TDA3x SoC for Advanced Driver Assistance Systems (ADAS) 15mm Package (ABF) Silicon Revision 2.0

1 Device Overview

1.1 Features

- Architecture designed for ADAS applications
- Video and image processing support
  - Full-HD video (1920 × 1080p, 60 fps)
  - Video input and video output
- Up to 2 C66x floating-point VLIW DSP
  - Fully object-code compatible with C67x and C64x+
  - Up to thirty-two 16 × 16-bit fixed-point multiplies per cycle
- Up to 512kB of on-chip L3 RAM
- Level 3 (L3) and Level 4 (L4) interconnects
- Memory Interface (EMIF) module
  - Supports DDR3/DDR3L up to DDR-1066
  - Supports DDR2 up to DDR-800
  - Supports LPDDR2 up to DDR-667
  - Up to 2GB supported
- Dual Arm® Cortex®-M4 Image Processor Unit (IPU)
- Vision accelerationPac
  - Embedded Vision Engine (EVE)
- Display subsystem
  - Display controller with DMA engine
  - CVIDEO / SD-DAC TV analog composite output
- Video Input Port (VIP) module
  - Support for up to 4 multiplexed input ports
- On-chip temperature sensor that is capable of generating temperature alerts
- General-Purpose Memory Controller (GPMC)
- Enhanced Direct Memory Access (EDMA) controller
- 3-port (2 external) Gigabit Ethernet (GMAC) switch
- Controller Area Network (DCAN) module
  - CAN 2.0B protocol
- Modular Controller Area Network (MCAN) module
  - CAN 2.0B protocol
- Eight 32-bit general-purpose timers
- Three configurable UART modules
- Four Multichannel Serial Peripheral Interfaces (McSPI)
- Quad SPI interface
- Two Inter-Integrated Circuit (I^2C™) ports
- Three Multichannel Audio Serial Port (McASP) modules
- Secure Digital Input Output Interface (SDIO)
- Up to 126 General-Purpose I/O (GPIO) pins
- Power, reset, and clock management
- On-chip debug with CTools technology
- Automotive AEC-Q100 qualified
- 15 × 15 mm, 0.65-mm pitch, 367-pin PBGA (ABF)
- Seven Dual Clock Comparators (DCC)
- Memory Cyclic Redundancy Check (CRC)
- TESOC (LBIST/PBIST) that enables field testing of logic and on-chip memory
- Error Signaling Module (ESM)
- Five instances of Real-Time Interrupt (RTI) modules that can be used as watch dog timers
- 8-channel 10-bit ADC
- MIPI® Camera Serial Interface 2 (CSI-2)
- PWMSS
- Full HW image pipe: DPC, CFA, 3D-NF, RGB-YUV
  - WDR, HW LDC and perspective

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

1.2 Applications

- Mono, stereo or tri-optic front camera
  - Object detection
  - Pedestrian detection
  - Traffic sign recognition
  - Lane detection and departure warning
  - Automatic emergency braking
  - Adaptive cruise control
  - Forward collision warning
  - High beam assist
- LVDS or ethernet surround view
  - 2D surround view
  - 3D surround view
  - Rear object detection
  - Parking assist
  - Pedestrian detection
  - Lane tracking
  - Drive recording
- Sensor fusion – vision, radar, ultrasonic, lidar sensors
  - Object data fusion
  - Raw data fusion

1.3 Description

TI's TDA3x System-on-Chip (SoC) is a highly optimized and scalable family of devices designed to meet the requirements of leading Advanced Driver Assistance Systems (ADAS). The TDA3x family enables broad ADAS applications in automobiles by integrating an optimal mix of performance, low power, smaller form factor and ADAS vision analytics processing that aims to facilitate a more autonomous and collision-free driving experience.

The TDA3x SoC enables sophisticated embedded vision technology in today's automobile by enabling the industry's broadest range of ADAS applications including front camera, rear camera, surround view, radar, and fusion on a single architecture.

The TDA3x SoC incorporates a heterogeneous, scalable architecture that includes a mix of Texas Instruments (TI)'s fixed and floating-point TMS320C66x digital signal processor (DSP) generation cores, Vision AccelerationPac (EVE), and dual-Cortex-M4 processors. The device allows low power profile in different package options (including Package-On-Package) to enable small form factor designs. TDA3x SoC also integrates a host of peripherals including multi-camera interfaces (both parallel and serial) for LVDS-based surround view systems, displays, CAN and GigB Ethernet AVB.

The Vision AccelerationPac for this family of products includes embedded vision engine (EVE) offloading the vision analytics functionality from the application processor while also reducing the power footprint. The Vision AccelerationPac is optimized for vision processing with a 32-bit RISC core for efficient program execution and a vector coprocessor for specialized vision processing.

Additionally, TI provides a complete set of development tools for the Arm, DSP, and EVE coprocessor, including C compilers, a DSP assembly optimizer to simplify programming and scheduling, and a debugging interface for visibility into source code execution.

The TDA3x ADAS processor is qualified according to AEC-Q100 standard.

Device Information

PART NUMBER	PACKAGE	BODY SIZE
TDA3LAxABFQ1	FCBGA (367)	15.0 mm × 15.0 mm
TDA3MVxABFQ1	FCBGA (367)	15.0 mm × 15.0 mm
TDA3MAxABFQ1	FCBGA (367)	15.0 mm × 15.0 mm
TDA3MDxABFQ1	FCBGA (367)	15.0 mm × 15.0 mm
TDA3LXxABFQ1	FCBGA (367)	15.0 mm × 15.0 mm

Copyright © 2016–2020, Texas Instruments Incorporated

1.4 Functional Block Diagram

Figure 1-1 is functional block diagram of the superset.

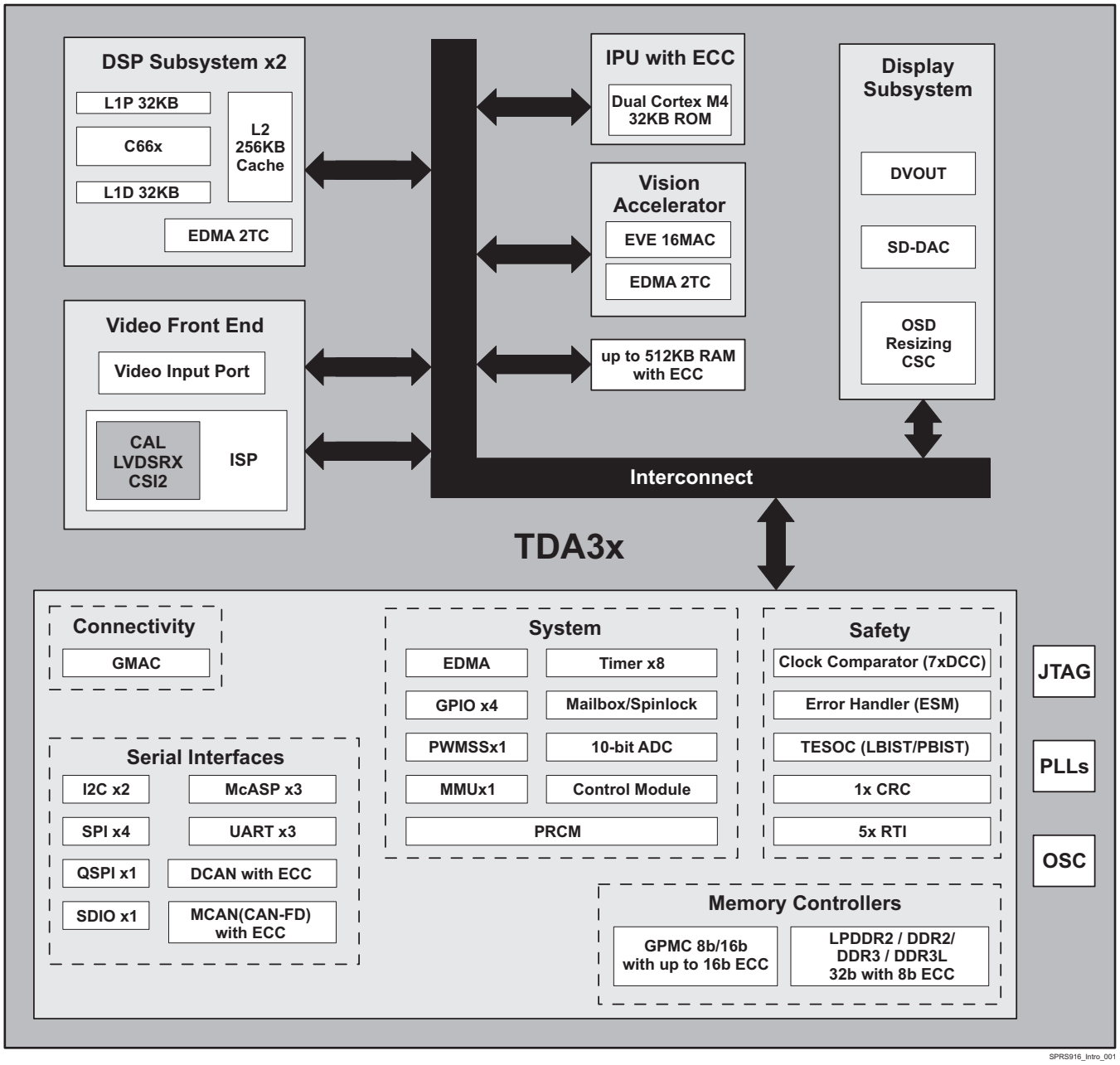


Figure 1-1. TDA3x Block Diagram

Copyright © 2016–2020, Texas Instruments Incorporated

Table of Contents

1 Device Overview 1
1.1 Features 1
1.2 Applications 2
1.3 Description 2
1.4 Functional Block Diagram 3
2 Revision History 5
3 Device Comparison 6
3.1 Related Products 8
4 Terminal Configuration and Functions 9
4.1 Terminal Assignment 9
4.2 Ball Characteristics 10
4.3 Multiplexing Characteristics 40
4.4 Signal Descriptions 51
5 Specifications 75
5.1 Absolute Maximum Ratings 76
5.2 ESD Ratings 76
5.3 Power-On Hours (POH)(1)(2)(3) 77
5.4 Recommended Operating Conditions 77
5.5 Operating Performance Points 79
5.6 Power Consumption Summary 89
5.7 Electrical Characteristics 90
5.8 Thermal Characteristics 96
5.9 Analog-to-Digital ADC Subsystem Electrical Specifications 97
5.10 Power Supply Sequences 99
6 Clock Specifications 105
6.1 Input Clock Specifications 106
6.2 DPLLs, DLLs Specifications 112
7 Timing Requirements and Switching Characteristics 116
7.1 Timing Test Conditions 116
7.2 Interface Clock Specifications 116
7.3 Timing Parameters and Information 116
7.4 Recommended Clock and Control Signal Transition Behavior 118
7.5 Video Input Ports (VIP) 119
7.6 Display Subsystem – Video Output Ports 124
7.7 Imaging Subsystem (ISS) 126
7.8 External Memory Interface (EMIF) 127
7.9 General-Purpose Memory Controller (GPMC) 127
7.10 General-Purpose Timers 148
7.11 Inter-Integrated Circuit Interface (I2C) 148
7.12 Universal Asynchronous Receiver Transmitter (UART) 151
7.13 Multichannel Serial Peripheral Interface (McSPI) 153
7.14 Quad Serial Peripheral Interface (QSPI) 159
7.15 Multichannel Audio Serial Port (McASP) 163
7.16 Controller Area Network Interface (DCAN and MCAN) 171
7.17 Ethernet Interface (GMAC_SW) 172
7.18 SDIO Controller 176
7.19 General-Purpose Interface (GPIO) 181
7.20 Test Interfaces 182
8 Applications, Implementation, and Layout 185
8.1 Introduction 185
8.2 Power Optimizations 186
8.3 Core Power Domains 197
8.4 Single-Ended Interfaces 206
8.5 Differential Interfaces 209
8.6 Clock Routing Guidelines 211
8.7 LPDDR2 Board Design and Layout Guidelines 212
8.8 DDR2 Board Design and Layout Guidelines 221
8.9 DDR3 Board Design and Layout Guidelines 233
8.10 CVIDEO/SD-DAC Guidelines and Electrical Data/Timing 256
9 Device and Documentation Support 258
9.1 Device Nomenclature 258
9.2 Tools and Software 260
9.3 Documentation Support 262
9.4 Related Links 262
9.5 Support Resources 262
9.6 Trademarks 262
9.7 Electrostatic Discharge Caution 262
9.8 Glossary 262
10 Mechanical, Packaging, and Orderable Information 263
10.1 Packaging Information 263

Copyright © 2016–2020, Texas Instruments Incorporated

2 Revision History

Changes from April 1, 2019 to February 29, 2020 (from G Revision (March 2019) to H Revision) **Page**

- Updated MMC naming in Section 1.1, *Features* 1
- Updated clarification notes regarding XTDA3SX part number in Table 3-1, *Device Comparison* 7
- Updated Table 5-10, *LVCMOS Analog OSC Buffers DC Electrical Characteristics* 94
- Updated Figure 7-36, *GMAC MDIO diagrams* and MDIO7 parameter values in Table 7-38, *Switching Characteristics Over Recommended Operating Conditions for MDIO Output* 173
- Updated clarification notes regarding XTDA3SX part number in Table 9-1, *Nomenclature Description* 258
- Updated Device Type section of Table 9-1, *Nomenclature Description* to include additional GP Prime variants 258

Copyright © 2016–2020, Texas Instruments Incorporated

3 Device Comparison

Table 3-1 shows a comparison between devices, highlighting the differences.

Table 3-1. Device Comparison[2][5]

FEATURES			DEVICE								
			TDA3MVx		TDA3MAx	TDA3MDx	TDA3LXx		TDA3LAx		
Features											
CTRL_WKUP_STD_FUSE_DIE_ID_2 [31:24] Base PN register bit field value[4][5]			TDA3MV: 147 (0x93) TDA3MV-FD: 148 (0x94)		TDA3MA: 149 (0x95)	TDA3MD: 157 (0x9D)	TDA3LX: 154 (0x9A) TDA3LX–FD: 150 (0x96)		TDA3LA: 151 (0x97)		
Processors/ Accelerators											
Speed Grades			R, S	D, R, S	D, R, S	D, S	D, R, S	B, D, R, S	B, D, R, S		
C66x VLIW DSP		DSP1	Yes		Yes	Yes	Yes		Yes		
		DSP2	Yes		Yes	Yes	No		No		
Display Subsystem		VOUT1	Yes		No	No	Yes		No		
		SD_DAC	Yes		No	No	Yes		No		
Embedded Vision Engine (EVE)		EVE1	Yes		Yes	No	Yes		Yes		
Dual Arm Cortex-M4 Image Processing Unit (IPU)		IPU1	Yes		Yes	Yes	Yes		Yes		
Imaging Subsystem Processor (ISS) with MIPI CSI-2 and CPI ports		ISP	Yes		No	No	Yes		No		
		WDR & Mesh LDC[1]	Yes		No	No	Yes		No		
		CAL_A	Yes		Yes	Yes	Yes		Yes		
		CAL_B	Yes		Yes	Yes	Yes		Yes		
		LVDS-RX	Yes		Yes	Yes	Yes		Yes		
		CPI	Yes		Yes	Yes	Yes		Yes		
Video Input Port (VIP)	VIP1	vin1a	Yes		Yes	Yes	Yes		Yes		
		vin1b	Yes		Yes	Yes	Yes		Yes		
		vin2a	Yes		Yes	Yes	Yes		Yes		
		vin2b	Yes		Yes	Yes	Yes		Yes		
Program/Data Storage											
On-Chip Shared Memory (RAM)		OCMC_RAM 1	512kB		512kB	512kB	256kB		256kB		
General-Purpose Memory Controller (GPMC)		GPMC	Yes		Yes	Yes	Yes		Yes		
LPDDR2/DDR2/DDR3/DDR3L Memory Controller		EMIF1 (optional with SECDED)	up to 2GB		up to 2GB	up to 2GB	up to 2GB		up to 2GB		
Peripherals											
Controller Area Network Interface (CAN)		DCAN1	Yes		Yes	Yes	Yes		Yes		
		MCAN	Yes[3]	Yes	Yes	Yes	Yes[3]	Yes	Yes		
Enhanced DMA (EDMA)		EDMA	Yes		Yes	Yes	Yes		Yes		
Embedded 8 channel ADC		ADC	Yes		Yes	Yes	Yes		Yes		
Ethernet Subsystem (Ethernet SS)		GMAC_SW[0]	RGMII Only		RGMII Only	RGMII Only	RGMII Only		RGMII Only		
		GMAC_SW[1]	RGMII Only		RGMII Only	RGMII Only	RGMII Only		RGMII Only		
General-Purpose IO (GPIO)		GPIO	Up to 126		Up to 126	Up to 126	Up to 126		Up to 126		
Inter-Integrated Circuit Interface (I2C)		I2C	2		2	2	2		2		
System Mailbox Module		MAILBOX	2		2	2	2		2		

Copyright © 2016–2020, Texas Instruments Incorporated

Table 3-1. Device Comparison[2][5] (continued)

FEATURES		DEVICE				
		TDA3MVx	TDA3MAx	TDA3MDx	TDA3LXx	TDA3LAx
Multichannel Audio Serial Port (McASP)	McASP1	16 serializers	16 serializers	16 serializers	16 serializers	16 serializers
	McASP2	6 serializers	6 serializers	6 serializers	6 serializers	6 serializers
	McASP3	6 serializers	6 serializers	6 serializers	6 serializers	6 serializers
MultiMedia Card/Secure Digital/Secure Digital Input Output Interface (MMC/SD/SDIO)	MMC	1x SDIO 4b	1x SDIO 4b	1x SDIO 4b	1x SDIO 4b	1x SDIO 4b
Multichannel Serial Peripheral Interface (McSPI)	McSPI	4	4	4	4	4
Quad SPI (QSPI)	QSPI	Yes	Yes	Yes	Yes	Yes
Spinlock Module	SPINLOCK	Yes	Yes	Yes	Yes	Yes
Timers, General-Purpose	TIMER	8	8	8	8	8
Dual Clock Comparators (DCC)	DCC	7	7	7	7	7
Pulse-Width Modulation Subsystem (PWMSS)	PWMSS1	Yes	Yes	Yes	Yes	Yes
Universal Asynchronous Receiver/Transmitter (UART)	UART	3	3	3	3	3
Memory Cyclic Redundancy Check (CRC)	CRC	Yes	Yes	Yes	Yes	Yes
TESOC (LBIST/PBIST)	LBIST/PBIST	Yes	Yes	Yes	Yes	Yes
Error Signaling Module (ESM)	ESM	Yes	Yes	Yes	Yes	Yes
Real Time Interrupt (RTI)	RTI	5	5	5	5	5

(1) Wide Dynamic Range and Lens Distortion Correction.

(2) Listed devices are a sample of devices available in TDA3x family. The device name decoder can provide the details of individual part number.

(3) Device supports FD (Flexible Data Rate) as an optional feature if the part number is designated with the “F” option.

(4) For more details about the CTRL_WKUP_STD_FUSE_DIE_ID_2 register and Base PN bit field, see the device TRM.

(5) XTDA3SX base part number with X speed grade indicator is the part number for the superset device. Software should constrain the features and speed used to match the intended production device. The Base PN register bit field value is 0x98.

Copyright © 2016–2020, Texas Instruments Incorporated

3.1 Related Products

Companion Products for TDA3 Review products that are frequently purchased or used in conjunction with this product.

Reference Designs for TDA3 TI Designs Reference Design Library is a robust reference design library spanning analog, embedded processor and connectivity. Created by TI experts to help you jump-start your system design, all TI Designs include schematic or block diagrams, BOMs and design files to speed your time to market. Search and download designs at ti.com/tidesigns.

Copyright © 2016–2020, Texas Instruments Incorporated

4 Terminal Configuration and Functions

4.1 Terminal Assignment

Figure 4-1 shows the ball locations for the 367 plastic ball grid array (PBGA) package and are used in conjunction with Table 4-2 through Table 4-29 to locate signal names and ball grid numbers.

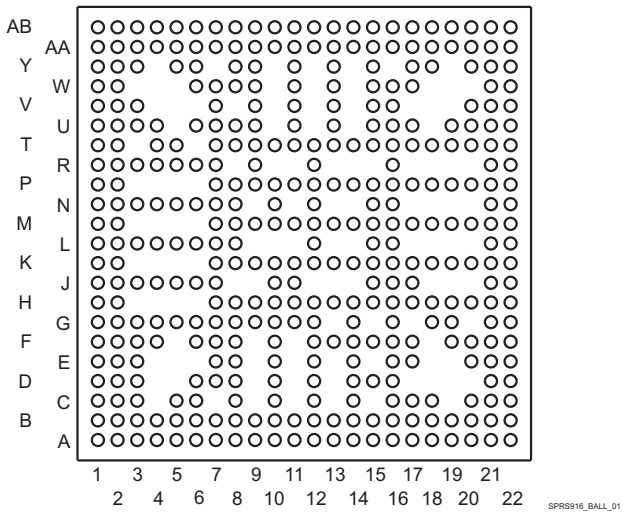


Figure 4-1. ABF FCBGA-N367 Package (Bottom View)

NOTE

The following bottom balls are not connected: C4 / C7 / C9 / C11 / C13 / C15 / C19 / D4 / D5 / D9 / D11 / D13 / D17 / D18 / D19 / D20 / E4 / E5 / E6 / E9 / E11 / E13 / E15 / E18 / E19 / F5 / F9 / F11 / F18 / G13 / G15 / G17 / G20 / H3 / H4 / H5 / H6 / J8 / J9 / J12 / J13 / J14 / J18 / J19 / J20 / K3 / K4 / K5 / K6 / L9 / L10 / L11 / L13 / L14 / L17 / L18 / L19 / L20 / M3 / M4 / M5 / M6 / N9 / N11 / N13 / N14 / N17 / N18 / N19 / N20 / P3 / P4 / P5 / P6 / R8 / R10 / R11 / R13 / R14 / R15 / R17 / R18 / R19 / R20 / T3 / T6 / U5 / U10 / U12 / U14 / U18 / V4 / V5 / V6 / V8 / V10 / V12 / V14 / V17 / V18 / V19 / W3 / W4 / W5 / W10 / W12 / W14 / W18 / W19 / W20 / Y4 / Y7 / Y10 / Y12 / Y14 / Y16 / Y19.

These balls do not exist on the package.

4.1.1 Unused Balls Connection Requirements

This section describes the Unused/Reserved balls connection requirements.

NOTE

The following balls are reserved: A2 / F6 / A21 / B1

These balls must be left unconnected.

NOTE

All unused power supply balls must be supplied with the voltages specified in the Section 5.4, *Recommended Operating Conditions,* unless alternative tie-off options are included in Section 4.4, *Signal Descriptions*.

Table 4-1. Unused Balls Specific Connection Requirements

BALLS	CONNECTION REQUIREMENTS
B21 / E22 / J5 / AA10 / AA5 / AA20 / W1 / T21	These balls must be connected to GND through an external pull resistor if unused
J2 / G5 / G4 / L3 / L4 / AB10 / J3 / AB5 / Y20 / W2 / T22 / L6 / L5	These balls must be connected to the corresponding power supply through an external pull resistor if unused
M19 / M20 / M21 / M22 / N22 / N21 / P19 / P18 / P20	These balls must be connected together to GND through a single external 10kΩ resistor if unused.

NOTE

All other unused signal balls **with** a Pad Configuration Register can be left unconnected with their internal pullup or pulldown resistor enabled.

NOTE

All other unused signal balls **without** a Pad Configuration Register can be left unconnected.

4.2 Ball Characteristics

Table 4-2 describes the terminal characteristics and the signals multiplexed on each ball. The following list describes the table column headers:

1. **BALL NUMBER:** Ball number(s) on the bottom side associated with each signal on the bottom.
2. **BALL NAME:** Mechanical name from package device (name is taken from muxmode 0).
3. **SIGNAL NAME:** Names of signals multiplexed on each ball (also notice that the name of the ball is the signal name in muxmode 0).

NOTE

Table 4-2 does not take into account the subsystem multiplexing signals. Subsystem multiplexing signals are described in Section 4.4, *Signal Descriptions*.

NOTE

In the Driver off mode, the buffer is configured in high-impedance.

4. **MA/LX/LA:** This column shows if the functionality is applicable for **TDA3MAx**, **TDA3LXx, TDA3LAx** devices. Note that the ball characteristics table presents the functionality of **TDA3MVx** device. If the cell is empty it means that the signal is available in all devices.

   MA – TDA3MAx, TDA3MDx
   LX – TDA3LXx
   LA – TDA3LAx

5. **MUXMODE:** Multiplexing mode number:
   a. MUXMODE 0 is the primary mode; this means that when MUXMODE=0 is set, the function mapped on the pin corresponds to the name of the pin. The primary muxmode is not necessarily the default muxmode.

   NOTE

   The default mode is the mode at the release of the reset; also see the RESET REL. MUXMODE column.

   b. MUXMODE 1 through 15 are possible muxmodes for alternate functions. On each pin, some

Copyright © 2016–2020, Texas Instruments Incorporated

muxmodes are effectively used for alternate functions, while some muxmodes are not used. Only MUXMODE values which correspond to defined functions should be used.

c. An empty box means Not Applicable.

6. **TYPE:** Signal type and direction:
   - I = Input
   - O = Output
   - IO = Input or Output
   - D = Open drain
   - DS = Differential Signaling
   - A = Analog
   - PWR = Power
   - GND = Ground
   - CAP = LDO Capacitor
7. **BALL RESET STATE:** The state of the terminal at power-on reset:
   - drive 0 (OFF): The buffer drives V_{OL} (pulldown or pullup resistor not activated).
   - drive 1 (OFF): The buffer drives V_{OH} (pulldown or pullup resistor not activated).
   - OFF: High-impedance
   - PD: High-impedance with an active pulldown resistor
   - PU: High-impedance with an active pullup resistor
   - An empty box means Not Applicable
8. **BALL RESET REL. STATE:** The state of the terminal at the deactivation of the rstoutn signal (also mapped to the PRCM SYS_WARM_OUT_RST signal).
   - drive 0 (OFF): The buffer drives V_{OL} (pulldown or pullup resistor not activated).
   - drive clk (OFF): The buffer drives a toggling clock (pulldown or pullup resistor not activated).
   - drive 1 (OFF): The buffer drives V_{OH} (pulldown or pullup resistor not activated).
   - OFF: High-impedance
   - PD: High-impedance with an active pulldown resistor
   - PU: High-impedance with an active pullup resistor
   - An empty box means Not Applicable

NOTE

For more information on the CORE_PWRON_RET_RST reset signal and its reset sources, see the *Reset Management Functional Description* section in the device TRM.

9. **BALL RESET REL. MUXMODE:** This muxmode is automatically configured at the release of the rstoutn signal (also mapped to the PRCM SYS_WARM_OUT_RST signal).

   An empty box means Not Applicable.
10. **IO VOLTAGE VALUE**: This column describes the IO voltage value (VDDS supply).

    An empty box means Not Applicable.
11. **POWER:** The voltage supply that powers the terminal IO buffers.

    An empty box means Not Applicable.
12. **HYS:** Indicates if the input buffer is with hysteresis:
    - Yes: With hysteresis
    - No: Without hysteresis
    - An empty box: Not Applicable

NOTE

For more information, see the hysteresis values in Section 5.7, *DC Electrical Characteristics*.

13. **BUFFER TYPE:** Drive strength of the associated output buffer.

Copyright © 2016–2020, Texas Instruments Incorporated

An empty box means Not Applicable.

NOTE

For programmable buffer strength:
- The default value is given in Table 4-2.
- A note describes all possible values according to the selected muxmode.

14. **PULL UP / DOWN TYPE:** Denotes the presence of an internal pullup or pulldown resistor. Pullup and pulldown resistors can be enabled or disabled via software.
    - PU: Internal pullup
    - PD: Internal pulldown
    - PU/PD: Internal pullup and pulldown
    - PUx/PDy: Programmable internal pullup and pulldown
    - PDy: Programmable internal pulldown
    - An empty box means No pull
15. **DSIS:** The deselected input state (DSIS) indicates the state driven on the peripheral input (logic "0" or logic "1") when the peripheral pin function is not selected by any of the CTRL_CORE_PADx registers.
    - 0: Logic 0 driven on the peripheral's input signal port.
    - 1: Logic 1 driven on the peripheral's input signal port.
    - blank: Pin state driven on the peripheral's input signal port.

NOTE

Configuring two pins to the same input signal is not supported as it can yield unexpected results. This can be easily prevented with the proper software configuration (Hi-Z mode is not an input signal).

NOTE

When a pad is set into a multiplexing mode which is not defined by pin multiplexing, that pad's behavior is undefined. This should be avoided.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
M19	adc_in0	adc_in0		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
M20	adc_in1	adc_in1		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
M21	adc_in2	adc_in2		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
M22	adc_in3	adc_in3		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
N22	adc_in4	adc_in4		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
N21	adc_in5	adc_in5		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
P19	adc_in6	adc_in6		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
P18	adc_in7	adc_in7		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
P20	adc_vrefp	adc_vrefp		0	A	OFF	OFF	0	1.8	vdda_adc		GPADC		
N15	cap_vddram_core1	cap_vddram_core1			CAP									
M15	cap_vddram_core2	cap_vddram_core2			CAP									
M14	cap_vddram_dspeve	cap_vddram_dspeve			CAP									
A11	csi2_0_dx0	csi2_0_dx0		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
A12	csi2_0_dx1	csi2_0_dx1		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
A13	csi2_0_dx2	csi2_0_dx2		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
A15	csi2_0_dx3	csi2_0_dx3		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
A16	csi2_0_dx4	csi2_0_dx4		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
B11	csi2_0_dy0	csi2_0_dy0		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
B12	csi2_0_dy1	csi2_0_dy1		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
B13	csi2_0_dy2	csi2_0_dy2		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
B15	csi2_0_dy3	csi2_0_dy3		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
B16	csi2_0_dy4	csi2_0_dy4		0	I	OFF	OFF	0	1.8	vdda_csi	Yes	LVCMOS CSI2	PU/PD	
T18	cvideo_rset	cvideo_rset	N / Y / N	0	A	OFF	OFF	0	1.8	vdda_dac		AVDAC		
T17	cvideo_tvout	cvideo_tvout	N / Y / N	0	A	OFF	OFF	0	1.8	vdda_dac		AVDAC		
P17	cvideo_vfb	cvideo_vfb	N / Y / N	0	A	OFF	OFF	0	1.8	vdda_dac		AVDAC		
N6	dcan1_rx	dcan1_rx		0	IO	PU	PU	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_10		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
N5	dcan1_tx	dcan1_tx		0	IO	PU	PU	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_9		14	IO									
		Driver off		15	I									
F2	ddr1_casn	ddr1_casn		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
G1	ddr1_ck	ddr1_ck		0	O	PD	drive clk (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
AB13	ddr1_dqm_ecc	ddr1_dqm_ecc		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AB10	ddr1_dqsn_ecc	ddr1_dqsn_ecc		0	IO	PU	PU	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA10	ddr1_dqs_ecc	ddr1_dqs_ecc		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
G2	ddr1_nck	ddr1_nck		0	O	PD	drive clk (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
F1	ddr1_rasn	ddr1_rasn		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
N1	ddr1_rst	ddr1_rst		0	O	PD	drive 0 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
E3	ddr1_wen	ddr1_wen		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
U4	ddr1_a0	ddr1_a0		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
C1	ddr1_a1	ddr1_a1		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
D3	ddr1_a2	ddr1_a2		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
R4	ddr1_a3	ddr1_a3		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
T4	ddr1_a4	ddr1_a4		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
N3	ddr1_a5	ddr1_a5		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
T2	ddr1_a6	ddr1_a6		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
N2	ddr1_a7	ddr1_a7		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
T1	ddr1_a8	ddr1_a8		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
U1	ddr1_a9	ddr1_a9		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
D1	ddr1_a10	ddr1_a10		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
R3	ddr1_a11	ddr1_a11		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
U2	ddr1_a12	ddr1_a12		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
C3	ddr1_a13	ddr1_a13		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
R2	ddr1_a14	ddr1_a14		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
V1	ddr1_a15	ddr1_a15		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
B3	ddr1_ba0	ddr1_ba0		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
A3	ddr1_ba1	ddr1_ba1		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
D2	ddr1_ba2	ddr1_ba2		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
F3	ddr1_cke0	ddr1_cke0		0	O	PD	drive 0 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
B2	ddr1_csn0	ddr1_csn0		0	O	PD	drive 1 (OFF)	0	1.2/1.35/1.5 /1.8	vdds_ddr2		LVCMOS DDR	PUx/PDy	
AA6	ddr1_d0	ddr1_d0		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA8	ddr1_d1	ddr1_d1		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y8	ddr1_d2	ddr1_d2		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA7	ddr1_d3	ddr1_d3		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AB4	ddr1_d4	ddr1_d4		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y5	ddr1_d5	ddr1_d5		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA4	ddr1_d6	ddr1_d6		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y6	ddr1_d7	ddr1_d7		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA18	ddr1_d8	ddr1_d8		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
Y21	ddr1_d9	ddr1_d9		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AA21	ddr1_d10	ddr1_d10		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
Y22	ddr1_d11	ddr1_d11		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AA19	ddr1_d12	ddr1_d12		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AB20	ddr1_d13	ddr1_d13		0	IO	PD	PD	0	1.2/1.35/1.5 /1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
Y17	ddr1_d14	ddr1_d14		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AB18	ddr1_d15	ddr1_d15		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AA3	ddr1_d16	ddr1_d16		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA2	ddr1_d17	ddr1_d17		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y3	ddr1_d18	ddr1_d18		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
V2	ddr1_d19	ddr1_d19		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
U3	ddr1_d20	ddr1_d20		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
V3	ddr1_d21	ddr1_d21		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y2	ddr1_d22	ddr1_d22		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y1	ddr1_d23	ddr1_d23		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
U21	ddr1_d24	ddr1_d24		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
T20	ddr1_d25	ddr1_d25		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
R21	ddr1_d26	ddr1_d26		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
U20	ddr1_d27	ddr1_d27		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
R22	ddr1_d28	ddr1_d28		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
V20	ddr1_d29	ddr1_d29		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
W22	ddr1_d30	ddr1_d30		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
U22	ddr1_d31	ddr1_d31		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AB8	ddr1_dqm0	ddr1_dqm0		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y18	ddr1_dqm1	ddr1_dqm1		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AB3	ddr1_dqm2	ddr1_dqm2		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
W21	ddr1_dqm3	ddr1_dqm3		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AA5	ddr1_dqs0	ddr1_dqs0		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
AA20	ddr1_dqs1	ddr1_dqs1		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
W1	ddr1_dqs2	ddr1_dqs2		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
T21	ddr1_dqs3	ddr1_dqs3		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
AB5	ddr1_dqsn0	ddr1_dqsn0		0	IO	PU	PU	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y20	ddr1_dqsn1	ddr1_dqsn1		0	IO	PU	PU	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
W2	ddr1_dqsn2	ddr1_dqsn2		0	IO	PU	PU	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
T22	ddr1_dqsn3	ddr1_dqsn3		0	IO	PU	PU	0	1.2/1.35/1.5/1.8	vdds_ddr3		LVCMOS DDR	PUx/PDy	
Y11	ddr1_ecc_d0	ddr1_ecc_d0		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA12	ddr1_ecc_d1	ddr1_ecc_d1		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA11	ddr1_ecc_d2	ddr1_ecc_d2		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
Y9	ddr1_ecc_d3	ddr1_ecc_d3		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA13	ddr1_ecc_d4	ddr1_ecc_d4		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AB11	ddr1_ecc_d5	ddr1_ecc_d5		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AA9	ddr1_ecc_d6	ddr1_ecc_d6		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
AB9	ddr1_ecc_d7	ddr1_ecc_d7		0	IO	PD	PD	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
P2	ddr1_odt0	ddr1_odt0		0	O	PD	drive 0 (OFF)	0	1.2/1.35/1.5/1.8	vdds_ddr1		LVCMOS DDR	PUx/PDy	
H1	emu0	emu0		0	IO	PU	PU	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_28		14	IO									
		Driver off		15	I									
H2	emu1	emu1		0	IO	PU	PU	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_29		14	IO									
		Driver off		15	I									
E8	gpmc_ad0	gpmc_ad0		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		rgmii1_rxd2		1	I									0
		gpio1_14		14	IO									
		sysboot0		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
A7	gpmc_ad1	gpmc_ad1		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		rgmii1_rxd1		1	I									0
		gpio1_15		14	IO									
		sysboot1		15	I									
F8	gpmc_ad2	gpmc_ad2		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		rgmii1_rxd0		1	I									0
		gpio1_16		14	IO									
		sysboot2		15	I									
B7	gpmc_ad3	gpmc_ad3		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		qspi1_rtclk		1	I									0
		gpio1_17		14	IO									
		sysboot3		15	I									
A6	gpmc_ad4	gpmc_ad4		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		cam_strobe	N / Y / N	1	O									
		gpio1_18		14	IO									
		sysboot4		15	I									
F7	gpmc_ad5	gpmc_ad5		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart2_txd		2	O									
		timer6		3	IO									
		spi3_d1		4	IO									0
		gpio1_19		14	IO									
		sysboot5 mcasp2_aclkx		15	I									
E7	gpmc_ad6	gpmc_ad6		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart2_rxd		2	I									1
		timer5		3	IO									
		spi3_d0		4	IO									0
		gpio1_20		14	IO									
		sysboot6 mcasp2_fsx		15	I									
C6	gpmc_ad7	gpmc_ad7		0	IO	OFF	OFF	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		cam_shutter	N / Y / N	1	O									
		timer4		3	IO									
		spi3_sclk		4	IO									0
		gpio1_21		14	IO									
		Driver off mcasp2_ahclkx		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
B6	gpmc_ad8	gpmc_ad8		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		timer7		3	IO									
		spi3_cs0		4	IO									1
		gpio1_22		14	IO									
		sysboot8 mcasp2_aclkr		15	I									
A5	gpmc_ad9	gpmc_ad9		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		eCAP1_in_PWM1_out		3	IO									0
		spi3_cs1		4	IO									1
		gpio1_23		14	IO									
		sysboot9 mcasp2_fsr		15	I									
D6	gpmc_ad10	gpmc_ad10		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		timer2		3	IO									
		gpio1_24		14	IO									
		sysboot10 mcasp2_axr0		15	I									
C5	gpmc_ad11	gpmc_ad11		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		timer3		3	IO									
		gpio1_25		14	IO									
		sysboot11 mcasp2_axr1		15	I									
B5	gpmc_ad12	gpmc_ad12		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		gpio1_26		14	IO									
		sysboot12 mcasp2_axr2		15	I									
D7	gpmc_ad13	gpmc_ad13		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		rgmii1_rxc		1	I									0
		gpio1_27		14	IO									
		sysboot13 mcasp2_axr3		15	I									
B4	gpmc_ad14	gpmc_ad14		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		spi2_cs1		4	IO									1
		gpio1_28		14	IO									
		sysboot14 mcasp2_axr4		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
A4	gpmc_ad15	gpmc_ad15		0	IO	OFF	OFF	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		spi2_cs0		4	IO									1
		gpio1_29		14	IO									
		sysboot15 mcasp2_axr5		15	I									
F12	gpmc_advn_ale	gpmc_advn_ale		0	O	PD	PD	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		rgmii1_txd2		1	O									
		ehrpwm1_tripzone_input		4	IO									0
		clkout1		5	O									
		dma_evt4		6	I									
		gpio1_3		14	IO									
		Driver off		15	I									
D12	gpmc_ben0	gpmc_ben0		0	O	PD	PD	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		rgmii1_txctl		1	O									
		ehrpwm1A		4	O									
		dma_evt2		6	I									
		gpio1_1		14	IO									
		Driver off		15	I									
E12	gpmc_ben1	gpmc_ben1		0	O	PD	PD	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		rgmii1_txd3		1	O									
		ehrpwm1B		4	O									
		dma_evt3		6	I									
		gpio1_2		14	IO									
		Driver off		15	I									
C12	gpmc_clk	gpmc_clk		0	IO	PD	PD	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	0
		rgmii1_txc		1	O									
		clkout0		5	O									
		dma_evt1		6	I									
		gpio1_0		14	IO									
		Driver off		15	I									
C10	gpmc_cs0	gpmc_cs0		0	O	PU	PU	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		rgmii1_rxctl		1	I									0
		gpio1_6		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
E10	gpmc_cs1	gpmc_cs1		0	O	PU	PU	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		qspi1_cs0		1	IO									1
		gpio1_7		14	IO									
		Driver off		15	I									
D10	gpmc_cs2	gpmc_cs2		0	O	PU	PU	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		qspi1_d3		1	IO									0
		gpio1_8		14	IO									
		Driver off		15	I									
A9	gpmc_cs3	gpmc_cs3		0	O	PU	PU	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		qspi1_d2		1	IO									0
		gpio1_9		14	IO									
		Driver off		15	I									
B9	gpmc_cs4	gpmc_cs4		0	O	PU	PU	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		qspi1_d0		1	IO									0
		gpio1_10		14	IO									
		Driver off		15	I									
F10	gpmc_cs5	gpmc_cs5		0	O	PU	PU	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		qspi1_d1		1	IO									0
		gpio1_11		14	IO									
		Driver off		15	I									
C8	gpmc_cs6	gpmc_cs6		0	O	PU	PU	15	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		qspi1_sclk		1	O									
		gpio1_12		14	IO									
		Driver off		15	I									
A10	gpmc_oen_ren	gpmc_oen_ren		0	O	PD	PD	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		rgmii1_txd1		1	O									
		ehrpwm1_synci		4	I									0
		clkout2		5	O									
		gpio1_4		14	IO									
		Driver off		15	I									
D8	gpmc_wait0	gpmc_wait0		0	I	PU	PU	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	1
		rgmii1_rxd3		1	I									0
		qspi1_rtclk		2	I									0
		dma_evt4		6	I									
		gpio1_13		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
B10	gpmc_wen	gpmc_wen		0	O	PD	PD	0	1.8/3.3	vddshv2	Yes	Dual Voltage LVCMOS	PU/PD	
		rgmii1_txd0		1	O									
		ehrpwm1_synco		4	O									
		gpio1_5		14	IO									
		Driver off		15	I									
L3	i2c1_scl	i2c1_scl		0	IO	OFF	OFF	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS I2C	PU	
L4	i2c1_sda	i2c1_sda		0	IO	OFF	OFF	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS I2C	PU	
L6	i2c2_scl	i2c2_scl		0	IO	OFF	OFF	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS I2C	PU	
L5	i2c2_sda	i2c2_sda		0	IO	OFF	OFF	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS I2C	PU	
W6	mcan_rx	mcan_rx		0	IO	PU	PU	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	1
		cam_nreset	N / Y / N	1	IO									
		vin2a_vsync0		2	I									
		spi1_cs3		3	IO									1
		uart3_txd		4	O									
		gpmc_cs7		5	O									
		vin1b_vsync1		7	I									0
		gpio4_12		14	IO									
		Driver off		15	I									
W7	mcan_tx	mcan_tx		0	IO	PU	PU	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	1
		vin2a_de0		1	I									
		vin2a_hsync0		2	I									
		spi1_cs2		3	IO									1
		uart3_rxd		4	I									1
		gpmc_wait1		6	I									1
		vin1b_hsync1		7	I									0
		vin1b_de1		8	I									0
		gpio4_11		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
B17	mdio_d	mdio_d		0	IO	PU	PU	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	1
		spi4_d0		4	IO									0
		esm_error		5	IO									0
		gpio3_18		14	IO									
		Driver off		15	I									
B19	mdio_mclk	mdio_mclk		0	O	PU	PU	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	1
		spi4_d1		4	IO									0
		gpio3_17		14	IO									
		Driver off		15	I									
G5	nmin	nmin		0	I	PU	PU	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	1
G3	porz	porz		0	I	OFF	OFF	0	1.8/3.3	vddshv1	Yes	IHHV1833	PU/PD	
G4	resetn	resetn		0	I	PU	PU	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
B18	rgmii0_rxc	rgmii0_rxc		0	I	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	0
		cam_strobe	N / Y / N	3	O									
		mmc_clk		5	IO									1
		gpio3_25		14	IO									
		Driver off		15	I									
C18	rgmii0_rxctl	rgmii0_rxctl		0	I	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	0
		cam_shutter	N / Y / N	3	O									
		mmc_cmd		5	IO									1
		gpio3_26		14	IO									
		Driver off		15	I									
C16	rgmii0_txc	rgmii0_txc		0	O	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	
		cam_strobe	N / Y / N	3	O									
		spi4_sclk		4	IO									0
		mmc_clk		5	IO									1
		gpio3_19		14	IO									
		Driver off		15	I									
C17	rgmii0_txctl	rgmii0_txctl		0	O	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	
		cam_shutter	N / Y / N	3	O									
		spi4_cs0		4	IO									1
		mmc_cmd		5	IO									1
		gpio3_20		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
A20	rgmii0_rxd0	rgmii0_rxd0		0	I	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	0
		mmc_dat3		5	IO									1
		gpio3_30		14	IO									
		Driver off		15	I									
C20	rgmii0_rxd1	rgmii0_rxd1		0	I	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	0
		mmc_dat2		5	IO									1
		gpio3_29		14	IO									
		Driver off		15	I									
B20	rgmii0_rxd2	rgmii0_rxd2		0	I	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	0
		mmc_dat1		5	IO									1
		gpio3_28		14	IO									
		Driver off		15	I									
A19	rgmii0_rxd3	rgmii0_rxd3		0	I	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	0
		mmc_dat0		5	IO									1
		gpio3_27		14	IO									
		Driver off		15	I									
F17	rgmii0_txd0	rgmii0_txd0		0	O	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	
		mmc_dat3		5	IO									1
		gpio3_24		14	IO									
		Driver off		15	I									
E17	rgmii0_txd1	rgmii0_txd1		0	O	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	
		mmc_dat2		5	IO									1
		gpio3_23		14	IO									
		Driver off		15	I									
D16	rgmii0_txd2	rgmii0_txd2		0	O	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	
		eCAP1_in_PWM1_out		3	IO									0
		mmc_dat1		5	IO									1
		gpio3_22		14	IO									
		Driver off		15	I									
E16	rgmii0_txd3	rgmii0_txd3		0	O	PD	PD	15	1.8/3.3	vddshv4	Yes	Dual Voltage LVCMOS	PU/PD	
		mmc_dat0		5	IO									1
		gpio3_21		14	IO									
		Driver off		15	I									
F4	rstoutn	rstoutn		0	O	PD	drive 1 (OFF)	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
J6	rtck	rtck		0	O	PU	drive clk (OFF)	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_27		14	IO									
		Driver off		15	I									
M2	spi1_sclk	spi1_sclk		0	IO	PD	PD	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart3_rxd		1	I									1
		gpio4_0		14	IO									
		Driver off		15	I									
L1	spi2_sclk	spi2_sclk		0	IO	PD	PD	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart3_rxd		1	I									1
		ehrpwm1A		2	O									
		timer3		3	IO									
		gpio4_5		14	IO									
		Driver off		15	I									
R6	spi1_cs0	spi1_cs0		0	IO	PU	PU	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	1
		uart3_txd		1	O									
		gpio4_3		14	IO									
		Driver off		15	I									
R5	spi1_cs1	spi1_cs1		0	IO	PU	PU	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	1
		spi3_cs1		1	IO									1
		timer6		4	IO									
		ehrpwm1_tripzone_input		7	IO									0
		gpio4_4		14	IO									
		Driver off		15	I									
T5	spi1_d0	spi1_d0		0	IO	OFF	OFF	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart3_rtsn		1	O									
		gpio4_2		14	IO									
		Driver off		15	I									
U6	spi1_d1	spi1_d1		0	IO	OFF	OFF	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart3_ctsn		1	I									1
		gpio4_1		14	IO									
		Driver off		15	I									
L2	spi2_cs0	spi2_cs0		0	IO	PU	PU	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	1
		uart3_txd		1	O									
		ehrpwm1B		2	O									
		timer4		3	IO									
		gpio4_8		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
R7	spi2_d0	spi2_d0		0	IO	OFF	OFF	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart3_rtsn		1	O									
		timer1		3	IO									
		gpio4_7		14	IO									
		sysboot7		15	I									
N4	spi2_d1	spi2_d1		0	IO	OFF	OFF	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	0
		uart3_ctsn		1	I									1
		timer5		3	IO									
		eCAP1_in_PWM1_out		7	IO									0
		gpio4_6		14	IO									
		Driver off		15	I									
J2	tclk	tclk		0	I	PU	PU	0	1.8/3.3	vddshv1	Yes	IQ1833	PU/PD	
J1	tdi	tdi		0	I	PU	PU	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_25		14	IO									
		Driver off		15	I									
J4	tdo	tdo		0	O	PU	PU	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio4_26		14	IO									
		Driver off		15	I									
J3	tms	tms		0	IO	OFF	OFF	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
J5	trstn	trstn		0	I	PD	PD	0	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
F14	uart1_ctsn	uart1_ctsn		0	I	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	1
		xref_clk1		1	I									
		uart3_rxd		2	I									1
		gpmc_a16		3	O									
		spi4_sclk		4	IO									0
		spi1_cs2		5	IO									1
		timer3		6	IO									
		ehrpwm1_synci		7	I									0
		clkout0		8	O									
		vin2a_hsync0		9	I									
		gpmc_a12		10	O									
		gpmc_clk		11	IO									0
		dcan1_tx		12	IO									
		gpio4_15		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
C14	uart1_rtsn	uart1_rtsn		0	O	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	
		uart3_txd		2	O									
		gpmc_a17		3	O									
		spi4_cs0		4	IO									1
		spi1_cs3		5	IO									1
		timer4		6	IO									
		ehrpwm1_synco		7	O									
		qspi1_rtclk		8	I									0
		vin2a_vsync0		9	I									
		gpmc_a13		10	O									
		dcan1_rx		12	IO									
		gpio4_16		14	IO									
		Driver off		15	I									
F13	uart1_rxd	uart1_rxd		0	I	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	1
		spi4_d1		4	IO									0
		qspi1_rtclk		5	I									0
		gpmc_a12		10	O									
		mcan_tx		12	IO									1
		gpio4_13		14	IO									
		Driver off		15	I									
E14	uart1_txd	uart1_txd		0	O	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	
		spi4_d0		4	IO									0
		gpmc_a13		10	O									
		mcan_rx		12	IO									1
		gpio4_14		14	IO									
		Driver off		15	I									
F15	uart2_ctsn	uart2_ctsn		0	I	OFF	OFF	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	1
		xref_clk1		2	I									
		gpmc_a18		3	O									
		spi3_sclk		4	IO									0
		qspi1_cs1		5	IO									1
		timer7		6	IO									
		vin2a_hsync0		9	I									
		gpmc_clk		10	IO									0
		mcan_tx		12	IO									1
		gpio4_19		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
F16	uart2_rtsn	uart2_rtsn		0	O	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	
		eCAP1_in_PWM1_out		1	IO									0
		gpmc_a19		3	O									
		spi3_cs0		4	IO									1
		timer8		6	IO									
		vin2a_vsync0		9	I									
		mcan_rx		12	IO									1
		gpio4_20		14	IO									
		Driver off		15	I									
D14	uart2_rxd	uart2_rxd		0	I	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	1
		spi3_d1		4	IO									0
		timer1		6	IO									
		ehrpwm1A		7	O									
		gpmc_clk		10	IO									0
		gpmc_a12		11	O									
		dcan1_tx		12	IO									
		gpio4_17		14	IO									
		Driver off		15	I									
D15	uart2_txd	uart2_txd		0	O	PU	PU	15	1.8/3.3	vddshv3	Yes	Dual Voltage LVCMOS	PU/PD	
		spi3_d0		4	IO									0
		timer2		6	IO									
		ehrpwm1B		7	O									
		gpmc_a13		11	O									
		dcan1_rx		12	IO									
		gpio4_18		14	IO									
		Driver off		15	I									
H12, H13, H7, J10, J11, J15, K12, L12, L15, N12, N16, P10, P14	vdd	vdd			PWR									
P22	vdda_adc	vdda_adc			PWR									
A14	vdda_csi	vdda_csi			PWR									
U19	vdda_dac	vdda_dac			PWR									
N8	vdda_ddr_dsp	vdda_ddr_dsp			PWR									
M8	vdda_gmac_core	vdda_gmac_core			PWR									
E21	vdda_osc	vdda_osc			PWR									
H14	vdda_per	vdda_per			PWR									
G12, J7, L16, P13, T11	vdds18v	vdds18v			PWR									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
P7, T9	vdds18v_ddr1	vdds18v_ddr1			PWR									
G7	vdds18v_ddr2	vdds18v_ddr2			PWR									
T16, V21	vdds18v_ddr3	vdds18v_ddr3			PWR									
K2, K7, L7, M7	vddshv1	vddshv1			PWR									
B8, G11, G8, G9	vddshv2	vddshv2			PWR									
G14	vddshv3	vddshv3			PWR									
A18, E20	vddshv4	vddshv4			PWR									
H17, J16, J21	vddshv5	vddshv5			PWR									
AA16, T10, T12, T13	vddshv6	vddshv6			PWR									
AA1, AB6, R1, T7, T8	vdds_ddr1	vdds_ddr1			PWR									
C2, E2, G6	vdds_ddr2	vdds_ddr2			PWR									
AA22, AB19, T15	vdds_ddr3	vdds_ddr3			PWR									
K8, L8, M9, P11, P12, P8, P9	vdd_dspeve	vdd_dspeve			PWR									
F22	vin1a_clk0	vin1a_clk0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_pclk		1	I									0
		clkout0		4	O									
		gpio1_30		14	IO									
		Driver off mcasp3_aclkx		15	I									
G18	vin1a_d0	vin1a_d0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data2		1	I									0
		gpio2_3		14	IO									
		Driver off mcasp3_axr1		15	I									
G21	vin1a_d1	vin1a_d1		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data3		1	I									0
		gpio2_4		14	IO									
		Driver off mcasp3_axr2		15	I									
G22	vin1a_d2	vin1a_d2		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data4		1	I									0
		gpio2_5		14	IO									
		Driver off mcasp3_axr3		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
H18	vin1a_d3	vin1a_d3		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data5		1	I									0
		gpio2_6		14	IO									
		Driver off mcasp3_axr4		15	I									
H20	vin1a_d4	vin1a_d4		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data6		1	I									0
		gpio2_7		14	IO									
		Driver off mcasp3_axr5		15	I									
H19	vin1a_d5	vin1a_d5		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data7		1	I									0
		gpio2_8		14	IO									
		xref_clk2 mcasp3_ahclkx		15	I									
H22	vin1a_d6	vin1a_d6		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data8		1	I									0
		gpio2_9		14	IO									
		Driver off mcasp3_fsx		15	I									
H21	vin1a_d7	vin1a_d7		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data9		1	I									0
		gpio2_10		14	IO									
		Driver off		15	I									
J17	vin1a_d8	vin1a_d8		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data10		1	I									0
		vin1b_d0		2	I									0
		gpmc_a8		3	O									
		sys_nirq2		7	I									
		gpio2_11		14	IO									
		Driver off		15	I									
K22	vin1a_d9	vin1a_d9		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data11		1	I									0
		vin1b_d1		2	I									0
		gpmc_a9		3	O									
		sys_nirq1		7	I									
		gpio2_12		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
K21	vin1a_d10	vin1a_d10		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data12		1	I									0
		vin1b_d2		2	I									0
		gpmc_a10		3	O									
		sys_nirq2		7	I									
		gpio2_13		14	IO									
		Driver off		15	I									
K18	vin1a_d11	vin1a_d11		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data13		1	I									0
		vin1b_d3		2	I									0
		gpmc_a11		3	O									
		sys_nirq1		7	I									
		gpio2_14		14	IO									
		Driver off		15	I									
K17	vin1a_d12	vin1a_d12		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data14		1	I									0
		vin1b_d4		2	I									0
		gpmc_a12		3	O									
		dma_evt1		6	I									
		gpio2_15		14	IO									
		Driver off		15	I									
K19	vin1a_d13	vin1a_d13		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_wen		1	I									0
		vin1b_d5		2	I									0
		gpmc_a13		3	O									
		dma_evt2		6	I									
		gpio2_16		14	IO									
		Driver off		15	I									
K20	vin1a_d14	vin1a_d14		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_fid		1	IO									0
		vin1b_d6		2	I									0
		gpmc_a14		3	O									
		gpio2_17		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
L21	vin1a_d15	vin1a_d15		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data15		1	I									0
		vin1b_d7		2	I									0
		gpmc_a15		3	O									
		gpio2_18		14	IO									
		Driver off		15	I									
F21	vin1a_de0	vin1a_de0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_hsync		1	IO									0
		vin1b_clk1		2	I									0
		clkout1		4	O									
		gpio1_31		14	IO									
		Driver off		15	I									
F20	vin1a_fld0	vin1a_fld0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_vsync		1	IO									0
		vin2b_clk1		2	I									0
		clkout2		4	O									
		gpio2_0		14	IO									
		Driver off mcasp3_aclkr		15	I									
F19	vin1a_hsync0	vin1a_hsync0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data0		1	I									0
		vin1a_de0		2	I									0
		gpio2_1		14	IO									
		Driver off mcasp3_fsr		15	I									
G19	vin1a_vsync0	vin1a_vsync0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	0
		cpi_data1		1	I									0
		gpio2_2		14	IO									
		Driver off mcasp3_axr0		15	I									
L22	vin2a_clk0	vin2a_clk0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	
		gpio2_19		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
M17	vin2a_de0	vin2a_de0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	
		cam_strobe	N / Y / N	1	O									
		vin2b_hsync1		2	I									0
		vin2b_de1		5	I									0
		gpio4_21		14	IO									
		Driver off		15	I									
M18	vin2a_fld0	vin2a_fld0		0	I	PD	PD	15	1.8/3.3	vddshv5	Yes	Dual Voltage LVCMOS	PU/PD	
		cam_shutter	N / Y / N	1	O									
		vin2b_vsync1		2	I									0
		gpio4_22		14	IO									
		Driver off		15	I									
AB17	vout1_clk	vout1_clk	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin1a_d12		2	I									0
		clkout0		4	O									
		vin2a_clk0		9	I									
		gpio2_20		14	IO									
		Driver off		15	I									
U17	vout1_de	vout1_de	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_aclkx		1	IO									0
		vin1a_d13		2	I									0
		clkout1		4	O									
		gpio2_21		14	IO									
		Driver off		15	I									
W17	vout1_fld	vout1_fld	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_fsx		1	IO									0
		vin1a_d14		2	I									0
		clkout2		4	O									
		gpio2_22		14	IO									
		Driver off		15	I									
AA17	vout1_hsync	vout1_hsync	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_aclkr		1	IO									0
		vin1a_d15		2	I									0
		vin2a_de0		9	I									
		gpio2_23		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
U16	vout1_vsync	vout1_vsync	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_fsr		1	IO									0
		vin2a_fld0		9	I									
		gpio2_24		14	IO									
		Driver off		15	I									
W16	vout1_d0	vout1_d0	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr0		1	IO									0
		mmc_clk		5	IO									1
		gpio2_25		14	IO									
		Driver off		15	I									
V16	vout1_d1	vout1_d1	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr1		1	IO									0
		mmc_cmd		5	IO									1
		gpio2_26		14	IO									
		Driver off		15	I									
U15	vout1_d2	vout1_d2	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr2		1	IO									0
		mcasp1_axr8		4	IO									0
		mmc_dat0		5	IO									1
		gpio2_27		14	IO									
		Driver off		15	I									
V15	vout1_d3	vout1_d3	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr3		1	IO									0
		mcasp1_axr9		4	IO									0
		mmc_dat1		5	IO									1
		gpio2_28		14	IO									
		Driver off		15	I									
Y15	vout1_d4	vout1_d4	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr4		1	IO									0
		mcasp1_axr10		4	IO									0
		mmc_dat2		5	IO									1
		gpio2_29		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
W15	vout1_d5	vout1_d5	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr5		1	IO									0
		mcasp1_axr11		4	IO									0
		mmc_dat3		5	IO									1
		vin2a_clk0		9	I									
		gpio2_30		14	IO									
		Driver off		15	I									
AA15	vout1_d6	vout1_d6	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr6		1	IO									0
		mcasp1_axr12		4	IO									0
		esm_error		5	IO									0
		emu2		6	O									
		vin2a_de0		9	I									
		gpio2_31		14	IO									
		Driver off		15	I									
AB15	vout1_d7	vout1_d7	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr7		1	IO									0
		eCAP1_in_PWM1_out		3	IO									0
		mcasp1_axr13		4	IO									0
		emu3		6	O									
		vin2a_fld0		9	I									
		gpio3_0		14	IO									
		Driver off		15	I									
AA14	vout1_d8	vout1_d8	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr8		1	IO									0
		vin2a_d0		2	I									0
		gpmc_a20		3	O									
		emu4		6	O									
		gpio3_1		14	IO									
		Driver off		15	I									
AB14	vout1_d9	vout1_d9	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr9		1	IO									0
		vin2a_d1		2	I									0
		gpmc_a21		3	O									
		emu5		6	O									
		gpio3_2		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
U13	vout1_d10	vout1_d10	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr10		1	IO									0
		vin2a_d2		2	I									0
		gpmc_a22		3	O									
		emu6		6	O									
		gpio3_3		14	IO									
		Driver off		15	I									
V13	vout1_d11	vout1_d11	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr11		1	IO									0
		vin2a_d3		2	I									0
		gpmc_a23		3	O									
		emu7		6	O									
		gpio3_4		14	IO									
		Driver off		15	I									
Y13	vout1_d12	vout1_d12	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr12		1	IO									0
		vin2a_d4		2	I									0
		gpmc_a24		3	O									
		emu8		6	O									
		gpio3_5		14	IO									
		Driver off mcasp2_ahclkx		15	I									
W13	vout1_d13	vout1_d13	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr13		1	IO									0
		vin2a_d5		2	I									0
		gpmc_a25		3	O									
		emu9		6	O									
		gpio3_6		14	IO									
		Driver off mcasp2_aclkr		15	I									
U11	vout1_d14	vout1_d14	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr14		1	IO									0
		vin2a_d6		2	I									0
		gpmc_a26		3	O									
		emu10		6	O									
		gpio3_7		14	IO									
		Driver off mcasp2_aclkx		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
V11	vout1_d15	vout1_d15	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_axr15		1	IO									0
		vin2a_d7		2	I									0
		gpmc_a27		3	O									
		emu11		6	O									
		gpio3_8		14	IO									
		Driver off mcasp2_fsx		15	I									
U9	vout1_d16	vout1_d16	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		mcasp1_ahclkx		1	O									
		vin2a_d8		2	I									0
		gpmc_a0		3	O									
		mcasp1_axr8		4	IO									0
		vin2b_d0		5	I									0
		emu12		6	O									
		gpio3_9		14	IO									
		Driver off		15	I									
W11	vout1_d17	vout1_d17	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d9		2	I									0
		gpmc_a1		3	O									
		mcasp1_axr9		4	IO									0
		vin2b_d1		5	I									0
		emu13		6	O									
		gpio3_10		14	IO									
		Driver off mcasp2_fsr		15	I									
V9	vout1_d18	vout1_d18	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d10		2	I									0
		gpmc_a2		3	O									
		mcasp1_axr10		4	IO									0
		vin2b_d2		5	I									0
		emu14		6	O									
		gpio3_11		14	IO									
		Driver off mcasp2_axr0		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics[1] (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
W9	vout1_d19	vout1_d19	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d11		2	I									0
		gpmc_a3		3	O									
		mcasp1_axr11		4	IO									0
		vin2b_d3		5	I									0
		emu15		6	O									
		gpio3_12		14	IO									
		Driver off mcasp2_axr1		15	I									
U8	vout1_d20	vout1_d20	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d12		2	I									0
		gpmc_a4		3	O									
		mcasp1_axr12		4	IO									0
		vin2b_d4		5	I									0
		emu16		6	O									
		gpio3_13		14	IO									
		Driver off mcasp2_axr2		15	I									
W8	vout1_d21	vout1_d21	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d13		2	I									0
		gpmc_a5		3	O									
		mcasp1_axr13		4	IO									0
		vin2b_d5		5	I									0
		emu17		6	O									
		gpio3_14		14	IO									
		Driver off mcasp2_axr3		15	I									
U7	vout1_d22	vout1_d22	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d14		2	I									0
		gpmc_a6		3	O									
		mcasp1_axr14		4	IO									0
		vin2b_d6		5	I									0
		emu18		6	O									
		gpio3_15		14	IO									
		Driver off mcasp2_axr4		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-2. Ball Characteristics(1) (continued)

BALL NUMBER [1]	BALL NAME [2]	SIGNAL NAME [3]	MA/LX/LA [4]	MUXMODE [5]	TYPE [6]	BALL RESET STATE [7]	BALL RESET REL. STATE [8]	BALL RESET REL. MUXMODE [9]	I/O VOLTAGE VALUE [10]	POWER [11]	HYS [12]	BUFFER TYPE [13]	PULL UP/DOWN TYPE [14]	DSIS [15]
V7	vout1_d23	vout1_d23	N / Y / N	0	O	PD	PD	15	1.8/3.3	vddshv6	Yes	Dual Voltage LVCMOS	PU/PD	
		vin2a_d15		2	I									0
		gpmc_a7		3	O									
		mcasp1_axr15		4	IO									0
		vin2b_d7		5	I									0
		emu19		6	O									
		gpio3_16		14	IO									
		Driver off mcasp2_axr5		15	I									
A1, A17, A22, A8, AB1, AB12, AB16, AB2, AB21, AB22, AB7, B22, E1, G10, G16, H10, H11, H15, H16, H8, H9, J22, K1, K10, K11, K13, K14, K15, K16, K9, M10, M11, M12, M13, M16, N10, N7, P1, P15, P16, R12, R16, R9, T14, V22	vss	vss			GND									
P21	vssa_adc	vssa_adc			GND									
B14	vssa_csi	vssa_csi			GND									
T19	vssa_dac	vssa_dac			GND									
D21	vssa_osc0	vssa_osc0			GND									
C22	vssa_osc1	vssa_osc1			GND									
E22	xi_osc0	xi_osc0		0	I			0	1.8	vdda_osc	Yes	LVCMOS Analog		
B21	xi_osc1	xi_osc1		0	I			0	1.8	vdda_osc	Yes	LVCMOS Analog		
D22	xo_osc0	xo_osc0		0	O			0	1.8	vdda_osc	Yes	LVCMOS Analog		
C21	xo_osc1	xo_osc1		0	O			0	1.8	vdda_osc	Yes	LVCMOS Analog		
M1	xref_clk0	xref_clk0		0	I	PD	PD	15	1.8/3.3	vddshv1	Yes	Dual Voltage LVCMOS	PU/PD	
		clkout0		1	O									
		spi3_cs0		4	IO									1
		spi2_cs1		5	IO									1
		spi1_cs0		6	IO									1
		spi1_cs1		7	IO									1
		gpio3_31		14	IO									
		Driver off		15	I									

Copyright © 2016–2020, Texas Instruments Incorporated

(1) N/A stands for Not Applicable.

(2) For more information on recommended operating conditions, see , *Recommended Operating Conditions*.

(3) The pullup or pulldown block strength is equal to: minimum = 50 μA, typical = 100 μA, maximum = 250 μA.

(4) The output impedance settings of this IO cell are programmable; by default, the value is DS[1:0] = 10, this means 40 Ω. For more information on DS[1:0] register configuration, see the Device TRM.

(5) In PUx / PDy, x and y = 60 to 300 μA.
The output impedance settings (or drive strengths) of this IO are programmable (60 Ω, 80 Ω, 120 Ω) depending on the values of the I[2:0] registers.

4.3 Multiplexing Characteristics

Table 4-3 describes the device multiplexing (no characteristics are available in this table).

NOTE

This table doesn't take into account subsystem multiplexing signals. Subsystem multiplexing signals are described in Section 4.4, *Signal Descriptions*.

NOTE

For more information, see the *Pad Configuration Registers* section in the device TRM.

NOTE

Configuring two pins to the same input signal is not supported as it can yield unexpected results. This can be easily prevented with the proper software configuration (Hi-Z mode is not an input signal).

NOTE

When a pad is set into a multiplexing mode which is not defined by pin multiplexing, that pad's behavior is undefined. This should be avoided.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in the corresponding tables.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
		E22	xi_osc0														
		N2	ddr1_a7														
		AB4	ddr1_d4														
		W1	ddr1_dqs2														
		U3	ddr1_d20														
		C1	ddr1_a1														
		M19	adc_in0														
		U1	ddr1_a9														
		Y6	ddr1_d7														
		A15	csi2_0_dx3														
		V1	ddr1_a15														
		AA2	ddr1_d17														
		T1	ddr1_a8														
		R3	ddr1_a11														
		AA3	ddr1_d16														
		Y1	ddr1_d23														
		Y17	ddr1_d14														
		AA20	ddr1_dqs1														
		AA6	ddr1_d0														
		F3	ddr1_cke0														
		Y20	ddr1_dqsn1														
		N21	adc_in5														
		T2	ddr1_a6														
		W2	ddr1_dqsn2														
		E3	ddr1_wen														
		P18	adc_in7														
		AA11	ddr1_ecc_d2														
		B3	ddr1_ba0														
		T17	cvideo_tvout														
		W22	ddr1_d30														
		B21	xi_osc1														
		V3	ddr1_d21														
		T20	ddr1_d25														
		A11	csi2_0_dx0														
		G2	ddr1_nck														
		U21	ddr1_d24														
		Y9	ddr1_ecc_d3														

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
		R21	ddr1_d26														
		U4	ddr1_a0														
		AB18	ddr1_d15														
		A3	ddr1_ba1														
		D2	ddr1_ba2														
		B15	csi2_0_dy3														
		AA21	ddr1_d10														
		AA8	ddr1_d1														
		B13	csi2_0_dy2														
		AB8	ddr1_dqm0														
		M22	adc_in3														
		D1	ddr1_a10														
		Y3	ddr1_d18														
		C21	xo_osc1														
		M20	adc_in1														
		R22	ddr1_d28														
		AA9	ddr1_ecc_d6														
		N3	ddr1_a5														
		P2	ddr1_odt0														
		T4	ddr1_a4														
		AB10	ddr1_dqsn_ecc														
		AB3	ddr1_dqm2														
		AA12	ddr1_ecc_d1														
		AA4	ddr1_d6														
		T18	cvideo_rset														
		N22	adc_in4														
		R4	ddr1_a3														
		V20	ddr1_d29														
		AB13	ddr1_dqm_ecc														
		AA5	ddr1_dqs0														
		A16	csi2_0_dx4														
		R2	ddr1_a14														
		Y2	ddr1_d22														
		Y21	ddr1_d9														
		W21	ddr1_dqm3														
		P20	adc_vrefp														

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
		Y5	ddr1_d5														
		F2	ddr1_casn														
		AB20	ddr1_d13														
		B11	csi2_0_dy0														
		AB9	ddr1_ecc_d7														
		D22	xo_osc0														
		U2	ddr1_a12														
		P19	adc_in6														
		AA18	ddr1_d8														
		U22	ddr1_d31														
		Y18	ddr1_dqm1														
		A13	csi2_0_dx2														
		T22	ddr1_dqsn3														
		G1	ddr1_ck														
		P17	cvideo_vfb														
		G3	porz														
		T21	ddr1_dqs3														
		Y22	ddr1_d11														
		AA19	ddr1_d12														
		AB5	ddr1_dqsn0														
		U20	ddr1_d27														
		AA13	ddr1_ecc_d4														
		B16	csi2_0_dy4														
		F1	ddr1_rasn														
		D3	ddr1_a2														
		AA10	ddr1_dqs_ecc														
		AA7	ddr1_d3														
		B2	ddr1_csn0														
		N1	ddr1_rst														
		V2	ddr1_d19														
		Y8	ddr1_d2														
		B12	csi2_0_dy1														
		C3	ddr1_a13														
		A12	csi2_0_dx1														
		AB11	ddr1_ecc_d5														
		M21	adc_in2														

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
		Y11	ddr1_ecc_d0														
0x1400	CTRL_CORE_PAD_GPMC_CLK	C12	gpmc_clk	rgmii1_txc				clkout0	dma_evt1							gpio1_0	Driver off
0x1404	CTRL_CORE_PAD_GPMC_BEN0	D12	gpmc_ben0	rgmii1_txctl			ehrpwm1A		dma_evt2							gpio1_1	Driver off
0x1408	CTRL_CORE_PAD_GPMC_BEN1	E12	gpmc_ben1	rgmii1_txd3			ehrpwm1B		dma_evt3							gpio1_2	Driver off
0x140C	CTRL_CORE_PAD_GPMC_ADVN_ALE	F12	gpmc_advn_ale	rgmii1_txd2			ehrpwm1_tripzone_input	clkout1	dma_evt4							gpio1_3	Driver off
0x1410	CTRL_CORE_PAD_GPMC_OEN_REN	A10	gpmc_oen_ren	rgmii1_txd1			ehrpwm1_synci	clkout2								gpio1_4	Driver off
0x1414	CTRL_CORE_PAD_GPMC_WEN	B10	gpmc_wen	rgmii1_txd0			ehrpwm1_synco									gpio1_5	Driver off
0x1418	CTRL_CORE_PAD_GPMC_CS0	C10	gpmc_cs0	rgmii1_rxctl												gpio1_6	Driver off
0x141C	CTRL_CORE_PAD_GPMC_CS1	E10	gpmc_cs1	qspi1_cs0												gpio1_7	Driver off
0x1420	CTRL_CORE_PAD_GPMC_CS2	D10	gpmc_cs2	qspi1_d3												gpio1_8	Driver off
0x1424	CTRL_CORE_PAD_GPMC_CS3	A9	gpmc_cs3	qspi1_d2												gpio1_9	Driver off
0x1428	CTRL_CORE_PAD_GPMC_CS4	B9	gpmc_cs4	qspi1_d0												gpio1_10	Driver off
0x142C	CTRL_CORE_PAD_GPMC_CS5	F10	gpmc_cs5	qspi1_d1												gpio1_11	Driver off
0x1430	CTRL_CORE_PAD_GPMC_CS6	C8	gpmc_cs6	qspi1_sclk												gpio1_12	Driver off
0x1434	CTRL_CORE_PAD_GPMC_WAIT0	D8	gpmc_wait0	rgmii1_rxd3	qspi1_rtclk				dma_evt4							gpio1_13	Driver off
0x1438	CTRL_CORE_PAD_GPMC_AD0	E8	gpmc_ad0	rgmii1_rxd2												gpio1_14	sysboot0
0x143C	CTRL_CORE_PAD_GPMC_AD1	A7	gpmc_ad1	rgmii1_rxd1												gpio1_15	sysboot1
0x1440	CTRL_CORE_PAD_GPMC_AD2	F8	gpmc_ad2	rgmii1_rxd0												gpio1_16	sysboot2
0x1444	CTRL_CORE_PAD_GPMC_AD3	B7	gpmc_ad3	qspi1_rtclk												gpio1_17	sysboot3
0x1448	CTRL_CORE_PAD_GPMC_AD4	A6	gpmc_ad4	cam_strobe												gpio1_18	sysboot4
0x144C	CTRL_CORE_PAD_GPMC_AD5	F7	gpmc_ad5		uart2_txd	timer6	spi3_d1									gpio1_19	sysboot5 mcasp2_aclkx
0x1450	CTRL_CORE_PAD_GPMC_AD6	E7	gpmc_ad6		uart2_rxd	timer5	spi3_d0									gpio1_20	sysboot6 mcasp2_fsx
0x1454	CTRL_CORE_PAD_GPMC_AD7	C6	gpmc_ad7	cam_shutter		timer4	spi3_sclk									gpio1_21	Driver off mcasp2_ahclkx

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
0x1458	CTRL_CORE_PAD_GPMC_AD8	B6	gpmc_ad8			timer7	spi3_cs0									gpio1_22	sysboot8 mcasp2_aclkr
0x145C	CTRL_CORE_PAD_GPMC_AD9	A5	gpmc_ad9			eCAP1_in_PWM1_out	spi3_cs1									gpio1_23	sysboot9 mcasp2_fsr
0x1460	CTRL_CORE_PAD_GPMC_AD10	D6	gpmc_ad10			timer2										gpio1_24	sysboot10 mcasp2_axr0
0x1464	CTRL_CORE_PAD_GPMC_AD11	C5	gpmc_ad11			timer3										gpio1_25	sysboot11 mcasp2_axr1
0x1468	CTRL_CORE_PAD_GPMC_AD12	B5	gpmc_ad12													gpio1_26	sysboot12 mcasp2_axr2
0x146C	CTRL_CORE_PAD_GPMC_AD13	D7	gpmc_ad13	rgmii1_rxc												gpio1_27	sysboot13 mcasp2_axr3
0x1470	CTRL_CORE_PAD_GPMC_AD14	B4	gpmc_ad14				spi2_cs1									gpio1_28	sysboot14 mcasp2_axr4
0x1474	CTRL_CORE_PAD_GPMC_AD15	A4	gpmc_ad15				spi2_cs0									gpio1_29	sysboot15 mcasp2_axr5
0x1478	CTRL_CORE_PAD_VIN1A_CLK0	F22	vin1a_clk0	cpi_pclk			clkout0									gpio1_30	Driver off mcasp3_aclkx
0x147C	CTRL_CORE_PAD_VIN1A_DE0	F21	vin1a_de0	cpi_hsync	vin1b_clk1		clkout1									gpio1_31	Driver off
0x1480	CTRL_CORE_PAD_VIN1A_FLD0	F20	vin1a_fld0	cpi_vsync	vin2b_clk1		clkout2									gpio2_0	Driver off mcasp3_aclkr
0x1484	CTRL_CORE_PAD_VIN1A_HSYNC0	F19	vin1a_hsync0	cpi_data0	vin1a_de0											gpio2_1	Driver off mcasp3_fsr
0x1488	CTRL_CORE_PAD_VIN1A_VSYNC0	G19	vin1a_vsync0	cpi_data1												gpio2_2	Driver off mcasp3_axr0
0x148C	CTRL_CORE_PAD_VIN1A_D0	G18	vin1a_d0	cpi_data2												gpio2_3	Driver off mcasp3_axr1
0x1490	CTRL_CORE_PAD_VIN1A_D1	G21	vin1a_d1	cpi_data3												gpio2_4	Driver off mcasp3_axr2
0x1494	CTRL_CORE_PAD_VIN1A_D2	G22	vin1a_d2	cpi_data4												gpio2_5	Driver off mcasp3_axr3
0x1498	CTRL_CORE_PAD_VIN1A_D3	H18	vin1a_d3	cpi_data5												gpio2_6	Driver off mcasp3_axr4
0x149C	CTRL_CORE_PAD_VIN1A_D4	H20	vin1a_d4	cpi_data6												gpio2_7	Driver off mcasp3_axr5

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
0x14A0	CTRL_CORE_PAD_VIN1A_D5	H19	vin1a_d5	cpi_data7												gpio2_8	xref_clk2 mcasp3_ahclkx
0x14A4	CTRL_CORE_PAD_VIN1A_D6	H22	vin1a_d6	cpi_data8												gpio2_9	Driver off mcasp3_fsx
0x14A8	CTRL_CORE_PAD_VIN1A_D7	H21	vin1a_d7	cpi_data9												gpio2_10	Driver off
0x14AC	CTRL_CORE_PAD_VIN1A_D8	J17	vin1a_d8	cpi_data10	vin1b_d0	gpmc_a8				sys_nirq2						gpio2_11	Driver off
0x14B0	CTRL_CORE_PAD_VIN1A_D9	K22	vin1a_d9	cpi_data11	vin1b_d1	gpmc_a9				sys_nirq1						gpio2_12	Driver off
0x14B4	CTRL_CORE_PAD_VIN1A_D10	K21	vin1a_d10	cpi_data12	vin1b_d2	gpmc_a10				sys_nirq2						gpio2_13	Driver off
0x14B8	CTRL_CORE_PAD_VIN1A_D11	K18	vin1a_d11	cpi_data13	vin1b_d3	gpmc_a11				sys_nirq1						gpio2_14	Driver off
0x14BC	CTRL_CORE_PAD_VIN1A_D12	K17	vin1a_d12	cpi_data14	vin1b_d4	gpmc_a12			dma_evt1							gpio2_15	Driver off
0x14C0	CTRL_CORE_PAD_VIN1A_D13	K19	vin1a_d13	cpi_wen	vin1b_d5	gpmc_a13			dma_evt2							gpio2_16	Driver off
0x14C4	CTRL_CORE_PAD_VIN1A_D14	K20	vin1a_d14	cpi_fid	vin1b_d6	gpmc_a14										gpio2_17	Driver off
0x14C8	CTRL_CORE_PAD_VIN1A_D15	L21	vin1a_d15	cpi_data15	vin1b_d7	gpmc_a15										gpio2_18	Driver off
0x14CC	CTRL_CORE_PAD_VIN2A_CLK0	L22	vin2a_clk0													gpio2_19	Driver off
0x14D0	CTRL_CORE_PAD_VIN2A_DE0	M17	vin2a_de0	cam_strobe	vin2b_hsync1			vin2b_de1								gpio4_21	Driver off
0x14D4	CTRL_CORE_PAD_VIN2A_FLD0	M18	vin2a_fld0	cam_shutter	vin2b_vsync1											gpio4_22	Driver off
0x14D8	CTRL_CORE_PAD_VOUT1_CLK	AB17	vout1_clk		vin1a_d12		clkout0					vin2a_clk0				gpio2_20	Driver off
0x14DC	CTRL_CORE_PAD_VOUT1_DE	U17	vout1_de	mcasp1_aclkx	vin1a_d13		clkout1									gpio2_21	Driver off
0x14E0	CTRL_CORE_PAD_VOUT1_FLD	W17	vout1_fld	mcasp1_fsx	vin1a_d14		clkout2									gpio2_22	Driver off
0x14E4	CTRL_CORE_PAD_VOUT1_HSYNC	AA17	vout1_hsync	mcasp1_aclkr	vin1a_d15							vin2a_de0				gpio2_23	Driver off
0x14E8	CTRL_CORE_PAD_VOUT1_VSYNC	U16	vout1_vsync	mcasp1_fsr								vin2a_fld0				gpio2_24	Driver off
0x14EC	CTRL_CORE_PAD_VOUT1_D0	W16	vout1_d0	mcasp1_axr0				mmc_clk								gpio2_25	Driver off
0x14F0	CTRL_CORE_PAD_VOUT1_D1	V16	vout1_d1	mcasp1_axr1				mmc_cmd								gpio2_26	Driver off
0x14F4	CTRL_CORE_PAD_VOUT1_D2	U15	vout1_d2	mcasp1_axr2			mcasp1_axr8	mmc_dat0								gpio2_27	Driver off
0x14F8	CTRL_CORE_PAD_VOUT1_D3	V15	vout1_d3	mcasp1_axr3			mcasp1_axr9	mmc_dat1								gpio2_28	Driver off

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
0x14FC	CTRL_CORE_PAD_VOUT1_D4	Y15	vout1_d4	mcasp1_axr4			mcasp1_axr10	mmc_dat2								gpio2_29	Driver off
0x1500	CTRL_CORE_PAD_VOUT1_D5	W15	vout1_d5	mcasp1_axr5			mcasp1_axr11	mmc_dat3				vin2a_clk0				gpio2_30	Driver off
0x1504	CTRL_CORE_PAD_VOUT1_D6	AA15	vout1_d6	mcasp1_axr6			mcasp1_axr12	esm_error	emu2			vin2a_de0				gpio2_31	Driver off
0x1508	CTRL_CORE_PAD_VOUT1_D7	AB15	vout1_d7	mcasp1_axr7		eCAP1_in_PWM1_out	mcasp1_axr13		emu3			vin2a_fld0				gpio3_0	Driver off
0x150C	CTRL_CORE_PAD_VOUT1_D8	AA14	vout1_d8	mcasp1_axr8	vin2a_d0	gpmc_a20			emu4							gpio3_1	Driver off
0x1510	CTRL_CORE_PAD_VOUT1_D9	AB14	vout1_d9	mcasp1_axr9	vin2a_d1	gpmc_a21			emu5							gpio3_2	Driver off
0x1514	CTRL_CORE_PAD_VOUT1_D10	U13	vout1_d10	mcasp1_axr10	vin2a_d2	gpmc_a22			emu6							gpio3_3	Driver off
0x1518	CTRL_CORE_PAD_VOUT1_D11	V13	vout1_d11	mcasp1_axr11	vin2a_d3	gpmc_a23			emu7							gpio3_4	Driver off
0x151C	CTRL_CORE_PAD_VOUT1_D12	Y13	vout1_d12	mcasp1_axr12	vin2a_d4	gpmc_a24			emu8							gpio3_5	Driver off mcasp2_ahclkx
0x1520	CTRL_CORE_PAD_VOUT1_D13	W13	vout1_d13	mcasp1_axr13	vin2a_d5	gpmc_a25			emu9							gpio3_6	Driver off mcasp2_aclkr
0x1524	CTRL_CORE_PAD_VOUT1_D14	U11	vout1_d14	mcasp1_axr14	vin2a_d6	gpmc_a26			emu10							gpio3_7	Driver off mcasp2_aclkx
0x1528	CTRL_CORE_PAD_VOUT1_D15	V11	vout1_d15	mcasp1_axr15	vin2a_d7	gpmc_a27			emu11							gpio3_8	Driver off mcasp2_fsx
0x152C	CTRL_CORE_PAD_VOUT1_D16	U9	vout1_d16	mcasp1_ahclkx	vin2a_d8	gpmc_a0	mcasp1_axr8	vin2b_d0	emu12							gpio3_9	Driver off
0x1530	CTRL_CORE_PAD_VOUT1_D17	W11	vout1_d17		vin2a_d9	gpmc_a1	mcasp1_axr9	vin2b_d1	emu13							gpio3_10	Driver off mcasp2_fsr
0x1534	CTRL_CORE_PAD_VOUT1_D18	V9	vout1_d18		vin2a_d10	gpmc_a2	mcasp1_axr10	vin2b_d2	emu14							gpio3_11	Driver off mcasp2_axr0
0x1538	CTRL_CORE_PAD_VOUT1_D19	W9	vout1_d19		vin2a_d11	gpmc_a3	mcasp1_axr11	vin2b_d3	emu15							gpio3_12	Driver off mcasp2_axr1
0x153C	CTRL_CORE_PAD_VOUT1_D20	U8	vout1_d20		vin2a_d12	gpmc_a4	mcasp1_axr12	vin2b_d4	emu16							gpio3_13	Driver off mcasp2_axr2
0x1540	CTRL_CORE_PAD_VOUT1_D21	W8	vout1_d21		vin2a_d13	gpmc_a5	mcasp1_axr13	vin2b_d5	emu17							gpio3_14	Driver off mcasp2_axr3
0x1544	CTRL_CORE_PAD_VOUT1_D22	U7	vout1_d22		vin2a_d14	gpmc_a6	mcasp1_axr14	vin2b_d6	emu18							gpio3_15	Driver off mcasp2_axr4
0x1548	CTRL_CORE_PAD_VOUT1_D23	V7	vout1_d23		vin2a_d15	gpmc_a7	mcasp1_axr15	vin2b_d7	emu19							gpio3_16	Driver off mcasp2_axr5

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
0x154C	CTRL_CORE_PAD_MCAN_TX	W7	mcan_tx	vin2a_de0	vin2a_hsync0	spi1_cs2	uart3_rxd		gpmc_wait1	vin1b_hsync1	vin1b_de1					gpio4_11	Driver off
0x1550	CTRL_CORE_PAD_MCAN_RX	W6	mcan_rx	cam_nreset	vin2a_vsync0	spi1_cs3	uart3_txd	gpmc_cs7		vin1b_vsync1						gpio4_12	Driver off
0x1554	CTRL_CORE_PAD_MDIO_MCLK	B19	mdio_mclk				spi4_d1									gpio3_17	Driver off
0x1558	CTRL_CORE_PAD_MDIO_D	B17	mdio_d				spi4_d0	esm_error								gpio3_18	Driver off
0x155C	CTRL_CORE_PAD_RGMII0_TXC	C16	rgmii0_txc			cam_strobe	spi4_sclk	mmc_clk								gpio3_19	Driver off
0x1560	CTRL_CORE_PAD_RGMII0_TXCTL	C17	rgmii0_txctl			cam_shutter	spi4_cs0	mmc_cmd								gpio3_20	Driver off
0x1564	CTRL_CORE_PAD_RGMII0_TXD3	E16	rgmii0_txd3					mmc_dat0								gpio3_21	Driver off
0x1568	CTRL_CORE_PAD_RGMII0_TXD2	D16	rgmii0_txd2			eCAP1_in_PWM1_out		mmc_dat1								gpio3_22	Driver off
0x156C	CTRL_CORE_PAD_RGMII0_TXD1	E17	rgmii0_txd1					mmc_dat2								gpio3_23	Driver off
0x1570	CTRL_CORE_PAD_RGMII0_TXD0	F17	rgmii0_txd0					mmc_dat3								gpio3_24	Driver off
0x1574	CTRL_CORE_PAD_RGMII0_RXC	B18	rgmii0_rxc			cam_strobe		mmc_clk								gpio3_25	Driver off
0x1578	CTRL_CORE_PAD_RGMII0_RXCTL	C18	rgmii0_rxctl			cam_shutter		mmc_cmd								gpio3_26	Driver off
0x157C	CTRL_CORE_PAD_RGMII0_RXD3	A19	rgmii0_rxd3					mmc_dat0								gpio3_27	Driver off
0x1580	CTRL_CORE_PAD_RGMII0_RXD2	B20	rgmii0_rxd2					mmc_dat1								gpio3_28	Driver off
0x1584	CTRL_CORE_PAD_RGMII0_RXD1	C20	rgmii0_rxd1					mmc_dat2								gpio3_29	Driver off
0x1588	CTRL_CORE_PAD_RGMII0_RXD0	A20	rgmii0_rxd0					mmc_dat3								gpio3_30	Driver off
0x158C	CTRL_CORE_PAD_XREF_CLK0	M1	xref_clk0	clkout0			spi3_cs0	spi2_cs1	spi1_cs0	spi1_cs1						gpio3_31	Driver off
0x1590	CTRL_CORE_PAD_SPI1_SCLK	M2	spi1_sclk	uart3_rxd												gpio4_0	Driver off
0x1594	CTRL_CORE_PAD_SPI1_D1	U6	spi1_d1	uart3_ctsn												gpio4_1	Driver off
0x1598	CTRL_CORE_PAD_SPI1_D0	T5	spi1_d0	uart3_rtsn												gpio4_2	Driver off
0x159C	CTRL_CORE_PAD_SPI1_CS0	R6	spi1_cs0	uart3_txd												gpio4_3	Driver off
0x15A0	CTRL_CORE_PAD_SPI1_CS1	R5	spi1_cs1	spi3_cs1			timer6			ehrpwm1_tripzone_input						gpio4_4	Driver off
0x15A4	CTRL_CORE_PAD_SPI2_SCLK	L1	spi2_sclk	uart3_rxd	ehrpwm1A	timer3										gpio4_5	Driver off
0x15A8	CTRL_CORE_PAD_SPI2_D1	N4	spi2_d1	uart3_ctsn		timer5				eCAP1_in_PWM1_out						gpio4_6	Driver off

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
0x15AC	CTRL_CORE_PAD_SPI2_D0	R7	spi2_d0	uart3_rtsn		timer1										gpio4_7	sysboot7
0x15B0	CTRL_CORE_PAD_SPI2_CS0	L2	spi2_cs0	uart3_txd	ehrpwm1B	timer4										gpio4_8	Driver off
0x15B8	CTRL_CORE_PAD_DCAN1_RX	N6	dcan1_rx													gpio4_10	Driver off
0x15B4	CTRL_CORE_PAD_DCAN1_TX	N5	dcan1_tx													gpio4_9	Driver off
0x15BC	CTRL_CORE_PAD_UART1_RXD	F13	uart1_rxd				spi4_d1	qspi1_rtclk					gpmc_a12		mcan_tx	gpio4_13	Driver off
0x15C0	CTRL_CORE_PAD_UART1_TXD	E14	uart1_txd				spi4_d0						gpmc_a13		mcan_rx	gpio4_14	Driver off
0x15C4	CTRL_CORE_PAD_UART1_CTSN	F14	uart1_ctsn	xref_clk1	uart3_rxd	gpmc_a16	spi4_sclk	spi1_cs2	timer3	ehrpwm1_synci	clkout0	vin2a_hsync0	gpmc_a12	gpmc_clk	dcan1_tx	gpio4_15	Driver off
0x15C8	CTRL_CORE_PAD_UART1_RTSN	C14	uart1_rtsn		uart3_txd	gpmc_a17	spi4_cs0	spi1_cs3	timer4	ehrpwm1_synco	qspi1_rtclk	vin2a_vsync0	gpmc_a13		dcan1_rx	gpio4_16	Driver off
0x15CC	CTRL_CORE_PAD_UART2_RXD	D14	uart2_rxd				spi3_d1		timer1	ehrpwm1A			gpmc_clk	gpmc_a12	dcan1_tx	gpio4_17	Driver off
0x15D0	CTRL_CORE_PAD_UART2_TXD	D15	uart2_txd				spi3_d0		timer2	ehrpwm1B				gpmc_a13	dcan1_rx	gpio4_18	Driver off
0x15D4	CTRL_CORE_PAD_UART2_CTSN	F15	uart2_ctsn		xref_clk1	gpmc_a18	spi3_sclk	qspi1_cs1	timer7			vin2a_hsync0	gpmc_clk		mcan_tx	gpio4_19	Driver off
0x15D8	CTRL_CORE_PAD_UART2_RTSN	F16	uart2_rtsn	eCAP1_in_PWM1_out		gpmc_a19	spi3_cs0		timer8			vin2a_vsync0			mcan_rx	gpio4_20	Driver off
0x15DC	CTRL_CORE_PAD_I2C1_SDA	L4	i2c1_sda														
0x15E0	CTRL_CORE_PAD_I2C1_SCL	L3	i2c1_scl														
0x15E4	CTRL_CORE_PAD_I2C2_SDA	L5	i2c2_sda														
0x15E8	CTRL_CORE_PAD_I2C2_SCL	L6	i2c2_scl														
0x15EC	CTRL_CORE_PAD_TMS	J3	tms														
0x15F0	CTRL_CORE_PAD_TDI	J1	tdi													gpio4_25	Driver off
0x15F4	CTRL_CORE_PAD_TDO	J4	tdo													gpio4_26	Driver off
0x15F8	CTRL_CORE_PAD_TCLK	J2	tclk														
0x15FC	CTRL_CORE_PAD_TRSTN	J5	trstn														
0x1600	CTRL_CORE_PAD_RTCK	J6	rtck													gpio4_27	Driver off
0x1604	CTRL_CORE_PAD_EMU0	H1	emu0													gpio4_28	Driver off
0x1608	CTRL_CORE_PAD_EMU1	H2	emu1													gpio4_29	Driver off

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-3. Multiplexing Characteristics (continued)

ADDRESS	REGISTER NAME	BALL NUMBER	MUXMODE[15:0] SETTINGS														
			0	1	2	3	4	5	6	7	8	9	10	11	12	14	15
0x160C	CTRL_CORE_PAD_RESETN	G4	resetn														
0x1610	CTRL_CORE_PAD_NMIN	G5	nmin														
0x1614	CTRL_CORE_PAD_RSTOUTN	F4	rstoutn														

1. NA in table stands for Not Applicable.

Copyright © 2016–2020, Texas Instruments Incorporated

4.4 Signal Descriptions

Many signals are available on multiple pins, according to the software configuration of the pin multiplexing options.

1. **SIGNAL NAME:** The name of the signal passing through the pin.

NOTE

The subsystem multiplexing signals are not described in Table 4-2 and Table 4-3.

2. **DESCRIPTION:** Description of the signal
3. **TYPE:** Signal direction and type:
   - I = Input
   - O = Output
   - IO = Input or output
   - D = Open Drain
   - DS = Differential
   - A = Analog
   - PWR = Power
   - GND = Ground
4. **BALL:** Associated ball(s) bottom

NOTE

For more information, see the *Control Module Register Manual* section in the device TRM.

4.4.1 Video Input Ports (VIP)

NOTE

For more information, see the *Video Input Port (VIP)* section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid for VIN1 and VIN2 if signals within a single IOSET are used. The IOSETs are defined in Table 7-3 and Table 7-4.

Table 4-4. VIP Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
Video Input 1			
vin1a_clk0	Video Input 1 Port A Clock input. Input clock for 8-bit 16-bit or 24-bit Port A video capture. Input data is sampled on the CLK0 edge.	I	F22
vin1a_d0	Video Input 1 Port A Data input	I	G18
vin1a_d1	Video Input 1 Port A Data input	I	G21
vin1a_d2	Video Input 1 Port A Data input	I	G22
vin1a_d3	Video Input 1 Port A Data input	I	H18
vin1a_d4	Video Input 1 Port A Data input	I	H20
vin1a_d5	Video Input 1 Port A Data input	I	H19
vin1a_d6	Video Input 1 Port A Data input	I	H22
vin1a_d7	Video Input 1 Port A Data input	I	H21
vin1a_d8	Video Input 1 Port A Data input	I	J17

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-4. VIP Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
vin1a_d9	Video Input 1 Port A Data input	I	K22
vin1a_d10	Video Input 1 Port A Data input	I	K21
vin1a_d11	Video Input 1 Port A Data input	I	K18
vin1a_d12	Video Input 1 Port A Data input	I	AB17, K17
vin1a_d13	Video Input 1 Port A Data input	I	K19, U17
vin1a_d14	Video Input 1 Port A Data input	I	K20, W17
vin1a_d15	Video Input 1 Port A Data input	I	AA17, L21
vin1a_de0	Video Input 1 Port A Field ID input	I	F19, F21
vin1a_fld0	Video Input 1 Port A Field ID input	I	F20
vin1a_hsync0	Video Input 1 Port A Horizontal Sync input	I	F19
vin1a_vsync0	Video Input 1 Port A Vertical Sync input	I	G19
vin1b_clk1	Video Input 1 Port B Clock input	I	F21
vin1b_d0	Video Input 1 Port B Data input	I	J17
vin1b_d1	Video Input 1 Port B Data input	I	K22
vin1b_d2	Video Input 1 Port B Data input	I	K21
vin1b_d3	Video Input 1 Port B Data input	I	K18
vin1b_d4	Video Input 1 Port B Data input	I	K17
vin1b_d5	Video Input 1 Port B Data input	I	K19
vin1b_d6	Video Input 1 Port B Data input	I	K20
vin1b_d7	Video Input 1 Port B Data input	I	L21
vin1b_de1	Video Input 1 Port B Field ID input	I	W7
vin1b_hsync1	Video Input 1 Port B Horizontal Sync input	I	W7
vin1b_vsync1	Video Input 1 Port B Vertical Sync input	I	W6
Video Input 2			
vin2a_clk0	Video Input 2 Port A Clock input	I	AB17, L22, W15
vin2a_d0	Video Input 2 Port A Data input	I	AA14
vin2a_d1	Video Input 2 Port A Data input	I	AB14
vin2a_d2	Video Input 2 Port A Data input	I	U13
vin2a_d3	Video Input 2 Port A Data input	I	V13
vin2a_d4	Video Input 2 Port A Data input	I	Y13
vin2a_d5	Video Input 2 Port A Data input	I	W13
vin2a_d6	Video Input 2 Port A Data input	I	U11
vin2a_d7	Video Input 2 Port A Data input	I	V11
vin2a_d8	Video Input 2 Port A Data input	I	U9
vin2a_d9	Video Input 2 Port A Data input	I	W11
vin2a_d10	Video Input 2 Port A Data input	I	V9
vin2a_d11	Video Input 2 Port A Data input	I	W9
vin2a_d12	Video Input 2 Port A Data input	I	U8
vin2a_d13	Video Input 2 Port A Data input	I	W8
vin2a_d14	Video Input 2 Port A Data input	I	U7
vin2a_d15	Video Input 2 Port A Data input	I	V7
vin2a_de0	Video Input 2 Port A Field ID input	I	AA15, AA17, M17, W7
vin2a_fld0	Video Input 2 Port A Field ID input	I	AB15, M18, U16
vin2a_hsync0	Video Input 2 Port A Horizontal Sync input	I	F14, F15, W7
vin2a_vsync0	Video Input 2 Port A Vertical Sync input	I	C14, F16, W6
vin2b_clk1	Video Input 2 Port B Clock input	I	F20
vin2b_d0	Video Input 2 Port B Data input	I	U9

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-4. VIP Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
vin2b_d1	Video Input 2 Port B Data input	I	W11
vin2b_d2	Video Input 2 Port B Data input	I	V9
vin2b_d3	Video Input 2 Port B Data input	I	W9
vin2b_d4	Video Input 2 Port B Data input	I	U8
vin2b_d5	Video Input 2 Port B Data input	I	W8
vin2b_d6	Video Input 2 Port B Data input	I	U7
vin2b_d7	Video Input 2 Port B Data input	I	V7
vin2b_de1	Video Input 2 Port B Field ID input	I	M17
vin2b_hsync1	Video Input 2 Port B Horizontal Sync input	I	M17
vin2b_vsync1	Video Input 2 Port B Vertical Sync input	I	M18

4.4.2 Display Subsystem – Video Output Ports

Table 4-5. DSS Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
DPI Video Output 1			
vout1_clk	Video Output 1 Clock output	O	AB17
vout1_d0	Video Output 1 Data output	O	W16
vout1_d1	Video Output 1 Data output	O	V16
vout1_d2	Video Output 1 Data output	O	U15
vout1_d3	Video Output 1 Data output	O	V15
vout1_d4	Video Output 1 Data output	O	Y15
vout1_d5	Video Output 1 Data output	O	W15
vout1_d6	Video Output 1 Data output	O	AA15
vout1_d7	Video Output 1 Data output	O	AB15
vout1_d8	Video Output 1 Data output	O	AA14
vout1_d9	Video Output 1 Data output	O	AB14
vout1_d10	Video Output 1 Data output	O	U13
vout1_d11	Video Output 1 Data output	O	V13
vout1_d12	Video Output 1 Data output	O	Y13
vout1_d13	Video Output 1 Data output	O	W13
vout1_d14	Video Output 1 Data output	O	U11
vout1_d15	Video Output 1 Data output	O	V11
vout1_d16	Video Output 1 Data output	O	U9
vout1_d17	Video Output 1 Data output	O	W11
vout1_d18	Video Output 1 Data output	O	V9
vout1_d19	Video Output 1 Data output	O	W9
vout1_d20	Video Output 1 Data output	O	U8
vout1_d21	Video Output 1 Data output	O	W8
vout1_d22	Video Output 1 Data output	O	U7
vout1_d23	Video Output 1 Data output	O	V7
vout1_de	Video Output 1 Data Enable output	O	U17
vout1_fld	Video Output 1 Field ID output. This signal is not used for embedded sync modes.	O	W17
vout1_hsync	Video Output 1 Horizontal Sync output. This signal is not used for embedded sync modes.	O	AA17
vout1_vsync	Video Output 1 Vertical Sync output. This signal is not used for embedded sync modes.	O	U16

Copyright © 2016–2020, Texas Instruments Incorporated

4.4.3 Digital-to-Analog Converter (SD_DAC)

NOTE

For more information, see *Video Encoder Overview* in the device TRM.

Table 4-6. CVIDEO SD_DAC Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
cvideo_tvout	SD_DAC TV analog composite output	A	T17
cvideo_vfb	SD_DAC input feedback thru resistor to out	A	P17
cvideo_rset	SD_DAC input reference current resistor setting	A	T18

4.4.4 Embedded 8 channel Analog-To-Digital Converter (ADC)

NOTE

For more information, see the *ADC Overview* in the device TRM.

Table 4-7. ADC Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
adc_in0	ADC analog channel input 0	A	M19
adc_in1	ADC analog channel input 1	A	M20
adc_in2	ADC analog channel input 2	A	M21
adc_in3	ADC analog channel input 3	A	M22
adc_in4	ADC analog channel input 4	A	N22
adc_in5	ADC analog channel input 5	A	N21
adc_in6	ADC analog channel input 6	A	P19
adc_in7	ADC analog channel input 7	A	P18
adc_vrefp	ADC positive reference voltage	A	P20

4.4.5 Camera Control

NOTE

For more information, see the *Imaging Subsystem (ISS)* section in the device TRM.

Table 4-8. Camera Control Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
cam_strobe	Camera flash activation trigger	O	A6, B18, C16, M17
cam_shutter	Camera mechanical shutter control	O	C6, C18, C17, M18
cam_nreset	Camera sensor reset	IO	W6

4.4.6 Camera Parallel Interface (CPI)

Table 4-9. CPI Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
cpi_pclk	Camera pixel clock	I	F22
cpi_hsync	Camera horizontal synchonization	IO	F21
cpi_vsync	Camera vertical synchonization	IO	F20
cpi_data0	Camera parallel data 0	I	F19

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-9. CPI Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
cpi_data1	Camera parallel data 1	I	G19
cpi_data2	Camera parallel data 2	I	G18
cpi_data3	Camera parallel data 3	I	G21
cpi_data4	Camera parallel data 4	I	G22
cpi_data5	Camera parallel data 5	I	H18
cpi_data6	Camera parallel data 6	I	H20
cpi_data7	Camera parallel data 7	I	H19
cpi_data8	Camera parallel data 8	I	H22
cpi_data9	Camera parallel data 9	I	H21
cpi_data10	Camera parallel data 10	I	J17
cpi_data11	Camera parallel data 11	I	K22
cpi_data12	Camera parallel data 12	I	K21
cpi_data13	Camera parallel data 13	I	K18
cpi_data14	Camera parallel data 14	I	K17
cpi_data15	Camera parallel data 15	I	L21
cpi_wen	Camera parallel external write enable	I	K19
cpi_fid	Camera parallel field identification for interlaced sensors (i mode)	IO	K20

Copyright © 2016–2020, Texas Instruments Incorporated

4.4.7 Imaging Subsystem (ISS)

NOTE

For more information, see the *Imaging Subsystem* in the device TRM.

CAUTION

The IO timings provided in Section 7 *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-6.

Table 4-10. CSI 2 Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
csi2_0_dx0	Serial Differential data/clock positive input - lane 0 (position 1)	I	A11
csi2_0_dy0	Serial Differential data/clock negative input - lane 0 (position 1)	I	B11
csi2_0_dx1	Serial Differential data/clock positive input - lane 1 (position 2)	I	A12
csi2_0_dy1	Serial Differential data/clock negative input - lane 1 (position 2)	I	B12
csi2_0_dx2	Serial Differential data/clock positive input - lane 2 (position 3)	I	A13
csi2_0_dy2	Serial Differential data/clock negative input - lane 2 (position 3)	I	B13
csi2_0_dx3	Serial Differential data/clock positive input - lane 3 (position 4)	I	A15
csi2_0_dy3	Serial Differential data/clock negative input - lane 3 (position 4)	I	B15
csi2_0_dx4	Serial Differential data positive input only - lane 4 (position 5) (1)	I	A16
csi2_0_dy4	Serial Differential data negative input only - lane 4 (position 5) (1)	I	B16

(1) Lane 4 (position 5) supports only data. For more information, see the *Imaging Subsystem* in the device TRM.

4.4.8 External Memory Interface (EMIF)

NOTE

For more information, see the *EMIF Controller* section in the device TRM.

NOTE

The index number 1 which is part of the EMIF1 signal prefixes (ddr1_*) listed in Table 4-11, EMIF Signal Descriptions, column "SIGNAL NAME" is not to be confused with DDR1 type of SDRAM memories.

Table 4-11. EMIF Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
ddr1_cke0	EMIF1 Clock Enable 0	O	F3
ddr1_nck	EMIF1 Negative Clock	O	G2
ddr1_odt0	EMIF1 On-Die Termination for Chip Select 0	O	P2
ddr1_rasn	EMIF1 Row Address Strobe; When LPDDR2 is used this signal functions as to ddr1_ca0	O	F1
ddr1_rst	EMIF1 Reset output	O	N1
ddr1_wen	EMIF1 Write Enable; When LPDDR2 is used this signal functions as ddr1_ca2	O	E3
ddr1_csn0	EMIF1 Chip Select 0	O	B2
ddr1_ck	EMIF1 Clock	O	G1
ddr1_casn	EMIF1 Column Address Strobe; When LPDDR2 is used this signal functions as ddr1_ca1	O	F2

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-11. EMIF Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
ddr1_ba0	EMIF1 Bank Address; When LPDDR2 is used this signal functions as ddr1_ca7	O	B3
ddr1_ba1	EMIF1 Bank Address; When LPDDR2 is used this signal functions as ddr1_ca8	O	A3
ddr1_ba2	EMIF1 Bank Address; When LPDDR2 is used this signal functions as ddr1_ca9	O	D2
ddr1_a0	EMIF1 Address Bus	O	U4
ddr1_a1	EMIF1 Address Bus; When LPDDR2 is used this signal functions as ddr1_ca5	O	C1
ddr1_a2	EMIF1 Address Bus; When LPDDR2 is used this signal functions as ddr1_ca6	O	D3
ddr1_a3	EMIF1 Address Bus	O	R4
ddr1_a4	EMIF1 Address Bus	O	T4
ddr1_a5	EMIF1 Address Bus	O	N3
ddr1_a6	EMIF1 Address Bus	O	T2
ddr1_a7	EMIF1 Address Bus	O	N2
ddr1_a8	EMIF1 Address Bus	O	T1
ddr1_a9	EMIF1 Address Bus	O	U1
ddr1_a10	EMIF1 Address Bus; When LPDDR2 is used this signal functions as ddr1_ca4	O	D1
ddr1_a11	EMIF1 Address Bus	O	R3
ddr1_a12	EMIF1 Address Bus	O	U2
ddr1_a13	EMIF1 Address Bus; When LPDDR2 is used this signal functions as ddr1_ca3	O	C3
ddr1_a14	EMIF1 Address Bus	O	R2
ddr1_a15	EMIF1 Address Bus	O	V1
ddr1_d0	EMIF1 Data Bus	IO	AA6
ddr1_d1	EMIF1 Data Bus	IO	AA8
ddr1_d2	EMIF1 Data Bus	IO	Y8
ddr1_d3	EMIF1 Data Bus	IO	AA7
ddr1_d4	EMIF1 Data Bus	IO	AB4
ddr1_d5	EMIF1 Data Bus	IO	Y5
ddr1_d6	EMIF1 Data Bus	IO	AA4
ddr1_d7	EMIF1 Data Bus	IO	Y6
ddr1_d8	EMIF1 Data Bus	IO	AA18
ddr1_d9	EMIF1 Data Bus	IO	Y21
ddr1_d10	EMIF1 Data Bus	IO	AA21
ddr1_d11	EMIF1 Data Bus	IO	Y22
ddr1_d12	EMIF1 Data Bus	IO	AA19
ddr1_d13	EMIF1 Data Bus	IO	AB20
ddr1_d14	EMIF1 Data Bus	IO	Y17
ddr1_d15	EMIF1 Data Bus	IO	AB18
ddr1_d16	EMIF1 Data Bus	IO	AA3
ddr1_d17	EMIF1 Data Bus	IO	AA2
ddr1_d18	EMIF1 Data Bus	IO	Y3
ddr1_d19	EMIF1 Data Bus	IO	V2
ddr1_d20	EMIF1 Data Bus	IO	U3
ddr1_d21	EMIF1 Data Bus	IO	V3
ddr1_d22	EMIF1 Data Bus	IO	Y2
ddr1_d23	EMIF1 Data Bus	IO	Y1
ddr1_d24	EMIF1 Data Bus	IO	U21
ddr1_d25	EMIF1 Data Bus	IO	T20
ddr1_d26	EMIF1 Data Bus	IO	R21
ddr1_d27	EMIF1 Data Bus	IO	U20

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-11. EMIF Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
ddr1_d28	EMIF1 Data Bus	IO	R22
ddr1_d29	EMIF1 Data Bus	IO	V20
ddr1_d30	EMIF1 Data Bus	IO	W22
ddr1_d31	EMIF1 Data Bus	IO	U22
ddr1_ecc_d0	EMIF1 ECC Data Bus	IO	Y11
ddr1_ecc_d1	EMIF1 ECC Data Bus	IO	AA12
ddr1_ecc_d2	EMIF1 ECC Data Bus	IO	AA11
ddr1_ecc_d3	EMIF1 ECC Data Bus	IO	Y9
ddr1_ecc_d4	EMIF1 ECC Data Bus	IO	AA13
ddr1_ecc_d5	EMIF1 ECC Data Bus	IO	AB11
ddr1_ecc_d6	EMIF1 ECC Data Bus	IO	AA9
ddr1_ecc_d7	EMIF1 ECC Data Bus	IO	AB9
ddr1_dqm0	EMIF1 Data Mask	IO	AB8
ddr1_dqm1	EMIF1 Data Mask	IO	Y18
ddr1_dqm2	EMIF1 Data Mask	IO	AB3
ddr1_dqm3	EMIF1 Data Mask	IO	W21
ddr1_dqm_ecc	EMIF1 ECC Data Mask	IO	AB13
ddr1_dqs0	Data strobe 0 input/output for byte 0 of the 32-bit data bus. This signal is output to the EMIF1 memory when writing and input when reading.	IO	AA5
ddr1_dqs1	Data strobe 1 input/output for byte 1 of the 32-bit data bus. This signal is output to the EMIF1 memory when writing and input when reading.	IO	AA20
ddr1_dqs2	Data strobe 2 input/output for byte 2 of the 32-bit data bus. This signal is output to the EMIF1 memory when writing and input when reading.	IO	W1
ddr1_dqs3	Data strobe 3 input/output for byte 3 of the 32-bit data bus. This signal is output to the EMIF1 memory when writing and input when reading.	IO	T21
ddr1_dqsn0	Data strobe 0 invert	IO	AB5
ddr1_dqsn1	Data strobe 1 invert	IO	Y20
ddr1_dqsn2	Data strobe 2 invert	IO	W2
ddr1_dqsn3	Data strobe 3 invert	IO	T22
ddr1_dqsn_ecc	EMIF1 ECC Complementary Data strobe	IO	AB10
ddr1_dqs_ecc	EMIF1 ECC Data strobe input/output. This signal is output to the EMIF1 memory when writing and input when reading.	IO	AA10

4.4.9 General-Purpose Memory Controller (GPMC)

NOTE

For more information, see the *General-Purpose Memory Controller* section in the device TRM.

Table 4-12. GPMC Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
gpmc_ad0	GPMC Data 0 in A/D nonmultiplexed mode and additionally Address 1 in A/D multiplexed mode	IO	E8
gpmc_ad1	GPMC Data 1 in A/D nonmultiplexed mode and additionally Address 2 in A/D multiplexed mode	IO	A7
gpmc_ad2	GPMC Data 2 in A/D nonmultiplexed mode and additionally Address 3 in A/D multiplexed mode	IO	F8
gpmc_ad3	GPMC Data 3 in A/D nonmultiplexed mode and additionally Address 4 in A/D multiplexed mode	IO	B7

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-12. GPMC Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
gpmc_ad4	GPMC Data 4 in A/D nonmultiplexed mode and additionally Address 5 in A/D multiplexed mode	IO	A6
gpmc_ad5	GPMC Data 5 in A/D nonmultiplexed mode and additionally Address 6 in A/D multiplexed mode	IO	F7
gpmc_ad6	GPMC Data 6 in A/D nonmultiplexed mode and additionally Address 7 in A/D multiplexed mode	IO	E7
gpmc_ad7	GPMC Data 7 in A/D nonmultiplexed mode and additionally Address 8 in A/D multiplexed mode	IO	C6
gpmc_ad8	GPMC Data 8 in A/D nonmultiplexed mode and additionally Address 9 in A/D multiplexed mode	IO	B6
gpmc_ad9	GPMC Data 9 in A/D nonmultiplexed mode and additionally Address 10 in A/D multiplexed mode	IO	A5
gpmc_ad10	GPMC Data 10 in A/D nonmultiplexed mode and additionally Address 11 in A/D multiplexed mode	IO	D6
gpmc_ad11	GPMC Data 11 in A/D nonmultiplexed mode and additionally Address 12 in A/D multiplexed mode	IO	C5
gpmc_ad12	GPMC Data 12 in A/D nonmultiplexed mode and additionally Address 13 in A/D multiplexed mode	IO	B5
gpmc_ad13	GPMC Data 13 in A/D nonmultiplexed mode and additionally Address 14 in A/D multiplexed mode	IO	D7
gpmc_ad14	GPMC Data 14 in A/D nonmultiplexed mode and additionally Address 15 in A/D multiplexed mode	IO	B4
gpmc_ad15	GPMC Data 15 in A/D nonmultiplexed mode and additionally Address 16 in A/D multiplexed mode	IO	A4
gpmc_a0	GPMC Address 0. Only used to effectively address 8-bit data nonmultiplexed memories	O	U9
gpmc_a1	GPMC address 1 in A/D nonmultiplexed mode and Address 17 in A/D multiplexed mode	O	W11
gpmc_a2	GPMC address 2 in A/D nonmultiplexed mode and Address 18 in A/D multiplexed mode	O	V9
gpmc_a3	GPMC address 3 in A/D nonmultiplexed mode and Address 19 in A/D multiplexed mode	O	W9
gpmc_a4	GPMC address 4 in A/D nonmultiplexed mode and Address 20 in A/D multiplexed mode	O	U8
gpmc_a5	GPMC address 5 in A/D nonmultiplexed mode and Address 21 in A/D multiplexed mode	O	W8
gpmc_a6	GPMC address 6 in A/D nonmultiplexed mode and Address 22 in A/D multiplexed mode	O	U7
gpmc_a7	GPMC address 7 in A/D nonmultiplexed mode and Address 23 in A/D multiplexed mode	O	V7
gpmc_a8	GPMC address 8 in A/D nonmultiplexed mode and Address 24 in A/D multiplexed mode	O	J17
gpmc_a9	GPMC address 9 in A/D nonmultiplexed mode and Address 25 in A/D multiplexed mode	O	K22
gpmc_a10	GPMC address 10 in A/D nonmultiplexed mode and Address 26 in A/D multiplexed mode	O	K21
gpmc_a11	GPMC address 11 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	K18
gpmc_a12	GPMC address 12 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	D14, F13, F14, K17
gpmc_a13	GPMC address 13 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	C14, D15, E14, K19
gpmc_a14	GPMC address 14 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	K20
gpmc_a15	GPMC address 15 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	L21

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-12. GPMC Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
gpmc_a16	GPMC address 16 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	F14
gpmc_a17	GPMC address 17 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	C14
gpmc_a18	GPMC address 18 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	F15
gpmc_a19	GPMC address 19 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	F16
gpmc_a20	GPMC address 20 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	AA14
gpmc_a21	GPMC address 21 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	AB14
gpmc_a22	GPMC address 22 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	U13
gpmc_a23	GPMC address 23 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	V13
gpmc_a24	GPMC address 24 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	Y13
gpmc_a25	GPMC address 25 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	W13
gpmc_a26	GPMC address 26 in A/D nonmultiplexed mode and unused in A/D multiplexed mode	O	U11
gpmc_a27	GPMC address 27 in A/D nonmultiplexed mode and Address 27 in A/D multiplexed mode	O	V11
gpmc_cs0	GPMC Chip Select 0 (active low)	O	C10
gpmc_cs1	GPMC Chip Select 1 (active low)	O	E10
gpmc_cs2	GPMC Chip Select 2 (active low)	O	D10
gpmc_cs3	GPMC Chip Select 3 (active low)	O	A9
gpmc_cs4	GPMC Chip Select 4 (active low)	O	B9
gpmc_cs5	GPMC Chip Select 5 (active low)	O	F10
gpmc_cs6	GPMC Chip Select 6 (active low)	O	C8
gpmc_cs7	GPMC Chip Select 7 (active low)	O	W6
gpmc_clk(1)	GPMC Clock output	IO	C12, D14, F14, F15
gpmc_advn_ale	GPMC address valid active low or address latch enable	O	F12
gpmc_oen_ren	GPMC output enable active low or read enable	O	A10
gpmc_wen	GPMC write enable active low	O	B10
gpmc_ben0	GPMC lower-byte enable active low	O	D12
gpmc_ben1	GPMC upper-byte enable active low	O	E12
gpmc_wait0	GPMC external indication of wait 0	I	D8
gpmc_wait1	GPMC external indication of wait 1	I	W7

(1) The gpio6_16.clkout0 signal can be used as an “always-on” alternative to gpmc_clk provided that the external device can support the associated timing. See Table 7-8, *GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 1 Load* and Table 7-10, *GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 5 Loads* for timing information.

4.4.10 Timers

NOTE

For more information, see the *Timers* section in the device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-13. Timers Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
timer1	PWM output/event trigger input	IO	D14, R7
timer2	PWM output/event trigger input	IO	D15, D6
timer3	PWM output/event trigger input	IO	C5, F14, L1
timer4	PWM output/event trigger input	IO	C14, C6, L2
timer5	PWM output/event trigger input	IO	E7, N4
timer6	PWM output/event trigger input	IO	F7, R5
timer7	PWM output/event trigger input	IO	B6, F15
timer8	PWM output/event trigger input	IO	F16

4.4.11 Inter-Integrated Circuit Interface (I^2C)

NOTE

For more information, see the *I2C Pins for Typical Connections in I2C Mode* section in the device TRM.

Table 4-14. I^2C Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
Inter-Integrated Circuit Interface (I2C1)			
i2c1_scl	I2C1 Clock	IOD	L3
i2c1_sda	I2C1 Data	IOD	L4
Inter-Integrated Circuit Interface (I2C2)			
i2c2_scl	I2C2 Clock	IOD	L6
i2c2_sda	I2C2 Data	IOD	L5

4.4.12 Universal Asynchronous Receiver Transmitter (UART)

NOTE

For more information, see the UART section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-19.

Table 4-15. UART Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
Universal Asynchronous Receiver/Transmitter (UART1)			
uart1_ctsn	UART1 clear to send active low	I	F14
uart1_rtsn	UART1 request to send active low	O	C14
uart1_rxd	UART1 Receive Data	I	F13
uart1_txd	UART1 Transmit Data	O	E14
Universal Asynchronous Receiver/Transmitter (UART2)			
uart2_ctsn	UART2 clear to send active low	I	F15
uart2_rtsn	UART2 request to send active low	O	F16
uart2_rxd	UART2 Receive Data	I	D14, E7

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-15. UART Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
uart2_txd	UART2 Transmit Data	O	D15, F7
Universal Asynchronous Receiver/Transmitter (UART3)			
uart3_ctsn	UART3 clear to send active low	I	N4, U6
uart3_rtsn	UART3 request to send active low	O	R7, T5
uart3_rxd	UART3 Receive Data	I	F14, L1, M2, W7
uart3_txd	UART3 Transmit Data	O	C14, L2, R6, W6

4.4.13 Multichannel Serial Peripheral Interface (McSPI)

NOTE

For more information, see the *Multichannel Serial Peripheral Interface (McSPI)* section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are applicable for all combinations of signals for SPI2 and SPI4. However, the timings are only valid for SPI1 and SPI3 if signals within a single IOSET are used. The IOSETs are defined in Table 7-22.

Table 4-16. SPI Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
Serial Peripheral Interface 1			
spi1_sclk	SPI1 Clock	IO	M2
spi1_d0	SPI1 Data. Can be configured as either MISO or MOSI.	IO	T5
spi1_d1	SPI1 Data. Can be configured as either MISO or MOSI.	IO	U6
spi1_cs0	SPI1 Chip Select	IO	M1, R6
spi1_cs1	SPI1 Chip Select	IO	M1, R5
spi1_cs2	SPI1 Chip Select	IO	F14, W7
spi1_cs3	SPI1 Chip Select	IO	C14, W6
Serial Peripheral Interface 2			
spi2_sclk	SPI2 Clock	IO	L1
spi2_d0	SPI2 Data. Can be configured as either MISO or MOSI.	IO	R7
spi2_d1	SPI2 Data. Can be configured as either MISO or MOSI.	IO	N4
spi2_cs0	SPI2 Chip Select	IO	A4, L2
spi2_cs1	SPI2 Chip Select	IO	B4, M1
Serial Peripheral Interface 3			
spi3_sclk	SPI3 Clock	IO	C6, F15
spi3_d0	SPI3 Data. Can be configured as either MISO or MOSI.	IO	D15, E7
spi3_d1	SPI3 Data. Can be configured as either MISO or MOSI.	IO	D14, F7
spi3_cs0	SPI3 Chip Select	IO	B6, F16, M1
spi3_cs1	SPI3 Chip Select	IO	A5, R5
Serial Peripheral Interface 4			
spi4_sclk	SPI4 Clock	IO	C16, F14
spi4_d0	SPI4 Data. Can be configured as either MISO or MOSI.	IO	B17, E14
spi4_d1	SPI4 Data. Can be configured as either MISO or MOSI.	IO	B19, F13

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-16. SPI Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
spi4_cs0	SPI4 Chip Select	IO	C14, C17

4.4.14 Quad Serial Peripheral Interface (QSPI)

NOTE

For more information, see the *Quad Serial Peripheral Interface* section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-25.

Table 4-17. QSPI Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
qspi1_sclk	QSPI1 Serial Clock	O	C8
qspi1_rtclk	QSPI1 Return Clock Input. Must be connected from QSPI1_SCLK on PCB. Refer to PCB Guidelines for QSPI1	I	B7, C14, D8, F13
qspi1_d0	QSPI1 Data[0]. This pin is output data for all commands/writes and for dual read and quad read modes it becomes input data pin during read phase.	IO	B9
qspi1_d1	QSPI1 Data[1]. Input read data in all modes.	IO	F10
qspi1_d2	QSPI1 Data[2]. This pin is used only in quad read mode as input data pin during read phase	IO	A9
qspi1_d3	QSPI1 Data[3]. This pin is used only in quad read mode as input data pin during read phase	IO	D10
qspi1_cs0	QSPI1 Chip Select[0]. This pin is used for QSPI1 boot modes.	IO	E10
qspi1_cs1	QSPI1 Chip Select[1]	IO	F15

4.4.15 Multichannel Audio Serial Port (McASP)

NOTE

For more information, see the *Multichannel Audio Serial Port (McASP)* section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-32.

Table 4-18. McASP Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
Multichannel Audio Serial Port 1			
mcasp1_axr0	McASP1 Transmit/Receive Data	IO	W16
mcasp1_axr1	McASP1 Transmit/Receive Data	IO	V16
mcasp1_axr2	McASP1 Transmit/Receive Data	IO	U15

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-18. McASP Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
mcasp1_axr3	McASP1 Transmit/Receive Data	IO	V15
mcasp1_axr4	McASP1 Transmit/Receive Data	IO	Y15
mcasp1_axr5	McASP1 Transmit/Receive Data	IO	W15
mcasp1_axr6	McASP1 Transmit/Receive Data	IO	AA15
mcasp1_axr7	McASP1 Transmit/Receive Data	IO	AB15
mcasp1_axr8	McASP1 Transmit/Receive Data	IO	AA14, U15, U9
mcasp1_axr9	McASP1 Transmit/Receive Data	IO	AB14, V15, W11
mcasp1_axr10	McASP1 Transmit/Receive Data	IO	U13, V9, Y15
mcasp1_axr11	McASP1 Transmit/Receive Data	IO	V13, W15, W9
mcasp1_axr12	McASP1 Transmit/Receive Data	IO	AA15, U8, Y13
mcasp1_axr13	McASP1 Transmit/Receive Data	IO	AB15, W13, W8
mcasp1_axr14	McASP1 Transmit/Receive Data	IO	U11, U7
mcasp1_axr15	McASP1 Transmit/Receive Data	IO	V11, V7
mcasp1_fsx	McASP1 Transmit Frame Sync	IO	W17
mcasp1_aclkr	McASP1 Receive Bit Clock	IO	AA17
mcasp1_fsr	McASP1 Receive Frame Sync	IO	U16
mcasp1_ahclkx	McASP1 Transmit High-Frequency Master Clock	O	U9
mcasp1_aclkx	McASP1 Transmit Bit Clock	IO	U17
Multichannel Audio Serial Port 2			
mcasp2_axr0	McASP2 Transmit/Receive Data	IO	D6, V9
mcasp2_axr1	McASP2 Transmit/Receive Data	IO	C5, W9
mcasp2_axr2	McASP2 Transmit/Receive Data	IO	B5, U8
mcasp2_axr3	McASP2 Transmit/Receive Data	IO	D7, W8
mcasp2_axr4	McASP2 Transmit/Receive Data	IO	B4, U7
mcasp2_axr5	McASP2 Transmit/Receive Data	IO	A4, V7
mcasp2_fsx	McASP2 Transmit Frame Sync	IO	E7, V11
mcasp2_aclkr	McASP2 Receive Bit Clock	IO	B6, W13
mcasp2_fsr	McASP2 Receive Frame Sync	IO	A5, W11
mcasp2_ahclkx	McASP2 Transmit High-Frequency Master Clock	O	C6, Y13
mcasp2_aclkx	McASP2 Transmit Bit Clock	IO	F7, U11
Multichannel Audio Serial Port 3			
mcasp3_axr0	McASP3 Transmit/Receive Data	IO	G19
mcasp3_axr1	McASP3 Transmit/Receive Data	IO	G18
mcasp3_axr2	McASP3 Transmit/Receive Data	IO	G21
mcasp3_axr3	McASP3 Transmit/Receive Data	IO	G22
mcasp3_axr4	McASP3 Transmit/Receive Data	IO	H18
mcasp3_axr5	McASP3 Transmit/Receive Data	IO	H20
mcasp3_fsx	McASP3 Transmit Frame Sync	IO	H22
mcasp3_ahclkx	McASP3 Transmit High-Frequency Master Clock	O	H19
mcasp3_aclkx	McASP3 Transmit Bit Clock	IO	F22
mcasp3_aclkr	McASP3 Receive Bit Clock	IO	F20
mcasp3_fsr	McASP3 Receive Frame Sync	IO	F19

4.4.16 Controller Area Network Interface (DCAN and MCAN)

NOTE

For more information, see the *DCAN* section in the device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-36.

Table 4-19. DCAN and MCAN Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
DCAN 1			
dcan1_rx	DCAN1 receive data pin	IO	C14, D15, N6
dcan1_tx	DCAN1 transmit data pin	IO	D14, F14, N5
MCAN			
mcan_rx	MCAN receive data pin	IO	E14, F16, W6
mcan_tx	MCAN transmit data pin	IO	F13, F15, W7

4.4.17 Ethernet Interface (GMAC_SW)

NOTE

For more information, see the *Gigabit Ethernet Switch (GMAC_SW)* section in the device TRM.

Table 4-20. GMAC Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
rgmii0_rxc	RGMII0 Receive Clock	I	B18
rgmii0_rxctl	RGMII0 Receive Control	I	C18
rgmii0_rxd0	RGMII0 Receive Data	I	A20
rgmii0_rxd1	RGMII0 Receive Data	I	C20
rgmii0_rxd2	RGMII0 Receive Data	I	B20
rgmii0_rxd3	RGMII0 Receive Data	I	A19
rgmii0_txc	RGMII0 Transmit Clock	O	C16
rgmii0_txctl	RGMII0 Transmit Enable	O	C17
rgmii0_txd0	RGMII0 Transmit Data	O	F17
rgmii0_txd1	RGMII0 Transmit Data	O	E17
rgmii0_txd2	RGMII0 Transmit Data	O	D16
rgmii0_txd3	RGMII0 Transmit Data	O	E16
rgmii1_rxc	RGMII1 Receive Clock	I	D7
rgmii1_rxctl	RGMII1 Receive Control	I	C10
rgmii1_rxd0	RGMII1 Receive Data	I	F8
rgmii1_rxd1	RGMII1 Receive Data	I	A7
rgmii1_rxd2	RGMII1 Receive Data	I	E8
rgmii1_rxd3	RGMII1 Receive Data	I	D8
rgmii1_txc	RGMII1 Transmit Clock	O	C12
rgmii1_txctl	RGMII1 Transmit Enable	O	D12
rgmii1_txd0	RGMII1 Transmit Data	O	B10
rgmii1_txd1	RGMII1 Transmit Data	O	A10
rgmii1_txd2	RGMII1 Transmit Data	O	F12
rgmii1_txd3	RGMII1 Transmit Data	O	E12
mdio_d	Management Data	IO	B17

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-20. GMAC Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
mdio_mclk	Management Data Serial Clock	O	B19

4.4.18 SDIO Controller

NOTE

For more information, see the *SDIO Controller* section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-51.

Table 4-21. SDIO Controller Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
Multi Media Card 1			
mmc_clk	MMC1 clock	IO	B18, C16, W16
mmc_cmd	MMC1 command	IO	C17, C18, V16
mmc_dat0	MMC1 data bit 0	IO	A19, E16, U15
mmc_dat1	MMC1 data bit 1	IO	B20, D16, V15
mmc_dat2	MMC1 data bit 2	IO	C20, E17, Y15
mmc_dat3	MMC1 data bit 3	IO	A20, F17, W15

4.4.19 General-Purpose Interface (GPIO)

NOTE

For more information, see the *General-Purpose Interface* section in the device TRM.

CAUTION

The IO timings provided in Section 7, *Timing Requirements and Switching Characteristics* are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-52.

Table 4-22. GPIOs Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
GPIO 1			
gpio1_0	General-Purpose Input/Output	IO	C12
gpio1_1	General-Purpose Input/Output	IO	D12
gpio1_2	General-Purpose Input/Output	IO	E12
gpio1_3	General-Purpose Input/Output	IO	F12
gpio1_4	General-Purpose Input/Output	IO	A10
gpio1_5	General-Purpose Input/Output	IO	B10
gpio1_6	General-Purpose Input/Output	IO	C10
gpio1_7	General-Purpose Input/Output	IO	E10

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-22. GPIOs Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
gpio1_8	General-Purpose Input/Output	IO	D10
gpio1_9	General-Purpose Input/Output	IO	A9
gpio1_10	General-Purpose Input/Output	IO	B9
gpio1_11	General-Purpose Input/Output	IO	F10
gpio1_12	General-Purpose Input/Output	IO	C8
gpio1_13	General-Purpose Input/Output	IO	D8
gpio1_14	General-Purpose Input/Output	IO	E8
gpio1_15	General-Purpose Input/Output	IO	A7
gpio1_16	General-Purpose Input/Output	IO	F8
gpio1_17	General-Purpose Input/Output	IO	B7
gpio1_18	General-Purpose Input/Output	IO	A6
gpio1_19	General-Purpose Input/Output	IO	F7
gpio1_20	General-Purpose Input/Output	IO	E7
gpio1_21	General-Purpose Input/Output	IO	C6
gpio1_22	General-Purpose Input/Output	IO	B6
gpio1_23	General-Purpose Input/Output	IO	A5
gpio1_24	General-Purpose Input/Output	IO	D6
gpio1_25	General-Purpose Input/Output	IO	C5
gpio1_26	General-Purpose Input/Output	IO	B5
gpio1_27	General-Purpose Input/Output	IO	D7
gpio1_28	General-Purpose Input/Output	IO	B4
gpio1_29	General-Purpose Input/Output	IO	A4
gpio1_30	General-Purpose Input/Output	IO	F22
gpio1_31	General-Purpose Input/Output	IO	F21
GPIO 2			
gpio2_0	General-Purpose Input/Output	IO	F20
gpio2_1	General-Purpose Input/Output	IO	F19
gpio2_2	General-Purpose Input/Output	IO	G19
gpio2_3	General-Purpose Input/Output	IO	G18
gpio2_4	General-Purpose Input/Output	IO	G21
gpio2_5	General-Purpose Input/Output	IO	G22
gpio2_6	General-Purpose Input/Output	IO	H18
gpio2_7	General-Purpose Input/Output	IO	H20
gpio2_8	General-Purpose Input/Output	IO	H19
gpio2_9	General-Purpose Input/Output	IO	H22
gpio2_10	General-Purpose Input/Output	IO	H21
gpio2_11	General-Purpose Input/Output	IO	J17
gpio2_12	General-Purpose Input/Output	IO	K22
gpio2_13	General-Purpose Input/Output	IO	K21
gpio2_14	General-Purpose Input/Output	IO	K18
gpio2_15	General-Purpose Input/Output	IO	K17
gpio2_16	General-Purpose Input/Output	IO	K19
gpio2_17	General-Purpose Input/Output	IO	K20
gpio2_18	General-Purpose Input/Output	IO	L21
gpio2_19	General-Purpose Input/Output	IO	L22
gpio2_20	General-Purpose Input/Output	IO	AB17
gpio2_21	General-Purpose Input/Output	IO	U17

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-22. GPIOs Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
gpio2_22	General-Purpose Input/Output	IO	W17
gpio2_23	General-Purpose Input/Output	IO	AA17
gpio2_24	General-Purpose Input/Output	IO	U16
gpio2_25	General-Purpose Input/Output	IO	W16
gpio2_26	General-Purpose Input/Output	IO	V16
gpio2_27	General-Purpose Input/Output	IO	U15
gpio2_28	General-Purpose Input/Output	IO	V15
gpio2_29	General-Purpose Input/Output	IO	Y15
gpio2_30	General-Purpose Input/Output	IO	W15
gpio2_31	General-Purpose Input/Output	IO	AA15
GPIO 3			
gpio3_0	General-Purpose Input/Output	IO	AB15
gpio3_1	General-Purpose Input/Output	IO	AA14
gpio3_2	General-Purpose Input/Output	IO	AB14
gpio3_3	General-Purpose Input/Output	IO	U13
gpio3_4	General-Purpose Input/Output	IO	V13
gpio3_5	General-Purpose Input/Output	IO	Y13
gpio3_6	General-Purpose Input/Output	IO	W13
gpio3_7	General-Purpose Input/Output	IO	U11
gpio3_8	General-Purpose Input/Output	IO	V11
gpio3_9	General-Purpose Input/Output	IO	U9
gpio3_10	General-Purpose Input/Output	IO	W11
gpio3_11	General-Purpose Input/Output	IO	V9
gpio3_12	General-Purpose Input/Output	IO	W9
gpio3_13	General-Purpose Input/Output	IO	U8
gpio3_14	General-Purpose Input/Output	IO	W8
gpio3_15	General-Purpose Input/Output	IO	U7
gpio3_16	General-Purpose Input/Output	IO	V7
gpio3_17	General-Purpose Input/Output	IO	B19
gpio3_18	General-Purpose Input/Output	IO	B17
gpio3_19	General-Purpose Input/Output	IO	C16
gpio3_20	General-Purpose Input/Output	IO	C17
gpio3_21	General-Purpose Input/Output	IO	E16
gpio3_22	General-Purpose Input/Output	IO	D16
gpio3_23	General-Purpose Input/Output	IO	E17
gpio3_24	General-Purpose Input/Output	IO	F17
gpio3_25	General-Purpose Input/Output	IO	B18
gpio3_26	General-Purpose Input/Output	IO	C18
gpio3_27	General-Purpose Input/Output	IO	A19
gpio3_28	General-Purpose Input/Output	IO	B20
gpio3_29	General-Purpose Input/Output	IO	C20
gpio3_30	General-Purpose Input/Output	IO	A20
gpio3_31	General-Purpose Input/Output	IO	M1
GPIO 4			
gpio4_0	General-Purpose Input/Output	IO	M2
gpio4_1	General-Purpose Input/Output	IO	U6
gpio4_2	General-Purpose Input/Output	IO	T5

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-22. GPIOs Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
gpio4_3	General-Purpose Input/Output	IO	R6
gpio4_4	General-Purpose Input/Output	IO	R5
gpio4_5	General-Purpose Input/Output	IO	L1
gpio4_6	General-Purpose Input/Output	IO	N4
gpio4_7	General-Purpose Input/Output	IO	R7
gpio4_8	General-Purpose Input/Output	IO	L2
gpio4_9	General-Purpose Input/Output	IO	N5
gpio4_10	General-Purpose Input/Output	IO	N6
gpio4_11	General-Purpose Input/Output	IO	W7
gpio4_12	General-Purpose Input/Output	IO	W6
gpio4_13	General-Purpose Input/Output	IO	F13
gpio4_14	General-Purpose Input/Output	IO	E14
gpio4_15	General-Purpose Input/Output	IO	F14
gpio4_16	General-Purpose Input/Output	IO	C14
gpio4_17	General-Purpose Input/Output	IO	D14
gpio4_18	General-Purpose Input/Output	IO	D15
gpio4_19	General-Purpose Input/Output	IO	F15
gpio4_20	General-Purpose Input/Output	IO	F16
gpio4_21	General-Purpose Input/Output	IO	M17
gpio4_22	General-Purpose Input/Output	IO	M18
gpio4_25	General-Purpose Input/Output	IO	J1
gpio4_26	General-Purpose Input/Output	IO	J4
gpio4_27	General-Purpose Input/Output	IO	J6
gpio4_28(1)	General-Purpose Input/Output	IO	H1
gpio4_29(1)	General-Purpose Input/Output	IO	H2

(1) gpio4_28 is multiplexed with EMU0 and gpio4_29 is multiplexed with EMU1. These pins will be sampled at reset release by the test and emulation logic. Therefore, if they are used as GPIO pins, they must return to the high state whenever the device enters reset. This can be controlled by logic driven from rstoutn. After the device exits reset (indicated by rstoutn rising), these can return to GPIO mode.

4.4.20 Pulse-Width Modulation Subsystem (PWMSS)

NOTE

For more information, see the *Pulse-Width Modulation Subsystem (PWMSS)* section in the device TRM.

Table 4-23. PWMSS Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
PWMSS1			
ehrpwm1A	EHRPWM1 Output A	O	D12, D14, L1
ehrpwm1B	EHRPWM1 Output B	O	D15, E12, L2
ehrpwm1_tripzone_input	EHRPWM1 Trip Zone Input	IO	F12, R5
eCAP1_in_PWM1_out	ECAP1 Capture Input / PWM Output	IO	A5, AB15, D16, F16, N4
ehrpwm1_synci	EHRPWM1 Sync Input	I	A10, F14
ehrpwm1_synco	EHRPWM1 Sync Output	O	B10, C14

Copyright © 2016–2020, Texas Instruments Incorporated

4.4.21 Test Interfaces

NOTE

For more information, see the *On-Chip Debug Support* section in the device TRM.

Table 4-24. Debug Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
rtck	JTAG return clock	O	J6
tclk	JTAG test clock	I	J2
tdi	JTAG test data	I	J1
tdo	JTAG test port data	O	J4
tms	JTAG test port mode select. An external pullup resistor should be used on this ball.	IO	J3
trstn	JTAG test reset	I	J5
emu0(1)	Emulator pin 0	IO	H1
emu1(1)	Emulator pin 1	IO	H2
emu2	Emulator pin 2	O	AA15
emu3	Emulator pin 3	O	AB15
emu4	Emulator pin 4	O	AA14
emu5	Emulator pin 5	O	AB14
emu6	Emulator pin 6	O	U13
emu7	Emulator pin 7	O	V13
emu8	Emulator pin 8	O	Y13
emu9	Emulator pin 9	O	W13
emu10	Emulator pin 10	O	U11
emu11	Emulator pin 11	O	V11
emu12	Emulator pin 12	O	U9
emu13	Emulator pin 13	O	W11
emu14	Emulator pin 14	O	V9
emu15	Emulator pin 15	O	W9
emu16	Emulator pin 16	O	U8
emu17	Emulator pin 17	O	W8
emu18	Emulator pin 18	O	U7
emu19	Emulator pin 19	O	V7

(1) EMU0 and EMU1 are multiplexed with GPIO. These pins will be sampled at reset release by the test and emulation logic. Therefore, if they are used as GPIO pins, they must return to the high state whenever the device enters reset. This can be controlled by logic driven from rstoutn. After the device exits reset (indicated by rstoutn rising), these can return to GPIO mode.

4.4.22 System and Miscellaneous

4.4.22.1 Sysboot

NOTE

For more information, see the *Initialization* section in the device TRM.

Table 4-25. Sysboot Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
sysboot0	Boot Mode Configuration 0. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	E8

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-25. Sysboot Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
sysboot1	Boot Mode Configuration 1. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	A7
sysboot2	Boot Mode Configuration 2. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	F8
sysboot3	Boot Mode Configuration 3. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	B7
sysboot4	Boot Mode Configuration 4. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	A6
sysboot5	Boot Mode Configuration 5. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	F7
sysboot6	Boot Mode Configuration 6. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	E7
sysboot7	Boot Mode Configuration 7. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	R7
sysboot8	Boot Mode Configuration 8. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	B6
sysboot9	Boot Mode Configuration 9. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	A5
sysboot10	Boot Mode Configuration 10. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	D6
sysboot11	Boot Mode Configuration 11. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	C5
sysboot12	Boot Mode Configuration 12. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	B5
sysboot13	Boot Mode Configuration 13. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	D7
sysboot14	Boot Mode Configuration 14. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	B4
sysboot15	Boot Mode Configuration 15. The value latched on this pin upon porz reset release will determine the boot mode configuration of the device.	I	A4

4.4.22.2 Power, Reset and Clock Management (PRCM)

NOTE

For more information, see the *Power, Reset, and Clock Management* section in the device TRM.

Table 4-26. PRCM Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
clkout0	Device Clock output 1. Can be used externally for devices with non-critical timing requirements, or for debug, or as a reference clock on GPMC as described in Table 7-8, *GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 1 Load* and Table 7-10, *GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 5 Loads*.	O	AB17, C12, F14, F22, M1
clkout1	Device Clock output 2. Can be used as a system clock for other devices.	O	F12, F21, U17
clkout2	Device Clock output 3. Can be used as a system clock for other devices.	O	A10, F20, W17
rstoutn	Reset out (Active low). This pin asserts low in response to any global reset condition on the device.	O	F4
resetn	Device Reset Input	I	G4
porz	Power on Reset (active low). This pin must be asserted low until all device supplies are valid (see reset sequence/requirements).	I	G3
xref_clk0	External Reference Clock 0. For Audio and other Peripherals.	I	M1
xref_clk1	External Reference Clock 1. For Audio and other Peripherals.	I	F14, F15

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-26. PRCM Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
xref_clk2	External Reference Clock 2. For Audio and other Peripherals.	I	H19
xi_osc0	System Oscillator OSC0 Crystal input / LVCMOS clock input. Functions as the input connection to a crystal when the internal oscillator OSC0 is used. Functions as an LVCMOS-compatible input clock when an external oscillator is used.	I	E22
xi_osc1	Auxiliary Oscillator OSC1 Crystal input / LVCMOS clock input. Functions as the input connection to a crystal when the internal oscillator OSC1 is used. Functions as an LVCMOS-compatible input clock when an external oscillator is used.	I	B21
xo_osc0	System Oscillator OSC0 Crystal output	O	D22
xo_osc1	Auxiliary Oscillator OSC1 Crystal output	O	C21

4.4.22.3 Enhanced Direct Memory Access (EDMA)

NOTE

For more information, see the *Enhanced DMA* section in the device TRM.

Table 4-27. EDMA Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
dma_evt1	Enhanced DMA Event Input 1	I	C12, K17
dma_evt2	Enhanced DMA Event Input 2	I	D12, K19
dma_evt3	Enhanced DMA Event Input 3	I	E12
dma_evt4	Enhanced DMA Event Input 4	I	F12, D8

4.4.22.4 Interrupt Controllers (INTC)

NOTE

For more information, see the *Interrupt Controllers* section in the device TRM.

Table 4-28. INTC Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
nmin	Non maskable interrupt input - active-low. This pin can be optionally routed to the DSP NMI input or as generic input to the Arm cores.	I	G5
sys_nirq1	External interrupt event to any device INTC	I	K18, K22
sys_nirq2	External interrupt event to any device INTC	I	J17, K21
esm_error	This signal indicates a severe device failure. For more information, see *Error Signaling Module* in the Device TRM.	IO	AA15 , B17

4.4.23 Power Supplies

NOTE

For more information, see the *External Voltage Inputs* section in the device TRM.

Table 4-29. Power Supply Signal Descriptions

SIGNAL NAME	DESCRIPTION	TYPE	BALL
vdd	Core voltage domain supply	PWR	H7 , H12 , H13 , J10 , J11 , J15 , K12 , L12 , L15 , N12 , N16 , P10 , P14

Copyright © 2016–2020, Texas Instruments Incorporated

Table 4-29. Power Supply Signal Descriptions (continued)

SIGNAL NAME	DESCRIPTION	TYPE	BALL
vss	Ground	GND	A1 , A8 , A17 , A22 , B22 , E1 , G10 , G16 , H8 , H9 , H10 , H11 , H15 , H16 , J22 , K1 , K9 , K10 , K11 , K13 , K14 , K15 , K16 , M10 , M11 , M12 , M13 , M16 , N7 , N10 , P1 , P15 , P16 , R9 , R12 , R16 , T14 , V22 , AB1 , AB2 , AB7 , AB12 , AB16 , AB21 , AB22
vdd_dspeve	DSP-EVE voltage domain supply	PWR	K8 , L8 , M9 , P8 , P9 , P11 , P12
vdda_per	PER PLL and PER HSDIVIDER analog power supply	PWR	H14
vdda_ddr_dsp	EVE PLL, DPLL_DDR and DDR HSDIVIDER analog power supply	PWR	N8
vdda_gmac_core	GMAC PLL, GMAC HSDIVIDER, DPLL_CORE and CORE HSDIVIDER analog power supply	PWR	M8
vdda_osc	IO supply for oscillator section	PWR	E21
vssa_osc0	OSC0 analog ground	GND	D21
vssa_osc1	OSC1 analog ground	GND	C22
vdda_csi	CSI analog power supply	PWR	A14
vssa_csi	CSI analog ground	GND	B14
vdda_dac	DAC analog power supply	PWR	U19
vssa_dac	DAC analog ground	GND	T19
vdda_adc	ADC analog power supply	PWR	P22
vssa_adc	ADC analog ground	GND	P21
vdds18v	1.8V power supply and Power Group bias supply	PWR	G12, J7, L16, P13, T11
vdds18v_ddr1	1.8v bias supply for Byte0, Byte2, ECC Byte, Addr Cmd	PWR	P7, T9
vdds18v_ddr2	1.8v bias supply for Addr Cmd	PWR	G7
vdds18v_ddr3	1.8v bias supply for Byte1, Byte3	PWR	T16, V21
vdds_ddr1	IO power supply for Byte0, Byte2, ECC Byte, Addr Cmd	PWR	R1, T7, T8, AA1, AB6
vdds_ddr2	IO power supply for Addr Cmd	PWR	C2, E2, G6
vdds_ddr3	IO power supply for Byte1, Byte3	PWR	T15, AA22, AB19
vddshv1	Dual Voltage (1.8V or 3.3V) power supply for the GENERAL Power Group pins	PWR	K2, K7, L7, M7
vddshv2	Dual Voltage (1.8V or 3.3V) power supply for the GPMC Power Group pins	PWR	G8, G9, G11, B8
vddshv3	Dual Voltage (1.8V or 3.3V) power supply for the UART1 and UART2 Power Group pins	PWR	G14
vddshv4	Dual Voltage (1.8V or 3.3V) power supply for the RGMII Power Group pins	PWR	A18, E20
vddshv5	Dual Voltage (1.8V or 3.3V) power supply for the VIN1 Power Group pins	PWR	H17, J16, J21
vddshv6	Dual Voltage (1.8V or 3.3V) power supply for the VOUT1 Power Group pins	PWR	T10, T12, T13, AA16
cap_vddram_core1(1)	SRAM array supply for core voltage domain memories	CAP	N15
cap_vddram_core2(1)	SRAM array supply for core voltage domain memories	CAP	M15
cap_vddram_dspeve(1)	SRAM array supply for DSP-EVE memories	CAP	M14

Copyright © 2016–2020, Texas Instruments Incorporated

(1) This pin must always be connected via a 1-uF capacitor to vss.

Copyright © 2016–2020, Texas Instruments Incorporated

5 Specifications

NOTE

For more information, see Power, Reset and Clock Management / PRCM Subsystem Environment / External Voltage Inputs or Initialization / Preinitialization / Power Requirements section of the Device TRM.

NOTE

The index number 1 which is part of the EMIF1 signal prefixes (ddr1_*) listed in Section 4.4.8, *External Memory Interface (EMIF)*, column "SIGNAL NAME" are not to be confused with DDR1 type of SDRAM memories.

NOTE

Audio Back End (ABE) module is not supported for this family of devices, but “ABE” name is still present in some clock or DPLL names.

CAUTION

All IO Cells are NOT Fail-safe compliant and should not be externally driven in absence of their IO supply.

Copyright © 2016–2020, Texas Instruments Incorporated

5.1 Absolute Maximum Ratings

Stresses beyond those listed as absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those listed under Section 5.4, *Recommended Operating Conditions*, is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

PARAMETER(1)	DESCRIPTION		MIN	MAX	UNIT
V_{SUPPLY} (Steady-State)	Supply Voltage Ranges (Steady-State)	Core (vdd, vdd_dspeve)	-0.3	1.5	V
		Analog (vdda_per, vdda_ddr_dsp, vdda_gmac_core, vdda_osc, vdda_csi, vdda_dac, vdda_adc)	-0.3	2.0	V
		vdds_ddr1, vdds_ddr2, vdds_ddr3 (1.35V mode)	-0.3	1.65	V
		vdds_ddr1, vdds_ddr2, vdds_ddr3 (1.5V mode)	-0.3	1.8	V
		vdds_ddr1, vdds_ddr2, vdds_ddr3 (1.8V mode)	-0.3	2.1	V
		vdds18v, vdds18v_ddr1, vdds18v_ddr2, vdds18v_ddr3	-0.3	2.1	V
		vddshv1-6 (1.8V mode)	-0.3	2.1	V
		vddshv1-6 (3.3V mode)	-0.3	3.8	V
V_{IO} (Steady-State)	Input and Output Voltage Ranges (Steady-State)	Core I/Os	-0.3	1.5	V
		Analog I/Os	-0.3	2.0	V
		I/O 1.35V	-0.3	1.65	V
		I/O 1.5V	-0.3	1.8	V
		1.8V I/Os	-0.3	2.1	V
		3.3V I/Os	-0.3	3.8	V
SR	Maximum slew rate, all supplies			10^5	V/s
V_{IO} (Transient Overshoot / Undershoot)	Input and Output Voltage Ranges (Transient Overshoot / Undershoot) Note: valid for up to 20% of the signal period			0.2×VDD (2)	V
T_J	Operating junction temperature range	Automotive	-40	+125	°C
T_{STG}	Storage temperature range after soldered onto PC Board		-55	+150	°C
Latch-up I-Test	I-test(3), All I/Os (if different levels then one line per level)		-100	100	mA
Latch-up OV-Test	Over-voltage Test(4), All supplies (if different levels then one line per level)		N/A	1.5×Vsupply max	V

(1) See I/Os supplied by this power pin in Table 4-2, *Ball Characteristics.*

(2) VDD is the voltage on the corresponding power-supply pin(s) for the IO.

(3) Per JEDEC JESD78 at 125°C with specified I/O pin injection current and clamp voltage of 1.5 times maximum recommended I/O voltage and negative 0.5 times maximum recommended I/O voltage.

(4) Per JEDEC JESD78 at 125°C.

5.2 ESD Ratings

			VALUE	UNIT
V_{ESD} Electrostatic discharge	Human-Body model (HBM), per AEC Q100-002(1)		±1000	V
	Charged-device model (CDM), per AEC Q100-011	All pins	±250	
		Corner pins (A1, AB1, A22, AB22)	±750	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

Copyright © 2016–2020, Texas Instruments Incorporated

5.3 Power-On Hours (POH)[1][2][3]

IP	DUTY CYCLE	VOLTAGE DOMAIN	VOLTAGE (V) (MAX)	FREQUENCY (MHz) (MAX)	Tj(°C)	POH
All	100%	All	All Support OPPs		Automotive Profile[1]	20000

(1) Automotive profile is defined as 20000 power on hours with junction temperature as follows: 5%@-40°C, 65%@70°C, 20%@110°C, 10%@125°C.

(2) POH is a functional of voltage, temperature and time. Usage at higher voltages and temperatures will result in a reduction in POH to achieve the same reliability performance. For assessment of alternate use cases, contact your local TI representative.

(3) The information in this section is provided solely for your convenience and does not extend or modify the warranty provided under TI's standard terms and conditions for TI semiconductor products.

5.4 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

PARAMETER	DESCRIPTION		MIN [2]	NOM	MAX DC [3]	MAX [2]	UNIT
Input Power Supply Voltage Range							
vdd	Core voltage domain supply		See Section 5.5				V
vdd_dspeve	DSP-EVE voltage domain supply		See Section 5.5				V
vdda_per	PER PLL and PER HSDIVIDER analog power supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdda_ddr_dsp	EVE PLL, DPLL_DDR and DDR HSDIVIDER analog power supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdda_gmac_core	GMAC PLL, GMAC HSDIVIDER, DPLL_CORE and CORE HSDIVIDER analog power supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdda_osc	I/O supply for oscillator section		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdda_csi	CSI analog power supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdda_dac	DAC analog power supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdda_adc	ADC analog power supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdds18v	1.8V power supply and Power Group bias supply		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdds18v_ddr1	1.8v bias supply for Byte0, Byte2, ECC Byte, Addr Cmd		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdds18v_ddr2	1.8v bias supply for Addr Cmd		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdds18v_ddr3	1.8v bias supply for Byte1, Byte3		1.71	1.80	1.836	1.89	V
	Maximum noise (peak-peak)			50			mV_{PPmax}
vdds_ddr1	EMIF power supply (1.8V for DDR2 mode / 1.5V for DDR3 mode / 1.35V DDR3L mode)	1.35-V Mode	1.28	1.35	1.377	1.42	V
		1.5-V Mode	1.43	1.50	1.53	1.57	
		1.8-V Mode	1.71	1.80	1.836	1.89	
	Maximum noise (peak-peak)	1.35-V Mode		50			mV_{PPmax}
		1.5-V Mode					
		1.8-V Mode					

Recommended Operating Conditions *(continued)*

over operating free-air temperature range (unless otherwise noted)

PARAMETER	DESCRIPTION		MIN [2]	NOM	MAX DC [3]	MAX [2]	UNIT
vdds_ddr2	EMIF power supply (1.8V for DDR2 mode / 1.5V for DDR3 mode / 1.35V DDR3L mode)	1.35-V Mode	1.28	1.35	1.377	1.42	V
		1.5-V Mode	1.43	1.50	1.53	1.57	
		1.8-V Mode	1.71	1.80	1.836	1.89	
	Maximum noise (peak-peak)	1.35-V Mode		50			mV_{PPmax}
		1.5-V Mode					
		1.8-V Mode					
vdds_ddr3	EMIF power supply (1.8V for DDR2 mode / 1.5V for DDR3 mode / 1.35V DDR3L mode)	1.35-V Mode	1.28	1.35	1.377	1.42	V
		1.5-V Mode	1.43	1.50	1.53	1.57	
		1.8-V Mode	1.71	1.80	1.836	1.89	
	Maximum noise (peak-peak)	1.35-V Mode		50			mV_{PPmax}
		1.5-V Mode					
		1.8-V Mode					
vddshv1	Dual Voltage (1.8V or 3.3V) power supply for the GENERAL Power Group pins	1.8-V Mode	1.71	1.80	1.836	1.89	V
		3.3-V Mode	3.135	3.30	3.366	3.465	
	Maximum noise (peak-peak)	1.8-V Mode		50			mV_{PPmax}
		3.3-V Mode					
vddshv2	Dual Voltage (1.8V or 3.3V) power supply for the GPMC Power Group pins	1.8-V Mode	1.71	1.80	1.836	1.89	V
		3.3-V Mode	3.135	3.30	3.366	3.465	
	Maximum noise (peak-peak)	1.8-V Mode		50			mV_{PPmax}
		3.3-V Mode					
vddshv3	Dual Voltage (1.8V or 3.3V) power supply for the UART1 and UART2 Power Group pins	1.8-V Mode	1.71	1.80	1.836	1.89	V
		3.3-V Mode	3.135	3.30	3.366	3.465	
	Maximum noise (peak-peak)	1.8-V Mode		50			mV_{PPmax}
		3.3-V Mode					
vddshv4	Dual Voltage (1.8V or 3.3V) power supply for the RGMII Power Group pins	1.8-V Mode	1.71	1.80	1.836	1.89	V
		3.3-V Mode	3.135	3.30	3.366	3.465	
	Maximum noise (peak-peak)	1.8-V Mode		50			mV_{PPmax}
		3.3-V Mode					
vddshv5	Dual Voltage (1.8V or 3.3V) power supply for the VIN1 Power Group pins	1.8-V Mode	1.71	1.80	1.836	1.89	V
		3.3-V Mode	3.135	3.30	3.366	3.465	
	Maximum noise (peak-peak)	1.8-V Mode		50			mV_{PPmax}
		3.3-V Mode					
vddshv6	Dual Voltage (1.8V or 3.3V) power supply for the VOUT1 Power Group pins	1.8-V Mode	1.71	1.80	1.836	1.89	V
		3.3-V Mode	3.135	3.30	3.366	3.465	
	Maximum noise (peak-peak)	1.8-V Mode		50			mV_{PPmax}
		3.3-V Mode					
vss	Ground supply		0				V

Copyright © 2016–2020, Texas Instruments Incorporated

Recommended Operating Conditions *(continued)*

over operating free-air temperature range (unless otherwise noted)

PARAMETER	DESCRIPTION		MIN (2)	NOM	MAX DC (3)	MAX (2)	UNIT
vssa_osc0	OSC0 analog ground			0			V
vssa_osc1	OSC1 analog ground			0			V
vssa_csi	CSI analog ground supply			0			V
vssa_dac	DAC analog ground supply			0			V
vssa_adc	ADC analog ground supply			0			V
T_J(1)	Operating junction temperature range	Automotive	-40			125(4)	°C

(1) Refer to Power on Hours table for limitations.

(2) The voltage at the device ball should never be below the MIN voltage or above the MAX voltage for any amount of time. This requirement includes dynamic voltage events such as AC ripple, voltage transients, voltage dips, etc.

(3) The DC voltage at the device ball should never be above the MAX DC voltage to avoid impact on device reliability and lifetime POH (Power-On-Hours). The MAX DC voltage is defined as the highest allowed DC regulated voltage, without transients, seen at the ball.

(4) The TSHUT feature of the SoC resets the device by default when one of the on-die temp sensors reports 123 °C. This is intended to protect the device from exceeding 125 °C. Though not recommended, the TSHUT temperature threshold can be modified in software if other mechanisms are in place to avoid exceeding 125 °C. Refer to the device TRM for details on the TSHUT feature.

5.5 Operating Performance Points

This section describes the operating conditions of the device. This section also contains the description of each Operating Performance Point (OPP) for processor clocks and device core clocks.

Table 5-1 describes the maximum supported frequency per speed grade for the devices.

Table 5-1. Speed Grade Maximum Frequency

DEVICE	MAXIMUM FREQUENCY (MHz)								
	DSP	EVE	IPU	ISS	L3	DDR3/DDR3L	DDR2	LPDDR2	ADC
TDA3xxA	250	250	212.8	212.8	266	333 (DDR-667)	333 (DDR-667)	333 (DDR-667)	20
TDA3xxB	355	355	212.8	212.8	266	532 (DDR-1066)	400 (DDR-800)	333 (DDR-667)	20
TDA3xxD	500	500	212.8	212.8	266	532 (DDR-1066)	400 (DDR-800)	333 (DDR-667)	20
TDA3xxR	745	667	212.8	212.8	266	532 (DDR-1066)	400 (DDR-800)	333 (DDR-667)	20
TDA3xxS	1000	900	212.8	212.8	266	532 (DDR-1066)	400 (DDR-800)	333 (DDR-667)	20

5.5.1 AVS Requirements

Adaptive Voltage Scaling (AVS) is required on most of the vdd_* supplies as defined in Table 5-2.

Table 5-2. AVS Requirements per vdd_* Supply

SUPPLY	AVS REQUIRED?
vdd	Yes, for all OPPs
vdd_dspeve	Yes, for all OPPs

5.5.2 Voltage And Core Clock Specifications

Table 5-3 shows the recommended OPP per voltage domain.

Table 5-3. Voltage Domains Operating Performance Points

DOMAIN	CONDITION	OPP_NOM			OPP_OD			OPP_HIGH/OPP_PLUS(6)			
		MIN (2)	NOM (1)	MAX (2)	MIN (2)	NOM (1)	MAX (2)	MIN (2)	NOM (1)	MAX DC (3)	MAX (2)
VD_CORE (V)	BOOT (Before AVS is enabled) (4)	1.02	1.06	1.11	Not Applicable			Not Applicable			
	After AVS is enabled (4)	AVS Voltage (5) – 3.5%	AVS Voltage (5)	1.20	Not Applicable			Not Applicable			
VD_DSPEVE (V)	BOOT (Before AVS is enabled) (4)	1.02	1.06	1.11	Not Applicable			Not Applicable			
	After AVS is enabled (4)	AVS Voltage (5) – 3.5%	AVS Voltage (5)	1.11	AVS Voltage (5) – 3.5%	AVS Voltage (5)	AVS Voltage (5) + 5%	AVS Voltage (5) – 3.5%	AVS Voltage (5)	AVS Voltage (5) + 2%	AVS Voltage (5) + 5%

(1) In a typical implementation, the power supply should target the NOM voltage.

(2) The voltage at the device ball should never be below the MIN voltage or above the MAX voltage for any amount of time. This requirement includes dynamic voltage events such as AC ripple, voltage transients, voltage dips, etc.

(3) The DC voltage at the device ball should never be above the MAX DC voltage to avoid impact on device reliability and lifetime POH (Power-On-Hours). The MAX DC voltage is defined as the highest allowed DC regulated voltage, without transients, seen at the ball.

(4) For all OPPs, AVS must be enabled to avoid impact on device reliability, lifetime POH (Power-On-Hours), and device power.

(5) The AVS voltages are device-dependent, voltage domain-dependent, and OPP-dependent. They must be read from the STD_FUSE_OPP. For information about STD_FUSE_OPP Registers address, refer to the *Control Module* section in the device TRM.

The power supply should be adjustable over the following ranges for each required OPP:
- OPP_NOM: 0.85V - 1.06V
- OPP_OD: 0.94V - 1.15V
- OPP_HIGH: 1.05V - 1.25V
- OPP_PLUS: 1.05V - 1.25V

The AVS Voltages will be within the above specified ranges.

(6) The required PRCM and DCC software configuration sequence for OPP_PLUS (DSP 1 GHz or EVE 900 MHz) is different than other OPPs. For more information, see *PRCM Software Configuration for OPP_PLUS* section of the device TRM.

Table 5-4 describes the standard processor clocks speed characteristics vs OPP of the device.

Table 5-4. Supported OPP vs Max Frequency(1)(2)

CLOCK	OPP_NOM	OPP_OD	OPP_HIGH	OPP_PLUS
	MAX FREQUENCY (MHz)	MAX FREQUENCY (MHz)	MAX FREQUENCY (MHz)	MAX FREQUENCY (MHz)
VD_DSPEVE				
DSP_CLK	500	709	745	1000
EVE_FCLK	500	667	667	900
VD_CORE				
CORE_IPU1_CLK	212.8	N/A	N/A	N/A
ISS	212.8	N/A	N/A	N/A
L3_CLK	266	N/A	N/A	N/A
DDR3 / DDR3L	532 (DDR-1066)	N/A	N/A	N/A
DDR2	400 (DDR-800)	N/A	N/A	N/A
LPPDR2	333 (DDR-667)	N/A	N/A	N/A
ADC	20	N/A	N/A	N/A

Copyright © 2016–2020, Texas Instruments Incorporated

(1) N/A stands for Not Applicable.

(2) Maximum supported frequency is limited to the device speed grade (see Table 5-1, *Speed Grade Maximum Frequency*).

5.5.3 Maximum Supported Frequency

Device modules either receive their clock directly from an external clock input, directly from a PLL, or from a PRCM. Table 5-5 lists the clock source options for each module on this device, along with the maximum frequency that module can accept. To ensure proper module functionality, the device PLLs and dividers must be programmed not to exceed the maximum frequencies listed in this table.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency

Module				Clock Sources		
Instance Name	**Input Clock Name**	**Clock Type**	**Max. Clock Allowed (MHz)**	**PRCM Clock Name**	**PLL / OSC / Source Clock Name**	**PLL / OSC / Source Name**
ADC	OCP_CLK	Int	133	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	ADC_CLK	Func	20	ADC_CLK	SYS_CLK1	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
CSI2	SCPCLK	Int & Func	106.4	ISS_MAIN_FCLK	CORE_ISS_MAIN_CLK	DPLL_CORE
COUNTER_32K	COUNTER_32K_FCLK	Func	0.032	FUNC_32K_CLK	SYS_CLK1/610	OSC0
	COUNTER_32K_ICLK	Int	38.4	WKUPAON_GICLK	SYS_CLK1	OSC0
CRC	OCP_CLK_PI	Int & Func	133	CRC_L3_GICLK	CORE_X2_CLK	DPLL_CORE
CTRL_MODULE_BANDGAP	L3INSTR_TS_GCLK	Int	5	L3INSTR_TS_GCLK	SYS_CLK1	OSC0
					ABE_LP_CLK	DPLL_DDR
CTRL_MODULE_CORE	L4CFG_L4_GICLK	Int	133	L4_ICLK	CORE_X2_CLK	DPLL_CORE
CTRL_MODULE_WKUP	WKUPAON_GICLK	Int	38.4	WKUPAON_GICLK	SYS_CLK1	OSC0
					ABE_LP_CLK	DPLL_DDR
DCAN1	DCAN1_FCLK	Func	20	DCAN1_SYS_CLK	SYS_CLK1	OSC0
					SYS_CLK2	OSC1
	DCAN1_ICLK	Int	133	WKUPAON_GICLK	SYS_CLK1	OSC0
					ABE_LP_CLK	DPLL_DDR
MCAN	MCAN_FCLK	Func	80	MCAN_CLK	MCAN_CLK	DPLL_GMAC_DSP
	MCAN_ICLK	Int	133	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC1	OCP_CLK_PI	Int	133	L4PER3_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC2	OCP_CLK_PI	Int	133	L4PER3_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC3	OCP_CLK_PI	Int	133	L4PER3_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC4	OCP_CLK_PI	Int	133	L4PER3_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC5	OCP_CLK_PI	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC6	OCP_CLK_PI	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DCC7	OCP_CLK_PI	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
DLL	EMIF_DLL_FCLK	Func	266	EMIF_DLL_GCLK	EMIF_DLL_GCLK	DPLL_DDR
DSP1	DSP1_FICLK	Int & Func	DSP_CLK	DSP1_GFCLK	DSP_GFCLK	DPLL_EVE_VID_DSP
						DPLL_CORE
						DPLL_GMAC_DSP
DSP2	DSP2_FICLK	Int & Func	DSP_CLK	DSP2_GFCLK	DSP_GFCLK	DPLL_EVE_VID_DSP
						DPLL_CORE
						DPLL_GMAC_DSP
DSS	DSS_FCK_CLK	Int & Func	192	DSS_GFCLK	DSS_GFCLK	DPLL_PER
	DSS_VP_CLK	Func	165	VID_PIX_CLK	VID_PIX_CLK	DPLL_EVE_VID_DSP

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	**Input Clock Name**	**Clock Type**	**Max. Clock Allowed (MHz)**	**PRCM Clock Name**	**PLL / OSC / Source Clock Name**	**PLL / OSC / Source Name**
DSS DISPC	DISPC_FCK_CLK	Int & Func	192	DSS_GFCLK	DSS_GFCLK	DPLL_PER
	DISPC_CLK1	Int	165	VID_PIX_CLK	VID_PIX_CLK	DPLL_EVE_VID_DSP
EFUSE_CTRL_CUST	ocp_clk	Int	133	CUSTEFUSE_L4_GICLK	CORE_X2_CLK	DPLL_CORE
	sys_clk	Func	38.4	CUSTEFUSE_SYS_GFCLK	SYS_CLK1	OSC0
ELM	ELM_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
EMIF_OCP_FW	L3_CLK	Int	266	EMIF_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	L4_CLKEN	Int	133	EMIF_L4_GICLK	CORE_X2_CLK	DPLL_CORE
EMIF_PHY	EMIF_PHY_FCLK	Func	DDR	EMIF_PHY_GCLK	EMIF_PHY_GCLK	DPLL_DDR
	EMIF_DLL_FCLK	Int	266	EMIF_DLL_GCLK	-	DPLL_DDR
EMIF	EMIF_ICLK	Int	266	EMIF_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	EMIF_L3_ICLK	Int	266	L3_EOCP_GICLK	-	-
	EMIF_FICLK	Func	DDR/2	EMIF_PHY_GCLK/2	EMIF_PHY_GCLK	DPLL_DDR
ESM	OCP_CLK	Int & Func	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
EVE	EVE_FCLK	Func	EVE_FCLK	EVE_CLK	EVE_GCLK	DPLL_CORE
						DPLL_GMAC_DSP
					EVE_GFCLK	DPLL_EVE_VID_DSP
GMAC_SW	CPTS_RFT_CLK	Func	266	GMAC_RFT_CLK	L3_ICLK	DPLL_CORE
					SYS_CLK1	OSC0
	MAIN_CLK	Int	125	GMAC_MAIN_CLK	GMAC_250M_CLK	DPLL_GMAC_DSP
	MHZ_250_CLK	Func	250	GMII_250MHZ_CLK	GMII_250MHZ_CLK	DPLL_GMAC_DSP
	MHZ_5_CLK	Func	5	RGMII_5MHZ_CLK	RMII_50MHZ_CLK/10	DPLL_GMAC_DSP
	MHZ_50_CLK	Func	50	RMII_50MHZ_CLK	GMAC_RMII_HS_CLK	DPLL_GMAC_DSP
GPIO1	GPIO1_ICLK	Int	38.4	WKUPAON_GICLK	SYS_CLK1	OSC0
	GPIO1_DBCLK	Func	0.032	WKUPAON_32K_GFCLK	SYS_CLK1/610	OSC0
GPIO2	GPIO2_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	GPIO2_DBCLK	Func	0.032	FUNC_32K_CLK	SYS_CLK1/610	OSC0
GPIO3	GPIO3_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	GPIO3_DBCLK	Func	0.032	FUNC_32K_CLK	SYS_CLK1/610	OSC0
GPIO4	GPIO4_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	GPIO4_DBCLK	Func	0.032	FUNC_32K_CLK	SYS_CLK1/610	OSC0
GPMC	GPMC_ICLK	Int & Func	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
I2C1	I2C1_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	I2C1_FCLK	Func	96	PER_96M_GFCLK	FUNC_192M_CLK	DPLL_PER
I2C2	I2C2_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	I2C2_FCLK	Func	96	PER_96M_GFCLK	FUNC_192M_CLK	DPLL_PER
IEEE1500_2_OCP	PI_L3CLK	Int & Func	266	L3INIT_L3_GICLK	CORE_X2_CLK	DPLL_CORE

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	**Input Clock Name**	**Clock Type**	**Max. Clock Allowed (MHz)**	**PRCM Clock Name**	**PLL / OSC / Source Clock Name**	**PLL / OSC / Source Name**
IPU1	IPU1_GFCLK	Int & Func	IPU_CLK	IPU1_GFCLK	DPLL_ABE_X2_CLK	DPLL_DDR
					CORE_IPU_ISS_BOOST_CLK	DPLL_CORE
L3_INSTR	L3_CLK	Int	L3_CLK	L3INSTR_L3_GICLK	CORE_X2_CLK	DPLL_CORE
L4_CFG	L4_CFG_CLK	Int	133	L4CFG_L3_GICLK	CORE_X2_CLK	DPLL_CORE
L4_PER1	L4_PER1_CLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
L4_PER2	L4_PER2_CLK	Int	133	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE
L4_PER3	L4_PER3_CLK	Int	133	L4PER3_L3_GICLK	CORE_X2_CLK	DPLL_CORE
L4_WKUP	L4_WKUP_CLK	Int	38.4	WKUPAON_GICLK	SYS_CLK1	OSC0
					ABE_LP_CLK	DPLL_DDR
MAILBOX1	MAILBOX1_FLCK	Int	133	L4CFG_L3_GICLK	CORE_X2_CLK	DPLL_CORE
MAILBOX2	MAILBOX2_FLCK	Int	133	L4CFG_L3_GICLK	CORE_X2_CLK	DPLL_CORE
MCASP1	MCASP1_AHCLKR	Func	50	MCASP1_AHCLKR	ABE_24M_GFCLK	DPLL_DDR
					ABE_SYS_CLK	SYS_CLK1
					FUNC_24M_GFCLK	DPLL_PER
					SYS_CLK1	OSC0
					ATL_CLK0	Module ATL
					ATL_CLK1	Module ATL
					ATL_CLK2	Module ATL
					ATL_CLK3	Module ATL
					SYS_CLK2	OSC1
					XREF_CLK0	REF_CLKIN0
					XREF_CLK1	REF_CLKIN1
					XREF_CLK2	REF_CLKIN2
	MCASP1_AHCLKX	Func	50	MCASP1_AHCLKX	ABE_24M_GFCLK	DPLL_DDR
					ABE_SYS_CLK	SYS_CLK1
					FUNC_24M_GFCLK	DPLL_PER
					SYS_CLK1	OSC0
					ATL_CLK0	Module ATL
					ATL_CLK1	Module ATL
					ATL_CLK2	Module ATL
					ATL_CLK3	Module ATL
					SYS_CLK2	OSC1
					XREF_CLK0	REF_CLKIN0
					XREF_CLK1	REF_CLKIN1
					XREF_CLK2	REF_CLKIN2
	MCASP1_FCLK	Func	133	MCASP1_AUX_GFCLK	L4_ICLK	DPLL_CORE
					SYS_CLK1	OSC0
	MCASP1_ICLK	Int	266	IPU_L3_GICLK	CORE_X2_CLK	DPLL_CORE

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	**Input Clock Name**	**Clock Type**	**Max. Clock Allowed (MHz)**	**PRCM Clock Name**	**PLL / OSC / Source Clock Name**	**PLL / OSC / Source Name**
MCASP2	MCASP2_AHCLKR	Func	50	MCASP6_AHCLKR	ABE_24M_GFCLK	DPLL_DDR
					ABE_SYS_CLK	SYS_CLK1
					FUNC_24M_GFCLK	DPLL_PER
					SYS_CLK1	OSC0
					ATL_CLK0	Module ATL
					ATL_CLK1	Module ATL
					ATL_CLK2	Module ATL
					ATL_CLK3	Module ATL
					SYS_CLK2	OSC1
					XREF_CLK0	REF_CLKIN0
					XREF_CLK1	REF_CLKIN1
					XREF_CLK2	REF_CLKIN2
	MCASP2_AHCLKX	Func	50	MCASP4_AHCLKX	ABE_24M_GFCLK	DPLL_DDR
					ABE_SYS_CLK	SYS_CLK1
					FUNC_24M_GFCLK	DPLL_PER
					SYS_CLK1	OSC0
					ATL_CLK0	Module ATL
					ATL_CLK1	Module ATL
					ATL_CLK2	Module ATL
					ATL_CLK3	Module ATL
					SYS_CLK2	OSC1
					XREF_CLK0	REF_CLKIN0
					XREF_CLK1	REF_CLKIN1
					XREF_CLK2	REF_CLKIN2
	MCASP2_FCLK	Func	133	MCASP4_AUX_GFCLK	L4_ICLK	DPLL_CORE
					SYS_CLK1	OSC0
	MCASP2_ICLK	Int	133	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	Input Clock Name	Clock Type	Max. Clock Allowed (MHz)	PRCM Clock Name	PLL / OSC / Source Clock Name	PLL / OSC / Source Name
MCASP3	MCASP3_AHCLKR	Func	50	MCASP7_AHCLKR	ABE_24M_GFCLK	DPLL_DDR
					ABE_SYS_CLK	SYS_CLK1
					FUNC_24M_GFCLK	DPLL_PER
					SYS_CLK1	OSC0
					ATL_CLK0	Module ATL
					ATL_CLK1	Module ATL
					ATL_CLK2	Module ATL
					ATL_CLK3	Module ATL
					SYS_CLK2	OSC1
					XREF_CLK0	REF_CLKIN0
					XREF_CLK1	REF_CLKIN1
					XREF_CLK2	REF_CLKIN2
	MCASP3_AHCLKX	Func	50	MCASP5_AHCLKX	ABE_24M_GFCLK	DPLL_DDR
					ABE_SYS_CLK	SYS_CLK1
					FUNC_24M_GFCLK	DPLL_PER
					SYS_CLK1	OSC0
					ATL_CLK0	Module ATL
					ATL_CLK1	Module ATL
					ATL_CLK2	Module ATL
					ATL_CLK3	Module ATL
					SYS_CLK2	OSC1
					XREF_CLK0	REF_CLKIN0
					XREF_CLK1	REF_CLKIN1
					XREF_CLK2	REF_CLKIN2
	MCASP3_FCLK	Func	133	MCASP5_AUX_GFCLK	L4_ICLK	DPLL_CORE
					SYS_CLK1	OSC0
	MCASP3_ICLK	Int	133	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE
MCSPI1	SPI1_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	SPI1_FCLK	Func	48	PER_48M_GFCLK	FUNC_192M_CLK	DPLL_PER
MCSPI2	SPI2_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	SPI2_FCLK	Func	48	PER_48M_GFCLK	FUNC_192M_CLK	DPLL_PER
MCSPI3	SPI3_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	SPI3_FCLK	Func	48	PER_48M_GFCLK	FUNC_192M_CLK	DPLL_PER
MCSPI4	SPI4_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	SPI4_FCLK	Func	48	PER_48M_GFCLK	FUNC_192M_CLK	DPLL_PER
MMC1	MMC_CLK_32K	Func	0.032	FUNC_32K_CLK	SYS_CLK1/610	OSC0
	MMC_FCLK	Func	192	MMC4_GFCLK	FUNC_192M_CLK	DPLL_PER
			48		FUNC_48M_FCLK	DPLL_PER
	MMC_ICLK	Int	133	L3INIT_L3_GICLK	CORE_X2_CLK	DPLL_CORE
MMU_EDMA	MMU_CLK	Int	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
OCMC_RAM	OCMC_L3_CLK	Int	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	**Input Clock Name**	**Clock Type**	**Max. Clock Allowed (MHz)**	**PRCM Clock Name**	**PLL / OSC / Source Clock Name**	**PLL / OSC / Source Name**
OCP_WP_NOC	PICLKOCPL3	Int	266	L3INSTR_L3_GICLK	CORE_X2_CLK	DPLL_CORE
PWMSS1	PWMSS1_GICLK	Int & Func	133	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE
QSPI	QSPI_ICLK	Int	266	L4PER2_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	QSPI_FCLK	Func	128	QSPI_GFCLK	FUNC_128M_CLK	DPLL_PER
					PER_QSPI_CLK	DPLL_PER
RTI1	OCP_CLK_PI	Int	133	WKUPAON_GICLK	CORE_X2_CLK	DPLL_CORE
	RTI_CLK_PI	Func	13	RTI1_CLK	SYS_CLK1/4	OSC0
					SYS_CLK2/4	OSC1
					FUNC_32K_CLK	OSC0
RTI2	OCP_CLK_PI	Int	133	WKUPAON_GICLK	CORE_X2_CLK	DPLL_CORE
	RTI_CLK_PI	Func	13	RTI2_CLK	SYS_CLK1/4	OSC0
					SYS_CLK2/4	OSC1
					FUNC_32K_CLK	OSC0
RTI3	OCP_CLK_PI	Int	133	WKUPAON_GICLK	CORE_X2_CLK	DPLL_CORE
	RTI_CLK_PI	Func	13	RTI3_CLK	SYS_CLK1/4	OSC0
					SYS_CLK2/4	OSC1
					FUNC_32K_CLK	OSC0
RTI4	OCP_CLK_PI	Int	133	WKUPAON_GICLK	CORE_X2_CLK	DPLL_CORE
	RTI_CLK_PI	Func	13	RTI4_CLK	SYS_CLK1/4	OSC0
					SYS_CLK2/4	OSC1
					FUNC_32K_CLK	OSC0
RTI5	OCP_CLK_PI	Int	133	WKUPAON_GICLK	CORE_X2_CLK	DPLL_CORE
	RTI_CLK_PI	Func	13	RTI5_CLK	SYS_CLK1/4	OSC0
					SYS_CLK2/4	OSC1
					FUNC_32K_CLK	OSC0
SD_DAC	CLKDAC	Func	50	VID_PIX_CLK	VID_PIX_CLK	DPLL_EVE_VID_DSP
SL2	piclk	Int	IVA_GCLK	IVA_GCLK	IVA_GFCLK	DPLL_IVA
SPINLOCK	SPINLOCK_ICLK	Int	133	L4CFG_L3_GICLK	CORE_X2_CLK	DPLL_CORE
TESOC	L3_CLK	Func	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	EXT_CLK	Func	50	EXT_CLK	TESOC_EXT_CLK	DPLL_CORE
TIMER1	TIMER1_ICLK	Int	133	WKUPAON_GICLK	SYS_CLK1	OSC0
					ABE_LP_CLK	DPLL_DDR
	TIMER1_FCLK	Func	38.4	TIMER1_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	Input Clock Name	Clock Type	Max. Clock Allowed (MHz)	PRCM Clock Name	PLL / OSC / Source Clock Name	PLL / OSC / Source Name
TIMER2	TIMER2_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER2_FCLK	Func	100	TIMER2_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
TIMER3	TIMER3_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER3_FCLK	Func	100	TIMER3_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
TIMER4	TIMER4_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER4_FCLK	Func	100	TIMER4_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
TIMER5	TIMER5_ICLK	Int	133	IPU_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER5_FCLK	Func	100	TIMER5_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
					CLKOUTMUX0_CLK	CLKOUTMUX0
TIMER6	TIMER6_ICLK	Int	133	IPU_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER6_FCLK	Func	100	TIMER6_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
					CLKOUTMUX0_CLK	CLKOUTMUX0

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-5. Maximum Supported Frequency (continued)

Module				Clock Sources		
Instance Name	Input Clock Name	Clock Type	Max. Clock Allowed (MHz)	PRCM Clock Name	PLL / OSC / Source Clock Name	PLL / OSC / Source Name
TIMER7	TIMER7_ICLK	Int	133	IPU_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER7_FCLK	Func	100	TIMER7_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
					CLKOUTMUX0_CLK	CLKOUTMUX0
TIMER8	TIMER8_ICLK	Int	133	IPU_L3_GICLK	CORE_X2_CLK	DPLL_CORE
	TIMER8_FCLK	Func	100	TIMER8_GFCLK	SYS_CLK1	OSC0
					FUNC_32K_CLK	OSC0
					SYS_CLK2	OSC1
					XREF_CLK0	xref_clk0
					XREF_CLK1	xref_clk1
					ABE_GICLK	DPLL_DDR
					CLKOUTMUX0_CLK	CLKOUTMUX0
TPCC	TPCC_GCLK	Int	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
TPTC1	TPTC0_GCLK	Int	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
TPTC2	TPTC1_GCLK	Int	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
UART1	UART1_FCLK	Func	192	UART1_GFCLK	FUNC_192M_CLK	DPLL_PER
			48		FUNC_48M_FCLK	DPLL_PER
	UART1_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
UART2	UART2_FCLK	Func	192	UART2_GFCLK	FUNC_192M_CLK	DPLL_PER
			48		FUNC_48M_FCLK	DPLL_PER
	UART2_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
UART3	UART3_FCLK	Func	192	UART3_GFCLK	FUNC_192M_CLK	DPLL_PER
			48		FUNC_48M_FCLK	DPLL_PER
	UART3_ICLK	Int	133	L4PER_L3_GICLK	CORE_X2_CLK	DPLL_CORE
VCP1	VCP1_CLK	Int	266	L3MAIN1_L3_GICLK	CORE_X2_CLK	DPLL_CORE
VIP1	PROC_CLK	Func	266	VIP1_GCLK	L3_ICLK	DPLL_CORE
	L3_CLK	Int			CORE_ISS_MAIN_CLK	DPLL_CORE
	L4_CLK	Int	133	VIP1_GCLKDIV2	VIP1_GCLK/2	DPLL_CORE

5.6 Power Consumption Summary

NOTE

Maximum power consumption for this SoC depends on the specific use conditions for the end system. Contact your TI representative for assistance in estimating maximum power consumption for the end system use case.

Copyright © 2016–2020, Texas Instruments Incorporated

5.7 Electrical Characteristics

NOTE

The data specified in Section 5.7.1 through Section 5.7.6 are subject to change.

NOTE

The interfaces or signals described in Section 5.7.1 through Section 5.7.6 correspond to the interfaces or signals available in multiplexing mode 0 (Function 1).

All interfaces or signals multiplexed on the balls described in these tables have the same DC electrical characteristics, unless multiplexing involves a PHY/GPIO combination in which case different DC electrical characteristics are specified for the different multiplexing modes (Functions).

5.7.1 LVCMOS DDR DC Electrical Characteristics

Table 5-6 summarizes the DC electrical characteristics for LVCMOS DDR Buffers.

NOTE

For more information on the I/O cell configurations (i[2:0], sr[1:0]), see *Control Module* section of the Device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-6. LVCMOS DDR DC Electrical Characteristics

PARAMETER			MIN	NOM	MAX	UNIT
Signal Names in MUXMODE 0 (Single-Ended Signals) ABF: ddr1_d[31:0], ddr1_a[15:0], ddr1_dqm[3:0], ddr1_ba[2:0], ddr1_csn[1:0], ddr1_cke[1:0], ddr1_odt[0], ddr1_casn, ddr1_rasn, ddr1_wen, ddr1_rst, ddr1_ecc_d[7:0], ddr1_dqm_ecc;						
Driver Mode						
V_{OH}	High-level output threshold (I_{OH} = 0.1 mA)		0.9×VDDS			V
V_{OL}	Low-level output threshold (I_{OL} = 0.1 mA)				0.1×VDDS	V
C_{PAD}	Pad capacitance (including package capacitance)				3	pF
Z_O	Output impedance (drive strength)	I[2:0] = 000 (Imp80)		80		Ω
		I[2:0] = 001 (Imp60)		60		
		I[2:0] = 010 (Imp48)		48		
		I[2:0] = 011 (Imp40)		40		
		I[2:0] = 100 (Imp34)		34		
Single-Ended Receiver Mode						
V_{IH}	High-level input threshold	DDR3/DDR3L	VREF+0.1		VDDS+0.2	V
V_{IL}	Low-level input threshold	DDR3/DDR3L	-0.2		VREF-0.1	V
V_{CM}	Input common-mode voltage		VREF -1%VDDS		VREF+ 1%VDDS	V
C_{PAD}	Pad capacitance (including package capacitance)					pF
Signal Names in MUXMODE 0 (Differential Signals): ddr1_dqs[3:0], ddr1_dqsn[3:0], ddr1_ck, ddr1_nck, ddr1_dqs_ecc, ddr1_dqsn_ecc;						
Driver Mode						
V_{OH}	High-level output threshold (I_{OH} = 0.1 mA)		0.9×VDDS			V
V_{OL}	Low-level output threshold (I_{OL} = 0.1 mA)				0.1×VDDS	V
C_{PAD}	Pad capacitance (including package capacitance)				3	pF
Z_O	Output impedance (drive strength)	I[2:0] = 000 (Imp80)		80		Ω
		I[2:0] = 001 (Imp60)		60		
		I[2:0] = 010 (Imp48)		48		
		I[2:0] = 011 (Imp40)		40		
		I[2:0] = 100 (Imp34)		34		
Single-Ended Receiver Mode						
V_{IH}	High-level input threshold	DDR3/DDR3L	VREF+0.1		VDDS+0.2	V
V_{IL}	Low-level input threshold	DDR3/DDR3L	-0.2		VREF-0.1	V
V_{CM}	Input common-mode voltage		VREF -1%VDDS		VREF+ 1%VDDS	V
C_{PAD}	Pad capacitance (including package capacitance)				3	pF
Differential Receiver Mode						
V_{SWING}	Input voltage swing	DDR3/DDR3L	0.4×vdds		0.6×vdds	V
V_{CM}	Input common-mode voltage		VREF -1%VDDS		VREF+ 1%VDDS	V
C_{PAD}	Pad capacitance (including package capacitance)				3	pF

Copyright © 2016–2020, Texas Instruments Incorporated

(1) VDDS stands for corresponding power supply (i.e. vdds_ddr1 or vdds_ddr2). For more information on the power supply name and the corresponding ball, see Table 4-2, POWER [11] column.

5.7.2 Dual Voltage LVCMOS I2C DC Electrical Characteristics

Table 5-7 summarizes the DC electrical characteristics for Dual Voltage LVCMOS I2C Buffers.

NOTE

For more information on the I/O cell configurations, see the Control Module section of the Device TRM.

Table 5-7. Dual Voltage LVCMOS I2C DC Electrical Characteristics

PARAMETER		MIN	NOM	MAX	UNIT
Signal Names in MUXMODE 0: i2c2_scl; i2c1_scl; i2c1_sda; i2c2_sda;					
Balls ABF: L3, L4, L6, L5;					
I^2C Standard Mode – 1.8 V					
V_{IH}	Input high-level threshold	0.7×VDDS			V
V_{IL}	Input low-level threshold			0.3×VDDS	V
V_{hys}	Hysteresis	0.1×VDDS			V
I_I	Input current at each I/O pin with an input voltage between 0.1×VDDS to 0.9×VDDS			12	µA
I_{OZ}	I_{OZ}(I_{PAD} Current) at each IO pin. PAD is swept from 0 to VDDS and the Max(I(PAD)) is measured and is reported as I_{OZ}			12	µA
C_I	Input capacitance			10	pF
V_{OL3}	Output low-level threshold open-drain at 3-mA sink current			0.2×VDDS	V
I_{OLmin}	Low-level output current @V_{OL}=0.2×VDDS	3			mA
t_{OF}	Output fall time from V_{IHmin} to V_{ILmax} with a bus capacitance CB from 5 pF to 400 pF			250	ns
I^2C Fast Mode – 1.8 V					
V_{IH}	Input high-level threshold	0.7×VDDS			V
V_{IL}	Input low-level threshold			0.3×VDDS	V
V_{hys}	Hysteresis	0.1×VDDS			V
I_I	Input current at each I/O pin with an input voltage between 0.1×VDDS to 0.9×VDDS			12	µA
I_{OZ}	I_{OZ}(I_{PAD} Current) at each IO pin. PAD is swept from 0 to VDDS and the Max(I(PAD)) is measured and is reported as I_{OZ}			12	µA
C_I	Input capacitance			10	pF
V_{OL3}	Output low-level threshold open-drain at 3-mA sink current			0.2×VDDS	V
I_{OLmin}	Low-level output current @V_{OL}=0.2×VDDS	3			mA
t_{OF}	Output fall time from V_{IHmin} to V_{ILmax} with a bus capacitance CB from 10 pF to 400 pF	20+0.1×Cb		250	ns
I^2C Standard Mode – 3.3 V					
V_{IH}	Input high-level threshold	0.7×VDDS			V
V_{IL}	Input low-level threshold			0.3×VDDS	V
V_{hys}	Hysteresis	0.05×VDDS			V
I_I	Input current at each I/O pin with an input voltage between 0.1×VDDS to 0.9×VDDS	31		80	µA
I_{OZ}	I_{OZ}(I_{PAD} Current) at each IO pin. PAD is swept from 0 to VDDS and the Max(I(PAD)) is measured and is reported as I_{OZ}	31		80	µA
C_I	Input capacitance			10	pF
V_{OL3}	Output low-level threshold open-drain at 3-mA sink current			0.4	V
I_{OLmin}	Low-level output current @V_{OL}=0.4V	3			mA

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-7. Dual Voltage LVCMOS I2C DC Electrical Characteristics (continued)

PARAMETER		MIN	NOM	MAX	UNIT
I_{OLmin}	Low-level output current @V_{OL}=0.6V for full drive load (400pF/400KHz)	6			mA
t_{OF}	Output fall time from V_{IHmin} to V_{ILmax} with a bus capacitance CB from 5 pF to 400 pF			250	ns
I^2C Fast Mode – 3.3 V					
V_{IH}	Input high-level threshold	0.7×VDDS			V
V_{IL}	Input low-level threshold			0.3×VDDS	V
V_{hys}	Hysteresis	0.05×VDDS			V
I_I	Input current at each I/O pin with an input voltage between 0.1×VDDS to 0.9×VDDS	31		80	µA
I_{OZ}	I_{OZ}(I_{PAD} Current) at each IO pin. PAD is swept from 0 to VDDS and the Max(I(PAD)) is measured and is reported as I_{OZ}	31		80	µA
C_I	Input capacitance			10	pF
V_{OL3}	Output low-level threshold open-drain at 3-mA sink current			0.4	V
I_{OLmin}	Low-level output current @V_{OL}=0.4V	3			mA
I_{OLmin}	Low-level output current @V_{OL}=0.6V for full drive load (400pF/400KHz)	6			mA
t_{OF}	Output fall time from VIHmin to VILmax with a bus capacitance CB from 10 pF to 200 pF (Proper External Resistor Value should be used as per I2C spec)	20+0.1×Cb		250	ns
	Output fall time from V_{IHmin} to V_{ILmax} with a bus capacitance CB from 300 pF to 400 pF (Proper External Resistor Value should be used as per I2C spec)	40		290	

(1) VDDS stands for corresponding power supply (i.e. vddshv3). For more information on the power supply name and the corresponding ball, see Table 4-2, POWER [11] column.

5.7.3 IQ1833 Buffers DC Electrical Characteristics

Table 5-8 summarizes the DC electrical characteristics for IQ1833 Buffers.

Table 5-8. IQ1833 Buffers DC Electrical Characteristics

PARAMETER		MIN	NOM	MAX	UNIT
Signal Names in MUXMODE 0: tclk;					
Balls ABF: J2;					
1.8-V Mode					
V_{IH}	Input high-level threshold	0.75 × VDDS			V
V_{IL}	Input low-level threshold			0.25 × VDDS	V
V_{HYS}	Input hysteresis voltage	100			mV
I_{IN}	Input current at each I/O pin	2		11	µA
C_{PAD}	Pad capacitance (including package capacitance)			1	pF
3.3-V Mode					
V_{IH}	Input high-level threshold	2.0			V
V_{IL}	Input low-level threshold			0.6	V
V_{HYS}	Input hysteresis voltage	400			mV
I_{IN}	Input current at each I/O pin	5		11	µA
C_{PAD}	Pad capacitance (including package capacitance)			1	pF

Copyright © 2016–2020, Texas Instruments Incorporated

(1) VDDS stands for corresponding power supply (i.e. vddshv1). For more information on the power supply name and the corresponding ball, see Table 4-2, POWER [11] column.

5.7.4 IHHV1833 Buffers DC Electrical Characteristics

Table 5-9 summarizes the DC electrical characteristics for IHHV1833 Buffers.

Table 5-9. IHHV1833 Buffers DC Electrical Characteristics

PARAMETER		MIN	NOM	MAX	UNIT
Signal Names in MUXMODE 0: porz;					
Balls ABF: G3;					
1.8-V Mode					
V_{IH}	Input high-level threshold	1.2			V
V_{IL}	Input low-level threshold			0.4	V
V_{HYS}	Input hysteresis voltage	40			mV
I_{IN}	Input current at each I/O pin	0.02		1	µA
C_{PAD}	Pad capacitance (including package capacitance)			1	pF
3.3-V Mode					
V_{IH}	Input high-level threshold	1.2			V
V_{IL}	Input low-level threshold			0.4	V
V_{HYS}	Input hysteresis voltage	40			mV
I_{IN}	Input current at each I/O pin	5		8	µA
C_{PAD}	Pad capacitance (including package capacitance)			1	pF

5.7.5 LVCMOS Analog OSC Buffers DC Electrical Characteristics

Table 5-10 summarizes the DC electrical characteristics for LVCMOS Analog OSC Buffers.

Table 5-10. LVCMOS Analog OSC Buffers DC Electrical Characteristics

PARAMETER	DESCRIPTION		MIN	NOM	MAX	UNIT
Signal Names in MUXMODE 0: xi_osc0, xi_osc1;						
Balls ABF: E22, B21;						
V_{IH}	Input high-level threshold		0.65×VDDS			V
V_{IL}	Input low-level threshold				0.35×VDDS	V
I_{OH}		hfenable=0	1.18			mA
		hfenable=1	2			mA
I_{OL}		hfenable=0	2			mA
		hfenable=1	3.2			mA
V_{HYS}	Input hysteresis voltage	MODE-1	150			mV
C_{PAD}	Capacitance connected on input and output Pad on Board, CL1=CL2		12		24	pF

(1) VDDS stands for corresponding power supply (i.e. vdda_osc). For more information on the power supply name and the corresponding ball, see Table 4-2, POWER [11] column.

5.7.6 LVCMOS CSI2 DC Electrical Characteristics

Table 5-11 summarizes the DC electrical characteristics for LVSMOS CSI2 Buffers.

Table 5-11. LVCMOS CSI2 DC Electrical Characteristics

PARAMETER	MIN	NOM	MAX	UNIT
Signals MUXMODE 0: csi2_0_dx[4:0]; csi2_0_dy[4:0];				

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-11. LVCMOS CSI2 DC Electrical Characteristics (continued)

PARAMETER		MIN	NOM	MAX	UNIT
Bottom Balls: A11 / B11 / A12 / B12 / A13 / B13 / A15 / B15 / A16 / B16					
MIPI D-PHY Mode Low-Power Receiver (LP-RX)					
V_{IH}	Input high-level voltage	880		1350	mV
V_{IL}	Input low-level voltage			550	mV
V_{ITH}	Input high-level threshold(1)			880	mV
V_{ITL}	Input low-level threshold(2)	550			mV
V_{HYS}	Input hysteresis(3)	25			mV
MIPI D-PHY Mode Ultralow Power Receiver (ULP-RX)					
V_{IL}	Input low-level voltage			300	mV
V_{ITL}	Input low-level threshold(4)	300			mV
V_{HYS}	Input hysteresis(3)	25			mV
MIPI D-PHY Mode High Speed Receiver (HS-RX)					
V_{IDTH}	Differential input high-level threshold	70			mV
V_{IDTL}	Differential input low-level threshold			–70	mV
V_{IDMAX}	Maximum differential input voltage(7)			270	mV
V_{IHHS}	Single-ended input high voltage(5)			460	mV
V_{ILHS}	Single-ended input low voltage(5)	–40			mV
V_{CMRXDC}	Differential input common-mode voltage(5)(6)	70		330	mV
Z_{ID}	Differential input impedance	80	100	125	Ω

(1) V_{ITH} is the voltage at which the receiver is required to detect a high state in the input signal.

(2) V_{ITL} is the voltage at which the receiver is required to detect a low state in the input signal. V_{ITL} is larger than the maximum single-ended line high voltage during HS transmission. Therefore, both low-power (LP) receivers will detect low during HS signaling.

(3) To reduce noise sensitivity on the received signal, the LP receiver is required to incorporate a hysteresis, V_{HYST}. V_{HYST} is the difference between the V_{ITH} threshold and the V_{ITL} threshold.

(4) V_{ITL} is the voltage at which the receiver is required to detect a low state in the input signal. Specification is relaxed for detecting 0 during ultralow power (ULP) state. The LP receiver is not required to detect HS single-ended voltage as 0 in this state.

(5) Excluding possible additional RF interference of 200 mV_{PP} beyond 450 MHz.

(6) This value includes a ground difference of 50 mV between the transmitter and the receiver, the static common-mode level tolerance and variations below 450 MHz.

(7) This number corresponds to the VOD_{MAX} transmitter.

(8) Common mode is defined as the average voltage level of X and Y: $V_{CMRX} = (V_X + V_Y) / 2$.

(9) Common mode ripple may be due to tR or tF and transmission line impairments in the PCB.

5.7.7 Dual Voltage LVCMOS DC Electrical Characteristics

Table 5-12 summarizes the DC electrical characteristics for Dual Voltage LVCMOS Buffers.

Table 5-12. Dual Voltage LVCMOS DC Electrical Characteristics

PARAMETER	DESCRIPTION	MIN	NOM	MAX	UNIT
1.8-V Mode					
V_{IH}	Input high-level threshold	0.65×VDDS			V
V_{IL}	Input low-level threshold			0.35×VDDS	V
V_{HYS}	Input hysteresis voltage	100			mV
V_{OH}	Output high-level threshold (I_{OH} = 2 mA)	VDDS-0.45			V
V_{OL}	Output low-level threshold (I_{OL} = 2 mA)			0.45	V
I_{DRIVE}	Pin Drive strength at PAD Voltage = 0.45 V or VDDS-0.45 V	6			mA
I_{IN}	Input current at each I/O pin			16	µA

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-12. Dual Voltage LVCMOS DC Electrical Characteristics (continued)

PARAMETER	DESCRIPTION	MIN	NOM	MAX	UNIT
I_{OZ}	I_{OZ}(I_{PAD} Current) at each IO pin. PAD is swept from 0 to VDDS and the Max(I(PAD)) is measured and is reported as I_{OZ}			11.5	µA
$I_{IN\ with\ pulldown\ enabled}$	Input current at each I/O pin with weak pulldown enabled measured when PAD = VDDS	60	120	200	µA
$I_{IN\ with\ pullup\ enabled}$	Input current at each I/O pin with weak pullup enabled measured when PAD = 0	60	120	210	µA
C_{PAD}	Pad capacitance (including package capacitance)			4	pF
Z_O	Output impedance (drive strength)		40		Ω
3.3-V Mode					
V_{IH}	Input high-level threshold	2			V
V_{IL}	Input low-level threshold			0.8	V
V_{HYS}	Input hysteresis voltage	200			mV
V_{OH}	Output high-level threshold (I_{OH} =100 µA)	VDDS-0.2			V
V_{OL}	Output low-level threshold (I_{OL} = 100 µA)			0.2	V
I_{DRIVE}	Pin Drive strength at PAD Voltage = 0.45 V or VDDS-0.45 V	6			mA
I_{IN}	Input current at each I/O pin			64	µA
I_{OZ}	I_{OZ}(I_{PAD} Current) at each IO pin. PAD is swept from 0 to VDDS and the Max(I(PAD)) is measured and is reported as I_{OZ}			64	µA
$I_{IN\ with\ pulldown\ enabled}$	Input current at each I/O pin with weak pulldown enabled measured when PAD = VDDS	10	100	290	µA
$I_{IN\ with\ pullup\ enabled}$	Input current at each I/O pin with weak pullup enabled measured when PAD = 0	40	100	200	µA
C_{PAD}	Pad capacitance (including package capacitance)			4	pF
Z_O	Output impedance (drive strength)		40		Ω

(1) VDDS stands for corresponding power supply. For more information on the power supply name and the corresponding ball, see Table 4-2, POWER [11] column.

5.8 Thermal Characteristics

For reliability and operability concerns, the maximum junction temperature of the Device has to be at or below the T_J value identified in Section 5.4, *Recommended Operating Conditions*.

A BCI compact thermal model for this Device is available and recommended for use when modeling thermal performance in a system.

Therefore, it is recommended to perform thermal simulations at the system level with the worst case device power consumption.

5.8.1 Package Thermal Characteristics

Table 5-13 provides the thermal resistance characteristics for the package used on this device.

NOTE

Power dissipation of 4.14 W and an ambient temperature of 65ºC is assumed for ABF package.

Table 5-13. Thermal Resistance Characteristics

NO.	PARAMETER	DESCRIPTION	°C/W(1)	AIR FLOW (m/s)(2)
T1	$R\Theta_{JC}$	Junction-to-case	1.41	N/A

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-13. Thermal Resistance Characteristics (continued)

NO.	PARAMETER	DESCRIPTION	°C/W(1)	AIR FLOW (m/s)(2)
T2	$R\Theta_{JB}$	Junction-to-board	5.96	N/A
T3	$R\Theta_{JA}$	Junction-to-free air	15.4	0
T4		Junction-to-moving air	13.1	1
T5			12.2	2
T6			11.6	3
T7	Ψ_{JT}	Junction-to-free air	0.94	0
T8		Junction-to-package top	0.94	1
T9			0.94	2
T10			0.94	3
T11	Ψ_{JB}	Junction-to-free air	5.12	0
T12		Junction-to-board	4.78	1
T13			4.63	2
T14			4.52	3

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [$R\Theta_{JC}$] value, which is based on a JEDEC defined 1S0P system) and will change based on environment as well as application. For more information, see these EIA/JEDEC standards:
- JESD51-2, *Integrated Circuits Thermal Test Method Environment Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-6, *Integrated Circuit Thermal Test Method Environmental Conditions - Forced Convection (Moving Air)*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Packages*

(2) m/s = meters per second

5.9 Analog-to-Digital ADC Subsystem Electrical Specifications

The analog-to-digital converter (ADC) module is a successive-approximation-register (SAR) generalpurpose analog-to-digital converter.

The main features of the ADC include:

- 10-bit data.
- 8 general-purpose ADC channels.
- 750 KSPS at 13.5-MHz ADC_CLK.
- Programmable FSM sequencer.
- Support interrupts and status, with masking

Table 5-14 summarizes the ADC subsystem electrical specifications.

Table 5-14. ADC Electrical Specifications

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Analog Input					
Full-scale Input Range			adc_vrefp		V
Vref	Should be less than or equal to vdds_18v.	1.62		vdds_18v	V
Differential Non-Linearity (DNL)		-1		1	LSB
Integral Non-Linearity (INL)	adc_vrefp = vdds_18v			±2	LSB
Gain Error	adc_vrefp = vdds_18v		±4		LSB
Offset Error	adc_vrefp = vdds_18v		±3		LSB
Input Sampling Capacitance			3.2	5	pF
Input Frequency adc_in[7:0]		0		30	kHz
Signal-to-Noise Ratio (SNR)	Input Signal: 30 kHz sine wave at -0.5 dB Full Scale		50		dB

Copyright © 2016–2020, Texas Instruments Incorporated

Table 5-14. ADC Electrical Specifications (continued)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Total Harmonic Distortion (THD)	1.8 Vpp, 30 kHz sine wave		60		dB
Spurious Free Dynamic Range	1.8 Vpp, 30 kHz sine wave		60		dB
Signal-to-Noise Plus Distortion	1.8 Vpp, 30 kHz sine wave		50		dB
adc_vrefp Input Impedance			20		Ω
Sampling Dynamics					
Time from Start to Start		17			Clock Cycles
Conversion Time + Error Correction		10 + 1			Clock Cycles
Acquisition time		4			Clock Cycles
Throughput Rate	CLK = 20 MHz (Pin : clk)			1	MSPS
Channel to Channel Isolation			90		dB
ADC Clock Frequency				See Table 5-1	MHz

(1) Connect adc_vrefp to vdda_adc when not using a positive external reference voltage.

(2) This parameter is valid when the respective AIN terminal is configured to operate as a general-purpose ADC input.

(3) The maximum sample rate assumes a conversion time of 13 ADC clock cycles with the acquisition time configured for the minimum of 2 ADC clock cycles, where it takes a total of 15 ADC clock cycles to sample the analog input and convert it to a positive binary weighted digital value.

Copyright © 2016–2020, Texas Instruments Incorporated

5.10 Power Supply Sequences

This section describes the power-up and power-down sequence required to ensure proper device operation.

Figure 5-1 through Figure 5-5 and associated notes describes the device Recommended Power Sequencing.

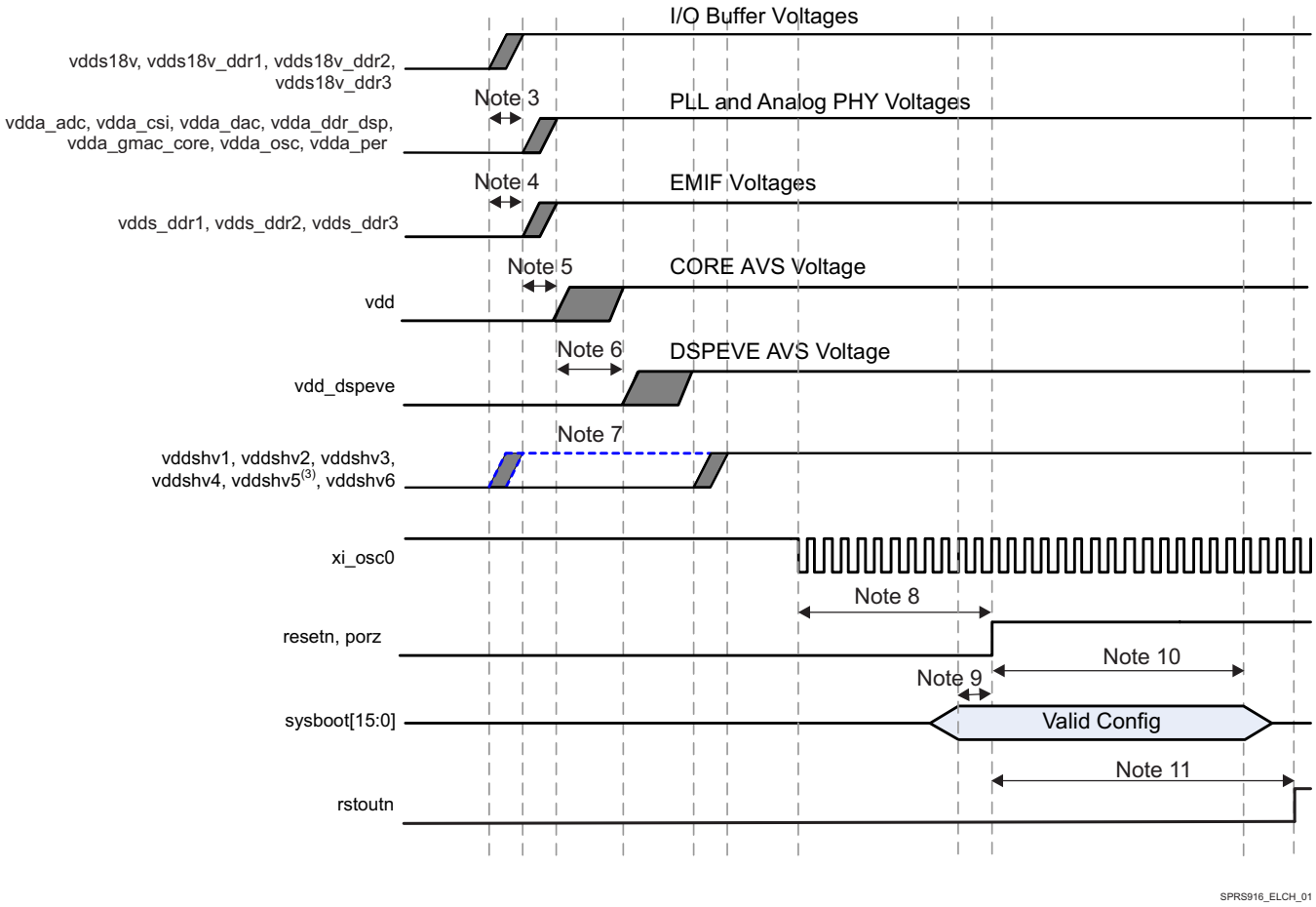


Figure 5-1. Power-Up Sequencing

(1) Grey shaded areas are windows where it is valid to ramp-up a voltage rail.

(2) Blue dashed lines are not valid windows but show alternate ramp-up possibilities based on whether I/O voltage levels are 1.8V or 3.3V (see associated note for more details).

(3) vdds18v_* and vdda_* rails should not be combined for best performance to avoid transient switching noise impacts on analog domains. vdda_* should not ramp-up before vdds18v_* but could ramp concurrently if design ensures final operational voltage will not be reached until after vdds18v. The preferred sequence is to follow all vdds18v_* to ensure circuit components and PCB design do not cause an inadvertent violation.

(4) vdds_ddr* should not ramp-up before vdds18v_*. The preferred sequence is to follow all vdds18v_* to ensure circuit components and PCB design do not cause an inadvertent violation. vdds_ddr* can ramp-up before, concurrently or after vdda_*, there are no dependencies between vdds_ddr* and vdda_* domains.

- vdds_ddr* supplies can be combined with vdds18v_* and vdds18v_ddr supplies for DDR2 mode of operation (1.8V) and ramped up together for simplified power sequencing.
- If vdds18v_ddr and vdds_ddr* are kept separate from vdds18v_* on board, then this combined DDR supply can come up together or after the vdds18v_* supply. The DDR supply in this case should never ramp up before the vdds18v_*.

(5) vdd should not ramp-up before vdds18v_* or vdds_ddr* domains.

(6) vdd_dspeve must not exceed vdd core supply and maintain at least 150mV lower voltage on vdd_dspeve vs vdd. vdd_dspeve could ramp concurrently with vdd if design ensures final operational voltage will not be reached until after vdd and maintains minimum of 150mV less than vdd during entire ramp time. The preferred sequence is to follow vdd to ensure circuit components and PCB design do not cause an inadvertent violation.

Copyright © 2016–2020, Texas Instruments Incorporated

(7) If any of the vddshv[1-6] power rails are used for 1.8V I/O signaling, then these rails can be combined with vdds18v_*. If 3.3V I/O signaling is required, then these rails must be the last to ramp following vdd_dspeve.

(8) resetn and porz must remain asserted low for a minimum of 12P(12) after xi_osc0 is stable at a valid frequency.

(9) Setup time: SYSBOOT[15:0] pins must be valid 2P(12) before porz is de-asserted high.

(10) Hold time: SYSBOOT[15:0] pins must be valid 15P(12) after porz is de-asserted high.

(11) resetn to rstoutn delay is 2ms.

(12) P = 1/(SYS_CLK1/610) frequency in ns.

(13) Ramped Up is defined as reaching the minimum operational voltage level for the corresponding power domain. For information about voltage levels, refer to , *Recommended Operating Conditions*.

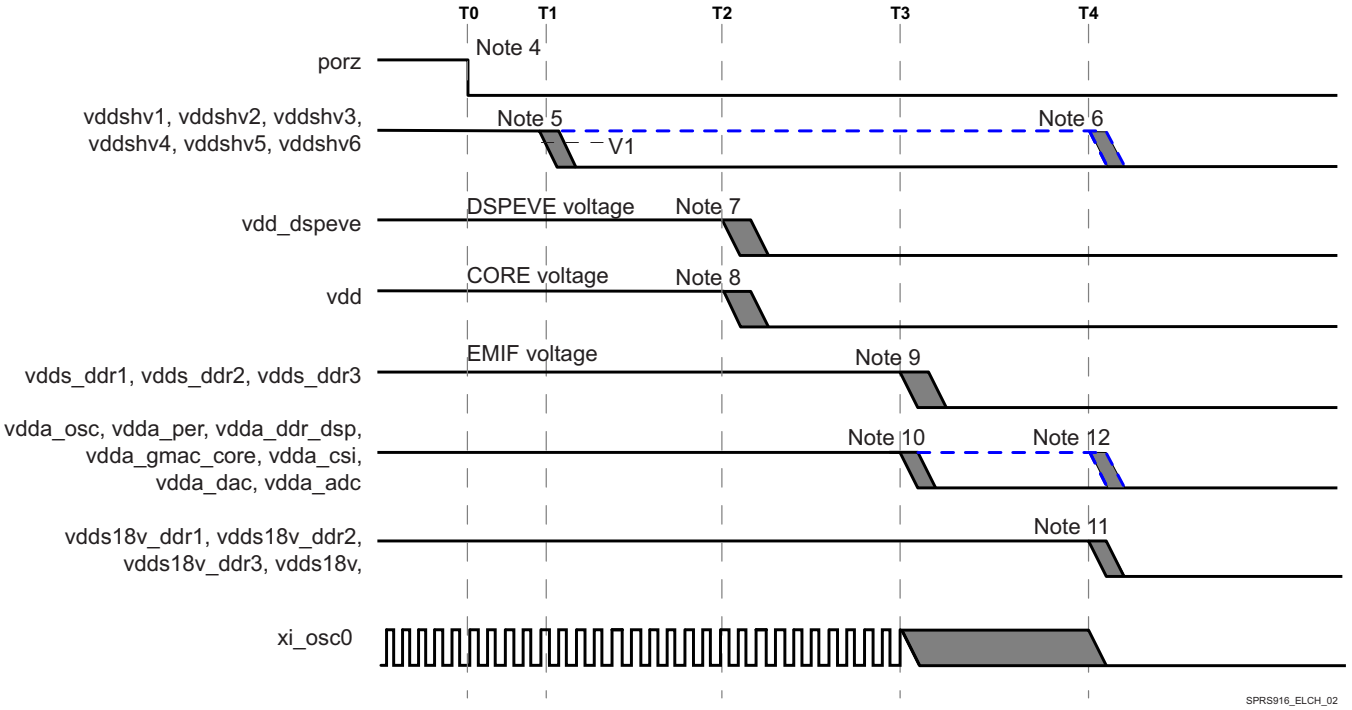


Figure 5-2. Recommended Power-Down Sequencing

(1) T1 ≥ 100 µs; T2 = 500 µs; T3 = 1.0 ms; T4 = 1.5 ms; V1 = 2.7 V. All "Tn" markers are intended to show total elapsed time, not interval times.

(2) Terminology:
- $V_{OPR\ MIN}$ = Minimum Operational Voltage level that ensures device functionality and specified performance in , *Recommended Operating Conditions*.
- V_{OFF} = OFF Voltage level is defined to be less than 0.6 V where any current draw has no impact to POH.
- Ramp Down = transition time from $V_{OPR\ MIN}$ to V_{OFF} and is slew rate independent.

(3) General timing diagram items:
- Grey shaded areas show valid transition times for supplies between $V_{OPR\ MIN}$ and V_{OFF}.
- Blue dashed lines are not valid windows but show alternate ramp possibilities based on the associated note.
- Dashed vertical lines show approximate elapse times based upon TI recommended PMIC power-down sequencer circuit performance.

(4) porz must be asserted low for 100 µs min to ensure SoC is set to a safe functional state before any voltage begins to ramp down.

(5) vddshv[1-6] domains supplied by 3.3 V:
- must remain greater than 2.7 V to enable Dual Voltage GPIO selector circuit operation for 100 µs min after porz is asserted low.
- must be in first group of supplies ramping down after porz has been asserted low for 100 µs min.
- must not exceed vdds18v by more than 2 V during ramp down, see Figure 5-3, "vdds18v versus vddshv[1-6] Discharge Relationship".

(6) vddshv[1-6] domains supplied by 1.8 V must ramp down concurrently with vdds18v and be sourced from common vdds18v supply.

(7) vdd_dspeve domain can ramp down before or concurrently with vdd.

(8) vdd must ramp down after or concurrently with vdd_dspeve.

(9) vdds_ddr[1-3] domains:
- should ramp down after vdd begins ramping down.

Copyright © 2016–2020, Texas Instruments Incorporated

- If DDR2 memory is used (requiring 1.8V supply),
  - then vdds_ddr[1-3] can be combined with vdds18v and vdds18v_ddr[1-3] domains and sourced from a common supply. Accordingly, all domains can ramp down concurrently with vdds18v.
  - if vdds_ddr[1-3] and vdds18v_ddr[1-3] are combined but kept separate from vdds18v, then the combined 1.8V DDR supply can ramp down before or concurrently with vdds18v.

(10) vdda_* domains:

- can ramp down before, concurrently or after vdds_ddr[1-3], there is no dependency between these supplies.
- can ramp down before or concurrently with vdds18v.
- must satisfy the vdds18v versus vdda_* discharge relationship (see Figure 5-5) if any of the vdda_* disable point is later or discharge rate is slower than vdds18v.

(11) vdds18v domain:

- should maintain $V_{OPR\ MIN}$ (V_{NOM} -5% = 1.71 V) until all other supplies start to ramp down.
- must satisfy the vdds18v versus vddshv[1-6] discharge relationship (see Figure 5-3) if any of the vddshv[1-6] is operating at 3.3 V.
- must satisfy the vdds18v versus vdds_ddr[1-3] discharge relationship (see Figure 5-4) if vdds_ddr[1-3] discharge rate is slower than vdds18v.

Figure 5-3 describes vddshv[1-6] supplies falling before vdds18v supplies delta.

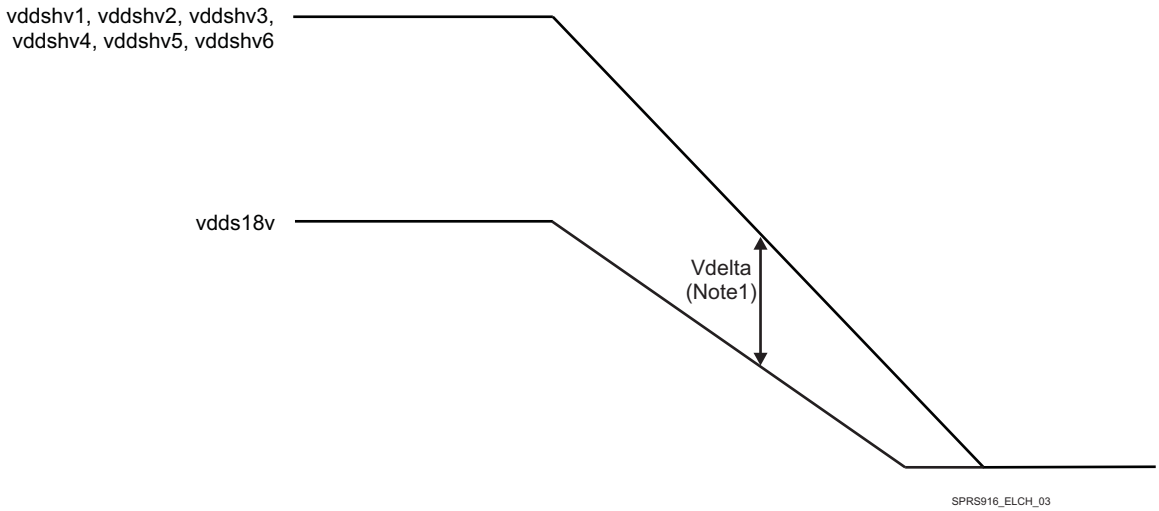


Figure 5-3. vdds18v versus vddshv[1-6] Discharge Relationship

(1) Vdelta MAX = 2 V

If vdds18v and vdds_ddr* are disabled at the same time due to a loss of input power event or if vdds_ddr* discharges more slowly than vdds18v, analysis has shown no reliability impacts when the elapsed time period beginning with vdds18v dropping below 1.0 V and ending with vdds_ddr* dropping below 0.6 V is less than 10 ms (Figure 5-4).

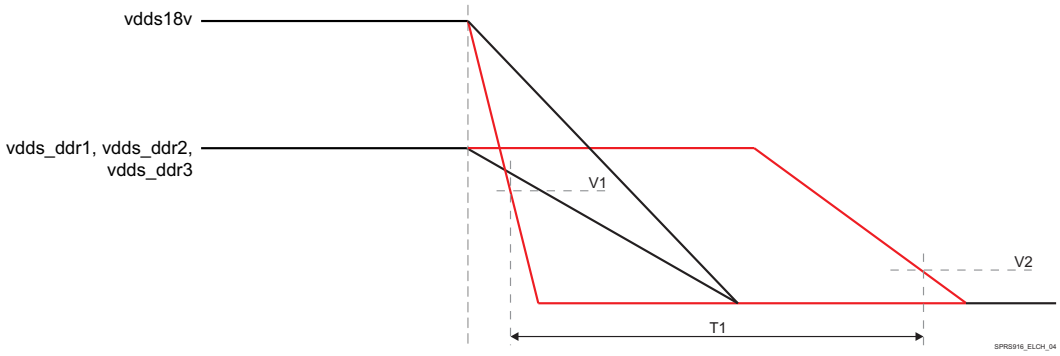


Figure 5-4. vdds18v and vdds_ddr* Discharge Relationship(1)

(1) V1 > 1.0 V; V2 < 0.6 V; T1 < 10 ms.

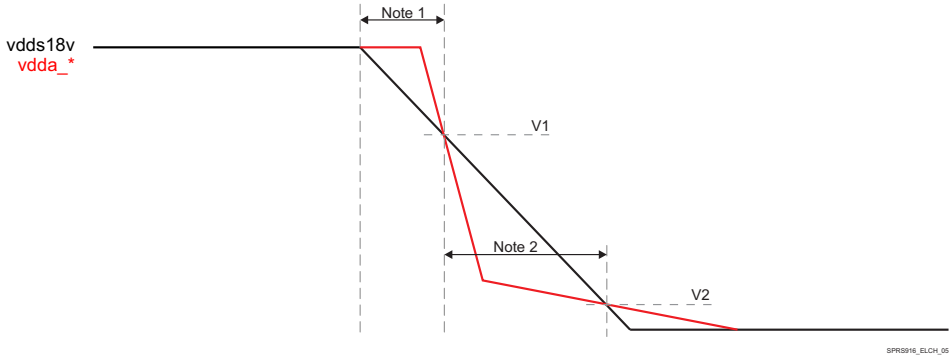


Figure 5-5. vdds18v and vdda_* Discharge Relationship(3)

(1) vdda_* can be ≥ vdds18v, until vdds18v drops below 1.62 V.

(2) vdds18v must be ≥ vdda_*, until vdds18v reaches 0.6 V.

(3) V1 = 1.62 V; V2 < 0.6 V.

Copyright © 2016–2020, Texas Instruments Incorporated

Figure 5-3 through Figure 5-6 and associated notes described the device Abrupt Power Down Sequence.

A ”loss of input power event” occurs when the system’s input power is unexpectedly removed. Normally, the recommended power-down sequence should be followed and can be accomplished within 1.5-2 ms of elapsed time. This is the typical range of elapsed time available following a loss of power event, see Section 8.3.7, *Loss of Input Power Event* for design recommendations. If sufficient elapse time is not provided, then an “abrupt” power-down sequence can be supported without impacting POH reliability if all of the following conditions are met (Figure 5-6).

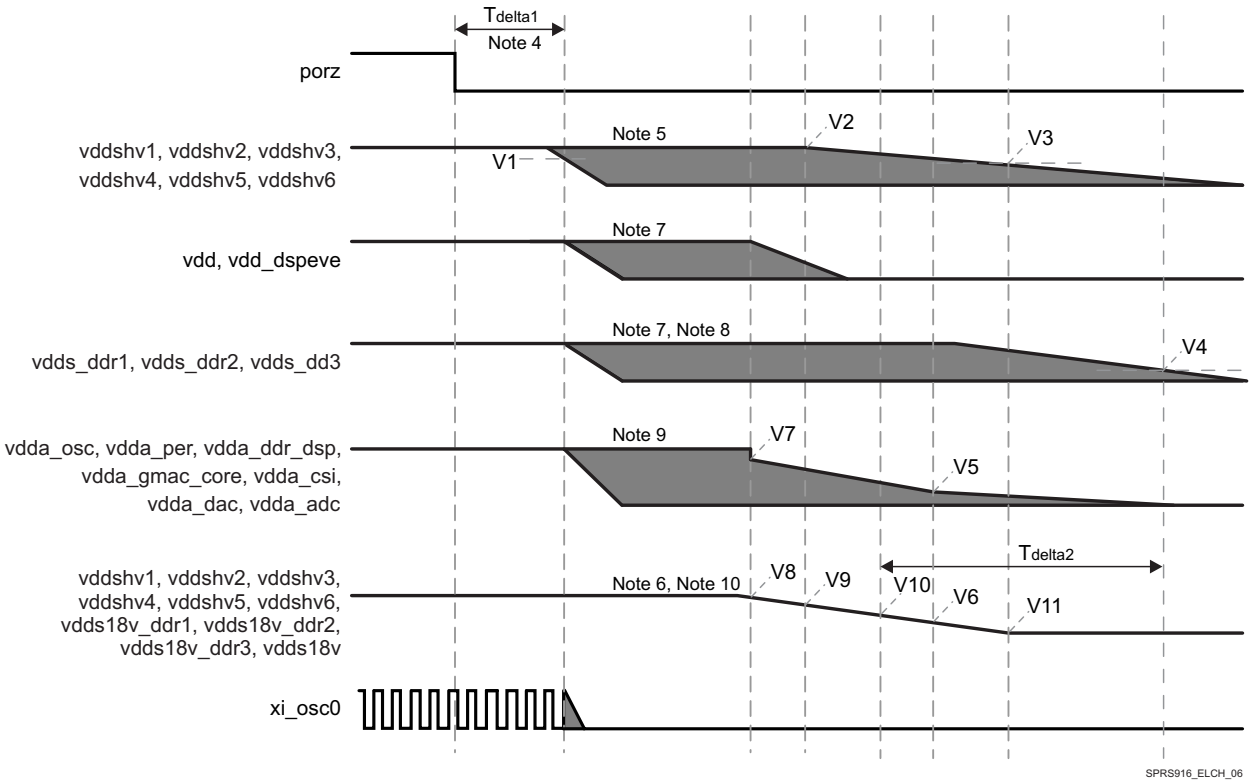


Figure 5-6. Abrupt Power-Down Sequencing(1)

(1) V1 = 2.7 V; V2 = 3.3 V; V3 = 2.0 V; V4 = V5 = V6 = 0.6 V; V7 = V8 = 1.62 V; V9 = 1.3 V; V10 = 1.0 V; V11 = 0.0 V; T_{delta1} > 100 µs; T_{delta2} < 10 ms.

(2) Terminology:
- $V_{OPR\ MIN}$ = Minimum Operational Voltage level that ensures device functionality and specified performance in , *Recommended Operating Conditions*.
- V_{OFF} = OFF Voltage level is defined to be less than 0.6 V, where any current draw has no impact to POH.
- Ramp Down = transition time from $V_{OPR\ MIN}$ to V_{OFF} and is slew rate independent.

(3) General timing diagram items:
- Grey shaded areas show valid transition times for supplies between $V_{OPR\ MIN}$ and V_{OFF}.
- Dashed vertical lines show approximate elapse times based upon TI recommended PMIC power-down sequencer circuit performance.

(4) porz must be asserted low for 100 µs min to ensure SoC is set to a safe functional state before any voltage begins to ramp down.

(5) vddshv[1-6] domains supplied by 3.3 V:
- must remain greater than 2.7 V to enable Dual Voltage GPIO selector circuit operation for 100µs min, after porz is asserted low.
- must not exceed vdds18v voltage level by more than 2V during ramp down, until vdds18v drops below V_{OFF} (0.6 V).

(6) vddshv[1-6] domains supplied by 1.8 V must ramp down concurrently with vdds18v and be sourced from common vdds18v supply.

(7) vdd_dspeve, vdd, vdds_ddr[1-3], vdda_* domains can all start to ramp down in any order after 100 µs low assertion of porz.

(8) vdds_ddr* domains:
- can remain at $V_{OPR\ MIN}$ or a level greater than vdds18v during ramp down.
- elapsed time from vdds18v dropping below 1.0 V to vdds_ddr[1-3] dropping below 0.6 V must not exceed 10 ms.

(9) vdda_* domains:

Copyright © 2016–2020, Texas Instruments Incorporated

- can start to ramp down before or concurrently with vdds18v.
- must not exceed vdds18v voltage level after vdds18v drops below 1.62 V until vdds18v drops below V_{OFF} (0.6 V).

(10) vdds18v domain should maintain a minimum level of 1.62 V (V_{NOM} – 10%) until vdd_dspeve and vdd start to ramp down.

Copyright © 2016–2020, Texas Instruments Incorporated

6 Clock Specifications

NOTE

For more information, see Power, Reset, and Clock Management / PRCM Subsystem Environment / External Clock Signals and Clock Management Functional Description section of the Device TRM.

NOTE

Audio Back End (ABE) module is not supported for this family of devices, but “ABE” name is still present in some clock or DPLL names.

The device operation requires the following clocks:

- The system clocks, SYS_CLK1 (Mandatory) and SYS_CLK2 (Optional) are the main clock sources of the device. They supply the reference clock to the DPLLs as well as functional clock to several modules.

Figure 6-1 shows the external input clock sources and the output clocks to peripherals.

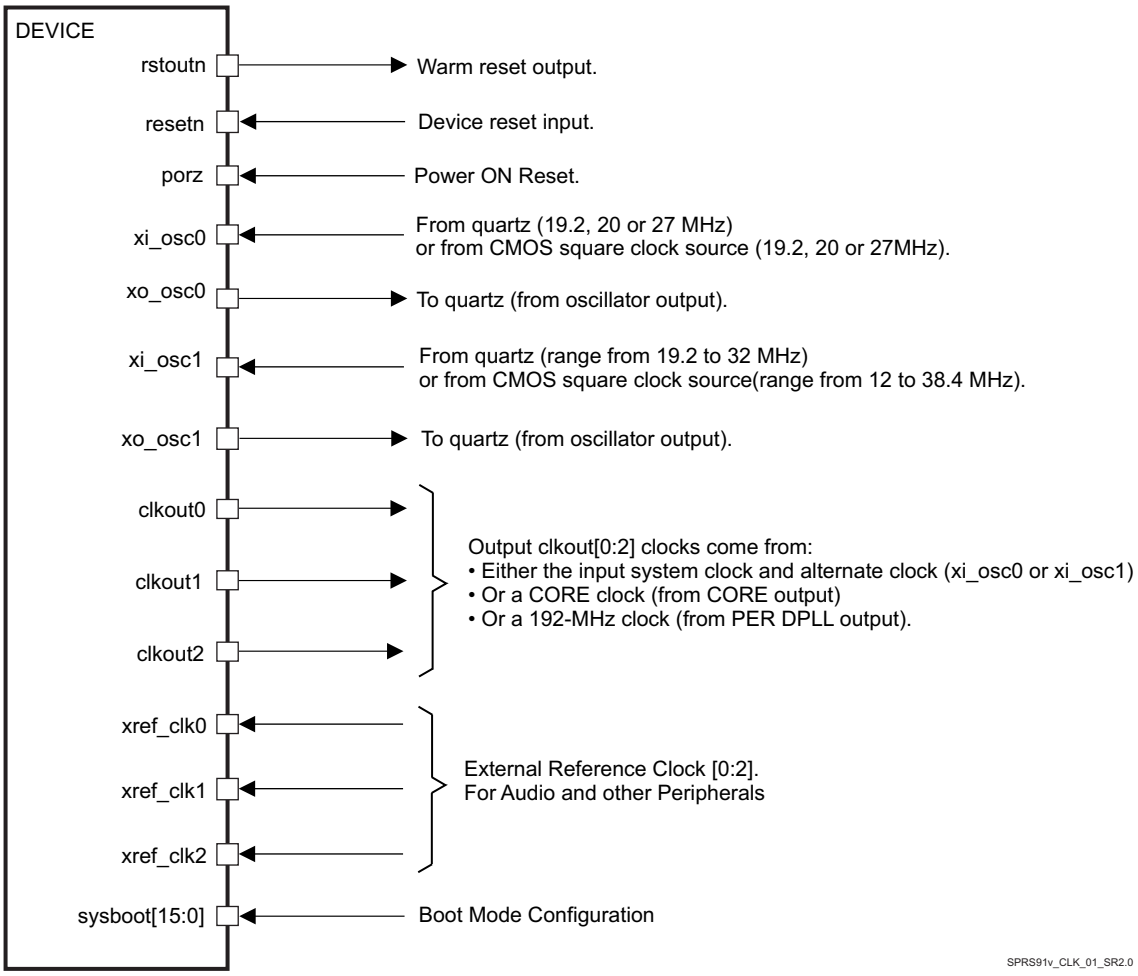


Figure 6-1. Clock Interface

6.1 Input Clock Specifications

6.1.1 Input Clock Requirements

- The source of the internal system clock (SYS_CLK1) could be either:
  - A CMOS clock that enters on the xi_osc0 ball (with xo_osc0 left unconnected on the CMOS clock case).
  - A crystal oscillator clock managed by xi_osc0 and xo_osc0.
- The source of the internal system clock (SYS_CLK2) could be either:
  - A CMOS clock that enters on the xi_osc1 ball (with xo_osc1 left unconnected on the CMOS clock case).
  - A crystal oscillator clock managed by xi_osc1 and xo_osc1.

6.1.2 System Oscillator OSC0 Input Clock

SYS_CLK1 is received directly from oscillator OSC0. For more information about SYS_CLK1, see the *Power, Reset, and Clock Management* section in the device TRM.

6.1.2.1 OSC0 External Crystal

An external crystal is connected to the device pins. Figure 6-2 describes the crystal implementation.

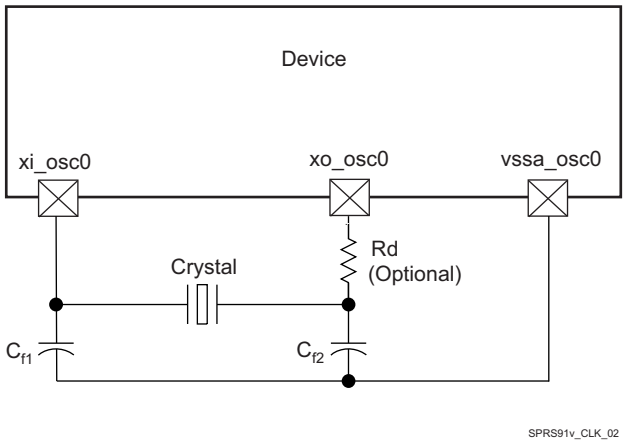


Figure 6-2. Crystal Implementation

NOTE

The load capacitors, C_{f1} and C_{f2} in Figure 6-2, should be chosen such that the below equation is satisfied. C_L in the equation is the load specified by the crystal manufacturer. All discrete components used to implement the oscillator circuit should be placed as close as possible to the associated oscillator xi_osc0, xo_osc0, and vssa_osc0 pins.

$$C_L = \frac{C_{f1} C_{f2}}{(C_{f1} + C_{f2})}$$

Figure 6-3. Load Capacitance Equation

The crystal must be in the fundamental mode of operation and parallel resonant. Table 6-1 summarizes the required electrical constraints.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 6-1. OSC0 Crystal Electrical Characteristics

NAME	DESCRIPTION			MIN	TYP	MAX	UNIT
f_p	Parallel resonance crystal frequency				19.2, 20, 27		MHz
C_{f1}	C_{f1} load capacitance for crystal parallel resonance with $C_{f1} = C_{f2}$			12		24	pF
C_{f2}	C_{f2} load capacitance for crystal parallel resonance with $C_{f1} = C_{f2}$			12		24	pF
ESR(C_{f1},C_{f2})	Crystal ESR					100	Ω
C_O	Crystal shunt capacitance	ESR = 30 Ω ESR = 40 Ω	19.2 MHz, 20 MHz, 27 MHz			7	pF
		ESR = 50 Ω	19.2 MHz, 20 MHz			7	pF
			27 MHz			5	pF
		ESR = 60 Ω	19.2 MHz, 20 MHz			7	pF
			27 MHz		Not Supported		-
		ESR = 80 Ω	19.2 MHz, 20 MHz			5	pF
			27 MHz		Not Supported		-
		ESR = 100 Ω	19.2 MHz, 20 MHz			3	pF
			27 MHz		Not Supported		-
L_M	Crystal motional inductance for f_p = 20 MHz				10.16		mH
C_M	Crystal motional capacitance				3.42		fF
$t_{j(xiosc0)}$	Frequency accuracy(1), xi_osc0		Ethernet not used			±200	ppm
			Ethernet RGMII using derived clock			±50	ppm

(1) Crystal characteristics should account for tolerance+stability+aging.

When selecting a crystal, the system design must take into account the temperature and aging characteristics of a crystal versus the user environment and expected lifetime of the system.

Table 6-2 details the switching characteristics of the oscillator and the requirements of the input clock.

Table 6-2. Oscillator Switching Characteristics-Crystal Mode

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
f_p	Oscillation frequency		19.2, 20, 27 MHz		MHz
t_{sX}	Start-up time			4	ms

6.1.2.2 OSC0 Input Clock

A 1.8-V LVCMOS-compatible clock input can be used instead of the internal oscillator to provide the SYS_CLK1 clock input to the system. The external connections to support this are shown in Figure 6-4. The xi_osc0 pin is connected to the 1.8-V LVCMOS-compatible clock source. The xi_osc0 pin is left unconnected. The vssa_osc0 pin is connected to board ground (vss).

Copyright © 2016–2020, Texas Instruments Incorporated

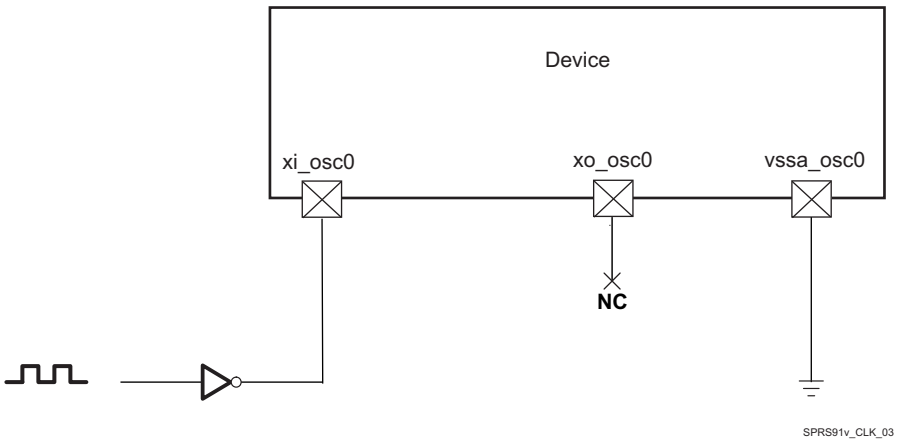


Figure 6-4. 1.8-V LVCMOS-Compatible Clock Input

Table 6-3 summarizes the OSC0 input clock electrical characteristics.

Table 6-3. OSC0 Input Clock Electrical Characteristics-Bypass Mode

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
f	Frequency		19.2, 20, 27		MHz
C_{IN}	Input capacitance	2.184	2.384	2.584	pF
I_{IN}	Input current (3.3V mode)	4	6	10	µA

Table 6-4 details the OSC0 input clock timing requirements.

Table 6-4. OSC0 Input Clock Timing Requirements

NAME	DESCRIPTION			MIN	TYP	MAX	UNIT
CK0	1 / $t_{c(xiosc0)}$	Frequency, xi_osc0		19.2, 20, 27			MHz
CK1	$t_{w(xiosc0)}$	Pulse duration, xi_osc0 low or high		0.45 × $t_{c(xiosc0)}$		0.55 × $t_{c(xiosc0)}$	ns
	$t_{j(xiosc0)}$	Period jitter(1), xi_osc0				0.01 × $t_{c(xiosc0)}$	ns
	$t_{R(xiosc0)}$	Rise time, xi_osc0				5	ns
	$t_{F(xiosc0)}$	Fall time, xi_osc0				5	ns
	$t_{j(xiosc0)}$	Frequency accuracy(2), xi_osc0	Ethernet not used			±200	ppm
			Ethernet RGMII using derived clock			±50	ppm

(1) Period jitter is meant here as follows:

– The maximum value is the difference between the longest measured clock period and the expected clock period

– The minimum value is the difference between the shortest measured clock period and the expected clock period

(2) Crystal characteristics should account for tolerance+stability+aging.

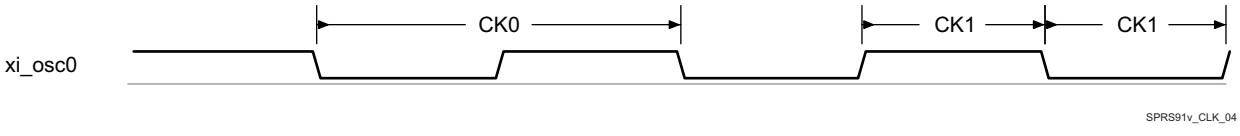


Figure 6-5. xi_osc0 Input Clock

6.1.3 *Auxiliary Oscillator OSC1 Input Clock*

SYS_CLK2 is received directly from oscillator OSC1. For more information about SYS_CLK2, see the *Power, Reset, and Clock Management* section in the device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

6.1.3.1 OSC1 External Crystal

An external crystal is connected to the device pins. Figure 6-6 describes the crystal implementation.

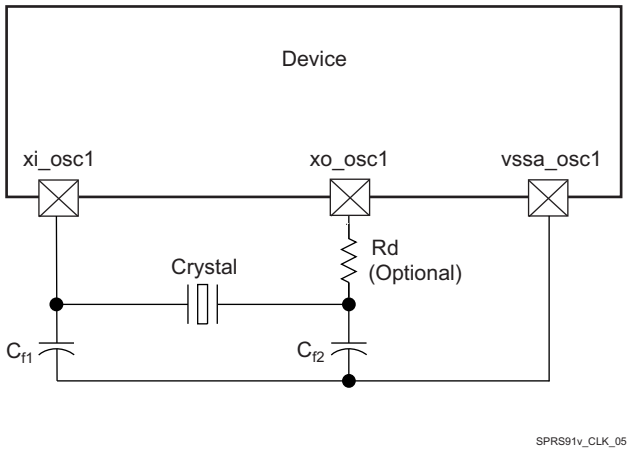


Figure 6-6. Crystal Implementation

NOTE

The load capacitors, C_{f1} and C_{f2} in Figure 6-6, should be chosen such that the below equation is satisfied. C_L in the equation is the load specified by the crystal manufacturer. All discrete components used to implement the oscillator circuit should be placed as close as possible to the associated oscillator xi_osc1, xo_osc1, and vssa_osc1 pins.

$$C_L = \frac{C_{f1} C_{f2}}{(C_{f1} + C_{f2})}$$

Figure 6-7. Load Capacitance Equation

The crystal must be in the fundamental mode of operation and parallel resonant. Table 6-5 summarizes the required electrical constraints.

Table 6-5. OSC1 Crystal Electrical Characteristics

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
f_p	Parallel resonance crystal frequency	Range from 19.2 to 32			MHz
C_{f1}	C_{f1} load capacitance for crystal parallel resonance with $C_{f1} = C_{f2}$	12		24	pF
C_{f2}	C_{f2} load capacitance for crystal parallel resonance with $C_{f1} = C_{f2}$	12		24	pF
ESR(C_{f1},C_{f2})	Crystal ESR			100	Ω

Copyright © 2016–2020, Texas Instruments Incorporated

Table 6-5. OSC1 Crystal Electrical Characteristics (continued)

NAME	DESCRIPTION			MIN	TYP	MAX	UNIT
C_O	Crystal shunt capacitance	ESR = 30 Ω	19.2 MHz ≤ f_p ≤ 32 MHz			7	pF
		ESR = 40 Ω	19.2 MHz ≤ f_p ≤ 32 MHz			5	pF
		ESR = 50 Ω	19.2 MHz ≤ f_p ≤ 25 MHz			7	pF
			25 MHz < f_p ≤ 27 MHz			5	pF
			27 MHz < f_p ≤ 32 MHz	Not Supported			-
		ESR = 60 Ω	19.2 MHz ≤ f_p ≤ 23 MHz			7	pF
			23 MHz < f_p ≤ 25 MHz			5	pF
			25 MHz < f_p ≤ 32 MHz	Not Supported			-
		ESR = 80 Ω	19.2 MHz ≤ f_p ≤ 23 MHz			5	pF
			23 MHz < f_p ≤ 25 MHz			3	pF
			25 MHz < f_p ≤ 32 MHz	Not Supported			-
		ESR = 100 Ω	19.2 MHz ≤ f_p ≤ 20 MHz			3	pF
			20 MHz < f_p ≤ 32 MHz	Not Supported			-
L_M	Crystal motional inductance for f_p = 20 MHz				10.16		mH
C_M	Crystal motional capacitance				3.42		fF
$t_{j(xiosc0)}$	Frequency accuracy(1), xi_osc1		Ethernet not used			±200	ppm
			Ethernet RGMII using derived clock			±50	ppm

(1) Crystal characteristics should account for tolerance+stability+aging.

When selecting a crystal, the system design must take into account the temperature and aging characteristics of a crystal versus the user environment and expected lifetime of the system.

Table 6-6 details the switching characteristics of the oscillator and the requirements of the input clock.

Table 6-6. Oscillator Switching Characteristics-Crystal Mode

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
f_p	Oscillation frequency	Range from 19.2 to 32			MHz
t_{sx}	Start-up time			4	ms

6.1.3.2 OSC1 Input Clock

A 1.8-V LVCMOS-compatible clock input can be used instead of the internal oscillator to provide the SYS_CLK2 clock input to the system. The external connections to support this are shown in, Figure 6-8. The xi_osc1 pin is connected to the 1.8-V LVCMOS-compatible clock sources. The xo_osc1 pin is left unconnected. The vssa_osc1 pin is connected to board ground (VSS).

Copyright © 2016–2020, Texas Instruments Incorporated

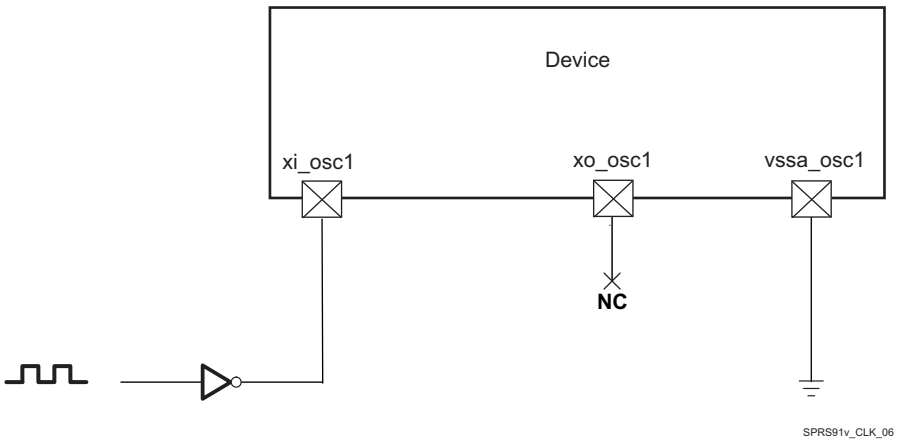


Figure 6-8. 1.8-V LVCMOS-Compatible Clock Input

Table 6-7 summarizes the OSC1 input clock electrical characteristics.

Table 6-7. OSC1 Input Clock Electrical Characteristics—Bypass Mode

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
f	Frequency	Range from 12 to 38.4			MHz
C_{IN}	Input capacitance	2.819	3.019	3.219	pF
I_{IN}	Input current (3.3V mode)	4	6	10	µA
t_{SX}	Start-up time(1)	See(2)			ms

(1) To switch from bypass mode to crystal or from crystal mode to bypass mode, there is a waiting time about 100 µs; however, if the chip comes from bypass mode to crystal mode the crystal will start-up after time mentioned in Table 6-6, t_{SX} parameter.

(2) Before the processor boots up and the oscillator is set to bypass mode, there is a waiting time when the internal oscillator is in application mode and receives a wave. The switching time in this case is about 100 µs.

Table 6-8 details the OSC1 input clock timing requirements.

Table 6-8. OSC1 Input Clock Timing Requirements

NAME	DESCRIPTION			MIN	TYP	MAX	UNIT
CK0	$1 / t_{c(xiosc1)}$	Frequency, xi_osc1		Range from 12 to 38.4			MHz
CK1	$t_{w(xiosc1)}$	Pulse duration, xi_osc1 low or high		0.45 × $t_{c(xiosc1)}$		0.55 × $t_{c(xiosc1)}$	ns
	$t_{j(xiosc1)}$	Period jitter(1), xi_osc1				0.01 × $t_{c(xiosc1)}$(3)	ns
	$t_{R(xiosc1)}$	Rise time, xi_osc1				5	ns
	$t_{F(xiosc1)}$	Fall time, xi_osc1				5	ns
	$t_{j(xiosc1)}$	Frequency accuracy(2), xi_osc1	Ethernet not used			±200	ppm
			Ethernet RGMII using derived clock			±50	ppm

(1) Period jitter is meant here as follows:

– The maximum value is the difference between the longest measured clock period and the expected clock period

– The minimum value is the difference between the shortest measured clock period and the expected clock period

(2) Crystal characteristics should account for tolerance+stability+aging.

(3) The Period jitter requirement for osc1 can be relaxed to 0.02*$t_{c(xiosc1)}$ under the following constraints:
a. The osc1/SYS_CLK2 clock bypasses all device PLLs
b. The osc1/SYS_CLK2 clock is only used to source the DSS pixel clock outputs

Copyright © 2016–2020, Texas Instruments Incorporated

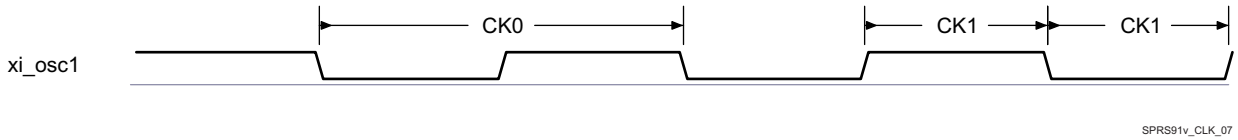


Figure 6-9. xi_osc1 Input Clock

6.1.4 RC On-die Oscillator Clock

RCOSC_32K_CLK is received directly through a network of resistor and capacitor (an RC network) inside of the SoC. This RC oscillator do not have good frequency stability. The Frequency range is described in Table 6-9, which depends on the temperature. For more information about RCOSC_32K_CLK see the Device TRM, Chapter: *Power, Reset, and Clock Management*.

Table 6-9. RC On-die Oscillator Clock Frequency Range

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
RCOSC_32K_CLK	Internal RC Oscillator	Range from 28 to 42			kHz

6.2 DPLLs, DLLs Specifications

NOTE

For more information, see:

- Power, Reset, and Clock Management / Clock Management Functional Description / Internal Clock Sources / Generators / Generic DPLL Overview Section

  and

- Display Subsystem / Display Subsystem Overview section of the Device TRM.

To generate high-frequency clocks, the device supports multiple on-chip DPLLs controlled directly by the PRCM module.

- They have their own independent power domain (each one embeds its own switch and can be controlled as an independent functional power domain)
- They are fed with ALWAYS ON system clock, with independent control per DPLL.

The different DPLLs managed by the PRCM are listed below:

- DPLL_CORE: It supplies all interface clocks and also few module functional clocks.
- DPLL_PER: It supplies several clock sources: a 192-MHz clock for the display functional clock , a 96-MHz functional clock to subsystems and peripherals.
- DPLL_GMAC_DSP: It supplies RGMII, EVE1 and DSP0 module functional clocks.
- DPLL_EVE_VID_DSP: It provides a few module functional clocks (EVE_GFCLK, VID_PIX_CLK and DSP1_CLK).
- DPLL_DDR: It generates clocks for the one External Memory Interface (EMIF) controller and its associated EMIF PHYs.

NOTE

The following DPLLs are controlled by the clock manager located in the always-on Core power domain (CM_CORE_AON):

- DPLL_CORE, DPLL_DDR, DPLL_GMAC_DSP, DPLL_PER, DPLL_EVE_VID_DSP.

For more information on CM_CORE_AON and CM_CORE or PRCM DPLLs, see the Power, Reset, and Clock Management (PRCM) chapter of the Device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

6.2.1 DPLL Characteristics

The DPLL has three relevant input clocks. One of them is the reference clock (CLKINP) used to generated the synthesized clock but can also be used as the bypass clock whenever the DPLL enters a bypass mode. It is therefore mandatory. The second one is a fast bypass clock (CLKINPULOW) used when selected as the bypass clock and is optional. The third clock (CLKINPHIF) is explained in the next paragraph.

The DPLL has three output clocks (namely CLKOUT, CLKOUTX2, and CLKOUTHIF). CLKOUT and CLKOUTX2 run at the bypass frequency whenever the DPLL enters a bypass mode. Both of them are generated from the lock frequency divided by a post-divider (namely M2 post-divider). The third clock, CLKOUTHIF, has no automatic bypass capability. It is an output of a post-divider (M3 post-divider) with the input clock selectable between the internal lock clock (Fdpll) and CLKINPHIF input of the PLL through an asynchronous multplexing.

For more information, see the Power, Reset, and Clock Management chapter of the Device TRM.

Table 6-10 summarizes DPLL type described in Section 6.2, *DPLLs, DLLs Specifications*.

Table 6-10. DPLL Control

DPLL NAME	CONTROLLED BY PRCM
DPLL_CORE	Yes(1)
DPLL_EVE_VID_DSP	Yes(1)
DPLL_GMAC_DSP	Yes(1)
DPLL_PER	Yes(1)
DPLL_DDR	Yes(1)

(1) DPLL is in the always-on domain.

Table 6-11 and summarize the DPLL characteristics and assume testing over recommended operating conditions.

Table 6-11. DPLL Characteristics

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT	COMMENTS
f_{input}	CLKINP input frequency	0.032		52	MHz	F_{INP}
$f_{internal}$	Internal reference frequency	0.15		52	MHz	REFCLK
$f_{CLKINPHIF}$	CLKINPHIF input frequency	10		1400	MHz	F_{INPHIF}
$f_{CLKINPULOW}$	CLKINPULOW input frequency	0.001		600	MHz	Bypass mode: f_{CLKOUT} = $f_{CLKINPULOW}$ / (M1 + 1) if ulowclken = 1(6)
f_{CLKOUT}	CLKOUT output frequency	20(1)		1800(2)	MHz	[M / (N + 1)] × F_{INP} × [1 / M2] (in locked condition)
$f_{CLKOUTx2}$	CLKOUTx2 output frequency	40(1)		2200(2)	MHz	2 × [M / (N + 1)] × F_{INP} × [1 / M2] (in locked condition)
$f_{CLKOUTHIF}$	CLKOUTHIF output frequency	20(3)		1400(4)	MHz	F_{INPHIF} / M3 if clkinphifsel = 1
		40(3)		2200(4)	MHz	2 × [M / (N + 1)] × F_{INP} × [1 / M3] if clkinphifsel = 0
$f_{CLKDCOLDO}$	DCOCLKLDO output frequency	40		2800	MHz	2 × [M / (N + 1)] × F_{INP} (in locked condition)
t_{lock}	Frequency lock time			6 + 350 × REFCLK	µs	
p_{lock}	Phase lock time			6 + 500 × REFCLK	µs	
$t_{relock-L}$	Relock time—Frequency lock(5) (LP relock time from bypass)			6 + 70 × REFCLK	µs	DPLL in LP relock time: lowcurrstdby = 1
$p_{relock-L}$	Relock time—Phase lock(5) (LP relock time from bypass)			6 + 120 × REFCLK	µs	DPLL in LP relock time: lowcurrstdby = 1
$t_{relock-F}$	Relock time—Frequency lock(5) (fast relock time from bypass)			3.55 + 70 × REFCLK	µs	DPLL in fast relock time: lowcurrstdby = 0
$p_{relock-F}$	Relock time—Phase lock(5) (fast relock time from bypass)			3.55 + 120 × REFCLK	µs	DPLL in fast relock time: lowcurrstdby = 0

(1) The minimum frequencies on CLKOUT and CLKOUTX2 are assuming M2 = 1.

For M2 > 1, the minimum frequency on these clocks will further scale down by factor of M2.

(2) The maximum frequencies on CLKOUT and CLKOUTX2 are assuming M2 = 1.

(3) The minimum frequency on CLKOUTHIF is assuming M3 = 1. For M3 > 1, the minimum frequency on this clock will further scale down by factor of M3.

(4) The maximum frequency on CLKOUTHIF is assuming M3 = 1.

(5) Relock time assumes typical operating conditions, 10°C maximum temperature drift.

(6) Bypass mode: f_{CLKOUT} = F_{INP} if ulowclken = 0. For more information, see the Device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

6.2.2 DLL Characteristics

Table 6-12 summarizes the DLL characteristics and assumes testing over recommended operating conditions.

Table 6-12. DLL Characteristics

NAME	DESCRIPTION	MIN	TYP	MAX	UNIT
f_{input}	Input clock frequency (EMIF_DLL_FCLK)			266	MHz
t_{lock}	Lock time			50k	cycles
t_{relock}	Relock time (a change of the DLL frequency implies that DLL must relock)			50k	cycles

6.2.2.1 DPLL and DLL Noise Isolation

NOTE

For more information on DPLL and DLL decoupling capacitor requirements, see the External Capacitors / Voltage Decoupling Capacitors / I/O and Analog Voltage Decoupling / VDDA Power Domain section.

7 Timing Requirements and Switching Characteristics

7.1 Timing Test Conditions

All timing requirements and switching characteristics are valid over the recommended operating conditions unless otherwise specified.

7.2 Interface Clock Specifications

7.2.1 Interface Clock Terminology

The interface clock is used at the system level to sequence the data and/or to control transfers accordingly with the interface protocol.

7.2.2 Interface Clock Frequency

The two interface clock characteristics are:

- The maximum clock frequency
- The maximum operating frequency

The interface clock frequency documented in this document is the maximum clock frequency, which corresponds to the maximum frequency programmable on this output clock. This frequency defines the maximum limit supported by the Device IC and does not take into account any system consideration (PCB, peripherals).

The system designer will have to consider these system considerations and the Device IC timing characteristics as well to define properly the maximum operating frequency that corresponds to the maximum frequency supported to transfer the data on this interface.

7.3 Timing Parameters and Information

The timing parameter symbols used in the timing requirement and switching characteristic tables are created in accordance with JEDEC Standard 100. To shorten the symbols, some of pin names and other related terminologies have been abbreviated as follows:

Table 7-1. Timing Parameters

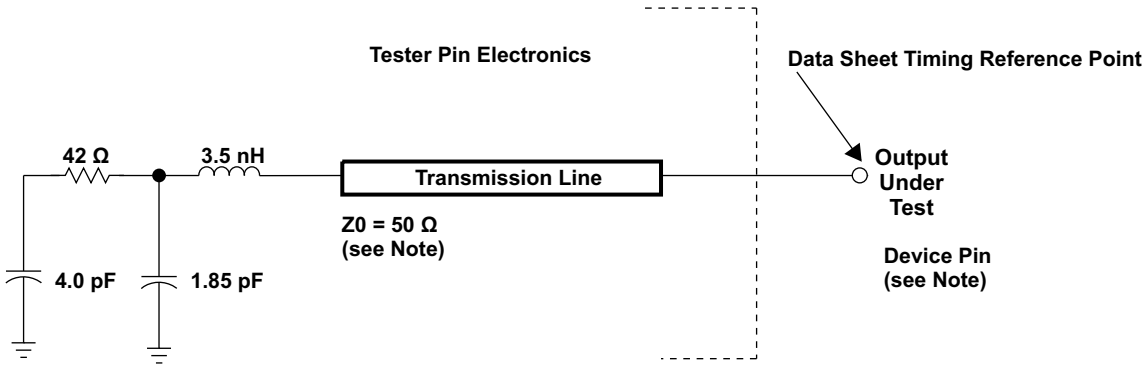
SUBSCRIPTS	
SYMBOL	**PARAMETER**
c	Cycle time (period)
d	Delay time
dis	Disable time
en	Enable time
h	Hold time
su	Setup time
START	Start bit
t	Transition time
v	Valid time
w	Pulse duration (width)
X	Unknown, changing, or don't care level
F	Fall time
H	High
L	Low
R	Rise time
V	Valid
IV	Invalid

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-1. Timing Parameters (continued)

SUBSCRIPTS	
SYMBOL	**PARAMETER**
AE	Active Edge
FE	First Edge
LE	Last Edge
Z	High impedance

7.3.1 Parameter Information



NOTE: The data sheet provides timing at the device pin. For output timing analysis, the tester pin electronics and its transmission line effects must be taken into account. A transmission line with a delay of 2 ns can be used to produce the desired transmission line effect. The transmission line is intended as a load only. It is not necessary to add or subtract the transmission line delay (2 ns) from the data sheet timings.

Input requirements in this data sheet are tested with an input slew rate of < 4 Volts per nanosecond (4 V/ns) at the device pin.

Figure 7-1. Test Load Circuit for AC Timing Measurements

The load capacitance value stated is only for characterization and measurement of AC timing signals.

This load capacitance value does not indicate the maximum load the device is capable of driving.

7.3.1.1 1.8 V and 3.3 V Signal Transition Levels

All input and output timing parameters are referenced to V_{ref} for both "0" and "1" logic levels. V_{ref} = (VDDI/O)/2.

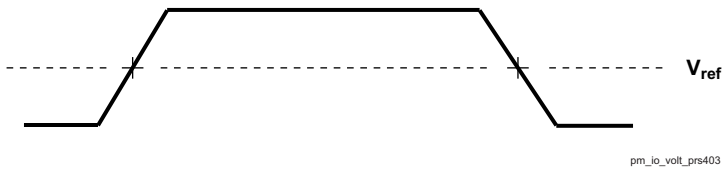


Figure 7-2. Input and Output Voltage Reference Levels for AC Timing Measurements

All rise and fall transition timing parameters are referenced to V_{IL} MAX and V_{IH} MIN for input clocks, V_{OL} MAX and V_{OH} MIN for output clocks.

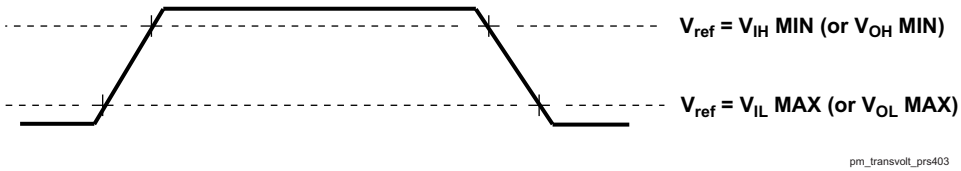


Figure 7-3. Rise and Fall Transition Time Voltage Reference Levels

7.3.1.2 1.8 V and 3.3 V Signal Transition Rates

The default SLEWCONTROL settings in each pad configuration register must be used to ensured timings, unless specific instructions otherwise are given in the individual timing subsections of the datasheet.

All timings are tested with an input edge rate of 4 volts per nanosecond (4 V/ns).

7.3.1.3 Timing Parameters and Board Routing Analysis

The timing parameter values specified in this data manual do not include delays by board routes. As a good board design practice, such delays must always be taken into account. Timing values may be adjusted by increasing/decreasing such delays. TI recommends utilizing the available I/O buffer information specification (IBIS) models to analyze the timing characteristics correctly. To properly use IBIS models to attain accurate timing analysis for a given system, see the Using IBIS Models for timing Analysis application report. If needed, external logic hardware such as buffers may be used to compensate any timing differences.

7.4 Recommended Clock and Control Signal Transition Behavior

All clocks and control signals must transition between V_{IH} and V_{IL} (or between V_{IL} and V_{IH}) in a monotonic manner. Monotonic transitions are more easily ensured with faster switching signals. Slower input transitions are more susceptible to glitches due to noise and special care should be taken for slow input clocks.

Copyright © 2016–2020, Texas Instruments Incorporated

7.5 Video Input Ports (VIP)

The device includes 1 Video Input Ports (VIP).

Table 7-2, Figure 7-4 and Figure 7-5 present timings and switching characteristics of the VIPs

Table 7-2. Timing Requirements for VIP (1)(2)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
V1	$t_{c(CLK)}$	Cycle time, vinx_clki(3)(5)		5.99 (1)		ns
V2	$t_{w(CLKH)}$	Pulse duration, vinx_clki high(3)(5)		0.45×P (2)		ns
V3	$t_{w(CLKL)}$	Pulse duration, vinx_clki low(3)(5)		0.45×P (2)		ns
V4	$t_{su(CTL/DATA-CLK)}$	Input setup time, Control (vinx_dei, vinx_vsynci, vinx_fldi, vinx_hsynci) and Data (vinx_dn) valid to vinx_clki transition (3)(4)(5)	All other IOSETs	2.52		ns
			VIN2 IOSET4	2.52		ns
			VIN2 IOSET5	3.7		ns
			VIN2 IOSET6	4.2		ns
V5	$t_{h(CLK-CTL/DATA)}$	Input hold time, Control (vinx_dei, vinx_vsynci, vinx_fldi, vinx_hsynci) and Data (vinx_dn) valid from vinx_clki transition(3)(4)(5)	All other IOSETs	-0.05		ns
			VIN2 IOSET4	3		ns
			VIN2 IOSET5	1		ns
			VIN2 IOSET6	1		ns

(1) For maximum frequency of 165 MHz.

(2) P = vinx_clki period.

(3) x in vinx = 1a, 1b, 2a and 2b.

(4) n in dn = 0 to 7 when x = 1b, 2b;
n = 0 to 23 when x = 1a and 2a;

(5) i in clki, dei, vsynci, hsynci and fldi = 0 or 1.

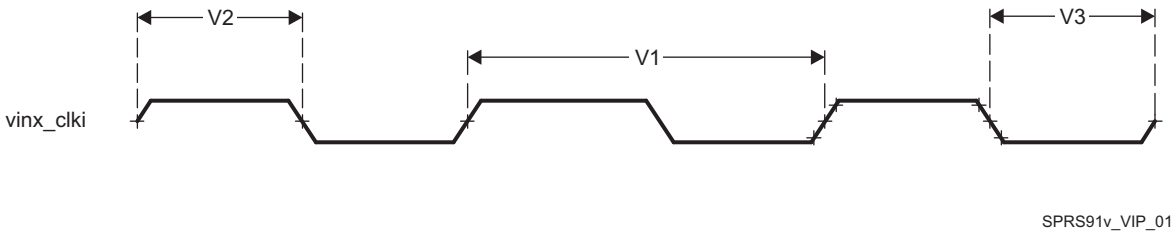


Figure 7-4. Video Input Ports Clock Signal

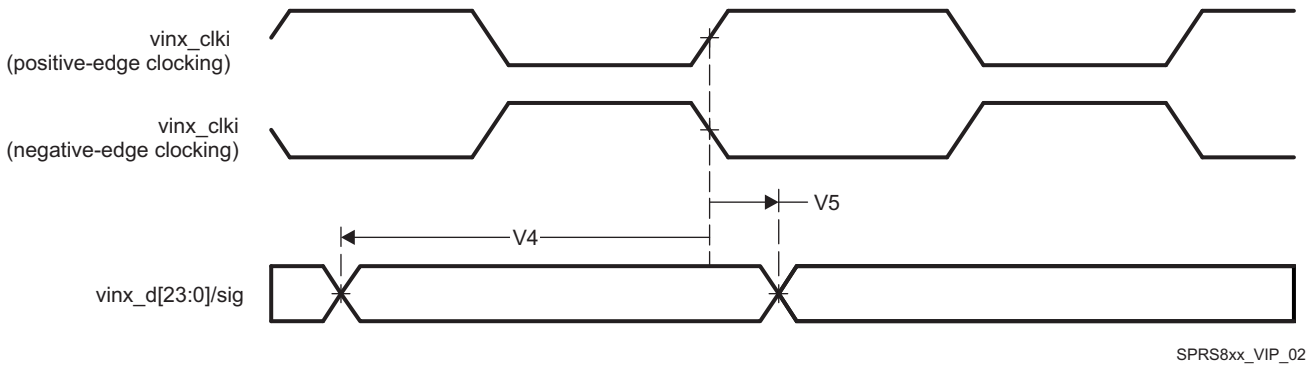


Figure 7-5. Video Input Ports Timings

CAUTION

The IO timings provided in this section are only valid for VIN1 and VIN2 if signals within a single IOSET are used. The IOSETs are defined in Table 7-3 and Table 7-4.

In Table 7-3 and Table 7-4 are presented the specific groupings of signals (IOSET) for use with vin1a, vin1b, vin2a and vin2b.

Table 7-3. VIN1 IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3		IOSET4	
	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX
vin1a								
vin1a_clk0	F22	0	F22	0	F22	0	F22	0
vin1a_de0	F21	0	F21	0	F21	0	F19	2
vin1a_fld0	F20	0	F20	0	F20	0	F20	0
vin1a_hsync0	F19	0	F19	0	F19	0	F19	0
vin1a_vsync0	G19	0	G19	0	G19	0	G19	0
vin1a_d0	G18	0	G18	0	G18	0	G18	0
vin1a_d1	G21	0	G21	0	G21	0	G21	0
vin1a_d2	G22	0	G22	0	G22	0	G22	0
vin1a_d3	H18	0	H18	0	H18	0	H18	0
vin1a_d4	H20	0	H20	0	H20	0	H20	0
vin1a_d5	H19	0	H19	0	H19	0	H19	0
vin1a_d6	H22	0	H22	0	H22	0	H22	0
vin1a_d7	H21	0	H21	0	H21	0	H21	0
vin1a_d8	J17	0			J17	0		
vin1a_d9	K22	0			K22	0		
vin1a_d10	K21	0			K21	0		
vin1a_d11	K18	0			K18	0		
vin1a_d12	K17	0			AB17	2		
vin1a_d13	K19	0			U17	2		
vin1a_d14	K20	0			W17	2		
vin1a_d15	L21	0			AA17	2		
vin1b								
vin1b_clk1							F21	2
vin1b_hsync1							W7	7
vin1b_vsync1							W6	7
vin1b_d0							J17	2
vin1b_d1							K22	2
vin1b_d2							K21	2
vin1b_d3							K18	2
vin1b_d4							K17	2
vin1b_d5							K19	2
vin1b_d6							K20	2
vin1b_d7							L21	2
vin1b_de1							W7	8

Copyright © 2016–2020, Texas Instruments Incorporated

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-4. VIN2 IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3		IOSET4		IOSET5		IOSET6	
	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX
vin2a												
vin2a_clk0	L22	0	AB17	9	L22	0	L22	0	L22	0	W15	9
vin2a_de0	M17	0	AA17	9			AA15	9	W7	1	AA17	9
vin2a_fld0	M18	0	U16	9			AB15	9	AB15	9	U16	9
vin2a_hsync0			W7	2	F14	9	F15	9	F15	9	W7	2
vin2a_vsync0	W6	2	W6	2	C14	9	F16	9	F16	9	W6	2
vin2a_d0	AA14	2	AA14	2	AA14	2	AA14	2	AA14	2	AA14	2
vin2a_d1	AB14	2	AB14	2	AB14	2	AB14	2	AB14	2	AB14	2
vin2a_d2	U13	2	U13	2	U13	2	U13	2	U13	2	U13	2
vin2a_d3	V13	2	V13	2	V13	2	V13	2	V13	2	V13	2
vin2a_d4	Y13	2	Y13	2	Y13	2	Y13	2	Y13	2	Y13	2
vin2a_d5	W13	2	W13	2	W13	2	W13	2	W13	2	W13	2
vin2a_d6	U11	2	U11	2	U11	2	U11	2	U11	2	U11	2
vin2a_d7	V11	2	V11	2	V11	2	V11	2	V11	2	V11	2
vin2a_d8			U9	2							U9	2
vin2a_d9			W11	2							W11	2
vin2a_d10			V9	2							V9	2
vin2a_d11			W9	2							W9	2
vin2a_d12			U8	2							U8	2
vin2a_d13			W8	2							W8	2
vin2a_d14			U7	2							U7	2
vin2a_d15			V7	2							V7	2
vin2b												
vin2b_clk1					F20	2						
vin2b_hsync1					M17	2						
vin2b_vsync1					M18	2						
vin2b_d0					U9	5						
vin2b_d1					W11	5						
vin2b_d2					V9	5						
vin2b_d3					W9	5						
vin2b_d4					U8	5						
vin2b_d5					W8	5						

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-4. VIN2 IOSETs (continued)

SIGNALS	IOSET1		IOSET2		IOSET3		IOSET4		IOSET5		IOSET6	
	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX
vin2b_d6					U7	5						
vin2b_d7					V7	5						

7.6 Display Subsystem – Video Output Ports

Display Parallel interfaces(DPI) channels are available in DSS named DPI Video Output 1.

Every VOUT interface consists of:

- 24-bit data bus (data[23:0])
- Horizontal synchronization signal (HSYNC)
- Vertical synchronization signal (VSYNC)
- Data enable (DE)
- Field ID (FID)
- Pixel clock (CLK)

NOTE

For more information, see the Display Subsystem section of the Device TRM.

CAUTION

All pads/balls configured as vouti_* signals must be programmed to use slow slew rate by setting the corresponding CTRL_CORE_PAD_*[SLEWCONTROL] register field to SLOW (0b1).

Table 7-5 and Figure 7-6 assume testing over the recommended operating conditions and electrical characteristic conditions.

Table 7-5. DPI Video Output 1 Switching Characteristics (1)(2)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
D1	$t_{c(clk)}$	Cycle time, output pixel clock vouti_clk		6.73		ns
D2	$t_{w(clkL)}$	Pulse duration, output pixel clock vouti_clk low		P×0.5-1		ns
D3	$t_{w(clkH)}$	Pulse duration, output pixel clock vouti_clk high		P×0.5-1		ns
D5	$t_{d(clk-ctlV)}$	Delay time, output pixel clock vouti_clk transition to output data vouti_d[23:0] valid	DPI1	-1.33	1.01	ns
D6	$t_{d(clk-dV)}$	Delay time, output pixel clock vouti_clk transition to output control signals vouti_vsync, vouti_hsync, vouti_de, and vouti_fld valid	DPI1	-1.33	1.01	ns

Copyright © 2016–2020, Texas Instruments Incorporated

(1) P = output vout1_clk period in ns.

(2) All pads/balls configured as vouti_* signals must be programmed to use slow slew rate by setting the corresponding CTRL_CORE_PAD_*[SLEWCONTROL] register field to SLOW (0b1).

(3) SERDES transceivers may be sensitive to the jitter profile of vouti_clk. See Application Note **SPRAC62** for additional guidance.

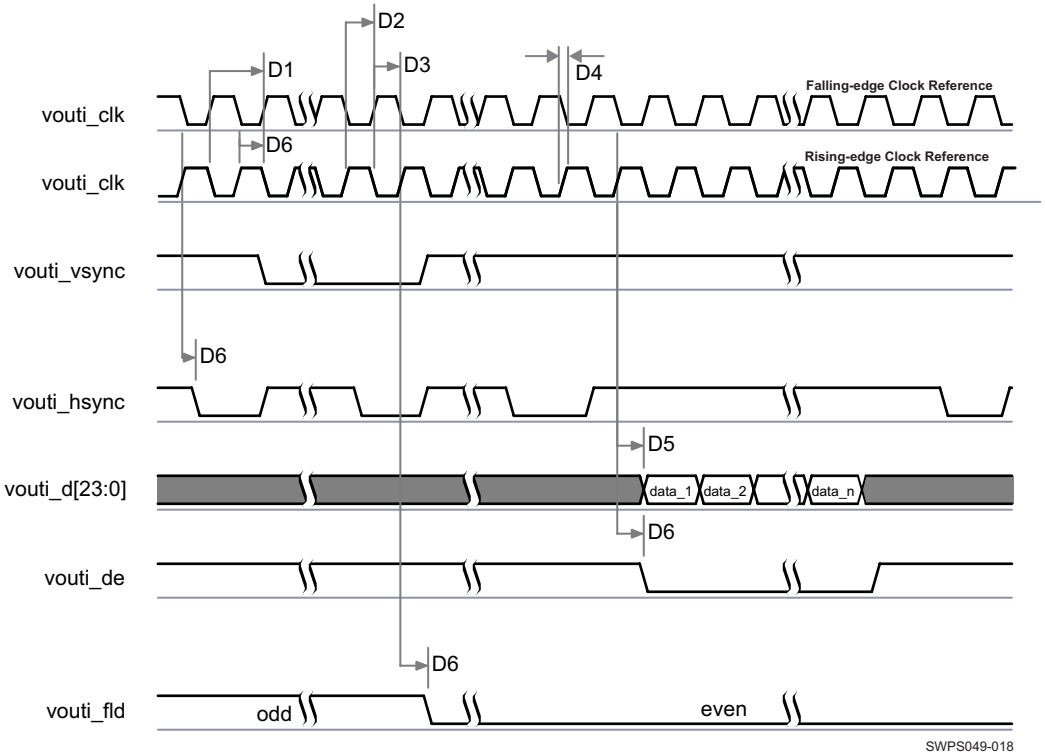


Figure 7-6. DPI Video Output (1)(2)(3)

(1) The configuration of assertion of the data can be programmed on the falling or rising edge of the pixel clock.

(2) The polarity and the pulse width of vout1_hsync and vout1_vsync are programmable, refer to the DSS section of the device TRM.

(3) The vout1_clk frequency can be configured, refer to the DSS section of the device TRM.

7.7 Imaging Subsystem (ISS)

NOTE

For more information, see the Imaging Subsystem chapter of the device TRM.

The imaging subsystem (ISS) deals with the processing of the pixel data coming from an external image sensor or data from memory (image format encoding and decoding can be done to and from memory). With its subparts, such as interfaces and interconnects, image signal processor (ISP), and still image coprocessor (SIMCOP), the ISS is a key component for the following use cases:

- Rear View Camera
- Front View Stereo Camera
- Surround View Camera

The ISS is mainly composed of CAL_A, CAL_B, LVDS-RX camera interfaces, a parallel interface (CPI), an ISP, and a block-based imaging accelerator (SIMCOP).

- The Camera Adapter Layer (CAL_A) supports MIPI® CSI2 protocol with four data lanes. The CAL_A is targeted as sensor capture interface and write DMA, while CAL_B is targeted as read DMA engine and does not support sensor capture.
- The LVDS receiver (LVDS-RX) support Sony / Aptina / Omnivision / Panasonic / AltaSens serial interfaces.
- The parallel interface (CPI) supports up to 16 data lanes.

All interfaces can use the image signal processor (ISP), but not concurrently. When one interface uses the ISP, the other must send data to memory. However, the ISP can still be used to process this data in memory-to-memory. Time multiplex processing is also possible.

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-6.

In Table 7-6 are presented the specific groupings of signals (IOSET) for use with ISS.

Table 7-6. Camera Parallel Interface (CPI) IOSETs

SIGNALS	IOSET1		IOSET2	
	BALL	MUX	BALL	MUX
cpi_pclk	F22	1	F22	1
cpi_data0	F19	1	F19	1
cpi_data1	G19	1	G19	1
cpi_data2	G18	1	G18	1
cpi_data3	G21	1	G21	1
cpi_data4	G22	1	G22	1
cpi_data5	H18	1	H18	1
cpi_data6	H20	1	H20	1
cpi_data7	H19	1	H19	1
cpi_data8	H22	1	H22	1
cpi_data9	H21	1	H21	1
cpi_data10	J17	1	J17	1
cpi_data11	K22	1	K22	1
cpi_data12	K21	1	K21	1

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-6. Camera Parallel Interface (CPI) IOSETs (continued)

SIGNALS	IOSET1		IOSET2	
	BALL	MUX	BALL	MUX
cpi_data13	K18	1	K18	1
cpi_data14	K17	1	K17	1
cpi_data15			L21	1
cpi_wen	K19	1	K19	1
cpi_fid	K20	1	K20	1
cpi_hsync	F21	1	F21	1
cpi_vsync	F20	1	F20	1
cam_nreset			W6	1
cam_strobe	B18	3	M17	1
cam_shutter	C18	3	M18	1

For more information, please contact your local TI representative.

7.8 External Memory Interface (EMIF)

The device has a dedicated interface to DDR3 and DDR3L SDRAM. It supports JEDEC standard compliant DDR3 and DDR3L SDRAM devices with the following features:

- 16-bit or 32-bit data path to external SDRAM memory
- Memory device capacity: 128Mb, 256Mb, 512Mb, 1Gb, 2Gb, 4Gb and 8Gb devices (Single die only)
- One interface with associated DDR3/DDR3L PHYs

NOTE

For more information, see the EMIF Controller section of the Device TRM.

7.9 General-Purpose Memory Controller (GPMC)

The GPMC is the unified memory controller that interfaces external memory devices such as:

- Asynchronous SRAM-like memories and ASIC devices
- Asynchronous page mode and synchronous burst NOR flash
- NAND flash

NOTE

For more information, see the General-Purpose Memory Controller section of the Device TRM.

7.9.1 GPMC/NOR Flash Interface Synchronous Timing

Table 7-7 through Table 7-10 assume testing over the recommended operating conditions and electrical characteristic conditions below (see Figure 7-7 through Figure 7-12).

Table 7-7. GPMC/NOR Flash Interface Timing Requirements - Synchronous Mode - 1 Load

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
F12	$t_{su(dV-clkH)}$	Setup time, read gpmc_ad[15:0] valid before gpmc_clk high	1.9		ns
F13	$t_{h(clkH-dV)}$	Hold time, read gpmc_ad[15:0] valid after gpmc_clk high	1		ns
F21	$t_{su(waitV-clkH)}$	Setup time, gpmc_wait[1:0] valid before gpmc_clk high	1.9		ns
F22	$t_{h(clkH-waitV)}$	Hold Time, gpmc_wait[1:0] valid after gpmc_clk high	1		ns

NOTE

Wait monitoring support is limited to a WaitMonitoringTime value > 0. For a full description of wait monitoring feature, see the Device TRM.

Table 7-8. GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 1 Load

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
F0	$t_{c(clk)}$	Cycle time, output clock gpmc_clk period (12)	11.3		ns
F2	$t_{d(clkH-nCSV)}$	Delay time, gpmc_clk rising edge to gpmc_cs[7:0] transition (14)	F-0.8	F+3.1	ns
F3	$t_{d(clkH-nCSIV)}$	Delay time, gpmc_clk rising edge to gpmc_cs[7:0] invalid (14)	E-0.8	E+3.1	ns
F4	$t_{d(ADDV-clk)}$	Delay time, gpmc_a[27:0] address bus valid to gpmc_clk first edge	B-0.8	B+3.1	ns
F5	$t_{d(clkH-ADDIV)}$	Delay time, gpmc_clk rising edge to gpmc_a[27:0] gpmc address bus invalid	-0.8		ns
F6	$t_{d(nBEV-clk)}$	Delay time, gpmc_ben[1:0] valid to gpmc_clk rising edge	B-3.8	B+1.1	ns
F7	$t_{d(clkH-nBEIV)}$	Delay time, gpmc_clk rising edge to gpmc_ben[1:0] invalid	D-0.4	D+1.1	ns
F8	$t_{d(clkH-nADV)}$	Delay time, gpmc_clk rising edge to gpmc_advn_ale transition (14)	G-0.8	G+3.1	ns
F9	$t_{d(clkH-nADVIV)}$	Delay time, gpmc_clk rising edge to gpmc_advn_ale invalid (14)	D-0.8	D+3.1	ns
F10	$t_{d(clkH-nOE)}$	Delay time, gpmc_clk rising edge to gpmc_oen_ren transition (14)	H-0.8	H+2.1	ns
F11	$t_{d(clkH-nOEIV)}$	Delay time, gpmc_clk rising edge to gpmc_oen_ren invalid (14)	E-0.8	E+2.1	ns
F14	$t_{d(clkH-nWE)}$	Delay time, gpmc_clk rising edge to gpmc_wen transition (14)	I-0.8	I+3.1	ns
F15	$t_{d(clkH-Data)}$	Delay time, gpmc_clk rising edge to gpmc_ad[15:0] data bus transition	J-1.1	J+3.92	ns
F17	$t_{d(clkH-nBE)}$	Delay time, gpmc_clk rising edge to gpmc_ben[1:0] transition	J-1.1	J+3.8	ns
F18	$t_{w(nCSV)}$	Pulse duration, gpmc_cs[7:0] low	A		ns
F19	$t_{w(nBEV)}$	Pulse duration, gpmc_ben[1:0] low	C		ns
F20	$t_{w(nADVV)}$	Pulse duration, gpmc_advn_ale low	K		ns
F23	$t_{d(CLK-GPIO)}$	Delay time, gpmc_clk transition to gpio6_16.clkout0 transition (13)	1.2	6.1	ns

Table 7-9. GPMC/NOR Flash Interface Timing Requirements - Synchronous Mode - 5 Loads

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
F12	$t_{su(dV-clkH)}$	Setup time, read gpmc_ad[15:0] valid before gpmc_clk high	2.5		ns
F13	$t_{h(clkH-dV)}$	Hold time, read gpmc_ad[15:0] valid after gpmc_clk high	1.9		ns
F21	$t_{su(waitV-clkH)}$	Setup time, gpmc_wait[1:0] valid before gpmc_clk high	2.5		ns
F22	$t_{h(clkH-waitV)}$	Hold Time, gpmc_wait[1:0] valid after gpmc_clk high	1.9		ns

Table 7-10. GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 5 Loads

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
F0	$t_{c(clk)}$	Cycle time, output clock gpmc_clk period (12)	15.04		ns
F2	$t_{d(clkH-nCSV)}$	Delay time, gpmc_clk rising edge to gpmc_cs[7:0] transition (14)	F+0.7 (6)	F+6.1 (6)	ns
F3	$t_{d(clkH-nCSIV)}$	Delay time, gpmc_clk rising edge to gpmc_cs[7:0] invalid (14)	E+0.7 (5)	E+6.1 (5)	ns
F4	$t_{d(ADDV-clk)}$	Delay time, gpmc_a[27:0] address bus valid to gpmc_clk first edge	B+0.7 (2)	B+6.1 (2)	ns
F5	$t_{d(clkH-ADDIV)}$	Delay time, gpmc_clk rising edge to gpmc_a[27:0] gpmc address bus invalid	0.7		ns
F6	$t_{d(nBEV-clk)}$	Delay time, gpmc_ben[1:0] valid to gpmc_clk rising edge	B-4.9	B+0.4	ns
F7	$t_{d(clkH-nBEIV)}$	Delay time, gpmc_clk rising edge to gpmc_ben[1:0] invalid	D-0.4	D+4.9	ns
F8	$t_{d(clkH-nADV)}$	Delay time, gpmc_clk rising edge to gpmc_advn_ale transition (14)	G+0.7 (7)	G+6.1 (7)	ns
F9	$t_{d(clkH-nADVIV)}$	Delay time, gpmc_clk rising edge to gpmc_advn_ale invalid (14)	D+0.7 (4)	D+6.1 (4)	ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-10. GPMC/NOR Flash Interface Switching Characteristics - Synchronous Mode - 5 Loads (continued)

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
F10	$t_{d(clkH-nOE)}$	Delay time, gpmc_clk rising edge to gpmc_oen_ren transition (14)	H+0.7 (8)	H+5.1 (8)	ns
F11	$t_{d(clkH-nOEIV)}$	Delay time, gpmc_clk rising edge to gpmc_oen_ren invalid (14)	E+0.7 (5)	E+5.1 (5)	ns
F14	$t_{d(clkH-nWE)}$	Delay time, gpmc_clk rising edge to gpmc_wen transition (14)	I+0.7 (9)	I+6.1 (9)	ns
F15	$t_{d(clkH-Data)}$	Delay time, gpmc_clk rising edge to gpmc_ad[15:0] data bus transition	J-0.4 (10)	J+4.9 (10)	ns
F17	$t_{d(clkH-nBE)}$	Delay time, gpmc_clk rising edge to gpmc_ben[1:0] transition	J-0.4 (10)	J+4.9 (10)	ns
F18	$t_{w(nCSV)}$	Pulse duration, gpmc_cs[7:0] low	A (1)		ns
F19	$t_{w(nBEV)}$	Pulse duration, gpmc_ben[1:0] low	C (3)		ns
F20	$t_{w(nADVV)}$	Pulse duration, gpmc_advn_ale low	K (11)		ns
F23	$t_{d(CLK-GPIO)}$	Delay time, gpmc_clk transition to gpio6_16.clkout0 transition (13)	1.2	6.1	ns

(1) For single read: A = (CSRdOffTime - CSOnTime) × (TimeParaGranularity + 1) × GPMC_FCLK period
For burst read: A = (CSRdOffTime - CSOnTime + (n - 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK period
For burst write: A = (CSWrOffTime - CSOnTime + (n - 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK period with n the page burst access number.

(2) B = ClkActivationTime × GPMC_FCLK

(3) For single read: C = RdCycleTime × (TimeParaGranularity + 1) × GPMC_FCLK
For burst read: C = (RdCycleTime + (n – 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For Burst write: C = (WrCycleTime + (n – 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK with n the page burst access number.

(4) For single read: D = (RdCycleTime – AccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For burst read: D = (RdCycleTime – AccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For burst write: D = (WrCycleTime – AccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK

(5) For single read: E = (CSRdOffTime – AccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For burst read: E = (CSRdOffTime – AccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For burst write: E = (CSWrOffTime – AccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK

(6) For nCS falling edge (CS activated):
Case GpmcFCLKDivider = 0 :
F = 0.5 × CSExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
F = 0.5 × CSExtraDelay × GPMC_FCLK if (ClkActivationTime and CSOnTime are odd) or (ClkActivationTime and CSOnTime are even)
F = (1 + 0.5 × CSExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
F = 0.5 × CSExtraDelay × GPMC_FCLK if ((CSOnTime – ClkActivationTime) is a multiple of 3)
F = (1 + 0.5 × CSExtraDelay) × GPMC_FCLK if ((CSOnTime – ClkActivationTime – 1) is a multiple of 3)
F = (2 + 0.5 × CSExtraDelay) × GPMC_FCLK if ((CSOnTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
F = 0.5 × CSExtraDelay × GPMC_FCLK if ((CSOnTime - ClkActivationTime) is a multiple of 4)
F = (1 + 0.5 × CSExtraDelay) × GPMC_FCLK if ((CSOnTime - ClkActivationTime - 1) is a multiple of 4)
F = (2 + 0.5 × CSExtraDelay) × GPMC_FCLK if ((CSOnTime - ClkActivationTime - 2) is a multiple of 4)
F = (3 + 0.5 × CSExtraDelay) × GPMC_FCLK if ((CSOnTime - ClkActivationTime - 3) is a multiple of 4)

(7) For ADV falling edge (ADV activated):
Case GpmcFCLKDivider = 0 :
G = 0.5 × ADVExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if (ClkActivationTime and ADVOnTime are odd) or (ClkActivationTime and ADVOnTime are even)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if ((ADVOnTime – ClkActivationTime) is a multiple of 3)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVOnTime – ClkActivationTime – 1) is a multiple of 3)
G = (2 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVOnTime – ClkActivationTime – 2) is a multiple of 3)
For ADV rising edge (ADV deactivated) in Reading mode:
Case GpmcFCLKDivider = 0:
G = 0.5 × ADVExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if (ClkActivationTime and ADVRdOffTime are odd) or (ClkActivationTime and ADVRdOffTime are even)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime) is a multiple of 3)

Copyright © 2016–2020, Texas Instruments Incorporated

G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime – 1) is a multiple of 3)
G = (2 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime) is a multiple of 4)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime – 1) is a multiple of 4)
G = (2 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime – 2) is a multiple of 4)
G = (3 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVRdOffTime – ClkActivationTime – 3) is a multiple of 4)
For ADV rising edge (ADV deactivated) in Writing mode:
Case GpmcFCLKDivider = 0:
G = 0.5 × ADVExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if (ClkActivationTime and ADVWrOffTime are odd) or (ClkActivationTime and ADVWrOffTime are even)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime) is a multiple of 3)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime – 1) is a multiple of 3)
G = (2 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
G = 0.5 × ADVExtraDelay × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime) is a multiple of 4)
G = (1 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime – 1) is a multiple of 4)
G = (2 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime – 2) is a multiple of 4)
G = (3 + 0.5 × ADVExtraDelay) × GPMC_FCLK if ((ADVWrOffTime – ClkActivationTime – 3) is a multiple of 4)

(8) For OE falling edge (OE activated):
Case GpmcFCLKDivider = 0:
- H = 0.5 × OEExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
- H = 0.5 × OEExtraDelay × GPMC_FCLK if (ClkActivationTime and OEOnTime are odd) or (ClkActivationTime and OEOnTime are even)
- H = (1 + 0.5 × OEExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
- H = 0.5 × OEExtraDelay × GPMC_FCLK if ((OEOnTime – ClkActivationTime) is a multiple of 3)
- H = (1 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOnTime – ClkActivationTime – 1) is a multiple of 3)
- H = (2 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOnTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
- H = 0.5 × OEExtraDelay × GPMC_FCLK if ((OEOnTime - ClkActivationTime) is a multiple of 4)
- H = (1 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOnTime - ClkActivationTime - 1) is a multiple of 4)
- H = (2 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOnTime - ClkActivationTime - 2) is a multiple of 4)
- H = (3 + 0.5 × OEExtraDelay)) × GPMC_FCLK if ((OEOnTime - ClkActivationTime - 3) is a multiple of 4)
For OE rising edge (OE deactivated):
Case GpmcFCLKDivider = 0:
- H = 0.5 × OEExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
- H = 0.5 × OEExtraDelay × GPMC_FCLK if (ClkActivationTime and OEOffTime are odd) or (ClkActivationTime and OEOffTime are even)
- H = (1 + 0.5 × OEExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
- H = 0.5 × OEExtraDelay × GPMC_FCLK if ((OEOffTime – ClkActivationTime) is a multiple of 3)
- H = (1 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOffTime – ClkActivationTime – 1) is a multiple of 3)
- H = (2 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOffTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
- H = 0.5 × OEExtraDelay × GPMC_FCLK if ((OEOffTime – ClkActivationTime) is a multiple of 4)
- H = (1 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOffTime – ClkActivationTime – 1) is a multiple of 4)
- H = (2 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOffTime – ClkActivationTime – 2) is a multiple of 4)
- H = (3 + 0.5 × OEExtraDelay) × GPMC_FCLK if ((OEOffTime – ClkActivationTime – 3) is a multiple of 4)

(9) For WE falling edge (WE activated):
Case GpmcFCLKDivider = 0:
- I = 0.5 × WEExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
- I = 0.5 × WEExtraDelay × GPMC_FCLK if (ClkActivationTime and WEOnTime are odd) or (ClkActivationTime and WEOnTime are even)
- I = (1 + 0.5 × WEExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
- I = 0.5 × WEExtraDelay × GPMC_FCLK if ((WEOnTime – ClkActivationTime) is a multiple of 3)
- I = (1 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOnTime – ClkActivationTime – 1) is a multiple of 3)
- I = (2 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOnTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
- I = 0.5 × WEExtraDelay × GPMC_FCLK if ((WEOnTime - ClkActivationTime) is a multiple of 4)
- I = (1 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOnTime - ClkActivationTime - 1) is a multiple of 4)
- I = (2 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOnTime - ClkActivationTime - 2) is a multiple of 4)
- I = (3 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOnTime - ClkActivationTime - 3) is a multiple of 4)
For WE rising edge (WE deactivated):

Copyright © 2016–2020, Texas Instruments Incorporated

Case GpmcFCLKDivider = 0:
- I = 0.5 × WEExtraDelay × GPMC_FCLK
Case GpmcFCLKDivider = 1:
- I = 0.5 × WEExtraDelay × GPMC_FCLK if (ClkActivationTime and WEOffTime are odd) or (ClkActivationTime and WEOffTime are even)
- I = (1 + 0.5 × WEExtraDelay) × GPMC_FCLK otherwise
Case GpmcFCLKDivider = 2:
- I = 0.5 × WEExtraDelay × GPMC_FCLK if ((WEOffTime – ClkActivationTime) is a multiple of 3)
- I = (1 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOffTime – ClkActivationTime – 1) is a multiple of 3)
- I = (2 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOffTime – ClkActivationTime – 2) is a multiple of 3)
Case GpmcFCLKDivider = 3:
- I = 0.5 × WEExtraDelay × GPMC_FCLK if ((WEOffTime - ClkActivationTime) is a multiple of 4)
- I = (1 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOffTime - ClkActivationTime - 1) is a multiple of 4)
- I = (2 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOffTime - ClkActivationTime - 2) is a multiple of 4)
- I = (3 + 0.5 × WEExtraDelay) × GPMC_FCLK if ((WEOffTime - ClkActivationTime - 3) is a multiple of 4)

(10) J = GPMC_FCLK period, where GPMC_FCLK is the General Purpose Memory Controller internal functional clock

(11) For read:
K = (ADVRdOffTime – ADVOnTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For write: K = (ADVWrOffTime – ADVOnTime) × (TimeParaGranularity + 1) × GPMC_FCLK

(12) The gpmc_clk output clock maximum and minimum frequency is programmable in the I/F module by setting the GPMC_CONFIG1_CSx configuration register bit fields GpmcFCLKDivider

(13) gpio6_16 programmed to MUXMODE=9 (clkout1), CM_CLKSEL_CLKOUTMUX1 programmed to 7 (CORE_DPLL_OUT_DCLK), CM_CLKSEL_CORE_DPLL_OUT_CLK_CLKOUTMUX programmed to 1.

(14) CSEXTRADELAY = 0, ADVEXTRADELAY = 0, WEEXTRADELAY = 0, OEEXTRADELAY = 0. Extra half-GPMC_FCLK cycle delay mode is not timed.

Copyright © 2016–2020, Texas Instruments Incorporated

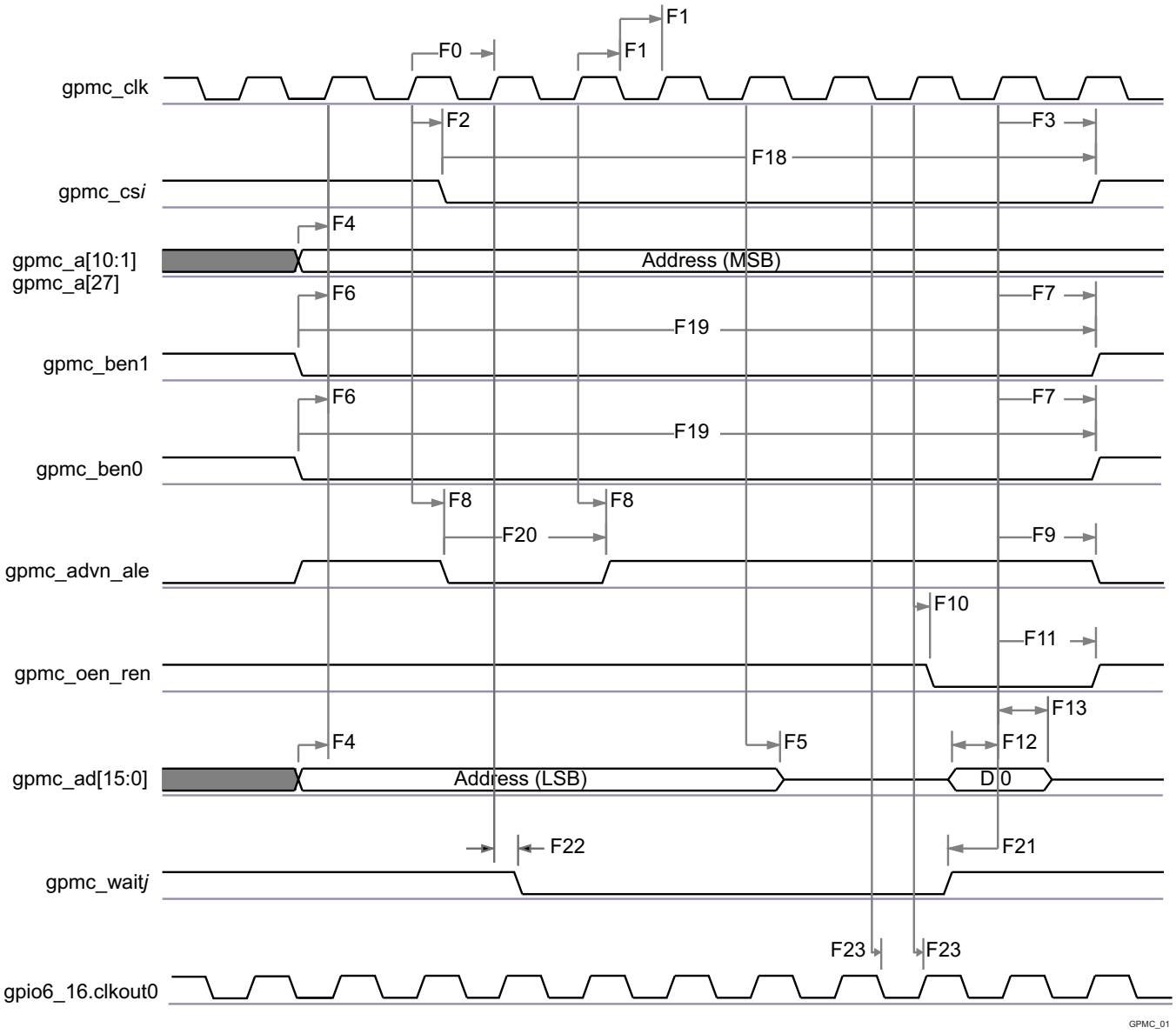


Figure 7-7. GPMC / Multiplexed 16bits NOR Flash - Synchronous Single Read - (GpmcFCLKDivider = 0)(1)(2)

(1) In gpmc_cs*i*, i = 0 to 7.

(2) In gpmc_waitj, j = 0 to 1.

Copyright © 2016–2020, Texas Instruments Incorporated

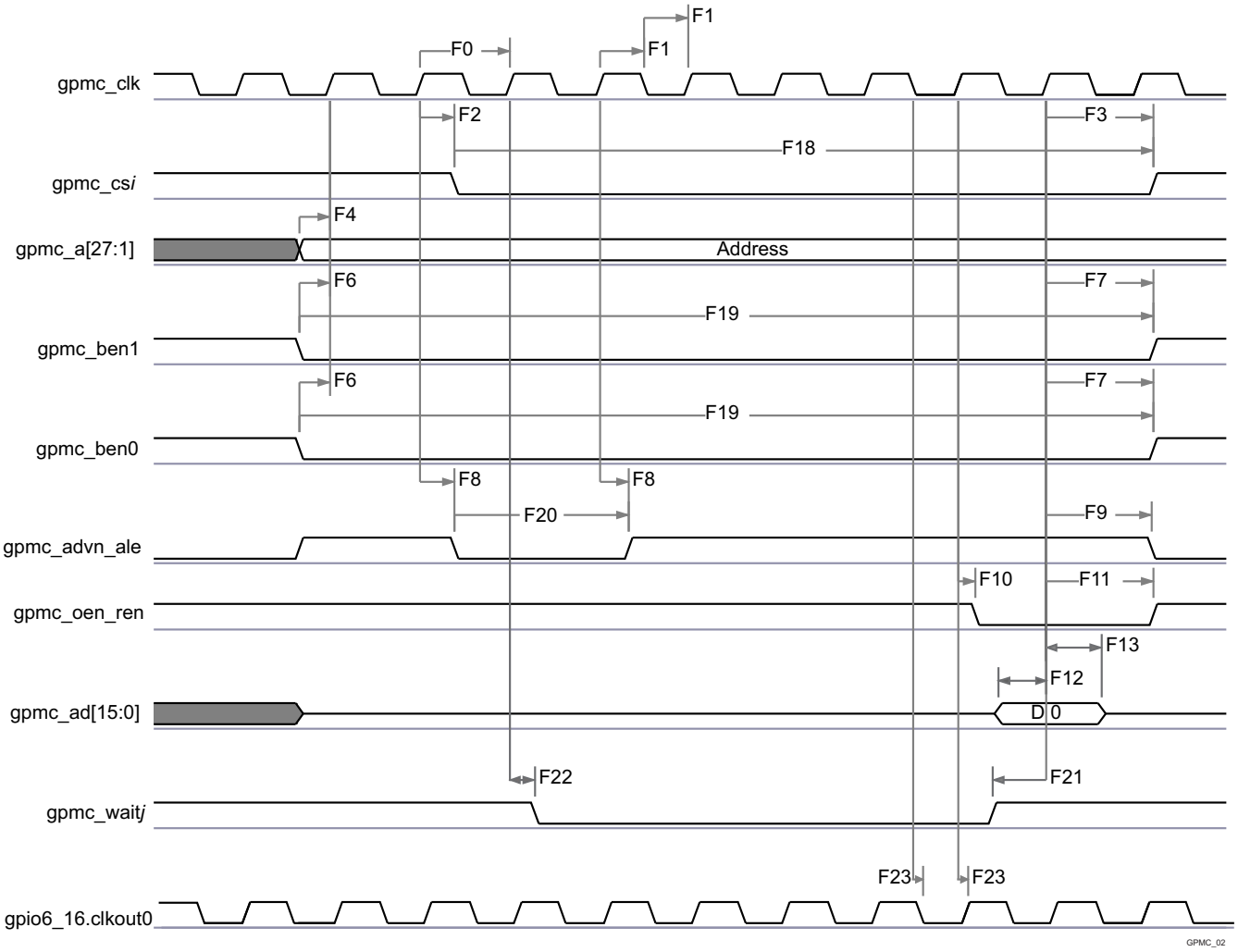


Figure 7-8. GPMC / Non-Multiplexed 16bits NOR Flash - Synchronous Single Read - (GpmcFCLKDivider = 0)(1)(2)

(1) In gpmc_cs*i*, i = 0 to 7.

(2) In gpmc_waitj, j = 0 to 1.

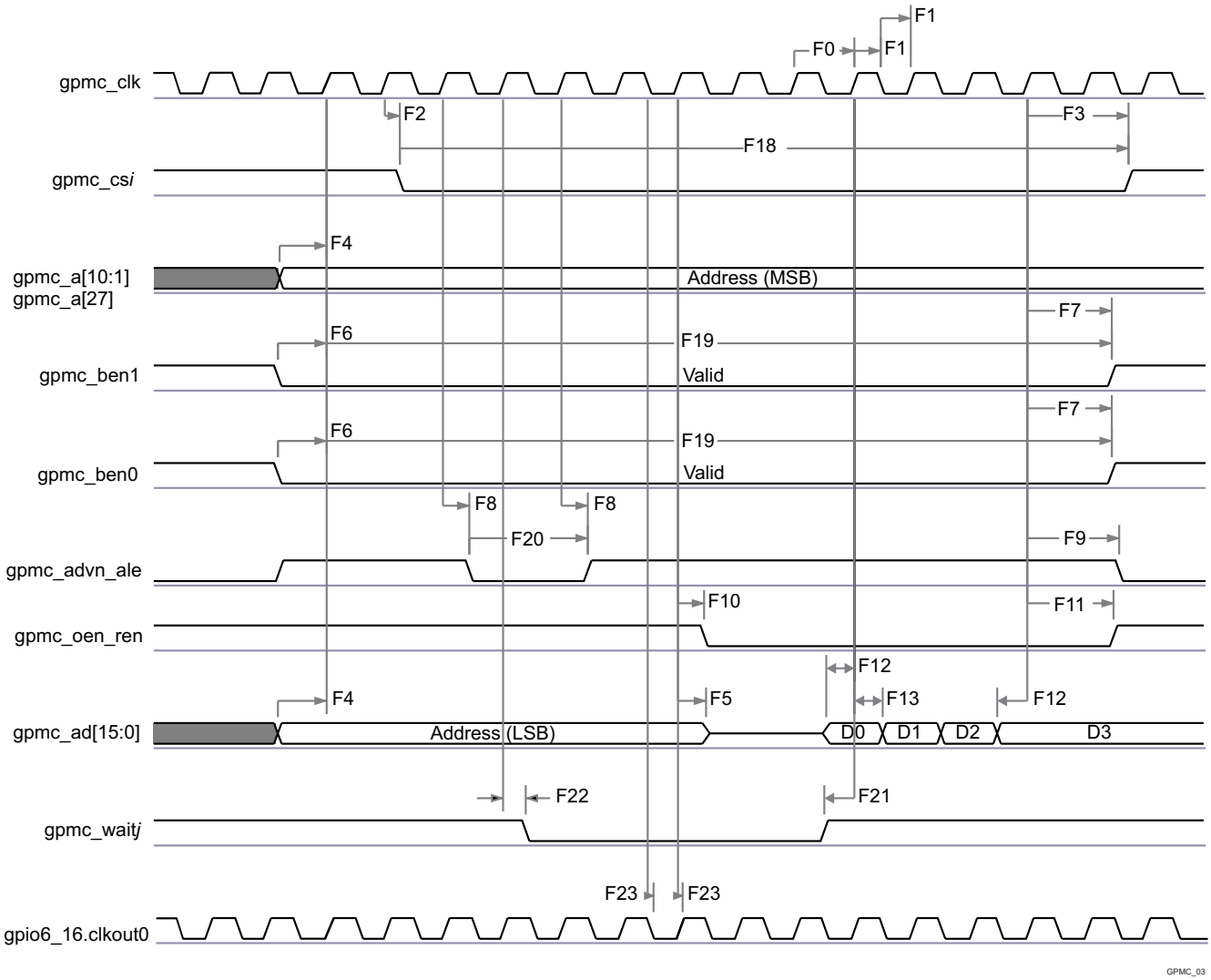


Figure 7-9. GPMC / Multiplexed 16bits NOR Flash - Synchronous Burst Read 4x16 bits - (GpmcFCLKDivider = 0)[(1)(2)]

(1) In gpmc_cs*i*, i= 0 to 7.

(2) In gpmc_waitj, j = 0 to 1.

Copyright © 2016–2020, Texas Instruments Incorporated

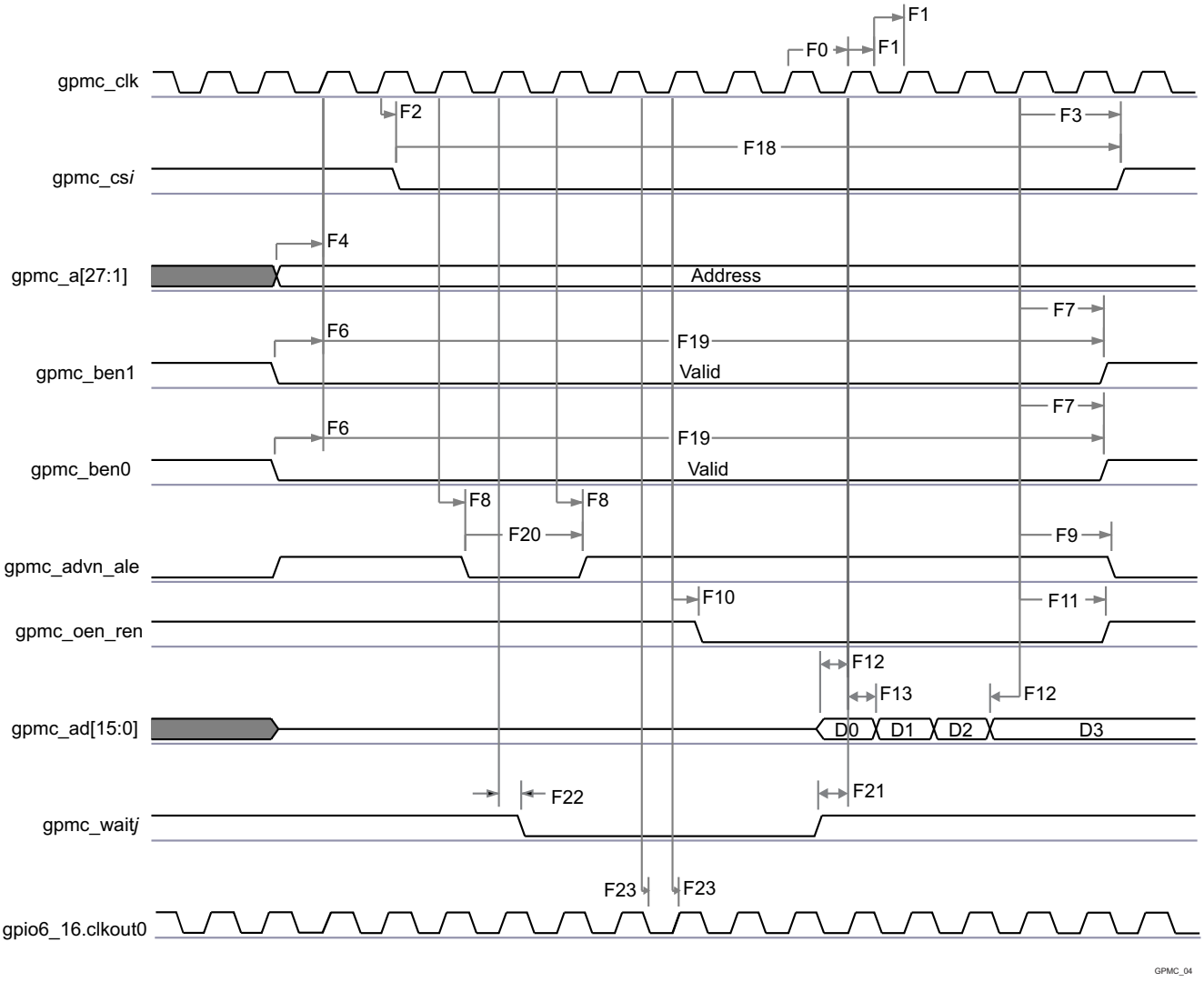


Figure 7-10. GPMC / Non-Multiplexed 16bits NOR Flash - Synchronous Burst Read 4x16 bits - (GpmcFCLKDivider = 0)[(1)][(2)]

(1) In gpmc_cs*i*, i = 0 to 7.

(2) In gpmc_waitj, j = 0 to 1.

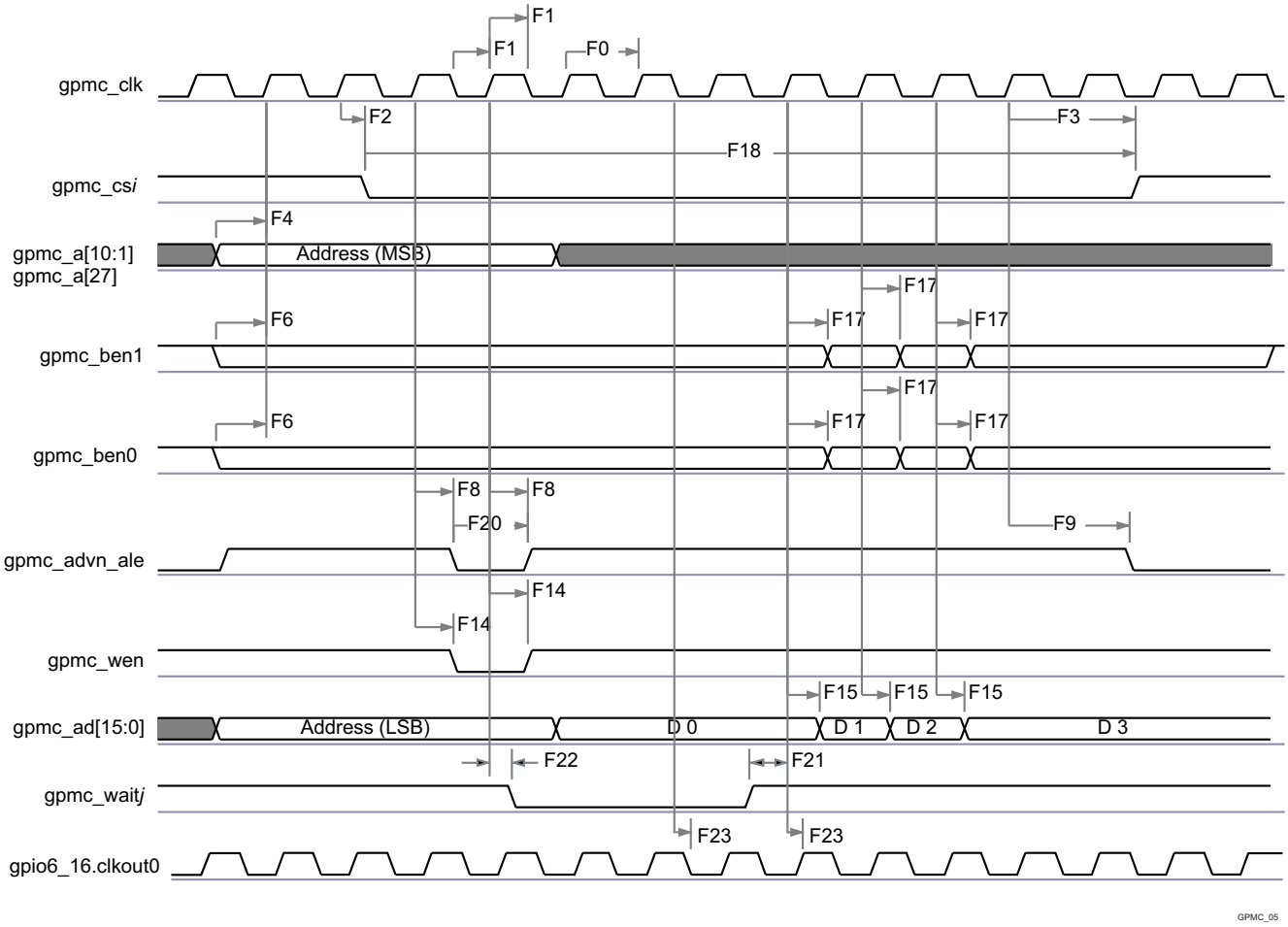


Figure 7-11. GPMC / Multiplexed 16bits NOR Flash - Synchronous Burst Write 4x16bits - (GpmcFCLKDivider = 0)(1)(2)

(1) In “gpmc_csi”, i = 0 to 7.

(2) In “gpmc_waitj”, j = 0 to 1.

Copyright © 2016–2020, Texas Instruments Incorporated

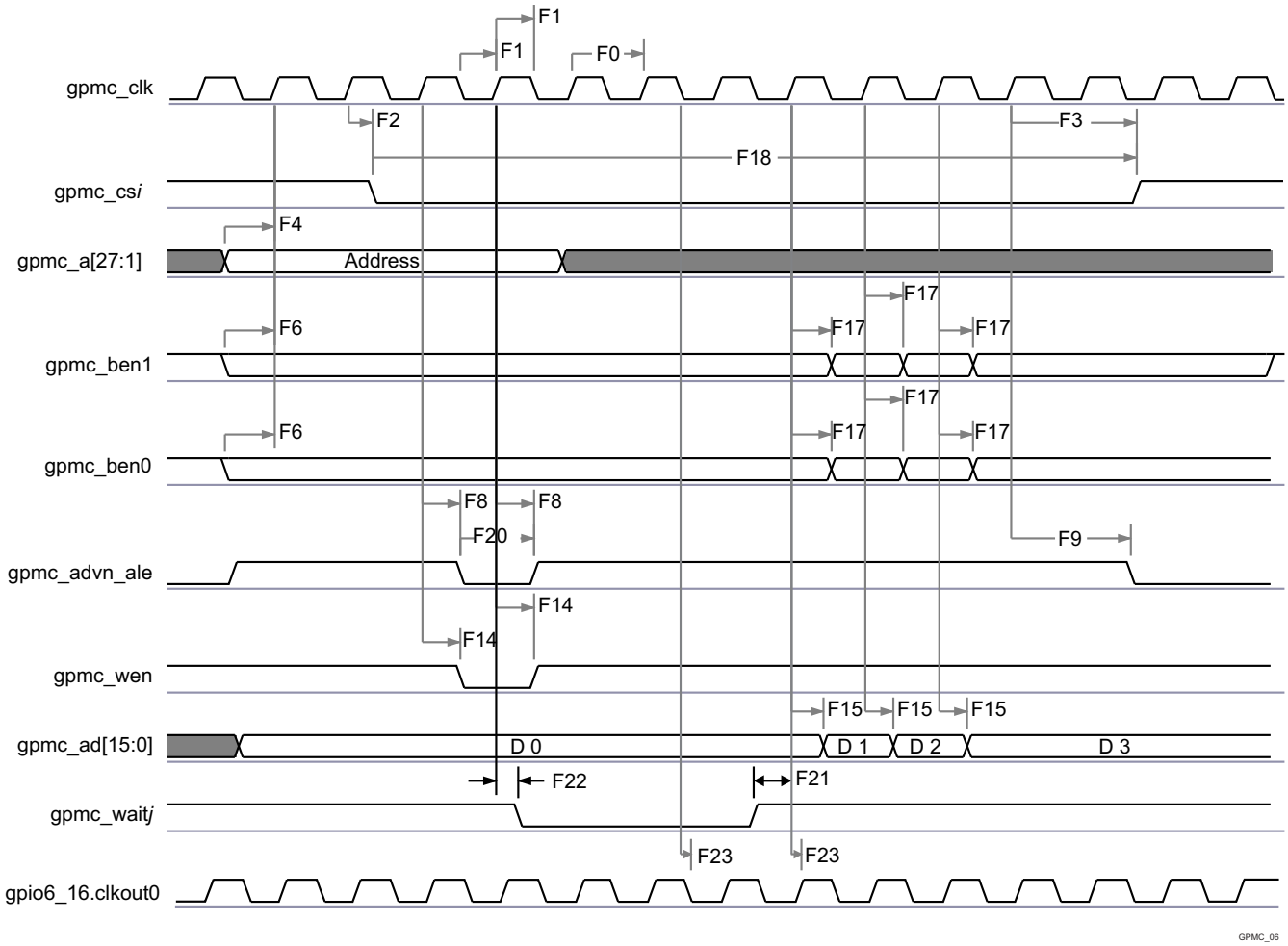


Figure 7-12. GPMC / Non-Multiplexed 16bits NOR Flash - Synchronous Burst Write 4x16bits - (GpmcFCLKDivider = 0)[(1)(2)]

(1) In "gpmc_csi", i = 1 to 7.

(2) In "gpmc_waitj", j = 0 to 1.

7.9.2 GPMC/NOR Flash Interface Asynchronous Timing

Table 7-11 and Table 7-12 assume testing over the recommended operating conditions and electrical characteristic conditions below (see Figure 7-13 through Figure 7-18).

Table 7-11. GPMC/NOR Flash Interface Timing Requirements - Asynchronous Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
FA5	$t_{acc(DAT)}$	Data Maximum Access Time (GPMC_FCLK cycles)		H (1)	cycles
FA20	$t_{acc1\text{-}pgmode(DAT)}$	Page Mode Successive Data Maximum Access Time (GPMC_FCLK cycles)		P (2)	cycles
FA21	$t_{acc2\text{-}pgmode(DAT)}$	Page Mode First Data Maximum Access Time (GPMC_FCLK cycles)		H (1)	cycles
-	$t_{su(DV\text{-}OEH)}$	Setup time, read gpmc_ad[15:0] valid before gpmc_oen_ren high	1.9		ns
-	$t_{h(OEH\text{-}DV)}$	Hold time, read gpmc_ad[15:0] valid after gpmc_oen_ren high	1		ns

(1) H = Access Time × (TimeParaGranularity + 1)

(2) P = PageBurstAccessTime × (TimeParaGranularity + 1)

Table 7-12. GPMC/NOR Flash Interface Switching Characteristics - Asynchronous Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
-	$t_{r(DO)}$	Rising time, gpmc_ad[15:0] output data	0.447	4.067	ns
-	$t_{f(DO)}$	Fallling time, gpmc_ad[15:0] output data	0.43	4.463	ns
FA0	$t_{w(nBEV)}$	Pulse duration, gpmc_ben[1:0] valid time		N	ns
FA1	$t_{w(nCSV)}$	Pulse duration, gpmc_cs[7:0] low		A	ns
FA3	$t_{d(nCSV-nADVIV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_advn_ale invalid	B - 0.2	B + 2.0	ns
FA4	$t_{d(nCSV-nOEIV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_oen_ren invalid (Single read)	C - 0.2	C + 2.0	ns
FA9	$t_{d(AV-nCSV)}$	Delay time, address bus valid to gpmc_cs[7:0] valid	J - 0.2	J + 2.0	ns
FA10	$t_{d(nBEV-nCSV)}$	Delay time, gpmc_ben[1:0] valid to gpmc_cs[7:0] valid	J - 0.2	J + 2.0	ns
FA12	$t_{d(nCSV-nADVV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_advn_ale valid	K - 0.2	K + 2.0	ns
FA13	$t_{d(nCSV-nOEV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_oen_ren valid	L - 0.2	L + 2.0	ns
FA16	$t_{w(AIV)}$	Pulse duration, address invalid between 2 successive R/W accesses	G		ns
FA18	$t_{d(nCSV-nOEIV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_oen_ren invalid (Burst read)	I - 0.2	I + 2.0	ns
FA20	$t_{w(AV)}$	Pulse duration, address valid : 2nd, 3rd and 4th accesses	D		ns
FA25	$t_{d(nCSV-nWEV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_wen valid	E - 2	E + 2.0	ns
FA27	$t_{d(nCSV-nWEIV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_wen invalid	F - 0.2	F + 2.0	ns
FA28	$t_{d(nWEV-DV)}$	Delay time, gpmc_ wen valid to data bus valid		2	ns
FA29	$t_{d(DV-nCSV)}$	Delay time, data bus valid to gpmc_cs[7:0] valid	J - 0.2	J + 2.0	ns
FA37	$t_{d(nOEV-AIV)}$	Delay time, gpmc_oen_ren valid to gpmc_ad[15:0] multiplexed address bus phase end		2	ns

(1) For single read: N = RdCycleTime × (TimeParaGranularity + 1) × GPMC_FCLK
For single write: N = WrCycleTime × (TimeParaGranularity + 1) × GPMC_FCLK
For burst read: N = (RdCycleTime + (n – 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For burst write: N = (WrCycleTime + (n – 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK

(2) For single read: A = (CSRdOffTime - CSOnTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For single write: A = (CSWrOffTime – CSOnTime) × (TimeParaGranularity + 1) × GPMC_FCLK
For burst read: A = (CSRdOffTime - CSOnTime + (n - 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK period
For burst write: A = (CSWrOffTime - CSOnTime + (n - 1) × PageBurstAccessTime) × (TimeParaGranularity + 1) × GPMC_FCLK period
with n the page burst access number.

(3) For reading: B = ((ADVRdOffTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (ADVExtraDelay – CSExtraDelay)) × GPMC_FCLK
For writing: B = ((ADVWrOffTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (ADVExtraDelay – CSExtraDelay)) × GPMC_FCLK

(4) C = ((OEOffTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (OEExtraDelay – CSExtraDelay)) × GPMC_FCLKFor single read: C = RdCycleTime × (TimeParaGranularity + 1) × GPMC_FCLK

(5) J = (CSOnTime × (TimeParaGranularity + 1) + 0.5 × CSExtraDelay) × GPMC_FCLK

(6) K = ((ADVOnTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (ADVExtraDelay – CSExtraDelay)) × GPMC_FCLK

(7) L = ((OEOnTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (OEExtraDelay – CSExtraDelay)) × GPMC_FCLK

(8) G = Cycle2CycleDelay × GPMC_FCLK × (TimeParaGranularity + 1)

(9) I = ((OEOffTime + (n – 1) × PageBurstAccessTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (OEExtraDelay – CSExtraDelay)) × GPMC_FCLK

(10) D = PageBurstAccessTime × (TimeParaGranularity + 1) × GPMC_FCLK

(11) E = ((WEOnTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (WEExtraDelay – CSExtraDelay)) × GPMC_FCLK

(12) F = ((WEOffTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (WEExtraDelay – CSExtraDelay)) × GPMC_FCLK

Copyright © 2016–2020, Texas Instruments Incorporated

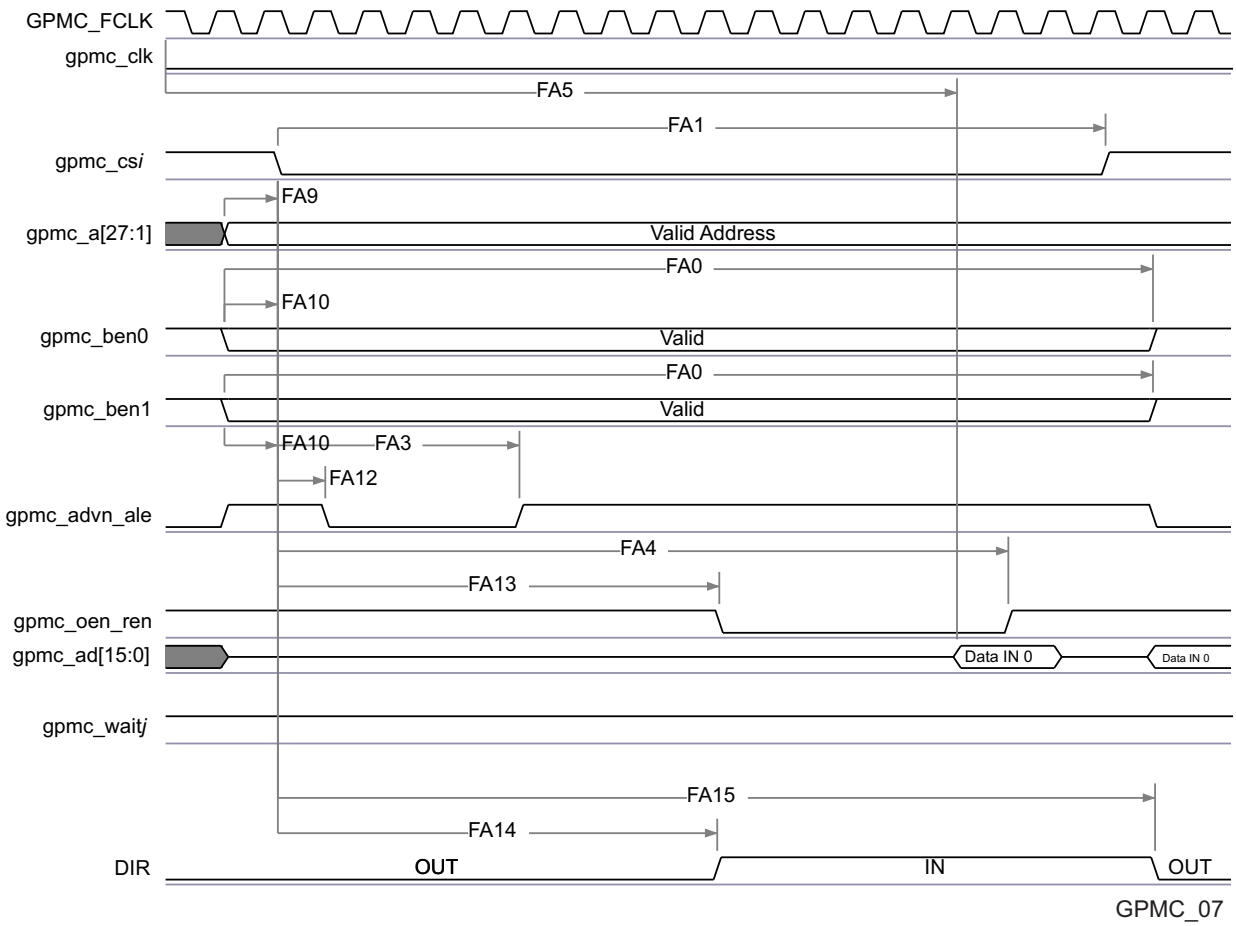


Figure 7-13. GPMC / NOR Flash - Asynchronous Read - Single Word Timing(1)(2)(3)

(1) In gpmc_cs*i*, i = 0 to 7. In gpmc_waitj, j = 0 to 1.

(2) FA5 parameter illustrates amount of time required to internally sample input data. It is expressed in number of GPMC functional clock cycles. From start of read cycle and after FA5 functional clock cycles, input Data will be internally sampled by active functional clock edge. FA5 value must be stored inside AccessTime register bits field.

(3) GPMC_FCLK is an internal clock (GPMC functional clock) not provided externally.

(4) The "DIR" (direction control) output signal is NOT pinned out on any of the device pads. It is an internal signal only representing a signal direction on the GPMC data bus.

Copyright © 2016–2020, Texas Instruments Incorporated

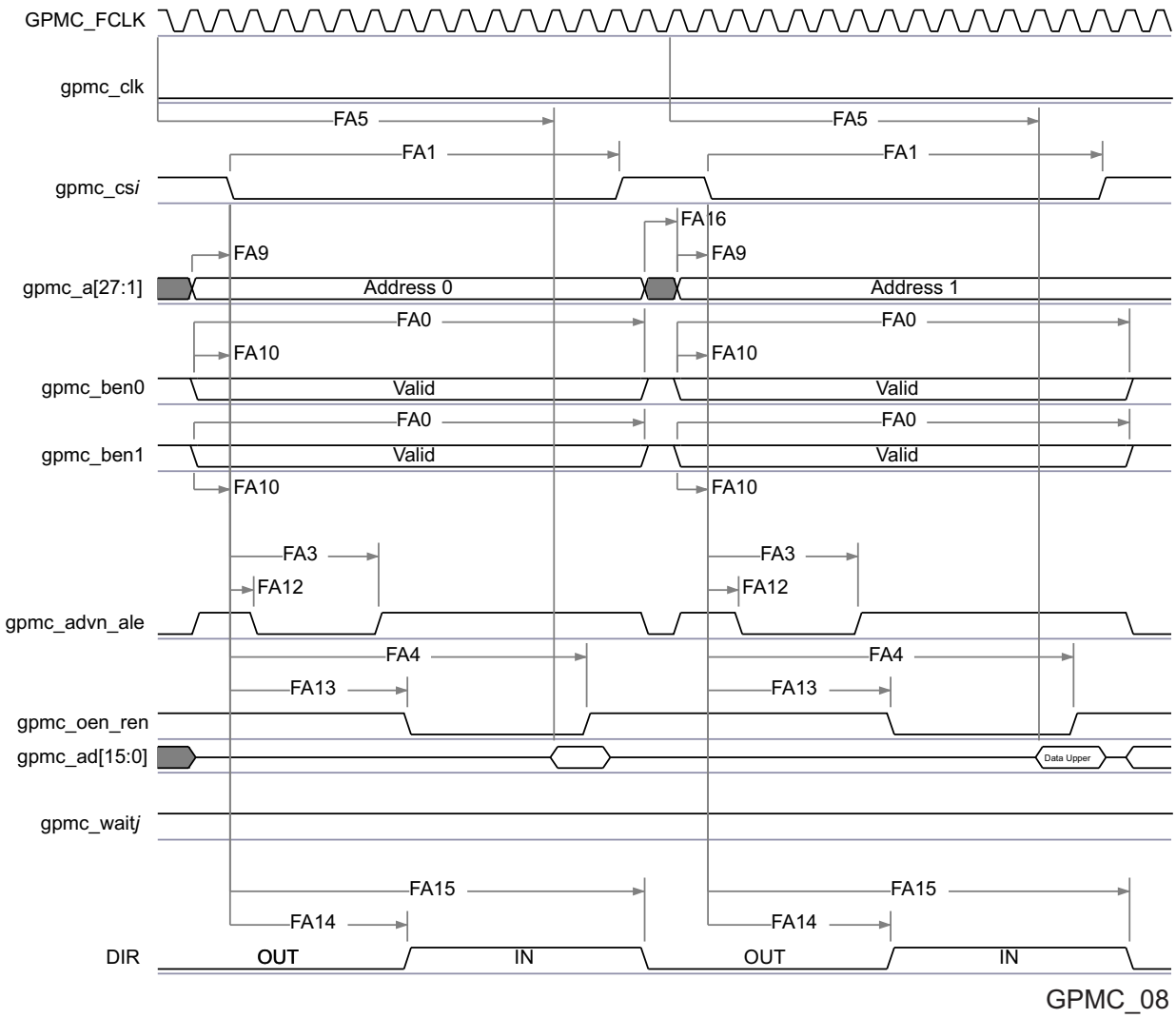


Figure 7-14. GPMC / NOR Flash - Asynchronous Read - 32-bit Timing(1)(2)(3)

(1) In “gpmc_csi”, i = 0 to 7. In “gpmc_waitj”, j = 0 to 1.

(2) FA5 parameter illustrates amount of time required to internally sample input Data. It is expressed in number of GPMC functional clock cycles. From start of read cycle and after FA5 functional clock cycles, input Data will be internally sampled by active functional clock edge. FA5 value should be stored inside AccessTime register bits field

(3) GPMC_FCLK is an internal clock (GPMC functional clock) not provided externally

(4) The "DIR" (direction control) output signal is NOT pinned out on any of the device pads. It is an internal signal only representing a signal direction on the GPMC data bus.

Copyright © 2016–2020, Texas Instruments Incorporated

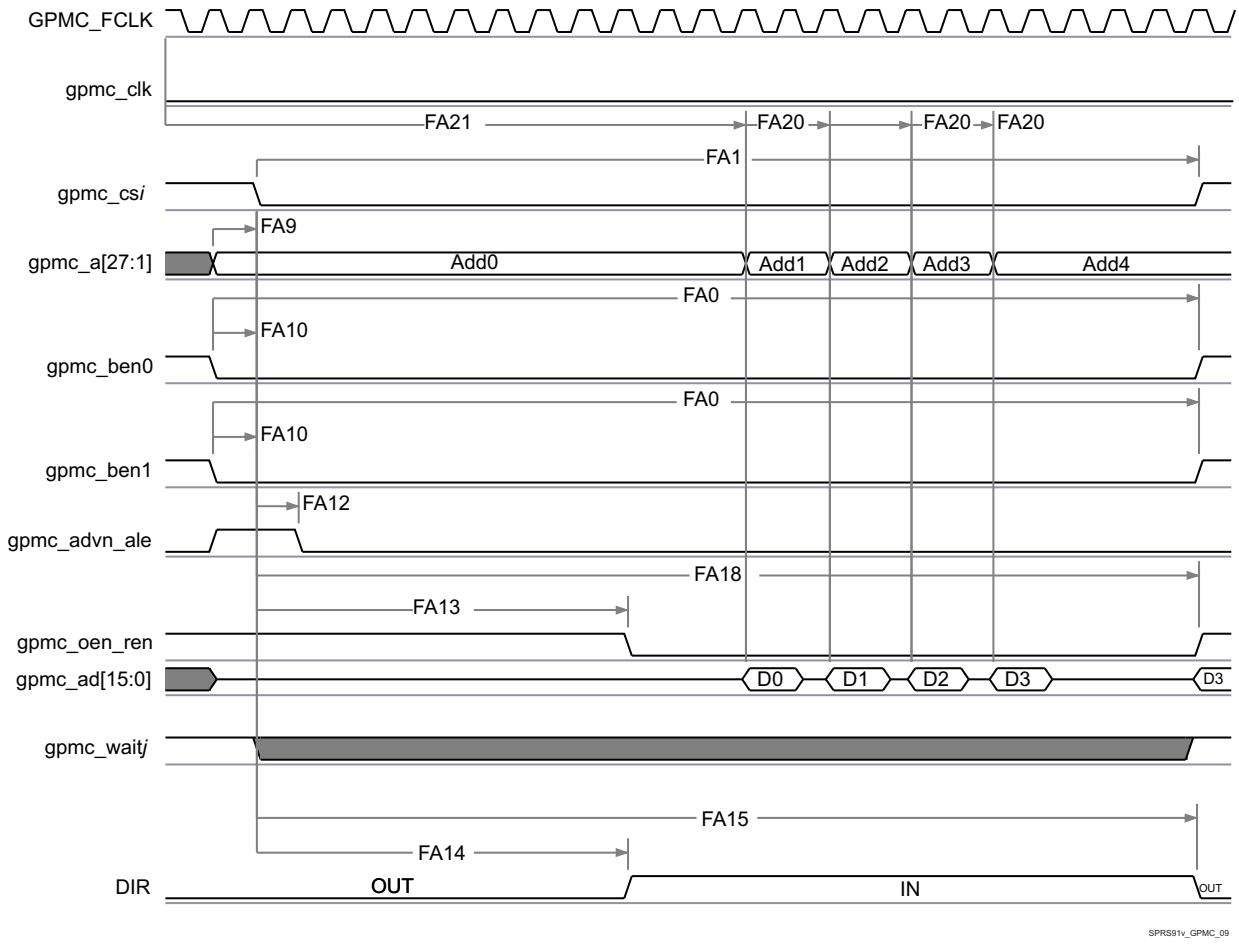


Figure 7-15. GPMC / NOR Flash - Asynchronous Read - Page Mode 4x16-bit Timing(1)(2)(3)(4)

(1) In “gpmc_csi”, i = 0 to 7. In “gpmc_waitj”, j = 0 to 1

(2) FA21 parameter illustrates amount of time required to internally sample first input Page Data. It is expressed in number of GPMC functional clock cycles. From start of read cycle and after FA21 functional clock cycles, First input Page Data will be internally sampled by active functional clock edge. FA21 calculation is detailled in a separated application note (ref …) and should be stored inside AccessTime register bits field.

(3) FA20 parameter illustrates amount of time required to internally sample successive input Page Data. It is expressed in number of GPMC functional clock cycles. After each access to input Page Data, next input Page Data will be internally sampled by active functional clock edge after FA20 functional clock cycles. FA20 is also the duration of address phases for successive input Page Data (excluding first input Page Data). FA20 value should be stored in PageBurstAccessTime register bits field.

(4) GPMC_FCLK is an internal clock (GPMC functional clock) not provided externally

(5) The "DIR" (direction control) output signal is NOT pinned out on any of the device pads. It is an internal signal only representing a signal direction on the GPMC data bus.

Copyright © 2016–2020, Texas Instruments Incorporated

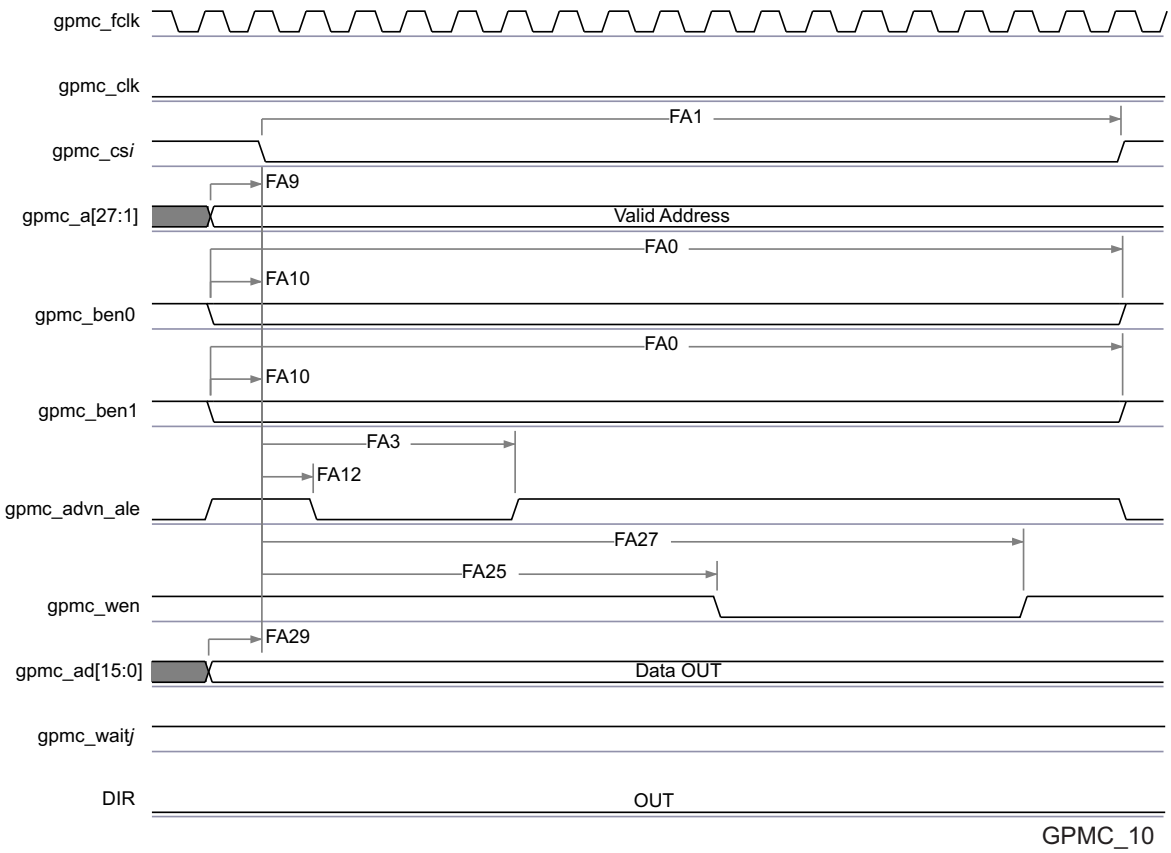


Figure 7-16. GPMC / NOR Flash - Asynchronous Write - Single Word Timing(1)

(1) In “gpmc_csi”, i = 0 to 7. In “gpmc_waitj”, j = 0 to 1.

(2) The "DIR" (direction control) output signal is NOT pinned out on any of the device pads. It is an internal signal only representing a signal direction on the GPMC data bus.

Copyright © 2016–2020, Texas Instruments Incorporated

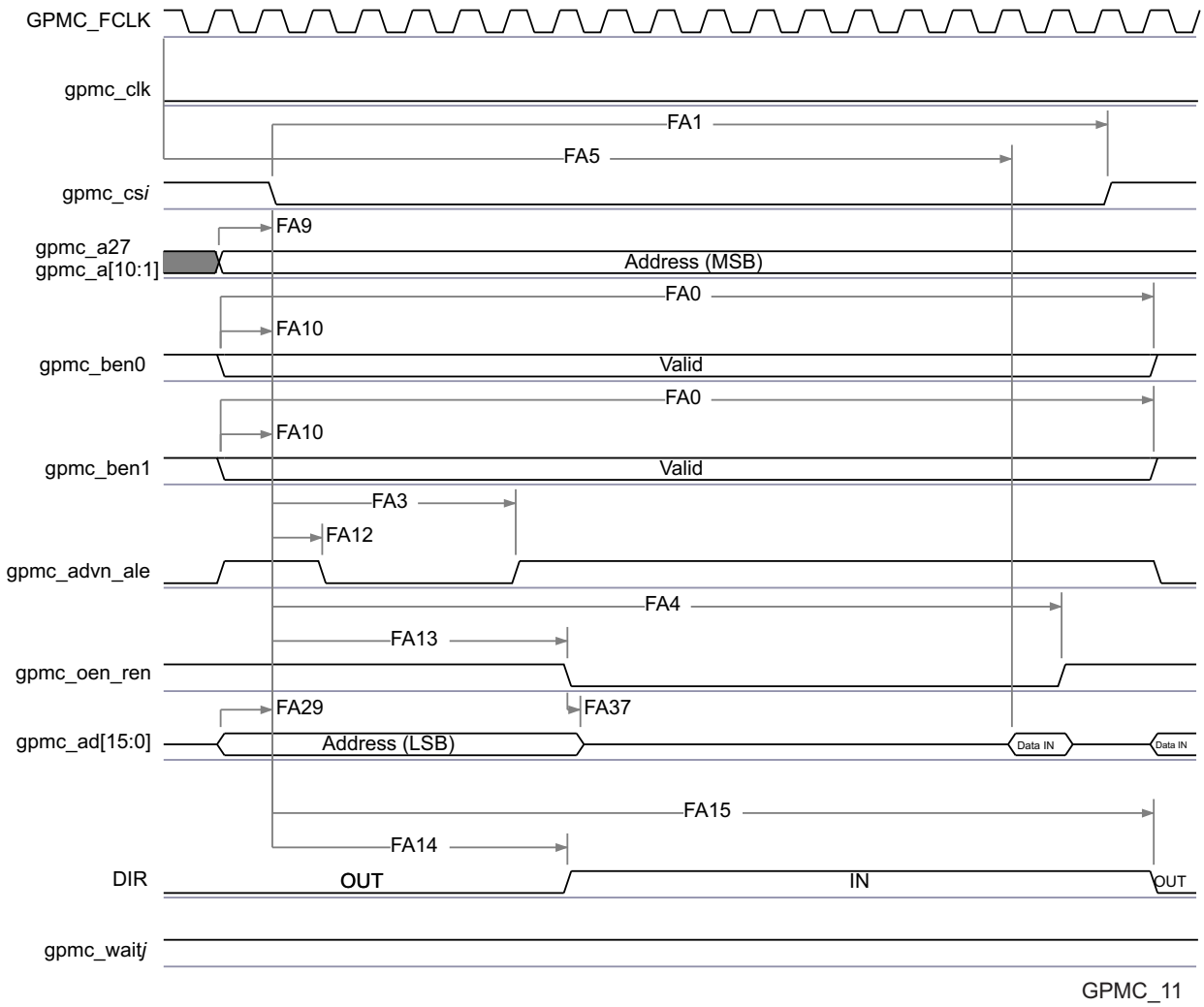


Figure 7-17. GPMC / Multiplexed NOR Flash - Asynchronous Read - Single Word Timing(1)(2)(3)

(1) In “gpmc_csi”, i = 0 to 7. In “gpmc_waitj”, j = 0 to 1

(2) FA5 parameter illustrates amount of time required to internally sample input Data. It is expressed in number of GPMC functional clock cycles. From start of read cycle and after FA5 functional clock cycles, input Data will be internally sampled by active functional clock edge. FA5 value should be stored inside AccessTime register bits field.

(3) GPMC_FCLK is an internal clock (GPMC functional clock) not provided externally

(4) The "DIR" (direction control) output signal is NOT pinned out on any of the device pads. It is an internal signal only representing a signal direction on the GPMC data bus.

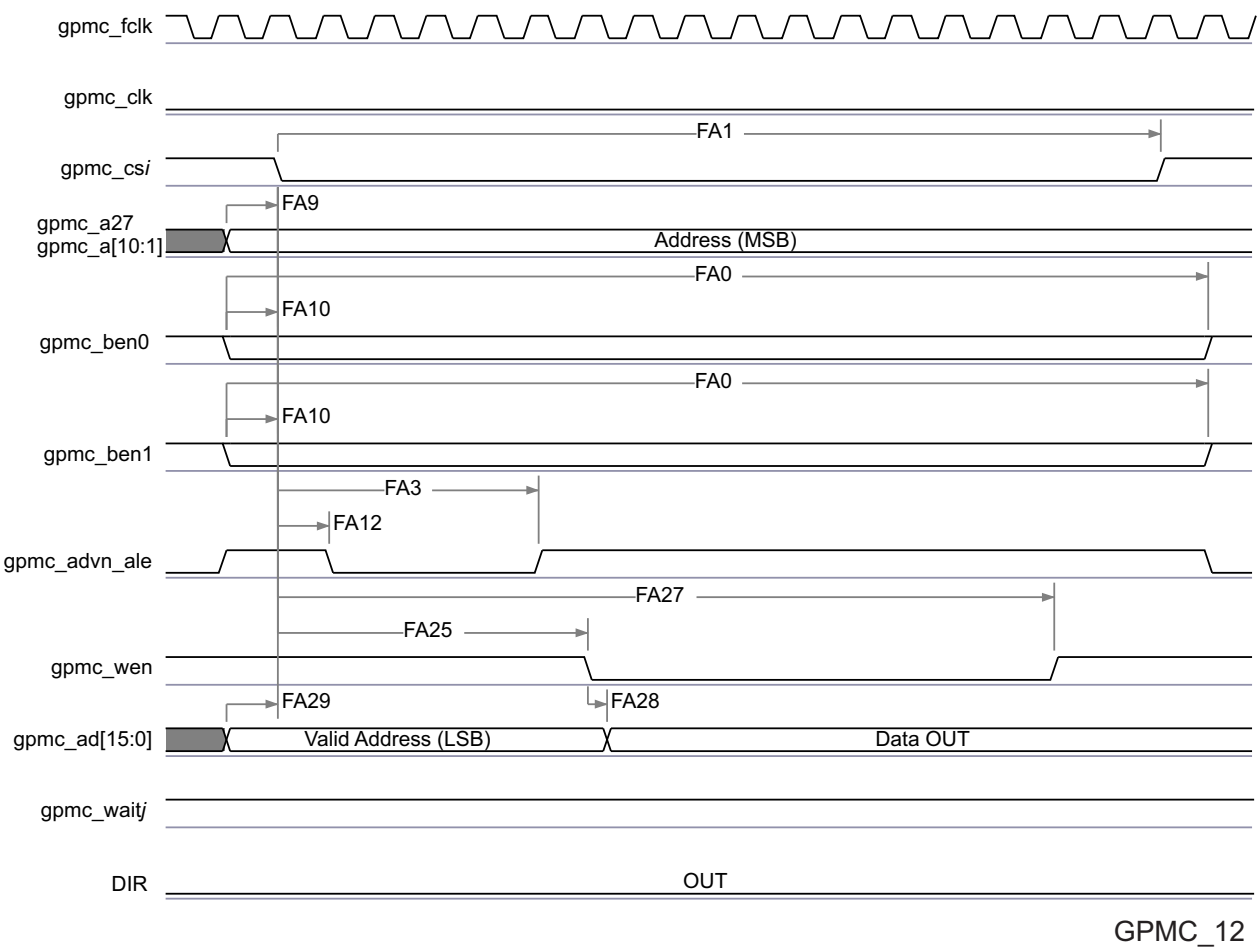


Figure 7-18. GPMC / Multiplexed NOR Flash - Asynchronous Write - Single Word Timing[(1)]

(1) In “gpmc_csi”, i = 0 to 7. In “gpmc_waitj”, j = 0 to 1.

(2) The "DIR" (direction control) output signal is NOT pinned out on any of the device pads. It is an internal signal only representing a signal direction on the GPMC data bus.

7.9.3 GPMC/NAND Flash Interface Asynchronous Timing

Table 7-13 and Table 7-14 assume testing over the recommended operating conditions and electrical characteristic conditions below (see Figure 7-19 through Figure 7-22).

Table 7-13. GPMC/NAND Flash Interface Timing Requirements[(1)]

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
GNF12	$t_{acc(DAT)}$	Data maximum access time (GPMC_FCLK Cycles)		J	cycles
-	$t_{su(DV-OEH)}$	Setup time, read gpmc_ad[15:0] valid before gpmc_oen_ren high	1.9		ns
-	$t_{h(OEH-DV)}$	Hold time, read gpmc_ad[15:0] valid after gpmc_oen_ren high	1		ns

(1) J = AccessTime × (TimeParaGranularity + 1)

Table 7-14. GPMC/NAND Flash Interface Switching Characteristics

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
-	$t_{r(DO)}$	Rising time, gpmc_ad[15:0] output data	0.447	4.067	ns
-	$t_{f(DO)}$	Fallling time, gpmc_ad[15:0] output data	0.43	4.463	ns
GNF0	$t_{w(nWEV)}$	Pulse duration, gpmc_wen valid time		A [(1)]	ns
GNF1	$t_{d(nCSV-nWEV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_wen valid	B - 0.2 [(2)]	B + 2.0 [(2)]	ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-14. GPMC/NAND Flash Interface Switching Characteristics (continued)

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
GNF2	$t_{d(CLEH-nWEV)}$	Delay time, gpmc_ben[1:0] high to gpmc_wen valid	C - 0.2 (3)	C + 2.0 (3)	ns
GNF3	$t_{d(nWEV-DV)}$	Delay time, gpmc_ad[15:0] valid to gpmc_wen valid	D - 0.2 (4)	D + 2.0 (4)	ns
GNF4	$t_{d(nWEIV-DIV)}$	Delay time, gpmc_wen invalid to gpmc_ad[15:0] invalid	E - 0.2 (5)	E + 2.0 (5)	ns
GNF5	$t_{d(nWEIV-CLEIV)}$	Delay time, gpmc_wen invalid to gpmc_ben[1:0] invalid	F - 0.2 (6)	F + 2.0 (6)	ns
GNF6	$t_{d(nWEIV-nCSIV)}$	Delay time, gpmc_wen invalid to gpmc_cs[7:0] invalid	G - 0.2 (7)	G + 2.0 (7)	ns
GNF7	$t_{d(ALEH-nWEV)}$	Delay time, gpmc_advn_ale high to gpmc_wen valid	C - 0.2 (3)	C + 2.0 (3)	ns
GNF8	$t_{d(nWEIV-ALEIV)}$	Delay time, gpmc_wen invalid to gpmc_advn_ale invalid	F - 0.2 (6)	F + 2.0 (6)	ns
GNF9	$t_{c(nWE)}$	Cycle time, write cycle time		H (8)	ns
GNF10	$t_{d(nCSV-nOEV)}$	Delay time, gpmc_cs[7:0] valid to gpmc_oen_ren valid	I - 0.2 (9)	I + 2.0 (9)	ns
GNF13	$t_{w(nOEV)}$	Pulse duration, gpmc_oen_ren valid time		K	ns
GNF14	$t_{c(nOE)}$	Cycle time, read cycle time		L (10)	ns
GNF15	$t_{d(nOEIV-nCSIV)}$	Delay time, gpmc_oen_ren invalid to gpmc_cs[7:0] invalid	M - 0.2 (11)	M + 2.0 (11)	ns

(1) A = (WEOffTime – WEOnTime) × (TimeParaGranularity + 1) × GPMC_FCLK

(2) B = ((WEOnTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (WEExtraDelay – CSExtraDelay)) × GPMC_FCLK

(3) C = ((WEOnTime – ADVOnTime) × (TimeParaGranularity + 1) + 0.5 × (WEExtraDelay – ADVExtraDelay)) × GPMC_FCLK

(4) D = (WEOnTime × (TimeParaGranularity + 1) + 0.5 × WEExtraDelay) × GPMC_FCLK

(5) E = (WrCycleTime – WEOffTime × (TimeParaGranularity + 1) – 0.5 × WEExtraDelay) × GPMC_FCLK

(6) F = (ADVWrOffTime – WEOffTime × (TimeParaGranularity + 1) + 0.5 × (ADVExtraDelay – WEExtraDelay) × GPMC_FCLK

(7) G = (CSWrOffTime – WEOffTime × (TimeParaGranularity + 1) + 0.5 × (CSExtraDelay – WEExtraDelay) × GPMC_FCLK

(8) H = WrCycleTime × (1 + TimeParaGranularity) × GPMC_FCLK

(9) I = ((OEOffTime + (n – 1) × PageBurstAccessTime – CSOnTime) × (TimeParaGranularity + 1) + 0.5 × (OEExtraDelay – CSExtraDelay)) × GPMC_FCLK

(10) K = (OEOffTime – OEOnTime) × (1 + TimeParaGranularity) × GPMC_FCLK

(11) L = RdCycleTime × (1 + TimeParaGranularity) × GPMC_FCLK

(12) M = (CSRdOffTime – OEOffTime × (TimeParaGranularity + 1) + 0.5 × (CSExtraDelay – OEExtraDelay) × GPMC_FCLK

Copyright © 2016–2020, Texas Instruments Incorporated

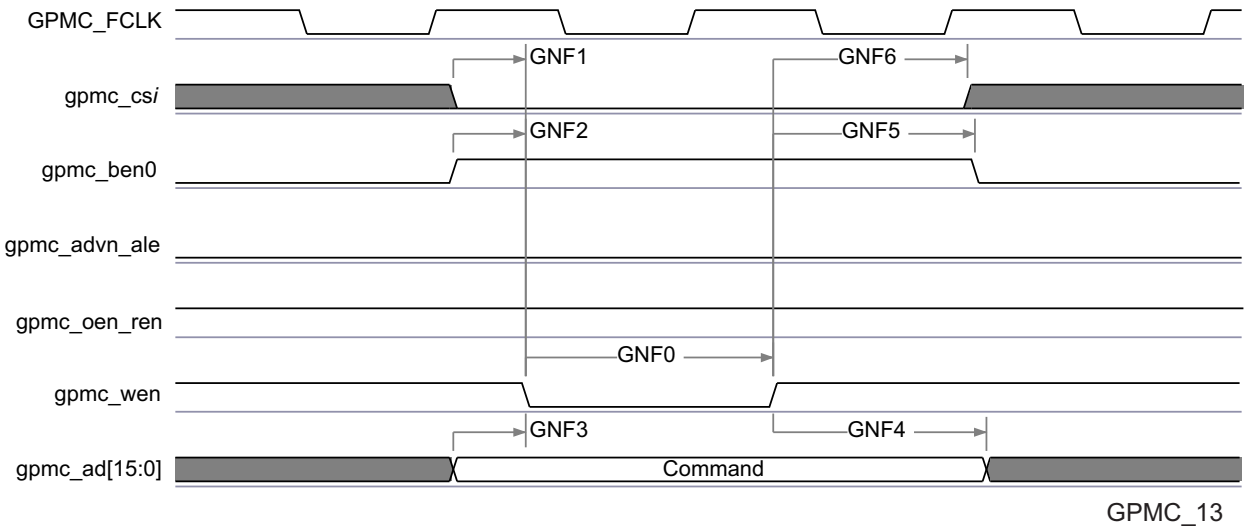


Figure 7-19. GPMC / NAND Flash - Command Latch Cycle Timing(1)

(1) In gpmc_cs*i*, i = 0 to 7.

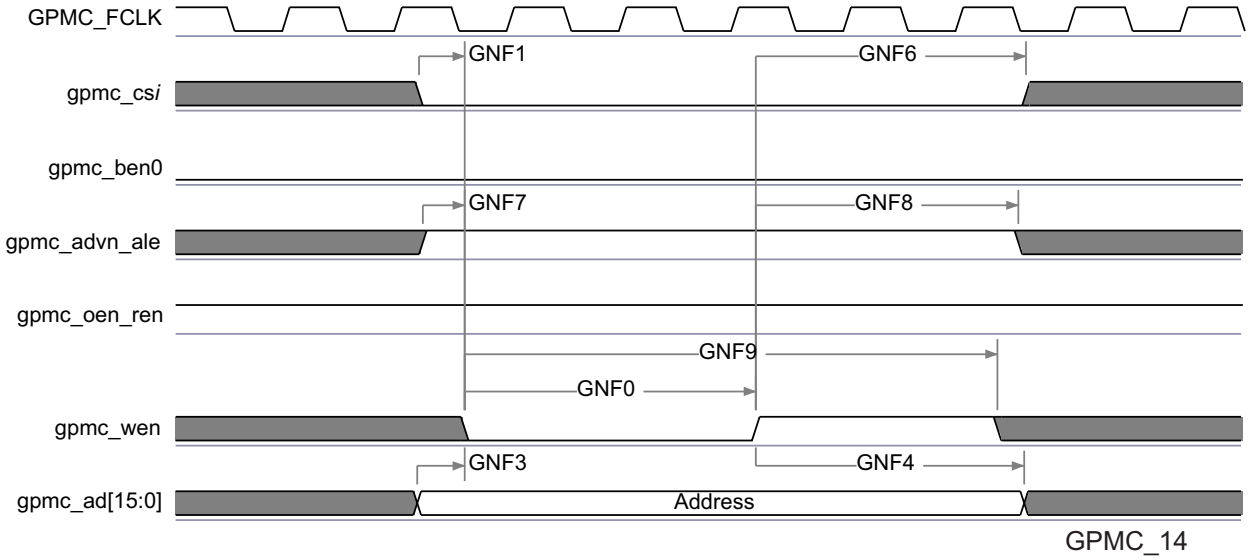


Figure 7-20. GPMC / NAND Flash - Address Latch Cycle Timing(1)

(1) In gpmc_cs*i*, i = 0 to 7.

Copyright © 2016–2020, Texas Instruments Incorporated

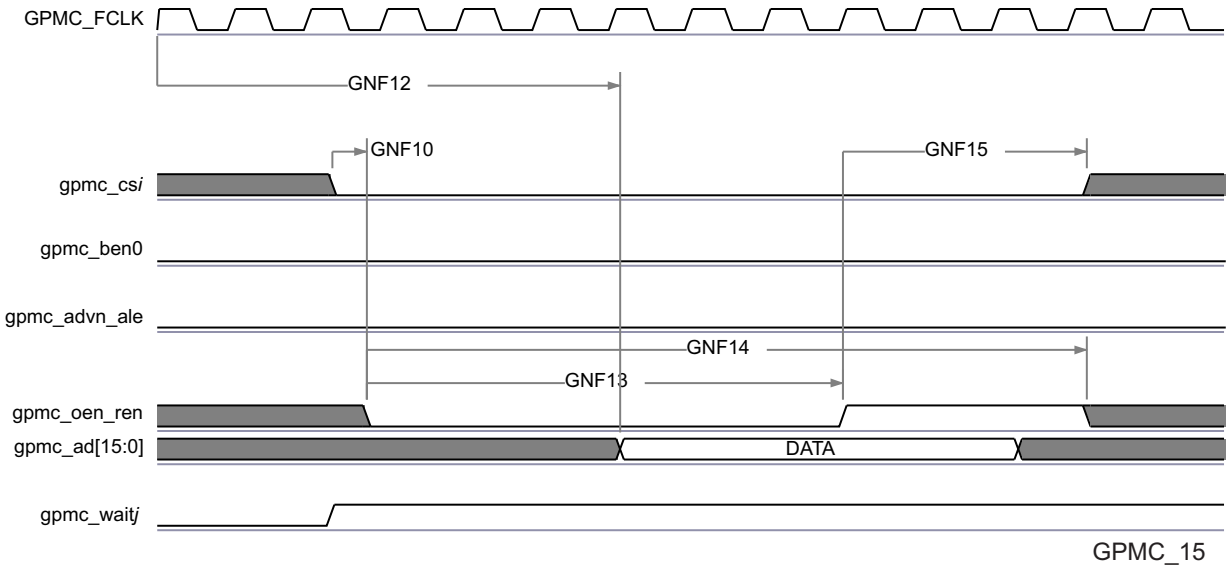


Figure 7-21. GPMC / NAND Flash - Data Read Cycle Timing(1)(2)(3)

(1) GNF12 parameter illustrates amount of time required to internally sample input Data. It is expressed in number of GPMC functional clock cycles. From start of read cycle and after GNF12 functional clock cycles, input data will be internally sampled by active functional clock edge. GNF12 value must be stored inside AccessTime register bits field.

(2) GPMC_FCLK is an internal clock (GPMC functional clock) not provided externally.

(3) In gpmc_cs*i*, i = 0 to 7. In gpmc_waitj, j = 0 to 1.

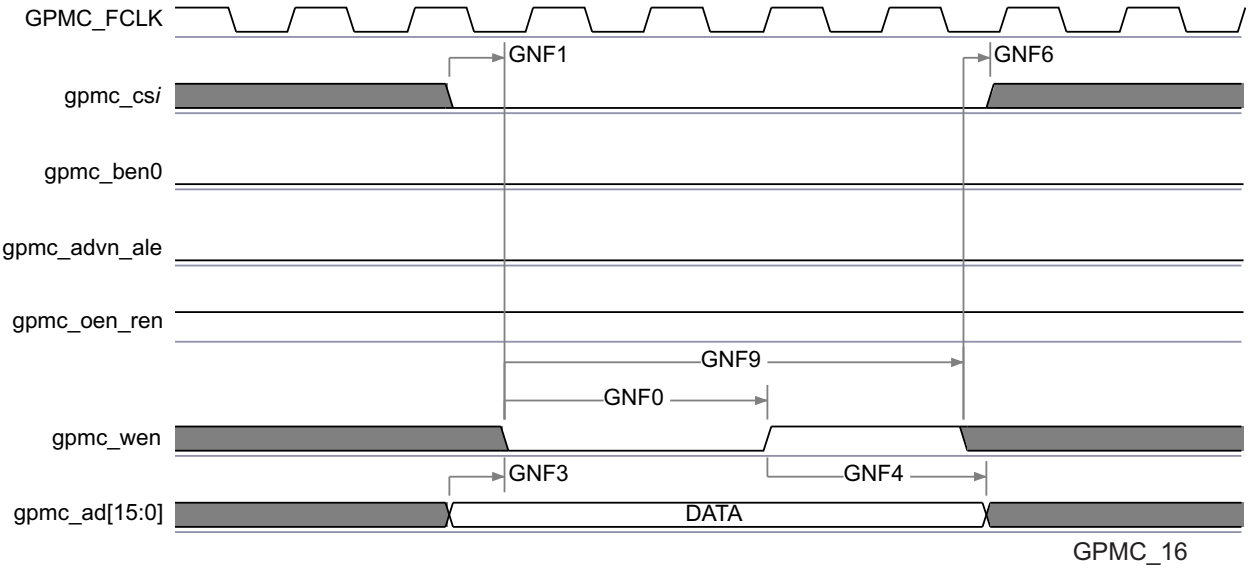


Figure 7-22. GPMC / NAND Flash - Data Write Cycle Timing(1)

(1) In gpmc_cs*i*, i = 0 to 7.

NOTE

To configure the desired virtual mode the user must set MODESELECT bit and DELAYMODE bit field for each corresponding pad control register.

The pad control registers are presented Table 4-3 and described in Device TRM, *Control Module* section.

7.10 General-Purpose Timers

The device has eight GP timers: TIMER1 through TIMER8.

- TIMER1 (1-ms tick) includes a specific function to generate accurate tick interrupts to the operating system and it belongs to the PD_WKUPAON domain.
- TIMER2 through TIMER8 belong to the PD_COREAON module.

Each timer can be clocked from the system clock (19.2, 20, or 27 MHz) or the 32-kHz clock. Select the clock source at the power, reset, and clock management (PRCM) module level.

Each timer provides an interrupt through the device IRQ_CROSSBAR.

Each timer is connected to an external pin by their PWM output or their event capture input pin (for external timer triggering).

7.10.1 GP Timer Features

The following are the main features of the GP timer controllers:

- Level 4 (L4) slave interface support:
  - 32-bit data bus width
  - 32- or 16-bit access supported
  - 8-bit access not supported
  - 10-bit address bus width
  - Burst mode not supported
  - Write nonposted transaction mode supported
- Interrupts generated on overflow, compare, and capture
- Free-running 32-bit upward counter
- Compare and capture modes
- Autoreload mode
- Start and stop mode
- Programmable divider clock source (2_n, where n = [0:8])
- Dedicated input trigger for capture mode and dedicated output trigger/PWM signal
- Dedicated GP output signal for using the TIMERi_GPO_CFG signal
- On-the-fly read/write register (while counting)
- 1-ms tick with 32.768-Hz functional clock generated (only TIMER1)

7.11 Inter-Integrated Circuit Interface (I2C)

The device includes 2 inter-integrated circuit (I2C) modules which provide an interface to other devices compliant with Philips Semiconductors Inter-IC bus (I2C-bus™) specification version 2.1. External components attached to this 2-wire serial bus can transmit/receive 8-bit data to/from the device through the I2C module.

NOTE

Note that, I2C1 and I2C2, due to characteristics of the open drain IO cells, HS mode is not supported

NOTE

Inter-integrated circuit i (i=1 to 2) module is also referred to as I2Ci.

NOTE

For more information, see the Multimaster I2C Controller section of the Device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-15 and Figure 7-23 assume testing over the recommended operating conditions and electrical characteristic conditions below.

Table 7-15. Timing Requirements for I2C Input Timings(1)

NO.	PARAMETER	DESCRIPTION	STANDARD MODE		FAST MODE		UNIT
			MIN	MAX	MIN	MAX	
1	$t_{c(SCL)}$	Cycle time, SCL	10		2.5		µs
2	$t_{su(SCLH-SDAL)}$	Setup time, SCL high before SDA low (for a repeated START condition)	4.7		0.6		µs
3	$t_{h(SDAL-SCLL)}$	Hold time, SCL low after SDA low (for a START and a repeated START condition)	4		0.6		µs
4	$t_{w(SCLL)}$	Pulse duration, SCL low	4.7		1.3		µs
5	$t_{w(SCLH)}$	Pulse duration, SCL high	4		0.6		µs
6	$t_{su(SDAV-SCLH)}$	Setup time, SDA valid before SCL high	250		100 (2)		ns
7	$t_{h(SCLL-SDAV)}$	Hold time, SDA valid after SCL low	0 (3)	3.45 (4)	0 (3)	0.9 (4)	µs
8	$t_{w(SDAH)}$	Pulse duration, SDA high between STOP and START conditions	4.7		1.3		µs
9	$t_{r(SDA)}$	Rise time, SDA		1000	$20 + 0.1C_b$ (5)	300	ns
10	$t_{r(SCL)}$	Rise time, SCL		1000	$20 + 0.1C_b$ (5)	300	ns
11	$t_{f(SDA)}$	Fall time, SDA		300	$20 + 0.1C_b$ (5)	300	ns
12	$t_{f(SCL)}$	Fall time, SCL		300	$20 + 0.1C_b$ (5)	300	ns
13	$t_{su(SCLH-SDAH)}$	Setup time, SCL high before SDA high (for STOP condition)	4		0.6		µs
14	$t_{w(SP)}$	Pulse duration, spike (must be suppressed)			0	50	ns
15	C_b (5)	Capacitive load for each bus line		400		400	pF

(1) The I2C pins SDA and SCL do not feature fail-safe I/O buffers. These pins could potentially draw current when the device is powered down.

(2) A Fast-mode I^2C-bus™ device can be used in a Standard-mode I^2C-bus system, but the requirement $t_{su(SDA-SCLH)} \geq 250$ ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t_r max + $t_{su(SDA-SCLH)} = 1000 + 250 = 1250$ ns (according to the Standard-mode I^2C-Bus Specification) before the SCL line is released.

(3) A device must internally provide a hold time of at least 300 ns for the SDA signal (referred to the V_{IHmin} of the SCL signal) to bridge the undefined region of the falling edge of SCL.

(4) The maximum $t_{h(SDA-SCLL)}$ has only to be met if the device does not stretch the low period [$t_{w(SCLL)}$] of the SCL signal.

(5) C_b = total capacitance of one bus line in pF. If mixed with HS-mode devices, faster fall-times are allowed.

Copyright © 2016–2020, Texas Instruments Incorporated

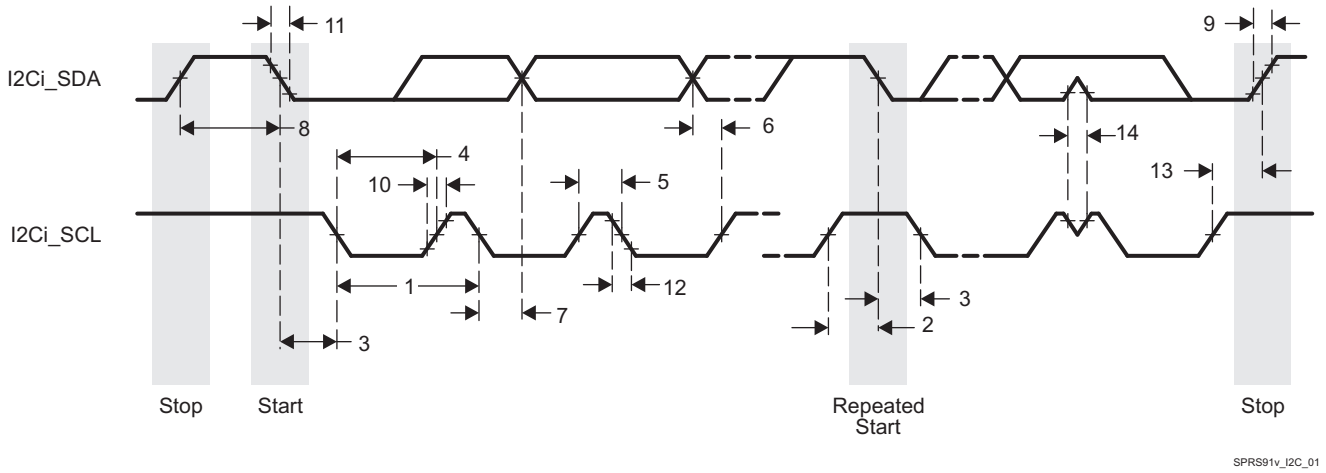


Figure 7-23. I2C Receive Timing

Table 7-16 and Figure 7-24 assume testing over the recommended operating conditions and electrical characteristic conditions below.

Table 7-16. Switching Characteristics Over Recommended Operating Conditions for I2C Output Timings(2)

NO.	PARAMETER	DESCRIPTION	STANDARD MODE		FAST MODE		UNIT
			MIN	MAX	MIN	MAX	
16	$t_{c(SCL)}$	Cycle time, SCL	10		2.5		µs
17	$t_{su(SCLH-SDAL)}$	Setup time, SCL high before SDA low (for a repeated START condition)	4.7		0.6		µs
18	$t_{h(SDAL-SCLL)}$	Hold time, SCL low after SDA low (for a START and a repeated START condition)	4		0.6		µs
19	$t_{w(SCLL)}$	Pulse duration, SCL low	4.7		1.3		µs
20	$t_{w(SCLH)}$	Pulse duration, SCL high	4		0.6		µs
21	$t_{su(SDAV-SCLH)}$	Setup time, SDA valid before SCL high	250		100		ns
22	$t_{h(SCLL-SDAV)}$	Hold time, SDA valid after SCL low (for I2C bus devices)	0	3.45	0	0.9	µs
23	$t_{w(SDAH)}$	Pulse duration, SDA high between STOP and START conditions	4.7		1.3		µs
24	$t_{r(SDA)}$	Rise time, SDA		1000	$20 + 0.1C_b$ (1)	300	ns
25	$t_{r(SCL)}$	Rise time, SCL		1000	$20 + 0.1C_b$ (1)	300	ns
26	$t_{f(SDA)}$	Fall time, SDA		300	$20 + 0.1C_b$ (1)	300	ns
27	$t_{f(SCL)}$	Fall time, SCL		300	$20 + 0.1C_b$ (1)	300	ns
28	$t_{su(SCLH-SDAH)}$	Setup time, SCL high before SDA high (for STOP condition)	4		0.6		µs
29	C_p	Capacitance for each I2C pin		10		10	pF

Copyright © 2016–2020, Texas Instruments Incorporated

(1) C_b = total capacitance of one bus line in pF. If mixed with HS-mode devices, faster fall-times are allowed.
(2) Software must properly configure the I2C module registers to achieve the timings shown in this table. See the Device TRM for details.

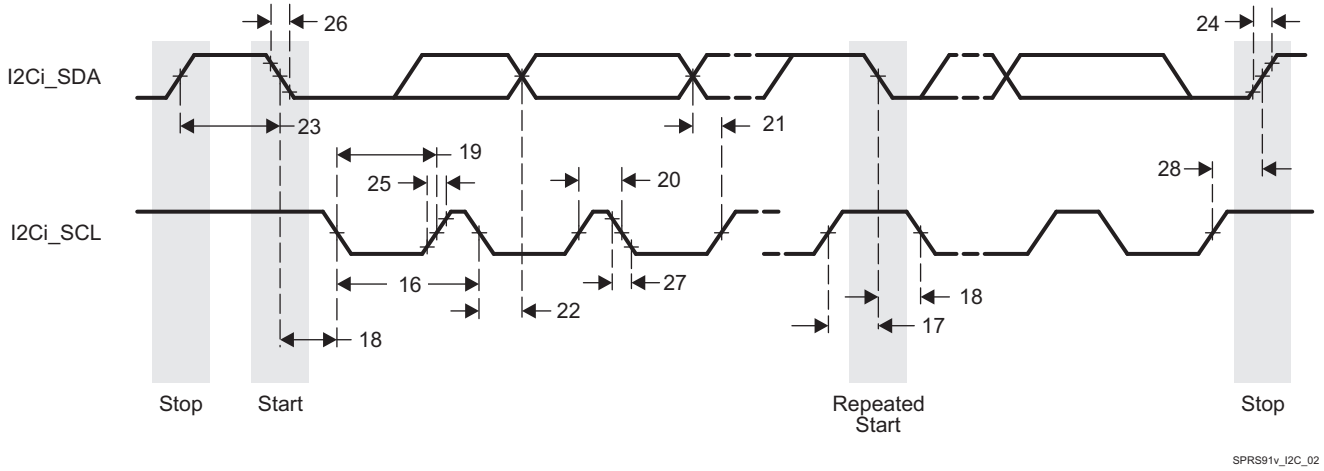


Figure 7-24. I2C Transmit Timing

7.12 Universal Asynchronous Receiver Transmitter (UART)

The UART performs serial-to-parallel conversions on data received from a peripheral device and parallel-to-serial conversion on data received from the CPU. There are 3 UART modules in the device. Each UART can be used for configuration and data exchange with a number of external peripheral devices or interprocessor communication between devices.

The UARTi (where i = 1 to 3) include the following features:

- 16C750 compatibility
- 64-byte FIFO buffer for receiver and 64-byte FIFO for transmitter
- Baud generation based on programmable divisors N (where N = 1…16 384) operating from a fixed functional clock of 48 MHz or 192 MHz
- Break character detection and generation
- Configurable data format:
  - Data bit: 5, 6, 7, or 8 bits
  - Parity bit: Even, odd, none
  - Stop-bit: 1, 1.5, 2 bit(s)
- Flow control: Hardware (RTS/CTS) or software (XON/XOFF)

NOTE

For more information, see the UART section of the Device TRM.

Table 7-17, Table 7-18 and Figure 7-25 assume testing over the recommended operating conditions and electrical characteristic conditions below.

Table 7-17. Timing Requirements for UART

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
4	$t_{w(RX)}$	Pulse width, receive data bit, 15/30/100pF high or low	0.96U(1)	1.05U(1)	ns
5	$t_{w(CTS)}$	Pulse width, receive start bit, 15/30/100pF high or low	0.96U(1)	1.05U(1)	ns
	$t_{d(RTS-TX)}$	Delay time, transmit start bit to transmit data	P(2)		ns
	$t_{d(CTS-TX)}$	Delay time, receive start bit to transmit data	P(2)		ns

(1) U = UART baud time = 1/programmed baud rate

(2) P = Clock period of the reference clock (FCLK, usually 48 MHz or 192MHz).

Table 7-18. Switching Characteristics Over Recommended Operating Conditions for UART

NO.	PARAMETER	DESCRIPTION		MIN	MAX	UNIT
	$f_{(baud)}$	Maximum programmable baud rate	15 pF		12	MHz
			30 pF		0.23	
			100 pF		0.115	
2	$t_{w(TX)}$	Pulse width, transmit data bit, 15/30/100 pF high or low		U - 2(1)	U + 2(1)	ns
3	$t_{w(RTS)}$	Pulse width, transmit start bit, 15/30/100 pF high or low		U - 2(1)	U + 2(1)	ns

(1) U = UART baud time = 1/programmed baud rate

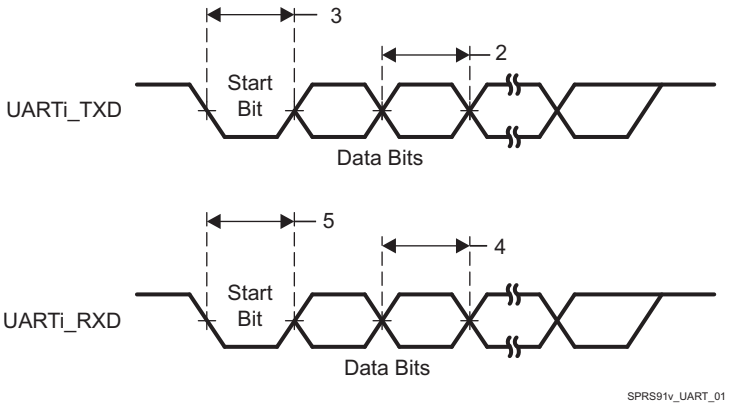


Figure 7-25. UART Timing

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-19.

In Table 7-19 are presented the specific groupings of signals (IOSET) for use with UART.

Table 7-19. UART1-3 IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
UART1						
uart1_rxd	F13	0	F13	0		
uart1_txd	E14	0	E14	0		
uart1_rtsn			C14	0		
uart1_ctsn			F14	0		
UART2						
uart2_rxd	E7	2	D14	0		
uart2_txd	F7	2	D15	0		
uart2_rtsn			F16	0		
uart2_ctsn			F15	0		
UART3						
uart3_rxd	W7	4	L1	1	M2	1
uart3_txd	W6	4	L2	1	R6	1
uart3_rtsn			R7	1	T5	1

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-19. UART1-3 IOSETs (continued)

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
uart3_ctsn			N4	1	U6	1

7.13 Multichannel Serial Peripheral Interface (McSPI)

The McSPI is a master/slave synchronous serial bus. There are four separate McSPI modules (SPI1, SPI2, SPI3, and SPI4) in the device. All these four modules support up to four external devices (four chip selects) and are able to work as both master and slave.

The McSPI modules include the following main features:

- Serial clock with programmable frequency, polarity, and phase for each channel
- Wide selection of SPI word lengths, ranging from 4 to 32 bits
- Up to four master channels, or single channel in slave mode
- Master multichannel mode:
  - Full duplex/half duplex
  - Transmit-only/receive-only/transmit-and-receive modes
  - Flexible input/output (I/O) port controls per channel
  - Programmable clock granularity
  - SPI configuration per channel. This means, clock definition, polarity enabling and word width
- Power management through wake-up capabilities
- Programmable timing control between chip select and external clock generation
- Built-in FIFO available for a single channel.
- Each SPI module supports multiple chip select pins spim_cs[i], where i = 1 to 4.

NOTE

For more information, see the Serial Communication Interface section of the device TRM.

NOTE

The McSPIm module (m = 1 to 4) is also referred to as SPIm.

Table 7-20, Figure 7-26 and Figure 7-27 present Timing Requirements for McSPI - Master Mode.

Table 7-20. Timing Requirements for SPI - Master Mode

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
SM1	$t_{c(SPICLK)}$	Cycle time, spi_sclk (1) (2)	SPI1/2/3/4	20.8		ns
SM2	$t_{w(SPICLKL)}$	Typical Pulse duration, spi_sclk low (1)		0.5×P-1 (3)		ns
SM3	$t_{w(SPICLKH)}$	Typical Pulse duration, spi_sclk high (1)		0.5×P-1 (3)		ns
SM4	$t_{su(MISO-SPICLK)}$	Setup time, spi_d[x] valid before spi_sclk active edge (1)		2.29		ns
SM5	$t_{h(SPICLK-MISO)}$	Hold time, spi_d[x] valid after spi_sclk active edge (1)		2.67		ns
SM6	$t_{d(SPICLK-SIMO)}$	Delay time, spi_sclk active edge to spi_d[x] transition (1)	SPI1/2/4	-3.57	3.57	ns
			SPI3	-3.57	3.57	ns
SM7	$t_{d(CS-SIMO)}$	Delay time, spi_cs[x] active edge to spi_d[x] transition			3.57	ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-20. Timing Requirements for SPI - Master Mode (continued)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
SM8	$t_{d(CS-SPICLK)}$	Delay time, spi_cs[x] active to spi_sclk first edge (1)	MASTER_PHA0 (4)	B-4.2 (5)		ns
			MASTER_PHA1 (4)	A-4.2 (6)		ns
SM9	$t_{d(SPICLK-CS)}$	Delay time, spi_sclk last edge to spi_cs[x] inactive (1)	MASTER_PHA0 (4)	A-4.2 (6)		ns
			MASTER_PHA1 (4)	B-4.2 (5)		ns

(1) This timing applies to all configurations regardless of SPI_CLK polarity and which clock edges are used to drive output data and capture input data.

(2) Related to the SPI_CLK maximum frequency.

(3) P = SPICLK period.

(4) SPI_CLK phase is programmable with the PHA bit of the SPI_CH(i)CONF register.

(5) B = (TCS + 0.5) × TSPICLKREF × Fratio, where TCS is a bit field of the SPI_CH(i)CONF register and Fratio = Even ≥2.

(6) When P = 20.8 ns, A = (TCS + 1) × TSPICLKREF, where TCS is a bit field of the SPI_CH(i)CONF register. When P > 20.8 ns, A = (TCS + 0.5) × Fratio × TSPICLKREF, where TCS is a bit field of the SPI_CH(i)CONF register.

(7) The IO timings provided in this section are applicable for all combinations of signals for spi1 and spi2. However, the timings are only valid for spi3 and spi4 if signals within a single IOSET are used. The IOSETs are defined in the following tables.

Copyright © 2016–2020, Texas Instruments Incorporated

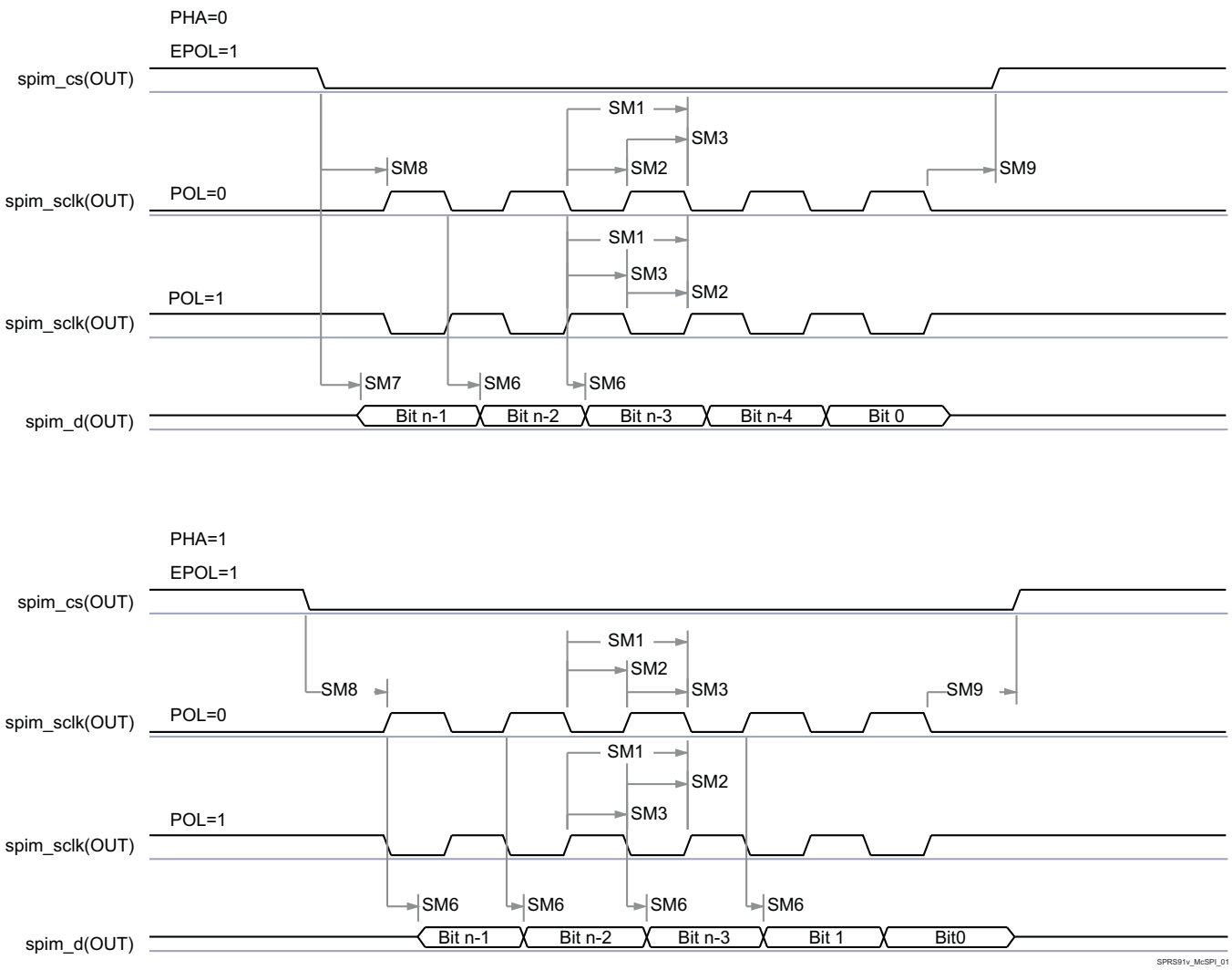


Figure 7-26. McSPI - Master Mode Transmit

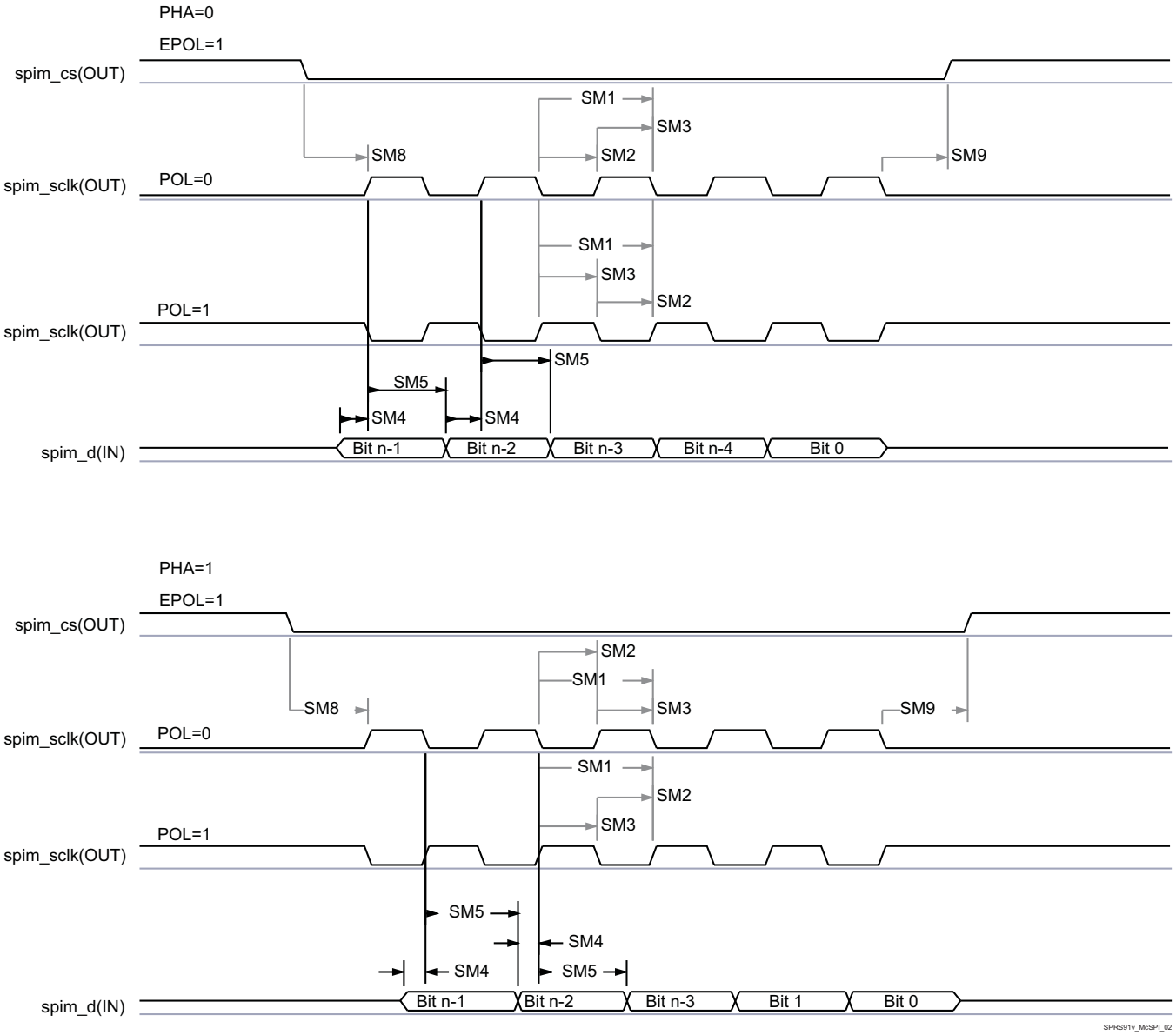


Figure 7-27. McSPI - Master Mode Receive

Table 7-21, Figure 7-28 and Figure 7-29 present Timing Requirements for McSPI - Slave Mode.

Table 7-21. Timing Requirements for SPI - Slave Mode(5)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
SS1 (1) (2)	$t_{c(SPICLK)}$	Cycle time, spi_sclk	SPI1	25		ns
			SPI2/3/4	33.3		ns
SS2 (1)	$t_{w(SPICLKL)}$ (3)	Typical Pulse duration, spi_sclk low		0.45×P		ns
SS3 (1)	$t_{w(SPICLKH)}$ (3)	Typical Pulse duration, spi_sclk high		0.45×P		ns
SS4 (1)	$t_{su(SIMO-SPICLK)}$	Setup time, spi_d[x] valid before spi_sclk active edge		2.82		ns
SS5 (1)	$t_{h(SPICLK-SIMO)}$	Hold time, spi_d[x] valid after spi_sclk active edge		2.82		ns
SS6 (1)	$t_{d(SPICLK-SOMI)}$	Delay time, spi_sclk active edge to mcspi_somi transition	SPI1	2	9.8	ns
			SPI2/3/4	2	21	ns
SS7 (4)	$t_{d(CS-SOMI)}$	Delay time, spi_cs[x] active edge to mcspi_somi transition			16	ns
SS8 (1)	$t_{su(CS-SPICLK)}$	Setup time, spi_cs[x] valid before spi_sclk first edge		2.82		ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-21. Timing Requirements for SPI - Slave Mode(5) (continued)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
SS9 (1)	$t_{h(SPICLK-CS)}$	Hold time, spi_cs[x] valid after spi_sclk last edge		2.82		ns

(1) This timing applies to all configurations regardless of SPI_CLK polarity and which clock edges are used to drive output data and capture input data.

(2) When operating the SPI interface in RX-only mode, the minimum Cycle time is 26ns (38.4MHz)

(3) P = SPICLK period.

(4) PHA = 0; SPI_CLK phase is programmable with the PHA bit of the SPI_CH(i)CONF register.

(5) The IO timings provided in this section are applicable for all combinations of signals for spi1 and spi2. However, the timings are only valid for spi3 and spi4 if signals within a single IOSET are used. The IOSETs are defined in the following tables.

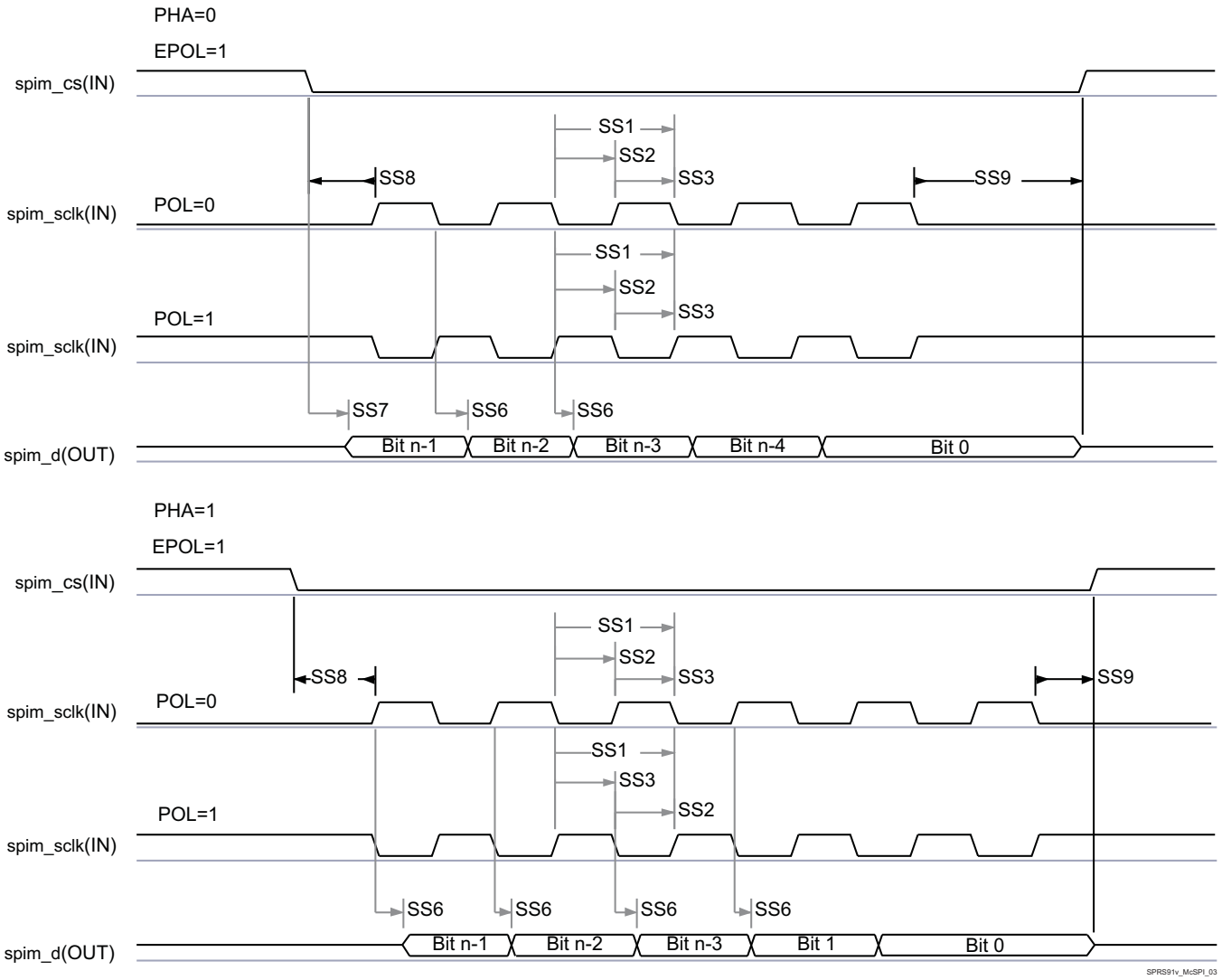


Figure 7-28. McSPI - Slave Mode Transmit

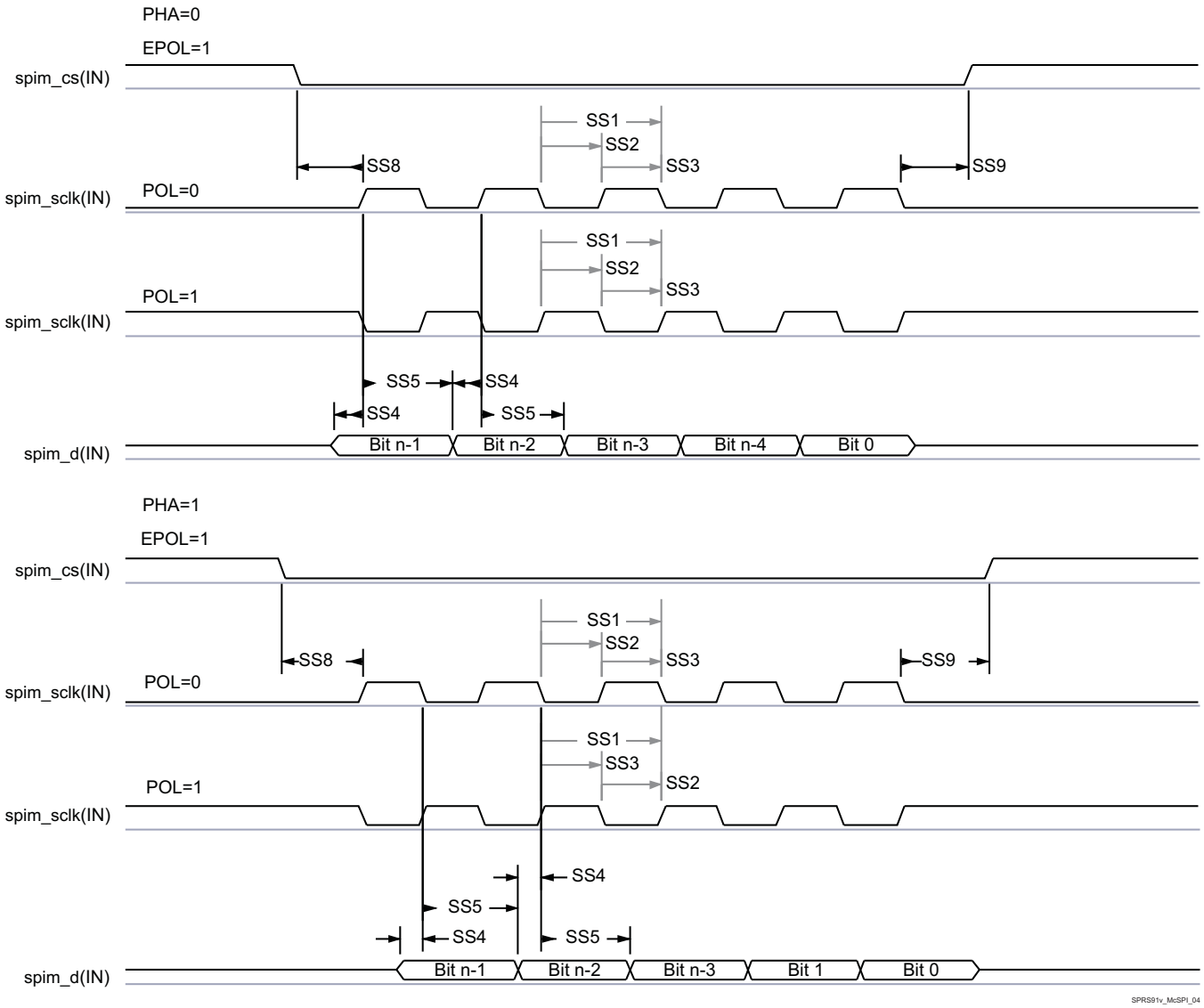


Figure 7-29. McSPI - Slave Mode Receive

CAUTION

The IO timings provided in this section are applicable for all combinations of signals for SPI2 and SPI4. However, the timings are only valid for SPI1 and SPI3 if signals within a single IOSET are used. The IOSETs are defined in Table 7-22.

In Table 7-22 are presented the specific groupings of signals (IOSET) for use with McSPI.

Table 7-22. McSPI1/3 IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
SPI1						
spi1_sclk	M2	0	M2	0	M2	0
spi1_d1	U6	0	U6	0	U6	0

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-22. McSPI1/3 IOSETs (continued)

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
spi1_d0	T5	0	T5	0	T5	0
spi1_cs0	R6	0	R6	0	R6	0
spi1_cs1					R5	0
spi1_cs2			F14	5		
spi1_cs3			C14	5		
SPI3						
spi3_sclk	F15	4	C6	4		
spi3_d1	D14	4	F7	4		
spi3_d0	D15	4	E7	4		
spi3_cs0	F16	4	B6	4		

7.14 Quad Serial Peripheral Interface (QSPI)

The Quad SPI (QSPI) module is a type of SPI module that allows single, dual or quad read access to external SPI devices. This module has a memory mapped register interface, which provides a direct interface for accessing data from external SPI devices and thus simplifying software requirements. It works as a master only. There is one QSPI module in the device and it is primary intended for fast booting from quad-SPI flash memories.

General SPI features:

- Programmable clock divider
- Six pin interface (DCLK, CS_N, DOUT, DIN, QDIN1, QDIN2)
- 4 external chip select signals
- Support for 3-, 4- or 6-pin SPI interface
- Programmable CS_N to DOUT delay from 0 to 3 DCLKs
- Programmable signal polarities
- Programmable active clock edge
- Software controllable interface allowing for any type of SPI transfer

NOTE

For more information, see the Quad Serial Peripheral Interface section of the Device TRM.

Table 7-23 and Table 7-24 present Timing and Switching Characteristics for Quad SPI Interface.

Table 7-23. Switching Characteristics for QSPI

No	PARAMETER	DESCRIPTION	Mode	MIN	MAX	UNIT
1	$t_{c(SCLK)}$	Cycle time, sclk	Default Timing Mode, Clock Mode 0	10.4		ns
			Default Timing Mode, Clock Mode 3	15.625		ns
2	$t_{w(SCLKL)}$	Pulse duration, sclk low		Y×P-1 (1)		ns
3	$t_{w(SCLKH)}$	Pulse duration, sclk high		Y×P-1 (1)		ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-23. Switching Characteristics for QSPI (continued)

No	PARAMETER	DESCRIPTION	Mode	MIN	MAX	UNIT
4	$t_{d(CS-SCLK)}$	Delay time, sclk falling edge to cs active edge, CS3:0	Default Timing Mode	-M×P-1 (2) (3)	-M×P+1 (2) (3)	ns
5	$t_{d(SCLK-CS)}$	Delay time, sclk falling edge to cs inactive edge, CS3:0	Default Timing Mode	N×P-1 (2) (3)	N×P+1 (2) (3)	ns
6	$t_{d(SCLK-D1)}$	Delay time, sclk falling edge to d[0] transition	Default Timing Mode	-1	1	ns
7	$t_{ena(CS-D1LZ)}$	Enable time, cs active edge to d[0] driven (lo-z)		-P-3.5	-P+2.5	ns
8	$t_{dis(CS-D1Z)}$	Disable time, cs active edge to d[0] tri-stated (hi-z)		-P-2.5	-P+2.0	ns
9	$t_{d(SCLK-D1)}$	Delay time, sclk first falling edge to first d[0] transition	PHA=0 Only, Default Timing Mode	-1-P	-1-P	ns

(1) The Y parameter is defined as follows: If DCLK_DIV is 0 or ODD then, Y equals 0.5. If DCLK_DIV is EVEN then, Y equals (DCLK_DIV/2) / (DCLK_DIV+1). For best performance, it is recommended to use a DCLK_DIV of 0 or ODD to minimize the duty cycle distortion. The HSDIVIDER on CLKOUTX2_H13 output of DPLL_PER can be used to achieve the desired clock divider ratio. All required details about clock division factor DCLK_DIV can be found in the device-specific Technical Reference Manual.

(2) P = SCLK period.

(3) M=QSPI_SPI_DC_REG.DDx + 1 when Clock Mode 0. M=QSPI_SPI_DC_REG.DDx when Clock Mode 3. N = 2 when Clock Mode 0. N = 3 when Clock Mode 3.

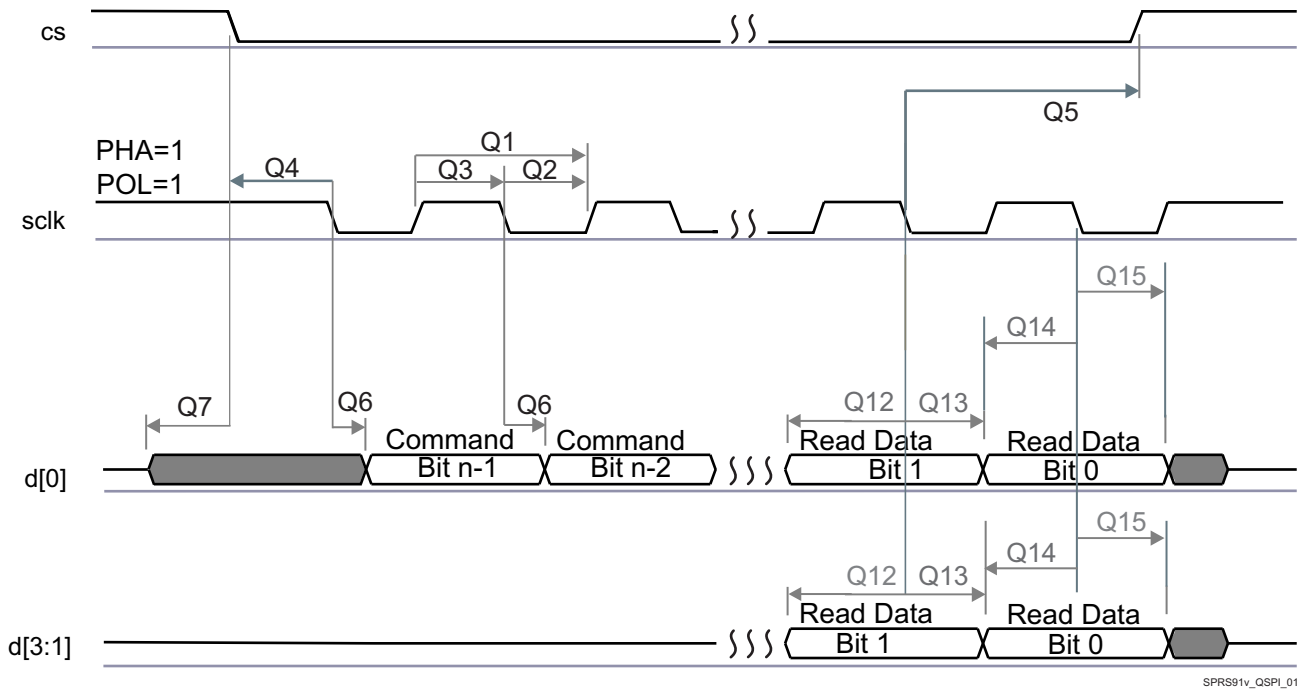


Figure 7-30. QSPI Read (Clock Mode 3)

Copyright © 2016–2020, Texas Instruments Incorporated

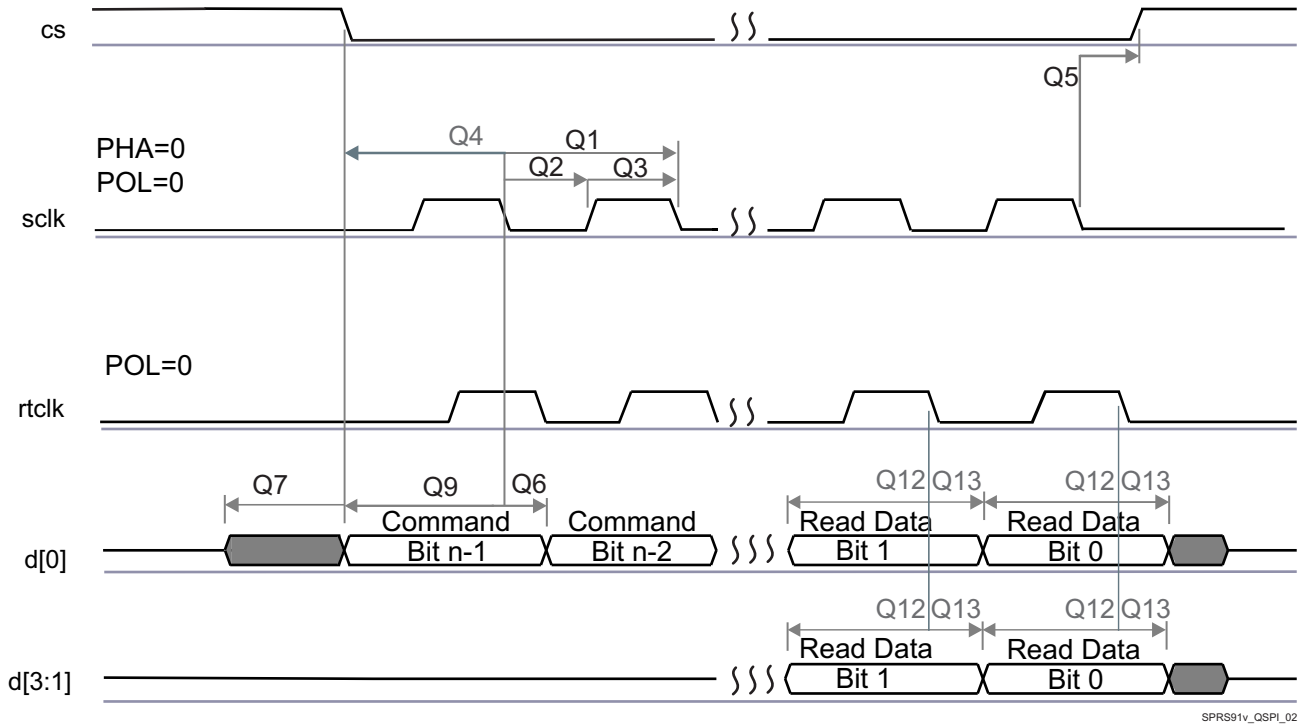


Figure 7-31. QSPI Read (Clock Mode 0)

CAUTION

The IO Timings provided in this section are only valid when all QSPI Chip Selects used in a system are configured to use the same Clock Mode (either Clock Mode 0 or Clock Mode 3).

Table 7-24. Timing Requirements for QSPI

No	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
12	$t_{su(D-RTCLK)}$	Setup time, d[3:0] valid before falling rtclk edge	Default Timing Mode, Clock Mode 0	2.9		ns
	$t_{su(D-SCLK)}$	Setup time, d[3:0] valid before falling sclk edge	Default Timing Mode, Clock Mode 3	5.7		ns
13	$t_{h(RTCLK-D)}$	Hold time, d[3:0] valid after falling rtclk edge	Default Timing Mode, Clock Mode 0	-0.1		ns
	$t_{h(SCLK-D)}$	Hold time, d[3:0] valid after falling sclk edge	Default Timing Mode, Clock Mode 3	0.1		ns

Table 7-24. Timing Requirements for QSPI (continued)

No	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
14	$t_{su(D-SCLK)}$	Setup time, final d[3:0] bit valid before final falling sclk edge	Default Timing Mode, Clock Mode 3	5.7-P (1)		ns
15	$t_{h(SCLK-D)}$	Hold time, final d[3:0] bit valid after final falling sclk edge	Default Timing Mode, Clock Mode 3	0.1+P (1)		ns

(1) P = SCLK period.

(2) Clock Modes 1 and 2 are not supported.

(3) The Device captures data on the falling clock edge in Clock Mode 0 and 3, as opposed to the traditional rising clock edge. Although non-standard, the falling-edge-based setup and hold time timings have been designed to be compatible with standard SPI devices that launch data on the falling edge in Clock Modes 0 and 3.

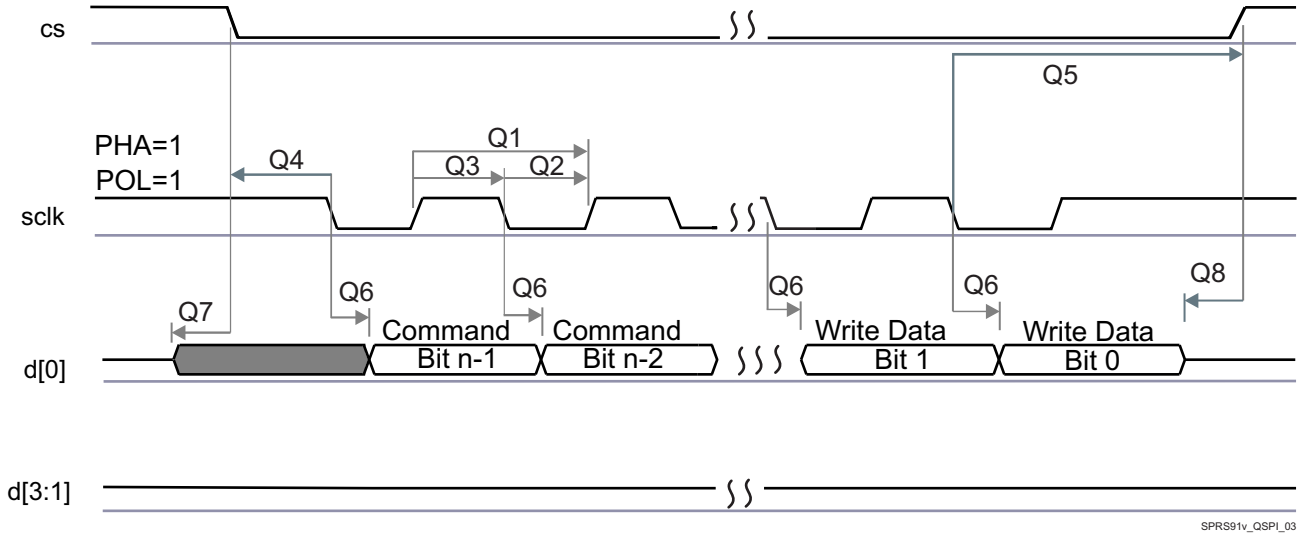


Figure 7-32. QSPI Write (Clock Mode 3)

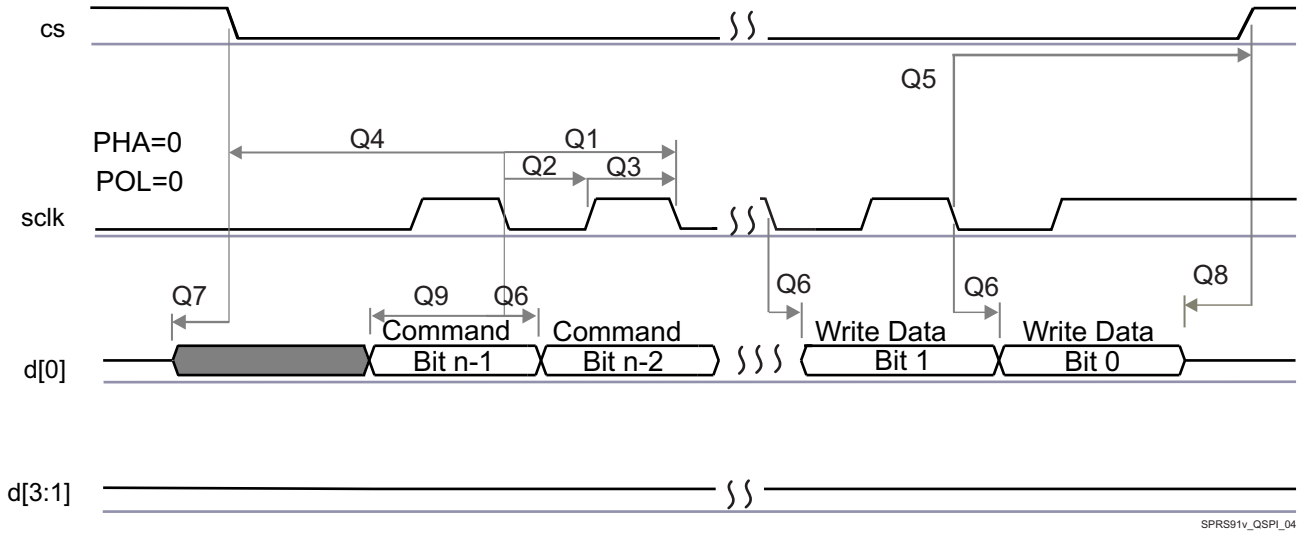


Figure 7-33. QSPI Write (Clock Mode 0)

Copyright © 2016–2020, Texas Instruments Incorporated

NOTE

To configure the desired virtual mode the user must set MODESELECT bit and DELAYMODE bit field for each corresponding pad control register.

The pad control registers are presented in Table 4-3 and described in Device TRM, *Control Module section*.

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-25.

In Table 7-25 are presented the specific groupings of signals (IOSET) for use with QSPI.

Table 7-25. QSPI IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3		IOSET4	
	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX
qspi1_sclk	C8	1	C8	1	C8	1	C8	1
qspi1_rtclk	C14	8	B7	1	F13	5	D8	2
qspi1_d0	B9	1	B9	1	B9	1	B9	1
qspi1_d1	F10	1	F10	1	F10	1	F10	1
qspi1_d2	A9	1	A9	1	A9	1	A9	1
qspi1_d3	D10	1	D10	1	D10	1	D10	1
qspi1_cs0	E10	1	E10	1	E10	1	E10	1
qspi1_cs1	F15	5	F15	5	F15	5	F15	5

7.15 Multichannel Audio Serial Port (McASP)

The multichannel audio serial port (McASP) functions as a general-purpose audio serial port optimized for the needs of multichannel audio applications. The McASP is useful for time-division multiplexed (TDM) stream, Inter-Integrated Sound (I2S) protocols, and inter-component digital audio interface transmission (DIT).

The device has integrated 3 McASP modules (McASP1-McASP3) with:configure the desired virtual

- McASP1 and McASP2 modules supporting 16 channels with independent TX/RX clock/sync domain
- McASP3 module supporting 4 channels with independent TX/RX clock/sync domain

NOTE

For more information, see the Serial Communication Interface section of the Device TRM.

Table 7-26, Table 7-27, Table 7-28 and Figure 7-34 present Timing Requirements for McASP1 to McASP3.

Table 7-26. Timing Requirements for McASP1 (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
1	$t_{c(AHCLKX)}$	Cycle time, AHCLKX		20		ns
2	$t_{w(AHCLKX)}$	Pulse duration, AHCLKX high or low		0.35P (2)		ns

Table 7-26. Timing Requirements for McASP1 (1) (continued)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
3	$t_{c(ACLKRX)}$	Cycle time, ACLKR/X	Any Other Conditions	20		ns
			ACLKX/AFSX (In Sync Mode), ACLKR/AFSR (In Async Mode), and AXR are all inputs	15.258		ns
4	$t_{w(ACLKRX)}$	Pulse duration, ACLKR/X high or low	Any Other Conditions	0.5R - 3 (3)		ns
			ACLKX/AFSX (In Sync Mode), ACLKR/AFSR (In Async Mode), and AXR are all inputs	0.38R (3)		ns
5	$t_{su(AFSRX-ACLK)}$	Setup time, AFSR/X input valid before ACLKR/X	ACLKR/X int	18.5		ns
			ACLKR/X ext in ACLKR/X ext out	3		ns
6	$t_{h(ACLK-AFSRX)}$	Hold time, AFSR/X input valid after ACLKR/X	ACLKR/X int	0.5		ns
			ACLKR/X ext in ACLKR/X ext out	0.4		ns
7	$t_{su(AXR-ACLK)}$	Setup time, AXR input valid before ACLKR/X	ACLKR/X int	18.5		ns
			ACLKR/X ext in ACLKR/X ext out	3		ns
8	$t_{h(ACLK-AXR)}$	Hold time, AXR input valid after ACLKR/X	ACLKR/X int	0.5		ns
			ACLKR/X ext in ACLKR/X ext out	0.4		ns

(1) ACLKR internal: ACLKRCTL.CLKRM=1, PDIR.ACLKR = 1
ACLKR external input: ACLKRCTL.CLKRM=0, PDIR.ACLKR=0
ACLKR external output: ACLKRCTL.CLKRM=0, PDIR.ACLKR=1
ACLKX internal: ACLKXCTL.CLKXM=1, PDIR.ACLKX = 1
ACLKX external input: ACLKXCTL.CLKXM=0, PDIR.ACLKX=0
ACLKX external output: ACLKXCTL.CLKXM=0, PDIR.ACLKX=1

(2) P = AHCLKX period in ns.

(3) R = ACLKR/X period in ns.

Table 7-27. Timing Requirements for McASP2 (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
1	$t_{c(AHCLKX)}$	Cycle time, AHCLKX		20		ns
2	$t_{w(AHCLKX)}$	Pulse duration, AHCLKX high or low		0.35P (2)		ns
3	$t_{c(ACLKRX)}$	Cycle time, ACLKR/X	Any Other Conditions	20		ns
			IOSET1 only, ACLKX/AFSX (In Sync Mode), ACLKR/AFSR (In Async Mode), and AXR are all inputs	15.258		ns
4	$t_{w(ACLKRX)}$	Pulse duration, ACLKR/X high or low	Any Other Conditions	0.5R - 3 (3)		ns
			IOSET1 only, ACLKX/AFSX (In Sync Mode), ACLKR/AFSR (In Async Mode), and AXR are all inputs	0.38R (3)		ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-27. Timing Requirements for McASP2 (1) (continued)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
5	$t_{su(AFSRX-ACLK)}$	Setup time, AFSR/X input valid before ACLKR/X	ACLKR/X int	18.5		ns
			IOSET1 (vout1_*): ACLKR/X ext in IOSET1 (vout1_*): ACLKR/X ext out	4		ns
			IOSET2 (gpmc_*): ACLKR/X ext in IOSET2 (gpmc_*): ACLKR/X ext out	3		ns
6	$t_{h(ACLK-AFSRX)}$	Hold time, AFSR/X input valid after ACLKR/X	ACLKR/X int	0.5		ns
			ACLKR/X ext in ACLKR/X ext out	0.4		ns
7	$t_{su(AXR-ACLK)}$	Setup time, AXR input valid before ACLKR/X	ACLKR/X int	18.5		ns
			IOSET1 (vout1_*): ACLKR/X ext in IOSET1 (vout1_*): ACLKR/X ext out	12		ns
			IOSET2 (gpmc_*): ACLKR/X ext in IOSET2 (gpmc_*): ACLKR/X ext out	3		ns
8	$t_{h(ACLK-AXR)}$	Hold time, AXR input valid after ACLKR/X	ACLKR/X int	0.5		ns
			ACLKR/X ext in ACLKR/X ext out	0.4		ns

(1) ACLKR internal: ACLKRCTL.CLKRM=1, PDIR.ACLKR = 1
ACLKR external input: ACLKRCTL.CLKRM=0, PDIR.ACLKR=0
ACLKR external output: ACLKRCTL.CLKRM=0, PDIR.ACLKR=1
ACLKX internal: ACLKXCTL.CLKXM=1, PDIR.ACLKX = 1
ACLKX external input: ACLKXCTL.CLKXM=0, PDIR.ACLKX=0
ACLKX external output: ACLKXCTL.CLKXM=0, PDIR.ACLKX=1

(2) P = AHCLKX period in ns.

(3) R = ACLKR/X period in ns.

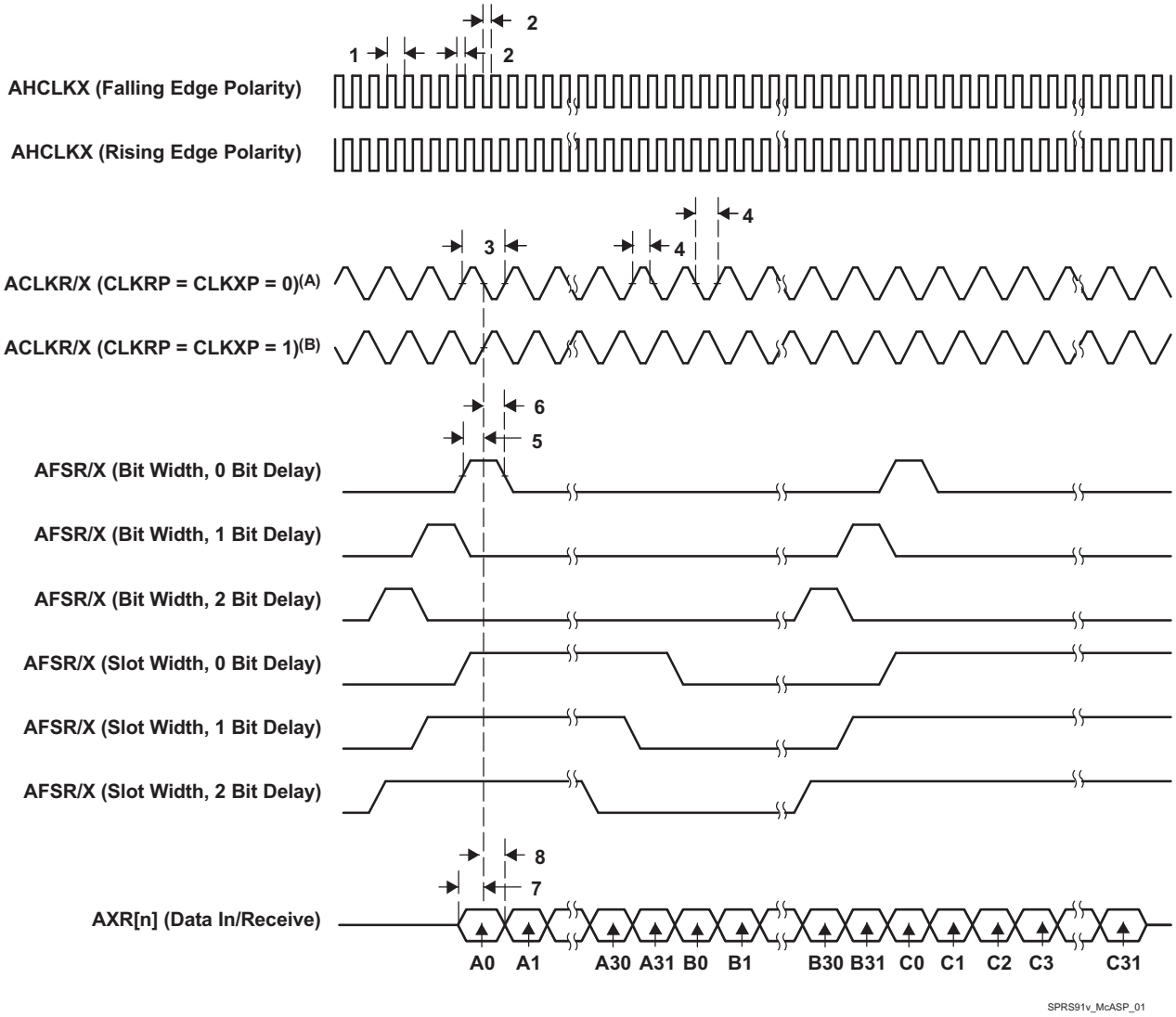
Table 7-28. Timing Requirements for McASP3 (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
1	$t_{c(AHCLKX)}$	Cycle time, AHCLKX		20		ns
2	$t_{w(AHCLKX)}$	Pulse duration, AHCLKX high or low		0.35P		ns
3	$t_{c(ACLKRX)}$	Cycle time, ACLKR/X		20		ns
4	$t_{w(ACLKRX)}$	Pulse duration, ACLKR/X high or low		0.5R - 3		ns
5	$t_{su(AFSRX-ACLK)}$	Setup time, AFSR/X input valid before ACLKR/X	ACLKR/X int	18.2		ns
			ACLKR/X ext in ACLKR/X ext out	4		ns
6	$t_{h(ACLK-AFSRX)}$	Hold time, AFSR/X input valid after ACLKR/X	ACLKR/X int	0.5		ns
			ACLKR/X ext in ACLKR/X ext out	0.4		ns
	$t_{su(AXR-ACLK)}$	Setup time, AXR input valid before ACLKX	ACLKX int (ASYNC=0)	18.2		ns
			ACLKR/X ext in ACLKR/X ext out	12		ns
8	$t_{h(ACLK-AXR)}$	Hold time, AXR input valid after ACLKX	ACLKX int (ASYNC=0)	0.5		ns
			ACLKR/X ext in ACLKR/X ext out	0.5		ns

(1) ACLKR internal: ACLKRCTL.CLKRM=1, PDIR.ACLKR = 1 (NOT SUPPORTED)
ACLKR external input: ACLKRCTL.CLKRM=0, PDIR.ACLKR=0
ACLKR external output: ACLKRCTL.CLKRM=0, PDIR.ACLKR=1
ACLKX internal: ACLKXCTL.CLKXM=1, PDIR.ACLKX = 1
ACLKX external input: ACLKXCTL.CLKXM=0, PDIR.ACLKX=0
ACLKX external output: ACLKXCTL.CLKXM=0, PDIR.ACLKX=1

(2) P = AHCLKX period in ns.

(3) R = ACLKR/X period in ns.



A. For CLKRP = CLKXP = 0, the McASP transmitter is configured for rising edge (to shift data out) and the McASP receiver is configured for falling edge (to shift data in).

B. For CLKRP = CLKXP = 1, the McASP transmitter is configured for falling edge (to shift data out) and the McASP receiver is configured for rising edge (to shift data in).

Figure 7-34. McASP Input Timing

Table 7-29, Table 7-30, Table 7-31 and Figure 7-35 present Switching Characteristics Over Recommended Operating Conditions for McASP1 to McASP3.

Table 7-29. Switching Characteristics Over Recommended Operating Conditions for McASP1 (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
9	$t_{c(AHCLKX)}$	Cycle time, AHCLKX		20		ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-29. Switching Characteristics Over Recommended Operating Conditions for McASP1 (1) (continued)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
10	$t_{w(AHCLKX)}$	Pulse duration, AHCLKX high or low		0.5P - 2.5 (2)		ns
11	$t_{c(ACLKRX)}$	Cycle time, ACLKR/X		20		ns
12	$t_{w(ACLKRX)}$	Pulse duration, ACLKR/X high or low		0.5P - 2.5 (3)		ns
13	$t_{d(ACLK-AFSXR)}$	Delay time, ACLKR/X transmit edge to AFSX/R output valid	ACLKR/X int	0	6	ns
			ACLKR/X ext in ACLKR/X ext out	2	22.2	ns
14	$t_{d(ACLK-AXR)}$	Delay time, ACLKR/X transmit edge to AXR output valid	ACLKR/X int	0	6	ns
			ACLKR/X ext in ACLKR/X ext out	2	22.2	ns

(1) ACLKR internal: ACLKRCTL.CLKRM=1, PDIR.ACLKR = 1
ACLKR external input: ACLKRCTL.CLKRM=0, PDIR.ACLKR=0
ACLKR external output: ACLKRCTL.CLKRM=0, PDIR.ACLKR=1
ACLKX internal: ACLKXCTL.CLKXM=1, PDIR.ACLKX = 1
ACLKX external input: ACLKXCTL.CLKXM=0, PDIR.ACLKX=0
ACLKX external output: ACLKXCTL.CLKXM=0, PDIR.ACLKX=1

(2) P = AHCLKX period in ns.

(3) R = ACLKR/X period in ns.

Table 7-30. Switching Characteristics Over Recommended Operating Conditions for McASP2 (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
9	$t_{c(AHCLKX)}$	Cycle time, AHCLKX		20		ns
10	$t_{w(AHCLKX)}$	Pulse duration, AHCLKX high or low		0.5P - 2.5 (2)		ns
11	$t_{c(ACLKRX)}$	Cycle time, ACLKR/X		20		ns
12	$t_{w(ACLKRX)}$	Pulse duration, ACLKR/X high or low		0.5P - 2.5 (3)		ns
13	$t_{d(ACLK-AFSXR)}$	Delay time, ACLKR/X transmit edge to AFSX/R output valid	ACLKR/X int	0	6	ns
			ACLKR/X ext in ACLKR/X ext out	2	22.2	ns
14	$t_{d(ACLK-AXR)}$	Delay time, ACLKR/X transmit edge to AXR output valid	ACLKR/X int	0	6	ns
			ACLKR/X ext in ACLKR/X ext out	2	22.2	ns

(1) ACLKR internal: ACLKRCTL.CLKRM=1, PDIR.ACLKR = 1
ACLKR external input: ACLKRCTL.CLKRM=0, PDIR.ACLKR=0
ACLKR external output: ACLKRCTL.CLKRM=0, PDIR.ACLKR=1
ACLKX internal: ACLKXCTL.CLKXM=1, PDIR.ACLKX = 1
ACLKX external input: ACLKXCTL.CLKXM=0, PDIR.ACLKX=0
ACLKX external output: ACLKXCTL.CLKXM=0, PDIR.ACLKX=1

(2) P = AHCLKX period in ns.

(3) R = ACLKR/X period in ns.

Table 7-31. Switching Characteristics Over Recommended Operating Conditions for McASP3 (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
9	$t_{c(AHCLKX)}$	Cycle time, AHCLKX		20		ns
10	$t_{w(AHCLKX)}$	Pulse duration, AHCLKX high or low		0.5P - 2.5		ns
11	$t_{c(ACLKRX)}$	Cycle time, ACLKR/X		20		ns
12	$t_{w(ACLKRX)}$	Pulse duration, ACLKR/X high or low		0.5P - 2.5		ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-31. Switching Characteristics Over Recommended Operating Conditions for McASP3 [(1)] (continued)

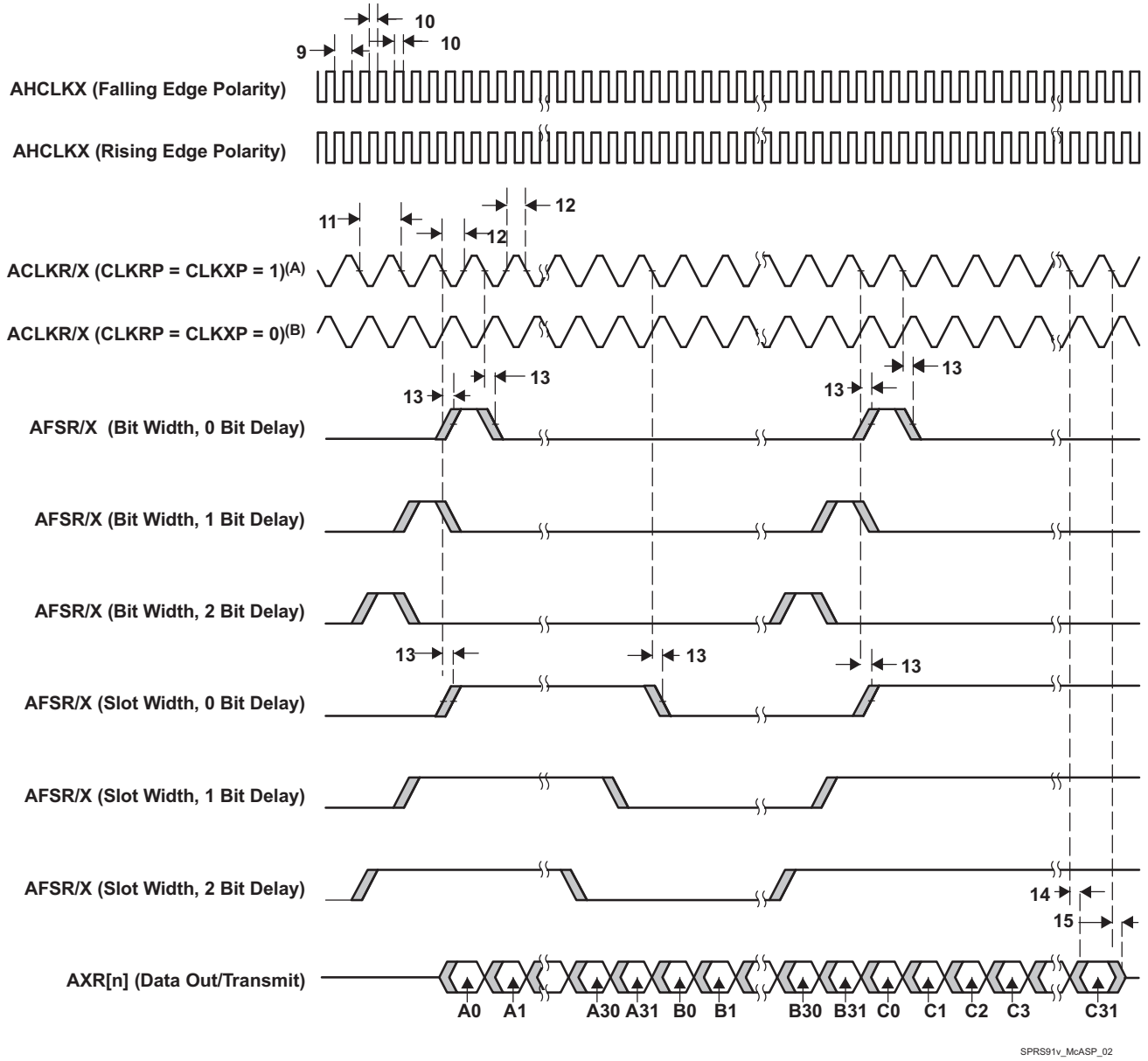
NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
13	$t_{d(ACLK-AFSXR)}$	Delay time, ACLKR/X transmit edge to AFSX/R output valid	ACLKR/X int	0	6	ns
			ACLKR/X ext in ACLKR/X ext out	2	23.1	ns
14	$t_{d(ACLK-AXR)}$	Delay time, ACLKR/X transmit edge to AXR output valid	ACLKR/X int	0	6	ns
			ACLKR/X ext in ACLKR/X ext out	2	23.1	ns

(1) ACLKR internal: ACLKRCTL.CLKRM=1, PDIR.ACLKR = 1
ACLKR external input: ACLKRCTL.CLKRM=0, PDIR.ACLKR=0
ACLKR external output: ACLKRCTL.CLKRM=0, PDIR.ACLKR=1
ACLKX internal: ACLKXCTL.CLKXM=1, PDIR.ACLKX = 1
ACLKX external input: ACLKXCTL.CLKXM=0, PDIR.ACLKX=0
ACLKX external output: ACLKXCTL.CLKXM=0, PDIR.ACLKX=1

(2) P = AHCLKX period in ns.

(3) R = ACLKR/X period in ns.

Copyright © 2016–2020, Texas Instruments Incorporated



A. For CLKRP = CLKXP = 1, the McASP transmitter is configured for falling edge (to shift data out) and the McASP receiver is configured for rising edge (to shift data in).

B. For CLKRP = CLKXP = 0, the McASP transmitter is configured for rising edge (to shift data out) and the McASP receiver is configured for falling edge (to shift data in).

Figure 7-35. McASP Output Timing

NOTE

To configure the desired virtual mode the user must set MODESELECT bit and DELAYMODE bit field for each corresponding pad control register.

The pad control registers are presented Table 4-3 and described in Device TRM, *Control Module section*.

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-32.

In Table 7-32 and Table 7-33 are presented the specific groupings of signals (IOSET) for use with McASP1 and McASP2.

Table 7-32. McASP1 IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
mcasp1_aclkx	U17	1	U17	1	U17	1
mcasp1_fsx	W17	1	W17	1	W17	1
mcasp1_aclkr	AA17	1				
mcasp1_fsr	U16	1				
mcasp1_axr0	W16	1	W16	1	W16	1
mcasp1_axr1	V16	1	V16	1	V16	1
mcasp1_axr2	U15	1				
mcasp1_axr3	V15	1				
mcasp1_axr4	Y15	1				
mcasp1_axr5	W15	1				
mcasp1_axr6	AA15	1				
mcasp1_axr7	AB15	1				
mcasp1_axr8	AA14	1	AA14	1	U15	4
mcasp1_axr9	AB14	1	AB14	1	V15	4
mcasp1_axr10			U13	1	Y15	4
mcasp1_axr11			V13	1	W15	4
mcasp1_axr12			Y13	1	AA15	4
mcasp1_axr13			W13	1	AB15	4
mcasp1_axr14			U11	1	U7	4
mcasp1_axr15			V11	1	V7	4

Table 7-33. McASP2 IOSETs

SIGNALS	IOSET1		IOSET2	
	BALL	MUX(1)	BALL	MUX(1)
mcasp2_ahclkx	Y13	15	C6	15
mcasp2_aclkx	U11	15	F7	15
mcasp2_fsx	V11	15	E7	15
mcasp2_aclkr	W13	15	B6	15
mcasp2_fsr	W11	15	A5	15
mcasp2_axr0	V9	15	D6	15
mcasp2_axr1	W9	15	C5	15
mcasp2_axr2	U8	15	B5	15
mcasp2_axr3	W8	15	D7	15
mcasp2_axr4	U7	15	B4	15
mcasp2_axr5	V7	15	A4	15

Copyright © 2016–2020, Texas Instruments Incorporated

(1) All McASP2 signals are virtual functions that present alternate multiplexing options. These virtual functions are controlled via CTRL_CORE_SMA_SW_* registers. For more information on how to use these options, please refer to the Device TRM, Chapter Control Module, Section Pad Configuration Registers.

7.16 Controller Area Network Interface (DCAN and MCAN)

7.16.1 DCAN

The device provides one DCAN interface for supporting distributed realtime control with a high level of security.

The DCAN interface implements the following features:

- Supports CAN protocol version 2.0 part A, B
- Bit rates up to 1 MBit/s
- 64 message objects
- Individual identifier mask for each message object
- Programmable FIFO mode for message objects
- Programmable loop-back modes for self-test operation
- Suspend mode for debug support
- Automatic bus on after Bus-Off state by a programmable 32-bit timer
- Message RAM single error correction and double error detection (SECDED) mechanism
- Direct access to Message RAM during test mode
- Support for two interrupt lines: Level 0 and Level 1, plus separate ECC interrupt line
- Local power down and wakeup support
- Automatic message RAM initialization
- Support for DMA access

7.16.2 MCAN

The device supports one MCAN module connecting to the CAN network through external (for the device) transceiver for connection to the physical layer. The MCAN module supports up to 5 Mbit/s data rate and is compliant to ISO 11898-1:2015.

The MCAN module implements the following features:

- Conforms with ISO 11898-1:2015
- Full CAN FD support (up to 64 data bytes)
- AUTOSAR and SAE J1939 support
- Up to 32 dedicated Transmit Buffers
- Configurable Transmit FIFO, up to 32 elements
- Configurable Transmit Queue, up to 32 elements
- Configurable Transmit Event FIFO, up to 32 elements
- Up to 64 dedicated Receive Buffers
- Two configurable Receive FIFOs, up to 64 elements each
- Up to 128 filter elements
- Internal Loopback mode for self-test
- Maskable interrupts, two interrupt lines
- Two clock domains (CAN clock/Host clock)
- Parity/ECC support - Message RAM single error correction and double error detection (SECDED) mechanism
- Local power-down and wakeup support
- Timestamp Counter

Copyright © 2016–2020, Texas Instruments Incorporated

NOTE

For more information, see the Serial Communication Interfaces / DCAN and MCAN sections of the Device TRM.

NOTE

Refer to the CAN Specification for calculations necessary to validate timing compliance. Jitter tolerance calculations must be performed to validate the implementation.

Table 7-34 and Table 7-35 present Timing and Switching characteristics for DCAN and MCAN Interface.

Table 7-34. Timing Requirements for CAN Receive

NO.	PARAMETER	DESCRIPTION	MIN	NOM	MAX	UNIT
	f(baud)	Maximum programmable baud rate			1	Mbps
-	$t_{d(CANnRX)}$	Delay time, CANnRX pin to receive shift register			10	ns

Table 7-35. Switching Characteristics Over Recommended Operating Conditions for CAN Transmit

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
	f(baud)	Maximum programmable baud rate		1	Mbps
-	$t_{d(CANnTX)}$	Delay time, Transmit shift register to CANnTX pin(1)		10	ns

(1) These values do not include rise/fall times of the output buffer.

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-36.

In Table 7-36 are presented the specific groupings of signals (IOSET) for use with DCAN and MCAN.

Table 7-36. DCAN and MCAN IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3		IOSET4	
	BALL	MUX	BALL	MUX	BALL	MUX	BALL	MUX
DCAN1								
dcan1_tx	N5	0	D14	12	F14	12		
dcan1_rx	N6	0	D15	12	C14	12		
MCAN								
mcan_tx			W7	0	F13	12	F15	12
mcan_rx			W6	0	E14	12	F16	12

7.17 Ethernet Interface (GMAC_SW)

The two-port gigabit ethernet switch subsystem (GMAC_SW) provides ethernet packet communication and can be configured as an ethernet switch. It provides Reduced Gigabit Media Independent Interface (RGMII), and the Management Data Input/Output (MDIO) for physical layer device (PHY) management.

NOTE

For more information, see the Gigabit Ethernet Switch (GMAC_SW) section of the Device TRM.

Copyright © 2016–2020, Texas Instruments Incorporated

NOTE

The Gigabit, Reduced and Media Independent Interface n (n = 0 to 1) are also referred to as RGMIIn

7.17.1 GMAC MDIO Interface Timings

Table 7-37, Table 7-38 and Figure 7-36 present Timing Requirements for MDIO.

Table 7-37. Timing Requirements for MDIO Input

No	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
MDIO1	$t_{c(MDC)}$	Cycle time, MDC	400		ns
MDIO2	$t_{w(MDCH)}$	Pulse Duration, MDC High	160		ns
MDIO3	$t_{w(MDCL)}$	Pulse Duration, MDC Low	160		ns
MDIO4	$t_{su(MDIO-MDC)}$	Setup time, MDIO valid before MDC High	90		ns
MDIO5	$t_{h(MDIO_MDC)}$	Hold time, MDIO valid from MDC High	0		ns

Table 7-38. Switching Characteristics Over Recommended Operating Conditions for MDIO Output

No	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
MDIO6	$t_{t(MDC)}$	Transition time, MDC		5	ns
MDIO7	$t_{d(MDC-MDIO)}$	Delay time, MDC low to MDIO valid	-150	150	ns

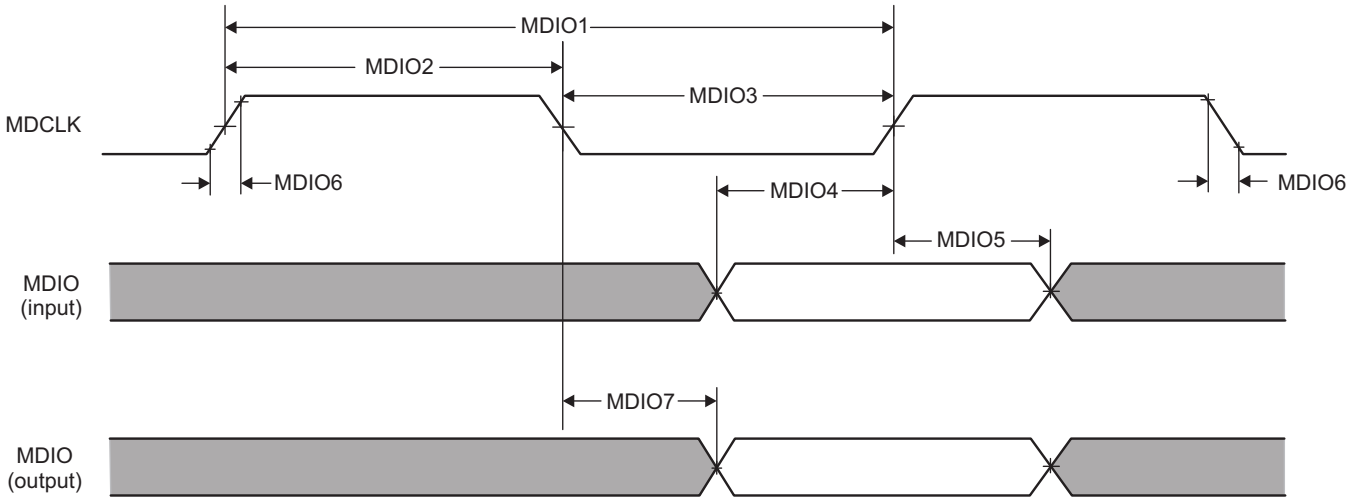


Figure 7-36. GMAC MDIO diagrams

7.17.2 GMAC RGMII Timings

Table 7-39, Table 7-40 and Figure 7-37 present Timing Requirements for receive RGMIIn operation.

Table 7-39. Timing Requirements for rgmiin_rxc - RGMIIn Operation

NO.	PARAMETER	DESCRIPTION	SPEED	MIN	MAX	UNIT
1	$t_{c(RXC)}$	Cycle time, rgmiin_rxc	10 Mbps	360	440	ns
			100 Mbps	36	44	ns
			1000 Mbps	7.2	8.8	ns
2	$t_{w(RXCH)}$	Pulse duration, rgmiin_rxc high	10 Mbps	160	240	ns
			100 Mbps	16	24	ns
			1000 Mbps	3.6	4.4	ns
3	$t_{w(RXCL)}$	Pulse duration, rgmiin_rxc low	10 Mbps	160	240	ns
			100 Mbps	16	24	ns
			1000 Mbps	3.6	4.4	ns
4	$t_{t(RXC)}$	Transition time, rgmiin_rxc	10 Mbps		0.75	ns
			100 Mbps		0.75	ns
			1000 Mbps		0.75	ns

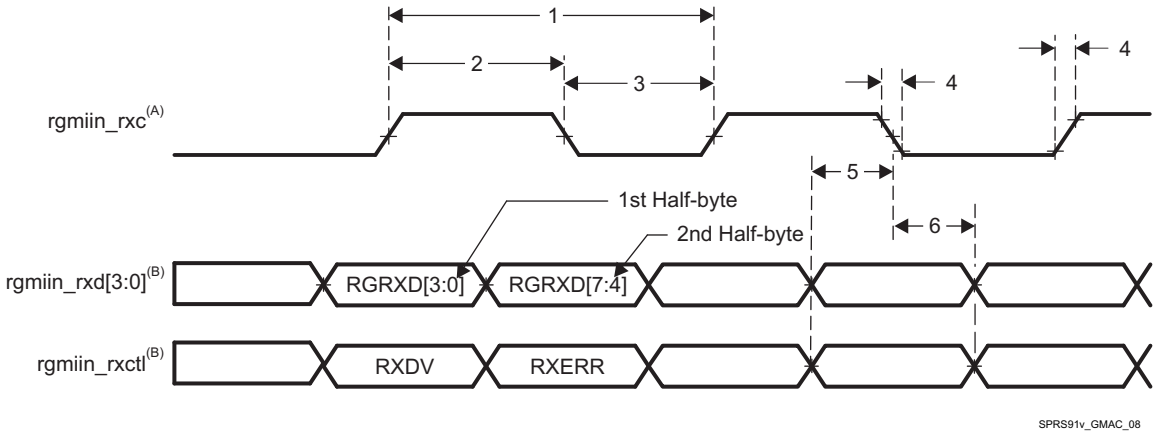
Table 7-40. Timing Requirements for GMAC RGMIIn Input Receive for 10/100/1000 Mbps

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
5	$t_{su(RXD-RXCH)}$	Setup time, receive selected signals valid before rgmiin_rxc high/low	1.15		ns
6	$t_{h(RXCH-RXD)}$	Hold time, receive selected signals valid after rgmiin_rxc high/low	1.15		ns

(1) For RGMII, receive selected signals include: rgmiin_rxd[3:0] and rgmiin_rxctl.

(2) RGMII0 requires that the 4 data pins rgmii0_rxd[3:0] and rgmii0_rxctl have their board propagation delays matched within 50pS of rgmii0_rxc.

(3) RGMII1 requires that the 4 data pins rgmii1_rxd[3:0] and rgmii1_rxctl have their board propagation delays matched within 50pS of rgmii1_rxc.



A. rgmiin_rxc must be externally delayed relative to the data and control pins.

B. Data and control information is received using both edges of the clocks. rgmiin_rxd[3:0] carries data bits 3-0 on the rising edge of rgmiin_rxc and data bits 7-4 on the falling edge ofrgmiin_rxc. Similarly, rgmiin_rxctl carries RXDV on rising edge of rgmiin_rxc and RXERR on falling edge of rgmiin_rxc.

Figure 7-37. GMAC Receive Interface Timing, RGMIIn operation

Table 7-41, Table 7-42 and Figure 7-38 present Switching Characteristics for rgmii*n*_txctl - RGMIIn Operation for 10/100/1000 Mbit/s

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-41. Switching Characteristics Over Recommended Operating Conditions for rgmiin_txctl - RGMIIn Operation for 10/100/1000 Mbit/s

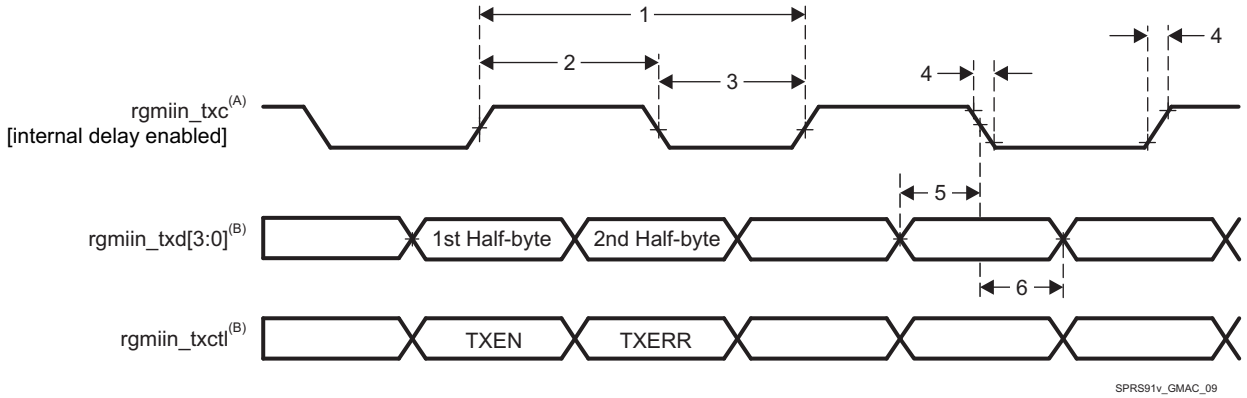
NO.	PARAMETER	DESCRIPTION	SPEED	MIN	MAX	UNIT
1	$t_{c(TXC)}$	Cycle time, rgmiin_txc	10 Mbps	360	440	ns
			100 Mbps	36	44	ns
			1000 Mbps	7.2	8.8	ns
2	$t_{w(TXCH)}$	Pulse duration, rgmiin_txc high	10 Mbps	160	240	ns
			100 Mbps	16	24	ns
			1000 Mbps	3.6	4.4	ns
3	$t_{w(TXCL)}$	Pulse duration, rgmiin_txc low	10 Mbps	160	240	ns
			100 Mbps	16	24	ns
			1000 Mbps	3.6	4.4	ns
4	$t_{t(TXC)}$	Transition time, rgmiin_txc	10 Mbps		0.75	ns
			100 Mbps		0.75	ns
			1000 Mbps		0.75	ns

Table 7-42. Switching Characteristics for GMAC RGMIIn Output Transmit for 10/100/1000 Mbps (1)

NO.	PARAMETER	DESCRIPTION	MODE	MIN	MAX	UNIT
5	$t_{osu(TXD-TXC)}$	Output Setup time, transmit selected signals valid to rgmiin_txc high/low	RGMII0, Internal Delay Enabled, 1000 Mbps			ns
			RGMII0, Internal Delay Enabled, 10/100 Mbps	1.2		ns
			RGMII1, Internal Delay Enabled, 1000 Mbps			ns
			RGMII1, Internal Delay Enabled, 10/100 Mbps	1.2		ns
6	$t_{oh(TXC-TXD)}$	Output Hold time, transmit selected signals valid after rgmiin_txc high/low	RGMII0, Internal Delay Enabled, 1000 Mbps			ns
			RGMII0, Internal Delay Enabled, 10/100 Mbps	1.2		ns
			RGMII1, Internal Delay Enabled, 1000 Mbps			ns
			RGMII1, Internal Delay Enabled, 10/100 Mbps	1.2		ns

Copyright © 2016–2020, Texas Instruments Incorporated

(1) For RGMII, transmit selected signals include: rgmiin_txd[3:0] and rgmiin_txctl.
(2) RGMII0 1000Mbps operation is not supported.
(3) RGMII1 1000Mbps operation is not supported.



A. TXC is delayed internally before being driven to the rgmiin_txc pin. This internal delay is always enabled.
B. Data and control information is transmitted using both edges of the clocks. rgmiin_txd[3:0] carries data bits 3-0 on the rising edge of rgmiin_txc and data bits 7-4 on the falling edge of rgmiin_txc. Similarly, rgmiin_txctl carries TXEN on rising edge of rgmiin_txc and TXERR of falling edge of rgmiin_txc.

Figure 7-38. GMAC Transmit Interface Timing RGMIIn operation

7.18 SDIO Controller

MMC interface is compliant with the SDIO3.0 standard v1.0, SD Part E1 and for generic SDIO devices, it supports the following applications:

- MMC 4-bit data, SD Default speed, SDR
- MMC 4-bit data, SD High speed, SDR
- MMC 4-bit data, UHS-I SDR12 (SD Standard v3.01), 4-bit data, SDR, half cycle
- MMC 4-bit data, UHS-I SDR25 (SD Standard v3.01), 4-bit data, SDR, half cycle

NOTE
For more information, see the SDIO Controller chapter of the Device TRM.

7.18.1 MMC, SD Default Speed

Figure 7-39, Figure 7-40, and Table 7-43 through Table 7-44 present Timing requirements and Switching characteristics for MMC - SD and SDIO Default speed in receiver and transmiter mode.

Table 7-43. Timing Requirements for MMC - Default Speed Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
DS5	$t_{su(cmdV-clkH)}$	Setup time, mmc_cmd valid before mmc_clk rising clock edge	5.11		ns
DS6	$t_{h(clkH-cmdV)}$	Hold time, mmc_cmd valid after mmc_clk rising clock edge	20.46		ns
DS7	$t_{su(dV-clkH)}$	Setup time, mmc_dat[i:0] valid before mmc_clk rising clock edge	5.11		ns
DS8	$t_{h(clkH-dV)}$	Hold time, mmc_dat[i:0] valid after mmc_clk rising clock edge	20.46		ns

(1) i in [i:0] = 3

Table 7-44. Switching Characteristics for MMC - SD/SDIO Default Speed Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
DS0	fop(clk)	Operating frequency, mmc_clk		24	MHz
DS1	$t_{w(clkH)}$	Pulse duration, mmc_clk high	0.5×P-0.270		ns

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-44. Switching Characteristics for MMC - SD/SDIO Default Speed Mode (continued)

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
DS2	$t_{w(clkL)}$	Pulse duration, mmc_clk low	0.5×P-0.270		ns
DS3	$t_{d(clkL-cmdV)}$	Delay time, mmc_clk falling clock edge to mmc_cmd transition	-14.93	14.93	ns
DS4	$t_{d(clkL-dV)}$	Delay time, mmc_clk falling clock edge to mmc_dat[i:0] transition	-14.93	14.93	ns

(1) P = output mmc_clk period in ns

(2) i in [i:0] = 3

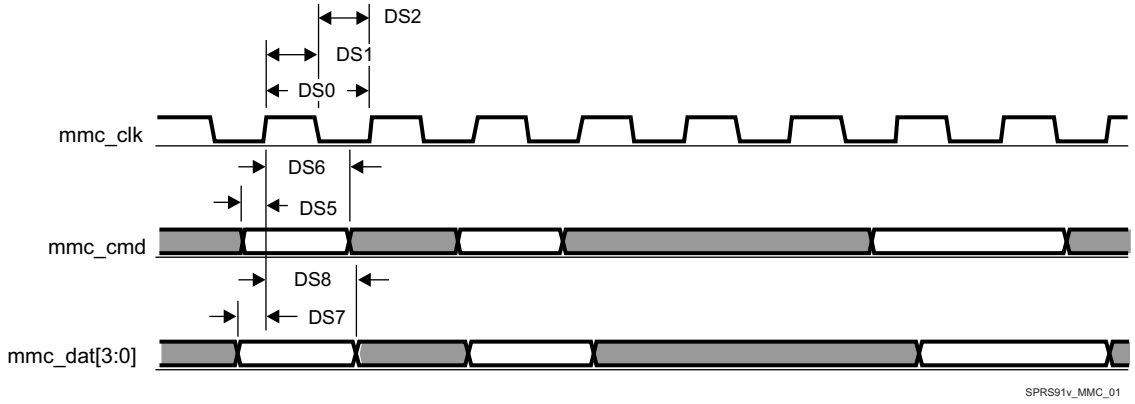


Figure 7-39. MMC/SD/SDIOj in - Default Speed - Receiver Mode

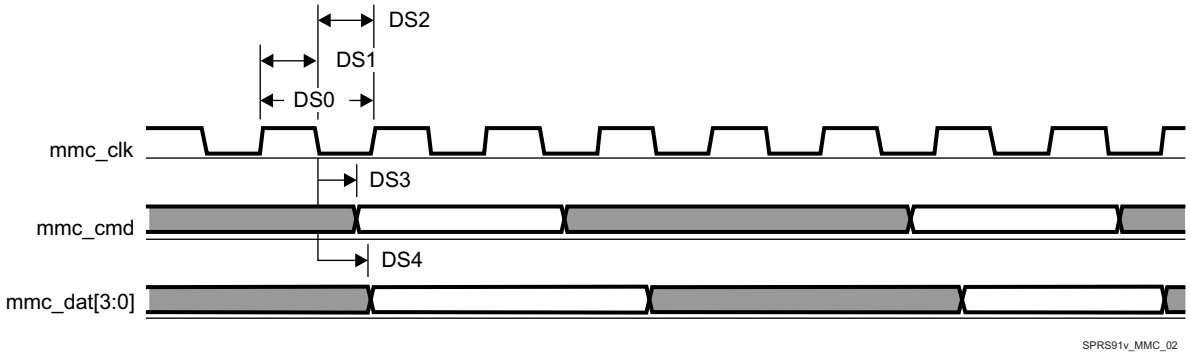


Figure 7-40. MMC/SD/SDIOj in - Default Speed - Transmiter Mode

7.18.2 MMC, SD High Speed

Figure 7-41, Figure 7-42, and Table 7-45 through Table 7-46 present Timing requirements and Switching characteristics for MMC - SD and SDIO High speed in receiver and transmiter mode.

Table 7-45. Timing Requirements for MMC - SD/SDIO High Speed Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
HS3	$t_{su(cmdV-clkH)}$	Setup time, mmc_cmd valid before mmc_clk rising clock edge	5.3		ns
HS4	$t_{h(clkH-cmdV)}$	Hold time, mmc_cmd valid after mmc_clk rising clock edge	2.6		ns
HS7	$t_{su(dV-clkH)}$	Setup time, mmc_dat[i:0] valid before mmc_clk rising clock edge	5.3		ns
HS8	$t_{h(clkH-dV)}$	Hold time, mmc_dat[i:0] valid after mmc_clk rising clock edge	2.6		ns

Copyright © 2016–2020, Texas Instruments Incorporated

(1) i in [i:0] = 3

Table 7-46. Switching Characteristics for MMC - SD/SDIO High Speed Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
HS1	fop(clk)	Operating frequency, mmc_clk		48	MHz
HS2H	$t_{w(clkH)}$	Pulse duration, mmc_clk high	0.5×P-0.270		ns
HS2L	$t_{w(clkL)}$	Pulse duration, mmc_clk low	0.5×P-0.270		ns
HS5	$t_{d(clkL-cmdV)}$	Delay time, mmc_clk falling clock edge to mmc_cmd transition	-7.6	3.6	ns
HS6	$t_{d(clkL-dV)}$	Delay time, mmc_clk falling clock edge to mmc_dat[i:0] transition	-7.6	3.6	ns

(1) P = output mmc_clk period in ns

(2) i in [i:0] = 3

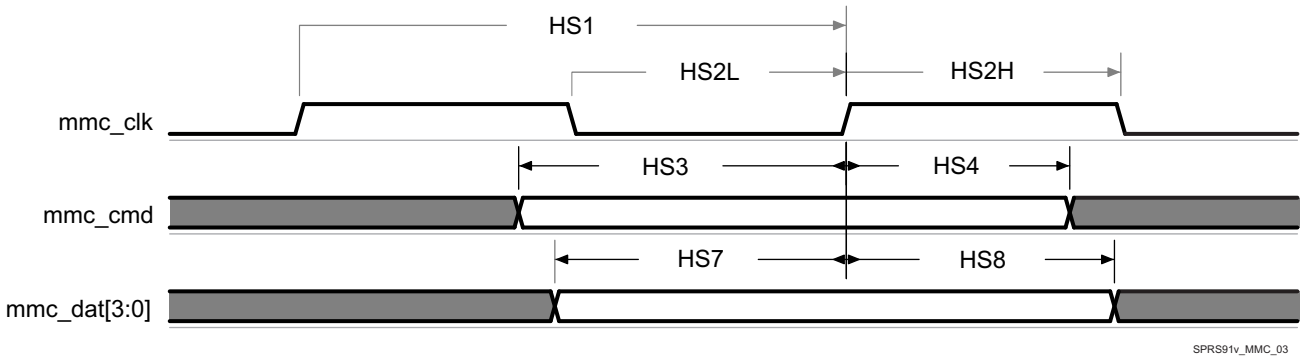


Figure 7-41. MMC/SD/SDIOj in - High Speed - Receiver Mode

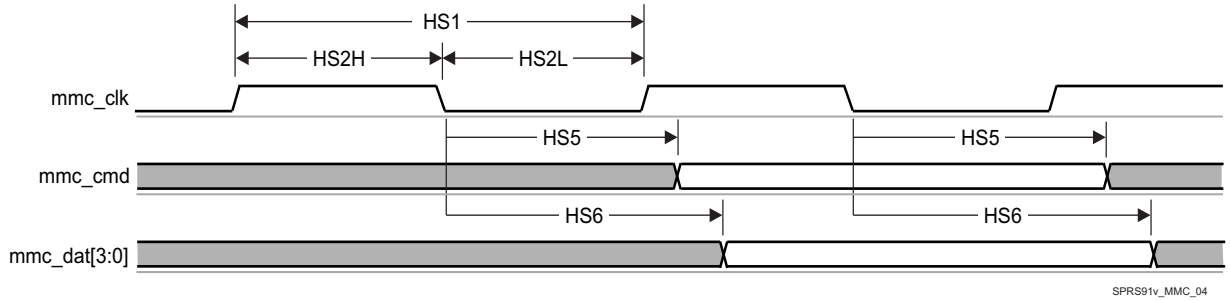


Figure 7-42. MMC/SD/SDIOj in - High Speed - Transmiter Mode

7.18.3 MMC, SD and SDIO SDR12 Mode

Figure 7-43, Figure 7-44, and Table 7-47, through Table 7-48 present Timing requirements and Switching characteristics for MMC - SD and SDIO SDR12 in receiver and transmiter mode.

Table 7-47. Timing Requirements for MMC - SDR12 Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
SDR125	$t_{su(cmdV-clkH)}$	Setup time, mmc_cmd valid before mmc_clk rising clock edge	25.99		ns
SDR126	$t_{h(clkH-cmdV)}$	Hold time, mmc_cmd valid after mmc_clk rising clock edge	1.6		ns
SDR127	$t_{su(dV-clkH)}$	Setup time, mmc_dat[i:0] valid before mmc_clk rising clock edge	25.99		ns
SDR128	$t_{h(clkH-dV)}$	Hold time, mmc_dat[i:0] valid after mmc_clk rising clock edge	1.6		ns

Copyright © 2016–2020, Texas Instruments Incorporated

(1) i in [i:0] = 3

Table 7-48. Switching Characteristics for MMC - SDR12 Mode

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
SDR120	fop(clk)	Operating frequency, mmc_clk		24	MHz
SDR121	$t_{w(clkH)}$	Pulse duration, mmc_clk high	0.5×P-0.270		ns
SDR122	$t_{w(clkL)}$	Pulse duration, mmc_clk low	0.5×P-0.270		ns
SDR123	$t_{d(clkL-cmdV)}$	Delay time, mmc_clk falling clock edge to mmc_cmd transition	-19.13	16.93	ns
SDR124	$t_{d(clkL-dV)}$	Delay time, mmc_clk falling clock edge to mmc_dat[i:0] transition	-19.13	16.93	ns

(1) P = output mmc_clk period in ns

(2) i in [i:0] = 3

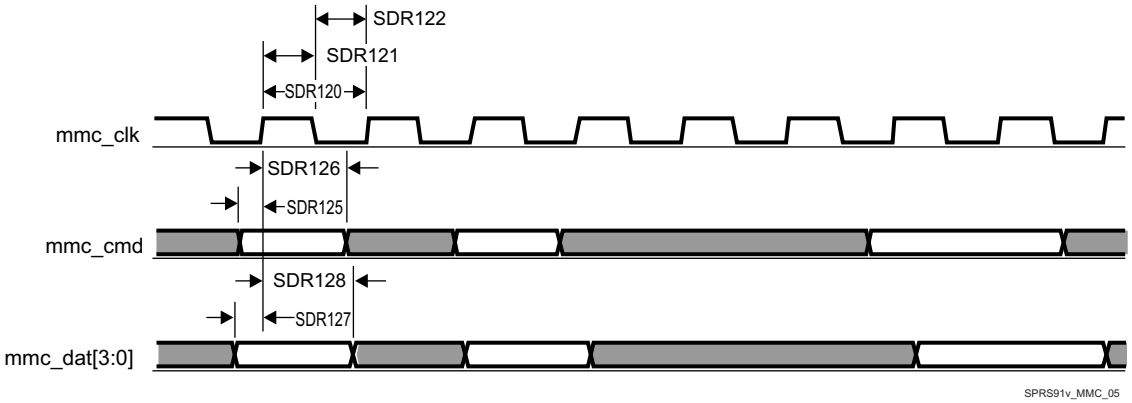


Figure 7-43. MMC/SD/SDIOj in - SDR12 - Receiver Mode

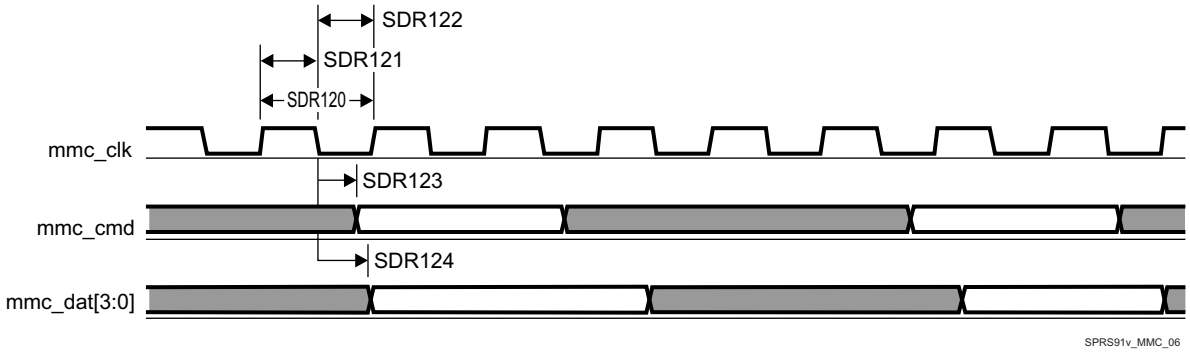


Figure 7-44. MMC/SD/SDIOj in - SDR12 - Transmiter Mode

7.18.4 MMC, SD SDR25 Mode

Figure 7-45, Figure 7-46, and Table 7-49, through Table 7-50 present Timing requirements and Switching characteristics for MMC - SD and SDIO SDR25 in receiver and transmiter mode.

Table 7-49. Timing Requirements for MMC - SDR25 Mode (1)

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
SDR253	$t_{su(cmdV-clkH)}$	Setup time, mmc_cmd valid before mmc_clk rising clock edge	5.3		ns
SDR254	$t_{h(clkH-cmdV)}$	Hold time, mmc_cmd valid after mmc_clk rising clock edge	1.6		ns
SDR257	$t_{su(dV-clkH)}$	Setup time, mmc_dat[i:0] valid before mmc_clk rising clock edge	5.3		ns
SDR258	$t_{h(clkH-dV)}$	Hold time, mmc_dat[i:0] valid after mmc_clk rising clock edge	1.6		ns

Copyright © 2016–2020, Texas Instruments Incorporated

(1) i in [i:0] = 3

Table 7-50. Switching Characteristics for MMC - SDR25 Mode (2)

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
SDR251	fop(clk)	Operating frequency, mmc_clk		48	MHz
SDR252H	$t_{w(clkH)}$	Pulse duration, mmc_clk high	0.5×P-0.270		ns
SDR252L	$t_{w(clkL)}$	Pulse duration, mmc_clk low	0.5×P-0.270		ns
SDR255	$t_{d(clkL-cmdV)}$	Delay time, mmc_clk falling clock edge to mmc_cmd transition	-8.8	6.6	ns
SDR256	$t_{d(clkL-dV)}$	Delay time, mmc_clk falling clock edge to mmc_dat[i:0] transition	-8.8	6.6	ns

(1) P = output mmc_clk period in ns

(2) i in [i:0] = 3

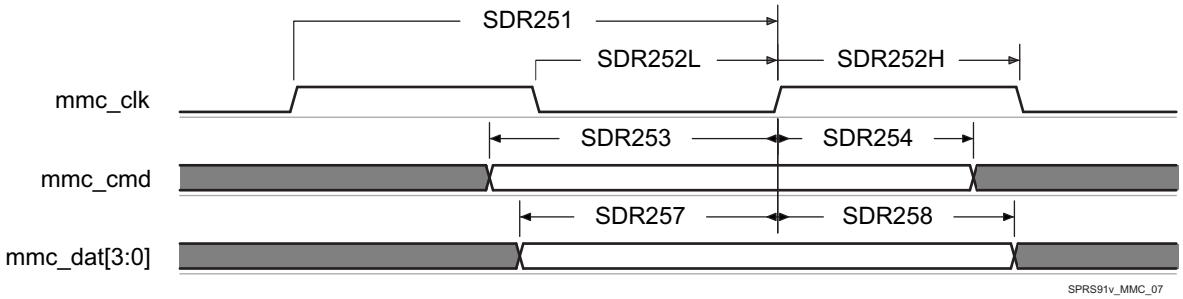


Figure 7-45. MMC/SD/SDIOj in - SDR25 - Receiver Mode

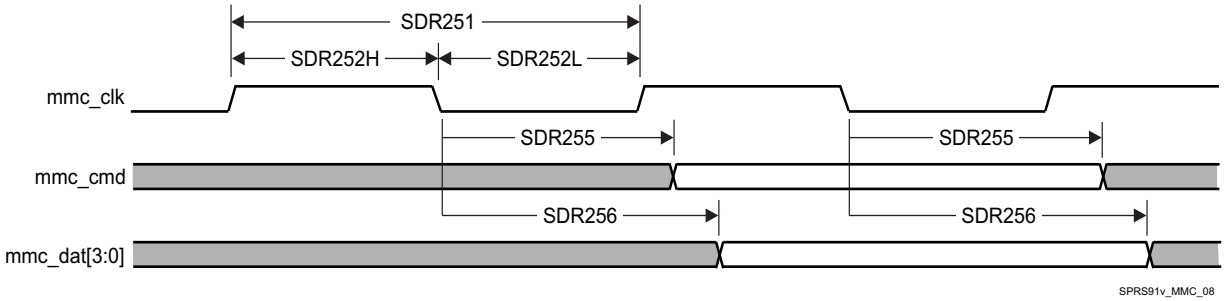


Figure 7-46. MMC/SD/SDIOj in - SDR25 - Transmiter Mode

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-51.

In Table 7-51 are presented the specific groupings of signals (IOSET) for use with MMC.

Table 7-51. MMC IOSETs

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
mmc_clk	C16	5	W16	5	B18	5
mmc_cmd	C17	5	V16	5	C18	5
mmc_dat0	E16	5	U15	5	A19	5
mmc_dat1	D16	5	V15	5	B20	5

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-51. MMC IOSETs (continued)

SIGNALS	IOSET1		IOSET2		IOSET3	
	BALL	MUX	BALL	MUX	BALL	MUX
mmc_dat2	E17	5	Y15	5	C20	5
mmc_dat3	F17	5	W15	5	A20	5

7.19 General-Purpose Interface (GPIO)

The general-purpose interface combines four general-purpose input/output (GPIO) banks. Each GPIO module provides up to 32 dedicated general-purpose pins with input and output capabilities; thus, the general-purpose interface supports up to 126 pins.

These pins can be configured for the following applications:

- Data input (capture)/output (drive)
- Keyboard interface with a debounce cell
- Interrupt generation in active mode upon the detection of external events. Detected events are processed by two parallel independent interrupt-generation submodules to support biprocessor operations
- Wake-up request generation in idle mode upon the detection of external events

NOTE

For more information, see the General-Purpose Interface chapter of the Device TRM.

NOTE

The general-purpose input/output i (i = 1 to 4) bank is also referred to as GPIOi.

CAUTION

The IO timings provided in this section are only valid if signals within a single IOSET are used. The IOSETs are defined in Table 7-52.

In Table 7-52 are presented the specific groupings of signals (IOSET) for use with GPIO.

Table 7-52. GPIO2/3/4 IOSETs

SIGNALS	IOSET1		IOSET2	
	BALL	MUX	BALL	MUX
GPIO2				
gpio2_11			J17	14
gpio2_12			K22	14
gpio2_13			K21	14
gpio2_14			K18	14
gpio2_20			AB17	14
gpio2_23	AA17	14	AA17	14
gpio2_24	U16	14	U16	14
gpio2_27	U15	14		
gpio2_28	V15	14		
gpio2_29	Y15	14		
gpio2_30	W15	14		
gpio2_31	AA15	14		

Copyright © 2016–2020, Texas Instruments Incorporated

Table 7-52. GPIO2/3/4 IOSETs (continued)

SIGNALS	IOSET1		IOSET2	
	BALL	MUX	BALL	MUX
GPIO3				
gpio3_0	AB15	14		
gpio3_9	U9	14	U9	14
gpio3_10	W11	14	W11	14
gpio3_11	V9	14	V9	14
gpio3_12	W9	14	W9	14
gpio3_13	U8	14	U8	14
gpio3_14	W8	14	W8	14
gpio3_15	U7	14		
gpio3_16	V7	14		
GPIO4				
gpio4_4			R5	14
gpio4_6			N4	14
gpio4_7			R7	14
gpio4_8			L2	14
gpio4_9			N5	14
gpio4_10			N6	14

7.20 Test Interfaces

The device includes the following Test interfaces:

- IEEE 1149.1 Standard-Test-Access Port (JTAG®)
- Trace Port Interface Unit (TPIU)

7.20.1 JTAG Electrical Data/Timing

Table 7-53, Table 7-54 and Figure 7-47 assume testing over the recommended operating conditions and electrical characteristic conditions below.

Table 7-53. Timing Requirements for IEEE 1149.1 JTAG

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
1	$t_{c(TCK)}$	Cycle time, TCK	62.29		ns
1a	$t_{w(TCKH)}$	Pulse duration, TCK high (40% of tc)	24.92		ns
1b	$t_{w(TCKL)}$	Pulse duration, TCK low (40% of tc)	24.92		ns
3	$t_{su(TDI-TCK)}$	Input setup time, TDI valid to TCK high	6.23		ns
	$t_{su(TMS-TCK)}$	Input setup time, TMS valid to TCK high	6.23		ns
4	$t_{h(TCK-TDI)}$	Input hold time, TDI valid from TCK high	31.15		ns
	$t_{h(TCK-TMS)}$	Input hold time, TMS valid from TCK high	31.15		ns

Table 7-54. Switching Characteristics Over Recommended Operating Conditions for IEEE 1149.1 JTAG

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
2	$t_{d(TCKL-TDOV)}$	Delay time, TCK low to TDO valid	0	30.5	ns

Copyright © 2016–2020, Texas Instruments Incorporated

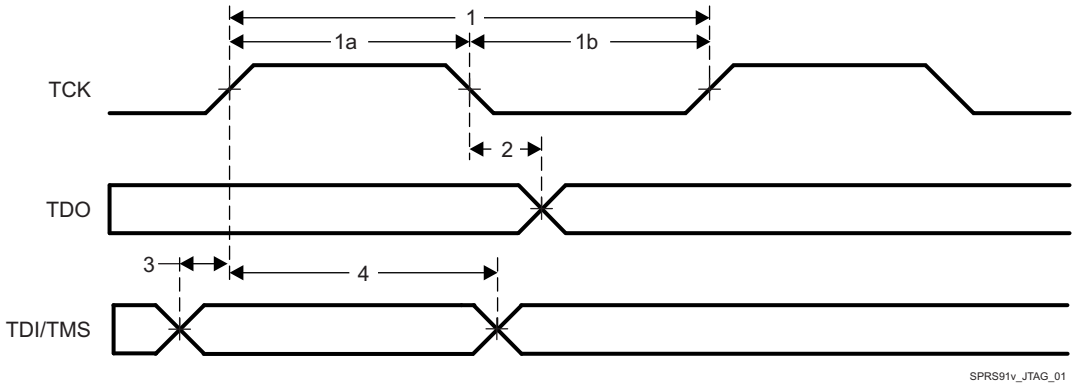


Figure 7-47. JTAG Timing

Table 7-55, Table 7-56 and Figure 7-48 assume testing over the recommended operating conditions and electrical characteristic conditions below.

Table 7-55. Timing Requirements for IEEE 1149.1 JTAG With RTCK

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
1	$t_{c(TCK)}$	Cycle time, TCK	62.29		ns
1a	$t_{w(TCKH)}$	Pulse duration, TCK high (40% of tc)	24.92		ns
1b	$t_{w(TCKL)}$	Pulse duration, TCK low(40% of tc)	24.92		ns
3	$t_{su(TDI-TCK)}$	Input setup time, TDI valid to TCK high	6.23		ns
	$t_{su(TMS-TCK)}$	Input setup time, TMS valid to TCK high	6.23		ns
4	$t_{h(TCK-TDI)}$	Input hold time, TDI valid from TCK high	31.15		ns
	$t_{h(TCK-TMS)}$	Input hold time, TMS valid from TCK high	31.15		ns

Table 7-56. Switching Characteristics Over Recommended Operating Conditions for IEEE 1149.1 JTAG With RTCK

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
5	$t_{d(TCK-RTCK)}$	Delay time, TCK to RTCK with no selected subpaths (i.e. ICEPick is the only tap selected - when the Arm is in the scan chain, the delay time is a function of the Arm functional clock).	0	27	ns
6	$t_{c(RTCK)}$	Cycle time, RTCK	62.29		ns
7	$t_{w(RTCKH)}$	Pulse duration, RTCK high (40% of tc)	24.92		ns
8	$t_{w(RTCKL)}$	Pulse duration, RTCK low (40% of tc)	24.92		ns

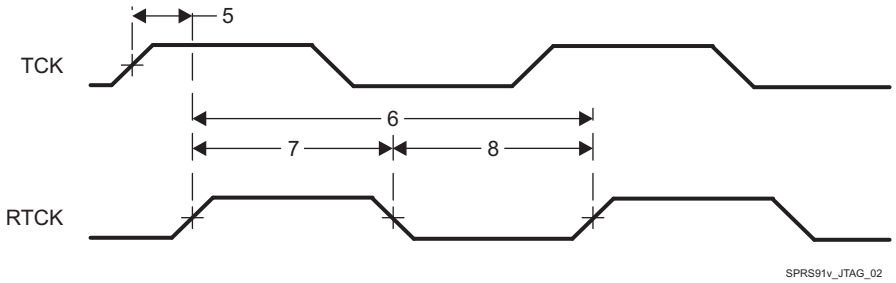


Figure 7-48. JTAG With RTCK Timing

7.20.2 Trace Port Interface Unit (TPIU)

7.20.2.1 TPIU PLL DDR Mode

Table 7-57 and Figure 7-49 assume testing over the recommended operating conditions and electrical characteristic conditions below.

Table 7-57. Switching Characteristics for TPIU

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
TPIU1	$t_{c(clk)}$	Cycle time, TRACECLK period	5.56		ns
TPIU4	$t_{d(clk\text{-}ctlV)}$	Skew time, TRACECLK transition to TRACECTL transition	-1.61	1.98	ns
TPIU5	$t_{d(clk\text{-}dataV)}$	Skew time, TRACECLK transition to TRACEDATA[17:0] transition	-1.61	1.98	ns

(1) P = TRACECLK period in ns

(2) The listed pulse duration is a typical value

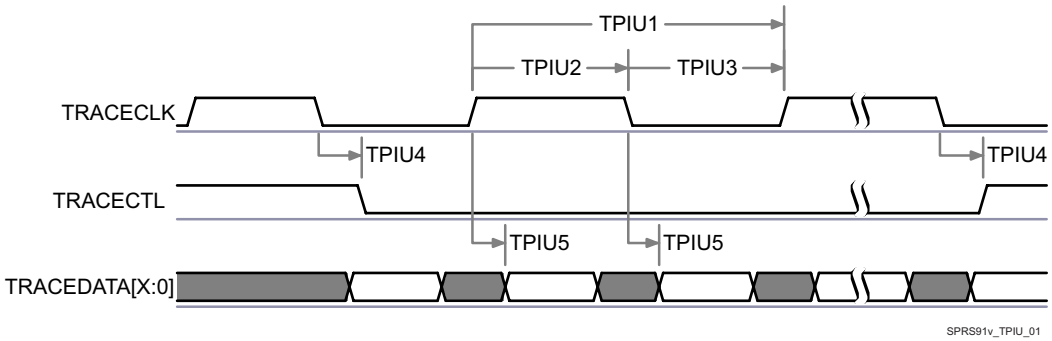


Figure 7-49. TPIU—PLL DDR Transmit Mode(1)

(1) In d[X:0], X is equal to 15 or 17.

Copyright © 2016–2020, Texas Instruments Incorporated

8 Applications, Implementation, and Layout

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test design implementation to confirm system functionality.

8.1 Introduction

This chapter is intended to communicate, guide and illustrate a PCB design strategy resulting in a PCB that can support TI's latest Application Processor. This Processor is a high-performance processor designed for automotive Infotainment based on enhanced OMAP™ architecture integrated on a 28-nm CMOS process technology.

These guidelines first focus on designing a robust Power Delivery Network (PDN) which is essential to achieve the desirable high performance processing available on Device. The general principles and step-by-step approach for implementing good power integrity (PI) with specific requirements will be described for the key Device power domains.

TI strongly believes that simulating a PCB's proposed PDN is required for first pass PCB design success. Key Device processor high-current power domains need to be evaluated for Power Rail IR Drop, Decoupling Capacitor Loop-Inductance and Power Rail Target Impedance. Only then can a PCB's PDN performance be truly accessed by comparing these model PI parameters vs. TI's recommended values. Ultimately for any high-volume product, TI recommends conducting a "Processor PDN Validation" test on prototype PCBs across processor "split lots" to verify PDN robustness meets desired performance goals for each customer's worst-case scenario. Please contact your TI representative to receive guidance on PDN PI modeling and validation testing.

Likewise, the methodology and requirements needed to route Device high speed, differential interfaces , single-ended interfaces (i.e. DDR3, QSPI) and general purpose interfaces using LVCMOS drivers that meet timing requirements while minimizing signal integrity (SI) distortions on the PCB's signaling traces. Signal trace lengths and flight times are aligned with FR-4 standard specification for PCBs.

Several different PCB layout stack-up examples have been presented to illustrate a typical number of layers, signal assignments and controlled impedance requirements. Different Device interface signals demand more or less complexity for routing and controlled impedance stack-ups. Optimizing the PCB's PDN stack-up needs with all of these different types of signal interfaces will ultimately determine the final layer count and layer assignments in each customer's PCB design.

This guideline must be used as a supplement in complement to TI's Application Processor, Power Management IC (PMIC) and Audio Companion components along with other TI component technical documentation (i.e. Technical Reference Manual, Data Manual, Data Sheets, Silicon Errata, Pin-Out Spreadsheet, Application Notes, etc.).

NOTE

Notwithstanding any provision to the contrary, TI makes no warranty expressed, implied, or statutory, including any implied warranty of merchantability of fitness for a specific purpose, for customer boards. The data described in this appendix are intended as guidelines only.

NOTE

These PCB guidelines are in a draft maturity and consequently, are subject to change depending on design verification testing conducted during IC development and validation. Note also that any references to Application Processor's ballout or pin muxing are subject to change following the processor's ballout maturity.

Copyright © 2016–2020, Texas Instruments Incorporated

8.1.1 Initial Requirements and Guidelines

Unless otherwise specified, the characteristic impedance for single-ended interfaces is recommended to be between 35 Ω and 65 Ω to minimize the overshoot or undershoot on far-end loads.

Characteristic impedance for differential interfaces must be routed as differential traces on the same layer. The trace width and spacing must be chosen to yield the recommended differential impedance. For more information see Section 8.5.1.

The PDN must be optimized for low trace resistance and low trace inductance for all high-current power nets from PMIC to the device.

An external interface using a connector must be protected following the IEC61000-4-2 level 4 system ESD.

8.2 Power Optimizations

This section describes the necessary steps for designing a robust Power Distribution Network (PDN):

- **Section 8.2.1, Step 1:** PCB Stack-up
- **Section 8.2.2, Step 2:** Physical Placement
- **Section 8.2.3, Step 3:** Static Analysis
- **Section 8.2.4, Step 4:** Frequency Analysis

8.2.1 Step 1: PCB Stack-up

The PCB stack-up (layer assignment) is an important factor in determining the optimal performance of the power distribution system. An optimized PCB stack-up for higher power integrity performance can be achieved by following these recommendations:

- Power and ground plane pairs must be closely coupled together. The capacitance formed between the planes can decouple the power supply at high frequencies. Whenever possible, the power and ground planes must be solid to provide continuous return path for return current.
- Use a thin dielectric between the power and ground plane pair. Capacitance is inversely proportional to the separation of the plane pair. Minimizing the separation distance (the dielectric thickness) maximizes the capacitance.
- Optimize the power and ground plane pair carrying high current supplies to key component power domains as close as possible to the same surface where these components are placed (see Figure 8-1). This will help to minimize "loop inductance" encountered between supply decoupling capacitors and component supply inputs and between power and ground plane pairs.

NOTE

1-2oz Cu weight for power / ground plane is preferred to enable better PCB heat spreading, helping to reduce Processor junction temperatures. In addition, it is preferable to have the power / ground planes be adjacent to the PCB surface on which the Processor is mounted.

Copyright © 2016–2020, Texas Instruments Incorporated

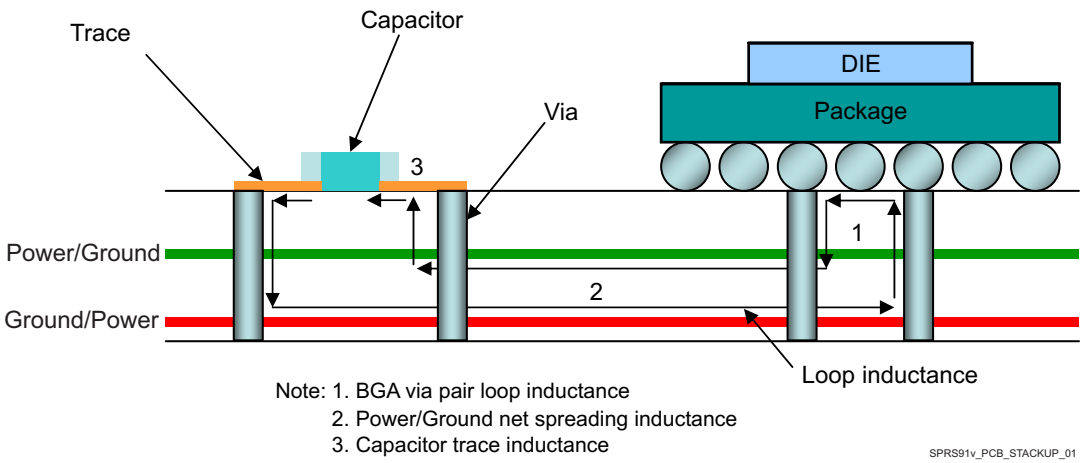


Figure 8-1. Minimize Loop Inductance With Proper Layer Assignment

The placement of power and ground planes in the PCB stackup (determined by layer assignment) has a significant impact on the parasitic inductances of power current path as shown in Figure 8-1. For this reason, it is recommended to consider layer order in the early stages of the PCB PDN design cycle, putting high-priority supplies in the top half of the stackup (assuming high load and priority components are mounted on the top-side of PCB) and low-priority supplies in the bottom half of the stackup as shown in the examples below (vias have parasitic inductances which impact the bottom layers more, so it is advised to put the sensitive and high-priority power supplies on the top/same layers).

8.2.2 Step 2: Physical Placement

A critical step in designing an optimized PDN is that proper care must be taken to making sure that the initial floor planning of the PCB layout is done with good power integrity design guidelines in mind. The following points are important for optimizing a PCB's PDN:

- Minimizing the physical distance between power sources and key high load components is the first step toward optimization. Placing source and load components on the same side of the PCB is desirable. This will minimize via inductance impact for high current loads and steps
- External trace routing between components must be as wide as possible. The wider the traces, the lower the DC resistance and consequently the lower the static IR drop.
- Whenever possible for the internal layers (routing and plane), wide traces and copper area fills are preferred for PDN layout. The routing of power nets in plane provide for more interplane capacitance and improved high frequency performance of the PDN.
- Whenever possible, use a via to component pin/pad ratio of 1:1 or better (i.e. especially decoupling capacitors, power inductors and current sensing resistors). Do not share vias among multiple capacitors for connecting power supply and ground planes.
- Placement of vias must be as close as possible or even within a component's solder pad if the PCB technology you are using provides this capability.
- To avoid any "ampacity" issue – maximum current-carrying capacity of each transitional via should be evaluated to determine the appropriate number of vias required to connect components.

  Adding vias to bring the "via-to-pad" ratio to 1:1 will improve PDN performance.
- For noise sensitive power supplies (i.e. Phase Lock-Loops, analog signals like audio and video), a Gnd shield can be used to isolate coplanar supplies that may have high step currents or high frequency switching transitions from coupling into low-noise supplies.

Copyright © 2016–2020, Texas Instruments Incorporated

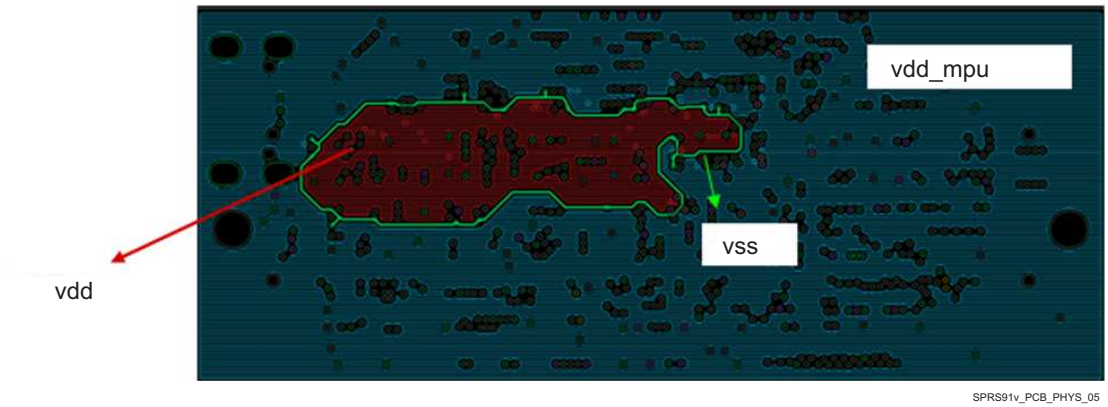


Figure 8-2. Coplanar Shielding of Power Net Using Ground Guard-band

8.2.3 Step 3: Static Analysis

Delivering reliable power to circuits is always of critical importance because voltage drops (also known as IR drops) can happen at every level within an electronic system, on-chip, within a package, and across the board. Robust system performance can only be ensured by understanding how the system elements will perform under typical stressful Use Cases. Therefore, it is a good practice to perform a Static or DC Analysis.

Static or DC analysis and design methodology results in a PDN design that minimizes voltage or IR drops across power and ground planes, traces and vias. This ensures the application processor's internal transistors will be operating within their specified voltage ranges for proper functionality. The amount of IR drop that will be encounter is based upon amount power drawn for a desired Use Case and PCB trace (widths, geometry and number of parallel traces) and via (size, type and number) characteristics.

Components that are distant from their power source are particularly susceptible to IR drop. Designs that rely on battery power must minimize voltage drops to avoid unacceptable power loss that can negatively impact system performance. Early assessments a PDN's static (DC) performance helps to determine basic power distribution parameters such as best system input power point, optimal PCB layer stackup, and copper area needed for load currents.

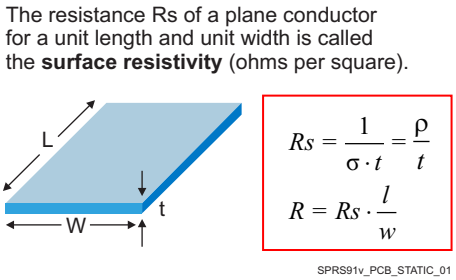


Figure 8-3. Depiction of Sheet Resistivity and Resistance

Ohm's Law (V = I × R) relates conduction current to voltage drop. At DC, the relation coefficient is a constant and represents the resistance of the conductor. Even current carrying conductors will dissipate power at high currents even though their resistance may be very small. Both voltage drop and power dissipation are proportional to the resistance of the conductor.

Figure 8-4 shows a PCB-level static IR drop budget defined between the power management device (PMIC) pins and the application processor's balls when the PMIC is supplying power.

- It is highly recommended to physically place the PMIC as close as possible to the processor and on the same side. The orientation of the PMIC vs. the processor should be aligned to minimize distance for the highest current rail.

Copyright © 2016–2020, Texas Instruments Incorporated

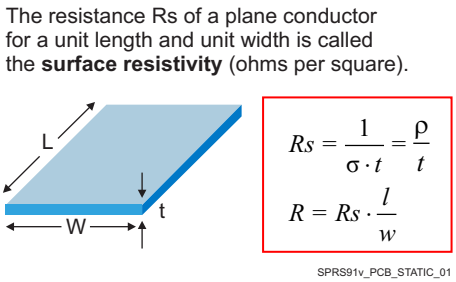


Figure 8-4. Static IR Drop Budget for PCB Only

The system-level IR drop budget is made up of three portions: on-chip, package, and PCB board. Static IR or dc analysis/design methodology consists of designing the PDN such that the voltage drop (under dc operating conditions) across power and ground pads of the transistors of the application processor device is within a specified value of the nominal voltage for proper functionality of the device.

A PCB system-level voltage drop budget for proper device functionality is typically 1.5% of nominal voltage. For a 1.35-V supply, this would be ≤20 mV.

To accurately analyze PCB static IR drop, the actual geometry of the PDN must be modeled properly and simulated to accurately characterize long distribution paths, copper weight impacts, electro-migration violations of current-carrying vias, and "Swiss-cheese" effects via placement has on power rails. It is recommended to perform the following analyses:

- Lumped resistance/IR drop analysis
- Distributed resistance/IR drop analysis

NOTE

The PMIC companion device supporting Processor has been designed with voltage sensing feedback loop capabilities that enable a remote sense of the SMPS output voltage at the point of use.

The NOTE above means the SMPS feedback signals and returns must be routed across PCB and connected to the Device input power ball for which a particular SMPS is supplying power. This feedback loop provides compensation for some of the voltage drop encountered across the PDN within limits. As such, the effective resistance of the PDN within this loop should be determined in order to optimize voltage compensation loop performance. The resistance of two PDN segments are of interest: one from the power inductor/bulk power filtering capacitor node to the Processor's input power and second is the entire PDN route from SMPS output pin/ball to the Processor input power.

In the following sections each methodology is described in detail and an example has been provided of analysis flow that can be used by the PCB designer to validate compliance to the requirements on their PCB PDN design.

8.2.3.1 PDN Resistance and IR Drop

Lumped methodology consists of grouping all of the power pins on both the PMIC (voltage source) and processor (current sink) devices. Then the PMIC source is set to an expected Use Case voltage level and the processor load has its Use Case current sink value set as well. Now the lumped/effective resistance for the power rail trace/plane routes can be determine based upon the actual layout's power rail etch wide, shape, length, via count and placement Figure 8-5 illustrates the pin-grouping/lumped concept.

The lumped methodology consists of importing the PCB layout database (from Cadence Allegro tool or any other layout design tool) into the static IR drop modeling and simulation tool of preference for the PCB designer. This is followed by applying the correct PCB stack-up information (thickness, material properties) of the PCB dielectric and metallization layers. The material properties of dielectric consist of permittivity (Dk) and loss tangent (Df).

Copyright © 2016–2020, Texas Instruments Incorporated

For the conductor layers, the correct conductivity needs to be programmed into the simulation tool. This is followed by pin-grouping of the power and ground nets, and applying appropriate voltage/current sources. The current and voltage information can be obtained from the power and voltage specifications of the device under different operating conditions / Use Cases.

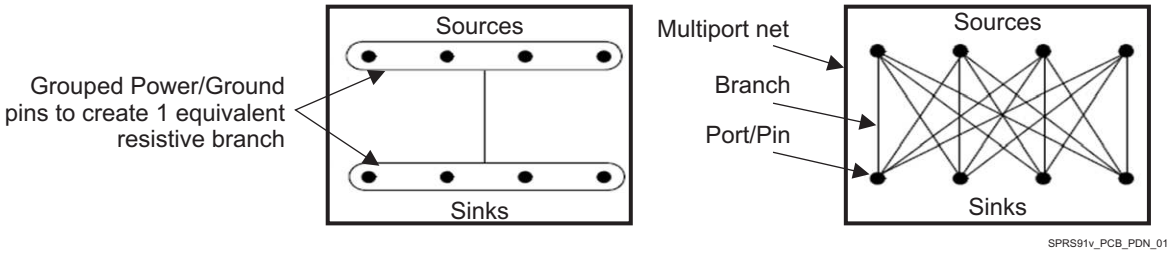


Figure 8-5. Pin-grouping concept: Lumped and Distributed Methodologies

8.2.4 Step 4: Frequency Analysis

Delivering low noise voltage sources are very important to allowing a system to operate at the lowest possible Operational Performance Point (OPP) for any one Use Case. An OPP is a combination of the supply voltage level and clocking rate for key internal processor domains. A SCH and PCB designed to provide low noise voltage supplies will then enable the processor to enter optimal OPPs for each Use Case that in turn will minimize power dissipation and junction temperatures on-die. Therefore, it is a good engineering practice to perform a Frequency Analysis over the key power domains.

Frequency analysis and design methodology results in a PDN design that minimizes transient noise voltages at the processor's input power balls. This allows the processor's internal transistors to operate near the minimum specified operating supply voltage levels. To accomplish this one must evaluate how a voltage supply will change due to impedance variations over frequency. This analysis will focus on the decoupling capacitor network (VDD_xxx and VSS/Gnd rails) at the load. Sufficient capacitance with a distribution of self-resonant points will provide for an overall lower impedance vs frequency response for each power domain.

Decoupling components that are distant from their load's input power are susceptible to encountering spreading loop inductance from the PCB design. Early analysis of each key power domain's frequency response helps to determine basic decoupling capacitor placement, optimal footprint, layer assignment, and types needed for minimizing supply voltage noise/fluctuations due to switching and load current transients.

NOTE

Evaluation of loop inductance values for decoupling capacitors placed ~300mils closer to the load's input power balls has shown an 18% reduction in loop inductance due to reduced distance.

- Decoupling capacitors must be carefully placed in order to minimize loop inductance impact on supply voltage transients. A real capacitor has characteristics not only of capacitance but also inductance and resistance.

  Figure 8-6 shows the parasitic model of a real capacitor. A real capacitor must be treated as an RLC circuit with effective series resistance (ESR) and effective series inductance (ESL).

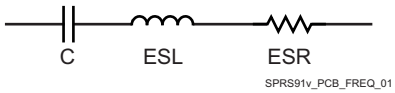


Figure 8-6. Characteristics of a Real Capacitor With ESL and ESR

The magnitude of the impedance of this series model is given as:

Copyright © 2016–2020, Texas Instruments Incorporated

$$|Z| = \sqrt{ESR^2 + \left(\omega ESL - \frac{1}{\omega C}\right)^2}$$

where : $\omega = 2\pi f$

SPRS91v_PCB_FREQ_02

Figure 8-7. Series Model Impedance Equation

Figure 8-8 shows the resonant frequency response of a typical capacitor with a self-resonant frequency of 55 MHz. The impedance of the capacitor is a combination of its series resistance and reactive capacitance and inductance as shown in the equation above.

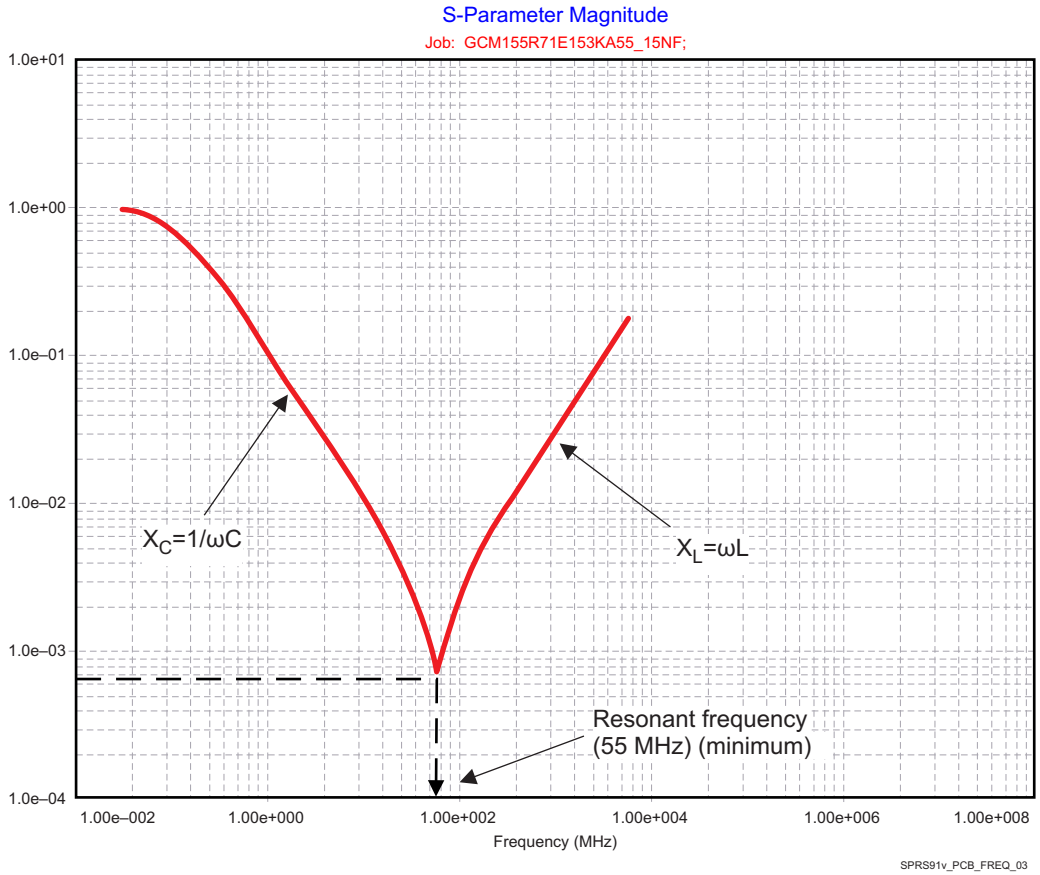


Figure 8-8. Typical Impedance Profile of a Capacitor

Because a capacitor has series inductance and resistance that impacts its effectiveness, it is important that the following recommendations are adopted in placing capacitors on the PDN.

Wherever possible, mount the capacitor with the geometry that minimizes the mounting inductance and resistance. This was shown earlier in Figure 8-1. The capacitor mounting inductance and resistance values include the inductance and resistance of the pads, trace, and vias. Whenever possible, use footprints that have the lowest inductance configuration as shown in Figure 8-9

The length of a trace used to connect a capacitor has a big impact on parasitic inductance and resistance of the mounting. This trace must be as short and as wide as possible. wherever possible, minimize distance to supply and Gnd vias by locating vias nearby or within the capacitor's solder pad landing. Further improvements can be made to the mounting by placing vias to the side of capacitor lands or doubling the number of vias as shown in Figure 8-9. If the PCB manufacturing processes allow it and if cost-effective, via-in-pad (VIP) geometries are strongly recommended.

Copyright © 2016–2020, Texas Instruments Incorporated

In addition to mounting inductance and resistance associated with placing a capacitor on the PCB, the effectiveness of a decoupling capacitor also depends on the spreading inductance and resistance that the capacitor sees with respect to the load. The spreading inductance and resistance is strongly dependent on the layer assignment in the PCB stack-up. Therefore, try to minimize X, Y and Z dimensions where the Z is due to PCB thickness (as shown in Figure 8-9).

From left (highest inductance) to right (lowest inductance) the capacitor footprint types shown in Figure 8-9 are known as:

- 2-via, Skinny End Exit (2vSEE)
- 2-via, Wide End Exit (2vWEE)
- 2-via, Wide Side Exit (2vWSE)
- 4-via, Wide Side Exit (4vWSE)
- 2-via, In-Pad (2vIP)

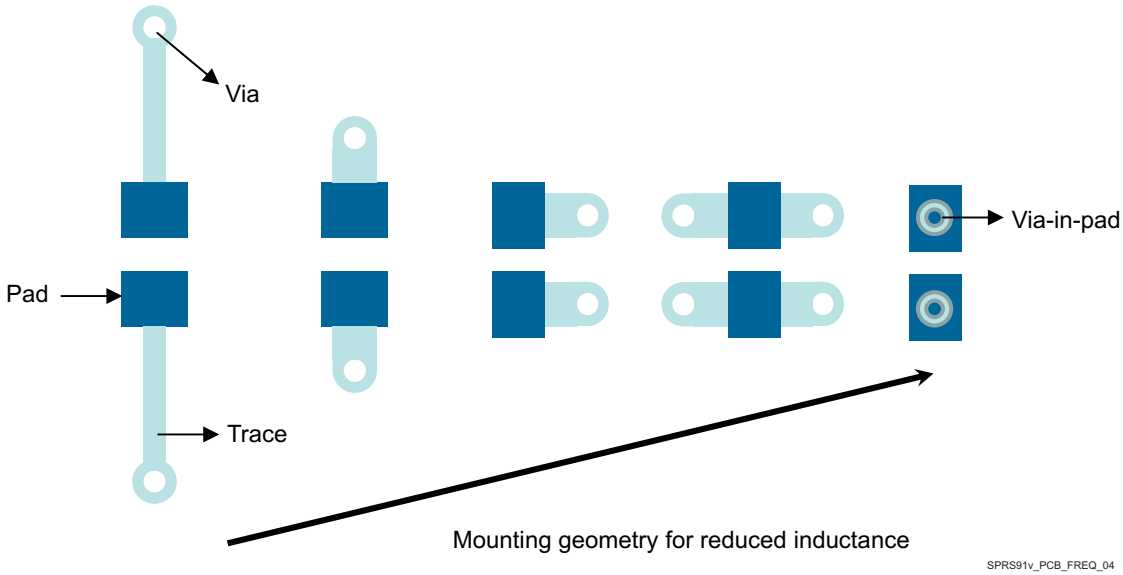


Figure 8-9. Capacitor Placement Geometry for Improved Mounting Inductance

NOTE

Evaluation of loop inductance values for decoupling capacitor footprints 2vSEE (worst case) vs 4vWSE (2nd best) has shown a 30% reduction in inductance when 4vWSE footprint was used in place of 2vSEE.

Decoupling Capacitor (Dcap) Strategy:

1. Use lowest inductance footprint and trace connection scheme possible for given PCB technology and layout area in order to minimize Dcap loop inductance to power pin as much as possible (see Figure 8-9).
2. Place Dcaps on "same-side" as component within their power plane outline to minimize "decoupling loop inductance". Target distance to power pin should be less than ~500mils depending upon PCB layout characteristics (plane's layer assignment and solid nature). Use PI modeling CAD tool to verify minimum inductance for top vs bottom-side placement.
3. Place Dcaps on "opposite-side" as component within their power plane outline if "same-side" is not feasible or if distance to power pin is greater than ~500mils for top-side location. Use PI modeling CAD tool to verify minimum inductance for top vs bottom-side placement.
4. Use minimum 10mil trace width for all voltage and gnd planes connections (i.e. Dcap pads, component power pins, etc.).

Copyright © 2016–2020, Texas Instruments Incorporated

5. Place all voltage and gnd plane vias "as close as possible" to point of use (i.e. Dcap pads, component power pins, etc.).
6. Use a "Power/Gnd pad/pin to via" ratio of 1:1 whenever possible. Do not exceed 2:1 ratio for small number of vias within restricted PCB areas (i.e. underneath BGA components).

Frequency analysis for the CORE power domain (vdd) has yielded the Impedance vs Frequency responses shown in Section 8.3.8.2, vdd Example Analysis.

8.2.5 System ESD Generic Guidelines

8.2.5.1 System ESD Generic PCB Guideline

Protection devices must be placed close to the ESD source which means close to the connector. This allows the device to subtract the energy associated with an ESD strike before it reaches the internal circuitry of the application board.

To help minimize the residual voltage pulse that will be built-up at the protection device due to its nonzero turn-on impedance, it is mandatory to route the ESD device with minimum stub length so that the low-resistive, low-inductive path from the signal to the ground is granted and not increasing the impedance between signal and ground.

For ESD protection array being railed to a power supply when no decoupling capacitor is available in close vicinity, consider using a decoupling capacitor (≥ 0.1 µF) tight to the VCC pin of the ESD protection. A positive strike will be partially diverted to this capacitance resulting in a lower residual voltage pulse.

Ensure that there is sufficient metallization for the supply of signals at the interconnect side (VCC and GND in Figure 8-10) from connector to external protection because the interconnect may see between 15-A to 30-A current in a short period of time during the ESD event.

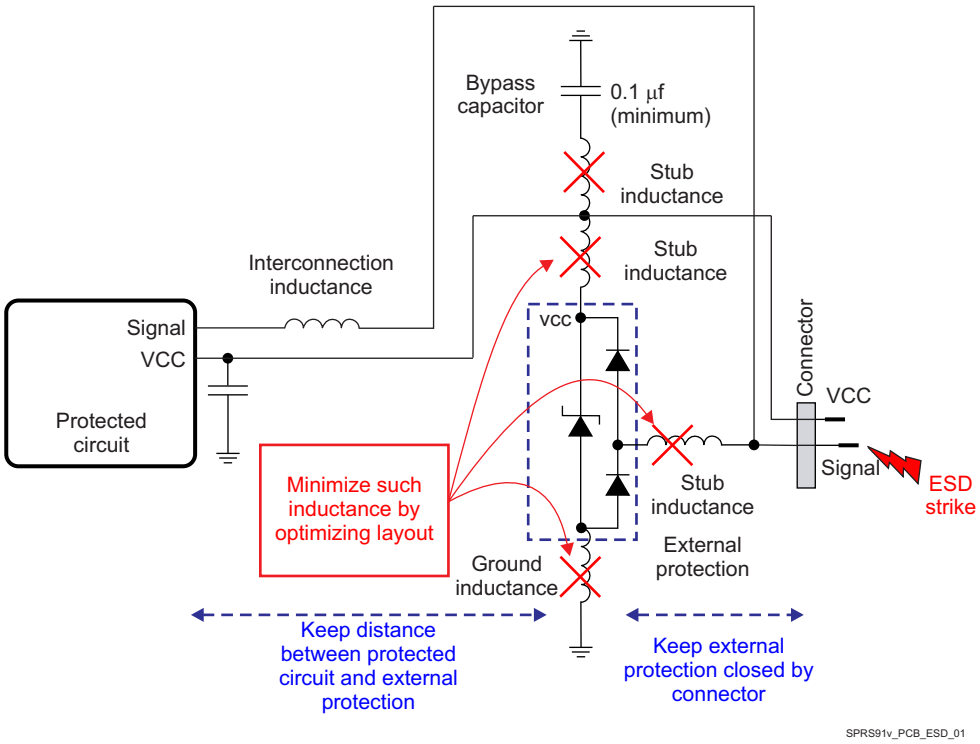


Figure 8-10. Placement Recommendation for an ESD External Protection

NOTE

To ensure normal behavior of the ESD protection (unwanted leakage), it is better to ground the ESD protection to the board ground rather than any local ground (example isolated shield or audio ground).

8.2.5.2 Miscellaneous EMC Guidelines to Mitigate ESD Immunity

- Avoid running critical signal traces (clocks, resets, interrupts, control signals, and so forth) near PCB edges.
- Add high frequency filtering: Decoupling capacitors close to the receivers rather than close to the drivers to minimize ESD coupling.
- Put a ground (guard) ring around the entire periphery of the PCB to act as a lightning rod.
- Connect the guard ring to the PCB ground plane to provide a low impedance path for ESD-coupled current on the ring.
- Fill unused portions of the PCB with ground plane.
- Minimize circuit loops between power and ground by using multilayer PCB with dedicated power and ground planes.
- Shield long line length (strip lines) to minimize radiated ESD.
- Avoid running traces over split ground planes. It is better to use a bridge connecting the two planes in one area.

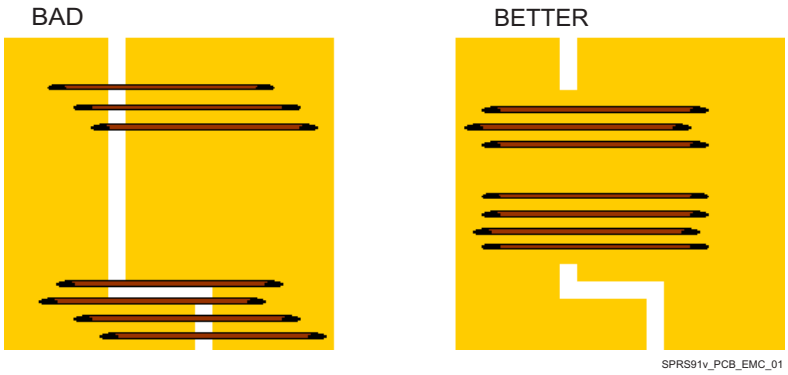


Figure 8-11. Trace Examples

- Always route signal traces and their associated ground returns as close to one another as possible to minimize the loop area enclosed by current flow:
  - At high frequencies current follows the path of least inductance.
  - At low frequencies current flows through the path of least resistance.

8.2.5.3 ESD Protection System Design Consideration

ESD protection system design consideration is covered in of this document. The following are additional considerations for ESD protection in a system.

- Metallic shielding for both ESD and EMI
- Chassis GND isolation from the board GND
- Air gap designed on board to absorb ESD energy
- Clamping diodes to absorb ESD energy
- Capacitors to divert ESD energy
- The use of external ESD components on the DP/DM lines may affect signal quality and are not recommended.

Copyright © 2016–2020, Texas Instruments Incorporated

8.2.6 EMI / EMC Issues Prevention

All high speed digital integrated circuits can be sources of unwanted radiation, which can affect nearby sensitive circuitry and cause the final product to have radiated emissions levels above the limits allowed by the EMC regulations if some preventative steps are not taken.

Likewise, analog and digital circuits can be susceptible to interference from the outside world and picked up by the circuitry interconnections.

To minimize the potential for EMI/EMC issues, the following guidelines are recommended to be followed.

8.2.6.1 Signal Bandwidth

To evaluate the frequency of a digital signal, an estimated rule of thumb is to consider its bandwidth f_{BW} with respect to its rise time, t_R:

$$f_{BW} \approx 0.35 / t_R$$

This frequency actually corresponds to the break point in the signal spectrum, where the harmonics start to decay at 40 dB per decade instead of 20 dB per decade.

8.2.6.2 Signal Routing

8.2.6.2.1 Signal Routing-Sensitive Signals and Shielding

Keep radio frequency (RF) sensitive circuitry (like GPS receivers, GSM/WCDMA, Bluetooth/WLAN transceivers, frequency modulation (FM) radio) away from high speed ICs (the device, power and audio manager, chargers, memories, and so forth) and ideally on the opposite side of the PCB. For improved protection it is recommended to place these emission sources in a shield can. If the shield can have a removable lid (two-piece shield), ensure there is low contact impedance between the fence and the lid. Leave some space between the lid and the components under it to limit the high-frequency currents induced in the lid. Limit the shield size to put any potential shield resonances above the frequencies of interest; see Figure 8-8, *Typical Impedance Profile of a Capacitor*.

8.2.6.2.2 Signal Routing-Outer Layer Routing

In case there is a need to use the outer layers for routing outside of shielded areas, it is recommended to route only static signals and ensure that these static signals do not carry any high-frequency components (due to parasitic coupling with other signals). In case of long traces, make provision for a bypass capacitor near the signal source.

Routing of high-frequency clock signals on outer layers, even for a short distance, is discouraged, because their emissions energy is concentrated at the discrete harmonics and can become significant even with poor radiators.

Coplanar shielding of traces on outer layers (placing ground near the sides of a track along its length) is effective only if the distance between the trace sides and the ground is smaller that the trace height above the ground reference plane. For modern multilayer PCBs this is often not possible, so coplanar shielding will not be effective. Do not route high-frequency traces near the periphery of the PCB, as the lack of a ground reference near the trace edges can increase EMI: see Section 8.2.6.3, *Ground Guidelines*.

8.2.6.3 Ground Guidelines

8.2.6.3.1 PCB Outer Layers

Ideally the areas on the top and bottom layers of the PCB that are not enclosed by a shield should be filled with ground after the routing is completed and connected with an adequate number of vias to the ground on the inner ground planes.

Copyright © 2016–2020, Texas Instruments Incorporated

8.2.6.3.2 Metallic Frames

Ensure that all metallic parts are well connected to the PCB ground (like LCD screens metallic frames, antennas reference planes, connector cages, flex cables grounds, and so forth). If using flex PCB ribbon cables to bring high-frequency signals off the PCB, ensure they are adequately shielded (coaxial cables or flex ribbons with a solid reference ground).

8.2.6.3.3 Connectors

For high-frequency signals going to connectors choose a fully shielded connector, if possible (for example, SD card connectors). For signals going to external connectors or which are routed over long distances, it is recommended to reduce their bandwidth by using low-pass filters (resistor, capacitor (RC) combinations or lossy ferrite inductors). These filters will help to prevent emissions from the board and can also improve the immunity from external disturbances.

8.2.6.3.4 Guard Ring on PCB Edges

The major advantage of a multilayer PCB with ground-plane is the ground return path below each and every signal or power trace.

As shown in Figure 8-12 the field lines of the signal return to PCB ground as long as an infinite ground is available.

Traces near the PCB-edges do not have this infinite ground and therefore may radiate more than the others. Thus, signals (clocks) or power traces (core power) identified to be critical must not be routed in the vicinity of PCB edges, or, if not avoidable, must be accompanied by a guard ring on the PCB edge.

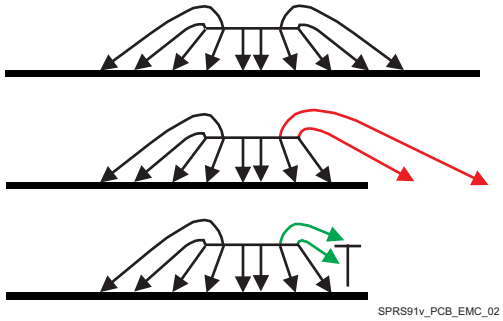


Figure 8-12. Field Lines of a Signal Above Ground



Figure 8-13. Guard Ring Routing

The intention of the guard ring is that HF-energy, that otherwise would have been emitted from the PCB edge, is reflected back into the board where it partially will be absorbed. For this purpose ground traces on the borders of all layers (including power layer) must be applied as shown in Figure 8-13.

As these traces must have the same (HF–) potential as the ground plane they must be connected to the ground plane at least every 10 mm.

Copyright © 2016–2020, Texas Instruments Incorporated

8.2.6.3.5 Analog and Digital Ground

For the optimum solution, the AGND and the DGND planes must be connected together at the power supply source in a same point. This ensures that both planes are at the same potential, while the transfer of noise from the digital to the analog domain is minimized.

8.3 Core Power Domains

This section provides boundary conditions and theoretical background to be applied as a guide for optimizing a PCB design. The decoupling capacitor and PDN characteristics tables shown below give recommended capacitors and PCB parameters to be followed for schematic and PCB designs. Board designs that meet the static and dynamic PDN characteristics shown in tables below will be aligned to the expected PDN performance needed to optimize SoC performance.

8.3.1 General Constraints and Theory

- Max PCB static/DC voltage drop (IRd) budget of **1.5% of supply voltage** when using PMICs **without remote sensing** as measured from PMIC's power inductor and filter capacitor node to Processor input including any ground return losses.
- Max PCB static/DC voltage drop (IRd) budget can be relaxed to **7.5% of supply voltage** when using TI recommended PMICs **with remote sensing** at the load as measured from PMIC's power inductor and filter capacitor node to Device's supply input including any ground return losses.
- PMIC component DM and guidelines should be referenced for the following:
  - Routing remote feedback sensing to optimize per each SMPS's implementation
  - Selecting power filtering capacitor values and PCB placement.
- Max Total Effective Resistance (R_{eff}) budget can range from **4 – 100 mΩ** for key Device power rails not including ground returns depending upon maximum load currents and maximum DC voltage drop budget (as discussed above).
- Max Device supply input voltage difference budget of **5 mV** under max current loading shall be maintained across all balls connected to a common power rail. This represents any voltage difference that may exist between a remote sense point to any power input.
- Max PCB Loop Inductance (LL) budget between Device's power inputs and local bulk and high frequency decoupling capacitors including ground returns should range from **0.4 – 2.5 nH depending upon maximum transient load currents.**
- Max PCB dynamic/AC peak-to-peak transient noise voltage budgets between PMIC and Device including ground returns are as follows:
  - **+/-3% of nominal supply voltage** for frequencies below the PMIC bandwidth (typ Fpmic ~ 200kHz)
  - **+/-5% of nominal supply voltage** for frequencies between Fpmic to Fpcb (typ 20 – 100MHz)

Copyright © 2016–2020, Texas Instruments Incorporated

- Max PCB Impedance (Z) vs Frequency (F) budget between Device's power inputs and PMIC's output power filter node including ground return is determined by applying the Frequency Domain Target Impedance Method to determine the PCB's maximum frequency of interest (Fpcb). Ideally a properly designed and decoupled PDN will exhibit smoothly increasing Z vs. F curve. There are 2 general regions of interest as can be seen in Figure 8-14.
  - 1st area is from DC (0Hz) up to Fpmic (typ a few 100 kHz) where a PMIC's transient response characteristic (i.e. Switching Freq, Compensation Loop BW) dominate. A PDN's Z is typically very low due to power filtering and bulk capacitor values when PDN has very low trace resistance (i.e. good Reff performance). The goal is to maintain a smoothly increasing Z that is less than Zt1 over this low frequency range. This will ensure that a max transient current event will not cause a voltage drop more than the PMIC's current step response can support (typ 3%).
  - 2nd area is from Fpmic up to Fpcb (typ 20-100MHz) where a PCB's inherent characteristics (i.e. parasitic capacitance, planar spreading inductances) dominate. A PDN's Z will naturally increase with frequency. At frequencies between Fpmic up to Fpcb, the goal is to maintain a smoothly increasing Z to be less than Zt2. This will ensue that the high frequency content of a max transient current event will not cause a voltage drop to be more than 5% of the min supply voltage.

$$Z_T = \frac{\text{Max Voltage Rail Drop}^{\text{Note1}}}{\text{Max Transient Current}^{\text{Note2}}}$$

$$Z_{T1} = \frac{\text{(Min Voltage) x (PMIC's Step Responce)}}{\text{(~50\% of Max DC Current)}} = \frac{\text{Vmin x 3\%(typ)}}{\text{Imax x ~50\%}}$$

$$Z_{T2} = \frac{\text{(Min Voltage) x (High-Freq Transient Noise)}}{\text{(~50\% of Max DC Current)}} = \frac{\text{Vmin x 5\%(typ)}}{\text{Imax x ~50\%}}$$

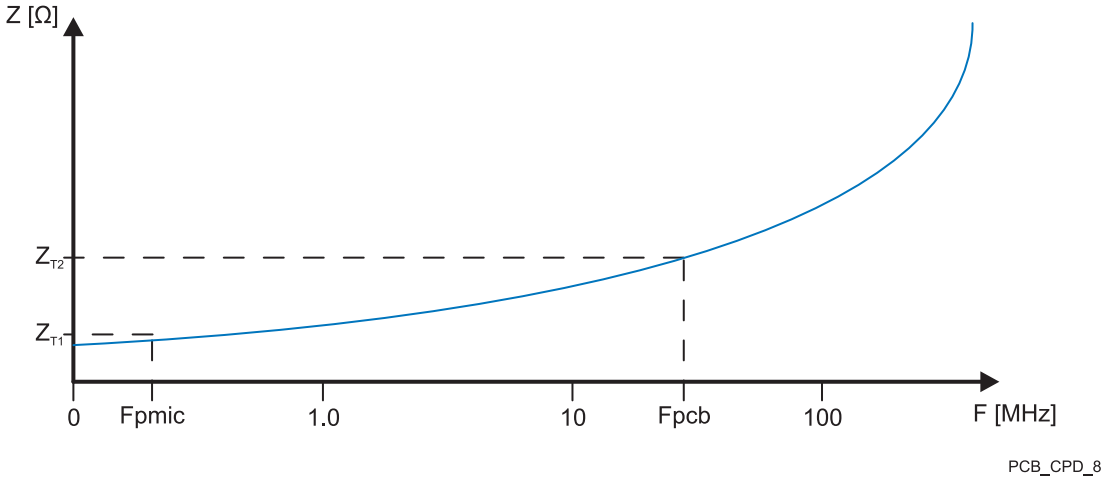


Figure 8-14. PDN's Target impedance

1.Voltage Rail Drop includes regulation accuracy, voltage distribution drops, and all dynamic events such as transient noise, AC ripple, voltage dips etc.

Copyright © 2016–2020, Texas Instruments Incorporated

2.Typical max transient current is defined as 50% of max current draw possible.

8.3.2 Voltage Decoupling

Recommended power supply decoupling capacitors main characteristics for commercial products whose ambient temperature is not to exceed +85C are shown in table below:

Table 8-1. Commercial Applications Recommended Decoupling Capacitors Characteristics(1)(2)(3)

VALUE	VOLTAGE [V]	PACKAGE	STABILITY	DIELECTRIC	CAPACITANCE TOLERANCE	TEMP RANGE [°C]	TEMP SENSITIVITY [%]	REFERENCE
22 µF	6,3	0603	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM188R60J226MEA0L
10 µF	4,0	0402	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM155R60G106ME44
4.7 µF	6,3	0402	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM155R60J475ME95
2.2 µF	6,3	0402	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM155R60J225ME95
1 µF	6,3	0201	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM033R60J105MEA2
470 nF	6,3	0201	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM033R60G474ME90
220 nF	6,3	0201	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM033R60J224ME90
100 nF	6,3	0201	Class 2	X5R	- / + 20%	-55 to + 85	- / + 15	GRM033R60J104ME19

(1) Minimum value for each PCB capacitor: 100 nF.

(2) Among the different capacitors, 470 nF is recommended (not required) to filter at 5-MHz to 10-MHz frequency range.

(3) In comparison with the EIA Class 1 dielectrics, Class 2 dielectric capacitors tend to have severe temperature drift, high dependence of capacitance on applied voltage, high voltage coefficient of dissipation factor, high frequency coefficient of dissipation, and problems with aging due to gradual change of crystal structure. Aging causes gradual exponential loss of capacitance and decrease of dissipation factor.

Recommended power supply decoupling capacitors main characteristics for automotive products are shown in table below:

Table 8-2. Automotive Applications Recommended Decoupling Capacitors Characteristics (1)(2)

VALUE	VOLTAGE [V]	PACKAGE	STABILITY	DIELECTRIC	CAPACITANCE TOLERANCE	TEMP RANGE [°C]	TEMP SENSITIVITY [%]	REFERENCE
22 µF	6,3	1206	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM31CR70J226ME23
10 µF	6,3	0805	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM21BR70J106ME22
4.7 µF	10	0805	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM21BC71A475MA73
2.2 µF	6,3	0603	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM188R70J225ME22
1 µF	16	0603	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM188R71C105MA64
470 nF	16	0603	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM188R71C474MA55
220 nF	25	0603	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM188L81C224MA37
100 nF	16	0402	Class 2	X7R	- / + 20%	-55 to + 125	- / + 15	GCM155R71C104MA55

(1) Minimum value for each PCB capacitor: 100 nF.

(2) Among the different capacitors, 470 nF is recommended (not required) to filter at 5-MHz to 10-MHz frequency range.

8.3.3 Static PDN Analysis

One power net parameter derived from a PCB's PDN static analysis is the Effective Resistance (Reff). This is the total PCB power net routing resistance that is the sum of all the individual power net segments used to deliver a supply voltage to the point of load and includes any series resistive elements (i.e. current sensing resistor) that may be installed between the PMIC outputs and Processor inputs.

Copyright © 2016–2020, Texas Instruments Incorporated

8.3.4 Dynamic PDN Analysis

Three power net parameters derived from a PCB's PDN dynamic analysis are the Loop Inductance (LL), Impedance (Z) and PCB Frequency of Interest (Fpcb).

- LL values shown are the recommended max PCB trace inductance between a decoupling capacitor's power supply and ground reference terminals when viewed from the decoupling capacitor with a "theoretical shorted" applied across the Processor's supply inputs to ground reference.
- Z values shown are the recommended max PCB trace impedances allowed between Fpmic up to Fpcb frequency range that limits transient noise drops to no more than 5% of min supply voltage during max transient current events.
- Fpcb (Frequency of Interest) is defined to be a power rail's max frequency after which adding a reasonable number of decoupling capacitors no longer significantly reduces the power rail impedance below the desired impedance target (Zt2). This is due to the dominance of the PCB's parasitic planar spreading and internal package inductances.

Table 8-3. Recommended PDN and Decoupling Characteristics (1)(2)(3)(4)(5)

PDN ANALYSIS:	STATIC	DYNAMIC			NUMBER OF RECOMMENDED DECOUPLING CAPACITORS PER SUPPLY							
Supply	Max R_{eff} (7) [mΩ]	Dec. Cap. Max LL (8) (6) [nH]	Max Impedance [mΩ]	Frequency range of Interest [MHz]	100 nF (6)	220 nF	470 nF	1µF	2.2 µF	4.7 µF	10 µF	22 µF
vdd_dspeve	33	2.5	54	≤20	6	1	1	1	1	1		1
vdd	83	2	87	≤50	6	1	1	1	1	1		
vdds_ddr1, vdds_ddr2, vdds_ddr3	33	2.5	200	≤100	8	4		2		2		1
cap_vddram_core1	N/A	6	N/A	N/A				1				
cap_vddram_core2	N/A	6	N/A	N/A				1				
cap_vddram_dspeve	N/A	6	N/A	N/A				1				

(1) For more information on peak-to-peak noise values, see the Recommended Operating Conditions table of the Electrical Characteristics chapter.

(2) ESL must be as low as possible and must not exceed 0.5 nH.

(3) The PDN (Power Delivery Network) impedance characteristics are defined versus the device activity (that runs at different frequency) based on the Recommended Operating Conditions table of the Electrical Characteristics chapter.

(4) The static drop requirement drives the maximum acceptable PCB resistance between the PMIC or the external SMPS and the processor power balls.

(5) Assuming that the external SMPS (power IC) feedback sense is taken close to processor power balls.

(6) High-frequency (30 to 70MHz) PCB decoupling capacitors

(7) Maximum Total R_{eff} from PMIC output to remote sensing feedback point located as close to the Device's point of load as possible.

(8) Maximum Loop Inductance for decoupling capacitor.

8.3.5 Power Supply Mapping

TPS65917 is a Power management IC (PMIC) that can be used for the Device design. TI is now investigating an optimized solution for high power use cases so the TPS65917 is subject to change. An alternate dual converter power solution using LP8732Q and LP8733Q are recommended. TI requires the use of one of these PMIC solutions for the following reasons:

- TI has validated its use with the Device
- Board level margins including transient response and output accuracy are analyzed and optimized for the entire system
- Support for power sequencing requirements (refer to Section 5.10 *Power Sequencing*)

Copyright © 2016–2020, Texas Instruments Incorporated

- Support for Adaptive Voltage Scaling (AVS) Class 0 requirements, including TI provided software

It is possible that some voltage domains on the device are unused in some systems. In such cases, to ensure device reliability, it is still required that the supply pins for the specific voltage domains are connected to some core power supply output.

These unused supplies though can be combined with any of the core supplies that are used (active) in the system. e.g. if IVA and GPU domains are not used, they can be combined with the CORE domain, thereby having a single power supply driving the combined CORE, IVA and GPU domains.

For the combined rail, the following relaxations do apply:

- The AVS voltage of active rail in the combined rail needs to be used to set the power supply
- The decoupling capacitance should be set according to the active rail in the combined rail

Whenever we allow for combining of rails mapped on any of the SMPSes, the PDN guidelines that are the most stringent of the rails combined should be implemented for the particular supply rail.

Table 8-4 illustrates the approved and validated power supply connections to the Device for the SMPS outputs of the TPS65917 and LP8732 combined with LP8733 PMICs.

Table 8-4. Power Supply Connections

TPS65917	DUAL CONVERTER SOLUTION	VALID COMBINATION 1:
SMPS1	LP8733Q Buck0	vdd_dspeve
SMPS2	LP8733Q Buck1	vdd
SMPS3	LP8732Q Buck0	vdds18v, vdds18v_ddr[3:1], vddshv[6:1]
SMPS4	LP8732Q Buck1	vdds_ddr1, vdds_ddr2, vdds_ddr3

Table 8-5 illustrates the LP8733 and LP8732 OTP IDs required for TDA3 processor systems using different DDR memory types.

Table 8-5. OTP ID Memory Types Support

DDR Type	LP8733Q	LP8732Q
	OTP VERSION	OTP VERSION
DDR2	2A	2D
LPDDR2	2A	2B
DDR3	2A	2F
DDR3L	2A	2E

8.3.6 DPLL Voltage Requirement

The voltage input to the DPLLs has a low noise requirement. Board designs should supply these voltage inputs with a low noise LDO to ensure they are isolated from any potential digital switching noise. The TPS65917 PMIC LDOLN output or LDO0 on LP8733Q dual power solution is specifically designed to meet this low noise requirement.

NOTE

For more information about Input Voltage Sources, see *DPLLs, DLLs Specifications*

Table 8-6 presents the voltage inputs that supply the DPLLs.

Table 8-6. Input Voltage Power Supplies for the DPLLs

POWER SUPPLY	DPLLs
vdda_per	DPLL_PER and PER HSDIVIDER analog power supply

Copyright © 2016–2020, Texas Instruments Incorporated

Table 8-6. Input Voltage Power Supplies for the DPLLs (continued)

POWER SUPPLY	DPLLs
vdda_ddr_dsp	DPLL_EVE_VID_DSP, DPLL_DDR and DDR HSDIVIDER analog power supply
vdda_gmac_core	GMAC PLL, GMAC HSDIVIDER, DPLL_CORE and CORE HSDIVIDER analog power supply

8.3.7 Loss of Input Power Event

A few key PDN design items needed to enable a controlled and compliant SoC power down sequence for a “Loss of Input Power” event are:

- “Loss of Input Power” early warning
  - TI EVM and Reference Design Study SCHs and PDNs achieve this by using the 1st Stage Converter’s (i.e. LM536033-Q1) Power Good status output to enable and disable the 2nd Stage PMIC devices (i.e. TPS65917/919, LP8733, and LP8732). If a different 1st Stage Converter is used, care must be taken to ensure an adequate “PG_Status” or “Vbatt_Status” signal is provided that can disable 2nd Stage PMIC to begin a controlled and compliant SoC power down sequence. The total elapsed time from asserting “PG_Status” low until SoC’s PMIC input voltage reaches minimum level of 2.75 V should be minimum of 1.5 ms and 2 ms preferred.
- Maximize discharge time of 1st Stage Vout (VSYS_3V3 power rail = input voltage to SoC PMIC).
  - TI EVM and Reference Design Study SCHs and PDNs achieve this by opening an in-line load switch immediately upon “PG_Status” low assertion in order to remove the SoC’s 3.3V IO load current from VSYS_3V3. This will extend the VSYS_3V3 power rail’s discharge time in order to maximize elapsed time for allowing SoC PMIC to execute a controlled and compliant power down sequence. Care should be taken to either disable or isolate any additional peripheral components that may be loading the VSYS_3V3 rail as well.
- Sufficient bulk decoupling capacitance on the 1st Stage Vout (VSYS_3V3 per PDN) that allows for desired 1.5 – 2 ms elapsed time as described above.
  - TI EVM and Reference Design Study SCHs and PDNs achieve this by using 200µF of total capacitance on VSYS_3V3. The 1st Stage Converter (i.e. LM536033-Q1) can typically drive a max of 400 µF to help extend VSYS_3V3 discharge time for a compliant SoC power down sequence.
- Optimizing the 2nd Stage SoC PMIC’s OTP settings that determines SoC power up and down sequences and total elapsed time needed for a controlled sequence.
  - TI EVM and Reference Design Study SCHs and PDNs achieve this by using optimized OTPs per the SCH and components used. The definition of these OTPs is captured in the detailed timing diagrams for both power up and down sequences. The PDN diagram typically shows a recommended PMIC OTP ID based upon the SoC and DDR memory types.

8.3.8 Example PCB Design

The following sections describe an example PCB design and its resulting PDN performance for the vdd_dspeve key processor power domain.

NOTE

Materials presented in this section are based on generic PDN analysis on PCB boards and are not specific to systems integrating the Device.

8.3.8.1 Example Stack-up

Layer Assignments:

- Layer Top: Signal and Segmented Power Plane
  - Processor and PMIC components placed on Top-side
- Layer 2: Gnd Plane1

Copyright © 2016–2020, Texas Instruments Incorporated

- Layer 3: Signals
- Layer n: Power Plane1
- Layer n+1: Power Plane 2
- Layer n+2: Signal
- Layer n+3: Gnd Plane2
- Layer Bottom: Signal and Segmented Power Planes
  - Decoupling caps, etc.

Via Technology: Through-hole

Copper Weight:

- ½ oz for all signal layers.
- 1-2oz for all power plane for improved PCB heat spreading

8.3.8.2 vdd_dspeve Example Analysis

Maximum acceptable PCB resistance (R_{eff}) between the PMIC and Processor input power balls should not exceed 33mΩ per Table 8-3 and (7).

Maximum decoupling capacitance loop inductance (LL) between Processor input power balls and decoupling capacitances should not exceed 2.5nH per Table 8-3 and (7) (ESL NOT included).

Impedance target for key frequency of interest between Processor input power balls and PMIC's SMPS output power balls should not exceed 54mΩ per Table 8-3 and (7).

Table 8-7. Example PCB vdd_dspeve PI Analysis Summary

PARAMETER	RECOMMENDATION	EXAMPLE PCB
OPP	OPP_NOM	
Clocking Rate	500 MHz	
Voltage Level	1 V	1 V
Max Current Draw	1 A	1 A
Max Effective Resistance: Power Inductor Segment Total R_{eff}	13 mΩ	11.4mΩ
Max Loop Inductance	< 2.5 nH	0.73 - 1.58 nH
Impedance Target	54 mΩ for F < 20 MHz	28.8 mΩ for F < 20MHz

Copyright © 2016–2020, Texas Instruments Incorporated

Figure 8-15 shows a PCB layout example and the resulting PI analysis results.

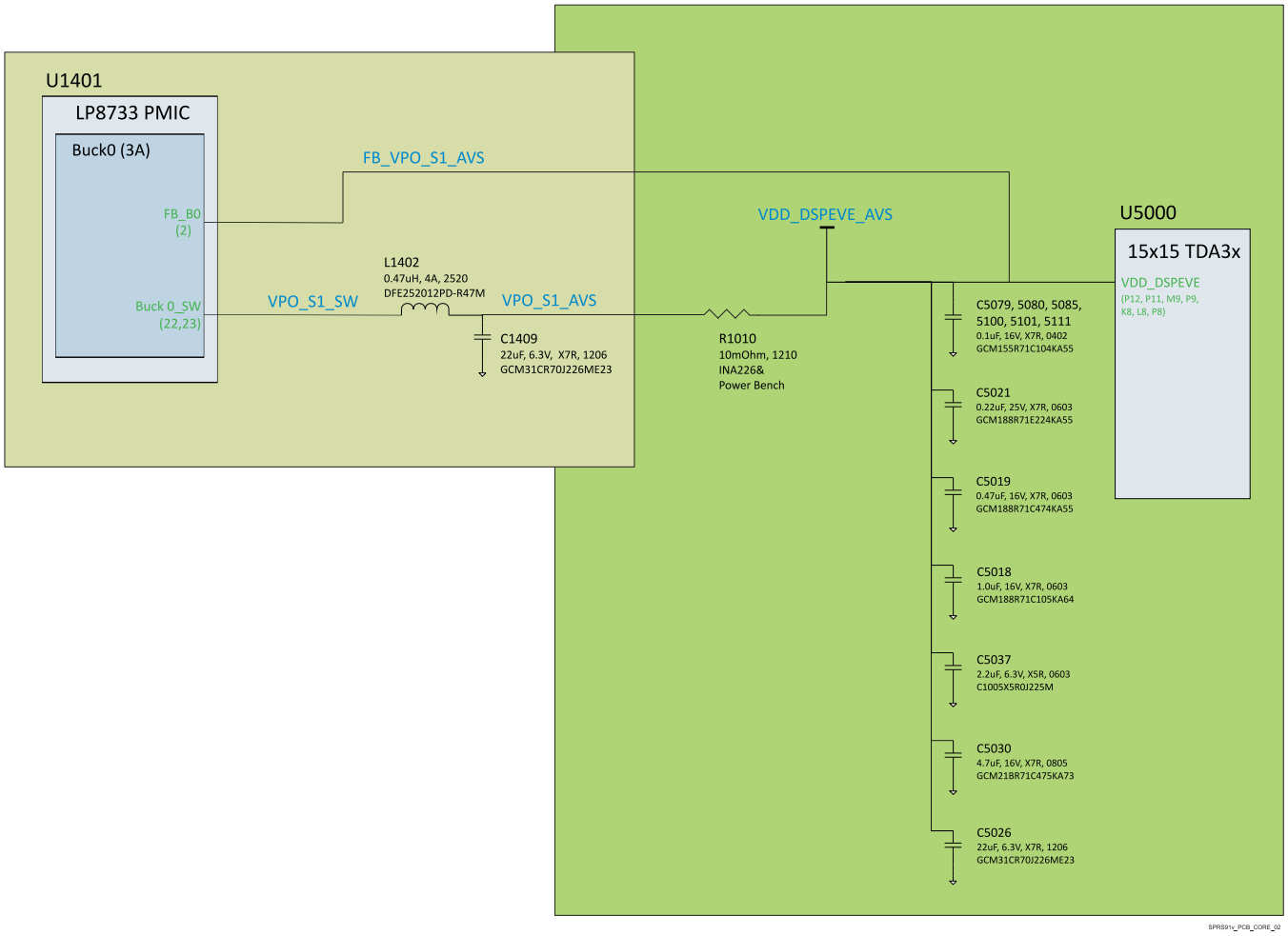


Figure 8-15. vdd_dspeve Simplified SCH Diagram

Table 8-8. DCap Scheme

VALUE [µF]	SIZE	QTY	CAPACITANCE [µF]
Cap Type: Automotive GCM series, X7R			
22	1206	1	22
4.7	805	1	4.7
2.2	603	1	2.2
1	603	1	1
0.47	603	1	0.47
0.22	603	1	0.22
0.1	402	6	0.6
TOTALS		12	31.19

Copyright © 2016–2020, Texas Instruments Incorporated

IR Drop: vdd_dspeve

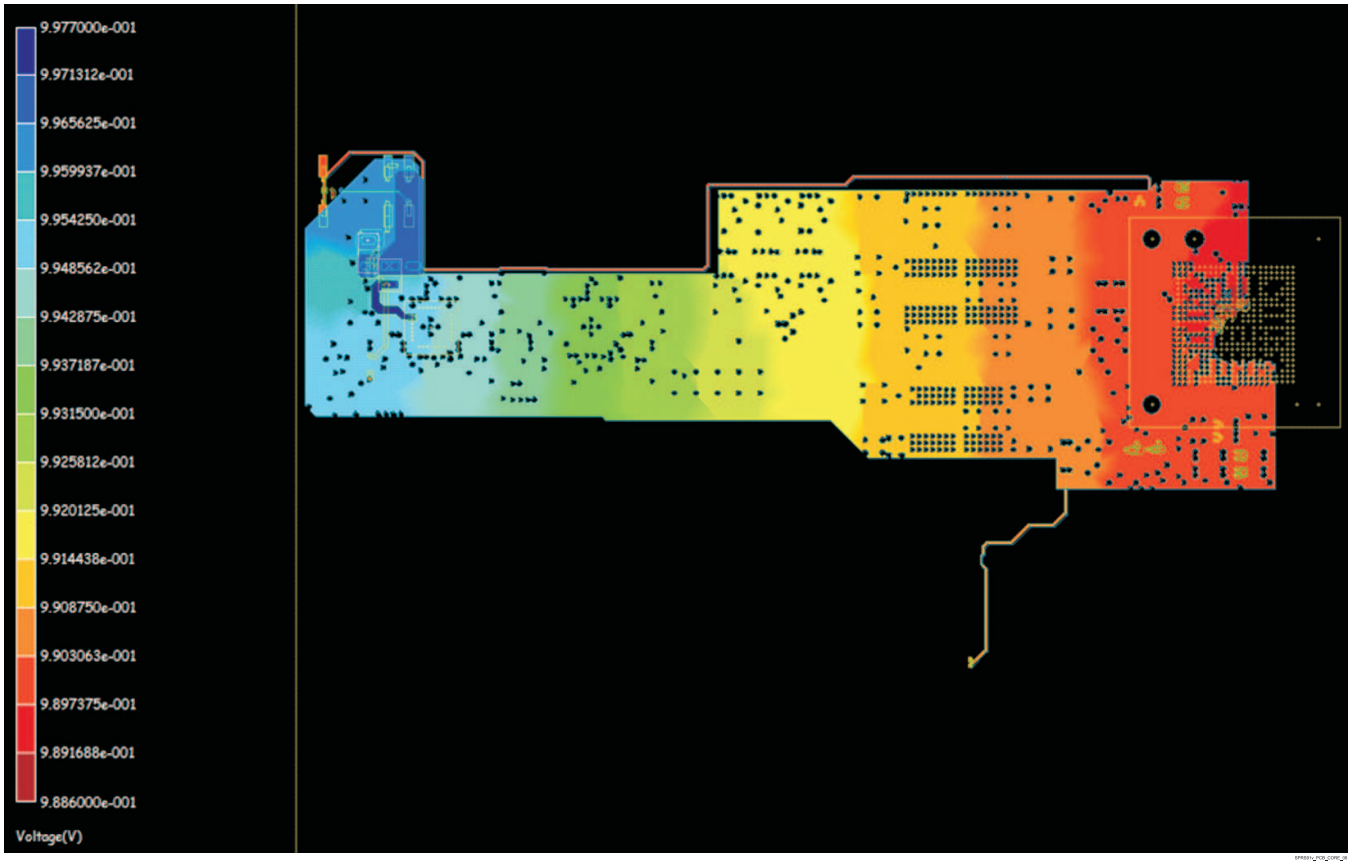


Figure 8-16. vdd_dspeve Voltage/IR Drop [All Layers]

Dynamic analysis of this PCB design for the CORE power domain determined the vdd_dspeve decoupling capacitor loop inductance and impedance vs frequency analysis shown below. As you can see, the loop inductance values ranged from 0.68 –1.79nH and were less than maximum 2.0nH recommended.

Table 8-9. Decoupling Design Detail Summary

CAP REFERENCE DESCRIPTION	LOOP INDUCTANCE AT 50MHz [nH]	FOOTPRINT TYPES	PCB SIDE	DISTANCE TO BALL-FIELD [mils]	VALUE	SIZE
C5101	0.73	2vWEE	Bottom	82	0.1	0402
C5100	0.78	2vWEE	Bottom	107	0.1	0402
C5085	0.84	2vWEE	Bottom	35	0.1	0402
C5019	1.09	4vWE	Top	631	0.47	0603
C5111	1.09	4vWE	Bottom	681	0.1	0402
C5030	1.11	4vWE	Top	738	4.7	0805
C5037	1.11	4vWE	Top	563	2.2	0603
C5018	1.14	4vWE	Top	681	1	0603
C5021	1.17	4vWE	Top	761	0.22	0603
C5026	1.18	4vWE	Top	792	22	1206
C5079	1.32	4vWE	Bottom	542	0.1	0402
C5080	1.58	4vWE	Bottom	602	0.1	0402

Copyright © 2016–2020, Texas Instruments Incorporated

Figure 8-17 shows vdd_dspeve Impedance vs Frequency characteristics.

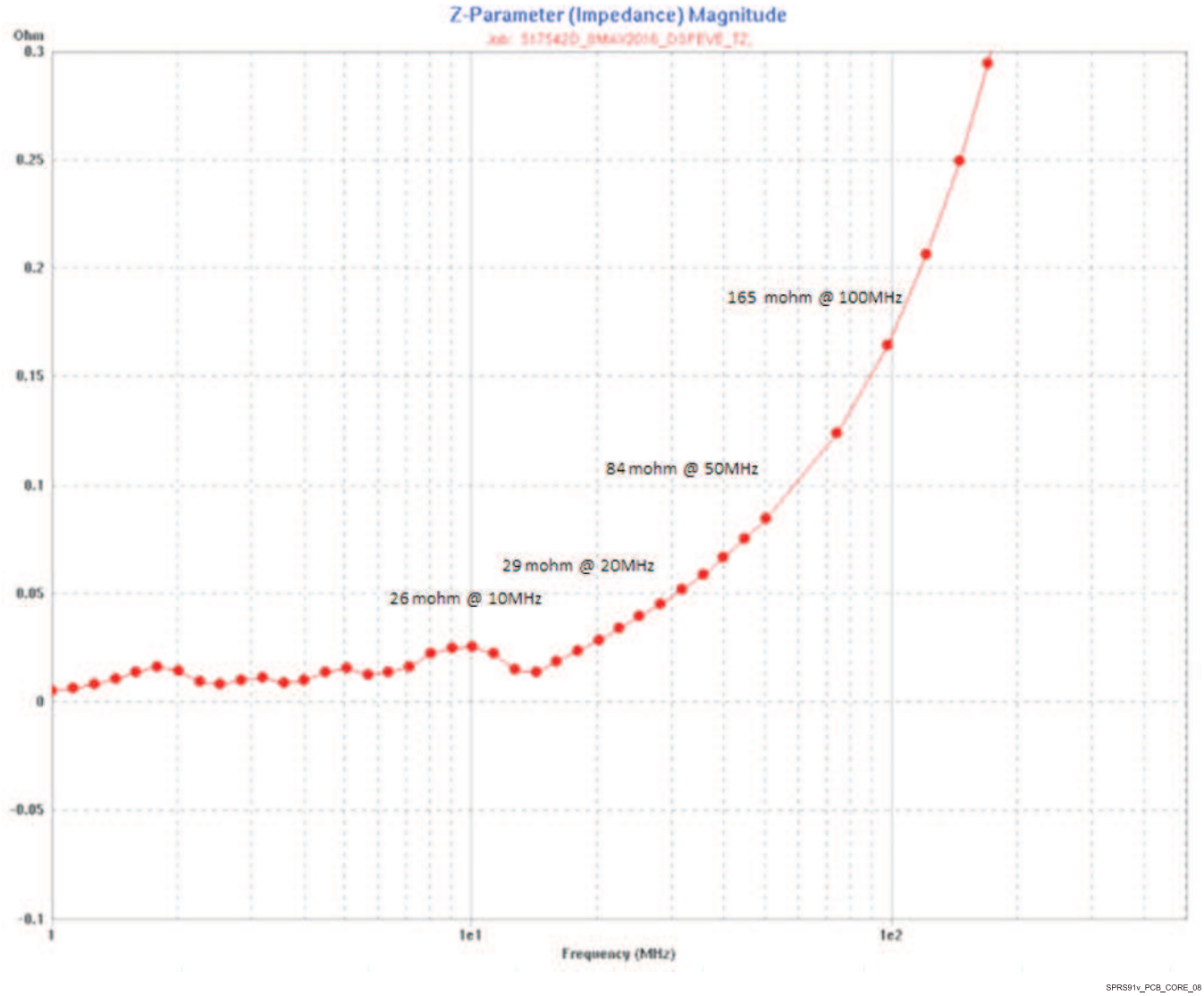


Figure 8-17. vdd_dspeve Impedance vs Frequency

8.4 Single-Ended Interfaces

8.4.1 General Routing Guidelines

The following paragraphs detail the routing guidelines that must be observed when routing the various functional LVCMOS interfaces.

Copyright © 2016–2020, Texas Instruments Incorporated

- Line spacing:
  - For a line width equal to W, the spacing between two lines must be 2W, at least. This minimizes the crosstalk between switching signals between the different lines. On the PCB, this is not achievable everywhere (for example, when breaking signals out from the device package), but it is recommended to follow this rule as much as possible. When violating this guideline, minimize the length of the traces running parallel to each other (see Figure 8-18).

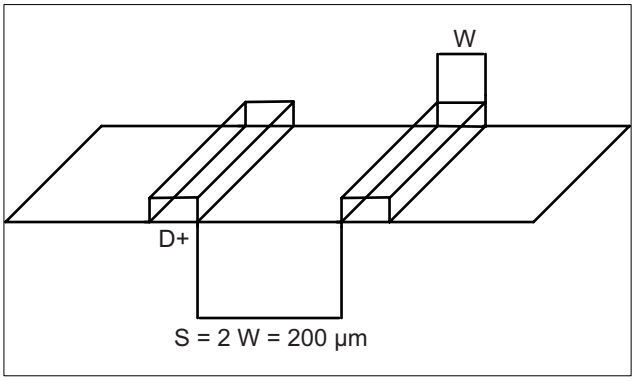


Figure 8-18. Ground Guard Illustration

- Length matching (unless otherwise specified):
  - For bus or traces at frequencies less than 10 MHz, the trace length matching (maximum length difference between the longest and the shortest lines) must be less than 25 mm.
  - For bus or traces at frequencies greater than 10 MHz, the trace length matching (maximum length difference between the longest and the shortest lines) must be less than 2.5 mm.
- Characteristic impedance
  - Unless otherwise specified, the characteristic impedance for single-ended interfaces is recommended to be between 35-Ω and 65-Ω.
- Multiple peripheral support
  - For interfaces where multiple peripherals have to be supported in the star topology, the length of each branch has to be balanced. Before closing the PCB design, it is highly recommended to verify signal integrity based on simulations including actual PCB extraction.

8.4.2 QSPI Board Design and Layout Guidelines

The following section details the routing guidelines that must be observed when routing the QSPI interfaces.

8.4.2.1 If QSPI is operated in Mode 0 (POL=0, PHA=0):

- The qspi1_sclk output signal must be looped back into the qspi1_rtclk input.
- The signal propagation delay from the qspi1_sclk ball to the QSPI device CLK input pin (A to C) must be approximately equal to the signal propagation delay from the QSPI device CLK pin to the qspi1_rtclk ball (C to D).
- The signal propagation delay from the QSPI device CLK pin to the qspi1_rtclk ball (C to D) must be approximately equal to the signal propagation delay of the control and data signals between the QSPI device and the SoC device (E to F, or F to E).
- The signal propagation delay from the qspi1_sclk signal to the series terminators (R2 = 10 Ω) near the QSPI device must be < 450pS (~7cm as stripline or ~8cm as microstrip)
- 50 Ω PCB routing is recommended along with series terminations, as shown in Figure 8-19.

Copyright © 2016–2020, Texas Instruments Incorporated

- Propagation delays and matching:
  - A to C = C to D = E to F
  - Matching skew: < 60pS
  - A to B < 450pS
  - B to C = as small as possible (<60pS)

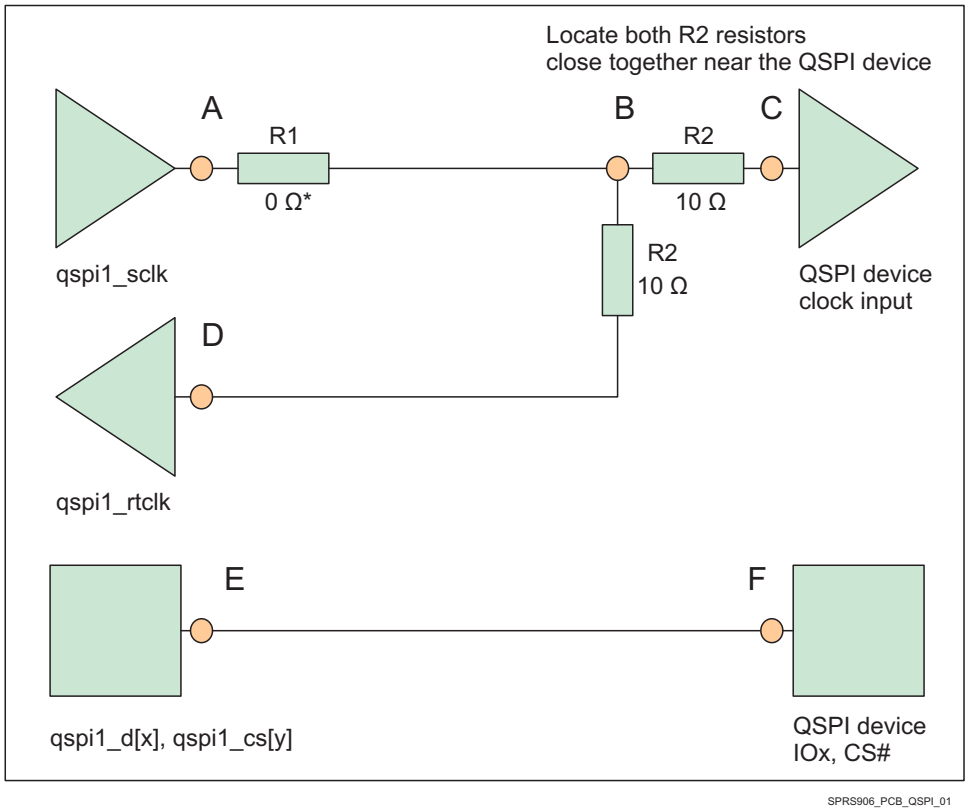


Figure 8-19. QSPI Interface High Level Schematic Mode 0 (POL=0, PHA=0)

NOTE

*0 Ω resistor (R1), located as close as possible to the qspi1_sclk pin, is placeholder for fine-tuning if needed.

8.4.2.2 If QSPI is operated in Mode 3 (POL=1, PHA=1):

- The qspi1_rtclk input can be left unconnected.
- The signal propagation delay from the qspi1_sclk signal to the QSPI device CLK pin (A to C) must be approximately equal to the signal propagation delay of the control and data signals between the QSPI device and the SoC device (E to F, or F to E).
- The signal propagation delay from the qspi1_sclk signal to the QSPI device CLK pin (A to C) must be < 450pS (~7cm as stripline or ~8cm as microstrip).
- 50 Ω PCB routing is recommended along with series terminations, as shown in Figure 8-20.
- Propagation delays and matching:
  - A to C = E to F.
  - Matching skew: < 60Ps
  - A to B < 450pS

Copyright © 2016–2020, Texas Instruments Incorporated

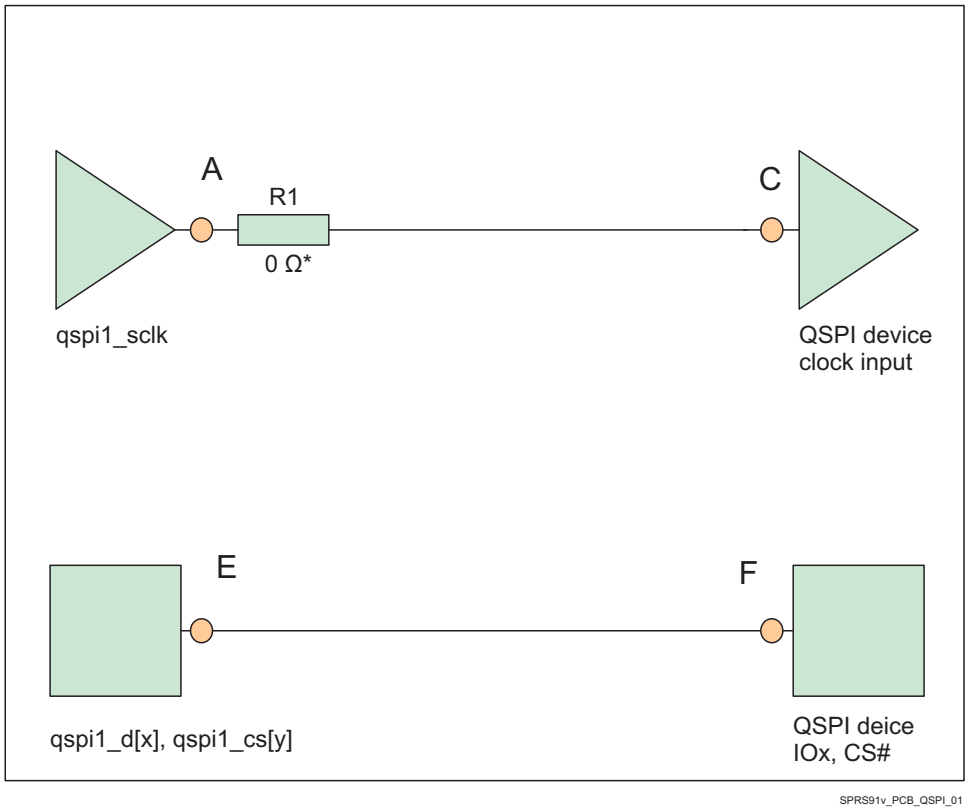


Figure 8-20. QSPI Interface High Level Schematic Mode 3 (POL=1, PHA=1)

NOTE

*0 Ω resistor (R1), located as close as possible to the qspi1_sclk pin, is placeholder for fine-tuning if needed.

8.5 Differential Interfaces

8.5.1 General Routing Guidelines

To maximize signal integrity, proper routing techniques for differential signals are important for high speed designs. The following general routing guidelines describe the routing guidelines for differential lanes and differential signals.

- As much as possible, no other high-frequency signals must be routed in close proximity to the differential pair.
- Must be routed as differential traces on the same layer. The trace width and spacing must be chosen to yield the differential impedance value recommended.
- Minimize external components on differential lanes (like external ESD, probe points).
- Through-hole pins are not recommended.
- Differential lanes mustn't cross image planes (ground planes).
- No sharp bend on differential lanes.
- Number of vias on the differential pairs must be minimized, and identical on each line of the differential pair. In case of multiple differential lanes in the same interface, all lines should have the same number of vias.
- Shielded routing is to be promoted as much as possible (for instance, signals must be routed on internal layers that are inside power and/or ground planes).

Copyright © 2016–2020, Texas Instruments Incorporated

8.5.2 CSI2 Board Design and Routing Guidelines

The MIPI D-PHY signals include the CSI2 camera serial interfaces to or from the Device.

For more information regarding the MIPI-PHY signals and corresponding balls, see Table 4-10, *CSI2 Signal Descriptions*.

For more information, you can also see the MIPI D-PHY specification v1-01-00_r0-03 (specifically the Interconnect and Lane Configuration and Annex B Interconnect Design Guidelines chapters).

In the next section, the PCB guidelines of the following differential interfaces are presented:

- CSI2_0 MIPI CSI-2 at 1.5 Gbps

Table 8-10 lists the MIPI D-PHY interface signals in the Device.

Table 8-10. MIPI D-PHY Interface Signals in the Device

SIGNAL NAME	BALL	SIGNAL NAME	BALL
csi2_0_dx0	A11	csi2_0_dy0	B11
csi2_0_dx1	A12	csi2_0_dy1	B12
csi2_0_dx2	A13	csi2_0_dy2	B13
csi2_0_dx3	A15	csi2_0_dy3	B15
csi2_0_dx4	A16	csi2_0_dy4	B16

8.5.2.1 CSI2_0 MIPI CSI-2 (1.5 Gbps)

8.5.2.1.1 General Guidelines

The general guidelines for the PCB differential lines are:

- Differential trace impedance Z_0 = 100 Ω (minimum = 85 Ω, maximum = 115 Ω)
- Total conductor length from the Device package pins to the peripheral device package pins is 25 to 30 cm with common FR4 PCB and flex materials.

NOTE

Longer interconnect length can be supported at the expense of detailed simulations of the complete link including driver and receiver models.

The general rule of thumb for the space S = 2 × W is not designated (see Figure 8-18, *Guard Illustration*). It is because although the S = 2 × W rule is a good rule of thumb, it is not always the best solution. The electrical performance will be checked with the frequency-domain specification. Even though the designer does not follow the S = 2 × W rule, the differential lines are ok if the lines satisfy the frequency-domain specification.

Because the MIPI signals are used for low-power, single-ended signaling in addition to their high speed differential implementation, the pairs must be loosely coupled.

8.5.2.1.2 Length Mismatch Guidelines

8.5.2.1.2.1 CSI2_0 MIPI CSI-2 (1.5 Gbps)

The guidelines of the length mismatch for CSI-2 are presented in Table 8-11.

Table 8-11. Length Mismatch Guidelines for CSI-2 (1.5 Gbps)

PARAMETER	TYPICAL VALUE	UNIT
Operating speed	1500	Mbps
UI (bit time)	667	ps
Intralane skew	Have to satisfy mode-conversion S parameters(1)	

Copyright © 2016–2020, Texas Instruments Incorporated

Table 8-11. Length Mismatch Guidelines for CSI-2 (1.5 Gbps) (continued)

PARAMETER	TYPICAL VALUE	UNIT
Interlane skew (UI / 50)	13.34	ps
PCB lane-to-lane skew (0.1 UI)	66.7	ps

(1) sdc12, scd21, scd12, sdc21, scd11, sdc11, scd22, and sdc22

8.5.2.1.3 Frequency-domain Specification Guidelines

After the PCB design is finished, the S-parameters of the PCB differential lines will be extracted with a 3D Maxwell Equation Solver such as the high-frequency structure simulator (HFSS) or equivalent, and compared to the frequency-domain specification as defined in the section 7 of the MIPI Alliance Specification for D-PHY Version v1-01-00_r0-03.

If the PCB lines satisfy the frequency-domain specification, the design is finished. Otherwise, the design needs to be improved.

8.6 Clock Routing Guidelines

8.6.1 Oscillator Ground Connection

Although the impedance of a ground plane is low it is, of course, not zero. Therefore, any noise current in the ground plane causes a voltage drop in the ground. Figure 8-21 shows the grounding scheme for slow (low frequency) clock generated from the internal oscillator.

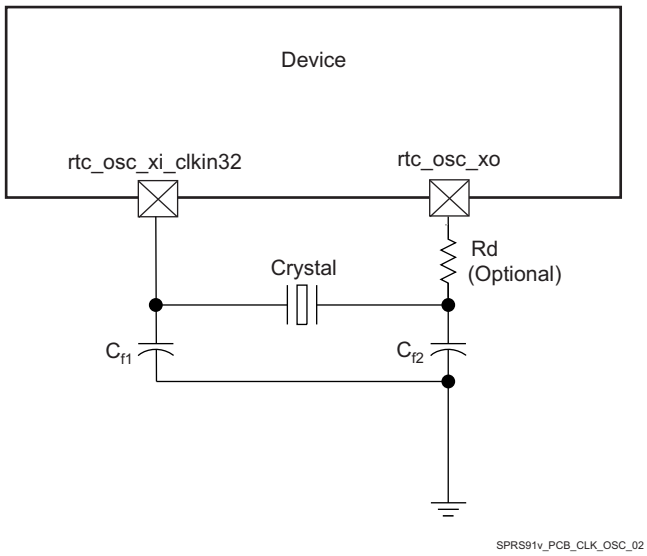
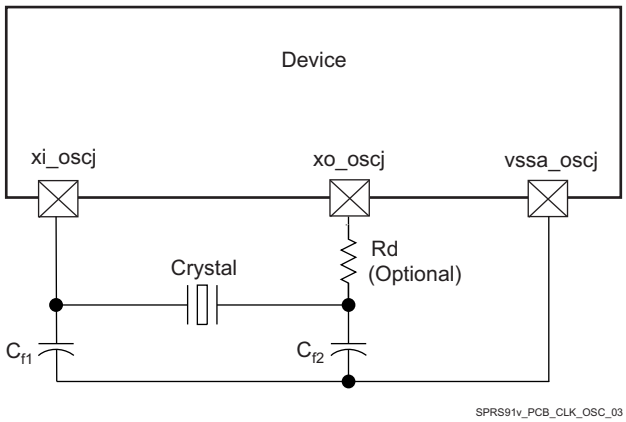


Figure 8-21. Grounding Scheme for Low-Frequency Clock

Figure 8-22 shows the grounding scheme for high-frequency clock.



(1) j in *_osc = 0 or 1

Figure 8-22. Grounding Scheme for High-Frequency Clock

8.7 LPDDR2 Board Design and Layout Guidelines

8.7.1 LPDDR2 Board Designs

TI only supports board designs using LPDDR2 memory that follow the guidelines in this document. The switching characteristics and timing diagram for the LPDDR2 memory interface are shown in Table 8-12 and Figure 8-23.

Table 8-12. Switching Characteristics for LPDDR2 Memory Interface

NO.	PARAMETER		MIN	MAX	UNIT
1	$t_{c(DDR_CK)}$	Cycle time, ddr1_ck and ddr1_nck	7.52	3.00(1)	ns

(1) The JEDEC JESD209-2F standard defines the maximum clock period of 100 ns for all standard-speed bin LPDDR2 memory. The device has only been tested per the limits published in this table.

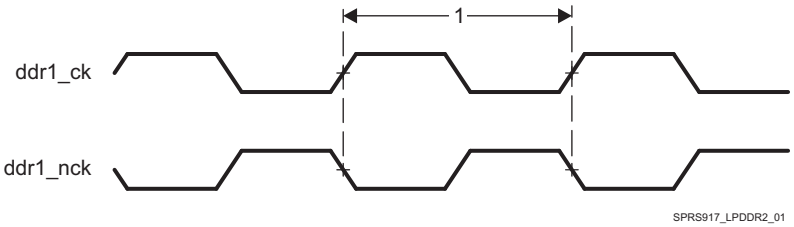


Figure 8-23. LPDDR2 Memory Interface Clock Timing

8.7.2 LPDDR2 Device Configurations

There is signal device configuration supported, supporting either 32b or 16b data widths. Table 8-13 lists all the supported configuration.

Table 8-13. Supported LPDDR2 Device Combinations

NUMBER OF LPDDR2 DEVICES	LPDDR2 DEVICE WIDTH (BITS)	MIRRORED?	LPDDR2 EMIF WIDTH (BITS)
1	32 / 16	N	32 / 16

Copyright © 2016–2020, Texas Instruments Incorporated

8.7.3 LPDDR2 Interface

8.7.3.1 LPDDR2 Interface Schematic

Figure 8-24 shows the schematic connections for 32-bit interface with or without ECC using one x32 LPDDR2 device.

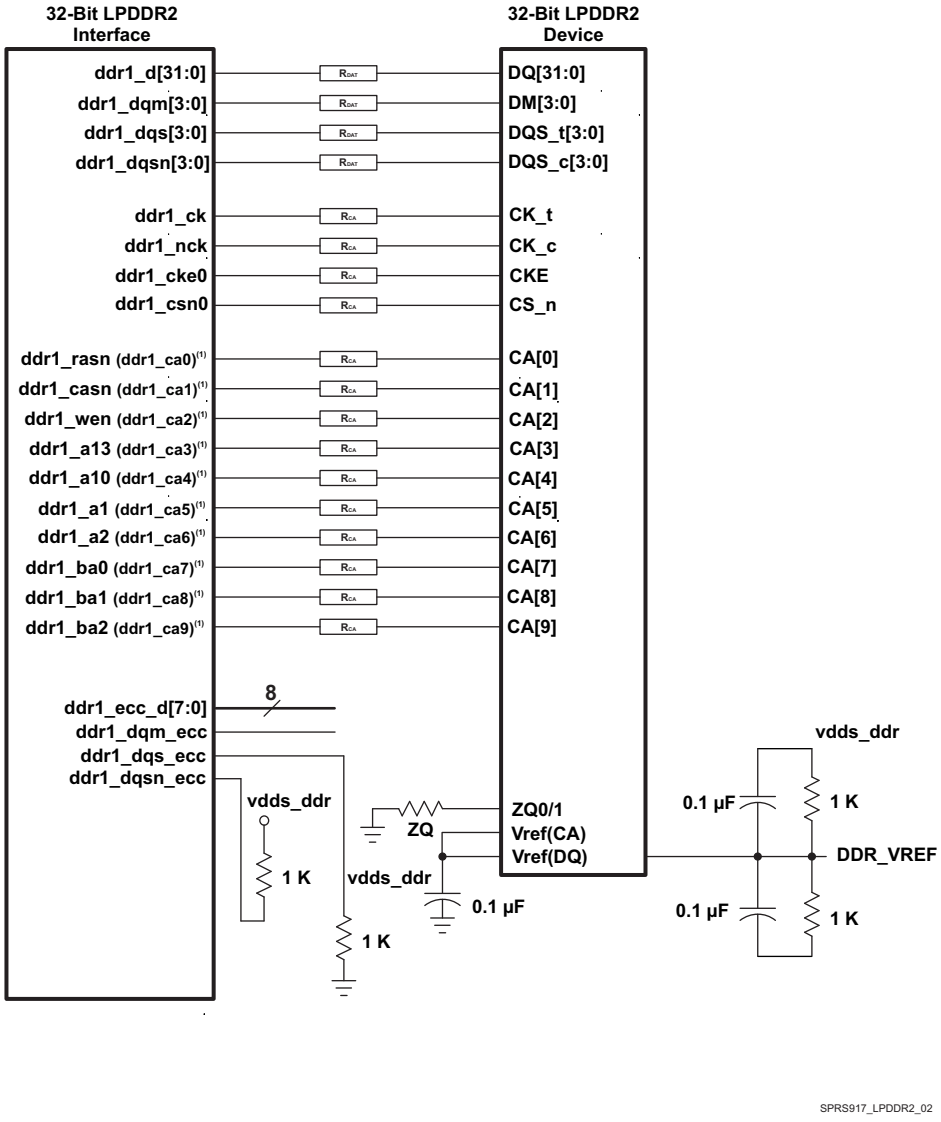


Figure 8-24. 32-Bit Interface with and without ECC using one x32 LPDDR2 device(1)(3)(4)

(1) When LPDDR2 memory are used, these signal function as ddr1_ca[9:0]. For more information, see Table 4-11, *EMIF1 Signal Descriptions*

(2) Rca is 10 Ω resistor and is to be placed near TDA3x device.

(3) The R_{DAT} is 22 Ω resistor and is to be placed near TDA3x device

(4) If ECC is required, pins available behind data lane 3 (data would then only use 16bit (lanes 1 and 2))

When not using a part of LPDDR2 interface (using x16 or not using the LPDDR2 interface):

- Connect the vdds_ddr supply to 1.8 V
- Tie off ddr1_dqs*x* (x=0,1,2,3) that are unused to vss via 1 kΩ
- Tie off ddr1_dqsn*x* (x=0,1,2,3) that are unused to vdds_ddr via 1 kΩ
- All other unused pins can be left as NC.

Note: All the unused DDR ADDR_CTRL lines used for DDR3 operation should be left as NC.

Copyright © 2016–2020, Texas Instruments Incorporated

8.7.3.2 Compatible JEDEC LPDDR2 Devices

Table 8-14 shows the supported LPDDR2 device configurations which are compatible with this interface.

Table 8-14. Compatible JEDEC LPDDR2 Devices (Per Interface)

NO.	PARAMETER	CONDITION	MIN	MAX	UNIT
1	JEDEC LPDDR2 device speed grade	$t_{c(DDR_CK)}$ and $t_{c(DDR_NCK)}$	LPDDR2-667		
2	JEDEC LPDDR2 device bit width		x16	x32	Bits
3	JEDEC LPDDR2 device count		1	1	Devices

8.7.3.3 LPDDR2 PCB Stackup

Table 8-15 shows the minimum stackup requirements. Additional layers may be added to the PCB stackup to accommodate other circuitry, enhance signal integrity and electromagnetic interference performance, or to reduce the size of the PCB footprint.

Table 8-15. Six-Layer PCB Stackup Suggestion

LAYER	TYPE	DESCRIPTION
1	Signal	Top signal routing
2	Plane	Ground
3	Signal	Signal routing
4	Plane	Split power plane
5	Plane	Ground
6	Signal	Bottom signal routing

PCB stackup specifications for LPDDR2 interface are listed in Table 8-16.

Table 8-16. PCB Stackup Specifications

NO.	PARAMETER	MIN	TYP	MAX	UNIT
1	PCB routing and plane layers	6			
2	Signal routing layers	3			
3	Full ground reference layers under LPDDR2 routing region(1)	1			
4	Full vdds_ddr power reference layers under the LPDDR2 routing region(1)	1			
5	Number of reference plane cuts allowed within LPDDR2 routing region(2)			0	
6	Number of layers between LPDDR2 routing layer and reference plane(3)			0	
7	PCB routing feature size		4		mils
8	PCB trace width, w		4		mils
9	PCB BGA escape via pad size(4)		18	20	mils
10	PCB BGA escape via hole size		8		mils
11	Single-ended impedance, Zo(5)		50	75	Ω
12	Impedance control(6)(7)	Zo-5	Zo	Zo+5	Ω

(1) Ground reference layers are preferred over power reference layers. Be sure to include bypass caps to accommodate reference layer return current as the trace routes switch routing layers.

(2) No traces should cross reference plane cuts within the LPDDR2 routing region. High speed signal traces crossing reference plane cuts create large return current paths which can lead to excessive crosstalk and EMI radiation.

(3) Reference planes are to be directly adjacent to the signal plane to minimize the size of the return current loop.

(4) An 18-mil pad assumes Via Channel is the most economical BGA escape. A 20-mil pad may be used if additional layers are available for power routing. An 18-mil pad is required for minimum layer count escape.

(5) Zo is the nominal singled-ended impedance selected for the PCB.

(6) This parameter specifies the AC characteristic impedance tolerance for each segment of a PCB signal trace relative to the chosen Zo defined by the single-ended impedance parameter.

(7) Tighter impedance control is required to ensure flight time skew is minimal.

Copyright © 2016–2020, Texas Instruments Incorporated

8.7.3.4 LPDDR2 Placement

Figure 8-25 shows the placement rules for the device as well as the LPDDR2 memory device. Placement restrictions are provided as a guidance to restrict maximum trace lengths and allow for proper routing space.

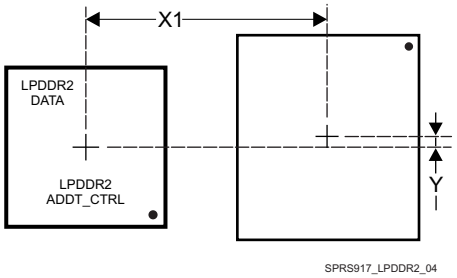


Figure 8-25. Placement Specifications

Table 8-17. Placement Specifications(1)

NO.	PARAMETER	MIN	MAX	UNIT
1	X1 Offset(2)(3)		900	mils
2	Y Offset		200	mils
3	Clearance from non-LPDDR2 signal to LPDDR2 keepout region(4)(5)	4		w

(1) LPDDR2 keepout region to encompass entire LPDDR2 routing area.

(2) Measurements from center of device to center of LPDDR2 device.

(3) Minimizing X1 and Y improves timing margins.

(4) w is defined as the signal trace width.

(5) Non-LPDDR2 signals allowed within LPDDR2 keepout region provided they are separated from LPDDR2 routing layers by a ground plane.

8.7.3.5 LPDDR2 Keepout Region

The region of the PCB used for LPDDR2 circuitry must be isolated from other signals. The LPDDR2 keepout region is defined for this purpose and is shown in Figure 8-26. This region should encompass all LPDDR2 circuitry and the region size varies with component placement and LPDDR2 routing. Non-LPDDR2 signals should not be routed on the same signal layer as LPDDR2 signals within the LPDDR2 keepout region. Non-LPDDR2 signals may be routed in the region provided they are routed on layers separated from LPDDR2 signal layers by a ground layer. No breaks should be allowed in the reference ground or vdds_ddr power plane in this region. In addition, the vdds_ddr power plane should cover the entire keepout region.

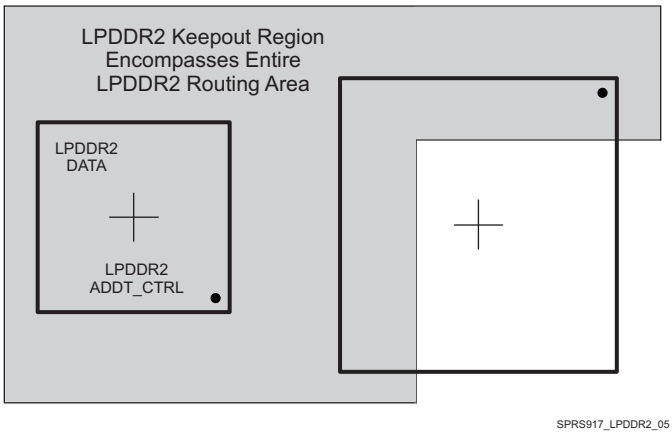


Figure 8-26. LPDDR2 Keepout Region

Copyright © 2016–2020, Texas Instruments Incorporated

8.7.3.6 LPDDR2 Net Classes

Table 8-18. Clock Net Class Definitions for the LPDDR2 Interface

CLOCK NET CLASS	PIN NAMES
CK	ddr1_ck and ddr1_nck
DQS0	ddr1_dqs0 and ddr1_dqsn0
DQS1	ddr1_dqs1 and ddr1_dqsn1
DQS2	ddr1_dqs2 and ddr1_dqsn2
DQS3	ddr1_dqs3 and ddr1_dqsn3

Table 8-19. Signal Net Class and Associated Clock Net Class for LPDDR2 Interface

SIGNAL NET CLASS	ASSOCIATED CLOCK NET CLASS	BALL NAMES
ADDR_CTRL	CK	ddr1_ba[2:0], ddr1_csn0, ddr1_cke0, ddr1_rasn, ddr1_casn, ddr1_wen, ddr1_a1, ddr1_a2, dr1_a10, ddr1_a13
DQ0	DQS0	ddr1_d[7:0], ddr1_dqm0, ddr1_dqs0, ddr1_dqsn0 (1)
DQ1	DQS1	ddr1_d[15:8], ddr1_dqm1, ddr1_dqs1, ddr1_dqsn1 (1)
DQ2	DQS2	ddr1_d[23:16], ddr1_dqm2, ddr1_dqs2, ddr1_dqsn2 (1)
DQ3	DQS3	ddr1_d[31:24], ddr1_dqm3, ddr1_dqs3, ddr1_dqsn3 (1)

(1) DQ data class includes DQS/N pins

8.7.3.7 LPDDR2 Signal Termination

On-device termination (ODT) is available for DQ[3:0] signal net classes, but is not specifically required for normal operation. System designers may evaluate the need for additional series termination if required based on signal integrity, EMI and overshoot/undershoot reduction.

On board series termination is recommended for all ADDR_CTRL and CK class signals. It is recommended a resistor with value of 10 Ω to be placed close to the TDA3x source pin (within 350 mils).

On board series termination is recommended for all DQx and DQSx class signals. It is recommended a resistor with value of 22 Ω to be placed close to the TDA3x source pin (within 500 mils).

8.7.3.8 LPDDR2 DDR_VREF Routing

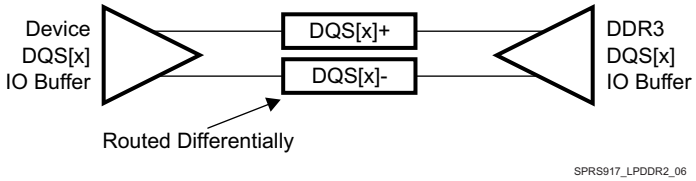
DDR_VREF is the reference voltage for the input buffers on the LPDDR2 memory. DDR_VREF is intended to be half the LPDDR2 power supply voltage and is typically generated with a voltage divider connected to the VDDS_DDR power supply. It should be routed as a nominal 20-mil wide trace with 0.1-µF bypass capacitors near each device connection. Narrowing of DDR_VREF is allowed to accommodate routing congestion.

8.7.4 Routing Specification

8.7.4.1 DQS[x] and DQ[x] Routing Specification

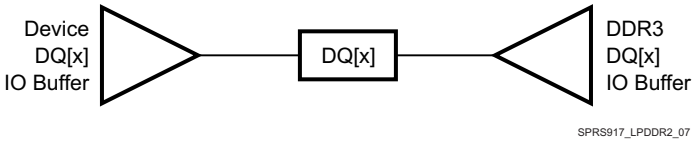
DQS[x] lines are point-to-point differential and DQ[x] lines are point-to-point single ended. Figure 8-27 and Figure 8-28 represent the supported topologies. Figure 8-29 and Figure 8-30 show the DQS[x] and DQ[x] routing. Figure 8-31 shows the DQLM for the LPDDR2 interface.

Copyright © 2016–2020, Texas Instruments Incorporated



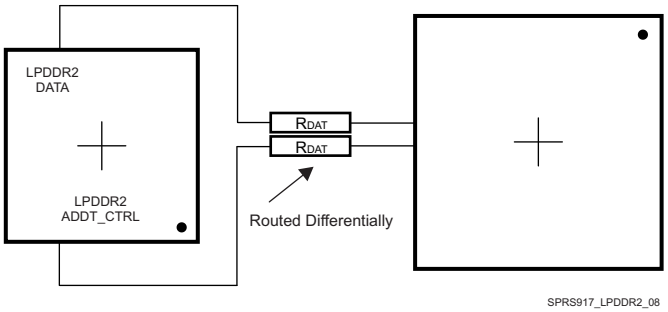
x = 0, 1, 2, 3

Figure 8-27. DQS[x] Topology



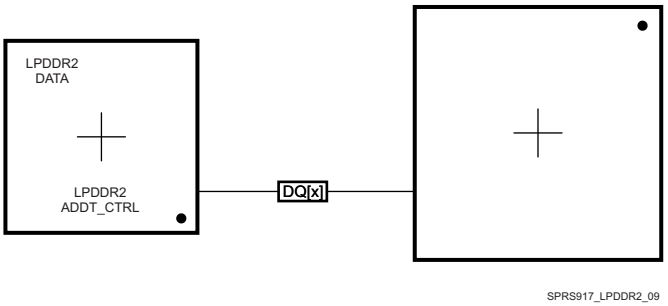
x = 0, 1, 2, 3

Figure 8-28. DQ[x] Topology



x = 0, 1, 2, 3

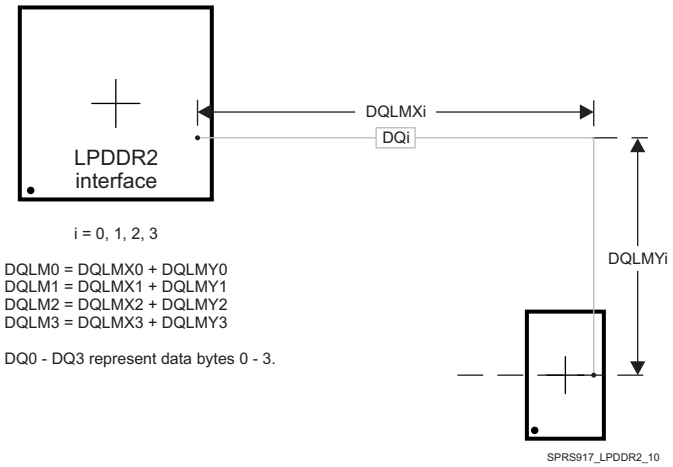
Figure 8-29. DQS[x] Routing



x = 0, 1, 2, 3

Figure 8-30. DQ[x] Routing

Copyright © 2016–2020, Texas Instruments Incorporated



There are four DQLMs, one for each data byte, in a 32-bit interface and two DQLMs, one for each data byte, in a 16-bit interface. Each DQLM is the longest Manhattan distance of the byte.

Figure 8-31. DQLM for LPDDR2 Interface

Trace routing specifications for the DQ[x] and the DQS[x] are specified in Table 8-20.

Table 8-20. DQS[x] and DQ[x] Routing Specification(1)(2)

NO.	PARAMETER	MIN	TYP	MAX	UNIT
1	DQ0 nominal length(3)(4)			DQLM0	mils
2	DQ1 nominal length(3)(5)			DQLM1	mils
3	DQ2 nominal length (3)(6)			DQLM2	mils
4	DQ3 nominal length (3)(7)			DQLM3	mils
5	DQ[x] skew(8)			10	ps
6	DQS[x] skew			5	ps
7	Via count per each trace in DQ[x], DQS[x]			2	
8	Via count difference across a given DQ[x], DQS[x]			0	
9	DQS[x]-to-DQ[x] skew(8)(9)			10	ps
10	Center-to-center DQ[x] to other LPDDR2 trace spacing(10)(11)	4			w
11	Center-to-center DQ[x] to other DQ[x] trace spacing(10)(12)	3			w
12	DQS[x] center-to-center spacing(13)				
13	DQS[x] center-to-center spacing to other net(10)	4			w

(1) DQS[x] represents the DQS0, DQS1, DQS2, DQS3 clock net classes, and DQ[x] represents the DQ0, DQ1, DQ2, DQ3 signal net classes.

(2) External termination disallowed. Data termination should use built-in ODT functionality.

(3) DQLMn is the longest Manhattan distance of a byte.

(4) DQLM0 is the longest Manhattan length for the DQ0 net class.

(5) DQLM1 is the longest Manhattan length for the DQ1 net class.

(6) DQLM2 is the longest Manhattan length for the DQ2 net class.

(7) DQLM3 is the longest Manhattan length for the DQ3 net class.

(8) Length matching is only done within a byte. Length matching across bytes is not required.

(9) Each DQS clock net class is length matched to its associated DQ signal net class.

(10) Center-to-center spacing is allowed to fall to minimum for up to 1000 mils of routed length.

(11) Other LPDDR2 trace spacing means signals that are not part of the same DQ[x] signal net class.

(12) This applies to spacing within same DQ[x] signal net class.

(13) DQS[x] pair spacing is set to ensure proper differential impedance. Differential impedance should be Zo x 2, where Zo is the single-ended impedance.

Copyright © 2016–2020, Texas Instruments Incorporated

8.7.4.2 CK and ADDR_CTRL Routing Specification

CK signals are routed as point-to-point differential, and ADDR_CTRL signals are routed as point-to-point single ended. The supported topology for CK and ADDR_CTRL are shown in Figure 8-32 through Figure 8-35. Note that ADDR_CTRL are routed very similar to DQ and CK is routed very similar to DQS.

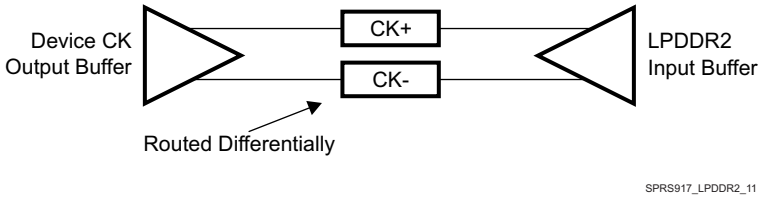


Figure 8-32. CK Signals Topology



Figure 8-33. ADDR_CTRL Signals Topology

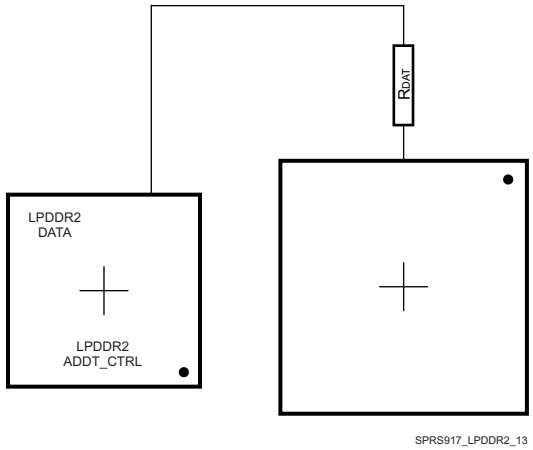


Figure 8-34. CK Signals Routing

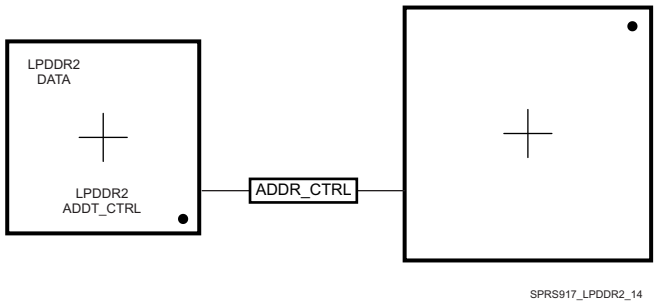
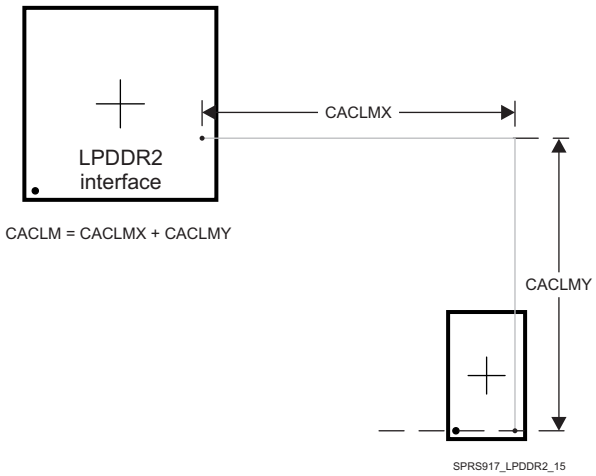


Figure 8-35. ADDR_CTRL Signals Routing

Copyright © 2016–2020, Texas Instruments Incorporated



CACLM is the longest Manhattan distance of the CK/ADDR_CTRL signal class.

Figure 8-36. CACLM for LPDDR2 Interface

Trace routing specifications for the CK and the ADD_CTRL are specified in Table 8-21.

Table 8-21. CK and ADDR_CTRL Routing Specification

NO.	PARAMETER	MIN	TYP	MAX	UNIT
1	CK and ADDR_CTRL nominal trace length(1)			CACLM	mils
2	ADDR_CTRL skew			20	ps
3	CK skew			5	ps
4	Via count per each trace ADDR_CTRL, CK			2	
5	Via count difference across ADDR_CTRL, CK			0	
6	ADDR_CTRL-to-CK skew			20	ps
7	Center-to-center ADDR_CTRL to other LPDDR2 trace spacing(2)(3)	4			w
8	Center-to-center ADDR_CTRL to other ADDR_CTRL trace spacing(2)	3			w
9	CK center-to-center spacing(4)				
10	CK center-to-center spacing to other net(2)	4			w

(1) CACLM is the longest Manhattan distance of ADDR_CTRL and CK.

(2) Center-to-center spacing is allowed to fall to minimum for up to 1000 mils of routed length.

(3) Other LPDDR2 trace spacing means signals that are not part of the same CK, ADDR_CTRL signal net class.

(4) CK pair spacing is set to ensure proper differential impedance. Differential impedance should be Zo x 2, where Zo is the single ended impedance.

8.8 DDR2 Board Design and Layout Guidelines

8.8.1 DDR2 General Board Layout Guidelines

To help ensure good signaling performance, consider the following board design guidelines:

- Avoid crossing splits in the power plane.
- Minimize Vref noise.
- Use the widest trace that is practical between decoupling capacitors and memory module.
- Maintain a single reference.
- Minimize ISI by keeping impedances matched.
- Minimize crosstalk by isolating sensitive bits, such as strobes, and avoiding return path discontinuities.
- Use proper low-pass filtering on the Vref pins.
- Keep the stub length as short as possible.
- Add additional spacing for on-clock and strobe nets to eliminate crosstalk.

Copyright © 2016–2020, Texas Instruments Incorporated

- Maintain a common ground reference for all bypass and decoupling capacitors.
- Take into account the differences in propagation delays between microstrip and stripline nets when evaluating timing constraints.

8.8.2 DDR2 Board Design and Layout Guidelines

8.8.2.1 Board Designs

TI only supports board designs that follow the guidelines outlined in this document. The switching characteristics and the timing diagram for the DDR2 memory controller are shown in Table 8-22 and Figure 8-37.

Table 8-22. Switching Characteristics Over Recommended Operating Conditions for DDR2 Memory Controller

NO.	PARAMETER	DESCRIPTION	MIN	MAX	UNIT
DDR21	$t_{c(DDR_CLK)}$	Cycle time, DDR_CLK	2.5	8	ns

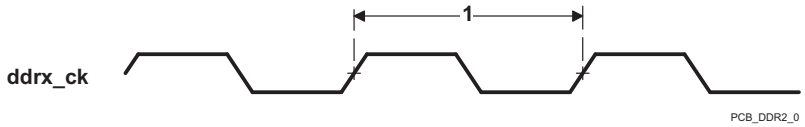


Figure 8-37. DDR2 Memory Controller Clock Timing

8.8.2.2 DDR2 Interface

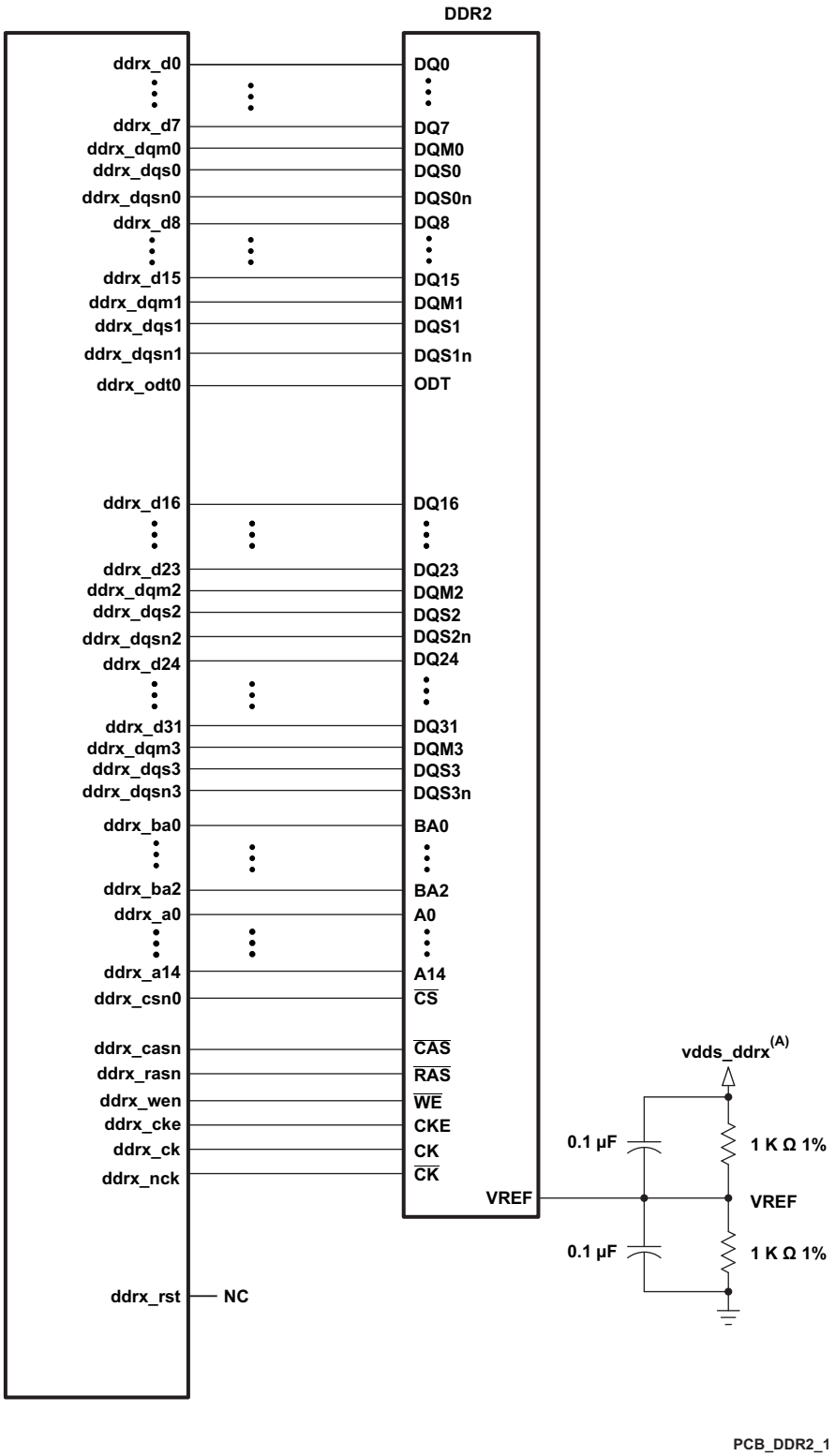
This section provides the timing specification for the DDR2 interface as a PCB design and manufacturing specification. The design rules constrain PCB trace length, PCB trace skew, signal integrity, cross-talk, and signal timing. These rules, when followed, result in a reliable DDR2 memory system without the need for a complex timing closure process. For more information regarding the guidelines for using this DDR2 specification, see the *Understanding TI's PCB Routing Rule-Based DDR Timing Specification* Application Report (Literature Number: SPRAAV0).

8.8.2.2.1 DDR2 Interface Schematic

Figure 8-38 shows the DDR2 interface schematic for a x32 DDR2 memory system. In Figure 8-39 the x16 DDR2 system schematic is identical except that the high-word DDR2 device is deleted.

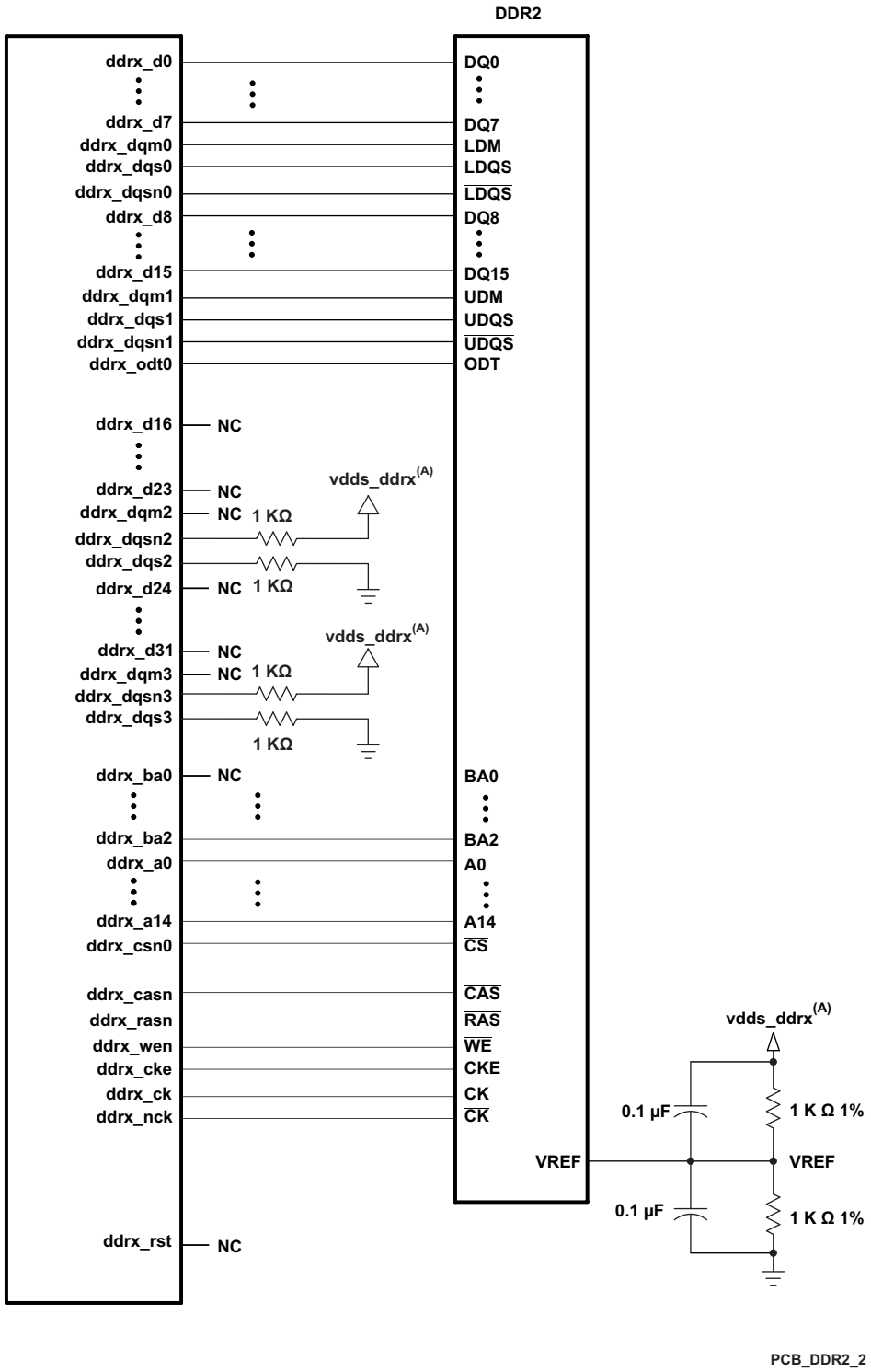
When not using all or part of a DDR2 interface, the proper method of handling the unused pins is to tie off the ddr*x*_dqs*i* pins to ground via a 1k-Ω resistor and to tie off the ddrx_dqsn*i* pins to the corresponding vdds_ddr*x* supply via a 1k-Ω resistor. This needs to be done for each byte not used. The vdds_ddr*x* and ddr*x*_vref0 power supply pins need to be connected to their respective power supplies even if DDR*x* is not being used. All other DDR interface pins can be left unconnected. Note that the supported modes for use of the DDR EMIF are 32-bits wide, 16-bits wide, or not used.

Copyright © 2016–2020, Texas Instruments Incorporated



A. vdds_ddr*x* is the power supply for the DDR2 memories and the Device DDR2 interface.
B. One of these capacitors can be eliminated if the divider and its capacitors are placed near a VREF pin.

Figure 8-38. 32-Bit DDR2 High-Level Schematic



A. vdds_ddr*x* is the power supply for the DDR2 memories and the Device DDR2 interface.
B. One of these capacitors can be eliminated if the divider and its capacitors are placed near a VREF pin.

Figure 8-39. 16-Bit DDR2 High-Level Schematic

Copyright © 2016–2020, Texas Instruments Incorporated

8.8.2.2.2 Compatible JEDEC DDR2 Devices

Table 8-23 shows the parameters of the JEDEC DDR2 devices that are compatible with this interface. Generally, the DDR2 interface is compatible with x16/x32 DDR2-800 speed grade DDR2 devices.

Table 8-23. Compatible JEDEC DDR2 Devices (Per Interface)

NO.	PARAMETER	MIN	MAX	UNIT
CJ21	JEDEC DDR2 device speed grade(1)	DDR2-800		
CJ22	JEDEC DDR2 device bit width	x16	x32	Bits
CJ23	JEDEC DDR2 device count(2)	1	1	Devices

(1) Higher DDR2 speed grades are supported due to inherent JEDEC DDR2 backwards compatibility.

(2) One DDR2 device is used for a 16-bit DDR2 and 32-bit DDR2 memory system.

8.8.2.2.3 PCB Stackup

The minimum stackup required for routing the Device is a six-layer stackup as shown in Table 8-24. Additional layers may be added to the PCB stackup to accommodate other circuitry or to reduce the size of the PCB footprint.

Table 8-24. Minimum PCB Stackup

LAYER	TYPE	DESCRIPTION
1	Signal	External Routing
2	Plane	Ground
3	Plane	Power
4	Signal	Internal routing
5	Plane	Ground
6	Signal	External Routing

Copyright © 2016–2020, Texas Instruments Incorporated

Complete stackup specifications are provided in Table 8-25.

Table 8-25. PCB Stackup Specifications

NO.	PARAMETER	MIN	TYP	MAX	UNIT
PS21	PCB routing/plane layers	6			
PS22	Signal routing layers	3			
PS23	Full ground reference layers under DDR2 routing region(1)	1			
PS24	Full vdds_ddr*x* power reference layers under the DDR2 routing region(1)	1			
PS25	Number of reference plane cuts allowed within DDR routing region(2)			0	
PS26	Number of layers between DDR2 routing layer and reference plane(3)			0	
PS27	PCB routing feature size		4		Mils
PS28	PCB trace width, w		4		Mils
PS29	Single-ended impedance, Zo	50		75	Ω
PS210	Impedance control(4)	Z-5	Z	Z+5	Ω

(1) Ground reference layers are preferred over power reference layers. Be sure to include bypass caps to accommodate reference layer return current as the trace routes switch routing layers. A full ground reference layer should be placed adjacent to each DDR routing layer in PCB stack up.

(2) No traces should cross reference plane cuts within the DDR routing region. High speed signal traces crossing reference plane cuts create large return current paths which can lead to excessive crosstalk and EMI radiation.

(3) Reference planes are to be directly adjacent to the signal plane to minimize the size of the return current loop.

(4) Z is the nominal singled-ended impedance selected for the PCB specified by PS29.

Copyright © 2016–2020, Texas Instruments Incorporated

8.8.2.2.4 Placement

Figure 8-40 shows the required placement for the Device as well as the DDR2 devices. The dimensions for this figure are defined in Table 8-26. The placement does not restrict the side of the PCB on which the devices are mounted. The ultimate purpose of the placement is to limit the maximum trace lengths and allow for proper routing space. For a 16-bit DDR memory system, the high-word DDR2 device is omitted from the placement.

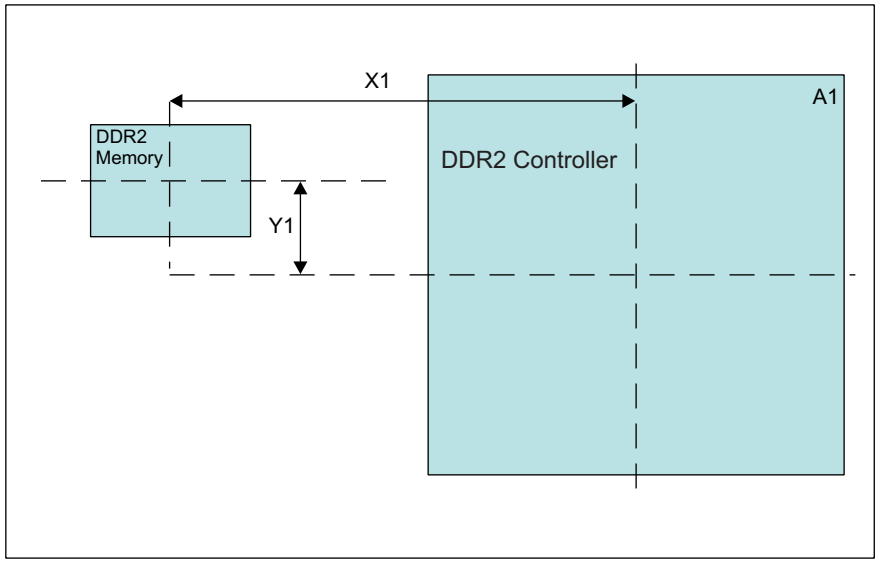


Figure 8-40. Device and DDR2 Device Placement

Table 8-26. Placement Specifications DDR2

NO.	PARAMETER	MIN	MAX	UNIT
KOD21	X1		1100	Mils
KOD22	Y1		500	Mils
KOD24	DDR2 keepout region (1)			
KOD25	Clearance from non-DDR2 signal to DDR2 keepout region (2) (3)	4		W

(1) DDR2 keepout region to encompass entire DDR2 routing area.

(2) Non-DDR2 signals allowed within DDR2 keepout region provided they are separated from DDR2 routing layers by a ground plane.

(3) If a device has more than one DDR controller, the signals from the other controller(s) are considered non-DDR2 and should be separated by this specification.

Copyright © 2016–2020, Texas Instruments Incorporated

8.8.2.2.5 DDR2 Keepout Region

The region of the PCB used for the DDR2 circuitry must be isolated from other signals. The DDR2 keepout region is defined for this purpose and is shown in Figure 8-41. The size of this region varies with the placement and DDR routing. Additional clearances required for the keepout region are shown in Table 8-26.

The region shown in Table 8-26 should encompass all the DDR2 circuitry and varies depending on placement. Non-DDR2 signals should not be routed on the DDR signal layers within the DDR2 keepout region. Non-DDR2 signals may be routed in the region, provided they are routed on layers separated from DDR2 signal layers by a ground layer. No breaks should be allowed in the reference ground layers in this region. In addition, the vdds_ddr*x* power plane should cover the entire keepout region. Routes for the two DDR interfaces must be separated by at least 4x; the more separation, the better.

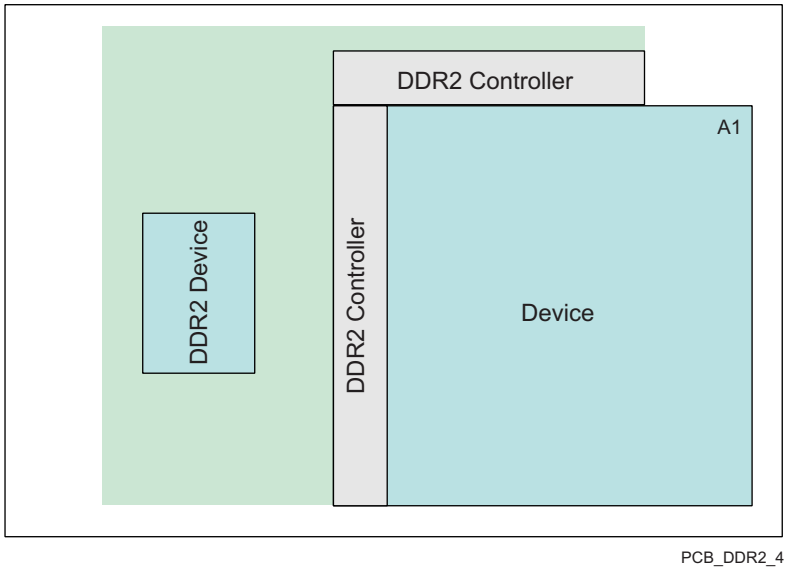


Figure 8-41. DDR2 Keepout Region

8.8.2.2.6 Bulk Bypass Capacitors

Bulk bypass capacitors are required for moderate speed bypassing of the DDR2 and other circuitry. Table 8-27 contains the minimum numbers and capacitance required for the bulk bypass capacitors. Note that this table only covers the bypass needs of the DDR2 interfaces and DDR2 device. Additional bulk bypass capacitance may be needed for other circuitry.

Table 8-27. Bulk Bypass Capacitors

NO.	PARAMETER	MIN	TYP	MAX	UNIT
BC21	vdds_ddrx bulk bypass capacitor (≥1µF) count(1)		10		Devices
BC22	vdds_ddrx bulk bypass total capacitance		50		µF

(1) These devices should be placed near the devices they are bypassing, but preference should be given to the placement of the high speed (HS) bypass capacitors and DDR2 signal routing.

8.8.2.2.7 High Speed Bypass Capacitors

TI recommends that a PDN/power integrity analysis is performed to ensure that capacitor selection and placement is optimal for a given implementation. This section provides guidelines that can serve as a good starting point.

Copyright © 2016–2020, Texas Instruments Incorporated

High speed (HS) bypass capacitors are critical for proper DDR2 interface operation. It is particularly important to minimize the parasitic series inductance of the HS bypass capacitors, processor/DDR power, and processor/DDR ground connections. Table 8-28 contains the specification for the HS bypass capacitors as well as for the power connections on the PCB. Generally speaking, it is good to:

1. Fit as many HS bypass capacitors as possible.
2. HS bypass capacitor value is < 1µF
3. Minimize the distance from the bypass cap to the pins/balls being bypassed.
4. Use the smallest physical sized capacitors possible with the highest capacitance readily available.
5. Connect the bypass capacitor pads to their vias using the widest traces possible and using the largest hole size via possible.
6. Minimize via sharing. Note the limites on via sharing shown in Table 8-28.

Table 8-28. High Speed Bypass Capacitors

NO.	PARAMETER	MIN	TYP	MAX	UNIT
HS21	HS bypass capacitor package size(1)		0201	0402	10 Mils
HS22	Distance, HS bypass capacitor to processor being bypassed(2)(3)(4)			400(12)	Mils
HS23	Processor HS bypass capacitor count (12)		12(11)		Devices
HS24	Processor HS bypass capacitor total capacitance per vdds_ddrx rail (12)		3.4		µF
HS25	Number of connection vias for each device power/ground ball per vdds_ddrx rail (5)	1			Vias
HS26	Trace length from device power/ground ball to connection via(2)		35	70	Mils
HS27	Distance, HS bypass capacitor to DDR device being bypassed(6)			150	Mils
HS28	Number of connection vias for each HS capacitor(8)(9)		4 (14)		Vias
HS29	DDR2 device HS bypass capacitor count(7)		12 (13)		Devices
HS210	DDR2 device HS bypass capacitor total capacitance(7)	0.85			µF
HS211	Trace length from bypass capacitor connect to connection via(2)(9)		35	100	Mils
HS212	Number of connection vias for each DDR2 device power/ground ball(10)	1			Vias
HS213	Trace length from DDR2 device power/ground ball to connection via(2)(8)		35	60	Mils

(1) LxW, 10-mil units, that is, a 0402 is a 40x20-mil surface-mount capacitor.

(2) Closer/shorter is better.

(3) Measured from the nearest processor power/ground ball to the center of the capacitor package.

(4) Three of these capacitors should be located underneath the processor, between the cluster of vdds_ddr*x* balls and ground balls, between the DDR interfaces on the package.

(5) See the Via Channel™ escape for the processor package.

(6) Measured from the DDR2 device power/ground ball to the center of the capacitor package.

(7) Per DDR2 device.

(8) An additional HS bypass capacitor can share the connection vias only if it is mounted on the opposite side of the board. No sharing of vias is permitted on the same side of the board.

(9) An HS bypass capacitor may share a via with a DDR device mounted on the same side of the PCB. A wide trace should be used for the connection and the length from the capacitor pad to the DDR device pad should be less than 150 mils.

(10) Up to a total of two pairs of DDR power/ground balls may share a via.

(11) The capacitor recommendations in this data manual reflect only the needs of this processor. Please see the memory vendor's guidelines for determining the appropriate decoupling capacitor arrangement for the memory device itself.

(12) For more information, see Section 8.3, *Core Power Domains*

(13) For more information refer to DDR2 specification.

(14) Preferred configuration is 4 vias: 2 to power and 2 to ground.

Copyright © 2016–2020, Texas Instruments Incorporated

8.8.2.2.8 Net Classes

Table 8-29 lists the clock net classes for the DDR2 interface. Table 8-30 lists the signal net classes, and associated clock net classes, for the signals in the DDR2 interface. These net classes are used for the termination and routing rules that follow.

Table 8-29. Clock Net Class Definitions

CLOCK NET CLASS	PIN NAMES
CK	ddr*x*_ck / ddr*x*_nck
DQS0	ddr*x*_dqs0 / ddr*x*_dqsn0
DQS1	ddr*x*_dqs1 / ddr*x*_dqsn1
DQS2(1)	ddr*x*_dqs2 / ddr*x*_dqsn2
DQS3(1)	ddr*x*_dqs3 / ddr*x*_dqsn3

(1) Only used on 32-bit wide DDR2 memory systems.

Table 8-30. Signal Net Class Definitions

SIGNAL NET CLASS	ASSOCIATED CLOCK NET CLASS	PIN NAMES
ADDR_CTRL	CK	ddr*x*_ba[2:0], ddr*x*_a[14:0], ddr*x*_csn*j*, ddr*x*_casn, ddr*x*_rasn, ddr*x*_wen, ddr*x*_cke, ddr*x*_odt*i*
DQ0	DQS0	ddr*x*_d[7:0], ddr*x*_dqm0
DQ1	DQS1	ddr*x*_d[15:8], ddr*x*_dqm1
DQ2(1)	DQS2	ddr*x*_d[23:16], ddr*x*_dqm2
DQ3(1)	DQS3	ddr*x*_d[31:24], ddr*x*_dqm3

(1) Only used on 32-bit wide DDR2 memory systems.

8.8.2.2.9 DDR2 Signal Termination

Signal terminators are NOT required in CK, ADDR_CTRL, and DATA net classes. Serial terminators may be used to reduce EMI risk; however, serial terminations are the only type permitted. ODTs are integrated on the data byte net classes. They should be enabled to ensure signal integrity. Table 8-31 shows the specifications for the series terminators.

Table 8-31. DDR2 Signal Terminations

NO.	PARAMETER	MIN	TYP	MAX	UNIT
ST21	CK net class(1)(2)	0		10	Ω
ST22	ADDR_CTRL net class(1) (2)(3)(4)	0		Zo	Ω
ST23	Data byte net classes (DQS0-DQS3, DQ0-DQ3)(5)	0		Zo	Ω

(1) Only series termination is permitted, parallel or SST specifically disallowed on board.

(2) Only required for EMI reduction.

(3) Terminator values larger than typical only recommended to address EMI issues.

(4) Termination value should be uniform across net class.

(5) No external terminations allowed for data byte net classes ODT is to be used.

8.8.2.2.10 VREF Routing

VREF (ddr*x*_vref0) is used as a reference by the input buffers of the DDR2 memories. VREF is intended to be half the DDR2 power supply voltage and should be created using a resistive divider as shown in Figure 8-39. Other methods of creating VREF are not recommended. Figure 8-42 shows the layout guidelines for VREF.

Copyright © 2016–2020, Texas Instruments Incorporated

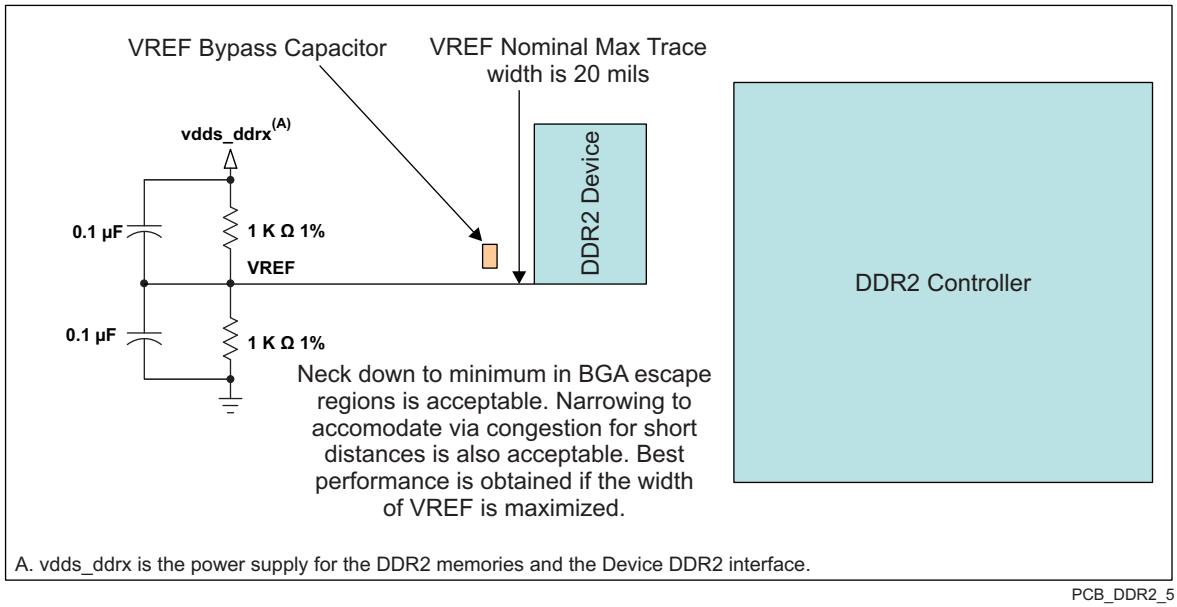


Figure 8-42. VREF Routing and Topology

8.8.2.3 DDR2 CK and ADDR_CTRL Routing

Figure 8-43 shows the topology of the routing for the CK and ADDR_CTRL net classes. The route is a point to point connection with required skew matching.

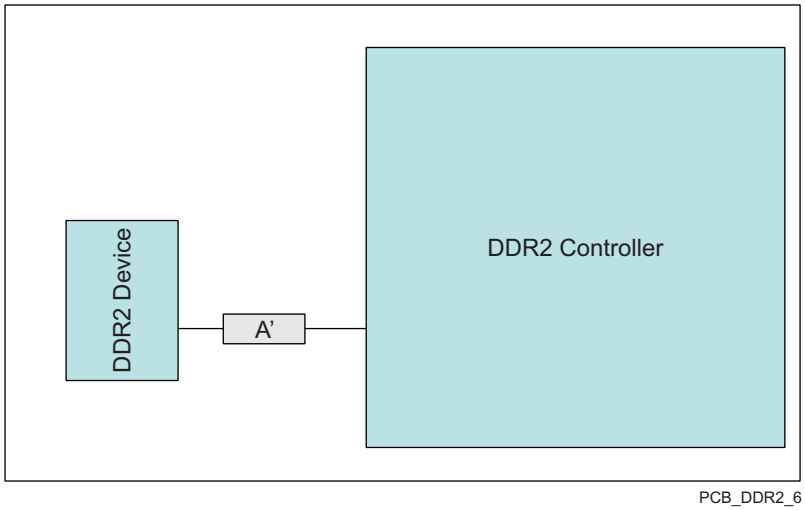


Figure 8-43. CK and ADDR_CTRL Routing and Topology

Table 8-32. CK and ADDR_CTRL Routing Specification

NO.	PARAMETER	MIN	MAX	UNIT
RSC21	Center-to-center ddr*x*_ck - ddr*x*_nck spacing		2w	
RSC22	ddr*x*_ck / ddr*x*_nck skew		5	ps
RSC25	Center-to-center CK to other DDR2 trace spacing(2)	4w		
RSC26	CK/ADDR_CTRL trace length(3)		680	ps
RSC27	ADDR_CTRL-to-CK skew mismatch		25	ps
RSC28	ADDR_CTRL-to-ADDR_CTRL skew mismatch		25	ps
RSC29	Center-to-center ADDR_CTRL to other DDR2 trace spacing(2)	4w		

Copyright © 2016–2020, Texas Instruments Incorporated

Table 8-32. CK and ADDR_CTRL Routing Specification (continued)

NO.	PARAMETER	MIN	MAX	UNIT
RSC210	Center-to-center ADDR_CTRL to other ADDR_CTRL trace spacing(2)	3w		

(1) Series terminator, if used, should be located closest to the Device.

(2) Center-to-center spacing is allowed to fall to minimum 2w for up to 500 mils of routed length to accommodate BGA escape and routing congestion.

(3) This is the longest routing length of the CK and ADDR_CTRL net classes.

Figure 8-44 shows the topology and routing for the DQS and DQ net classes; the routes are point to point. Skew matching across bytes is not needed nor recommended. The termination resistor should be placed near the processor.

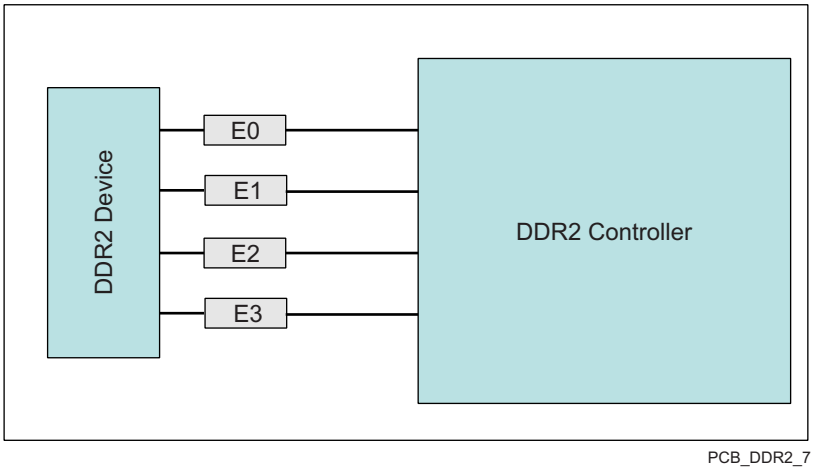


Figure 8-44. DQS and DQ Routing and Topology

Table 8-33. DQS and DQ Routing Specification

NO.	PARAMETER	MIN	MAX	UNIT
RSDQ21	Center-to-center DQS-DQSn spacing in E0|E1|E2|E3	2w		
RSDQ22	DQS-DQSn skew in E0|E1|E2|E3		5	ps
RSDQ23	Center-to-center DQS to other DDR2 trace spacing(1)	4w		
RSDQ24	DQS/DQ trace length (2)(3)(4)		325	ps
RSDQ25	DQ-to-DQS skew mismatch(2)(3)(4)		10	ps
RSDQ26	DQ-to-DQ skew mismatch(2)(3)(4)		10	ps
RSDQ27	DQ-to-DQ/DQS via count mismatch(2)(3)(4)		1	Vias
RSDQ28	Center-to-center DQ to other DDR2 trace spacing(1)(5)	4w		
RSDQ29	Center-to-center DQ to other DQ trace spacing(1)(6)(7)	3w		
RSDQ210	DQ/DQS E skew mismatch(2)(3)(4)		25	ps

(1) Center-to-center spacing is allowed to fall to minimum 2w for up to 500 mils of routed length to accommodate BGA escape and routing congestion.

(2) A 16-bit DDR memory system has two sets of data net classes; one for data byte 0, and one for data byte 1, each with an associated DQS (2 DQSs) per DDR EMIF used.

(3) A 32-bit DDR memory system has four sets of data net classes; one each for data bytes 0 through 3, and each associated with a DQS (4 DQSs) per DDR EMIF used.

(4) There is no need, and it is not recommended, to skew match across data bytes; that is, from DQS0 and data byte 0 to DQS1 and data byte1.

(5) DQs from other DQS domains are considered *other DDR2 trace*.

(6) DQs from other data bytes are considered *other DDR2 trace*.

(7) This is the longest routing distance of each of the DQS and DQ net classes.

8.9 DDR3 Board Design and Layout Guidelines

Copyright © 2016–2020, Texas Instruments Incorporated

8.9.1 DDR3 General Board Layout Guidelines

To help ensure good signaling performance, consider the following board design guidelines:

- Avoid crossing splits in the power plane.
- Use the widest trace that is practical between decoupling capacitors and memory module.
- Maintain a single reference
- Minimize ISI by keeping impedances matched.
- Minimize crosstalk by isolating sensitive bits, such as strobes, and avoiding return path discontinuities.
- Keep the stub length as short as possible.
- Add additional spacing for on-clock and strobe nets to eliminate crosstalk.
- Maintain a common ground reference for all bypass and decoupling capacitors.
- Take into account the differences in propagation delays between microstrip and stripline nets when evaluating timing constraints.

8.9.2 DDR3 Board Design and Layout Guidelines

8.9.2.1 Board Designs

TI only supports board designs using DDR3 memory that follow the guidelines in this document. The switching characteristics and timing diagram for the DDR3 memory controller are shown in Table 8-34 and Figure 8-45.

Table 8-34. Switching Characteristics Over Recommended Operating Conditions for DDR3 Memory Controller

NO.	PARAMETER		MIN	MAX	UNIT
1	$t_{c(DDR_CLK)}$	Cycle time, DDR_CLK	1.875	2.5(1)	ns

(1) This is the absolute maximum the clock period can be. Actual maximum clock period may be limited by DDR3 speed grade and operating frequency (see the DDR3 memory device data sheet).

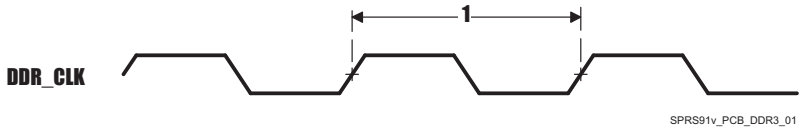


Figure 8-45. DDR3 Memory Controller Clock Timing

8.9.2.2 DDR3 Device Combinations

There are several possible combinations of device counts and single- or dual-side mounting, Table 8-35 summarizes the supported device configurations.

Table 8-35. Supported DDR3 Device Combinations

NUMBER OF DDR3 DEVICES	DDR3 DEVICE WIDTH (BITS)	ECC DEVICE WIDTH (BITS)	MIRRORED?	DDR3 EMIF WIDTH (BITS)
1	1x16	-	N	16
2	2x8	-	Y(1)	16
2	2x16	-	N	32
2	2x16	-	Y(1)	32
2	1x16	1x8	N	16
3	2x8	1x8	N	16
3	2x16	1x8	N	32

Copyright © 2016–2020, Texas Instruments Incorporated

(1) Two DDR3 devices are mirrored when one device is placed on the top of the board and the second device is placed on the bottom of the board.

8.9.2.3 DDR3 Interface Schematic

8.9.2.3.1 32-Bit DDR3 Interface

The DDR3 interface schematic varies, depending upon the width of the DDR3 devices used and the width of the bus used (16 or 32 bits). General connectivity is straightforward and very similar. 16-bit DDR devices look like two 8-bit devices. Figure 8-46 and show the schematic connections for 32-bit interfaces using x16 devices.

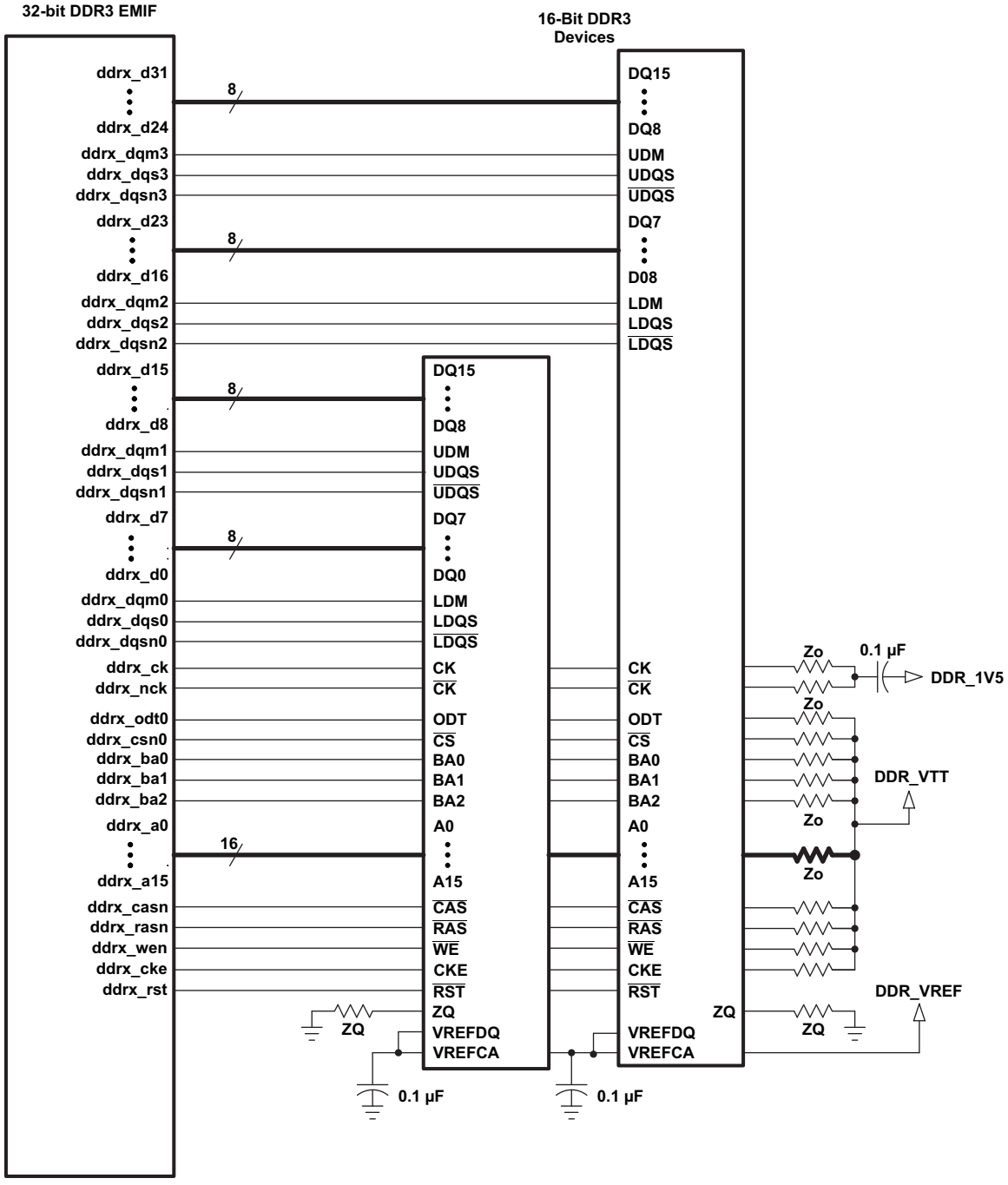
8.9.2.3.2 16-Bit DDR3 Interface

Note that the 16-bit wide interface schematic is practically identical to the 32-bit interface (see Figure 8-46); only the high-word DDR memories are removed and the unused DQS inputs are tied off.

When not using all or part of a DDR interface, the proper method of handling the unused pins is to tie off the ddrx_dqs*i* pins to ground via a 1k-Ω resistor and to tie off the ddrx_dqsn*i* pins to the corresponding vdds_ddr*x* supply via a 1k-Ω resistor. This needs to be done for each byte not used. Although these signals have internal pullups and pulldowns, external pullups and pulldowns provide additional protection against external electrical noise causing activity on the signals.

The vdds_ddr and vdds18v_ddrx power supply pins need to be connected to their respective power supplies even if upper data byte lanes are not being used. All other DDR interface pins can be left unconnected. Note that the supported modes for use of the DDR EMIF are 32-bits wide, 16-bits wide, or not used.

Copyright © 2016–2020, Texas Instruments Incorporated



Zo — Termination is required. See terminator comments.

ZQ — Value determined according to the DDR memory device data sheet.

Figure 8-46. 32-Bit, One-Bank DDR3 Interface Schematic Using Two 16-Bit DDR3 Devices

8.9.2.4 Compatible JEDEC DDR3 Devices

Table 8-36 shows the parameters of the JEDEC DDR3 devices that are compatible with this interface. Generally, the DDR3 interface is compatible with DDR3-1066 devices in the x8 or x16 widths.

Table 8-36. Compatible JEDEC DDR3 Devices

NO.	PARAMETER	CONDITION	MIN	MAX	UNIT
1	JEDEC DDR3 device speed grade(1)	DDR clock rate = 400MHz	DDR3-800	DDR3-1600	
		400MHz< DDR clock rate ≤ 533MHz	DDR3-1066	DDR3-1600	
2	JEDEC DDR3 device bit width		x8	x16	Bits
3	JEDEC DDR3 device count(2)		1	3	Devices

(1) Refer to Table 8-34 Switching Characteristics Over Recommended Operating Conditions for DDR3 Memory Controller for the range of supported DDR clock rates.

(2) For valid DDR3 device configurations and device counts, see Table 8-35 *DDR3 Device Combinations*.

8.9.2.5 PCB Stackup

The minimum stackup for routing the DDR3 interface is a six-layer stack up as shown in Table 8-37. Additional layers may be added to the PCB stackup to accommodate other circuitry, enhance SI/EMI performance, or to reduce the size of the PCB footprint. Complete stackup specifications are provided in Table 8-38.

Table 8-37. Six-Layer PCB Stackup Suggestion

LAYER	TYPE	DESCRIPTION
1	Signal	Top routing mostly vertical
2	Plane	Ground
3	Plane	Split power plane
4	Plane	Split power plane or Internal routing
5	Plane	Ground
6	Signal	Bottom routing mostly horizontal

Copyright © 2016–2020, Texas Instruments Incorporated

Table 8-38. PCB Stackup Specifications

NO.	PARAMETER	MIN	TYP	MAX	UNIT
PS1	PCB routing/plane layers	6			
PS2	Signal routing layers	3			
PS3	Full ground reference layers under DDR3 routing region(1)	1			
PS4	Full 1.5-V power reference layers under the DDR3 routing region(1)	1			
PS5	Number of reference plane cuts allowed within DDR routing region(2)			0	
PS6	Number of layers between DDR3 routing layer and reference plane(3)			0	
PS7	PCB routing feature size		4		Mils
PS8	PCB trace width, w		4		Mils
PS9	Single-ended impedance, Zo	50		75	Ω
PS10	Impedance control(5)	Z-5	Z	Z+5	Ω

(1) Ground reference layers are preferred over power reference layers. Be sure to include bypass caps to accommodate reference layer return current as the trace routes switch routing layers.

(2) No traces should cross reference plane cuts within the DDR routing region. High speed signal traces crossing reference plane cuts create large return current paths which can lead to excessive crosstalk and EMI radiation.

(3) Reference planes are to be directly adjacent to the signal plane to minimize the size of the return current loop.

(4) An 18-mil pad assumes Via Channel is the most economical BGA escape. A 20-mil pad may be used if additional layers are available for power routing. An 18-mil pad is required for minimum layer count escape.

(5) Z is the nominal singled-ended impedance selected for the PCB specified by PS9.

8.9.2.6 Placement

Figure 8-47 shows the required placement for the processor as well as the DDR3 devices. The dimensions for this figure are defined in Table 8-39. The placement does not restrict the side of the PCB on which the devices are mounted. The ultimate purpose of the placement is to limit the maximum trace lengths and allow for proper routing space. For a 16-bit DDR memory system, the high-word DDR3 devices are omitted from the placement.

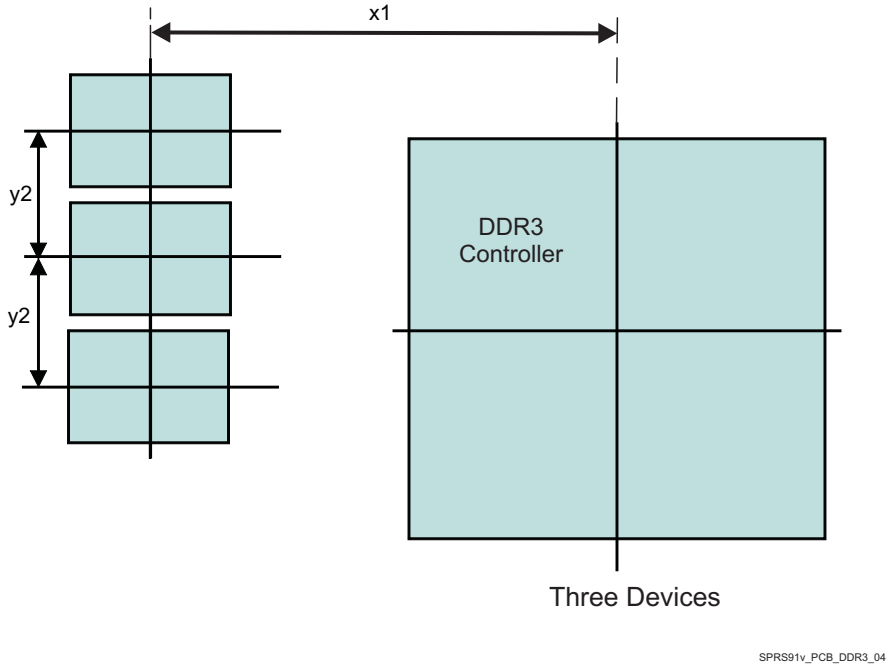


Figure 8-47. Placement Specifications

Table 8-39. Placement Specifications

No.	PARAMETER	MIN	MAX	UNIT
KOD31	X1		1700	Mils
KOD34	Y1		1800	Mils
KOD35	Y2		600	Mils
KOD36	DDR3 keepout region(1)			
KOD37	Clearance from non-DDR3 signal to DDR3 keepout region (2)(3)	4		W

(1) DDR3 keepout region to encompass entire DDR3 routing area.

(2) Non-DDR3 signals allowed within DDR3 keepout region provided they are separated from DDR3 routing layers by a ground plane.

(3) If a device has more than one DDR controller, the signals from the other controller(s) are considered non-DDR3 and should be separated by this specification.

8.9.2.7 DDR3 Keepout Region

The region of the PCB used for DDR3 circuitry must be isolated from other signals. The DDR3 keepout region is defined for this purpose and is shown in Figure 8-48. The size of this region varies with the placement and DDR routing. Additional clearances required for the keepout region are shown in Table 8-39. Non-DDR3 signals should not be routed on the DDR signal layers within the DDR3 keepout region. Non-DDR3 signals may be routed in the region, provided they are routed on layers separated from the DDR signal layers by a ground layer. No breaks should be allowed in the reference ground layers in this region. In addition, the 1.5-V DDR3 power plane should cover the entire keepout region. Also note that the two signals from the DDR3 controller should be separated from each other by the specification in Table 8-39 (see KOD37).

Copyright © 2016–2020, Texas Instruments Incorporated

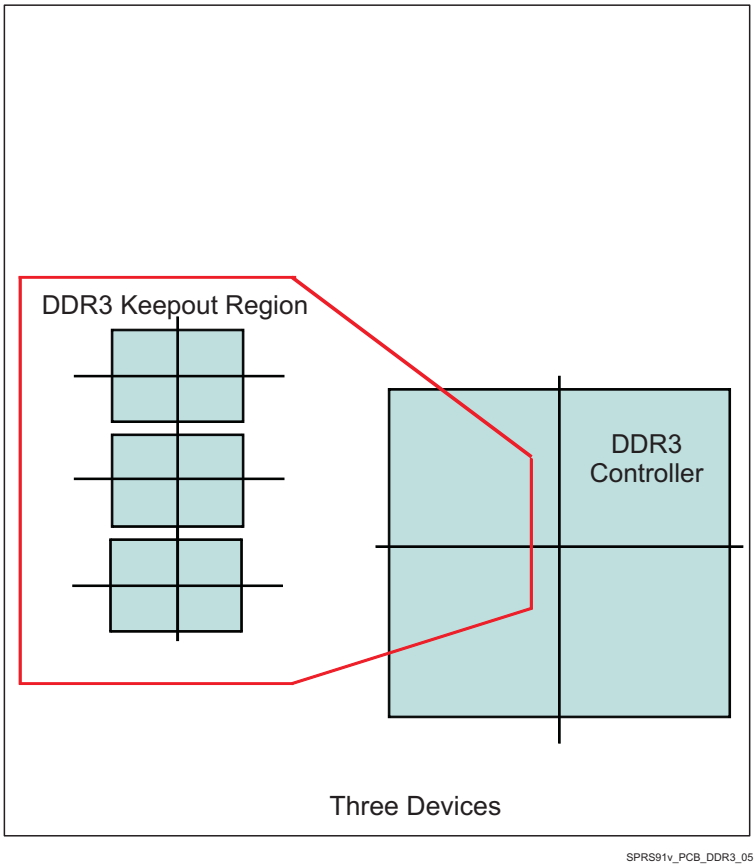


Figure 8-48. DDR3 Keepout Region

8.9.2.8 Bulk Bypass Capacitors

Bulk bypass capacitors are required for moderate speed bypassing of the DDR3 and other circuitry. Table 8-40 contains the minimum numbers and capacitance required for the bulk bypass capacitors. Note that this table only covers the bypass needs of the DDR3 controllers and DDR3 devices. Additional bulk bypass capacitance may be needed for other circuitry.

Table 8-40. Bulk Bypass Capacitors

NO.	PARAMETER	MIN	MAX	UNIT
1	vdds_ddr*x* bulk bypass capacitor count(1)	1		Devices
2	vdds_ddr*x* bulk bypass total capacitance	22		µF

(1) These devices should be placed near the devices they are bypassing, but preference should be given to the placement of the high speed (HS) bypass capacitors and DDR3 signal routing.

8.9.2.9 High Speed Bypass Capacitors

High speed (HS) bypass capacitors are critcal for proper DDR3 interface operation. It is particularly important to minimize the parasitic series inductance of the HS bypass capacitors, processor/DDR power, and processor/DDR ground connections. Table 8-41 contains the specification for the HS bypass capacitors as well as for the power connections on the PCB. Generally speaking, it is good to:

1. Fit as many HS bypass capacitors as possible.
2. Minimize the distance from the bypass cap to the pins/balls being bypassed.
3. Use the smallest physical sized capacitors possible with the highest capacitance readily available.
4. Connect the bypass capacitor pads to their vias using the widest traces possible and using the largest hole size via possible.
5. Minimize via sharing. Note the limites on via sharing shown in Table 8-41.

Table 8-41. High Speed Bypass Capacitors

NO.	PARAMETER	MIN	TYP	MAX	UNIT
1	HS bypass capacitor package size(1)		0201	0402	10 Mils
2	Distance, HS bypass capacitor to processor being bypassed(2)(3)(4)			400	Mils
3	Processor HS bypass capacitor count per vdds_ddrx rail(12)	See Table 8-3 and (11)			Devices
4	Processor HS bypass capacitor total capacitance per vdds_ddrx rail(12)	See Table 8-3 and (11)			µF
5	Number of connection vias for each device power/ground ball(5)				Vias
6	Trace length from device power/ground ball to connection via(2)		35	70	Mils
7	Distance, HS bypass capacitor to DDR device being bypassed(6)			150	Mils
8	DDR3 device HS bypass capacitor count(7)	12			Devices
9	DDR3 device HS bypass capacitor total capacitance(7)	0.85			µF
10	Number of connection vias for each HS capacitor(8)(9)	2			Vias
11	Trace length from bypass capacitor connect to connection via(2)(9)		35	100	Mils
12	Number of connection vias for each DDR3 device power/ground ball(10)	1			Vias
13	Trace length from DDR3 device power/ground ball to connection via(2)(8)		35	60	Mils

(1) LxW, 10-mil units, that is, a 0402 is a 40x20-mil surface-mount capacitor.

(2) Closer/shorter is better.

(3) Measured from the nearest processor power/ground ball to the center of the capacitor package.

(4) Three of these capacitors should be located underneath the processor, between the cluster of DDR_1V5 balls and ground balls, between the DDR interfaces on the package.

(5) See the Via Channel™ escape for the processor package.

(6) Measured from the DDR3 device power/ground ball to the center of the capacitor package.

(7) Per DDR3 device.

(8) An additional HS bypass capacitor can share the connection vias only if it is mounted on the opposite side of the board. No sharing of vias is permitted on the same side of the board.

(9) An HS bypass capacitor may share a via with a DDR device mounted on the same side of the PCB. A wide trace should be used for the connection and the length from the capacitor pad to the DDR device pad should be less than 150 mils.

(10) Up to a total of two pairs of DDR power/ground balls may share a via.

(11) The capacitor recommendations in this data manual reflect only the needs of this processor. Please see the memory vendor's guidelines for determining the appropriate decoupling capacitor arrangement for the memory device itself.

(12) For more information, see Section 8.3, *Core Power Domains*.

Copyright © 2016–2020, Texas Instruments Incorporated

8.9.2.9.1 Return Current Bypass Capacitors

Use additional bypass capacitors if the return current reference plane changes due to DDR3 signals hopping from one signal layer to another. The bypass capacitor here provides a path for the return current to hop planes along with the signal. As many of these return current bypass capacitors should be used as possible. These are returns for signal current, the signal via size may be used for these capacitors.

8.9.2.10 Net Classes

Table 8-42 lists the clock net classes for the DDR3 interface. Table 8-43 lists the signal net classes, and associated clock net classes, for signals in the DDR3 interface. These net classes are used for the termination and routing rules that follow.

Table 8-42. Clock Net Class Definitions

CLOCK NET CLASS	processor PIN NAMES
CK	ddrx_ck/ddrx_nck
DQS0	ddrx_dqs0 / ddrx_dqsn0
DQS1	ddrx_dqs1 / ddrx_dqsn1
DQS2(1)	ddrx_dqs2 / ddrx_dqsn2
DQS3(1)	ddrx_dqs3 / ddrx_dqsn3

(1) Only used on 32-bit wide DDR3 memory systems.

Table 8-43. Signal Net Class Definitions

SIGNAL NET CLASS	ASSOCIATED CLOCK NET CLASS	PROCESSOR PIN NAMES
ADDR_CTRL	CK	ddr*x*_ba[2:0], ddr*x*_a[15:0], ddr*x*_csn*j*, ddr*x*_casn, ddr*x*_rasn, ddr*x*_wen, ddr*x*_cke, ddrx_odt*i*
DQ0	DQS0	ddr*x*_d[7:0], ddr*x*_dqm0
DQ1	DQS1	ddr*x*_d[15:8], ddr*x*_dqm1
DQ2(1)	DQS2	ddr*x*_d[23:16], ddr*x*_dqm2
DQ3(1)	DQS3	ddr*x*_d[31:24], ddr*x*_dqm3

(1) Only used on 32-bit wide DDR3 memory systems.

8.9.2.11 DDR3 Signal Termination

Signal terminators are required for the CK and ADDR_CTRL net classes. The data lines are terminated by ODT and, thus, the PCB traces should be unterminated. Detailed termination specifications are covered in the routing rules in the following sections.

8.9.2.12 VTT

Like VREF, the nominal value of the VTT supply is half the DDR3 supply voltage. Unlike VREF, VTT is expected to source and sink current, specifically the termination current for the ADDR_CTRL net class Thevinen terminators. VTT is needed at the end of the address bus and it should be routed as a power sub-plane. VTT should be bypassed near the terminator resistors.

8.9.2.13 CK and ADDR_CTRL Topologies and Routing Definition

The CK and ADDR_CTRL net classes are routed similarly and are length matched to minimize skew between them. CK is a bit more complicated because it runs at a higher transition rate and is differential. The following subsections show the topology and routing for various DDR3 configurations for CK and ADDR_CTRL. The figures in the following subsections define the terms for the routing specification detailed in Table 8-44.

8.9.2.13.1 Three DDR3 Devices

Three DDR3 devices are supported on the DDR EMIF consisting of two x16 DDR3 devices and one device for ECC, arranged as one bank (CS). These three devices may be mounted on a single side of the PCB, or may be mirrored in two pairs to save board space at a cost of increased routing complexity and parts on the backside of the PCB.

8.9.2.13.1.1 CK and ADDR_CTRL Topologies, Three DDR3 Devices

Figure 8-49 shows the topology of the CK net classes and Figure 8-50 shows the topology for the corresponding ADDR_CTRL net classes.

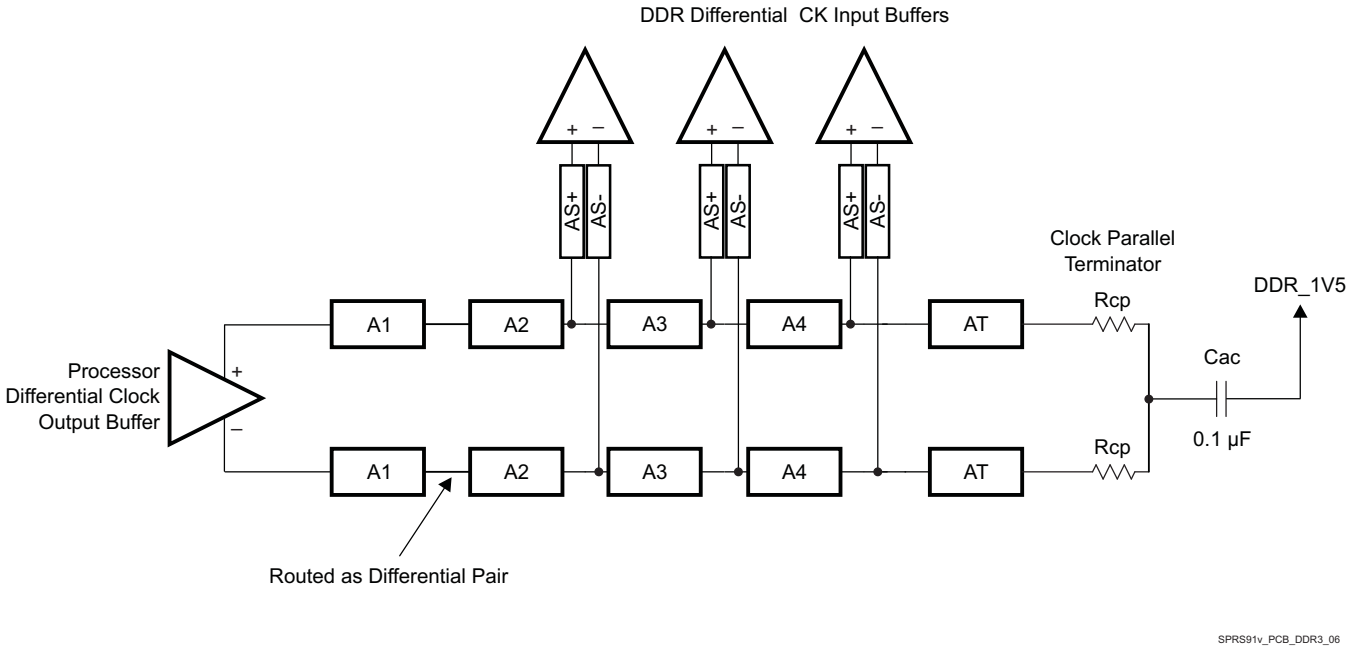


Figure 8-49. CK Topology for Three DDR3 Devices

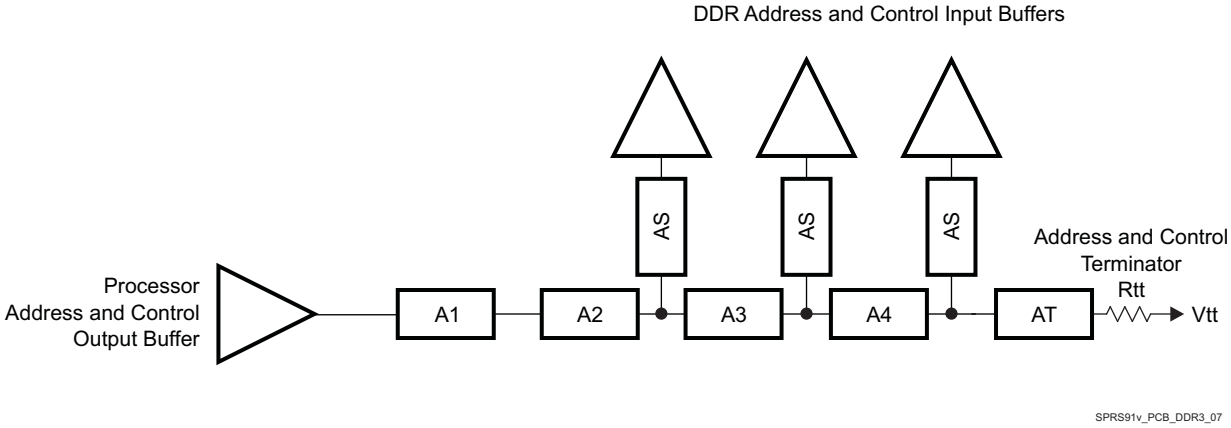


Figure 8-50. ADDR_CTRL Topology for Three DDR3 Devices

8.9.2.13.1.2 CK and ADDR_CTRL Routing, Three DDR3 Devices

Figure 8-51 shows the CK routing for three DDR3 devices placed on the same side of the PCB. Figure 8-52 shows the corresponding ADDR_CTRL routing.

Copyright © 2016–2020, Texas Instruments Incorporated

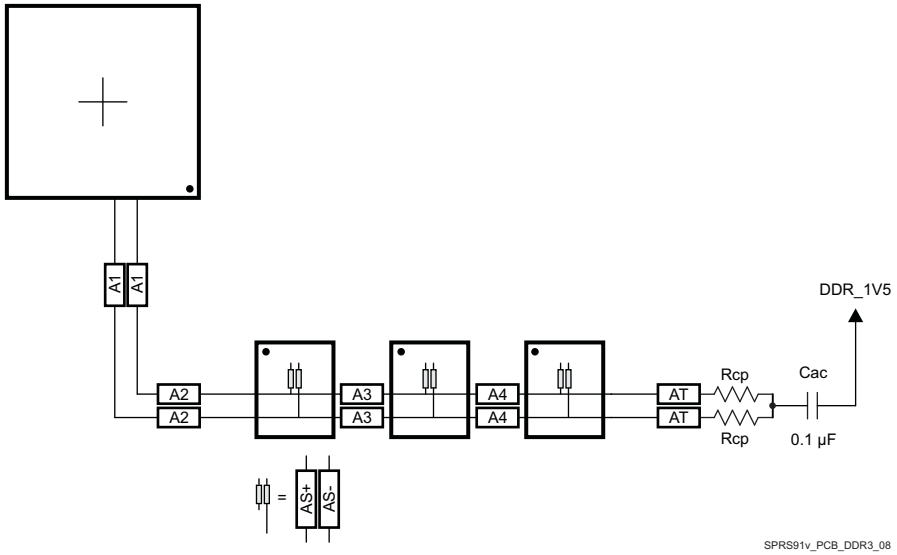


Figure 8-51. CK Routing for Three Single-Side DDR3 Devices

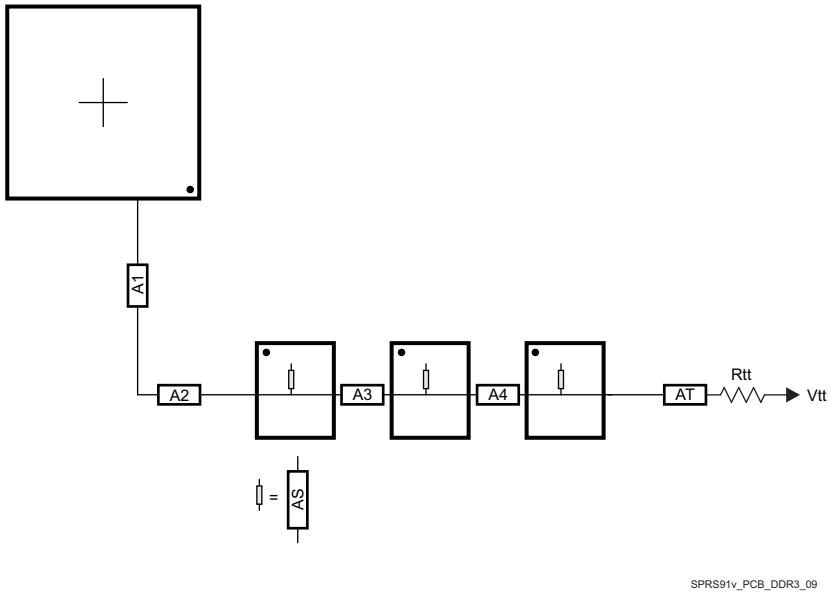


Figure 8-52. ADDR_CTRL Routing for Three Single-Side DDR3 Devices

To save PCB space, the two DDR3 memories may be mounted as one mirrored pair at a cost of increased routing and assembly complexity. Figure 8-53 and Figure 8-54 show the routing for CK and ADDR_CTRL, respectively, for two DDR3 devices mirrored in a pair configuration.

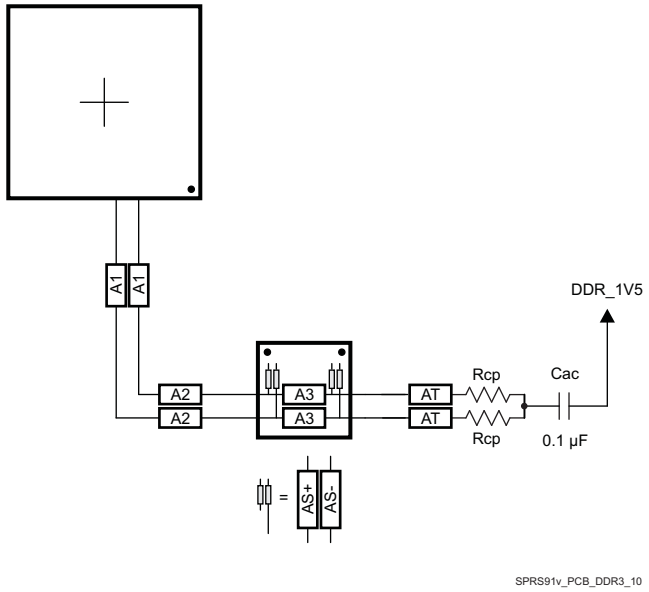


Figure 8-53. CK Routing for Two Mirrored DDR3 Devices

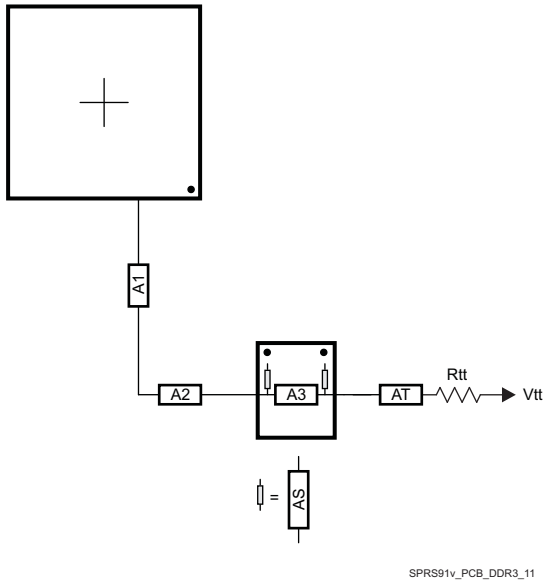


Figure 8-54. ADDR_CTRL Routing for Two Mirrored DDR3 Devices

8.9.2.13.2 Two DDR3 Devices

Two DDR3 devices are supported on the DDR EMIF consisting of two x8 DDR3 devices arranged as one bank (CS), 16 bits wide, or two x16 DDR3 devices arranged as one bank (CS), 32 bits wide. These two devices may be mounted on a single side of the PCB, or may be mirrored in a pair to save board space at a cost of increased routing complexity and parts on the backside of the PCB.

8.9.2.13.2.1 CK and ADDR_CTRL Topologies, Two DDR3 Devices

Figure 8-55 shows the topology of the CK net classes and Figure 8-56 shows the topology for the corresponding ADDR_CTRL net classes.

Copyright © 2016–2020, Texas Instruments Incorporated

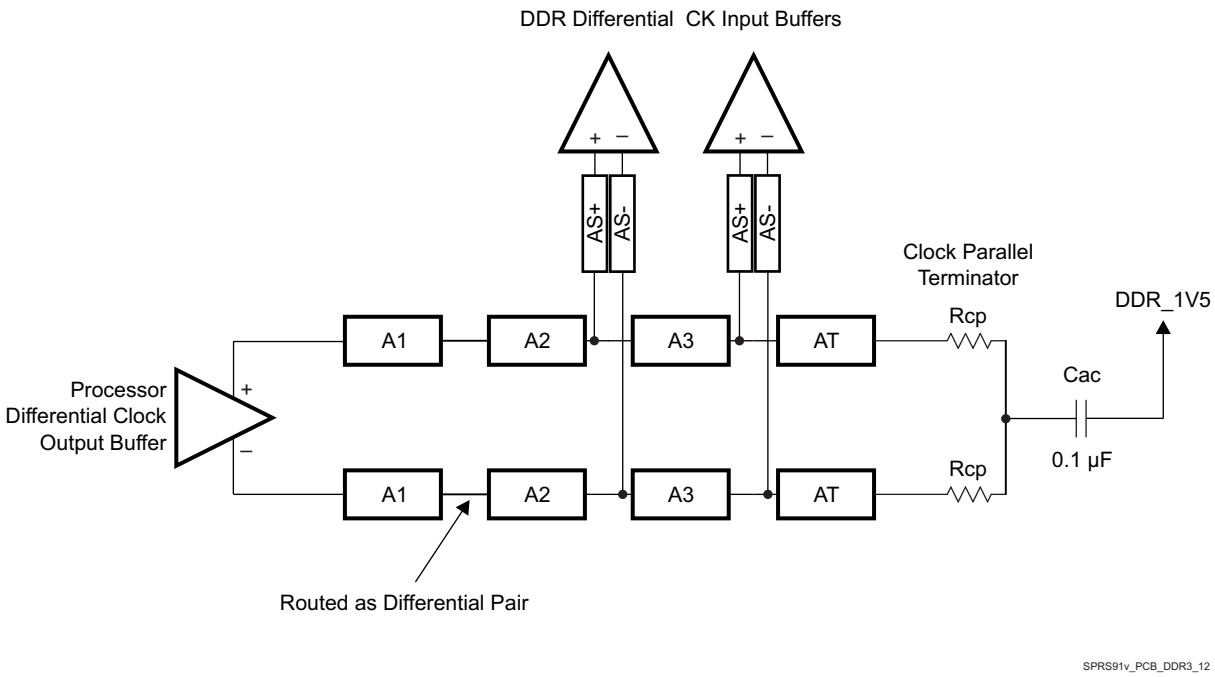


Figure 8-55. CK Topology for Two DDR3 Devices

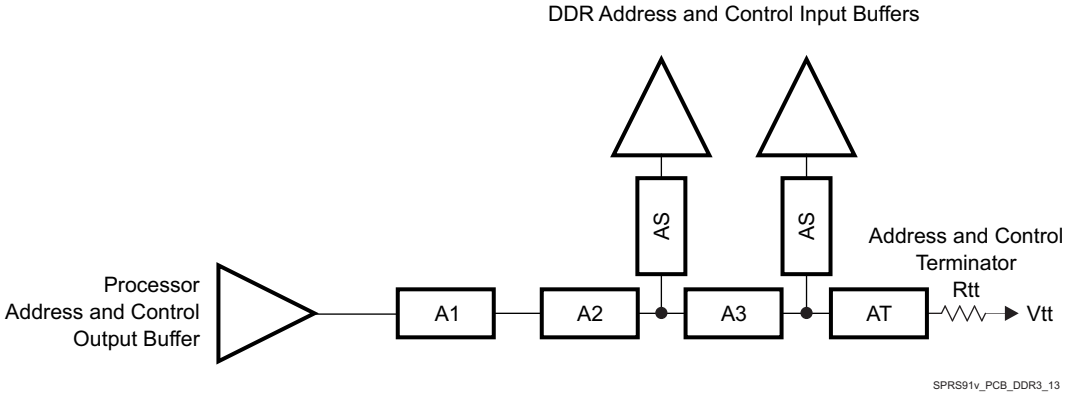


Figure 8-56. ADDR_CTRL Topology for Two DDR3 Devices

8.9.2.13.2.2 CK and ADDR_CTRL Routing, Two DDR3 Devices

Figure 8-57 shows the CK routing for two DDR3 devices placed on the same side of the PCB. Figure 8-58 shows the corresponding ADDR_CTRL routing.

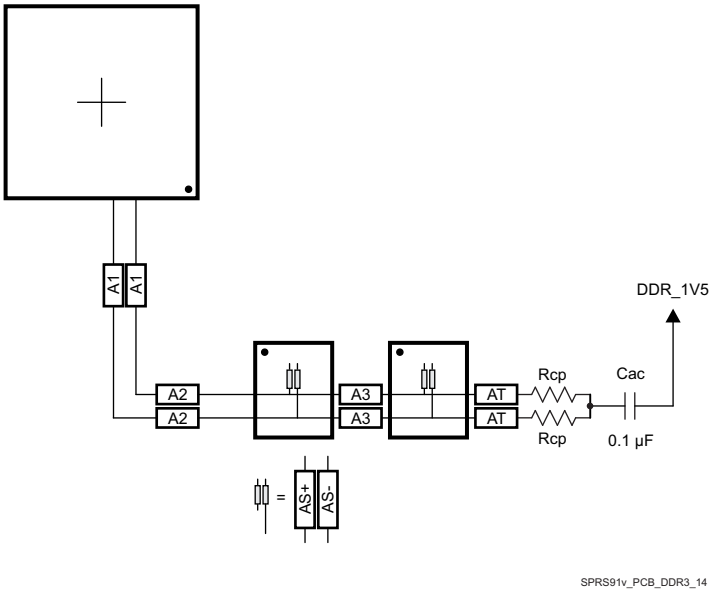


Figure 8-57. CK Routing for Two Single-Side DDR3 Devices

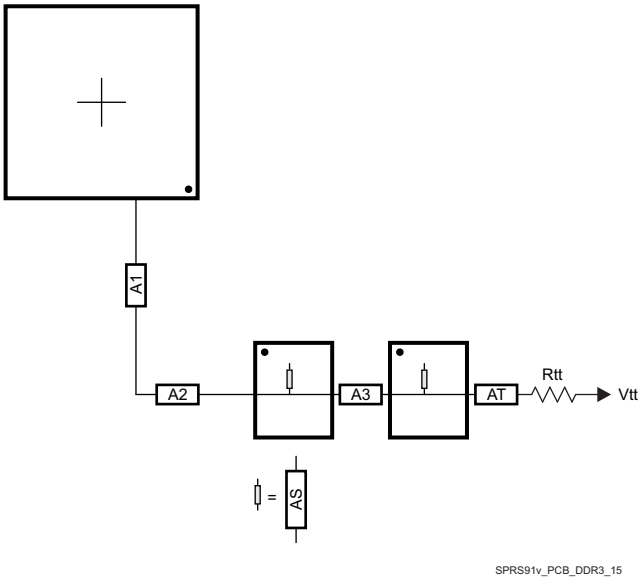


Figure 8-58. ADDR_CTRL Routing for Two Single-Side DDR3 Devices

To save PCB space, the two DDR3 memories may be mounted as a mirrored pair at a cost of increased routing and assembly complexity. Figure 8-59 and Figure 8-60 show the routing for CK and ADDR_CTRL, respectively, for two DDR3 devices mirrored in a single-pair configuration.

Copyright © 2016–2020, Texas Instruments Incorporated

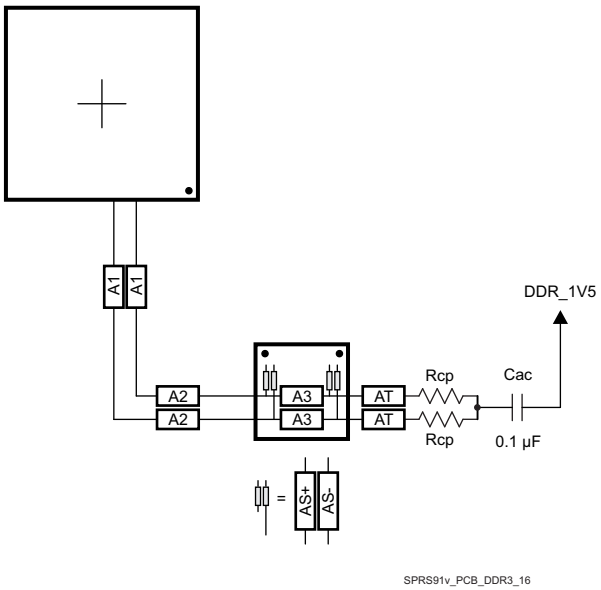


Figure 8-59. CK Routing for Two Mirrored DDR3 Devices

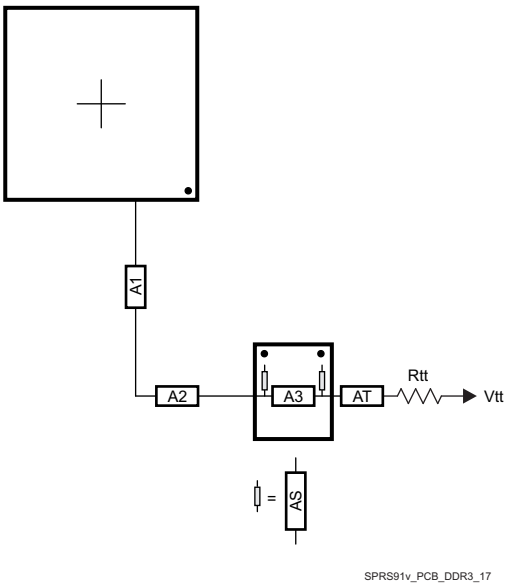


Figure 8-60. ADDR_CTRL Routing for Two Mirrored DDR3 Devices

8.9.2.13.3 One DDR3 Device

A single DDR3 device is supported on the DDR EMIF consisting of one x16 DDR3 device arranged as one bank (CS), 16 bits wide.

8.9.2.13.3.1 CK and ADDR_CTRL Topologies, One DDR3 Device

Figure 8-61 shows the topology of the CK net classes and Figure 8-62 shows the topology for the corresponding ADDR_CTRL net classes.

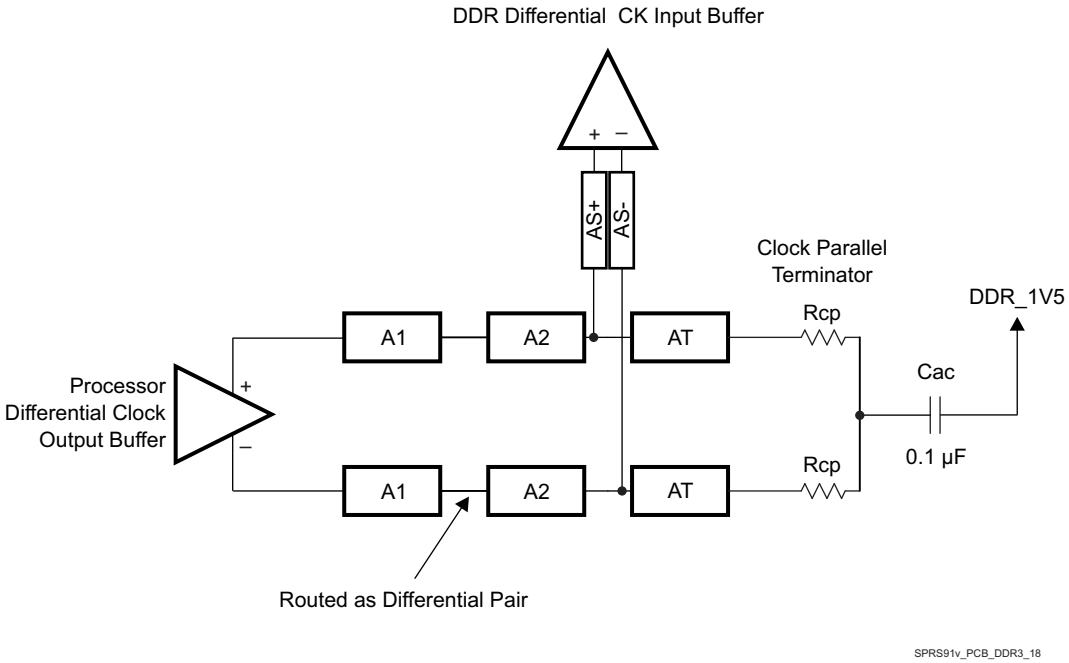


Figure 8-61. CK Topology for One DDR3 Device

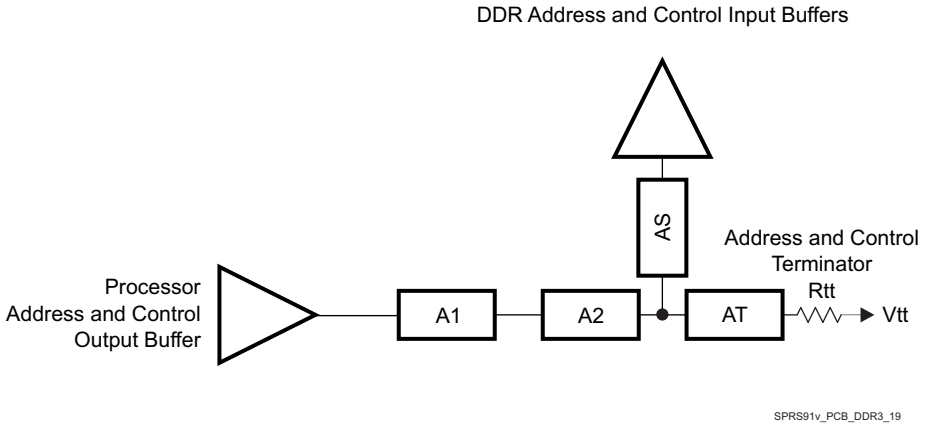


Figure 8-62. ADDR_CTRL Topology for One DDR3 Device

8.9.2.13.3.2 CK and ADDR/CTRL Routing, One DDR3 Device

Figure 8-63 shows the CK routing for one DDR3 device placed on the same side of the PCB. Figure 8-64 shows the corresponding ADDR_CTRL routing.

Copyright © 2016–2020, Texas Instruments Incorporated

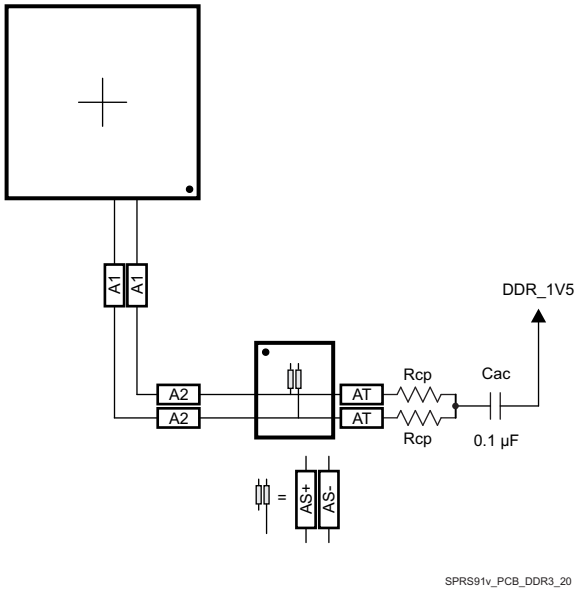


Figure 8-63. CK Routing for One DDR3 Device

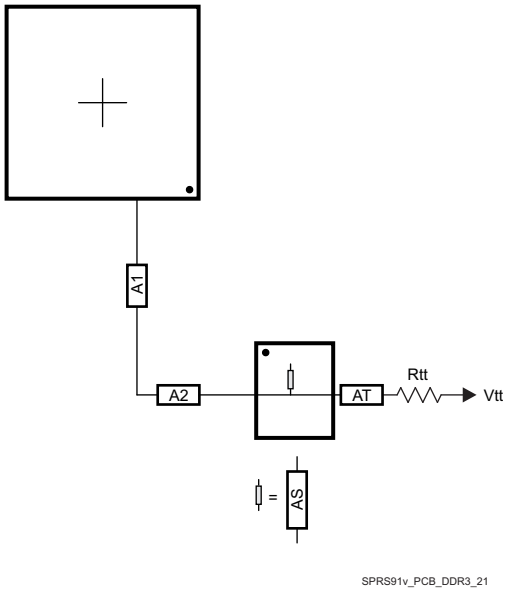


Figure 8-64. ADDR_CTRL Routing for One DDR3 Device

8.9.2.14 Data Topologies and Routing Definition

No matter the number of DDR3 devices used, the data line topology is always point to point, so its definition is simple.

Care should be taken to minimize layer transitions during routing. If a layer transition is necessary, it is better to transition to a layer using the same reference plane. If this cannot be accommodated, ensure there are nearby ground vias to allow the return currents to transition between reference planes if both reference planes are ground or vdds_ddr. Ensure there are nearby bypass capacitors to allow the return currents to transition between reference planes if one of the reference planes is ground. The goal is to minimize the size of the return current loops.

Copyright © 2016–2020, Texas Instruments Incorporated

8.9.2.14.1 DQS and DQ/DM Topologies, Any Number of Allowed DDR3 Devices

DQS lines are point-to-point differential, and DQ/DM lines are point-to-point singled ended. Figure 8-65 and Figure 8-66 show these topologies.

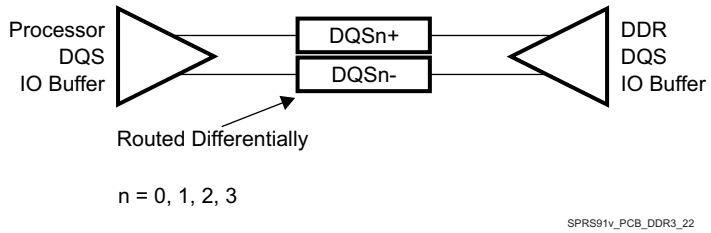


Figure 8-65. DQS Topology

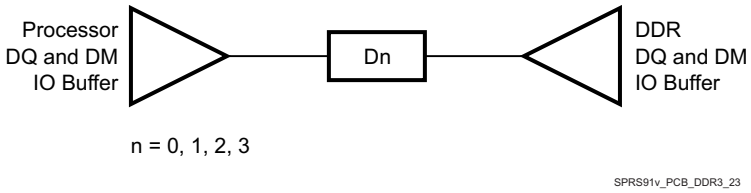


Figure 8-66. DQ/DM Topology

8.9.2.14.2 DQS and DQ/DM Routing, Any Number of Allowed DDR3 Devices

Figure 8-67 and Figure 8-68 show the DQS and DQ/DM routing.

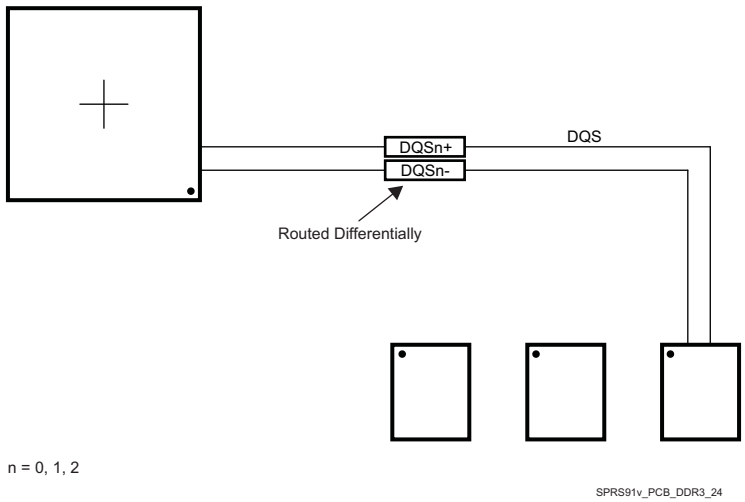


Figure 8-67. DQS Routing With Any Number of Allowed DDR3 Devices

Copyright © 2016–2020, Texas Instruments Incorporated

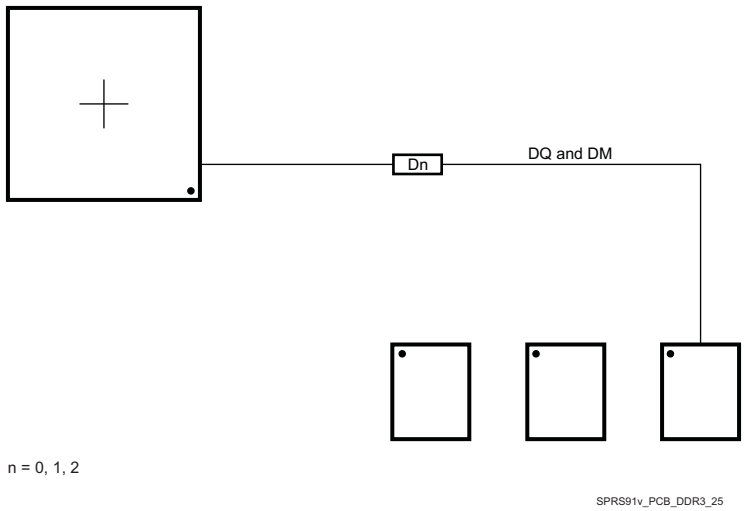


Figure 8-68. DQ/DM Routing With Any Number of Allowed DDR3 Devices

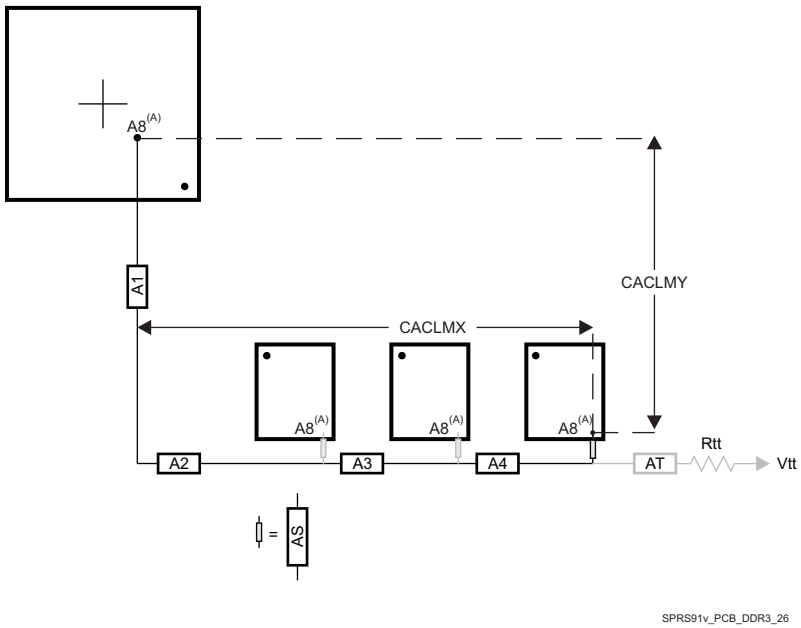
8.9.2.15 Routing Specification

8.9.2.15.1 CK and ADDR_CTRL Routing Specification

Skew within the CK and ADDR_CTRL net classes directly reduces setup and hold margin and, thus, this skew must be controlled. The only way to practically match lengths on a PCB is to lengthen the shorter traces up to the length of the longest net in the net class and its associated clock. A metric to establish this maximum length is Manhattan distance. The Manhattan distance between two points on a PCB is the length between the points when connecting them only with horizontal or vertical segments. A reasonable trace route length is to within a percentage of its Manhattan distance. CACLM is defined as Clock Address Control Longest Manhattan distance.

Given the clock and address pin locations on the processor and the DDR3 memories, the maximum possible Manhattan distance can be determined given the placement. Figure 8-69 and Figure 8-70 show this distance for three loads and two loads, respectively. It is from this distance that the specifications on the lengths of the transmission lines for the address bus are determined. CACLM is determined similarly for other address bus configurations; that is, it is based on the longest net of the CK/ADDR_CTRL net class. For CK and ADDR_CTRL routing, these specifications are contained in Table 8-44.

Copyright © 2016–2020, Texas Instruments Incorporated



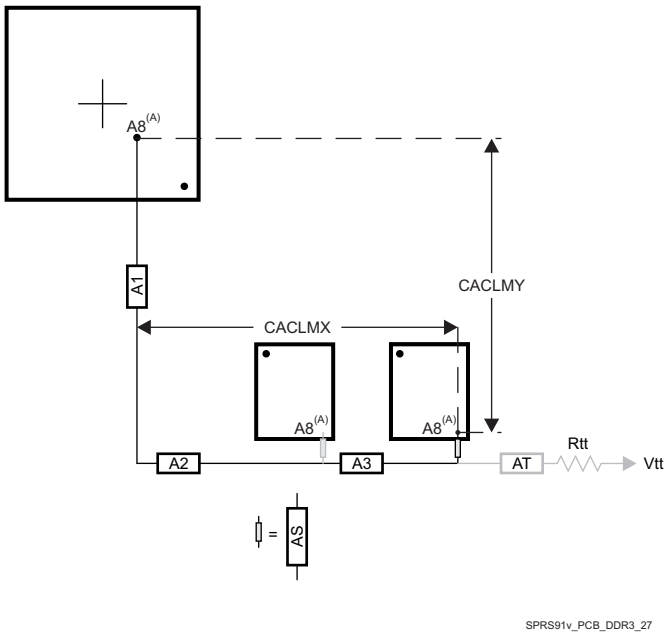
A. It is very likely that the longest CK/ADDR_CTRL Manhattan distance will be for Address Input 8 (A8) on the DDR3 memories. CACLM is based on the longest Manhattan distance due to the device placement. Verify the net class that satisfies this criteria and use as the baseline for CK/ADDR_CTRL skew matching and length control.

The length of shorter CK/ADDR_CTRL stubs as well as the length of the terminator stub are not included in this length calculation. Non-included lengths are grayed out in the figure.

Assuming A8 is the longest, CALM = CACLMY + CACLMX + 300 mils.
The extra 300 mils allows for routing down lower than the DDR3 memories and returning up to reach A8.

Figure 8-69. CACLM for Three Address Loads on One Side of PCB

Copyright © 2016–2020, Texas Instruments Incorporated



A. It is very likely that the longest CK/ADDR_CTRL Manhattan distance will be for Address Input 8 (A8) on the DDR3 memories. CACLM is based on the longest Manhattan distance due to the device placement. Verify the net class that satisfies this criteria and use as the baseline for CK/ADDR_CTRL skew matching and length control.

The length of shorter CK/ADDR_CTRL stubs as well as the length of the terminator stub are not included in this length calculation. Non-included lengths are grayed out in the figure.

Assuming A8 is the longest, CALM = CACLMY + CACLMX + 300 mils.
The extra 300 mils allows for routing down lower than the DDR3 memories and returning up to reach A8.

Figure 8-70. CACLM for Two Address Loads on One Side of PCB

Table 8-44. CK and ADDR_CTRL Routing Specification(2)(3)

NO.	PARAMETER	MIN	TYP	MAX	UNIT
CARS31	A1+A2 length			500(1)	ps
CARS32	A1+A2 skew			29	ps
CARS33	A3 length			125	ps
CARS34	A3 skew(4)			6	ps
CARS35	A3 skew(5)			6	ps
CARS36	A4 length			125	ps
CARS37	A4 skew			6	ps
CARS38	AS length		5	17(1)	ps
CARS39	AS skew		1.3	14(1)	ps
CARS310	AS+/AS- length		5	12	ps
CARS311	AS+/AS- skew			1	ps
CARS312	AT length(6)		75		ps
CARS313	AT skew(7)		14		ps
CARS314	AT skew(8)			1	ps
CARS315	CK/ADDR_CTRL trace length			1020	ps
CARS316	Vias per trace			3(1)	vias
CARS317	Via count difference			1(15)	vias
CARS318	Center-to-center CK to other DDR3 trace spacing(9)	4w			
CARS319	Center-to-center ADDR_CTRL to other DDR3 trace spacing(9)(10)	4w			
CARS320	Center-to-center ADDR_CTRL to other ADDR_CTRL trace spacing(9)	3w			

Copyright © 2016–2020, Texas Instruments Incorporated

Table 8-44. CK and ADDR_CTRL Routing Specification[2][3] (continued)

NO.	PARAMETER	MIN	TYP	MAX	UNIT
CARS321	CK center-to-center spacing[11][12]				
CARS322	CK spacing to other net[9]	4w			
CARS323	Rcp[13]	Zo-1	Zo	Zo+1	Ω
CARS324	Rtt[13][14]	Zo-5	Zo	Zo+5	Ω

(1) Max value is based upon conservative signal integrity approach. This value could be extended only if detailed signal integrity analysis of rise time and fall time confirms desired operation.

(2) The use of vias should be minimized.

(3) Additional bypass capacitors are required when using the DDR_1V5 plane as the reference plane to allow the return current to jump between the DDR_1V5 plane and the ground plane when the net class switches layers at a via.

(4) Non-mirrored configuration (all DDR3 memories on same side of PCB).

(5) Mirrored configuration (one DDR3 device on top of the board and one DDR3 device on the bottom).

(6) While this length can be increased for convenience, its length should be minimized.

(7) ADDR_CTRL net class only (not CK net class). Minimizing this skew is recommended, but not required.

(8) CK net class only.

(9) Center-to-center spacing is allowed to fall to minimum (2w) for up to 1250 mils of routed length.

(10) The ADDR_CTRL net class of the other DDR EMIF is considered *other DDR3 trace spacing*.

(11) CK spacing set to ensure proper differential impedance.

(12) The most important thing to do is control the impedance so inadvertent impedance mismatches are not created. Generally speaking, center-to-center spacing should be either 2w or slightly larger than 2w to achieve a differential impedance equal to twice the singleended impedance, Zo.

(13) Source termination (series resistor at driver) is specifically not allowed.

(14) Termination values should be uniform across the net class.

(15) Via count difference may increase by 1 only if accurate 3-D modeling of the signal flight times – including accurately modeled signal propagation through vias – has been applied to ensure all segment skew maximums are not exceeded.

8.9.2.15.2 DQS and DQ Routing Specification

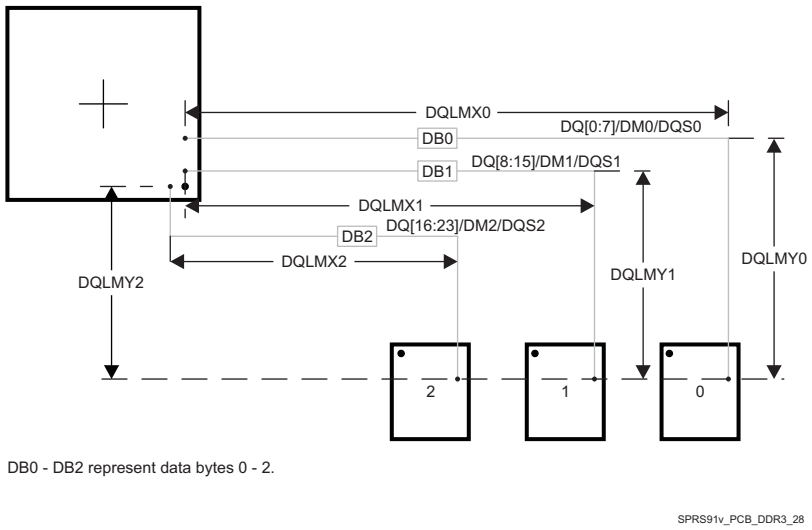
Skew within the DQS and DQ/DM net classes directly reduces setup and hold margin and thus this skew must be controlled. The only way to practically match lengths on a PCB is to lengthen the shorter traces up to the length of the longest net in the net class and its associated clock. As with CK and ADDR_CTRL, a reasonable trace route length is to within a percentage of its Manhattan distance. DQLMn is defined as DQ Longest Manhattan distance n, where n is the byte number. For a 32-bit interface, there are three DQLMs, DQLM0-DQLM2. Likewise, for a 16-bit interface, there are two DQLMs, DQLM0-DQLM1.

NOTE

It is not required, nor is it recommended, to match the lengths across all bytes. Length matching is only required within each byte.

Given the DQS and DQ/DM pin locations on the processor and the DDR3 memories, the maximum possible Manhattan distance can be determined given the placement. Figure 8-71 shows this distance for four loads. It is from this distance that the specifications on the lengths of the transmission lines for the data bus are determined. For DQS and DQ/DM routing, these specifications are contained in Table 8-45.

Copyright © 2016–2020, Texas Instruments Incorporated



There are three DQLMs, one for each byte (32-bit interface). Each DQLM is the longest Manhattan distance of the byte; therefore:
DQLM0 = DQLMX0 + DQLMY0
DQLM1 = DQLMX1 + DQLMY1
DQLM2 = DQLMX2 + DQLMY2

Figure 8-71. DQLM for Any Number of Allowed DDR3 Devices

Table 8-45. Data Routing Specification(2)

NO.	PARAMETER	MIN	TYP	MAX	UNIT
DRS31	DB0 length			340	ps
DRS32	DB1 length			340	ps
DRS33	DB2 length			340	ps
DRS35	DBn skew(3)			5	ps
DRS36	DQSn+ to DQSn- skew			1	ps
DRS37	DQSn to DBn skew(3)(4)			5(10)	ps
DRS38	Vias per trace			2(1)	vias
DRS39	Via count difference			0(10)	vias
DRS310	Center-to-center DBn to other DDR3 trace spacing(6)	4			w(5)
DRS311	Center-to-center DBn to other DBn trace spacing(7)	3			w(5)
DRS312	DQSn center-to-center spacing(8)(9)				
DRS313	DQSn center-to-center spacing to other net	4			w(5)

(1) Max value is based upon conservative signal integrity approach. This value could be extended only if detailed signal integrity analysis of rise time and fall time confirms desired operation.

(2) External termination disallowed. Data termination should use built-in ODT functionality.

(3) Length matching is only done within a byte. Length matching across bytes is neither required nor recommended.

(4) Each DQS pair is length matched to its associated byte.

(5) Center-to-center spacing is allowed to fall to minimum (2w) for up to 1250 mils of routed length.

(6) Other DDR3 trace spacing means other DDR3 net classes not within the byte.

(7) This applies to spacing within the net classes of a byte.

(8) DQS pair spacing is set to ensure proper differential impedance.

(9) The most important thing to do is control the impedance so inadvertent impedance mismatches are not created. Generally speaking, center-to-center spacing should be either 2w or slightly larger than 2w to achieve a differential impedance equal to twice the singleended impedance, Zo.

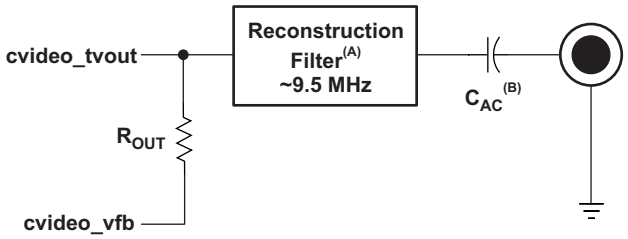
(10) Via count difference may increase by 1 only if accurate 3-D modeling of the signal flight times – including accurately modeled signal propagation through vias – has been applied to ensure DBn skew and DQSn to DBn skew maximums are not exceeded.

Copyright © 2016–2020, Texas Instruments Incorporated

8.10 CVIDEO/SD-DAC Guidelines and Electrical Data/Timing

The device's analog video CVIDEO/SD-DAC TV analog composite output can be operate in one of two modes: Normal mode and TVOUT Bypass mode. In Normal mode, the device's internal video amplifier is used. In TVOUT Bypass mode, the internal video amplifier is bypassed and an external amplifier is required.

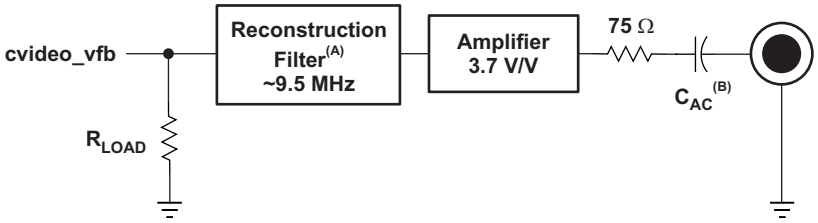
Figure 8-72 shows a typical circuit that permits connecting the analog video output from the device to standard 75-Ω impedance video systems in Normal mode.



A. Reconstruction Filter (optional)
B. AC coupling capacitor (optional)

Figure 8-72. TV Output (Normal Mode)

Figure 8-73 shows a typical circuit that permits connecting the analog video output from the device to standard 75-Ω impedance video systems in TVOUT Bypass mode.



A. Reconstruction Filter (optional). Note: An amplifier with an integrated reconstruction filter can alternatively be used instead of a discrete reconstruction filter.
B. AC coupling capacitor (optional)

Figure 8-73. TV Output (TVOUT Bypass Mode)

During board design, the onboard traces and parasitics must be matched for the channel. The video DAC output pins (cvideo_tvout / cvideo_vfb) are very high-frequency analog signals and must be routed with extreme care. As a result, the paths of these signals must be as short as possible, and as isolated as possible from other interfering signals. In TVOUT Bypass mode, the load resistor and amplifier/buffer should be placed as close as possible to the cvideo_vfb pin. Other layout guidelines include:

- Take special care to bypass the vdda_dac power supply pin with a capacitor.
- In **TVOUT Bypass mode**, place the R_{LOAD} resistor as close as possible to the Reconstruction Filter and Amplifier. In addition, place the 75-Ω resistor as close as possible (< 0.5 inch) to the Amplifier/buffer output pin. To maintain a high-quality video signal, the onboard traces after the 75-Ω resistor should have a characteristic impedance of 75 Ω (± 20%).
- In **Normal mode**,cvideo_vfb is the most sensitive pin in the TV out system. The R_{OUT} resistor should be placed as close as possible to the device pins. To maintain a high-quality video signal, the onboard traces leading to the cvideo_tvout pin should have a characteristic impedance of 75 Ω (± 20%) starting from the closest possible place to the device pin output.
- Minimize input trace lengths to the device to reduce parasitic capacitance.
- Include solid ground return paths.
- Match trace lengths as close as possible within a video format group.

Copyright © 2016–2020, Texas Instruments Incorporated

Table 8-46 and Table 8-47 present the Static and Dynamic CVIDEO / SD-DAC TV analog composite output specifications

Table 8-46. Static CVIDEO/SD-DAC Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Reference Current Setting Resistor (R_{SET})	Normal Mode	4653	4700	4747	Ω
	TVOUT Bypass Mode	9900	10000	10100	Ω
Output resistor between cvideo_tvout and cvideo_vfb pins (R_{OUT})	Normal Mode	2673	2700	2727	Ω
	TVOUT Bypass Mode	N/A			
Load Resistor (R_{LOAD})	Normal Mode	75-Ω Inside the Display			
	TVOUT Bypass Mode	1485	1500	1515	Ω
AC-Coupling Capacitor (Optional) [C_{AC}]	Normal Mode	220			µF
	TVOUT Bypass Mode	See External Amplifier Specification			
Total Capacitance from cvideo_tvout to vssa_dac	Normal Mode			300	pF
	TVOUT Bypass Mode	N/A			
Resolution			10		Bits
Integral Non-Linearity (INL), Best Fit	Normal Mode	-4		4	LSB
	TVOUT Bypass Mode	-1		1	LSB
Differential Non-Linearity (DNL)	Normal Mode	-2.5		2.5	LSB
	TVOUT Bypass Mode	-1		1	LSB
Full-Scale Output Voltage	Normal Mode (R_{LOAD} = 75 Ω)		1.3		V
	TVOUT Bypass Mode (R_{LOAD} = 1.5 kΩ)		0.7		V
Full-Scale Output Current	Normal Mode	N/A			
	TVOUT Bypass Mode		470		uA
Gain Error	Normal Mode (Composite) and TVOUT Bypass Mode	-10		10	%FS
	Normal Mode (S-Video)	-20		20	%FS
Gain Mismatch (Luma-to-Chroma)	Normal Mode (Composite)	N/A			
	Normal Mode (S-Video)	-10		10	%
Output Impedance	Looking into cvideo_tvout nodes		75		Ω

Table 8-47. Dynamic CVIDEO/SD-DAC Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Update Rate (F_{CLK})			54	60	MHz
Signal Bandwidth	3 dB		6		MHz
Spurious-Free Dynamic Range (SFDR) within bandwidth	F_{CLK} = 54 MHz, F_{OUT} = 1 MHz		50		dBc
Signal-to-Noise Ration (SNR)	F_{CLK} = 54 MHz, F_{OUT} = 1 MHz		54		dB
Power Supply Rejection (PSR)	Normal Mode, 100 mVpp @ 6 MHz on vdda_dac		6		dB
	TVOUT Bypass Mode, 100 mVpp @ 6 MHz on vdda_dac		20		

Copyright © 2016–2020, Texas Instruments Incorporated

9 Device and Documentation Support

TI offers an extensive line of development tools, including tools to evaluate the performance of the processors, generate code, develop algorithm implementations, and fully integrate and debug software and hardware modules are listed below.

9.1 Device Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all microprocessors (MPUs) and support tools. Each device has one of three prefixes: X, P, or null (no prefix) (for example, TDA3x). Texas Instruments recommends two of three possible prefix designators for its support tools: TMDX and TMDS. These prefixes represent evolutionary stages of product development from engineering prototypes (TMDX) through fully qualified production devices and tools (TMDS).

Device development evolutionary flow:

X Experimental device that is not necessarily representative of the final device's electrical specifications and may not use production assembly flow.

P Prototype device that is not necessarily the final silicon die and may not necessarily meet final electrical specifications.

null Production version of the silicon die that is fully qualified.

Support tool development evolutionary flow:

TMDX Development-support product that has not yet completed Texas Instruments internal qualification testing.

TMDS Fully-qualified development-support product.

X and P devices and TMDX development-support tools are shipped against the following disclaimer:

"Developmental product is intended for internal evaluation purposes."

Production devices and TMDS development-support tools have been characterized fully, and the quality and reliability of the device have been demonstrated fully. TI's standard warranty applies.

Predictions show that prototype devices (X or P) have a greater failure rate than the standard production devices. Texas Instruments recommends that these devices not be used in any production system because their expected end-use failure rate still is undefined. Only qualified production devices are to be used.

For orderable part numbers of TDA3x devices in the ABF package type, see the Package Option Addendum of this document, the TI website (ti.com), or contact your TI sales representative.

For additional description of the device nomenclature markings on the die, see the TDA3x SoC for Advanced Driver Assistance Systems (ADAS) Silicon Revision 2.0, 1.0A, 1.0.

9.1.1 Standard Package Symbolization

NOTE

Some devices may have a cosmetic circular marking visible on the top of the device package which results from the production test process. In addition, some devices may also show a color variation in the package substrate which results from the substrate manufacturer. These differences are cosmetic only with no reliability impact.

Copyright © 2016–2020, Texas Instruments Incorporated

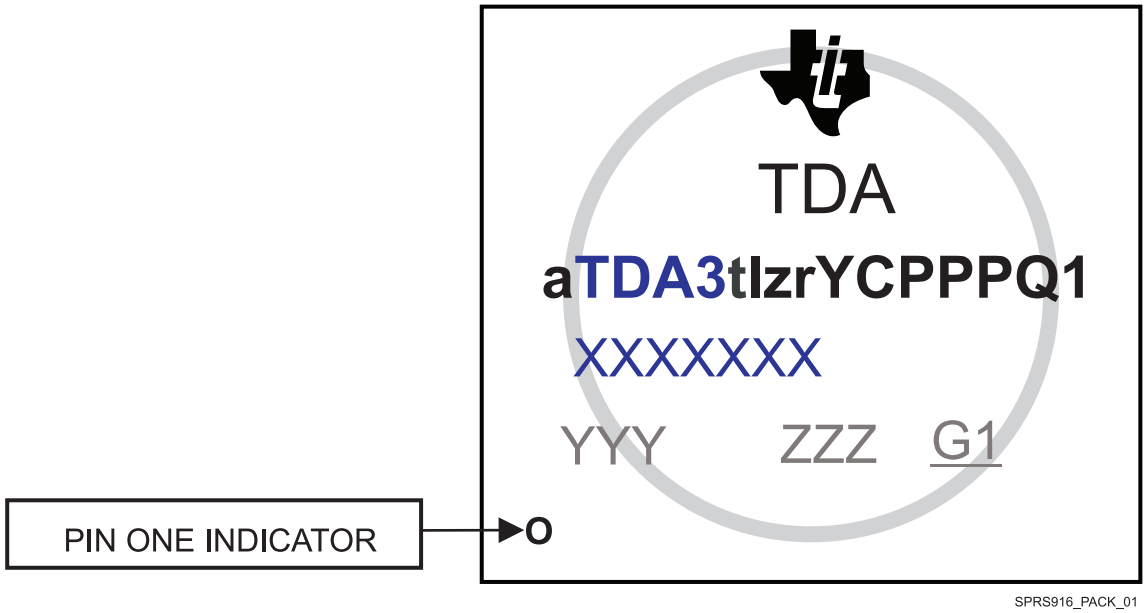


Figure 9-1. Printed Device Reference

9.1.2 Device Naming Convention

Table 9-1. Nomenclature Description

FIELD PARAMETER	FIELD DESCRIPTION	VALUES		DESCRIPTION
		MARKING	ORDERABLE	
a	Device evolution stage	X	*Contact TI*	Prototype
		P		Preproduction (production test flow, no reliability data)
		BLANK		Production
TDA3[2]	Base production part number	TDA3		ADAS 3rd Generation Family
t	Device Tier	S		Super
		M		Mid
		L		Low
l	Device Identity	A		Scene Analysis
		V		Scene Viewing
		D		Dual-DSP Scene Analysis
		R		Radar
		X		ADAS Superset
z	Device Speed	A		Indicates the speed grade for each of the cores in the device. For more information see , *Device Comparison Table* and Table 5-1, *Speed Grade Maximum Frequency*
		B		
		D		
		R		
		S		
r	Device revision	BLANK		SR 1.0
		A		SR 1.0A
		B		SR 2.0
Y	Device type	BLANK		Standard devices
		E		GP Prime Emulation (E) devices
		J		JTAG lock & random key devices

Table 9-1. Nomenclature Description (continued)

FIELD PARAMETER	FIELD DESCRIPTION	VALUES		DESCRIPTION
		MARKING	ORDERABLE	
		D		GP Prime prototype devices with TI Development keys (D)
		S		GP Prime devices
		n		GP Prime devices with customer key (n=1-9, Z...)
C	CAN2 designator	BLANK		Standard CAN
		F		CAN-FD
PPP	Package designator	ABF		ABF FCBGA-N367 (15mm x 15mm) Package
c	Carrier designator	*N/A*	BLANK	Tray
		N/A	R	Tape & Reel
Q1	Automotive Designator	BLANK		Does not meet automotive qualification
		Q1		Meets Q100 equal requirements, with exceptions as specified in DM.
XXXXXXX		*As marked*	*N/A*	Lot Trace Code
YYY		*As marked*	*N/A*	Production Code, For TI use only
ZZZ		As marked	N/A	Production Code, For TI use only
O		*As marked*	*N/A*	Pin one designator
G1		*As marked*	*N/A*	ECAT—Green package designator

(1) To designate the stages in the product development cycle, TI assigns prefixes to the part numbers. These prefixes represent evolutionary stages of product development from engineering prototypes through fully qualified production devices.
Prototype devices are shipped against the following disclaimer:
"This product is still in development and is intended for internal evaluation purposes."
Notwithstanding any provision to the contrary, TI makes no warranty expressed, implied, or statutory, including any implied warranty of merchantability of fitness for a specific purpose, of this device.

(2) XTDA3SX base part number with X speed grade indicator is the part number for the superset device. Software should constrain the features and speed used to match the intended production device.

NOTE

BLANK in the symbol or part number is collapsed so there are no gaps between characters.

9.2 Tools and Software

The following products support development for TDA3x platforms:

Design Kits and Evaluation Modules

TDA3X Evaluation Module The TDA3x evaluation module (EVM) is an evaluation platform designed to speed up development efforts and reduce time-to-market for ADAS applications. The EVM also integrates a host of peripherals including multicamera interfaces (both parallel and serial) for LVDS-based surround view systems, displays, CAN, and GigB Ethernet AVB. The EVM also integrates key peripherals such as Ethernet, FPD-Link and HDMI, while provides interfaces for popular imagers.

Software

Processor SDK for TDAx ADAS SoCs - Linux and TI-RTOS Support Processor SDK-Vision (Vision SDK) and Processor SDK-Radar (Radar SDK) are multi-processor software development kits for TDAx processors. The software framework allows users to create different ADAS application data flows involving radar capture, radar processing, video capture, video pre-processing, video analytics algorithms and video display. This release also integrates Processor SDK Linux to enable Automotive ADAS features and demos which needs Linux and GPU. The SDK has foundational drivers, compute & vision kernels for EVE and DSP. It also has demo use cases using TI sample algorithms which exercises different CPUs and HW accelerators in the ADAS SoC and shows customers how to effectively use different sub-systems.

Copyright © 2016–2020, Texas Instruments Incorporated

Development Tools

Clock Tree Tool for Sitara, Automotive, Vision Analytics, & Digital Signal Processors The Clock Tree Tool (CTT) for Sitara™ Arm®, Automotive, and Digital Signal Processors is an interactive clock tree configuration software that provides information about the clocks and modules in these TI devices. It allows the user to: Visualize the device clock tree. Interact with clock tree elements and view the effect on PRCM registers. Interact with the PRCM registers and view the effect on the device clock tree. View a trace of all the device registers affected by the user interaction with clock tree.

Pin mux tool The Pin MUX Utility is a software tool which provides a Graphical User Interface for configuring pin multiplexing settings, resolving conflicts and specifying I/O cell characteristics for TI MPUs. Results are output as C header/code files that can be imported into software development kits (SDKs) or used to configure customer's custom software. Version 4 of the Pin Mux utility adds the capability of automatically selecting a mux configuration that satisfies the entered requirements.

XDS110 JTAG Debug Probe The Texas Instruments XDS110 is a new class of debug probe (emulator) for TI embedded processors. The XDS110 replaces the XDS100 family while supporting a wider variety of standards (IEEE1149.1, IEEE1149.7, SWD) in a single pod. Also, all XDS debug probes support Core and System Trace in all Arm and DSP processors that feature an Embedded Trace Buffer (ETB).

The Texas Instruments XDS110 connects to the target board via a TI 20-pin connector (with multiple adapters for TI 14-pin and, Arm 10-pin and Arm 20-pin) and to the host PC via USB2.0 High Speed (480Mbps). It also features two additional connections: the Auxiliary 14-pin port connector that enables EnergyTrace™, a full duplex UART port and four General-Purpose I/Os, and the Expansion 30-pin connector to connect the XDS110 EnergyTrace HDR add-on.

Models

TDA3x BSDL Model BSDL Model

TDA3x IBIS Model IBIS Model

TDA3x Thermal Model Thermal Model

For a complete listing of development-support tools for the processor platform, visit the Texas Instruments website at ti.com. For information on pricing and availability, contact the nearest TI field sales office or authorized distributor.

Copyright © 2016–2020, Texas Instruments Incorporated

9.3 Documentation Support

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

The following documents describe the TDA3x devices.

Technical Reference Manual

TDA3x SoC for Advanced Driver Assistance Systems (ADAS) Silicon Revision 2.0, 1.0A, 1.0 Technical Reference Manual Details the integration, the environment, the functional description, and the programming models for each peripheral and subsystem in the TDA3 family of devices.

Errata

TDA3x SoC for Advanced Driver Assistance Systems (ADAS) Silicon Revision 2.0, 1.0A, 1.0 Silicon Errata Describes the known exceptions to the functional specifications for the device.

9.4 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

Table 9-2. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TDA3MV	Click here	Click here	Click here	Click here	Click here
TDA3MA	Click here	Click here	Click here	Click here	Click here
TDA3MD	Click here	Click here	Click here	Click here	Click here
TDA3LX	Click here	Click here	Click here	Click here	Click here
TDA3LA	Click here	Click here	Click here	Click here	Click here

9.5 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

9.6 Trademarks

E2E is a trademark of Texas Instruments.
Arm, Cortex are registered trademarks of Arm Limited (or its subsidiaries) in the US and/or elsewhere.
JTAG is a registered trademark of JTAG Technologies B.V. .
MIPI is a registered trademark of MIPI Alliance, Inc.
I^2C is a trademark of NXP Semiconductors.
All other trademarks are the property of their respective owners.

9.7 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

9.8 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

Copyright © 2016–2020, Texas Instruments Incorporated

10 Mechanical, Packaging, and Orderable Information

10.1 Packaging Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

Copyright © 2016–2020, Texas Instruments Incorporated

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TDA3LABBABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LABBABFQ1 TDA 775 775 ABF G1	Samples
TDA3LABBABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LABBABFQ1 TDA 775 775 ABF G1	Samples
TDA3LADBABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LADBABFQ1 TDA 775 775 ABF G1	Samples
TDA3LADBABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LADBABFQ1 TDA 775 775 ABF G1	Samples
TDA3LADBJFABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LADBJFABFQ1 TDA 775 775 ABF G1	Samples
TDA3LADBJFABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LADBJFABFQ1 TDA 775 775 ABF G1	Samples
TDA3LXBBABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LXBBABFQ1 TDA 775 775 ABF G1	Samples
TDA3LXBBABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LXBBABFQ1 TDA 775 775 ABF G1	Samples
TDA3LXRBFABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LXRBFABFQ1 TDA 775 775 ABF G1	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TDA3LXRBFABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3LXRBFABFQ1 TDA 775 775 ABF G1	Samples
TDA3MADBABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MADBABFQ1 TDA 775 775 ABF G1	Samples
TDA3MADBABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MADBABFQ1 TDA 775 775 ABF G1	Samples
TDA3MADBFABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MADBFABFQ1 TDA 775 775 ABF G1	Samples
TDA3MADBFABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MADBFABFQ1 TDA 775 775 ABF G1	Samples
TDA3MASBABFQ1	ACTIVE	FCBGA	ABF	367	90	TBD	Call TI	Call TI	-40 to 125		Samples
TDA3MASBABFRQ1	ACTIVE	FCBGA	ABF	367	750	TBD	Call TI	Call TI	-40 to 125		Samples
TDA3MDDBABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MDDBABFQ1 TDA 775 775 ABF G1	Samples
TDA3MDDBABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MDDBABFQ1 TDA 775 775 ABF G1	Samples
TDA3MVDBABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MVDBABFQ1 TDA 775 775 ABF G1	Samples
TDA3MVDBABFRQ1	ACTIVE	FCBGA	ABF	367	750	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MVDBABFQ1 TDA 775	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
										775 ABF G1	
TDA3MVRBFABFQ1	ACTIVE	FCBGA	ABF	367	90	Green (RoHS & no Sb/Br)	SNAGCU	Level-3-250C-168 HR	-40 to 125	TDA3MVRBFABFQ1 TDA 775 775 ABF G1	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

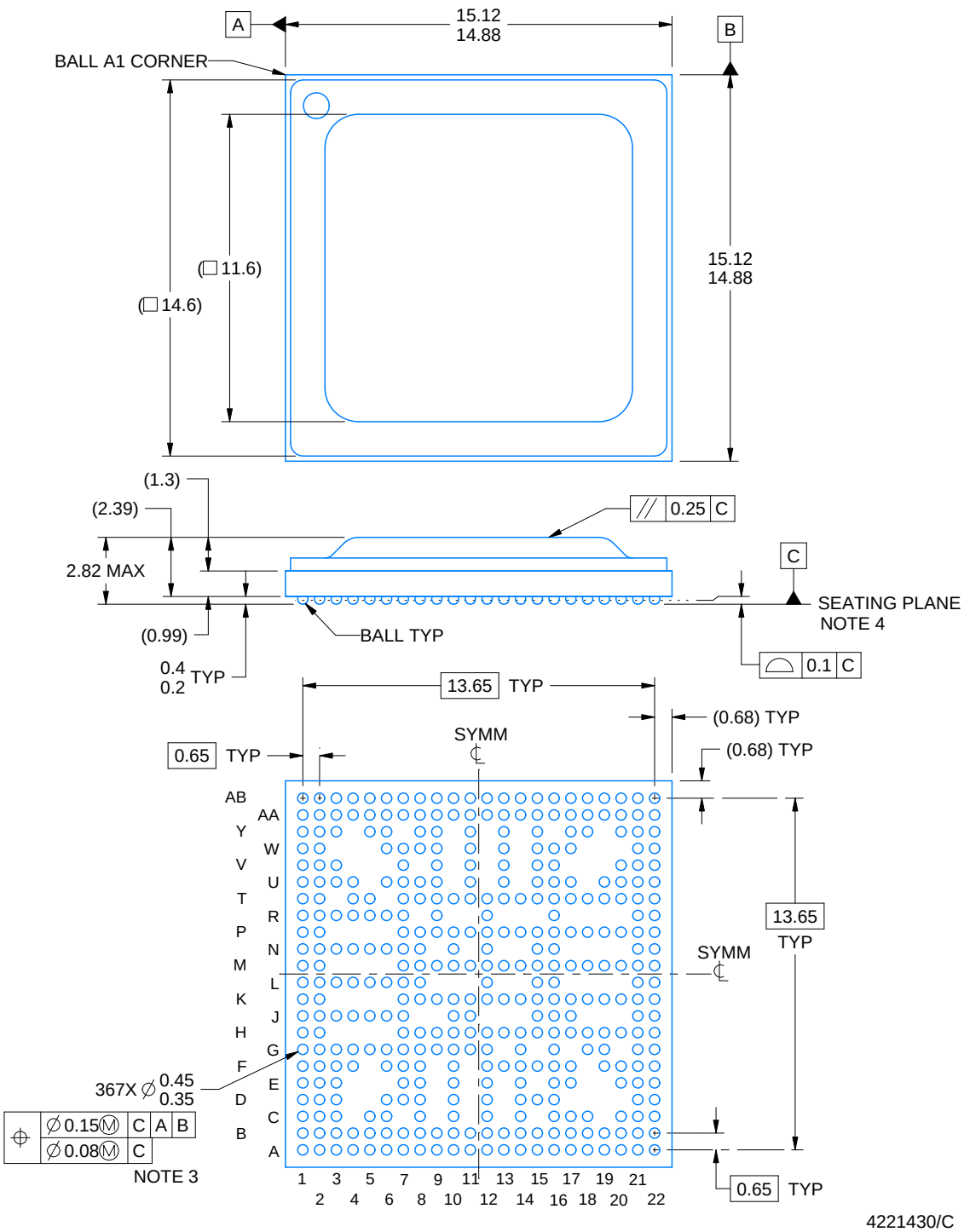
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

PACKAGE OUTLINE

ABF0367A

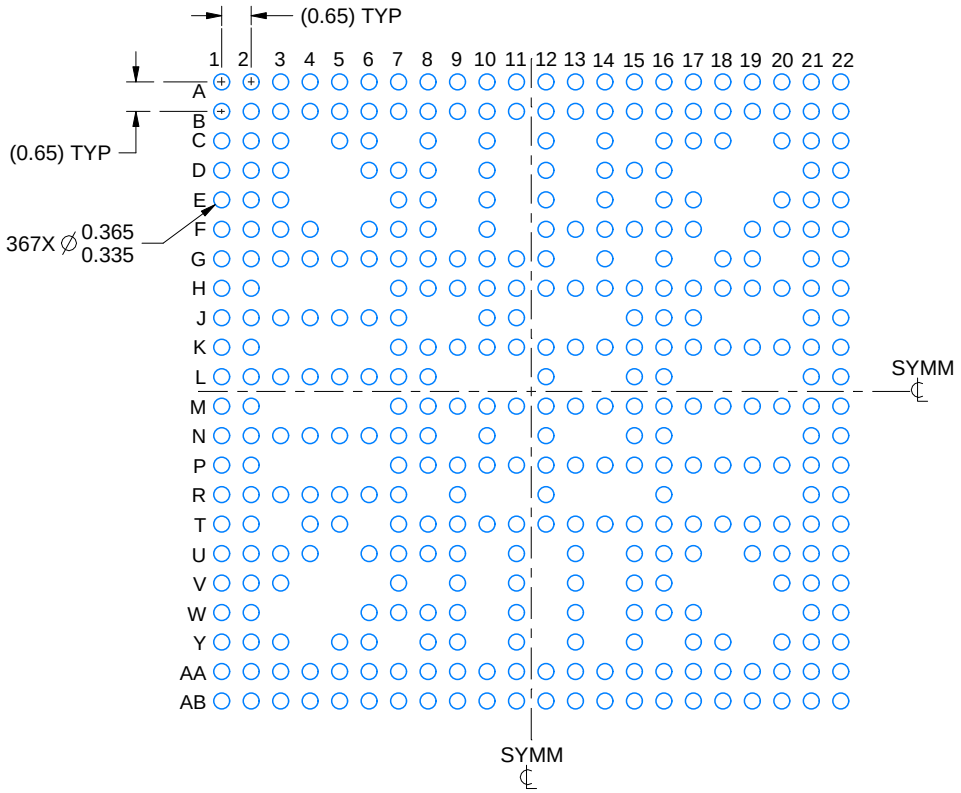
FCBGA - 2.82 mm max height

BALL GRID ARRAY

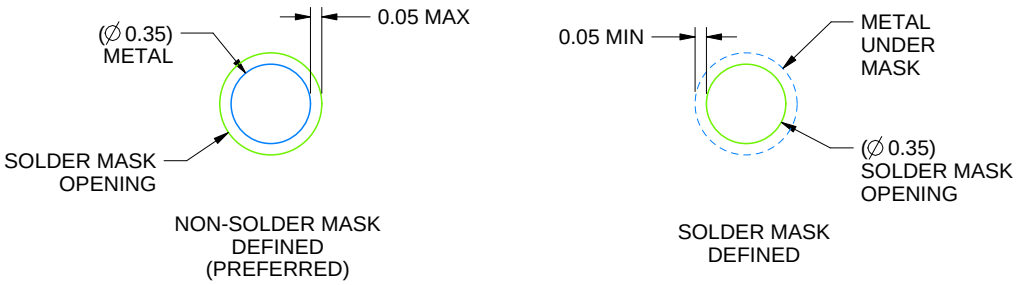


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Dimension is measured at the maximum solder ball diameter, parallel to primary datum C.
4. Primary datum C and seating plane are defined by the spherical crown of the solder balls.



LAND PATTERN EXAMPLE
SCALE:6X

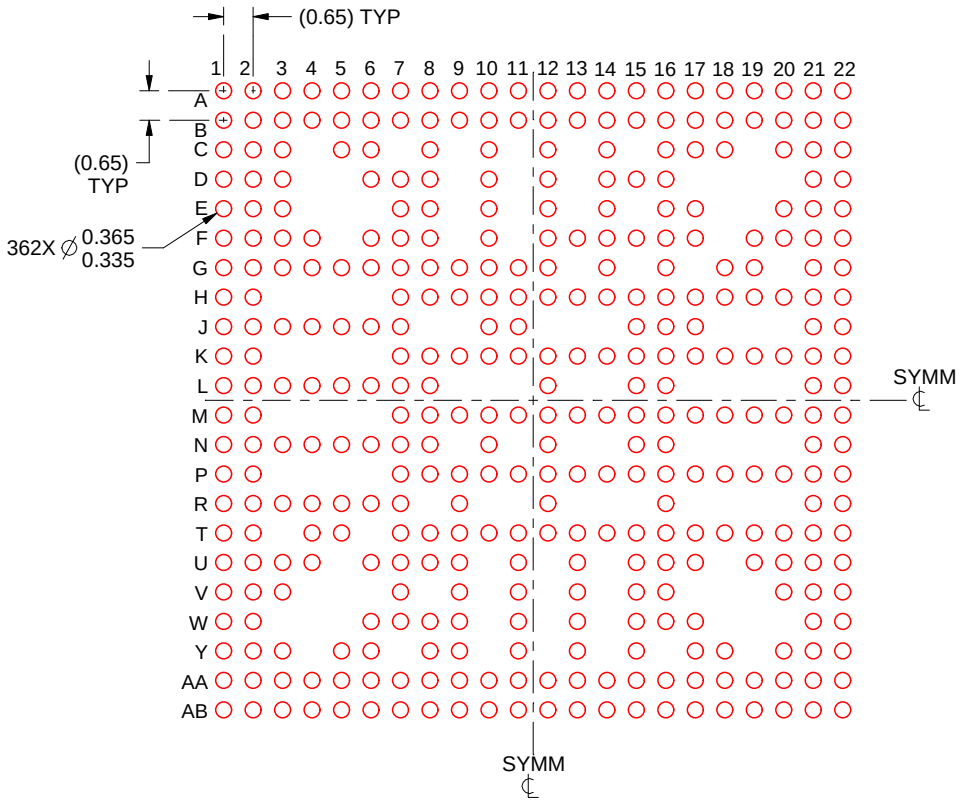


SOLDER MASK DETAILS
NOT TO SCALE

4221430/C 04/2019

NOTES: (continued)

5. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints.
For more information, see Texas Instruments literature number SPRU811 (www.ti.com/lit/spru811).



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:6X

4221430/C 04/2019

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated