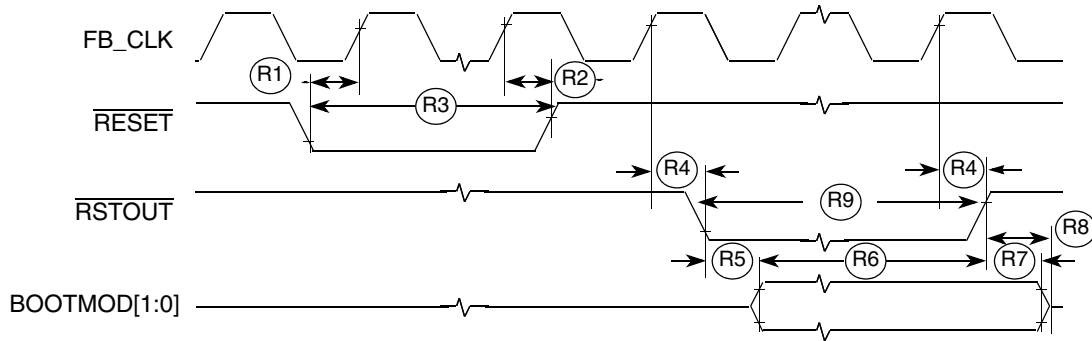


Figure 10.  $\overline{\text{RESET}}$  and configuration override timing

## 4.10 FlexBus timing specifications

All processor bus timings are synchronous; input setup/hold and output delay are given in respect to the rising edge of a reference clock, FB\_CLK. The FB\_CLK frequency may be the same as the internal system bus frequency or an integer divider of that frequency.

The following timing numbers indicate when data is latched or driven onto the external bus, relative to the FlexBus output clock (FB\_CLK). All other timing relationships can be derived from these values.

All FlexBus signals use pad type pad\_fsr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

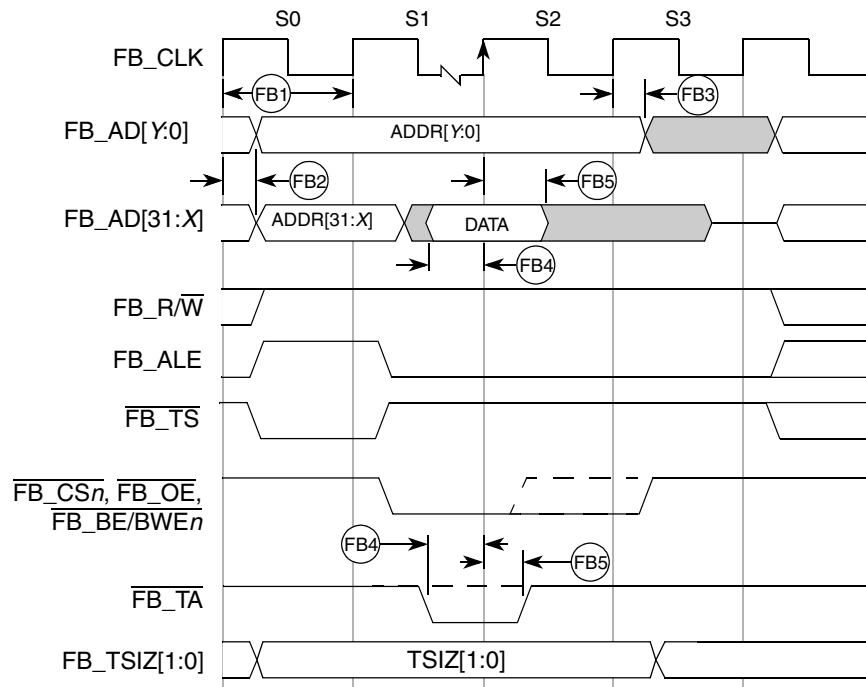
Table 16. FlexBus timing specifications

| Num | Characteristic         | Min | Max  | Unit | Notes        |
|-----|------------------------|-----|------|------|--------------|
|     | Frequency of operation | —   | 62.5 | MHz  |              |
| FB1 | Clock period           | 16  | —    | ns   |              |
| FB2 | Output valid           | —   | 6.0  | ns   | <sup>1</sup> |
| FB3 | Output hold            | 0.5 | —    | ns   | <sup>1</sup> |
| FB4 | Input setup            | 5.5 | —    | ns   | <sup>2</sup> |
| FB5 | Input hold             | 0   | —    | ns   | <sup>2</sup> |

<sup>1</sup> Specification is valid for all FB\_AD[31:0], FB\_R/W, FB\_ALE, FB\_TS, FB\_CS $\bar{n}$ , FB\_OE, FB\_BE/BWE $\bar{n}$ , and FB\_TSIZ[1:0].

<sup>2</sup> Specification is valid for all FB\_AD[31:0] and  $\overline{\text{FB\_TA}}$ .

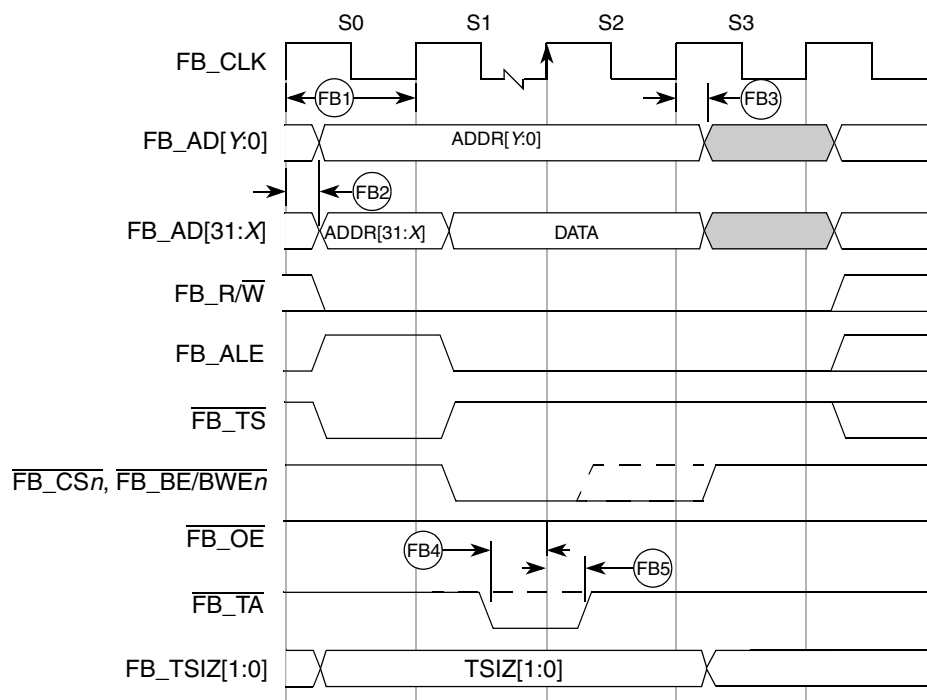
1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.



**Note:**

- <sup>1</sup> FB2 and FB3 output specifications are valid for all FB\_AD[31:0], FB\_R/W, FB\_ALE, FB\_TS, FB\_CS $\bar{n}$ , FB\_OE, FB\_BE/BWE $\bar{n}$ , and FB\_TSIZ[1:0].
- <sup>2</sup> FB4 and FB5 input specifications are valid for all FB\_AD[31:0] and FB\_TA.

**Figure 11. FlexBus read timing**


**Note:**

- <sup>1</sup> FB2 and FB3 output specifications are valid for all FB\_AD[31:0], FB\_R/W, FB\_ALE, FB\_TS, FB\_CS $\bar{n}$ , FB\_OE, FB\_BE/BWEn, and FB\_TSIZ[1:0].
- <sup>2</sup> FB4 and FB5 input specifications are valid for all FB\_AD[31:0] and FB\_TA.

**Figure 12. FlexBus write timing**

## 4.11 NAND flash controller (NFC) timing specifications

The NAND flash controller (NFC) implements the interface to standard NAND flash memory devices. This section describes the timing parameters of the NFC.

All NFC signals use pad type pad\_fsr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

**Table 17. NFC timing specifications**

| Num | Characteristic                          | Symbol    | Min                        | Max             | Unit |
|-----|---|-----------|----------------------------|-----------------|------|
|     | Frequency of operation                  |           | —                          | 40 <sup>1</sup> | MHz  |
| NF1 | Clock period                            | $t_{NFC}$ | 25                         | —               | ns   |
| NF2 | NFC_CLE setup time                      | $t_{CLS}$ | $1.5 \times t_{NFC}$       | —               | ns   |
| NF3 | NFC_CLE hold time                       | $t_{CLH}$ | $t_{NFC}$                  | —               | ns   |
| NF4 | $\overline{\text{NFC\_CE}}$ setup time  | $t_{CS}$  | $1.5 \times t_{NFC}$       | —               | ns   |
| NF5 | $\overline{\text{NFC\_CE}}$ hold time   | $t_{CH}$  | $t_{NFC}$                  | —               | ns   |
| NF6 | $\overline{\text{NFC\_WE}}$ pulse width | $t_{WP}$  | $0.5 \times t_{NFC} - 0.5$ | —               | ns   |

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

Table 17. NFC timing specifications (continued)

| Num  | Characteristic                             | Symbol    | Min                        | Max | Unit |
|------|--|-----------|----------------------------|-----|------|
| NF7  | NFC_ALE setup time                         | $t_{ALS}$ | $1.5 \times t_{NFC}$       | —   | ns   |
| NF8  | NFC_ALE hold time                          | $t_{ALH}$ | $t_{NFC}$                  | —   | ns   |
| NF9  | Data setup time                            | $t_{DS}$  | $0.5 \times t_{NFC} - 4$   | —   | ns   |
| NF10 | Data hold time                             | $t_{DH}$  | $0.5 \times t_{NFC} - 10$  | —   | ns   |
| NF11 | Write cycle time                           | $t_{WC}$  | $t_{NFC}$                  | —   | ns   |
| NF12 | $\overline{\text{NFC\_WE}}$ high hold time | $t_{WH}$  | $0.5 \times t_{NFC} - 1$   | —   | ns   |
| NF13 | Ready to $\overline{\text{NFC\_RE}}$ low   | $t_{RR}$  | $4.5 \times t_{NFC}$       | —   | ns   |
| NF14 | $\overline{\text{NFC\_RE}}$ pulse width    | $t_{RP}$  | $0.5 \times t_{NFC} - 0.5$ | —   | ns   |
| NF15 | Read cycle time                            | $t_{RC}$  | $t_{NFC}$                  | —   | ns   |
| NF16 | $\overline{\text{NFC\_RE}}$ high hold time | $t_{REH}$ | $0.5 \times t_{NFC} - 1$   | —   | ns   |
| NF17 | Data in setup time                         | $t_{DSU}$ | 6                          | —   | ns   |

<sup>1</sup> 50 MHz maximum frequency can only be used if the part is in EDO (enhanced data out) mode.

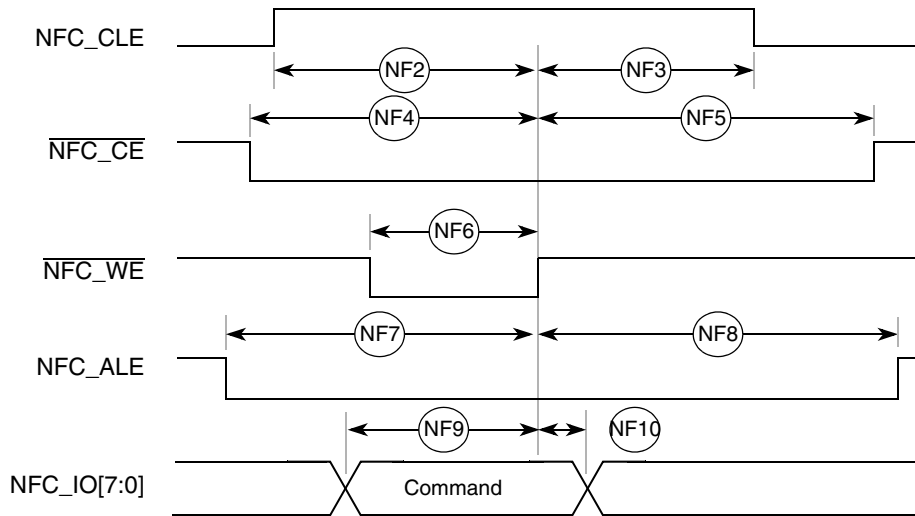


Figure 13. Command latch cycle timing



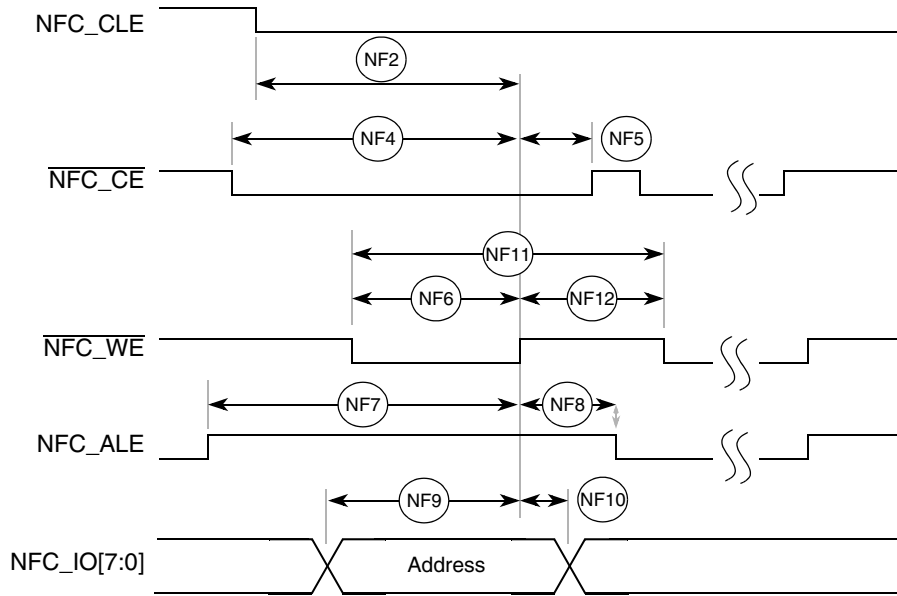


Figure 14. Address latch cycle timing

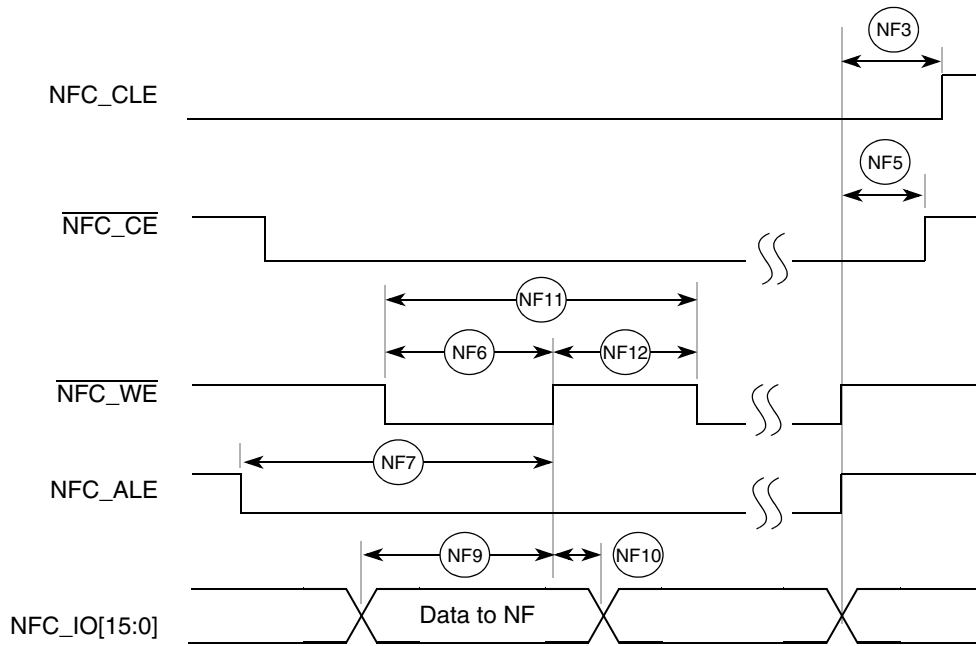


Figure 15. Write data latch timing

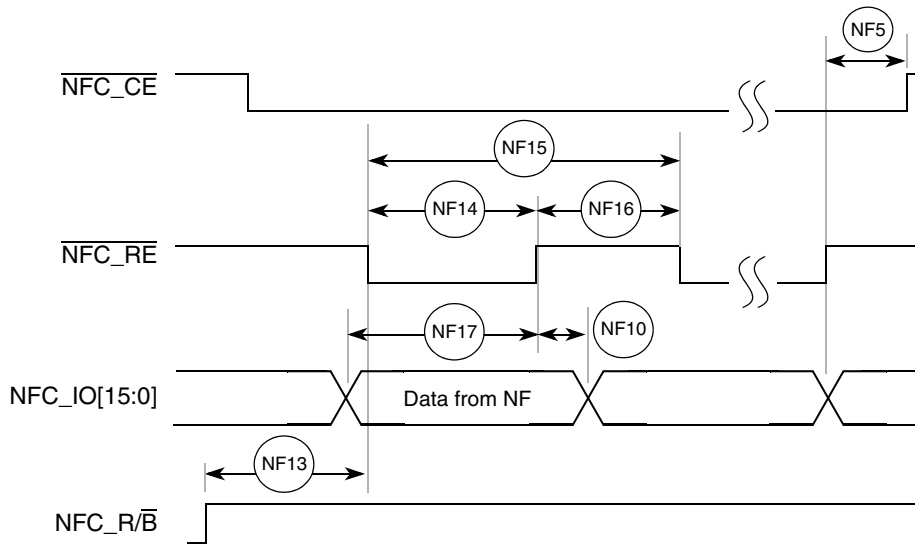


Figure 16. Read data latch timing

## 4.12 DDR SDRAM controller timing specifications

The following timing numbers must be followed to properly latch or drive data onto the SDRAM memory bus. All timing numbers are relative to the DQS byte lanes.

Table 18. SDRAM timing specifications

| Num  | Characteristic  | Symbol      | Min                       | Max                        | Unit       | Notes  |
|------|---|-------------|---------------------------|----------------------------|------------|--------|
|      | Frequency of operation  |             | 100                       | 250                        | MHz        |        |
| DD1  | Clock period  | $t_{SDCK}$  | 4.0                       | 10.0                       | ns         |        |
| DD2  | Pulse width high  | $t_{SDCKH}$ | 0.45                      | 0.55                       | $t_{SDCK}$ | 1      |
| DD3  | Pulse width low   | $t_{SDCKL}$ | 0.45                      | 0.55                       | $t_{SDCK}$ | 3      |
| DD4  | Address, $\overline{SD\_CKE}$ , $\overline{SD\_CAS}$ , $\overline{SD\_RAS}$ , $\overline{SD\_WE}$ , $\overline{SD\_CS}[1:0]$ — output valid | $t_{CMV}$   | —                         | $0.5 \times t_{SDCK} + 1$  | ns         | 2      |
| DD5  | Address, $\overline{SD\_CKE}$ , $\overline{SD\_CAS}$ , $\overline{SD\_RAS}$ , $\overline{SD\_WE}$ , $\overline{SD\_CS}[1:0]$ — output hold  | $t_{CMH}$   | $0.5 \times t_{SDCK} - 1$ | —                          | ns         |        |
| DD6  | Write command to first DQS latching transition  | $t_{DQSS}$  | —                         | $WL + 0.2 \times t_{SDCK}$ | ns         |        |
| DD7  | Data and data mask output setup (DQ→DQS) relative to DQS (DDR write mode)   | $t_{QS}$    | 0.4                       | —                          | ns         | 3<br>4 |
| DD8  | Data and data mask output hold (DQS→DQ) relative to DQS (DDR write mode)  | $t_{QH}$    | 0.4                       | —                          | ns         | 5      |
| DD9  | Input data skew relative to DQS (input setup)   | $t_{IS}$    | —                         | 0.5                        | ns         | 6      |
| DD10 | Input data hold relative to DQS.  | $t_{IH}$    | $0.375 \times t_{SDCK}$   | —                          | ns         | 7      |

<sup>1</sup> Pulse width high plus pulse width low cannot exceed min and max clock period.

<sup>2</sup> Command output valid should be 1/2 the memory bus clock ( $t_{SDCK}$ ) plus some minor adjustments for process, temperature, and voltage variations.

- <sup>3</sup> This specification relates to the required input setup time of DDR memories. The microprocessor's output setup should be larger than the input setup of the DDR memories. If it is not larger, then the input setup on the memory is in violation. SD\_D[31:24] is relative to SD\_DQS[3]; SD\_D[23:16] is relative to SD\_DQS[2]
- <sup>4</sup> The first data beat is valid before the first rising edge of DQS and after the DQS write preamble. The remaining data beats are valid for each subsequent DQS edge.
- <sup>5</sup> This specification relates to the required hold time of DDR memories. SD\_D[31:24] is relative to SD\_DQS[3]; SD\_D[23:16] is relative to SD\_DQS[2]
- <sup>6</sup> Data input skew is derived from each DQS clock edge. It begins with a DQS transition and ends when the last data line becomes valid. This input skew must include DDR memory output skew and system level board skew (due to routing or other factors).
- <sup>7</sup> Data input hold is derived from each DQS clock edge. It begins with a DQS transition and ends when the first data line becomes invalid.

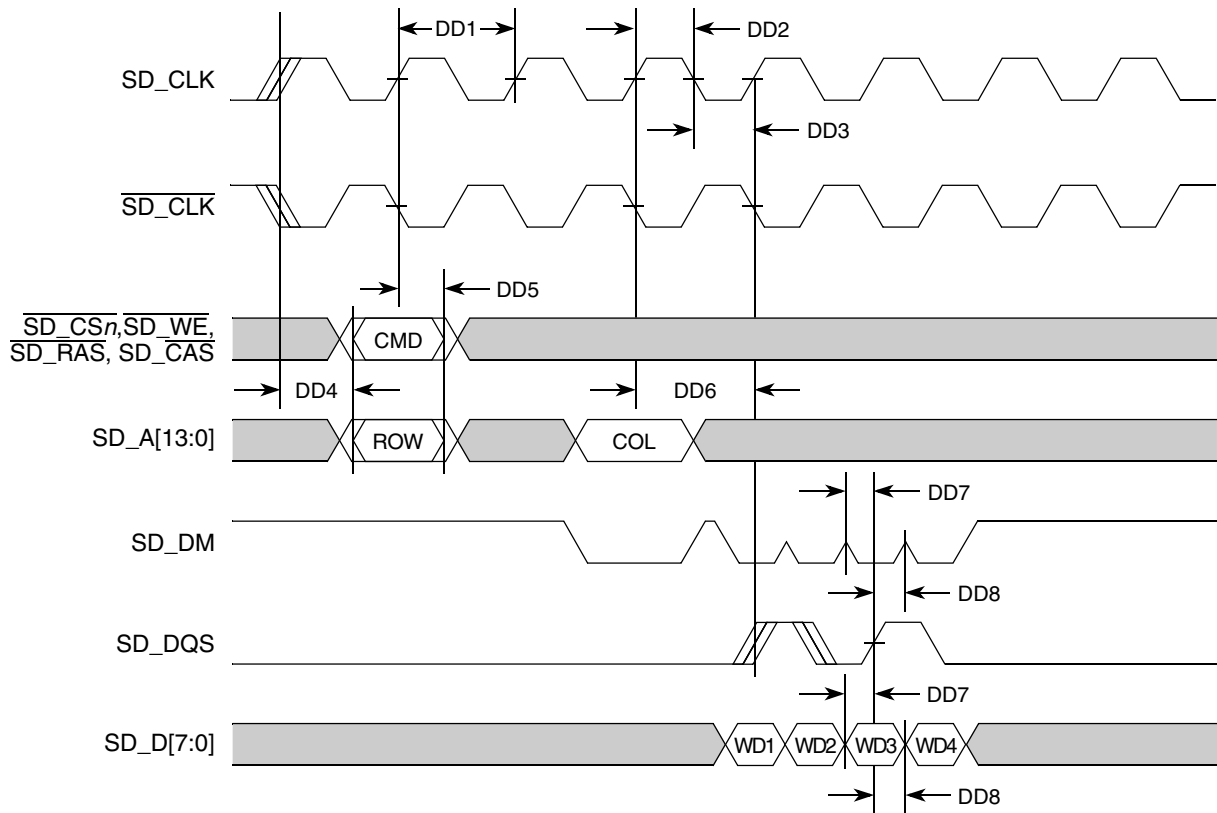


Figure 17. DDR write timing

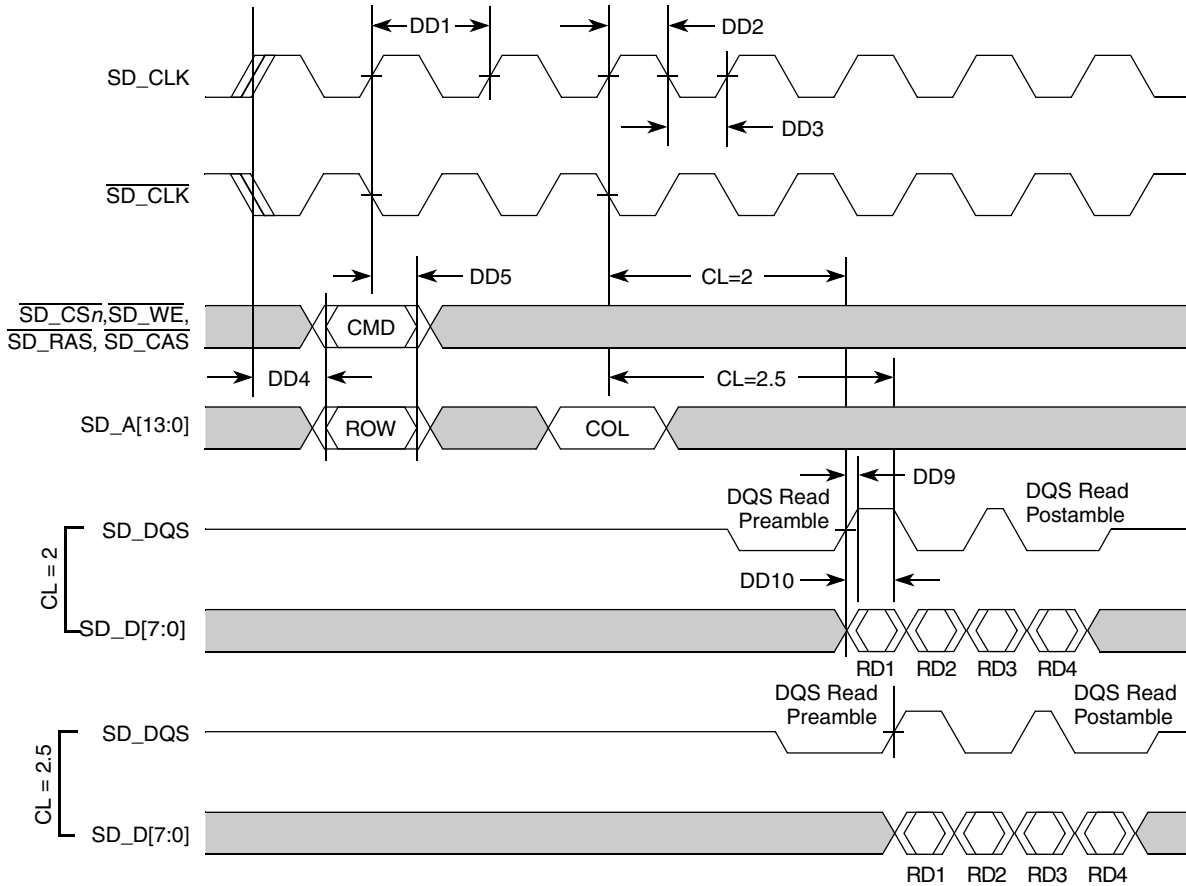


Figure 18. DDR read timing

### 4.13 USB transceiver timing specifications

The MCF5441x device is compliant with industry standard USB 2.0 specification.

### 4.14 ULPI timing specifications

The ULPI interface is fully compliant with the industry standard UTMI+ Low Pin Interface. Control and data timing requirements for the ULPI pins are given in Table 19. These timings apply to synchronous mode only. All timings are measured with respect to the clock as seen at the USB\_CLKIN pin on the MCF5441x. The ULPI PHY is the source of the 60MHz clock.

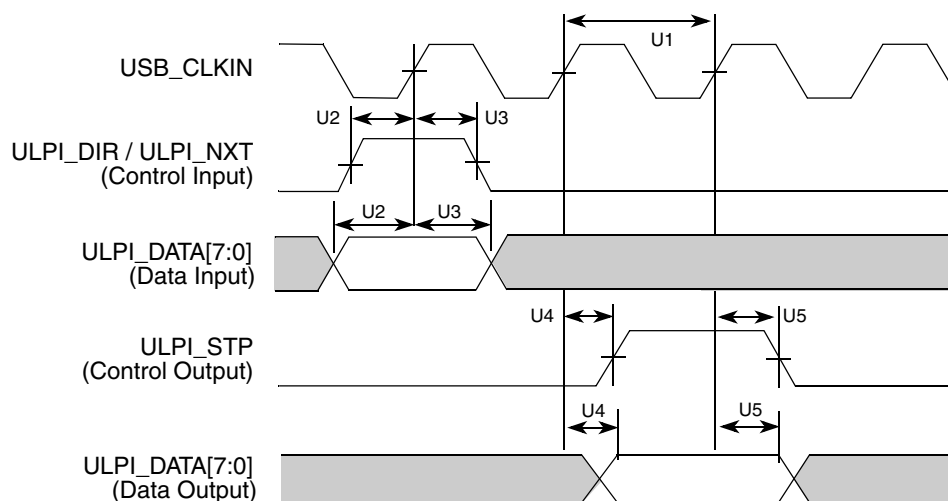
#### NOTE

The USB controller requires a 60-MHz clock, even if using the on-chip FS/LS transceiver instead of the ULPI interface. In this case, the 60-MHz clock can be generated by the PLL or input on the USB\_CLKIN pin.

All ULPI signals use pad type pad\_fsr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

**Table 19. ULPI interface timing**

| Num | Characteristic                  | Min | Nominal | Max | Units |
|-----|---------------------------------|-----|---------|-----|-------|
|     | USB_CLKIN operating frequency   | —   | 60      | —   | MHz   |
|     | USB_CLKIN duty cycle            | —   | 50      | —   | %     |
| U1  | USB_CLKIN clock period          | —   | 16.67   | —   | ns    |
| U2  | Input setup (control and data)  | 5.0 | —       | —   | ns    |
| U3  | Input hold (control and data)   | 1.0 | —       | —   | ns    |
| U4  | Output valid (control and data) | —   | —       | 9.5 | ns    |
| U5  | Output hold (control and data)  | 1.0 | —       | —   | ns    |



**Figure 19. ULPI timing diagram**

## 4.15 eSDHC timing specifications

This section describes the electrical information of the eSDHC.

All eSDHC signals use pad type pad\_msr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>2</sup>

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.
2. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

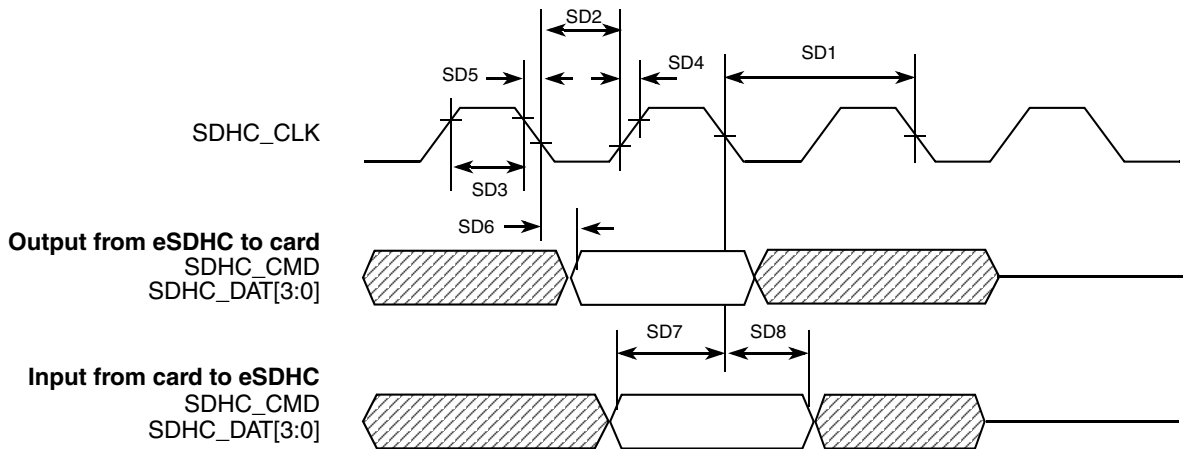
### 4.15.1 eSDHC timing specifications

Figure 20 depicts the timing of eSDHC, and Table 20 lists the eSDHC timing characteristics.

**Table 20. eSDHC interface timing specifications**

| ID   | Parameter                             | Symbols    | Min | Max | Unit |
|--|---------------------------------------|------------|-----|-----|------|
| <b>Card Input Clock</b>  |                                       |            |     |     |      |
| SD1  | Clock frequency (low speed)           | $f_{PP}^1$ | 0   | 400 | kHz  |
|  | Clock frequency (SD/SDIO full speed)  | $f_{PP}^2$ | 0   | 40  | MHz  |
|  | Clock frequency (MMC full speed)      | $f_{PP}^3$ | 0   | 20  | MHz  |
|  | Clock frequency (identification mode) | $f_{OD}^4$ | 100 | 400 | kHz  |
| SD2  | Clock low time                        | $t_{WL}$   | 7   | —   | ns   |
| SD3  | Clock high time                       | $t_{WH}$   | 7   | —   | ns   |
| SD4  | Clock rise time                       | $t_{TLH}$  | —   | 3   | ns   |
| SD5  | Clock fall time                       | $t_{THL}$  | —   | 3   | ns   |
| <b>eSDHC Output / card inputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK)</b> |                                       |            |     |     |      |
| SD6  | eSDHC output delay (output valid)     | $t_{OD}$   | -5  | 5   | ns   |
| <b>eSDHC Input / card outputs SDHC_CMD, SDHC_DAT (reference to SDHC_CLK)</b> |                                       |            |     |     |      |
| SD7  | eSDHC input setup time                | $t_{ISU}$  | 5   | —   | ns   |
| SD8  | eSDHC input hold time                 | $t_{IH}$   | 0   | —   | ns   |

- <sup>1</sup> In low speed mode, card clock must be lower than 400 kHz, voltage ranges from 2.7 to 3.6 V.
- <sup>2</sup> In normal data transfer mode for SD/SDIO card, clock frequency can be any value from 0 to 25 MHz.
- <sup>3</sup> In normal data transfer mode for MMC card, clock frequency can be any value from 0 to 20 MHz.
- <sup>4</sup> In card identification mode, card clock must be 100 kHz– 400 kHz, voltage ranges from 2.7 to 3.6 V.



**Figure 20. eSDHC timing**

## 4.15.2 eSDHC electrical DC characteristics

Table 21 lists the eSDHC electrical DC characteristics.

**Table 21. MMC/SD interface electrical specifications**

| Num                            | Parameter             | Design value | Min                   | Max                   | Unit       | Condition/remark                           |
|--------------------------------|-----------------------|--------------|-----------------------|-----------------------|------------|--|
| <b>Bus signal line load</b>    |                       |              |                       |                       |            |  |
| 7                              | Pull-up resistance    | 47           | 10                    | 100                   | k $\Omega$ | Internal PU                                |
| 8                              | Open drain resistance | NA           | NA                    | NA                    | k $\Omega$ | For MMC cards only                         |
| <b>Open drain signal level</b> |                       |              |                       |                       |            | For MMC cards only                         |
| 9                              | Output high voltage   |              | $V_{DD} - 0.2$        |                       | V          | $I_{OH} = -100 \mu A$                      |
| 10                             | Output low voltage    |              |                       | 0.3                   | V          | $I_{OL} = 2 \text{ mA}$                    |
| <b>Bus signal levels</b>       |                       |              |                       |                       |            |  |
| 11                             | Output high voltage   |              | $0.75 \times V_{DD}$  |                       | V          | $I_{OH} = -100 \mu A @ V_{DD} \text{ min}$ |
| 12                             | Output low voltage    |              |                       | $0.125 \times V_{DD}$ | V          | $I_{OL} = 100 \mu A @ V_{DD} \text{ min}$  |
| 13                             | Input high voltage    |              | $0.625 \times V_{DD}$ | $V_{DD} + 3$          | V          |  |
| 14                             | Input low voltage     |              | $V_{SS} - 0.3$        | $0.25 \times V_{DD}$  | V          |  |

## 4.16 SIM timing specifications

Each SIM card interface consist of a total of 12 pins (two separate ports of six pins each. Mostly one port with 5 pins is used).

The interface is meant to be used with synchronous SIM cards. This means that the SIM module provides a clock for the SIM card to use. The frequency of this clock is normally 372 times the data rate on the TX/RX pins, however SIM module can work with CLK equal to 16 times the data rate on TX/RX pins.

There is no timing relationship between the clock and the data. The clock that the SIM module provides to the SIM card is used by the SIM card to recover the clock from the data, like a standard UART. All six (or five when a bidirectional TXRX is used) of the pins for each half of the SIM module are asynchronous to each other. There are no required timing relationships between the signals in normal mode. However, there are some in reset and power down sequences.

All SIM signals use pad type pad\_msr. SIM timing is fairly relaxed compared to other interfaces and can be met at 50 pF loading with any slew rate setting other than 00.<sup>1</sup>

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

### 4.16.1 General timing requirements

Figure 21 shows the timing of the SIM module, and Table 22 lists the timing parameters.

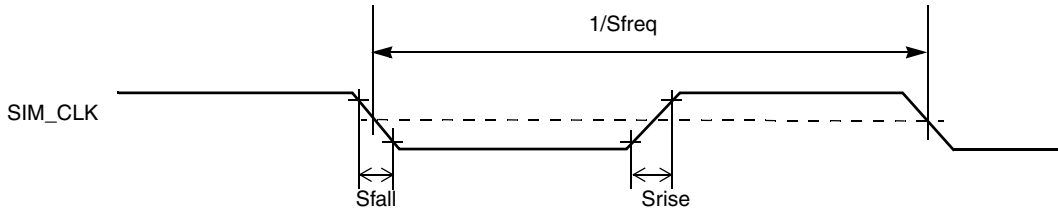


Figure 21. SIM clock timing diagram

Table 22. SIM timing specification—High Drive strength

| Num | Description                                | Symbol | Min  | Max                             | Unit |
|-----|--|--------|------|---------------------------------|------|
| 1   | SIM clock frequency (SIM_CLK) <sup>1</sup> | Sfreq  | 0.01 | 5 (Some new cards may reach 10) | MHz  |
| 2   | SIM_CLK rise time <sup>2</sup>             | Srise  | –    | 20                              | ns   |
| 3   | SIM_CLK fall time <sup>3</sup>             | Sfall  | –    | 20                              | ns   |
| 4   | SIM input transition time (RX, SIM_PD)     | Strans | –    | 25                              | ns   |

<sup>1</sup> 50% duty cycle clock

<sup>2</sup> With C = 50pF

<sup>3</sup> With C = 50pF

### 4.16.2 Reset sequence

#### 4.16.2.1 Cards with internal reset

The reset sequence for this kind of SIM card is as follows (see Figure 22):

- After powerup, the clock signal is enabled on SIM\_CLK (time T0)
- After 200 clock cycles, RX must be high.
- The card must send a response on RX acknowledging the reset between 400 and 40,000 clock cycles after T0.

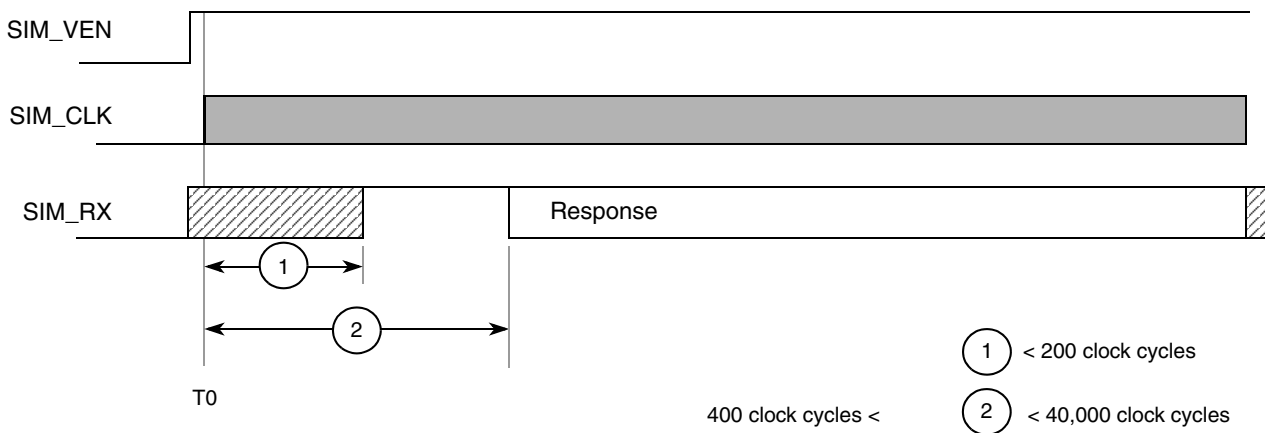


Figure 22. Internal-reset card reset sequence



### 4.16.2.2 Cards with active-low reset

The sequence of reset for this kind of card is as follows (see Figure 23):

1. After powerup, the clock signal is enabled on SIM\_CLK (time T0)
2. After 200 clock cycles, RX must be high.
3. SIM\_RST must remain low for at least 40,000 clock cycles after T0 (no response is to be received on RX during those 40,000 clock cycles)
4. SIM\_RST is set high (time T1)
5. SIM\_RST must remain high for at least 40,000 clock cycles after T1 and a response must be received on RX between 400 and 40,000 clock cycles after T1.

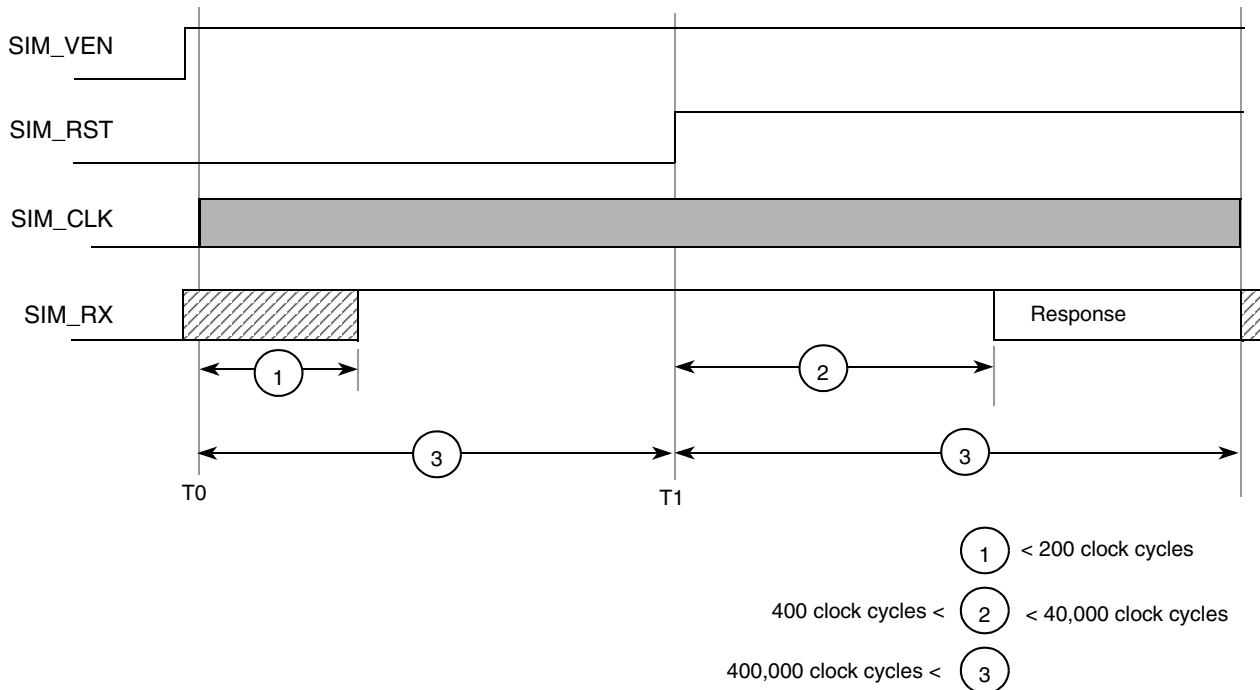


Figure 23. Active-low-reset card reset sequence

### 4.16.3 Power-down sequence

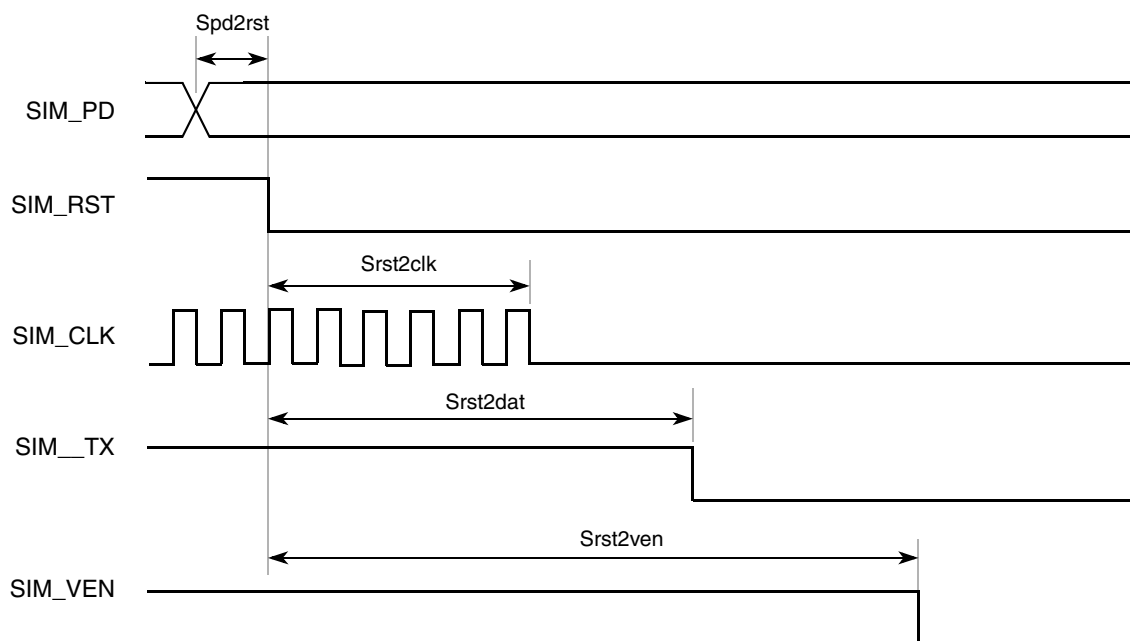
Power down sequence for SIM interface is as follows:

1. SIM\_PD port detects the removal of the SIM card
2. SIM\_RST goes low
3. SIM\_CLK goes low
4. SIM\_TX goes low
5. SIM\_VEN goes low

Each of these steps is completed in one CKIL period (usually 32 kHz). Power-down may be started in response to a card-removal detection or launched by the processor. Figure 24 and Table 23 show the usual timing requirements for this sequence, with  $F_{ckil}$  = CKIL frequency value.

**Table 23. Timing requirements for power-down sequence**

| Num | Description                          | Symbol        | Min                 | Max | Unit    |
|-----|--------------------------------------|---------------|---------------------|-----|---------|
| 1   | SIM reset to SIM clock stop          | $S_{rst2clk}$ | $0.9 \div f_{CKIL}$ | 0.8 | $\mu s$ |
| 2   | SIM reset to SIM TX data low         | $S_{rst2dat}$ | $1.8 \div f_{CKIL}$ | 1.2 | $\mu s$ |
| 3   | SIM reset to SIM voltage enable low  | $S_{rst2ven}$ | $2.7 \div f_{CKIL}$ | 1.8 | $\mu s$ |
| 4   | SIM presence detect to SIM reset low | $S_{pd2rst}$  | $0.9 \div f_{CKIL}$ | 25  | ns      |



**Figure 24. SmartCard interface power-down AC timing**

## 4.17 SSI timing specifications

This section provides the AC timings for the SSI in master (clocks driven) and slave modes (clocks input). All timings are given for non-inverted serial clock polarity ( $SSI\_TCR[TSCKP] = 0$ ,  $SSI\_RCR[RSCKP] = 0$ ) and a non-inverted frame sync ( $SSI\_TCR[TFSI] = 0$ ,  $SSI\_RCR[RFSI] = 0$ ). If the polarity of the clock and/or the frame sync have been inverted, all the timings remain valid by inverting the clock signal ( $SSI\_BCLK$ ) and/or the frame sync ( $SSI\_FS$ ) shown in the figures below.

All SSI signals use pad type pad\_msr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF. When the  $SSI\_MCLK$  output is not used, the maximum SSI bit clock ( $SSI\_BCLK$ ) frequency is such that timing can also be met at slew rate settings 10 and 01.<sup>1</sup>

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

**Table 24. SSI timing — master modes<sup>1</sup>**

| Num | Description                                  | Symbol     | Min   | Max | Units      | Notes        |
|-----|--|------------|-------|-----|------------|--------------|
| S1  | SSI_MCLK cycle time                          | $t_{MCLK}$ | 15.15 | —   | ns         | <sup>2</sup> |
| S2  | SSI_MCLK pulse width high / low              |            | 45%   | 55% | $t_{MCLK}$ |              |
| S3  | SSI_BCLK cycle time                          | $t_{BCLK}$ | 80    | —   | ns         | <sup>3</sup> |
| S4  | SSI_BCLK pulse width                         |            | 45%   | 55% | $t_{BCLK}$ |              |
| S5  | SSI_BCLK to SSI_FS output valid              |            | —     | 15  | ns         |              |
| S6  | SSI_BCLK to SSI_FS output invalid            |            | 0     | —   | ns         |              |
| S7  | SSI_BCLK to SSI_TXD valid                    |            | —     | 15  | ns         |              |
| S8  | SSI_BCLK to SSI_TXD invalid / high impedance |            | 0     | —   | ns         |              |
| S9  | SSI_RXD / SSI_FS input setup before SSI_BCLK |            | 15    | —   | ns         |              |
| S10 | SSI_RXD / SSI_FS input hold after SSI_BCLK   |            | 0     | —   | ns         |              |

<sup>1</sup> All timings specified with a capacitive load of 25pF.

<sup>2</sup> SSI\_MCLK can be generated from SSI\_CLKIN or a divided version of the internal system clock ( $f_{sys}$ ).

<sup>3</sup> SSI\_BCLK can be derived from SSI\_CLKIN or a divided version of the internal system clock ( $f_{sys}$ ).

**Table 25. SSI timing — slave modes<sup>1</sup>**

| Num | Description  | Symbol     | Min | Max | Units      | Notes |
|-----|--|------------|-----|-----|------------|-------|
| S11 | SSI_BCLK cycle time  | $t_{BCLK}$ | 80  | —   | ns         |       |
| S12 | SSI_BCLK pulse width high / low                              |            | 45% | 55% | $t_{BCLK}$ |       |
| S13 | SSI_FS input setup before SSI_BCLK                           |            | 10  | —   | ns         |       |
| S14 | SSI_FS input hold after SSI_BCLK                             |            | 2   | —   | ns         |       |
| S15 | SSI_BCLK to SSI_TXD / SSI_FS output valid                    |            | —   | 15  | ns         |       |
| S16 | SSI_BCLK to SSI_TXD / SSI_FS output invalid / high impedance |            | 0   | —   | ns         |       |
| S17 | SSI_RXD setup before SSI_BCLK                                |            | 15  | —   | ns         |       |
| S18 | SSI_RXD hold after SSI_BCLK                                  |            | 2   | —   | ns         |       |

<sup>1</sup> All timings specified with a capacitive load of 25pF.

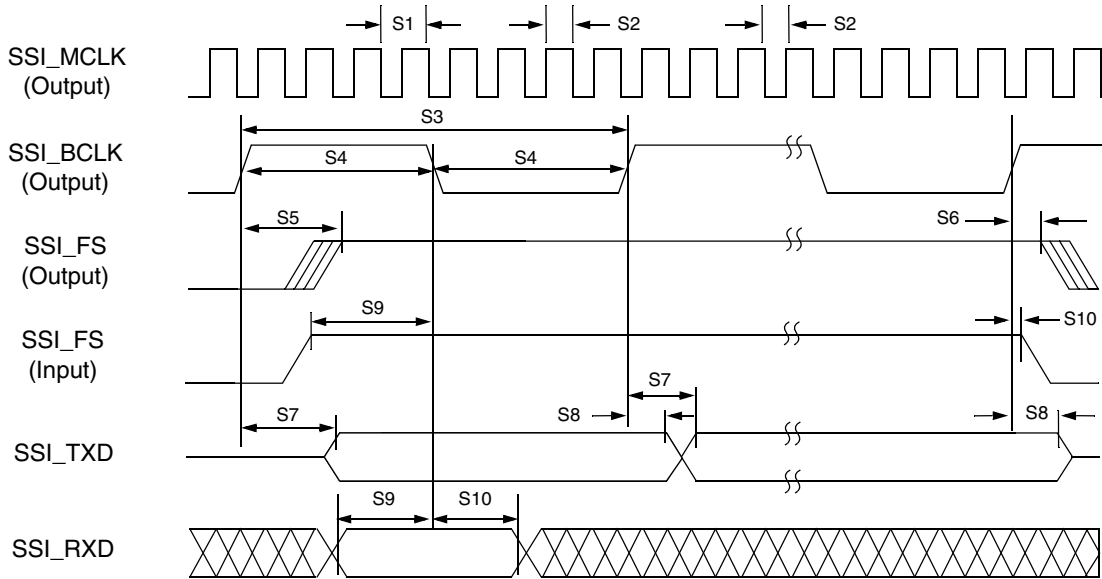


Figure 25. SSI timing — master modes

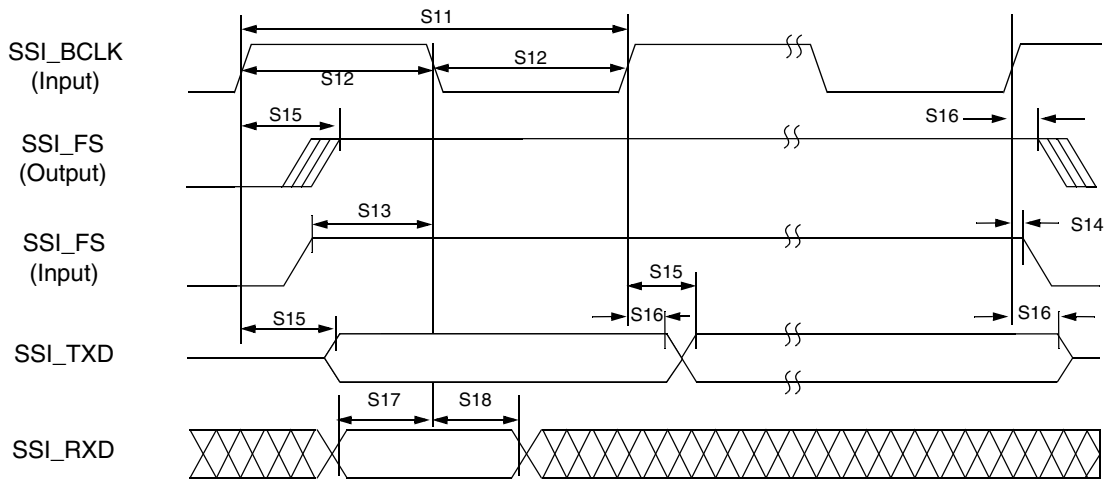


Figure 26. SSI timing — slave modes

## 4.18 12-bit ADC specifications

Table 26. ADC parameters<sup>1</sup>

| Characteristic  | Name       | Min        | Typical | Max        | Unit |
|---|------------|------------|---------|------------|------|
| Frequency of operation  |            | 200kHz     | —       | 12MHz      |      |
| ADC clock period  | $t_{ADC}$  | 8.33       | —       | 500        | ns   |
| Low reference voltage   | $V_{REFL}$ | $V_{SS}$   | —       | $V_{REFH}$ | V    |
| High reference voltage  | $V_{REFH}$ | $V_{REFL}$ | —       | $AV_{DD}$  | V    |
| Integral non-linearity (10% to 90% input signal range) <sup>2</sup> | INL        | —          | $\pm 3$ | —          | lsb  |

Table 26. ADC parameters<sup>1</sup> (continued)

| Characteristic  | Name                  | Min        | Typical | Max | Unit                                 |
|---|-----------------------|------------|---------|-----|--------------------------------------|
| Differential non-linearity (10% to 90% input signal range) <sup>3</sup> | DNL                   | —          | ±0.6    | —   | lsb                                  |
| Monotonicity  |                       | Guaranteed |         |     |                                      |
| Conversion time   |                       | —          | —       | 6   | t <sub>ADC</sub> cycles              |
| Sample time   |                       | —          | —       | 1   | t <sub>ADC</sub> cycles              |
| ADC power-up time <sup>4</sup>  | t <sub>ADPU</sub>     | —          | —       | 13  | t <sub>ADC</sub> cycles <sup>5</sup> |
| Recovery from auto standby  | t <sub>REC</sub>      | —          | 0       | 6   | t <sub>ADC</sub> cycles              |
| Input impedance   | X <sub>IN</sub>       | —          | 2k      | —   | Ω                                    |
| Input injection current <sup>6</sup> , per pin                          | I <sub>ADI</sub>      | —          | —       | 3   | mA                                   |
| V <sub>REFH</sub> current   | I <sub>VREFH</sub>    | —          | 100     | —   | nA                                   |
| Offset voltage internal reference (at the y intercept)                  | V <sub>OFFSET0</sub>  | —          | ±20     | —   | LSB                                  |
| Offset voltage internal reference (at the 50% FSR point)                | V <sub>OFFSET50</sub> | —          | ±12     | —   | LSB                                  |
| Gain error (transfer path)  | E <sub>GAIN</sub>     | —          | ±0.2    | —   | %                                    |
| Spurious free dynamic range   | SFDR                  | —          | 57      | —   | dB                                   |
| Signal-to-noise plus distortion   | SINAD                 | —          | 55      | —   | dB                                   |
| Signal-to-noise ratio   | SNR                   | —          | 60      | —   | dB                                   |
| Effective number of bits  | ENOB                  | —          | 9       | —   | Bits                                 |

<sup>1</sup> All ADC parameter measurements are preliminary pending full characterization.

These measurements were made at V<sub>DD</sub> = 3.3 V, V<sub>REFH</sub> = 3.3 V, and V<sub>REFL</sub> = ground.

<sup>2</sup> INL measured from V<sub>IN</sub> = 0.1V<sub>REFH</sub> to V<sub>IN</sub> = 0.9V<sub>REFH</sub>

<sup>3</sup> INL measured from V<sub>IN</sub> = 0.1V<sub>REFH</sub> to V<sub>IN</sub> = 0.9V<sub>REFH</sub>

<sup>4</sup> Includes power-up of ADC and V<sub>REF</sub>

<sup>5</sup> ADC clock cycles

<sup>6</sup> The current that can be injected or sourced from an unselected ADC signal input without impacting the performance of the ADC

## 4.19 12-bit DAC timing specifications

Table 27 shows electrical specifications of DAC.

 Table 27. DAC parameters<sup>1</sup>

| Characteristic  | Name | Min         | Typical | Max         | Unit     |
|---|------|-------------|---------|-------------|----------|
| Range of digital input words: 497 to 3599 (0x1F1–0xE0F) | LSB  | —           | 806     | —           | μV       |
| Monotonicity  |      | Guaranteed  |         |             |          |
| Conversion time (high-speed)                            |      | 1           | —       | —           | us       |
| Conversion time (low-speed)                             |      | 2           | —       | —           | us       |
| Conversion rate (high-speed)                            |      | —           | —       | 1M          | conv/sec |
| Conversion rate (low-speed)                             |      | —           | —       | 500K        | conv/sec |
| Output swing  |      | AVSS + 0.04 | —       | AVDD – 0.04 | V        |

**Table 27. DAC parameters<sup>1</sup> (continued)**

| Characteristic                           | Name              | Min | Typical | Max  | Unit |
|--|-------------------|-----|---------|------|------|
| Integral non-linearity (497 to 3599)     | INL               | —   | —       | ±8.0 | lsb  |
| Differential non-linearity (497 to 3599) | DNL               | —   | —       | ±0.5 | lsb  |
| Gain error (497 to 3599)                 | E <sub>GAIN</sub> | —   | ±0.26   | —    | %    |
| Effective number of bits                 | ENOB              | 9   | —       | —    | bits |
| DAC power-up time                        | t <sub>DAPU</sub> | —   | —       | 11   | us   |
| Output load resistance                   | R <sub>L</sub>    | 3K  | —       | —    | Ohm  |
| Output load capacitance                  | C <sub>L</sub>    | —   | 400     | —    | pF   |
| Power supply ripple rejection            | PSRR              | —   | 60      | —    | dB   |

<sup>1</sup> All measurements were made at V<sub>DD</sub> = 3.3V, V<sub>REFH</sub> = 3.3V, and V<sub>REFL</sub> = ground

## 4.20 mcPWM timing specifications

**Table 28. mcPWM timing**

| Num | Characteristic                | Min | Max | Unit |
|-----|-------------------------------|-----|-----|------|
| G1  | FB_CLK high to output valid   | —   | 7   | ns   |
| G2  | FB_CLK high to output invalid | 1   | —   | ns   |
| G3  | Input valid to FB_CLK high    | 3   | —   | ns   |
| G4  | FB_CLK high to input invalid  | 1   | —   | ns   |

## 4.21 I<sup>2</sup>C timing specifications

Table 29 lists specifications for the I<sup>2</sup>C input timing parameters shown in Figure 27.

**Table 29. I<sup>2</sup>C input timing specifications between SCL and SDA**

| Num | Characteristic   | Min | Max | Units              |
|-----|--|-----|-----|--------------------|
| I1  | Start condition hold time  | 2   | —   | 1/f <sub>SYS</sub> |
| I2  | Clock low period   | 8   | —   | 1/f <sub>SYS</sub> |
| I3  | I2C_SCL/I2C_SDA rise time (V <sub>IL</sub> = 0.5 V to V <sub>IH</sub> = 2.4 V) | —   | 1   | ms                 |
| I4  | Data hold time   | 0   | —   | ns                 |
| I5  | I2C_SCL/I2C_SDA fall time (V <sub>IH</sub> = 2.4 V to V <sub>IL</sub> = 0.5 V) | —   | 1   | ms                 |
| I6  | Clock high time  | 4   | —   | 1/f <sub>SYS</sub> |
| I7  | Data setup time  | 0   | —   | ns                 |
| I8  | Start condition setup time (for repeated start condition only)                 | 2   | —   | 1/f <sub>SYS</sub> |
| I9  | Stop condition setup time  | 2   | —   | 1/f <sub>SYS</sub> |

Table 30 lists specifications for the I<sup>2</sup>C output timing parameters shown in Figure 27.

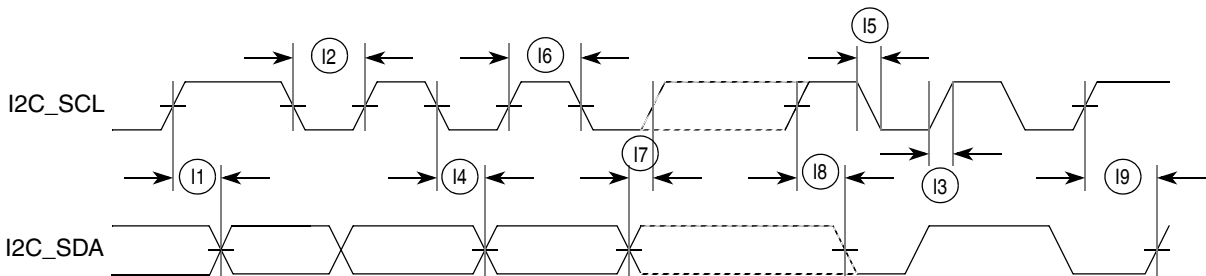
**Table 30. I<sup>2</sup>C output timing specifications between SCL and SDA**

| Num             | Characteristic   | Min | Max | Units              |
|-----------------|--|-----|-----|--------------------|
| I1 <sup>1</sup> | Start condition hold time  | 6   | —   | 1/f <sub>SYS</sub> |
| I2 <sup>1</sup> | Clock low period   | 10  | —   | 1/f <sub>SYS</sub> |
| I3 <sup>2</sup> | I2C_SCL/I2C_SDA rise time (V <sub>IL</sub> = 0.5 V to V <sub>IH</sub> = 2.4 V) | —   | —   | μs                 |
| I4 <sup>1</sup> | Data hold time   | 7   | —   | 1/f <sub>SYS</sub> |
| I5 <sup>3</sup> | I2C_SCL/I2C_SDA fall time (V <sub>IH</sub> = 2.4 V to V <sub>IL</sub> = 0.5 V) | —   | 3   | ns                 |
| I6 <sup>1</sup> | Clock high time  | 10  | —   | 1/f <sub>SYS</sub> |
| I7 <sup>1</sup> | Data setup time  | 2   | —   | 1/f <sub>SYS</sub> |
| I8 <sup>1</sup> | Start condition setup time (for repeated start condition only)                 | 20  | —   | 1/f <sub>SYS</sub> |
| I9 <sup>1</sup> | Stop condition setup time  | 10  | —   | 1/f <sub>SYS</sub> |

<sup>1</sup> Output numbers depend on the value programmed into the IFDR; an IFDR programmed with the maximum frequency (IFDR = 0x20) results in minimum output timings as shown in Table 30. The I<sup>2</sup>C interface is designed to scale the actual data transition time to move it to the middle of the SCL low period. The actual position is affected by the prescale and division values programmed into the IFDR. However, the numbers given in Table 30 are minimum values.

<sup>2</sup> Because I2C\_SCL and I2C\_SDA are open-collector-type outputs, which the processor can only actively drive low, the time I2C\_SCL or I2C\_SDA take to reach a high level depends on external signal capacitance and pull-up resistor values.

<sup>3</sup> Specified at a nominal 50-pF load.


**Figure 27. I<sup>2</sup>C input/output timings**

## 4.22 Ethernet assembly timing specifications

The following timing specs are defined at the chip I/O pin and must be translated appropriately to arrive at timing specs/constraints for the physical interface.

All Ethernet signals use pad type pad\_fsr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

<sup>1</sup> These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

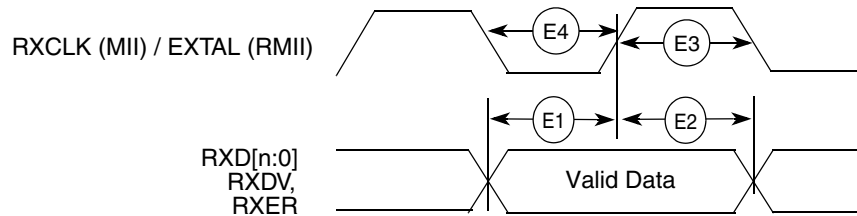
### 4.22.1 Receive signal timing specifications

The following timing specs meet the requirements for MII and RMII interfaces for a range of transceiver devices.

**Table 31. Receive signal timing**

| Num | Characteristic                                   | MII mode |     | RMII mode |     | Unit         |
|-----|--|----------|-----|-----------|-----|--------------|
|     |  | Min      | Max | Min       | Max |              |
| —   | RXCLK frequency                                  | —        | 25  | —         | 50  | MHz          |
| E1  | RXD[n:0], RXDV, RXER to RXCLK setup <sup>1</sup> | 5        | —   | 4         | —   | ns           |
| E2  | RXCLK to RXD[n:0], RXDV, RXER hold <sup>1</sup>  | 5        | —   | 2         | —   | ns           |
| E3  | RXCLK pulse width high                           | 35%      | 65% | 35%       | 65% | RXCLK period |
| E4  | RXCLK pulse width low                            | 35%      | 65% | 35%       | 65% | RXCLK period |

<sup>1</sup> In MII mode, n = 3; In RMII mode, n = 1



**Figure 28. MII/RMII receive signal timing diagram**

### 4.22.2 Transmit signal timing specifications

**Table 32. Transmit signal timing**

| Num | Characteristic                                     | MII mode |     | RMII mode |     | Unit               |
|-----|--|----------|-----|-----------|-----|--------------------|
|     |  | Min      | Max | Min       | Max |                    |
| —   | TXCLK frequency                                    | —        | 25  | —         | 50  | MHz                |
| E5  | TXCLK to TXD[n:0], TXEN, TXER invalid <sup>1</sup> | 4        | —   | 5         | —   | ns                 |
| E6  | TXCLK to TXD[n:0], TXEN, TXER valid <sup>1</sup>   | —        | 25  | —         | 14  | ns                 |
| E7  | TXCLK pulse width high                             | 35%      | 65% | 35%       | 65% | t <sub>TXCLK</sub> |
| E8  | TXCLK pulse width low                              | 35%      | 65% | 35%       | 65% | t <sub>TXCLK</sub> |

<sup>1</sup> In MII mode, n = 3; In RMII mode, n = 1



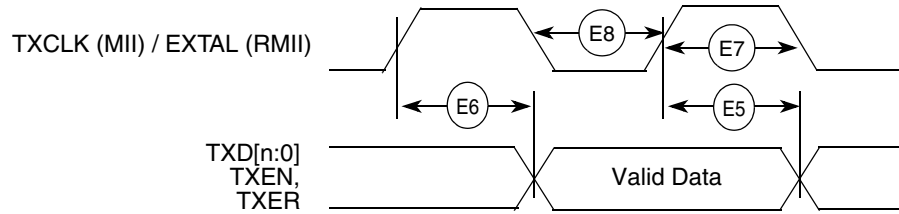


Figure 29. MII/RMII transmit signal timing diagram

### 4.22.3 Asynchronous input signal timing specifications

Table 33. MII/RMII transmit signal timing

| Num | Characteristic               | Min | Max | Unit         |
|-----|------------------------------|-----|-----|--------------|
| E9  | CRS, COL minimum pulse width | 1.5 | —   | TXCLK period |

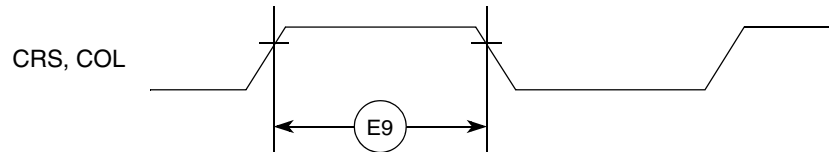


Figure 30. MII/RMII async inputs timing diagram

### 4.22.4 MDIO serial management timing specifications

Table 34. MDIO serial management channel signal timing

| Num | Characteristic             | Symbol    | Min | Max | Unit        |
|-----|----------------------------|-----------|-----|-----|-------------|
| E10 | MDC cycle time             | $t_{MDC}$ | 400 | —   | ns          |
| E11 | MDC pulse width            |           | 40  | 60  | % $t_{MDC}$ |
| E12 | MDC to MDIO output valid   |           | —   | 375 | ns          |
| E13 | MDC to MDIO output invalid |           | 25  | —   | ns          |
| E14 | MDIO input to MDC setup    |           | 10  | —   | ns          |
| E15 | MDIO input to MDC hold     |           | 0   | —   | ns          |

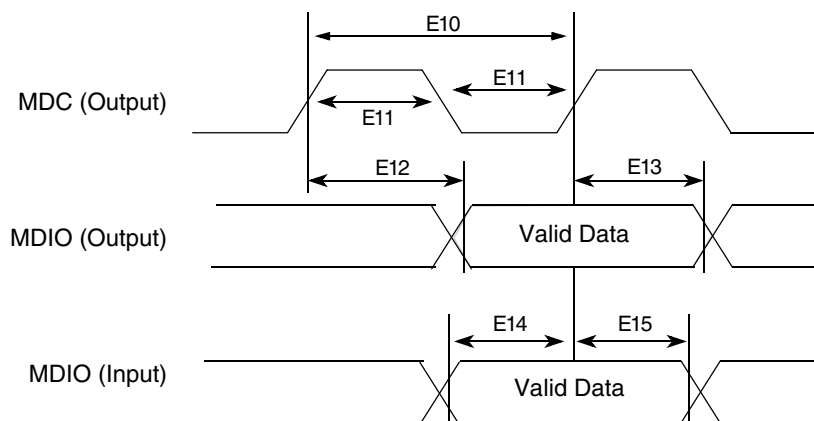


Figure 31. MDIO serial management channel timing diagram

### 4.23 32-bit timer module timing specifications

Table 35 lists timer module AC timings.

Table 35. Timer module AC timing specifications

| Name | Characteristic                  | Min | Max | Unit          |
|------|---------------------------------|-----|-----|---------------|
| T1   | DTnIN cycle time ( $n = 0:3$ )  | 3   | —   | $1/f_{SYS/2}$ |
| T2   | DTnIN pulse width ( $n = 0:3$ ) | 1   | —   | $1/f_{SYS/2}$ |

### 4.24 DSPI timing specifications

The DMA Serial Peripheral Interface (DSPI) provides a synchronous serial bus with master and slave operations. Many of the transfer attributes are programmable. Table 36 provides DSPI timing characteristics for classic SPI timing modes. Refer to the DSPI chapter of the *MCF54418 Reference Manual* for information on the modified transfer formats used for communicating with slower peripheral devices.

All DSPI signals use pad type pad\_msr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

Table 36. DSPI module AC timing specifications<sup>1</sup>

| Name               | Characteristic              | Symbol    | Min                      | Max                      | Unit | Notes |
|--------------------|-----------------------------|-----------|--------------------------|--------------------------|------|-------|
| <b>Master Mode</b> |                             |           |                          |                          |      |       |
| —                  | DSPI_SCK frequency          | $f_{SCK}$ | —                        | 50                       | MHz  |       |
| DS1                | DSPI_SCK cycle time         | $t_{SCK}$ | 20                       | —                        | ns   | 2     |
| DS2                | DSPI_SCK duty cycle         | —         | $(t_{SCK} \div 2) - 2.0$ | $(t_{SCK} \div 2) + 2.0$ | ns   | 3     |
| DS3                | DSPI_PCSn to DSPI_SCK delay | $t_{CSC}$ | $(t_{SCK} \div 2) - 2.0$ | —                        | ns   | 4     |
| DS4                | DSPI_SCK to DSPI_PCSn delay | $t_{ASC}$ | $(t_{SCK} \div 2) - 3.0$ | —                        | ns   | 5     |
| DS5                | DSPI_SCK to DSPI_SOUT valid | —         | —                        | 5                        | ns   |       |

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

**Table 36. DSPI module AC timing specifications<sup>1</sup> (continued)**

| Name              | Characteristic   | Symbol    | Min                      | Max                      | Unit | Notes |
|-------------------|--|-----------|--------------------------|--------------------------|------|-------|
| DS6               | DSPI_SCK to DSPI_SOUT invalid                          | —         | -5                       | —                        | ns   |       |
| DS7               | DSPI_SIN to DSPI_SCK input setup                       | —         | 6                        | —                        | ns   |       |
| DS8               | DSPI_SCK to DSPI_SIN input hold                        | —         | 0                        | —                        | ns   |       |
| <b>Slave Mode</b> |  |           |                          |                          |      |       |
| —                 | DSPI_SCK frequency                                     | $f_{SCK}$ | —                        | $f_{SYS} \div 8$         | MHz  |       |
| DS9               | DSPI_SCK cycle time                                    | $t_{SCK}$ | $8 \div f_{SYS}$         | —                        | ns   |       |
| DS10              | DSPI_SCK duty cycle                                    | —         | $(t_{SCK} \div 2) - 2.0$ | $(t_{SCK} \div 2) + 2.0$ | ns   |       |
| DS11              | DSPI_SCK to DSPI_SOUT valid                            | —         | —                        | 12                       | ns   |       |
| DS12              | DSPI_SCK to DSPI_SOUT invalid                          | —         | 0                        | —                        | ns   |       |
| DS13              | DSPI_SIN to DSPI_SCK input setup                       | —         | 2                        | —                        | ns   |       |
| DS14              | DSPI_SCK to DSPI_SIN input hold                        | —         | 7                        | —                        | ns   |       |
| DS15              | $\overline{DSPI\_SS}$ active to DSPI_SOUT driven       | —         | —                        | 10                       | ns   |       |
| DS16              | $\overline{DSPI\_SS}$ inactive to DSPI_SOUT not driven | —         | —                        | 10                       | ns   |       |

<sup>1</sup> Timings shown are for DMCR[MTE] = 0 (classic SPI) and DCTAR $\eta$ [CPHA] = 0. Data is sampled on the DSPI\_SIN pin on the odd-numbered DSPI\_SCK edges and driven on the DSPI\_SOUT pin on even-numbered DSPI edges.

<sup>2</sup> When in master mode, the baud rate is programmable in DCTAR $\eta$ [DBR], DCTAR $\eta$ [PBR], and DCTAR $\eta$ [BR].

<sup>3</sup> This specification assumes a 50/50 duty cycle setting. The duty cycle is programmable in DCTAR $\eta$ [DBR], DCTAR $\eta$ [CPHA], and DCTAR $\eta$ [PBR].

<sup>4</sup> The DSPI\_PCS $n$  to DSPI\_SCK delay is programmable in DCTAR $\eta$ [PCSSCK] and DCTAR $\eta$ [CSSCK].

<sup>5</sup> The DSPI\_SCK to DSPI\_PCS $n$  delay is programmable in DCTAR $\eta$ [PASC] and DCTAR $\eta$ [ASC].

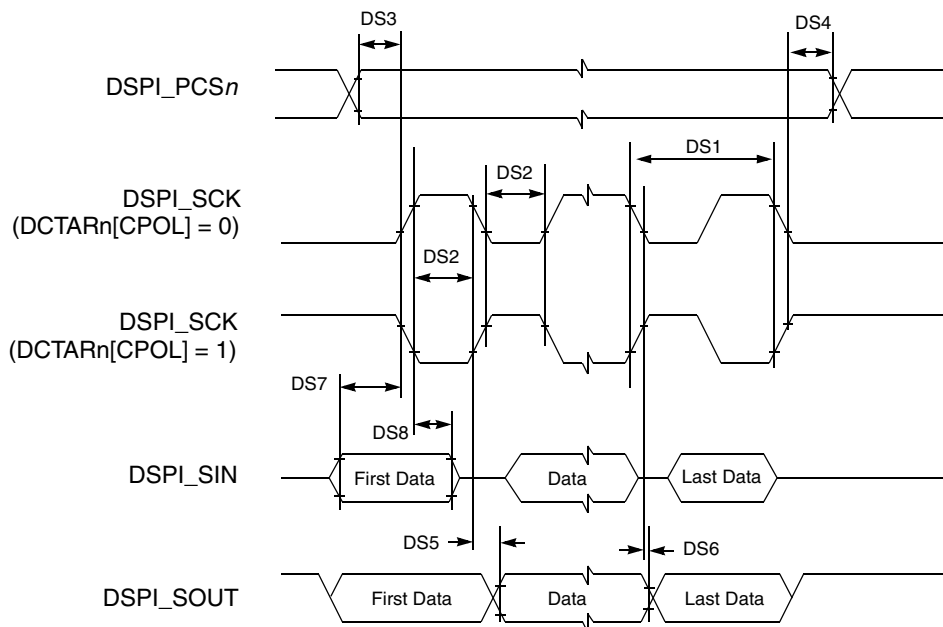


Figure 32. DSPI Classic SPI timing — master Mode

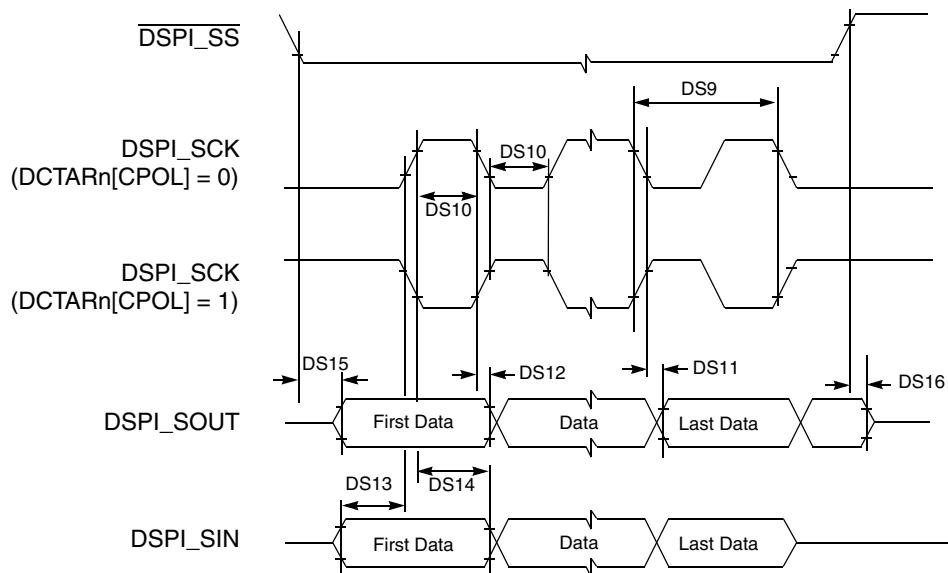


Figure 33. DSPI Classic SPI timing — slave mode

## 4.25 SBF timing specifications

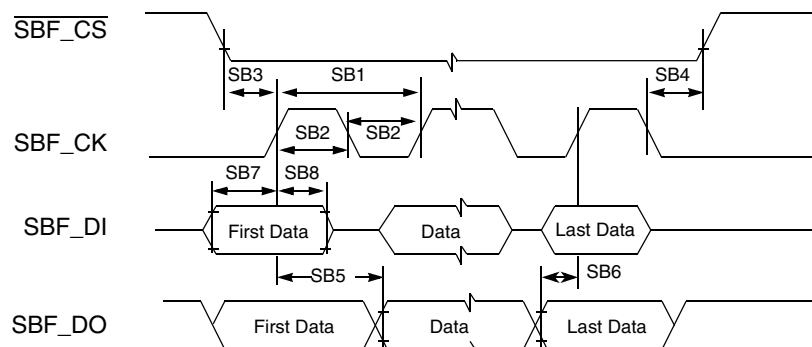
The Serial boot facility (SBF) provides a means to read configuration information and system boot code from a broad array of SPI-compatible EEPROMs, flashes, FRAMs, nVSRAMs, etc. Table 37 provides the AC timing specifications for the SBF.

All SBF signals use pad type pad\_msr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

**Table 37. SBF AC timing specifications**

| Name | Characteristic                              | Symbol             | Min                      | Max  | Unit               | Notes |
|------|---|--------------------|--------------------------|------|--------------------|-------|
| —    | SBF_CK frequency                            | $f_{\text{SBFCK}}$ | —                        | 62.5 | MHz                |       |
| SB1  | SBF_CK cycle time                           | $t_{\text{SBFCK}}$ | 16.67                    | —    | ns                 | 1     |
| SB2  | SBF_CK high/low time                        | —                  | 30%                      | —    | $t_{\text{SBFCK}}$ |       |
| SB3  | $\overline{\text{SBF\_CS}}$ to SBF_CK delay | —                  | $t_{\text{SBFCK}} - 2.0$ | —    | ns                 |       |
| SB4  | SBF_CK to $\overline{\text{SBF\_CS}}$ delay | —                  | $t_{\text{SBFCK}} - 2.0$ | —    | ns                 |       |
| SB5  | SBF_CK to SBF_DO valid                      | —                  | —                        | 5    | ns                 |       |
| SB6  | SBF_CK to SBF_DO invalid                    | —                  | -5                       | —    | ns                 |       |
| SB7  | SBF_DI to SBF_SCK input setup               | —                  | 10                       | —    | ns                 |       |
| SB8  | SBF_CK to SBF_DI input hold                 | —                  | 0                        | —    | ns                 |       |

<sup>1</sup> At reset, the SBF\_CK cycle time is  $t_{\text{REF}} \times 60$ . The first byte of data read from the serial memory contains a divider value that is used to set the SBF\_CK cycle time for the duration of the serial boot process.



**Figure 34. SBF timing**

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

## 4.26 1-Wire timing specifications

Specifications for the 1-Wire interface are provided by Maxim Integrated Products, Inc. Please refer to data sheet information for the appropriate device at [www.maxim-ic.com](http://www.maxim-ic.com).

## 4.27 General purpose I/O timing specifications

Table 38. GPIO timing<sup>1</sup>

| Num | Characteristic                     | Min | Max | Unit |
|-----|------------------------------------|-----|-----|------|
| G1  | FB_CLK high to GPIO output valid   | —   | 9   | ns   |
| G2  | FB_CLK high to GPIO output invalid | 1   | —   | ns   |
| G3  | GPIO input valid to FB_CLK high    | 9   | —   | ns   |
| G4  | FB_CLK high to GPIO input invalid  | 1.5 | —   | ns   |

<sup>1</sup> These general purpose specifications apply to the following signals:  $\overline{IRQn}$ , all UART signals, all timer signals, FlexCAN signals,  $\overline{DACKn}$  and  $\overline{DREQn}$ , and all signals configured as GPIO.

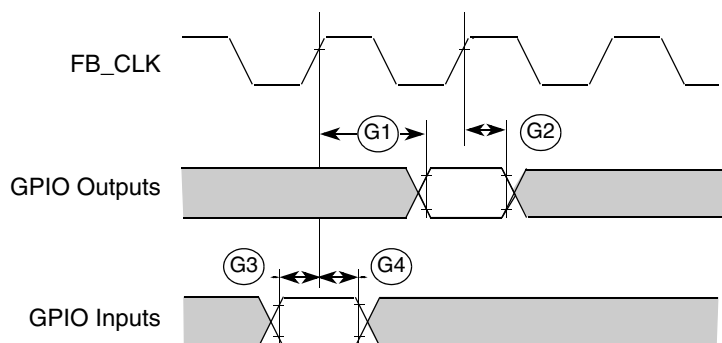


Figure 35. GPIO timing

## 4.28 Rapid general purpose I/O timing specifications

RGPIO signals use a mix of pad types: pad\_fsr, pad\_msr, and pad\_ssr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.

Table 39. RGPIO timing

| Num | Characteristic                       | Min | Max | Unit |
|-----|--------------------------------------|-----|-----|------|
| RG1 | PST_CLK high to RGPIO output valid   | —   | 6   | ns   |
| RG2 | PST_CLK high to RGPIO output Invalid | 0.5 | —   | ns   |
| RG3 | RGPIO input valid to PST_CLK high    | 6   | —   | ns   |
| RG4 | PST_CLK high to RGPIO input invalid  | 1.5 | —   | ns   |

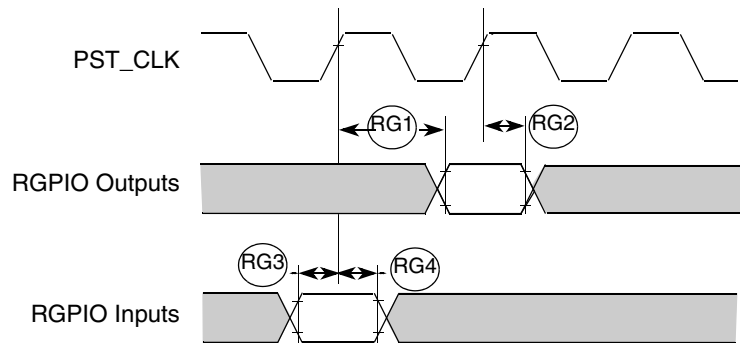


Figure 36. RGPIO timing

## 4.29 JTAG and boundary scan timing specifications

All JTAG signals use pad type pad\_msr except for TCLK which use pad type pad\_fsr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

Table 40. JTAG and boundary scan timing

| Num | Characteristics <sup>1</sup>                                | Min | Max | Unit |
|-----|---|-----|-----|------|
| J1  | TCLK frequency of operation                                 | DC  | 25  | MHz  |
| J2  | TCLK cycle period   | 40  | —   | ns   |
| J3  | TCLK clock pulse width                                      | 20  | —   | ns   |
| J4  | TCLK rise and fall times                                    | —   | 3   | ns   |
| J5  | Boundary scan input data setup time to TCLK rise            | 4   | —   | ns   |
| J6  | Boundary scan input data hold time after TCLK rise          | 20  | —   | ns   |
| J7  | TCLK low to boundary scan output data valid                 | —   | 13  | ns   |
| J8  | TCLK low to boundary scan output high-Z                     | —   | 13  | ns   |
| J9  | TMS, TDI input data setup time to TCLK rise                 | 4   | —   | ns   |
| J10 | TMS, TDI input data hold time after TCLK rise               | 10  | —   | ns   |
| J11 | TCLK low to TDO data valid                                  | —   | 12  | ns   |
| J12 | TCLK low to TDO high-Z                                      | —   | 0   | ns   |
| J13 | $\overline{\text{TRST}}$ assert time                        | 32  | —   | ns   |
| J14 | $\overline{\text{TRST}}$ setup time (negation) to TCLK high | 8   | —   | ns   |

<sup>1</sup> JTAG\_EN is expected to be a static signal. Hence, specific timing is not associated with it.

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

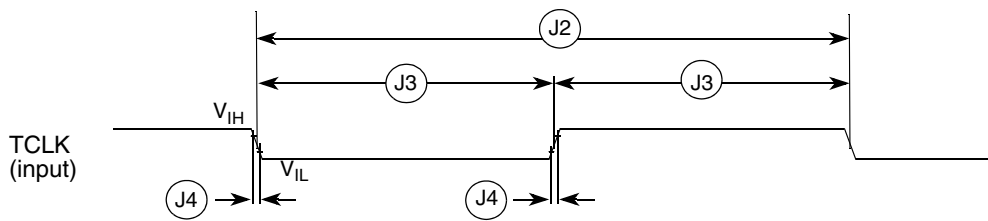


Figure 37. Test clock input timing

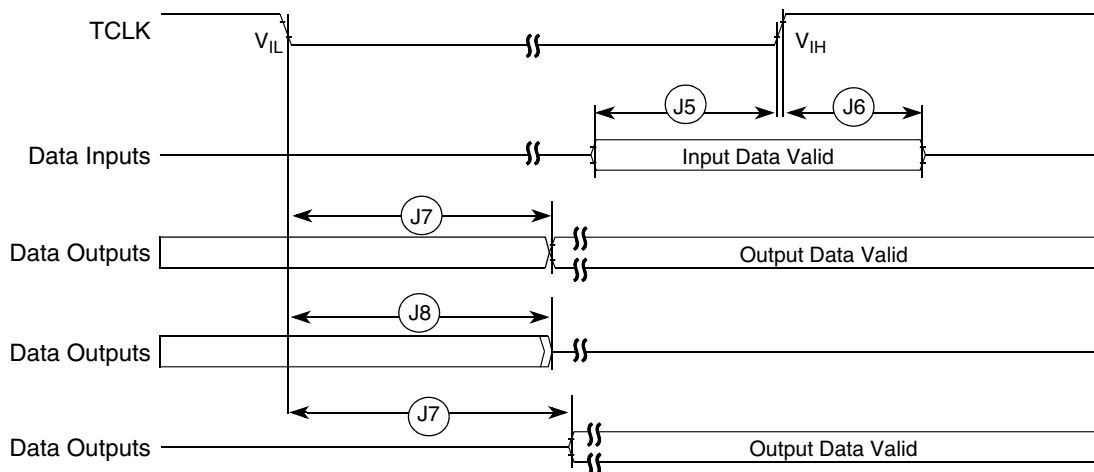


Figure 38. Boundary scan (JTAG) timing

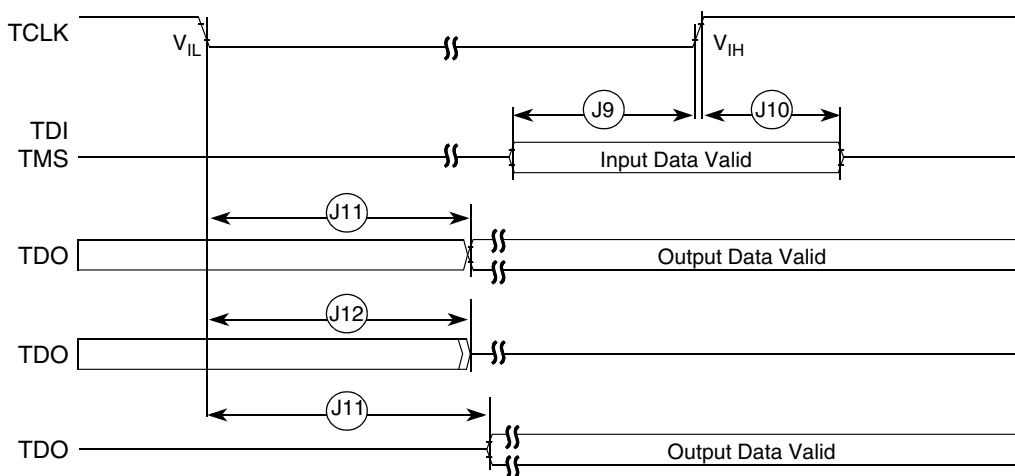


Figure 39. Test access port timing

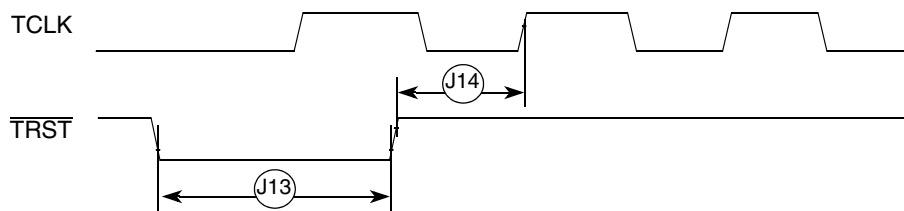


Figure 40. TRST timing



## 4.30 Debug AC timing specifications

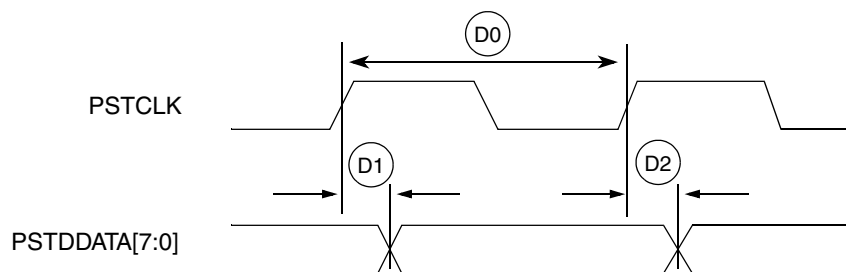
Table 41 lists specifications for the debug AC timing parameters shown in Figure 41 and Table 42.

All debug signals use pad type pad\_msr except for PSTCLK which use pad type pad\_fsr. The following timing specifications assume a pad slew rate setting of 11 and a load of 50 pF.<sup>1</sup>

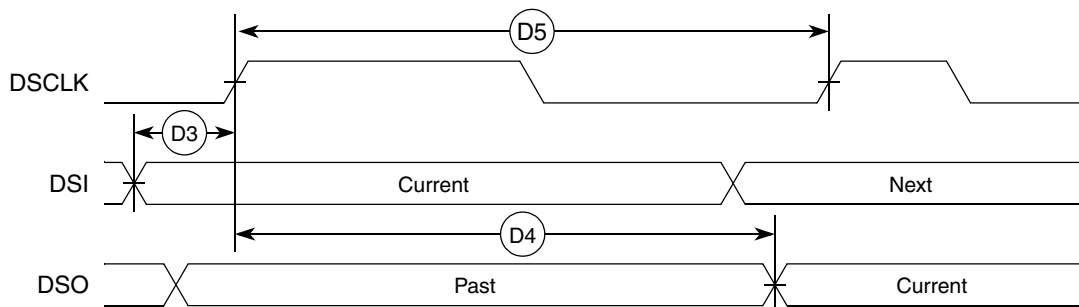
**Table 41. Debug AC timing specification**

| Num             | Characteristic                    | Min | Max | Units              |
|-----------------|-----------------------------------|-----|-----|--------------------|
| D0              | PSTCLK cycle time                 | 0.5 | 0.5 | $1/f_{\text{SYS}}$ |
| D1              | PSTCLK rising to PSTDDATA valid   | —   | 3.0 | ns                 |
| D2              | PSTCLK rising to PSTDDATA invalid | 0.5 | —   | ns                 |
| D3              | DSI-to-DSCLK setup                | 1   | —   | PSTCLK             |
| D4 <sup>1</sup> | DSCLK-to-DSO hold                 | 4   | —   | PSTCLK             |
| D5              | DSCLK cycle time                  | 5   | —   | PSTCLK             |
| D6              | BKPT assertion time               | 1   | —   | PSTCLK             |

<sup>1</sup> DSCLK and DSI are synchronized internally. D4 is measured from the synchronized DSCLK input relative to the rising edge of PSTCLK.



**Figure 41. Real-time trace AC timing**



**Figure 42. BDM serial port AC timing**

1. These timing parameters are specified assuming maximum operating frequency and the fastest pad slew rate setting (11). When operating this interface at lower frequencies, increase the slew rate by using the 10, 01, or 00 setting to increase edge rise and fall times, thus reducing EMI.

## 5 Package information

The latest package outline drawings are available on the product summary pages on <http://www.freescale.com/coldfire>. Table 42 lists the case outline numbers per device. Use these numbers in the web page's keyword search engine to find the latest package outline drawings.

**Table 42. Package information**

| Device   | Package type | Case outline numbers |
|----------|--------------|----------------------|
| MCF54410 | 196 MAPBGA   | 98ASA00321D          |
| MCF54415 | 256 MAPBGA   | 98ARH98219A          |
| MCF54416 |              |                      |
| MCF54417 |              |                      |
| MCF54418 |              |                      |

## 6 Product documentation

Documentation is available from a local Freescale distributor, a Freescale sales office, the Freescale Literature Distribution Center, or through the Freescale world-wide web address at <http://www.freescale.com/coldfire>.

## 7 Revision history

Table 43 summarizes revisions to this document.

**Table 43. Revision history**

| Rev. No. | Date        | Summary of changes  |
|----------|-------------|---|
| 2        | 10 Jun 2009 | <p>In <a href="#">Section 2.2, "Supply voltage sequencing"</a> added the following note:</p> <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;">All I/O VDD pins must be powered on when the device is functioning, except when in standby mode.</p> <p style="text-align: center;">In standby mode, all I/O VDD pins, except VSTBY_RTC (battery), can be switched off.</p> <p>Added <a href="#">Section 3.2, "Pinout—169 MAPBGA"</a> and <a href="#">Section 3.3, "Pinout—256 MAPBGA"</a> and updated <a href="#">Table 5</a> with pin locations.</p> <p>In <a href="#">Section 4.1, "Absolute maximum ratings"</a>:</p> <ul style="list-style-type: none"> <li>• Added USB OTG, USB host, ADC, DAC/ADC, and RTC standby supply voltages</li> </ul> <p>In <a href="#">Section 4.5, "DC electrical specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Added RTC standby supply voltage</li> <li>• Split out Power Supplies and I/O Characteristics to two separate tables</li> </ul> <p>In <a href="#">Section 4.10, "FlexBus timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed maximum frequency to 100MHz and updated specs throughout the table</li> <li>• Changed FB2 maximum from 5 to 6</li> <li>• Added notes to <a href="#">Figure 11</a> and <a href="#">Figure 12</a></li> </ul> <p>In <a href="#">Section 4.12, "DDR SDRAM controller timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed minimum frequency from 50 to 100</li> <li>• Changed maximum DD1 from 20 to 10</li> <li>• Changed DD5 from 2 to <math>0.5 \times t_{SDCK} - 1</math></li> <li>• Changed DD6 from <math>1.2 \times t_{SDCK}</math> to <math>WL + 0.2 \times t_{SDCK}</math></li> <li>• Changed DD7 from 1.5 to 0.7</li> <li>• Changed DD8 from 1.0 to 0.7</li> <li>• Changed DD9 from 1.0 to 0.5</li> <li>• Changed DD10 from <math>0.25 \times t_{SDCK} + 0.5</math> to <math>0.375 \times t_{SDCK}</math></li> </ul> <p>In <a href="#">Section 4.17, "SSI timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed S7, S9, S15, and S17 from 10 to 15</li> </ul> <p>In <a href="#">Section 4.22.2, "Transmit signal timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed E5 for MII from 5 to 4</li> </ul> <p>In <a href="#">Section 4.20, "mCPWM timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed G2 from 2 to 1</li> </ul> <p>In <a href="#">Section 4.24, "DSPI timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed DS3 from <math>(2 \times 1/f_{sys}) - 2.0</math> to <math>(t_{sck}^3 2) - 2.0</math></li> <li>• Changed DS4 from <math>(2 \times 1/f_{sys}) - 3.0</math> to <math>(t_{sck}^3 2) - 3.0</math></li> <li>• Changed DS7 from 7 to 6</li> <li>• Changed DS11 from 4 to 12</li> </ul> <p>In <a href="#">Section 4.25, "SBF timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed SB5 maximum from 5 to 3</li> <li>• Changed SB6 minimum from -5 to 5</li> </ul> <p>In <a href="#">Section 4.26, "1-Wire timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Added link to 1-wire specs</li> </ul> <p>In <a href="#">Section 4.27, "General purpose I/O timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed G2 from 1.5 to 1</li> </ul> <p>In <a href="#">Section 4.28, "Rapid general purpose I/O timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed RG1 from 3 to 6</li> <li>• Changed RG2 from 1.5 to 0.5</li> <li>• Changed RG3 from 3 to 6</li> </ul> <p>In <a href="#">Section 4.29, "JTAG and boundary scan timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed J9-12 and J14 from TBD</li> </ul> <p>In <a href="#">Section 4.30, "Debug AC timing specifications"</a>:</p> <ul style="list-style-type: none"> <li>• Changed D2 from 1.5 to 0.5</li> </ul> |

**Table 43. Revision history (continued)**

| Rev. No. | Date         | Summary of changes  |
|----------|--------------|---|
| 3        | 31 July 2009 | Changed 169MAPBGA package to 196MAPBGA throughout.<br>MCF54410 device now supports a single SSI module and one Ethernet controller with IEEE 1588 support   |
| 4        | 17 Aug 2009  | Updated MCF5441x Signal Information and Muxing table with 196MAPBGA pin locations<br>Changed SD_Dn pin locations on 256 MAPBGA package<br>Added note to <a href="#">Section 4.6</a> , "Output pad loading and slew rate"  |
| 5        | 29 Jan 2010  | Added orderable part numbers  |
| 6        |              | Swapped locations of RTC_EXTAL and RTC_XTAL pins in <a href="#">Table 5</a> , <a href="#">Figure 7</a> , and <a href="#">Figure 8</a><br>Corrected instances of MCF5445x to MCF5441x<br>Added thermal characteristics to <a href="#">Table 7</a><br>Added case outline numbers to <a href="#">Table 42</a><br>Changed PLL supply voltage from "-0.5 to +2.0" to "-0.3 to +4.0" in <a href="#">Table 6</a><br>Miscellaneous corrections based on information from shared review comments by team members |
| 7        | October 2011 | <ul style="list-style-type: none"> <li>Updated the pinouts in <a href="#">Table 5</a>, "MCF5441x Signal information and muxing".</li> <li>Updated the <a href="#">Figure 7</a>, "MCF54410 Pinout (196 MAPBGA)".</li> <li>Removed the symbol ADC_IN7/DAC1_OUT from <a href="#">Table 9</a>, "Latch-up results".</li> <li>Updated <a href="#">Table 11</a>, "I/O electrical specifications".</li> <li>Updated <a href="#">Table 13</a>, "DDR pad drive strengths".</li> </ul>                             |
| 8        | June 2012    | <ul style="list-style-type: none"> <li>In <a href="#">Table 7</a>, added the thermal characteristics for the 196 MAPBGA package.</li> <li>In <a href="#">Table 42</a>, updated the case outline number for the 196 MAPBGA package from "98ARH98217" to "98ASA00321D".</li> </ul>  |

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