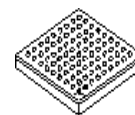




# IMX35



## Package Information

Plastic package  
Case 5284 17 x 17 mm, 0.8 mm Pitch

# i.MX35 Applications Processors for Automotive Products

Silicon Revisions 2.0 and 2.1

## Ordering Information

See [Table 1 on page 3](#) for ordering information.

## 1 Introduction

The i.MX35 Auto Application Processor family is designed for automotive infotainment and navigation applications. These processors are AECQ100 Grade 3 qualified and rated for ambient operating temperatures up to 85 °C.

The i.MX35 multimedia applications processor represents the next step in low-power, high-performance application processors.

Based on an ARM11 microprocessor core running at up to 532 MHz, the device offers the following features and optimized system cost for the target applications.

- Audio connectivity and telematics:
  - Compressed audio playback from storage devices (CD, USB, HDD or SD card)
  - PlayFromDevice (1-wire and 2-wire support) for portable media players

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Because of an order from the United States International Trade Commission, BGA-packaged product lines and part numbers indicated here currently are not available from Freescale for import or sale in the United States prior to September 2010: MCIMX351AVM4B, MCIMX351AVM5B, MCIMX355AVM4B, MCIMX355AVM5B, MCIMX356AVM4B, and MCIMX356AVM5B.

- iPod/iPhone control and playback
- High-speed CD ripping to USB, SD/MMC or HDD for virtual CD changer
- Audio processing for hands-free telephony: Bluetooth, AEC/NS, and microphone beam forming
- Speech recognition
- A/V connectivity and navigation:
  - Includes audio connectivity and telematics features
  - Map display and route calculation
  - QVGA video decode, WVGA video display
  - Sophisticated graphical user interface

The i.MX35 processor takes advantage of the ARM1136JF-S™ core running at 532 MHz that is boosted by a multilevel cache system, and features peripheral devices such as an autonomous image processing unit, a vector floating point (VFP11) co-processor, and a RISC-based DMA controller.

The i.MX35 supports connections to various types of external memories, such as SDRAM, mobile DDR and DDR2, SLC and MLC NAND Flash, NOR Flash and SRAM. The device can be connected to a variety of external devices such as high-speed USB2.0 OTG, ATA, MMC/SDIO, and Compact Flash.

## 1.1 Features

The i.MX35 is designed for automotive infotainment video-enabled applications. It provides low-power solutions for applications demanding high-performance multimedia and graphics.

The i.MX35 is based on the ARM1136 platform, which has the following features:

- ARM1136JF-S processor, version r1p3
- 16-Kbyte L1 instruction cache
- 16-Kbyte L1 data cache
- 128-Kbyte L2 cache, version r0p4
- 128 Kbytes of internal SRAM
- Vector floating point unit (VFP11)

To boost multimedia performance, the following hardware accelerators are integrated:

- Image processing unit (IPU)
- OpenVG 1.1 graphics processing unit (GPU) (not available for the MCIMX351)

The MCIMX35 provides the following interfaces to external devices (some of these interfaces are muxed and not available simultaneously):

- 2 controller area network (CAN) interfaces
- 2 SDIO/MMC interfaces, 1 SDIO/CE-ATA interface (CE-ATA is not available for the MCIMX351)
- 32-bit mobile DDR, DDR2 (4-bank architecture), and SDRAM (up to 133 MHz)
- 2 configurable serial peripheral interfaces (CSPI) (up to 52 Mbps each)
- Enhanced serial audio interface (ESAI)

- 2 synchronous serial interfaces (SSI)
- Ethernet MAC 10/100 Mbps
- 1 USB 2.0 host with ULPI interface or internal full-speed PHY. Up to 480 Mbps if external HS PHY is used.
- 1 USB 2.0 OTG (up to 480 Mbps) controller with internal high-speed OTG PHY
- Flash controller—MLC/SLC NAND and NOR
- GPIO with interrupt capabilities
- 3 I<sup>2</sup>C modules (up to 400 Kbytes each)
- JTAG
- Key pin port
- Media local bus (MLB) interface
- Asynchronous sample rate converter (ASRC)
- 1-Wire
- Parallel camera sensor (4/8/10/16-bit data port for video color models: YCC, YUV, 30 Mpixels/s)
- Parallel display (primary up to 24-bit, 1024 x 1024)
- Parallel ATA (up to 66 Mbytes) (not available for the MCIMX351)
- PWM
- SPDIF transceiver
- 3 UART (up to 4.0 Mbps each)

## 1.2 Ordering Information

Table 1 provides the ordering information for the i.MX35 processors for automotive applications.

**Table 1. Ordering Information**

| Description | Part Number <sup>1</sup> | Silicon Revision | Package <sup>2</sup> | Speed   | Operating Temperature Range (°C) | Signal Ball Map Locations | Ball Map |
|-------------|--------------------------|------------------|----------------------|---------|----------------------------------|---------------------------|----------|
| i.MX351     | MCIMX351AVM4B!           | 2.0              | 5284                 | 400 MHz | –40 to 85                        | Table 91                  | Table 93 |
| i.MX351     | MCIMX351AVM5B!           | 2.0              | 5284                 | 532 MHz | –40 to 85                        | Table 91                  | Table 93 |
| i.MX355     | MCIMX355AVM4B!           | 2.0              | 5284                 | 400 MHz | –40 to 85                        | Table 91                  | Table 93 |
| i.MX355     | MCIMX355AVM5B!           | 2.0              | 5284                 | 532 MHz | –40 to 85                        | Table 91                  | Table 93 |
| i.MX356     | MCIMX356AVM4B!           | 2.0              | 5284                 | 400 MHz | –40 to 85                        | Table 91                  | Table 93 |
| i.MX356     | MCIMX356AVM5B!           | 2.0              | 5284                 | 532 MHz | –40 to 85                        | Table 91                  | Table 93 |
| i.MX351     | MCIMX351AJQ4C            | 2.1              | 5284                 | 400MHz  | -40 to 85                        | Table 92                  | Table 94 |
| i.MX351     | MCIMX351AJQ5C            | 2.1              | 5284                 | 532MHz  | -40 to 85                        | Table 92                  | Table 94 |
| i.MX355     | MCIMX355AJQ4C            | 2.1              | 5284                 | 400MHz  | -40 to 85                        | Table 92                  | Table 94 |
| i.MX355     | MCIMX355AJQ5C            | 2.1              | 5284                 | 532MHz  | -40 to 85                        | Table 92                  | Table 94 |

**Table 1. Ordering Information (continued)**

| Description | Part Number <sup>1</sup> | Silicon Revision | Package <sup>2</sup> | Speed  | Operating Temperature Range (°C) | Signal Ball Map Locations | Ball Map                 |
|-------------|--------------------------|------------------|----------------------|--------|----------------------------------|---------------------------|--------------------------|
| i.MX356     | MCIMX356AJQ4C            | 2.1              | 5284                 | 400MHz | -40 to 85                        | <a href="#">Table 92</a>  | <a href="#">Table 94</a> |
| i.MX356     | MCIMX356AJQ5C            | 2.1              | 5284                 | 532MHz | -40 to 85                        | <a href="#">Table 92</a>  | <a href="#">Table 94</a> |

<sup>1</sup> Because of an order from the United States International Trade Commission, BGA-packaged product lines and part numbers indicated here currently are not available from Freescale for import or sale in the United States prior to September 2010:  
Indicated by the Icon (!)

<sup>2</sup> Case 5284 is RoHS-compliant, lead-free, MSL = 3, 1.

The ball map for silicon revision 2.1 is different than the ballmap for silicon revision 2.0. The layout for each revision is not compatible, so it is important that the correct ballmap be used to implement the layout. See [Section 5, “Package Information and Pinout.”](#)

[Table 2](#) shows the functional differences between the different parts in the i.MX35 family.

**Table 2. Functional Differences in the i.MX35 Parts**

| Module                           | MCIMX351 | MCIMX355 | MCIMX356 |
|----------------------------------|----------|----------|----------|
| I2C (3)                          | Yes      | Yes      | Yes      |
| CSPI (2)                         | Yes      | Yes      | Yes      |
| SSI/I2S (2)                      | Yes      | Yes      | Yes      |
| ESAI                             | Yes      | Yes      | Yes      |
| SPDIF I/O                        | Yes      | Yes      | Yes      |
| USB HS Host                      | Yes      | Yes      | Yes      |
| USB OTG                          | Yes      | Yes      | Yes      |
| FlexCAN (2)                      | Yes      | Yes      | Yes      |
| MLB                              | Yes      | Yes      | Yes      |
| Ethernet                         | Yes      | Yes      | Yes      |
| 1-Wire                           | Yes      | Yes      | Yes      |
| KPP                              | Yes      | Yes      | Yes      |
| SDIO/MMC (2)                     | Yes      | Yes      | Yes      |
| SDIO/Memory Stick                | Yes      | Yes      | Yes      |
| External Memory Controller (EMC) | Yes      | Yes      | Yes      |
| JTAG                             | Yes      | Yes      | Yes      |
| PATA                             | —        | Yes      | Yes      |
| CE-ATA                           | —        | Yes      | Yes      |

**Table 2. Functional Differences in the i.MX35 Parts (continued)**

| Module                                                                                                                         | MCIMX351 | MCIMX355 | MCIMX356 |
|--------------------------------------------------------------------------------------------------------------------------------|----------|----------|----------|
| Image Processing Unit (IPU) (inversion and rotation, pre- and post-processing, camera interface, blending, display controller) | —        | Yes      | Yes      |
| Open VG graphics acceleration (GPU)                                                                                            | —        | —        | Yes      |

## 1.3 Block Diagram

Figure 1 is the i.MX35 simplified interface block diagram.

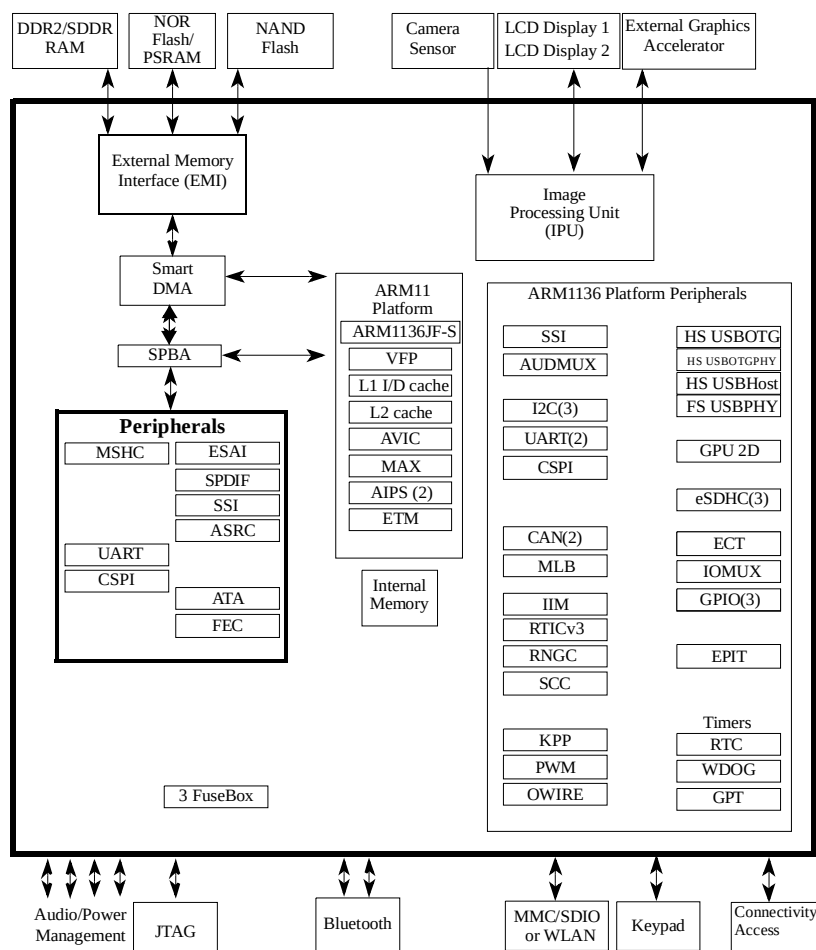


Figure 1. i.MX35 Simplified Interface Block Diagram

## 2 Functional Description and Application Information

The i.MX35 consists of the following major subsystems:

- ARM1136 Platform—AP domain
- SDMA Platform and EMI—Shared domain

### 2.1 Application Processor Domain Overview

The applications processor (AP) and its domain are responsible for running the operating system and applications software, providing the user interface, and supplying access to integrated and external peripherals. The AP domain is built around an ARM1136JF-S core with 16-Kbyte instruction and data L1 caches, an MMU, a 128-Kbyte L2 cache, a multiported crossbar switch, and advanced debug and trace interfaces.

The i.MX35 core is intended to operate at a maximum frequency of 532 MHz to support the required multimedia use cases. Furthermore, an image processing unit (IPU) is integrated into the AP domain to offload the ARM11 core from performing functions such as color space conversion, image rotation and scaling, graphics overlay, and pre- and post-processing.

The functionality of AP Domain peripherals includes the user interface; the connectivity, display, security, and memory interfaces; and 128 Kbytes of multipurpose SRAM.

## 2.2 Shared Domain Overview

The shared domain is composed of the shared peripherals, a smart DMA engine (SDMA) and a number of miscellaneous modules. For maximum flexibility, some peripherals are directly accessible by the SDMA engine.

The i.MX35 has a hierarchical memory architecture including L1 caches and a unified L2 cache. This reduces the bandwidth demands for the external bus and external memory. The external memory subsystem supports a flexible external memory system, including support for SDRAM (SDR, DDR2 and mobile DDR) and NAND Flash.

## 2.3 Advanced Power Management Overview

To address the continuing need to reduce power consumption, the following techniques are incorporated in the i.MX35:

- Clock gating
- Power gating
- Power-optimized synthesis
- Well biasing

The insertion of gating into the clock paths allows unused portions of the chip to be disabled. Because static CMOS logic consumes only leakage power, significant power savings can be realized.

“Well biasing” is applying a voltage that is greater than  $V_{DD}$  to the nwells, and one that is lower than  $V_{SS}$  to the pwells. The effect of applying this well back bias voltage reduces the subthreshold channel leakage. For the 90-nm digital process, it is estimated that the subthreshold leakage is reduced by a factor of ten over the nominal leakage. Additionally, the supply voltage for internal logic can be reduced from 1.4 V to 1.22 V.

## 2.4 ARM11 Microprocessor Core

The CPU of the i.MX35 is the ARM1136JF-S core, based on the ARM v6 architecture. This core supports the ARM Thumb<sup>®</sup> instruction sets, features Jazelle<sup>®</sup> technology (which enables direct execution of Java byte codes) and a range of SIMD DSP instructions that operate on 16-bit or 8-bit data values in 32-bit registers.

The ARM1136JF-S processor core features are as follows:

- Integer unit with integral EmbeddedICE<sup>™</sup> logic
- Eight-stage pipeline

- Branch prediction with return stack
- Low-interrupt latency
- Instruction and data memory management units (MMUs), managed using micro TLB structures backed by a unified main TLB
- Instruction and data L1 caches, including a non-blocking data cache with hit-under-miss
- Virtually indexed/physically addressed L1 caches
- 64-bit interface to both L1 caches
- Write buffer (bypassable)
- High-speed Advanced Micro Bus Architecture (AMBA)<sup>™</sup> L2 interface
- Vector floating point co-processor (VFP) for 3D graphics and hardware acceleration of other floating-point applications
- ETM<sup>™</sup> and JTAG-based debug support

Table 3 summarizes information about the i.MX35 core.

**Table 3. i.MX35 Core**

| Core Acronym     | Core Name        | Brief Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Integrated Memory Features                                                                                                                                                                   |
|------------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ARM11 or ARM1136 | ARM1136 Platform | The ARM1136 <sup>™</sup> platform consists of the ARM1136JF-S core, the ETM real-time debug modules, a 6 × 5 multi-layer AHB crossbar switch (MAX), and a vector floating processor (VFP).<br>The i.MX35 provides a high-performance ARM11 microprocessor core and highly integrated system functions. The ARM Application Processor (AP) and other subsystems address the needs of the personal, wireless, and portable product market with integrated peripherals, advanced processor core, and power management capabilities. | <ul style="list-style-type: none"> <li>• 16-Kbyte instruction cache</li> <li>• 16-Kbyte data cache</li> <li>• 128-Kbyte L2 cache</li> <li>• 32-Kbyte ROM</li> <li>• 128-Kbyte RAM</li> </ul> |

## 2.5 Module Inventory

Table 4 shows an alphabetical listing of the modules in the MCIMX35. For extended descriptions of the modules, see the MCIMX35 reference manual.

**Table 4. Digital and Analog Modules**

| Block Mnemonic | Block Name                         | Domain <sup>1</sup> | Subsystem                    | Brief Description                                                                                                                                                                                                                                                                                                                    |
|----------------|------------------------------------|---------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-WIRE         | 1-Wire interface                   | ARM                 | ARM1136 platform peripherals | 1-Wire provides the communication line to a 1-Kbit add-only memory. the interface can send or receive 1 bit at a time.                                                                                                                                                                                                               |
| ASRC           | Asynchronous sample rate converter | SDMA                | Connectivity peripherals     | The ASRC is designed to convert the sampling rate of a signal associated to an input clock into a signal associated to a different output clock. It supports a concurrent sample rate conversion of about –120 dB THD+N. The sample rate conversion of each channel is associated to a pair of incoming and outgoing sampling rates. |



**Table 4. Digital and Analog Modules (continued)**

| Block Mnemonic | Block Name                               | Domain <sup>1</sup> | Subsystem                 | Brief Description                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------|------------------------------------------|---------------------|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ATA            | ATA module                               | SDMA                | Connectivity peripherals  | The ATA block is an AT attachment host interface. Its main use is to interface with IDE hard disk drives and ATAPI optical disk drives. It interfaces with the ATA device over a number of ATA signals.                                                                                                                                                                                                                     |
| AUDMUX         | Digital audio mux                        | ARM                 | Multimedia peripherals    | The AUDMUX is a programmable interconnect for voice, audio, and synchronous data routing between host serial interfaces (SSIs) and peripheral serial interfaces (audio codecs). The AUDMUX has two sets of interfaces: internal ports to on-chip peripherals and external ports to off-chip audio devices. Data is routed by configuring the appropriate internal and external ports.                                       |
| CAN(2)         | CAN module                               | ARM                 | Connectivity peripherals  | The CAN protocol is primarily designed to be used as a vehicle serial data bus running at 1 Mbps.                                                                                                                                                                                                                                                                                                                           |
| CCM            | Clock control module                     | ARM                 | Clocks                    | This block generates all clocks for the peripherals in the SDMA platform. The CCM also manages ARM1136 platform low-power modes (WAIT, STOP), disabling peripheral clocks appropriately for power conservation, and provides alternate clock sources for the ARM1136 and SDMA platforms.                                                                                                                                    |
| CSPI(2)        | Configurable serial peripheral interface | SDMA, ARM           | Connectivity peripherals  | This module is a serial interface equipped with data FIFOs; each master/slave-configurable SPI module is capable of interfacing to both serial port interface master and slave devices. The CSPI ready (SPI_RDY) and slave select (SS) control signals enable fast data communication with fewer software interrupts.                                                                                                       |
| ECT            | Embedded cross trigger                   | SDMA, ARM           | Debug                     | ECT (embedded cross trigger) is an IP for real-time debug purposes. It is a programmable matrix allowing several subsystems to interact with each other. ECT receives signals required for debugging purposes (from cores, peripherals, buses, external inputs, and so on) and propagates them (propagation programmed through software) to the different debug resources available within the SoC.                         |
| EMI            | External memory interface                | SDMA                | External memory interface | The EMI module provides access to external memory for the ARM and other masters. It is composed of the following main submodules:<br>M3IF—provides arbitration between multiple masters requesting access to the external memory.<br>SDRAM CTRL—interfaces to mDDR, DDR2 (4-bank architecture type), and SDR interfaces.<br>NANDFC—provides an interface to NAND Flash memories.<br>WEIM—interfaces to NOR Flash and PSRAM. |
| EPIT(2)        | Enhanced periodic interrupt timer        | ARM                 | Timer peripherals         | Each EPIT is a 32-bit “set-and-forget” timer that starts counting after the EPIT is enabled by software. It is capable of providing precise interrupts at regular intervals with minimal processor intervention. It has a 12-bit prescaler to adjust the input clock frequency to the required time setting for the interrupts, and the counter value can be programmed on the fly.                                         |

**Table 4. Digital and Analog Modules (continued)**

| Block Mnemonic | Block Name                              | Domain <sup>1</sup> | Subsystem                | Brief Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------|-----------------------------------------|---------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ESAI           | Enhanced serial audio interface         | SDMA                | Connectivity peripherals | The enhanced serial audio interface (ESAI) provides a full-duplex serial port for serial communication with a variety of serial devices, including industry-standard codecs, SPDIF transceivers, and other DSPs. The ESAI consists of independent transmitter and receiver sections, each section with its own clock generator.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| eSDHCv2 (3)    | Enhanced secure digital host controller | ARM                 | Connectivity peripherals | The eSDHCv2 consists of four main modules: CE-ATA, MMC, SD and SDIO. CE-ATA is a hard drive interface that is optimized for embedded applications of storage. The MultiMediaCard (MMC) is a universal, low-cost, data storage and communication media to applications such as electronic toys, organizers, PDAs, and smart phones. The secure digital (SD) card is an evolution of MMC and is specifically designed to meet the security, capacity, performance, and environment requirements inherent in emerging audio and video consumer electronic devices. SD cards are categorized into Memory and I/O. A memory card enables a copyright protection mechanism that complies with the SDMI security standard. SDIO cards provide high-speed data I/O (such as wireless LAN via SDIO interface) with low power consumption.<br><b>Note:</b> CE-ATA is not available for the MCIMX351. |
| FEC            | Ethernet                                | SDMA                | Connectivity peripherals | The Ethernet media access controller (MAC) is designed to support both 10 and 100 Mbps Ethernet/IEEE 802.3 networks. An external transceiver interface and transceiver function are required to complete the interface to the media                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| GPIO(3)        | General purpose I/O modules             | ARM                 | Pins                     | Used for general purpose input/output to external ICs. Each GPIO module supports 32 bits of I/O.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| GPT            | General purpose timers                  | ARM                 | Timer peripherals        | Each GPT is a 32-bit free-running or set-and-forget mode timer with a programmable prescaler and compare and capture registers. A timer counter value can be captured using an external event and can be configured to trigger a capture event on either the leading or trailing edges of an input pulse. When the timer is configured to operate in set-and-forget mode, it is capable of providing precise interrupts at regular intervals with minimal processor intervention. The counter has output compare logic to provide the status and interrupt at comparison. This timer can be configured to run either on an external clock or on an internal clock.                                                                                                                                                                                                                         |
| GPU2D          | Graphics processing unit 2Dv1           | ARM                 | Multimedia peripherals   | This module accelerates OpenVG and GDI graphics.<br><b>Note:</b> Not available for the MCIMX351.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

**Table 4. Digital and Analog Modules (continued)**

| Block Mnemonic      | Block Name                            | Domain <sup>1</sup> | Subsystem                    | Brief Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------|---------------------------------------|---------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I <sup>2</sup> C(3) | I <sup>2</sup> C module               | ARM                 | ARM1136 platform peripherals | Inter-integrated circuit (I <sup>2</sup> C) is an industry-standard, bidirectional serial bus that provides a simple, efficient method of data exchange, minimizing the interconnection between devices. I <sup>2</sup> C is suitable for applications requiring occasional communications over a short distance among many devices. The interface operates at up to 100 kbps with maximum bus loading and timing. The I <sup>2</sup> C system is a true multiple-master bus, with arbitration and collision detection that prevent data corruption if multiple devices attempt to control the bus simultaneously. This feature supports complex applications with multiprocessor control and can be used for rapid testing and alignment of end products through external connections to an assembly-line computer.   |
| IIM                 | IC identification module              | ARM                 | Security modules             | The IIM provides the primary user-visible mechanism for interfacing with on-chip fuse elements. Among the uses for the fuses are unique chip identifiers, mask revision numbers, cryptographic keys, and various control signals requiring a fixed value.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| IOMUX               | External signals and pin multiplexing | ARM                 | Pins                         | Each I/O multiplexer provides a flexible, scalable multiplexing solution with the following features: <ul style="list-style-type: none"> <li>• Up to eight output sources multiplexed per pin</li> <li>• Up to four destinations for each input pin</li> <li>• Unselected input paths held at constant levels for reduced power consumption</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| IPUv1               | Image processing unit                 | ARM                 | Multimedia peripherals       | The IPU supports video and graphics processing functions. It also provides the interface for image sensors and displays. The IPU performs the following main functions: <ul style="list-style-type: none"> <li>• Preprocessing of data from the sensor or from the external system memory</li> <li>• Postprocessing of data from the external system memory</li> <li>• Post-filtering of data from the system memory with support of the MPEG-4 (both deblocking and deringing) and H.264 post-filtering algorithms</li> <li>• Displaying video and graphics on a synchronous (dumb or memory-less) display</li> <li>• Displaying video and graphics on an asynchronous (smart) display</li> <li>• Transferring data between IPU sub-modules and to/from the system memory with flexible pixel reformatting</li> </ul> |
| KPP                 | Keypin port                           | ARM                 | Connectivity peripherals     | Can be used for either keypin matrix scanning or general purpose I/O.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| MLB                 | Media local bus                       | ARM                 | Connectivity peripherals     | The MLB is designed to interface to an automotive MOST ring.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| OSCAUD              | OSC audio reference oscillator        | Analog              | Clock                        | The OSCAUDIO oscillator provides a stable frequency reference for the PLLs. This oscillator is designed to work in conjunction with an external 24.576-MHz crystal.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

**Table 4. Digital and Analog Modules (continued)**

| Block Mnemonic | Block Name                                   | Domain <sup>1</sup>           | Subsystem                    | Brief Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------|----------------------------------------------|-------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| OSC24M         | OSC24M 24-MHz reference oscillator           | Analog                        | Clock                        | The signal from the external 24-MHz crystal is the source of the CLK24M signal fed into USB PHY as the reference clock and to the real time clock (RTC).                                                                                                                                                                                                                                                                                                                                                                             |
| MPLL PPLL      | Digital phase-locked loops                   | SDMA                          | Clocks                       | DPLLs are used to generate the clocks:<br>MCU PLL (MPLL)—programmable<br>Peripheral PLL (PPLL)—programmable                                                                                                                                                                                                                                                                                                                                                                                                                          |
| PWM            | Pulse-width modulator                        | ARM                           | ARM1136 platform peripherals | The pulse-width modulator (PWM) is optimized to generate sound from stored sample audio images; it can also generate tones.                                                                                                                                                                                                                                                                                                                                                                                                          |
| RTC            | Real-time clock                              | ARM                           | Clocks                       | Provides the ARM1136 platform with a clock function (days, hours, minutes, seconds) and includes alarm, sampling timer, and minute stopwatch capabilities.                                                                                                                                                                                                                                                                                                                                                                           |
| SDMA           | Smart DMA engine                             | SDMA                          | System controls              | The SDMA provides DMA capabilities inside the processor. It is a shared module that implements 32 DMA channels and has an interface to connect to the ARM1136 platform subsystem, EMI interface, and the peripherals.                                                                                                                                                                                                                                                                                                                |
| SJC            | Secure JTAG controller                       | ARM                           | Pins                         | The secure JTAG controller (SJC) provides debug and test control with maximum security.                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| SPBA           | SDMA peripheral bus arbiter                  | SDMA                          | System controls              | The SPBA controls access to the SDMA peripherals. It supports shared peripheral ownership and access rights to an owned peripheral.                                                                                                                                                                                                                                                                                                                                                                                                  |
| S/PDIF         | Serial audio interface                       | SDMA                          | Connectivity peripherals     | Sony/Philips digital transceiver interface                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| SSI(2)         | Synchronous serial interface                 | SDMA, ARM(2)                  | Connectivity peripherals     | The SSI is a full-duplex serial port that allows the processor connected to it to communicate with a variety of serial protocols, including the Freescale Semiconductor SPI standard and the I <sup>2</sup> C sound (I <sup>2</sup> S) bus standard. The SSIs interface to the AUDMUX for flexible audio routing.                                                                                                                                                                                                                    |
| UART(3)        | Universal asynchronous receiver/transmitters | ARM (UART1,2)<br>SDMA (UART3) | Connectivity peripherals     | Each UART provides serial communication capability with external devices through an RS-232 cable using the standard RS-232 non-return-to-zero (NRZ) encoding format. Each module transmits and receives characters containing either 7 or 8 bits (program-selectable). Each UART can also provide low-speed IrDA compatibility through the use of external circuitry that converts infrared signals to electrical signals (for reception) or transforms electrical signals to signals that drive an infrared LED (for transmission). |

**Table 4. Digital and Analog Modules (continued)**

| Block Mnemonic | Block Name               | Domain <sup>1</sup> | Subsystem                | Brief Description                                                                                                                                                                                                                                                                                                                                                                        |
|----------------|--------------------------|---------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| USBOH          | High-speed USB on-the-go | SDMA                | Connectivity peripherals | The USB module provides high performance USB on-the-go (OTG) functionality (up to 480 Mbps), compliant with the USB 2.0 specification, the OTG supplement, and the ULPI 1.0 low pin count specification. The module has DMA capabilities handling data transfer between internal buffers and system memory.                                                                              |
| WDOG           | Watchdog modules         | ARM                 | Timer peripherals        | Each module protects against system failures by providing a method of escaping from unexpected events or programming errors. Once activated, the timer must be serviced by software on a periodic basis. If servicing does not take place, the watchdog times out and then either asserts a system reset signal or an interrupt request signal, depending on the software configuration. |

<sup>1</sup> ARM = ARM1136 platform, SDMA = SDMA platform

### 3 Signal Descriptions: Special Function Related Pins

Some special functional requirements are supported in the device. The details about these special functions and the corresponding pin names are listed in [Table 5](#).

**Table 5. Special Function Related Pins**

| Function Name             | Pin Name   | Mux Mode | Detailed Description                                                                                                                                                                                                                                                   |
|---------------------------|------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| External ARM Clock        | EXT_ARMCLK | ALT0     | External clock input for ARM clock.                                                                                                                                                                                                                                    |
| External Peripheral Clock | I2C1_CLK   | ALT6     | External peripheral clock source.                                                                                                                                                                                                                                      |
| External 32-kHz Clock     | CAPTURE    | ALT4     | External clock input of 32 kHz, used when the internal 24M Oscillator is powered off, which could be configured either from CAPTURE or CSPI1_SS1.                                                                                                                      |
|                           | CSPI1_SS1  | ALT2     |                                                                                                                                                                                                                                                                        |
| Clock Out                 | CLKO       | ALT0     | Clock-out pin from CCM, clock source is controllable and can also be used for debug.                                                                                                                                                                                   |
| Power Ready               | GPIO1_0    | ALT1     | PMIC power-ready signal, which can be configured either from GPIO1_0 or TX1.                                                                                                                                                                                           |
|                           | TX1        | ALT1     |                                                                                                                                                                                                                                                                        |
| Tamper Detect             | GPIO1_1    | ALT6     | Tamper-detect logic is used to issue a security violation. This logic is activated if the tamper-detect input is asserted. Tamper-detect logic is enabled by the bit of IOMUXC_GPRA[2]. After enabling the logic, it is impossible to disable it until the next reset. |

## 4 Electrical Characteristics

The following sections provide the device-level and module-level electrical characteristics for the i.MX35 processor.

### 4.1 i.MX35 Chip-Level Conditions

This section provides the device-level electrical characteristics for the IC. See [Table 6](#) for a quick reference to the individual tables and sections.

**Table 6. i.MX35 Chip-Level Conditions**

| Characteristics                          | Table/Location                     |
|------------------------------------------|------------------------------------|
| <a href="#">Absolute Maximum Ratings</a> | <a href="#">Table 7 on page 14</a> |
| <a href="#">i.MX35 Operating Ranges</a>  | <a href="#">Table 8 on page 15</a> |
| <a href="#">Interface Frequency</a>      | <a href="#">Table 9 on page 16</a> |

#### CAUTION

Stresses beyond those listed in [Table 7](#) may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in [Table 8](#) is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**Table 7. Absolute Maximum Ratings**

| Parameter                 | Symbol                      | Min. | Max.              | Units |
|---------------------------|-----------------------------|------|-------------------|-------|
| Supply voltage (core)     | $V_{DD_{max}}$ <sup>1</sup> | −0.5 | 1.47              | V     |
| Supply voltage (I/O)      | $NVCC_{max}$                | −0.5 | 3.6               | V     |
| Input voltage range       | $V_{I_{max}}$               | −0.5 | 3.6               | V     |
| Storage temperature       | $T_{storage}$               | −40  | 125               | °C    |
| ESD damage immunity:      | $V_{esd}$                   |      |                   | V     |
| Human Body Model (HBM)    |                             | —    | 2000 <sup>2</sup> |       |
| Charge Device Model (CDM) |                             | —    | 500 <sup>3</sup>  |       |

<sup>1</sup> VDD is also known as QVCC.

<sup>2</sup> HBM ESD classification level according to the AEC-Q100-002 standard

<sup>3</sup> Corner pins max. 750 V

## 4.1.1 i.MX35 Operating Ranges

Table 8 provides the recommended operating ranges. The term NVCC in this section refers to the associated supply rail of an input or output.

**Table 8. i.MX35 Operating Ranges**

| Parameter                                                | Symbol                | Min. | Typical | Max. | Units |
|----------------------------------------------------------|-----------------------|------|---------|------|-------|
| Core Operating Voltage<br>0 < f <sub>ARM</sub> < 400 MHz | V <sub>DD</sub>       | 1.22 | —       | 1.47 | V     |
| Core Operating Voltage<br>0 < f <sub>ARM</sub> < 532 MHz |                       | 1.33 | —       | 1.47 | V     |
| State Retention Voltage                                  |                       | 1    | —       | —    | V     |
| EMI <sup>1</sup>                                         | NVCC_EMI1,2,3         | 1.7  | —       | 3.6  | V     |
| WTDG, Timer, CCM, CSPI1                                  | NVCC_CRM              | 1.75 | —       | 3.6  | V     |
| NANDF                                                    | NVCC_NANDF            | 1.75 | —       | 3.6  | V     |
| ATA, USB generic                                         | NVCC_ATA              | 1.75 | —       | 3.6  | V     |
| eSDHC1                                                   | NVCC_SDIO             | 1.75 | —       | 3.6  | V     |
| CSI, SDIO2                                               | NVCC_CSI              | 1.75 | —       | 3.6  | V     |
| JTAG                                                     | NVCC_JTAG             | 1.75 | —       | 3.6  | V     |
| LCDC, TTM, I2C1                                          | NVCC_LCDC             | 1.75 | —       | 3.6  | V     |
| I2Sx2, ESAI, I2C2, UART2, UART1, FEC                     | NVCC_MISC             | 1.75 | —       | 3.6  | V     |
| MLB                                                      | NVCC_MLB <sup>2</sup> | 1.75 | —       | 3.6  | V     |
| USB OTG PHY                                              | PHY1_VDDA             | 3.17 | 3.3     | 3.43 | V     |
| USB OTG PHY                                              | USBPHY1_VDDA_BIAS     | 3.17 | 3.3     | 3.43 | V     |
| USB OTG PHY                                              | USBPHY1_UPLLVDD       | 3.17 | 3.3     | 3.43 | V     |
| USB HOST PHY                                             | PHY2_VDD              | 3.0  | 3.3     | 3.6  | V     |
| OSC24M                                                   | OSC24M_VDD            | 3.0  | 3.3     | 3.6  | V     |
| OSC_AUDIO                                                | OSC_AUDIO_VDD         | 3.0  | 3.3     | 3.6  | V     |
| MPLL                                                     | MVDD                  | 1.4  | —       | 1.65 | V     |
| PPLL                                                     | PVDD                  | 1.4  | —       | 1.65 | V     |
| Fusebox program supply voltage                           | FUSE_VDD <sup>3</sup> | 3.0  | 3.6     | 3.6  | V     |
| Operating ambient temperature range                      | T <sub>A</sub>        | −40  | —       | 85   | °C    |
| Junction temperature range                               | T <sub>J</sub>        | −40  | —       | 105  | °C    |

<sup>1</sup> EMI I/O interface power supply should be set up according to external memory. For example, if using SDRAM then NVCC\_EMI1,2,3 should all be set at 3.3 V (typ.). If using MDDR or DDR2, NVCC\_EMI1,2,3 must be set at 1.8 V (typ.).

<sup>2</sup> MLB interface I/O pads can be programmed to function as GPIO by setting NVCC\_MLB to 1.8 or 3.3 V, but if used as MLB pads, NVCC\_MLB must be set to 2.5 V in order to be compliant with external MOST devices. NVCC\_MLB may be left floating.

<sup>3</sup> The Fusebox read supply is connected to supply of the full speed USB PHY. FUSE\_VDD is only used for programming. It is recommended that FUSE\_VDD be connected to ground when not being used for programming.

## 4.1.2 Interface Frequency Limits

Table 9 provides information on interface frequency limits.

**Table 9. Interface Frequency**

| ID | Parameter          | Symbol            | Min. | Typ. | Max. | Units |
|----|--------------------|-------------------|------|------|------|-------|
| 1  | JTAG TCK Frequency | f <sub>JTAG</sub> | DC   | 5    | 10   | MHz   |

## 4.2 Power Modes

Table 10 provides descriptions of the power modes of the i.MX35 processor.

**Table 10. i.MX35 Power Modes**

| Power Mode | Description                                                                                                                                                                                                                                                                                                                                                                                         | QVCC (ARM/L2 Peripheral) |        | MVDD/PVDD |       | OSC24M_VDD<br>OSC_AUDIO_VDD |      |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------|-----------|-------|-----------------------------|------|
|            |                                                                                                                                                                                                                                                                                                                                                                                                     | Typ.                     | Max.   | Typ.      | Max.  | Typ.                        | Max. |
| Wait       | VDD1,2,3,4 = 1.1 V (min.)<br>ARM is in wait for interrupt mode.<br>MAX is active.<br>L2 cache is kept powered.<br>MCU PLL is on (400 MHz)<br>PER PLL is off (can be configured) (default: 300 MHz)<br>Module clocks are gated off (can be configured by CGR register).<br>OSC 24M is ON.<br>OSC audio is off (can be configured).<br>RNGC internal osc is off.                                      | 16 mA                    | 170 mA | 7.2 mA    | 14 mA | 1.2 mA                      | 3 mA |
| Doze       | VDD1,2,3,4 = 1.1 V (min.)<br>ARM is in wait for interrupt mode.<br>MAX is halted.<br>L2 cache is kept powered.<br>L2 cache control logic off.<br>AWB enabled.<br>MCU PLL is on(400 MHz)<br>PER PLL is off (can be configured). (300 Mhz).<br>Module clocks are gated off (can be configured by CGR register).<br>OSC 24M is ON.<br>OSC audio is off (can be configured)<br>RNGC internal osc is off | 12.4 mA                  | 105 mA | 7.2 mA    | 14 mA | 1.2 mA                      | 3 mA |



Table 10. i.MX35 Power Modes (continued)

| Power Mode                                                                         | Description                                                                                                                                                                                                                                                                                         | QVCC (ARM/L2 Peripheral) |       | MVDD/PVDD   |        | OSC24M_VDD<br>OSC_AUDIO_VDD |            |
|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------|-------------|--------|-----------------------------|------------|
|                                                                                    |                                                                                                                                                                                                                                                                                                     | Typ.                     | Max.  | Typ.        | Max.   | Typ.                        | Max.       |
| Stop                                                                               | VDD1,2,3,4 = 1.1 V (min.)<br>ARM is in wait for interrupt mode.<br>MAX is halted<br>L2 cache is kept powered.<br>L2 cache control logic off.<br>AWB enabled.<br>MCU PLL is off.<br>PER PLL is off.<br>All clocks are gated off.<br>OSC 24 MHz is on<br>OSC audio is off<br>RNGC internal osc is off | 1.1 mA                   | 77 mA | 400 $\mu$ A | 2.2 mA | 1.2 mA                      | 2.2 mA     |
| Static                                                                             | VDD1,2,3,4 = 1.1 V (min.)<br>ARM is in wait for interrupt mode.<br>MAX is halted<br>L2 cache is kept powered.<br>L2 cache control logic off.<br>AWB enabled.<br>MCU PLL is off.<br>PER PLL is off.<br>All clocks are gated off.<br>OSC 24MHz is on<br>OSC audio is off<br>RNGC internal osc is off  | 820 $\mu$ A              | 72 mA | 50 $\mu$ A  | 1.7 mA | 24 $\mu$ A                  | 35 $\mu$ A |
| <b>Note:</b> Typical column: TA = 25 °C<br><b>Note:</b> Maximum column: TA = 85 °C |                                                                                                                                                                                                                                                                                                     |                          |       |             |        |                             |            |

## 4.3 Supply Power-Up/Power-Down Requirements and Restrictions

This section provides power-up and power-down sequence guidelines for the i.MX35 processor.

### CAUTION

Any i.MX35 board design must comply with the power-up and power-down sequence guidelines as described in this section to guarantee reliable operation of the device. Any deviation from these sequences can result in irreversible damage to the i.MX35 processor (worst-case scenario).

## NOTE

Deviation from these sequences can also result in one or both of the following:

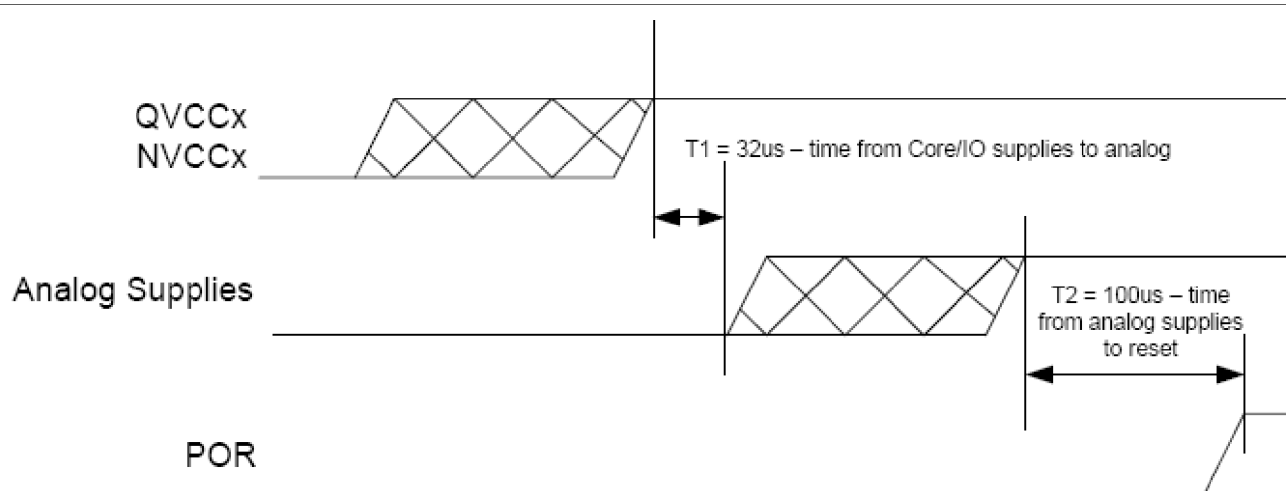
- Excessive current during power-up phase
- Prevent the device from booting

### 4.3.1 Powering Up

The power-up sequence should be completed as follows:

1. Assert Power on Reset ( $\overline{\text{POR}}$ ).
2. Turn on digital logic domain and IO power supply: VDD<sub>n</sub>, NVCC<sub>x</sub>
3. Wait until VDD<sub>n</sub> and NVCC<sub>x</sub> power supplies are stable + 32  $\mu\text{s}$ .
4. Turn on all other power supplies: PHY1\_VDDA, USBPHY1\_VDDA\_BIAS, PHY2\_VDD, USBPHY1\_UPLLVD, OSC24M\_VDD, OSC\_AUDIO\_VDD, MVDD, PVDD, FUSEVDD. (FUSEVDD is tied to GND if fuses are not being programmed.)
5. Wait until PHY1\_VDDA, USBPHY1\_VDDA\_BIAS, PHY2\_VDD, USBPHY1\_UPLLVD, OSC24M\_VDD, OSC\_AUDIO\_VDD, MVDD, PVDD, (FUSEVDD, optional). Power supplies are stable + 100  $\mu\text{s}$ .
6. Deassert the  $\overline{\text{POR}}$  signal.

Figure 2 shows the power-up sequence and timing.



Analog supplies include the following:  
 PHY1\_VDDA, USBPHY1\_VDDA\_BIAS,  
 PHY2\_VDD, USBPHY1\_UPLLVD,   
 OSC24M\_VDD, OSC\_AUDIO\_VDD,  
 MVDD, PVDD, FUSEVDD.  
 Note: FUSEVDD shall be tied to GND if  
 not programming fuse

Figure 2. i.MX35 Power-Up Sequence and Timing

### 4.3.2 Powering Down

The power-up sequence in reverse order is recommended for powering down. However, all power supplies can be shut down at the same time.

## 4.4 Reset Timing

There are two ways of resetting the i.MX35 using external pins:

- Power On Reset (using the POR\_B pin)
- System Reset (using the RESET\_IN\_B pin)

### 4.4.1 Power On Reset

POR\_B is normally connected to a power management integrated circuit (PMIC). The PMIC asserts POR\_B while the power supplies are turned on and negates POR\_B after the power up sequence is finished. See Figure 2.

Assuming the i.MX35 chip is already fully powered; it is still possible to reset all of the modules to their default reset by asserting POR\_B for at least 4 CKIL cycles and later de-asserting POR\_B. This method of resetting the i.MX35 can also be supported by tying the POR\_B and RESET\_IN\_B pins together.

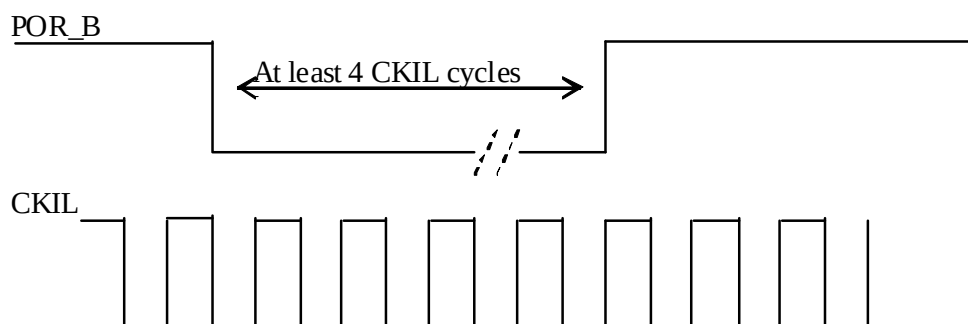


Figure 3. Timing Between POR\_B and CKIL for Complete Reset of i.MX35

#### 4.4.2 System Reset

System reset can be achieved by asserting RESET\_IN\_B for at least 4 CKIL cycles and later negating RESET\_IN\_B. The following modules are not reset upon system reset: RTC, PLLs, CCM, and IIM. POR\_B pin must be deasserted all the time.

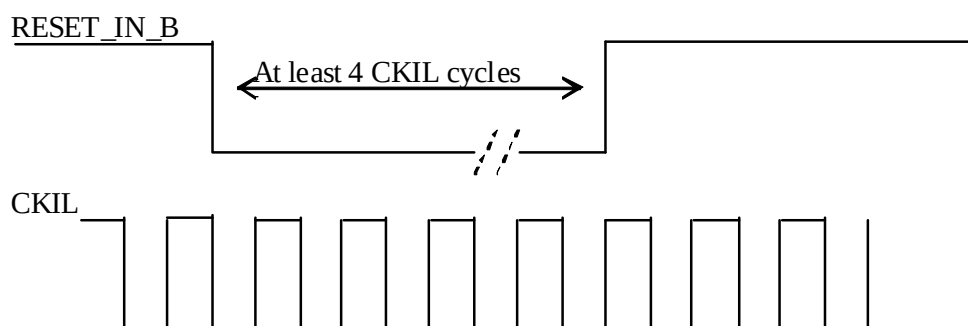


Figure 4. Timing Between RESET\_IN\_B and CKIL for i.MX35 System Reboot

#### 4.5 Power Characteristics

The table shows values representing maximum current numbers for the i.MX35 under worst case voltage and temperature conditions. These values are derived from the i.MX35 with core clock speeds up to 532 MHz. Common supplies have been bundled according to the i.MX35 power-up sequence requirements. Peak numbers are provided for system designers so that the i.MX35 power supply requirements will be satisfied during startup and transient conditions. Freescale recommends that system current measurements be taken with customer-specific use-cases to reflect normal operating conditions in the end system.

**Table 11. Power Consumption**

| Power Supply                                                                                               | Voltage (V) | Max Current (mA) |
|------------------------------------------------------------------------------------------------------------|-------------|------------------|
| QVCC                                                                                                       | 1.47        | 400              |
| MVDD, PVDD                                                                                                 | 1.65        | 20               |
| NVCC_EMI1, NVCC_EMI2, NVCC_EMI3, NVCC_LCDC, NVCC_NFC                                                       | 1.9         | 90               |
| FUSE_VDD (This rail is typically tied to ground; it only needs a voltage if system fuse burning is needed) | 3.6         | 62               |
| NVCC_MISC, NVCC_CSI, NVCC_SDIO, NVCC_CRM, NVCC_ATA, NVCC_MLB, NVCC_JTAG                                    | 3.6         | 60               |
| OSC24M_VDD, OSC_AUDIO_VDD, PHY1_VDDA, PHY2_VDD, USBPHY1_UPLLVD, USBPHY1_VDDA_BIAS                          | 3.6         | 25               |

The method for obtaining max current is as follows:

1. Measure worst case power consumption on individual rails using directed test on i.MX35.
2. Correlate worst case power consumption power measurements with worst case power consumption simulations.
3. Combine common voltage rails based on power supply sequencing requirements
4. Guard band worst case numbers for temperature and process variation. Guard band is based on process data and correlated with actual data measured on i.MX35.
5. The sum of individual rails is greater than real world power consumption, as a real system does not typically maximize power consumption on all peripherals simultaneously.

## 4.6 Thermal Characteristics

The thermal resistance characteristics for the device are given in [Table 12](#). These values were measured under the following conditions:

- Two-layer substrate
- Substrate solder mask thickness: 0.025 mm
- Substrate metal thicknesses: 0.016 mm
- Substrate core thickness: 0.200 mm
- Core via I.D: 0.168 mm, Core via plating 0.016 mm.
- Full array map design, but nearly all balls under die are power or ground.
- Die Attach: 0.033 mm non-conductive die attach,  $k = 0.3 \text{ W/m K}$
- Mold compound:  $k = 0.9 \text{ W/m K}$

**Table 12. Thermal Resistance Data**

| Rating                                              | Condition               | Symbol     | Value | Unit                 |
|-----------------------------------------------------|-------------------------|------------|-------|----------------------|
| Junction to ambient <sup>1</sup> natural convection | Single layer board (1s) | $R_{eJA}$  | 53    | $^{\circ}\text{C/W}$ |
| Junction to ambient <sup>1</sup> natural convection | Four layer board (2s2p) | $R_{eJA}$  | 30    | $^{\circ}\text{C/W}$ |
| Junction to ambient <sup>1</sup> (at 200 ft/min)    | Single layer board (1s) | $R_{eJMA}$ | 44    | $^{\circ}\text{C/W}$ |

**Table 12. Thermal Resistance Data (continued)**

| Rating                                           | Condition               | Symbol            | Value | Unit |
|--------------------------------------------------|-------------------------|-------------------|-------|------|
| Junction to ambient <sup>1</sup> (at 200 ft/min) | Four layer board (2s2p) | R <sub>eJMA</sub> | 27    | °C/W |
| Junction to boards <sup>2</sup>                  | —                       | R <sub>eJB</sub>  | 19    | °C/W |

**Table 12. Thermal Resistance Data (continued)**

| Rating                               | Condition          | Symbol       | Value | Unit |
|--------------------------------------|--------------------|--------------|-------|------|
| Junction to case (top) <sup>3</sup>  | —                  | $R_{eJCtop}$ | 10    | °C/W |
| Junction to package top <sup>4</sup> | Natural convection | $\Psi_{JT}$  | 2     | °C/W |

- <sup>1</sup> Junction-to-ambient thermal resistance determined per JEDC JESD51-3 and JESD51-6. Thermal test board meets JEDEC specification for this package.
- <sup>2</sup> Junction-to-board thermal resistance determined per JEDC JESD51-8. Thermal test board meets JEDEC specification for this package.
- <sup>3</sup> Junction-to-case at the top of the package determined using MIL-STD 883 Method 1012.1. The cold plate temperature is used for the case temperature. Reported value includes the thermal resistance of the interface layer.
- <sup>4</sup> Thermal characterization parameter indicating the temperature difference between the package top and the junction temperature per JEDEC JESD51-2. When Greek letters are not available, this thermal characterization parameter is written as Psi-JT.

## 4.7 I/O Pin DC Electrical Characteristics

I/O pins are of two types: GPIO and DDR. DDR pins can be configured in three different drive strength modes: mobile DDR, SDRAM, and DDR2. The SDRAM and mobile DDR modes can be further customized at three drive strength levels: normal, high, and max.

Table 13 shows currents for the different DDR pin drive strength modes.

**Table 13. DDR Pin Drive Strength Mode Current Levels**

| Drive Mode         | Normal | High   | Max.    |
|--------------------|--------|--------|---------|
| Mobile DDR (1.8 V) | 3.6 mA | 7.2 mA | 10.8 mA |
| SDRAM (1.8 V)      | —      | —      | 6.5 mA  |
| SDRAM (3.3 V)      | 4 mA   | 8 mA   | 12 mA   |
| DDR2 (1.8 V)       | —      | —      | 13.4 mA |

Table 14 shows the DC electrical characteristics for GPIO, DDR2, mobile DDR, and SDRAM pins. The term NVCC refers to the power supply voltage that feeds the I/O of the module in question. For example, NVCC for the SD/MMC interface refers to NVCC\_SDIO.

**Table 14. I/O Pin DC Electrical Characteristics**

| Pin  | DC Electrical Characteristics                                                        | Symbol | Test Condition                             | Min.                      | Typ. | Max.               | Unit |
|------|--------------------------------------------------------------------------------------|--------|--------------------------------------------|---------------------------|------|--------------------|------|
| GPIO | High-level output voltage                                                            | Voh    | Ioh = -1 mA<br>Ioh = specified drive       | NVCC - 0.15<br>0.8 × NVCC | —    | —                  | V    |
|      | Low-level output voltage                                                             | Vol    | Iol = 1 mA<br>Iol = specified drive        | —                         | —    | 0.15<br>0.2 × NVCC | V    |
|      | High-level output current for slow mode<br>(Voh = 0.8 × NVCC)                        | Ioh    | Standard drive<br>High drive<br>Max. drive | -2.0<br>-4.0<br>-8.0      | —    | —                  | mA   |
|      | High-level output current for fast mode<br>(Voh = 0.8 × NVCC)                        | Ioh    | Standard drive<br>High drive<br>Max. drive | -4.0<br>-6.0<br>-8.0      | —    | —                  | mA   |
|      | Low-level output current for slow mode<br>(Voh = 0.2 × NVCC)                         | Iol    | Standard drive<br>High drive<br>Max. drive | 2.0<br>4.0<br>8.0         | —    | —                  | mA   |
|      | Low-level output current for fast mode<br>(Voh = 0.2 × NVCC)                         | Iol    | Standard drive<br>High drive<br>Max. drive | 4.0<br>6.0<br>8.0         | —    | —                  | mA   |
|      | High-level DC Input Voltage with 1.8 V, 3.3 V NVCC (for digital cells in input mode) | VIH    | —                                          | 0.7 × NVCC                | —    | NVCC               | V    |
|      | Low-level DC Input Voltage with 1.8 V, 3.3 V NVCC (for digital cells in input mode)  | VIL    | —                                          | -0.3 V                    | —    | 0.3 × NVCC         | V    |
|      | Input Hysteresis                                                                     | VHYS   | OVDD = 3.3 V<br>OVDD = 1.8 V               | 370<br>290                | —    | 420<br>320         | mV   |
|      | Schmitt trigger VT+                                                                  | VT+    | —                                          | 0.5 × NVCC                | —    | —                  | V    |
|      | Schmitt trigger VT-                                                                  | VT-    | —                                          | —                         | —    | 0.5 × NVCC         | V    |
|      | Pull-up resistor (22 KΩ PU)                                                          | Rpu    | Vi = 0                                     | —                         | 22   | —                  | KΩ   |
|      | Pull-up resistor (47 KΩ PU)                                                          | Rpu    | Vi = 0                                     | —                         | 47   | —                  | KΩ   |
|      | Pull-up resistor (100 KΩ PU)                                                         | Rpu    | Vi = 0                                     | —                         | 100  | —                  | KΩ   |
|      | Pull-down resistor (100 KΩ PD)                                                       | Rpd    | Vi = NVCC                                  | —                         | 100  | —                  | KΩ   |



**Table 14. I/O Pin DC Electrical Characteristics (continued)**

| Pin        | DC Electrical Characteristics                     | Symbol     | Test Condition                                              | Min.                               | Typ.          | Max.                      | Unit |
|------------|---------------------------------------------------|------------|-------------------------------------------------------------|------------------------------------|---------------|---------------------------|------|
| DDR2       | High-level output voltage                         | Voh        | —                                                           | NVCC – 0.28                        | —             | —                         | V    |
|            | Low-level output voltage                          | Vol        | —                                                           | —                                  | —             | 0.28                      | V    |
|            | Output min. source current                        | Ioh        | —                                                           | –13.4                              | —             | —                         | mA   |
|            | Output min. sink current                          | Iol        | —                                                           | 13.4                               | —             | —                         | mA   |
|            | DC input logic high                               | VIH(dc)    | —                                                           | $NVCC \div 2 + 0.125$              | —             | $NVCC + 0.3$              | V    |
|            | DC input logic low                                | VIL(dc)    | —                                                           | –0.3 V                             | —             | $NVCC \div 2 - 0.125$     | V    |
|            | DC input signal voltage (for differential signal) | Vin(dc)    | —                                                           | –0.3                               | —             | $NVCC + 0.3$              | V    |
|            | DC differential input voltage                     | Vid(dc)    | —                                                           | 0.25                               | —             | $NVCC + 0.6$              | V    |
|            | Termination voltage                               | Vtt        | —                                                           | $NVCC \div 2 - 0.04$               | $NVCC \div 2$ | $NVCC \div 2 + 0.04$      | V    |
|            | Input current (no pull-up/down)                   | IIN        | —                                                           | —                                  | —             | ±1                        | μA   |
|            | Tri-state I/O supply current                      | Icc – NVCC | —                                                           | —                                  | —             | ±1                        | μA   |
| Mobile DDR | High-level output voltage                         | —          | I <sub>OH</sub> = –1mA<br>I <sub>OH</sub> = specified drive | $NVCC - 0.08$<br>$0.8 \times NVCC$ | —             | —                         | V    |
|            | Low-level output voltage                          | —          | I <sub>OL</sub> = 1mA<br>I <sub>OL</sub> = specified drive  | —                                  | —             | 0.08<br>$0.2 \times NVCC$ | V    |
|            | High-level output current (Voh = 0.8 × NVCCV)     | —          | Standard drive<br>High drive<br>Max. drive                  | –3.6<br>–7.2<br>–10.8              | —             | —                         | mA   |
|            | Low-level output current (Vol = 0.2 × NVCCV)      | —          | Standard Drive<br>High Drive<br>Max. Drive                  | 3.6<br>7.2<br>10.8                 | —             | —                         | mA   |
|            | High-Level DC CMOS input voltage                  | VIH        | —                                                           | $0.7 \times NVCC$                  | —             | $NVCC + 0.3$              | V    |
|            | Low-Level DC CMOS input voltage                   | VIL        | —                                                           | –0.3                               | —             | $0.2 \times NVCC$         | V    |
|            | Differential receiver VTH+                        | VTH+       | —                                                           | —                                  | —             | 100                       | mV   |
|            | Differential receiver VTH–                        | VTH–       | —                                                           | –100                               | —             | —                         | mV   |
|            | Input current (no pull-up/down)                   | IIN        | VI = 0<br>VI = NVCC                                         | —                                  | —             | ±1                        | μA   |
|            | Tri-state I/O supply current                      | Icc – NVCC | VI = NVCC or 0                                              | —                                  | —             | ±1                        | μA   |

**Table 14. I/O Pin DC Electrical Characteristics (continued)**

| Pin            | DC Electrical Characteristics   | Symbol     | Test Condition                                        | Min.                  | Typ. | Max.      | Unit |
|----------------|---------------------------------|------------|-------------------------------------------------------|-----------------------|------|-----------|------|
| SDR<br>(1.8 V) | High-level output voltage       | Voh        | Ioh = 5.7 mA                                          | OVDD – 0.28           | —    | —         | V    |
|                | Low-level output voltage        | Vol        | Ioh = 5.7 mA                                          | —                     | —    | 0.4       | V    |
|                | High-level output current       | Ioh        | Max. drive                                            | 5.7                   | —    | —         | mA   |
|                | Low-level output current        | Iol        | Max. drive                                            | 7.3                   | —    | —         | mA   |
|                | High-level DC Input Voltage     | VIH        | —                                                     | 1.4                   | —    | 1.98      | V    |
|                | Low-level DC Input Voltage      | VIL        | —                                                     | –0.3                  | —    | 0.8       | V    |
|                | Input current (no pull-up/down) | IIN        | VI = 0<br>VI = NVCC                                   | —                     | —    | 150<br>80 | μA   |
|                | Tri-state I/O supply current    | Icc (NVCC) | VI = OVDD or 0                                        | —                     | —    | 1180      | μA   |
|                | Tri-state core supply current   | Icc (NVCC) | VI = VDD or 0                                         | —                     | —    | 1220      | μA   |
| SDR<br>(3.3 V) | High-level output voltage       | Voh        | Ioh=specified drive<br>(Ioh = –4, –8, –12,<br>–16 mA) | 2.4                   | —    | —         | V    |
|                | Low-level output voltage        | Vol        | Ioh=specified drive<br>(Ioh = 4, 8, 12,<br>16 mA)     | —                     | —    | 0.4       | V    |
|                | High-level output current       | Ioh        | Standard drive<br>High drive<br>Max. drive            | –4.0<br>–8.0<br>–12.0 | —    | —         | mA   |
|                | Low-level output current        | Iol        | Standard drive<br>High drive<br>Max. drive            | 4.0<br>8.0<br>12.0    | —    | —         | mA   |
|                | High-level DC Input Voltage     | VIH        | —                                                     | 2.0                   | —    | 3.6       | V    |
|                | Low-level DC Input Voltage      | VIL        | —                                                     | –0.3V                 | —    | 0.8       | V    |
|                | Input current (no pull-up/down) | IIN        | VI = 0<br><br>VI = NVCC                               | —                     | —    | ±1        | μA   |
|                | Tri-state I/O supply current    | Icc (NVCC) | VI = NVCC or 0                                        | —                     | —    | ±1        | μA   |

## 4.8 I/O Pin AC Electrical Characteristics

Figure 5 shows the load circuit for output pins.

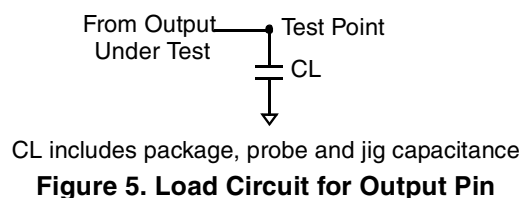


Figure 6 shows the output pin transition time waveform.

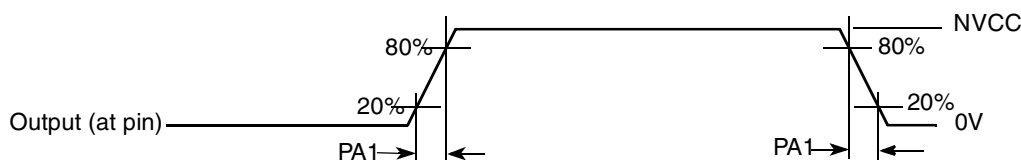


Figure 6. Output Pin Transition Time Waveform

## 4.8.1 AC Electrical Test Parameter Definitions

AC electrical characteristics in Table 15 through Table 20 are not applicable for the output open drain pull-down driver.

The  $dI/dt$  parameters are measured with the following methodology:

- The zero voltage source is connected between pin and load capacitance.
- The current (through this source) derivative is calculated during output transitions.

Table 15. AC Electrical Characteristics of GPIO Pins in Slow Slew Rate Mode  
[NVCC = 3.0 V–3.6 V]

| Parameter                             | Symbol | Test Condition | Min. Rise/Fall         | Typ. Rise/Fall         | Max. Rise/Fall         | Units |
|---------------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Duty cycle                            | Fduty  | —              | 40                     | —                      | 60                     | %     |
| Output pin slew rate (max. drive)     | tps    | 25 pF<br>50 pF | 0.79/1.12<br>0.49/0.73 | 1.30/1.77<br>0.84/1.23 | 2.02/2.58<br>1.19/1.58 | V/ns  |
| Output pin slew rate (high drive)     | tps    | 25 pF<br>50 pF | 0.48/0.72<br>0.27/0.42 | 0.76/1.10<br>0.41/0.62 | 1.17/1.56<br>0.63/0.86 | V/ns  |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>50 pF | 0.25/0.40<br>0.14/0.21 | 0.40/0.59<br>0.21/0.32 | 0.60/0.83<br>0.32/0.44 | V/ns  |
| Output pin $dI/dt$ (max. drive)       | tdit   | 25 pF<br>50 pF | 15<br>16               | 36<br>38               | 76<br>80               | mA/ns |
| Output pin $dI/dt$ (high drive)       | tdit   | 25 pF<br>50 pF | 8<br>9                 | 20<br>21               | 45<br>47               | mA/ns |
| Output pin $dI/dt$ (standard drive)   | tdit   | 25 pF<br>50 pF | 4<br>4                 | 10<br>10               | 22<br>23               | mA/ns |

Table 16. AC Electrical Characteristics of GPIO Pins in Slow Slew Rate Mode  
[NVCC = 1.65 V–1.95 V]

| Parameter                         | Symbol | Test Condition | Min. Rise/Fall         | Typ.                   | Max. Rise/Fall         | Units |
|-----------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Duty cycle                        | Fduty  | —              | 40                     | —                      | 60                     | %     |
| Output pin slew rate (max. drive) | tps    | 25 pF<br>50 pF | 0.30/0.42<br>0.20/0.29 | 0.54/0.73<br>0.35/0.50 | 0.91/1.20<br>0.60/0.80 | V/ns  |

**Table 16. AC Electrical Characteristics of GPIO Pins in Slow Slew Rate Mode  
[NVCC = 1.65 V–1.95 V] (continued)**

| Parameter                             | Symbol | Test Condition | Min.<br>Rise/Fall      | Typ.                   | Max.<br>Rise/Fall      | Units |
|---------------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Output pin slew rate (high drive)     | tps    | 25 pF<br>50 pF | 0.19/0.28<br>0.12/0.18 | 0.34/0.49<br>0.34/0.49 | 0.58/0.79<br>0.36/0.49 | V/ns  |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>50 pF | 0.12/0.18<br>0.07/0.11 | 0.20/0.30<br>0.11/0.17 | 0.34/0.47<br>0.20/0.27 | V/ns  |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF | 7<br>7                 | 21<br>22               | 56<br>58               | mA/ns |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF | 5<br>5                 | 14<br>15               | 38<br>40               | mA/ns |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF | 2<br>2                 | 7<br>7                 | 18<br>19               | mA/ns |

**Table 17. AC Electrical Characteristics of GPIO Pins in Fast Slew Rate Mode for  
[NVCC = 3.0 V–3.6 V]**

| Parameter                             | Symbol | Test Condition | Min.<br>rise/fall      | Typ.                   | Max.<br>Rise/Fall      | Units |
|---------------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Duty cycle                            | Fduty  | —              | 40                     | —                      | 60                     | %     |
| Output pin slew rate (max. drive)     | tps    | 25 pF<br>50 pF | 0.96/1.40<br>0.54/0.83 | 1.54/2.10<br>0.85/1.24 | 2.30/3.00<br>1.26/1.70 | V/ns  |
| Output pin slew rate (high drive)     | tps    | 25 pF<br>50 pF | 0.76/1.10<br>0.41/0.64 | 1.19/1.71<br>0.63/0.95 | 1.78/2.39<br>0.95/1.30 | V/ns  |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>50 pF | 0.52/0.78<br>0.28/0.44 | 0.80/1.19<br>0.43/0.64 | 1.20/1.60<br>0.63/0.87 | V/ns  |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF | 46<br>49               | 108<br>113             | 250<br>262             | mA/ns |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF | 35<br>37               | 82<br>86               | 197<br>207             | mA/ns |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF | 22<br>23               | 52<br>55               | 116<br>121             | mA/ns |

**Table 18. AC Electrical Characteristics, GPIO Pins in Fast Slew Rate Mode  
[NVCC = 1.65 V–1.95 V]**

| Parameter                         | Symbol | Test Condition | Min.<br>Rise/Fall      | Typ.                   | Max.<br>Rise/Fall      | Units |
|-----------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Duty cycle                        | Fduty  | —              | 40                     | —                      | 60                     | %     |
| Output pin slew rate (max. drive) | tps    | 25 pF<br>50 pF | 0.40/0.57<br>0.25/0.36 | 0.72/0.97<br>0.43/0.61 | 1.2/1.5<br>0.72/0.95   | V/ns  |
| Output pin slew rate (high drive) | tps    | 25 pF<br>50 pF | 0.38/0.48<br>0.20/0.30 | 0.59/0.81<br>0.34/0.50 | 0.98/1.27<br>0.56/0.72 | V/ns  |

**Table 18. AC Electrical Characteristics, GPIO Pins in Fast Slew Rate Mode**  
[NVCC = 1.65 V–1.95 V] (continued)

| Parameter                             | Symbol | Test Condition | Min.<br>Rise/Fall      | Typ.                   | Max.<br>Rise/Fall      | Units |
|---------------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Output pin slew rate (standard drive) | tps    | 25 pF<br>50 pF | 0.23/0.32<br>0.13/0.20 | 0.40/0.55<br>0.23/0.34 | 0.66/0.87<br>0.38/0.52 | V/ns  |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF | 7<br>7                 | 43<br>46               | 112<br>118             | mA/ns |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF | 11<br>12               | 31<br>33               | 81<br>85               | mA/ns |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF | 9<br>10                | 27<br>28               | 71<br>74               | mA/ns |

**Table 19. AC Electrical Characteristics of GPIO Pins in Slow Slew Rate Mode**  
[NVCC = 2.25 V–2.75 V]

| Parameter                             | Symbol | Test Condition          | Min.<br>Rise/Fall                   | Typ.                                | Max.<br>Rise/Fall                   | Units |
|---------------------------------------|--------|-------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------|
| Duty cycle                            | Fduty  | —                       | 40                                  | —                                   | 60                                  | %     |
| Output pin slew rate (max. drive)     | tps    | 25 pF<br>40 pF<br>50 pF | 0.63/0.85<br>0.52/0.67<br>0.41/0.59 | 1.10/1.40<br>0.90/1.10<br>0.73/0.99 | 1.86/2.20<br>1.53/1.73<br>1.20/1.50 | V/ns  |
| Output pin slew rate (high drive)     | tps    | 25 pF<br>40 pF<br>50 pF | 0.40/0.58<br>0.33/0.43<br>0.25/0.37 | 0.71/0.98<br>0.56/0.70<br>0.43/0.60 | 1.16/1.40<br>0.93/1.07<br>0.68/0.90 | V/ns  |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>40 pF<br>50 pF | 0.24/0.36<br>0.19/0.25<br>0.13/0.21 | 0.41/0.59<br>0.32/0.35<br>0.23/0.33 | 0.66/0.87<br>0.51/0.59<br>0.36/0.48 | V/ns  |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF          | 22<br>23                            | 62<br>65                            | 148<br>151                          | mA/ns |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF          | 15<br>16                            | 42<br>44                            | 102<br>107                          | mA/ns |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF          | 7<br>8                              | 21<br>22                            | 52<br>54                            | mA/ns |

**Table 20. AC Electrical Characteristics of GPIO Pins in Fast Slew Rate Mode**  
[NVCC = 2.25 V–2.75 V]

| Parameter  | Symbol | Test Condition | Min.<br>Rise/Fall | Typ. | Max.<br>Rise/Fall | Units | Notes |
|------------|--------|----------------|-------------------|------|-------------------|-------|-------|
| Duty cycle | Fduty  | —              | 40                | —    | 60                | %     | —     |

**Table 20. AC Electrical Characteristics of GPIO Pins in Fast Slew Rate Mode**  
[NVCC = 2.25 V–2.75 V] (continued)

| Parameter                             | Symbol | Test Condition          | Min. Rise/Fall                      | Typ.                                | Max. Rise/Fall                      | Units | Notes |
|---------------------------------------|--------|-------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------|-------|
| Output pin slew rate (max. drive)     | tps    | 25 pF<br>40 pF<br>50 pF | 0.84/1.10<br>0.68/0.83<br>0.58/0.72 | 1.45/1.80<br>1.14/1.34<br>0.86/1.10 | 2.40/2.80<br>1.88/2.06<br>1.40/1.70 | V/ns  | 2     |
| Output pin slew rate (high drive)     | tps    | 25 pF<br>40 pF<br>50 pF | 0.69/0.96<br>0.55/0.69<br>0.40/0.59 | 1.18/1.50<br>0.92/1.10<br>0.67/0.95 | 1.90/2.30<br>1.49/1.67<br>1.10/1.30 | V/ns  |       |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>40 pF<br>50 pF | 0.24/0.36<br>0.37/0.47<br>0.13/0.21 | 0.80/1.00<br>0.62/0.76<br>0.45/0.65 | 1.30/1.60<br>1.00/1.14<br>0.70/0.95 | V/ns  |       |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF          | 46<br>49                            | 124<br>131                          | 310<br>324                          | mA/ns | 3     |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF          | 33<br>35                            | 89<br>94                            | 290<br>304                          | mA/ns |       |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF          | 28<br>29                            | 75<br>79                            | 188<br>198                          | mA/ns |       |

## 4.8.2 AC Electrical Characteristics for DDR Pins (DDR2, Mobile DDR, and SDRAM Modes)

**Table 21. AC Electrical Characteristics of DDR Type IO Pins in DDR2 Mode**

| Parameter            | Symbol | Test Condition | Min. Rise/Fall         | Typ.                  | Max. Rise/Fall         | Units |
|----------------------|--------|----------------|------------------------|-----------------------|------------------------|-------|
| Duty cycle           | Fduty  | —              | 45                     | 50                    | 55                     | %     |
| Clock frequency      | f      | —              | —                      | 133                   | —                      | MHz   |
| Output pin slew rate | tps    | 25 pF<br>50 pF | 0.86/0.98<br>0.46/0.54 | 1.35/1.5<br>0.72/0.81 | 2.15/2.19<br>1.12/1.16 | V/ns  |
| Output pin di/dt     | tdit   | 25 pF<br>50 pF | 65<br>70               | 157<br>167            | 373<br>396             | mA/ns |

**Table 22. AC Requirements of DDR2 Pins**

| Parameter <sup>1</sup>                                      | Symbol  | Min.             | Max.             | Units |
|-------------------------------------------------------------|---------|------------------|------------------|-------|
| AC input logic high                                         | VIH(ac) | NVCC ÷ 2 + 0.25  | NVCC + 0.3       | V     |
| AC input logic low                                          | VIL(ac) | –0.3             | NVCC ÷ 2 – 0.25  | V     |
| AC differential cross point voltage for output <sup>2</sup> | Vox(ac) | NVCC ÷ 2 – 0.125 | NVCC ÷ 2 + 0.125 | V     |

<sup>1</sup> The Jedec SSTL\_18 specification (JESD8-15a) for an SSTL interface for class II operation supersedes any specification in this document.

<sup>2</sup> The typical value of Vox(ac) is expected to be about 0.5 × NVCC and Vox(ac) is expected to track variation in NVCC. Vox(ac) indicates the voltage at which the differential output signal must cross. Load = 25 pF.

**Table 23. AC Electrical Characteristics of DDR Type IO Pins in mDDR Mode**

| Parameter                             | Symbol | Test Condition | Min.<br>Rise/Fall      | Typ.                   | Max.<br>Rise/Fall      | Units |
|---------------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Duty cycle                            | Fduty  | —              | 45                     | 50                     | 55                     | %     |
| Clock frequency                       | f      | —              | —                      | 133                    | —                      | MHz   |
| Output pin slew rate (max. drive)     | tps    | 25 pF<br>50 pF | 0.80/0.92<br>0.43/0.50 | 1.35/1.50<br>0.72/0.81 | 2.23/2.27<br>1.66/1.68 | V/ns  |
| Output pin slew rate (high drive)     | tps    | 25 pF<br>50 pF | 0.37/0.43<br>0.19/0.23 | 0.62/0.70<br>0.33/0.37 | 1.03/1.05<br>0.75/0.77 | V/ns  |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>50 pF | 0.18/0.22<br>0.10/0.12 | 0.31/0.35<br>0.16/0.18 | 0.51/0.53<br>0.38/0.39 | V/ns  |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF | 64<br>69               | 171<br>183             | 407<br>432             | mA/ns |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF | 37<br>39               | 100<br>106             | 232<br>246             | mA/ns |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF | 18<br>20               | 50<br>52               | 116<br>123             | mA/ns |

**Table 24. AC Electrical Characteristics of DDR Type IO Pins in SDRAM Mode**

| Parameter                             | Symbol | Test Condition | Min.<br>Rise/Fall      | Min. Clock<br>Frequency | Max.<br>Rise/Fall      | Units |
|---------------------------------------|--------|----------------|------------------------|-------------------------|------------------------|-------|
| Clock frequency                       | f      | —              | —                      | 125                     | —                      | MHz   |
| Output pin slew rate (max. drive)     | tps    | 25 pF<br>50 pF | 1.11/1.20<br>0.97/0.65 | 1.74/1.75<br>0.92/0.94  | 2.42/2.46<br>1.39/1.30 | V/ns  |
| Output pin slew rate (high drive)     | tps    | 25 pF<br>50 pF | 0.76/0.80<br>0.40/0.43 | 1.16/1.19<br>0.61/0.63  | 1.76/1.66<br>0.93/0.87 | V/ns  |
| Output pin slew rate (standard drive) | tps    | 25 pF<br>50 pF | 0.38/0.41<br>0.20/0.22 | 0.59/0.60<br>0.31/0.32  | 0.89/0.82<br>0.47/0.43 | V/ns  |
| Output pin di/dt (max. drive)         | tdit   | 25 pF<br>50 pF | 89<br>94               | 198<br>209              | 398<br>421             | mA/ns |
| Output pin di/dt (high drive)         | tdit   | 25 pF<br>50 pF | 59<br>62               | 132<br>139              | 265<br>279             | mA/ns |
| Output pin di/dt (standard drive)     | tdit   | 25 pF<br>50 pF | 29<br>31               | 65<br>69                | 132<br>139             | mA/ns |

**Table 25. AC Electrical Characteristics of DDR Type IO Pins in SDRAM Mode Max Drive (1.8 V)**

| Parameter                                      | Symbol | Test Condition | Min.<br>Rise/Fall      | Typ.                   | Max.<br>Rise/Fall      | Units |
|------------------------------------------------|--------|----------------|------------------------|------------------------|------------------------|-------|
| Clock frequency                                | f      | —              | 125                    | —                      | —                      | MHz   |
| Output pin slew rate (max. drive) <sup>1</sup> | tps    | 25 pF<br>50 pF | 2.83/2.68<br>1.59/1.49 | 1.84/1.85<br>1.03/1.05 | 1.21/1.40<br>0.70/0.75 | V/ns  |

**Table 25. AC Electrical Characteristics of DDR Type IO Pins in SDRAM Mode Max Drive (1.8 V) (continued)**

| Parameter                                  | Symbol | Test Condition | Min.<br>Rise/Fall | Typ.       | Max.<br>Rise/Fall | Units |
|--------------------------------------------|--------|----------------|-------------------|------------|-------------------|-------|
| Output pin di/dt (max. drive) <sup>2</sup> | didt   | 25 pF<br>50 pF | 89<br>95          | 202<br>213 | 435<br>456        | mA/ns |
| Input pin transition times <sup>3</sup>    | trfi   | 1.0 pF         | 0.07/0.08         | 0.11/0.12  | 0.16/0.20         | ns    |
| Input pin propagation delay, 50%–50%       | tpi    | 1.0 pF         | 0.35/1.17         | 0.63/1.53  | 1.16/2.04         | ns    |
| Input pin propagation delay, 40%–60%       | tpi    | 1.0 pF         | 1.18/1.99         | 1.45/2.35  | 1.97/2.85         | ns    |

<sup>1</sup> Min. condition for tps: wcs model, 1.1 V, IO 1.65 V, and 105 °C. tps is measured between VIL to VIH for rising edge and between VIH to VIL for falling edge.

<sup>2</sup> Max. condition for didt: bcs model, 1.3 V, IO 1.95 V, and –40 °C.

<sup>3</sup> Max. condition for tpi and trfi: wcs model, 1.1 V, IO 1.65 V and 105 °C. Min. condition for tpi and trfi: bcs model, 1.3 V, IO 1.95 V and –40 °C. Input transition time from pad is 5 ns (20%–80%).

## 4.9 Module-Level AC Electrical Specifications

This section contains the AC electrical information (including timing specifications) for the modules of the i.MX35. The modules are listed in alphabetical order.

### 4.9.1 AUDMUX Electrical Specifications

The AUDMUX provides a programmable interconnect logic for voice, audio and data routing between internal serial interfaces (SSI) and external serial interfaces (audio and voice codecs). The AC timing of AUDMUX external pins is hence governed by the SSI module. See the electrical specification for SSI.

### 4.9.2 CSPI AC Electrical Specifications

The i.MX35 provides two CSPI modules. CSPI ports are multiplexed in the i.MX35 with other pins. See the “External Signals and Multiplexing” chapter of the reference manual for more details.



Figure 7 and Figure 8 depict the master mode and slave mode timings of the CSPI, and Table 26 lists the timing parameters.

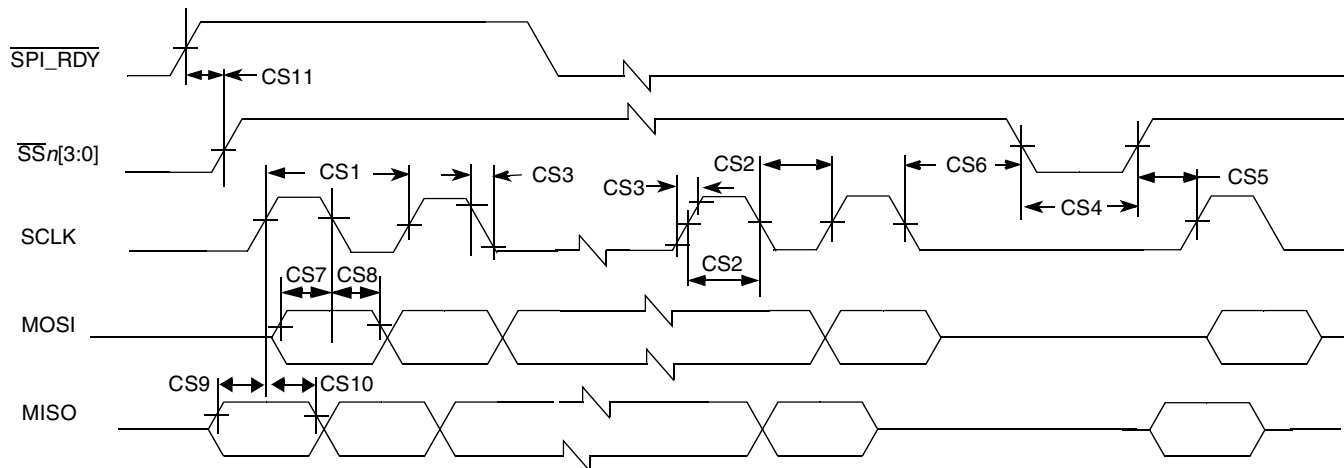


Figure 7. CSPI Master Mode Timing Diagram

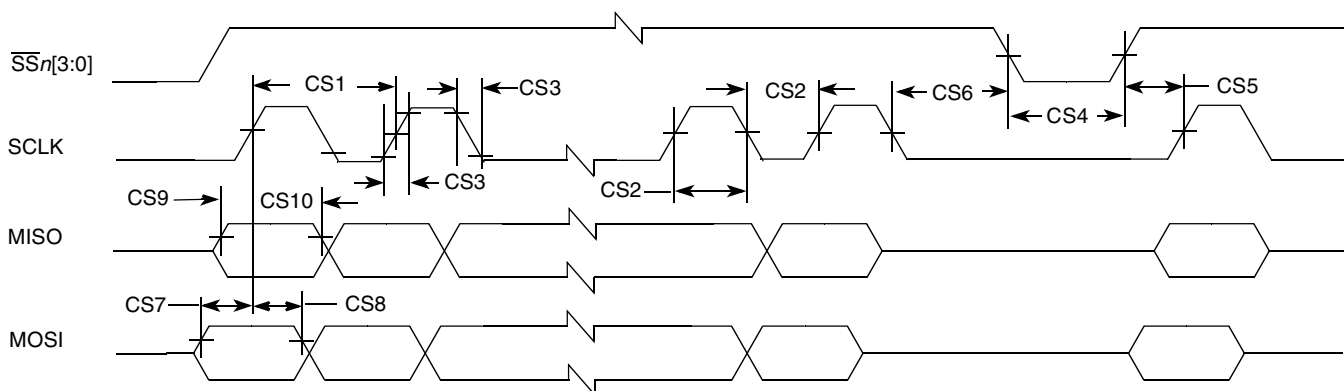


Figure 8. CSPI Slave Mode Timing Diagram

Table 26. CSPI Interface Timing Parameters

| ID  | Parameter                                       | Symbol          | Min. | Max. | Units |
|-----|-------------------------------------------------|-----------------|------|------|-------|
| CS1 | SCLK cycle time                                 | $t_{clk}$       | 60   | —    | ns    |
| CS2 | SCLK high or low time                           | $t_{SW}$        | 30   | —    | ns    |
| CS3 | SCLK rise or fall                               | $t_{RISE/FALL}$ | —    | 7.6  | ns    |
| CS4 | $\overline{SSn}[3:0]$ pulse width               | $t_{CSLH}$      | 30   | —    | ns    |
| CS5 | $\overline{SSn}[3:0]$ lead time (CS setup time) | $t_{SCS}$       | 30   | —    | ns    |
| CS6 | $\overline{SSn}[3:0]$ lag time (CS hold time)   | $t_{HCS}$       | 30   | —    | ns    |
| CS7 | MOSI setup time                                 | $t_{Smosi}$     | 5    | —    | ns    |
| CS8 | MOSI hold time                                  | $t_{Hmosi}$     | 5    | —    | ns    |
| CS9 | MISO setup time                                 | $t_{Smiso}$     | 5    | —    | ns    |

**Table 26. CSPI Interface Timing Parameters (continued)**

| ID   | Parameter                        | Symbol      | Min. | Max. | Units |
|------|----------------------------------|-------------|------|------|-------|
| CS10 | MISO hold time                   | $t_{Hmiso}$ | 5    | —    | ns    |
| CS11 | $\overline{SPI\_RDY}$ setup time | $t_{SDRY}$  | 5    | —    | ns    |

### 4.9.3 DPLL Electrical Specifications

There are three PLLs inside the i.MX35, all based on the same PLL design. The reference clock for these PLLs is normally generated from an external 24-MHz crystal connected to an internal oscillator via EXTAL24M and XTAL24 pins. It is also possible to connect an external 24-MHz clock directly to EXTAL24M, bypassing the internal oscillator.

DPLL specifications are listed in [Table 27](#).

**Table 27. DPLL Specifications**

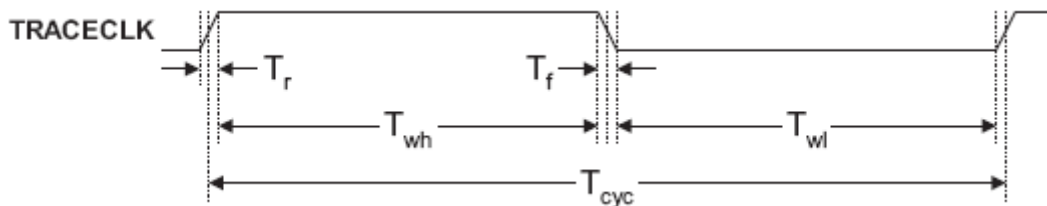
| Parameter                                        | Min. | Typ. | Max.                 | Unit                | Comments                                                                     |
|--------------------------------------------------|------|------|----------------------|---------------------|------------------------------------------------------------------------------|
| Reference clock frequency                        | 10   | 24   | 100                  | MHz                 |                                                                              |
| Max. allowed reference clock phase noise         | —    | —    | 0.03<br>0.01<br>0.15 | 2 Tdck <sup>1</sup> | Fmodulation < 50 kHz<br>50 kHz < Fmodulation 300 Hz<br>Fmodulation > 300 KHz |
| Frequency lock time (FOL mode or non-integer MF) | —    | —    | 80                   | μs                  | —                                                                            |
| Phase lock time                                  | —    | —    | 100                  | μs                  | —                                                                            |
| Max. allowed PL voltage ripple                   | —    | —    | 150<br>100<br>150    | mV                  | Fmodulation < 50 kHz<br>50 kHz < Fmodulation 300 Hz<br>Fmodulation > 300 KHz |

<sup>1</sup> There are two PLL are used in the i.MX35, MPLL and PPLL. Both are based on same DPLL design.

### 4.9.4 Embedded Trace Macrocell (ETM) Electrical Specifications

ETM is an ARM protocol. The timing specifications in this section are given as a guide for a test point access (TPA) that supports TRACECLK frequencies up to 133 MHz.

[Figure 9](#) depicts the TRACECLK timings of ETM, and [Table 28](#) lists the timing parameters.

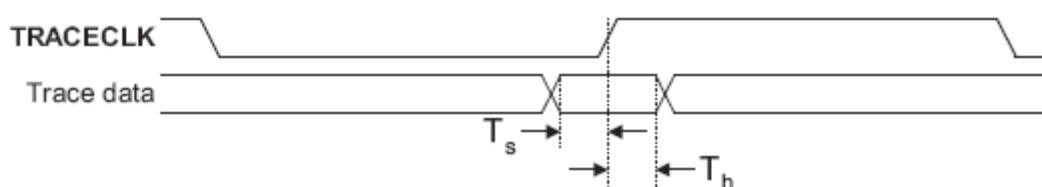


**Figure 9. ETM TRACECLK Timing Diagram**

**Table 28. ETM TRACECLK Timing Parameters**

| ID        | Parameter                | Min.                | Max. | Unit |
|-----------|--------------------------|---------------------|------|------|
| $T_{cyc}$ | Clock period             | Frequency dependent | —    | ns   |
| $T_{wl}$  | Low pulse width          | 2                   | —    | ns   |
| $T_{wh}$  | High pulse width         | 2                   | —    | ns   |
| $T_r$     | Clock and data rise time | —                   | 3    | ns   |
| $T_f$     | Clock and data fall time | —                   | 3    | ns   |

Figure 10 depicts the setup and hold requirements of the trace data pins with respect to TRACECLK, and Table 29 lists the timing parameters.



**Figure 10. Trace Data Timing Diagram**

**Table 29. ETM Trace Data Timing Parameters**

| ID    | Parameter  | Min. | Max. | Unit |
|-------|------------|------|------|------|
| $T_s$ | Data setup | 2    | —    | ns   |
| $T_h$ | Data hold  | 1    | —    | ns   |

#### 4.9.4.1 Half-Rate Clocking Mode

When half-rate clocking is used, the trace data signals are sampled by the TPA on both the rising and falling edges of TRACECLK, where TRACECLK is half the frequency of the clock shown in Figure 10. The same  $T_s$  and  $T_h$  parameters from Table 29 still apply with respect to the falling edge of the TRACECLK signal.

### 4.9.5 EMI Electrical Specifications

This section provides electrical parametrics and timing for the EMI module.

#### 4.9.5.1 NAND Flash Controller Interface (NFC)

The i.MX35 NFC supports normal timing mode, using two flash clock cycles for one access of  $\overline{RE}$  and  $\overline{WE}$ . AC timings are provided as multiplications of the clock cycle and fixed delay. Figure 11, Figure 12,

Figure 13, and Figure 14 depict the relative timing requirements among different signals of the NFC at module level for normal mode. Table 30 lists the timing parameters.

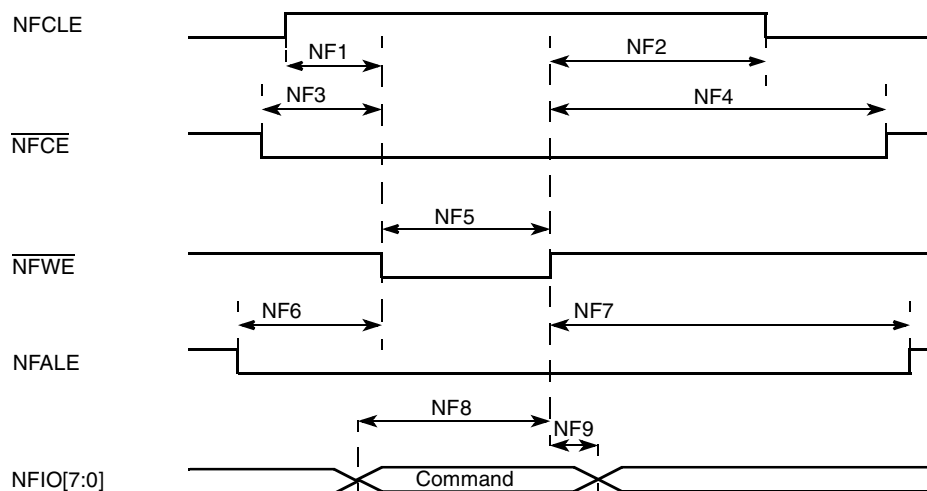


Figure 11. Command Latch Cycle Timing Diagram

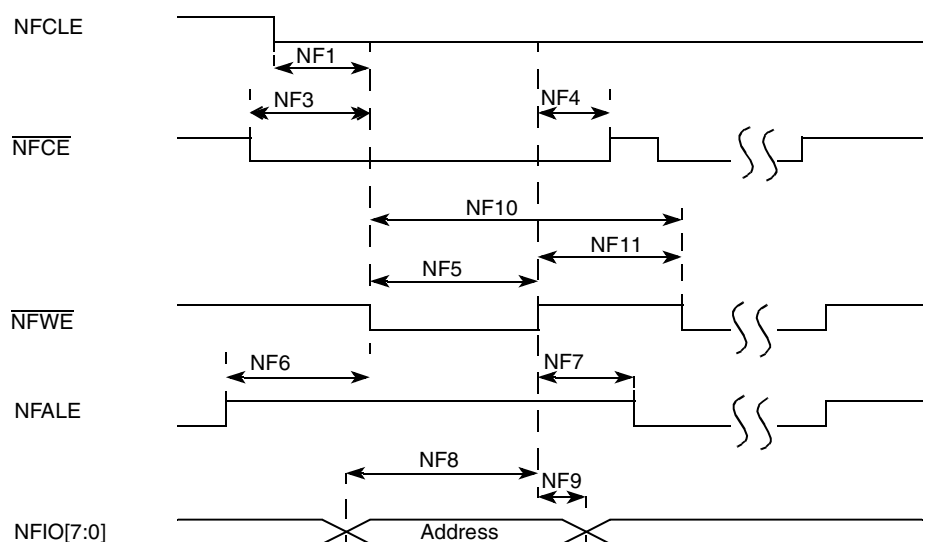
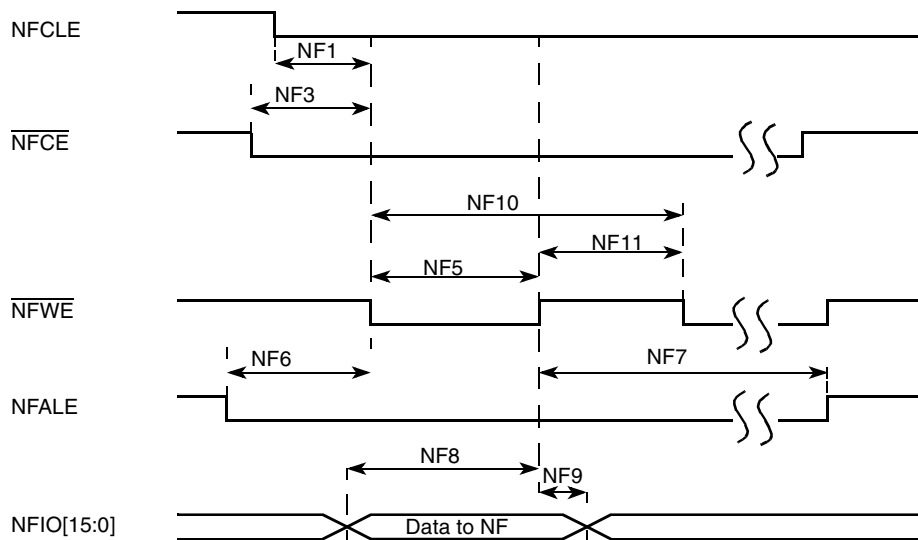
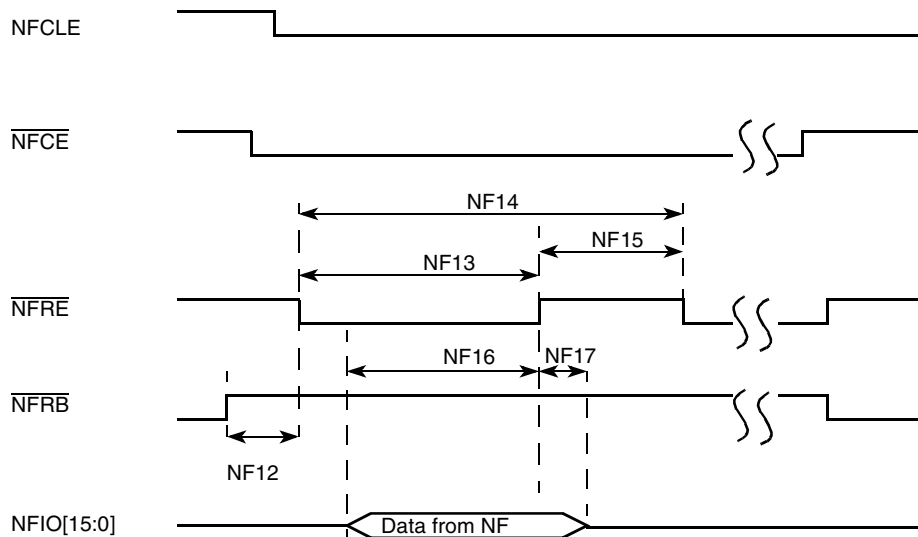


Figure 12. Address Latch Cycle Timing Diagram



**Figure 13. Write Data Latch Cycle Timing Diagram**



**Figure 14. Read Data Latch Cycle Timing Diagram**

**Table 30. NFC Timing Parameters<sup>1</sup>**

| ID  | Parameter                           | Symbol | Timing<br>T = NFC Clock Cycle <sup>2</sup> |      | Example Timing for<br>NFC Clock ≈ 33 MHz<br>T = 30 ns |      | Unit |
|-----|-------------------------------------|--------|--------------------------------------------|------|-------------------------------------------------------|------|------|
|     |                                     |        | Min.                                       | Max. | Min.                                                  | Max. |      |
| NF1 | NFCLE setup time                    | tCLS   | T – 1.0 ns                                 | —    | 29                                                    | —    | ns   |
| NF2 | NFCLE hold time                     | tCLH   | T – 2.0 ns                                 | —    | 25                                                    | —    | ns   |
| NF3 | $\overline{\text{NFCE}}$ setup time | tCS    | T – 1.0 ns                                 | —    | 29                                                    | —    | ns   |
| NF4 | $\overline{\text{NFCE}}$ hold time  | tCH    | T – 2.0 ns                                 | —    | 209                                                   | —    | ns   |

**Table 30. NFC Timing Parameters<sup>1</sup> (continued)**

| ID   | Parameter                                                 | Symbol | Timing<br>T = NFC Clock Cycle <sup>2</sup> |      | Example Timing for<br>NFC Clock $\approx$ 33 MHz<br>T = 30 ns |      | Unit |
|------|-----------------------------------------------------------|--------|--------------------------------------------|------|---------------------------------------------------------------|------|------|
|      |                                                           |        | Min.                                       | Max. | Min.                                                          | Max. |      |
| NF5  | $\overline{\text{NF\_WP}}$ pulse width                    | tWP    | T – 1.5 ns                                 |      | 29.5                                                          |      | ns   |
| NF6  | NFALE setup time                                          | tALS   | T                                          | —    | 30                                                            | —    | ns   |
| NF7  | NFALE hold time                                           | tALH   | T – 3.0 ns                                 | —    | 27.5                                                          | —    | ns   |
| NF8  | Data setup time                                           | tDS    | T                                          | —    | 30                                                            | —    | ns   |
| NF9  | Data hold time                                            | tDH    | T – 5.0 ns                                 | —    | 106                                                           | —    | ns   |
| NF10 | Write cycle time                                          | tWC    | 2T                                         |      | 59                                                            |      | ns   |
| NF11 | $\overline{\text{NFW}}\overline{\text{E}}$ hold time      | tWH    | T – 2.5 ns                                 |      | 27                                                            |      | ns   |
| NF12 | Ready to $\overline{\text{NFR}}\overline{\text{E}}$ low   | tRR    | 6T                                         | —    | 8400                                                          | —    | ns   |
| NF13 | $\overline{\text{NFR}}\overline{\text{E}}$ pulse width    | tRP    | 1.5T                                       | —    | 44.5                                                          | —    | ns   |
| NF14 | READ cycle time                                           | tRC    | 2T                                         | —    | 58                                                            | —    | ns   |
| NF15 | $\overline{\text{NFR}}\overline{\text{E}}$ high hold time | tREH   | 0.5T – 2.5 ns                              |      | 11                                                            | —    | ns   |
| NF16 | Data setup on READ                                        | tDSR   | N/A                                        |      | 9                                                             | —    | ns   |
| NF17 | Data hold on READ                                         | tDHR   | N/A                                        |      | 52                                                            | —    | ns   |

<sup>1</sup> The flash clock maximum frequency is 50 MHz.

<sup>2</sup> Subject to DPLL jitter specification listed in [Table 27, "DPLL Specifications,"](#) on page 34.

## NOTE

High is defined as 80% of signal value and low is defined as 20% of signal value.

Timing for HCLK is 133 MHz and internal NFC clock (flash clock) is approximately 33 MHz (30 ns). All timings are listed according to this NFC clock frequency (multiples of NFC clock phases), except NF16 and NF17, which are not NFC clock related.

### 4.9.5.2 Wireless External Interface Module (WEIM)

All WEIM output control signals may be asserted and deasserted by internal clocks related to the BCLK rising edge or falling edge according to the corresponding assertion or negation control fields. The address always begins related to BCLK falling edge but may be ended both on rising and falling edge in muxed mode according to control register configuration. Output data begins related to BCLK rising edge except in muxed mode where both rising and falling edge may be used according to control register configuration.

Input data,  $\overline{ECB}$  and  $\overline{DTACK}$  all captured according to BCLK rising edge time. Figure 15 depicts the timing of the WEIM module, and Table 31 lists the timing parameters.

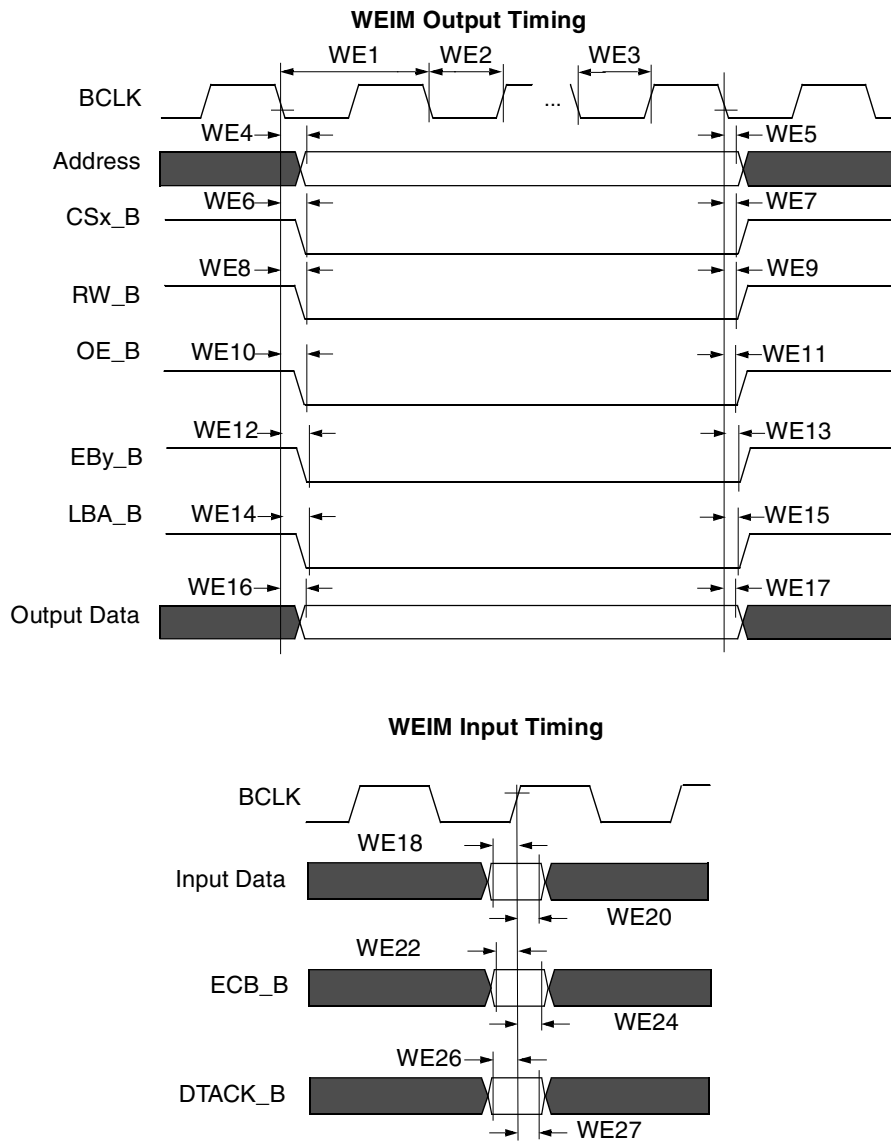


Figure 15. WEIM Bus Timing Diagram

**Table 31. WEIM Bus Timing Parameters<sup>1</sup>**

| ID   | Parameter                                     | Min. | Max. | Unit |
|------|-----------------------------------------------|------|------|------|
| WE1  | BCLK cycle time <sup>2</sup>                  | 14.5 | —    | ns   |
| WE2  | BCLK low-level width <sup>2</sup>             | 7    | —    | ns   |
| WE3  | BCLK high-level width <sup>2</sup>            | 7    | —    | ns   |
| WE4  | Clock fall to address valid                   | 15   | 21   | ns   |
| WE5  | Clock rise/fall to address invalid            | 22   | 25   | ns   |
| WE6  | Clock rise/fall to CSx_B valid                | 15   | 19   | ns   |
| WE7  | Clock rise/fall to CSx_B invalid              | 3.6  | 5    | ns   |
| WE8  | Clock rise/fall to RW_B valid                 | 8    | 12   | ns   |
| WE9  | Clock rise/fall to RW_B invalid               | 3    | 8    | ns   |
| WE10 | Clock rise/fall to OE_B valid                 | 7    | 12   | ns   |
| WE11 | Clock rise/fall to OE_B invalid               | 3.8  | 5.5  | ns   |
| WE12 | Clock rise/fall to EBy_B valid                | 6    | 11.5 | ns   |
| WE13 | Clock rise/fall to EBy_B invalid              | 6    | 10   | ns   |
| WE14 | Clock rise/fall to LBA_B valid                | 17.5 | 20   | ns   |
| WE15 | Clock rise/fall to LBA_B invalid              | 0    | 1    | ns   |
| WE16 | Clock rise/fall to Output Data valid          | 5    | 10   | ns   |
| WE17 | Clock rise to Output Data invalid             | 0    | 2.5  | ns   |
| WE18 | Input Data Valid to Clock rise <sup>3</sup>   | 1    | —    | ns   |
| WE20 | Clock rise to Input Data invalid <sup>3</sup> | 1    | —    | ns   |
| WE22 | ECB_B setup time <sup>3</sup>                 | 5    | —    | ns   |
| WE24 | ECB_B hold time <sup>3</sup>                  | 0    | —    | ns   |
| WE26 | DTACK_B setup time                            | 5.4  | —    | ns   |
| WE27 | DTACK_B hold time                             | –3.2 | —    | ns   |

<sup>1</sup> “High” is defined as 80% of signal value, and “low” is defined as 20% of signal value.

<sup>2</sup> BCLK parameters are measured from the 50% point. For example, “high” is defined as 50% of signal value and “low” is defined as 50% of signal value.

<sup>3</sup> Parameters W18, W20, W22, and W24 are tested when FCE=1. i.MX35 does not support FCE=0.

## NOTE

Test conditions: load capacitance, 25 pF. Recommended drive strength for all controls, address, and BCLK is set to maximum drive.

Recommended drive strength for all controls, address and BCLK is set to maximum drive.



Figure 16 through Figure 21 depict some examples of basic WEIM accesses to external memory devices with the timing parameters mentioned in Table 31 for specific control parameter settings.

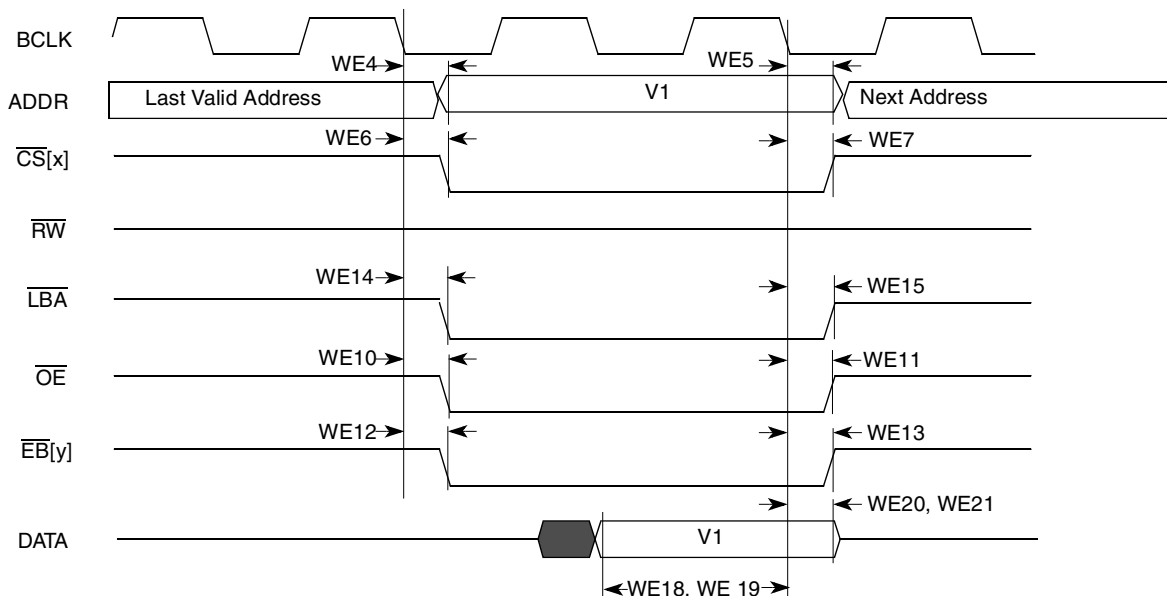


Figure 16. Synchronous Memory Timing Diagram for Read Access—WSC = 1

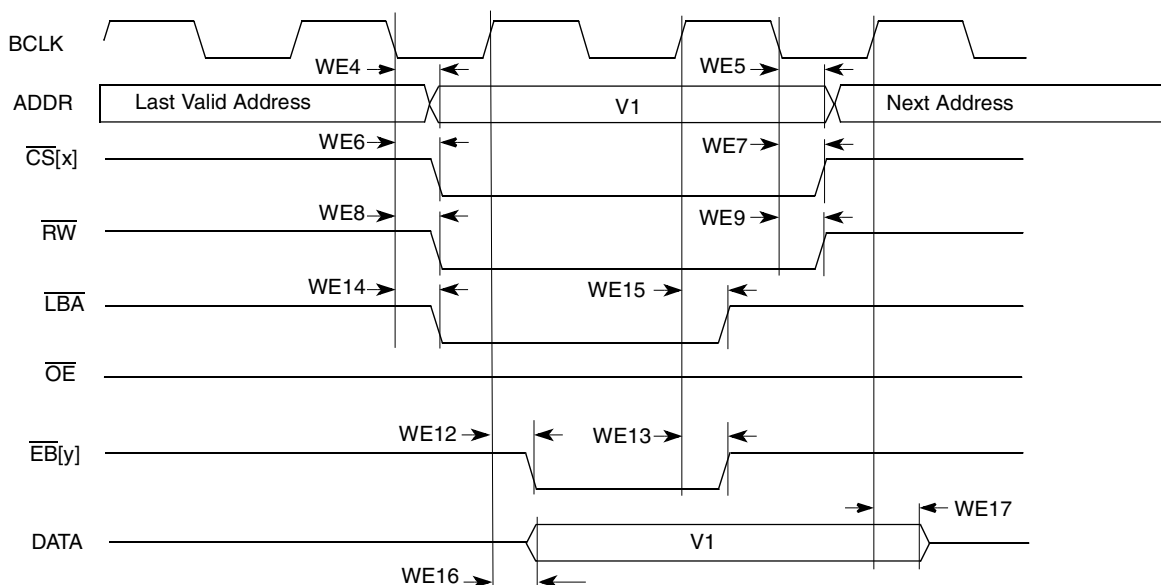
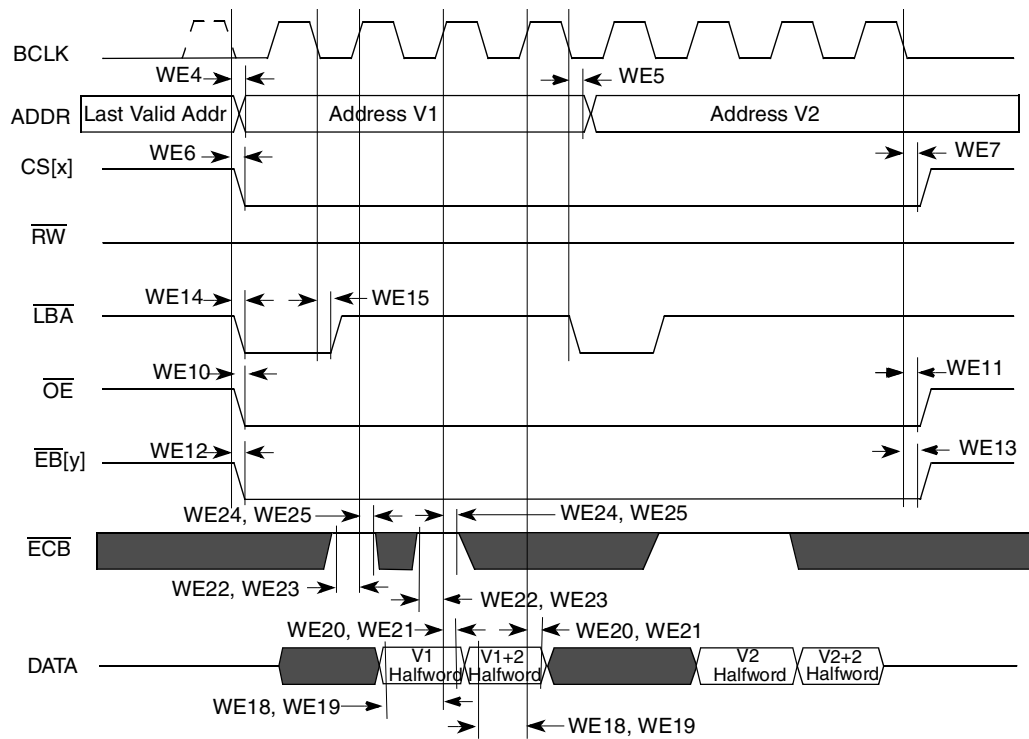
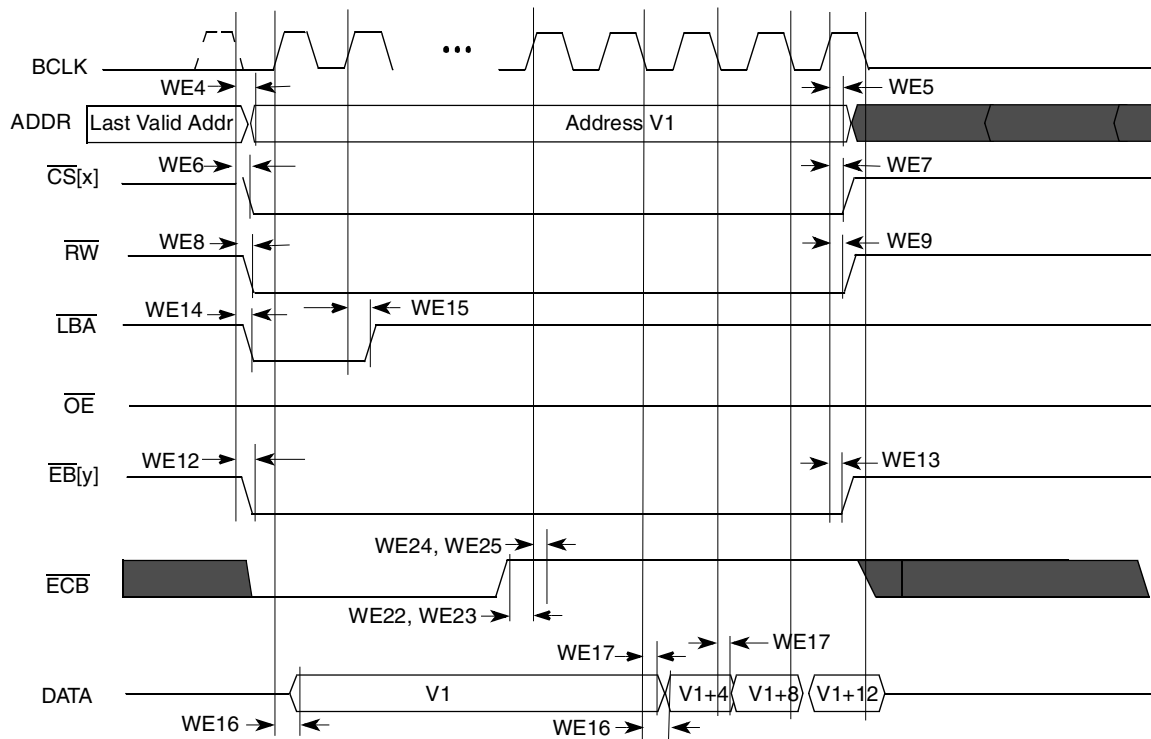


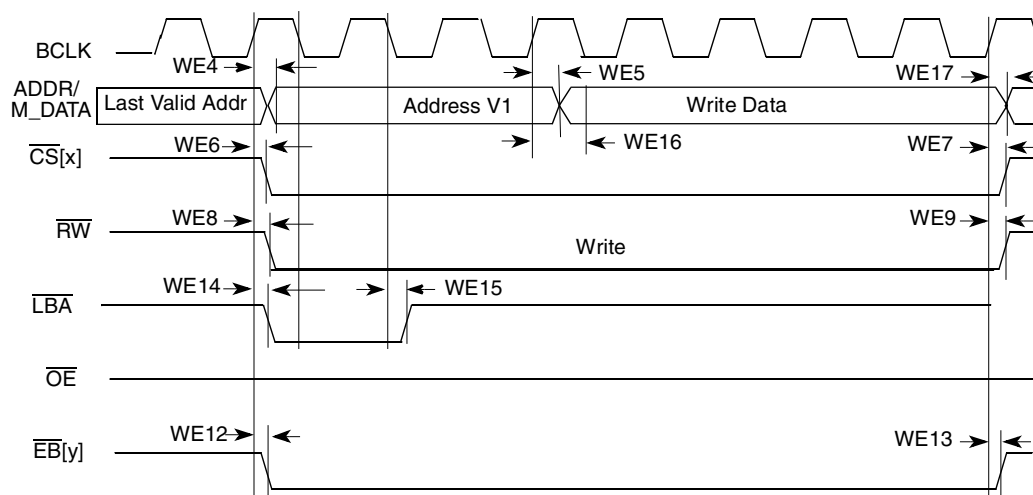
Figure 17. Synchronous Memory Timing Diagram for Write Access—WSC = 1, EBWA = 1, EBWN = 1, LBN = 1



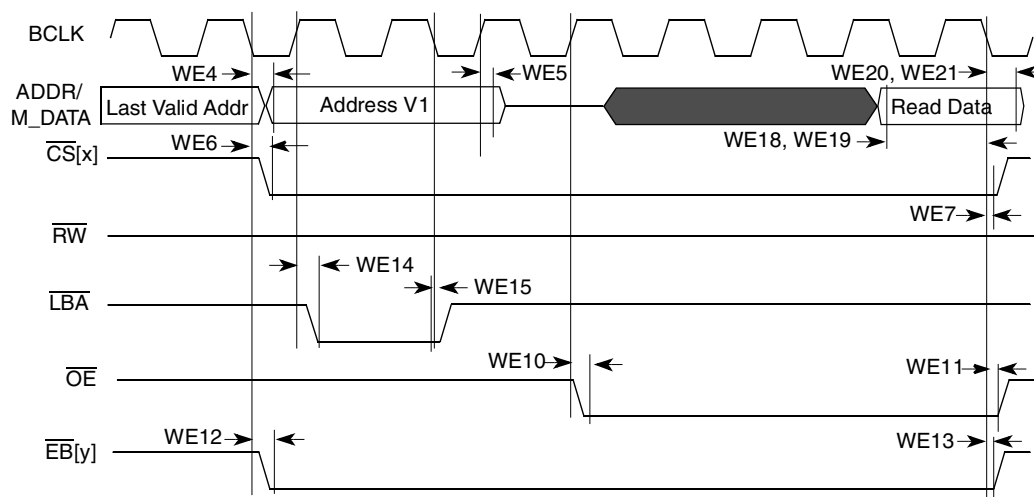
**Figure 18. Synchronous Memory Timing Diagram for Two Non-Sequential Read Accesses—  
WSC = 2, SYNC = 1, DOL = 0**



**Figure 19. Synchronous Memory Timing Diagram for Burst Write Access—  
BCS = 1, WSC = 4, SYNC = 1, DOL = 0, PSR = 1**



**Figure 20. Muxed A/D Mode Timing Diagram for Synchronous Write Access—  
WSC = 7, LBA = 1, LBN = 1, LAH = 1**



**Figure 21. Muxed A/D Mode Timing Diagram for Synchronous Read Access—  
WSC = 7, LBA = 1, LBN = 1, LAH = 1, OEA = 7**

Figure 22 through Figure 26, and Table 32 help to determine timing parameters relative chip select (CS) state for asynchronous and DTACK WEIM accesses with corresponding WEIM bit fields and the timing parameters mentioned above.

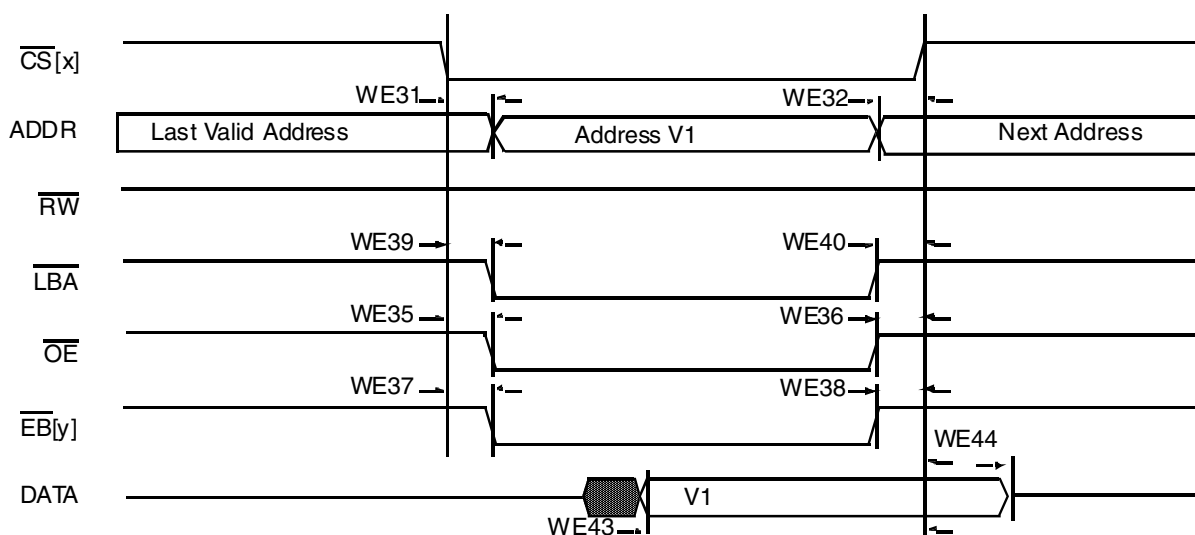


Figure 22. Asynchronous Memory Read Access

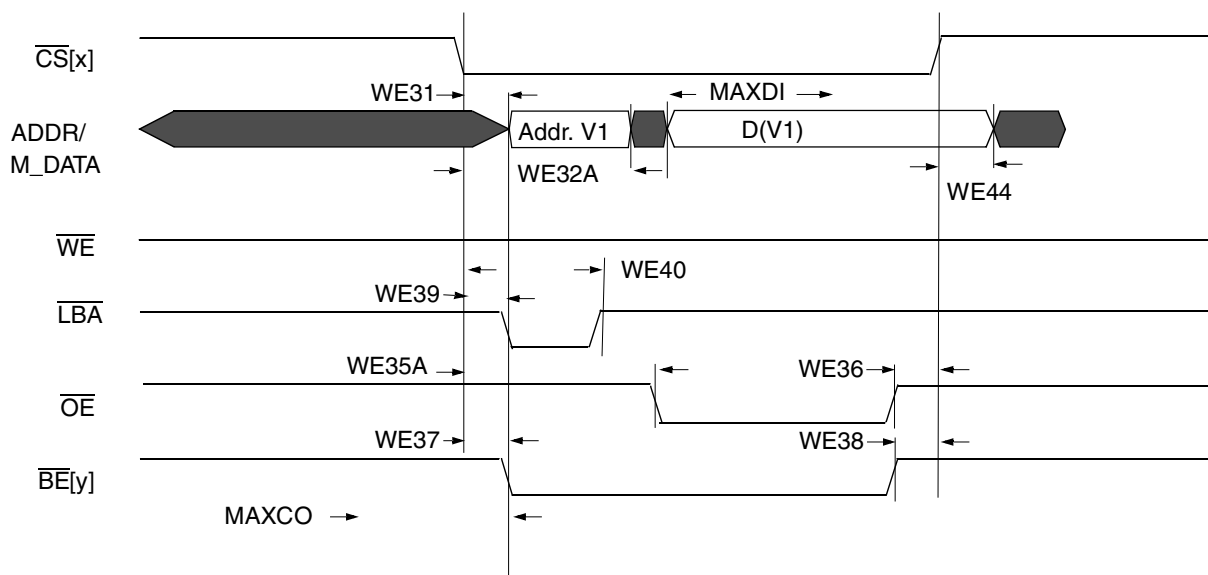
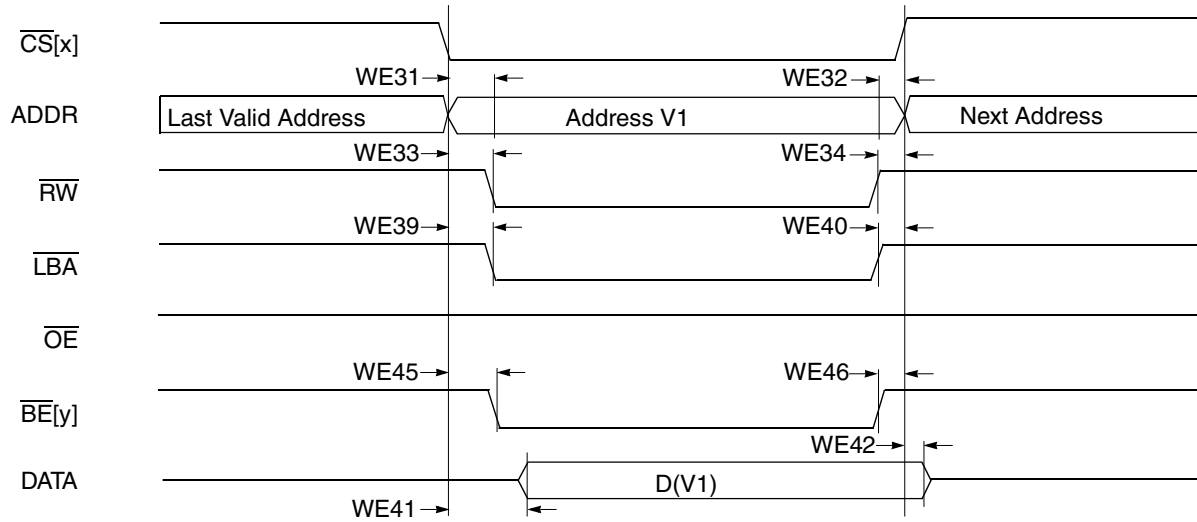
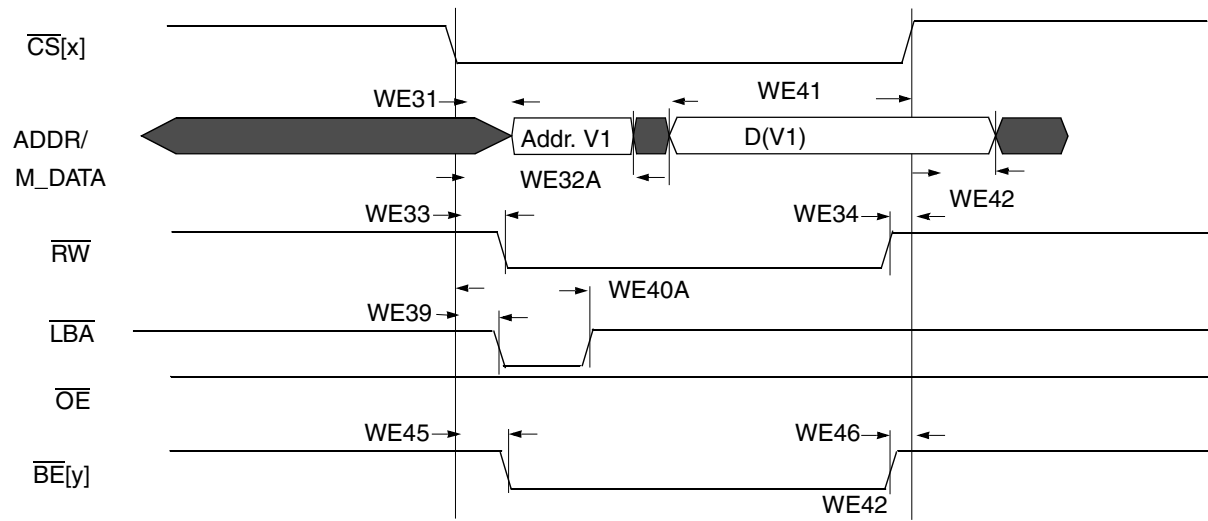


Figure 23. Asynchronous A/D muxed Read Access (RWSC = 5)



**Figure 24. Asynchronous Memory Write Access**



**Figure 25. Asynchronous A/D Mux Write Access**

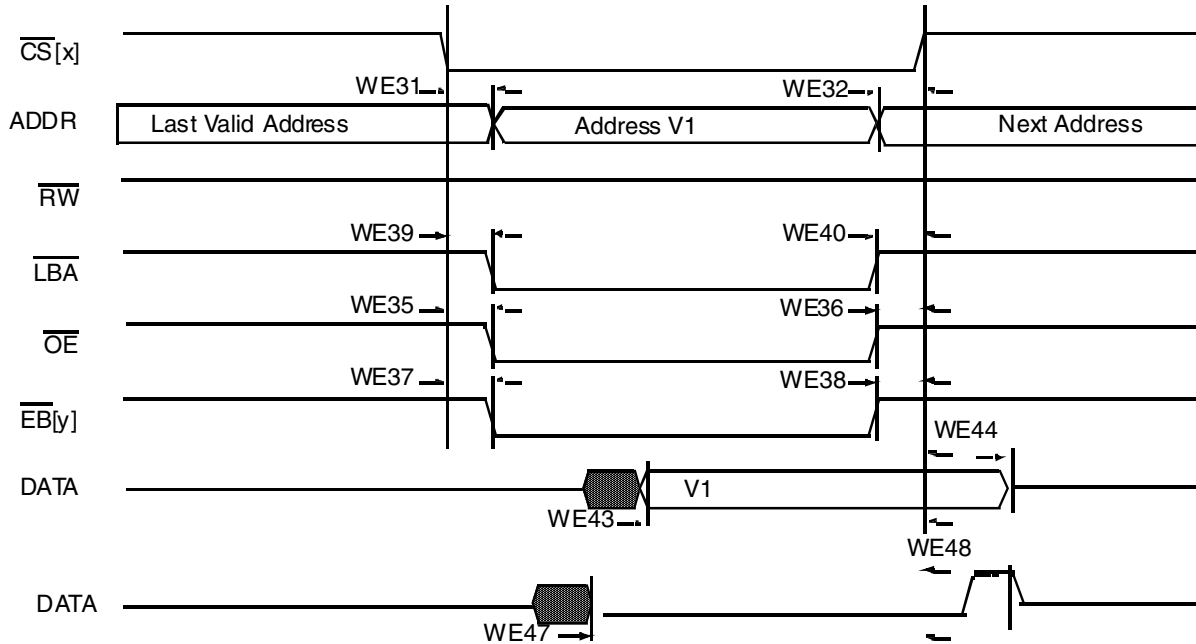


Figure 26. DTACK Read Access

Table 32. WEIM Asynchronous Timing Parameters Relative Chip Select Table

| Ref No.           | Parameter                                                              | Determination By Synchronous Measured Parameters <sup>1</sup> | Min                                        | Max (If 133 MHz is supported by SoC)      | Unit |
|-------------------|------------------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------|-------------------------------------------|------|
| WE31              | $\overline{CS}[x]$ valid to Address valid                              | $WE4 - WE6 - CSA^2$                                           | —                                          | $3 - CSA$                                 | ns   |
| WE32              | Address invalid to $\overline{CS}[x]$ invalid                          | $WE7 - WE5 - CSN^3$                                           | —                                          | $3 - CSN$                                 | ns   |
| WE32A (muxed A/D) | $\overline{CS}[x]$ valid to address invalid                            | $WE4 - WE7 + (LBN + LBA + 1 - CSA^2)$                         | $-3 + (LBN + LBA + 1 - CSA)$               | —                                         | ns   |
| WE33              | $\overline{CS}[x]$ valid to $\overline{WE}$ valid                      | $WE8 - WE6 + (WEA - CSA)$                                     | —                                          | $3 + (WEA - CSA)$                         | ns   |
| WE34              | $\overline{WE}$ invalid to $\overline{CS}[x]$ invalid                  | $WE7 - WE9 + (WEN - CSN)$                                     | —                                          | $3 - (WEN\_CSN)$                          | ns   |
| WE35              | $\overline{CS}[x]$ valid to $\overline{OE}$ valid                      | $WE10 - WE6 + (OEA - CSA)$                                    | —                                          | $3 + (OEA - CSA)$                         | ns   |
| WE35A (muxed A/D) | $\overline{CS}[x]$ valid to $\overline{OE}$ valid                      | $WE10 - WE6 + (OEA + RLBN + RLBA + ADH + 1 - CSA)$            | $-3 + (OEA + RLBN + RLBA + ADH + 1 - CSA)$ | $3 + (OEA + RLBN + RLBA + ADH + 1 - CSA)$ | ns   |
| WE36              | $\overline{OE}$ invalid to $\overline{CS}[x]$ invalid                  | $WE7 - WE11 + (OEN - CSN)$                                    | —                                          | $3 - (OEN - CSN)$                         | ns   |
| WE37              | $\overline{CS}[x]$ valid to $\overline{BE}[y]$ valid (read access)     | $WE12 - WE6 + (RBEA - CSA)$                                   | —                                          | $3 + (RBEA^4 - CSA)$                      | ns   |
| WE38              | $\overline{BE}[y]$ invalid to $\overline{CS}[x]$ invalid (read access) | $WE7 - WE13 + (RBEN - CSN)$                                   | —                                          | $3 - (RBEN^5 - CSN)$                      | ns   |
| WE39              | $\overline{CS}[x]$ valid to $\overline{LBA}$ valid                     | $WE14 - WE6 + (LBA - CSA)$                                    | —                                          | $3 + (LBA - CSA)$                         | ns   |
| WE40              | $\overline{LBA}$ invalid to $\overline{CS}[x]$ invalid                 | $WE7 - WE15 - CSN$                                            | —                                          | $3 - CSN$                                 | ns   |

**Table 32. WEIM Asynchronous Timing Parameters Relative Chip Select Table (continued)**

| Ref No.           | Parameter                                                               | Determination By Synchronous Measured Parameters <sup>1</sup> | Min                             | Max (If 133 MHz is supported by SoC) | Unit |
|-------------------|-------------------------------------------------------------------------|---------------------------------------------------------------|---------------------------------|--------------------------------------|------|
| WE40A (muxed A/D) | $\overline{CS}[x]$ valid to $\overline{LBA}$ invalid                    | $WE14 - WE6 + (LBN + LBA + 1 - CSA)$                          | $-3 + (LBN + LBA + 1 - CSA)$    | $3 + (LBN + LBA + 1 - CSA)$          | ns   |
| WE41              | $\overline{CS}[x]$ valid to Output Data valid                           | $WE16 - WE6 - WCSA$                                           | —                               | $3 - WCSA$                           | ns   |
| WE41A (muxed A/D) | $\overline{CS}[x]$ valid to Output Data valid                           | $WE16 - WE6 + (WLBN + WLBA + ADH + 1 - WCSA)$                 | —                               | $3 + (WLBN + WLBA + ADH + 1 - WCSA)$ | ns   |
| WE42              | Output Data invalid to $\overline{CS}[x]$ Invalid                       | $WE17 - WE7 - CSN$                                            | —                               | $3 - CSN$                            | ns   |
| WE43              | Input Data valid to $\overline{CS}[x]$ invalid                          | $MAXCO - MAXCSO + MAXDI$                                      | $MAXCO^6 - MAXCSO^7 + MAXDI^8$  | —                                    | ns   |
| WE44              | $\overline{CS}[x]$ invalid to Input Data invalid                        | 0                                                             | 0                               | —                                    | ns   |
| WE45              | $\overline{CS}[x]$ valid to $\overline{BE}[y]$ valid (write access)     | $WE12 - WE6 + (WBEA - CSA)$                                   | —                               | $3 + (WBEA - CSA)$                   | ns   |
| WE46              | $\overline{BE}[y]$ invalid to $\overline{CS}[x]$ invalid (write access) | $WE7 - WE13 + (WBEN - CSN)$                                   | —                               | $-3 + (WBEN - CSN)$                  | ns   |
| WE47              | $\overline{DTACK}$ valid to $\overline{CS}[x]$ invalid                  | $MAXCO - MAXCSO + MAXDTI$                                     | $MAXCO^6 - MAXCSO^7 + MAXDTI^9$ | —                                    | ns   |
| WE48              | $\overline{CS}[x]$ Invalid to $\overline{DTACK}$ invalid                | 0                                                             | 0                               | —                                    | ns   |

<sup>1</sup> For the value of parameters WE4–WE21, see column BCD = 0 in [Table 31](#).

<sup>2</sup>  $\overline{CS}$  Assertion. This bit field determines when the  $\overline{CS}$  signal is asserted during read/write cycles.

<sup>3</sup>  $\overline{CS}$  Negation. This bit field determines when the  $\overline{CS}$  signal is negated during read/write cycles.

<sup>4</sup>  $\overline{BE}$  Assertion. This bit field determines when the  $\overline{BE}$  signal is asserted during read cycles.

<sup>5</sup>  $\overline{BE}$  Negation. This bit field determines when the  $\overline{BE}$  signal is negated during read cycles.

<sup>6</sup> Output maximum delay from internal driving ADDR/control FFs to chip outputs.

<sup>7</sup> Output maximum delay from  $\overline{CS}[x]$  internal driving FFs to  $\overline{CS}[x]$  out.

<sup>8</sup> DATA maximum delay from chip input data to its internal FF.

<sup>9</sup>  $\overline{DTACK}$  maximum delay from chip dtack input to its internal FF.

**Note:** All configuration parameters (CSA, CSN, WBEA, WBEN, LBA, LBN, OEN, OEA, RBEA, and RBEN) are in cycle units.

### 4.9.5.3 ESDCTL Electrical Specifications

Figure 27 through Figure 36 depict the timings pertaining to the ESDCTL module, which interfaces with mobile DDR or SDR SDRAM. Table 33 through Table 42 list the timing parameters.

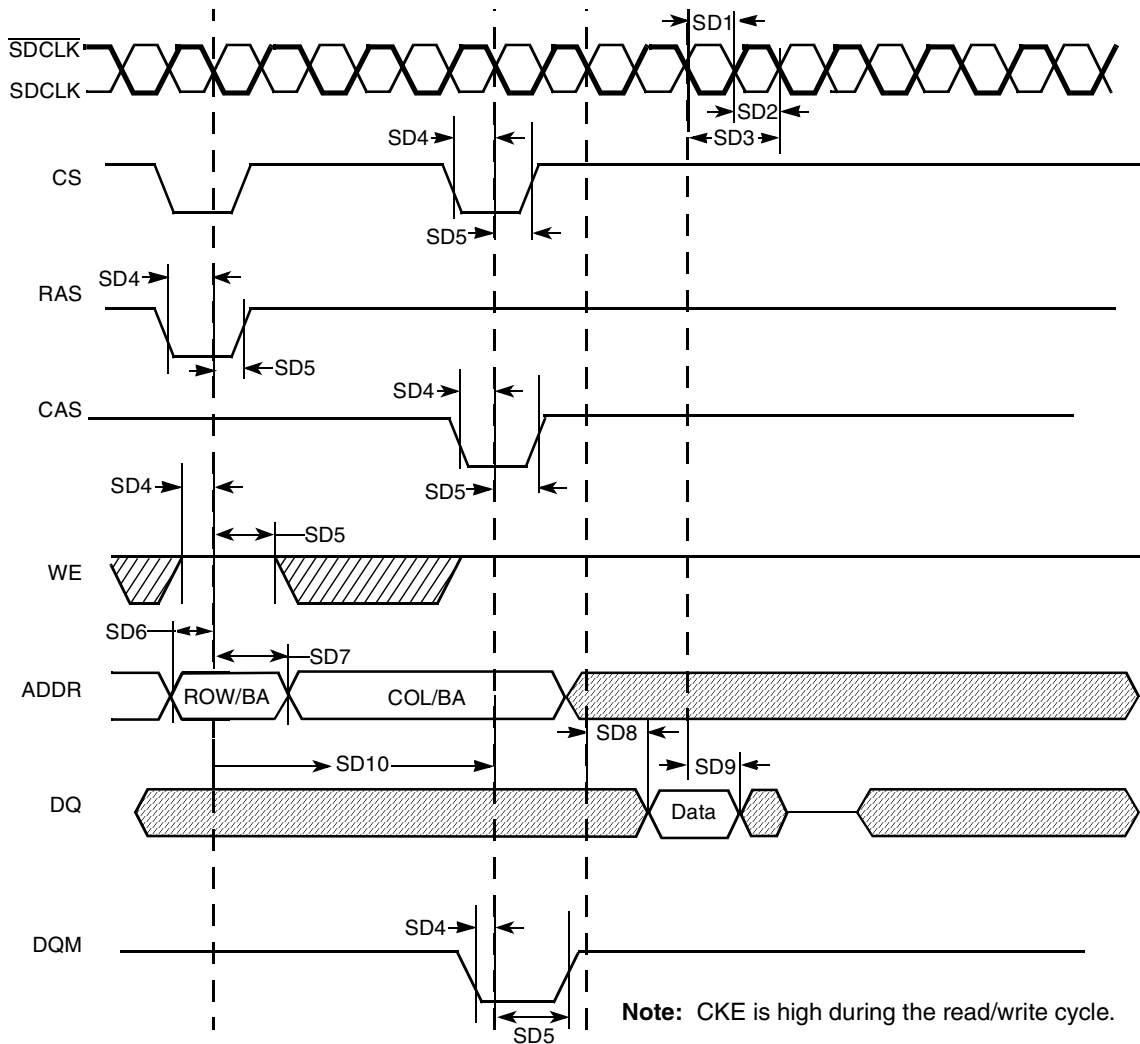


Figure 27. SDRAM Read Cycle Timing Diagram

Table 33. DDR/SDR SDRAM Read Cycle Timing Parameters

| ID  | Parameter                             | Symbol | Min. | Max. | Unit |
|-----|---------------------------------------|--------|------|------|------|
| SD1 | SDRAM clock high-level width          | tCH    | 3.4  | 4.1  | ns   |
| SD2 | SDRAM clock low-level width           | tCL    | 3.4  | 4.1  | ns   |
| SD3 | SDRAM clock cycle time                | tCK    | 7.0  | —    | ns   |
| SD4 | CS, RAS, CAS, WE, DQM, CKE setup time | tCMS   | 2.0  | —    | ns   |
| SD5 | CS, RAS, CAS, WE, DQM, CKE hold time  | tCMH   | 1.8  | —    | ns   |
| SD6 | Address setup time                    | tAS    | 2.0  | —    | ns   |



**Table 33. DDR/SDR SDRAM Read Cycle Timing Parameters (continued)**

| ID   | Parameter                           | Symbol | Min. | Max. | Unit  |
|------|-------------------------------------|--------|------|------|-------|
| SD7  | Address hold time                   | tAH    | 1.8  | —    | ns    |
| SD8  | SDRAM access time                   | tAC    | —    | 6.47 | ns    |
| SD9  | Data out hold time <sup>1</sup>     | tOH    | 1.2  | —    | ns    |
| SD10 | Active to read/write command period | tRC    | 10   | —    | clock |

<sup>1</sup> Timing parameters are relevant only to SDR SDRAM. For the specific DDR SDRAM data related timing parameters, see [Table 41](#) and [Table 42](#).

### NOTE

SDR SDRAM CLK parameters are measured from the 50% point—that is, high is defined as 50% of signal value and low is defined as 50% of signal value. SD1 + SD2 does not exceed 7.5 ns for 133 MHz.

The timing parameters are similar to the ones used in SDRAM data sheets—that is, [Table 33](#) indicates SDRAM requirements. All output signals are driven by the ESDCTL at the negative edge of SDCLK and the parameters are measured at maximum memory frequency.

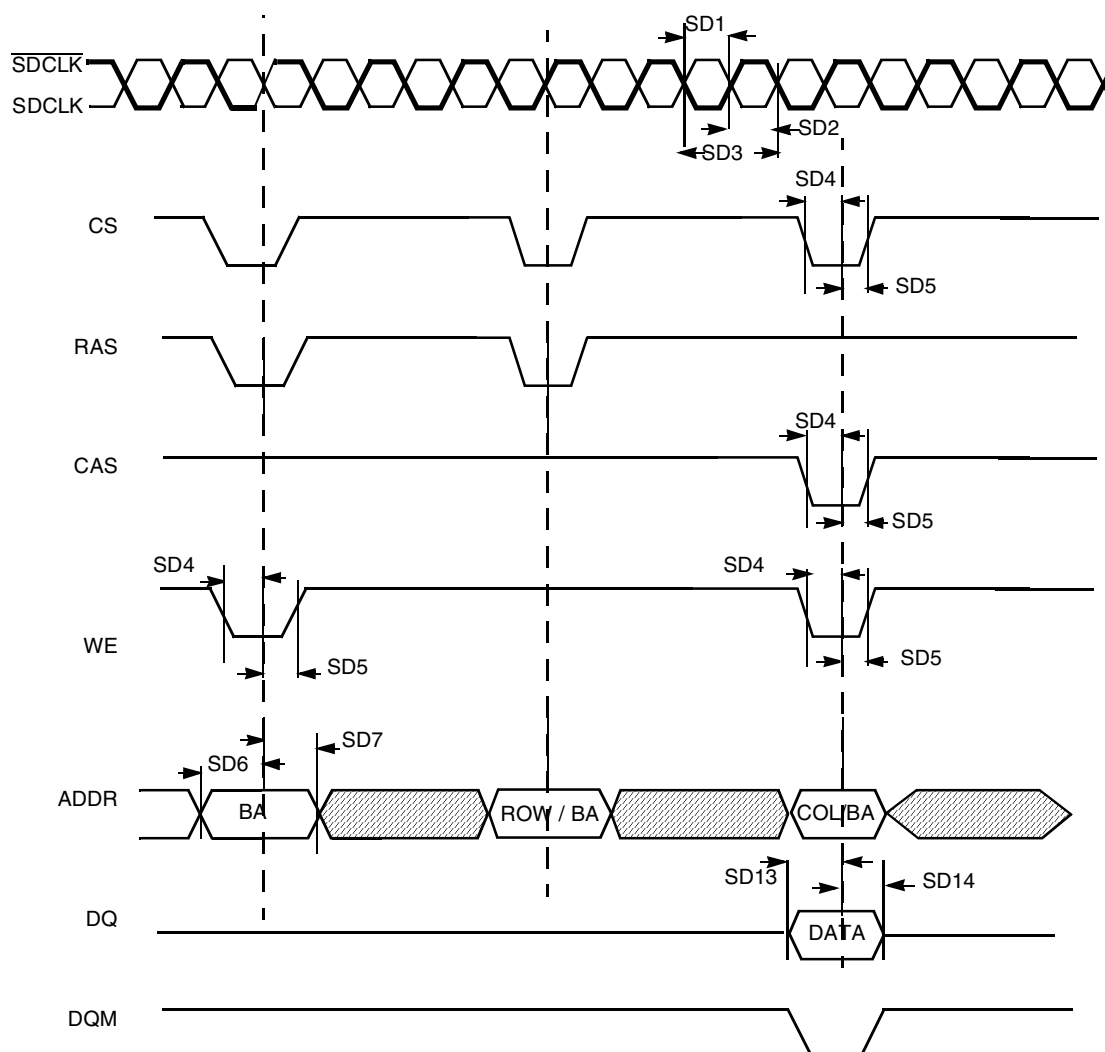


Figure 28. SDR SDRAM Write Cycle Timing Diagram

Table 34. SDR SDRAM Write Timing Parameters

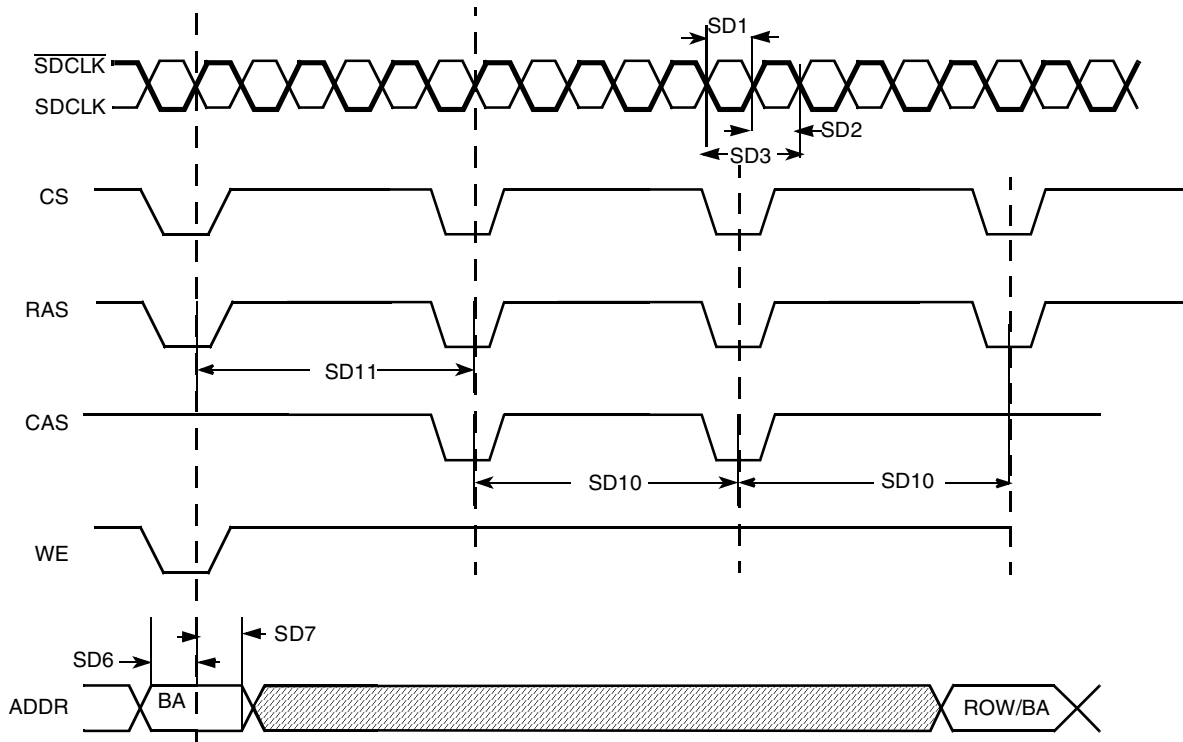
| ID   | Parameter                             | Symbol | Min. | Max. | Unit |
|------|---------------------------------------|--------|------|------|------|
| SD1  | SDRAM clock high-level width          | tCH    | 0.45 | 0.55 | ns   |
| SD2  | SDRAM clock low-level width           | tCL    | 0.45 | 0.55 | ns   |
| SD3  | SDRAM clock cycle time                | tCK    | 7.0  | —    | ns   |
| SD4  | CS, RAS, CAS, WE, DQM, CKE setup time | tCMS   | 2.4  | —    | ns   |
| SD5  | CS, RAS, CAS, WE, DQM, CKE hold time  | tCMH   | 1.4  | —    | ns   |
| SD6  | Address setup time                    | tAS    | 2.4  | —    | ns   |
| SD7  | Address hold time                     | tAH    | 1.4  | —    | ns   |
| SD13 | Data setup time                       | tDS    | 2.4  | —    | ns   |
| SD14 | Data hold time                        | tDH    | 1.4  | —    | ns   |

## NOTE

Test conditions are: pin voltage 1.7 V–1.95 V, capacitance 15 pF for all pins (both DDR and non-DDR pins), drive strength is high (7.2 mA). “High” is defined as 80% of signal value and “low” is defined as 20% of signal value.

SDR SDRAM CLK parameters are measured from the 50% point—that is, “high” is defined as 50% of signal value, and “low” is defined as 50% of signal value.  $t_{CH} + t_{CL}$  will not exceed 7.5 ns for 133 MHz. DDR SDRAM CLK parameters are measured at the crossing point of  $\overline{SDCLK}$  and  $SDCLK$  (inverted clock).

The timing parameters are similar to the ones used in SDRAM data sheets. [Table 34](#) indicates SDRAM requirements. All output signals are driven by the ESDCTL at the negative edge of  $SDCLK$ , and the parameters are measured at maximum memory frequency.



**Figure 29. SDRAM Refresh Timing Diagram**

**Table 35. SDRAM Refresh Timing Parameters**

| ID  | Parameter                    | Symbol   | Min. | Max. | Unit |
|-----|------------------------------|----------|------|------|------|
| SD1 | SDRAM clock high-level width | $t_{CH}$ | 3.4  | 4.1  | ns   |
| SD2 | SDRAM clock low-level width  | $t_{CL}$ | 3.4  | 4.1  | ns   |
| SD3 | SDRAM clock cycle time       | $t_{CK}$ | 7.5  | —    | ns   |
| SD6 | Address setup time           | $t_{AS}$ | 1.8  | —    | ns   |

**Table 35. SDRAM Refresh Timing Parameters (continued)**

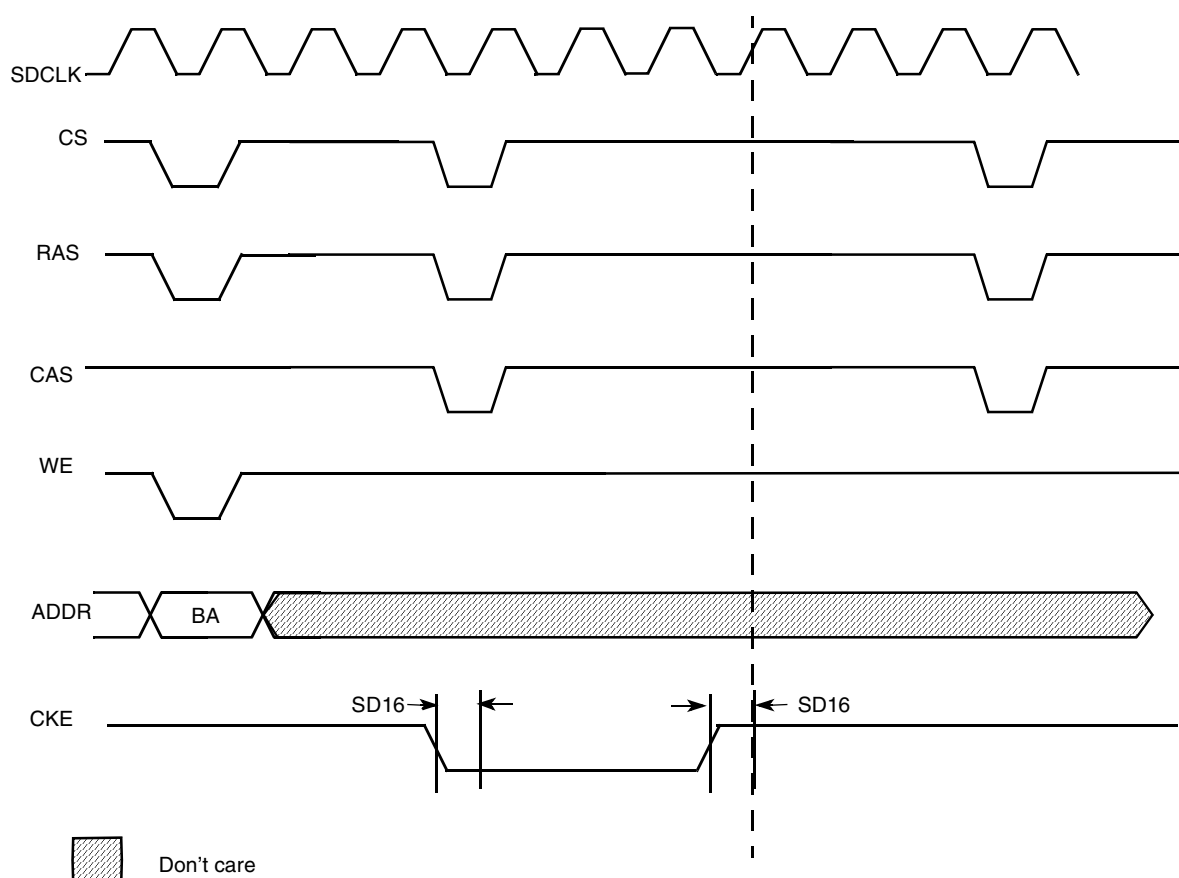
| ID   | Parameter                                  | Symbol | Min. | Max. | Unit  |
|------|--------------------------------------------|--------|------|------|-------|
| SD7  | Address hold time                          | tAH    | 1.8  | —    | ns    |
| SD10 | Precharge cycle period <sup>1</sup>        | tRP    | 1    | 4    | clock |
| SD11 | Auto precharge command period <sup>1</sup> | tRC    | 2    | 20   | clock |

<sup>1</sup> SD10 and SD11 are determined by SDRAM controller register settings.

### NOTE

SDR SDRAM CLK parameters are measured from the 50% point—that is, “high” is defined as 50% of signal value and “low” is defined as 50% of signal value.

The timing parameters are similar to the ones used in SDRAM data sheets. [Table 35](#) indicates SDRAM requirements. All output signals are driven by the ESDCTL at the negative edge of SDCLK, and the parameters are measured at maximum memory frequency.



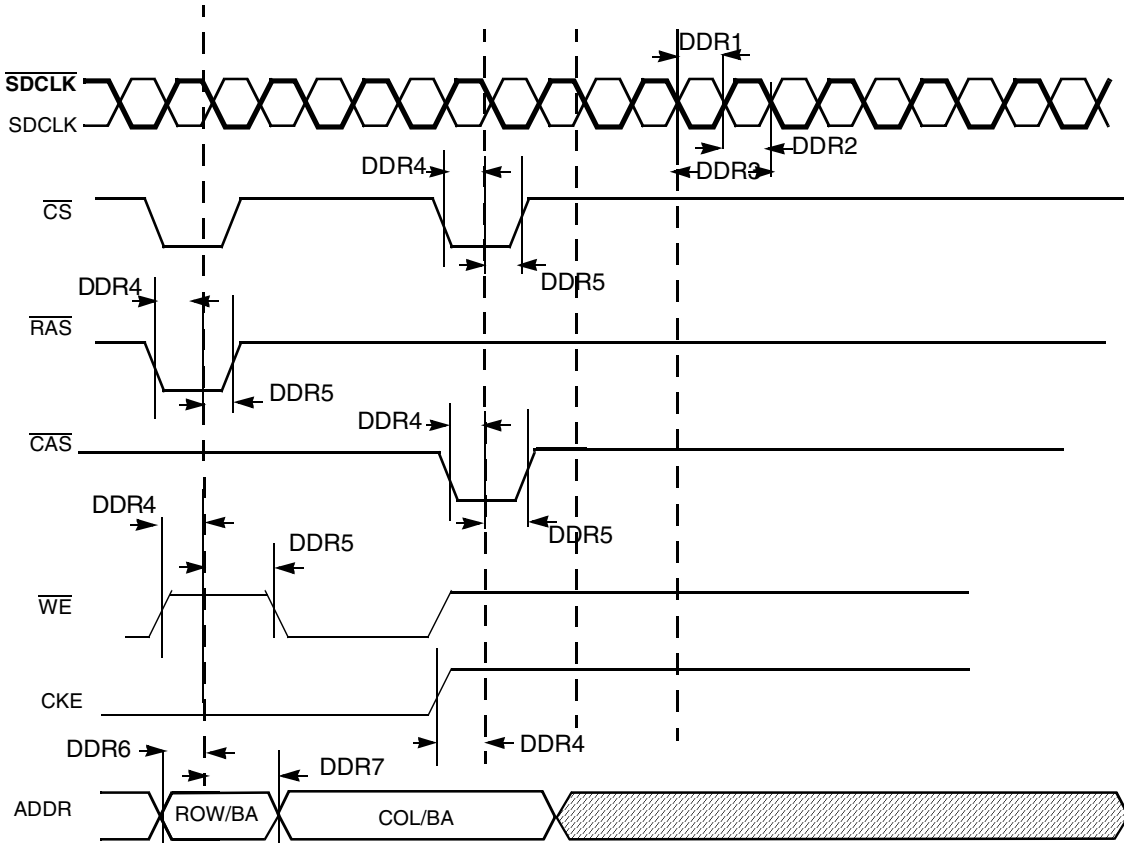
**Figure 30. SDRAM Self-Refresh Cycle Timing Diagram**

## NOTE

The clock will continue to run unless both CKEs are low. Then the clock will be stopped in low state.

**Table 36. SDRAM Self-Refresh Cycle Timing Parameters**

| ID   | Parameter             | Symbol | Min. | Max. | Unit |
|------|-----------------------|--------|------|------|------|
| SD16 | CKE output delay time | tCKS   | 1.8  | —    | ns   |



**Figure 31. DDR2 SDRAM Basic Timing Parameters**

**Table 37. DDR2 SDRAM Timing Parameter Table**

| ID   | PARAMETER                        | Symbol           | DDR2-400 |      | Unit |
|------|----------------------------------|------------------|----------|------|------|
|      |                                  |                  | Min      | Max  |      |
| DDR1 | SDRAM clock high-level width     | tCH              | 0.45     | 0.55 | tck  |
| DDR2 | SDRAM clock low-level width      | tCL              | 0.45     | 0.55 | tck  |
| DDR3 | SDRAM clock cycle time           | tck              | 7.0      | 8.0  | ns   |
| DDR4 | CS, RAS, CAS, CKE, WE setup time | tis <sup>1</sup> | 0.35     | —    | ns   |

**Table 37. DDR2 SDRAM Timing Parameter Table**

| ID   | PARAMETER                       | Symbol     | DDR2-400 |     | Unit |
|------|---------------------------------|------------|----------|-----|------|
|      |                                 |            | Min      | Max |      |
| DDR5 | CS, RAS, CAS, CKE, WE hold time | $t_{IH}^1$ | 0.475    | —   | ns   |
| DDR6 | Address output setup time       | $t_{IS}^1$ | 0.35     | —   | ns   |
| DDR7 | Address output hold time        | $t_{IH}^1$ | 0.475    | —   | ns   |

**NOTE**

These values are for command/address slew rate of 1 V/ns and SDCLK, SDCLK\_B differential slew rate of 2 V/ns. For different values, use the derating table.

**Table 38. Derating Values for DDR2-400, DDR2-533**

| tIS, tIH Derating Values for DDR2-400, DDR2-533  |              |              |              |              |              |       |      |       |       |
|--------------------------------------------------|--------------|--------------|--------------|--------------|--------------|-------|------|-------|-------|
| CK,CK Differential Slew Rate                     |              |              |              |              |              |       |      | Units | Notes |
| 2.0 V/ns                                         |              | 1.5 V/ns     |              | 1.0 V/ns     |              |       |      |       |       |
| $\Delta tIS$                                     | $\Delta tIH$ | $\Delta tIS$ | $\Delta tIH$ | $\Delta tIS$ | $\Delta tIH$ |       |      |       |       |
| Com-<br>mand/Ad-<br>dress Slew<br>rate<br>(V/ns) | 4.0          | +187         | +94          | +217         | +124         | +247  | +154 | ps    | 1     |
|                                                  | 3.5          | +179         | +89          | +209         | +119         | +239  | +149 | ps    | 1     |
|                                                  | 3.0          | +167         | +83          | +197         | +113         | +227  | +143 | ps    | 1     |
|                                                  | 2.5          | +150         | +75          | +180         | +105         | +210  | +135 | ps    | 1     |
|                                                  | 2.0          | +125         | +45          | +155         | +75          | +185  | +105 | ps    | 1     |
|                                                  | 1.5          | +83          | +21          | +113         | +51          | +143  | +81  | ps    | 1     |
|                                                  | 1.0          | 0            | 0            | +30          | +30          | +60   | 60   | ps    | 1     |
|                                                  | 0.9          | -11          | -14          | +19          | +16          | +49   | +46  | ps    | 1     |
|                                                  | 0.8          | -25          | -31          | +5           | -1           | +35   | +29  | ps    | 1     |
|                                                  | 0.7          | -43          | -54          | -13          | -24          | +17   | +6   | ps    | 1     |
|                                                  | 0.6          | -67          | -83          | -37          | -53          | -7    | -23  | ps    | 1     |
|                                                  | 0.5          | -110         | -125         | -80          | -95          | -50   | -65  | ps    | 1     |
|                                                  | 0.4          | -175         | -188         | -145         | -158         | -115  | -128 | ps    | 1     |
|                                                  | 0.3          | -285         | -292         | -255         | -262         | -225  | -232 | ps    | 1     |
|                                                  | 0.25         | -350         | -375         | -320         | -345         | -290  | -315 | ps    | 1     |
|                                                  | 0.2          | -525         | -500         | -495         | -470         | -465  | -440 | ps    | 1     |
| 0.15                                             | -800         | -708         | -770         | -678         | -740         | -648  | ps   | 1     |       |
| 0.1                                              | -1450        | -1125        | -1420        | -1095        | -1390        | -1065 | ps   | 1     |       |

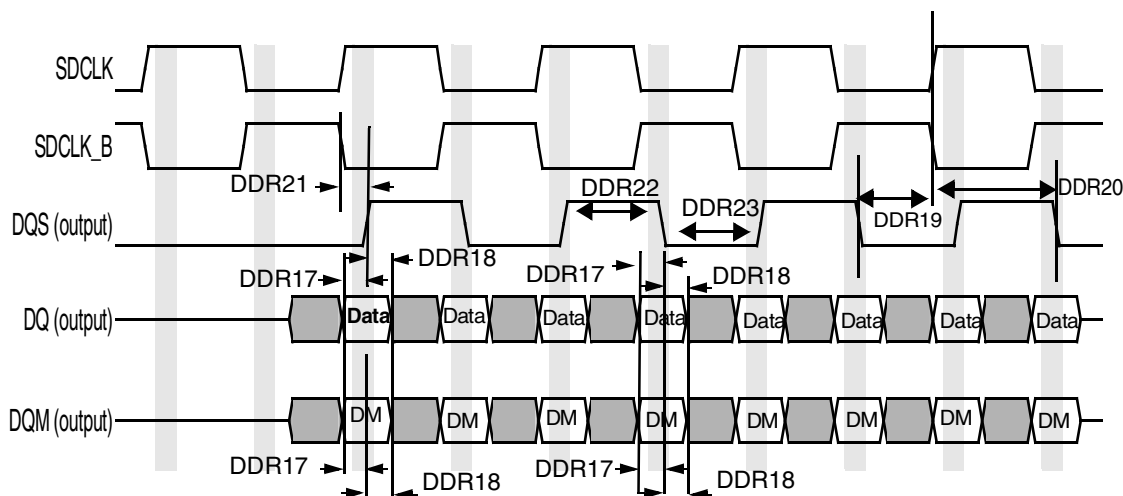


Figure 32. DDR2 SDRAM Write Cycle Timing Diagram

Figure 33. DDR2 SDRAM Write Cycle Parameters

| ID    | PARAMETER                                                 | Symbol     | DDR2-400 |      | Unit |
|-------|-----------------------------------------------------------|------------|----------|------|------|
|       |                                                           |            | Min      | Max  |      |
| DDR17 | DQ and DQM setup time to DQS (single-ended strobe)        | tDS1(base) | 0.025    | —    | ns   |
| DDR18 | DQ and DQM hold time to DQS (single-ended strobe)         | tDH1(base) | 0.025    | —    | ns   |
| DDR19 | Write cycle DQS falling edge to SDCLK output setup time.  | tDSS       | 0.2      | —    | tCK  |
| DDR20 | Write cycle DQS falling edge to SDCLK output hold time.   | tDSH       | 0.2      | —    | tCK  |
| DDR21 | DQS latching rising transitions to associated clock edges | tDQSS      | −0.25    | 0.25 | tCK  |
| DDR22 | DQS high level width                                      | tDQSH      | 0.35     | —    | tCK  |
| DDR23 | DQS low level width                                       | tDQSL      | 0.35     | —    | tCK  |

#### NOTE

These values are for DQ/DM slew rate of 1 V/ns and DQS slew rate of 1 V/ns. For different values use the derating table.

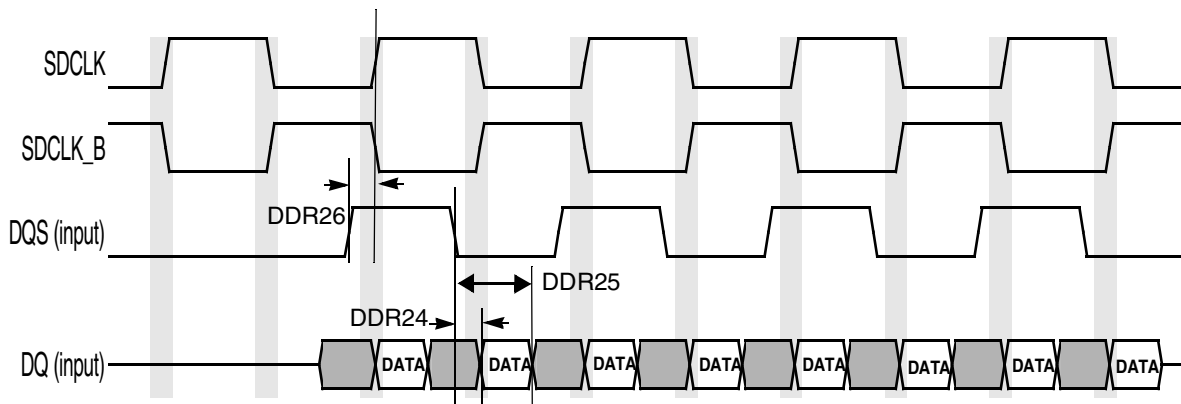
**Table 39. DDR Single-ended Slew Rate**

| ΔtDS1, ΔtDH1 derating values for DDR2-400, DDR2-533 (All units in 'ps'; the note applies to the entire table) |     |                            |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|---------------------------------------------------------------------------------------------------------------|-----|----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                                                                                                               |     | DQS Single-ended Slew Rate |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|                                                                                                               |     | 2.0 V/ns                   |           | 1.5 V/ns  |           | 1.0 V/ns  |           | 0.9 V/ns  |           | 0.8 V/ns  |           | 0.7 V/ns  |           | 0.6 V/ns  |           | 0.5 V/ns  |           | 0.4 V/ns  |           |
|                                                                                                               |     | ΔtD<br>S1                  | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 | ΔtD<br>S1 | ΔtD<br>H1 |
| DQ<br>Slew<br>rate<br>V/ns                                                                                    | 2.0 | 188                        | 188       | 167       | 146       | 125       | 63        | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
|                                                                                                               | 1.5 | 146                        | 167       | 125       | 125       | 83        | 42        | 81        | 43        | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         |
|                                                                                                               | 1.0 | 63                         | 125       | 42        | 83        | 0         | 0         | -2        | 1         | -7        | -13       | -         | -         | -         | -         | -         | -         | -         | -         |
|                                                                                                               | 0.9 | -                          | -         | 31        | 69        | -11       | -14       | -13       | -13       | -18       | -27       | -29       | -45       | -         | -         | -         | -         | -         | -         |
|                                                                                                               | 0.8 | -                          | -         | -         | -         | -25       | -31       | -27       | -30       | -32       | -44       | -43       | -62       | -60       | -86       | -         | -         | -         | -         |
|                                                                                                               | 0.7 | -                          | -         | -         | -         | -         | -         | -45       | -53       | -50       | -67       | -61       | -85       | -78       | -109      | -108      | -152      | -         | -         |
|                                                                                                               | 0.6 | -                          | -         | -         | -         | -         | -         | -         | -         | -74       | -96       | -85       | -114      | -102      | -138      | -132      | -181      | -183      | -246      |
|                                                                                                               | 0.5 | -                          | -         | -         | -         | -         | -         | -         | -         | -         | -         | -128      | -156      | -145      | -180      | -175      | -223      | -226      | -288      |
| 0.4                                                                                                           | -   | -                          | -         | -         | -         | -         | -         | -         | -         | -         | -         | -         | -210      | -243      | -240      | -286      | -291      | -351      |           |

**NOTE**

SDR SDRAM CLK parameters are measured from the 50% point—that is, “high” is defined as 50% of signal value and “low” is defined as 50% of signal value. DDR SDRAM CLK parameters are measured at the crossing point of  $\overline{SDCLK}$  and  $\overline{SDCLK}$  (inverted clock).

Test conditions are: Capacitance 15 pF for DDR PADS. Recommended drive strength is Medium for  $\overline{SDCLK}$  and High for Address and controls.



**Figure 34. DDR2 SDRAM DQ vs. DQS and SDCLK READ Cycle Timing Diagram**



**Table 40. DDR2 SDRAM Read Cycle Parameter Table**

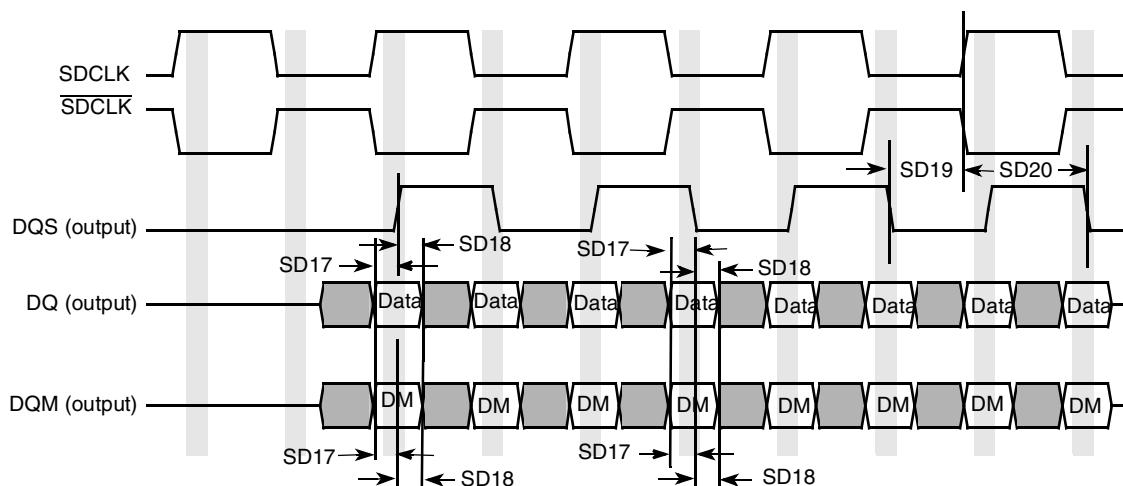
| ID    | PARAMETER                                                                    | Symbol | DDR2-400 |      | Unit |
|-------|------------------------------------------------------------------------------|--------|----------|------|------|
|       |                                                                              |        | Min      | Max  |      |
| DDR24 | DQS – DQ Skew (defines the Data valid window in read cycles related to DQS). | tDQSQ  | —        | 0.35 | ns   |
| DDR25 | DQS DQ in HOLD time from DQS <sup>1</sup>                                    | tQH    | 2.925    | —    | ns   |
| DDR26 | DQS output access time from SDCLK posedge                                    | tDQSK  | –0.5     | 0.5  | ns   |

<sup>1</sup>The value was calculated for an SDCLK frequency of 133 MHz by the formula  $t_{QH} = t_{HP} - t_{QHS} = \min(t_{CL}, t_{CH}) - t_{QHS} = 0.45 \times t_{CK} - t_{QHS} = 0.45 \times 7.5 - 0.45 = 2.925$  ns.

### NOTE

SDRAM CLK and DQS-related parameters are measured from the 50% point—that is, “high” is defined as 50% of signal value and “low” is defined as 50% of signal value. DDR SDRAM CLK parameters are measured at the crossing point of SDCLK and  $\overline{\text{SDCLK}}$  (inverted clock).

Test conditions are: Capacitance 15 pF for DDR PADS. Recommended drive strength is Medium for SDCLK and High for Address and controls.



**Figure 35. Mobile DDR SDRAM Write Cycle Timing Diagram**

**Table 41. Mobile DDR SDRAM Write Cycle Timing Parameters<sup>1</sup>**

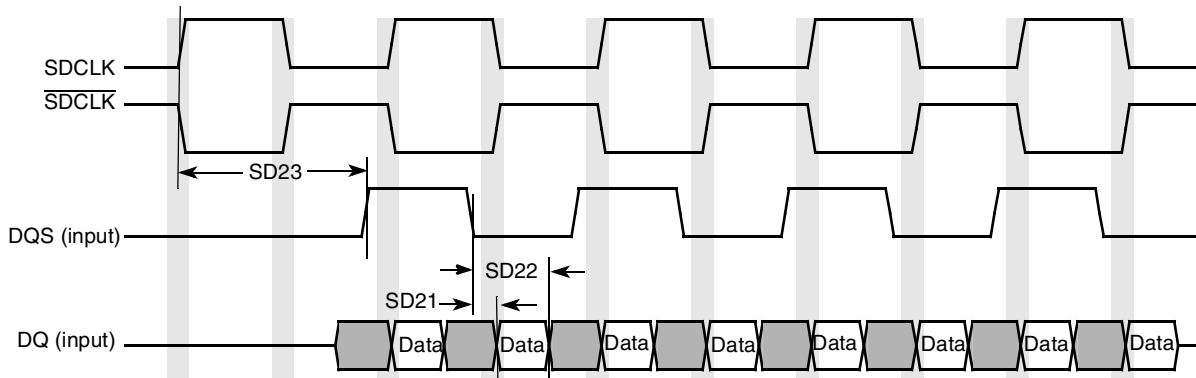
| ID   | Parameter                                                | Symbol | Min. | Max. | Unit |
|------|----------------------------------------------------------|--------|------|------|------|
| SD17 | DQ and DQM setup time to DQS                             | tDS    | 0.95 | —    | ns   |
| SD18 | DQ and DQM hold time to DQS                              | tDH    | 0.95 | —    | ns   |
| SD19 | Write cycle DQS falling edge to SDCLK output delay time. | tDSS   | 1.8  | —    | ns   |
| SD20 | Write cycle DQS falling edge to SDCLK output hold time.  | tDSH   | 1.8  | —    | ns   |

<sup>1</sup> Test condition: Measured using delay line 5 programmed as follows: ESDCDLY5[15:0] = 0x0703.

## NOTE

SDRAM CLK and DQS-related parameters are measured from the 50% point—that is, “high” is defined as 50% of signal value and “low” is defined as 50% of signal value.

The timing parameters are similar to the ones used in SDRAM data sheets. [Table 41](#) indicates SDRAM requirements. All output signals are driven by the ESDCTL at the negative edge of SDCLK, and the parameters are measured at maximum memory frequency.



**Figure 36. Mobile DDR SDRAM DQ versus DQS and SDCLK Read Cycle Timing Diagram**

**Table 42. Mobile DDR SDRAM Read Cycle Timing Parameters**

| ID   | Parameter                                                                    | Symbol | Min. | Max. | Unit |
|------|------------------------------------------------------------------------------|--------|------|------|------|
| SD21 | DQS – DQ Skew (defines the Data valid window in read cycles related to DQS). | tDQSQ  | —    | 0.85 | ns   |
| SD22 | DQS DQ HOLD time from DQS                                                    | tQH    | 2.3  | —    | ns   |
| SD23 | DQS output access time from SDCLK posedge                                    | tDQSCK | —    | 6.7  | ns   |

## NOTE

SDRAM CLK and DQS-related parameters are measured from the 50% point—that is, “high” is defined as 50% of signal value, and “low” is defined as 50% of signal value.

The timing parameters are similar to the ones used in SDRAM data sheets. [Table 42](#) indicates SDRAM requirements. All output signals are driven by the ESDCTL at the negative edge of SDCLK, and the parameters are measured at maximum memory frequency.

## 4.9.6 Enhanced Serial Audio Interface (ESAI) Timing Specifications

The ESAI consists of independent transmitter and receiver sections, each section with its own clock generator. Table 43 shows the interface timing values. The number field in the table refers to timing signals found in Figure 37 and Figure 38.

Table 43. Enhanced Serial Audio Interface Timing

| No. | Characteristics <sup>1,2</sup>                                        | Symbol      | Expression <sup>2</sup>                | Min.         | Max.         | Condition <sup>3</sup> | Unit |
|-----|-----------------------------------------------------------------------|-------------|----------------------------------------|--------------|--------------|------------------------|------|
| 62  | Clock cycle <sup>4</sup>                                              | $t_{SSICC}$ | $4 \times T_C$<br>$4 \times T_C$       | 30.0<br>30.0 | —<br>—       | i ck<br>i ck           | ns   |
| 63  | Clock high period<br>• For internal clock<br>• For external clock     | —<br>—      | $2 \times T_C - 9.0$<br>$2 \times T_C$ | 6<br>15      | —<br>—       | —<br>—                 | ns   |
| 64  | Clock low period<br>• For internal clock<br>• For external clock      | —<br>—      | $2 \times T_C - 9.0$<br>$2 \times T_C$ | 6<br>15      | —<br>—       | —<br>—                 | ns   |
| 65  | SCKR rising edge to FSR out (bl) high                                 | —<br>—      | —<br>—                                 | —<br>—       | 17.0<br>7.0  | x ck<br>i ck a         | ns   |
| 66  | SCKR rising edge to FSR out (bl) low                                  | —<br>—      | —<br>—                                 | —<br>—       | 17.0<br>7.0  | x ck<br>i ck a         | ns   |
| 67  | SCKR rising edge to FSR out (wr) high <sup>5</sup>                    | —<br>—      | —<br>—                                 | —<br>—       | 19.0<br>9.0  | x ck<br>i ck a         | ns   |
| 68  | SCKR rising edge to FSR out (wr) low <sup>5</sup>                     | —<br>—      | —<br>—                                 | —<br>—       | 19.0<br>9.0  | x ck<br>i ck a         | ns   |
| 69  | SCKR rising edge to FSR out (wl) high                                 | —<br>—      | —<br>—                                 | —<br>—       | 16.0<br>6.0  | x ck<br>i ck a         | ns   |
| 70  | SCKR rising edge to FSR out (wl) low                                  | —<br>—      | —<br>—                                 | —<br>—       | 17.0<br>7.0  | x ck<br>i ck a         | ns   |
| 71  | Data in setup time before SCKR (SCK in synchronous mode) falling edge | —<br>—      | —<br>—                                 | 12.0<br>19.0 | —<br>—       | x ck<br>i ck           | ns   |
| 72  | Data in hold time after SCKR falling edge                             | —<br>—      | —<br>—                                 | 3.5<br>9.0   | —<br>—       | x ck<br>i ck           | ns   |
| 73  | FSR input (bl, wr) high before SCKR falling edge <sup>5</sup>         | —<br>—      | —<br>—                                 | 2.0<br>12.0  | —<br>—       | x ck<br>i ck a         | ns   |
| 74  | FSR input (wl) high before SCKR falling edge                          | —<br>—      | —<br>—                                 | 2.0<br>12.0  | —<br>—       | x ck<br>i ck a         | ns   |
| 75  | FSR input hold time after SCKR falling edge                           | —<br>—      | —<br>—                                 | 2.5<br>8.5   | —<br>—       | x ck<br>i ck a         | ns   |
| 78  | SCKT rising edge to FST out (bl) high                                 | —<br>—      | —<br>—                                 | —<br>—       | 18.0<br>8.0  | x ck<br>i ck           | ns   |
| 79  | SCKT rising edge to FST out (bl) low                                  | —<br>—      | —<br>—                                 | —<br>—       | 20.0<br>10.0 | x ck<br>i ck           | ns   |

**Table 43. Enhanced Serial Audio Interface Timing (continued)**

| No. | Characteristics <sup>1,2</sup>                                      | Symbol | Expression <sup>2</sup> | Min.        | Max.         | Condition <sup>3</sup> | Unit |
|-----|---------------------------------------------------------------------|--------|-------------------------|-------------|--------------|------------------------|------|
| 80  | SCKT rising edge to FST out (wr) high <sup>5</sup>                  | —<br>— | —<br>—                  | —<br>—      | 20.0<br>10.0 | x ck<br>i ck           | ns   |
| 81  | SCKT rising edge to FST out (wr) low <sup>5</sup>                   | —<br>— | —<br>—                  | —<br>—      | 22.0<br>12.0 | x ck<br>i ck           | ns   |
| 82  | SCKT rising edge to FST out (wl) high                               | —<br>— | —<br>—                  | —<br>—      | 19.0<br>9.0  | x ck<br>i ck           | ns   |
| 83  | SCKT rising edge to FST out (wl) low                                | —<br>— | —<br>—                  | —<br>—      | 20.0<br>10.0 | x ck<br>i ck           | ns   |
| 84  | SCKT rising edge to data out enable from high impedance             | —<br>— | —<br>—                  | —<br>—      | 22.0<br>17.0 | x ck<br>i ck           | ns   |
| 86  | SCKT rising edge to data out valid                                  | —<br>— | —<br>—                  | —<br>—      | 18.0<br>13.0 | x ck<br>i ck           | ns   |
| 87  | SCKT rising edge to data out high impedance <sup>6,7</sup>          | —<br>— | —<br>—                  | —<br>—      | 21.0<br>16.0 | x ck<br>i ck           | ns   |
| 89  | FST input (bl, wr) setup time before SCKT falling edge <sup>5</sup> | —<br>— | —<br>—                  | 2.0<br>18.0 | —<br>—       | x ck<br>i ck           | ns   |
| 90  | FST input (wl) setup time before SCKT falling edge                  | —<br>— | —<br>—                  | 2.0<br>18.0 | —<br>—       | x ck<br>i ck           | ns   |
| 91  | FST input hold time after SCKT falling edge                         | —<br>— | —<br>—                  | 4.0<br>5.0  | —<br>—       | x ck<br>i ck           | ns   |

- <sup>1</sup> i ck = internal clock  
x ck = external clock  
i ck a = internal clock, asynchronous mode  
(asynchronous implies that SCKT and SCKR are two different clocks)  
i ck s = internal clock, synchronous mode  
(synchronous implies that SCKT and SCKR are the same clock)

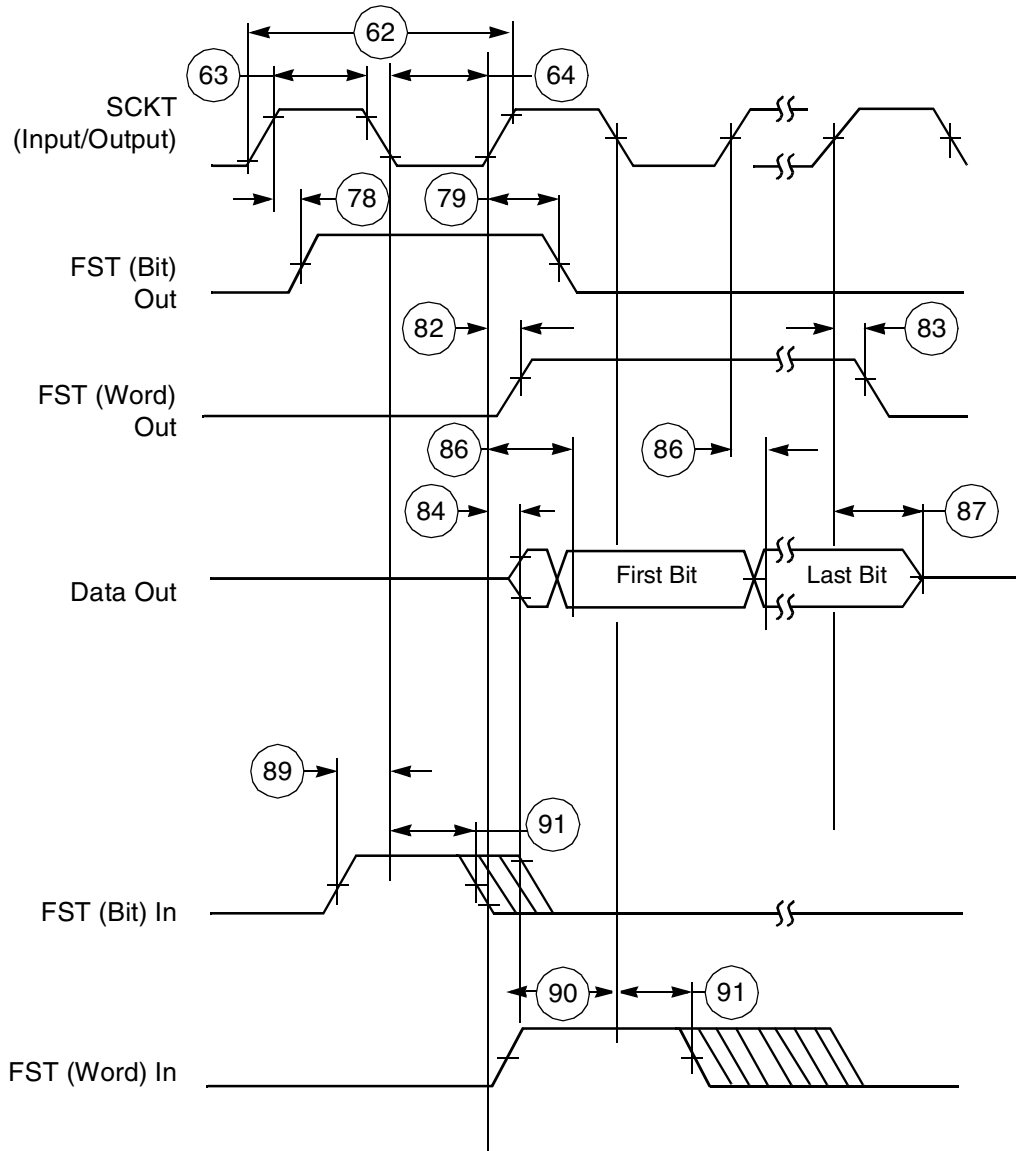
- <sup>2</sup> bl = bit length  
wl = word length  
wr = word length relative

- <sup>3</sup> SCKT(SCKT pin) = transmit clock  
SCKR(SCKR pin) = receive clock  
FST(FST pin) = transmit frame sync  
FSR(FSR pin) = receive frame sync  
HCKT(HCKT pin) = transmit high frequency clock  
HCKR(HCKR pin) = receive high frequency clock

- <sup>4</sup> For the internal clock, the external clock cycle is defined by lcyc and the ESAI control register.

- <sup>5</sup> The word-relative frame sync signal waveform relative to the clock operates in the same manner as the bit-length frame sync signal waveform, but it spreads from one serial clock before the first bit clock (like the bit length frame sync signal), until the second-to-last bit clock of the first word in the frame.

- <sup>6</sup> Periodically sampled and not 100% tested.



**Figure 37. ESAI Transmitter Timing**

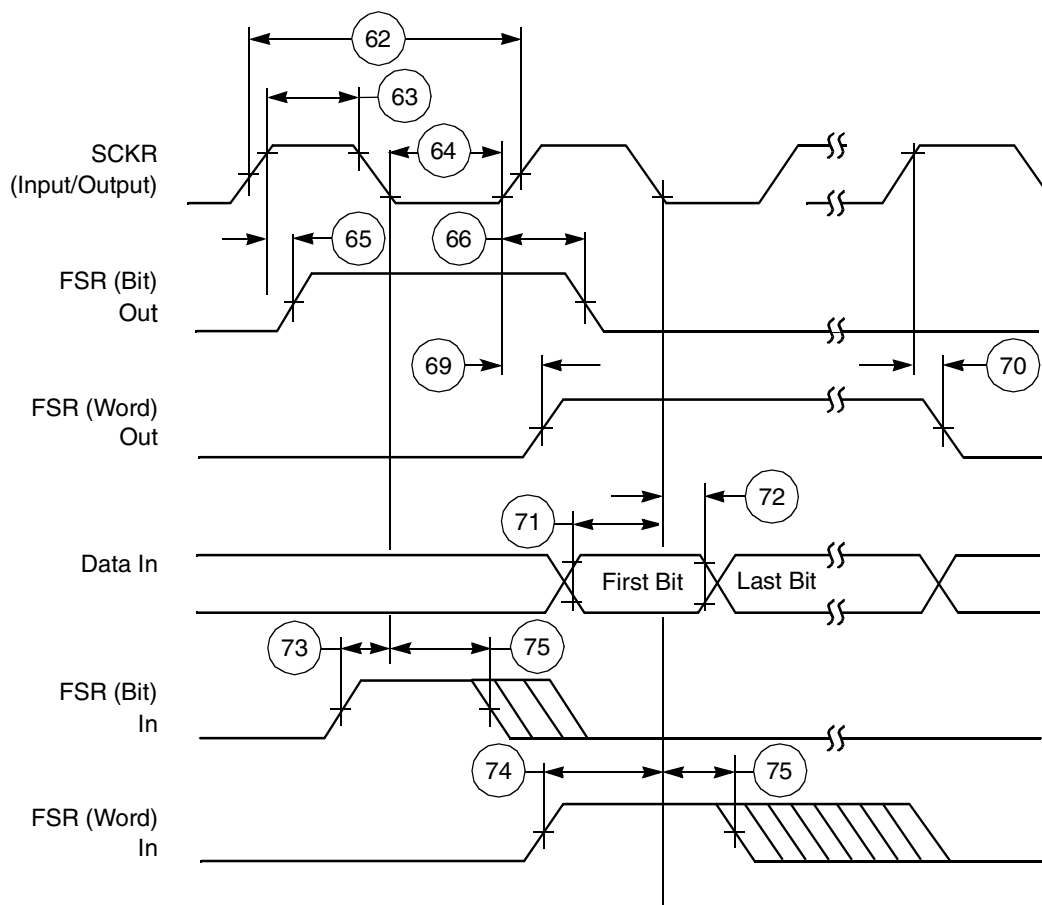
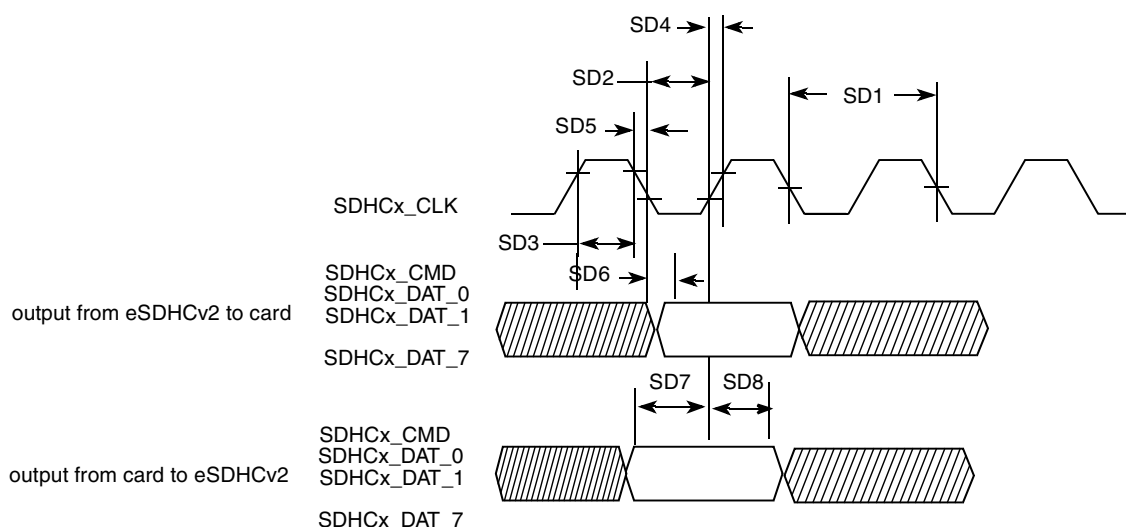


Figure 38. ESAI Receiver Timing

#### 4.9.7 eSDHCv2 AC Electrical Specifications

Figure 39 depicts the timing of eSDHCv2, and Table 44 lists the eSDHCv2 timing characteristics. The following definitions apply to values and signals described in Table 44:

- LS: low-speed mode. Low-speed card can tolerate a clock up to 400 kHz.
- FS: full-speed mode. For a full-speed MMC card, the card clock can reach 20 MHz; a full-speed SD/SDIO card can reach 25 MHz.
- HS: high-speed mode. For a high-speed MMC card, the card clock can reach 52 MHz; SD/SDIO can reach 50 MHz.



**Figure 39. eSDHCv2 Timing**

**Table 44. eSDHCv2 Interface Timing Specification**

| 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/High Speed) | $f_{PP}^2$ | 0    | 25/50 | MHz  |
|                                                             | Clock frequency (MMC Full Speed/High Speed)     | $f_{PP}^3$ | 0    | 20/52 | MHz  |
|                                                             | Clock frequency (Identification Mode)           | $f_{OD}$   | 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 CMD, DAT (Reference to CLK)</b> |                                                 |            |      |       |      |
| SD6                                                         | eSDHC output delay                              | $t_{OD}$   | —3   | 3     | ns   |
| <b>eSDHC Input/Card Outputs CMD, DAT (Reference to CLK)</b> |                                                 |            |      |       |      |
| SD7                                                         | eSDHC input setup time                          | $t_{ISU}$  | 5    | —     | ns   |
| SD8                                                         | eSDHC input hold time                           | $t_{IH}^4$ | 2.5  | —     | ns   |

<sup>1</sup> In low-speed mode, the card clock must be lower than 400 kHz, voltage ranges from 2.7 to 3.6 V.

<sup>2</sup> In normal-speed mode for the SD/SDIO card, clock frequency can be any value between 0–25 MHz. In high-speed mode, clock frequency can be any value between 0–50 MHz.

<sup>3</sup> In normal-speed mode for MMC card, clock frequency can be any value between 0 and 20 MHz. In high-speed mode, clock frequency can be any value between 0–52 MHz.

<sup>4</sup> To satisfy hold timing, the delay difference between clock input and cmd/data input must not exceed 2 ns.

## 4.9.8 Fast Ethernet Controller (FEC) AC Electrical Specifications

This section describes the electrical information of the FEC module. The FEC is designed to support both 10- and 100-Mbps Ethernet networks. An external transceiver interface and transceiver function are required to complete the interface to the media. The FEC supports the 10/100 Mbps Media Independent Interface (MII) using a total of 18 pins. The 10-Mbps 7-wire interface that is restricted to a 10-Mbps data rate uses seven of the MII pins for connection to an external Ethernet transceiver.

### 4.9.8.1 FEC AC Timing

This section describes the AC timing specifications of the FEC. The MII signals are compatible with transceivers operating at a voltage of 3.3 V.

### 4.9.8.2 MII Receive Signal Timing

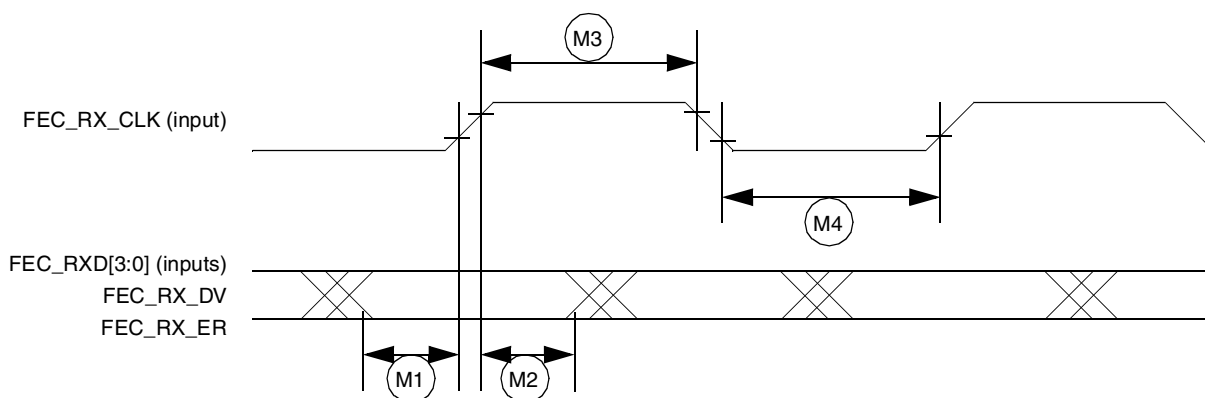
The MII receive timing signals consist of FEC\_RXD[3:0], FEC\_RX\_DV, FEC\_RX\_ER, and FEC\_RX\_CLK. The receiver functions correctly up to a FEC\_RX\_CLK maximum frequency of 25 MHz + 1%. There is no minimum frequency requirement. Additionally, the processor clock frequency must exceed twice the FEC\_RX\_CLK frequency. [Table 45](#) lists MII receive channel timings.

**Table 45. MII Receive Signal Timing**

| Num. | Characteristic <sup>1</sup>                            | Min. | Max. | Unit              |
|------|--------------------------------------------------------|------|------|-------------------|
| M1   | FEC_RXD[3:0], FEC_RX_DV, FEC_RX_ER to FEC_RX_CLK setup | 5    | —    | ns                |
| M2   | FEC_RX_CLK to FEC_RXD[3:0], FEC_RX_DV, FEC_RX_ER hold  | 5    | —    | ns                |
| M3   | FEC_RX_CLK pulse width high                            | 35%  | 65%  | FEC_RX_CLK period |
| M4   | FEC_RX_CLK pulse width low                             | 35%  | 65%  | FEC_RX_CLK period |

<sup>1</sup> FEC\_RX\_DV, FEC\_RX\_CLK, and FEC\_RXD0 have the same timing when in 10 Mbps 7-wire interface mode.

[Figure 40](#) shows the MII receive signal timings listed in [Table 45](#).



**Figure 40. MII Receive Signal Timing Diagram**



### 4.9.8.3 MII Transmit Signal Timing

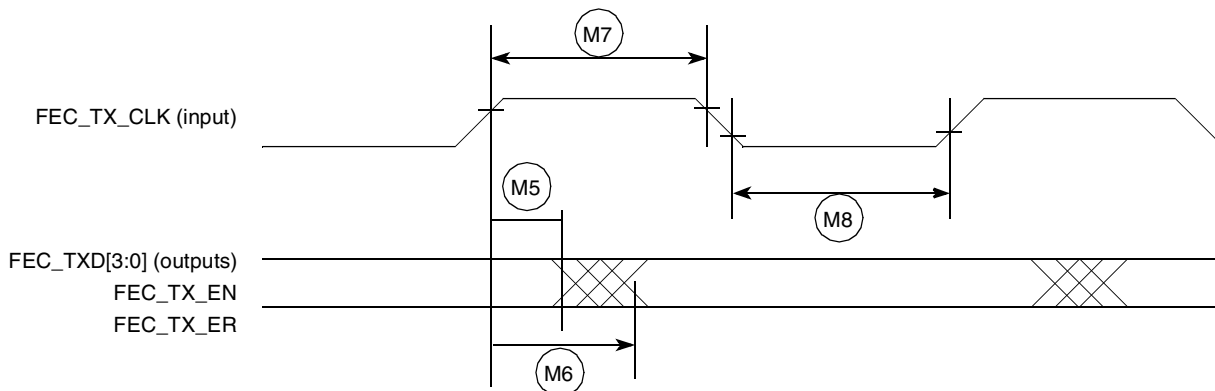
The transmitter timing signals consist of FEC\_TXD[3:0], FEC\_TX\_EN, FEC\_TX\_ER, and FEC\_TX\_CLK. The transmitter functions correctly up to a FEC\_TX\_CLK maximum frequency of 25 MHz + 1%. There is no minimum frequency requirement. Additionally, the processor clock frequency must exceed twice the FEC\_TX\_CLK frequency. Table 46 lists MII transmit channel timings.

**Table 46. MII Transmit Signal Timing**

| Num | Characteristic <sup>1</sup>                              | Min. | Max. | Unit              |
|-----|----------------------------------------------------------|------|------|-------------------|
| M5  | FEC_TX_CLK to FEC_TXD[3:0], FEC_TX_EN, FEC_TX_ER invalid | 5    | —    | ns                |
| M6  | FEC_TX_CLK to FEC_TXD[3:0], FEC_TX_EN, FEC_TX_ER valid   | —    | 20   | ns                |
| M7  | FEC_TX_CLK pulse width high                              | 35%  | 65%  | FEC_TX_CLK period |
| M8  | FEC_TX_CLK pulse width low                               | 35%  | 65%  | FEC_TX_CLK period |

<sup>1</sup> FEC\_TX\_EN, FEC\_TX\_CLK, and FEC\_TXD0 have the same timing when in 10 Mbps 7-wire interface mode.

Figure 41 shows the MII transmit signal timings listed in Table 46.



**Figure 41. MII Transmit Signal Timing Diagram**

### 4.9.8.4 MII Asynchronous Inputs Signal Timing

The MII asynchronous timing signals are FEC\_CRD and FEC\_COL. Table 47 lists MII asynchronous inputs signal timing.

**Table 47. MII Asynch Inputs Signal Timing**

| Num             | Characteristic                         | Min. | Max. | Unit              |
|-----------------|----------------------------------------|------|------|-------------------|
| M9 <sup>1</sup> | FEC_CRD to FEC_COL minimum pulse width | 1.5  | —    | FEC_TX_CLK period |

<sup>1</sup> FEC\_COL has the same timing in 10 Mbit 7-wire interface mode.

Figure 42 shows MII asynchronous input timings listed in Table 47.

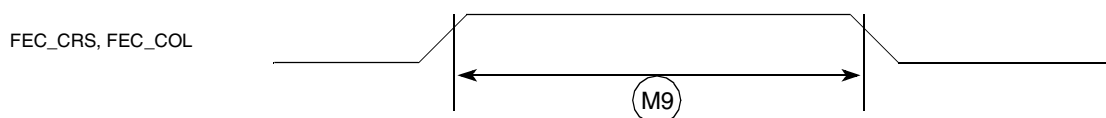


Figure 42. MII Asynch Inputs Timing Diagram

#### 4.9.8.5 MII Serial Management Channel Timing

Serial management channel timing is accomplished using FEC\_MDIO and FEC\_MDC. The FEC functions correctly with a maximum MDC frequency of 2.5 MHz. Table 48 lists MII serial management channel timings.

The MDC frequency should be equal to or less than 2.5 MHz to be compliant with the IEEE 802.3 MII specification. However the FEC can function correctly with a maximum MDC frequency of 15 MHz.

Table 48. MII Transmit Signal Timing

| Num | Characteristic                                                              | Min. | Max. | Units          |
|-----|-----------------------------------------------------------------------------|------|------|----------------|
| M10 | FEC_MDC falling edge to FEC_MDIO output invalid (minimum propagation delay) | 0    | —    | ns             |
| M11 | FEC_MDC falling edge to FEC_MDIO output valid (max. propagation delay)      | —    | 5    | ns             |
| M12 | FEC_MDIO (input) to FEC_MDC rising edge setup                               | 18   | —    | ns             |
| M13 | FEC_MDIO (input) to FEC_MDC rising edge hold                                | 0    | —    | ns             |
| M14 | FEC_MDC pulse width high                                                    | 40%  | 60%  | FEC_MDC period |
| M15 | FEC_MDC pulse width low                                                     | 40%  | 60%  | FEC_MDC period |

Figure 43 shows MII serial management channel timings listed in Table 48.

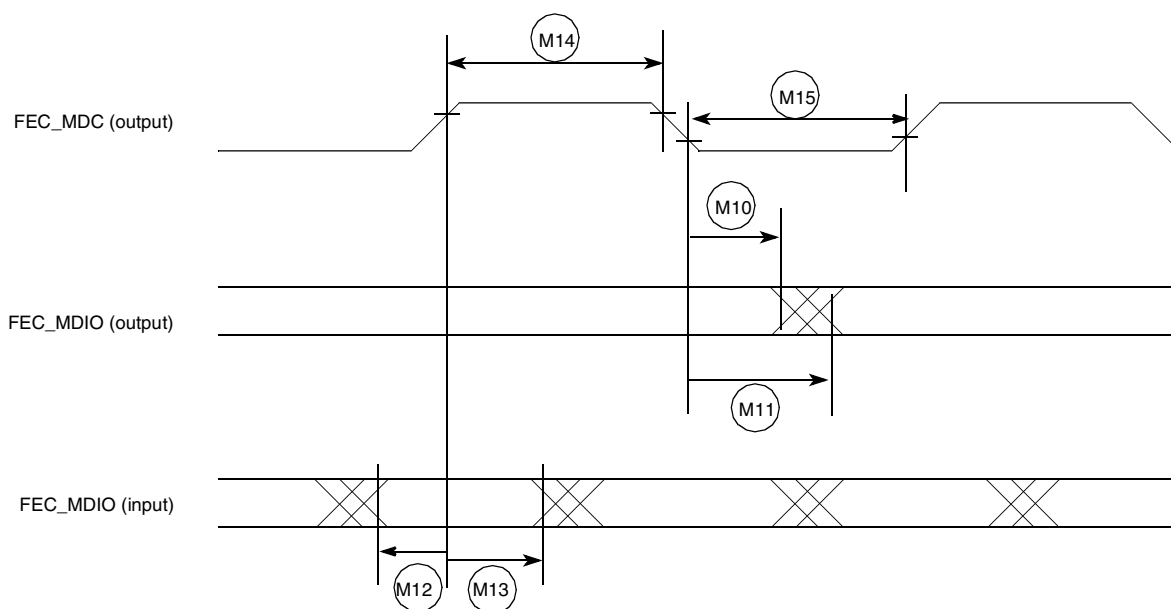


Figure 43. MII Serial Management Channel Timing Diagram

#### 4.9.9 FIR Electrical Specifications

FIR implements asynchronous infrared protocols (FIR, MIR) defined by IrDA<sup>®</sup> (Infrared Data Association). Refer to the IrDA<sup>®</sup> website for details on FIR and MIR protocols.

#### 4.9.10 FlexCAN Module AC Electrical Specifications

The electrical characteristics are related to the CAN transceiver outside the chip. The i.MX35 has two CAN modules available for systems design. Tx and Rx ports for both modules are multiplexed with other I/O pins. Refer to the IOMUX chapter of the *MCIMX35 Multimedia Applications Processor Reference Manual* to see which pins expose Tx and Rx pins; these ports are named TXCAN and RXCAN, respectively.

## 4.9.11 I<sup>2</sup>C AC Electrical Specifications

This section describes the electrical characteristics of the I<sup>2</sup>C module.

### 4.9.11.1 I<sup>2</sup>C Module Timing

Figure 44 depicts the timing of the I<sup>2</sup>C module. Table 49 lists the I<sup>2</sup>C module timing parameters.

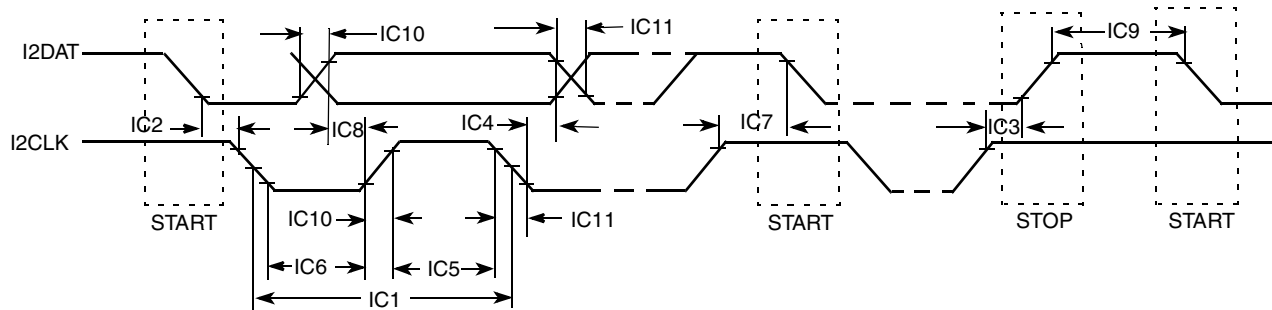


Figure 44. I<sup>2</sup>C Bus Timing Diagram

Table 49. I<sup>2</sup>C Module Timing Parameters

| ID   | Parameter                                           | Standard Mode  |                   | Fast Mode        |                  | Unit |
|------|-----------------------------------------------------|----------------|-------------------|------------------|------------------|------|
|      |                                                     | Min.           | Max.              | Min.             | Max.             |      |
| IC1  | I2CLK cycle time                                    | 10             | —                 | 2.5              | —                | μs   |
| IC2  | Hold time (repeated) START condition                | 4.0            | —                 | 0.6              | —                | μs   |
| IC3  | Set-up time for STOP condition                      | 4.0            | —                 | 0.6              | —                | μs   |
| IC4  | Data hold time                                      | 0 <sup>1</sup> | 3.45 <sup>2</sup> | 0 <sup>1</sup>   | 0.9 <sup>2</sup> | μs   |
| IC5  | HIGH Period of I2CLK Clock                          | 4.0            | —                 | 0.6              | —                | μs   |
| IC6  | LOW Period of the I2CLK Clock                       | 4.7            | —                 | 1.3              | —                | μs   |
| IC7  | Set-up time for a repeated START condition          | 4.7            | —                 | 0.6              | —                | μs   |
| IC8  | Data set-up time                                    | 250            | —                 | 100 <sup>3</sup> | —                | ns   |
| IC9  | Bus free time between a STOP and START condition    | 4.7            | —                 | 1.3              | —                | μs   |
| IC10 | Rise time of both I2DAT and I2CLK signals           | —              | 1000              | —                | 300              | ns   |
| IC11 | Fall time of both I2DAT and I2CLK signals           | —              | 300               | —                | 300              | ns   |
| IC12 | Capacitive load for each bus line (C <sub>b</sub> ) | —              | 400               | —                | 400              | pF   |

<sup>1</sup> A device must internally provide a hold time of at least 300 ns for the I2DAT signal in order to bridge the undefined region of the falling edge of I2CLK.

<sup>2</sup> The maximum hold time has to be met only if the device does not stretch the LOW period (ID IC6) of the I2CLK signal.

<sup>3</sup> A fast-mode I<sup>2</sup>C-bus device can be used in a standard-mode I<sup>2</sup>C-bus system, but the requirement of set-up time (ID IC7) of 250 ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the I2CLK signal. If such a device does stretch the LOW period of the I2CLK signal, it must output the next data bit to the I2DAT line max\_rise\_time (ID No IC10) + data\_setup\_time (ID No IC8) = 1000 + 250 = 1250 ns (according to the Standard-mode I<sup>2</sup>C-bus specification) before the I2CLK line is released.

## 4.9.12 IPU—Sensor Interfaces

This section contains a list of supported camera sensors, a functional description, and the electrical characteristics.

### 4.9.12.1 Supported Camera Sensors

Table 50 lists the known supported camera sensors at the time of publication.

**Table 50. Supported Camera Sensors<sup>1</sup>**

| Vendor                 | Model                                                                                                                         |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Conexant               | CX11646, CX20490 <sup>2</sup> , CX20450 <sup>2</sup>                                                                          |
| Agilent                | HDCCP-2010, ADCS-1021 <sup>2</sup> , ADCS-1021 <sup>2</sup>                                                                   |
| Toshiba                | TC90A70                                                                                                                       |
| ICMedia                | ICM202A, ICM102 <sup>2</sup>                                                                                                  |
| iMagic                 | IM8801                                                                                                                        |
| Transchip              | TC5600, TC5600J, TC5640, TC5700, TC6000                                                                                       |
| Fujitsu                | MB86S02A                                                                                                                      |
| Micron                 | MI-SOC-0133                                                                                                                   |
| Matsushita             | MN39980                                                                                                                       |
| STMicro                | W6411, W6500, W6501 <sup>2</sup> , W6600 <sup>2</sup> , W6552 <sup>2</sup> , STV0974 <sup>2</sup>                             |
| OmniVision             | OV7620, OV6630, OV2640                                                                                                        |
| Sharp                  | LZ0P3714 (CCD)                                                                                                                |
| Motorola               | MC30300 (Python) <sup>2</sup> , SCM20014 <sup>2</sup> , SCM20114 <sup>2</sup> , SCM22114 <sup>2</sup> , SCM20027 <sup>2</sup> |
| National Semiconductor | LM9618 <sup>2</sup>                                                                                                           |

<sup>1</sup> Freescale Semiconductor does not recommend one supplier over another and in no way suggests that these are the only camera suppliers.

<sup>2</sup> These sensors have not been validated at the time of publication.

### 4.9.12.2 Functional Description

There are three timing modes supported by the IPU.

#### 4.9.12.2.1 Pseudo BT.656 Video Mode

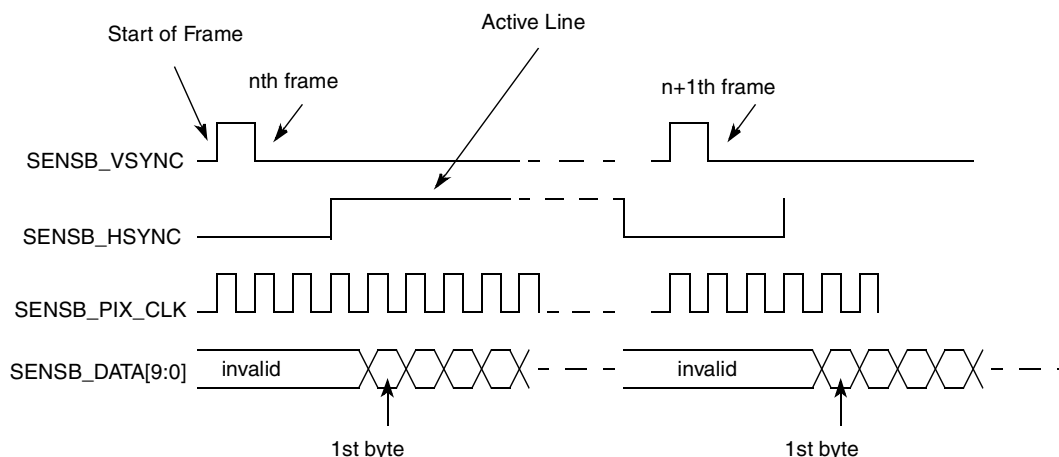
Smart camera sensors, which typically include image processing capability, support video mode transfer operations. They use an embedded timing syntax to replace the SENSB\_VSYNC and SENSB\_HSYNC signals. The timing syntax is defined by the BT.656 standard.

This operation mode follows the recommendations of the ITU BT.656 specifications. The only control signal used is SENSB\_PIX\_CLK. Start-of-frame and active-line signals are embedded in the data stream. An active line starts with a SAV code and ends with an EAV code. In some cases, digital blanking is

inserted in between EAV and SAV code. The CSI decodes and filters out the timing coding from the data stream, thus recovering SENSB\_VSYNC and SENSB\_HSYNC signals for internal use.

#### 4.9.12.2.2 Gated Clock Mode

The SENSB\_VSYNC, SENSB\_HSYNC, and SENSB\_PIX\_CLK signals are used in this mode. See [Figure 45](#).

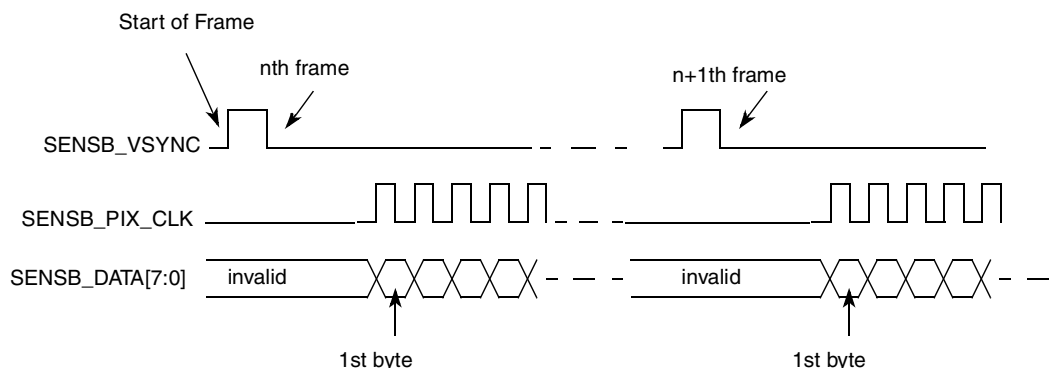


**Figure 45. Gated Clock Mode Timing Diagram**

A frame starts with a rising edge on SENSB\_VSYNC (all the timing corresponds to straight polarity of the corresponding signals). Then SENSB\_HSYNC goes to high and hold for the entire line. The pixel clock is valid as long as SENSB\_HSYNC is high. Data is latched at the rising edge of the valid pixel clocks. SENSB\_HSYNC goes to low at the end of the line. Pixel clocks then become invalid and the CSI stops receiving data from the stream. For the next line, the SENSB\_HSYNC timing repeats. For the next frame, the SENSB\_VSYNC timing repeats.

#### 4.9.12.2.3 Non-Gated Clock Mode

The timing is the same as the gated-clock mode (described in [Section 4.9.12.2.2, “Gated Clock Mode”](#)), except for the SENSB\_HSYNC signal, which is not used. See [Figure 46](#). All incoming pixel clocks are valid and will cause data to be latched into the input FIFO. The SENSB\_PIX\_CLK signal is inactive (states low) until valid data is going to be transmitted over the bus.



**Figure 46. Non-Gated Clock Mode Timing Diagram**

The timing described in Figure 46 is that of a Motorola sensor. Some other sensors may have slightly different timing. The CSI can be programmed to support rising/falling-edge triggered SENS\_B\_VSYNC; active-high/low SENS\_B\_HSYNC; and rising/falling-edge triggered SENS\_B\_PIX\_CLK.

### 4.9.12.3 Electrical Characteristics

Figure 47 depicts the sensor interface timing, and Table 51 lists the timing parameters.

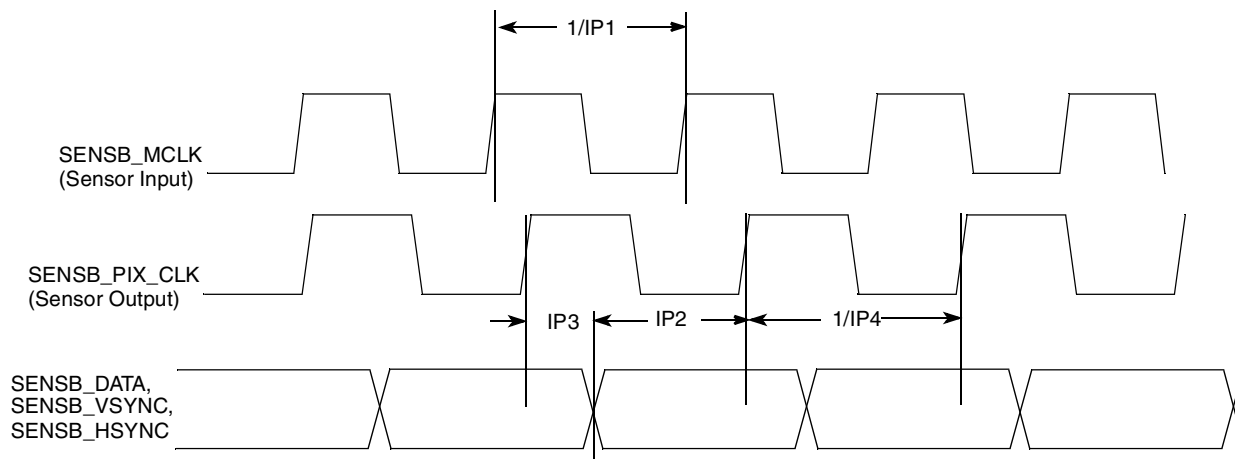


Figure 47. Sensor Interface Timing Diagram

Table 51. Sensor Interface Timing Parameters

| ID  | Parameter                             | Symbol | Min. | Max. | Units |
|-----|---------------------------------------|--------|------|------|-------|
| IP1 | Sensor input clock frequency          | Fmck   | 0.01 | 133  | MHz   |
| IP2 | Data and control setup time           | Tsu    | 5    | —    | ns    |
| IP3 | Data and control holdup time          | Thd    | 3    | —    | ns    |
| IP4 | Sensor output (pixel) clock frequency | Fpck   | 0.01 | 133  | MHz   |

### 4.9.13 IPU—Display Interfaces

This section describes the following types of display interfaces:

- [Section 4.9.13.1, “Synchronous Interfaces”](#)
- [Section 4.9.13.2, “Interface to Sharp HR-TFT Panels”](#)
- [Section 4.9.13.3, “Synchronous Interface to Dual-Port Smart Displays”](#)
- [Section 4.9.13.4, “Asynchronous Interfaces”](#)
- [Section 4.9.13.5, “Serial Interfaces, Functional Description”](#)

### 4.9.13.1 Synchronous Interfaces

This section discusses the interfaces to active matrix TFT LCD panels, Sharp HR-TFT, and dual-port smart displays.

#### 4.9.13.1.4 Interface to Active Matrix TFT LCD Panels, Functional Description

Figure 48 depicts the LCD interface timing for a generic active matrix color TFT panel. In this figure, signals are shown with negative polarity. The sequence of events for active matrix interface timing is as follows:

- DISP\_B\_D3\_CLK latches data into the panel on its negative edge (when positive polarity is selected). In active mode, DISP\_B\_D3\_CLK runs continuously.
- DISP\_B\_D3\_HSYNC causes the panel to start a new line.
- DISP\_B\_D3\_VSYNC causes the panel to start a new frame. It always encompasses at least one HSYNC pulse.
- DISP\_B\_D3\_DRDY acts like an output enable signal to the CRT display. This output enables the data to be shifted to the display. When disabled, the data is invalid and the trace is off.

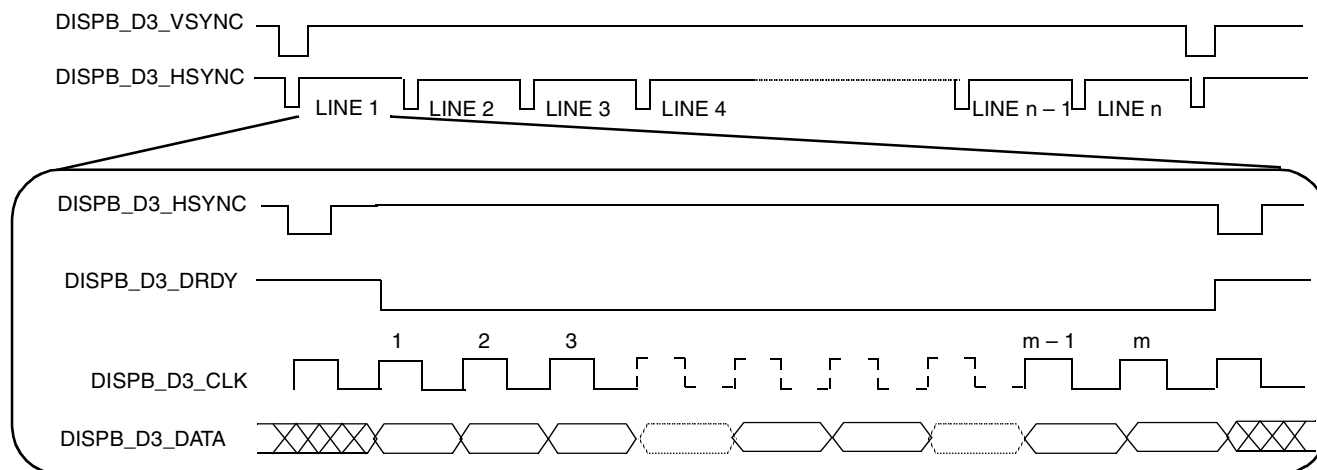


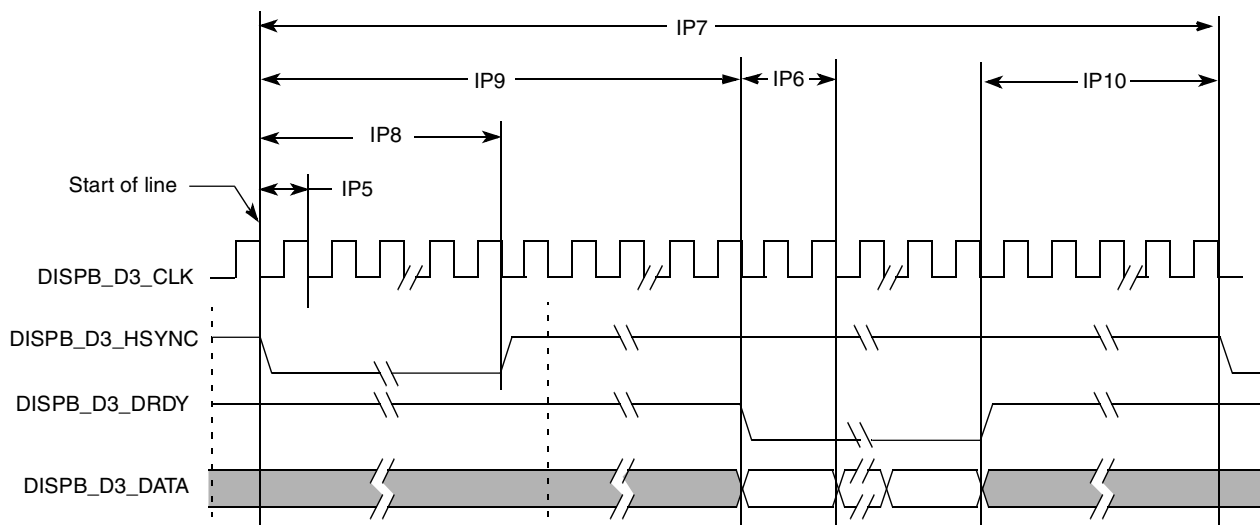
Figure 48. Interface Timing Diagram for TFT (Active Matrix) Panels

#### 4.9.13.1.5 Interface to Active Matrix TFT LCD Panels, Electrical Characteristics

Figure 49 depicts the horizontal timing (timing of one line), including both the horizontal sync pulse and the data. All figure parameters shown are programmable. The timing images correspond to inverse polarity

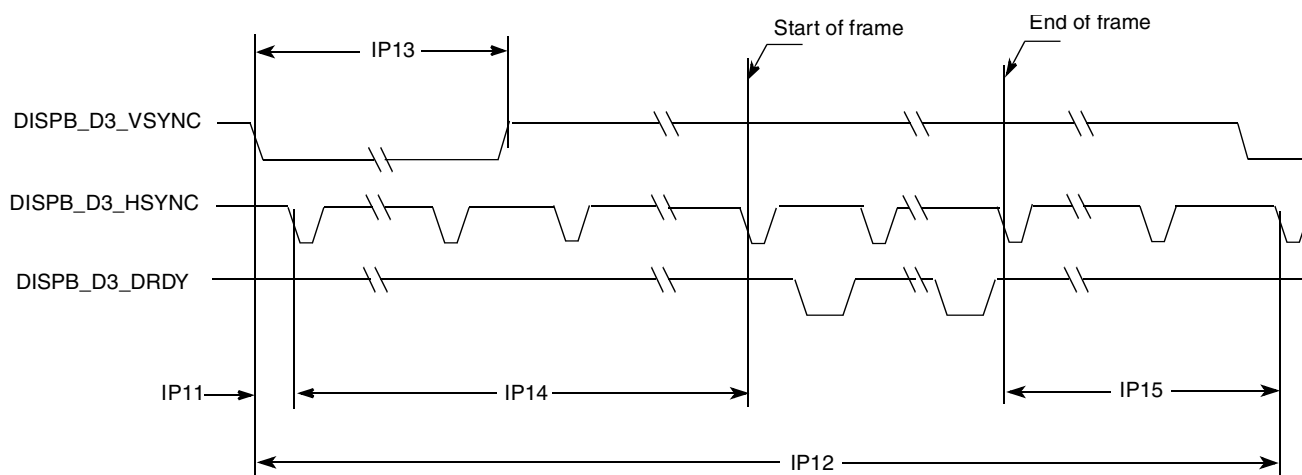


of the DISPB\_D3\_CLK signal and active-low polarity of the DISPB\_D3\_HSYNC, DISPB\_D3\_VSYNC and DISPB\_D3\_DRDY signals.



**Figure 49. TFT Panels Timing Diagram—Horizontal Sync Pulse**

Figure 50 depicts the vertical timing (timing of one frame). All figure parameters shown are programmable.



**Figure 50. TFT Panels Timing Diagram—Vertical Sync Pulse**

Table 52 shows timing parameters of signals presented in Figure 49 and Figure 50.

**Table 52. Synchronous Display Interface Timing Parameters—Pixel Level**

| ID  | Parameter                      | Symbol | Value                            | Units |
|-----|--------------------------------|--------|----------------------------------|-------|
| IP5 | Display interface clock period | Tdicp  | Tdicp <sup>1</sup>               | ns    |
| IP6 | Display pixel clock period     | Tdpcp  | (DISP3_IF_CLK_CNT_D + 1) × Tdicp | ns    |
| IP7 | Screen width                   | Tsw    | (SCREEN_WIDTH + 1) × Tdpcp       | ns    |
| IP8 | HSYNC width                    | Thsw   | (H_SYNC_WIDTH + 1) × Tdpcp       | ns    |

**Table 52. Synchronous Display Interface Timing Parameters—Pixel Level (continued)**

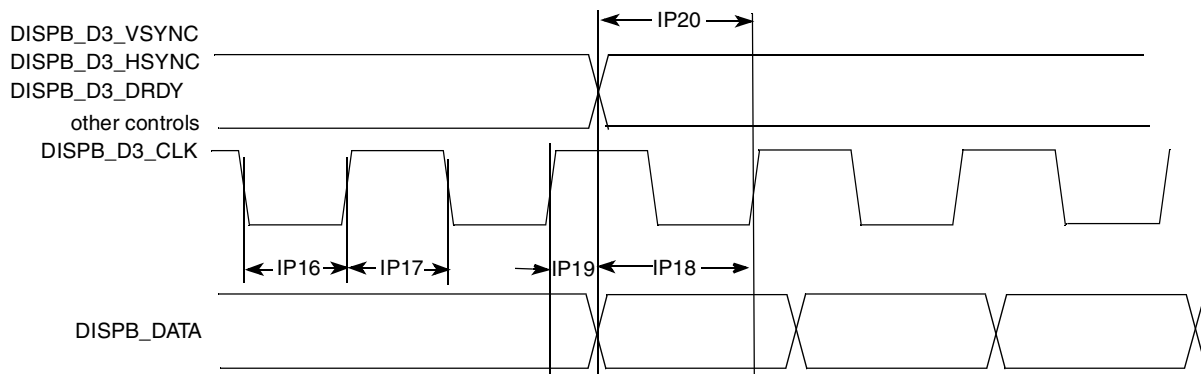
| ID   | Parameter                   | Symbol | Value                                                                                        | Units |
|------|-----------------------------|--------|----------------------------------------------------------------------------------------------|-------|
| IP9  | Horizontal blank interval 1 | Thbi1  | BGXP × Tdpcp                                                                                 | ns    |
| IP10 | Horizontal blank interval 2 | Thbi2  | (SCREEN_WIDTH – BGXP – FW) × Tdpcp                                                           | ns    |
| IP11 | HSYNC delay                 | Thsd   | H_SYNC_DELAY × Tdpcp                                                                         | ns    |
| IP12 | Screen height               | Tsh    | (SCREEN_HEIGHT + 1) × Tsw                                                                    | ns    |
| IP13 | VSYNC width                 | Tvsw   | if V_SYNC_WIDTH_L = 0 than<br>(V_SYNC_WIDTH + 1) × Tdpcp<br>else<br>(V_SYNC_WIDTH + 1) × Tsw | ns    |
| IP14 | Vertical blank interval 1   | Tvbi1  | BGYP × Tsw                                                                                   | ns    |
| IP15 | Vertical blank interval 2   | Tvbi2  | (SCREEN_HEIGHT – BGYP – FH) × Tsw                                                            | ns    |

<sup>1</sup> Display interface clock period immediate value

Display interface clock period average value.

$$\bar{T}_{dicp} = T_{HSP\_CLK} \cdot \frac{DISP3\_IF\_CLK\_PER\_WR}{HSP\_CLK\_PERIOD}$$

Figure 51 depicts the synchronous display interface timing for access level, and Table 53 lists the timing parameters. The DISP3\_IF\_CLK\_DOWN\_WR and DISP3\_IF\_CLK\_UP\_WR parameters are set via the DI\_DISP3\_TIME\_CONF Register.



**Figure 51. Synchronous Display Interface Timing Diagram—Access Level**

**Table 53. Synchronous Display Interface Timing Parameters—Access Level**

| ID   | Parameter                                             | Symbol | Min.                        | Typ. <sup>1</sup>                       | Max.                        | Units |
|------|-------------------------------------------------------|--------|-----------------------------|-----------------------------------------|-----------------------------|-------|
| IP16 | Display interface clock low time                      | Tckl   | Tdicd – Tdicu – 1.5         | Tdicd <sup>2</sup> – Tdicu <sup>3</sup> | Tdicd – Tdicu + 1.5         | ns    |
| IP17 | Display interface clock high time                     | Tckh   | Tdicp – Tdicd + Tdicu – 1.5 | Tdicp – Tdicd + Tdicu                   | Tdicp – Tdicd + Tdicu + 1.5 | ns    |
| IP18 | Data setup time                                       | Tdsu   | Tdicd – 3.5                 | Tdicu                                   | —                           | ns    |
| IP19 | Data holdup time                                      | Tdhd   | Tdicp – Tdicd – 3.5         | Tdicp – Tdicu                           | —                           | ns    |
| IP20 | Control signals setup time to display interface clock | Tcsu   | Tdicd – 3.5                 | Tdicu                                   | —                           | ns    |

<sup>1</sup> The exact conditions have not been finalized, but will likely match the current customer requirement for their specific display. These conditions may be device specific.

<sup>2</sup> Display interface clock down time

$$T_{dicd} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot \text{DISP3\_IF\_CLK\_DOWN\_WR}}{HSP\_CLK\_PERIOD} \right]$$

<sup>3</sup> Display interface clock up time

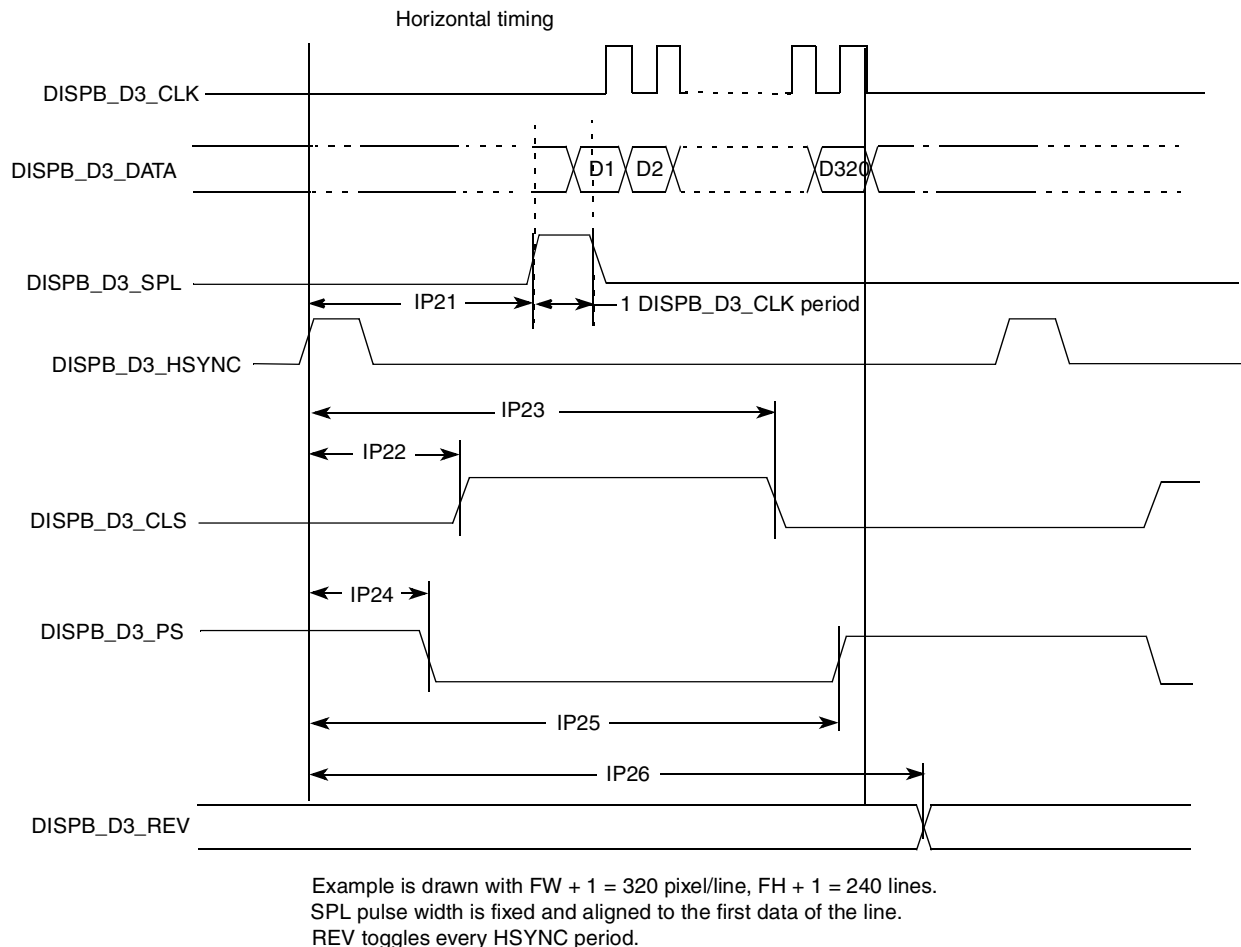
$$T_{dicu} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot \text{DISP3\_IF\_CLK\_UP\_WR}}{HSP\_CLK\_PERIOD} \right]$$

where CEIL(X) rounds the elements of X to the nearest integers toward infinity.

#### 4.9.13.2 Interface to Sharp HR-TFT Panels

Figure 52 depicts the Sharp HR-TFT panel interface timing, and Table 54 lists the timing parameters. The CLS\_RISE\_DELAY, CLS\_FALL\_DELAY, PS\_FALL\_DELAY, PS\_RISE\_DELAY, REV\_TOGGLE\_DELAY parameters are defined in the SDC\_SHARP\_CONF\_1 and SDC\_SHARP\_CONF\_2 registers. For other Sharp interface timing characteristics, refer to

Section 4.9.13.1.5, “Interface to Active Matrix TFT LCD Panels, Electrical Characteristics.” The timing images correspond to straight polarity of the Sharp signals.



**Figure 52. Sharp HR-TFT Panel Interface Timing Diagram—Pixel Level**

**Table 54. Sharp Synchronous Display Interface Timing Parameters—Pixel Level**

| ID   | Parameter                 | Symbol     | Value                                | Units |
|------|---------------------------|------------|--------------------------------------|-------|
| IP21 | SPL rise time             | $T_{splr}$ | $(BGXP - 1) \times T_{dpcp}$         | ns    |
| IP22 | CLS rise time             | $T_{clsr}$ | $CLS\_RISE\_DELAY \times T_{dpcp}$   | ns    |
| IP23 | CLS fall time             | $T_{clsf}$ | $CLS\_FALL\_DELAY \times T_{dpcp}$   | ns    |
| IP24 | CLS rise and PS fall time | $T_{psf}$  | $PS\_FALL\_DELAY \times T_{dpcp}$    | ns    |
| IP25 | PS rise time              | $T_{psr}$  | $PS\_RISE\_DELAY \times T_{dpcp}$    | ns    |
| IP26 | REV toggle time           | $T_{rev}$  | $REV\_TOGGLE\_DELAY \times T_{dpcp}$ | ns    |

### 4.9.13.3 Synchronous Interface to Dual-Port Smart Displays

Functionality and electrical characteristics of the synchronous interface to dual-port smart displays are identical to parameters of the synchronous interface. See [Section 4.9.13.1.5, “Interface to Active Matrix TFT LCD Panels, Electrical Characteristics.”](#)

#### 4.9.13.3.6 Interface to a TV Encoder—Functional Description

The interface has an 8-bit data bus, transferring a single 8-bit value (Y/U/V) in each cycle. The bits D7–D0 of the value are mapped to bits LD17–LD10 of the data bus, respectively. [Figure 53](#) depicts the interface timing.

- The frequency of the clock DISPB\_D3\_CLK is 27 MHz.
- The DISPB\_D3\_HSYNC, DISPB\_D3\_VSYNC and DISPB\_D3\_DRDY signals are active low.
- The transition to the next row is marked by the negative edge of the DISPB\_D3\_HSYNC signal. It remains low for a single clock cycle.
- The transition to the next field/frame is marked by the negative edge of the DISPB\_D3\_VSYNC signal. It remains low for at least one clock cycle.
  - At a transition to an odd field (of the next frame), the negative edges of DISPB\_D3\_VSYNC and DISPB\_D3\_HSYNC coincide.
  - At a transition to an even field (of the same frame), they do not coincide.
- The active intervals—during which data is transferred—are marked by the DISPB\_D3\_HSYNC signal being high.

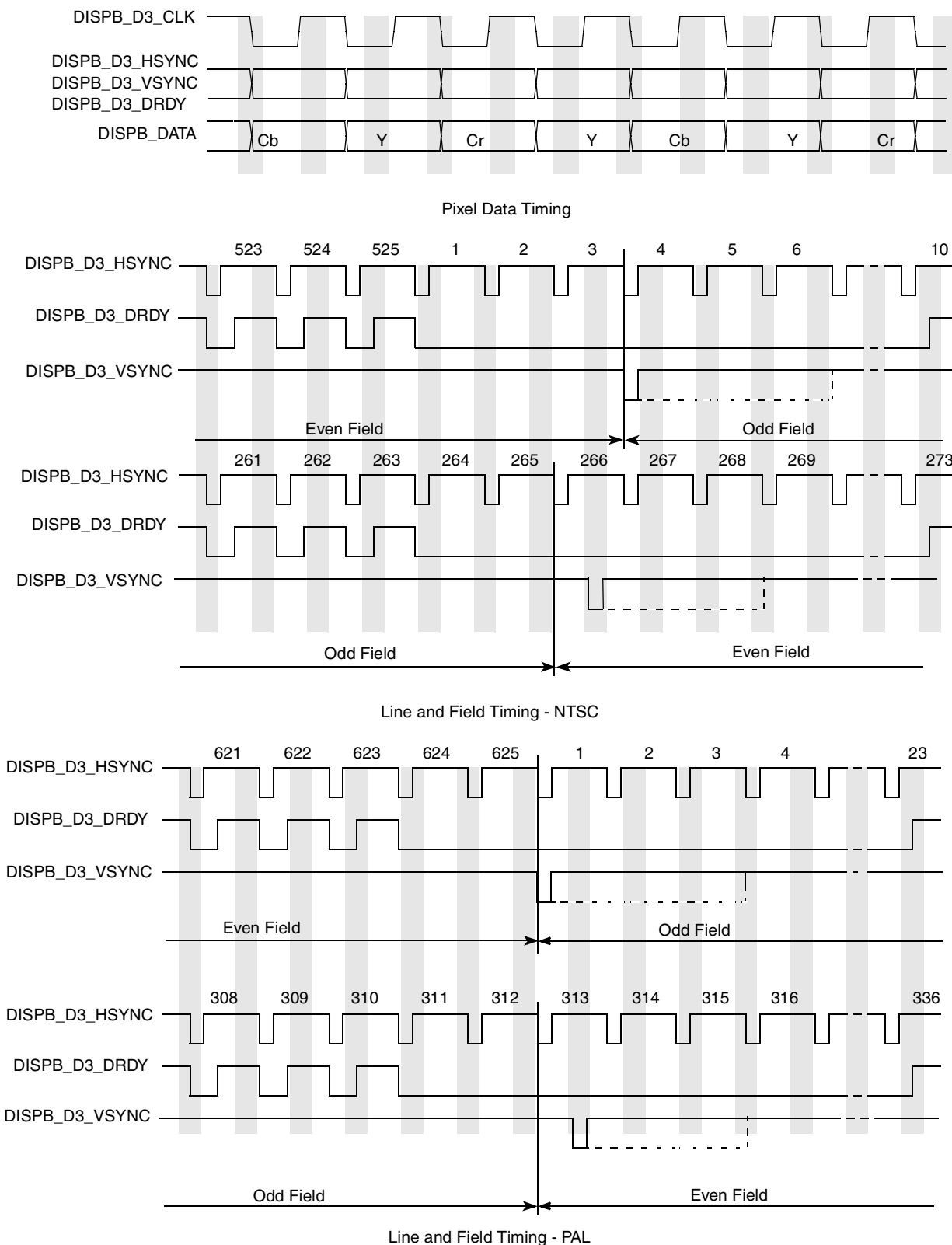


Figure 53. TV Encoder Interface Timing Diagram

#### 4.9.13.3.7 Interface to a TV Encoder, Electrical Characteristics

The timing characteristics of the TV encoder interface are identical to the synchronous display characteristics. See [Section 4.9.13.1.5, “Interface to Active Matrix TFT LCD Panels, Electrical Characteristics.”](#)

#### 4.9.13.4 Asynchronous Interfaces

This section discusses the asynchronous parallel and serial interfaces.

##### 4.9.13.4.8 Parallel Interfaces, Functional Description

The IPU supports the following asynchronous parallel interfaces:

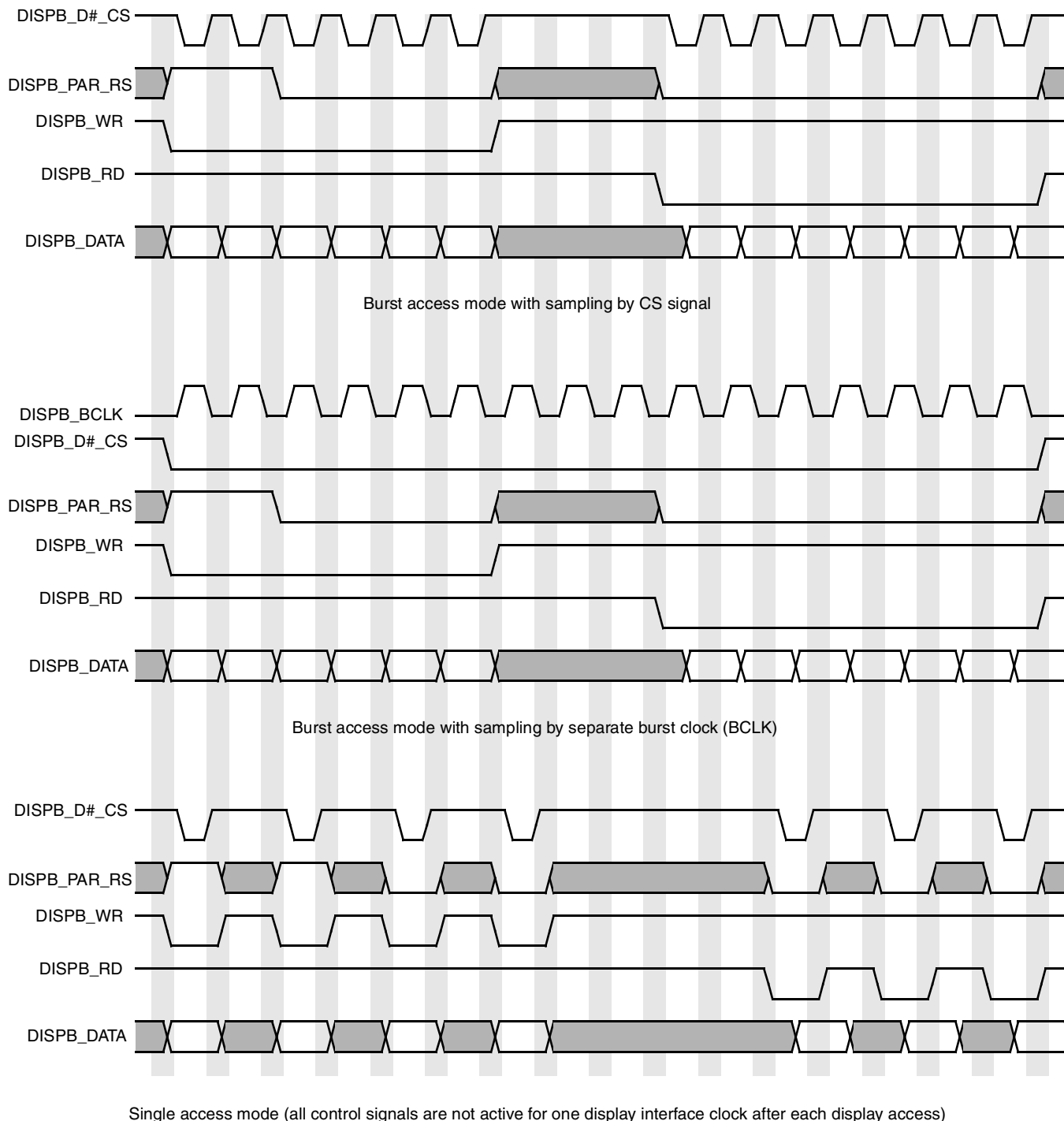
- System 80 interface
  - Type 1 (sampling with the chip select signal) with and without byte enable signals.
  - Type 2 (sampling with the read and write signals) with and without byte enable signals.
- System 68k interface
  - Type 1 (sampling with the chip select signal) with or without byte enable signals.
  - Type 2 (sampling with the read and write signals) with or without byte enable signals.

For each of four system interfaces, there are three burst modes:

1. Burst mode without a separate clock—The burst length is defined by the corresponding parameters of the IDMAC (when data is transferred from the system memory) or by the HBURST signal (when the MCU directly accesses the display via the slave AHB bus). For system 80 and system 68k type 1 interfaces, data is sampled by the CS signal and other control signals change only when transfer direction is changed during the burst. For type 2 interfaces, data is sampled by the WR/RD signals (system 80) or by the ENABLE signal (system 68k), and the CS signal stays active during the whole burst.
2. Burst mode with the separate clock DISPB\_BCLK—In this mode, data is sampled with the DISPB\_BCLK clock. The CS signal stays active during whole burst transfer. Other controls are changed simultaneously with data when the bus state (read, write or wait) is altered. The CS signals and other controls move to non-active state after burst has been completed.
3. Single access mode—In this mode, slave AHB and DMA burst are broken to single accesses. The data is sampled with CS or other controls according to the interface type as described above. All controls (including CS) become non-active for one display interface clock after each access. This mode corresponds to the ATI single access mode.

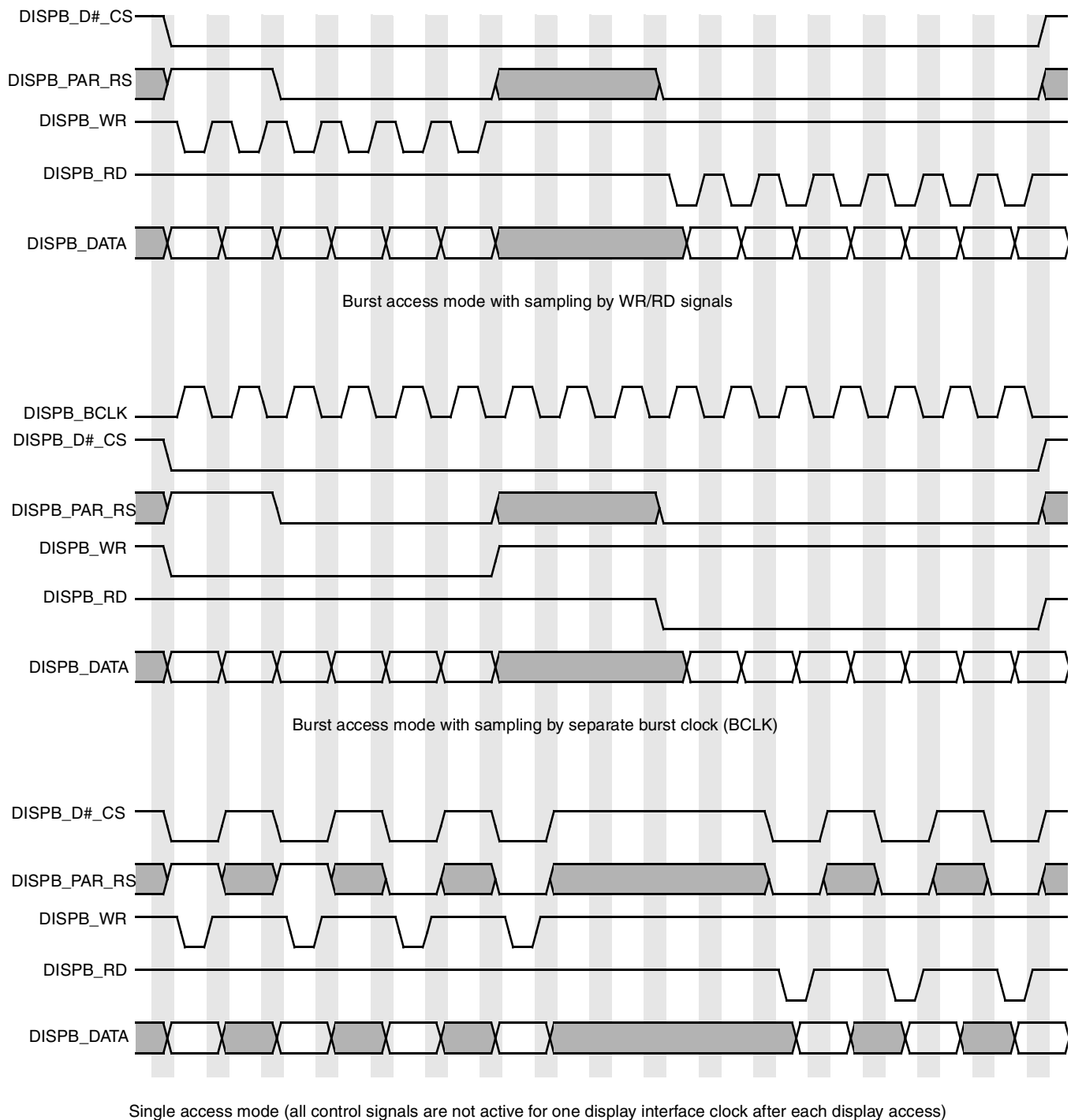
Both system 80 and system 68k interfaces are supported for all described modes as depicted in [Figure 54](#), [Figure 55](#), [Figure 56](#), and [Figure 57](#). These timing images correspond to active-low DISPB\_Dn\_CS, DISPB\_Dn\_WR and DISPB\_Dn\_RD signals.

Additionally, the IPU allows a programmable pause between two bursts. The pause is defined in the HSP\_CLK cycles. It allows the prevention of timing violation between two sequential bursts or two accesses to different displays. The range of this pause is from 4 to 19 HSP\_CLK cycles.

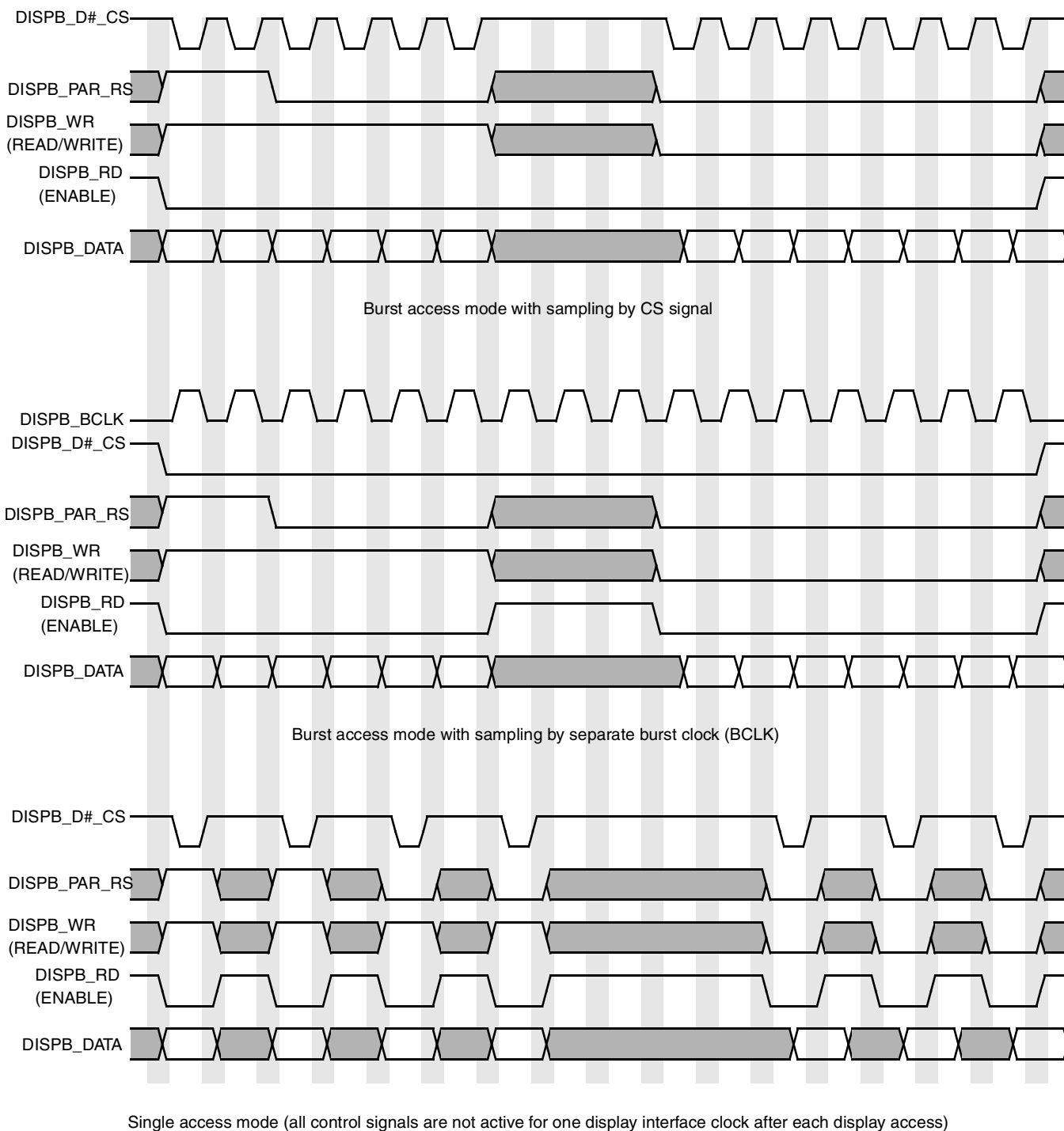


**Figure 54. Asynchronous Parallel System 80 Interface (Type 1) Burst Mode Timing Diagram**

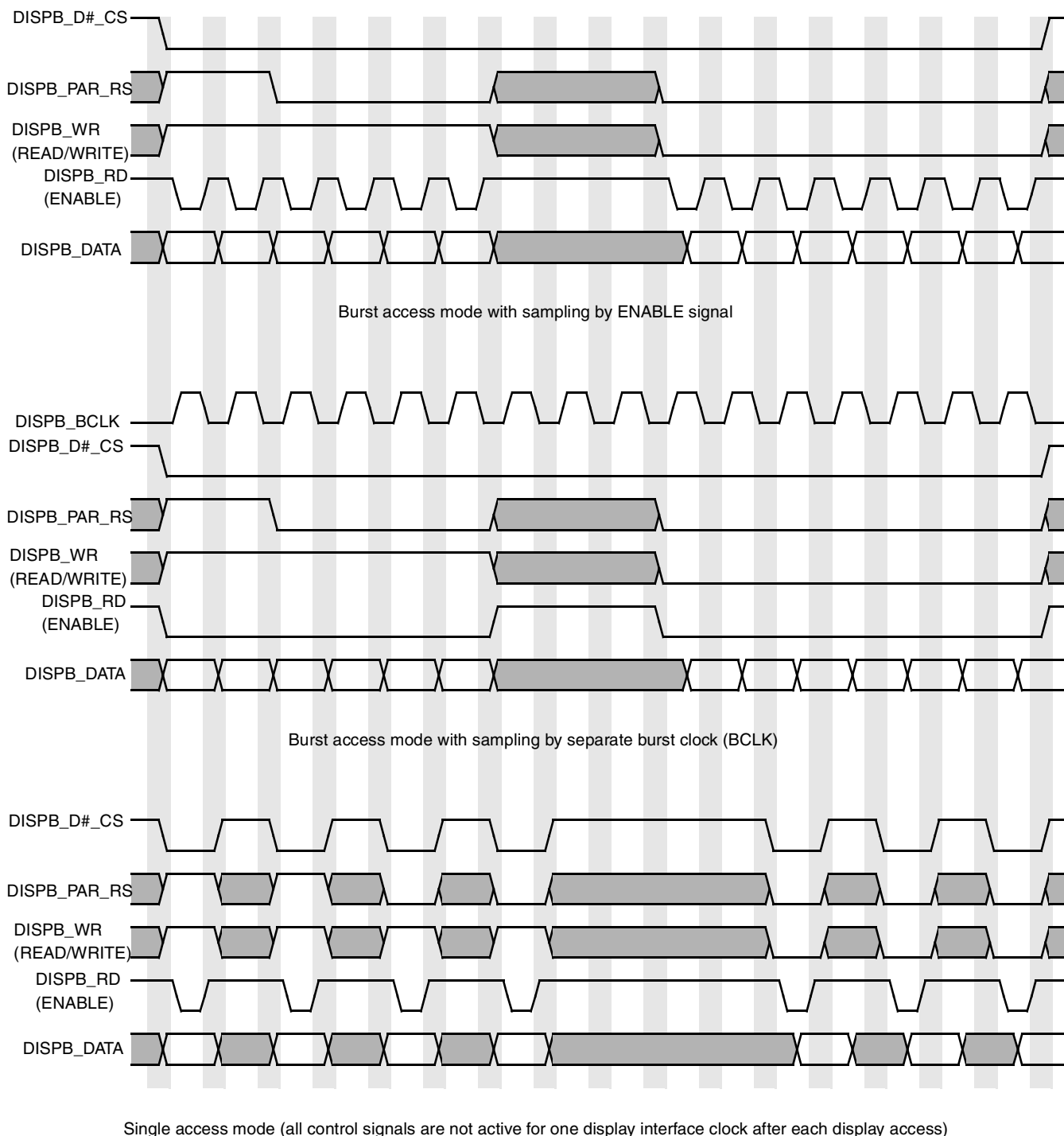




**Figure 55. Asynchronous Parallel System 80 Interface (Type 2) Burst Mode Timing Diagram**



**Figure 56. Asynchronous Parallel System 68k Interface (Type 1) Burst Mode Timing Diagram**

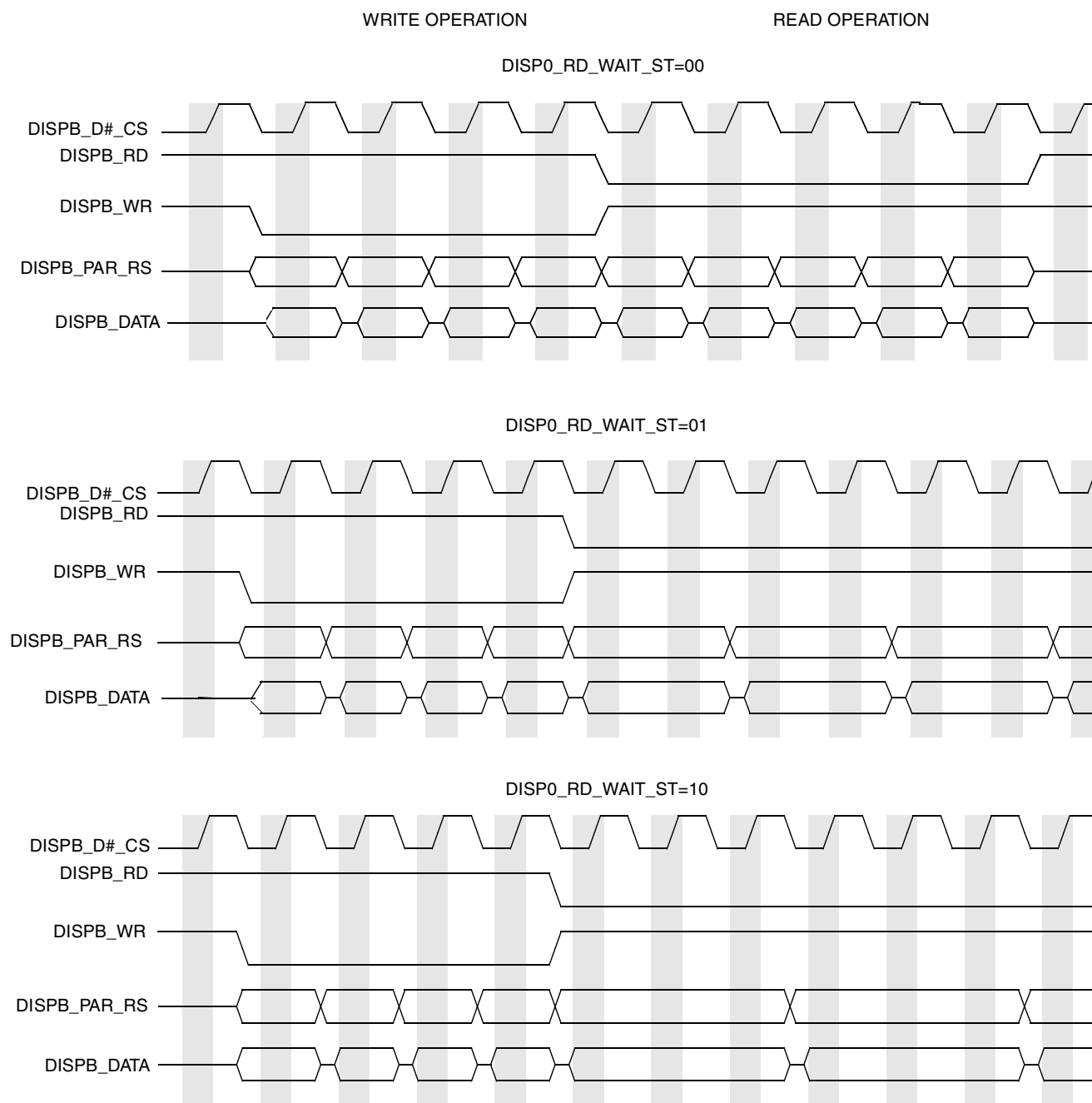


Single access mode (all control signals are not active for one display interface clock after each display access)

**Figure 57. Asynchronous Parallel System 68k Interface (Type 2) Burst Mode Timing Diagram**

Display read operation can be performed with wait states when each read access takes up to 4 display interface clock cycles according to the **DISP0\_RD\_WAIT\_ST** parameter in the

DI\_DISPn\_TIME\_CONF\_3 registers ( $n = 0, 1, 2$ ). [Figure 58](#) shows the timing of the parallel interface with read wait states.



### Figure 58. Parallel Interface Timing Diagram—Read Wait States

#### 4.9.13.4.9 Parallel Interfaces, Electrical Characteristics

Figure 59, Figure 61, Figure 60, and Figure 62 depict timing of asynchronous parallel interfaces based on the system 80 and system 68k interfaces. Table 55 lists the timing parameters at display access level. All

timing images are based on active low control signals (signal polarity is controlled via the DI\_DISP\_SIG\_POL register).

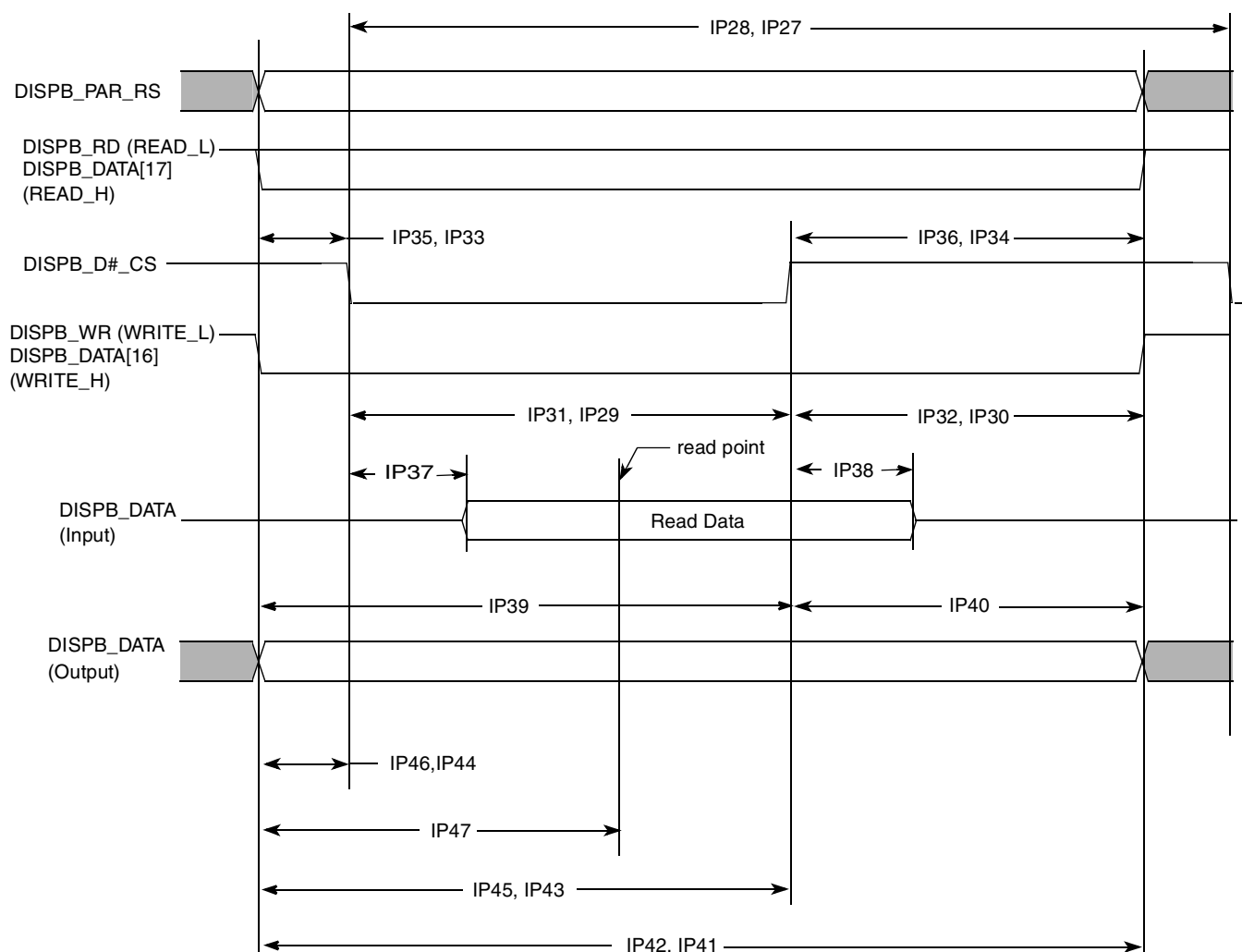
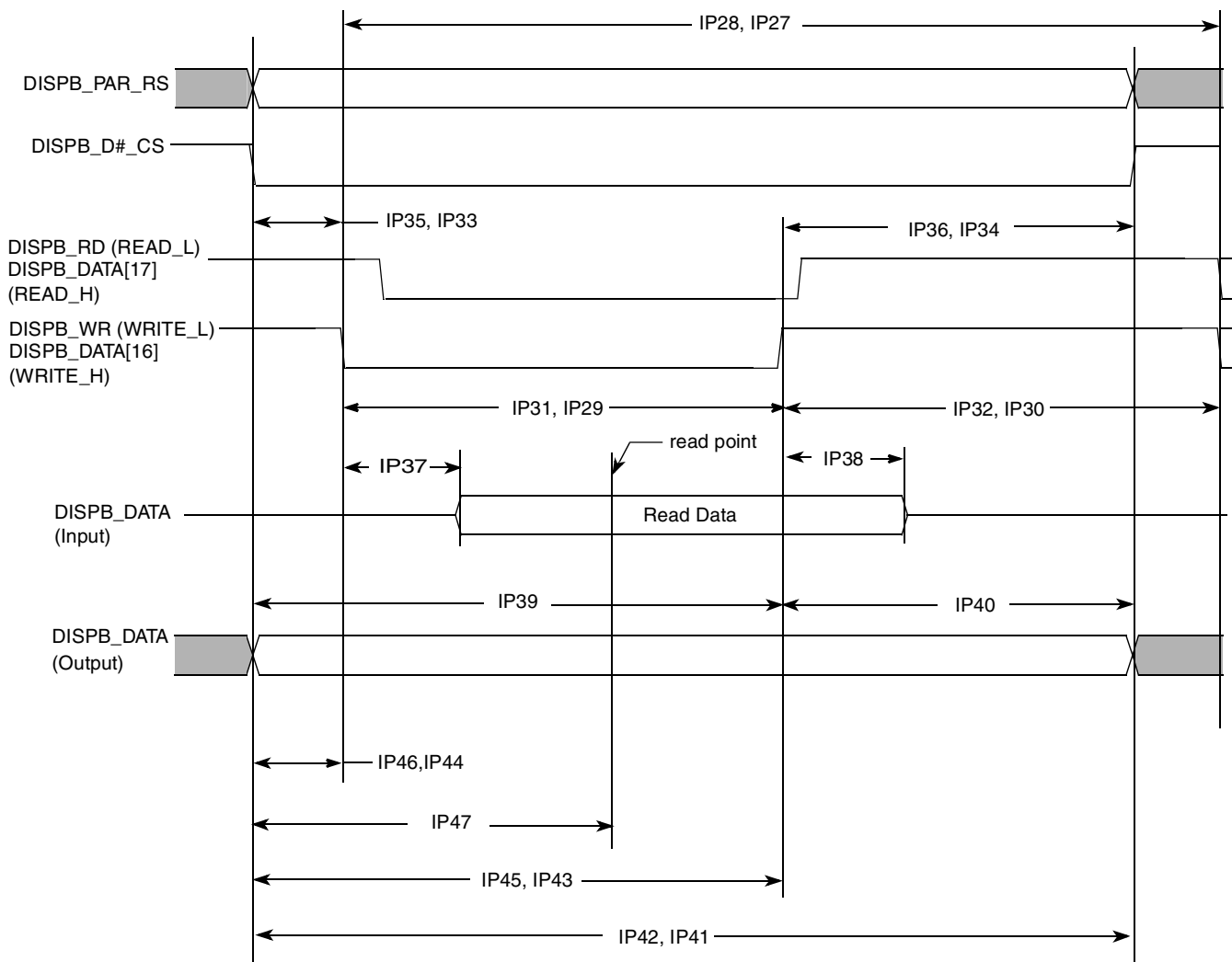
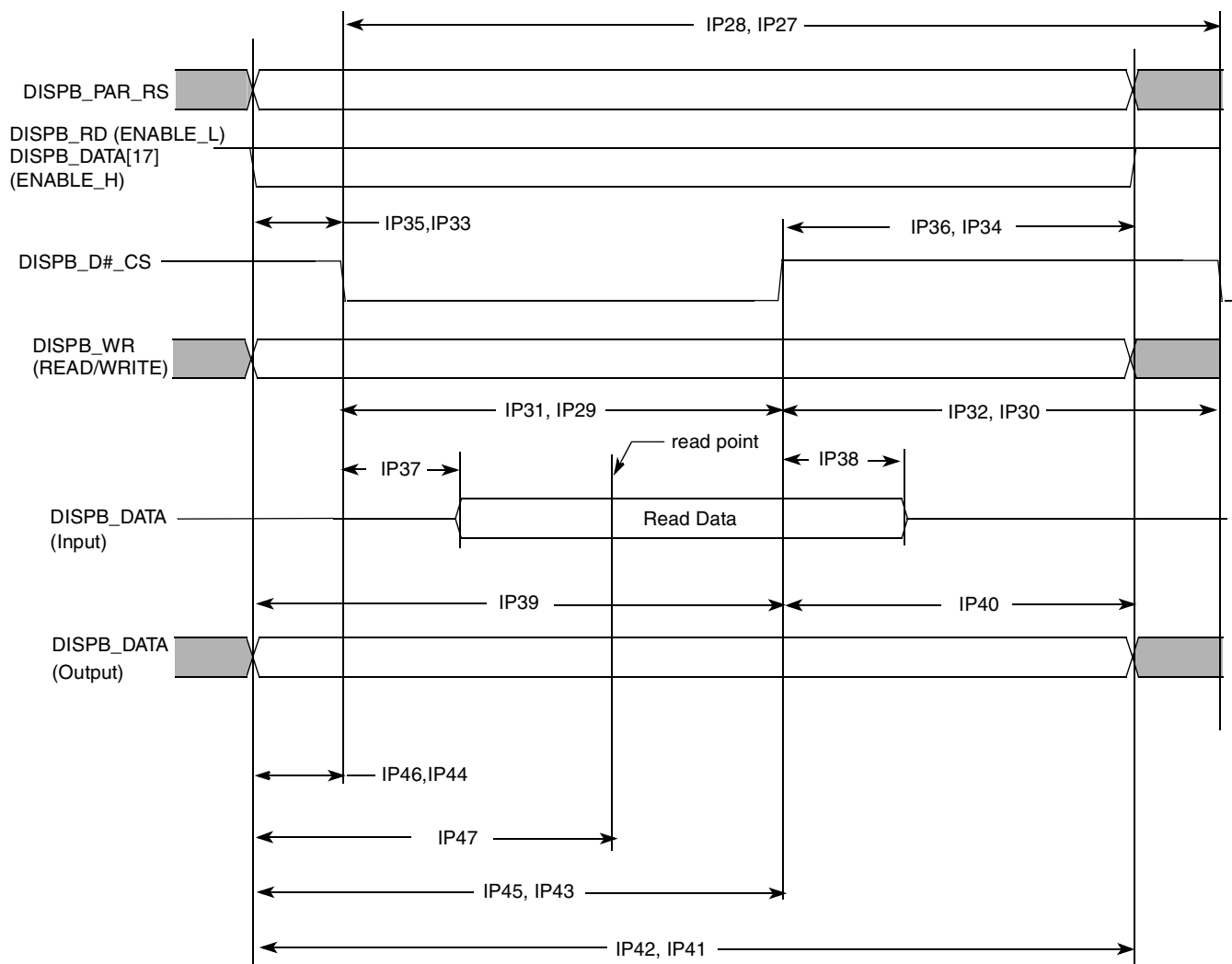


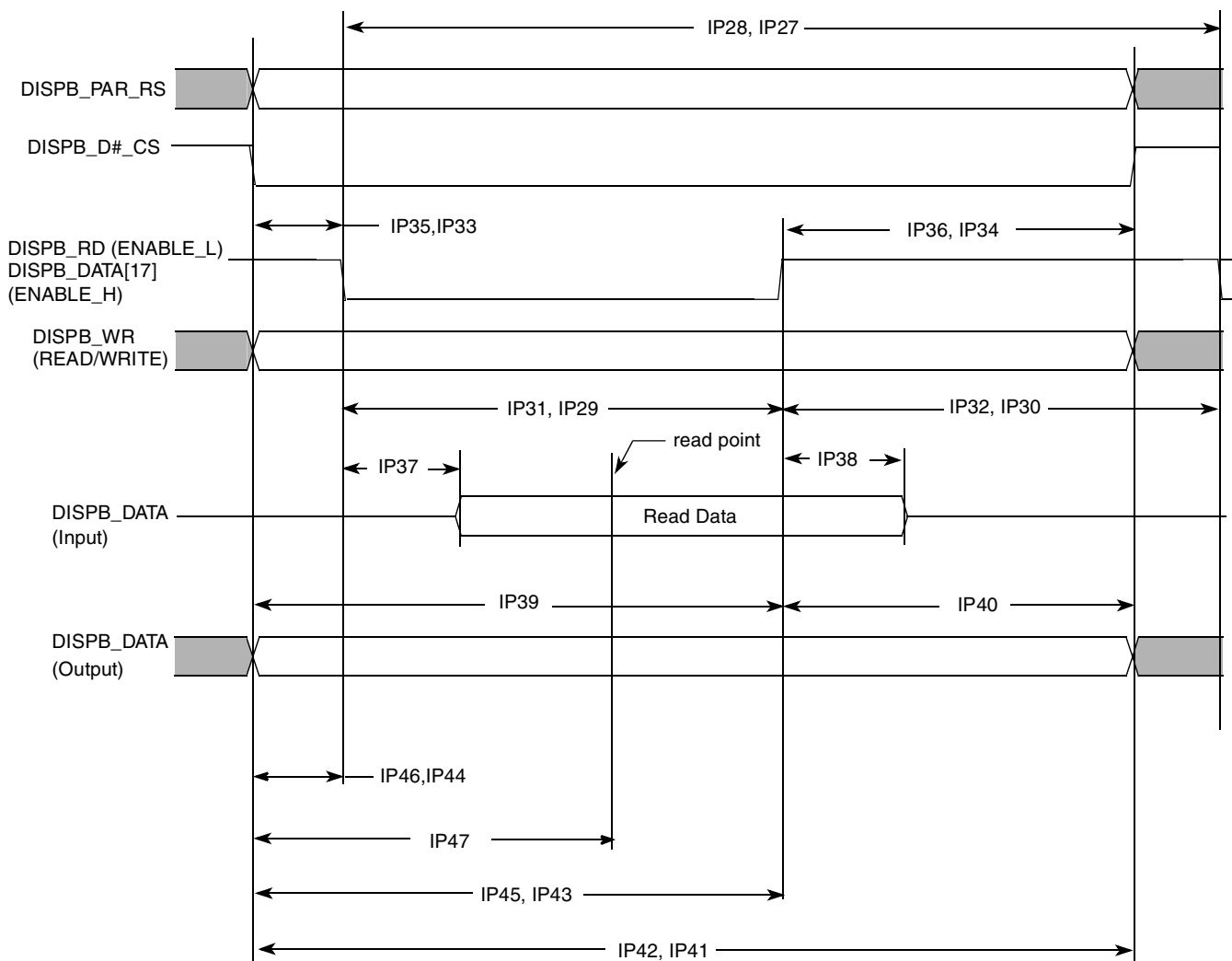
Figure 59. Asynchronous Parallel System 80 Interface (Type 1) Timing Diagram



**Figure 60. Asynchronous Parallel System 80 Interface (Type 2) Timing Diagram**



**Figure 61. Asynchronous Parallel System 68k Interface (Type 1) Timing Diagram**



**Figure 62. Asynchronous Parallel System 68k Interface (Type 2) Timing Diagram**

**Table 55. Asynchronous Parallel Interface Timing Parameters—Access Level**

| ID   | Parameter                    | Symbol | Min.                           | Typ. <sup>1</sup>                         | Max.                           | Units |
|------|------------------------------|--------|--------------------------------|-------------------------------------------|--------------------------------|-------|
| IP27 | Read system cycle time       | Tcycr  | Tdicpr – 1.5                   | Tdicpr <sup>2</sup>                       | Tdicpr + 1.5                   | ns    |
| IP28 | Write system cycle time      | Tcycw  | Tdicpw – 1.5                   | Tdicpw <sup>3</sup>                       | Tdicpw + 1.5                   | ns    |
| IP29 | Read low pulse width         | Trl    | Tdicdr – Tdicur – 1.5          | Tdicdr <sup>4</sup> – Tdicur <sup>5</sup> | Tdicdr – Tdicur + 1.5          | ns    |
| IP30 | Read high pulse width        | Trh    | Tdicpr – Tdicdr + Tdicur – 1.5 | Tdicpr – Tdicdr + Tdicur                  | Tdicpr – Tdicdr + Tdicur + 1.5 | ns    |
| IP31 | Write low pulse width        | Twl    | Tdicdw – Tdicuw – 1.5          | Tdicdw <sup>6</sup> – Tdicuw <sup>7</sup> | Tdicdw – Tdicuw + 1.5          | ns    |
| IP32 | Write high pulse width       | Twh    | Tdicpw – Tdicdw + Tdicuw – 1.5 | Tdicpw – Tdicdw + Tdicuw                  | Tdicpw – Tdicdw + Tdicuw + 1.5 | ns    |
| IP33 | Controls setup time for read | Tdcsr  | Tdicur – 1.5                   | Tdicur                                    | —                              | ns    |
| IP34 | Controls hold time for read  | Tdchr  | Tdicpr – Tdicdr – 1.5          | Tdicpr – Tdicdr                           | —                              | ns    |



**Table 55. Asynchronous Parallel Interface Timing Parameters—Access Level (continued)**

| ID   | Parameter                                | Symbol | Min.                       | Typ. <sup>1</sup> | Max.                                                  | Units |
|------|------------------------------------------|--------|----------------------------|-------------------|-------------------------------------------------------|-------|
| IP35 | Controls setup time for write            | Tdcsw  | Tdicuw – 1.5               | Tdicuw            | —                                                     | ns    |
| IP36 | Controls hold time for write             | Tdchw  | Tdicpw – Tdicdw – 1.5      | Tdicpw – Tdicdw   | —                                                     | ns    |
| IP37 | Slave device data delay <sup>8</sup>     | Tracc  | 0                          | —                 | Tdrp <sup>9</sup> – Tlbd <sup>10</sup> – Tdicur – 1.5 | ns    |
| IP38 | Slave device data hold time <sup>8</sup> | Troh   | Tdrp – Tlbd – Tdicdr + 1.5 | —                 | Tdicpr – Tdicdr – 1.5                                 | ns    |
| IP39 | Write data setup time                    | Tds    | Tdicdw – 1.5               | Tdicdw            | —                                                     | ns    |
| IP40 | Write data hold time                     | Tdh    | Tdicpw – Tdicdw – 1.5      | Tdicpw – Tdicdw   | —                                                     | ns    |
| IP41 | Read period <sup>2</sup>                 | Tdicpr | Tdicpr – 1.5               | Tdicpr            | Tdicpr + 1.5                                          | ns    |
| IP42 | Write period <sup>3</sup>                | Tdicpw | Tdicpw – 1.5               | Tdicpw            | Tdicpw + 1.5                                          | ns    |
| IP43 | Read down time <sup>4</sup>              | Tdicdr | Tdicdr – 1.5               | Tdicdr            | Tdicdr + 1.5                                          | ns    |
| IP44 | Read up time <sup>5</sup>                | Tdicur | Tdicur – 1.5               | Tdicur            | Tdicur + 1.5                                          | ns    |
| IP45 | Write down time <sup>6</sup>             | Tdicdw | Tdicdw – 1.5               | Tdicdw            | Tdicdw + 1.5                                          | ns    |
| IP46 | Write up time <sup>7</sup>               | Tdicuw | Tdicuw – 1.5               | Tdicuw            | Tdicuw + 1.5                                          | ns    |
| IP47 | Read time point <sup>9</sup>             | Tdrp   | Tdrp – 1.5                 | Tdrp              | Tdrp + 1.5                                            | ns    |

<sup>1</sup>The exact conditions have not been finalized, but will likely match the current customer requirement for their specific display. These conditions may be device-specific.

<sup>2</sup> Display interface clock period value for read:

$$T_{dicpr} = T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{DISP\#\_IF\_CLK\_PER\_RD}{HSP\_CLK\_PERIOD} \right]$$

<sup>3</sup> Display interface clock period value for write:

$$T_{dicpw} = T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{DISP\#\_IF\_CLK\_PER\_WR}{HSP\_CLK\_PERIOD} \right]$$

<sup>4</sup> Display interface clock down time for read:

$$T_{dicdr} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_DOWN\_RD}{HSP\_CLK\_PERIOD} \right]$$

<sup>5</sup> Display interface clock up time for read:

$$T_{dicur} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_UP\_RD}{HSP\_CLK\_PERIOD} \right]$$

<sup>6</sup> Display interface clock down time for write:

$$T_{dicdw} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_DOWN\_WR}{HSP\_CLK\_PERIOD} \right]$$

<sup>7</sup> Display interface clock up time for write:

$$T_{dicuw} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_UP\_WR}{HSP\_CLK\_PERIOD} \right]$$

<sup>8</sup> This parameter is a requirement to the display connected to the IPU

<sup>9</sup> Data read point

$$T_{drp} = T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{DISP\#\_READ\_EN}{HSP\_CLK\_PERIOD} \right]$$

<sup>10</sup> Loopback delay  $T_{lbd}$  is the cumulative propagation delay of read controls and read data. It includes an IPU output delay, a device – level output delay, board delays, a device – level input delay, an IPU input delay. This value is device specific.

The following parameters are programmed via the DI\_DISP#\_TIME\_CONF\_1, DI\_DISP#\_TIME\_CONF\_2, and DI\_HSP\_CLK\_PER registers:

- DISP#\_IF\_CLK\_PER\_WR, DISP#\_IF\_CLK\_PER\_RD
- HSP\_CLK\_PERIOD
- DISP#\_IF\_CLK\_DOWN\_WR
- DISP#\_IF\_CLK\_UP\_WR
- DISP#\_IF\_CLK\_DOWN\_RD
- DISP#\_IF\_CLK\_UP\_RD
- DISP#\_READ\_EN

#### 4.9.13.5 Serial Interfaces, Functional Description

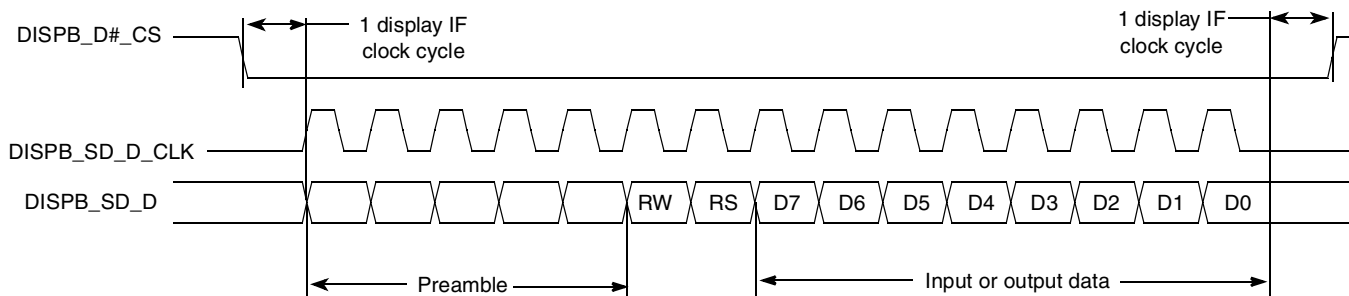
The IPU supports the following types of asynchronous serial interfaces:

- 3-wire (with bidirectional data line)
- 4-wire (with separate data input and output lines)
- 5-wire type 1 (with sampling RS by the serial clock)
- 5-wire type 2 (with sampling RS by the chip select signal)

**Figure 63** depicts timing of the 3-wire serial interface. The timing images correspond to active-low DISPB\_D#\_CS signal and the straight polarity of the DISPB\_SD\_D\_CLK signal.

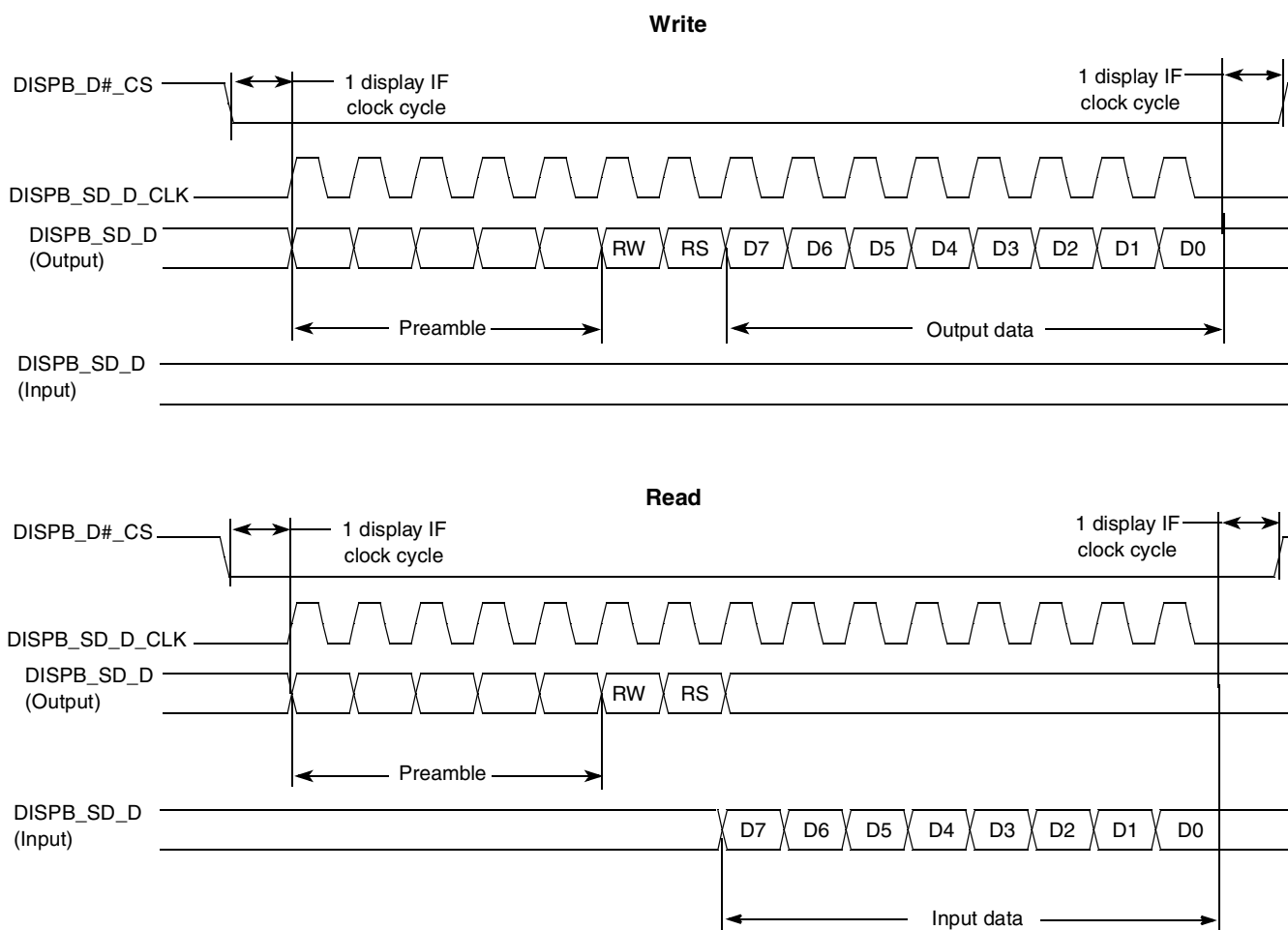
For this interface, a bidirectional data line is used outside the device. The IPU still uses separate input and output data lines (IPP\_IND\_DISP\_B\_SD\_D and IPP\_DO\_DISP\_B\_SD\_D). The I/O mux connects the internal data lines to the bidirectional external line according to the IPP\_OBE\_DISP\_B\_SD\_D signal provided by the IPU.

Each data transfer can be preceded by an optional preamble with programmable length and contents. The preamble is followed by read/write (RW) and address (RS) bits. The order of these bits is programmable. The RW bit can be disabled. The following data can consist of one word or of a whole burst. The interface parameters are controlled by the DI\_SER\_DISP $_n$ \_CONF registers ( $n = 1, 2$ ).



**Figure 63. 3-Wire Serial Interface Timing Diagram**

Figure 64 depicts timing of the 4-wire serial interface. For this interface, there are separate input and output data lines both inside and outside the device.



**Figure 64. 4-Wire Serial Interface Timing Diagram**

Figure 65 depicts timing of the 5-wire serial interface (Type 1). For this interface, a separate RS line is added. When a burst is transmitted within a single active chip select interval, the RS can be changed at boundaries of words.

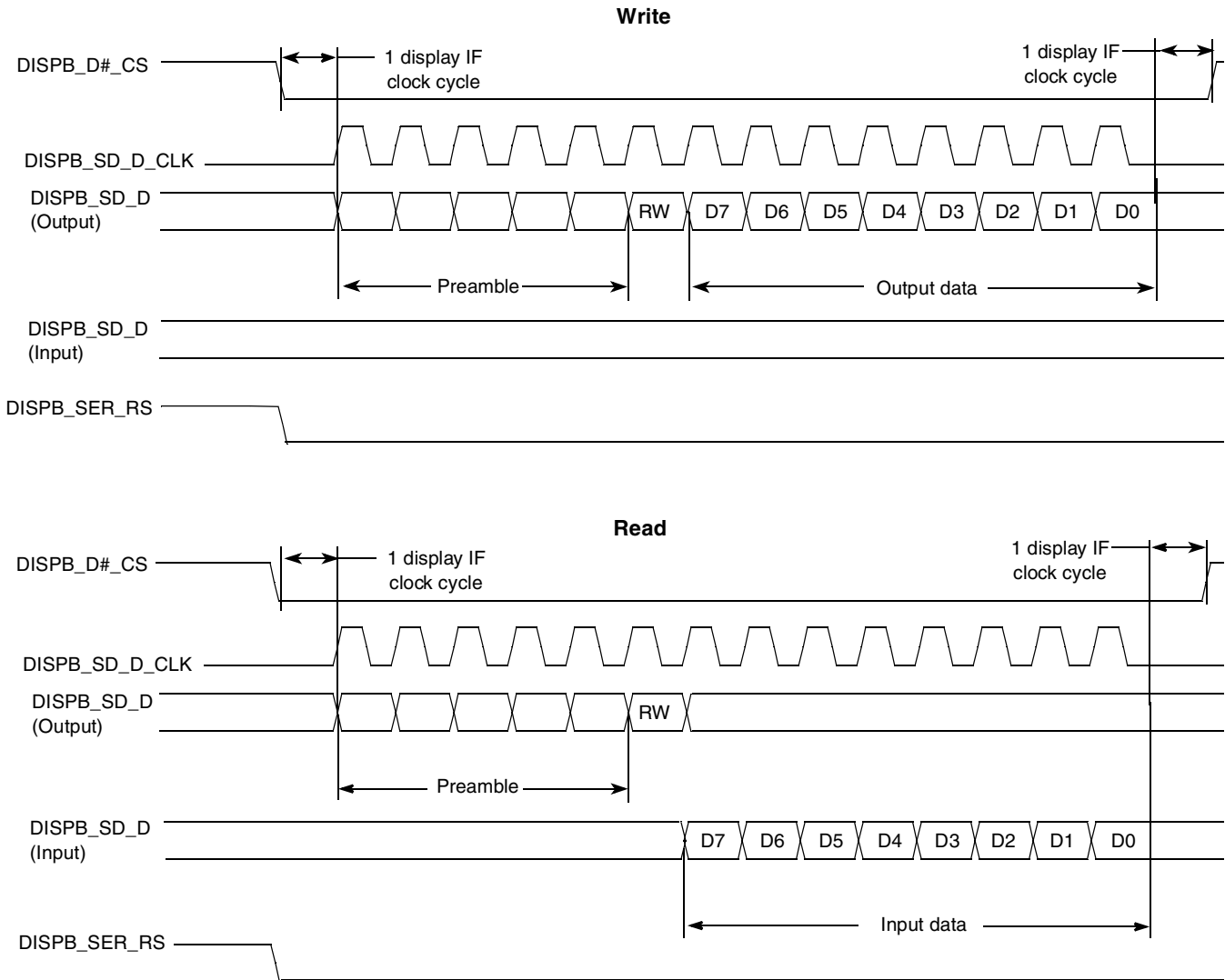


Figure 65. 5-Wire Serial Interface (Type 1) Timing Diagram

Figure 66 depicts timing of the 5-wire serial interface (Type 2). For this interface, a separate RS line is added. When a burst is transmitted within a single active chip select interval, the RS can be changed at boundaries of words.

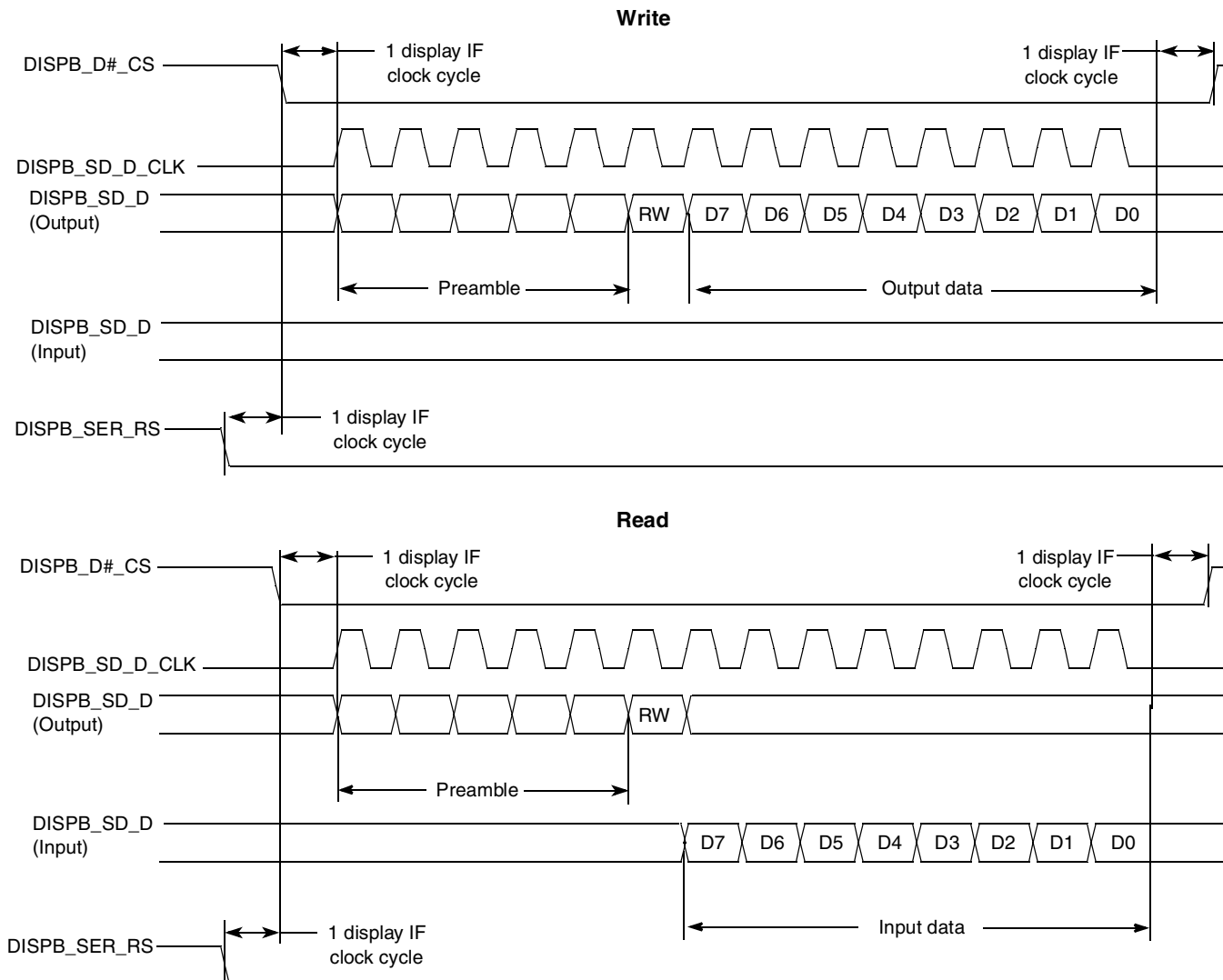


Figure 66. 5-Wire Serial Interface (Type 2) Timing Diagram

#### 4.9.13.5.10 Serial Interfaces, Electrical Characteristics

Figure 67 depicts timing of the serial interface. Table 56 lists the timing parameters at display access level.

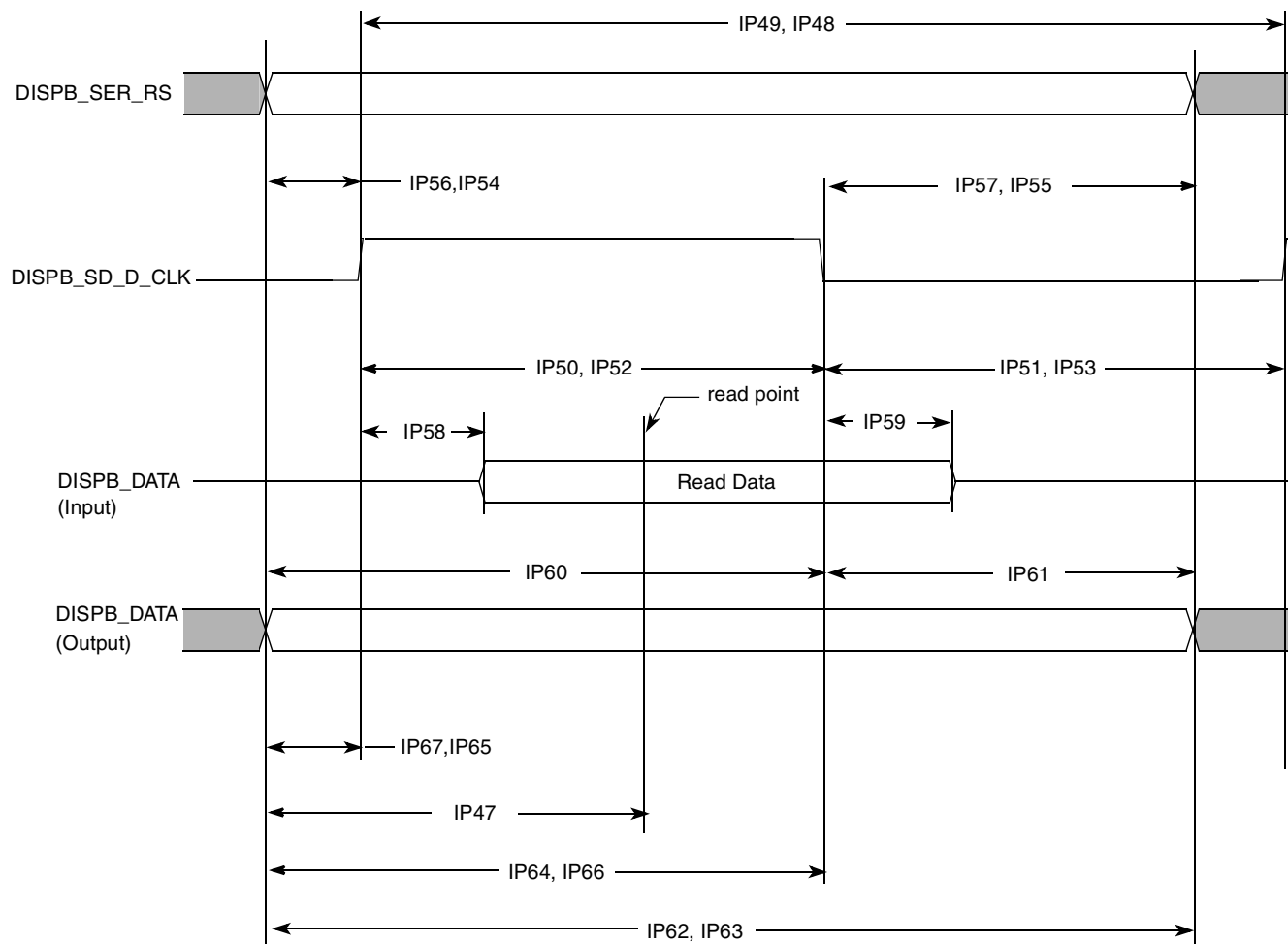


Figure 67. Asynchronous Serial Interface Timing Diagram

Table 56. Asynchronous Serial Interface Timing Parameters—Access Level

| ID   | Parameter                    | Symbol             | Min.                                                               | Typ. <sup>1</sup>                                                 | Max.                                                               | Units |
|------|------------------------------|--------------------|--------------------------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------|-------|
| IP48 | Read system cycle time       | T <sub>cyrcr</sub> | T <sub>dicpr</sub> – 1.5                                           | T <sub>dicpr</sub> <sup>2</sup>                                   | T <sub>dicpr</sub> + 1.5                                           | ns    |
| IP49 | Write system cycle time      | T <sub>cycw</sub>  | T <sub>dicpw</sub> – 1.5                                           | T <sub>dicpw</sub> <sup>3</sup>                                   | T <sub>dicpw</sub> + 1.5                                           | ns    |
| IP50 | Read clock low pulse width   | T <sub>rl</sub>    | T <sub>dicdr</sub> – T <sub>dicur</sub> – 1.5                      | T <sub>dicdr</sub> <sup>4</sup> – T <sub>dicur</sub> <sup>5</sup> | T <sub>dicdr</sub> – T <sub>dicur</sub> + 1.5                      | ns    |
| IP51 | Read clock high pulse width  | T <sub>rh</sub>    | T <sub>dicpr</sub> – T <sub>dicdr</sub> + T <sub>dicur</sub> – 1.5 | T <sub>dicpr</sub> – T <sub>dicdr</sub> + T <sub>dicur</sub>      | T <sub>dicpr</sub> – T <sub>dicdr</sub> + T <sub>dicur</sub> + 1.5 | ns    |
| IP52 | Write clock low pulse width  | T <sub>wl</sub>    | T <sub>dicdw</sub> – T <sub>dicuw</sub> – 1.5                      | T <sub>dicdw</sub> <sup>6</sup> – T <sub>dicuw</sub> <sup>7</sup> | T <sub>dicdw</sub> – T <sub>dicuw</sub> + 1.5                      | ns    |
| IP53 | Write clock high pulse width | T <sub>wh</sub>    | T <sub>dicpw</sub> – T <sub>dicdw</sub> + T <sub>dicuw</sub> – 1.5 | T <sub>dicpw</sub> – T <sub>dicdw</sub> + T <sub>dicuw</sub>      | T <sub>dicpw</sub> – T <sub>dicdw</sub> + T <sub>dicuw</sub> + 1.5 | ns    |
| IP54 | Controls setup time for read | T <sub>dcsr</sub>  | T <sub>dicur</sub> – 1.5                                           | T <sub>dicur</sub>                                                | —                                                                  | ns    |

**Table 56. Asynchronous Serial Interface Timing Parameters—Access Level (continued)**

| ID   | Parameter                                | Symbol | Min.                       | Typ. <sup>1</sup> | Max.                                                  | Units |
|------|------------------------------------------|--------|----------------------------|-------------------|-------------------------------------------------------|-------|
| IP55 | Controls hold time for read              | Tdchr  | Tdicpr – Tdicdr – 1.5      | Tdicpr – Tdicdr   | —                                                     | ns    |
| IP56 | Controls setup time for write            | Tdcsw  | Tdicuw – 1.5               | Tdicuw            | —                                                     | ns    |
| IP57 | Controls hold time for write             | Tdchw  | Tdicpw – Tdicdw – 1.5      | Tdicpw – Tdicdw   | —                                                     | ns    |
| IP58 | Slave device data delay <sup>8</sup>     | Tracc  | 0                          | —                 | Tdrp <sup>9</sup> – Tlbd <sup>10</sup> – Tdicur – 1.5 | ns    |
| IP59 | Slave device data hold time <sup>8</sup> | Troh   | Tdrp – Tlbd – Tdicdr + 1.5 | —                 | Tdicpr – Tdicdr – 1.5                                 | ns    |
| IP60 | Write data setup time                    | Tds    | Tdicdw – 1.5               | Tdicdw            | —                                                     | ns    |
| IP61 | Write data hold time                     | Tdh    | Tdicpw – Tdicdw – 1.5      | Tdicpw – Tdicdw   | —                                                     | ns    |
| IP62 | Read period <sup>2</sup>                 | Tdicpr | Tdicpr – 1.5               | Tdicpr            | Tdicpr + 1.5                                          | ns    |
| IP63 | Write period <sup>3</sup>                | Tdicpw | Tdicpw – 1.5               | Tdicpw            | Tdicpw + 1.5                                          | ns    |
| IP64 | Read down time <sup>4</sup>              | Tdicdr | Tdicdr – 1.5               | Tdicdr            | Tdicdr + 1.5                                          | ns    |
| IP65 | Read up time <sup>5</sup>                | Tdicur | Tdicur – 1.5               | Tdicur            | Tdicur + 1.5                                          | ns    |
| IP66 | Write down time <sup>6</sup>             | Tdicdw | Tdicdw – 1.5               | Tdicdw            | Tdicdw + 1.5                                          | ns    |
| IP67 | Write up time <sup>7</sup>               | Tdicuw | Tdicuw – 1.5               | Tdicuw            | Tdicuw + 1.5                                          | ns    |
| IP68 | Read time point <sup>9</sup>             | Tdrp   | Tdrp – 1.5                 | Tdrp              | Tdrp + 1.5                                            | ns    |

<sup>1</sup> The exact conditions have not been finalized, but will likely match the current customer requirement for their specific display. These conditions may be device specific.

<sup>2</sup> Display interface clock period value for read:

$$T_{dicpr} = T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{DISP\#\_IF\_CLK\_PER\_RD}{HSP\_CLK\_PERIOD} \right]$$

<sup>3</sup> Display interface clock period value for write:

$$T_{dicpw} = T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{DISP\#\_IF\_CLK\_PER\_WR}{HSP\_CLK\_PERIOD} \right]$$

<sup>4</sup> Display interface clock down time for read:

$$T_{dicdr} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_DOWN\_RD}{HSP\_CLK\_PERIOD} \right]$$

<sup>5</sup> Display interface clock up time for read:

$$T_{dicur} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_UP\_RD}{HSP\_CLK\_PERIOD} \right]$$

<sup>6</sup> Display interface clock down time for write:

$$T_{dicdw} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_DOWN\_WR}{HSP\_CLK\_PERIOD} \right]$$

<sup>7</sup> Display interface clock up time for write:

$$T_{dicuw} = \frac{1}{2} T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{2 \cdot DISP\#\_IF\_CLK\_UP\_WR}{HSP\_CLK\_PERIOD} \right]$$

<sup>8</sup> This parameter is a requirement to the display connected to the IPU.

<sup>9</sup> Data read point:

$$T_{drp} = T_{HSP\_CLK} \cdot \text{ceil} \left[ \frac{DISP\#\_READ\_EN}{HSP\_CLK\_PERIOD} \right]$$

<sup>10</sup> Loopback delay  $T_{lbd}$  is the cumulative propagation delay of read controls and read data. It includes an IPU output delay, a device-level output delay, board delays, a device-level input delay, and an IPU input delay. This value is device specific.

The following parameters are programmed via the DI\_DISP#\_TIME\_CONF\_1, DI\_DISP#\_TIME\_CONF\_2, and DI\_HSP\_CLK\_PER registers:

- DISP#\_IF\_CLK\_PER\_WR
- DISP#\_IF\_CLK\_PER\_RD
- HSP\_CLK\_PERIOD
- DISP#\_IF\_CLK\_DOWN\_WR
- DISP#\_IF\_CLK\_UP\_WR
- DISP#\_IF\_CLK\_DOWN\_RD
- DISP#\_IF\_CLK\_UP\_RD
- DISP#\_READ\_EN

#### 4.9.14 Memory Stick Host Controller (MSHC)

Figure 68, Figure 69, and Figure 70 depict the MSHC timings, and Table 57 and Table 58 list the timing parameters.

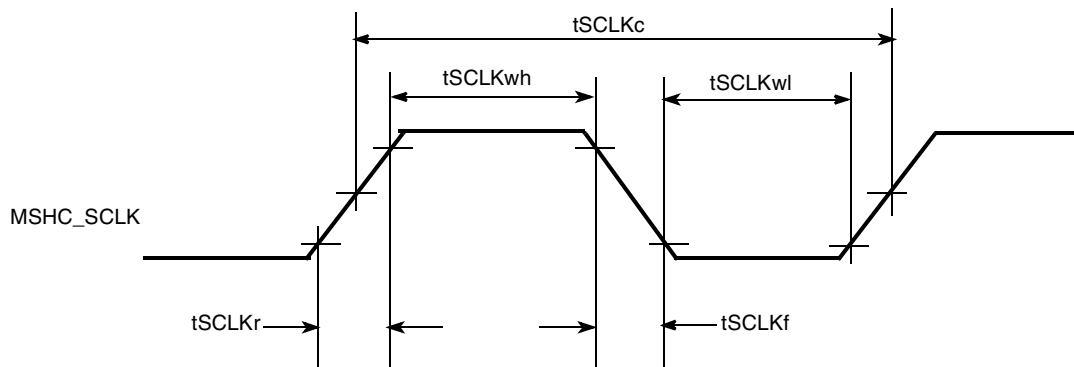
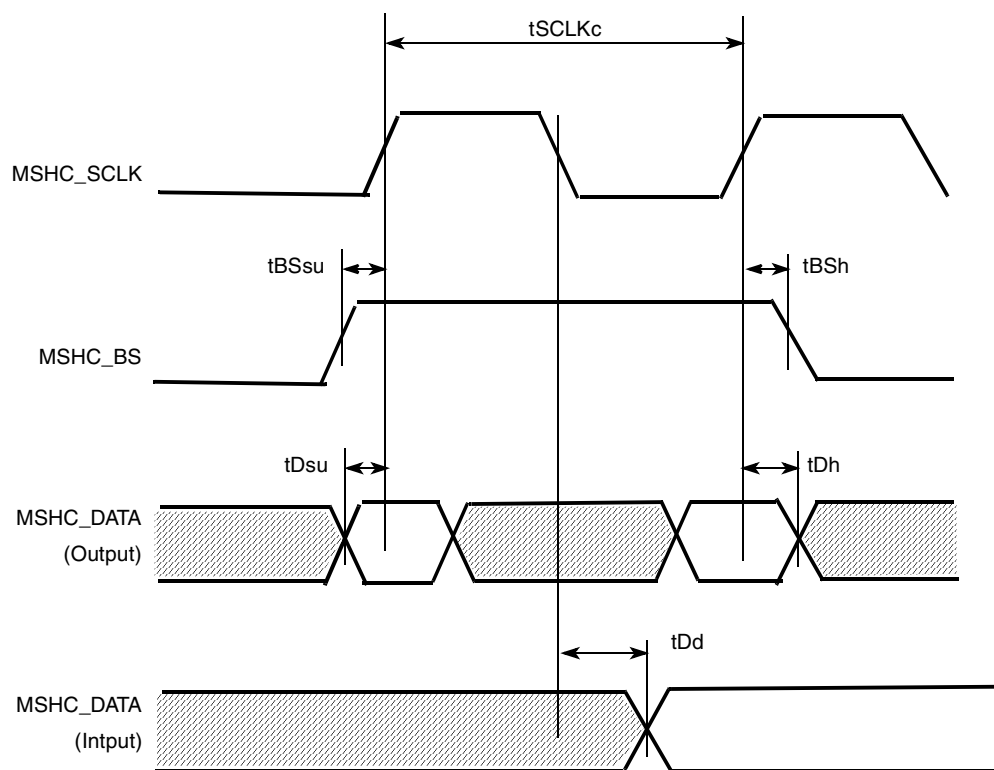
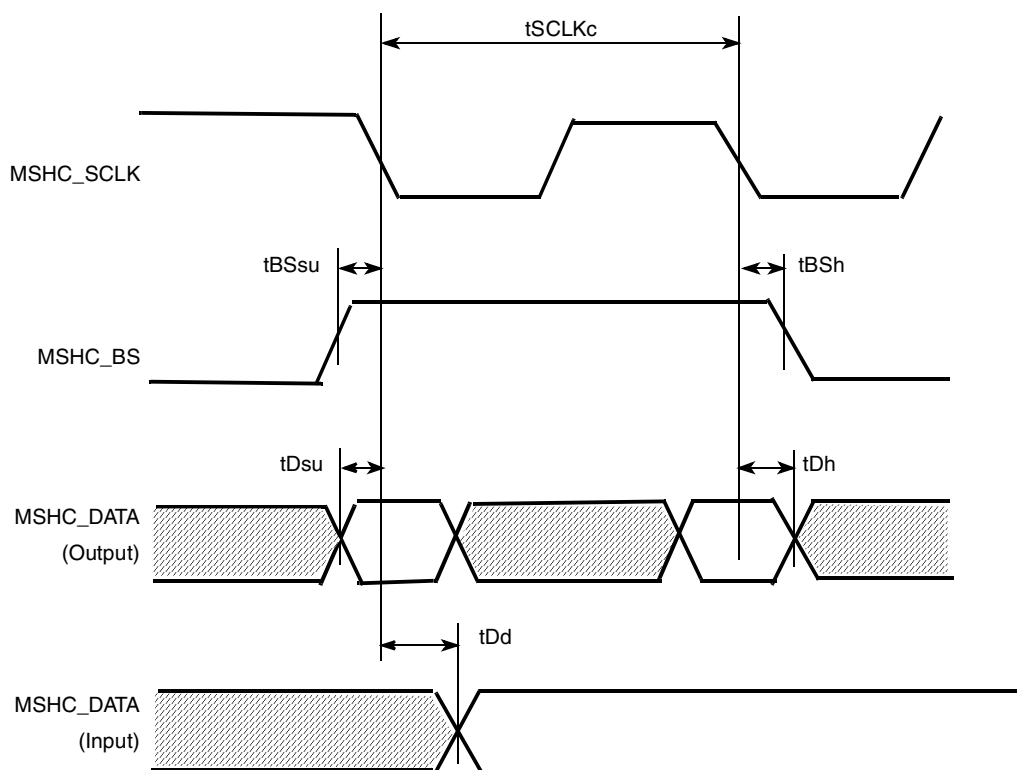


Figure 68. MSHC\_CLK Timing Diagram





**Figure 69. Transfer Operation Timing Diagram (Serial)**



**Figure 70. Transfer Operation Timing Diagram (Parallel)**

### NOTE

The memory stick host controller is designed to meet the timing requirements per Sony's *Memory Stick Pro Format Specifications*. Tables in this section detail the specifications' requirements for parallel and serial modes, and not the i.MX35 timing.

**Table 57. Serial Interface Timing Parameters<sup>1</sup>**

| Signal    | Parameter      | Symbol  | Standards |      | Unit |
|-----------|----------------|---------|-----------|------|------|
|           |                |         | Min.      | Max. |      |
| MSHC_SCLK | Cycle          | tSCLKc  | 50        | —    | ns   |
|           | H pulse length | tSCLKwh | 15        | —    | ns   |
|           | L pulse length | tSCLKwl | 15        | —    | ns   |
|           | Rise time      | tSCLKr  | —         | 10   | ns   |
|           | Fall time      | tSCLKf  | —         | 10   | ns   |
| MSHC_BS   | Setup time     | tBSsu   | 5         | —    | ns   |
|           | Hold time      | tBSh    | 5         | —    | ns   |

**Table 57. Serial Interface Timing Parameters<sup>1</sup> (continued)**

| Signal    | Parameter         | Symbol | Standards |      | Unit |
|-----------|-------------------|--------|-----------|------|------|
|           |                   |        | Min.      | Max. |      |
| MSHC_DATA | Setup time        | tDsu   | 5         | —    | ns   |
|           | Hold time         | tDh    | 5         | —    | ns   |
|           | Output delay time | tDd    | —         | 15   | ns   |

<sup>1</sup> Timing is guaranteed for NVCC from 2.7 V through 3.1 V and up to a maximum overdrive NVCC of 3.3 V. See NVCC restrictions described in [Table 58](#).

**Table 58. Parallel Interface Timing Parameters<sup>1</sup>**

| Signal    | Parameter         | Symbol  | Standards |      | Unit |
|-----------|-------------------|---------|-----------|------|------|
|           |                   |         | Min.      | Max. |      |
| MSHC_SCLK | Cycle             | tSCLKc  | 25        | —    | ns   |
|           | H pulse length    | tSCLKwh | 5         | —    | ns   |
|           | L pulse length    | tSCLKwl | 5         | —    | ns   |
|           | Rise time         | tSCLKr  | —         | 10   | ns   |
|           | Fall time         | tSCLKf  | —         | 10   | ns   |
| MSHC_BS   | Setup time        | tBSsu   | 8         | —    | ns   |
|           | Hold time         | tBSH    | 1         | —    | ns   |
| MSHC_DATA | Setup time        | tDsu    | 8         | —    | ns   |
|           | Hold time         | tDh     | 1         | —    | ns   |
|           | Output delay time | tDd     | —         | 15   | ns   |

<sup>1</sup> Timing is guaranteed for NVCC from 2.7 V through 3.1 V and up to a maximum overdrive NVCC of 3.3 V. See the NVCC restrictions described in [Table 8](#).

## 4.9.15 MediaLB Controller Electrical Specifications

This section describes the electrical information of the MediaLB Controller module.

**Table 59. MLB 256/512 Fs Timing Parameters**

| Parameter                               | Symbol            | Min    | Typ              | Max               | Units | Comment                                                                                                                                        |
|-----------------------------------------|-------------------|--------|------------------|-------------------|-------|------------------------------------------------------------------------------------------------------------------------------------------------|
| MLBCLK operating frequency <sup>1</sup> | f <sub>mck</sub>  | 11.264 | 12.288<br>24.576 | 24.6272<br>25.600 | MHz   | Min: 256 × Fs at 44.0 kHz<br>Typ: 256 × Fs at 48.0 kHz<br>Typ: 512 × Fs at 48.0 kHz<br>Max: 512 × Fs at 48.1 kHz<br>Max: 512 × Fs PLL unlocked |
| MLBCLK rise time                        | t <sub>mckr</sub> | —      | —                | 3                 | ns    | V <sub>IL</sub> TO V <sub>IH</sub>                                                                                                             |

**Table 59. MLB 256/512 Fs Timing Parameters (continued)**

| Parameter                                           | Symbol      | Min        | Typ        | Max        | Units | Comment                                           |
|-----------------------------------------------------|-------------|------------|------------|------------|-------|---------------------------------------------------|
| MLB fall time                                       | $t_{mckf}$  | —          | —          | 3          | ns    | $V_{IH}$ TO $V_{IL}$                              |
| MLBCLK cycle time                                   | $t_{mckc}$  | —<br>—     | 81<br>40   | —<br>—     | ns    | $256 \times F_s$<br>$512 \times F_s$              |
| MLBCLK low time                                     | $t_{mckl}$  | 31.5<br>30 | 37<br>35.5 | —<br>—     | ns    | $256 \times F_s$<br>$256 \times F_s$ PLL unlocked |
|                                                     |             | 14.5<br>14 | 17<br>16.5 | —<br>—     | ns    | $512 \times F_s$<br>$512 \times F_s$ PLL unlocked |
| MLBCLK high time                                    | $t_{mckh}$  | 31.5<br>30 | 38<br>36.5 | —<br>—     | ns    | $256 \times F_s$<br>$256 \times F_s$ PLL unlocked |
|                                                     |             | 14.5<br>14 | 17<br>16.5 | —<br>—     | ns    | $512 \times F_s$<br>$512 \times F_s$ PLL unlocked |
| MLBCLK pulse width variation                        | $t_{mpwv}$  | —          | —          | 2          | ns pp | Note <sup>2</sup>                                 |
| MLBSIG/MLBDAT input valid to MLBCLK falling         | $t_{dsmcf}$ | 1          | —          | —          | ns    | —                                                 |
| MLBSIG/MLBDAT input hold from MLBCLK low            | $t_{dhmcf}$ | 0          | —          | —          | ns    | —                                                 |
| MLBSIG/MLBDAT output high impedance from MLBCLK low | $t_{mcfdz}$ | 0          | —          | $t_{mckl}$ | ns    | —                                                 |
| Bus Hold Time                                       | $t_{mdzh}$  | 4          | —          | —          | ns    | Note <sup>3</sup>                                 |

<sup>1</sup> The MLB controller can shut off MLBCLK to place MediaLB in a low-power state.

<sup>2</sup> Pulse width variation is measured at 1.25 V by triggering on one edge of MLBCLK and measuring the spread on the other edge, measured in ns peak-to-peak (pp)

<sup>3</sup> The board must be designed to insure that the high-impedance bus does not leave the logic state of the final driven bit for this time period. Therefore, coupling must be minimized while meeting the maximum capacitive load listed.

Ground = 0.0 V; load capacitance = 40 pF; MediaLB speed = 1024 Fs;  $F_s$  = 48 kHz; all timing parameters specified from the valid voltage threshold as listed below unless otherwise noted.

**Table 60. MLB Device 1024Fs Timing Parameters**

| Parameter                               | Symbol     | Min        | Typ        | Max               | Units | Comment                                                                                                                                               |
|-----------------------------------------|------------|------------|------------|-------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| MLBCLK Operating Frequency <sup>1</sup> | $f_{mck}$  | 45.056     | 49.152     | 49.2544<br>51.200 | MHz   | Min: $1024 \times F_s$ at 44.0 kHz<br>Typ: $1024 \times F_s$ at 48.0 kHz<br>Max: $1024 \times F_s$ at 48.1 kHz<br>Max: $1024 \times F_s$ PLL unlocked |
| MLBCLK rise time                        | $t_{mckr}$ | —          | —          | 1                 | ns    | $V_{IL}$ TO $V_{IH}$                                                                                                                                  |
| MLB fall time                           | $t_{mckf}$ | —          | —          | 1                 | ns    | $V_{IH}$ TO $V_{IL}$                                                                                                                                  |
| MLBCLK cycle time                       | $t_{mckc}$ | —          | 20.3       | —                 | ns    | —                                                                                                                                                     |
| MLBCLK low time                         | $t_{mckl}$ | 6.5<br>6.1 | 7.7<br>7.3 | —                 | ns    | PLL unlocked                                                                                                                                          |

**Table 60. MLB Device 1024Fs Timing Parameters (continued)**

| Parameter                                           | Symbol      | Min        | Typ          | Max        | Units | Comment           |
|-----------------------------------------------------|-------------|------------|--------------|------------|-------|-------------------|
| MLBCLK high time                                    | $t_{mckh}$  | 9.7<br>9.3 | 10.6<br>10.2 | —<br>—     | ns    | PLL unlocked      |
| MLBCLK pulse width variation                        | $t_{mpwv}$  | —          | —            | 0.7        | ns pp | Note <sup>2</sup> |
| MLBSIG/MLBDAT input valid to MLBCLK falling         | $t_{dsmcf}$ | 1          | —            | —          | ns    | —                 |
| MLBSIG/MLBDAT input hold from MLBCLK low            | $t_{dhmcf}$ | 0          | —            | —          | ns    | —                 |
| MLBSIG/MLBDAT output high impedance from MLBCLK low | $t_{mcfdz}$ | 0          | —            | $t_{mckl}$ | ns    | —                 |
| Bus Hold Time                                       | $t_{mdzh}$  | 2          | —            | —          | ns    | Note <sup>3</sup> |

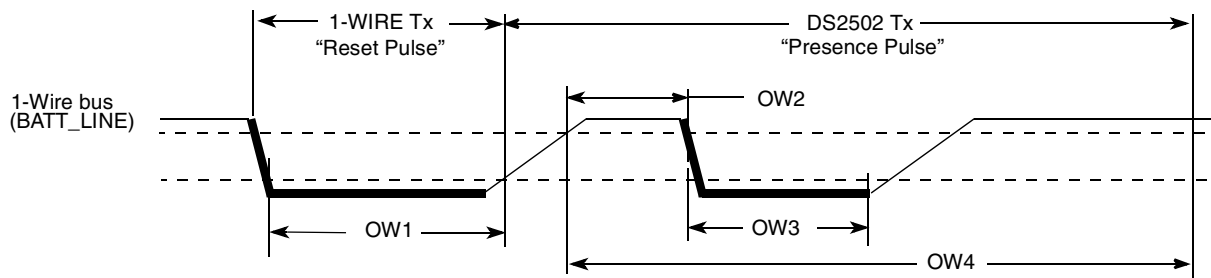
<sup>1</sup> The MLB Controller can shut off MLBCLK to place MediaLB in a low-power state.

<sup>2</sup> Pulse width variation is measured at 1.25 V by triggering on one edge of MLBCLK and measuring the spread on the other edge, measured in ns peak-to-peak (pp)

<sup>3</sup> The board must be designed to insure that the high-impedance bus does not leave the logic state of the final driven bit for this time period. Therefore, coupling must be minimized while meeting the maximum capacitive load listed.

#### 4.9.16 1-Wire Timing Specifications

Figure 71 depicts the RPP timing, and Table 61 lists the RPP timing parameters.



**Figure 71. Reset and Presence Pulses (RPP) Timing Diagram**

**Table 61. RPP Sequence Delay Comparisons Timing Parameters**

| ID  | Parameters           | Symbol     | Min. | Typ. | Max. | Units   |
|-----|----------------------|------------|------|------|------|---------|
| OW1 | Reset time low       | $t_{RSTL}$ | 480  | 511  | —    | $\mu$ s |
| OW2 | Presence detect high | $t_{PDH}$  | 15   | —    | 60   | $\mu$ s |
| OW3 | Presence detect low  | $t_{PDL}$  | 60   | —    | 240  | $\mu$ s |
| OW4 | Reset time high      | $t_{RSTH}$ | 480  | 512  | —    | $\mu$ s |

Figure 72 depicts write 0 sequence timing, and Table 62 lists the timing parameters.

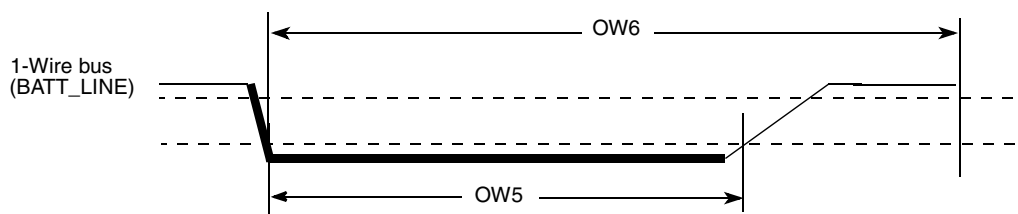


Figure 72. Write 0 Sequence Timing Diagram

Table 62. WR0 Sequence Timing Parameters

| ID  | Parameter              | Symbol         | Min. | Typ. | Max. | Units   |
|-----|------------------------|----------------|------|------|------|---------|
| OW5 | Write 0 low time       | $t_{WR0\_low}$ | 60   | 100  | 120  | $\mu s$ |
| OW6 | Transmission time slot | $t_{SLOT}$     | OW5  | 117  | 120  | $\mu s$ |

Figure 73 shows write 1 sequence timing, and Figure 74 depicts the read sequence timing. Table 63 lists the timing parameters.

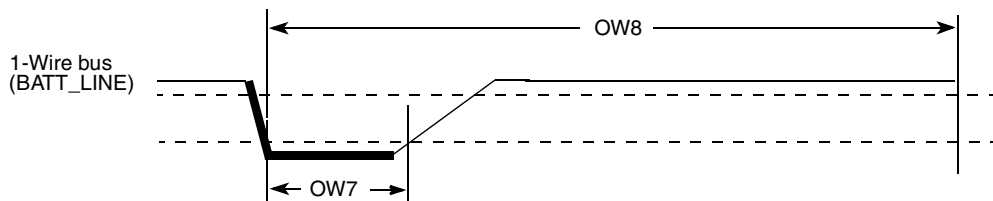


Figure 73. Write 1 Sequence Timing Diagram

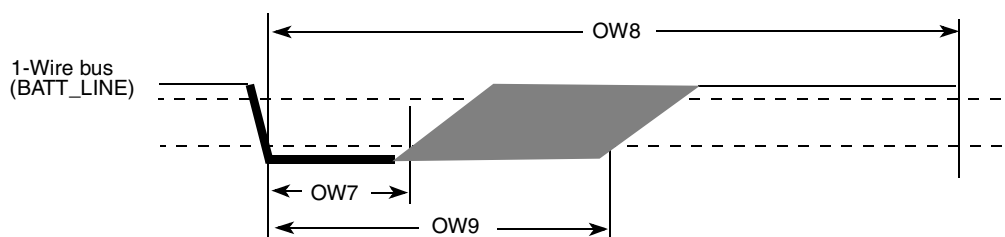


Figure 74. Read Sequence Timing Diagram

Table 63. WR1/RD Timing Parameters

| ID  | Parameter              | Symbol        | Min. | Typ. | Max. | Units   |
|-----|------------------------|---------------|------|------|------|---------|
| OW7 | Write 1/read low time  | $t_{LOW1}$    | 1    | 5    | 15   | $\mu s$ |
| OW8 | Transmission time slot | $t_{SLOT}$    | 60   | 117  | 120  | $\mu s$ |
| OW9 | Release time           | $t_{RELEASE}$ | 15   | —    | 45   | $\mu s$ |

## 4.9.17 Parallel ATA Module AC Electrical Specifications

The parallel ATA module can work on PIO/multiword DMA/ultra-DMA transfer modes (not available for the MCIMX351). Each transfer mode has a different data transfer rate, Ultra DMA mode 4 data transfer rate is up to 100 MBps.

The parallel ATA module interface consists of a total of 29 pins. Some pins have different functions in different transfer modes. There are various requirements for timing relationships among the function pins, in compliance with the ATA/ATAPI-6 specification, and these requirements are configurable by the ATA module registers.

### 4.9.17.1 General Timing Requirements

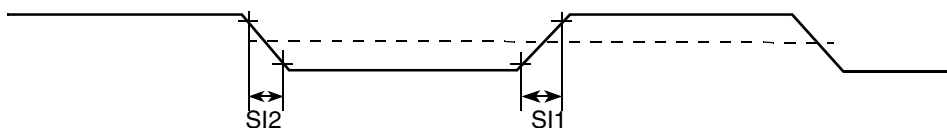
Table 64 and Figure 75 define the AC characteristics of the interface signals on all data transfer modes.

**Table 64. AC Characteristics of All Interface Signals**

| ID  | Parameter                                                               | Symbol       | Min. | Max. | Unit |
|-----|-------------------------------------------------------------------------|--------------|------|------|------|
| SI1 | Rising edge slew rate for any signal on the ATA interface <sup>1</sup>  | $S_{rise}^1$ | —    | 1.25 | V/ns |
| SI2 | Falling edge slew rate for any signal on the ATA interface <sup>1</sup> | $S_{fall}^1$ | —    | 1.25 | V/ns |
| SI3 | Host interface signal capacitance at the host connector                 | $C_{host}$   | —    | 20   | pF   |

<sup>1</sup> SRISE and SFALL meet this requirement when measured at the sender's connector from 10–90% of full signal amplitude with all capacitive loads from 15 pF through 40 pF, where all signals have the same capacitive load value.

ATA Interface Signals



**Figure 75. ATA Interface Signals Timing Diagram**

### 4.9.17.2 ATA Electrical Specifications (ATA Bus, Bus Buffers)

This section discusses ATA parameters. For a detailed description, refer to the ATA-6 specification.

Level shifters are required for 3.3-V or 5.0-V compatibility on the ATA interface.

The use of bus buffers introduces delays on the bus and introduces skew between signal lines. These factors make it difficult to operate the bus at the highest speed (UDMA-5) when bus buffers are used. Use of bus buffers is not recommended if fast UDMA mode is required.

The ATA specification imposes a slew rate limit on the ATA bus. According to this limit, any signal driven on the bus should have a slew rate between 0.4 and 1.2 V/ns with a 40 pF load. Few vendors of bus buffers specify the slew rate of the outgoing signals.

When bus buffers are used the ata\_data bus buffer is bidirectional, and uses the direction control signal ata\_buffer\_en. When ata\_buffer\_en is asserted, the bus should drive from host to device. When

ata\_buffer\_en is negated, the bus drives from device to host. Steering of the signal is such that contention on the host and device tri-state buses is always avoided.

### 4.9.17.3 Timing Parameters

Table 65 shows the parameters used in the timing equations. These parameters depend on the implementation of the ATA interface on silicon, the bus buffer used, the cable delay, and the cable skew.

**Table 65. ATA Timing Parameters**

| Name    | Description                                                                                                                                                                                                                                                                    | Value/<br>Contributing Factor <sup>1</sup> |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|
| T       | Bus clock period (ipg_clk_ata)                                                                                                                                                                                                                                                 | Peripheral clock frequency                 |
| ti_ds   | Set-up time <b>ata_data</b> to <b>ata_iordy</b> edge (UDMA-in only)<br><br>UDMA0<br>UDMA1<br>UDMA2, UDMA3<br>UDMA4<br>UDMA5                                                                                                                                                    | 15 ns<br>10 ns<br>7 ns<br>5 ns<br>4 ns     |
| ti_dh   | Hold time <b>ata_iordy</b> edge to <b>ata_data</b> (UDMA-in only)<br><br>UDMA0, UDMA1, UDMA2, UDMA3, UDMA4<br>UDMA5                                                                                                                                                            | 5.0 ns<br>4.6 ns                           |
| tco     | Propagation delay bus clock L-to-H to <b>ata_cs0</b> , <b>ata_cs1</b> , <b>ata_da2</b> , <b>ata_da1</b> , <b>ata_da0</b> , <b>ata_dior</b> , <b>ata_diow</b> , <b>ata_dmack</b> , <b>ata_data</b> , <b>ata_buffer_en</b>                                                       | 12.0 ns                                    |
| tsu     | Set-up time <b>ata_data</b> to bus clock L-to-H                                                                                                                                                                                                                                | 8.5 ns                                     |
| tsui    | Set-up time <b>ata_iordy</b> to bus clock H-to-L                                                                                                                                                                                                                               | 8.5 ns                                     |
| thi     | Hold time <b>ata_iordy</b> to bus clock H to L                                                                                                                                                                                                                                 | 2.5 ns                                     |
| tskew1  | Maximum difference in propagation delay bus clock L-to-H to any of following signals <b>ata_cs0</b> , <b>ata_cs1</b> , <b>ata_da2</b> , <b>ata_da1</b> , <b>ata_da0</b> , <b>ata_dior</b> , <b>ata_diow</b> , <b>ata_dmack</b> , <b>ata_data</b> (write), <b>ata_buffer_en</b> | 7 ns                                       |
| tskew2  | Maximum difference in buffer propagation delay for any of following signals <b>ata_cs0</b> , <b>ata_cs1</b> , <b>ata_da2</b> , <b>ata_da1</b> , <b>ata_da0</b> , <b>ata_dior</b> , <b>ata_diow</b> , <b>ata_dmack</b> , <b>ata_data</b> (write), <b>ata_buffer_en</b>          | Transceiver                                |
| tskew3  | Maximum difference in buffer propagation delay for any of following signals <b>ata_iordy</b> , <b>ata_data</b> (read)                                                                                                                                                          | Transceiver                                |
| tbuf    | Maximum buffer propagation delay                                                                                                                                                                                                                                               | Transceiver                                |
| tcable1 | Cable propagation delay for <b>ata_data</b>                                                                                                                                                                                                                                    | Cable                                      |
| tcable2 | Cable propagation delay for control signals <b>ata_dior</b> , <b>ata_diow</b> , <b>ata_iordy</b> , <b>ata_dmack</b>                                                                                                                                                            | Cable                                      |
| tskew4  | Maximum difference in cable propagation delay between <b>ata_iordy</b> and <b>ata_data</b> (read)                                                                                                                                                                              | Cable                                      |
| tskew5  | Maximum difference in cable propagation delay between ( <b>ata_dior</b> , <b>ata_diow</b> , <b>ata_dmack</b> ) and <b>ata_cs0</b> , <b>ata_cs1</b> , <b>ata_da2</b> , <b>ata_da1</b> , <b>ata_da0</b> , <b>ata_data</b> (write)                                                | Cable                                      |
| tskew6  | Maximum difference in cable propagation delay without accounting for ground bounce                                                                                                                                                                                             | Cable                                      |

<sup>1</sup> Values provided where applicable.



#### 4.9.17.4 PIO Mode Timing

Figure 76 shows timing for PIO read, and Table 66 lists the timing parameters for PIO read.

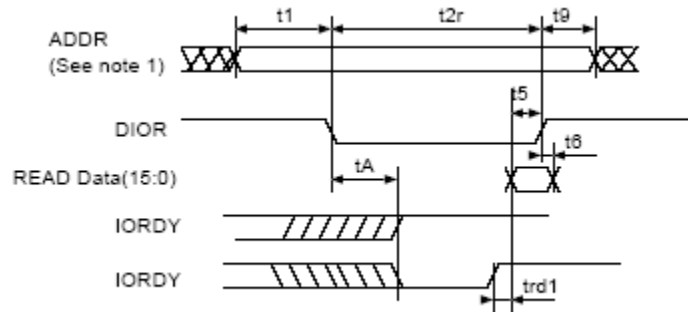


Figure 76. PIO Read Timing Diagram

Table 66. PIO Read Timing Parameters

| ATA Parameter | Parameter from Figure 76 | Value                                                                                                                                                                                                                                                     | Controlling Variable        |
|---------------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| t1            | t1                       | $t1 \text{ (min.)} = \text{time\_1} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew5})$                                                                                                                                                           | time_1                      |
| t2            | t2r                      | $t2 \text{ min.)} = \text{time\_2r} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew5})$                                                                                                                                                           | time_2r                     |
| t9            | t9                       | $t9 \text{ (min.)} = \text{time\_9} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew6})$                                                                                                                                                           | time_3                      |
| t5            | t5                       | $t5 \text{ (min.)} = t_{co} + t_{su} + t_{buf} + t_{buf} + t_{cable1} + t_{cable2}$                                                                                                                                                                       | If not met, increase time_2 |
| t6            | t6                       | 0                                                                                                                                                                                                                                                         | —                           |
| tA            | tA                       | $tA \text{ (min.)} = (1.5 + \text{time\_ax}) \times T - (t_{co} + t_{sui} + t_{cable2} + t_{cable2} + 2 \times t_{buf})$                                                                                                                                  | time_ax                     |
| trd           | trd1                     | $\text{trd1 (max.)} = (-\text{trd}) + (\text{tskew3} + \text{tskew4})$<br>$\text{trd1 (min.)} = (\text{time\_pio\_rdx} - 0.5) \times T - (t_{su} + t_{hi})$<br>$(\text{time\_pio\_rdx} - 0.5) \times T > t_{su} + t_{hi} + \text{tskew3} + \text{tskew4}$ | time_pio_rdx                |
| t0            | —                        | $t0 \text{ (min.)} = (\text{time\_1} + \text{time\_2} + \text{time\_9}) \times T$                                                                                                                                                                         | time_1, time_2r, time_9     |

Figure 77 shows timing for PIO write, and Table 67 lists the timing parameters for PIO write.

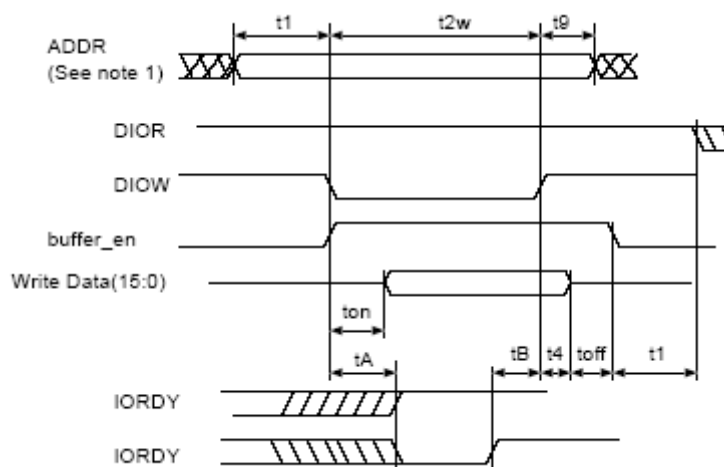


Figure 77. PIO Write Timing Diagram

Table 67. PIO Write Timing Parameters

| ATA Parameter | Parameter from Figure 77 | Value                                                                                                                         | Controlling Variable         |
|---------------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| t1            | t1                       | $t1 \text{ (min.)} = \text{time\_1} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew5})$                               | time_1                       |
| t2            | t2w                      | $t2 \text{ (min.)} = \text{time\_2w} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew5})$                              | time_2w                      |
| t9            | t9                       | $t9 \text{ (min.)} = \text{time\_9} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew6})$                               | time_9                       |
| t3            | —                        | $t3 \text{ (min.)} = (\text{time\_2w} - \text{time\_on}) \times T - (\text{tskew1} + \text{tskew2} + \text{tskew5})$          | If not met, increase time_2w |
| t4            | t4                       | $t4 \text{ (min.)} = \text{time\_4} \times T - \text{tskew1}$                                                                 | time_4                       |
| tA            | tA                       | $tA = (1.5 + \text{time\_ax}) \times T - (\text{tco} + \text{tsui} + \text{tcable2} + \text{tcable2} + 2 \times \text{tbuf})$ | time_ax                      |
| t0            | —                        | $t0 \text{ (min.)} = (\text{time\_1} + \text{time\_2} + \text{time\_9}) \times T$                                             | time_1, time_2r, time_9      |
| —             | —                        | Avoid bus contention when switching buffer on by making ton long enough.                                                      | —                            |
| —             | —                        | Avoid bus contention when switching buffer off by making toff long enough.                                                    | —                            |

Figure 78 shows timing for MDMA read, and Figure 79 shows timing for MDMA write. Table 68 lists the timing parameters for MDMA read and write.

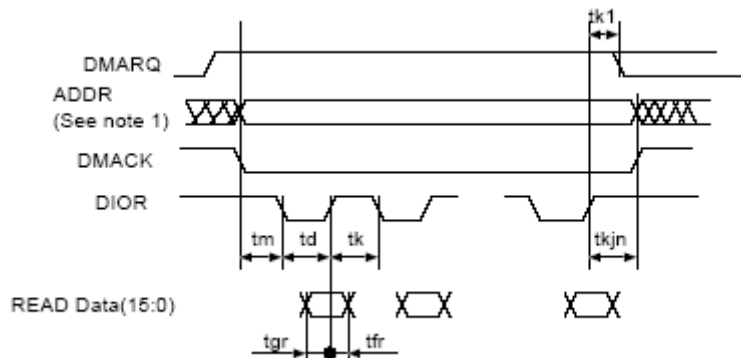


Figure 78. MDMA Read Timing Diagram

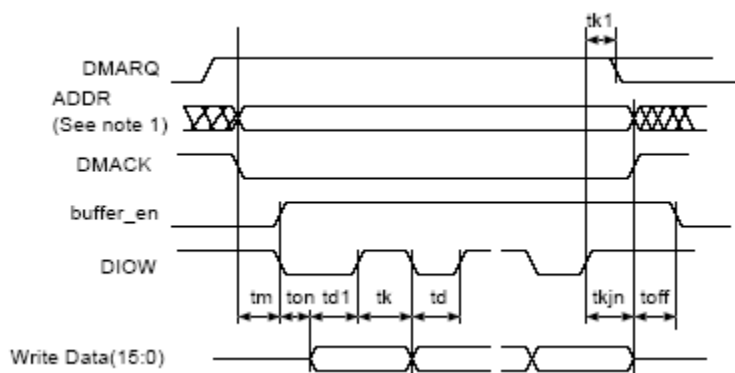


Figure 79. MDMA Write Timing Diagram

Table 68. MDMA Read and Write Timing Parameters

| ATA Parameter | Parameter from Figure 78, Figure 79 | Value                                                                                                                      | Controlling Variable |
|---------------|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------|----------------------|
| tm, ti        | tm                                  | $tm \text{ (min.)} = ti \text{ (min.)} = time\_m \times T - (tskew1 + tskew2 + tskew5)$                                    | time_m               |
| td            | td, td1                             | $td1 \text{ (min.)} = td \text{ (min.)} = time\_d \times T - (tskew1 + tskew2 + tskew6)$                                   | time_d               |
| tk            | tk                                  | $tk \text{ (min.)} = time\_k \times T - (tskew1 + tskew2 + tskew6)$                                                        | time_k               |
| t0            | —                                   | $t0 \text{ (min.)} = (time\_d + time\_k) \times T$                                                                         | time_d, time_k       |
| tg(read)      | tgr                                 | $tgr \text{ (min. - read)} = tco + tsu + tbuf + tbuf + tcable1 + tcable2$<br>$tgr \text{ (min. - drive)} = td - te(drive)$ | time_d               |
| tf(read)      | tfr                                 | $tfr \text{ (min. - drive)} = 0$                                                                                           | —                    |
| tg(write)     | —                                   | $tg \text{ (min. - write)} = time\_d \times T - (tskew1 + tskew2 + tskew5)$                                                | time_d               |
| tf(write)     | —                                   | $tf \text{ (min. - write)} = time\_k \times T - (tskew1 + tskew2 + tskew6)$                                                | time_k               |
| tL            | —                                   | $tL \text{ (max.)} = (time\_d + time\_k - 2) \times T - (tsu + tco + 2 \times tbuf + 2 \times tcable2)$                    | time_d, time_k       |

Table 68. MDMA Read and Write Timing Parameters (continued)

| ATA Parameter | Parameter from Figure 78, Figure 79 | Value                                                                                                                 | Controlling Variable |
|---------------|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------|----------------------|
| tn, tj        | tkjn                                | $tn = tj = tkjn = (\max(\text{time\_k}, \text{time\_jn}) \times T - (\text{tskew1} + \text{tskew2} + \text{tskew6}))$ | time_jn              |
| —             | ton<br>toff                         | ton = time_on $\times$ T – tskew1<br>toff = time_off $\times$ T – tskew1                                              | —                    |

#### 4.9.17.5 UDMA-In Timing

Figure 80 shows timing when the UDMA-in transfer starts, Figure 81 shows timing when the UDMA-in host terminates transfer, Figure 82 shows timing when the UDMA-in device terminates transfer, and Table 69 lists the timing parameters for the UDMA-in burst.

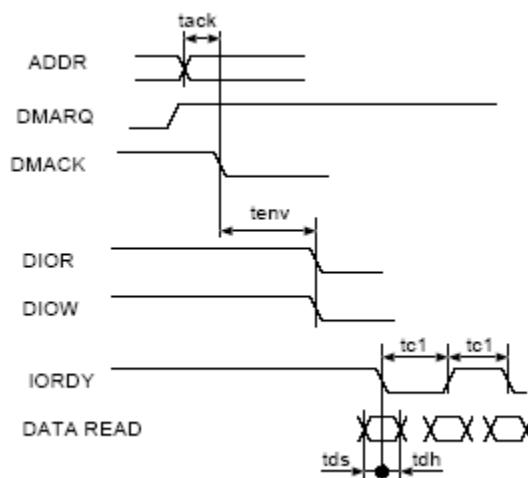


Figure 80. UDMA-In Transfer Starts Timing Diagram

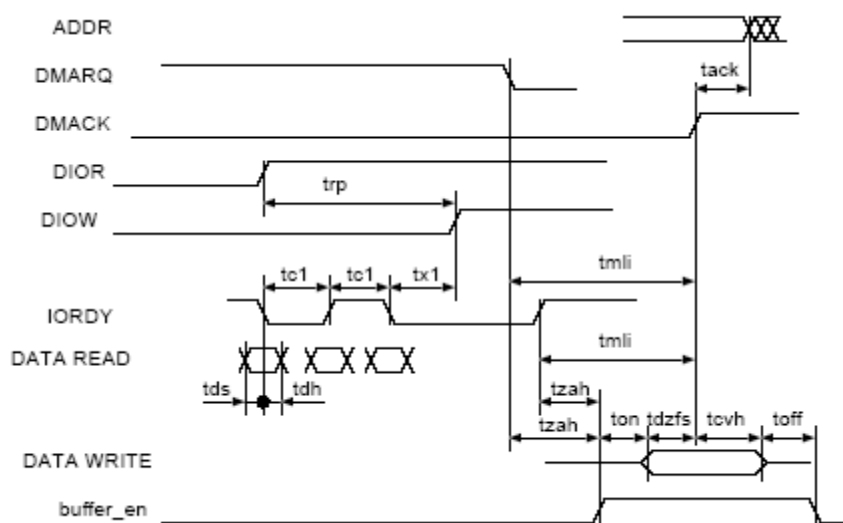
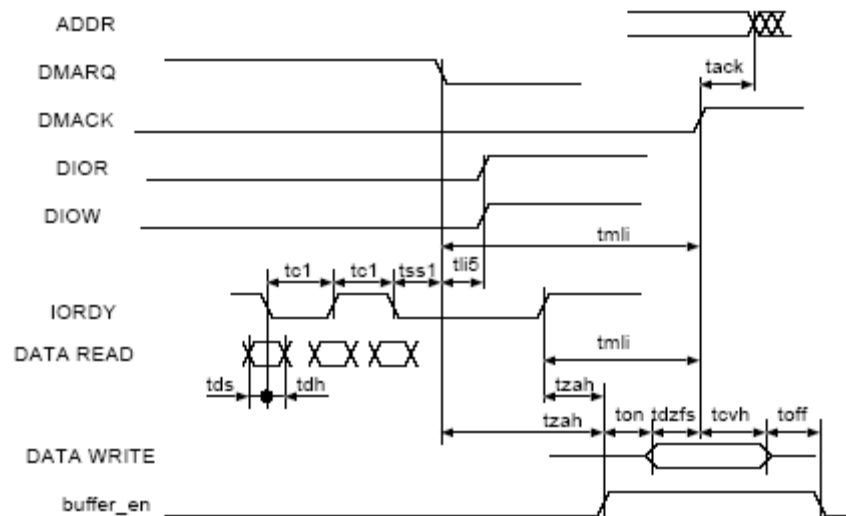


Figure 81. UDMA-In Host Terminates Transfer Timing Diagram



### Figure 82. UDMA-In Device Terminates Transfer Timing Diagram

### Table 69. UDMA-In Burst Timing Parameters

| ATA Parameter | Parameters from<br>Figure 80,<br>Figure 81,<br>Figure 82 | Description                                                                                                                                                                  | Controlling Variable                         |
|---------------|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| tack          | tack                                                     | $\text{tack (min.)} = (\text{time\_ack} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                         | time_ack                                     |
| tenv          | tenv                                                     | $\text{tenv (min.)} = (\text{time\_env} \times T) - (\text{tskew1} + \text{tskew2})$<br>$\text{tenv (max.)} = (\text{time\_env} \times T) + (\text{tskew1} + \text{tskew2})$ | time_env                                     |
| tds           | tds1                                                     | $\text{tds} - (\text{tskew3}) - \text{ti\_ds} > 0$                                                                                                                           | tskew3, ti_ds, ti_dh<br>should be low enough |
| tdh           | tdh1                                                     | $\text{tdh} - (\text{tskew3}) - \text{ti\_dh} > 0$                                                                                                                           |                                              |
| tcyc          | tc1                                                      | $(\text{tcyc} - \text{tskew}) > T$                                                                                                                                           | T big enough                                 |
| trp           | trp                                                      | $\text{trp (min.)} = \text{time\_rp} \times T - (\text{tskew1} + \text{tskew2} + \text{tskew6})$                                                                             | time_rp                                      |
| —             | tx1 <sup>1</sup>                                         | $(\text{time\_rp} \times T) - (\text{tco} + \text{tsu} + 3T + 2 \times \text{tbuf} + 2 \times \text{tcable2}) > \text{trfs (drive)}$                                         | time_rp                                      |
| tmli          | tmli1                                                    | $\text{tmli1 (min.)} = (\text{time\_mlix} + 0.4) \times T$                                                                                                                   | time_mlix                                    |
| tzah          | tzah                                                     | $\text{tzah (min.)} = (\text{time\_zah} + 0.4) \times T$                                                                                                                     | time_zah                                     |
| tdzfs         | tdzfs                                                    | $\text{tdzfs} = (\text{time\_dzfs} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                              | time_dzfs                                    |
| tcvh          | tcvh                                                     | $\text{tcvh} = (\text{time\_cvh} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                                | time_cvh                                     |
| —             | ton<br>toff                                              | ton = $\text{time\_on} \times T - \text{tskew1}$<br>toff = $\text{time\_off} \times T - \text{tskew1}$                                                                       | —                                            |

<sup>1</sup> There is a special timing requirement in the ATA host that requires the internal DIOW to go high three clocks after the last active edge on the DSTROBE signal. The equation given on this line tries to capture this constraint.

2. Make ton and toff large enough to avoid bus contention.

#### 4.9.17.6 UDMA-Out Timing

Figure 83 shows timing when the UDMA-out transfer starts, Figure 84 shows timing when the UDMA-out host terminates transfer, Figure 85 shows timing when the UDMA-out device terminates transfer, and Table 70 lists the timing parameters for the UDMA-out burst.

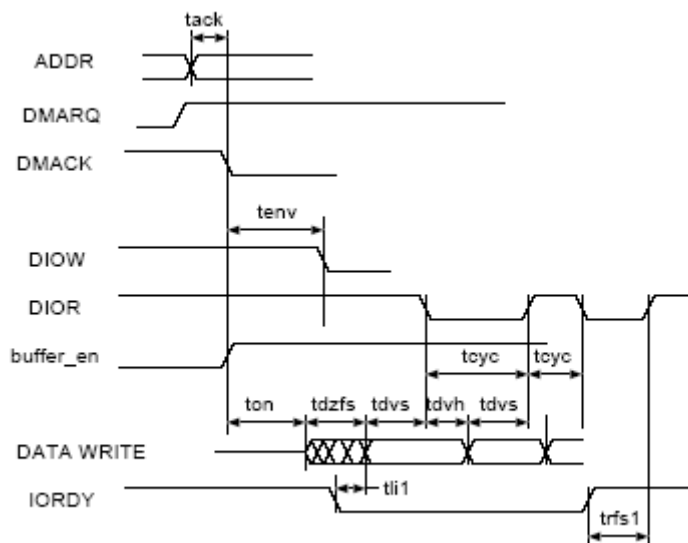


Figure 83. UDMA-Out Transfer Starts Timing Diagram

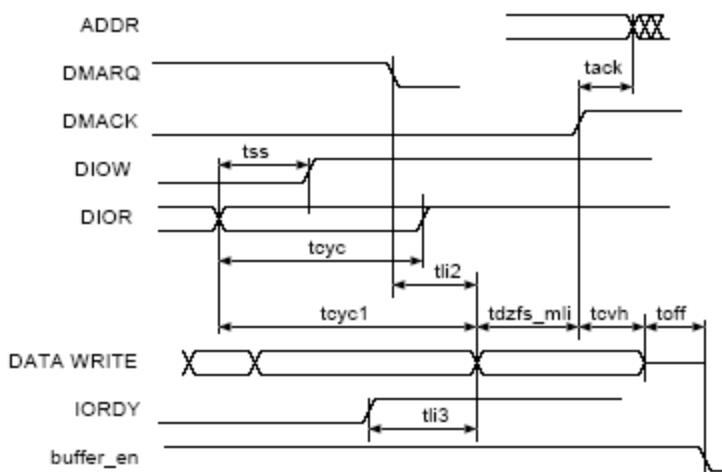


Figure 84. UDMA-Out Host Terminates Transfer Timing Diagram

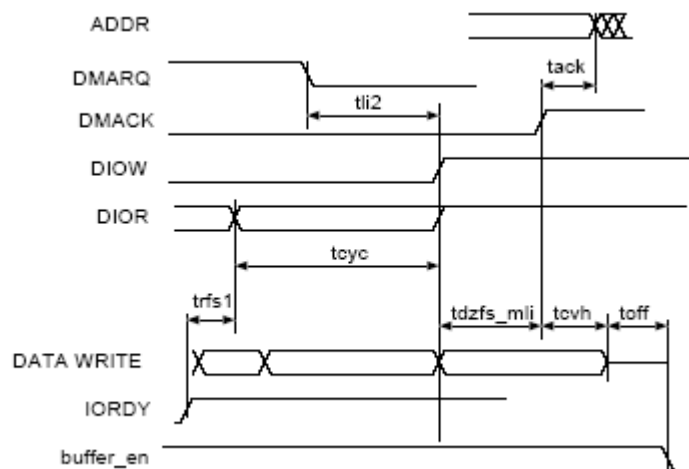


Figure 85. UDMA-Out Device Terminates Transfer Timing Diagram

Table 70. UDMA-Out Burst Timing Parameters

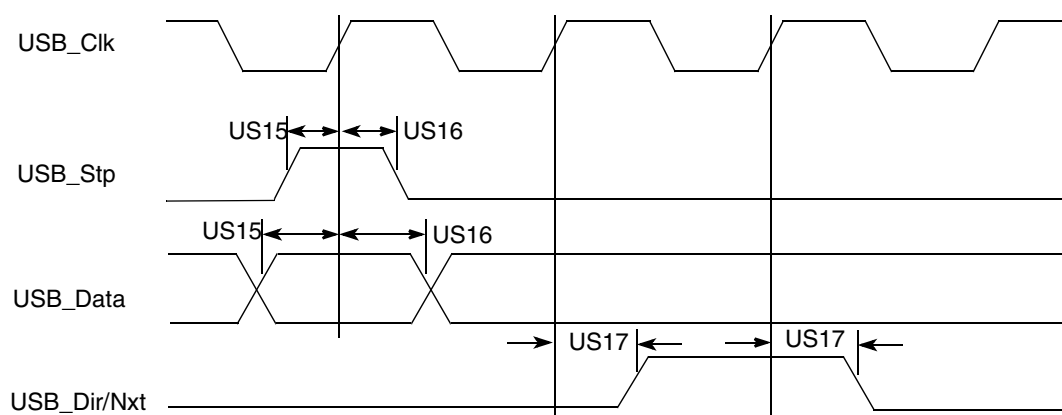
| ATA Parameter | Parameter from Figure 83, Figure 84, Figure 85 | Value                                                                                                                                                                          | Controlling Variable |
|---------------|------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| tack          | tack                                           | $tack \text{ (min.)} = (\text{time\_ack} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                          | time_ack             |
| tenv          | tenv                                           | $tenv \text{ (min.)} = (\text{time\_env} \times T) - (\text{tskew1} + \text{tskew2})$<br>$tenv \text{ (max.)} = (\text{time\_env} \times T) + (\text{tskew1} + \text{tskew2})$ | time_env             |
| tdvs          | tdvs                                           | $tdvs = (\text{time\_dvs} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                                         | time_dvs             |
| tdvh          | tdvh                                           | $tdvs = (\text{time\_dvh} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                                         | time_dvh             |
| tcyc          | tcyc                                           | $tcyc = \text{time\_cyc} \times T - (\text{tskew1} + \text{tskew2})$                                                                                                           | time_cyc             |
| t2cyc         | —                                              | $t2cyc = \text{time\_cyc} \times 2 \times T$                                                                                                                                   | time_cyc             |
| trfs1         | trfs                                           | $trfs = 1.6 \times T + \text{tsui} + \text{tco} + \text{tbuf} + \text{tbuf}$                                                                                                   | —                    |
| —             | tdzfs                                          | $tdzfs = \text{time\_dzfs} \times T - (\text{tskew1})$                                                                                                                         | time_dzfs            |
| tss           | tss                                            | $tss = \text{time\_ss} \times T - (\text{tskew1} + \text{tskew2})$                                                                                                             | time_ss              |
| tmli          | tdzfs_mli                                      | $tdzfs\_mli = \max. (\text{time\_dzfs}, \text{time\_mli}) \times T - (\text{tskew1} + \text{tskew2})$                                                                          | —                    |
| tli           | tli1                                           | $tli1 > 0$                                                                                                                                                                     | —                    |
| tli           | tli2                                           | $tli2 > 0$                                                                                                                                                                     | —                    |
| tli           | tli3                                           | $tli3 > 0$                                                                                                                                                                     | —                    |
| tcvh          | tcvh                                           | $tcvh = (\text{time\_cvh} \times T) - (\text{tskew1} + \text{tskew2})$                                                                                                         | time_cvh             |
| —             | ton<br>toff                                    | $ton = \text{time\_on} \times T - \text{tskew1}$<br>$toff = \text{time\_off} \times T - \text{tskew1}$                                                                         | —                    |

## 4.9.18 Parallel Interface (ULPI) Timing

Electrical and timing specifications of the parallel interface are presented in the subsequent sections.

**Table 71. Signal Definitions—Parallel Interface**

| Name          | Direction | Signal Description                                                                                 |
|---------------|-----------|----------------------------------------------------------------------------------------------------|
| USB_Clk       | In        | Interface clock. All interface signals are synchronous to the clock.                               |
| USB_Data[7:0] | I/O       | Bidirectional data bus, driven low by the link during idle. Bus ownership is determined by Dir.    |
| USB_Dir       | In        | Direction. Control the direction of the data bus.                                                  |
| USB_Stp       | Out       | Stop. The link asserts this signal for 1 clock cycle to stop the data stream currently on the bus. |
| USB_Nxt       | In        | Next. The PHY asserts this signal to throttle the data.                                            |



**Figure 86. USB Transmit/Receive Waveform in Parallel Mode**

**Table 72. USB Timing Specification in VP\_VM Unidirectional Mode**

| ID   | Parameter  | Min. | Max. | Unit | Conditions / Reference Signal |
|------|------------|------|------|------|-------------------------------|
| US15 | USB_TXOE_B | —    | 6.0  | ns   | 10 pF                         |
| US16 | USB_DAT_VP | —    | 0.0  | ns   | 10 pF                         |
| US17 | USB_SE0_VM | —    | 9.0  | ns   | 10 pF                         |

## 4.9.19 PWM Electrical Specifications

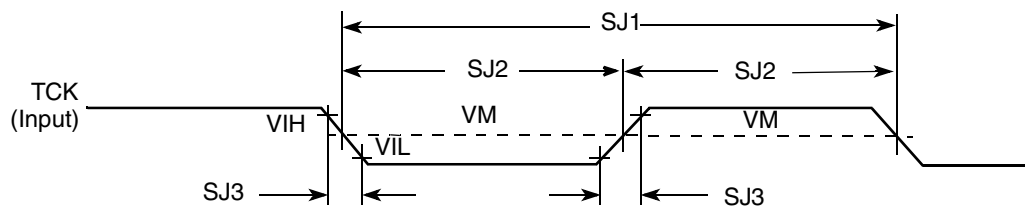
This section describes the electrical information of the PWM. The PWM can be programmed to select one of three clock signals as its source frequency. The selected clock signal is passed through a prescaler before being input to the counter. The output is available at the pulse-width modulator output (PWMO) external



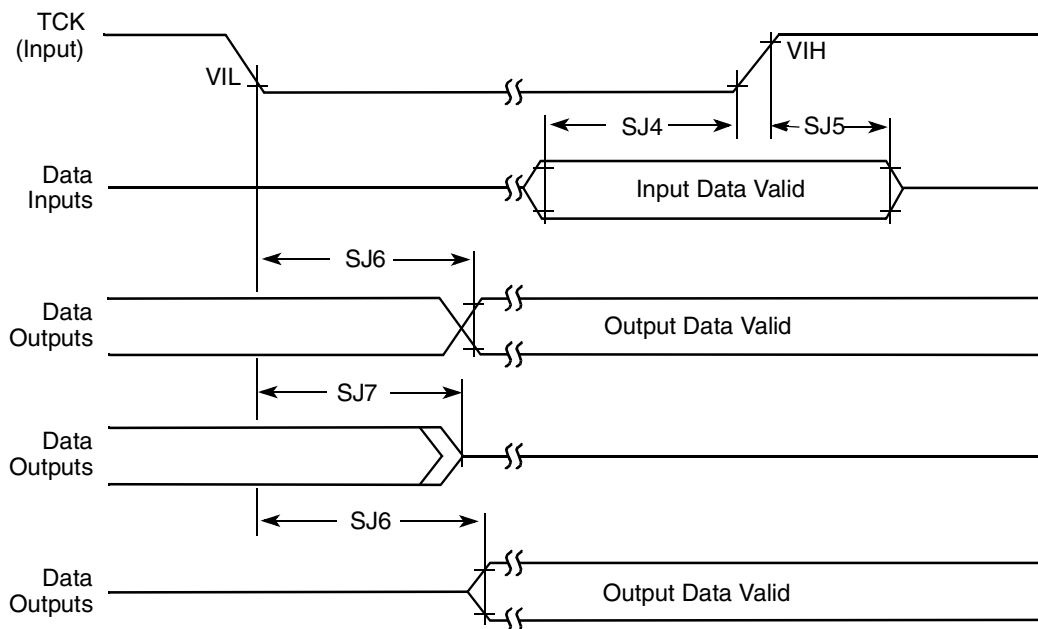
pin. The modulated signal of the module is observed at this pin. It can be viewed as a clock signal whose period and duty cycle can be varied with different settings of the PWM. The smallest period is two `ipg_clk` periods with duty cycle of 50 percent.

## 4.9.20 SJC Electrical Specifications

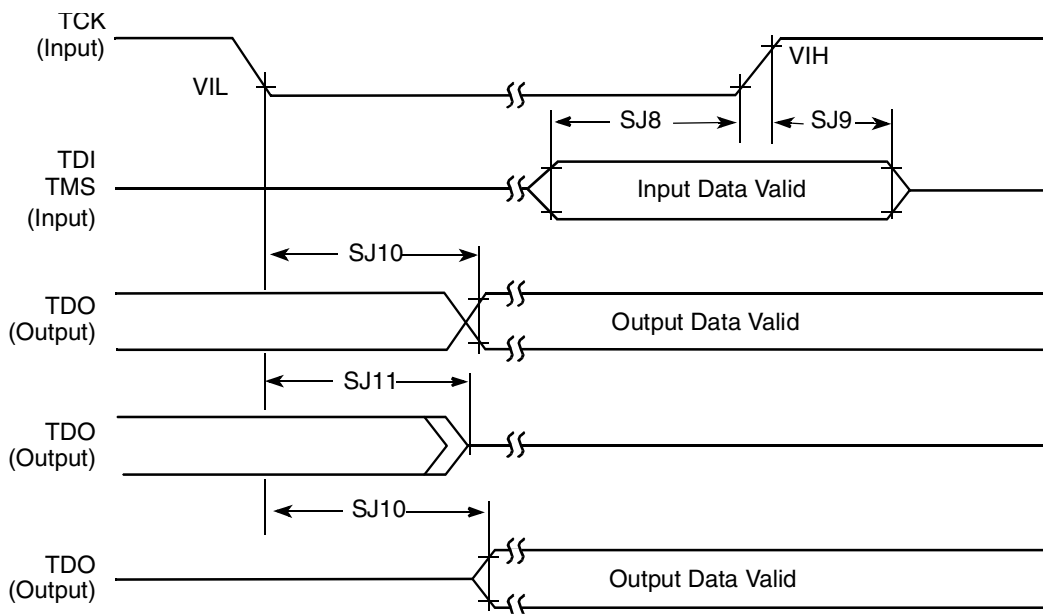
This section details the electrical characteristics for the SJC module. [Figure 87](#) depicts the SJC test clock input timing. [Figure 88](#) depicts the SJC boundary scan timing, [Figure 89](#) depicts the SJC test access port, [Figure 90](#) depicts the SJC `TRST` timing, and [Table 73](#) lists the SJC timing parameters.



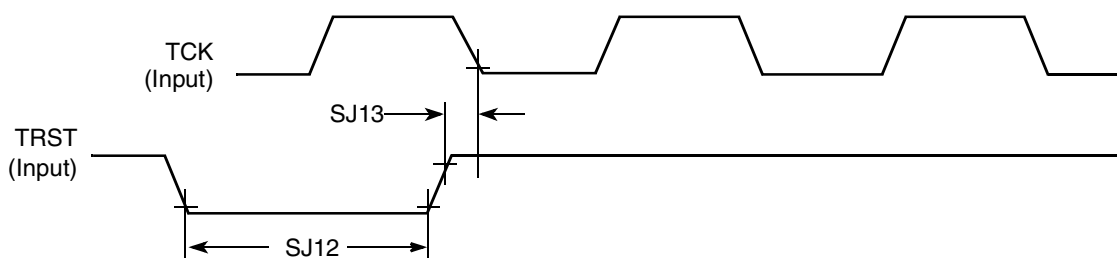
**Figure 87. Test Clock Input Timing Diagram**



**Figure 88. Boundary Scan (JTAG) Timing Diagram**



**Figure 89. Test Access Port Timing Diagram**



**Figure 90. TRST Timing Diagram**

**Table 73. SJC Timing Parameters**

| ID   | Parameter                                   | All Frequencies  |      | Unit |
|------|---------------------------------------------|------------------|------|------|
|      |                                             | Min.             | Max. |      |
| SJ1  | TCK cycle time                              | 100 <sup>1</sup> | —    | ns   |
| SJ2  | TCK clock pulse width measured at $V_M^{2}$ | 40               | —    | ns   |
| SJ3  | TCK rise and fall times                     | —                | 3    | ns   |
| SJ4  | Boundary scan input data set-up time        | 10               | —    | ns   |
| SJ5  | Boundary scan input data hold time          | 50               | —    | ns   |
| SJ6  | TCK low to output data valid                | —                | 50   | ns   |
| SJ7  | TCK low to output high impedance            | —                | 50   | ns   |
| SJ8  | TMS, TDI data set-up time                   | 10               | —    | ns   |
| SJ9  | TMS, TDI data hold time                     | 50               | —    | ns   |
| SJ10 | TCK low to TDO data valid                   | —                | 44   | ns   |

**Table 73. SJC Timing Parameters (continued)**

| ID   | Parameter                                       | All Frequencies |      | Unit |
|------|-------------------------------------------------|-----------------|------|------|
|      |                                                 | Min.            | Max. |      |
| SJ11 | TCK low to TDO high impedance                   | —               | 44   | ns   |
| SJ12 | $\overline{\text{TRST}}$ assert time            | 100             | —    | ns   |
| SJ13 | $\overline{\text{TRST}}$ set-up time to TCK low | 40              | —    | ns   |

<sup>1</sup> On cases where SDMA TAP is put in the chain, the max. TCK frequency is limited by max. ratio of 1:8 of SDMA core frequency to TCK limitation. This implies max. frequency of 8.25 MHz (or 121.2 ns) for 66 MHz IPG clock.

<sup>2</sup>  $V_M$  = mid point voltage

### 4.9.21 SPDIF Timing

SPDIF data is sent using bi-phase marking code. When encoding, the SPDIF data signal is modulated by a clock that is twice the bit rate of the data signal.

Figure 91 shows SPDIF timing parameters, including the timing of the modulating Rx clock (SRCK) for SPDIF in Rx mode and the timing of the modulating Tx clock (STCLK). for SPDIF in Tx mode.

**Table 74. SPDIF Timing Parameters**

| Parameters                                        | Symbol  | Timing Parameter Range |      | Units |
|---------------------------------------------------|---------|------------------------|------|-------|
|                                                   |         | Min.                   | Max. |       |
| SPDIFIN Skew: asynchronous inputs, no specs apply | —       | —                      | 0.7  | ns    |
| SPDIFOUT output (Load = 50 pf)                    | —       | —                      | 1.5  | ns    |
| • Skew                                            | —       | —                      | 24.2 |       |
| • Transition rising                               | —       | —                      | 31.3 |       |
| • Transition falling                              | —       | —                      | —    | ns    |
| SPDIFOUT1 output (Load = 30 pf)                   | —       | —                      | 1.5  |       |
| • Skew                                            | —       | —                      | 13.6 |       |
| • Transition rising                               | —       | —                      | 18.0 | ns    |
| • Transition falling                              | —       | —                      | —    |       |
| Modulating Rx clock (SRCK) period                 | srckp   | 40.0                   | —    | ns    |
| SRCK high period                                  | srckph  | 16.0                   | —    | ns    |
| SRCK low period                                   | srckpl  | 16.0                   | —    | ns    |
| Modulating Tx clock (STCLK) period                | stclkp  | 40.0                   | —    | ns    |
| STCLK high period                                 | stclkph | 16.0                   | —    | ns    |
| STCLK low period                                  | stclkpl | 16.0                   | —    | ns    |

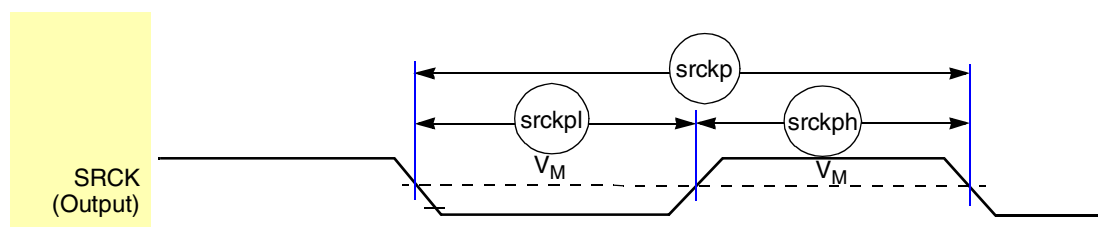


Figure 91. SRCK Timing

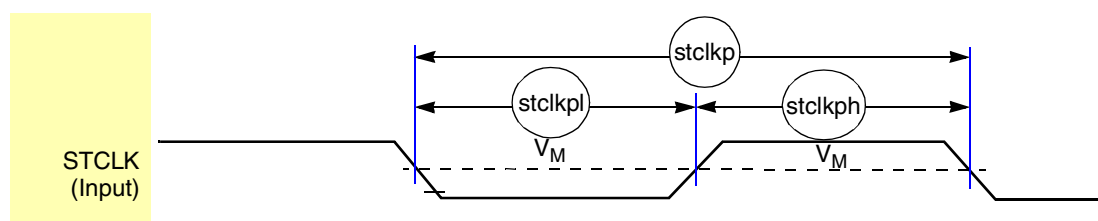


Figure 92. STCLK Timing

## 4.9.22 SSI Electrical Specifications

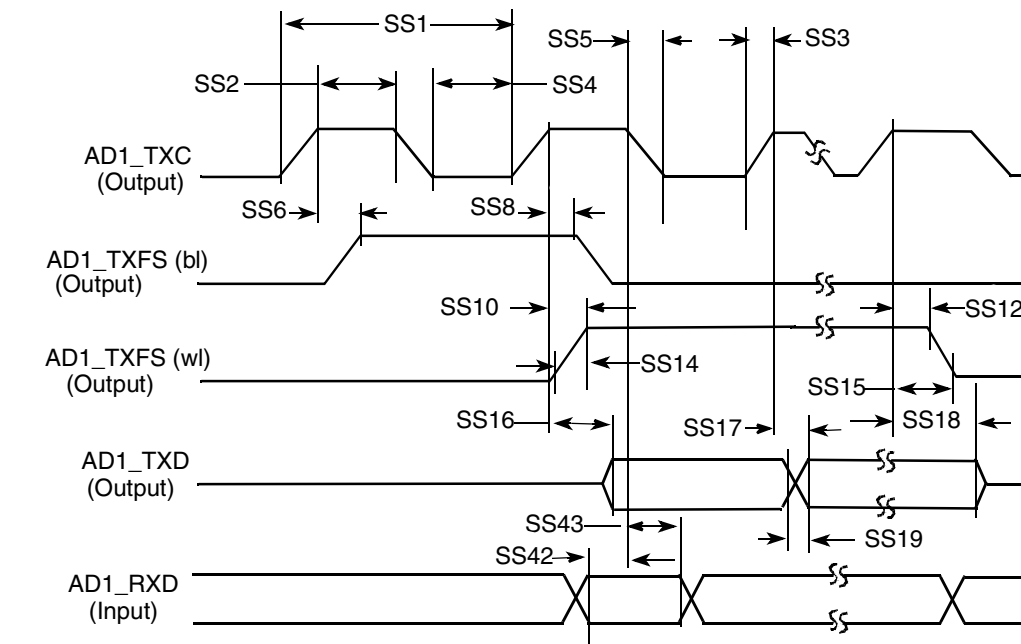
This section describes electrical characteristics of the SSI.

### NOTE

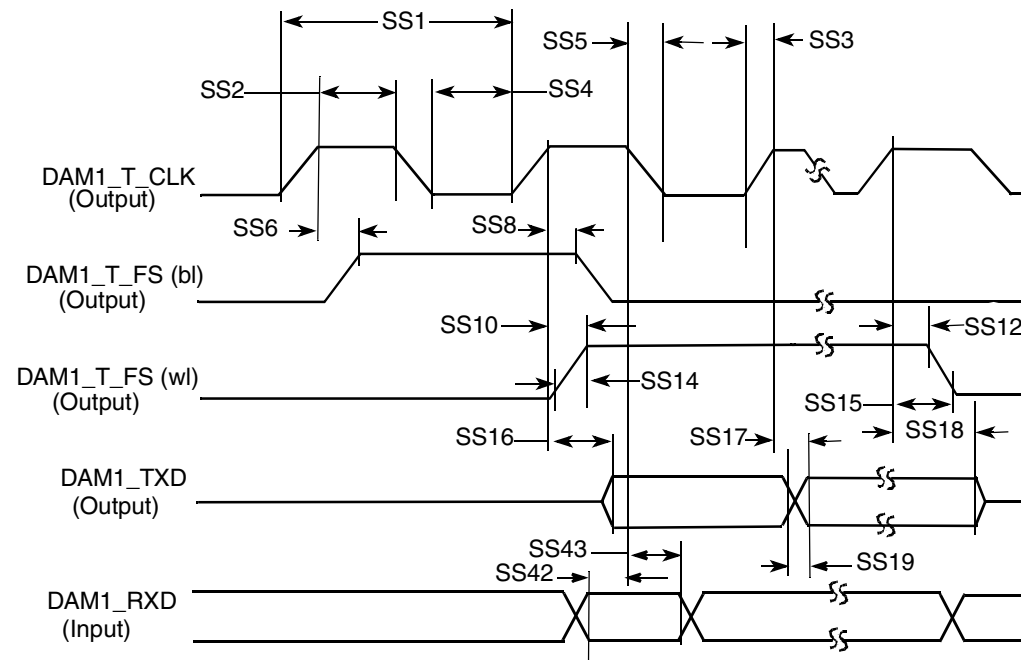
- All of the timing for the SSI is given for a non-inverted serial clock polarity (TSCKP/RSCKP = 0) and a non-inverted frame sync (TFSI/RFSI = 0). If the polarity of the clock and/or the frame sync have been inverted, all the timing remains valid by inverting the clock signal STCK/SRCK and/or the frame sync STFS/SRFS shown in the tables and in the figures.
- All timing is on AUDMUX signals when SSI is being used for data transfer.
- “Tx” and “Rx” refer to the transmit and receive sections of the SSI, respectively.
- For internal frame sync operations using the external clock, the FS timing will be the same as that of Tx Data (for example, during AC97 mode of operation).

#### 4.9.22.1 SSI Transmitter Timing with Internal Clock

Figure 93 depicts the SSI transmitter timing with internal clock, and Table 75 lists the timing parameters.



Note: SRXD Input in Synchronous mode only



Note: SRXD Input in Synchronous mode only

**Figure 93. SSI Transmitter with Internal Clock Timing Diagram**

**Table 75. SSI Transmitter with Internal Clock Timing Parameters**

| ID                                          | Parameter                                      | Min. | Max. | Unit |
|---------------------------------------------|------------------------------------------------|------|------|------|
| <b>Internal Clock Operation</b>             |                                                |      |      |      |
| SS1                                         | (Tx/Rx) CK clock period                        | 81.4 | —    | ns   |
| SS2                                         | (Tx/Rx) CK clock high period                   | 36.0 | —    | ns   |
| SS3                                         | (Tx/Rx) CK clock rise time                     | —    | 6    | ns   |
| SS4                                         | (Tx/Rx) CK clock low period                    | 36.0 | —    | ns   |
| SS5                                         | (Tx/Rx) CK clock fall time                     | —    | 6    | ns   |
| SS6                                         | (Tx) CK high to FS (bl) high                   | —    | 15.0 | ns   |
| SS8                                         | (Tx) CK high to FS (bl) low                    | —    | 15.0 | ns   |
| SS10                                        | (Tx) CK high to FS (wl) high                   | —    | 15.0 | ns   |
| SS12                                        | (Tx) CK high to FS (wl) low                    | —    | 15.0 | ns   |
| SS14                                        | (Tx/Rx) Internal FS rise time                  | —    | 6    | ns   |
| SS15                                        | (Tx/Rx) Internal FS fall time                  | —    | 6    | ns   |
| SS16                                        | (Tx) CK high to STXD valid from high impedance | —    | 15.0 | ns   |
| SS17                                        | (Tx) CK high to STXD high/low                  | —    | 15.0 | ns   |
| SS18                                        | (Tx) CK high to STXD high impedance            | —    | 15.0 | ns   |
| SS19                                        | STXD rise/fall time                            | —    | 6    | ns   |
| <b>Synchronous Internal Clock Operation</b> |                                                |      |      |      |
| SS42                                        | SRXD setup before (Tx) CK falling              | 10.0 | —    | ns   |
| SS43                                        | SRXD hold after (Tx) CK falling                | 0    | —    | ns   |
| SS52                                        | Loading                                        | —    | 25   | pF   |

#### 4.9.22.2 SSI Receiver Timing with Internal Clock

Figure 94 depicts the SSI receiver timing with internal clock. Table 76 lists the timing parameters shown in Figure 94.

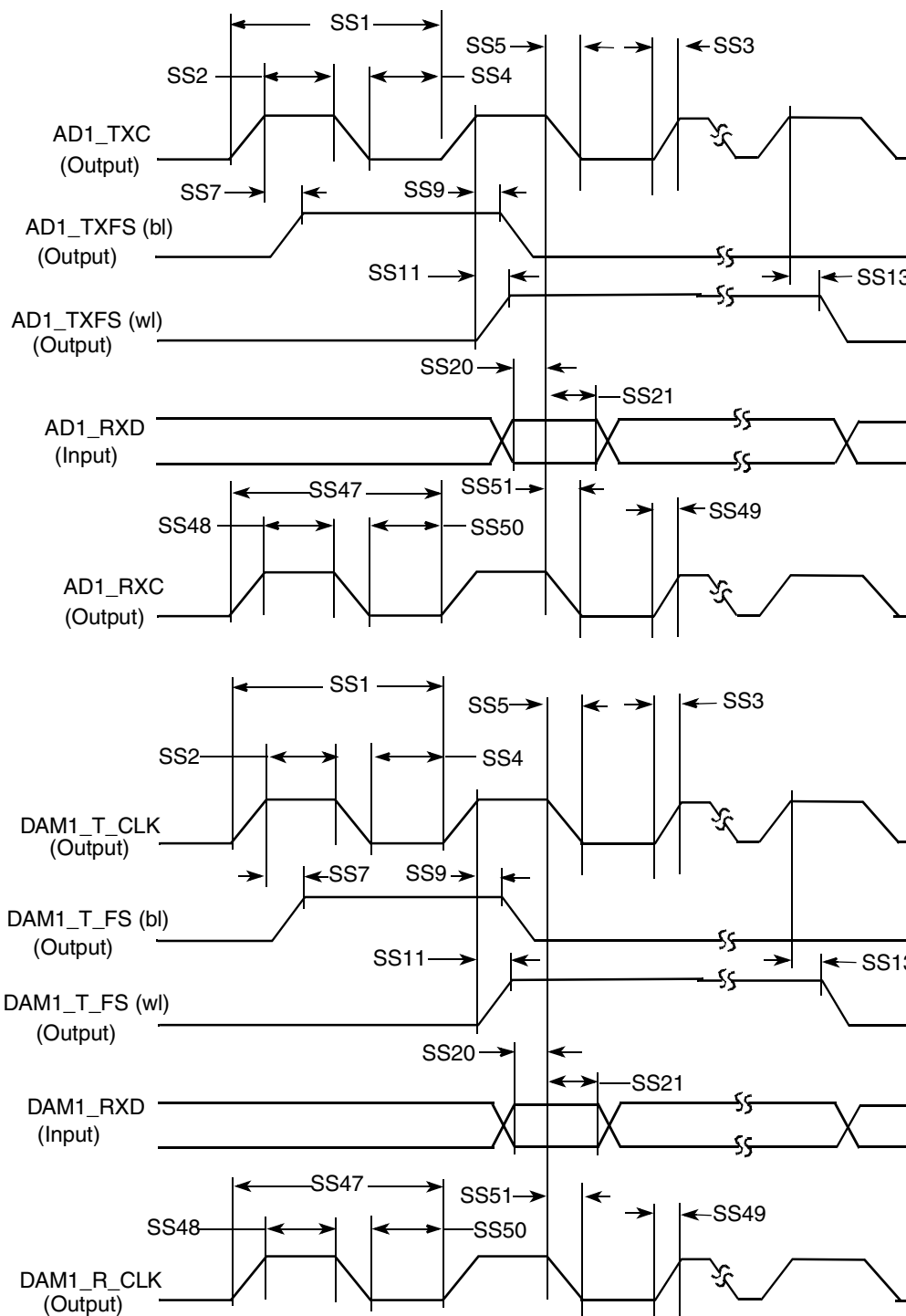


Figure 94. SSI Receiver with Internal Clock Timing Diagram

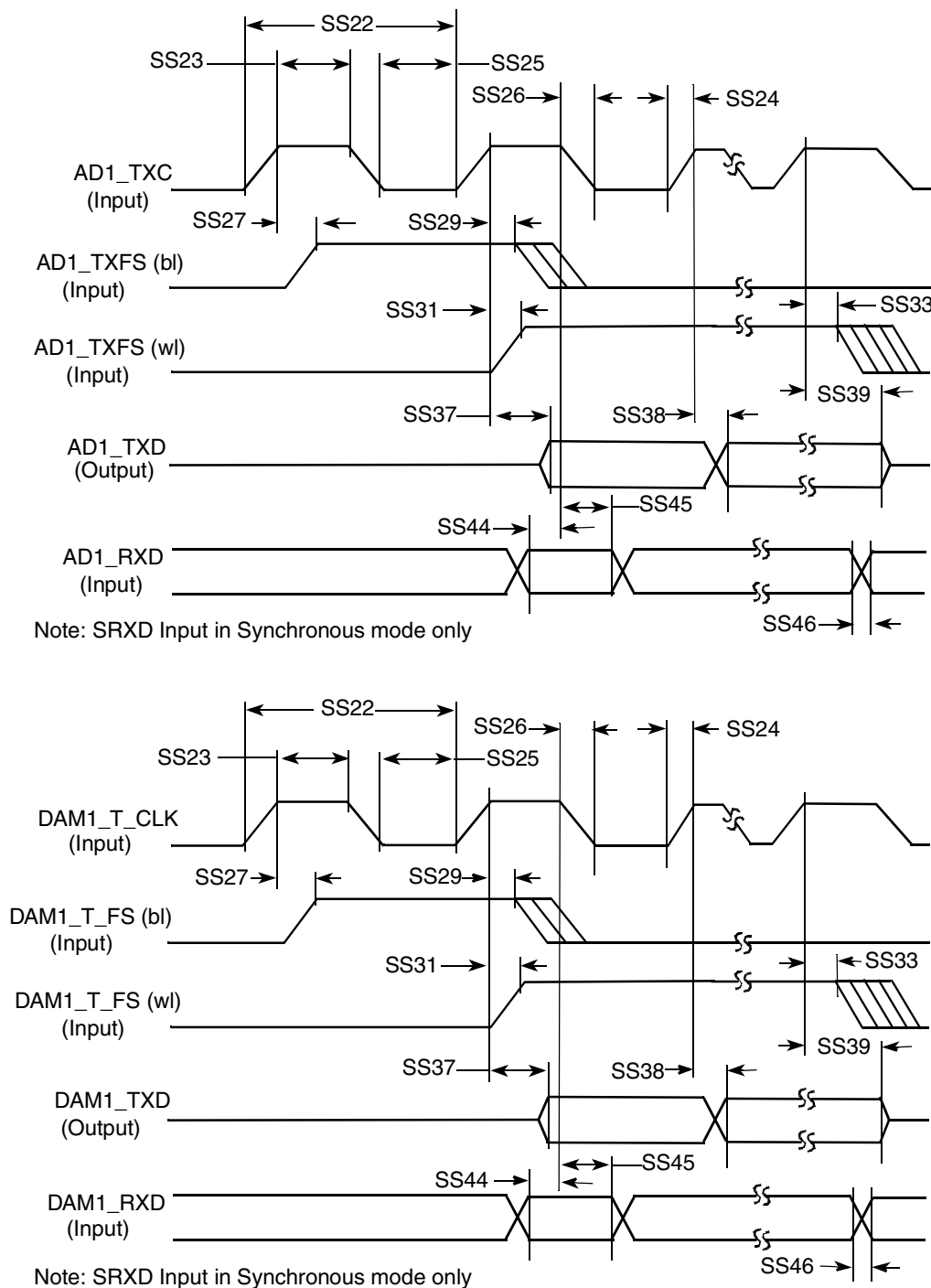
**Table 76. SSI Receiver with Internal Clock Timing Parameters**

| ID                                  | Parameter                          | Min.  | Max. | Unit |
|-------------------------------------|------------------------------------|-------|------|------|
| <b>Internal Clock Operation</b>     |                                    |       |      |      |
| SS1                                 | (Tx/Rx) CK clock period            | 81.4  | —    | ns   |
| SS2                                 | (Tx/Rx) CK clock high period       | 36.0  | —    | ns   |
| SS3                                 | (Tx/Rx) CK clock rise time         | —     | 6    | ns   |
| SS4                                 | (Tx/Rx) CK clock low period        | 36.0  | —    | ns   |
| SS5                                 | (Tx/Rx) CK clock fall time         | —     | 6    | ns   |
| SS7                                 | (Rx) CK high to FS (bl) high       | —     | 15.0 | ns   |
| SS9                                 | (Rx) CK high to FS (bl) low        | —     | 15.0 | ns   |
| SS11                                | (Rx) CK high to FS (wl) high       | —     | 15.0 | ns   |
| SS13                                | (Rx) CK high to FS (wl) low        | —     | 15.0 | ns   |
| SS20                                | SRXD setup time before (Rx) CK low | 10.0  | —    | ns   |
| SS21                                | SRXD hold time after (Rx) CK low   | 0     | —    | ns   |
| <b>Oversampling Clock Operation</b> |                                    |       |      |      |
| SS47                                | Oversampling clock period          | 15.04 | —    | ns   |
| SS48                                | Oversampling clock high period     | 6     | —    | ns   |
| SS49                                | Oversampling clock rise time       | —     | 3    | ns   |
| SS50                                | Oversampling clock low period      | 6     | —    | ns   |
| SS51                                | Oversampling clock fall time       | —     | 3    | ns   |



### 4.9.22.3 SSI Transmitter Timing with External Clock

Figure 95 depicts the SSI transmitter timing with external clock, and Table 77 lists the timing parameters.



**Figure 95. SSI Transmitter with External Clock Timing Diagram**

**Table 77. SSI Transmitter with External Clock Timing Parameters**

| ID                                          | Parameter                                      | Min.  | Max. | Unit |
|---------------------------------------------|------------------------------------------------|-------|------|------|
| <b>External Clock Operation</b>             |                                                |       |      |      |
| SS22                                        | (Tx/Rx) CK clock period                        | 81.4  | —    | ns   |
| SS23                                        | (Tx/Rx) CK clock high period                   | 36.0  | —    | ns   |
| SS24                                        | (Tx/Rx) CK clock rise time                     | —     | 6.0  | ns   |
| SS25                                        | (Tx/Rx) CK clock low period                    | 36.0  | —    | ns   |
| SS26                                        | (Tx/Rx) CK clock fall time                     | —     | 6.0  | ns   |
| SS27                                        | (Tx) CK high to FS (bl) high                   | −10.0 | 15.0 | ns   |
| SS29                                        | (Tx) CK high to FS (bl) low                    | 10.0  | —    | ns   |
| SS31                                        | (Tx) CK high to FS (wl) high                   | −10.0 | 15.0 | ns   |
| SS33                                        | (Tx) CK high to FS (wl) low                    | 10.0  | —    | ns   |
| SS37                                        | (Tx) CK high to STXD valid from high impedance | —     | 15.0 | ns   |
| SS38                                        | (Tx) CK high to STXD high/low                  | —     | 15.0 | ns   |
| SS39                                        | (Tx) CK high to STXD high impedance            | —     | 15.0 | ns   |
| <b>Synchronous External Clock Operation</b> |                                                |       |      |      |
| SS44                                        | SRXD setup before (Tx) CK falling              | 10.0  | —    | ns   |
| SS45                                        | SRXD hold after (Tx) CK falling                | 2.0   | —    | ns   |
| SS46                                        | SRXD rise/fall time                            | —     | 6.0  | ns   |

#### 4.9.22.4 SSI Receiver Timing with External Clock

Figure 96 depicts the SSI receiver timing with external clock, and Table 78 lists the timing parameters.

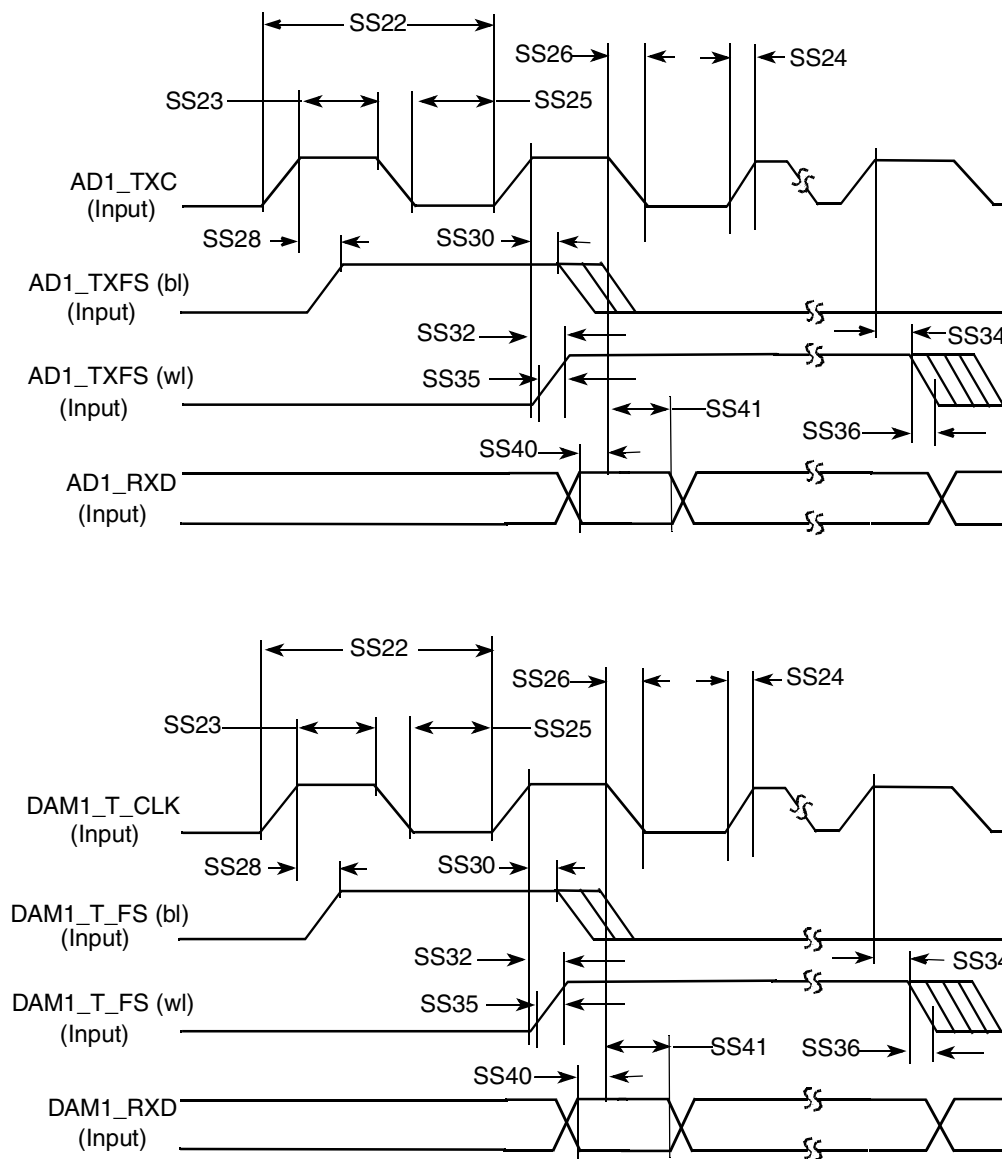


Figure 96. SSI Receiver with External Clock Timing Diagram

Table 78. SSI Receiver with External Clock Timing Parameters

| ID                              | Parameter                    | Min. | Max. | Unit |
|---------------------------------|------------------------------|------|------|------|
| <b>External Clock Operation</b> |                              |      |      |      |
| SS22                            | (Tx/Rx) CK clock period      | 81.4 | —    | ns   |
| SS23                            | (Tx/Rx) CK clock high period | 36.0 | —    | ns   |
| SS24                            | (Tx/Rx) CK clock rise time   | —    | 6.0  | ns   |

**Table 78. SSI Receiver with External Clock Timing Parameters (continued)**

| ID   | Parameter                          | Min.  | Max. | Unit |
|------|------------------------------------|-------|------|------|
| SS25 | (Tx/Rx) CK clock low period        | 36.0  | —    | ns   |
| SS26 | (Tx/Rx) CK clock fall time         | —     | 6.0  | ns   |
| SS28 | (Rx) CK high to FS (bl) high       | −10.0 | 15.0 | ns   |
| SS30 | (Rx) CK high to FS (bl) low        | 10.0  | —    | ns   |
| SS32 | (Rx) CK high to FS (wl) high       | −10.0 | 15.0 | ns   |
| SS34 | (Rx) CK high to FS (wl) low        | 10.0  | —    | ns   |
| SS35 | (Tx/Rx) External FS rise time      | —     | 6.0  | ns   |
| SS36 | (Tx/Rx) External FS fall time      | —     | 6.0  | ns   |
| SS40 | SRXD setup time before (Rx) CK low | 10.0  | —    | ns   |
| SS41 | SRXD hold time after (Rx) CK low   | 2.0   | —    | ns   |

## 4.9.23 UART Electrical

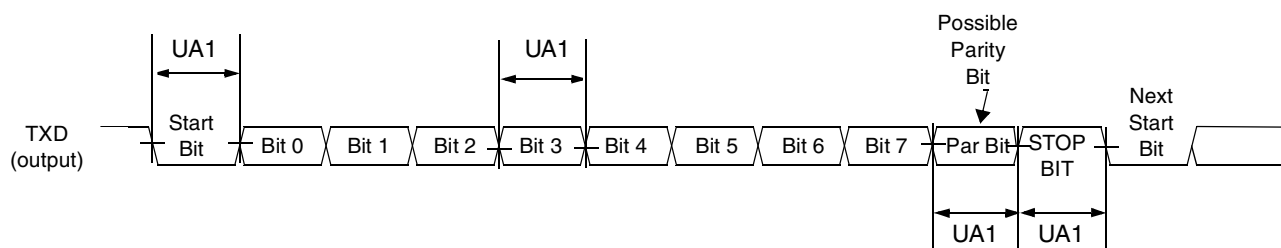
This section describes the electrical information of the UART module.

### 4.9.23.1 UART RS-232 Serial Mode Timing

The following subsections give the UART transmit and receive timings in RS-232 serial mode.

#### 4.9.23.1.11 UART Transmitter

Figure 97 depicts the transmit timing of UART in RS-232 serial mode, with 8 data bit/1 stop bit format. Table 79 lists the UART RS-232 serial mode transmit timing characteristics.



**Figure 97. UART RS-232 Serial Mode Transmit Timing Diagram**

**Table 79. RS-232 Serial Mode Transmit Timing Parameters**

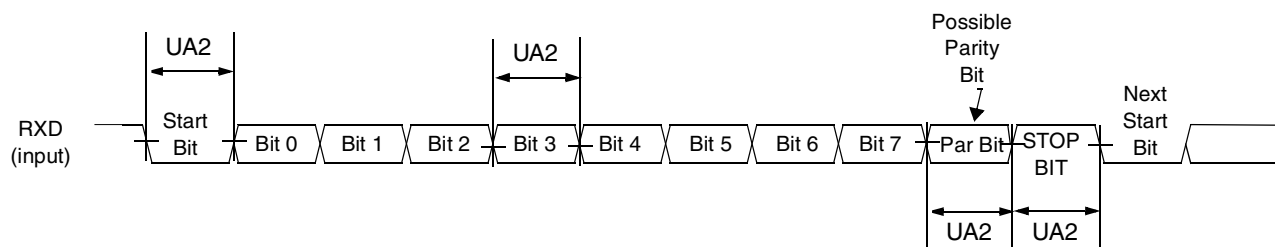
| ID  | Parameter         | Symbol     | Min.                                                       | Max.                                                   | Units |
|-----|-------------------|------------|------------------------------------------------------------|--------------------------------------------------------|-------|
| UA1 | Transmit Bit Time | $t_{Tbit}$ | $1/F_{baud\_rate}^1 - \frac{T_{ref\_clk}^2}{T_{ref\_clk}}$ | $1/F_{baud\_rate} + \frac{T_{ref\_clk}}{T_{ref\_clk}}$ | —     |

<sup>1</sup>  $F_{baud\_rate}$ : Baud rate frequency. The maximum baud rate the UART can support is  $(ipg\_perclk \text{ frequency})/16$ .

<sup>2</sup>  $T_{ref\_clk}$ : The period of UART reference clock  $ref\_clk$  ( $ipg\_perclk$  after RFDIV divider).

#### 4.9.23.1.12 UART Receiver

Figure 98 depicts the RS-232 serial mode receive timing, with 8 data bit/1 stop bit format. Table 80 lists serial mode receive timing characteristics.



**Figure 98. UART RS-232 Serial Mode Receive Timing Diagram**

**Table 80. RS-232 Serial Mode Receive Timing Parameters**

| ID  | Parameter                     | Symbol     | Min.                                                      | Max.                                                    | Units |
|-----|-------------------------------|------------|-----------------------------------------------------------|---------------------------------------------------------|-------|
| UA2 | Receive Bit Time <sup>1</sup> | $t_{Rbit}$ | $1/F_{baud\_rate}^2 - \frac{1}{16 \times F_{baud\_rate}}$ | $1/F_{baud\_rate} + \frac{1}{16 \times F_{baud\_rate}}$ | —     |

<sup>1</sup> The UART receiver can tolerate  $1/(16 \times F_{baud\_rate})$  tolerance in each bit. But accumulation tolerance in one frame must not exceed  $3/(16 \times F_{baud\_rate})$ .

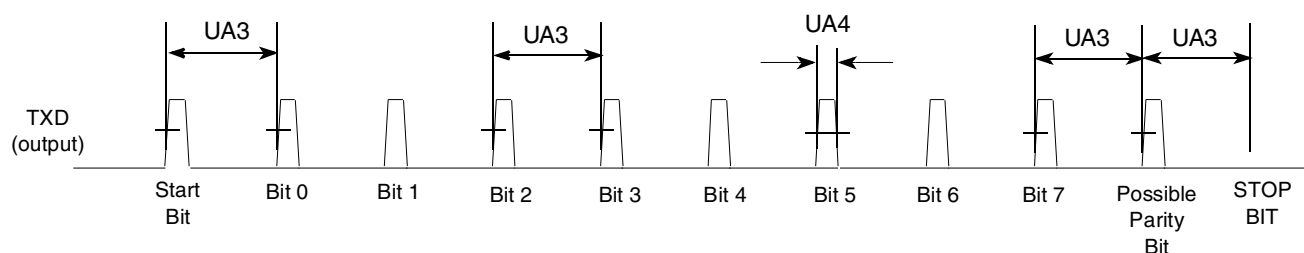
<sup>2</sup>  $F_{baud\_rate}$ : Baud rate frequency. The maximum baud rate the UART can support is  $(ipg\_perclk \text{ frequency}) \div 16$ .

#### 4.9.23.2 UART IrDA Mode Timing

The following subsections give the UART transmit and receive timings in IrDA mode.

##### 4.9.23.2.13 UART IrDA Mode Transmitter

Figure 99 depicts the UART IrDA mode transmit timing, with 8 data bit/1 stop bit format. Table 81 lists the transmit timing characteristics.



**Figure 99. UART IrDA Mode Transmit Timing Diagram**

**Table 81. IrDA Mode Transmit Timing Parameters**

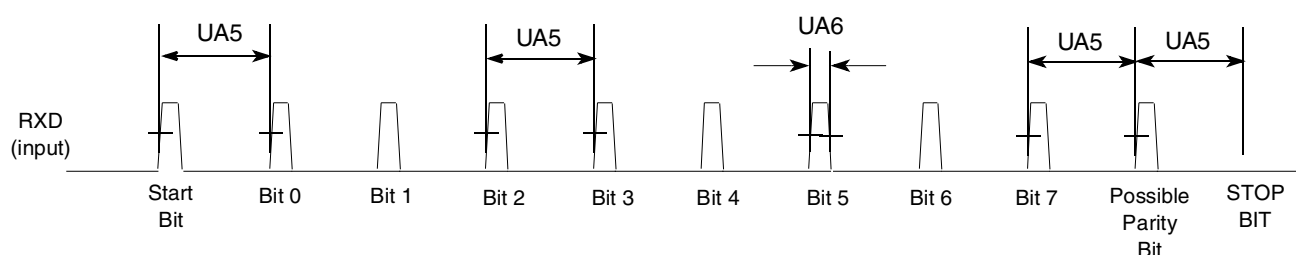
| ID  | Parameter                      | Symbol         | Min.                                                              | Max.                                                              | Units |
|-----|--------------------------------|----------------|-------------------------------------------------------------------|-------------------------------------------------------------------|-------|
| UA3 | Transmit bit time in IrDA mode | $t_{TIRbit}$   | $\frac{1}{F_{baud\_rate}} - \frac{T_{ref\_clk}}{2}$               | $\frac{1}{F_{baud\_rate}} + T_{ref\_clk}$                         | —     |
| UA4 | Transmit IR pulse duration     | $t_{TIRpulse}$ | $(\frac{3}{16}) \times (\frac{1}{F_{baud\_rate}}) - T_{ref\_clk}$ | $(\frac{3}{16}) \times (\frac{1}{F_{baud\_rate}}) + T_{ref\_clk}$ | —     |

<sup>1</sup>  $F_{baud\_rate}$ : Baud rate frequency. The maximum baud rate the UART can support is  $(ipg\_perclk \text{ frequency})/16$ .

<sup>2</sup>  $T_{ref\_clk}$ : The period of UART reference clock  $ref\_clk$  ( $ipg\_perclk$  after RFDIV divider).

#### 4.9.23.2.14 UART IrDA Mode Receiver

Figure 100 depicts the UART IrDA mode receive timing, with 8 data bit/1 stop bit format. Table 82 lists the receive timing characteristics.



**Figure 100. UART IrDA Mode Receive Timing Diagram**

**Table 82. IrDA Mode Receive Timing Parameters**

| ID  | Parameter                                  | Symbol         | Min.                                                              | Max.                                                              | Units |
|-----|--------------------------------------------|----------------|-------------------------------------------------------------------|-------------------------------------------------------------------|-------|
| UA5 | Receive bit time <sup>1</sup> in IrDA mode | $t_{RIRbit}$   | $\frac{1}{F_{baud\_rate}} - \frac{1}{(16 \times F_{baud\_rate})}$ | $\frac{1}{F_{baud\_rate}} + \frac{1}{(16 \times F_{baud\_rate})}$ | —     |
| UA6 | Receive IR pulse duration                  | $t_{RIRpulse}$ | 1.41 $\mu s$                                                      | $(\frac{5}{16}) \times (\frac{1}{F_{baud\_rate}})$                | —     |

<sup>1</sup> The UART receiver can tolerate  $1/(16 \times F_{baud\_rate})$  tolerance in each bit. But accumulation tolerance in one frame must not exceed  $3/(16 \times F_{baud\_rate})$ .

<sup>2</sup>  $F_{baud\_rate}$ : Baud rate frequency. The maximum baud rate the UART can support is  $(ipg\_perclk \text{ frequency}) \div 16$ .

#### 4.9.24 USB Electrical Specifications

In order to support four different serial interfaces, the USB serial transceiver can be configured to operate in one of four modes:

- DAT\_SE0 bidirectional, 3-wire mode
- DAT\_SE0 unidirectional, 6-wire mode
- VP\_VM bidirectional, 4-wire mode
- VP\_VM unidirectional, 6-wire mode

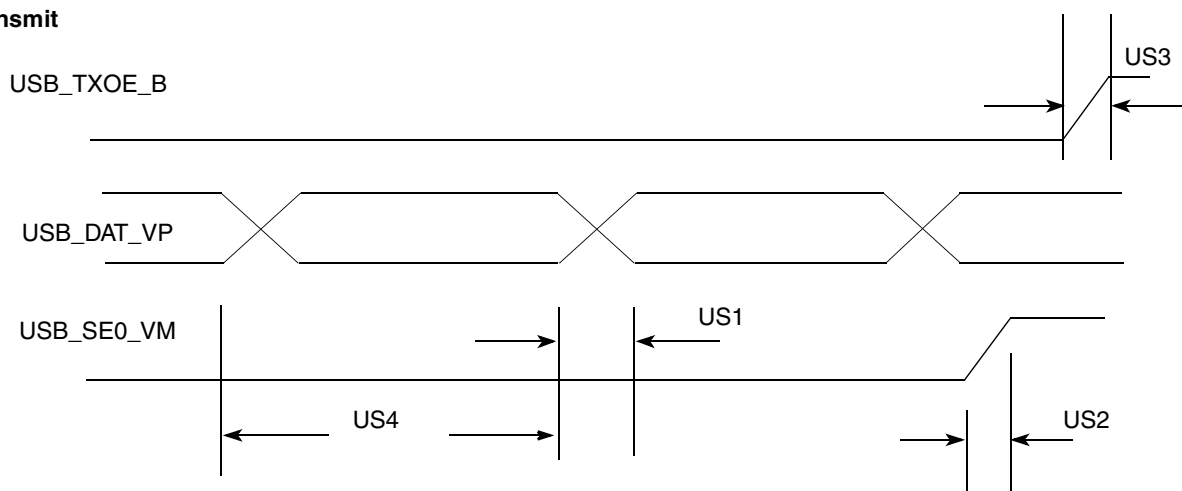
#### 4.9.24.1 DAT\_SE0 Bidirectional Mode

Table 83 defines the signals for DAT\_SE0 bidirectional mode. Figure 101 and Figure 102 show the transmit and receive waveforms respectively.

**Table 83. Signal Definitions—DAT\_SE0 Bidirectional Mode**

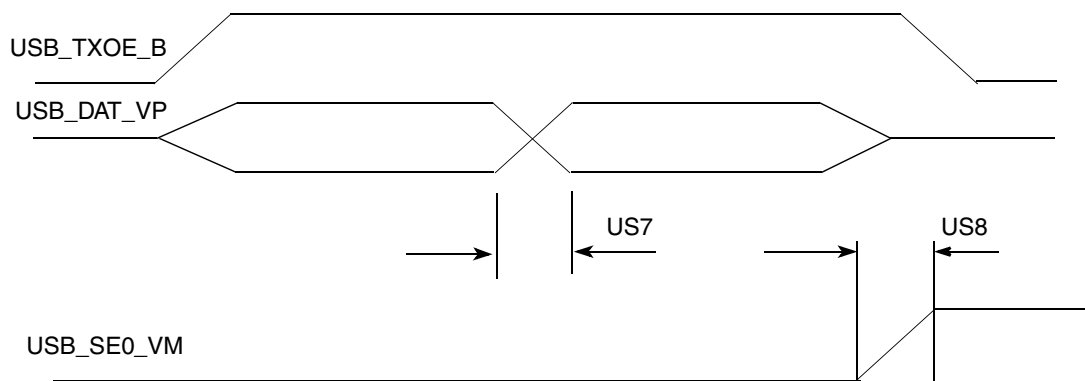
| Name       | Direction | Signal Description                                                             |
|------------|-----------|--------------------------------------------------------------------------------|
| USB_TXOE_B | Out       | Transmit enable, active low                                                    |
| USB_DAT_VP | Out<br>In | Tx data when USB_TXOE_B is low<br>Differential Rx data when USB_TXOE_B is high |
| USB_SE0_VM | Out<br>In | SE0 drive when USB_TXOE_B is low<br>SE0 Rx indicator when USB_TXOE_B is high   |

##### Transmit



**Figure 101. USB Transmit Waveform in DAT\_SE0 Bidirectional Mode**

##### Receive



**Figure 102. USB Receive Waveform in DAT\_SE0 Bidirectional Mode**

Table 84 describes the port timing specification in DAT\_SE0 bidirectional mode.

**Table 84. Port Timing Specification in DAT\_SE0 Bidirectional Mode**

| No. | Parameter         | Signal Name | Direction | Min. | Max. | Unit | Conditions/Reference Signal |
|-----|-------------------|-------------|-----------|------|------|------|-----------------------------|
| US1 | Tx rise/fall time | USB_DAT_VP  | Out       | —    | 5.0  | ns   | 50 pF                       |
| US2 | Tx rise/fall time | USB_SE0_VM  | Out       | —    | 5.0  | ns   | 50 pF                       |
| US3 | Tx rise/fall time | USB_TXOE_B  | Out       | —    | 5.0  | ns   | 50 pF                       |
| US4 | Tx duty cycle     | USB_DAT_VP  | Out       | 49.0 | 51.0 | %    | —                           |
| US7 | Rx rise/fall time | USB_DAT_VP  | In        | —    | 3.0  | ns   | 35 pF                       |
| US8 | Rx rise/fall time | USB_SE0_VM  | In        | —    | 3.0  | ns   | 35 pF                       |

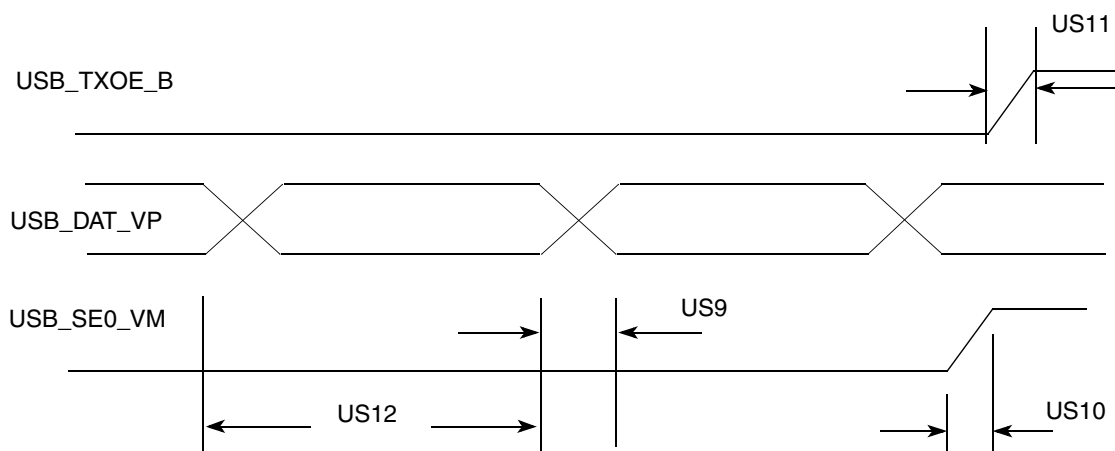
#### 4.9.24.2 DAT\_SE0 Unidirectional Mode

Table 85 defines the signals for DAT\_SE0 unidirectional mode. Figure 103 and Figure 104 show the transmit and receive waveforms respectively.

**Table 85. Signal Definitions—DAT\_SE0 Unidirectional Mode**

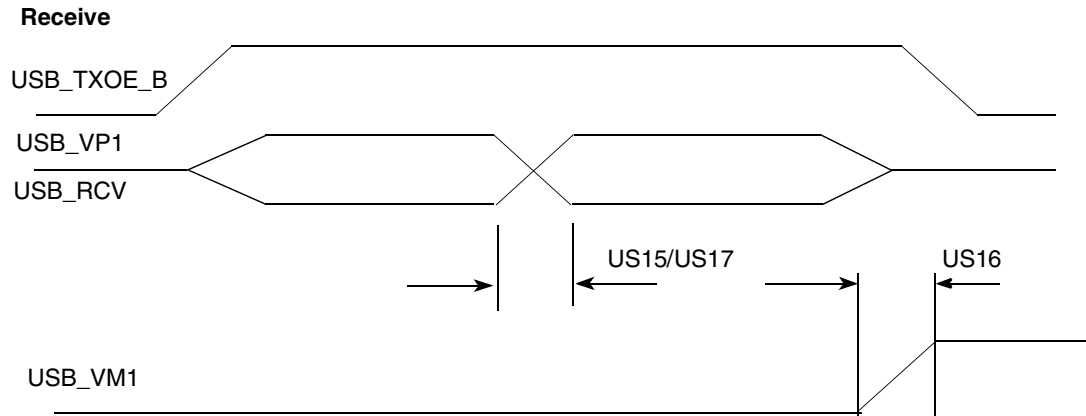
| Name       | Direction | Signal Description                           |
|------------|-----------|----------------------------------------------|
| USB_TXOE_B | Out       | Transmit enable, active low                  |
| USB_DAT_VP | Out       | Tx data when USB_TXOE_B is low               |
| USB_SE0_VM | Out       | SE0 drive when USB_TXOE_B is low             |
| USB_VP1    | In        | Buffered data on DP when USB_TXOE_B is high  |
| USB_VM1    | In        | Buffered data on DM when USB_TXOE_B is high  |
| USB_RCV    | In        | Differential Rx data when USB_TXOE_B is high |

##### Transmit



**Figure 103. USB Transmit Waveform in DAT\_SE0 Unidirectional Mode**





**Figure 104. USB Receive Waveform in DAT\_SE0 Unidirectional Mode**

Table 86 describes the port timing specification in DAT\_SE0 unidirectional mode.

**Table 86. USB Port Timing Specification in DAT\_SE0 Unidirectional Mode**

| No.  | Parameter         | Signal Name | Signal Source | Min. | Max. | Unit | Condition/<br>Reference Signal |
|------|-------------------|-------------|---------------|------|------|------|--------------------------------|
| US9  | Tx rise/fall time | USB_DAT_VP  | Out           | —    | 5.0  | ns   | 50 pF                          |
| US10 | Tx rise/fall time | USB_SE0_VM  | Out           | —    | 5.0  | ns   | 50 pF                          |
| US11 | Tx rise/fall time | USB_TXOE_B  | Out           | —    | 5.0  | ns   | 50 pF                          |
| US12 | Tx duty cycle     | USB_DAT_VP  | Out           | 49.0 | 51.0 | %    | —                              |
| US15 | Rx rise/fall time | USB_VP1     | In            | —    | 3.0  | ns   | 35 pF                          |
| US16 | Rx rise/fall time | USB_VM1     | In            | —    | 3.0  | ns   | 35 pF                          |
| US17 | Rx rise/fall time | USB_RCV     | In            | —    | 3.0  | ns   | 35 pF                          |

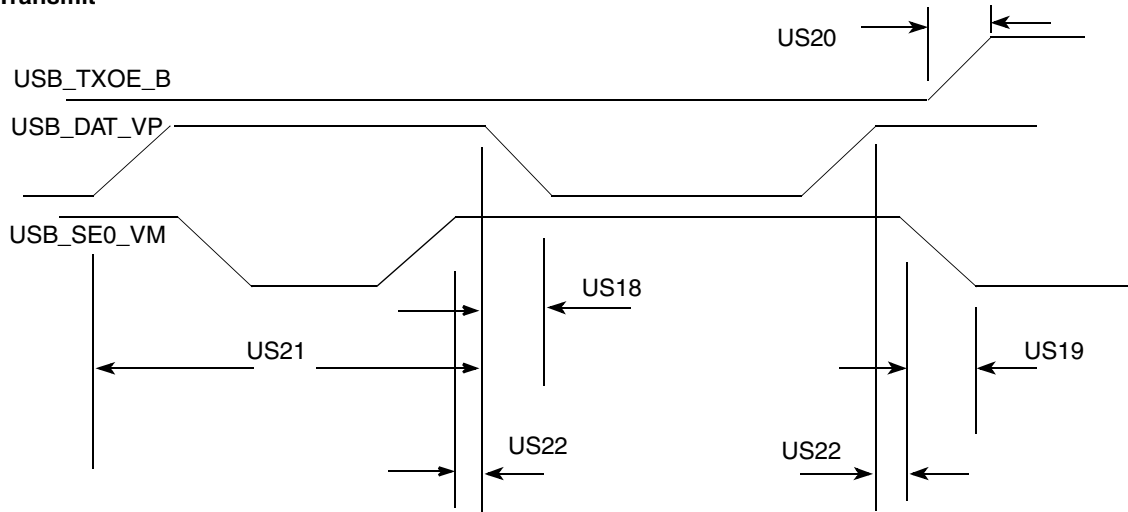
#### 4.9.24.3 VP\_VM Bidirectional Mode

Table 87 defines the signals for VP\_VM bidirectional mode. Figure 105 and Figure 106 show the transmit and receive waveforms respectively.

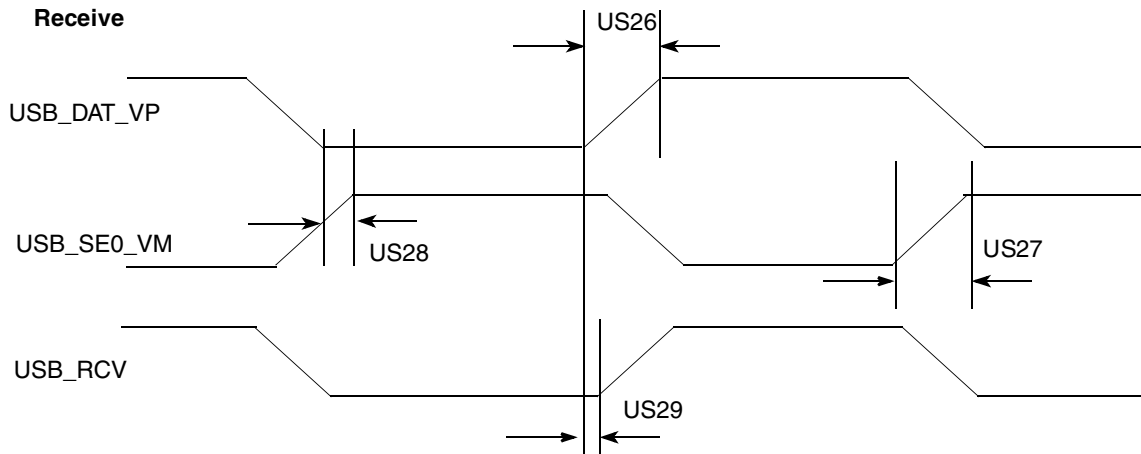
**Table 87. Signal Definitions—VP\_VM Bidirectional Mode**

| Name       | Direction           | Signal Description                                                      |
|------------|---------------------|-------------------------------------------------------------------------|
| USB_TXOE_B | Out                 | Transmit enable, active low                                             |
| USB_DAT_VP | Out (Tx)<br>In (Rx) | Tx VP data when USB_TXOE_B is low<br>Rx VP data when USB_TXOE_B is high |
| USB_SE0_VM | Out (Tx)<br>In (Rx) | Tx VM data when USB_TXOE_B low<br>Rx VM data when USB_TXOE_B high       |
| USB_RCV    | In                  | Differential Rx data                                                    |

### Transmit



**Figure 105. USB Transmit Waveform in VP\_VM Bidirectional Mode**



**Figure 106. USB Receive Waveform in VP\_VM Bidirectional Mode**

Table 88 describes the port timing specification in VP\_VM bidirectional mode.

**Table 88. USB Port Timing Specification in VP\_VM Bidirectional Mode**

| No.  | Parameter         | Signal Name | Direction | Min. | Max. | Unit | Condition/<br>Reference Signal |
|------|-------------------|-------------|-----------|------|------|------|--------------------------------|
| US18 | Tx rise/fall time | USB_DAT_VP  | Out       | —    | 5.0  | ns   | 50 pF                          |
| US19 | Tx rise/fall time | USB_SE0_VM  | Out       | —    | 5.0  | ns   | 50 pF                          |
| US20 | Tx rise/fall time | USB_TXOE_B  | Out       | —    | 5.0  | ns   | 50 pF                          |
| US21 | Tx duty cycle     | USB_DAT_VP  | Out       | 49.0 | 51.0 | %    | —                              |
| US22 | Tx overlap        | USB_SE0_VM  | Out       | −3.0 | +3.0 | ns   | USB_DAT_VP                     |
| US26 | Rx rise/fall time | USB_DAT_VP  | In        | —    | 3.0  | ns   | 35 pF                          |
| US27 | Rx rise/fall time | USB_SE0_VM  | In        | —    | 3.0  | ns   | 35 pF                          |

**Table 88. USB Port Timing Specification in VP\_VM Bidirectional Mode (continued)**

| No.  | Parameter | Signal Name | Direction | Min. | Max. | Unit | Condition/<br>Reference Signal |
|------|-----------|-------------|-----------|------|------|------|--------------------------------|
| US28 | Rx skew   | USB_DAT_VP  | In        | −4.0 | +4.0 | ns   | USB_SE0_VM                     |
| US29 | Rx skew   | USB_RCV     | In        | −6.0 | +2.0 | ns   | USB_DAT_VP                     |

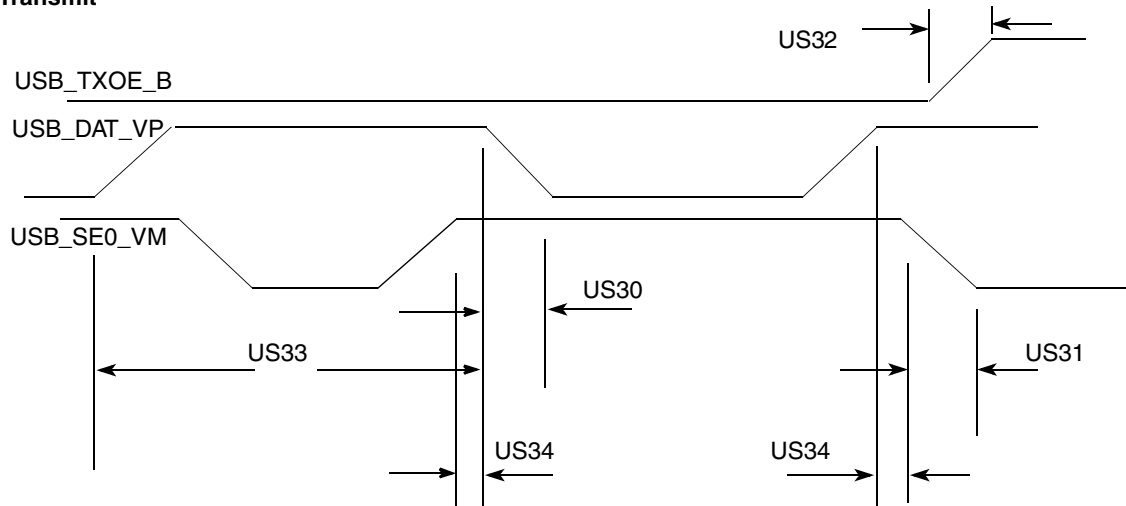
#### 4.9.24.4 VP\_VM Unidirectional Mode

Table 89 defines the signals for VP\_VM unidirectional mode. Figure 107 and Figure 108 show the transmit and receive waveforms respectively.

**Table 89. Signal Definitions—VP\_VM Unidirectional Mode**

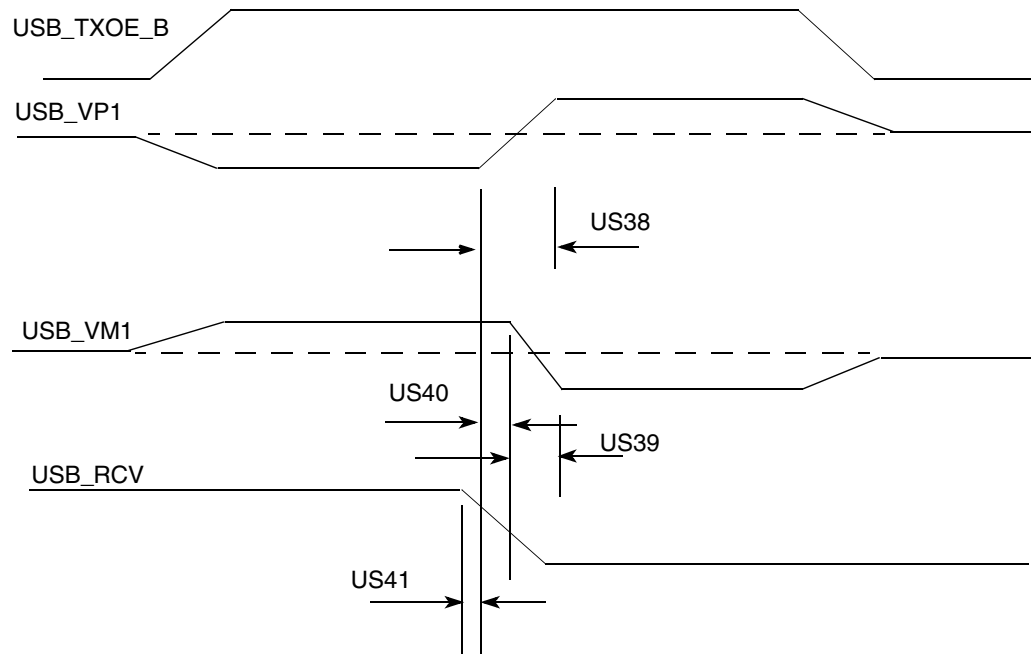
| Name       | Direction | Signal Description                 |
|------------|-----------|------------------------------------|
| USB_TXOE_B | Out       | Transmit enable, active low        |
| USB_DAT_VP | Out       | Tx VP data when USB_TXOE_B is low  |
| USB_SE0_VM | Out       | Tx VM data when USB_TXOE_B is low  |
| USB_VP1    | In        | Rx VP data when USB_TXOE_B is high |
| USB_VM1    | In        | Rx VM data when USB_TXOE_B is high |
| USB_RCV    | In        | Differential Rx data               |

**Transmit**



**Figure 107. USB Transmit Waveform in VP\_VM Unidirectional Mode**

## Receive



**Figure 108. USB Receive Waveform in VP\_VM Unidirectional Mode**

Table 90 describes the port timing specification in VP\_VM unidirectional mode.

**Table 90. USB Timing Specification in VP\_VM Unidirectional Mode**

| No.  | Parameter         | Signal     | Direction | Min. | Max. | Unit | Conditions/Reference Signal |
|------|-------------------|------------|-----------|------|------|------|-----------------------------|
| US30 | Tx rise/fall time | USB_DAT_VP | Out       | —    | 5.0  | ns   | 50 pF                       |
| US31 | Tx rise/fall time | USB_SE0_VM | Out       | —    | 5.0  | ns   | 50 pF                       |
| US32 | Tx rise/fall time | USB_TXOE_B | Out       | —    | 5.0  | ns   | 50 pF                       |
| US33 | Tx duty cycle     | USB_DAT_VP | Out       | 49.0 | 51.0 | %    | —                           |
| US34 | Tx overlap        | USB_SE0_VM | Out       | −3.0 | +3.0 | ns   | USB_DAT_VP                  |
| US38 | Rx rise/fall time | USB_VP1    | In        | —    | 3.0  | ns   | 35 pF                       |
| US39 | Rx rise/fall time | USB_VM1    | In        | —    | 3.0  | ns   | 35 pF                       |
| US40 | Rx skew           | USB_VP1    | In        | −4.0 | +4.0 | ns   | USB_VM1                     |
| US41 | Rx skew           | USB_RCV    | In        | −6.0 | +2.0 | ns   | USB_VP1                     |

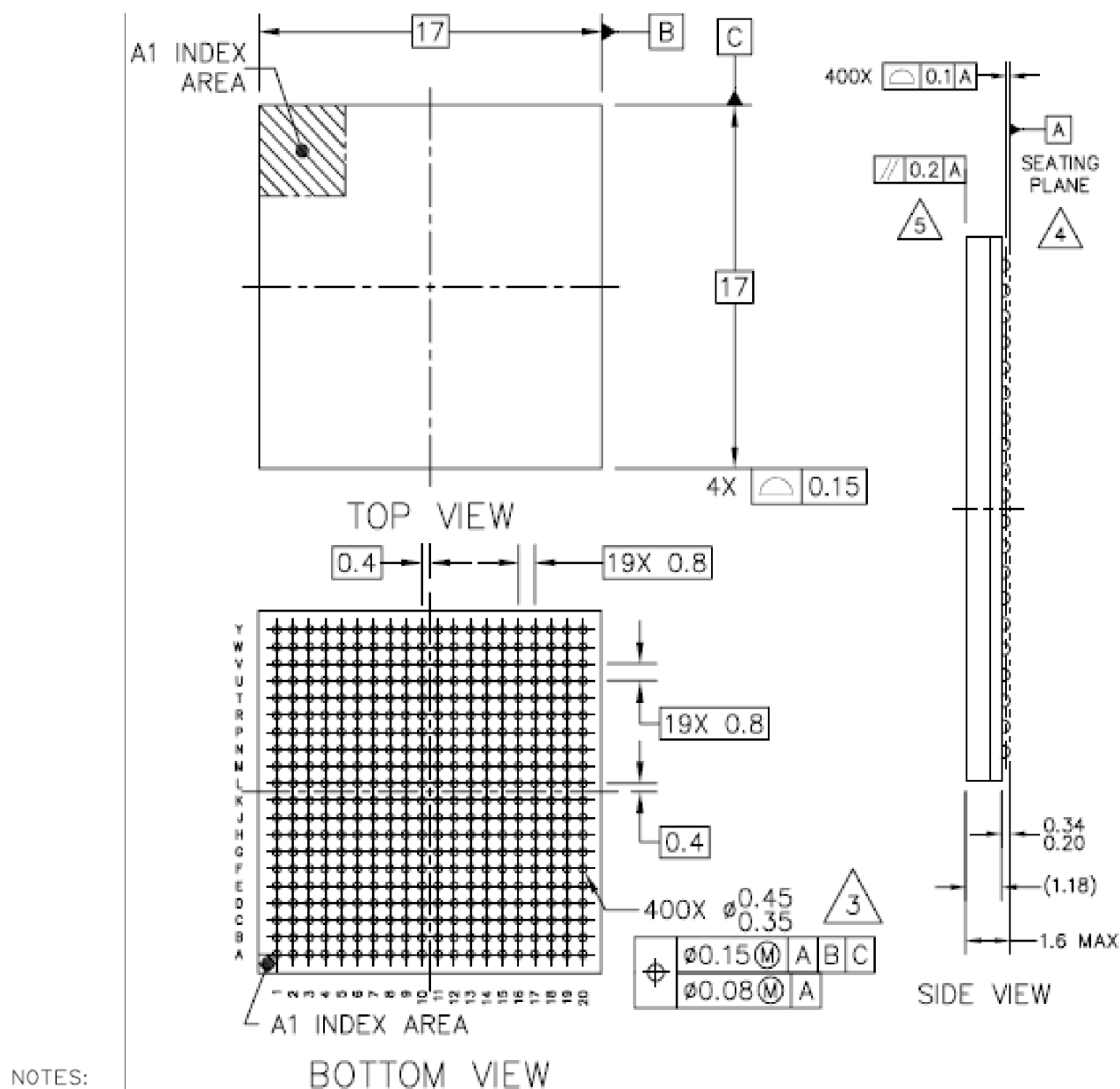
## 5 Package Information and Pinout

This section includes the following:

- Mechanical package drawing
- Pin/contact assignment information

## 5.1 MAPBGA Production Package 1568-01, 17 × 17 mm, 0.8 Pitch

See [Figure 109](#) for the package drawing and dimensions of the production package.



1. ALL DIMENSIONS IN MILLIMETERS.
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
3. MAXIMUM SOLDER BALL DIAMETER MEASURED PARALLEL TO DATUM A.
4. DATUM A, THE SEATING PLANE, IS DETERMINED BY THE SPHERICAL CROWNS OF THE SOLDER BALLS.
5. PARALLELISM MEASUREMENT SHALL EXCLUDE ANY EFFECT OF MARK ON TOP SURFACE OF PACKAGE.

**Figure 109. Production Package: Mechanical Drawing**

## 5.2 MAPBGA Signal Assignments

Table 91 and Table 92 list MAPBGA signals, alphabetized by signal name, for silicon revisions 2.0 and 2.1, respectively. Table 93 and Table 94 show the signal assignment on the i.MX35 ball map for silicon revisions 2.0 and 2.1, respectively. The ball map for silicon revision 2.1 is different than the ballmap for silicon revision 2.0. The layout for each revision is not compatible, so it is important that the correct ballmap be used to implement the layout.

**Table 91. Silicon Revision 2.0 Signal Ball Map Locations**

| Signal ID                | Ball Location | Signal ID                | Ball Location |
|--------------------------|---------------|--------------------------|---------------|
| A0                       | A5            | ATA_DATA7 <sup>1</sup>   | Y3            |
| A1                       | D7            | ATA_DATA8 <sup>1</sup>   | U4            |
| A10                      | F15           | ATA_DATA9 <sup>1</sup>   | W3            |
| A11                      | D5            | ATA_DIOR <sup>1</sup>    | Y6            |
| A12                      | F6            | ATA_DIOW <sup>1</sup>    | W6            |
| A13                      | B3            | ATA_DMACK <sup>1</sup>   | V6            |
| A14                      | D14           | ATA_DMARQ <sup>1</sup>   | T3            |
| A15                      | D15           | ATA_INTRQ <sup>1</sup>   | V2            |
| A16                      | D13           | ATA_IORDY <sup>1</sup>   | U6            |
| A17                      | D12           | ATA_RESET_B <sup>1</sup> | T6            |
| A18                      | E11           | BCLK                     | E14           |
| A19                      | D11           | BOOT_MODE0               | W10           |
| A2                       | E7            | BOOT_MODE1               | U9            |
| A20                      | D10           | CAPTURE                  | V12           |
| A21                      | E10           | CAS                      | E16           |
| A22                      | D9            | CLK_MODE0                | Y10           |
| A23                      | E9            | CLK_MODE1                | T10           |
| A24                      | D8            | CLKO                     | V10           |
| A25                      | E8            | COMPARE                  | T12           |
| A3                       | C6            | CONTRAST <sup>1</sup>    | L16           |
| A4                       | D6            | CS0                      | F17           |
| A5                       | B5            | CS1                      | E19           |
| A6                       | C5            | CS2                      | B20           |
| A7                       | A4            | CS3                      | C19           |
| A8                       | B4            | CS4                      | E18           |
| A9                       | A3            | CS5                      | F19           |
| ATA_BUFF_EN <sup>1</sup> | T5            | CSI_D10 <sup>1</sup>     | V16           |
| ATA_CS0 <sup>1</sup>     | V7            | CSI_D11 <sup>1</sup>     | T15           |
| ATA_CS1 <sup>1</sup>     | T7            | CSI_D12 <sup>1</sup>     | W16           |
| ATA_DA0 <sup>1</sup>     | R4            | CSI_D13 <sup>1</sup>     | V15           |
| ATA_DA1 <sup>1</sup>     | V1            | CSI_D14 <sup>1</sup>     | U14           |
| ATA_DA2 <sup>1</sup>     | R5            | CSI_D15 <sup>1</sup>     | Y16           |
| ATA_DATA0 <sup>1</sup>   | Y5            | CSI_D8 <sup>1</sup>      | U15           |
| ATA_DATA1 <sup>1</sup>   | W5            | CSI_D9 <sup>1</sup>      | W17           |
| ATA_DATA10 <sup>1</sup>  | V3            | CSI_HSYNC <sup>1</sup>   | V14           |
| ATA_DATA11 <sup>1</sup>  | Y2            | CSI_MCLK <sup>1</sup>    | W15           |
| ATA_DATA12 <sup>1</sup>  | U3            | CSI_PIXCLK <sup>1</sup>  | Y15           |

**Table 91. Silicon Revision 2.0 Signal Ball Map Locations (continued)**

| Signal ID               | Ball Location | Signal ID              | Ball Location |
|-------------------------|---------------|------------------------|---------------|
| ATA_DATA13 <sup>1</sup> | W2            | CSI_VSYNC <sup>1</sup> | T14           |
| ATA_DATA14 <sup>1</sup> | W1            | CSPI1_MISO             | V9            |
| ATA_DATA15 <sup>1</sup> | T4            | CSPI1_MOSI             | W9            |
| ATA_DATA2 <sup>1</sup>  | V5            | CSPI1_SCLK             | W8            |
| ATA_DATA3               | U5            | CSPI1_SPI_RDY          | T8            |
| ATA_DATA4               | Y4            | CSPI1_SS0              | Y8            |
| ATA_DATA5               | W4            | CSPI1_SS1              | U8            |
| ATA_DATA6               | V4            | CTS1                   | R3            |
| CTS2                    | G5            | FEC_TDATA0             | P5            |
| D0                      | A2            | FEC_TDATA1             | M4            |
| D1                      | D4            | FEC_TDATA2             | M5            |
| D10                     | D2            | FEC_TDATA3             | L6            |
| D11                     | E6            | FEC_TX_CLK             | P4            |
| D12                     | E3            | FEC_TX_EN              | T1            |
| D13                     | F5            | FEC_TX_ERR             | N4            |
| D14                     | D1            | FSR                    | K5            |
| D15                     | E2            | FST                    | J1            |
| D2                      | B2            | FUSE_VDD               | P13           |
| D3                      | E5            | FUSE_VSS               | M11           |
| D3_CLS <sup>1</sup>     | L17           | GPIO1_0                | T11           |
| D3_DRDY <sup>1</sup>    | L20           | GPIO1_1                | Y11           |
| D3_FPSHIFT <sup>1</sup> | L15           | GPIO2_0                | U11           |
| D3_HSYNC <sup>1</sup>   | L18           | GPIO3_0                | V11           |
| D3_REV <sup>1</sup>     | M17           | HCKR                   | K2            |
| D3_SPL <sup>1</sup>     | M18           | HCKT                   | J5            |
| D3_VSYNC <sup>1</sup>   | M19           | I2C1_CLK               | M20           |
| D4                      | C3            | I2C1_DAT               | N17           |
| D5                      | B1            | I2C2_CLK               | L3            |
| D6                      | D3            | I2C2_DAT               | M1            |
| D7                      | C2            | LBA                    | D20           |
| D8                      | C1            | LD0 <sup>1</sup>       | F20           |
| D9                      | E4            | LD1 <sup>1</sup>       | G18           |
| DE_B                    | W19           | LD10 <sup>1</sup>      | H20           |
| DQM0                    | B19           | LD11 <sup>1</sup>      | J18           |
| DQM1                    | D17           | LD12 <sup>1</sup>      | J16           |
| DQM2                    | D16           | LD13 <sup>1</sup>      | J19           |
| DQM3                    | C18           | LD14 <sup>1</sup>      | J17           |
| EB0                     | F18           | LD15 <sup>1</sup>      | J20           |
| EB1                     | F16           | LD16 <sup>1</sup>      | K14           |
| ECB                     | D19           | LD17 <sup>1</sup>      | K19           |
| EXT_ARMCLK              | V8            | LD18 <sup>1</sup>      | K18           |
| EXTAL_AUDIO             | W20           | LD19 <sup>1</sup>      | K20           |
| EXTAL24M                | T20           | LD2 <sup>1</sup>       | G17           |
| FEC_COL                 | P3            | LD20 <sup>1</sup>      | K16           |
| FEC_CRS                 | N5            | LD21 <sup>1</sup>      | K17           |
| FEC_MDC                 | R1            | LD22 <sup>1</sup>      | K15           |



**Table 91. Silicon Revision 2.0 Signal Ball Map Locations (continued)**

| Signal ID  | Ball Location | Signal ID         | Ball Location |
|------------|---------------|-------------------|---------------|
| FEC_MDIO   | P1            | LD23 <sup>1</sup> | L19           |
| FEC_RDATA0 | P2            | LD3 <sup>1</sup>  | G16           |
| FEC_RDATA1 | N2            | LD4 <sup>1</sup>  | G19           |
| FEC_RDATA2 | M3            | LD5 <sup>1</sup>  | H16           |
| FEC_RDATA3 | N1            | LD6 <sup>1</sup>  | H18           |
| FEC_RX_CLK | R2            | LD7 <sup>1</sup>  | G20           |
| FEC_RX_DV  | T2            | LD8 <sup>1</sup>  | H17           |
| FEC_RX_ERR | N3            | LD9 <sup>1</sup>  | H19           |
| MA10       | C4            | NVCC_EMI2         | G12           |
| MGND       | N11           | NVCC_EMI2         | F13           |
| MLB_CLK    | W13           | NVCC_EMI2         | F14           |
| MLB_DAT    | Y13           | NVCC_EMI3         | G14           |
| MLB_SIG    | W12           | NVCC_JTAG         | P16           |
| MVDD       | P11           | NVCC_LCDC         | H14           |
| NF_CE0     | G3            | NVCC_LCDC         | J14           |
| NFALE      | F2            | NVCC_LCDC         | L14           |
| NFCLE      | E1            | NVCC_LCDC         | M14           |
| NFRB       | F3            | NVCC_MISC         | K6            |
| NFRE_B     | F1            | NVCC_MISC         | K7            |
| NFWE_B     | G2            | NVCC_MISC         | L8            |
| NFWP_B     | F4            | NVCC_MLB          | R10           |
| NGND_ATA   | M9            | NVCC_NFC          | G6            |
| NGND_ATA   | P9            | NVCC_NFC          | H6            |
| NGND_ATA   | L10           | NVCC_NFC          | H7            |
| NGND_CRM   | L11           | NVCC_SDIO         | P14           |
| NGND_CSI   | N10           | OE                | E20           |
| NGND_EMI1  | H8            | OSC_AUDIO_VDD     | V20           |
| NGND_EMI1  | H10           | OSC_AUDIO_VSS     | U19           |
| NGND_EMI1  | J10           | OSC24M_VDD        | T19           |
| NGND_EMI2  | J11           | OSC24M_VSS        | T18           |
| NGND_EMI3  | J12           | PGND              | M12           |
| NGND_EMI3  | K12           | PHY1_VDDA         | M15           |
| NGND_JTAG  | M13           | PHY1_VDDA         | N20           |
| NGND_LCDC  | K11           | PHY1_VSSA         | N16           |
| NGND_LCDC  | L12           | PHY1_VSSA         | P20           |
| NGND_MISC  | M7            | PHY2_VDD          | R13           |
| NGND_MISC  | K8            | PHY2_VSS          | P12           |
| NGND_MLB   | M10           | POR_B             | W11           |
| NGND_NFC   | K9            | POWER_FAIL        | Y9            |
| NGND_SDIO  | N12           | PVDD              | N13           |
| NVCC_ATA   | N6            | RAS               | E15           |
| NVCC_ATA   | P6            | RESET_IN_B        | U10           |
| NVCC_ATA   | P7            | RTCK              | U18           |
| NVCC_ATA   | P8            | RTS1              | U1            |
| NVCC_CRM   | R9            | RTS2              | G1            |
| NVCC_CSI   | R11           | RW                | C20           |

**Table 91. Silicon Revision 2.0 Signal Ball Map Locations (continued)**

| Signal ID | Ball Location | Signal ID       | Ball Location |
|-----------|---------------|-----------------|---------------|
| NVCC_EMI1 | G7            | RXD1            | U2            |
| NVCC_EMI1 | G8            | RXD2            | H3            |
| NVCC_EMI1 | G9            | SCK4            | L4            |
| NVCC_EMI1 | H9            | SCK5            | L5            |
| NVCC_EMI1 | F10           | SCKR            | K3            |
| NVCC_EMI1 | G10           | SCKT            | J4            |
| NVCC_EMI1 | F11           | SD0             | C17           |
| NVCC_EMI1 | G11           | SD1             | A19           |
| SD1_CLK   | V18           | SDCLK           | E12           |
| SD1_CMD   | Y19           | SDCLK_B         | E13           |
| SD1_DATA0 | R14           | SDQS0           | B17           |
| SD1_DATA1 | U16           | SDQS1           | A13           |
| SD1_DATA2 | W18           | SDQS2           | A10           |
| SD1_DATA3 | V17           | SDQS3           | C7            |
| SD10      | A15           | SDWE            | G15           |
| SD11      | B15           | SJC_MOD         | U17           |
| SD12      | C13           | SRXD4           | L1            |
| SD13      | B14           | SRXD5           | K4            |
| SD14      | A14           | STXD4           | M2            |
| SD15      | B13           | STXD5           | K1            |
| SD16      | C12           | STXFS4          | L2            |
| SD17      | C11           | STXFS5          | J6            |
| SD18      | A12           | TCK             | R17           |
| SD19      | B12           | TDI             | P15           |
| SD2       | B18           | TDO             | R15           |
| SD2_CLK   | W14           | TEST_MODE       | Y7            |
| SD2_CMD   | U13           | TMS             | R16           |
| SD2_DATA0 | V13           | TRSTB           | T16           |
| SD2_DATA1 | T13           | TTM_PIN         | M16           |
| SD2_DATA2 | Y14           | TX0             | G4            |
| SD2_DATA3 | U12           | TX1             | H1            |
| SD20      | B11           | TX2_RX3         | H5            |
| SD21      | A11           | TX3_RX2         | J2            |
| SD22      | C10           | TX4_RX1         | H4            |
| SD23      | B10           | TX5_RX0         | J3            |
| SD24      | A9            | TXD1            | R6            |
| SD25      | C9            | TXD2            | H2            |
| SD26      | B9            | USBOTG_OC       | U7            |
| SD27      | A8            | USBOTG_PWR      | W7            |
| SD28      | B8            | USBPHY1_DM      | N19           |
| SD29      | C8            | USBPHY1_DP      | P19           |
| SD3       | C16           | USBPHY1_RREF    | R19           |
| SD30      | A7            | USBPHY1_UID     | N18           |
| SD31      | B7            | USBPHY1_UPLLGN  | N14           |
| SD4       | A18           | USBPHY1_UPLLVDD | N15           |
| SD5       | C15           | USBPHY1_UPLLVDD | P17           |

**Table 91. Silicon Revision 2.0 Signal Ball Map Locations (continued)**

| Signal ID | Ball Location | Signal ID         | Ball Location |
|-----------|---------------|-------------------|---------------|
| SD6       | A17           | USBPHY1_VBUS      | P18           |
| SD7       | B16           | USBPHY1_VDDA_BIAS | R20           |
| SD8       | C14           | USBPHY1_VSSA_BIAS | R18           |
| SD9       | A16           | USBPHY2_DM        | Y17           |
| SDBA0     | A6            | USBPHY2_DP        | Y18           |
| SDBA1     | B6            | VDD               | M6            |
| SDCKE0    | D18           | VDD               | F7            |
| SDCKE1    | E17           | VDD               | J7            |
| VDD       | L7            | VSS               | L9            |
| VDD       | N7            | VSS               | N9            |
| VDD       | R7            | VSS               | K10           |
| VDD       | F8            | VSS               | P10           |
| VDD       | R8            | VSS               | H11           |
| VDD       | F9            | VSS               | H12           |
| VDD       | F12           | VSS               | H13           |
| VDD       | R12           | VSS               | J13           |
| VDD       | G13           | VSS               | K13           |
| VDD       | H15           | VSS               | L13           |
| VDD       | J15           | VSS               | T17           |
| VSS       | A1            | VSS               | A20           |
| VSS       | Y1            | VSS               | Y20           |
| VSS       | J8            | VSTBY             | T9            |
| VSS       | M8            | WDOG_RST          | Y12           |
| VSS       | N8            | XTAL_AUDIO        | V19           |
| VSS       | J9            | XTAL24M           | U20           |

<sup>1</sup> Not available for the MCIMX351.

**Table 92. Silicon Revision 2.1 Signal Ball Map Locations**

| Signal ID                | Ball Location | Signal ID     | Ball Location |
|--------------------------|---------------|---------------|---------------|
| A0                       | A5            | ATA_DATA7     | Y3            |
| A1                       | D7            | ATA_DATA8     | U4            |
| A10                      | F15           | ATA_DATA9     | W3            |
| A11                      | D5            | ATA_DIOR      | Y6            |
| A12                      | F6            | ATA_DIOW      | W6            |
| A13                      | B3            | ATA_DMACK     | V6            |
| A14                      | D14           | ATA_DMARQ     | T3            |
| A15                      | D15           | ATA_INTRQ     | V2            |
| A16                      | D13           | ATA_IORDY     | U6            |
| A18                      | D12           | ATA_RESET_B   | T6            |
| SDQS1                    | E11           | SDQS0         | E14           |
| A19                      | D11           | BOOT_MODE0    | W10           |
| A2                       | E7            | BOOT_MODE1    | U9            |
| A21                      | D10           | CAPTURE       | V12           |
| SDQS2                    | E10           | RAS           | E16           |
| A22                      | D9            | CLK_MODE0     | Y10           |
| SDQS3                    | E9            | CLK_MODE1     | T10           |
| A24                      | D8            | CLKO          | V10           |
| A25                      | E8            | COMPARE       | T12           |
| A3                       | C6            | CONTRAST      | L16           |
| A4                       | D6            | CS0           | F17           |
| A5                       | B5            | CS1           | E19           |
| A6                       | C5            | CS2           | B20           |
| A7                       | A4            | CS3           | C19           |
| A8                       | B4            | CS4           | E18           |
| A9                       | A3            | CS5           | F19           |
| ATA_BUFF_EN <sup>1</sup> | T5            | CSI_D10       | V16           |
| ATA_CS0                  | V7            | CSI_D11       | T15           |
| ATA_CS1                  | T7            | CSI_D12       | W16           |
| ATA_DA0                  | R4            | CSI_D13       | V15           |
| ATA_DA1                  | V1            | CSI_D14       | U14           |
| ATA_DA2                  | R5            | CSI_D15       | Y16           |
| ATA_DATA0                | Y5            | CSI_D8        | U15           |
| ATA_DATA1                | W5            | CSI_D9        | W17           |
| ATA_DATA10               | V3            | CSI_HSYNC     | V14           |
| ATA_DATA11               | Y2            | CSI_MCLK      | W15           |
| ATA_DATA12               | U3            | CSI_PIXCLK    | Y15           |
| ATA_DATA13               | W2            | CSI_VSYNC     | T14           |
| ATA_DATA14               | W1            | CSPI1_MISO    | V9            |
| ATA_DATA15               | T4            | CSPI1_MOSI    | W9            |
| ATA_DATA2                | V5            | CSPI1_SCLK    | W8            |
| ATA_DATA3                | U5            | CSPI1_SPI_RDY | T8            |
| ATA_DATA4                | Y4            | CSPI1_SS0     | Y8            |
| ATA_DATA5                | W4            | CSPI1_SS1     | U8            |
| ATA_DATA6                | V4            | CTS1          | R3            |

**Table 92. Silicon Revision 2.1 Signal Ball Map Locations (continued)**

| Signal ID   | Ball Location | Signal ID  | Ball Location |
|-------------|---------------|------------|---------------|
| CTS2        | G5            | FEC_TDATA0 | P5            |
| D0          | A2            | FEC_TDATA1 | M4            |
| D1          | D4            | FEC_TDATA2 | M5            |
| D10         | D2            | FEC_TDATA3 | L6            |
| D11         | E6            | FEC_TX_CLK | P4            |
| D12         | E3            | FEC_TX_EN  | T1            |
| D13         | F5            | FEC_TX_ERR | N4            |
| D14         | D1            | FSR        | K5            |
| D15         | E2            | FST        | J1            |
| D2          | B2            | FUSE_VDD   | P13           |
| D3          | E5            | FUSE_VSS   | M11           |
| D3_CLS      | L17           | GPIO1_0    | T11           |
| D3_DRDY     | L20           | GPIO1_1    | Y11           |
| D3_FPSHIFT  | L15           | GPIO2_0    | U11           |
| D3_HSYNC    | L18           | GPIO3_0    | V11           |
| D3_REV      | M17           | HCKR       | K2            |
| D3_SPL      | M18           | HCKT       | J5            |
| D3_VSYNC    | M19           | I2C1_CLK   | M20           |
| D4          | C3            | I2C1_DAT   | N17           |
| D5          | B1            | I2C2_CLK   | L3            |
| D6          | D3            | I2C2_DAT   | M1            |
| D7          | C2            | LBA        | D20           |
| D8          | C1            | LD0        | F20           |
| D9          | E4            | LD1        | G18           |
| DE_B        | W19           | LD10       | H20           |
| DQM0        | B19           | LD11       | J18           |
| SDCKE1      | D17           | LD12       | J16           |
| DQM2        | D16           | LD13       | J19           |
| DQM3        | C18           | LD14       | J17           |
| EB0         | F18           | LD15       | J20           |
| EB1         | F16           | LD16       | K14           |
| ECB         | D19           | LD17       | K19           |
| EXT_ARMCLK  | V8            | LD18       | K18           |
| EXTAL_AUDIO | W20           | LD19       | K20           |
| EXTAL24M    | T20           | LD2        | G17           |
| FEC_COL     | P3            | LD20       | K16           |
| FEC_CRS     | N5            | LD21       | K17           |
| FEC_MDC     | R1            | LD22       | K15           |
| FEC_MDIO    | P1            | LD23       | L19           |
| FEC_RDATA0  | P2            | LD3        | G16           |
| FEC_RDATA1  | N2            | LD4        | G19           |
| FEC_RDATA2  | M3            | LD5        | H16           |
| FEC_RDATA3  | N1            | LD6        | H18           |
| FEC_RX_CLK  | R2            | LD7        | G20           |
| FEC_RX_DV   | T2            | LD8        | H17           |
| FEC_RX_ERR  | N3            | LD9        | H19           |

**Table 92. Silicon Revision 2.1 Signal Ball Map Locations (continued)**

| Signal ID | Ball Location | Signal ID     | Ball Location |
|-----------|---------------|---------------|---------------|
| MA10      | C4            | NVCC_EMI2     | G12           |
| MGND      | N11           | NVCC_EMI2     | F13           |
| MLB_CLK   | W13           | VSS           | F14           |
| MLB_DAT   | Y13           | NVCC_EMI3     | G14           |
| MLB_SIG   | W12           | NVCC_JTAG     | P16           |
| MVDD      | P11           | NVCC_LCDC     | H14           |
| NF_CEO    | G3            | NVCC_LCDC     | J14           |
| NFALE     | F2            | NVCC_LCDC     | L14           |
| NFCLE     | E1            | NVCC_LCDC     | M14           |
| NFRB      | F3            | NVCC_MISC     | K6            |
| NFRE_B    | F1            | NVCC_MISC     | K7            |
| NFWE_B    | G2            | NVCC_MISC     | L8            |
| NFWP_B    | F4            | NVCC_MLB      | R10           |
| NGND_ATA  | M9            | NVCC_NFC      | G6            |
| NGND_ATA  | P9            | NVCC_NFC      | H6            |
| NGND_ATA  | L10           | NVCC_NFC      | H7            |
| NGND_CRM  | L11           | NVCC_SDIO     | P14           |
| NGND_CSI  | N10           | OE            | E20           |
| NGND_EMI1 | H8            | OSC_AUDIO_VDD | V20           |
| NVCC_EMI1 | H10           | OSC_AUDIO_VSS | U19           |
| NGND_EMI1 | J10           | OSC24M_VDD    | T19           |
| NGND_EMI2 | J11           | OSC24M_VSS    | T18           |
| NGND_EMI3 | J12           | PGND          | M12           |
| NGND_EMI3 | K12           | PHY1_VDDA     | M15           |
| NGND_JTAG | M13           | PHY1_VDDA     | N20           |
| NGND_LCDC | K11           | PHY1_VSSA     | N16           |
| NGND_LCDC | L12           | PHY1_VSSA     | P20           |
| NGND_MISC | M7            | PHY2_VDD      | R13           |
| NGND_MISC | K8            | PHY2_VSS      | P12           |
| NGND_MLB  | M10           | POR_B         | W11           |
| NGND_NFC  | K9            | POWER_FAIL    | Y9            |
| NGND_SDIO | N12           | PVDD          | N13           |
| NVCC_ATA  | N6            | BCLK          | E15           |
| NVCC_ATA  | P6            | RESET_IN_B    | U10           |
| NVCC_ATA  | P7            | RTCK          | U18           |
| NVCC_ATA  | P8            | RTS1          | U1            |
| NVCC_CRM  | R9            | RTS2          | G1            |
| NVCC_CSI  | R11           | RW            | C20           |
| NVCC_EMI1 | G7            | RXD1          | U2            |
| NVCC_EMI1 | G8            | RXD2          | H3            |
| NVCC_EMI1 | G9            | SCK4          | L4            |
| NVCC_EMI1 | H9            | SCK5          | L5            |
| NGND_EMI1 | F10           | SCKR          | K3            |
| NVCC_EMI1 | G10           | SCKT          | J4            |
| NVCC_EMI1 | F11           | DQM1          | C17           |
| NVCC_EMI1 | G11           | SD1           | A19           |

**Table 92. Silicon Revision 2.1 Signal Ball Map Locations (continued)**

| Signal ID | Ball Location | Signal ID         | Ball Location |
|-----------|---------------|-------------------|---------------|
| SD1_CLK   | V18           | SDCLK             | E12           |
| SD1_CMD   | Y19           | SDCLK_B           | E13           |
| SD1_DATA0 | R14           | SD0               | B17           |
| SD1_DATA1 | U16           | SD15              | A13           |
| SD1_DATA2 | W18           | SD23              | A10           |
| SD1_DATA3 | V17           | A23               | C7            |
| SD10      | A15           | SDWE              | G15           |
| SD11      | B15           | SJC_MOD           | U17           |
| A17       | C13           | SRXD4             | L1            |
| SD13      | B14           | SRXD5             | K4            |
| SD14      | A14           | STXD4             | M2            |
| SD12      | B13           | STXD5             | K1            |
| SD16      | C12           | STXFS4            | L2            |
| SD17      | C11           | STXFS5            | J6            |
| SD18      | A12           | TCK               | R17           |
| SD19      | B12           | TDI               | P15           |
| SD2       | B18           | TDO               | R15           |
| SD2_CLK   | W14           | TEST_MODE         | Y7            |
| SD2_CMD   | U13           | TMS               | R16           |
| SD2_DATA0 | V13           | TRSTB             | T16           |
| SD2_DATA1 | T13           | TTM_PIN           | M16           |
| SD2_DATA2 | Y14           | TX0               | G4            |
| SD2_DATA3 | U12           | TX1               | H1            |
| SD20      | B11           | TX2_RX3           | H5            |
| SD21      | A11           | TX3_RX2           | J2            |
| A20       | C10           | TX4_RX1           | H4            |
| SD22      | B10           | TX5_RX0           | J3            |
| SD24      | A9            | TXD1              | R6            |
| SD25      | C9            | TXD2              | H2            |
| SD26      | B9            | USBOTG_OC         | U7            |
| SD27      | A8            | USBOTG_PWR        | W7            |
| SD28      | B8            | USBPHY1_DM        | N19           |
| SD29      | C8            | USBPHY1_DP        | P19           |
| SD3       | C16           | USBPHY1_RREF      | R19           |
| SD30      | A7            | USBPHY1_UID       | N18           |
| SD31      | B7            | USBPHY1_UPLLGN    | N14           |
| SD4       | A18           | USBPHY1_UPLLVDD   | N15           |
| SD5       | C15           | USBPHY1_UPLLVDD   | P17           |
| SD6       | A17           | USBPHY1_VBUS      | P18           |
| SD7       | B16           | USBPHY1_VDDA_BIAS | R20           |
| SD8       | C14           | USBPHY1_VSSA_BIAS | R18           |
| SD9       | A16           | USBPHY2_DM        | Y17           |
| SDBA0     | A6            | USBPHY2_DP        | Y18           |
| SDBA1     | B6            | VDD               | M6            |
| SDCKE0    | D18           | VDD               | F7            |
| CAS       | E17           | VDD               | J7            |

**Table 92. Silicon Revision 2.1 Signal Ball Map Locations (continued)**

| Signal ID | Ball Location | Signal ID  | Ball Location |
|-----------|---------------|------------|---------------|
| VDD       | L7            | VSS        | L9            |
| VDD       | N7            | VSS        | N9            |
| VDD       | R7            | VSS        | K10           |
| VDD       | F8            | VSS        | P10           |
| VDD       | R8            | VSS        | H11           |
| VDD       | F9            | VSS        | H12           |
| VDD       | F12           | NVCC_EMI2  | H13           |
| VDD       | R12           | VSS        | J13           |
| VDD       | G13           | VSS        | K13           |
| VDD       | H15           | VSS        | L13           |
| VDD       | J15           | VSS        | T17           |
| VSS       | A1            | VSS        | A20           |
| VSS       | Y1            | VSS        | Y20           |
| VSS       | J8            | VSTBY      | T9            |
| VSS       | M8            | WDOG_RST   | Y12           |
| VSS       | N8            | XTAL_AUDIO | V19           |
| VSS       | J9            | XTAL24M    | U20           |

<sup>1</sup> Not available for the MCIMX351.



**Table 93. Silicon Revision 2.0 Ball Map—17 x 17, 0.8 mm Pitch<sup>1</sup>**

|   | 1          | 2          | 3          | 4          | 5           | 6           | 7           | 8             | 9           | 10          | 11        | 12        | 13        | 14               | 15               | 16        | 17               | 18                 | 19            | 20                 |   |
|---|------------|------------|------------|------------|-------------|-------------|-------------|---------------|-------------|-------------|-----------|-----------|-----------|------------------|------------------|-----------|------------------|--------------------|---------------|--------------------|---|
| A | VSS        | D0         | A9         | A7         | A0          | SDBA0       | SD30        | SD27          | SD24        | SDQS2       | SD21      | SD18      | SDQS1     | SD14             | SD10             | SD9       | SD6              | SD4                | SD1           | VSS                | A |
| B | D5         | D2         | A13        | A8         | A5          | SDBA1       | SD31        | SD28          | SD26        | SD23        | SD20      | SD19      | SD15      | SD13             | SD11             | SD7       | SDQS0            | SD2                | DQM0          | CS2                | B |
| C | D8         | D7         | D4         | MA10       | A6          | A3          | SDQS3       | SD29          | SD25        | SD22        | SD17      | SD16      | SD12      | SD8              | SD5              | SD3       | SD0              | DQM3               | CS3           | RW                 | C |
| D | D14        | D10        | D6         | D1         | A11         | A4          | A1          | A24           | A22         | A20         | A19       | A17       | A16       | A14              | A15              | DQM2      | DQM1             | SDCKE0             | ECB           | LBA                | D |
| E | NFCL_E     | D15        | D12        | D9         | D3          | D11         | A2          | A25           | A23         | A21         | A18       | SDCLK     | SDCLK_B   | BCLK             | RAS              | CAS       | SDCKE1           | CS4                | CS1           | OE                 | E |
| F | NFRE_B     | NFAL_E     | NFRB       | NFWP_B     | D13         | A12         | VDD         | VDD           | VDD         | NVCC_EM11   | NVCC_EM11 | VDD       | NVCC_EM12 | NVCC_EM12        | A10              | EB1       | CS0              | EB0                | CS5           | LD0                | F |
| G | RTS2       | NFWE_B     | NFC_E0     | TX0        | CTS2        | NVCC_NFC    | NVCC_EM11   | NVCC_EM11     | NVCC_EM11   | NVCC_EM11   | NVCC_EM11 | NVCC_EM12 | VDD       | NVCC_EM13        | SDWE             | LD3       | LD2              | LD1                | LD4           | LD7                | G |
| H | TX1        | TXD2       | RXD2       | TX4_RX1    | TX2_RX3     | NVCC_NFC    | NVCC_NFC    | NGND_EM11     | NVCC_EM11   | NGND_EM11   | VSS       | VSS       | VSS       | NVCC_LCDC        | VDD              | LD5       | LD8              | LD6                | LD9           | LD10               | H |
| J | FST        | TX3_RX2    | TX5_RX0    | SCKT       | HCKT        | STXFS5      | VDD         | VSS           | VSS         | NGND_EM11   | NGND_EM12 | NGND_EM13 | VSS       | NVCC_LCDC        | VDD              | LD12      | LD14             | LD11               | LD13          | LD15               | J |
| K | STXD5      | HCKR       | SCKR       | SRXD5      | FSR         | NVCC_MISC   | NVCC_MISC   | NGND_MISC     | NGND_NFC    | VSS         | NGND_LCDC | NGND_EM13 | VSS       | LD16             | LD22             | LD20      | LD21             | LD18               | LD17          | LD19               | K |
| L | SRXD4      | STXFS4     | I2C2_CLK   | SCK4       | SCK5        | FEC_TDATA3  | VDD         | NVCC_MISC     | VSS         | NGND_AT_A   | NGND_CR_M | NGND_LCDC | VSS       | NVCC_LCDC        | D3_FPSHIFT       | CONTRAST  | D3_CLS           | D3_HSYNC           | LD23          | D3_DRDY            | L |
| M | I2C2_DAT   | STXD4      | FEC_RDATA2 | FEC_TDATA1 | FEC_TDATA2  | VDD         | NGND_MISC   | VSS           | NGND_AT_A   | NGND_MLB    | FUSE_VSS  | PGND      | NGND_JTAG | NVCC_LCDC        | PHY1_VDDA        | TTM_PIN   | D3_REV           | D3_SPL             | D3_VSYNC      | I2C1_CLK           | M |
| N | FEC_RDATA3 | FEC_RDATA1 | FEC_RX_ERR | FEC_TX_ERR | FEC_CR_S    | NVCC_AT_A   | VDD         | VSS           | VSS         | NGND_CS1    | MGN_D     | NGND_SDIO | PVDD      | USBP_HY1_UPLLGND | USBP_HY1_UPLLVDD | PHY1_VSSA | I2C1_DAT         | USBP_HY1_UID       | USBP_HY1_DM   | PHY1_VDDA          | N |
| P | FEC_MDIO   | FEC_RDATA0 | FEC_COL    | FEC_TX_CLK | FEC_TDATA0  | NVCC_AT_A   | NVCC_AT_A   | NVCC_AT_A     | NGND_AT_A   | VSS         | MVD_D     | PHY2_VSS  | FUSE_VDD  | NVCC_SDIO        | TDI              | NVCC_JTAG | USBP_HY1_UPLLVDD | USBP_HY1_VBUS      | USBP_HY1_DP   | PHY1_VSSA          | P |
| R | FEC_MDC    | FEC_RX_CLK | CTS1       | ATA_DA0    | ATA_DA2     | TXD1        | VDD         | VDD           | NVCC_CR_M   | NVCC_MLB    | NVCC_CS1  | VDD       | PHY2_VDD  | SD1_DATA0        | TDO              | TMS       | TCK              | USBP_HY1_VSSA_BIAS | USBP_HY1_RREF | USBP_HY1_VDDA_BIAS | R |
| T | FEC_TX_EN  | FEC_RX_DV  | ATA_DMA_RQ | ATA_DATA15 | ATA_BUFF_EN | ATA_RESET_B | ATA_CS1     | CSPI1_SPI_RDY | VSTBY       | CLK_MOD_E1  | GPIO1_0   | COMPARE   | SD2_DATA1 | CS1_VSYNC        | CS1_D11          | TRST_B    | VSS              | OSC2_4M_VSS        | OSC2_4M_VDD   | EXTAL24M           | T |
| U | RTS1       | RXD1       | ATA_DATA12 | ATA_DATA8  | ATA_DATA3   | ATA_IORDY   | USB_OTG_OC  | CSPI1_SS1     | BOOT_MO_DE1 | RESET_IN_B  | GPIO2_0   | SD2_DATA3 | SD2_CMD   | CS1_D14          | CS1_D8           | SD1_DATA1 | SJC_MOD          | RTCK               | OSC_AUDIO_VSS | XTAL24M            | U |
| V | ATA_DA1    | ATA_I_NTRQ | ATA_DATA10 | ATA_DATA6  | ATA_DATA2   | ATA_DMA_CLK | ATA_CS0     | EXT_ARM_CLK   | CSPI1_MISO  | CLKO        | GPIO3_0   | CAPTURE   | SD2_DATA0 | CS1_HSYNC        | CS1_D13          | CS1_D10   | SD1_DATA3        | SD1_CLK            | XTAL_AUDIO    | OSC_AUDIO_VDD      | V |
| W | ATA_DATA14 | ATA_DATA13 | ATA_DATA9  | ATA_DATA5  | ATA_DATA1   | ATA_DIO_W   | USB_OTG_PWR | CSPI1_SCLK    | CSPI1_MOSI  | BOOT_MO_DE0 | POR_B     | MLB_SIG   | MLB_CLK   | SD2_CLK          | CS1_MCLK         | CS1_D12   | CS1_D9           | SD1_DATA2          | DE_B          | EXTAL_AUDIO        | W |
| Y | VSS        | ATA_DATA11 | ATA_DATA7  | ATA_DATA4  | ATA_DATA0   | ATA_DIOR    | TEST_MODE   | CSPI1_SS0     | POWER_FAIL  | CLK_MOD_E0  | GPIO1_1   | WDORG_RST | MLB_DAT   | SD2_DATA2        | CS1_PIXCLK       | CS1_D15   | USBP_HY2_DM      | USBP_HY2_DP        | SD1_CMD       | VSS                | Y |

<sup>1</sup> See Table 92 for pins unavailable in the MCIMX351 SoC.

**Table 94. Silicon Revision 2.1 Ball Map—17 x 17, 0.8 mm Pitch**

|   | 1           | 2           | 3           | 4           | 5           | 6            | 7            | 8             | 9           | 10          | 11        | 12         | 13         | 14                | 15                | 16         | 17            | 18                 | 19              | 20                 |   |
|---|-------------|-------------|-------------|-------------|-------------|--------------|--------------|---------------|-------------|-------------|-----------|------------|------------|-------------------|-------------------|------------|---------------|--------------------|-----------------|--------------------|---|
| A | GND         | D0          | A9          | A7          | A0          | SDBA0        | SD30         | SD27          | SD24        | SD23        | SD21      | SD18       | SD15       | SD14              | SD10              | SD9        | SD6           | SD4                | SD1             | GND                | A |
| B | D5          | D2          | A13         | A8          | A5          | SDBA1        | SD31         | SD28          | SD26        | SD22        | SD20      | SD19       | SD12       | SD13              | SD11              | SD7        | SD0           | SD2                | DQM0            | CS2                | B |
| C | D8          | D7          | D4          | MA10        | A6          | A3           | A23          | SD29          | SD25        | A20         | SD17      | SD16       | A17        | SD8               | SD5               | SD3        | DQM1          | DQM3               | CS3             | RW                 | C |
| D | D14         | D10         | D6          | D1          | A11         | A4           | A1           | A24           | A22         | A21         | A19       | A18        | A16        | A14               | A15               | DQM2       | SDCKE1        | SDCKE0             | ECB             | LBA                | D |
| E | NFCL E      | D15         | D12         | D9          | D3          | D11          | A2           | A25           | SDQS3       | SDQS2       | SDQS1     | SDCLK      | SDCLK_B    | SDQS0             | BCLK              | RAS        | CAS           | CS4                | CS1             | OE                 | E |
| F | NFRE_B      | NFAL E      | NFRB        | NFW_P_B     | D13         | A12          | VDD7         | VDD7          | VDD7        | GND         | NVCC_EMI1 | VDD7       | NVCC_EMI2  | GND               | A10               | EB1        | CS0           | EB0                | CS5             | LD0                | F |
| G | RTS2        | NFW_E_B     | NF_C E0     | TX0         | CTS2        | NVCC_NFC     | NVCC_EMI1    | NVCC_EMI1     | NVCC_EMI1   | NVCC_EMI1   | NVCC_EMI1 | NVCC_EMI2  | VDD6       | NVCC_EMI3         | SDW E             | LD3        | LD2           | LD1                | LD4             | LD7                | G |
| H | TX1         | TXD2        | RXD2        | TX4_RX1     | TX2_RX3     | NVCC_NFC     | NVCC_NFC     | GND           | NVCC_EMI1   | NVCC_EMI1   | GND       | GND        | NVCC_EMI2  | NVCC_LCD C        | VDD5              | LD5        | LD8           | LD6                | LD9             | LD10               | H |
| J | FST         | TX3_RX2     | TX5_RX0     | SCKT        | HCKT        | STXF S5      | VDD1         | GND           | GND         | GND         | GND       | GND        | GND        | NVCC_LCD C        | VDD5              | LD12       | LD14          | LD11               | LD13            | LD15               | J |
| K | STXD5       | HCKR        | SCKR        | SRXD5       | FSR         | NVCC_MIS C   | NVCC_MIS C   | GND           | GND         | GND         | GND       | GND        | GND        | LD16              | LD22              | LD20       | LD21          | LD18               | LD17            | LD19               | K |
| L | SRXD4       | STXF S4     | I2C2_CLK    | SCK4        | SCK5        | FEC_TDAT A3  | VDD2         | NVCC_MIS C    | GND         | GND         | GND       | GND        | GND        | NVCC_LCD C        | D3_FPSHIFT        | CONT RAST  | D3_C LS       | D3_H SYNC          | LD23            | D3_D RDY           | L |
| M | I2C2_DAT    | STXD4       | FEC_RDAT A2 | FEC_TDAT A1 | FEC_TDAT A2 | VDD2         | GND          | GND           | GND         | GND         | FUSE_VSS  | PGND       | GND        | NVCC_LCD C        | PHY1_VDD A        | TTM PAD    | D3_R EV       | D3_S PL            | D3_V SYNC       | I2C1_CLK           | M |
| N | FEC_RDAT A3 | FEC_RDAT A1 | FEC_RX_E RR | FEC_TX_E RR | FEC_CRS     | NVCC_ATA     | VDD3         | GND           | GND         | GND         | MGN D     | GND        | PVDD       | USBP_HY1_UPLL VDD | USBP_HY1_UPLL VDD | PHY1_VSS A | I2C1_DAT      | USBP_HY1_UID       | USBP_HY1_DM     | PHY1_VDD A         | N |
| P | FEC_MDIO    | FEC_RDAT A0 | FEC_COL     | FEC_TX_C LK | FEC_TDAT A0 | NVCC_ATA     | NVCC_ATA     | NVCC_ATA      | GND         | GND         | MVD D     | PHY2_VSS   | FUSE_VDD   | NVCC_SDI O        | TDI               | NVCC_JTA G | USBP_HY1_VBUS | USBP_HY1_DP        | USBP_HY1_DP     | PHY1_VSS A         | P |
| R | FEC_MDC     | FEC_RX_C LK | CTS1        | ATA_DA0     | ATA_DA2     | TXD1         | VDD3         | VDD3          | NVCC_CRM    | NVCC_MLB    | NVCC_CSI  | VDD4       | PHY2_VDD   | SD1_DATA 0        | TDO               | TMS        | TCK           | USBP_HY1_VSSA_BIAS | USBP_HY1_RREF   | USBP_HY1_VDDA_BIAS | R |
| T | FEC_TX_E N  | FEC_RX_D V  | ATA_DMA RQ  | ATA_DATA 15 | ATA_BUFF_EN | ATA_RESE T_B | ATA_CS1      | CSP11_SPI_RDY | VSTB Y      | CLK_MOD E1  | GPIO 1_0  | COM PARE   | SD2_DATA 1 | CSI_V SYNC        | CSI_D11           | TRST B     | GND           | OSC2_4M_V SS       | OSC2_4M_V DD    | EXTA L24M          | T |
| U | RTS1        | RXD1        | ATA_DATA 12 | ATA_DATA 8  | ATA_DATA 3  | ATA_I ORDY   | USBO_TG_O C  | CSP11_SS1     | BOOT_MOD E1 | RESE T_IN_B | GPIO 2_0  | SD2_DATA 3 | SD2_CMD    | CSI_D14           | CSI_D8            | SD1_DATA 1 | SJC_MOD       | RTCK               | OSC_AUDI O_VS S | XTAL2 4M           | U |
| V | ATA_DA1     | ATA_I NTRQ  | ATA_DATA 10 | ATA_DATA 6  | ATA_DATA 2  | ATA_DMAC K   | ATA_CS0      | EXT_ARM CLK   | CSP11_MIS O | CLKO        | GPIO 3_0  | CAPT URE   | SD2_DATA 0 | CSI_HSYN C        | CSI_D13           | CSI_D10    | SD1_DATA 3    | SD1_CLK            | XTAL_AUDI O     | OSC_AUDI O_VD D    | V |
| W | ATA_DATA 14 | ATA_DATA 13 | ATA_DATA 9  | ATA_DATA 5  | ATA_DATA 1  | ATA_DIOW     | USBO_TG_P WR | CSP11_SCL K   | CSP11_MOS I | BOOT_MOD E0 | POR_B     | MLB_SIG    | MLB_CLK    | SD2_CLK           | CSI_MCLK          | CSI_D12    | CSI_D9        | SD1_DATA 2         | DE_B            | EXTA_L_AU DIO      | W |
| Y | GND         | ATA_DATA 11 | ATA_DATA 7  | ATA_DATA 4  | ATA_DATA 0  | ATA_DIOR     | TEST_MOD E   | CSP11_SS0     | POWER_F AIL | CLK_MOD E0  | GPIO 1_1  | WDOG_RST   | MLB_DAT    | SD2_DATA 2        | CSI_P IXCLK       | CSI_D15    | USBP_HY2_DM   | USBP_HY2_DP        | SD1_CMD         | GND                | Y |
|   | 1           | 2           | 3           | 4           | 5           | 6            | 7            | 8             | 9           | 10          | 11        | 12         | 13         | 14                | 15                | 16         | 17            | 18                 | 19              | 20                 |   |

Because of an order from the United States International Trade Commission, BGA-packaged product lines and part numbers indicated here currently are not available from Freescale for import or sale in the United States prior to September 2010: MCIMX351AVM4B, MCIMX351AVM5B, MCIMX355AVM4B, MCIMX355AVM5B, MCIMX356AVM4B, and MCIMX356AVM5B.

## 6 Product Documentation

All related product documentation for the i.MX35 processor is located at <http://www.freescale.com/imx>.

## 7 Revision History

Table 95 shows the revision history of this document. Note: There were no revisions of this document between revision 1 and revision 4.

**Table 95. i.MX35 Data Sheet Revision History**

| Revision Number | Date       | Substantive Change(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6               | 10/21/2009 | <ul style="list-style-type: none"><li>Added information for silicon rev. 2.1</li><li>Updated Table 1, "Ordering Information."</li><li>Added Table 92, "Silicon Revision 2.1 Signal Ball Map Locations."</li><li>Added Table 94, "Silicon Revision 2.1 Ball Map—17 x 17, 0.8 mm Pitch."</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 5               | 08/06/2009 | <ul style="list-style-type: none"><li>Filled in TBDs in Table 14.</li><li>Revised Figure 15 and Table 31 by removing FCE = 0 and FCE = 1. Added footnote 3 to the table.</li><li>Added Table 25, "AC Electrical Characteristics of DDR Type IO Pins in SDRAM Mode Max Drive (1.8 V)."</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 4               | 04/30/2009 | <p>Note: There were no revisions of this document between revision 1 and revision 4.</p> <ul style="list-style-type: none"><li>In Section 4.3.1, "Powering Up," reverse positions of steps 5 and 6.</li><li>Updated values in Table 10, "i.MX35 Power Modes."</li><li>Added Section 4.4, "Reset Timing."</li><li>In Section 4.8.2, "AC Electrical Characteristics for DDR Pins (DDR2, Mobile DDR, and SDRAM Modes)," removed Slow Slew rate tables, relabeled Table 23, "AC Electrical Characteristics of DDR Type IO Pins in mDDR Mode," and Table 24, "AC Electrical Characteristics of DDR Type IO Pins in SDRAM Mode," to exclude mention of slew rate.</li><li>In Section 4.9.5.2, "Wireless External Interface Module (WEIM)," modified Figure 16, "Synchronous Memory Timing Diagram for Read Access—WSC = 1," through Figure 21, "Muxed A/D Mode Timing Diagram for Synchronous Read Access— WSC = 7, LBA = 1, LBN = 1, LAH = 1, OEA = 7."</li><li>In Section 4.9.6, "Enhanced Serial Audio Interface (ESAI) Timing Specifications," modified Figure 37, "ESAI Transmitter Timing," and Figure 38, "ESAI Receiver Timing," to remove extraneous signals. Removed a note from Figure 37, "ESAI Transmitter Timing."</li></ul> |
| 1               | 12/2008    | <ul style="list-style-type: none"><li>Updated Section 4.3.1, "Powering Up."</li><li>Section 4.7, "Module-Level AC Electrical Specifications": Updated NFC, SDRAM and mDDR SDRAM timing. Inserted DDR2 SDRAM timing.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 0               | 10/2008    | Initial public release                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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