



# THE DATASHEET OF TMS320F28235ZJZS



# TMS320F2833x, TMS320F2823x Digital Signal Controllers (DSCs)

## 1 Device Overview

### 1.1 Features

- High-performance static CMOS technology
  - Up to 150 MHz (6.67-ns cycle time)
  - 1.9-V/1.8-V core, 3.3-V I/O design
- High-performance 32-bit CPU (TMS320C28x)
  - IEEE 754 single-precision Floating-Point Unit (FPU) (F2833x only)
  - $16 \times 16$  and  $32 \times 32$  MAC operations
  - $16 \times 16$  dual MAC
  - Harvard bus architecture
  - Fast interrupt response and processing
  - Unified memory programming model
  - Code-efficient (in C/C++ and Assembly)
- Six-channel DMA controller (for ADC, McBSP, ePWM, XINTF, and SARAM)
- 16-bit or 32-bit External Interface (XINTF)
  - More than  $2\text{M} \times 16$  address reach
- On-chip memory
  - F28335, F28333, F28235:  $256\text{K} \times 16$  flash,  $34\text{K} \times 16$  SARAM
  - F28334, F28234:  $128\text{K} \times 16$  flash,  $34\text{K} \times 16$  SARAM
  - F28332, F28232:  $64\text{K} \times 16$  flash,  $26\text{K} \times 16$  SARAM
  - $1\text{K} \times 16$  OTP ROM
- Boot ROM ( $8\text{K} \times 16$ )
  - With software boot modes (through SCI, SPI, CAN, I2C, McBSP, XINTF, and parallel I/O)
  - Standard math tables
- Clock and system control
  - On-chip oscillator
  - Watchdog timer module
- GPIO0 to GPIO63 pins can be connected to one of the eight external core interrupts
- Peripheral Interrupt Expansion (PIE) block that supports all 58 peripheral interrupts
- 128-bit security key/lock
  - Protects flash/OTP/RAM blocks
  - Prevents firmware reverse-engineering
- Enhanced control peripherals
  - Up to 18 PWM outputs
  - Up to 6 HRPWM outputs with 150-ps MEP resolution
  - Up to 6 event capture inputs
  - Up to 2 Quadrature Encoder interfaces
  - Up to 8 32-bit timers (6 for eCAPs and 2 for eQEPs)
  - Up to 9 16-bit timers (6 for ePWMs and 3 XINTCTRs)
- Three 32-bit CPU timers
- Serial port peripherals
  - Up to 2 CAN modules
  - Up to 3 SCI (UART) modules
  - Up to 2 McBSP modules (configurable as SPI)
  - One SPI module
  - One Inter-Integrated Circuit (I2C) bus
- 12-bit ADC, 16 channels
  - 80-ns conversion rate
  - $2 \times 8$  channel input multiplexer
  - Two sample-and-hold
  - Single/simultaneous conversions
  - Internal or external reference
- Up to 88 individually programmable, multiplexed GPIO pins with input filtering
- JTAG boundary scan support
  - IEEE Standard 1149.1-1990 Standard Test Access Port and Boundary Scan Architecture
- Advanced emulation features
  - Analysis and breakpoint functions
  - Real-time debug using hardware
- Development support includes
  - ANSI C/C++ compiler/assembler/linker
  - Code Composer Studio™ IDE
  - DSP/BIOS™ and SYS/BIOS
  - Digital motor control and digital power software libraries
- Low-power modes and power savings
  - IDLE, STANDBY, HALT modes supported
  - Disable individual peripheral clocks
- Endianness: Little endian



- Package options:
  - Lead-free, green packaging
  - 176-ball plastic Ball Grid Array (BGA) (ZJZ)
  - 179-ball MicroStar BGA™ (ZHH)
  - 176-pin Low-Profile Quad Flatpack (LQFP) (PGF)
  - 176-pin Thermally Enhanced Low-Profile Quad Flatpack (HLQFP) (PTP)
- Temperature options:
  - A: –40°C to 85°C (PGF, ZHH, ZJZ)
  - S: –40°C to 125°C (PTP, ZJZ)
  - Q: –40°C to 125°C (PTP, ZJZ) (AEC Q100 qualification for automotive applications)

## 1.2 Applications

- [Advanced Driver Assistance Systems \(ADAS\)](#)
- [Building automation](#)
- [Electronic point of sale](#)
- [Electric Vehicle/Hybrid Electric Vehicle \(EV/HEV\) powertrain](#)
- [Factory automation](#)
- [Grid infrastructure](#)
- [Industrial transport](#)
- [Medical, healthcare and fitness](#)
- [Motor drives](#)
- [Power delivery](#)
- [Telecom infrastructure](#)
- [Test and measurement](#)

## 1.3 Description

**C2000™ 32-bit microcontrollers** are optimized for processing, sensing, and actuation to improve closed-loop performance in **real-time control applications** such as **industrial motor drives**; **solar inverters and digital power**; **electrical vehicles and transportation**; **motor control**; and **sensing and signal processing**. The C2000 line includes the **Delfino™ Premium Performance** family and the **Piccolo™ Entry Performance** family.

TMS320C2000™ 32-bit microcontrollers are optimized for processing, sensing, and actuation to improve closed-loop performance in **real-time control applications**. The **C2000™** microcontrollers line includes the **Delfino™ Premium Performance microcontroller** family and the **Piccolo™ Entry Performance microcontroller** family.

The TMS320F28335, TMS320F28334, TMS320F28333, TMS320F28332, TMS320F28235, TMS320F28234, and TMS320F28232 devices, members of the TMS320C28x/ Delfino™ DSC/MCU generation, are highly integrated, high-performance solutions for demanding control applications.

Throughout this document, the devices are abbreviated as F28335, F28334, F28333, F28332, F28235, F28234, and F28232, respectively. **F2833x Device Comparison** and **F2823x Device Comparison** provide a summary of features for each device.

To learn more about the C2000 MCUs, visit the C2000 Overview at [www.ti.com/c2000](http://www.ti.com/c2000).

**Device Information<sup>(1)</sup>**

| PART NUMBER     | PACKAGE             | BODY SIZE         |
|-----------------|---------------------|-------------------|
| TMS320F28335ZHH | BGA MicroStar (179) | 12.0 mm × 12.0 mm |
| TMS320F28334ZHH | BGA MicroStar (179) | 12.0 mm × 12.0 mm |
| TMS320F28332ZHH | BGA MicroStar (179) | 12.0 mm × 12.0 mm |
| TMS320F28235ZHH | BGA MicroStar (179) | 12.0 mm × 12.0 mm |
| TMS320F28234ZHH | BGA MicroStar (179) | 12.0 mm × 12.0 mm |
| TMS320F28232ZHH | BGA MicroStar (179) | 12.0 mm × 12.0 mm |
| TMS320F28335ZJZ | BGA (176)           | 15.0 mm × 15.0 mm |
| TMS320F28334ZJZ | BGA (176)           | 15.0 mm × 15.0 mm |
| TMS320F28332ZJZ | BGA (176)           | 15.0 mm × 15.0 mm |
| TMS320F28235ZJZ | BGA (176)           | 15.0 mm × 15.0 mm |
| TMS320F28234ZJZ | BGA (176)           | 15.0 mm × 15.0 mm |
| TMS320F28232ZJZ | BGA (176)           | 15.0 mm × 15.0 mm |
| TMS320F28335PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28334PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28333PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28332PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28235PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28234PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28232PGF | LQFP (176)          | 24.0 mm × 24.0 mm |
| TMS320F28335PTP | HLQFP (176)         | 24.0 mm × 24.0 mm |
| TMS320F28334PTP | HLQFP (176)         | 24.0 mm × 24.0 mm |
| TMS320F28332PTP | HLQFP (176)         | 24.0 mm × 24.0 mm |
| TMS320F28235PTP | HLQFP (176)         | 24.0 mm × 24.0 mm |
| TMS320F28234PTP | HLQFP (176)         | 24.0 mm × 24.0 mm |
| TMS320F28232PTP | HLQFP (176)         | 24.0 mm × 24.0 mm |

(1) For more information on these devices, see **Mechanical, Packaging, and Orderable Information**.

## 1.4 Functional Block Diagram

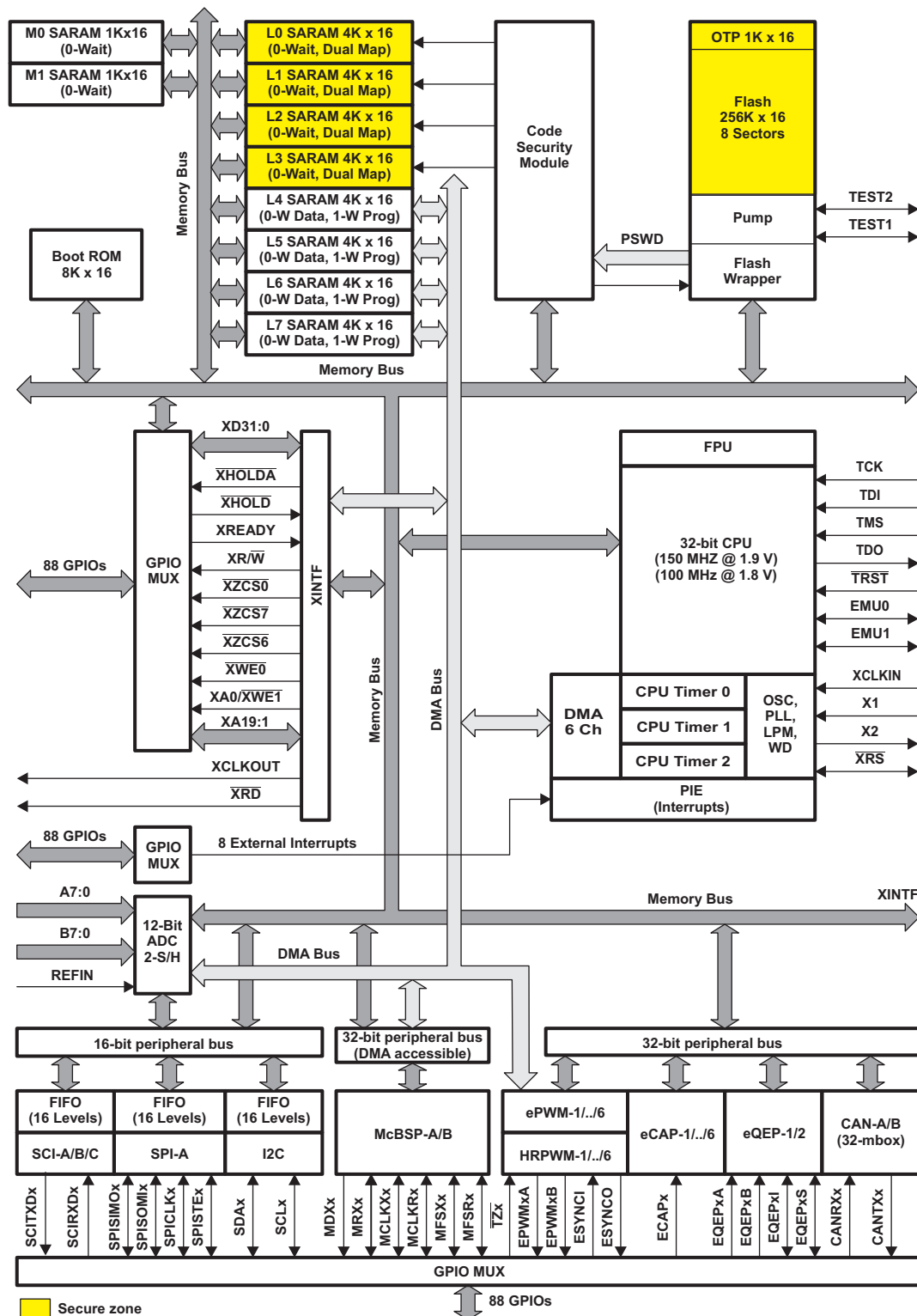


Figure 1-1. Functional Block Diagram

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## 2 Revision History

| Changes from October 18, 2016 to April 22, 2019 (from N Revision (October 2016) to O Revision)                                                                                                                                                                | Page                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| • <a href="#">Section 1.1</a> (Features): Updated "Package Options" feature. ....                                                                                                                                                                             | <a href="#">1</a>   |
| • <a href="#">Section 1.2</a> (Applications): Updated section. ....                                                                                                                                                                                           | <a href="#">2</a>   |
| • <a href="#">Section 1.3</a> (Description): Updated section. ....                                                                                                                                                                                            | <a href="#">3</a>   |
| • <a href="#">Section 3.1</a> (Related Products): Updated section. ....                                                                                                                                                                                       | <a href="#">9</a>   |
| • <a href="#">Table 4-1</a> (Signal Descriptions): Updated DESCRIPTION of XRS. ....                                                                                                                                                                           | <a href="#">20</a>  |
| • <a href="#">Table 5-4</a> (Clocking and Nomenclature (150-MHz Devices)): Updated footnote about smallest valid "Low-speed peripheral clock prescaler register" value. ....                                                                                  | <a href="#">42</a>  |
| • <a href="#">Section 5.9.2.1</a> (Power Management and Supervisory Circuit Solutions): Updated section. ....                                                                                                                                                 | <a href="#">43</a>  |
| • <a href="#">Section 5.9.4.5.1</a> (Master Mode Timing): Updated section. ....                                                                                                                                                                               | <a href="#">61</a>  |
| • <a href="#">Table 5-31</a> (SPI Master Mode External Timing (Clock Phase = 0)): Updated MIN value (for both BRR EVEN and BRR ODD) for Parameter 23, $t_{d(SPC)M}$ . ....                                                                                    | <a href="#">61</a>  |
| • <a href="#">Table 5-32</a> (SPI Master Mode External Timing (Clock Phase = 1)): Updated MIN value (for both BRR EVEN and BRR ODD) for Parameter 23, $t_{d(SPC)M}$ . ....                                                                                    | <a href="#">63</a>  |
| • <a href="#">Section 5.9.4.5.2</a> (Slave Mode Timing): Updated section. ....                                                                                                                                                                                | <a href="#">64</a>  |
| • <a href="#">Section 5.9.6.2</a> (Synchronous Mode (USEREADY = 1, READYMODE = 0)): Updated "XTIMING register configuration restrictions" table by changing XRDATIVE value from "≥ 1" to "≥ 2" and XWRACTIVE value from "≥ 1" to "≥ 2". ....                  | <a href="#">75</a>  |
| • <a href="#">Section 5.9.6.2</a> (Synchronous Mode (USEREADY = 1, READYMODE = 0)): Updated "Examples of valid and invalid timing" table by changing Valid XRDATIVE value from "1" to "2" and Valid XWRACTIVE value from "1" to "2". ....                     | <a href="#">75</a>  |
| • <a href="#">Section 5.9.6.3</a> (Asynchronous Mode (USEREADY = 1, READYMODE = 1)): Updated "Examples of valid and invalid timing" table (X2TIMING = 1 row) by changing Valid XRDATIVE value from "1" to "2" and Valid XWRACTIVE value from "1" to "2". .... | <a href="#">76</a>  |
| • <a href="#">Table 5-61</a> (Flash Parameters at 150-MHz SYSCLKOUT): Added MAX Program Time values and MAX Erase Time values. Added footnote about program time. Added footnote about maximum flash parameter. ....                                          | <a href="#">92</a>  |
| • <a href="#">Section 6.2.7</a> (Analog-to-Digital Converter (ADC) Module): Updated equations by which the digital value of the input analog voltage is derived. ....                                                                                         | <a href="#">122</a> |
| • <a href="#">Table 6-32</a> (PIE Peripheral Interrupts): Added footnote about ADCINT. ....                                                                                                                                                                   | <a href="#">167</a> |
| • <a href="#">Section 8.1</a> (Getting Started): Updated section. ....                                                                                                                                                                                        | <a href="#">178</a> |
| • <a href="#">Section 8.3</a> (Tools and Software): Updated section. ....                                                                                                                                                                                     | <a href="#">180</a> |
| • <a href="#">Section 8.4</a> (Documentation Support): Updated section. ....                                                                                                                                                                                  | <a href="#">182</a> |
| • <a href="#">Section 9.1</a> (Packaging Information): Added link to Packaging information website. ....                                                                                                                                                      | <a href="#">186</a> |

### 3 Device Comparison

**Table 3-1. F2833x Device Comparison**

| FEATURE                                          |                                            | TYPE <sup>(1)</sup> | F28335 (150 MHz)      | F28334 (150 MHz)      | F28333 (100 MHz)      | F28332 (100 MHz) |
|--------------------------------------------------|--------------------------------------------|---------------------|-----------------------|-----------------------|-----------------------|------------------|
| Instruction cycle                                |                                            | –                   | 6.67 ns               | 6.67 ns               | 10 ns                 | 10 ns            |
| Floating-point unit                              |                                            | –                   | Yes                   | Yes                   | Yes                   | Yes              |
| 3.3-V on-chip flash (16-bit word)                |                                            | –                   | 256K                  | 128K                  | 256K                  | 64K              |
| Single-access RAM (SARAM) (16-bit word)          |                                            | –                   | 34K                   | 34K                   | 34K                   | 26K              |
| One-time programmable (OTP) ROM (16-bit word)    |                                            | –                   | 1K                    | 1K                    | 1K                    | 1K               |
| Code security for on-chip flash/SARAM/OTP blocks |                                            | –                   | Yes                   | Yes                   | Yes                   | Yes              |
| Boot ROM (8K × 16)                               |                                            | –                   | Yes                   | Yes                   | Yes                   | Yes              |
| 16/32-bit External Interface (XINTF)             |                                            | 1                   | Yes                   | Yes                   | Yes                   | Yes              |
| 6-channel Direct Memory Access (DMA)             |                                            | 0                   | Yes                   | Yes                   | Yes                   | Yes              |
| PWM channels                                     |                                            | 0                   | ePWM1/2/3/4/5/6       | ePWM1/2/3/4/5/6       | ePWM1/2/3/4/5/6       | ePWM1/2/3/4/5/6  |
| HRPWM channels                                   |                                            | 0                   | ePWM1A/2A/3A/4A/5A/6A | ePWM1A/2A/3A/4A/5A/6A | ePWM1A/2A/3A/4A/5A/6A | ePWM1A/2A/3A/4A  |
| 32-bit capture inputs or auxiliary PWM outputs   |                                            | 0                   | eCAP1/2/3/4/5/6       | eCAP1/2/3/4           | eCAP1/2/3/4/5/6       | eCAP1/2/3/4      |
| 32-bit QEP channels (four inputs/channel)        |                                            | 0                   | eQEP1/2               | eQEP1/2               | eQEP1/2               | eQEP1/2          |
| Watchdog timer                                   |                                            | –                   | Yes                   | Yes                   | Yes                   | Yes              |
| 12-bit ADC                                       | No. of channels                            | 2                   | 16                    | 16                    | 16                    | 16               |
|                                                  | MSPS                                       |                     | 12.5                  | 12.5                  | 12.5                  | 12.5             |
|                                                  | Conversion time                            |                     | 80 ns                 | 80 ns                 | 80 ns                 | 80 ns            |
| 32-bit CPU timers                                |                                            | –                   | 3                     | 3                     | 3                     | 3                |
| Multichannel Buffered Serial Port (McBSP)/SPI    |                                            | 1                   | 2 (A/B)               | 2 (A/B)               | 2 (A/B)               | 1 (A)            |
| Serial Peripheral Interface (SPI)                |                                            | 0                   | 1                     | 1                     | 1                     | 1                |
| Serial Communications Interface (SCI)            |                                            | 0                   | 3 (A/B/C)             | 3 (A/B/C)             | 3 (A/B/C)             | 2 (A/B)          |
| Enhanced Controller Area Network (eCAN)          |                                            | 0                   | 2 (A/B)               | 2 (A/B)               | 2 (A/B)               | 2 (A/B)          |
| Inter-Integrated Circuit (I2C)                   |                                            | 0                   | 1                     | 1                     | 1                     | 1                |
| General-purpose I/O pins (shared)                |                                            | –                   | 88                    | 88                    | 88                    | 88               |
| External interrupts                              |                                            | –                   | 8                     | 8                     | 8                     | 8                |
| Packaging                                        | 176-Pin PGF                                | –                   | Yes                   | Yes                   | Yes                   | Yes              |
|                                                  | 176-Pin PTP                                | –                   | Yes                   | Yes                   | –                     | Yes              |
|                                                  | 179-Ball ZHH                               | –                   | Yes                   | Yes                   | –                     | Yes              |
|                                                  | 176-Ball ZJZ                               | –                   | Yes                   | Yes                   | –                     | Yes              |
| Temperature options                              | A: –40°C to 85°C                           | –                   | PGF, ZHH, ZJZ         | PGF, ZHH, ZJZ         | PGF                   | PGF, ZHH, ZJZ    |
|                                                  | S: –40°C to 125°C                          | –                   | PTP, ZJZ              | PTP, ZJZ              | –                     | PTP, ZJZ         |
|                                                  | Q: –40°C to 125°C (AEC Q100 Qualification) | –                   | PTP, ZJZ              | PTP, ZJZ              | –                     | PTP, ZJZ         |

- (1) A type change represents a major functional feature difference in a peripheral module. Within a peripheral type, there may be minor differences between devices that do not affect the basic functionality of the module. These device-specific differences are listed in the [C2000 real-time control peripherals reference guide](#) and in the peripheral reference guides.

**Table 3-2. F2823x Device Comparison**

| FEATURE                                             |                                                  | TYPE <sup>(1)</sup> | F28235 (150 MHz)      | F28234 (150 MHz)      | F28232 (100 MHz) |
|-----------------------------------------------------|--------------------------------------------------|---------------------|-----------------------|-----------------------|------------------|
| Instruction cycle                                   |                                                  | –                   | 6.67 ns               | 6.67 ns               | 10 ns            |
| Floating-point unit                                 |                                                  | –                   | <b>No</b>             | <b>No</b>             | <b>No</b>        |
| 3.3-V on-chip flash (16-bit word)                   |                                                  | –                   | 256K                  | 128K                  | 64K              |
| Single-access RAM (SARAM)<br>(16-bit word)          |                                                  | –                   | 34K                   | 34K                   | 26K              |
| One-time programmable (OTP) ROM<br>(16-bit word)    |                                                  | –                   | 1K                    | 1K                    | 1K               |
| Code security for on-chip<br>flash/SARAM/OTP blocks |                                                  | –                   | Yes                   | Yes                   | Yes              |
| Boot ROM (8K × 16)                                  |                                                  | –                   | Yes                   | Yes                   | Yes              |
| 16/32-bit External Interface (XINTF)                |                                                  | 1                   | Yes                   | Yes                   | Yes              |
| 6-channel Direct Memory Access (DMA)                |                                                  | 0                   | Yes                   | Yes                   | Yes              |
| PWM channels                                        |                                                  | 0                   | ePWM1/2/3/4/5/6       | ePWM1/2/3/4/5/6       | ePWM1/2/3/4/5/6  |
| HRPWM channels                                      |                                                  | 0                   | ePWM1A/2A/3A/4A/5A/6A | ePWM1A/2A/3A/4A/5A/6A | ePWM1A/2A/3A/4A  |
| 32-bit capture inputs or auxiliary PWM<br>outputs   |                                                  | 0                   | eCAP1/2/3/4/5/6       | eCAP1/2/3/4           | eCAP1/2/3/4      |
| 32-bit QEP channels (four inputs/channel)           |                                                  | 0                   | eQEP1/2               | eQEP1/2               | eQEP1/2          |
| Watchdog timer                                      |                                                  | –                   | Yes                   | Yes                   | Yes              |
| 12-bit ADC                                          | No. of channels                                  | 2                   | 16                    | 16                    | 16               |
|                                                     | MSPS                                             |                     | 12.5                  | 12.5                  | 12.5             |
|                                                     | Conversion time                                  |                     | 80 ns                 | 80 ns                 | 80 ns            |
| 32-bit CPU timers                                   |                                                  | –                   | 3                     | 3                     | 3                |
| Multichannel Buffered Serial Port<br>(McBSP)/SPI    |                                                  | 1                   | 2 (A/B)               | 2 (A/B)               | 1 (A)            |
| Serial Peripheral Interface (SPI)                   |                                                  | 0                   | 1                     | 1                     | 1                |
| Serial Communications Interface (SCI)               |                                                  | 0                   | 3 (A/B/C)             | 3 (A/B/C)             | 2 (A/B)          |
| Enhanced Controller Area Network<br>(eCAN)          |                                                  | 0                   | 2 (A/B)               | 2 (A/B)               | 2 (A/B)          |
| Inter-Integrated Circuit (I2C)                      |                                                  | 0                   | 1                     | 1                     | 1                |
| General-purpose I/O pins (shared)                   |                                                  | –                   | 88                    | 88                    | 88               |
| External interrupts                                 |                                                  | –                   | 8                     | 8                     | 8                |
| Packaging                                           | 176-Pin PGF                                      | –                   | Yes                   | Yes                   | Yes              |
|                                                     | 176-Pin PTP                                      | –                   | Yes                   | Yes                   | Yes              |
|                                                     | 179-Ball ZHH                                     | –                   | Yes                   | Yes                   | Yes              |
|                                                     | 176-Ball ZJZ                                     | –                   | Yes                   | Yes                   | Yes              |
| Temperature options                                 | A: –40°C to 85°C                                 | –                   | PGF, ZHH, ZJZ         | PGF, ZHH, ZJZ         | PGF, ZHH, ZJZ    |
|                                                     | S: –40°C to 125°C                                | –                   | PTP, ZJZ              | PTP, ZJZ              | PTP, ZJZ         |
|                                                     | Q: –40°C to 125°C<br>(AEC Q100<br>Qualification) | –                   | PTP, ZJZ              | PTP, ZJZ              | PTP, ZJZ         |

(1) A type change represents a major functional feature difference in a peripheral module. Within a peripheral type, there may be minor differences between devices that do not affect the basic functionality of the module. These device-specific differences are listed in the [C2000 real-time control peripherals reference guide](#) and in the peripheral reference guides.

### 3.1 Related Products

For information about other devices in the [Delfino](#) family of products, see the following links:

#### Original Delfino™ series:

##### [TMS320F2833x Delfino™ Microcontrollers](#)

The F2833x series is the original Delfino MCU. It is the first C2000™ MCU that is offered with a floating-point unit (FPU). It has the first-generation ePWM timers that are used throughout the rest of the Delfino and Piccolo™ families. The 12.5-MSPS, 12-bit ADC is still class-leading for an integrated analog-to-digital converter. The F2833x has a 150-MHz CPU and up to 512KB of on-chip Flash. It is available in a 176-pin QFP or 179-ball BGA package.

##### [TMS320C2834x Delfino™ Microcontrollers](#)

The C2834x series removes the on-chip Flash memory and integrated ADC to enable the fastest available clock speeds of up to 300 MHz. It is available in a 179-ball BGA or 256-ball BGA package.

#### Newest Delfino™ series:

##### [TMS320F2837xD Delfino™ Microcontrollers](#)

The F2837xD series sets a new standard for performance with dual subsystems. Each subsystem consists of a C28x CPU and a parallel control law accelerator (CLA), each running at 200 MHz. Enhancing performance are TMU and VCU [accelerators](#). New capabilities include multiple 16-bit/12-bit mode ADCs, DAC, Sigma-Delta filters, USB, configurable logic block (CLB), on-chip oscillators, and enhanced versions of all peripherals. The F2837xD is available with up to 1MB of Flash. It is available in a 176-pin QFP or 337-pin BGA package.

##### [TMS320F2837xS Delfino™ Microcontrollers](#)

The F2837xS series is a pin-to-pin compatible version of F2837xD but with only one C28x-CPU-and-CLA subsystem enabled. It is also available in a 100-pin QFP to enable compatibility with the Piccolo™ [TMS320F2807x](#) series.



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#### NOTE

The thermal pad should be soldered to the ground (GND) plane of the PCB because this will provide the best thermal conduction path. For this device, the thermal pad is not electrically shorted to the internal die  $V_{SS}$ ; therefore, the thermal pad does not provide an electrical connection to the PCB ground. To make optimum use of the thermal efficiencies designed into the PowerPAD™ package, the PCB must be designed with this technology in mind. A thermal land is required on the surface of the PCB directly underneath the thermal pad. The thermal land should be soldered to the thermal pad; the thermal land should be as large as needed to dissipate the required heat. An array of thermal vias should be used to connect the thermal pad to the internal GND plane of the board. See [PowerPAD™ thermally enhanced package](#) for more details on using the PowerPAD package.

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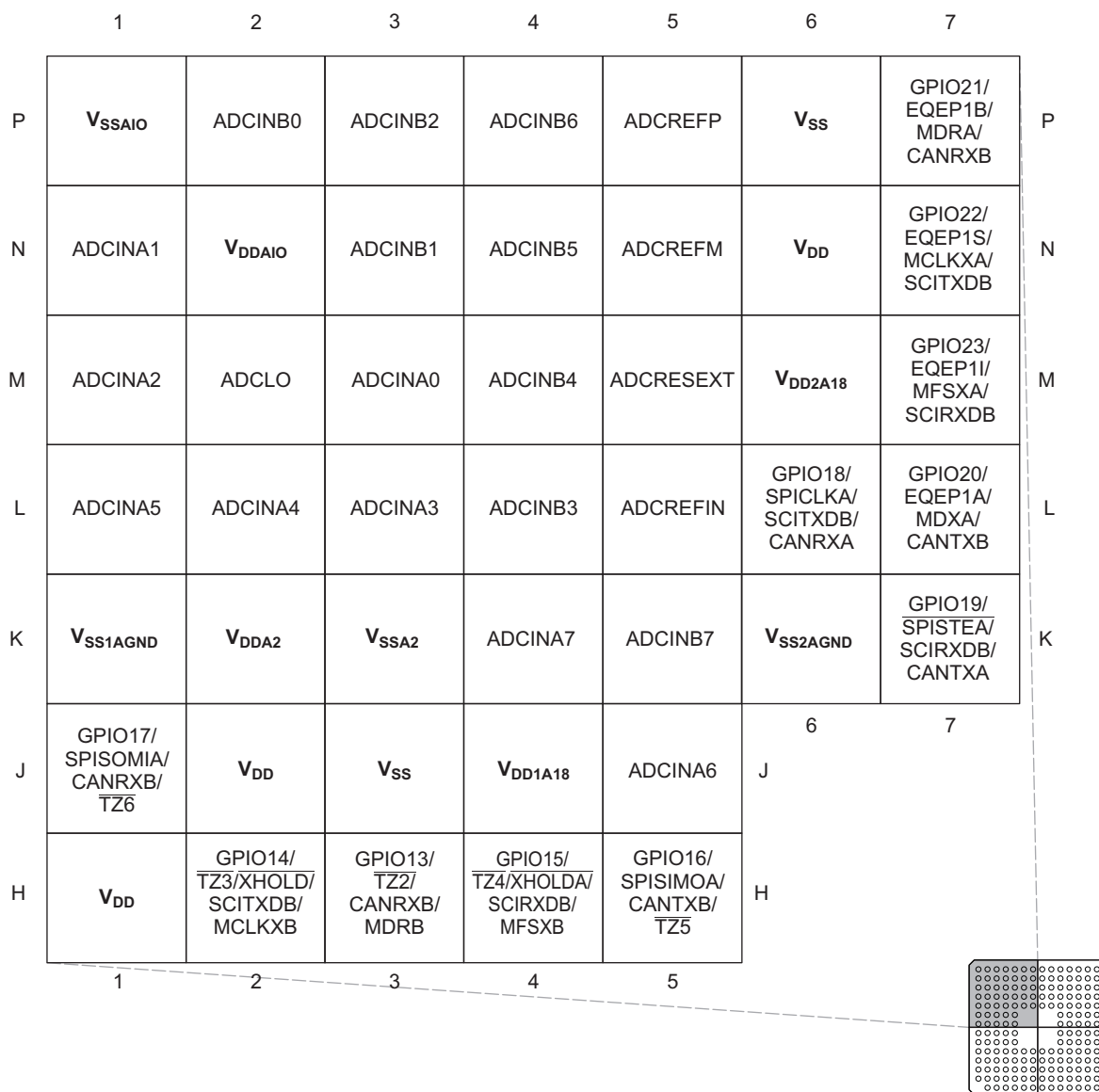


Figure 4-2. F2833x, F2823x 179-Ball ZHH MicroStar BGA (Upper-Left Quadrant) (Bottom View)

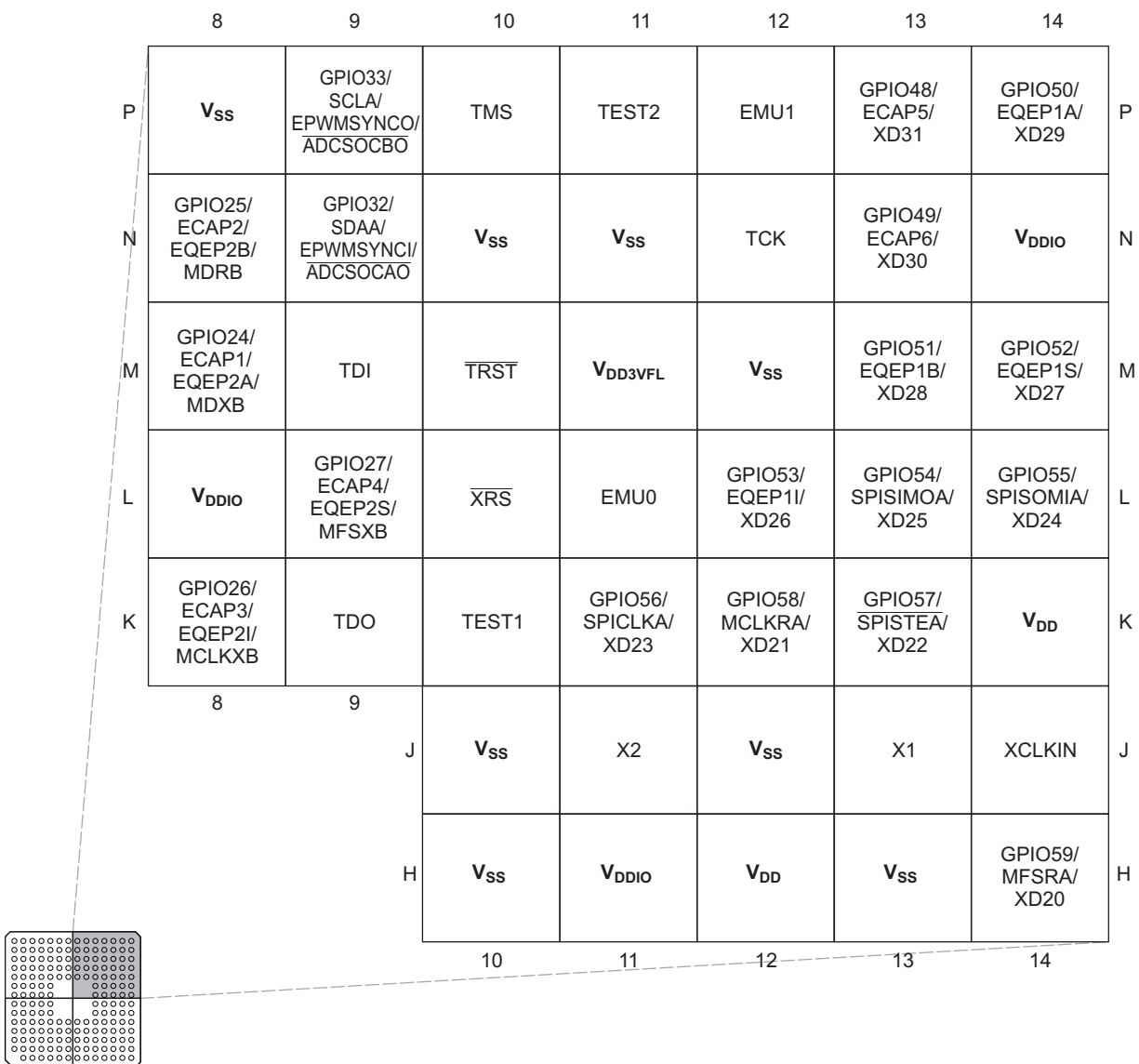


**Figure 4-3. F2833x, F2823x 179-Ball ZHH MicroStar BGA (Upper-Right Quadrant) (Bottom View)**

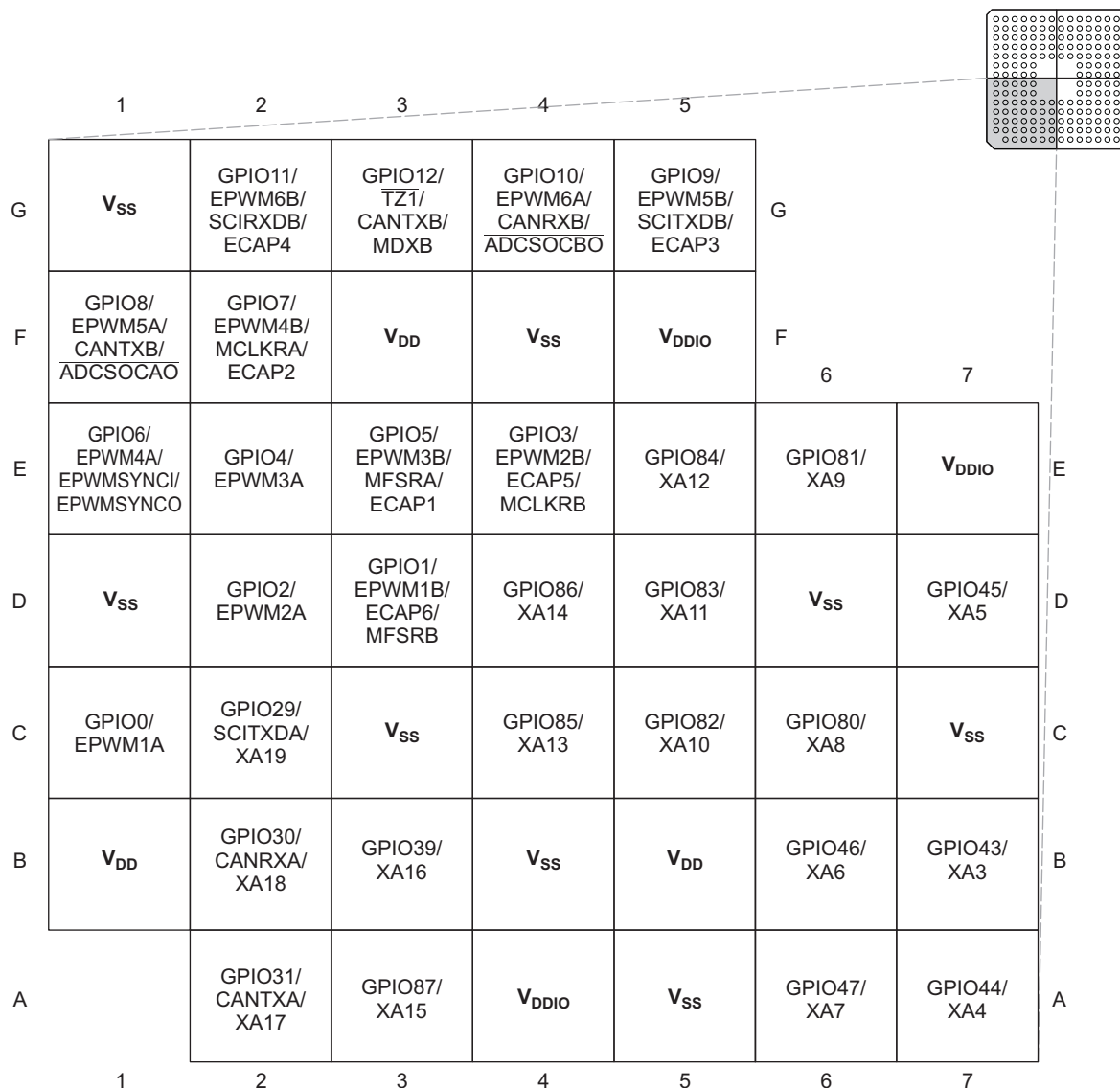


Figure 4-4. F2833x, F2823x 179-Ball ZHH MicroStar BGA (Lower-Left Quadrant) (Bottom View)



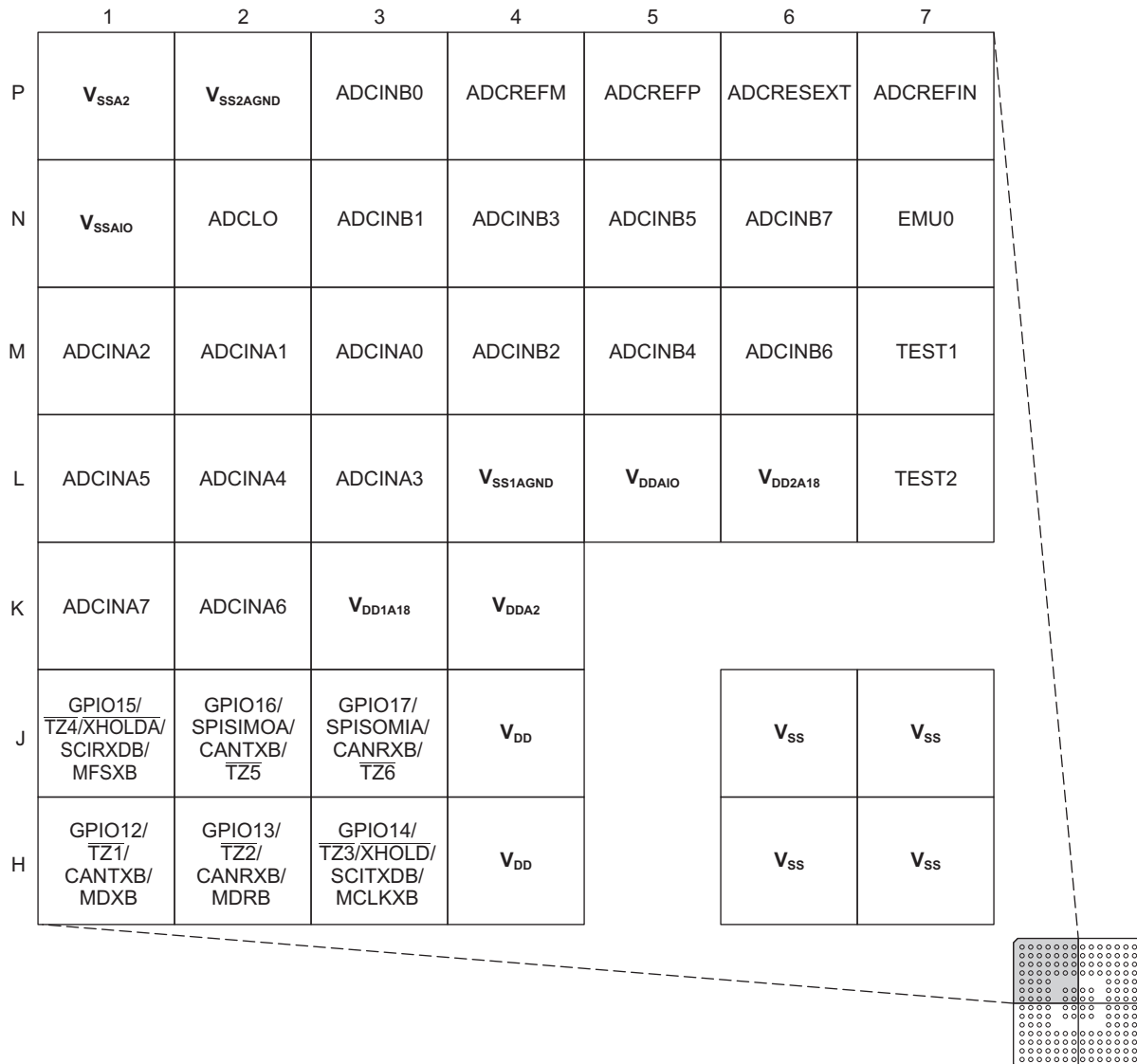


Figure 4-6. F2833x, F2823x 176-Ball ZJZ Plastic BGA (Upper-Left Quadrant) (Bottom View)

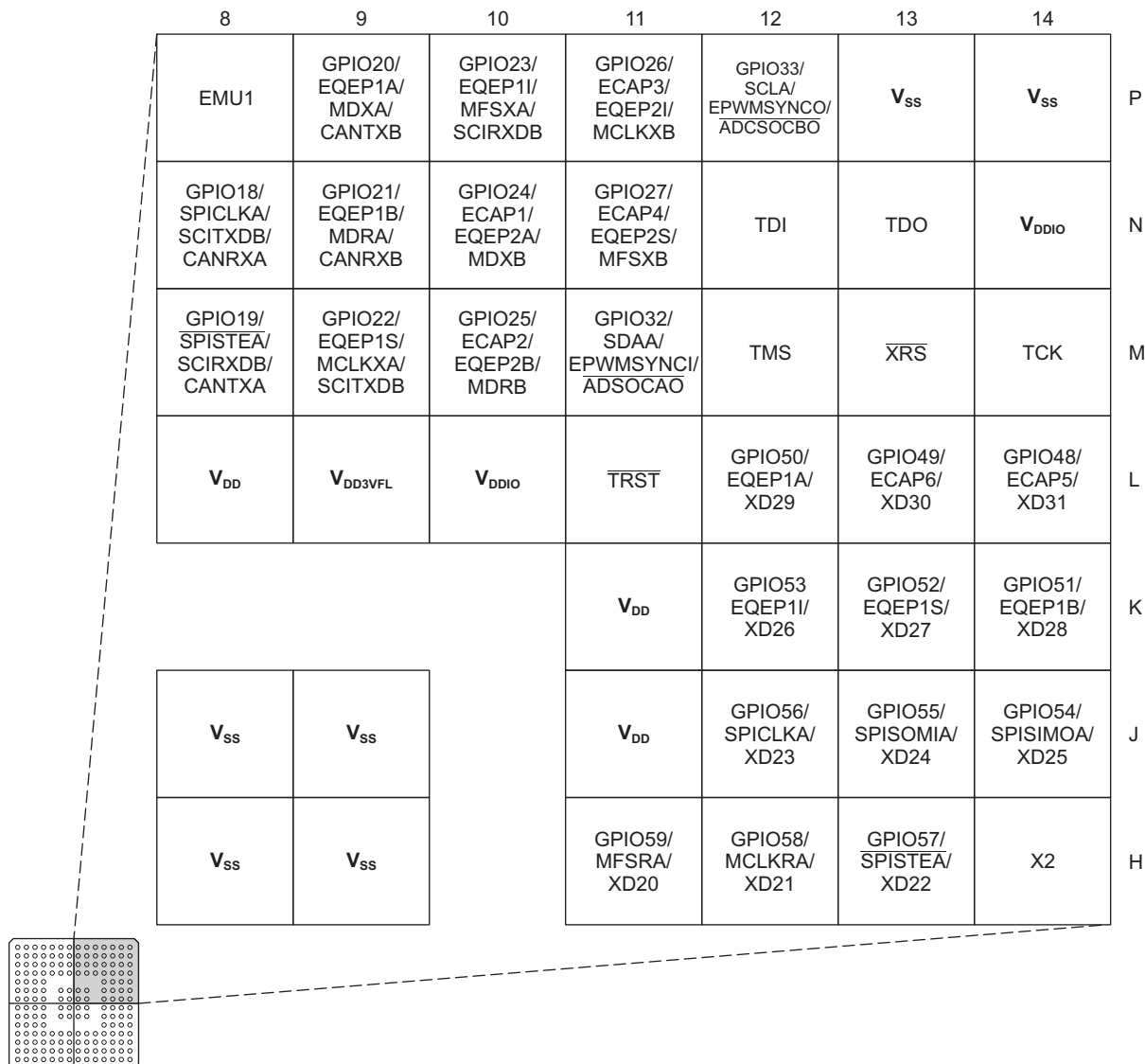


**Figure 4-7. F2833x, F2823x 176-Ball ZJZ Plastic BGA (Upper-Right Quadrant) (Bottom View)**

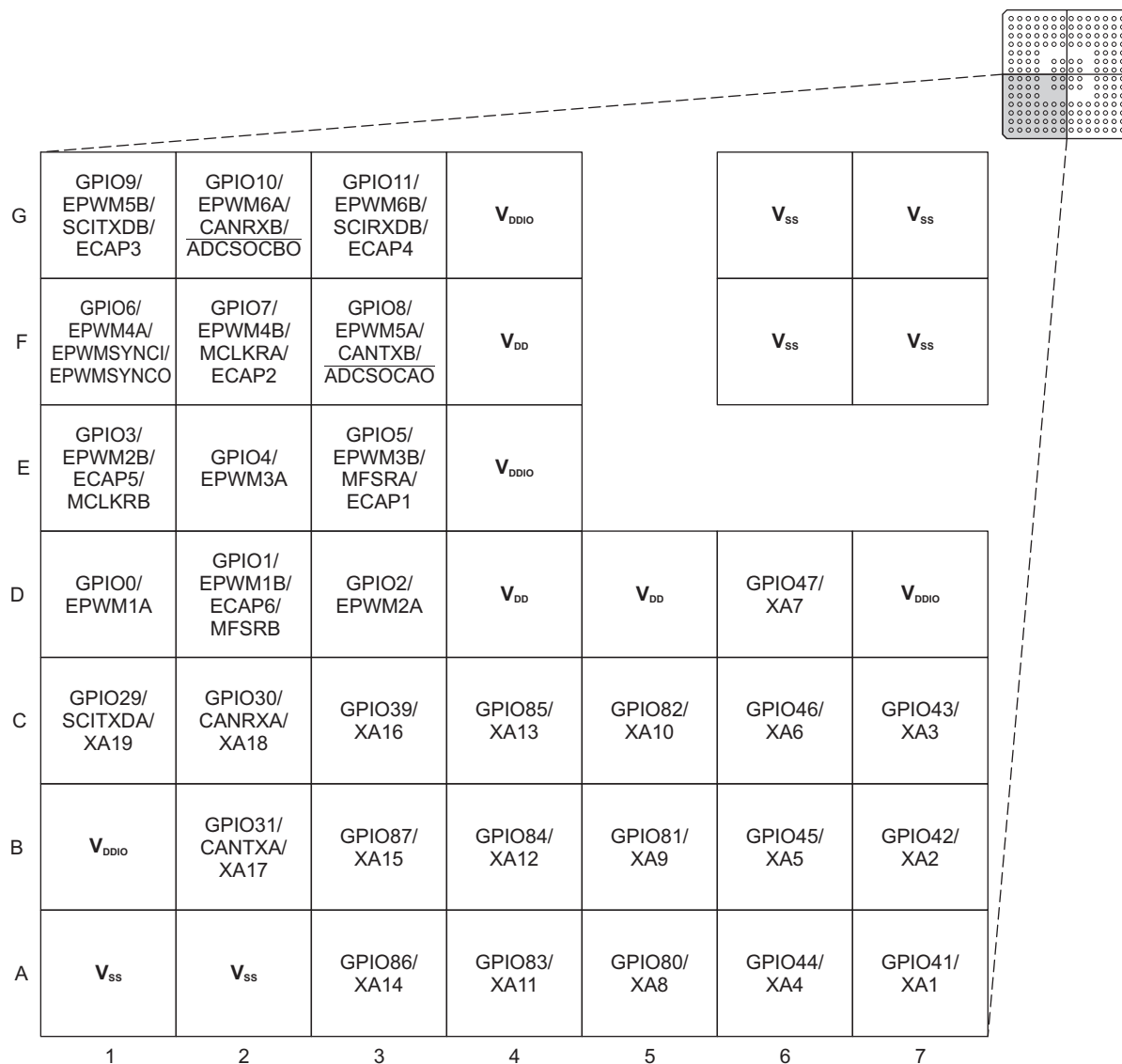


Figure 4-8. F2833x, F2823x 176-Ball ZJZ Plastic BGA (Lower-Left Quadrant) (Bottom View)

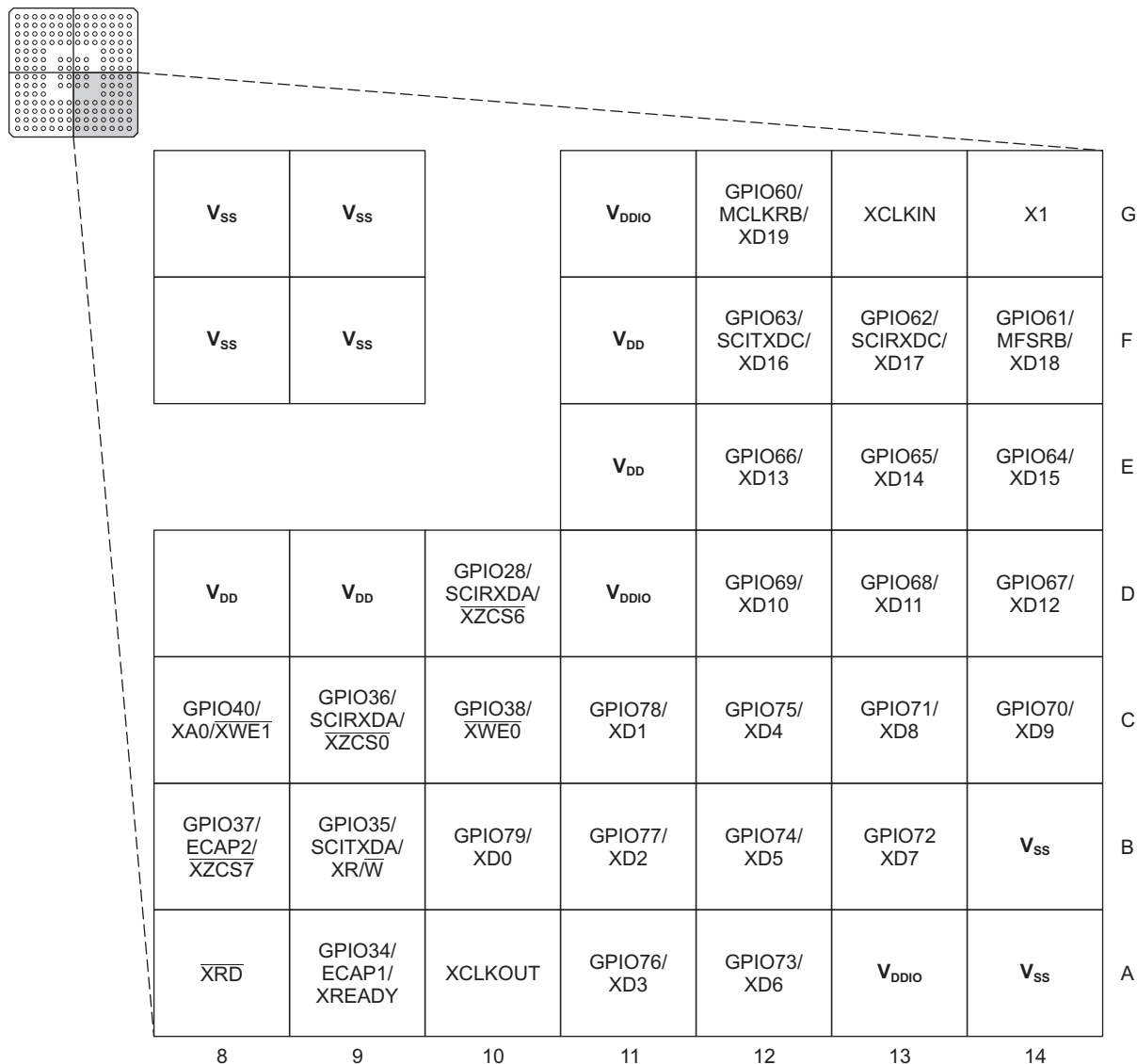


Figure 4-9. F2833x, F2823x 176-Ball ZJZ Plastic BGA (Lower-Right Quadrant) (Bottom View)

## 4.2 Signal Descriptions

Table 4-1 describes the signals. The GPIO function (shown in *Italics*) is the default at reset. The peripheral signals that are listed under them are alternate functions. Some peripheral functions may not be available in all devices. See Table 3-1 and Table 3-2 for details. Inputs are not 5-V tolerant. All pins capable of producing an XINTF output function have a drive strength of 8 mA (typical). This is true even if the pin is not configured for XINTF functionality. All other pins have a drive strength of 4-mA drive typical (unless otherwise indicated). All GPIO pins are I/O/Z and have an internal pullup, which can be selectively enabled or disabled on a per-pin basis. This feature only applies to the GPIO pins. The pullups on GPIO0–GPIO11 pins are not enabled at reset. The pullups on GPIO12–GPIO87 are enabled upon reset.

**Table 4-1. Signal Descriptions**

| NAME                     | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------------|----------------------|---------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| JTAG                     |                      |               |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| $\overline{\text{TRST}}$ | 78                   | M10           | L11           | JTAG test reset with internal pulldown. $\overline{\text{TRST}}$ , when driven high, gives the scan system control of the operations of the device. If this signal is not connected or driven low, the device operates in its functional mode, and the test reset signals are ignored.<br>NOTE: $\overline{\text{TRST}}$ is an active high test pin and must be maintained low at all times during normal device operation. An external pulldown resistor is required on this pin. The value of this resistor should be based on drive strength of the debugger pods applicable to the design. A 2.2-k $\Omega$ resistor generally offers adequate protection. Because this is application-specific, TI recommends validating each target board for proper operation of the debugger and the application. (I, $\downarrow$ )                                             |
| TCK                      | 87                   | N12           | M14           | JTAG test clock with internal pullup (I, $\uparrow$ )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| TMS                      | 79                   | P10           | M12           | JTAG test-mode select (TMS) with internal pullup. This serial control input is clocked into the TAP controller on the rising edge of TCK. (I, $\uparrow$ )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| TDI                      | 76                   | M9            | N12           | JTAG test data input (TDI) with internal pullup. TDI is clocked into the selected register (instruction or data) on a rising edge of TCK. (I, $\uparrow$ )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| TDO                      | 77                   | K9            | N13           | JTAG scan out, test data output (TDO). The contents of the selected register (instruction or data) are shifted out of TDO on the falling edge of TCK. (O/Z 8 mA drive)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| EMU0                     | 85                   | L11           | N7            | Emulator pin 0. When $\overline{\text{TRST}}$ is driven high, this pin is used as an interrupt to or from the emulator system and is defined as input/output through the JTAG scan. This pin is also used to put the device into boundary-scan mode. With the EMU0 pin at a logic-high state and the EMU1 pin at a logic-low state, a rising edge on the $\overline{\text{TRST}}$ pin would latch the device into boundary-scan mode. (I/O/Z, 8 mA drive $\uparrow$ )<br><b>NOTE:</b> An external pullup resistor is required on this pin. The value of this resistor should be based on the drive strength of the debugger pods applicable to the design. A 2.2-k $\Omega$ to 4.7-k $\Omega$ resistor is generally adequate. Because this is application-specific, TI recommends validating each target board for proper operation of the debugger and the application. |
| EMU1                     | 86                   | P12           | P8            | Emulator pin 1. When $\overline{\text{TRST}}$ is driven high, this pin is used as an interrupt to or from the emulator system and is defined as input/output through the JTAG scan. This pin is also used to put the device into boundary-scan mode. With the EMU0 pin at a logic-high state and the EMU1 pin at a logic-low state, a rising edge on the $\overline{\text{TRST}}$ pin would latch the device into boundary-scan mode. (I/O/Z, 8 mA drive $\uparrow$ )<br><b>NOTE:</b> An external pullup resistor is required on this pin. The value of this resistor should be based on the drive strength of the debugger pods applicable to the design. A 2.2-k $\Omega$ to 4.7-k $\Omega$ resistor is generally adequate. Because this is application-specific, TI recommends validating each target board for proper operation of the debugger and the application. |
| FLASH                    |                      |               |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| V <sub>DD3VFL</sub>      | 84                   | M11           | L9            | 3.3-V Flash Core Power Pin. This pin should be connected to 3.3 V at all times.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| TEST1                    | 81                   | K10           | M7            | Test Pin. Reserved for TI. Must be left unconnected. (I/O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| TEST2                    | 82                   | P11           | L7            | Test Pin. Reserved for TI. Must be left unconnected. (I/O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

(1) I = Input, O = Output, Z = High impedance, OD = Open drain,  $\uparrow$  = Pullup,  $\downarrow$  = Pulldown

**Table 4-1. Signal Descriptions (continued)**

| NAME                    | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------------------|----------------------|---------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| CLOCK                   |                      |               |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| XCLKOUT                 | 138                  | C11           | A10           | Output clock derived from SYSCLKOUT. XCLKOUT is either the same frequency, one-half the frequency, or one-fourth the frequency of SYSCLKOUT. This is controlled by bits 18:16 (XTIMCLK) and bit 2 (CLKMODE) in the XINTCNF2 register. At reset, XCLKOUT = SYSCLKOUT/4. The XCLKOUT signal can be turned off by setting XINTCNF2[CLKOFF] to 1. Unlike other GPIO pins, the XCLKOUT pin is not placed in high-impedance state during a reset. (O/Z, 8 mA drive).                                                                                                                                                                                                                                           |
| XCLKIN                  | 105                  | J14           | G13           | External Oscillator Input. This pin is to feed a clock from an external 3.3-V oscillator. In this case, the X1 pin must be tied to GND. If a crystal/resonator is used (or if an external 1.9-V oscillator is used to feed clock to X1 pin), this pin must be tied to GND. (I)                                                                                                                                                                                                                                                                                                                                                                                                                           |
| X1                      | 104                  | J13           | G14           | Internal/External Oscillator Input. To use the internal oscillator, a quartz crystal or a ceramic resonator may be connected across X1 and X2. The X1 pin is referenced to the 1.9-V/1.8-V core digital power supply. A 1.9-V/1.8-V external oscillator may be connected to the X1 pin. In this case, the XCLKIN pin must be connected to ground. If a 3.3-V external oscillator is used with the XCLKIN pin, X1 must be tied to GND. (I)                                                                                                                                                                                                                                                                |
| X2                      | 102                  | J11           | H14           | Internal Oscillator Output. A quartz crystal or a ceramic resonator may be connected across X1 and X2. If X2 is not used, it must be left unconnected. (O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| RESET                   |                      |               |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| $\overline{\text{XRS}}$ | 80                   | L10           | M13           | Device Reset (in) and Watchdog Reset (out).<br>Device reset. $\overline{\text{XRS}}$ causes the device to terminate execution. The PC will point to the address contained at the location 0x3FFFC0. When $\overline{\text{XRS}}$ is brought to a high level, execution begins at the location pointed to by the PC. This pin is driven low by the DSC when a watchdog reset occurs. During watchdog reset, the $\overline{\text{XRS}}$ pin is driven low for the watchdog reset duration of 512 OSCCLK cycles. (I/OD, $\uparrow$ )<br>The output buffer of this pin is an open drain with an internal pullup. If this pin is driven by an external device, it should be done using an open-drain device. |
| ADC SIGNALS             |                      |               |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| ADCINA7                 | 35                   | K4            | K1            | ADC Group A, Channel 7 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA6                 | 36                   | J5            | K2            | ADC Group A, Channel 6 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA5                 | 37                   | L1            | L1            | ADC Group A, Channel 5 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA4                 | 38                   | L2            | L2            | ADC Group A, Channel 4 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA3                 | 39                   | L3            | L3            | ADC Group A, Channel 3 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA2                 | 40                   | M1            | M1            | ADC Group A, Channel 2 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA1                 | 41                   | N1            | M2            | ADC Group A, Channel 1 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINA0                 | 42                   | M3            | M3            | ADC Group A, Channel 0 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB7                 | 53                   | K5            | N6            | ADC Group B, Channel 7 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB6                 | 52                   | P4            | M6            | ADC Group B, Channel 6 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB5                 | 51                   | N4            | N5            | ADC Group B, Channel 5 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB4                 | 50                   | M4            | M5            | ADC Group B, Channel 4 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB3                 | 49                   | L4            | N4            | ADC Group B, Channel 3 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB2                 | 48                   | P3            | M4            | ADC Group B, Channel 2 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB1                 | 47                   | N3            | N3            | ADC Group B, Channel 1 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCINB0                 | 46                   | P2            | P3            | ADC Group B, Channel 0 input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| ADCLO                   | 43                   | M2            | N2            | Low Reference (connect to analog ground) (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| ADCRESEXT               | 57                   | M5            | P6            | ADC External Current Bias Resistor. Connect a 22-k $\Omega$ resistor to analog ground.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| ADCREFIN                | 54                   | L5            | P7            | External reference input (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

**Table 4-1. Signal Descriptions (continued)**

| NAME                          | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                                                                                                                                                  |
|-------------------------------|----------------------|---------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                               | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                                                                                                                                                             |
| ADCREFP                       | 56                   | P5            | P5            | Internal Reference Positive Output. Requires a low ESR (under 1.5 $\Omega$ ) ceramic bypass capacitor of 2.2 $\mu$ F to analog ground. (O)<br><b>NOTE:</b> Use the ADC Clock rate to derive the ESR specification from the capacitor data sheet that is used in the system. |
| ADCREFM                       | 55                   | N5            | P4            | Internal Reference Medium Output. Requires a low ESR (under 1.5 $\Omega$ ) ceramic bypass capacitor of 2.2 $\mu$ F to analog ground. (O)<br><b>NOTE:</b> Use the ADC Clock rate to derive the ESR specification from the capacitor data sheet that is used in the system.   |
| <b>CPU AND I/O POWER PINS</b> |                      |               |               |                                                                                                                                                                                                                                                                             |
| V <sub>DDA2</sub>             | 34                   | K2            | K4            | ADC Analog Power Pin                                                                                                                                                                                                                                                        |
| V <sub>SSA2</sub>             | 33                   | K3            | P1            | ADC Analog Ground Pin                                                                                                                                                                                                                                                       |
| V <sub>DDAIO</sub>            | 45                   | N2            | L5            | ADC Analog I/O Power Pin                                                                                                                                                                                                                                                    |
| V <sub>SSAIO</sub>            | 44                   | P1            | N1            | ADC Analog I/O Ground Pin                                                                                                                                                                                                                                                   |
| V <sub>DD1A18</sub>           | 31                   | J4            | K3            | ADC Analog Power Pin                                                                                                                                                                                                                                                        |
| V <sub>SS1AGND</sub>          | 32                   | K1            | L4            | ADC Analog Ground Pin                                                                                                                                                                                                                                                       |
| V <sub>DD2A18</sub>           | 59                   | M6            | L6            | ADC Analog Power Pin                                                                                                                                                                                                                                                        |
| V <sub>SS2AGND</sub>          | 58                   | K6            | P2            | ADC Analog Ground Pin                                                                                                                                                                                                                                                       |
| V <sub>DD</sub>               | 4                    | B1            | D4            | CPU and Logic Digital Power Pins                                                                                                                                                                                                                                            |
| V <sub>DD</sub>               | 15                   | B5            | D5            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 23                   | B11           | D8            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 29                   | C8            | D9            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 61                   | D13           | E11           |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 101                  | E9            | F4            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 109                  | F3            | F11           |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 117                  | F13           | H4            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 126                  | H1            | J4            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 139                  | H12           | J11           |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 146                  | J2            | K11           |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 154                  | K14           | L8            |                                                                                                                                                                                                                                                                             |
| V <sub>DD</sub>               | 167                  | N6            |               |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 9                    | A4            | A13           | Digital I/O Power Pin                                                                                                                                                                                                                                                       |
| V <sub>DDIO</sub>             | 71                   | B10           | B1            |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 93                   | E7            | D7            |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 107                  | E12           | D11           |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 121                  | F5            | E4            |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 143                  | L8            | G4            |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 159                  | H11           | G11           |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             | 170                  | N14           | L10           |                                                                                                                                                                                                                                                                             |
| V <sub>DDIO</sub>             |                      |               | N14           |                                                                                                                                                                                                                                                                             |

**Table 4-1. Signal Descriptions (continued)**

| NAME                               | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                         |
|------------------------------------|----------------------|---------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
|                                    | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                                    |
| V <sub>SS</sub>                    | 3                    | A5            | A1            | Digital Ground Pins                                                                                                                                |
| V <sub>SS</sub>                    | 8                    | A10           | A2            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 14                   | A11           | A14           |                                                                                                                                                    |
| V <sub>SS</sub>                    | 22                   | B4            | B14           |                                                                                                                                                    |
| V <sub>SS</sub>                    | 30                   | C3            | F6            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 60                   | C7            | F7            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 70                   | C9            | F8            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 83                   | D1            | F9            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 92                   | D6            | G6            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 103                  | D14           | G7            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 106                  | E8            | G8            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 108                  | E14           | G9            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 118                  | F4            | H6            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 120                  | F12           | H7            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 125                  | G1            | H8            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 140                  | H10           | H9            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 144                  | H13           | J6            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 147                  | J3            | J7            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 155                  | J10           | J8            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 160                  | J12           | J9            |                                                                                                                                                    |
| V <sub>SS</sub>                    | 166                  | M12           | P13           |                                                                                                                                                    |
| V <sub>SS</sub>                    | 171                  | N10           | P14           |                                                                                                                                                    |
| V <sub>SS</sub>                    |                      | N11           |               |                                                                                                                                                    |
| V <sub>SS</sub>                    |                      | P6            |               |                                                                                                                                                    |
| V <sub>SS</sub>                    |                      | P8            |               |                                                                                                                                                    |
| GPIO AND PERIPHERAL SIGNALS        |                      |               |               |                                                                                                                                                    |
| GPIO0<br>EPWM1A<br>-<br>-          | 5                    | C1            | D1            | General-purpose input/output 0 (I/O/Z)<br>Enhanced PWM1 Output A and HRPWM channel (O)<br>-<br>-                                                   |
| GPIO1<br>EPWM1B<br>ECAP6<br>MFSRB  | 6                    | D3            | D2            | General-purpose input/output 1 (I/O/Z)<br>Enhanced PWM1 Output B (O)<br>Enhanced Capture 6 input/output (I/O)<br>McBSP-B receive frame synch (I/O) |
| GPIO2<br>EPWM2A<br>-<br>-          | 7                    | D2            | D3            | General-purpose input/output 2 (I/O/Z)<br>Enhanced PWM2 Output A and HRPWM channel (O)<br>-<br>-                                                   |
| GPIO3<br>EPWM2B<br>ECAP5<br>MCLKRB | 10                   | E4            | E1            | General-purpose input/output 3 (I/O/Z)<br>Enhanced PWM2 Output B (O)<br>Enhanced Capture 5 input/output (I/O)<br>McBSP-B receive clock (I/O)       |
| GPIO4<br>EPWM3A<br>-<br>-          | 11                   | E2            | E2            | General-purpose input/output 4 (I/O/Z)<br>Enhanced PWM3 output A and HRPWM channel (O)<br>-<br>-                                                   |
| GPIO5<br>EPWM3B<br>MFSRA<br>ECAP1  | 12                   | E3            | E3            | General-purpose input/output 5 (I/O/Z)<br>Enhanced PWM3 output B (O)<br>McBSP-A receive frame synch (I/O)<br>Enhanced Capture input/output 1 (I/O) |

Table 4-1. Signal Descriptions (continued)

| NAME                                             | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------------------|----------------------|---------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                  | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| GPIO6<br>EPWM4A<br>EPWMSYNCI<br>EPWMSYNCO        | 13                   | E1            | F1            | General-purpose input/output 6 (I/O/Z)<br>Enhanced PWM4 output A and HRPWM channel (O)<br>External ePWM sync pulse input (I)<br>External ePWM sync pulse output (O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| GPIO7<br>EPWM4B<br>MCLKRA<br>ECAP2               | 16                   | F2            | F2            | General-purpose input/output 7 (I/O/Z)<br>Enhanced PWM4 output B (O)<br>McBSP-A receive clock (I/O)<br>Enhanced capture input/output 2 (I/O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| GPIO8<br>EPWM5A<br>CANTXB<br>ADCSOCAO            | 17                   | F1            | F3            | General-purpose Input/Output 8 (I/O/Z)<br>Enhanced PWM5 output A and HRPWM channel (O)<br>Enhanced CAN-B transmit (O)<br>ADC start-of-conversion A (O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| GPIO9<br>EPWM5B<br>SCITXDB<br>ECAP3              | 18                   | G5            | G1            | General-purpose input/output 9 (I/O/Z)<br>Enhanced PWM5 output B (O)<br>SCI-B transmit data(O)<br>Enhanced capture input/output 3 (I/O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| GPIO10<br>EPWM6A<br>CANRXB<br>ADCSOCBO           | 19                   | G4            | G2            | General-purpose input/output 10 (I/O/Z)<br>Enhanced PWM6 output A and HRPWM channel (O)<br>Enhanced CAN-B receive (I)<br>ADC start-of-conversion B (O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| GPIO11<br>EPWM6B<br>SCIRXDB<br>ECAP4             | 20                   | G2            | G3            | General-purpose input/output 11 (I/O/Z)<br>Enhanced PWM6 output B (O)<br>SCI-B receive data (I)<br>Enhanced CAP Input/Output 4 (I/O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| GPIO12<br>TZ1<br>CANTXB<br>MDXB                  | 21                   | G3            | H1            | General-purpose input/output 12 (I/O/Z)<br>Trip Zone input 1 (I)<br>Enhanced CAN-B transmit (O)<br>McBSP-B transmit serial data (O)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| GPIO13<br>TZ2<br>CANRXB<br>MDRB                  | 24                   | H3            | H2            | General-purpose input/output 13 (I/O/Z)<br>Trip Zone input 2 (I)<br>Enhanced CAN-B receive (I)<br>McBSP-B receive serial data (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| GPIO14<br><br>TZ3/XHOLD<br><br>SCITXDB<br>MCLKXB | 25                   | H2            | H3            | General-purpose input/output 14 (I/O/Z)<br><br>Trip Zone input 3/External Hold Request. <u>XHOLD</u> , when active (low), requests the external interface (XINTF) to release the external bus and place all buses and strobes into a high-impedance state. To prevent this from happening when <u>TZ3</u> signal goes active, disable this function by writing XINTCNF2[HOLD] = 1. If this is not done, the XINTF bus will go into high impedance anytime <u>TZ3</u> goes low. On the ePWM side, <u>TZn</u> signals are ignored by default, unless they are enabled by the code. The XINTF will release the bus when any current access is complete and there are no pending accesses on the XINTF. (I)<br><br>SCI-B Transmit (O)<br>McBSP-B transmit clock (I/O) |
| GPIO15<br><br>TZ4/XHOLDA<br><br>SCIRXDB<br>MFSXB | 26                   | H4            | J1            | General-purpose input/output 15 (I/O/Z)<br><br>Trip Zone input 4/External Hold Acknowledge. The pin function for this option is based on the direction chosen in the GPADIR register. If the pin is configured as an input, then <u>TZ4</u> function is chosen. If the pin is configured as an output, then <u>XHOLDA</u> function is chosen. <u>XHOLDA</u> is driven active (low) when the XINTF has granted an <u>XHOLD</u> request. All XINTF buses and strobe signals will be in a high-impedance state. <u>XHOLDA</u> is released when the <u>XHOLD</u> signal is released. External devices should only drive the external bus when <u>XHOLDA</u> is active (low). (I/O)<br><br>SCI-B receive (I)<br>McBSP-B transmit frame synch (I/O)                     |
| GPIO16<br>SPISIMOA<br>CANTXB<br>TZ5              | 27                   | H5            | J2            | General-purpose input/output 16 (I/O/Z)<br>SPI slave in, master out (I/O)<br>Enhanced CAN-B transmit (O)<br>Trip Zone input 5 (I)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

**Table 4-1. Signal Descriptions (continued)**

| NAME                                   | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                    |
|----------------------------------------|----------------------|---------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
|                                        | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                               |
| GPIO17<br>SPISOMIA<br>CANRXB<br>TZ6    | 28                   | J1            | J3            | General-purpose input/output 17 (I/O/Z)<br>SPI-A slave out, master in (I/O)<br>Enhanced CAN-B receive (I)<br>Trip zone input 6 (I)            |
| GPIO18<br>SPICLKA<br>SCITXDB<br>CANRXA | 62                   | L6            | N8            | General-purpose input/output 18 (I/O/Z)<br>SPI-A clock input/output (I/O)<br>SCI-B transmit (O)<br>Enhanced CAN-A receive (I)                 |
| GPIO19<br>SPISTEA<br>SCIRXDB<br>CANTXA | 63                   | K7            | M8            | General-purpose input/output 19 (I/O/Z)<br>SPI-A slave transmit enable input/output (I/O)<br>SCI-B receive (I)<br>Enhanced CAN-A transmit (O) |
| GPIO20<br>EQEP1A<br>MDXA<br>CANTXB     | 64                   | L7            | P9            | General-purpose input/output 20 (I/O/Z)<br>Enhanced QEP1 input A (I)<br>McBSP-A transmit serial data (O)<br>Enhanced CAN-B transmit (O)       |
| GPIO21<br>EQEP1B<br>MDRA<br>CANRXB     | 65                   | P7            | N9            | General-purpose input/output 21 (I/O/Z)<br>Enhanced QEP1 input B (I)<br>McBSP-A receive serial data (I)<br>Enhanced CAN-B receive (I)         |
| GPIO22<br>EQEP1S<br>MCLKXA<br>SCITXDB  | 66                   | N7            | M9            | General-purpose input/output 22 (I/O/Z)<br>Enhanced QEP1 strobe (I/O)<br>McBSP-A transmit clock (I/O)<br>SCI-B transmit (O)                   |
| GPIO23<br>EQEP1I<br>MFSXA<br>SCIRXDB   | 67                   | M7            | P10           | General-purpose input/output 23 (I/O/Z)<br>Enhanced QEP1 index (I/O)<br>McBSP-A transmit frame synch (I/O)<br>SCI-B receive (I)               |
| GPIO24<br>ECAP1<br>EQEP2A<br>MDXB      | 68                   | M8            | N10           | General-purpose input/output 24 (I/O/Z)<br>Enhanced capture 1 (I/O)<br>Enhanced QEP2 input A (I)<br>McBSP-B transmit serial data (O)          |
| GPIO25<br>ECAP2<br>EQEP2B<br>MDRB      | 69                   | N8            | M10           | General-purpose input/output 25 (I/O/Z)<br>Enhanced capture 2 (I/O)<br>Enhanced QEP2 input B (I)<br>McBSP-B receive serial data (I)           |
| GPIO26<br>ECAP3<br>EQEP2I<br>MCLKXB    | 72                   | K8            | P11           | General-purpose input/output 26 (I/O/Z)<br>Enhanced capture 3 (I/O)<br>Enhanced QEP2 index (I/O)<br>McBSP-B transmit clock (I/O)              |
| GPIO27<br>ECAP4<br>EQEP2S<br>MFSXB     | 73                   | L9            | N11           | General-purpose input/output 27 (I/O/Z)<br>Enhanced capture 4 (I/O)<br>Enhanced QEP2 strobe (I/O)<br>McBSP-B transmit frame synch (I/O)       |
| GPIO28<br>SCIRXDA<br>XZCS6             | 141                  | E10           | D10           | General-purpose input/output 28 (I/O/Z)<br>SCI receive data (I)<br>External Interface zone 6 chip select (O)                                  |
| GPIO29<br>SCITXDA<br>XA19              | 2                    | C2            | C1            | General-purpose input/output 29. (I/O/Z)<br>SCI transmit data (O)<br>External Interface Address Line 19 (O)                                   |
| GPIO30<br>CANRXA<br>XA18               | 1                    | B2            | C2            | General-purpose input/output 30 (I/O/Z)<br>Enhanced CAN-A receive (I)<br>External Interface Address Line 18 (O)                               |
| GPIO31<br>CANTXA<br>XA17               | 176                  | A2            | B2            | General-purpose input/output 31 (I/O/Z)<br>Enhanced CAN-A transmit (O)<br>External Interface Address Line 17 (O)                              |

**Table 4-1. Signal Descriptions (continued)**

| NAME                                    | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                                                                                                                                                                                                                |
|-----------------------------------------|----------------------|---------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                         | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                                                                                                                                                                                                           |
| GPIO32<br>SDAA<br>EPWMSYNCI<br>ADCSOCAO | 74                   | N9            | M11           | General-purpose input/output 32 (I/O/Z)<br>I2C data open-drain bidirectional port (I/OD)<br>Enhanced PWM external sync pulse input (I)<br>ADC start-of-conversion A (O)                                                                                                                                   |
| GPIO33<br>SCLA<br>EPWMSYNCO<br>ADCSOCBO | 75                   | P9            | P12           | General-purpose Input/Output 33 (I/O/Z)<br>I2C clock open-drain bidirectional port (I/OD)<br>Enhanced PWM external synch pulse output (O)<br>ADC start-of-conversion B (O)                                                                                                                                |
| GPIO34<br>ECAP1<br>XREADY               | 142                  | D10           | A9            | General-purpose Input/Output 34 (I/O/Z)<br>Enhanced Capture input/output 1 (I/O)<br>External Interface Ready signal. Note that this pin is always (directly) connected to the XINTF. If an application uses this pin as a GPIO while also using the XINTF, it should configure the XINTF to ignore READY. |
| GPIO35<br>SCITXDA<br>XR/W               | 148                  | A9            | B9            | General-purpose Input/Output 35 (I/O/Z)<br>SCI-A transmit data (O)<br>External Interface read, not write strobe                                                                                                                                                                                           |
| GPIO36<br>SCIRXDA<br>XZCS0              | 145                  | C10           | C9            | General-purpose Input/Output 36 (I/O/Z)<br>SCI receive data (I)<br>External Interface zone 0 chip select (O)                                                                                                                                                                                              |
| GPIO37<br>ECAP2<br>XZCS7                | 150                  | D9            | B8            | General-purpose Input/Output 37 (I/O/Z)<br>Enhanced Capture input/output 2 (I/O)<br>External Interface zone 7 chip select (O)                                                                                                                                                                             |
| GPIO38<br>-<br>XWE0                     | 137                  | D11           | C10           | General-purpose Input/Output 38 (I/O/Z)<br>-<br>External Interface Write Enable 0 (O)                                                                                                                                                                                                                     |
| GPIO39<br>-<br>XA16                     | 175                  | B3            | C3            | General-purpose Input/Output 39 (I/O/Z)<br>-<br>External Interface Address Line 16 (O)                                                                                                                                                                                                                    |
| GPIO40<br>-<br>XA0/XWE1                 | 151                  | D8            | C8            | General-purpose Input/Output 40 (I/O/Z)<br>-<br>External Interface Address Line 0/External Interface Write Enable 1 (O)                                                                                                                                                                                   |
| GPIO41<br>-<br>XA1                      | 152                  | A8            | A7            | General-purpose Input/Output 41 (I/O/Z)<br>-<br>External Interface Address Line 1 (O)                                                                                                                                                                                                                     |
| GPIO42<br>-<br>XA2                      | 153                  | B8            | B7            | General-purpose Input/Output 42 (I/O/Z)<br>-<br>External Interface Address Line 2 (O)                                                                                                                                                                                                                     |
| GPIO43<br>-<br>XA3                      | 156                  | B7            | C7            | General-purpose Input/Output 43 (I/O/Z)<br>-<br>External Interface Address Line 3 (O)                                                                                                                                                                                                                     |
| GPIO44<br>-<br>XA4                      | 157                  | A7            | A6            | General-purpose Input/Output 44 (I/O/Z)<br>-<br>External Interface Address Line 4 (O)                                                                                                                                                                                                                     |
| GPIO45<br>-<br>XA5                      | 158                  | D7            | B6            | General-purpose Input/Output 45 (I/O/Z)<br>-<br>External Interface Address Line 5 (O)                                                                                                                                                                                                                     |
| GPIO46<br>-<br>XA6                      | 161                  | B6            | C6            | General-purpose Input/Output 46 (I/O/Z)<br>-<br>External Interface Address Line 6 (O)                                                                                                                                                                                                                     |
| GPIO47<br>-<br>XA7                      | 162                  | A6            | D6            | General-purpose Input/Output 47 (I/O/Z)<br>-<br>External Interface Address Line 7 (O)                                                                                                                                                                                                                     |
| GPIO48<br>ECAP5<br>XD31                 | 88                   | P13           | L14           | General-purpose Input/Output 48 (I/O/Z)<br>Enhanced Capture input/output 5 (I/O)<br>External Interface Data Line 31 (I/O/Z)                                                                                                                                                                               |
| GPIO49<br>ECAP6<br>XD30                 | 89                   | N13           | L13           | General-purpose Input/Output 49 (I/O/Z)<br>Enhanced Capture input/output 6 (I/O)<br>External Interface Data Line 30 (I/O/Z)                                                                                                                                                                               |

**Table 4-1. Signal Descriptions (continued)**

| NAME                       | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                                                              |
|----------------------------|----------------------|---------------|---------------|-------------------------------------------------------------------------------------------------------------------------|
|                            | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                                                         |
| GPIO50<br>EQEP1A<br>XD29   | 90                   | P14           | L12           | General-purpose Input/Output 50 (I/O/Z)<br>Enhanced QEP1 input A (I)<br>External Interface Data Line 29 (I/O/Z)         |
| GPIO51<br>EQEP1B<br>XD28   | 91                   | M13           | K14           | General-purpose Input/Output 51 (I/O/Z)<br>Enhanced QEP1 input B (I)<br>External Interface Data Line 28 (I/O/Z)         |
| GPIO52<br>EQEP1S<br>XD27   | 94                   | M14           | K13           | General-purpose Input/Output 52 (I/O/Z)<br>Enhanced QEP1 Strobe (I/O)<br>External Interface Data Line 27 (I/O/Z)        |
| GPIO53<br>EQEP1I<br>XD26   | 95                   | L12           | K12           | General-purpose Input/Output 53 (I/O/Z)<br>Enhanced QEP1 Index (I/O)<br>External Interface Data Line 26 (I/O/Z)         |
| GPIO54<br>SPISIMOA<br>XD25 | 96                   | L13           | J14           | General-purpose Input/Output 54 (I/O/Z)<br>SPI-A slave in, master out (I/O)<br>External Interface Data Line 25 (I/O/Z)  |
| GPIO55<br>SPISOMIA<br>XD24 | 97                   | L14           | J13           | General-purpose Input/Output 55 (I/O/Z)<br>SPI-A slave out, master in (I/O)<br>External Interface Data Line 24 (I/O/Z)  |
| GPIO56<br>SPICLKA<br>XD23  | 98                   | K11           | J12           | General-purpose Input/Output 56 (I/O/Z)<br>SPI-A clock (I/O)<br>External Interface Data Line 23 (I/O/Z)                 |
| GPIO57<br>SPISTEA<br>XD22  | 99                   | K13           | H13           | General-purpose Input/Output 57 (I/O/Z)<br>SPI-A slave transmit enable (I/O)<br>External Interface Data Line 22 (I/O/Z) |
| GPIO58<br>MCLKRA<br>XD21   | 100                  | K12           | H12           | General-purpose Input/Output 58 (I/O/Z)<br>McBSP-A receive clock (I/O)<br>External Interface Data Line 21 (I/O/Z)       |
| GPIO59<br>MFSRA<br>XD20    | 110                  | H14           | H11           | General-purpose Input/Output 59 (I/O/Z)<br>McBSP-A receive frame synch (I/O)<br>External Interface Data Line 20 (I/O/Z) |
| GPIO60<br>MCLKRB<br>XD19   | 111                  | G14           | G12           | General-purpose Input/Output 60 (I/O/Z)<br>McBSP-B receive clock (I/O)<br>External Interface Data Line 19 (I/O/Z)       |
| GPIO61<br>MFSRB<br>XD18    | 112                  | G12           | F14           | General-purpose Input/Output 61 (I/O/Z)<br>McBSP-B receive frame synch (I/O)<br>External Interface Data Line 18 (I/O/Z) |
| GPIO62<br>SCIRXDC<br>XD17  | 113                  | G13           | F13           | General-purpose Input/Output 62 (I/O/Z)<br>SCI-C receive data (I)<br>External Interface Data Line 17 (I/O/Z)            |
| GPIO63<br>SCITXDC<br>XD16  | 114                  | G11           | F12           | General-purpose Input/Output 63 (I/O/Z)<br>SCI-C transmit data (O)<br>External Interface Data Line 16 (I/O/Z)           |
| GPIO64<br>-<br>XD15        | 115                  | G10           | E14           | General-purpose Input/Output 64 (I/O/Z)<br>-<br>External Interface Data Line 15 (I/O/Z)                                 |
| GPIO65<br>-<br>XD14        | 116                  | F14           | E13           | General-purpose Input/Output 65 (I/O/Z)<br>-<br>External Interface Data Line 14 (I/O/Z)                                 |
| GPIO66<br>-<br>XD13        | 119                  | F11           | E12           | General-purpose Input/Output 66 (I/O/Z)<br>-<br>External Interface Data Line 13 (I/O/Z)                                 |
| GPIO67<br>-<br>XD12        | 122                  | E13           | D14           | General-purpose Input/Output 67 (I/O/Z)<br>-<br>External Interface Data Line 12 (I/O/Z)                                 |
| GPIO68<br>-<br>XD11        | 123                  | E11           | D13           | General-purpose Input/Output 68 (I/O/Z)<br>-<br>External Interface Data Line 11 (I/O/Z)                                 |

**Table 4-1. Signal Descriptions (continued)**

| NAME                | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                              |
|---------------------|----------------------|---------------|---------------|-----------------------------------------------------------------------------------------|
|                     | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                         |
| GPIO69<br>-<br>XD10 | 124                  | F10           | D12           | General-purpose Input/Output 69 (I/O/Z)<br>-<br>External Interface Data Line 10 (I/O/Z) |
| GPIO70<br>-<br>XD9  | 127                  | D12           | C14           | General-purpose Input/Output 70 (I/O/Z)<br>-<br>External Interface Data Line 9 (I/O/Z)  |
| GPIO71<br>-<br>XD8  | 128                  | C14           | C13           | General-purpose Input/Output 71 (I/O/Z)<br>-<br>External Interface Data Line 8 (I/O/Z)  |
| GPIO72<br>-<br>XD7  | 129                  | B14           | B13           | General-purpose Input/Output 72 (I/O/Z)<br>-<br>External Interface Data Line 7 (I/O/Z)  |
| GPIO73<br>-<br>XD6  | 130                  | C12           | A12           | General-purpose Input/Output 73 (I/O/Z)<br>-<br>External Interface Data Line 6 (I/O/Z)  |
| GPIO74<br>-<br>XD5  | 131                  | C13           | B12           | General-purpose Input/Output 74 (I/O/Z)<br>-<br>External Interface Data Line 5 (I/O/Z)  |
| GPIO75<br>-<br>XD4  | 132                  | A14           | C12           | General-purpose Input/Output 75 (I/O/Z)<br>-<br>External Interface Data Line 4 (I/O/Z)  |
| GPIO76<br>-<br>XD3  | 133                  | B13           | A11           | General-purpose Input/Output 76 (I/O/Z)<br>-<br>External Interface Data Line 3 (I/O/Z)  |
| GPIO77<br>-<br>XD2  | 134                  | A13           | B11           | General-purpose Input/Output 77 (I/O/Z)<br>-<br>External Interface Data Line 2 (I/O/Z)  |
| GPIO78<br>-<br>XD1  | 135                  | B12           | C11           | General-purpose Input/Output 78 (I/O/Z)<br>-<br>External Interface Data Line 1 (I/O/Z)  |
| GPIO79<br>-<br>XD0  | 136                  | A12           | B10           | General-purpose Input/Output 79 (I/O/Z)<br>-<br>External Interface Data Line 0 (I/O/Z)  |
| GPIO80<br>-<br>XA8  | 163                  | C6            | A5            | General-purpose Input/Output 80 (I/O/Z)<br>-<br>External Interface Address Line 8 (O)   |
| GPIO81<br>-<br>XA9  | 164                  | E6            | B5            | General-purpose Input/Output 81 (I/O/Z)<br>-<br>External Interface Address Line 9 (O)   |
| GPIO82<br>-<br>XA10 | 165                  | C5            | C5            | General-purpose Input/Output 82 (I/O/Z)<br>-<br>External Interface Address Line 10 (O)  |
| GPIO83<br>-<br>XA11 | 168                  | D5            | A4            | General-purpose Input/Output 83 (I/O/Z)<br>-<br>External Interface Address Line 11 (O)  |
| GPIO84<br>-<br>XA12 | 169                  | E5            | B4            | General-purpose Input/Output 84 (I/O/Z)<br>External Interface Address Line 12 (O)       |
| GPIO85<br>-<br>XA13 | 172                  | C4            | C4            | General-purpose Input/Output 85 (I/O/Z)<br>-<br>External Interface Address Line 13 (O)  |
| GPIO86<br>-<br>XA14 | 173                  | D4            | A3            | General-purpose Input/Output 86 (I/O/Z)<br>-<br>External Interface Address Line 14 (O)  |

**Table 4-1. Signal Descriptions (continued)**

| NAME                    | PIN NO.              |               |               | DESCRIPTION <sup>(1)</sup>                                                             |
|-------------------------|----------------------|---------------|---------------|----------------------------------------------------------------------------------------|
|                         | PGF,<br>PTP<br>PIN # | ZHH<br>BALL # | ZJZ<br>BALL # |                                                                                        |
| GPIO87<br>-<br>XA15     | 174                  | A3            | B3            | General-purpose Input/Output 87 (I/O/Z)<br>-<br>External Interface Address Line 15 (O) |
| $\overline{\text{XRD}}$ | 149                  | B9            | A8            | External Interface Read Enable                                                         |

## 5 Specifications

This section provides the absolute maximum ratings and the recommended operating conditions.

### 5.1 Absolute Maximum Ratings<sup>(1)(2)</sup>

Unless otherwise noted, the list of absolute maximum ratings are specified over operating temperature ranges.

|                                      |                                                                                   | MIN  | MAX | UNIT |
|--------------------------------------|-----------------------------------------------------------------------------------|------|-----|------|
| Supply voltage                       | $V_{DDIO}$ , $V_{DD3VFL}$ with respect to $V_{SS}$                                | -0.3 | 4.6 | V    |
|                                      | $V_{DDA2}$ , $V_{DDAIO}$ with respect to $V_{SSA}$                                | -0.3 | 4.6 |      |
|                                      | $V_{DD}$ with respect to $V_{SS}$                                                 | -0.3 | 2.5 |      |
|                                      | $V_{DD1A18}$ , $V_{DD2A18}$ with respect to $V_{SSA}$                             | -0.3 | 2.5 |      |
|                                      | $V_{SSA2}$ , $V_{SSAIO}$ , $V_{SS1AGND}$ , $V_{SS2AGND}$ with respect to $V_{SS}$ | -0.3 | 0.3 |      |
| Input voltage                        | $V_{IN}$                                                                          | -0.3 | 4.6 | V    |
| Output voltage                       | $V_O$                                                                             | -0.3 | 4.6 | V    |
| Input clamp current                  | $I_{IK}$ ( $V_{IN} < 0$ or $V_{IN} > V_{DDIO}$ ) <sup>(3)</sup>                   | -20  | 20  | mA   |
| Output clamp current                 | $I_{OK}$ ( $V_O < 0$ or $V_O > V_{DDIO}$ )                                        | -20  | 20  | mA   |
| Operating ambient temperature, $T_A$ | A version <sup>(4)</sup>                                                          | -40  | 85  | °C   |
|                                      | S version                                                                         | -40  | 125 |      |
|                                      | Q version                                                                         | -40  | 125 |      |
| Junction temperature                 | $T_J$ <sup>(4)</sup>                                                              | -40  | 150 | °C   |
| Storage temperature                  | $T_{stg}$ <sup>(4)</sup>                                                          | -65  | 150 | °C   |

(1) Stresses beyond those listed under *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 indicated under [Section 5.4](#) is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to  $V_{SS}$ , unless otherwise noted.

(3) Continuous clamp current per pin is  $\pm 2$  mA. This includes the analog inputs which have an internal clamping circuit that clamps the voltage to a diode drop above  $V_{DDA2}$  or below  $V_{SSA2}$ .

(4) One or both of the following conditions may result in a reduction of overall device life:

- long-term high-temperature storage
- extended use at maximum temperature

For additional information, see [Semiconductor and IC package thermal metrics](#).

## 5.2 ESD Ratings – Automotive

|                                           |                         |                                                         |                                                              | VALUE | UNIT |
|-------------------------------------------|-------------------------|---------------------------------------------------------|--------------------------------------------------------------|-------|------|
| TMS320F2833x, TMS320F2823x in PTP Package |                         |                                                         |                                                              |       |      |
| V <sub>(ESD)</sub>                        | Electrostatic discharge | Human body model (HBM), per AEC Q100-002 <sup>(1)</sup> |                                                              | ±2000 | V    |
|                                           |                         | Charged-device model (CDM), per AEC Q100-011            | All pins                                                     | ±500  |      |
|                                           |                         |                                                         | Corner pins on 176-pin PTP: 1, 44, 45, 88, 89, 132, 133, 176 | ±750  |      |
| TMS320F2833x, TMS320F2823x in ZJZ Package |                         |                                                         |                                                              |       |      |
| V <sub>(ESD)</sub>                        | Electrostatic discharge | Human body model (HBM), per AEC Q100-002 <sup>(1)</sup> |                                                              | ±2000 | V    |
|                                           |                         | Charged-device model (CDM), per AEC Q100-011            | All pins                                                     | ±500  |      |
|                                           |                         |                                                         | Corner pins on 176-ball ZJZ: A1, A14, P1, P14                | ±750  |      |

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

## 5.3 ESD Ratings – Commercial

|                                            |                                                                                |  | VALUE | UNIT |
|--------------------------------------------|--------------------------------------------------------------------------------|--|-------|------|
| TMS320F2833x, TMS320F2823x in PGF Package  |                                                                                |  |       |      |
| V <sub>(ESD)</sub> Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              |  | ±2000 | V    |
|                                            | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> |  | ±500  |      |
| TMS320F2833x, TMS320F2823x in ZHH Package  |                                                                                |  |       |      |
| V <sub>(ESD)</sub> Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              |  | ±2000 | V    |
|                                            | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> |  | ±500  |      |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 5.4 Recommended Operating Conditions

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

|                                                                                                    |                             | MIN                   | NOM | MAX                   | UNIT |
|----------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|-----|-----------------------|------|
| Device supply voltage, I/O, $V_{DDIO}$                                                             |                             | 3.135                 | 3.3 | 3.465                 | V    |
| Device supply voltage CPU, $V_{DD}$                                                                | Device operation @ 150 MHz  | 1.805                 | 1.9 | 1.995                 | V    |
|                                                                                                    | Device operation @ 100 MHz  | 1.71                  | 1.8 | 1.89                  |      |
| Supply ground, $V_{SS}$ , $V_{SSIO}$ , $V_{SSAIO}$ ,<br>$V_{SSA2}$ , $V_{SS1AGND}$ , $V_{SS2AGND}$ |                             | 0                     |     |                       | V    |
| ADC supply voltage (3.3 V),<br>$V_{DDA2}$ , $V_{DDAIO}$                                            |                             | 3.135                 | 3.3 | 3.465                 | V    |
| ADC supply voltage,<br>$V_{DD1A18}$ , $V_{DD2A18}$                                                 | Device operation @ 150 MHz  | 1.805                 | 1.9 | 1.995                 | V    |
|                                                                                                    | Device operation @ 100 MHz  | 1.71                  | 1.8 | 1.89                  |      |
| Flash supply voltage, $V_{DD3VFL}$                                                                 |                             | 3.135                 | 3.3 | 3.465                 | V    |
| Device clock frequency (system clock),<br>$f_{SYSCLKOUT}$                                          | F28335/F28334/F28235/F28234 | 2                     |     | 150                   | MHz  |
|                                                                                                    | F28333/F28332/F28232        | 2                     |     | 100                   |      |
| High-level input voltage, $V_{IH}$                                                                 | All inputs except X1        | 2                     |     | $V_{DDIO}$            | V    |
|                                                                                                    | X1                          | $0.7 * V_{DD} - 0.05$ |     | $V_{DD}$              |      |
| Low-level input voltage, $V_{IL}$                                                                  | All inputs except X1        |                       |     | 0.8                   | V    |
|                                                                                                    | X1                          |                       |     | $0.3 * V_{DD} + 0.05$ |      |
| High-level output source current,<br>$V_{OH} = 2.4$ V, $I_{OH}$                                    | All I/Os except Group 2     |                       |     | –4                    | mA   |
|                                                                                                    | Group 2 <sup>(1)</sup>      |                       |     | –8                    |      |
| Low-level output sink current,<br>$V_{OL} = V_{OL MAX}$ , $I_{OL}$                                 | All I/Os except Group 2     |                       |     | 4                     | mA   |
|                                                                                                    | Group 2 <sup>(1)</sup>      |                       |     | 8                     |      |
| Ambient temperature, $T_A$                                                                         | A version                   | –40                   |     | 85                    | °C   |
|                                                                                                    | S version                   | –40                   |     | 125                   |      |
|                                                                                                    | Q version                   | –40                   |     | 125                   |      |
| Junction temperature, $T_J$                                                                        |                             |                       |     | 125                   | °C   |

(1) Group 2 pins are as follows: GPIO28, GPIO29, GPIO30, GPIO31, TDO, XCLKOUT, EMU0, EMU1, XINTF pins, GPIO35-87,  $\overline{XRD}$ .

## 5.5 Power Consumption Summary

**Table 5-1. TMS320F28335/F28235 Current Consumption by Power-Supply Pins at 150-MHz SYSCLKOUT**

| MODE                               | TEST CONDITIONS                                                                                                                                                                                                                                                                                                                                                                                                                                                    | I <sub>DD</sub>    |        | I <sub>DDIO</sub> <sup>(1)</sup> |        | I <sub>DD3VFL</sub> <sup>(2)</sup> |       | I <sub>DDA18</sub> <sup>(3)</sup> |       | I <sub>DDA33</sub> <sup>(4)</sup> |       |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|--------|----------------------------------|--------|------------------------------------|-------|-----------------------------------|-------|-----------------------------------|-------|
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | TYP <sup>(5)</sup> | MAX    | TYP <sup>(5)</sup>               | MAX    | TYP                                | MAX   | TYP <sup>(5)</sup>                | MAX   | TYP <sup>(5)</sup>                | MAX   |
| Operational (Flash) <sup>(6)</sup> | The following peripheral clocks are enabled:<br><ul style="list-style-type: none"> <li>ePWM1, ePWM2, ePWM3, ePWM4, ePWM5, ePWM6</li> <li>eCAP1, eCAP2, eCAP3, eCAP4, eCAP5, eCAP6</li> <li>eQEP1, eQEP2</li> <li>eCAN-A</li> <li>SCI-A, SCI-B (FIFO mode)</li> <li>SPI-A (FIFO mode)</li> <li>ADC</li> <li>I2C</li> <li>CPU-Timer 0, CPU-Timer 1, CPU-Timer 2</li> </ul> All PWM pins are toggled at 150 kHz.<br>All I/O pins are left unconnected. <sup>(7)</sup> | 290 mA             | 315 mA | 30 mA                            | 50 mA  | 35 mA                              | 40 mA | 30 mA                             | 35 mA | 1.5 mA                            | 2 mA  |
| IDLE                               | Flash is powered down. XCLKOUT is turned off. The following peripheral clocks are enabled:<br><ul style="list-style-type: none"> <li>eCAN-A</li> <li>SCI-A</li> <li>SPI-A</li> <li>I2C</li> </ul>                                                                                                                                                                                                                                                                  | 100 mA             | 120 mA | 60 μA                            | 120 μA | 2 μA                               | 10 μA | 5 μA                              | 60 μA | 15 μA                             | 20 μA |
| STANDBY                            | Flash is powered down. Peripheral clocks are off.                                                                                                                                                                                                                                                                                                                                                                                                                  | 8 mA               | 15 mA  | 60 μA                            | 120 μA | 2 μA                               | 10 μA | 5 μA                              | 60 μA | 15 μA                             | 20 μA |
| HALT <sup>(8)</sup>                | Flash is powered down. Peripheral clocks are off. Input clock is disabled. <sup>(9)</sup>                                                                                                                                                                                                                                                                                                                                                                          | 150 μA             |        | 60 μA                            | 120 μA | 2 μA                               | 10 μA | 5 μA                              | 60 μA | 15 μA                             | 20 μA |

- (1) I<sub>DDIO</sub> current is dependent on the electrical loading on the I/O pins.
- (2) The I<sub>DD3VFL</sub> current indicated in this table is the flash read-current and does not include additional current for erase/write operations. During flash programming, extra current is drawn from the V<sub>DD</sub> and V<sub>DD3VFL</sub> rails, as indicated in [Table 5-61](#). If the user application involves on-board flash programming, this extra current must be taken into account while architecting the power-supply stage.
- (3) I<sub>DDA18</sub> includes current into V<sub>DD1A18</sub> and V<sub>DD2A18</sub> pins. To realize the I<sub>DDA18</sub> currents shown for IDLE, STANDBY, and HALT, clock to the ADC module must be turned off explicitly by writing to the PCLKCR0 register.
- (4) I<sub>DDA33</sub> includes current into V<sub>DDA2</sub> and V<sub>DDAIO</sub> pins.
- (5) The TYP numbers are applicable over room temperature and nominal voltage. MAX numbers are at 125°C, and MAX voltage (V<sub>DD</sub> = 2.0 V; V<sub>DDIO</sub>, V<sub>DD3VFL</sub>, V<sub>DDA</sub> = 3.6 V).
- (6) When the identical code is run off SARAM, I<sub>DD</sub> would increase as the code operates with zero wait states.
- (7) The following is done in a loop:
  - Data is continuously transmitted out of the SCI-A, SCI-B, SPI-A, McBSP-A, and eCAN-A ports.
  - Multiplication/addition operations are performed.
  - Watchdog is reset.
  - ADC is performing continuous conversion. Data from ADC is transferred to SARAM through the DMA.
  - 32-bit read/write of the XINTF is performed.
  - GPIO19 is toggled.
- (8) HALT mode I<sub>DD</sub> currents will increase with temperature in a nonlinear fashion.
- (9) If a quartz crystal or ceramic resonator is used as the clock source, the HALT mode shuts down the internal oscillator.

### NOTE

The peripheral - I/O multiplexing implemented in the device prevents all available peripherals from being used at the same time. This is because more than one peripheral function may share an I/O pin. It is, however, possible to turn on the clocks to all the peripherals at the same time, although such a configuration is not useful. If this is done, the current drawn by the device will be more than the numbers specified in the current consumption tables.

**Table 5-2. TMS320F28334/F28234 Current Consumption by Power-Supply Pins at 150-MHz SYSCLKOUT**

| MODE                               | TEST CONDITIONS                                                                                                                                                                                                                                                                                                                                                                                                                                                    | $I_{DD}$           |        | $I_{DDIO}^{(1)}$   |             | $I_{DD3VFL}^{(2)}$ |            | $I_{DDA18}^{(3)}$  |            | $I_{DDA33}^{(4)}$  |            |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|--------|--------------------|-------------|--------------------|------------|--------------------|------------|--------------------|------------|
|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | TYP <sup>(5)</sup> | MAX    | TYP <sup>(5)</sup> | MAX         | TYP                | MAX        | TYP <sup>(5)</sup> | MAX        | TYP <sup>(5)</sup> | MAX        |
| Operational (Flash) <sup>(6)</sup> | The following peripheral clocks are enabled:<br><ul style="list-style-type: none"> <li>ePWM1, ePWM2, ePWM3, ePWM4, ePWM5, ePWM6</li> <li>eCAP1, eCAP2, eCAP3, eCAP4, eCAP5, eCAP6</li> <li>eQEP1, eQEP2</li> <li>eCAN-A</li> <li>SCI-A, SCI-B (FIFO mode)</li> <li>SPI-A (FIFO mode)</li> <li>ADC</li> <li>I2C</li> <li>CPU-Timer 0, CPU-Timer 1, CPU-Timer 2</li> </ul> All PWM pins are toggled at 150 kHz.<br>All I/O pins are left unconnected. <sup>(7)</sup> | 290 mA             | 315 mA | 30 mA              | 50 mA       | 35 mA              | 40 mA      | 30 mA              | 35 mA      | 1.5 mA             | 2 mA       |
| IDLE                               | Flash is powered down. XCLKOUT is turned off. The following peripheral clocks are enabled:<br><ul style="list-style-type: none"> <li>eCAN-A</li> <li>SCI-A</li> <li>SPI-A</li> <li>I2C</li> </ul>                                                                                                                                                                                                                                                                  | 100 mA             | 120 mA | 60 $\mu$ A         | 120 mA      | 2 $\mu$ A          | 10 $\mu$ A | 5 $\mu$ A          | 60 $\mu$ A | 15 $\mu$ A         | 20 $\mu$ A |
| STANDBY                            | Flash is powered down. Peripheral clocks are off.                                                                                                                                                                                                                                                                                                                                                                                                                  | 8 mA               | 15 mA  | 60 $\mu$ A         | 120 $\mu$ A | 2 $\mu$ A          | 10 $\mu$ A | 5 $\mu$ A          | 60 $\mu$ A | 15 $\mu$ A         | 20 $\mu$ A |
| HALT <sup>(8)</sup>                | Flash is powered down. Peripheral clocks are off. Input clock is disabled. <sup>(9)</sup>                                                                                                                                                                                                                                                                                                                                                                          | 150 $\mu$ A        |        | 60 $\mu$ A         | 120 $\mu$ A | 2 $\mu$ A          | 10 $\mu$ A | 5 $\mu$ A          | 60 $\mu$ A | 15 $\mu$ A         | 20 $\mu$ A |

- (1)  $I_{DDIO}$  current is dependent on the electrical loading on the I/O pins.
- (2) The  $I_{DD3VFL}$  current indicated in this table is the flash read-current and does not include additional current for erase/write operations. During flash programming, extra current is drawn from the  $V_{DD}$  and  $V_{DD3VFL}$  rails, as indicated in Table 5-61. If the user application involves on-board flash programming, this extra current must be taken into account while architecting the power-supply stage.
- (3)  $I_{DDA18}$  includes current into  $V_{DD1A18}$  and  $V_{DD2A18}$  pins. To realize the  $I_{DDA18}$  currents shown for IDLE, STANDBY, and HALT, clock to the ADC module must be turned off explicitly by writing to the PCLKCR0 register.
- (4)  $I_{DDA33}$  includes current into  $V_{DDA2}$  and  $V_{DDAIO}$  pins.
- (5) The TYP numbers are applicable over room temperature and nominal voltage. MAX numbers are at 125°C, and MAX voltage ( $V_{DD} = 2.0$  V;  $V_{DDIO}$ ,  $V_{DD3VFL}$ ,  $V_{DDA} = 3.6$  V).
- (6) When the identical code is run off SARAM,  $I_{DD}$  would increase as the code operates with zero wait states.
- (7) The following is done in a loop:
  - Data is continuously transmitted out of the SCI-A, SCI-B, SPI-A, McBSP-A, and eCAN-A ports.
  - Multiplication/addition operations are performed.
  - Watchdog is reset.
  - ADC is performing continuous conversion. Data from ADC is transferred to SARAM through the DMA.
  - 32-bit read/write of the XINTF is performed.
  - GPIO19 is toggled.
- (8) HALT mode  $I_{DD}$  currents will increase with temperature in a nonlinear fashion.
- (9) If a quartz crystal or ceramic resonator is used as the clock source, the HALT mode shuts down the internal oscillator.

### 5.5.1 Reducing Current Consumption

The 2833x and 2823x DSCs incorporate a method to reduce the device current consumption. Because each peripheral unit has an individual clock-enable bit, reduction in current consumption can be achieved by turning off the clock to any peripheral module that is not used in a given application. Furthermore, any one of the three low-power modes could be taken advantage of to reduce the current consumption even further. [Table 5-3](#) indicates the typical reduction in current consumption achieved by turning off the clocks.

**Table 5-3. Typical Current Consumption by Various Peripherals (at 150 MHz)<sup>(1)</sup>**

| PERIPHERAL<br>MODULE | I <sub>DD</sub> CURRENT<br>REDUCTION/MODULE (mA) <sup>(2)</sup> |
|----------------------|-----------------------------------------------------------------|
| ADC                  | 8 <sup>(3)</sup>                                                |
| I2C                  | 2.5                                                             |
| eQEP                 | 5                                                               |
| ePWM                 | 5                                                               |
| eCAP                 | 2                                                               |
| SCI                  | 5                                                               |
| SPI                  | 4                                                               |
| eCAN                 | 8                                                               |
| McBSP                | 7                                                               |
| CPU-Timer            | 2                                                               |
| XINTF                | 10 <sup>(4)</sup>                                               |
| DMA                  | 10                                                              |
| FPU                  | 15                                                              |

- (1) All peripheral clocks are disabled upon reset. Writing to or reading from peripheral registers is possible only after the peripheral clocks are turned on.
- (2) For peripherals with multiple instances, the current quoted is per module. For example, the 5 mA number quoted for ePWM is for one ePWM module.
- (3) This number represents the current drawn by the digital portion of the ADC module. Turning off the clock to the ADC module results in the elimination of the current drawn by the analog portion of the ADC (I<sub>DDA18</sub>) as well.
- (4) Operating the XINTF bus has a significant effect on IDDIO current. It will increase considerably based on the following:
  - How many address/data pins toggle from one cycle to another
  - How fast they toggle
  - Whether 16-bit or 32-bit interface is used and
  - The load on these pins.

Following are other methods to reduce power consumption further:

- The Flash module may be powered down if code is run off SARAM. This results in a current reduction of 35 mA (typical) in the V<sub>DD3VFL</sub> rail.
- I<sub>DDIO</sub> current consumption is reduced by 15 mA (typical) when XCLKOUT is turned off.
- Significant savings in I<sub>DDIO</sub> may be realized by disabling the pullups on pins that assume an output function and on XINTF pins. A savings of 35 mW (typical) can be achieved by this.

The baseline I<sub>DD</sub> current (current when the core is executing a dummy loop with no peripherals enabled) is 165 mA, (typical). To arrive at the I<sub>DD</sub> current for a given application, the current-drawn by the peripherals (enabled by that application) must be added to the baseline I<sub>DD</sub> current.

## 5.5.2 Current Consumption Graphs

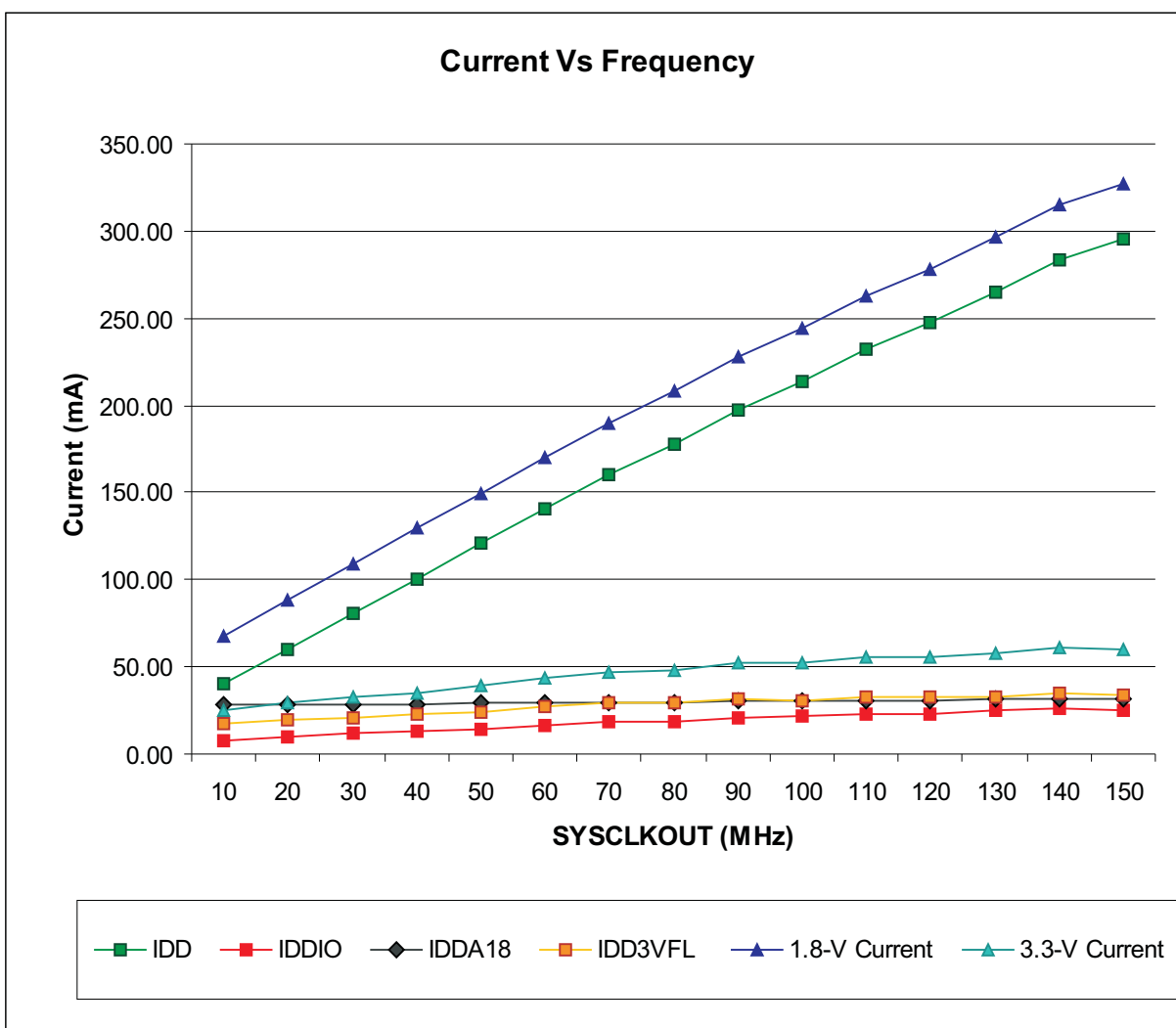


Figure 5-1. Typical Operational Current Versus Frequency (F28335, F28235, F28334, F28234)

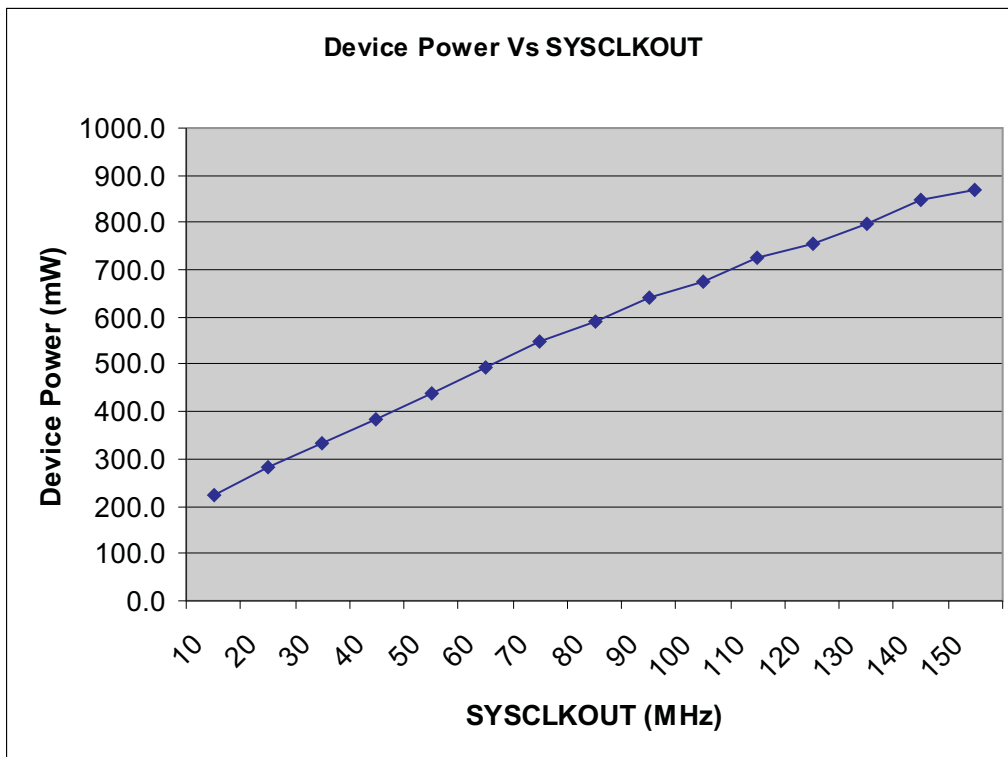


**Figure 5-2. Typical Operational Power Versus Frequency (F28335, F28235, F28334, F28234)**

**NOTE**

Typical operational current for 100-MHz devices (28x32) can be estimated from [Figure 5-1](#). Compared to 150-MHz devices, the analog and flash module currents remain unchanged. While a marginal decrease in IDDIO current can be expected due to the reduced external activity of peripheral pins, current reduction is primarily in I<sub>DD</sub>.

## 5.6 Electrical Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER       |                                             |                           | TEST CONDITIONS                                                |                                               | MIN                     | TYP  | MAX  | UNIT |
|-----------------|---------------------------------------------|---------------------------|----------------------------------------------------------------|-----------------------------------------------|-------------------------|------|------|------|
| V <sub>OH</sub> | High-level output voltage                   |                           | I <sub>OH</sub> = I <sub>OH</sub> MAX                          |                                               | 2.4                     |      |      | V    |
|                 |                                             |                           | I <sub>OH</sub> = 50 μA                                        |                                               | V <sub>DDIO</sub> – 0.2 |      |      |      |
| V <sub>OL</sub> | Low-level output voltage                    |                           | I <sub>OL</sub> = I <sub>OL</sub> MAX                          |                                               | 0.4                     |      |      | V    |
| I <sub>IL</sub> | Input current (low level)                   | Pin with pullup enabled   | V <sub>DDIO</sub> = 3.3 V, V <sub>IN</sub> = 0 V               | All I/Os (including $\overline{\text{XRS}}$ ) | –80                     | –140 | –190 | μA   |
|                 |                                             | Pin with pulldown enabled | V <sub>DDIO</sub> = 3.3 V, V <sub>IN</sub> = 0 V               |                                               |                         |      |      |      |
| I <sub>IH</sub> | Input current (high level)                  | Pin with pullup enabled   | V <sub>DDIO</sub> = 3.3 V, V <sub>IN</sub> = V <sub>DDIO</sub> |                                               | ±2                      |      |      | μA   |
|                 |                                             | Pin with pulldown enabled | V <sub>DDIO</sub> = 3.3 V, V <sub>IN</sub> = V <sub>DDIO</sub> |                                               | 28                      | 50   | 80   |      |
| I <sub>OZ</sub> | Output current, pullup or pulldown disabled |                           | V <sub>O</sub> = V <sub>DDIO</sub> or 0 V                      |                                               | ±2                      |      |      | μA   |
| C <sub>I</sub>  | Input capacitance                           |                           |                                                                |                                               | 2                       |      |      | pF   |

## 5.7 Thermal Resistance Characteristics

### 5.7.1 PGF Package

|                                |                         | $^{\circ}\text{C/W}^{(1) (2)}$ | AIR FLOW (lfm) <sup>(3)</sup> |
|--------------------------------|-------------------------|--------------------------------|-------------------------------|
| $R\theta_{JC}$                 | Junction-to-case        | 8.2                            | 0                             |
| $R\theta_{JB}$                 | Junction-to-board       | 28.1                           | 0                             |
| $R\theta_{JA}$<br>(High k PCB) | Junction-to-free air    | 44                             | 0                             |
|                                |                         | 34.5                           | 150                           |
|                                |                         | 33                             | 250                           |
|                                |                         | 31                             | 500                           |
| $\Psi_{JT}$                    | Junction-to-package top | 0.12                           | 0                             |
|                                |                         | 0.48                           | 150                           |
|                                |                         | 0.57                           | 250                           |
|                                |                         | 0.74                           | 500                           |
| $\Psi_{JB}$                    | Junction-to-board       | 28.1                           | 0                             |
|                                |                         | 26.3                           | 150                           |
|                                |                         | 25.9                           | 250                           |
|                                |                         | 25.2                           | 500                           |

(1)  $^{\circ}\text{C/W}$  = degrees Celsius per watt

(2) 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 Environmental Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(3) lfm = linear feet per minute

### 5.7.2 PTP Package

|                                |                         | $^{\circ}\text{C/W}^{(1) (2)}$ | AIR FLOW (lfm) <sup>(3)</sup> |
|--------------------------------|-------------------------|--------------------------------|-------------------------------|
| $R\theta_{JC}$                 | Junction-to-case        | 12.1                           | 0                             |
| $R\theta_{JB}$                 | Junction-to-board       | 5.1                            | 0                             |
| $R\theta_{JA}$<br>(High k PCB) | Junction-to-free air    | 17.4                           | 0                             |
|                                |                         | 11.7                           | 150                           |
|                                |                         | 10.1                           | 250                           |
|                                |                         | 8.8                            | 500                           |
| $\Psi_{JT}$                    | Junction-to-package top | 0.2                            | 0                             |
|                                |                         | 0.3                            | 150                           |
|                                |                         | 0.4                            | 250                           |
|                                |                         | 0.5                            | 500                           |
| $\Psi_{JB}$                    | Junction-to-board       | 5.0                            | 0                             |
|                                |                         | 4.7                            | 150                           |
|                                |                         | 4.7                            | 250                           |
|                                |                         | 4.6                            | 500                           |

(1)  $^{\circ}\text{C/W}$  = degrees Celsius per watt

(2) 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 Environmental Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(3) lfm = linear feet per minute

### 5.7.3 ZHH Package

|                                  |                         | °C/W <sup>(1) (2)</sup> | AIR FLOW (lfm) <sup>(3)</sup> |
|----------------------------------|-------------------------|-------------------------|-------------------------------|
| R <sub>θJC</sub>                 | Junction-to-case        | 8.8                     | 0                             |
| R <sub>θJB</sub>                 | Junction-to-board       | 12.5                    | 0                             |
| R <sub>θJA</sub><br>(High k PCB) | Junction-to-free air    | 32.8                    | 0                             |
|                                  |                         | 24.1                    | 150                           |
|                                  |                         | 22.9                    | 250                           |
|                                  |                         | 20.9                    | 500                           |
| Psi <sub>JT</sub>                | Junction-to-package top | 0.09                    | 0                             |
|                                  |                         | 0.3                     | 150                           |
|                                  |                         | 0.36                    | 250                           |
|                                  |                         | 0.48                    | 500                           |
| Psi <sub>JB</sub>                | Junction-to-board       | 12.4                    | 0                             |
|                                  |                         | 11.8                    | 150                           |
|                                  |                         | 11.7                    | 250                           |
|                                  |                         | 11.5                    | 500                           |

(1) °C/W = degrees Celsius per watt

(2) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC [R<sub>θJC</sub>] 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 Environmental Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(3) lfm = linear feet per minute

### 5.7.4 ZJZ Package

|                                  |                         | °C/W <sup>(1) (2)</sup> | AIR FLOW (lfm) <sup>(3)</sup> |
|----------------------------------|-------------------------|-------------------------|-------------------------------|
| R <sub>θJC</sub>                 | Junction-to-case        | 11.4                    | 0                             |
| R <sub>θJB</sub>                 | Junction-to-board       | 12                      | 0                             |
| R <sub>θJA</sub><br>(High k PCB) | Junction-to-free air    | 29.6                    | 0                             |
|                                  |                         | 20.9                    | 150                           |
|                                  |                         | 19.7                    | 250                           |
|                                  |                         | 18                      | 500                           |
| Psi <sub>JT</sub>                | Junction-to-package top | 0.2                     | 0                             |
|                                  |                         | 0.78                    | 150                           |
|                                  |                         | 0.91                    | 250                           |
|                                  |                         | 1.11                    | 500                           |
| Psi <sub>JB</sub>                | Junction-to-board       | 12.2                    | 0                             |
|                                  |                         | 11.6                    | 150                           |
|                                  |                         | 11.5                    | 250                           |
|                                  |                         | 11.3                    | 500                           |

(1) °C/W = degrees Celsius per watt

(2) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC [R<sub>θJC</sub>] 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 Environmental Conditions - Natural Convection (Still Air)*
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- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(3) lfm = linear feet per minute

## 5.8 Thermal Design Considerations

Based on the end application design and operational profile, the  $I_{DD}$  and  $I_{DDIO}$  currents could vary. Systems with more than 1 Watt power dissipation may require a product level thermal design. Care should be taken to keep  $T_j$  within specified limits. In the end applications,  $T_{case}$  should be measured to estimate the operating junction temperature  $T_j$ .  $T_{case}$  is normally measured at the center of the package top side surface. The thermal application note [Semiconductor and IC package thermal metrics](#) helps to understand the thermal metrics and definitions.

## 5.9 Timing and Switching Characteristics

### 5.9.1 Timing Parameter Symbolology

Timing parameter symbols used are created in accordance with JEDEC Standard 100. To shorten the symbols, some of the pin names and other related terminology have been abbreviated as follows:

| Lowercase subscripts and their meanings: |                        | Letters and symbols and their meanings: |                                        |
|------------------------------------------|------------------------|-----------------------------------------|----------------------------------------|
| a                                        | access time            | H                                       | High                                   |
| c                                        | cycle time (period)    | L                                       | Low                                    |
| d                                        | delay time             | V                                       | Valid                                  |
| f                                        | fall time              | X                                       | Unknown, changing, or don't care level |
| h                                        | hold time              | Z                                       | High impedance                         |
| r                                        | rise time              |                                         |                                        |
| su                                       | setup time             |                                         |                                        |
| t                                        | transition time        |                                         |                                        |
| v                                        | valid time             |                                         |                                        |
| w                                        | pulse duration (width) |                                         |                                        |

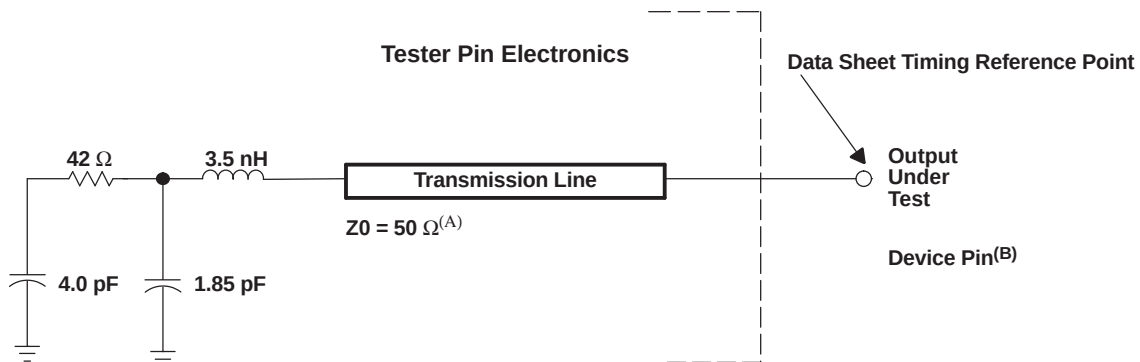
#### 5.9.1.1 General Notes on Timing Parameters

All output signals from the 28x devices (including XCLKOUT) are derived from an internal clock such that all output transitions for a given half-cycle occur with a minimum of skewing relative to each other.

The signal combinations shown in the following timing diagrams may not necessarily represent actual cycles. For actual cycle examples, see the appropriate cycle description section of this document.

#### 5.9.1.2 Test Load Circuit

This test load circuit is used to measure all switching characteristics provided in this document.



- 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.
- 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 or longer 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 or longer) from the data sheet timing.

**Figure 5-3. 3.3-V Test Load Circuit**

### 5.9.1.3 Device Clock Table

This section provides the timing requirements and switching characteristics for the various clock options available. [Table 5-4](#) and [Table 5-5](#) list the cycle times of various clocks.

**Table 5-4. Clocking and Nomenclature (150-MHz Devices)**

|                          |                              | MIN  | NOM                 | MAX               | UNIT |
|--------------------------|------------------------------|------|---------------------|-------------------|------|
| On-chip oscillator clock | $t_{c(OSC)}$ , Cycle time    | 28.6 |                     | 50                | ns   |
|                          | Frequency                    | 20   |                     | 35                | MHz  |
| XCLKIN <sup>(1)</sup>    | $t_{c(CI)}$ , Cycle time     | 6.67 |                     | 250               | ns   |
|                          | Frequency                    | 4    |                     | 150               | MHz  |
| SYSCLKOUT                | $t_{c(SCO)}$ , Cycle time    | 6.67 |                     | 500               | ns   |
|                          | Frequency                    | 2    |                     | 150               | MHz  |
| XCLKOUT                  | $t_{c(XCO)}$ , Cycle time    | 6.67 |                     | 2000              | ns   |
|                          | Frequency                    | 0.5  |                     | 150               | MHz  |
| HSPCLK <sup>(2)</sup>    | $t_{c(HCO)}$ , Cycle time    | 6.67 | 13.3 <sup>(3)</sup> |                   | ns   |
|                          | Frequency                    |      | 75 <sup>(3)</sup>   | 150               | MHz  |
| LSPCLK <sup>(2)</sup>    | $t_{c(LCO)}$ , Cycle time    | 13.3 | 26.7 <sup>(3)</sup> |                   | ns   |
|                          | Frequency                    |      | 37.5 <sup>(3)</sup> | 75 <sup>(4)</sup> | MHz  |
| ADC clock                | $t_{c(ADCCLK)}$ , Cycle time | 40   |                     |                   | ns   |
|                          | Frequency                    |      |                     | 25                | MHz  |

(1) This also applies to the X1 pin if a 1.9-V oscillator is used.

(2) Lower LSPCLK and HSPCLK will reduce device power consumption.

(3) This is the default value if SYSCLKOUT = 150 MHz.

(4) Although LSPCLK is capable of reaching 100 MHz, it is specified at 75 MHz because the smallest valid "Low-speed peripheral clock prescaler register" value is "1" for 150-MHz devices.

**Table 5-5. Clocking and Nomenclature (100-MHz Devices)**

|                          |                              | MIN  | NOM               | MAX  | UNIT |
|--------------------------|------------------------------|------|-------------------|------|------|
| On-chip oscillator clock | $t_{c(OSC)}$ , Cycle time    | 28.6 |                   | 50   | ns   |
|                          | Frequency                    | 20   |                   | 35   | MHz  |
| XCLKIN <sup>(1)</sup>    | $t_{c(CI)}$ , Cycle time     | 10   |                   | 250  | ns   |
|                          | Frequency                    | 4    |                   | 100  | MHz  |
| SYSCLKOUT                | $t_{c(SCO)}$ , Cycle time    | 10   |                   | 500  | ns   |
|                          | Frequency                    | 2    |                   | 100  | MHz  |
| XCLKOUT                  | $t_{c(XCO)}$ , Cycle time    | 10   |                   | 2000 | ns   |
|                          | Frequency                    | 0.5  |                   | 100  | MHz  |
| HSPCLK <sup>(2)</sup>    | $t_{c(HCO)}$ , Cycle time    | 10   | 20 <sup>(3)</sup> |      | ns   |
|                          | Frequency                    |      | 50 <sup>(3)</sup> | 100  | MHz  |
| LSPCLK <sup>(2)</sup>    | $t_{c(LCO)}$ , Cycle time    | 10   | 40 <sup>(3)</sup> |      | ns   |
|                          | Frequency                    |      | 25 <sup>(3)</sup> | 100  | MHz  |
| ADC clock                | $t_{c(ADCCLK)}$ , Cycle time | 40   |                   |      | ns   |
|                          | Frequency                    |      |                   | 25   | MHz  |

(1) This also applies to the X1 pin if a 1.8-V oscillator is used.

(2) Lower LSPCLK and HSPCLK will reduce device power consumption.

(3) This is the default value if SYSCLKOUT = 100 MHz.

## 5.9.2 Power Sequencing

No requirements are placed on the power-up and power-down sequences of the various power pins to ensure the correct reset state for all the modules. However, if the 3.3-V transistors in the level shifting output buffers of the I/O pins are powered prior to the 1.9-V/1.8-V transistors, it is possible for the output buffers to turn on, causing a glitch to occur on the pin during power up. To avoid this behavior, power the  $V_{DD}$  pins prior to or simultaneously with the  $V_{DDIO}$  pins, ensuring that the  $V_{DD}$  pins have reached 0.7 V before the  $V_{DDIO}$  pins reach 0.7 V.

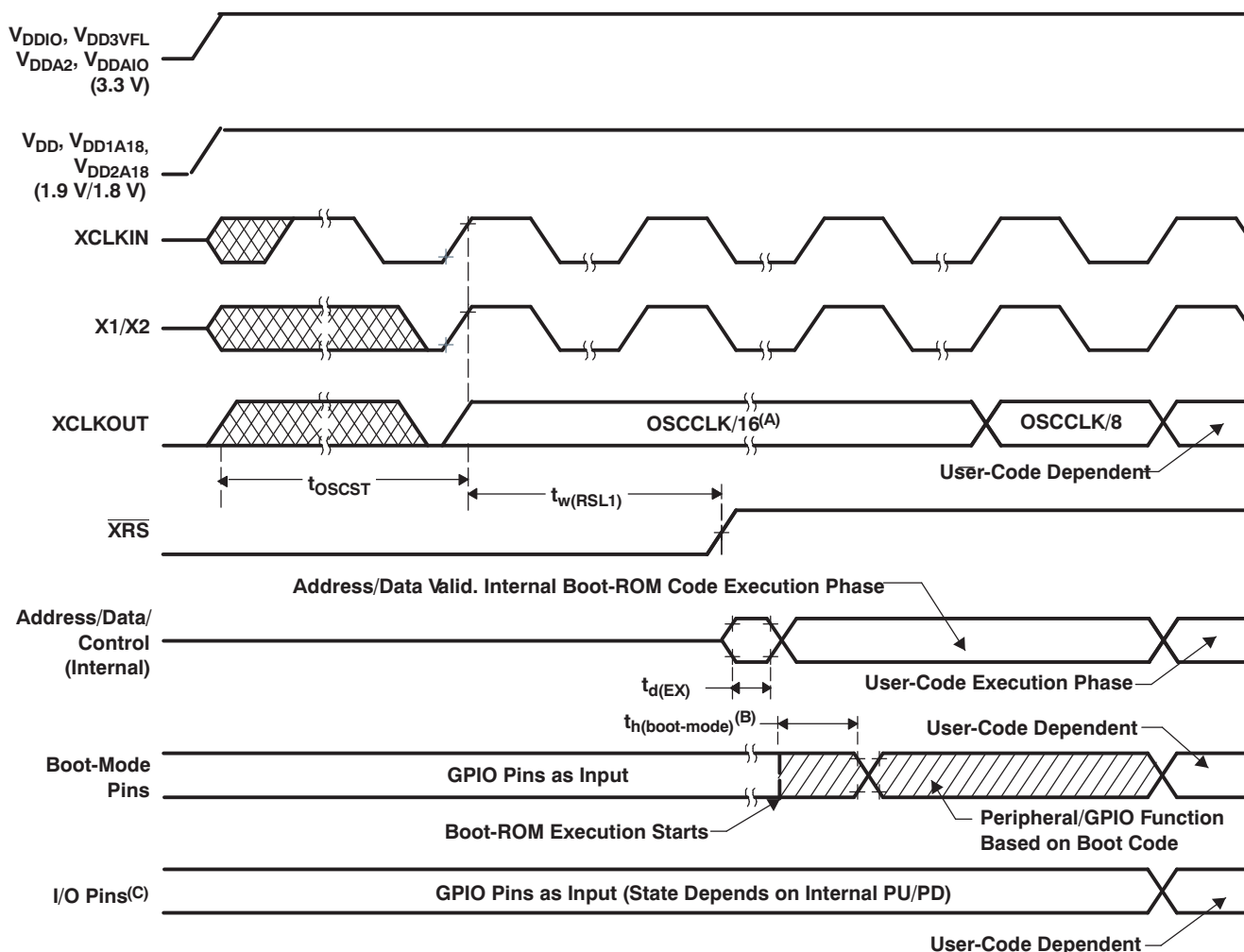
There are some requirements on the  $\overline{XRS}$  pin:

1. During power up, the  $\overline{XRS}$  pin must be held low for  $t_{w(RSL1)}$  after the input clock is stable (see [Table 5-6](#)). This is to enable the entire device to start from a known condition.
2. During power down, the  $\overline{XRS}$  pin must be pulled low at least 8  $\mu$ s prior to  $V_{DD}$  reaching 1.5 V. Meeting this requirement is important to help prevent unintended flash program or erase.

No voltage larger than a diode drop (0.7 V) above  $V_{DDIO}$  should be applied to any digital pin (for analog pins, this value is 0.7 V above  $V_{DDA}$ ) before powering up the device. Furthermore,  $V_{DDIO}$  and  $V_{DDA}$  should always be within 0.3 V of each other. Voltages applied to pins on an unpowered device can bias internal P-N junctions in unintended ways and produce unpredictable results.

### 5.9.2.1 Power Management and Supervisory Circuit Solutions

LDO selection depends on the total power consumed in the end application. Go to the [Power Management](#) page for a list of TI power management ICs. Click the [Reference designs](#) tab for specific power management reference designs.



- Upon power up, SYSCLKOUT is OSCCLK/4. Because both the XTIMCLK and CLKMODE bits in the XINTCNF2 register come up with a reset state of 1, SYSCLKOUT is further divided by 4 before it appears at XCLKOUT. This explains why XCLKOUT = OSCCLK/16 during this phase. Subsequently, boot ROM changes SYSCLKOUT to OSCCLK/2. Because the XTIMCLK register is unchanged by the boot ROM, XCLKOUT is OSCCLK/8 during this phase.
- After reset, the boot ROM code samples Boot Mode pins. Based on the status of the Boot Mode pin, the boot code branches to destination memory or boot code function. If boot ROM code executes after power-on conditions (in debugger environment), the boot code execution time is based on the current SYSCLKOUT speed. The SYSCLKOUT will be based on user environment and could be with or without PLL enabled.
- See [Section 5.9.2](#) for requirements to ensure a high-impedance state for GPIO pins during power up.

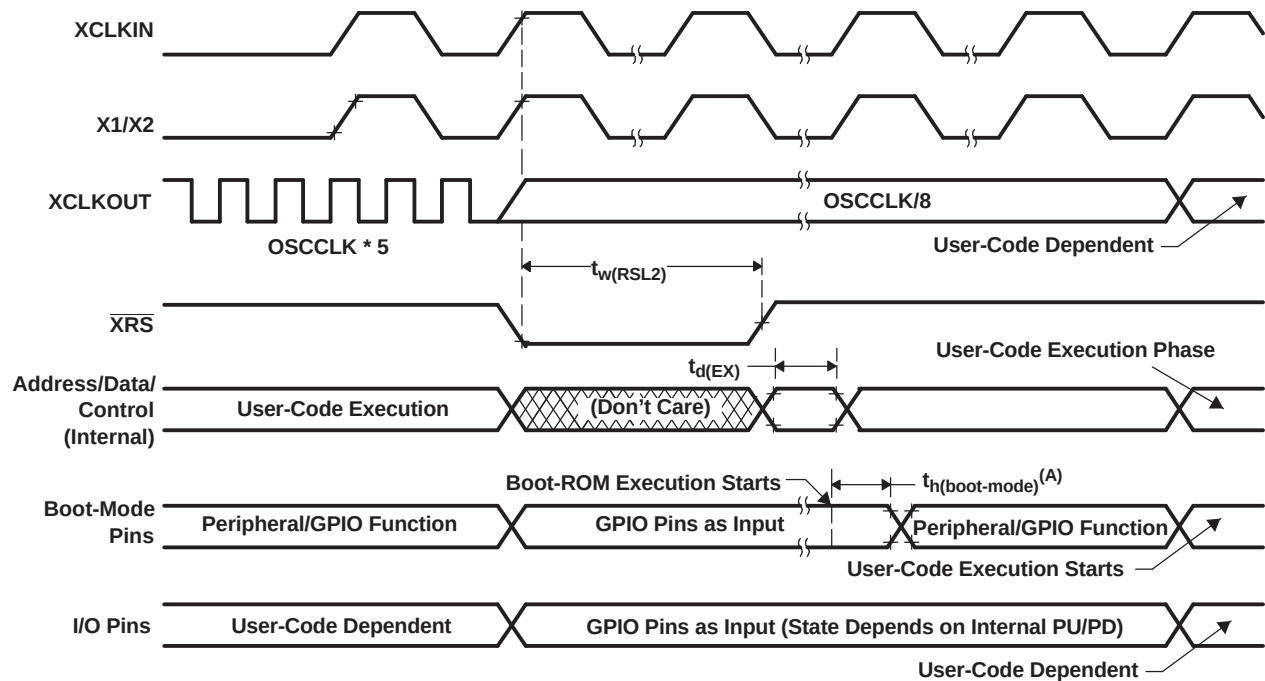
**Figure 5-4. Power-on Reset**

**Table 5-6. Reset ( $\overline{\text{XRS}}$ ) Timing Requirements**

|                                     |                                                                    |            | MIN                       | NOM                       | MAX | UNIT   |
|-------------------------------------|--------------------------------------------------------------------|------------|---------------------------|---------------------------|-----|--------|
| $t_{w(\text{RSL1})}$ <sup>(1)</sup> | Pulse duration, stable input clock to $\overline{\text{XRS}}$ high |            | $32t_{c(\text{OSCCLK})}$  |                           |     | cycles |
| $t_{w(\text{RSL2})}$                | Pulse duration, $\overline{\text{XRS}}$ low                        | Warm reset | $32t_{c(\text{OSCCLK})}$  |                           |     | cycles |
| $t_{w(\text{WDRS})}$                | Pulse duration, reset pulse generated by watchdog                  |            |                           | $512t_{c(\text{OSCCLK})}$ |     | cycles |
| $t_{d(\text{EX})}$                  | Delay time, address/data valid after $\overline{\text{XRS}}$ high  |            |                           | $32t_{c(\text{OSCCLK})}$  |     | cycles |
| $t_{\text{OSCST}}$ <sup>(2)</sup>   | Oscillator start-up time                                           |            | 1                         | 10                        |     | ms     |
| $t_{h(\text{boot-mode})}$           | Hold time for boot-mode pins                                       |            | $200t_{c(\text{OSCCLK})}$ |                           |     | cycles |

(1) In addition to the  $t_{w(\text{RSL1})}$  requirement,  $\overline{\text{XRS}}$  must be low at least for 1 ms after  $V_{\text{DD}}$  reaches 1.5 V.

(2) Dependent on crystal/resonator and board design.



- A. After reset, the Boot ROM code samples BOOT Mode pins. Based on the status of the Boot Mode pin, the boot code branches to destination memory or boot code function. If Boot ROM code executes after power-on conditions (in debugger environment), the Boot code execution time is based on the current SYSCLKOUT speed. The SYSCLKOUT will be based on user environment and could be with or without PLL enabled.

**Figure 5-5. Warm Reset**

Figure 5-6 shows an example for the effect of writing into PLLCR register. In the first phase, PLLCR = 0x0004 and SYSCLKOUT = OSCCLK × 2. The PLLCR is then written with 0x0008. Right after the PLLCR register is written, the PLL lock-up phase begins. During this phase, SYSCLKOUT = OSCCLK/2. After the PLL lock-up is complete (which takes 131072 OSCCLK cycles), SYSCLKOUT reflects the new operating frequency, OSCCLK × 4.

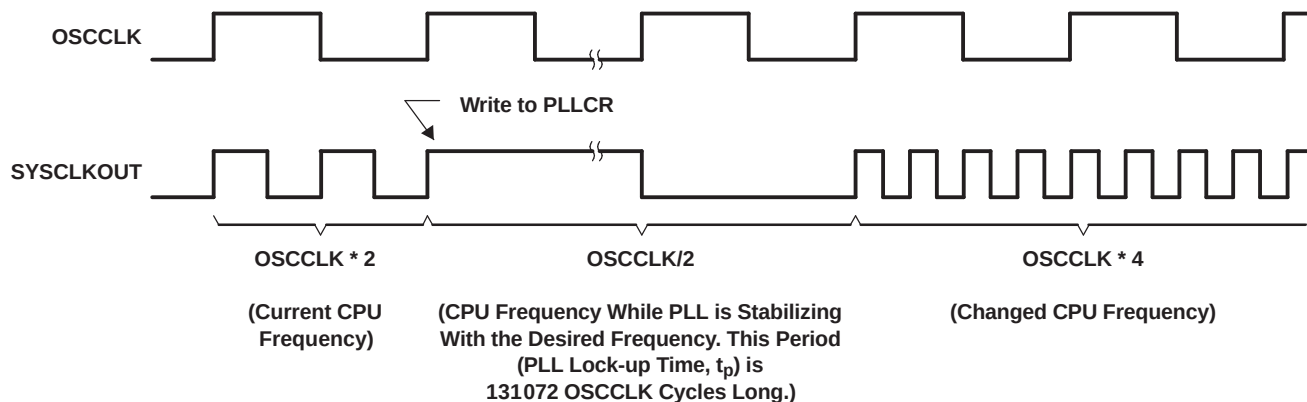


Figure 5-6. Example of Effect of Writing Into PLLCR Register

### 5.9.3 Clock Requirements and Characteristics

**Table 5-7. Input Clock Frequency**

| PARAMETER      |                                                       |                                                     |                | MIN   | TYP | MAX | UNIT |
|----------------|-------------------------------------------------------|-----------------------------------------------------|----------------|-------|-----|-----|------|
| f <sub>x</sub> | Input clock frequency                                 | Resonator (X1/X2)                                   |                | 20    |     | 35  | MHz  |
|                |                                                       | Crystal (X1/X2)                                     |                | 20    |     | 35  |      |
|                |                                                       | External oscillator/clock source (XCLKIN or X1 pin) | 150-MHz device | 4     |     | 150 |      |
|                |                                                       |                                                     | 100-MHz device | 4     |     | 100 |      |
| f <sub>l</sub> | Limp mode SYSCLKOUT frequency range (with /2 enabled) |                                                     |                | 1 - 5 |     |     | MHz  |

**Table 5-8. XCLKIN Timing Requirements – PLL Enabled**

| NO. |                                                                                        | MIN  | MAX | UNIT |
|-----|----------------------------------------------------------------------------------------|------|-----|------|
| C8  | $t_{c(CI)}$ Cycle time, XCLKIN                                                         | 33.3 | 200 | ns   |
| C9  | $t_{f(CI)}$ Fall time, XCLKIN <sup>(1)</sup>                                           |      | 6   | ns   |
| C10 | $t_{r(CI)}$ Rise time, XCLKIN <sup>(1)</sup>                                           |      | 6   | ns   |
| C11 | $t_{w(CIL)}$ Pulse duration, XCLKIN low as a percentage of $t_{c(CI)}$ <sup>(1)</sup>  | 45%  | 55% |      |
| C12 | $t_{w(CIH)}$ Pulse duration, XCLKIN high as a percentage of $t_{c(CI)}$ <sup>(1)</sup> | 45%  | 55% |      |

(1) This applies to the X1 pin also.

**Table 5-9. XCLKIN Timing Requirements – PLL Disabled**

| NO. |              |                                                                           | MIN               | MAX  | UNIT |    |
|-----|--------------|---------------------------------------------------------------------------|-------------------|------|------|----|
| C8  | $t_{c(CI)}$  | Cycle time, XCLKIN                                                        | 150-MHz device    | 6.67 | 250  | ns |
|     |              |                                                                           | 100-MHz device    | 10   | 250  |    |
| C9  | $t_{f(CI)}$  | Fall time, XCLKIN <sup>(1)</sup>                                          | Up to 30 MHz      |      | 6    | ns |
|     |              |                                                                           | 30 MHz to 150 MHz |      | 2    |    |
| C10 | $t_{r(CI)}$  | Rise time, XCLKIN <sup>(1)</sup>                                          | Up to 30 MHz      |      | 6    | ns |
|     |              |                                                                           | 30 MHz to 150 MHz |      | 2    |    |
| C11 | $t_{w(CIL)}$ | Pulse duration, XCLKIN low as a percentage of $t_{c(CI)}$ <sup>(1)</sup>  |                   | 45%  | 55%  |    |
| C12 | $t_{w(CIH)}$ | Pulse duration, XCLKIN high as a percentage of $t_{c(CI)}$ <sup>(1)</sup> |                   | 45%  | 55%  |    |

(1) This applies to the X1 pin also.

The possible configuration modes are shown in [Table 6-38](#).

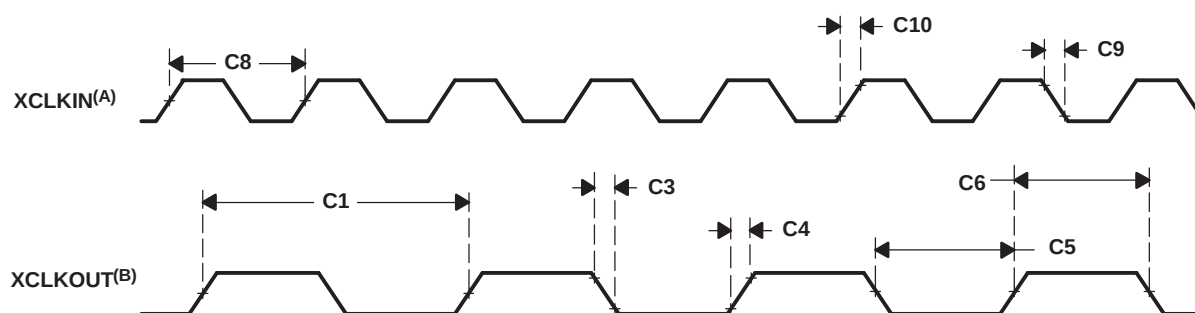
**Table 5-10. XCLKOUT Switching Characteristics (PLL Bypassed or Enabled)<sup>(1) (2)</sup>**

| NO. | PARAMETER                                  |                | MIN  | TYP    | MAX                            | UNIT   |
|-----|--------------------------------------------|----------------|------|--------|--------------------------------|--------|
| C1  | $t_{c(XCO)}$ Cycle time, XCLKOUT           | 150-MHz device | 6.67 |        |                                | ns     |
|     |                                            | 100-MHz device | 10   |        |                                |        |
| C3  | $t_{f(XCO)}$ Fall time, XCLKOUT            |                | 2    |        |                                | ns     |
| C4  | $t_{r(XCO)}$ Rise time, XCLKOUT            |                | 2    |        |                                | ns     |
| C5  | $t_{w(XCOL)}$ Pulse duration, XCLKOUT low  | H – 2          |      |        | H + 2                          | ns     |
| C6  | $t_{w(XCOH)}$ Pulse duration, XCLKOUT high | H – 2          |      |        | H + 2                          | ns     |
|     | $t_p$ PLL lock time                        |                |      | 131072 | $t_{c(OSCCLK)}$ <sup>(3)</sup> | cycles |

(1) A load of 40 pF is assumed for these parameters.

(2)  $H = 0.5t_{c(XCO)}$

(3) OSCCLK is either the output of the on-chip oscillator or the output from an external oscillator.



- A. The relationship of XCLKIN to XCLKOUT depends on the divide factor chosen. The waveform relationship shown is intended to illustrate the timing parameters only and may differ based on actual configuration.
- B. XCLKOUT configured to reflect SYSCLKOUT.

**Figure 5-7. Clock Timing**

## 5.9.4 Peripherals

### 5.9.4.1 General-Purpose Input/Output (GPIO)

#### 5.9.4.1.1 GPIO - Output Timing

**Table 5-11. General-Purpose Output Switching Characteristics**

| PARAMETER    |                                       |           | MIN | MAX | UNIT |
|--------------|---------------------------------------|-----------|-----|-----|------|
| $t_{r(GPO)}$ | Rise time, GPIO switching low to high | All GPIOs |     | 8   | ns   |
| $t_{f(GPO)}$ | Fall time, GPIO switching high to low | All GPIOs |     | 8   | ns   |
| $t_{GPO}$    | Toggling frequency, GPO pins          |           |     | 25  | MHz  |

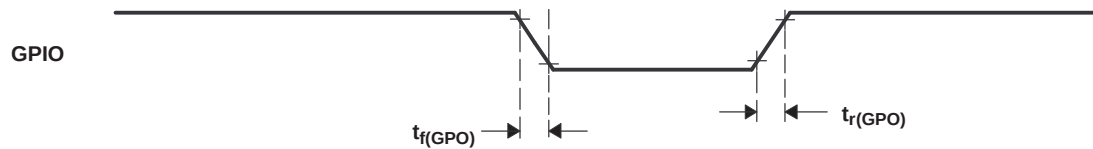


**Figure 5-8. General-Purpose Output Timing**

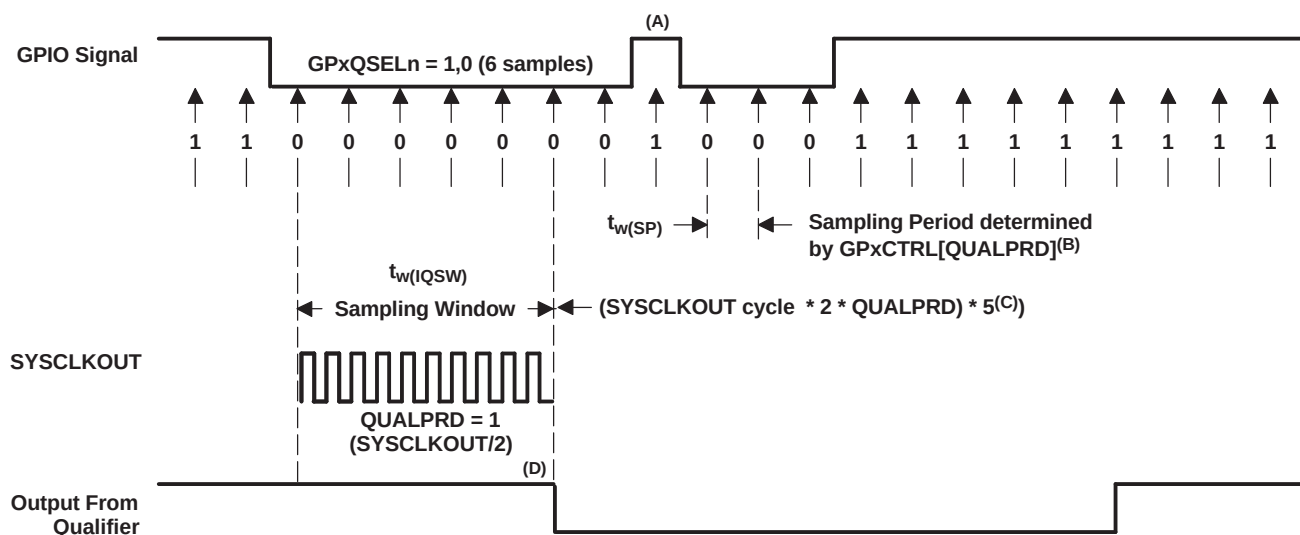
### 5.9.4.1.2 GPIO - Input Timing

Table 5-12. General-Purpose Input Timing Requirements

|                    |                                 |                      | MIN                                     | MAX | UNIT   |
|--------------------|---------------------------------|----------------------|-----------------------------------------|-----|--------|
| $t_{W(SP)}$        | Sampling period                 | QUALPRD = 0          | $1t_{c(SCO)}$                           |     | cycles |
|                    |                                 | QUALPRD $\neq$ 0     | $2t_{c(SCO)} * QUALPRD$                 |     |        |
| $t_{W(IQSW)}$      | Input qualifier sampling window |                      | $t_{W(SP)} * (n^{(1)} - 1)$             |     | cycles |
| $t_{W(GPI)}^{(2)}$ | Pulse duration, GPIO low/high   | Synchronous mode     | $2t_{c(SCO)}$                           |     | cycles |
|                    |                                 | With input qualifier | $t_{W(IQSW)} + t_{W(SP)} + 1t_{c(SCO)}$ |     |        |

(1) "n" represents the number of qualification samples as defined by GPxQSELn register.

(2) For  $t_{w(GPI)}$ , pulse width is measured from  $V_{IL}$  to  $V_{IL}$  for an active low signal and  $V_{IH}$  to  $V_{IH}$  for an active high signal.



- This glitch will be ignored by the input qualifier. The QUALPRD bit field specifies the qualification sampling period. It can vary from 00 to 0xFF. If QUALPRD = 00, then the sampling period is 1 SYSCLKOUT cycle. For any other value "n", the qualification sampling period is 2n SYSCLKOUT cycles (that is, at every 2n SYSCLKOUT cycles, the GPIO pin will be sampled).
- The qualification period selected through the GPxCTRL register applies to groups of 8 GPIO pins.
- The qualification block can take either three or six samples. The GPxQSELn Register selects which sample mode is used.
- In the example shown, for the qualifier to detect the change, the input should be stable for 10 SYSCLKOUT cycles or greater. In other words, the inputs should be stable for  $(5 \times QUALPRD \times 2)$  SYSCLKOUT cycles. This would ensure 5 sampling periods for detection to occur. Because external signals are driven asynchronously, a 13-SYSCLKOUT-wide pulse ensures reliable recognition.

Figure 5-9. Sampling Mode

### 5.9.4.1.3 Sampling Window Width for Input Signals

The following section summarizes the sampling window width for input signals for various input qualifier configurations.

Sampling frequency denotes how often a signal is sampled with respect to SYSCLKOUT.

Sampling frequency =  $\text{SYSCLKOUT} / (2 \times \text{QUALPRD})$ , if  $\text{QUALPRD} \neq 0$

Sampling frequency =  $\text{SYSCLKOUT}$ , if  $\text{QUALPRD} = 0$

Sampling period =  $\text{SYSCLKOUT cycle} \times 2 \times \text{QUALPRD}$ , if  $\text{QUALPRD} \neq 0$

In the above equations, SYSCLKOUT cycle indicates the time period of SYSCLKOUT.

Sampling period =  $\text{SYSCLKOUT cycle}$ , if  $\text{QUALPRD} = 0$

In a given sampling window, either 3 or 6 samples of the input signal are taken to determine the validity of the signal. This is determined by the value written to GPxQSELn register.

#### Case 1:

Qualification using three samples

Sampling window width =  $(\text{SYSCLKOUT cycle} \times 2 \times \text{QUALPRD}) \times 2$ , if  $\text{QUALPRD} \neq 0$

Sampling window width =  $(\text{SYSCLKOUT cycle}) \times 2$ , if  $\text{QUALPRD} = 0$

#### Case 2:

Qualification using six samples

Sampling window width =  $(\text{SYSCLKOUT cycle} \times 2 \times \text{QUALPRD}) \times 5$ , if  $\text{QUALPRD} \neq 0$

Sampling window width =  $(\text{SYSCLKOUT cycle}) \times 5$ , if  $\text{QUALPRD} = 0$

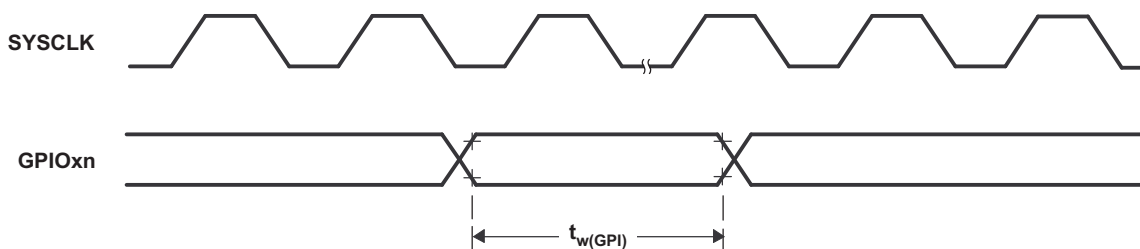


**Figure 5-10. General-Purpose Input Timing**

#### 5.9.4.1.4 Low-Power Mode Wakeup Timing

Table 5-13 shows the timing requirements, Table 5-14 shows the switching characteristics, and Figure 5-11 shows the timing diagram for IDLE mode.

**Table 5-13. IDLE Mode Timing Requirements<sup>(1)</sup>**

|                          |                                         | MIN                     | MAX                                         | UNIT   |
|--------------------------|-----------------------------------------|-------------------------|---------------------------------------------|--------|
| t <sub>w(WAKE-INT)</sub> | Pulse duration, external wake-up signal | Without input qualifier | 2t <sub>c(SCO)</sub>                        | cycles |
|                          |                                         | With input qualifier    | 5t <sub>c(SCO)</sub> + t <sub>w(IOSW)</sub> |        |

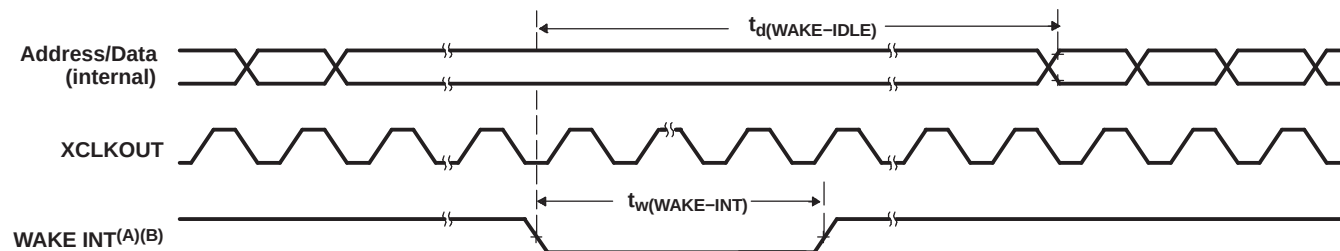
(1) For an explanation of the input qualifier parameters, see Table 5-12.

**Table 5-14. IDLE Mode Switching Characteristics<sup>(1)</sup>**

| PARAMETER                 |                                                                             | TEST CONDITIONS         | MIN | MAX                                            | UNIT   |
|---------------------------|-----------------------------------------------------------------------------|-------------------------|-----|------------------------------------------------|--------|
| t <sub>d(WAKE-IDLE)</sub> | Delay time, external wake signal to program execution resume <sup>(2)</sup> |                         |     |                                                |        |
|                           | Wake-up from flash<br>• Flash module in active state                        | Without input qualifier |     | 20t <sub>c(SCO)</sub>                          | cycles |
|                           |                                                                             | With input qualifier    |     | 20t <sub>c(SCO)</sub> + t <sub>w(IQSW)</sub>   |        |
|                           | Wake-up from flash<br>• Flash module in sleep state                         | Without input qualifier |     | 1050t <sub>c(SCO)</sub>                        | cycles |
|                           |                                                                             | With input qualifier    |     | 1050t <sub>c(SCO)</sub> + t <sub>w(IQSW)</sub> |        |
|                           | Wake-up from SARAM                                                          | Without input qualifier |     | 20t <sub>c(SCO)</sub>                          | cycles |
|                           |                                                                             | With input qualifier    |     | 20t <sub>c(SCO)</sub> + t <sub>w(IQSW)</sub>   |        |

(1) For an explanation of the input qualifier parameters, see Table 5-12.

(2) This is the time taken to begin execution of the instruction that immediately follows the IDLE instruction. execution of an ISR (triggered by the wake up) signal involves additional latency.



A. WAKE INT can be any enabled interrupt,  $\overline{WDINT}$ ,  $XNMI$ , or  $\overline{XRS}$ .

B. From the time the IDLE instruction is executed to place the device into low-power mode (LPM), wakeup should not be initiated until at least 4 OSCCLK cycles have elapsed.

**Figure 5-11. IDLE Entry and Exit Timing**

**Table 5-15. STANDBY Mode Timing Requirements**

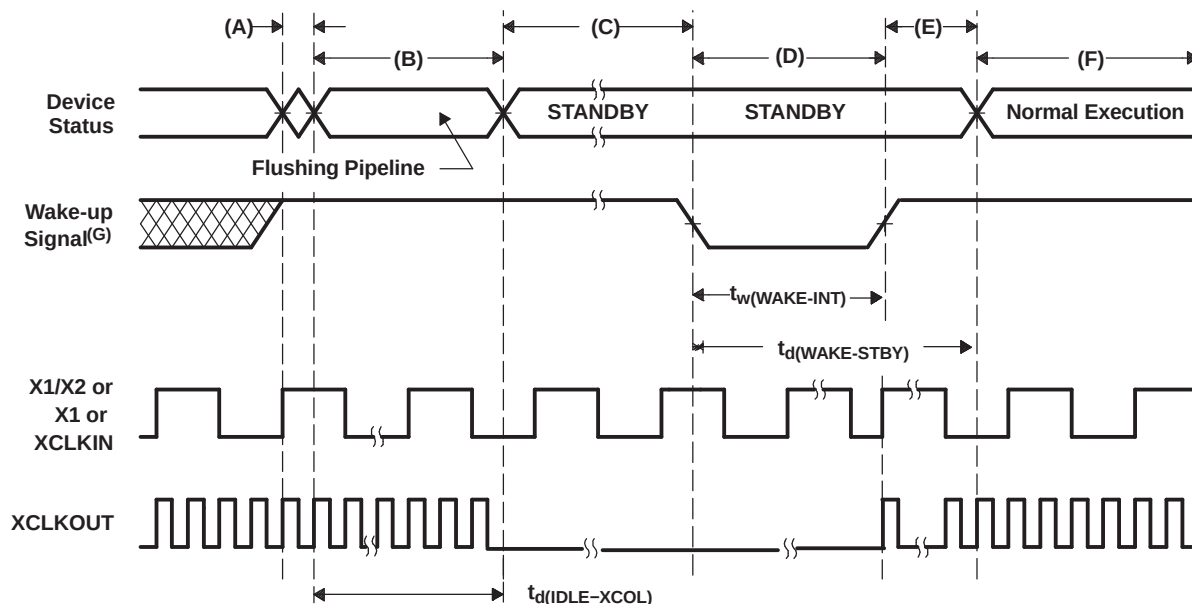
|                          |                                         |                                         | MIN                                      | MAX | UNIT   |
|--------------------------|-----------------------------------------|-----------------------------------------|------------------------------------------|-----|--------|
| t <sub>w(WAKE-INT)</sub> | Pulse duration, external wake-up signal | Without input qualification             | 3t <sub>c(OSCCLK)</sub>                  |     | cycles |
|                          |                                         | With input qualification <sup>(1)</sup> | (2 + QUALSTDBY) * t <sub>c(OSCCLK)</sub> |     |        |

(1) QUALSTDBY is a 6-bit field in the LPMCR0 register.

**Table 5-16. STANDBY Mode Switching Characteristics**

| PARAMETER                  |                                                                             | TEST CONDITIONS         | MIN                    | MAX                                                  | UNIT   |
|----------------------------|-----------------------------------------------------------------------------|-------------------------|------------------------|------------------------------------------------------|--------|
| t <sub>d</sub> (IDLE-XCOL) | Delay time, IDLE instruction executed to XCLKOUT low                        |                         | 32t <sub>c</sub> (SCO) | 45t <sub>c</sub> (SCO)                               | cycles |
| t <sub>d</sub> (WAKE-STBY) | Delay time, external wake signal to program execution resume <sup>(1)</sup> |                         |                        |                                                      |        |
|                            | • Wake up from flash<br>– Flash module in active state                      | Without input qualifier |                        | 100t <sub>c</sub> (SCO)                              | cycles |
|                            |                                                                             | With input qualifier    |                        | 100t <sub>c</sub> (SCO) + t <sub>w</sub> (WAKE-INT)  |        |
|                            | • Wake up from flash<br>– Flash module in sleep state                       | Without input qualifier |                        | 1125t <sub>c</sub> (SCO)                             | cycles |
|                            |                                                                             | With input qualifier    |                        | 1125t <sub>c</sub> (SCO) + t <sub>w</sub> (WAKE-INT) |        |
|                            | • Wake up from SARAM                                                        | Without input qualifier |                        | 100t <sub>c</sub> (SCO)                              | cycles |
|                            |                                                                             | With input qualifier    |                        | 100t <sub>c</sub> (SCO) + t <sub>w</sub> (WAKE-INT)  |        |

(1) This is the time taken to begin execution of the instruction that immediately follows the IDLE instruction. execution of an ISR (triggered by the wake up signal) involves additional latency.



- A. IDLE instruction is executed to put the device into STANDBY mode.
- B. The PLL block responds to the STANDBY signal. SYSCLKOUT is held for the number of cycles indicated below before being turned off:
  - 16 cycles, when DIVSEL = 00 or 01
  - 32 cycles, when DIVSEL = 10
  - 64 cycles, when DIVSEL = 11

This delay enables the CPU pipeline and any other pending operations to flush properly. If an access to XINTF is in progress and its access time is longer than this number then it will fail. It is recommended to enter STANDBY mode from SARAM without an XINTF access in progress.
- C. Clock to the peripherals are turned off. However, the PLL and watchdog are not shut down. The device is now in STANDBY mode.
- D. The external wake-up signal is driven active.
- E. After a latency period, the STANDBY mode is exited.
- F. Normal execution resumes. The device will respond to the interrupt (if enabled).
- G. From the time the IDLE instruction is executed to place the device into low-power mode (LPM), wakeup should not be initiated until at least 4 OSCCLK cycles have elapsed.

**Figure 5-12. STANDBY Entry and Exit Timing Diagram**

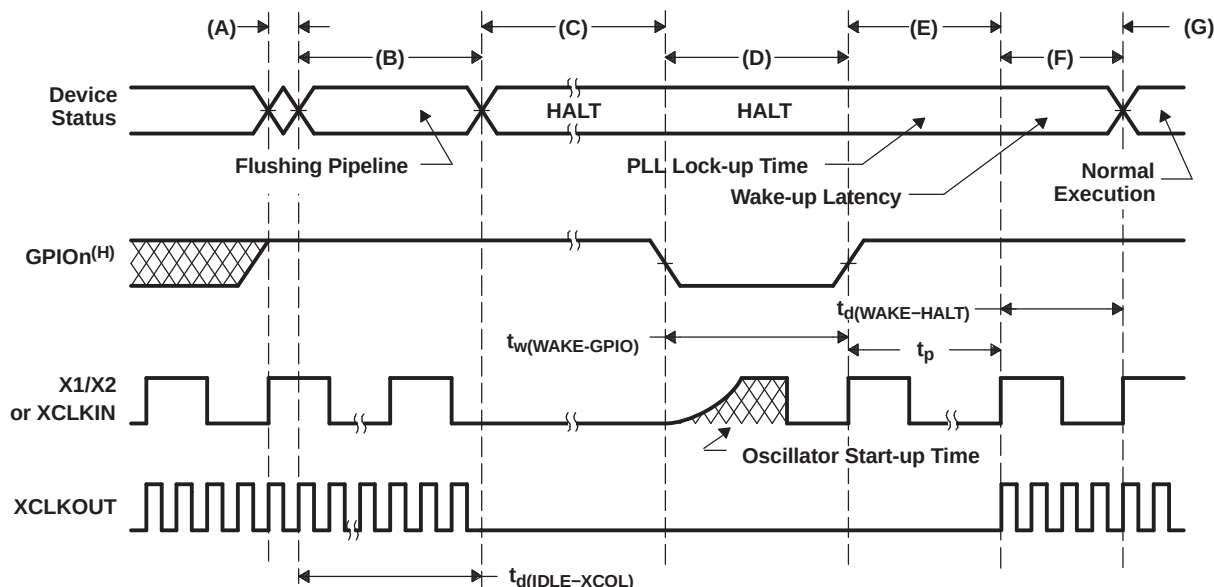
**Table 5-17. HALT Mode Timing Requirements**

|                    |                                                | MIN                                | MAX | UNIT   |
|--------------------|------------------------------------------------|------------------------------------|-----|--------|
| $t_{w(WAKE-GPIO)}$ | Pulse duration, GPIO wake-up signal            | $t_{oscst} + 2t_{c(OSCCLK)}^{(1)}$ |     | cycles |
| $t_{w(WAKE-XRS)}$  | Pulse duration, $\overline{XRS}$ wakeup signal | $t_{oscst} + 8t_{c(OSCCLK)}$       |     | cycles |

(1) See [Table 5-6](#) for an explanation of  $t_{oscst}$ .

**Table 5-18. HALT Mode Switching Characteristics**

| PARAMETER          |                                                                                                                                                     | MIN                   | MAX              | UNIT   |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|------------------|--------|
| $t_{d(IDLE-XCOL)}$ | Delay time, IDLE instruction executed to XCLKOUT low                                                                                                | $32t_{c(SCO)}$        | $45t_{c(SCO)}$   | cycles |
| $t_p$              | PLL lock-up time                                                                                                                                    | $131072t_{c(OSCCLK)}$ |                  | cycles |
| $t_{d(WAKE-HALT)}$ | Delay time, PLL lock to program execution resume                                                                                                    |                       |                  |        |
|                    | <ul style="list-style-type: none"> <li>Wake up from flash <ul style="list-style-type: none"> <li>Flash module in sleep state</li> </ul> </li> </ul> |                       | $1125t_{c(SCO)}$ | cycles |
|                    | <ul style="list-style-type: none"> <li>Wake up from SARAM</li> </ul>                                                                                |                       | $35t_{c(SCO)}$   | cycles |



- A. IDLE instruction is executed to put the device into HALT mode.
- B. The PLL block responds to the HALT signal. SYSCLKOUT is held for the number of cycles indicated below before oscillator is turned off and the CLKIN to the core is stopped:
  - 16 cycles, when DIVSEL = 00 or 01
  - 32 cycles, when DIVSEL = 10
  - 64 cycles, when DIVSEL = 11
 This delay enables the CPU pipeline and any other pending operations to flush properly. If an access to XINTF is in progress and its access time is longer than this number then it will fail. It is recommended to enter HALT mode from SARAM without an XINTF access in progress.
- C. Clocks to the peripherals are turned off and the PLL is shut down. If a quartz crystal or ceramic resonator is used as the clock source, the internal oscillator is shut down as well. The device is now in HALT mode and consumes absolute minimum power.
- D. When the GPION pin (used to bring the device out of HALT) is driven low, the oscillator is turned on and the oscillator wake-up sequence is initiated. The GPIO pin should be driven high only after the oscillator has stabilized. This enables the provision of a clean clock signal during the PLL lock sequence. Because the falling edge of the GPIO pin asynchronously begins the wakeup process, care should be taken to maintain a low noise environment prior to entering and during HALT mode.
- E. Once the oscillator has stabilized, the PLL lock sequence is initiated, which takes 131,072 OSCCLK (X1/X2 or X1 or XCLKIN) cycles. Note that these 131,072 clock cycles are applicable even when the PLL is disabled (that is, code execution will be delayed by this duration even when the PLL is disabled).
- F. Clocks to the core and peripherals are enabled. The HALT mode is now exited. The device will respond to the interrupt (if enabled), after a latency.
- G. Normal operation resumes.
- H. From the time the IDLE instruction is executed to place the device into low-power mode (LPM), wakeup should not be initiated until at least 4 OSCCLK cycles have elapsed.

**Figure 5-13. HALT Wakeup Using GPION**

## 5.9.4.2 Enhanced Control Peripherals

### 5.9.4.2.1 Enhanced Pulse Width Modulator (ePWM) Timing

PWM refers to PWM outputs on ePWM1–6. [Table 5-19](#) shows the ePWM timing requirements and [Table 5-20](#), ePWM switching characteristics.

**Table 5-19. ePWM Timing Requirements<sup>(1)</sup>**

|                |                        | MIN                  | MAX                         | UNIT   |
|----------------|------------------------|----------------------|-----------------------------|--------|
| $t_{w(SYCIN)}$ | Sync input pulse width | Asynchronous         | $2t_{c(SCO)}$               | cycles |
|                |                        | Synchronous          | $2t_{c(SCO)}$               |        |
|                |                        | With input qualifier | $1t_{c(SCO)} + t_{w(IQSW)}$ |        |

(1) For an explanation of the input qualifier parameters, see [Table 5-12](#).

**Table 5-20. ePWM Switching Characteristics**

| PARAMETER         | TEST CONDITIONS                                                                                     | MIN           | MAX | UNIT   |
|-------------------|-----------------------------------------------------------------------------------------------------|---------------|-----|--------|
| $t_{w(PWM)}$      | Pulse duration, PWMx output high/low                                                                | 20            |     | ns     |
| $t_{w(SYNCOUT)}$  | Sync output pulse width                                                                             | $8t_{c(SCO)}$ |     | cycles |
| $t_{d(PWM)tza}$   | Delay time, trip input active to PWM forced high<br>Delay time, trip input active to PWM forced low | no pin load   | 25  | ns     |
| $t_{d(TZ-PWM)HZ}$ | Delay time, trip input active to PWM Hi-Z                                                           |               | 20  | ns     |

### 5.9.4.2.2 Trip-Zone Input Timing

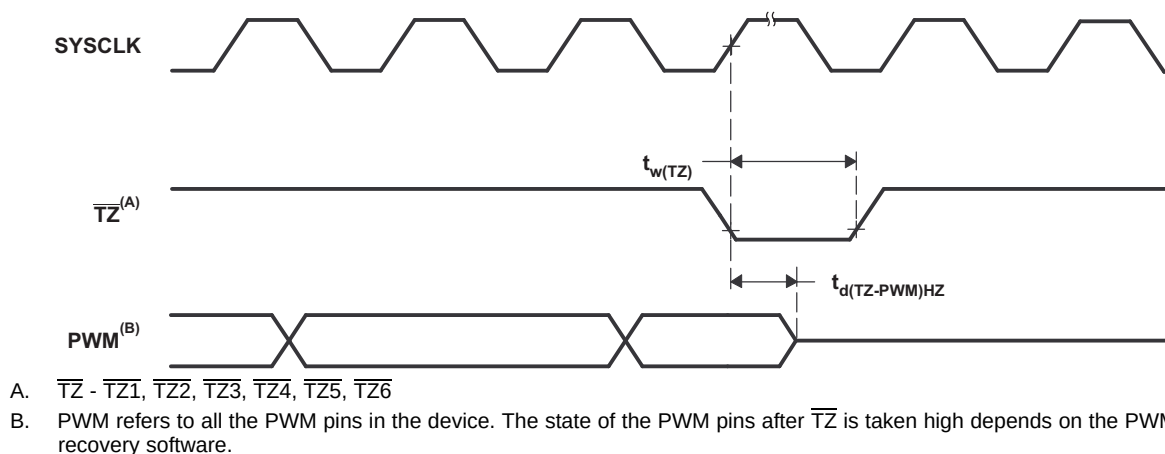


**Figure 5-14. PWM Hi-Z Characteristics**

**Table 5-21. Trip-Zone Input Timing Requirements<sup>(1)</sup>**

|             |                                            | MIN                  | MAX                         | UNIT   |
|-------------|--------------------------------------------|----------------------|-----------------------------|--------|
| $t_{w(TZ)}$ | Pulse duration, $\overline{TZx}$ input low | Asynchronous         | $1t_{c(SCO)}$               | cycles |
|             |                                            | Synchronous          | $2t_{c(SCO)}$               |        |
|             |                                            | With input qualifier | $1t_{c(SCO)} + t_{w(IQSW)}$ |        |

(1) For an explanation of the input qualifier parameters, see [Table 5-12](#).

### 5.9.4.2.3 High-Resolution PWM Timing

Table 5-22 shows the high-resolution PWM switching characteristics.

**Table 5-22. High-Resolution PWM Characteristics at SYSCLKOUT = (60–150 MHz)**

|                                                       | MIN | TYP | MAX | UNIT |
|-------------------------------------------------------|-----|-----|-----|------|
| Micro Edge Positioning (MEP) step size <sup>(1)</sup> |     | 150 | 310 | ps   |

- (1) The MEP step size will be largest at high temperature and minimum voltage on V<sub>DD</sub>. MEP step size will increase with higher temperature and lower voltage and decrease with lower temperature and higher voltage. Applications that use the HRPWM feature should use MEP Scale Factor Optimizer (SFO) estimation software functions. See the TI software libraries for details of using SFO function in end applications. SFO functions help to estimate the number of MEP steps per SYSCLKOUT period dynamically while the HRPWM is in operation.

### 5.9.4.2.4 Enhanced Capture (eCAP) Timing

Table 5-23 shows the eCAP timing requirement and Table 5-24 shows the eCAP switching characteristics.

**Table 5-23. Enhanced Capture (eCAP) Timing Requirements<sup>(1)</sup>**

|                                        |                      | MIN                         | MAX | UNIT   |
|----------------------------------------|----------------------|-----------------------------|-----|--------|
| $t_{w(CAP)}$ Capture input pulse width | Asynchronous         | $2t_{c(SCO)}$               |     | cycles |
|                                        | Synchronous          | $2t_{c(SCO)}$               |     |        |
|                                        | With input qualifier | $1t_{c(SCO)} + t_{w(IQSW)}$ |     |        |

- (1) For an explanation of the input qualifier parameters, see Table 5-12.

**Table 5-24. eCAP Switching Characteristics**

| PARAMETER                                           | TEST CONDITIONS | MIN | MAX | UNIT |
|-----------------------------------------------------|-----------------|-----|-----|------|
| $t_{w(APWM)}$ Pulse duration, APWMx output high/low |                 | 20  |     | ns   |

### 5.9.4.2.5 Enhanced Quadrature Encoder Pulse (eQEP) Timing

Table 5-25 shows the eQEP timing requirement and Table 5-26 shows the eQEP switching characteristics.

**Table 5-25. Enhanced Quadrature Encoder Pulse (eQEP) Timing Requirements<sup>(1)</sup>**

|                                           |                                          | MIN                            | MAX | UNIT   |
|-------------------------------------------|------------------------------------------|--------------------------------|-----|--------|
| $t_{w(QEPP)}$ QEP input period            | Asynchronous <sup>(2)</sup> /synchronous | $2t_{c(SCO)}$                  |     | cycles |
|                                           | With input qualifier                     | $2[1t_{c(SCO)} + t_{w(IQSW)}]$ |     |        |
| $t_{w(INDEXH)}$ QEP Index Input High time | Asynchronous <sup>(2)</sup> /synchronous | $2t_{c(SCO)}$                  |     | cycles |
|                                           | With input qualifier                     | $2t_{c(SCO)} + t_{w(IQSW)}$    |     |        |
| $t_{w(INDEXL)}$ QEP Index Input Low time  | Asynchronous <sup>(2)</sup> /synchronous | $2t_{c(SCO)}$                  |     | cycles |
|                                           | With input qualifier                     | $2t_{c(SCO)} + t_{w(IQSW)}$    |     |        |
| $t_{w(STROBH)}$ QEP Strobe High time      | Asynchronous <sup>(2)</sup> /synchronous | $2t_{c(SCO)}$                  |     | cycles |
|                                           | With input qualifier                     | $2t_{c(SCO)} + t_{w(IQSW)}$    |     |        |
| $t_{w(STROBL)}$ QEP Strobe Input Low time | Asynchronous <sup>(2)</sup> /synchronous | $2t_{c(SCO)}$                  |     | cycles |
|                                           | With input qualifier                     | $2t_{c(SCO)} + t_{w(IQSW)}$    |     |        |

- (1) For an explanation of the input qualifier parameters, see Table 5-12.  
(2) Refer to the [TMS320F2833x](#), [TMS320F2823x DSC silicon errata](#) for limitations in the asynchronous mode.

**Table 5-26. eQEP Switching Characteristics**

| PARAMETER                                                                      | TEST CONDITIONS | MIN | MAX           | UNIT   |
|--------------------------------------------------------------------------------|-----------------|-----|---------------|--------|
| $t_{d(CNTR)xin}$ Delay time, external clock to counter increment               |                 |     | $4t_{c(SCO)}$ | cycles |
| $t_{d(PCS-OUT)QEP}$ Delay time, QEP input edge to position compare sync output |                 |     | $6t_{c(SCO)}$ | cycles |

#### 5.9.4.2.6 ADC Start-of-Conversion Timing

**Table 5-27. External ADC Start-of-Conversion Switching Characteristics**

| PARAMETER                                     | MIN            | MAX | UNIT   |
|-----------------------------------------------|----------------|-----|--------|
| $t_{w(ADCSOCL)}$ Pulse duration, ADCSOCxO low | $32t_{c(HCO)}$ |     | cycles |

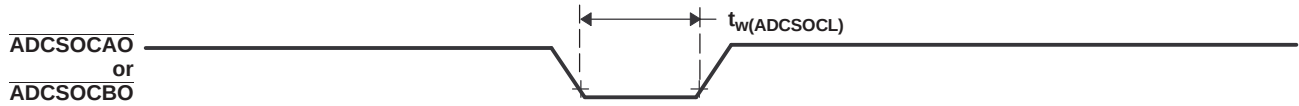


**Figure 5-15. ADCSOCxO or ADCSOCBO Timing**

#### 5.9.4.3 External Interrupt Timing

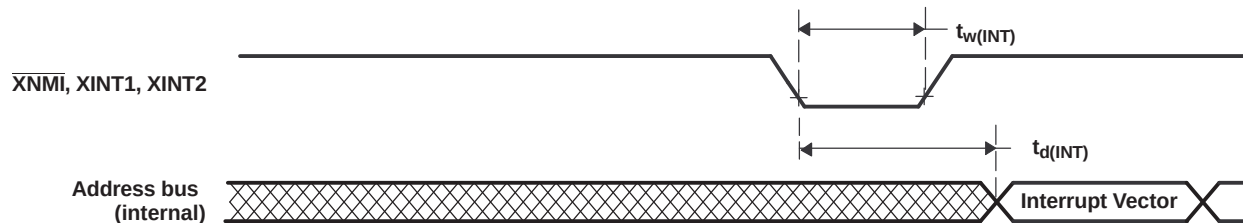


**Figure 5-16. External Interrupt Timing**

**Table 5-28. External Interrupt Timing Requirements<sup>(1)</sup>**

|                                                                |                | MIN                         | MAX | UNIT   |
|----------------------------------------------------------------|----------------|-----------------------------|-----|--------|
| $t_{w(INT)}$ <sup>(2)</sup> Pulse duration, INT input low/high | Synchronous    | $1t_{c(SCO)}$               |     | cycles |
|                                                                | With qualifier | $1t_{c(SCO)} + t_{w(IQSW)}$ |     |        |

(1) For an explanation of the input qualifier parameters, see [Table 5-12](#).

(2) This timing is applicable to any GPIO pin configured for ADCSOC functionality.

**Table 5-29. External Interrupt Switching Characteristics<sup>(1)</sup>**

| PARAMETER                                                       | MIN                          | MAX | UNIT   |
|-----------------------------------------------------------------|------------------------------|-----|--------|
| $t_{d(INT)}$ Delay time, INT low/high to interrupt-vector fetch | $t_{w(IQSW)} + 12t_{c(SCO)}$ |     | cycles |

(1) For an explanation of the input qualifier parameters, see [Table 5-12](#).

#### 5.9.4.4 I2C Electrical Specification and Timing

Table 5-30. I2C Timing

|            |                                                                                   | TEST CONDITIONS                                                                                                                   | MIN             | MAX            | UNIT    |
|------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------|---------|
| $f_{SCL}$  | SCL clock frequency                                                               | I2C clock module frequency is between 7 MHz and 12 MHz and I2C prescaler and clock divider registers are configured appropriately |                 | 400            | kHz     |
| $V_{IL}$   | Low level input voltage                                                           |                                                                                                                                   |                 | $0.3 V_{DDIO}$ | V       |
| $V_{IH}$   | High level input voltage                                                          |                                                                                                                                   | $0.7 V_{DDIO}$  |                | V       |
| $V_{hys}$  | Input hysteresis                                                                  |                                                                                                                                   | $0.05 V_{DDIO}$ |                | V       |
| $V_{OL}$   | Low level output voltage                                                          | 3-mA sink current                                                                                                                 | 0               | 0.4            | V       |
| $t_{LOW}$  | Low period of SCL clock                                                           | I2C clock module frequency is between 7 MHz and 12 MHz and I2C prescaler and clock divider registers are configured appropriately | 1.3             |                | $\mu s$ |
| $t_{HIGH}$ | High period of SCL clock                                                          | I2C clock module frequency is between 7 MHz and 12 MHz and I2C prescaler and clock divider registers are configured appropriately | 0.6             |                | $\mu s$ |
| $I_I$      | Input current with an input voltage between $0.1 V_{DDIO}$ and $0.9 V_{DDIO}$ MAX |                                                                                                                                   | -10             | 10             | $\mu A$ |

### 5.9.4.5 Serial Peripheral Interface (SPI) Timing

This section contains both Master Mode and Slave Mode timing data.

#### 5.9.4.5.1 Master Mode Timing

Table 5-31 lists the master mode timing (clock phase = 0) and Table 5-32 lists the master mode timing (clock phase = 1). Figure 5-17 and Figure 5-18 show the timing waveforms.

**Table 5-31. SPI Master Mode External Timing (Clock Phase = 0)<sup>(1)(2)(3)(4)(5)</sup>**

| NO. | PARAMETER                                                        | BRR EVEN                                 |                       | BRR ODD                                  |                                          | UNIT |
|-----|------------------------------------------------------------------|------------------------------------------|-----------------------|------------------------------------------|------------------------------------------|------|
|     |                                                                  | MIN                                      | MAX                   | MIN                                      | MAX                                      |      |
| 1   | $t_{c(SPC)M}$ Cycle time, SPICLK                                 | $4t_{c(LSPCLK)}$                         | $128t_{c(LSPCLK)}$    | $5t_{c(LSPCLK)}$                         | $127t_{c(LSPCLK)}$                       | ns   |
| 2   | $t_{w(SPC1)M}$ Pulse duration, SPICLK first pulse                | $0.5t_{c(SPC)M} - 10$                    | $0.5t_{c(SPC)M} + 10$ | $0.5t_{c(SPC)M} + 0.5t_{c(LSPCLK)} - 10$ | $0.5t_{c(SPC)M} + 0.5t_{c(LSPCLK)} + 10$ | ns   |
| 3   | $t_{w(SPC2)M}$ Pulse duration, SPICLK second pulse               | $0.5t_{c(SPC)M} - 10$                    | $0.5t_{c(SPC)M} + 10$ | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} - 10$ | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} + 10$ | ns   |
| 4   | $t_{d(SIMO)M}$ Delay time, SPICLK to SPISIMO valid               |                                          | 10                    |                                          | 10                                       | ns   |
| 5   | $t_{v(SIMO)M}$ Valid time, SPISIMO valid after SPICLK            | $0.5t_{c(SPC)M} - 10$                    |                       | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} - 10$ |                                          | ns   |
| 8   | $t_{su(SOMI)M}$ Setup time, SPISOMI before SPICLK                | 35                                       |                       | 35                                       |                                          | ns   |
| 9   | $t_{h(SOMI)M}$ Hold time, SPISOMI valid after SPICLK             | 0                                        |                       | 0                                        |                                          | ns   |
| 23  | $t_{d(SPC)M}$ Delay time, $\overline{SPISTE}$ active to SPICLK   | $1.5t_{c(SPC)M} - 3t_{c(SYSCLOCK)} - 10$ |                       | $1.5t_{c(SPC)M} - 3t_{c(SYSCLOCK)} - 10$ |                                          | ns   |
| 24  | $t_{d(STE)M}$ Delay time, SPICLK to $\overline{SPISTE}$ inactive | $0.5t_{c(SPC)M} - 10$                    |                       | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} - 10$ |                                          | ns   |

(1) The MASTER / SLAVE bit (SPICTL.2) is set and the CLOCK PHASE bit (SPICTL.3) is cleared.

(2)  $t_{c(SPC)}$  = SPI clock cycle time = LSPCLK/4 or LSPCLK/(SPIBRR + 1)

(3)  $t_{c(LCO)}$  = LSPCLK cycle time

(4) Internal clock prescalers must be adjusted such that the SPI clock speed is limited to the following SPI clock rate:  
Master mode transmit 25-MHz MAX, master mode receive 12.5-MHz MAX  
Slave mode transmit 12.5-MHz MAX, slave mode receive 12.5-MHz MAX.

(5) The active edge of the SPICLK signal referenced is controlled by the clock polarity bit (SPICCR.6).

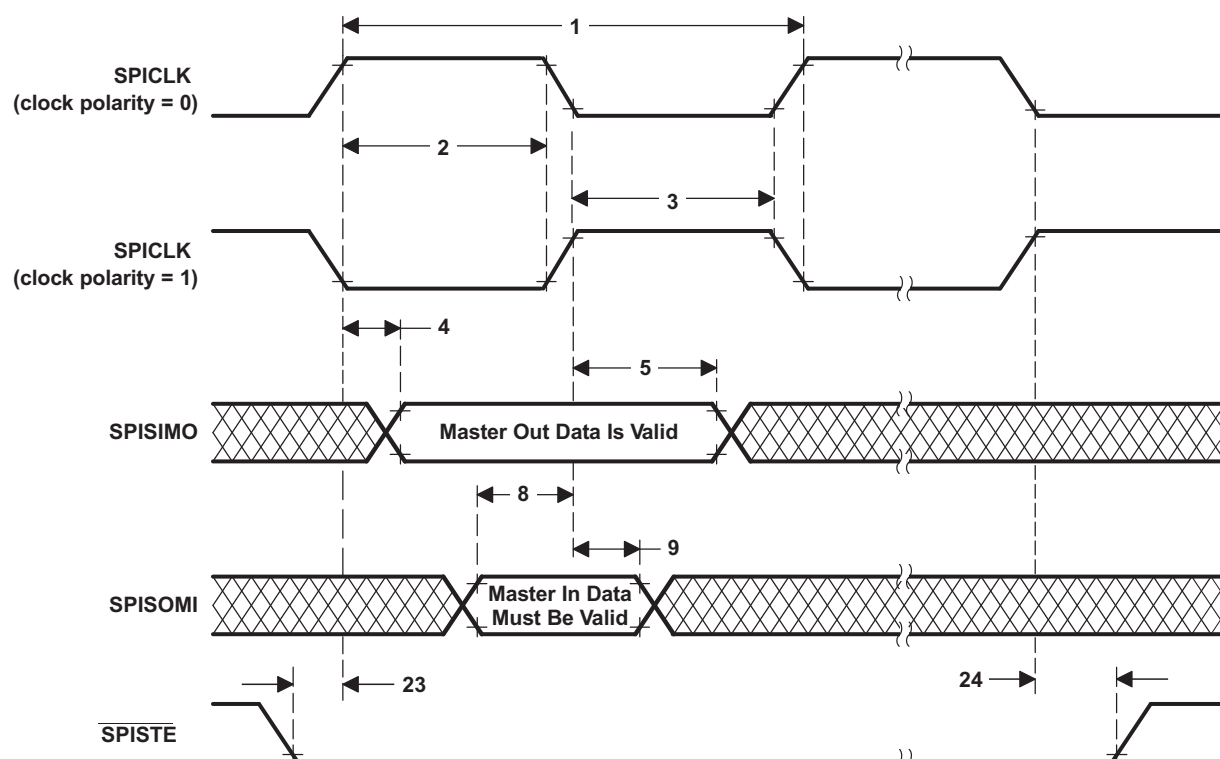


Figure 5-17. SPI Master Mode External Timing (Clock Phase = 0)

**Table 5-32. SPI Master Mode External Timing (Clock Phase = 1)<sup>(1)(2)(3)(4)(5)</sup>**

| NO. | PARAMETER                                                        | BRR EVEN                               |                       | BRR ODD                                  |                                          | UNIT |
|-----|------------------------------------------------------------------|----------------------------------------|-----------------------|------------------------------------------|------------------------------------------|------|
|     |                                                                  | MIN                                    | MAX                   | MIN                                      | MAX                                      |      |
| 1   | $t_{c(SPC)M}$ Cycle time, SPICLK                                 | $4t_{c(LSPCLK)}$                       | $128t_{c(LSPCLK)}$    | $5t_{c(LSPCLK)}$                         | $127t_{c(LSPCLK)}$                       | ns   |
| 2   | $t_{w(SPC1)M}$ Pulse duration, SPICLK first pulse                | $0.5t_{c(SPC)M} - 10$                  | $0.5t_{c(SPC)M} + 10$ | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} - 10$ | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} + 10$ | ns   |
| 3   | $t_{w(SPC2)M}$ Pulse duration, SPICLK second pulse               | $0.5t_{c(SPC)M} - 10$                  | $0.5t_{c(SPC)M} + 10$ | $0.5t_{c(SPC)M} + 0.5t_{c(LSPCLK)} - 10$ | $0.5t_{c(SPC)M} + 0.5t_{c(LSPCLK)} + 10$ | ns   |
| 6   | $t_{d(SIMO)M}$ Delay time, SPISIMO valid to SPICLK               | $0.5t_{c(SPC)M} - 10$                  |                       | $0.5t_{c(SPC)M} + 0.5t_{c(LSPCLK)} - 10$ |                                          | ns   |
| 7   | $t_{v(SIMO)M}$ Valid time, SPISIMO valid after SPICLK            | $0.5t_{c(SPC)M} - 10$                  |                       | $0.5t_{c(SPC)M} - 0.5t_{c(LSPCLK)} - 10$ |                                          | ns   |
| 10  | $t_{su(SOMI)M}$ Setup time, SPISOMI before SPICLK                | 35                                     |                       | 35                                       |                                          | ns   |
| 11  | $t_{h(SOMI)M}$ Hold time, SPISOMI valid after SPICLK             | 0                                      |                       | 0                                        |                                          | ns   |
| 23  | $t_{d(SPC)M}$ Delay time, $\overline{SPISTE}$ active to SPICLK   | $2t_{c(SPC)M} - 3t_{c(SYSCLOCK)} - 10$ |                       | $2t_{c(SPC)M} - 3t_{c(SYSCLOCK)} - 10$   |                                          | ns   |
| 24  | $t_{d(STE)M}$ Delay time, SPICLK to $\overline{SPISTE}$ inactive | $0.5t_{c(SPC)} - 10$                   |                       | $0.5t_{c(SPC)} - 0.5t_{c(LSPCLK)} - 10$  |                                          | ns   |

- (1) The MASTER/S�AVE bit (SPICTL.2) is set and the CLOCK PHASE bit (SPICTL.3) is set.  
(2)  $t_{c(SPC)} = \text{SPI clock cycle time} = \text{LSPCLK}/4$  or  $\text{LSPCLK}/(\text{SPIBRR} + 1)$   
(3) Internal clock prescalers must be adjusted such that the SPI clock speed is limited to the following SPI clock rate:  
Master mode transmit 25 MHz MAX, master mode receive 12.5 MHz MAX  
Slave mode transmit 12.5 MHz MAX, slave mode receive 12.5 MHz MAX.  
(4)  $t_{c(LCO)} = \text{LSPCLK cycle time}$   
(5) The active edge of the SPICLK signal referenced is controlled by the CLOCK POLARITY bit (SPICCR.6).

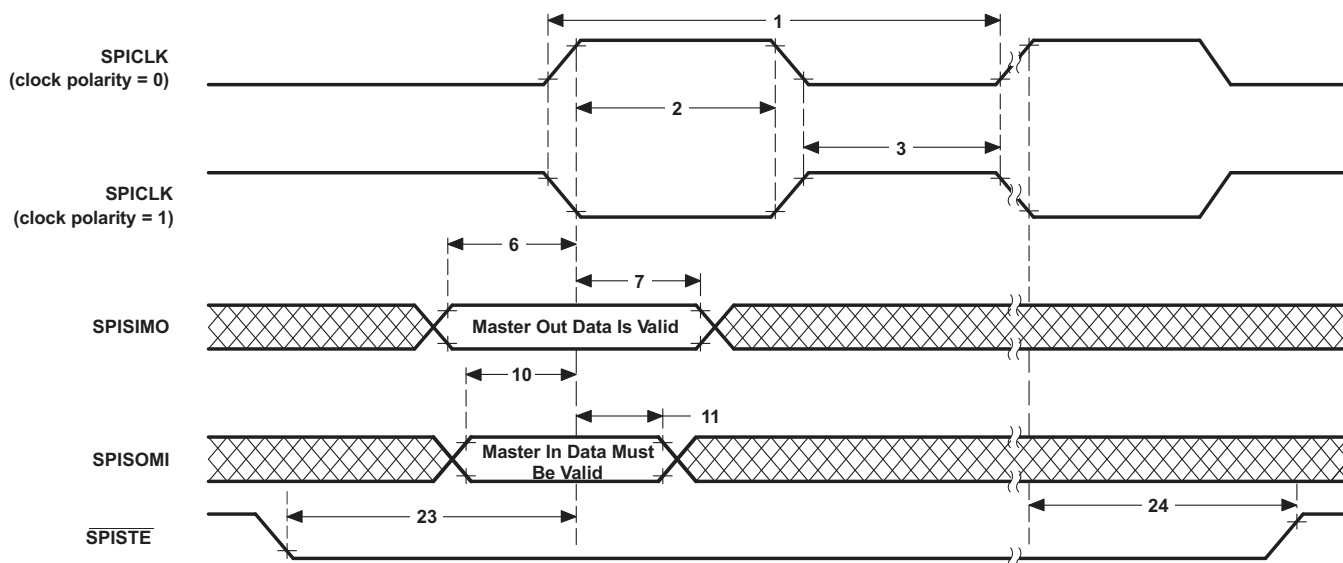


**Figure 5-18. SPI Master Mode External Timing (Clock Phase = 1)**

### 5.9.4.5.2 Slave Mode Timing

Table 5-33 lists the slave mode timing (clock phase = 0) and Table 5-34 lists the slave mode timing (clock phase = 1). Figure 5-19 and Figure 5-20 show the timing waveforms.

Table 5-33. SPI Slave Mode External Timing (Clock Phase = 0)<sup>(1)(2)(3)(4)(5)</sup>

| NO. | PARAMETER                                                           | MIN                  | MAX | UNIT |
|-----|---------------------------------------------------------------------|----------------------|-----|------|
| 12  | $t_{c(SPC)S}$ Cycle time, SPICLK                                    | $4t_{c(SYSCLK)}$     |     | ns   |
| 13  | $t_{w(SPC1)S}$ Pulse duration, SPICLK first pulse                   | $2t_{c(SYSCLK)} - 1$ |     | ns   |
| 14  | $t_{w(SPC2)S}$ Pulse duration, SPICLK second pulse                  | $2t_{c(SYSCLK)} - 1$ |     | ns   |
| 15  | $t_{d(SOMI)S}$ Delay time, SPICLK to SPISOMI valid                  |                      | 35  | ns   |
| 16  | $t_{v(SOMI)S}$ Valid time, SPISOMI data valid after SPICLK          | 0                    |     | ns   |
| 19  | $t_{su(SIMO)S}$ Setup time, SPISIMO valid before SPICLK             | $1.5t_{c(SYSCLK)}$   |     | ns   |
| 20  | $t_{h(SIMO)S}$ Hold time, SPISIMO data valid after SPICLK           | $1.5t_{c(SYSCLK)}$   |     | ns   |
| 25  | $t_{su(STE)S}$ Setup time, $\overline{SPISTE}$ active before SPICLK | $1.5t_{c(SYSCLK)}$   |     | ns   |
| 26  | $t_{h(STE)S}$ Hold time, $\overline{SPISTE}$ inactive after SPICLK  | $1.5t_{c(SYSCLK)}$   |     | ns   |

- (1) The MASTER / SLAVE bit (SPICTL.2) is cleared and the CLOCK PHASE bit (SPICTL.3) is cleared.
- (2)  $t_{c(SPC)} = \text{SPI clock cycle time} = \text{LSPCLK}/4$  or  $\text{LSPCLK}/(\text{SPIBRR} + 1)$
- (3) Internal clock prescalers must be adjusted such that the SPI clock speed is limited to the following SPI clock rate:  
Master mode transmit 25-MHz MAX, master mode receive 12.5-MHz MAX  
Slave mode transmit 12.5-MHz MAX, slave mode receive 12.5-MHz MAX.
- (4)  $t_{c(LCO)} = \text{LSPCLK cycle time}$
- (5) The active edge of the SPICLK signal referenced is controlled by the CLOCK POLARITY bit (SPICCR.6).

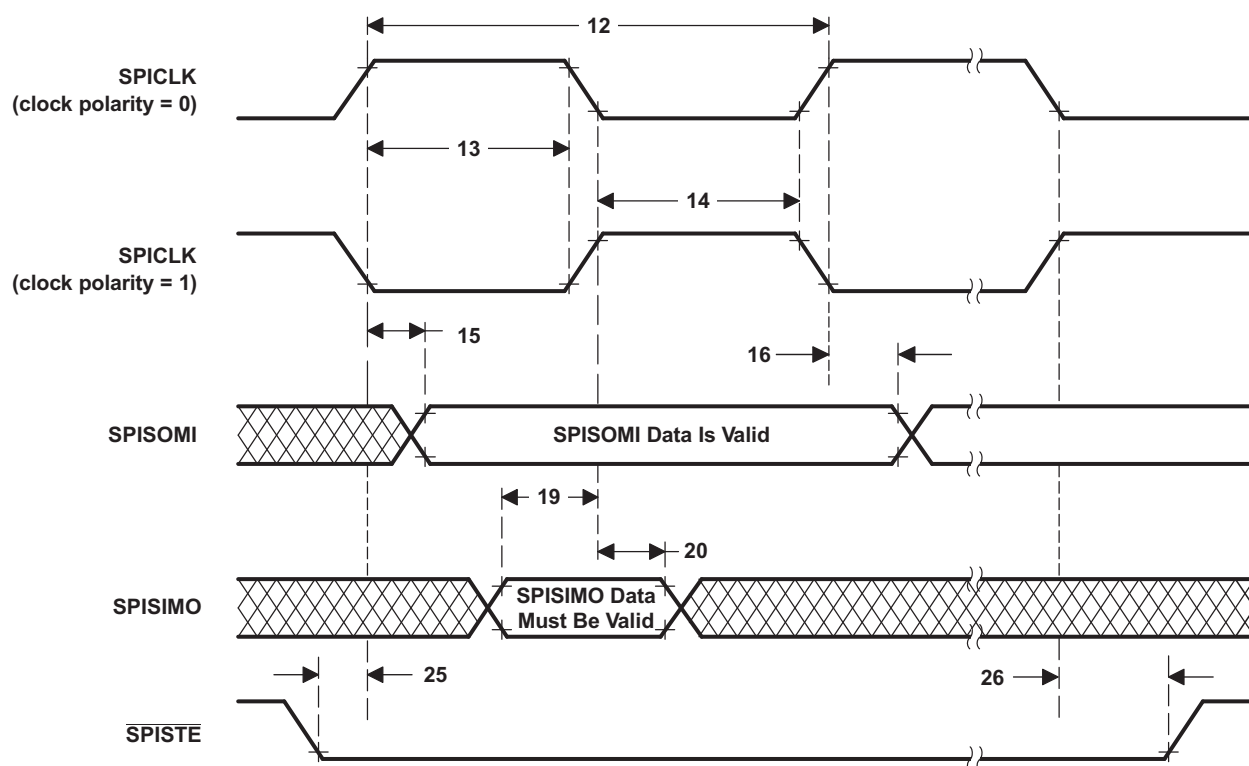
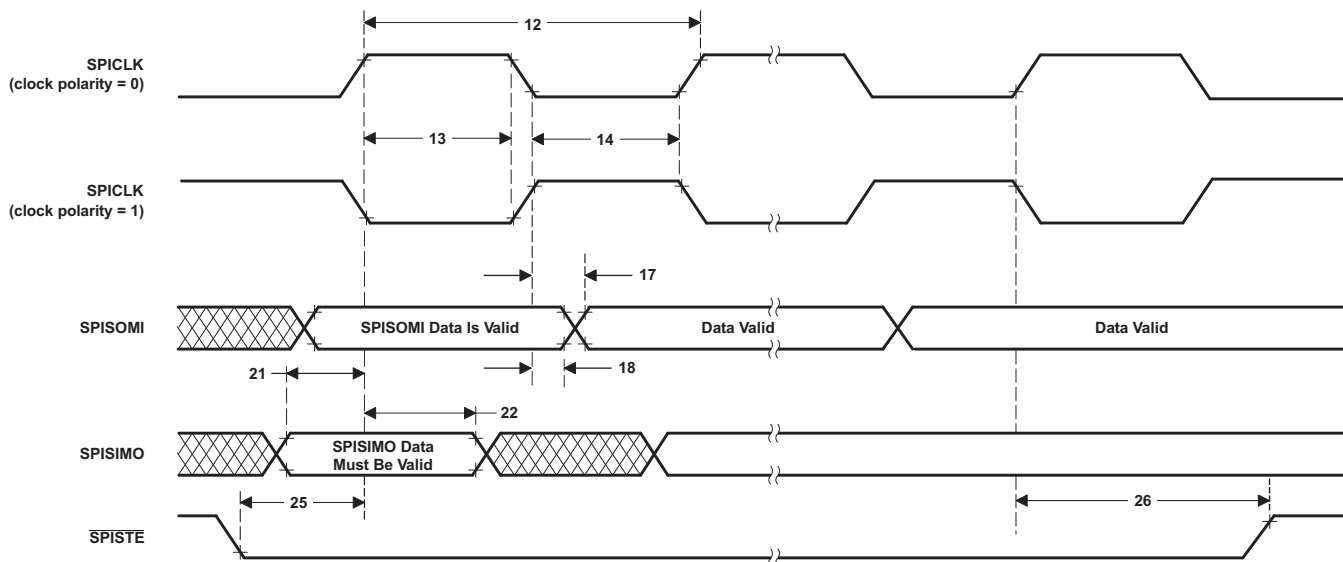


Figure 5-19. SPI Slave Mode External Timing (Clock Phase = 0)

**Table 5-34. SPI Slave Mode External Timing (Clock Phase = 1)<sup>(1)(2)(3)(4)</sup>**

| NO. | PARAMETER       |                                                      | MIN                  | MAX | UNIT |
|-----|-----------------|------------------------------------------------------|----------------------|-----|------|
| 12  | $t_{c(SPC)S}$   | Cycle time, SPICLK                                   | $4t_{c(SYSCLK)}$     |     | ns   |
| 13  | $t_{w(SPC1)S}$  | Pulse duration, SPICLK first pulse                   | $2t_{c(SYSCLK)} - 1$ |     | ns   |
| 14  | $t_{w(SPC2)S}$  | Pulse duration, SPICLK second pulse                  | $2t_{c(SYSCLK)} - 1$ |     | ns   |
| 17  | $t_{d(SOMI)S}$  | Delay time, SPICLK to SPISOMI valid                  |                      | 35  | ns   |
| 18  | $t_{v(SOMI)S}$  | Valid time, SPISOMI data valid after SPICLK          | 0                    |     | ns   |
| 21  | $t_{su(SIMO)S}$ | Setup time, SPISIMO valid before SPICLK              | $1.5t_{c(SYSCLK)}$   |     | ns   |
| 22  | $t_{h(SIMO)S}$  | Hold time, SPISIMO data valid after SPICLK           | $1.5t_{c(SYSCLK)}$   |     | ns   |
| 25  | $t_{su(STE)S}$  | Setup time, $\overline{SPISTE}$ active before SPICLK | $1.5t_{c(SYSCLK)}$   |     | ns   |
| 26  | $t_{h(STE)S}$   | Hold time, $\overline{SPISTE}$ inactive after SPICLK | $1.5t_{c(SYSCLK)}$   |     | ns   |

- (1) The MASTER / SLAVE bit (SPICTL.2) is cleared and the CLOCK PHASE bit (SPICTL.3) is cleared.  
(2)  $t_{c(SPC)} = \text{SPI clock cycle time} = \text{LSPCLK}/4$  or  $\text{LSPCLK}/(\text{SPIBRR} + 1)$   
(3) Internal clock prescalers must be adjusted such that the SPI clock speed is limited to the following SPI clock rate:  
Master mode transmit 25-MHz MAX, master mode receive 12.5-MHz MAX  
Slave mode transmit 12.5-MHz MAX, slave mode receive 12.5-MHz MAX.  
(4) The active edge of the SPICLK signal referenced by the CLOCK POLARITY bit (SPICCR.6).


**Figure 5-20. SPI Slave Mode External Timing (Clock Phase = 1)**

## 5.9.4.6 Multichannel Buffered Serial Port (McBSP) Timing

### 5.9.4.6.1 McBSP Transmit and Receive Timing

**Table 5-35. McBSP Timing Requirements<sup>(1) (2)</sup>**

| NO. |                                                  |                                               |            | MIN   | MAX               | UNIT |
|-----|--------------------------------------------------|-----------------------------------------------|------------|-------|-------------------|------|
|     | McBSP module clock (CLKG, CLKX, CLKR) range      |                                               |            | 1     |                   | kHz  |
|     |                                                  |                                               |            |       | 25 <sup>(3)</sup> | MHz  |
|     | McBSP module cycle time (CLKG, CLKX, CLKR) range |                                               |            | 40    |                   | ns   |
|     |                                                  |                                               |            |       | 1                 | ms   |
| M11 | $t_{c(CKRX)}$                                    | Cycle time, CLKR/X                            | CLKR/X ext | 2P    |                   | ns   |
| M12 | $t_{w(CKRX)}$                                    | Pulse duration, CLKR/X high or CLKR/X low     | CLKR/X ext | P – 7 |                   | ns   |
| M13 | $t_{r(CKRX)}$                                    | Rise time, CLKR/X                             | CLKR/X ext |       | 7                 | ns   |
| M14 | $t_{f(CKRX)}$                                    | Fall time, CLKR/X                             | CLKR/X ext |       | 7                 | ns   |
| M15 | $t_{su(FRH-CKRL)}$                               | Setup time, external FSR high before CLKR low | CLKR int   | 18    |                   | ns   |
|     |                                                  |                                               | CLKR ext   | 2     |                   |      |
| M16 | $t_{h(CKRL-FRH)}$                                | Hold time, external FSR high after CLKR low   | CLKR int   | 0     |                   | ns   |
|     |                                                  |                                               | CLKR ext   | 6     |                   |      |
| M17 | $t_{su(DRV-CKRL)}$                               | Setup time, DR valid before CLKR low          | CLKR int   | 18    |                   | ns   |
|     |                                                  |                                               | CLKR ext   | 2     |                   |      |
| M18 | $t_{h(CKRL-DRV)}$                                | Hold time, DR valid after CLKR low            | CLKR int   | 0     |                   | ns   |
|     |                                                  |                                               | CLKR ext   | 6     |                   |      |
| M19 | $t_{su(FXH-CKXL)}$                               | Setup time, external FSX high before CLKX low | CLKX int   | 18    |                   | ns   |
|     |                                                  |                                               | CLKX ext   | 2     |                   |      |
| M20 | $t_{h(CKXL-FXH)}$                                | Hold time, external FSX high after CLKX low   | CLKX int   | 0     |                   | ns   |
|     |                                                  |                                               | CLKX ext   | 6     |                   |      |

(1) Polarity bits CLKRP = CLKXP = FSRP = FSXP = 0. If the polarity of any of the signals is inverted, then the timing references of that signal are also inverted.

- (2)  $2P = 1/CLKG$  in ns. CLKG is the output of sample rate generator mux.  $CLKG = \frac{CLKSRG}{(1 + CLKGDV)}$  CLKS RG can be LSPCLK, CLKX, CLKR as source.  $CLKSRG \leq (SYSCLKOUT/2)$ . McBSP performance is limited by I/O buffer switching speed.
- (3) Internal clock prescalers must be adjusted such that the McBSP clock (CLKG, CLKX, CLKR) speeds are not greater than the I/O buffer speed limit (25 MHz).

**Table 5-36. McBSP Switching Characteristics<sup>(1) (2)</sup>**

| NO. | PARAMETER            |                                                                                            |            | MIN                  | MAX                  | UNIT |
|-----|----------------------|--------------------------------------------------------------------------------------------|------------|----------------------|----------------------|------|
| M1  | $t_{c(CKRX)}$        | Cycle time, CLKR/X                                                                         | CLKR/X int | 2P                   |                      | ns   |
| M2  | $t_{w(CKRXH)}$       | Pulse duration, CLKR/X high                                                                | CLKR/X int | D – 5 <sup>(3)</sup> | D + 5 <sup>(3)</sup> | ns   |
| M3  | $t_{w(CKRXL)}$       | Pulse duration, CLKR/X low                                                                 | CLKR/X int | C – 5 <sup>(3)</sup> | C + 5 <sup>(3)</sup> | ns   |
| M4  | $t_{d(CKRH-FRV)}$    | Delay time, CLKR high to internal FSR valid                                                | CLKR int   | 0                    | 4                    | ns   |
|     |                      |                                                                                            | CLKR ext   | 3                    | 27                   |      |
| M5  | $t_{d(CKXH-FXV)}$    | Delay time, CLKX high to internal FSX valid                                                | CLKX int   | 0                    | 4                    | ns   |
|     |                      |                                                                                            | CLKX ext   | 3                    | 27                   |      |
| M6  | $t_{dis(CKXH-DXHZ)}$ | Disable time, CLKX high to DX high impedance following last data bit                       | CLKX int   |                      | 8                    | ns   |
|     |                      |                                                                                            | CLKX ext   |                      | 14                   |      |
| M7  | $t_{d(CKXH-DXV)}$    | Delay time, CLKX high to DX valid.                                                         | CLKX int   |                      | 9                    | ns   |
|     |                      | This applies to all bits except the first bit transmitted.                                 | CLKX ext   |                      | 28                   |      |
|     |                      | Delay time, CLKX high to DX valid                                                          | DXENA = 0  | CLKX int             | 8                    |      |
|     |                      |                                                                                            |            | CLKX ext             | 14                   |      |
|     |                      | Only applies to first bit transmitted when in Data Delay 1 or 2 (XDATDLY=01b or 10b) modes | DXENA = 1  | CLKX int             | P + 8                |      |
|     |                      |                                                                                            |            | CLKX ext             | P + 14               |      |
| M8  | $t_{en(CKXH-DX)}$    | Enable time, CLKX high to DX driven                                                        | DXENA = 0  | CLKX int             | 0                    | ns   |
|     |                      |                                                                                            |            | CLKX ext             | 6                    |      |
|     |                      | Only applies to first bit transmitted when in Data Delay 1 or 2 (XDATDLY=01b or 10b) modes | DXENA = 1  | CLKX int             | P                    |      |
|     |                      |                                                                                            |            | CLKX ext             | P + 6                |      |
| M9  | $t_{d(FXH-DXV)}$     | Delay time, FSX high to DX valid                                                           | DXENA = 0  | FSX int              | 8                    | ns   |
|     |                      |                                                                                            |            | FSX ext              | 14                   |      |
|     |                      | Only applies to first bit transmitted when in Data Delay 0 (XDATDLY=00b) mode.             | DXENA = 1  | FSX int              | P + 8                |      |
|     |                      |                                                                                            |            | FSX ext              | P + 14               |      |
| M10 | $t_{en(FXH-DX)}$     | Enable time, FSX high to DX driven                                                         | DXENA = 0  | FSX int              | 0                    | ns   |
|     |                      |                                                                                            |            | FSX ext              | 6                    |      |
|     |                      | Only applies to first bit transmitted when in Data Delay 0 (XDATDLY=00b) mode              | DXENA = 1  | FSX int              | P                    |      |
|     |                      |                                                                                            |            | FSX ext              | P + 6                |      |

(1) Polarity bits CLKRP = CLKXP = FSRP = FSXP = 0. If the polarity of any of the signals is inverted, then the timing references of that signal are also inverted.

(2) 2P = 1/CLKG in ns.

(3) C = CLKRX low pulse width = P

D = CLKRX high pulse width = P

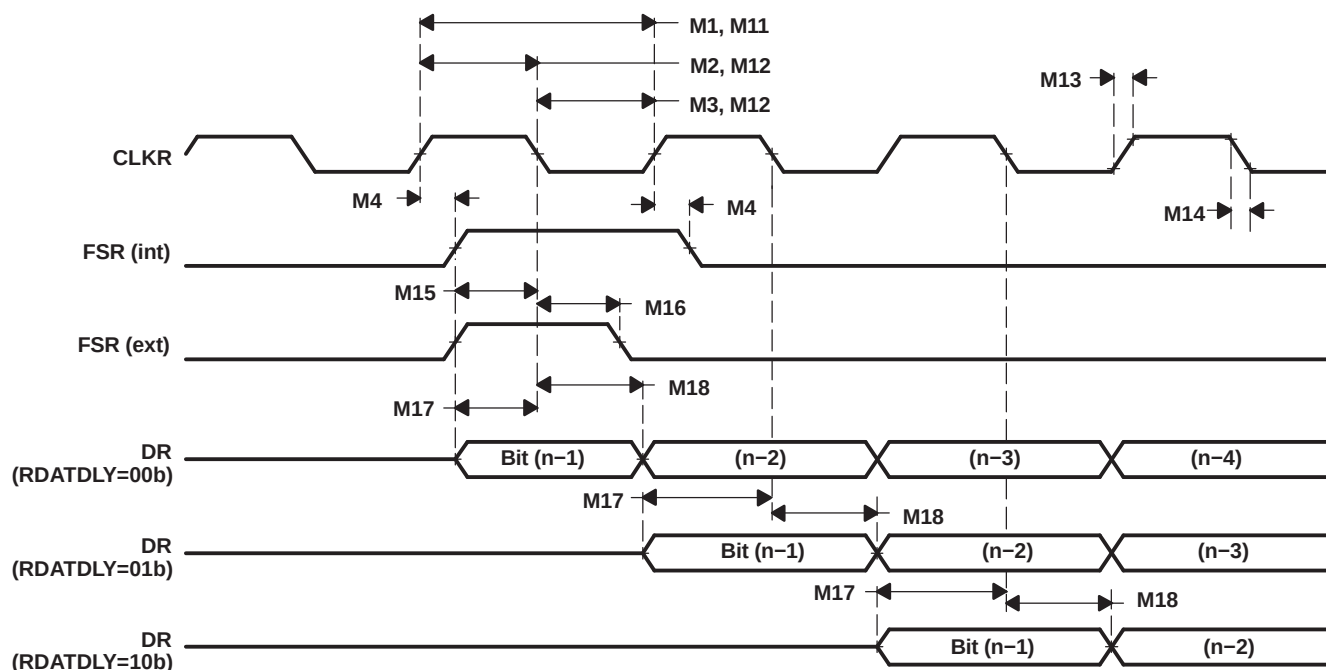


Figure 5-21. McBSP Receive Timing

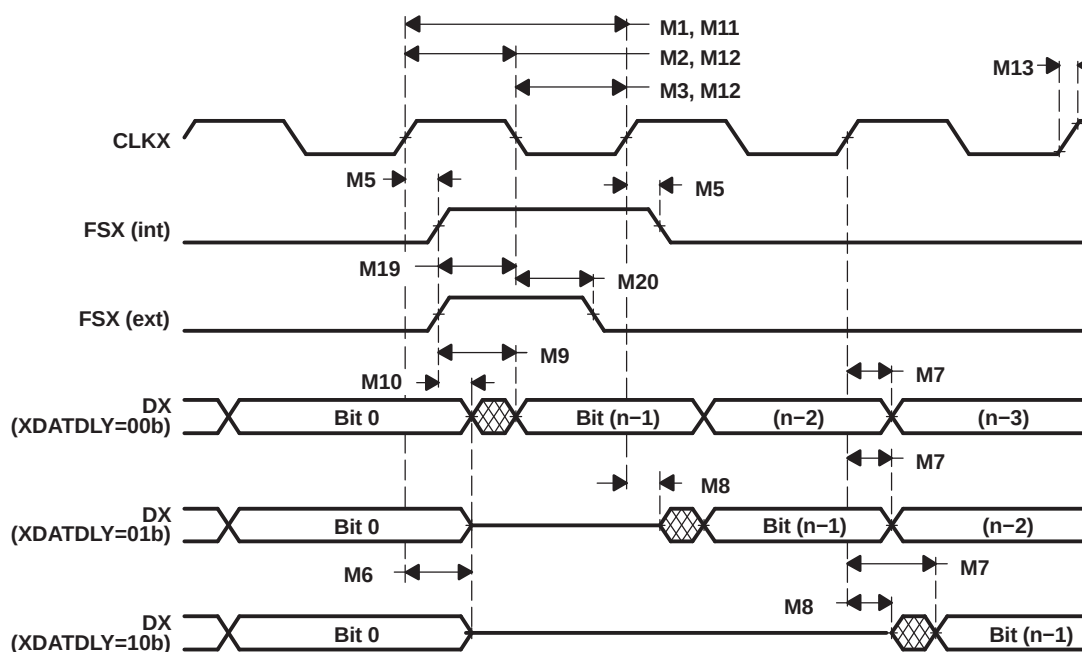


Figure 5-22. McBSP Transmit Timing

#### 5.9.4.6.2 McBSP as SPI Master or Slave Timing

**Table 5-37. McBSP as SPI Master or Slave Timing Requirements (CLKSTP = 10b, CLKXP = 0)<sup>(1)</sup>**

| NO. |                     |                                      | MASTER            |     | SLAVE   |     | UNIT |
|-----|---------------------|--------------------------------------|-------------------|-----|---------|-----|------|
|     |                     |                                      | MIN               | MAX | MIN     | MAX |      |
| M30 | $t_{su}(DRV-CKXL)$  | Setup time, DR valid before CLKX low | 30                |     | 8P – 10 |     | ns   |
| M31 | $t_h(CKXL-DRV)$     | Hold time, DR valid after CLKX low   | 1                 |     | 8P – 10 |     | ns   |
| M32 | $t_{su}(BFXL-CKXH)$ | Setup time, FSX low before CLKX high |                   |     | 8P + 10 |     | ns   |
| M33 | $t_c(CKX)$          | Cycle timez, CLKX                    | 2P <sup>(2)</sup> |     | 16P     |     | ns   |

(1) For all SPI slave modes, CLKX must be a minimum of 8 CLKG cycles. Furthermore, CLKG should be LSPCLK/2 by setting CLKSM = CLKGDV = 1.

(2) 2P = 1/CLKG

**Table 5-38. McBSP as SPI Master or Slave Switching Characteristics (CLKSTP = 10b, CLKXP = 0)**

| NO. | PARAMETER           |                                                                       | MASTER            |     | SLAVE  |     | UNIT |
|-----|---------------------|-----------------------------------------------------------------------|-------------------|-----|--------|-----|------|
|     |                     |                                                                       | MIN               | MAX | MIN    | MAX |      |
| M24 | $t_h(CKXL-FXL)$     | Hold time, FSX low after CLKX low                                     | 2P <sup>(1)</sup> |     |        |     | ns   |
| M25 | $t_d(FXL-CKXH)$     | Delay time, FSX low to CLKX high                                      | P                 |     |        |     | ns   |
| M28 | $t_{dis}(FXH-DXHZ)$ | Disable time, DX high impedance following last data bit from FSX high | 6                 |     | 6P + 6 |     | ns   |
| M29 | $t_d(FXL-DXV)$      | Delay time, FSX low to DX valid                                       | 6                 |     | 4P + 6 |     | ns   |

(1) 2P = 1/CLKG

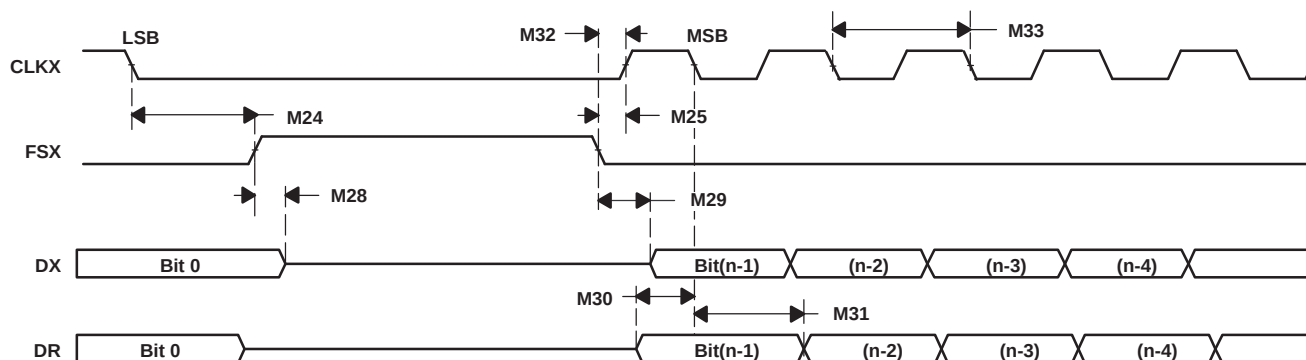


**Figure 5-23. McBSP Timing as SPI Master or Slave: CLKSTP = 10b, CLKXP = 0**

**Table 5-39. McBSP as SPI Master or Slave Timing Requirements (CLKSTP = 11b, CLKXP = 0)<sup>(1)</sup>**

| NO. |                    |                                       | MASTER            |     | SLAVE    |     | UNIT |
|-----|--------------------|---------------------------------------|-------------------|-----|----------|-----|------|
|     |                    |                                       | MIN               | MAX | MIN      | MAX |      |
| M39 | $t_{su}(DRV-CKXH)$ | Setup time, DR valid before CLKX high | 30                |     | 8P – 10  |     | ns   |
| M40 | $t_h(CKXH-DRV)$    | Hold time, DR valid after CLKX high   | 1                 |     | 8P – 10  |     | ns   |
| M41 | $t_{su}(FXL-CKXH)$ | Setup time, FSX low before CLKX high  |                   |     | 16P + 10 |     | ns   |
| M42 | $t_c(CKX)$         | Cycle time, CLKX                      | 2P <sup>(2)</sup> |     | 16P      |     | ns   |

(1) For all SPI slave modes, CLKX must be a minimum of 8 CLKG cycles. Furthermore, CLKG should be LSPCLK/2 by setting CLKSM = CLKGDV = 1.

(2) 2P = 1/CLKG

**Table 5-40. McBSP as SPI Master or Slave Switching Characteristics (CLKSTP = 11b, CLKXP = 0)**

| NO. | PARAMETER            |                                                                       | MASTER            |     | SLAVE  |     | UNIT |
|-----|----------------------|-----------------------------------------------------------------------|-------------------|-----|--------|-----|------|
|     |                      |                                                                       | MIN               | MAX | MIN    | MAX |      |
| M34 | $t_h(CKXL-FXL)$      | Hold time, FSX low after CLKX low                                     | P                 |     |        |     | ns   |
| M35 | $t_d(FXL-CKXH)$      | Delay time, FSX low to CLKX high                                      | 2P <sup>(1)</sup> |     |        |     | ns   |
| M37 | $t_{dis}(CKXL-DXHZ)$ | Disable time, DX high impedance following last data bit from CLKX low | P + 6             |     | 7P + 6 |     | ns   |
| M38 | $t_d(FXL-DXV)$       | Delay time, FSX low to DX valid                                       | 6                 |     | 4P + 6 |     | ns   |

(1) 2P = 1/CLKG

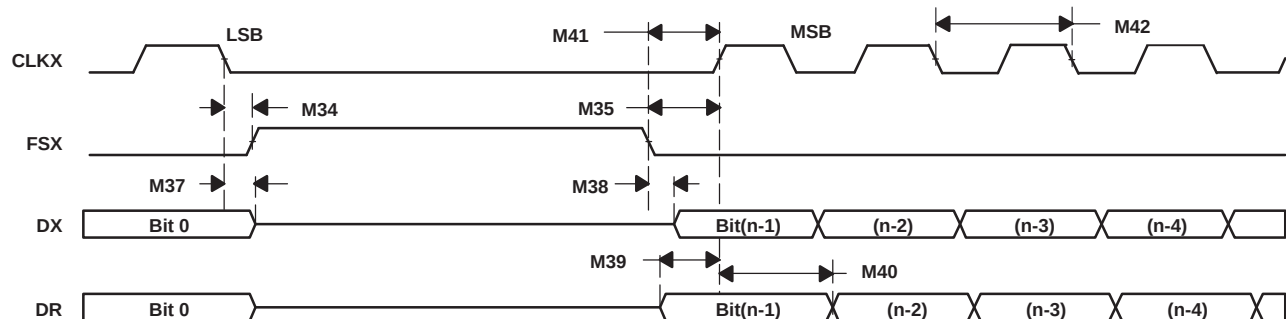


**Figure 5-24. McBSP Timing as SPI Master or Slave: CLKSTP = 11b, CLKXP = 0**

**Table 5-41. McBSP as SPI Master or Slave Timing Requirements (CLKSTP = 10b, CLKXP = 1)<sup>(1)</sup>**

| NO. |                    |                                       | MASTER            |     | SLAVE   |     | UNIT |
|-----|--------------------|---------------------------------------|-------------------|-----|---------|-----|------|
|     |                    |                                       | MIN               | MAX | MIN     | MAX |      |
| M49 | $t_{su}(DRV-CKXH)$ | Setup time, DR valid before CLKX high | 30                |     | 8P – 10 |     | ns   |
| M50 | $t_h(CKXH-DRV)$    | Hold time, DR valid after CLKX high   | 1                 |     | 8P – 10 |     | ns   |
| M51 | $t_{su}(FXL-CKXL)$ | Setup time, FSX low before CLKX low   |                   |     | 8P + 10 |     | ns   |
| M52 | $t_c(CKX)$         | Cycle time, CLKX                      | 2P <sup>(2)</sup> |     | 16P     |     | ns   |

(1) For all SPI slave modes, CLKX must be a minimum of 8 CLKG cycles. Furthermore, CLKG should be LSPCLK/2 by setting CLKSM = CLKGDV = 1.

(2) 2P = 1/CLKG

**Table 5-42. McBSP as SPI Master or Slave Switching Characteristics (CLKSTP = 10b, CLKXP = 1)**

| NO. | PARAMETER           | MASTER                                                                |                   | SLAVE  |     | UNIT |
|-----|---------------------|-----------------------------------------------------------------------|-------------------|--------|-----|------|
|     |                     | MIN                                                                   | MAX               | MIN    | MAX |      |
| M43 | $t_h(CKXH-FXL)$     | Hold time, FSX low after CLKX high                                    | 2P <sup>(1)</sup> |        |     | ns   |
| M44 | $t_d(FXL-CKXL)$     | Delay time, FSX low to CLKX low                                       | P                 |        |     | ns   |
| M47 | $t_{dis}(FXH-DXHZ)$ | Disable time, DX high impedance following last data bit from FSX high | 6                 | 6P + 6 |     | ns   |
| M48 | $t_d(FXL-DXV)$      | Delay time, FSX low to DX valid                                       | 6                 | 4P + 6 |     | ns   |

(1) 2P = 1/CLKG

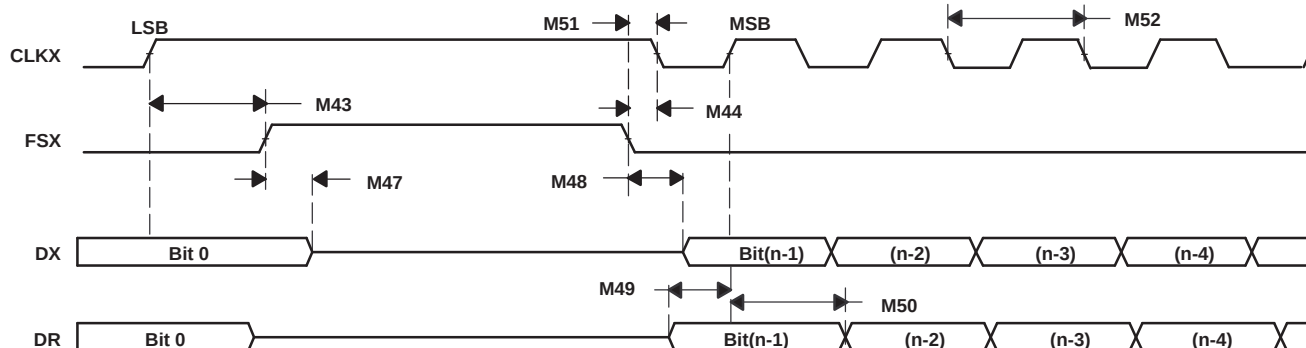


**Figure 5-25. McBSP Timing as SPI Master or Slave: CLKSTP = 10b, CLKXP = 1**

**Table 5-43. McBSP as SPI Master or Slave Timing Requirements (CLKSTP = 11b, CLKXP = 1)<sup>(1)</sup>**

| NO. |                    |                                      | MASTER            |     | SLAVE    |     | UNIT |
|-----|--------------------|--------------------------------------|-------------------|-----|----------|-----|------|
|     |                    |                                      | MIN               | MAX | MIN      | MAX |      |
| M58 | $t_{su(DRV-CKXL)}$ | Setup time, DR valid before CLKX low | 30                |     | 8P – 10  |     | ns   |
| M59 | $t_h(CKXL-DRV)$    | Hold time, DR valid after CLKX low   | 1                 |     | 8P – 10  |     | ns   |
| M60 | $t_{su(FXL-CKXL)}$ | Setup time, FSX low before CLKX low  |                   |     | 16P + 10 |     | ns   |
| M61 | $t_c(CKX)$         | Cycle time, CLKX                     | 2P <sup>(2)</sup> |     | 16P      |     | ns   |

(1) For all SPI slave modes, CLKX must be a minimum of 8 CLKG cycles. Furthermore, CLKG should be LSPCLK/2 by setting CLKSM = CLKGDV = 1.

(2) 2P = 1/CLKG

**Table 5-44. McBSP as SPI Master or Slave Switching Characteristics (CLKSTP = 11b, CLKXP = 1)<sup>(1)</sup>**

| NO. | PARAMETER            |                                                                        | MASTER <sup>(2)</sup> |     | SLAVE  |         | UNIT |
|-----|----------------------|------------------------------------------------------------------------|-----------------------|-----|--------|---------|------|
|     |                      |                                                                        | MIN                   | MAX | MIN    | MAX     |      |
| M53 | $t_h(CKXH-FXL)$      | Hold time, FSX low after CLKX high                                     | P                     |     |        |         | ns   |
| M54 | $t_d(FXL-CKXL)$      | Delay time, FSX low to CLKX low                                        | 2P <sup>(1)</sup>     |     |        |         | ns   |
| M55 | $t_d(CLKXH-DXV)$     | Delay time, CLKX high to DX valid                                      | –2                    | 0   | 3P + 6 | 5P + 20 | ns   |
| M56 | $t_{dis}(CKXH-DXHZ)$ | Disable time, DX high impedance following last data bit from CLKX high | P + 6                 |     | 7P + 6 |         | ns   |
| M57 | $t_d(FXL-DXV)$       | Delay time, FSX low to DX valid                                        | 6                     |     | 4P + 6 |         | ns   |

(1) 2P = 1/CLKG

(2) C = CLKX low pulse width = P

D = CLKX high pulse width = P

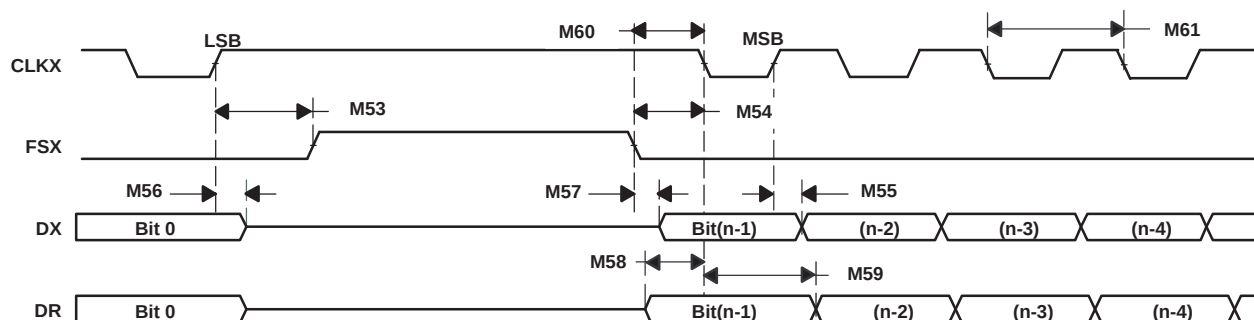


**Figure 5-26. McBSP Timing as SPI Master or Slave: CLKSTP = 11b, CLKXP = 1**

### 5.9.5 Emulator Connection Without Signal Buffering for the DSP

Figure 5-27 shows the connection between the DSP and JTAG header for a single-processor configuration. If the distance between the JTAG header and the DSP is greater than 6 inches, the emulation signals must be buffered. If the distance is less than 6 inches, buffering is typically not needed. Figure 5-27 shows the simpler, no-buffering situation. For the pullup/pulldown resistor values, see the pin description section. For details on buffering JTAG signals and multiple processor connections, see the [TMS320F/C24x DSP controllers CPU and instruction set reference guide](#).

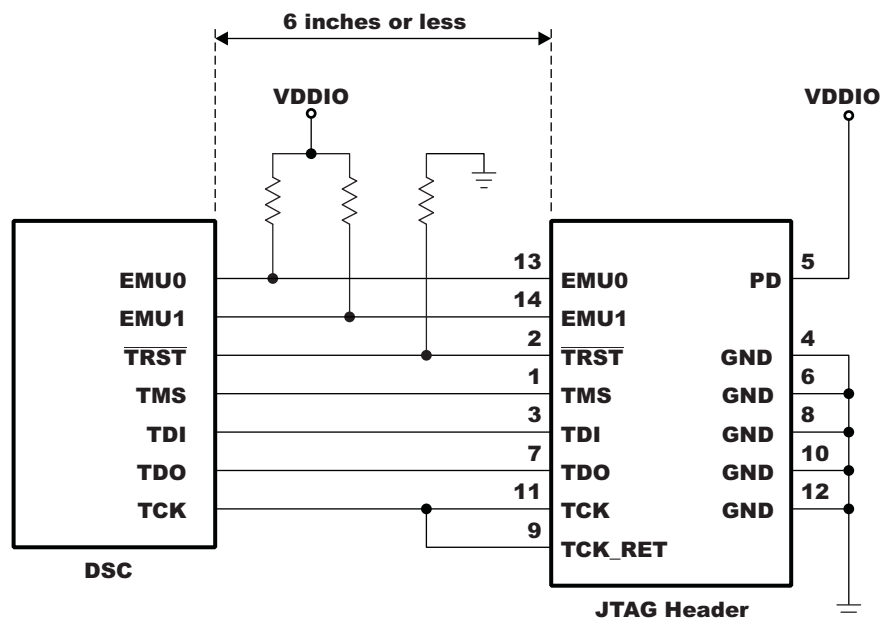


Figure 5-27. Emulator Connection Without Signal Buffering for the DSP

## 5.9.6 External Interface (XINTF) Timing

Each XINTF access consists of three parts: Lead, Active, and Trail. The user configures the Lead/Active/Trail wait states in the XTIMING registers. There is one XTIMING register for each XINTF zone. Table 5-45 shows the relationship between the parameters configured in the XTIMING register and the duration of the pulse in terms of XTIMCLK cycles.

**Table 5-45. Relationship Between Parameters Configured in XTIMING and Duration of Pulse**

| DESCRIPTION                    | DURATION (ns) <sup>(1)</sup> <sup>(2)</sup> |                                                    |
|--------------------------------|---------------------------------------------|----------------------------------------------------|
|                                | X2TIMING = 0                                | X2TIMING = 1                                       |
| LR Lead period, read access    | $XRDLEAD \times t_{c(XTIM)}$                | $(XRDLEAD \times 2) \times t_{c(XTIM)}$            |
| AR Active period, read access  | $(XRDACTIVE + WS + 1) \times t_{c(XTIM)}$   | $(XRDACTIVE \times 2 + WS + 1) \times t_{c(XTIM)}$ |
| TR Trail period, read access   | $XRDTRAIL \times t_{c(XTIM)}$               | $(XRDTRAIL \times 2) \times t_{c(XTIM)}$           |
| LW Lead period, write access   | $XWRLEAD \times t_{c(XTIM)}$                | $(XWRLEAD \times 2) \times t_{c(XTIM)}$            |
| AW Active period, write access | $(XWRACTIVE + WS + 1) \times t_{c(XTIM)}$   | $(XWRACTIVE \times 2 + WS + 1) \times t_{c(XTIM)}$ |
| TW Trail period, write access  | $XWRTRAIL \times t_{c(XTIM)}$               | $(XWRTRAIL \times 2) \times t_{c(XTIM)}$           |

(1)  $t_{c(XTIM)}$  – Cycle time, XTIMCLK

(2) WS refers to the number of wait states inserted by hardware when using XREADY. If the zone is configured to ignore XREADY (USEREADY = 0), then WS = 0.

Minimum wait-state requirements must be met when configuring each zone's XTIMING register. These requirements are in addition to any timing requirements as specified by that device's data sheet. No internal device hardware is included to detect illegal settings.

### 5.9.6.1 USEREADY = 0

If the XREADY signal is ignored (USEREADY = 0), then:

Lead:  $LR \geq t_{c(XTIM)}$

$LW \geq t_{c(XTIM)}$

These requirements result in the following XTIMING register configuration restrictions:

| XRDLEAD  | XRDACTIVE | XRDTRAIL | XWRLEAD  | XWRACTIVE | XWRTRAIL | X2TIMING |
|----------|-----------|----------|----------|-----------|----------|----------|
| $\geq 1$ | $\geq 0$  | $\geq 0$ | $\geq 1$ | $\geq 0$  | $\geq 0$ | 0, 1     |

Examples of valid and invalid timing when not sampling XREADY:

|                        | XRDLEAD | XRDACTIVE | XRDTRAIL | XWRLEAD | XWRACTIVE | XWRTRAIL | X2TIMING |
|------------------------|---------|-----------|----------|---------|-----------|----------|----------|
| Invalid <sup>(1)</sup> | 0       | 0         | 0        | 0       | 0         | 0        | 0, 1     |
| Valid                  | 1       | 0         | 0        | 1       | 0         | 0        | 0, 1     |

(1) No hardware to detect illegal XTIMING configurations

### 5.9.6.2 Synchronous Mode (USEREADY = 1, READYMODE = 0)

If the XREADY signal is sampled in the synchronous mode (USEREADY = 1, READYMODE = 0), then:

- 1 Lead:  $LR \geq t_{c(XTIM)}$   
 $LW \geq t_{c(XTIM)}$
- 2 Active:  $AR \geq 2 \times t_{c(XTIM)}$   
 $AW \geq 2 \times t_{c(XTIM)}$

#### NOTE

Restriction does not include external hardware wait states.

These requirements result in the following XTIMING register configuration restrictions:

| XRDLEAD  | XRDACTIVE | XRDTRAIL | XWRLEAD  | XWRACTIVE | XWRTRAIL | X2TIMING |
|----------|-----------|----------|----------|-----------|----------|----------|
| $\geq 1$ | $\geq 2$  | $\geq 0$ | $\geq 1$ | $\geq 2$  | $\geq 0$ | 0, 1     |

Examples of valid and invalid timing when using synchronous XREADY:

|                        | XRDLEAD | XRDACTIVE | XRDTRAIL | XWRLEAD | XWRACTIVE | XWRTRAIL | X2TIMING |
|------------------------|---------|-----------|----------|---------|-----------|----------|----------|
| Invalid <sup>(1)</sup> | 0       | 0         | 0        | 0       | 0         | 0        | 0, 1     |
| Invalid <sup>(1)</sup> | 1       | 0         | 0        | 1       | 0         | 0        | 0, 1     |
| Valid                  | 1       | 2         | 0        | 1       | 2         | 0        | 0, 1     |

(1) No hardware to detect illegal XTIMING configurations

### 5.9.6.3 Asynchronous Mode (USEREADY = 1, READYMODE = 1)

If the XREADY signal is sampled in the asynchronous mode (USEREADY = 1, READYMODE = 1), then:

- 1 Lead:  $LR \geq t_{c(XTIM)}$   
 $LW \geq t_{c(XTIM)}$
- 2 Active:  $AR \geq 2 \times t_{c(XTIM)}$   
 $AW \geq 2 \times t_{c(XTIM)}$
- 3 Lead + Active:  $LR + AR \geq 4 \times t_{c(XTIM)}$   
 $LW + AW \geq 4 \times t_{c(XTIM)}$

#### NOTE

Restrictions do not include external hardware wait states.

These requirements result in the following XTIMING register configuration restrictions:

| XRDLEAD  | XRDACTIVE | XRDTRAIL | XWRLEAD  | XWRACTIVE | XWRTRAIL | X2TIMING |
|----------|-----------|----------|----------|-----------|----------|----------|
| $\geq 1$ | $\geq 2$  | 0        | $\geq 1$ | $\geq 2$  | 0        | 0, 1     |

or

| XRDLEAD  | XRDACTIVE | XRDTRAIL | XWRLEAD  | XWRACTIVE | XWRTRAIL | X2TIMING |
|----------|-----------|----------|----------|-----------|----------|----------|
| $\geq 2$ | $\geq 1$  | 0        | $\geq 2$ | $\geq 1$  | 0        | 0, 1     |

Examples of valid and invalid timing when using asynchronous XREADY:

|                        | XRDLEAD | XRDACTIVE | XRDTRAIL | XWRLEAD | XWRACTIVE | XWRTRAIL | X2TIMING |
|------------------------|---------|-----------|----------|---------|-----------|----------|----------|
| Invalid <sup>(1)</sup> | 0       | 0         | 0        | 0       | 0         | 0        | 0, 1     |
| Invalid <sup>(1)</sup> | 1       | 0         | 0        | 1       | 0         | 0        | 0, 1     |
| Invalid <sup>(1)</sup> | 1       | 1         | 0        | 1       | 1         | 0        | 0        |
| Valid                  | 1       | 2         | 0        | 1       | 2         | 0        | 1        |
| Valid                  | 1       | 2         | 0        | 1       | 2         | 0        | 0, 1     |
| Valid                  | 2       | 1         | 0        | 2       | 1         | 0        | 0, 1     |

(1) No hardware to detect illegal XTIMING configurations

Unless otherwise specified, all XINTF timing is applicable for the clock configurations listed in [Table 5-46](#).

**Table 5-46. XINTF Clock Configurations**

| MODE          | SYCLKOUT | XTIMCLK                | XCLKOUT                  |
|---------------|----------|------------------------|--------------------------|
| 1<br>Example: | 150 MHz  | SYCLKOUT<br>150 MHz    | SYCLKOUT<br>150 MHz      |
| 2<br>Example: | 150 MHz  | SYCLKOUT<br>150 MHz    | 1/2 SYCLKOUT<br>75 MHz   |
| 3<br>Example: | 150 MHz  | 1/2 SYCLKOUT<br>75 MHz | 1/2 SYCLKOUT<br>75 MHz   |
| 4<br>Example: | 150 MHz  | 1/2 SYCLKOUT<br>75 MHz | 1/4 SYCLKOUT<br>37.5 MHz |

The relationship between SYCLKOUT and XTIMCLK is shown in [Figure 5-28](#).

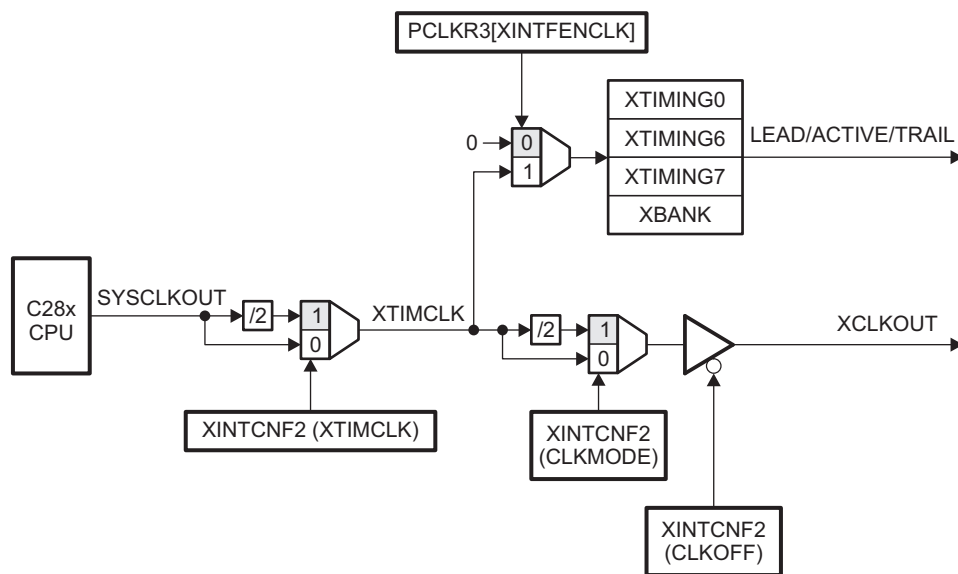


**Figure 5-28. Relationship Between SYCLKOUT and XTIMCLK**

#### 5.9.6.4 XINTF Signal Alignment to XCLKOUT

For each XINTF access, the number of lead, active, and trail cycles is based on the internal clock XTIMCLK. Strokes such as  $\overline{\text{XRD}}$ ,  $\overline{\text{XWE0}}$ ,  $\overline{\text{XWE1}}$ , and zone chip-select ( $\overline{\text{XZCS}}$ ) change state in relationship to the rising edge of XTIMCLK. The external clock, XCLKOUT, can be configured to be either equal to or one-half the frequency of XTIMCLK.

For the case where XCLKOUT = XTIMCLK, all of the XINTF strobes will change state with respect to the rising edge of XCLKOUT. For the case where XCLKOUT = one-half XTIMCLK, some strobes will change state either on the rising edge of XCLKOUT or the falling edge of XCLKOUT. In the XINTF timing tables, the notation XCOHL is used to indicate that the parameter is with respect to either case; XCLKOUT rising edge (high) or XCLKOUT falling edge (low). If the parameter is always with respect to the rising edge of XCLKOUT, the notation XCOH is used.

For the case where XCLKOUT = one-half XTIMCLK, the XCLKOUT edge with which the change will be aligned can be determined based on the number of XTIMCLK cycles from the start of the access to the point at which the signal changes. If this number of XTIMCLK cycles is even, the alignment will be with respect to the rising edge of XCLKOUT. If this number is odd, then the signal will change with respect to the falling edge of XCLKOUT. Examples include the following:

- Strokes that change at the beginning of an access always align to the rising edge of XCLKOUT. This is because all XINTF accesses begin with respect to the rising edge of XCLKOUT.

|           |                             |                                     |
|-----------|-----------------------------|-------------------------------------|
| Examples: | XZCSL                       | Zone chip-select active low         |
|           | XR $\overline{\text{NW}}$ L | XR $\overline{\text{W}}$ active low |

- Strokes that change at the beginning of the active period will align to the rising edge of XCLKOUT if the total number of lead XTIMCLK cycles for the access is even. If the number of lead XTIMCLK cycles is odd, then the alignment will be with respect to the falling edge of XCLKOUT.

|           |      |                                                                 |
|-----------|------|-----------------------------------------------------------------|
| Examples: | XRDL | $\overline{\text{XRD}}$ active low                              |
|           | XWEL | $\overline{\text{XWE1}}$ or $\overline{\text{XWE0}}$ active low |

- Strokes that change at the beginning of the trail period will align to the rising edge of XCLKOUT if the total number of lead + active XTIMCLK cycles (including hardware waitstates) for the access is even. If the number of lead + active XTIMCLK cycles (including hardware waitstates) is odd, then the alignment will be with respect to the falling edge of XCLKOUT.

|           |      |                                                                    |
|-----------|------|--------------------------------------------------------------------|
| Examples: | XRDH | $\overline{\text{XRD}}$ inactive high                              |
|           | XWEH | $\overline{\text{XWE1}}$ or $\overline{\text{XWE0}}$ inactive high |

- Strokes that change at the end of the access will align to the rising edge of XCLKOUT if the total number of lead + active + trail XTIMCLK cycles (including hardware waitstates) is even. If the number of lead + active + trail XTIMCLK cycles (including hardware waitstates) is odd, then the alignment will be with respect to the falling edge of XCLKOUT.

|           |                            |                                        |
|-----------|----------------------------|----------------------------------------|
| Examples: | XZCSH                      | Zone chip-select inactive high         |
|           | XR $\overline{\text{NWH}}$ | XR $\overline{\text{W}}$ inactive high |

### 5.9.6.5 External Interface Read Timing

**Table 5-47. External Interface Read Timing Requirements**

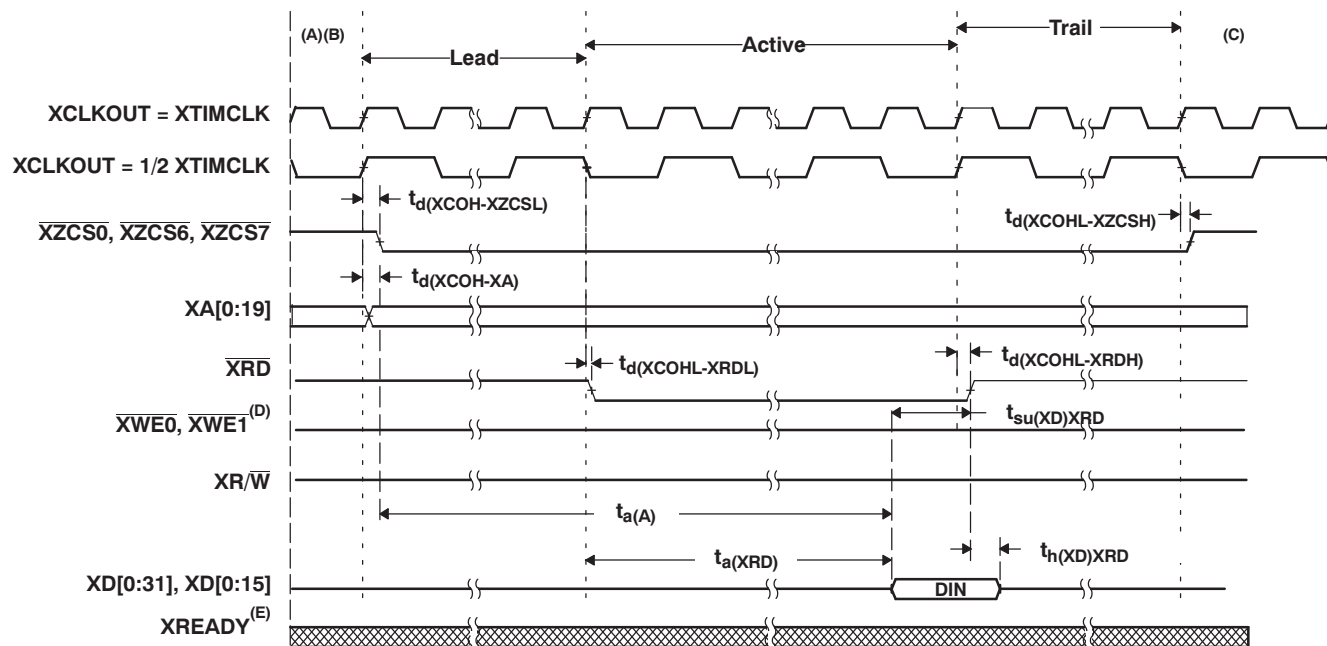
|                 |                                                                          | MIN | MAX                    | UNIT |
|-----------------|--------------------------------------------------------------------------|-----|------------------------|------|
| $t_{a(A)}$      | Access time, read data from address valid                                |     | $(LR + AR) - 16^{(1)}$ | ns   |
| $t_{a(XRD)}$    | Access time, read data valid from $\overline{XRD}$ active low            |     | $AR - 14^{(1)}$        | ns   |
| $t_{su(XD)XRD}$ | Setup time, read data valid before $\overline{XRD}$ strobe inactive high | 14  |                        | ns   |
| $t_h(XD)XRD$    | Hold time, read data valid after $\overline{XRD}$ inactive high          | 0   |                        | ns   |

(1) LR = Lead period, read access. AR = Active period, read access. See Table 5-45.

**Table 5-48. External Interface Read Switching Characteristics**

| PARAMETER          |                                                                | MIN  | MAX | UNIT |
|--------------------|----------------------------------------------------------------|------|-----|------|
| $t_d(XCOH-XZCSL)$  | Delay time, XCLKOUT high to zone chip-select active low        |      | 1   | ns   |
| $t_d(XCOHL-XZCSH)$ | Delay time, XCLKOUT high/low to zone chip-select inactive high | -1   | 0.5 | ns   |
| $t_d(XCOH-XA)$     | Delay time, XCLKOUT high to address valid                      |      | 1.5 | ns   |
| $t_d(XCOHL-XRDL)$  | Delay time, XCLKOUT high/low to $\overline{XRD}$ active low    |      | 0.5 | ns   |
| $t_d(XCOHL-XRDH)$  | Delay time, XCLKOUT high/low to $\overline{XRD}$ inactive high | -1.5 | 0.5 | ns   |
| $t_h(XA)XZCSH$     | Hold time, address valid after zone chip-select inactive high  | (1)  |     | ns   |
| $t_h(XA)XRD$       | Hold time, address valid after $\overline{XRD}$ inactive high  | (1)  |     | ns   |

(1) During inactive cycles, the XINTF address bus always holds the last address put out on the bus except XA0, which remains high. This includes alignment cycles.



- All XINTF accesses (lead period) begin on the rising edge of XCLKOUT. When necessary, the device inserts an alignment cycle before an access to meet this requirement.
- During alignment cycles, all signals transition to their inactive state.
- XA[0:19] holds the last address put on the bus during inactive cycles, including alignment cycles except XA0, which remains high.
- $\overline{\text{XWE1}}$  is used in 32-bit data bus mode. In 16-bit mode, this signal is XA0.
- For USEREADY = 0, the external XREADY input signal is ignored.

**Figure 5-29. Example Read Access**

XTIMING register parameters used for this example:

| XRDL | XRDACTIVE | XRDTAIL | USEREADY | X2TIMING | XWRLEAD            | XWRACTIVE          | XWRTRAIL           | READYMODE          |
|------|-----------|---------|----------|----------|--------------------|--------------------|--------------------|--------------------|
| ≥ 1  | ≥ 0       | ≥ 0     | 0        | 0        | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> |

(1) N/A = Not applicable (or "Don't care") for this example

### 5.9.6.6 External Interface Write Timing

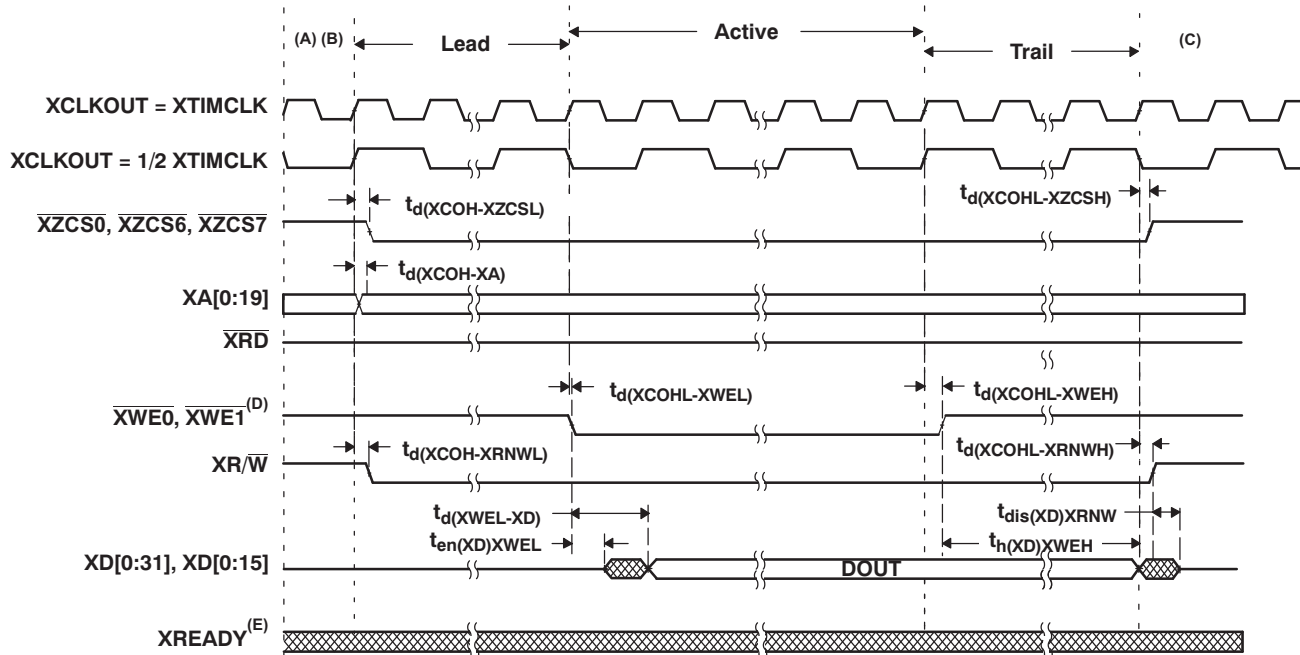
**Table 5-49. External Interface Write Switching Characteristics**

| PARAMETER            |                                                                                          | MIN                     | MAX | UNIT |
|----------------------|------------------------------------------------------------------------------------------|-------------------------|-----|------|
| $t_{d(XCOH-XZCSL)}$  | Delay time, XCLKOUT high to zone chip-select active low                                  |                         | 1   | ns   |
| $t_{d(XCOHL-XZCSH)}$ | Delay time, XCLKOUT high or low to zone chip-select inactive high                        | –1                      | 0.5 | ns   |
| $t_{d(XCOH-XA)}$     | Delay time, XCLKOUT high to address valid                                                |                         | 1.5 | ns   |
| $t_{d(XCOHL-XWEL)}$  | Delay time, XCLKOUT high/low to $\overline{XWE0}$ , $\overline{XWE1}$ <sup>(1)</sup> low |                         | 2   | ns   |
| $t_{d(XCOHL-XWEH)}$  | Delay time, XCLKOUT high/low to $\overline{XWE0}$ , $\overline{XWE1}$ high               |                         | 2   | ns   |
| $t_{d(XCOH-XRNWL)}$  | Delay time, XCLKOUT high to $\overline{XR/W}$ low                                        |                         | 1   | ns   |
| $t_{d(XCOHL-XRNWH)}$ | Delay time, XCLKOUT high/low to $\overline{XR/W}$ high                                   | –1                      | 0.5 | ns   |
| $t_{en(XD)XWEL}$     | Enable time, data bus driven from $\overline{XWE0}$ , $\overline{XWE1}$ low              | 0                       |     | ns   |
| $t_{d(XWEL-XD)}$     | Delay time, data valid after $\overline{XWE0}$ , $\overline{XWE1}$ active low            |                         | 1   | ns   |
| $t_{h(XA)XZCSH}$     | Hold time, address valid after zone chip-select inactive high                            | <sup>(2)</sup>          |     | ns   |
| $t_{h(XD)XWE}$       | Hold time, write data valid after $\overline{XWE0}$ , $\overline{XWE1}$ inactive high    | $TW - 2$ <sup>(3)</sup> |     | ns   |
| $t_{dis(XD)XRNW}$    | Maximum time for DSP to release the data bus after $\overline{XR/W}$ inactive high       |                         | 4   | ns   |

(1)  $\overline{XWE1}$  is used in 32-bit data bus mode only. In 16-bit mode, this signal is XA0.

(2) During inactive cycles, the XINTF address bus will always hold the last address put out on the bus except XA0, which remains high. This includes alignment cycles.

(3)  $TW$  = Trail period, write access. See [Table 5-45](#).



- A. All XINTF accesses (lead period) begin on the rising edge of XCLKOUT. When necessary, the device inserts an alignment cycle before an access to meet this requirement.
- B. During alignment cycles, all signals transition to their inactive state.
- C. XA[0:19] holds the last address put on the bus during inactive cycles, including alignment cycles except XA0, which remains high.
- D. XWE1 is used in 32-bit data bus mode. In 16-bit mode, this signal is XA0.
- E. For USEREADY = 0, the external XREADY input signal is ignored.

Figure 5-30. Example Write Access

XTIMING register parameters used for this example:

| XRDLEAD            | XRDACTIVE          | XRDTRAIL           | USEREADY | X2TIMING | XWRLEAD | XWRACTIVE | XWRTRAIL | READYMODE          |
|--------------------|--------------------|--------------------|----------|----------|---------|-----------|----------|--------------------|
| N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | 0        | 0        | ≥ 1     | ≥ 0       | ≥ 0      | N/A <sup>(1)</sup> |

(1) N/A = Not applicable (or "Don't care") for this example

### 5.9.6.7 External Interface Ready-on-Read Timing With One External Wait State

**Table 5-50. External Interface Read Switching Characteristics (Ready-on-Read, One Wait State)**

| PARAMETER            |                                                                | MIN   | MAX | UNIT |
|----------------------|----------------------------------------------------------------|-------|-----|------|
| $t_{d(XCOH-XZCSL)}$  | Delay time, XCLKOUT high to zone chip-select active low        |       | 1   | ns   |
| $t_{d(XCOHL-XZCSH)}$ | Delay time, XCLKOUT high/low to zone chip-select inactive high | –1    | 0.5 | ns   |
| $t_{d(XCOH-XA)}$     | Delay time, XCLKOUT high to address valid                      |       | 1.5 | ns   |
| $t_{d(XCOHL-XRDL)}$  | Delay time, XCLKOUT high/low to $\overline{XRD}$ active low    |       | 0.5 | ns   |
| $t_{d(XCOHL-XRDH)}$  | Delay time, XCLKOUT high/low to $\overline{XRD}$ inactive high | – 1.5 | 0.5 | ns   |
| $t_{h(XA)XZCSH}$     | Hold time, address valid after zone chip-select inactive high  | (1)   |     | ns   |
| $t_{h(XA)XRD}$       | Hold time, address valid after $\overline{XRD}$ inactive high  | (1)   |     | ns   |

- (1) During inactive cycles, the XINTF address bus always holds the last address put out on the bus, except XA0, which remains high. This includes alignment cycles.

**Table 5-51. External Interface Read Timing Requirements (Ready-on-Read, One Wait State)**

|                 |                                                                          | MIN                             | MAX | UNIT |
|-----------------|--------------------------------------------------------------------------|---------------------------------|-----|------|
| $t_{a(A)}$      | Access time, read data from address valid                                | $(LR + AR) - 16$ <sup>(1)</sup> |     | ns   |
| $t_{a(XRD)}$    | Access time, read data valid from $\overline{XRD}$ active low            | $AR - 14$ <sup>(1)</sup>        |     | ns   |
| $t_{su(XD)XRD}$ | Setup time, read data valid before $\overline{XRD}$ strobe inactive high | 14                              |     | ns   |
| $t_{h(XD)XRD}$  | Hold time, read data valid after $\overline{XRD}$ inactive high          | 0                               |     | ns   |

- (1) LR = Lead period, read access. AR = Active period, read access. See Table 5-45.

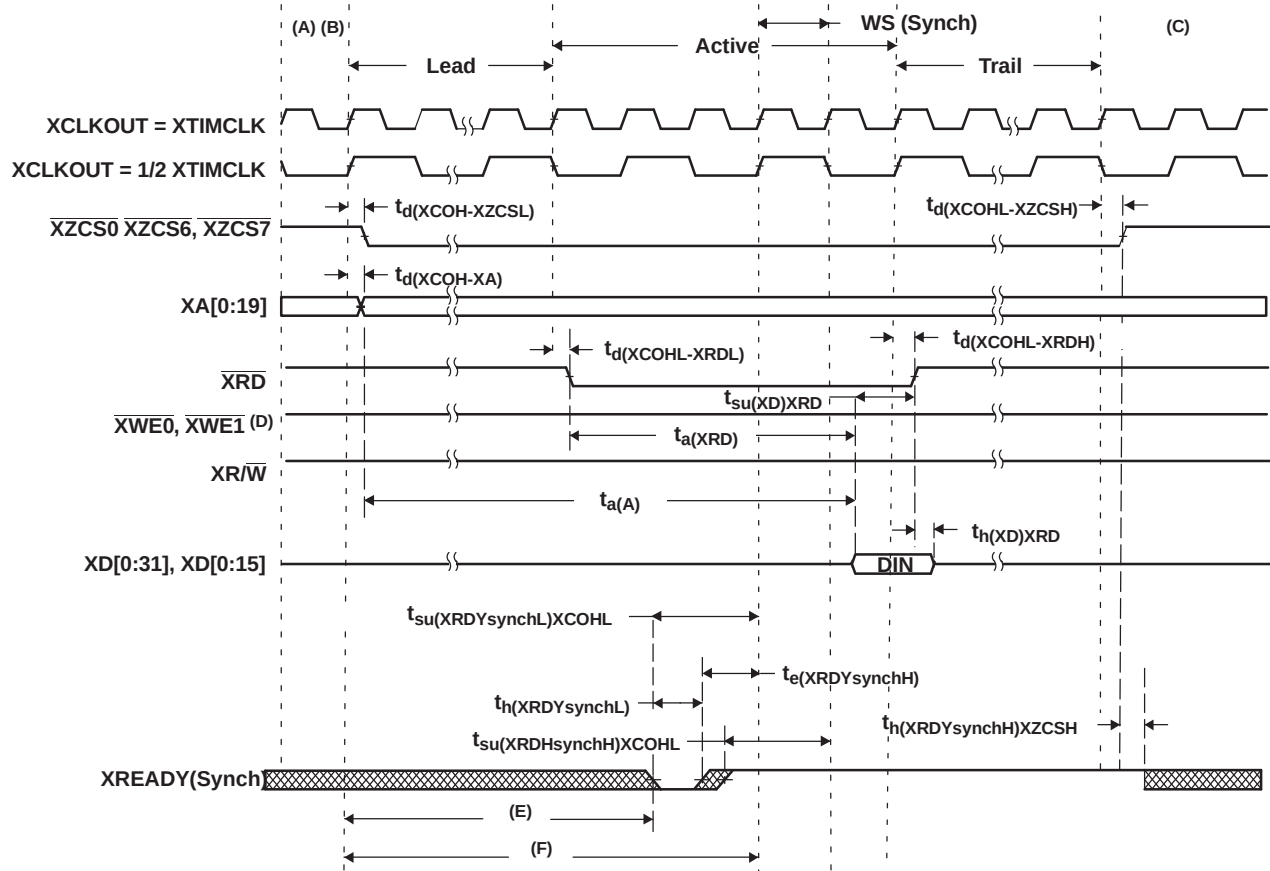
**Table 5-52. Synchronous XREADY Timing Requirements (Ready-on-Read, One Wait State)<sup>(1)</sup>**

|                           |                                                                                 | MIN | MAX | UNIT |
|---------------------------|---------------------------------------------------------------------------------|-----|-----|------|
| $t_{su(XRDYsynchL)XCOHL}$ | Setup time, XREADY (synchronous) low before XCLKOUT high/low                    | 12  |     | ns   |
| $t_{h(XRDYsynchL)}$       | Hold time, XREADY (synchronous) low                                             | 6   |     | ns   |
| $t_{e(XRDYsynchH)}$       | Earliest time XREADY (synchronous) can go high before the sampling XCLKOUT edge |     | 3   | ns   |
| $t_{su(XRDYsynchH)XCOHL}$ | Setup time, XREADY (synchronous) high before XCLKOUT high/low                   | 12  |     | ns   |
| $t_{h(XRDYsynchH)XZCSH}$  | Hold time, XREADY (synchronous) held high after zone chip select high           | 0   |     | ns   |

- (1) The first XREADY (synchronous) sample occurs with respect to E in Figure 5-31:  
 $E = (XRDLEAD + XRDACTIVE) t_{c(XTIM)}$   
 When first sampled, if XREADY (synchronous) is found to be high, then the access will finish. If XREADY (synchronous) is found to be low, it is sampled again each  $t_{c(XTIM)}$  until it is found to be high.  
 For each sample (n) the setup time (F) with respect to the beginning of the access can be calculated as:  
 $F = (XRDLEAD + XRDACTIVE + n - 1) t_{c(XTIM)} - t_{su(XRDYsynchL)XCOHL}$   
 where n is the sample number: n = 1, 2, 3, and so forth.

**Table 5-53. Asynchronous XREADY Timing Requirements (Ready-on-Read, One Wait State)**

|                            |                                                                                  | MIN | MAX | UNIT |
|----------------------------|----------------------------------------------------------------------------------|-----|-----|------|
| $t_{su(XRDYAsynchL)XCOHL}$ | Setup time, XREADY (asynchronous) low before XCLKOUT high/low                    | 11  |     | ns   |
| $t_{h(XRDYAsynchL)}$       | Hold time, XREADY (asynchronous) low                                             | 6   |     | ns   |
| $t_{e(XRDYAsynchH)}$       | Earliest time XREADY (asynchronous) can go high before the sampling XCLKOUT edge |     | 3   | ns   |
| $t_{su(XRDYAsynchH)XCOHL}$ | Setup time, XREADY (asynchronous) high before XCLKOUT high/low                   | 11  |     | ns   |
| $t_{h(XRDYAsynchH)XZCSH}$  | Hold time, XREADY (asynchronous) held high after zone chip select high           | 0   |     | ns   |



**Legend:**

= Don't care. Signal can be high or low during this time.

- A. All XINTF accesses (lead period) begin on the rising edge of XCLKOUT. When necessary, the device inserts an alignment cycle before an access to meet this requirement.
- B. During alignment cycles, all signals transition to their inactive state.
- C. During inactive cycles, the XINTF address bus always holds the last address put out on the bus except XA0, which remains high. This includes alignment cycles.
- D.  $\overline{XWE1}$  is valid only in 32-bit data bus mode. In 16-bit mode, this signal is XA0.
- E. For each sample, setup time from the beginning of the access (E) can be calculated as:  

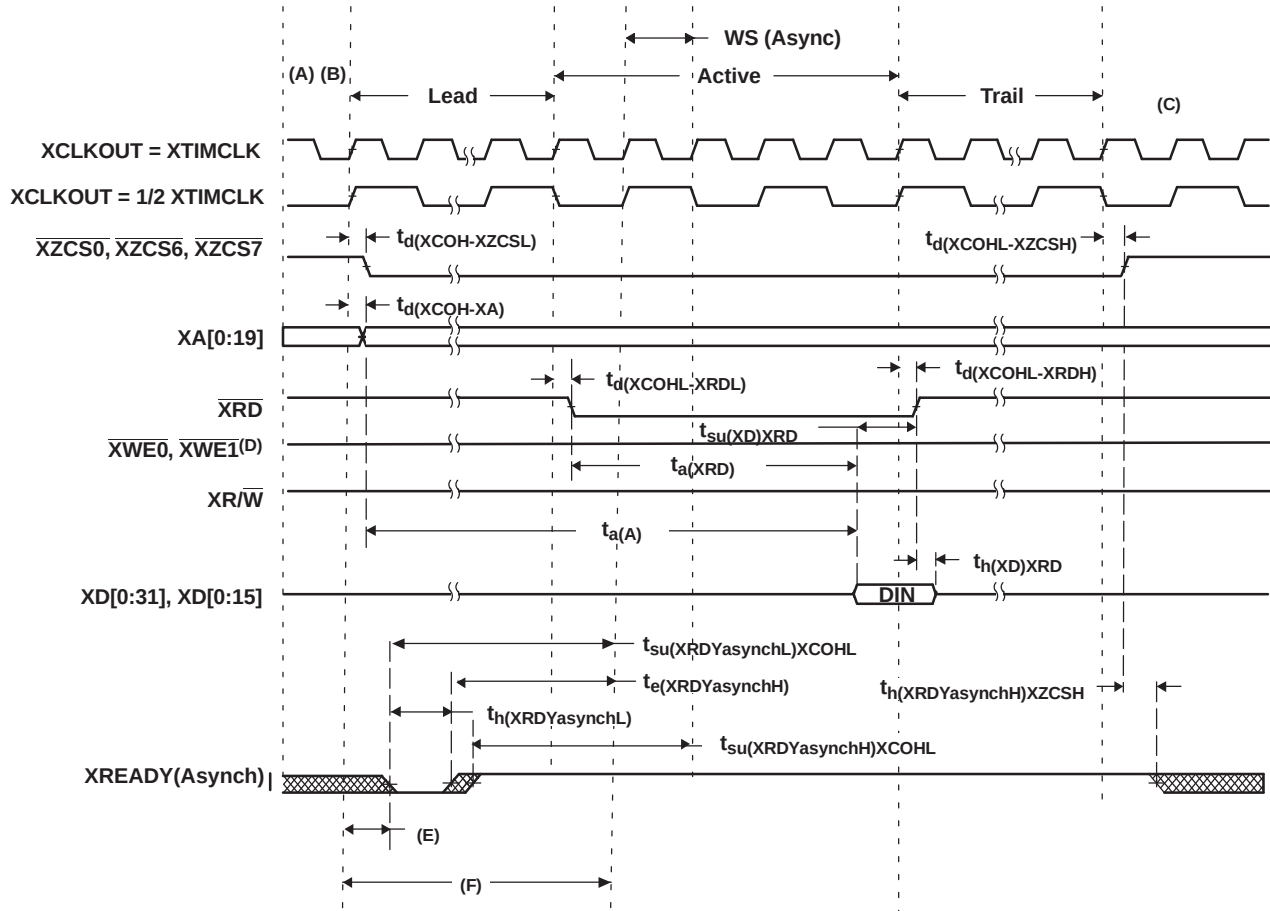
$$D = (XRDLEAD + XRDACTIVE + n - 1) t_{c(XTIM)} - t_{su(XRDYsynchL)XCOHL}$$
- F. Reference for the first sample is with respect to this point:  $F = (XRDLEAD + XRDACTIVE) t_{c(XTIM)}$  where n is the sample number: n = 1, 2, 3, and so forth.

**Figure 5-31. Example Read With Synchronous XREADY Access**

XTIMING register parameters used for this example:

| XRDLEAD  | XRDACTIVE | XRDTRAIL | USEREADY | X2TIMING | XWRLEAD            | XWRACTIVE          | XWRTRAIL           | READYMODE          |
|----------|-----------|----------|----------|----------|--------------------|--------------------|--------------------|--------------------|
| $\geq 1$ | 3         | $\geq 1$ | 1        | 0        | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | 0 = XREADY (Synch) |

(1) N/A = "Don't care" for this example



**Legend:**

= Don't care. Signal can be high or low during this time.

- A. All XINTF accesses (lead period) begin on the rising edge of XCLKOUT. When necessary, the device will insert an alignment cycle before an access to meet this requirement.
- B. During alignment cycles, all signals will transition to their inactive state.
- C. During inactive cycles, the XINTF address bus will always hold the last address put out on the bus except XA0, which remains high. This includes alignment cycles.
- D.  $\overline{XWE1}$  is valid only in 32-bit data bus mode. In 16-bit mode, this signal is XA0.
- E. For each sample, setup time from the beginning of the access can be calculated as:  

$$E = (XRDLEAD + XRDACTIVE - 3 + n) t_{c(XTIM)} - t_{su(XRDYasynchL)XCOHL}$$
 where n is the sample number: n = 1, 2, 3, and so forth.
- F. Reference for the first sample is with respect to this point:  $F = (XRDLEAD + XRDACTIVE - 2) t_{c(XTIM)}$

**Figure 5-32. Example Read With Asynchronous XREADY Access**

XTIMING register parameters used for this example:

| XRDLEAD | XRDACTIVE | XRDTRAIL | USEREADY | X2TIMING | XWRLEAD            | XWRACTIVE          | XWRTRAIL           | READYMODE          |
|---------|-----------|----------|----------|----------|--------------------|--------------------|--------------------|--------------------|
| ≥ 1     | 3         | ≥ 1      | 1        | 0        | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | 1 = XREADY (Async) |

(1) N/A = "Don't care" for this example

### 5.9.6.8 External Interface Ready-on-Write Timing With One External Wait State

**Table 5-54. External Interface Write Switching Characteristics (Ready-on-Write, One Wait State)**

| PARAMETER            |                                                                                                      | MIN                   | MAX | UNIT |
|----------------------|------------------------------------------------------------------------------------------------------|-----------------------|-----|------|
| $t_{d(XCOH-XZCSL)}$  | Delay time, XCLKOUT high to zone chip-select active low                                              |                       | 1   | ns   |
| $t_{d(XCOHL-XZCSH)}$ | Delay time, XCLKOUT high or low to zone chip-select inactive high                                    | – 1                   | 0.5 | ns   |
| $t_{d(XCOH-XA)}$     | Delay time, XCLKOUT high to address valid                                                            |                       | 1.5 | ns   |
| $t_{d(XCOHL-XWEL)}$  | Delay time, XCLKOUT high/low to $\overline{XWE0}$ , $\overline{XWE1}$ low <sup>(1)</sup>             |                       | 2   | ns   |
| $t_{d(XCOHL-XWEH)}$  | Delay time, XCLKOUT high/low to $\overline{XWE0}$ , $\overline{XWE1}$ high <sup>(1)</sup>            |                       | 2   | ns   |
| $t_{d(XCOH-XRNWL)}$  | Delay time, XCLKOUT high to $\overline{XR/W}$ low                                                    |                       | 1   | ns   |
| $t_{d(XCOHL-XRNWH)}$ | Delay time, XCLKOUT high/low to $\overline{XR/W}$ high                                               | – 1                   | 0.5 | ns   |
| $t_{en(XD)XWEL}$     | Enable time, data bus driven from $\overline{XWE0}$ , $\overline{XWE1}$ low <sup>(1)</sup>           | 0                     |     | ns   |
| $t_{d(XWEL-XD)}$     | Delay time, data valid after $\overline{XWE0}$ , $\overline{XWE1}$ active low <sup>(1)</sup>         |                       | 1   | ns   |
| $t_{h(XA)XZCSH}$     | Hold time, address valid after zone chip-select inactive high                                        | (2)                   |     | ns   |
| $t_{h(XD)XWE}$       | Hold time, write data valid after $\overline{XWE0}$ , $\overline{XWE1}$ inactive high <sup>(1)</sup> | TW – 2 <sup>(3)</sup> |     | ns   |
| $t_{dis(XD)XRNW}$    | Maximum time for DSP to release the data bus after $\overline{XR/W}$ inactive high                   |                       | 4   | ns   |

- (1)  $\overline{XWE1}$  is used in 32-bit data bus mode only. In 16-bit, this signal is XA0.  
(2) During inactive cycles, the XINTF address bus always holds the last address put out on the bus except XA0, which remains high. This includes alignment cycles.  
(3) TW = trail period, write access (see Table 5-45)

**Table 5-55. Synchronous XREADY Timing Requirements (Ready-on-Write, One Wait State)<sup>(1)</sup>**

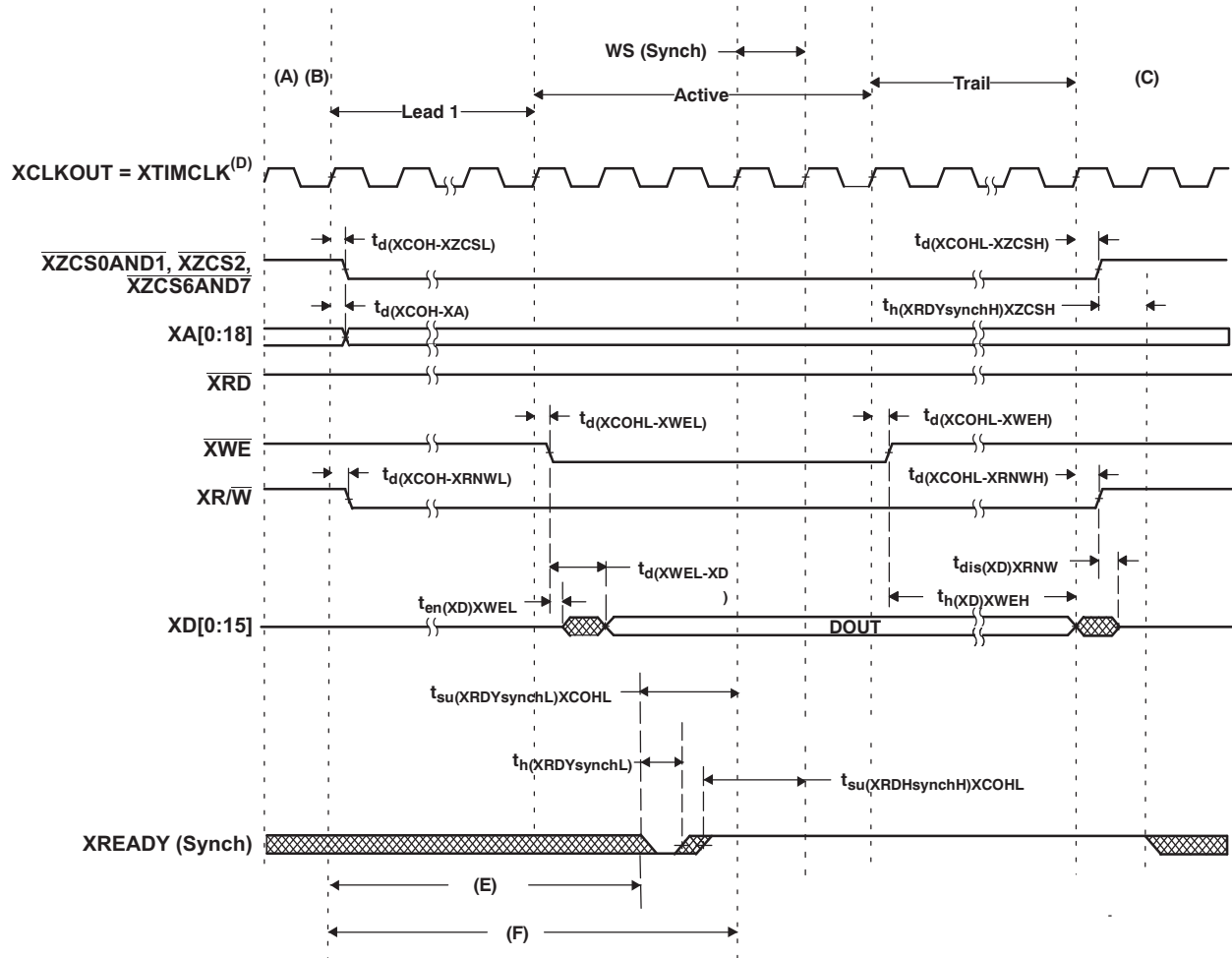
|                           |                                                                                 | MIN | MAX | UNIT |
|---------------------------|---------------------------------------------------------------------------------|-----|-----|------|
| $t_{su(XRDYsynchL)XCOHL}$ | Setup time, XREADY (synchronous) low before XCLKOUT high/low                    | 12  |     | ns   |
| $t_{h(XRDYsynchL)}$       | Hold time, XREADY (synchronous) low                                             | 6   |     | ns   |
| $t_{e(XRDYsynchH)}$       | Earliest time XREADY (synchronous) can go high before the sampling XCLKOUT edge |     | 3   | ns   |
| $t_{su(XRDYsynchH)XCOHL}$ | Setup time, XREADY (synchronous) high before XCLKOUT high/low                   | 12  |     | ns   |
| $t_{h(XRDYsynchH)XZCSH}$  | Hold time, XREADY (synchronous) held high after zone chip select high           | 0   |     | ns   |

- (1) The first XREADY (synchronous) sample occurs with respect to E in Figure 5-33:  
 $E = (XWRLEAD + XWRACTIVE) t_{c(XTIM)}$   
When first sampled, if XREADY (synchronous) is high, then the access will complete. If XREADY (synchronous) is low, it is sampled again each  $t_{c(XTIM)}$  until it is high.  
For each sample, setup time from the beginning of the access can be calculated as:  
 $F = (XWRLEAD + XWRACTIVE + n - 1) t_{c(XTIM)} - t_{su(XRDYsynchL)XCOHL}$   
where n is the sample number: n = 1, 2, 3, and so forth.

**Table 5-56. Asynchronous XREADY Timing Requirements (Ready-on-Write, One Wait State)<sup>(1)</sup>**

|                            |                                                                                  | MIN | MAX | UNIT |
|----------------------------|----------------------------------------------------------------------------------|-----|-----|------|
| $t_{su(XRDYasynchL)XCOHL}$ | Setup time, XREADY (asynchronous) low before XCLKOUT high/low                    | 11  |     | ns   |
| $t_{h(XRDYasynchL)}$       | Hold time, XREADY (asynchronous) low                                             | 6   |     | ns   |
| $t_{e(XRDYasynchH)}$       | Earliest time XREADY (asynchronous) can go high before the sampling XCLKOUT edge |     | 3   | ns   |
| $t_{su(XRDYasynchH)XCOHL}$ | Setup time, XREADY (asynchronous) high before XCLKOUT high/low                   | 11  |     | ns   |
| $t_{h(XRDYasynchH)XZCSH}$  | Hold time, XREADY (asynchronous) held high after zone chip select high           | 0   |     | ns   |

- (1) The first XREADY (synchronous) sample occurs with respect to E in Figure 5-33:  
 $E = (XWRLEAD + XWRACTIVE - 2) t_{c(XTIM)}$ . When first sampled, if XREADY (asynchronous) is high, then the access will complete. If XREADY (asynchronous) is low, it is sampled again each  $t_{c(XTIM)}$  until it is high.  
For each sample, setup time from the beginning of the access can be calculated as:  
 $F = (XWRLEAD + XWRACTIVE - 3 + n) t_{c(XTIM)} - t_{su(XRDYasynchL)XCOHL}$   
where n is the sample number: n = 1, 2, 3, and so forth.



**Legend:**

= Don't care. Signal can be high or low during this time.

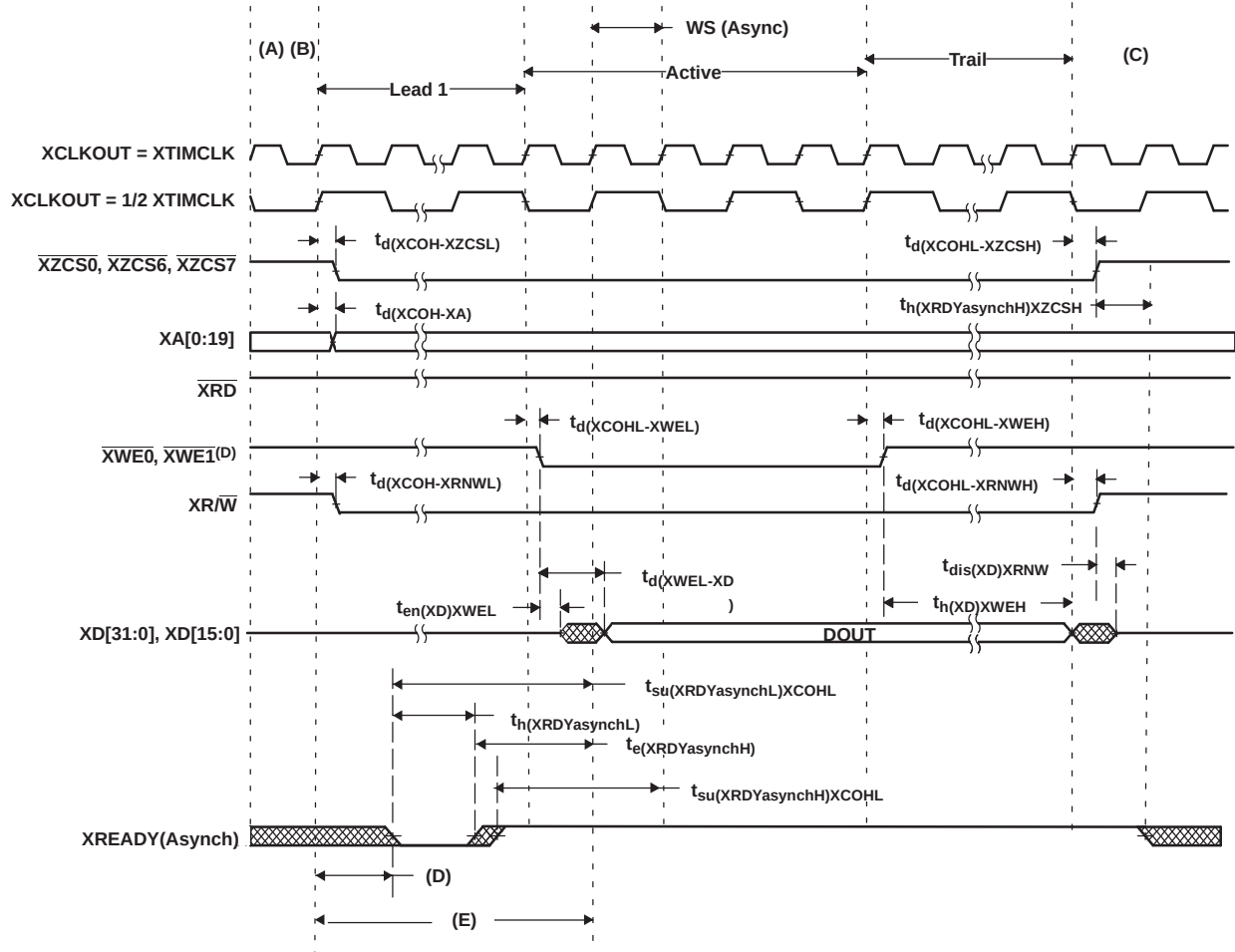
- A. All XINTF accesses (lead period) begin on the rising edge of XCLKOUT. When necessary, the device inserts an alignment cycle before an access to meet this requirement.
- B. During alignment cycles, all signals will transition to their inactive state.
- C. During inactive cycles, the XINTF address bus always holds the last address put out on the bus except XA0, which remains high. This includes alignment cycles.
- D. XWE1 is used in 32-bit data bus mode only. In 16-bit, this signal is XA0.
- E. For each sample, setup time from the beginning of the access can be calculated as  $E = (XWRLEAD + XWRACTIVE + n - 1) t_{c(XTIM)} - t_{su(XRDYsynchL)XCOH}$  where n is the sample number: n = 1, 2, 3, and so forth.
- F. Reference for the first sample is with respect to this point:  $F = (XWRLEAD + XWRACTIVE) t_{c(XTIM)}$

**Figure 5-33. Write With Synchronous XREADY Access**

XTIMING register parameters used for this example:

| XRDLEAD            | XRDACTIVE          | XRDTRAIL           | USEREADY | X2TIMING | XWRLEAD | XWRACTIVE | XWRTRAIL | READYMODE          |
|--------------------|--------------------|--------------------|----------|----------|---------|-----------|----------|--------------------|
| N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | 1        | 0        | ≥ 1     | 3         | ≥ 1      | 0 = XREADY (Synch) |

(1) N/A = "Don't care" for this example.



**Legend:**

= Don't care. Signal can be high or low during this time.

- All XINTF accesses (lead period) begin on the rising edge of XCLKOUT. When necessary, the device inserts an alignment cycle before an access to meet this requirement.
- During alignment cycles, all signals transition to their inactive state.
- During inactive cycles, the XINTF address bus always holds the last address put out on the bus except XA0, which remains high. This includes alignment cycles.
- $\overline{XWE1}$  is used in 32-bit data bus mode only. In 16-bit, this signal is XA0.
- For each sample, set up time from the beginning of the access can be calculated as:  $E = (XWRLEAD + XWRACTIVE - 3 + n) t_{c(XTIM)} - t_{su(XRDYasynchL)XCOHL}$  where  $n$  is the sample number:  $n = 1, 2, 3$ , and so forth.
- Reference for the first sample is with respect to this point:  $F = (XWRLEAD + XWRACTIVE - 2) t_{c(XTIM)}$

**Figure 5-34. Write With Asynchronous XREADY Access**

XTIMING register parameters used for this example:

| XRDLEAD            | XRDACTIVE          | XRDTRAIL           | USEREADY | X2TIMING | XWRLEAD | XWRACTIVE | XWRTRAIL | READYMODE          |
|--------------------|--------------------|--------------------|----------|----------|---------|-----------|----------|--------------------|
| N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | N/A <sup>(1)</sup> | 1        | 0        | ≥ 1     | 3         | ≥ 1      | 1 = XREADY (Async) |

(1) N/A = "Don't care" for this example

### 5.9.6.9 $\overline{\text{XHOLD}}$ and $\overline{\text{XHOLDA}}$ Timing

If the  $\text{HOLD}$  mode bit is set while  $\overline{\text{XHOLD}}$  and  $\overline{\text{XHOLDA}}$  are both low (external bus accesses granted), the  $\overline{\text{XHOLDA}}$  signal is forced high (at the end of the current cycle) and the external interface is taken out of high-impedance mode.

On a reset ( $\overline{\text{XRS}}$ ), the  $\text{HOLD}$  mode bit is set to 0. If the  $\overline{\text{XHOLD}}$  signal is active low on a system reset, the bus and all signal strobes must be in high-impedance mode, and the  $\overline{\text{XHOLDA}}$  signal is also driven active low.

When  $\text{HOLD}$  mode is enabled and  $\overline{\text{XHOLDA}}$  is active low (external bus grant active), the CPU can still execute code from internal memory. If an access is made to the external interface, the CPU is stalled until the  $\overline{\text{XHOLD}}$  signal is removed.

An external DMA request, when granted, places the following signals in a high-impedance mode:

|                                                   |                           |
|---------------------------------------------------|---------------------------|
| $\text{XA}[19:0]$                                 | $\overline{\text{XZCS0}}$ |
| $\text{XD}[31:0], \text{XD}[15:0]$                | $\overline{\text{XZCS6}}$ |
| $\overline{\text{XWE0}}, \overline{\text{XWE1}},$ | $\overline{\text{XZCS7}}$ |
| $\overline{\text{XRD}}$                           |                           |
| $\text{XR}/\overline{\text{W}}$                   |                           |

All other signals not listed in this group remain in their default or functional operational modes during these signal events.

**Table 5-57.  $\overline{\text{XHOLD}}/\overline{\text{XHOLDA}}$  Timing Requirements ( $\text{XCLKOUT} = \text{XTIMCLK}$ )<sup>(1)(2)</sup>**

|                        |                                                                                     | MIN | MAX                                             | UNIT |
|------------------------|-------------------------------------------------------------------------------------|-----|-------------------------------------------------|------|
| $t_{d(\text{HL-HIZ})}$ | Delay time, $\overline{\text{XHOLD}}$ low to Hi-Z on all address, data, and control |     | $4t_{c(\text{XTIM})} + 30$                      | ns   |
| $t_{d(\text{HL-HAL})}$ | Delay time, $\overline{\text{XHOLD}}$ low to $\overline{\text{XHOLDA}}$ low         |     | $5t_{c(\text{XTIM})} + 30$                      | ns   |
| $t_{d(\text{HH-HAH})}$ | Delay time, $\overline{\text{XHOLD}}$ high to $\overline{\text{XHOLDA}}$ high       |     | $3t_{c(\text{XTIM})} + 30$                      | ns   |
| $t_{d(\text{HH-BV})}$  | Delay time, $\overline{\text{XHOLD}}$ high to bus valid                             |     | $4t_{c(\text{XTIM})} + 30$                      | ns   |
| $t_{d(\text{HL-HAL})}$ | Delay time, $\overline{\text{XHOLD}}$ low to $\overline{\text{XHOLDA}}$ low         |     | $4t_{c(\text{XTIM})} + 2t_{c(\text{XCO})} + 30$ | ns   |

- (1) When a low signal is detected on  $\overline{\text{XHOLD}}$ , all pending XINTF accesses will be completed before the bus is placed in a high-impedance state.
- (2) The state of  $\overline{\text{XHOLD}}$  is latched on the rising edge of  $\text{XTIMCLK}$ .

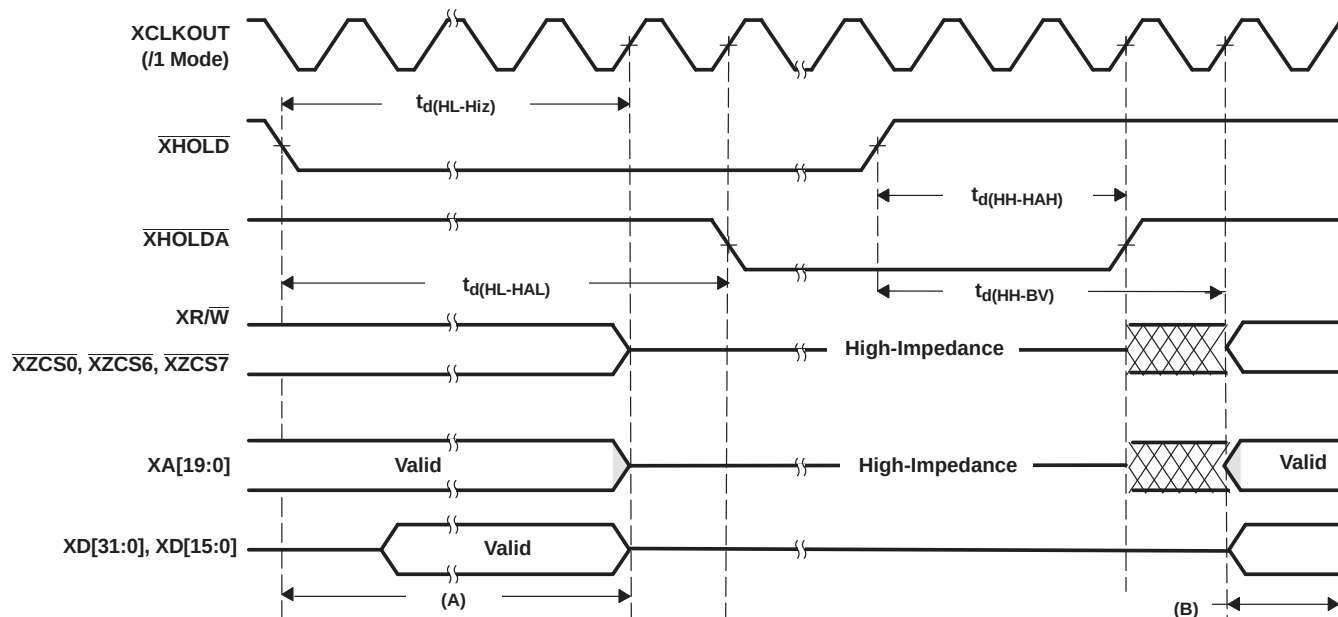
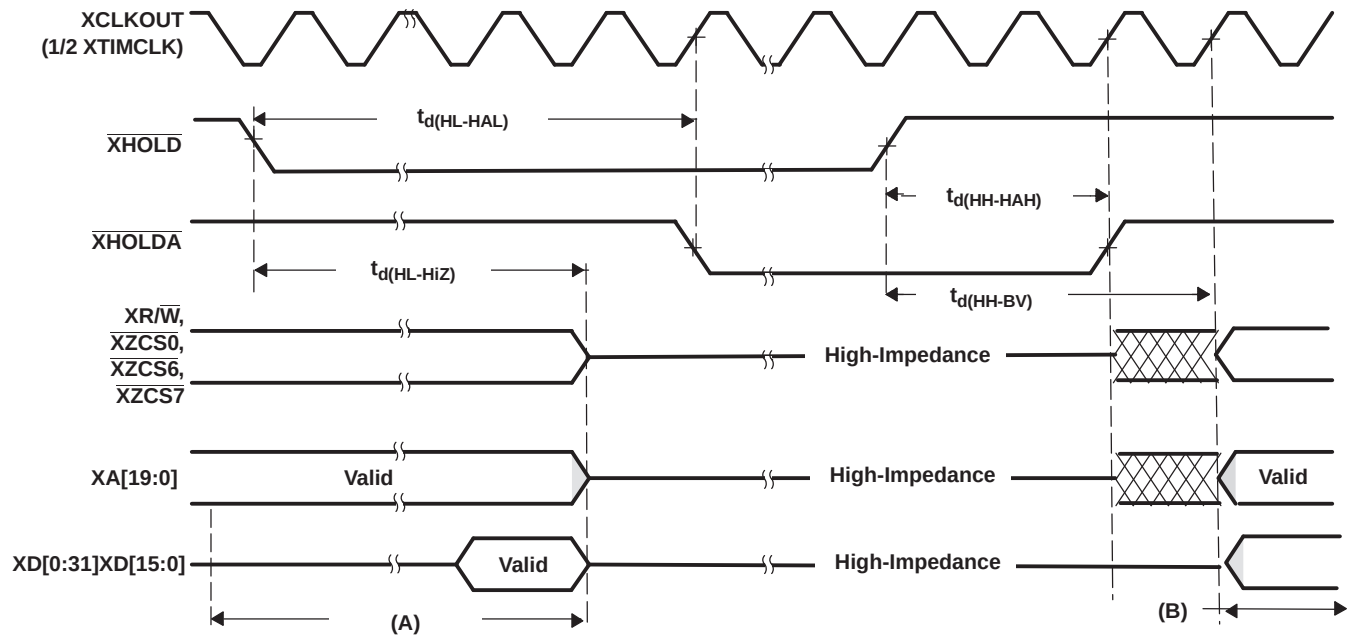


**Figure 5-35. External Interface Hold Waveform**

**Table 5-58.  $\overline{\text{XHOLD}}/\overline{\text{XHOLDA}}$  Timing Requirements ( $\text{XCLKOUT} = 1/2 \text{XTIMCLK}$ )<sup>(1) (2) (3)</sup>**

|                        |                                                                                     | MIN | MAX                                             | UNIT |
|------------------------|-------------------------------------------------------------------------------------|-----|-------------------------------------------------|------|
| $t_{d(\text{HL-HiZ})}$ | Delay time, $\overline{\text{XHOLD}}$ low to Hi-Z on all address, data, and control |     | $4t_{c(\text{XTIM})} + t_{c(\text{XCO})} + 30$  | ns   |
| $t_{d(\text{HL-HAL})}$ | Delay time, $\overline{\text{XHOLD}}$ low to $\overline{\text{XHOLDA}}$ low         |     | $4t_{c(\text{XTIM})} + 2t_{c(\text{XCO})} + 30$ | ns   |
| $t_{d(\text{HH-HAH})}$ | Delay time, $\overline{\text{XHOLD}}$ high to $\overline{\text{XHOLDA}}$ high       |     | $4t_{c(\text{XTIM})} + 30$                      | ns   |
| $t_{d(\text{HH-BV})}$  | Delay time, $\overline{\text{XHOLD}}$ high to bus valid                             |     | $6t_{c(\text{XTIM})} + 30$                      | ns   |

- (1) When a low signal is detected on  $\overline{\text{XHOLD}}$ , all pending XINTF accesses will be completed before the bus is placed in a high-impedance state.
- (2) The state of  $\overline{\text{XHOLD}}$  is latched on the rising edge of  $\text{XTIMCLK}$ .
- (3) After the  $\overline{\text{XHOLD}}$  is detected low or high, all bus transitions and  $\overline{\text{XHOLDA}}$  transitions occur with respect to the rising edge of  $\text{XCLKOUT}$ . Thus, for this mode where  $\text{XCLKOUT} = 1/2 \text{XTIMCLK}$ , the transitions can occur up to 1  $\text{XTIMCLK}$  cycle earlier than the maximum value specified.



- A. All pending XINTF accesses are completed.
- B. Normal XINTF operation resumes.

**Figure 5-36.  $\overline{\text{XHOLD}}/\overline{\text{XHOLDA}}$  Timing Requirements ( $\text{XCLKOUT} = 1/2 \text{XTIMCLK}$ )**

## 5.9.7 Flash Timing

**Table 5-59. Flash Endurance for A and S Temperature Material<sup>(1)</sup>**

|                  |                                                    | ERASE/PROGRAM<br>TEMPERATURE | MIN   | TYP   | MAX | UNIT   |
|------------------|----------------------------------------------------|------------------------------|-------|-------|-----|--------|
| N <sub>f</sub>   | Flash endurance for the array (write/erase cycles) | 0°C to 85°C (ambient)        | 20000 | 50000 |     | cycles |
| N <sub>OTP</sub> | OTP endurance for the array (write cycles)         | 0°C to 85°C (ambient)        |       |       | 1   | write  |

(1) Write/erase operations outside of the temperature ranges indicated are not specified and may affect the endurance numbers.

**Table 5-60. Flash Endurance for Q Temperature Material<sup>(1)</sup>**

|                  |                                                    | ERASE/PROGRAM<br>TEMPERATURE | MIN   | TYP   | MAX | UNIT   |
|------------------|----------------------------------------------------|------------------------------|-------|-------|-----|--------|
| N <sub>f</sub>   | Flash endurance for the array (write/erase cycles) | –40°C to 125°C (ambient)     | 20000 | 50000 |     | cycles |
| N <sub>OTP</sub> | OTP endurance for the array (write cycles)         | –40°C to 125°C (ambient)     |       |       | 1   | write  |

(1) Write/erase operations outside of the temperature ranges indicated are not specified and may affect the endurance numbers.

**Table 5-61. Flash Parameters at 150-MHz SYSCLKOUT**

| PARAMETER                           |                                                                        | TEST<br>CONDITIONS | MIN | TYP  | MAX                 | UNIT |
|-------------------------------------|------------------------------------------------------------------------|--------------------|-----|------|---------------------|------|
| Program<br>Time <sup>(1)</sup>      | 16-Bit Word                                                            |                    |     | 50   |                     | μs   |
|                                     | 32K Sector                                                             |                    |     | 1000 | 2000 <sup>(2)</sup> | ms   |
|                                     | 16K Sector                                                             |                    |     | 500  | 2000 <sup>(2)</sup> | ms   |
| Erase Time <sup>(3)</sup>           | 32K Sector                                                             | Q grade            |     | 2    | 12 <sup>(2)</sup>   | s    |
|                                     | 16K Sector                                                             |                    |     | 2    | 12 <sup>(2)</sup>   |      |
| Erase Time <sup>(3)</sup>           | 32K Sector                                                             | A, S grade         |     | 2    | 15 <sup>(2)</sup>   | s    |
|                                     | 16K Sector                                                             |                    |     | 2    | 15 <sup>(2)</sup>   |      |
| I <sub>DD3VFLP</sub> <sup>(4)</sup> | V <sub>DD3VFL</sub> current consumption during the Erase/Program cycle | Erase              |     | 75   |                     | mA   |
|                                     |                                                                        | Program            |     | 35   |                     | mA   |
| I <sub>DDP</sub> <sup>(4)</sup>     | V <sub>DD</sub> current consumption during Erase/Program cycle         |                    |     | 180  |                     | mA   |
| I <sub>DDIOP</sub> <sup>(4)</sup>   | V <sub>DDIO</sub> current consumption during Erase/Program cycle       |                    |     | 20   |                     | mA   |

- (1) Program time is at the maximum device frequency. The programming time indicated in this table is applicable only when all the required code/data is available in the device RAM, ready for programming. Program time includes overhead of the flash state machine but does not include the time to transfer the following into RAM:
- the code that uses flash API to program the flash
  - the Flash API itself
  - Flash data to be programmed
- (2) Maximum flash parameter mentioned are for the first 100 program and erase cycles.
- (3) The on-chip flash memory is in an erased state when the device is shipped from TI. As such, erasing the flash memory is not required prior to programming, when programming the device for the first time. However, the erase operation is needed on all subsequent programming operations.
- (4) Typical parameters as seen at room temperature including function call overhead, with all peripherals off. It is important to maintain a stable power supply during the entire flash programming process. It is conceivable that device current consumption during flash programming could be higher than normal operating conditions. The power supply used should ensure V<sub>MIN</sub> on the supply rails at all times, as specified in the Recommended Operating Conditions of the data sheet. Any brown-out or interruption to power during erasing/programming could potentially corrupt the password locations and lock the device permanently. Powering a target board (during flash programming) through the USB port is not recommended, as the port may be unable to respond to the power demands placed during the programming process.

**Table 5-62. Flash/OTP Access Timing**

| PARAMETER           |                          | MIN | MAX | UNIT |
|---------------------|--------------------------|-----|-----|------|
| t <sub>a(fp)</sub>  | Paged Flash access time  | 37  |     | ns   |
| t <sub>a(fr)</sub>  | Random Flash access time | 37  |     | ns   |
| t <sub>a(OTP)</sub> | OTP access time          | 60  |     | ns   |

**Table 5-63. Flash Data Retention Duration**

| PARAMETER              |                         | TEST CONDITIONS          | MIN | MAX | UNIT  |
|------------------------|-------------------------|--------------------------|-----|-----|-------|
| $t_{\text{retention}}$ | Data retention duration | $T_J = 55^\circ\text{C}$ | 15  |     | years |

**Table 5-64. Minimum Required Flash/OTP Wait-States at Different Frequencies**

| SYSCLOCKOUT (MHz) | SYSCLOCKOUT (ns) | PAGE WAIT-STATE | RANDOM WAIT-STATE <sup>(1)</sup> | OTP WAIT-STATE |
|-------------------|------------------|-----------------|----------------------------------|----------------|
| 150               | 6.67             | 5               | 5                                | 8              |
| 120               | 8.33             | 4               | 4                                | 7              |
| 100               | 10               | 3               | 3                                | 5              |
| 75                | 13.33            | 2               | 2                                | 4              |
| 50                | 20               | 1               | 1                                | 2              |
| 30                | 33.33            | 1               | 1                                | 1              |
| 25                | 40               | 1               | 1                                | 1              |
| 15                | 66.67            | 1               | 1                                | 1              |
| 4                 | 250              | 1               | 1                                | 1              |

(1) Page and random wait-state must be  $\geq 1$ .

The equations to compute the Flash page wait-state and random wait-state in [Table 5-64](#) are as follows:

$$\text{Flash Page Wait State} = \left\lceil \left( \frac{t_{a(f \cdot p)}}{t_{c(SCO)}} \right) - 1 \right\rceil \text{ round up to the next highest integer or 1, whichever is larger}$$

$$\text{Flash Random Wait State} = \left\lceil \left( \frac{t_{a(f \cdot r)}}{t_{c(SCO)}} \right) - 1 \right\rceil \text{ round up to the next highest integer or 1, whichever is larger}$$

The equation to compute the OTP wait-state in [Table 5-64](#) is as follows:

$$\text{OTP Wait State} = \left\lceil \left( \frac{t_{a(OTP)}}{t_{c(SCO)}} \right) - 1 \right\rceil \text{ round up to the next highest integer or 1, whichever is larger}$$

## 5.10 On-Chip Analog-to-Digital Converter

**Table 5-65. ADC Electrical Characteristics (over recommended operating conditions)<sup>(1)(2)</sup>**

| PARAMETER                                                                                                              |                                   | MIN   | TYP   | MAX  | UNIT   |
|------------------------------------------------------------------------------------------------------------------------|-----------------------------------|-------|-------|------|--------|
| <b>DC SPECIFICATIONS<sup>(3)</sup></b>                                                                                 |                                   |       |       |      |        |
| Resolution                                                                                                             |                                   | 12    |       |      | Bits   |
| ADC clock                                                                                                              |                                   | 0.001 |       | 25   | MHz    |
| <b>ACCURACY</b>                                                                                                        |                                   |       |       |      |        |
| INL (Integral nonlinearity)                                                                                            | 1-12.5 MHz ADC clock (6.25 MSPS)  |       |       | ±1.5 | LSB    |
|                                                                                                                        | 12.5-25 MHz ADC clock (12.5 MSPS) |       |       | ±2   | LSB    |
| DNL (Differential nonlinearity) <sup>(4)</sup>                                                                         |                                   |       |       | ±1   | LSB    |
| Offset error <sup>(5)(3)</sup>                                                                                         |                                   | –15   |       | 15   | LSB    |
| Overall gain error with internal reference <sup>(6)(3)</sup>                                                           |                                   | –30   |       | 30   | LSB    |
| Overall gain error with external reference <sup>(3)</sup>                                                              |                                   | –30   |       | 30   | LSB    |
| Channel-to-channel offset variation                                                                                    |                                   |       | ±4    |      | LSB    |
| Channel-to-channel gain variation                                                                                      |                                   |       | ±4    |      | LSB    |
| <b>ANALOG INPUT</b>                                                                                                    |                                   |       |       |      |        |
| Analog input voltage (ADCINx to ADCLO) <sup>(7)</sup>                                                                  |                                   | 0     |       | 3    | V      |
| ADCLO                                                                                                                  |                                   | –5    | 0     | 5    | mV     |
| Input capacitance                                                                                                      |                                   |       | 10    |      | pF     |
| Input leakage current                                                                                                  |                                   |       |       | ±5   | μA     |
| <b>INTERNAL VOLTAGE REFERENCE<sup>(6)</sup></b>                                                                        |                                   |       |       |      |        |
| V <sub>ADCREFP</sub> - ADCREFP output voltage at the pin based on internal reference                                   |                                   |       | 1.275 |      | V      |
| V <sub>ADCREFM</sub> - ADCREFM output voltage at the pin based on internal reference                                   |                                   |       | 0.525 |      | V      |
| Voltage difference, ADCREFP - ADCREFM                                                                                  |                                   |       | 0.75  |      | V      |
| Temperature coefficient                                                                                                |                                   |       | 50    |      | PPM/°C |
| <b>EXTERNAL VOLTAGE REFERENCE<sup>(6)(8)</sup></b>                                                                     |                                   |       |       |      |        |
| V <sub>ADCREFIN</sub> - External reference voltage input on ADCREFIN pin 0.2% or better accurate reference recommended | ADCREFSEL[15:14] = 11b            |       | 1.024 |      | V      |
|                                                                                                                        | ADCREFSEL[15:14] = 10b            |       | 1.500 |      | V      |
|                                                                                                                        | ADCREFSEL[15:14] = 01b            |       | 2.048 |      | V      |
| <b>AC SPECIFICATIONS</b>                                                                                               |                                   |       |       |      |        |
| SINAD (100 kHz) Signal-to-noise ratio + distortion                                                                     |                                   |       | 67.5  |      | dB     |
| SNR (100 kHz) Signal-to-noise ratio                                                                                    |                                   |       | 68    |      | dB     |
| THD (100 kHz) Total harmonic distortion                                                                                |                                   |       | –79   |      | dB     |
| ENOB (100 kHz) Effective number of bits                                                                                |                                   |       | 10.9  |      | Bits   |
| SFDR (100 kHz) Spurious free dynamic range                                                                             |                                   |       | 83    |      | dB     |

(1) Tested at 25 MHz ADCCLK.

(2) All voltages listed in this table are with respect to V<sub>SSA2</sub>.

(3) ADC parameters for gain error and offset error are only specified if the ADC calibration routine is executed from the Boot ROM. See [Section 6.2.7.3](#) for more information.

(4) TI specifies that the ADC will have no missing codes.

(5) 1 LSB has the weighted value of 3.0/4096 = 0.732 mV.

(6) A single internal/external band gap reference sources both ADCREFP and ADCREFM signals, and hence, these voltages track together. The ADC converter uses the difference between these two as its reference. The total gain error listed for the internal reference is inclusive of the movement of the internal bandgap over temperature. Gain error over temperature for the external reference option will depend on the temperature profile of the source used.

(7) Voltages above V<sub>DDA</sub> + 0.3 V or below V<sub>SS</sub> - 0.3 V applied to an analog input pin may temporarily affect the conversion of another pin. To avoid this, the analog inputs should be kept within these limits.

(8) TI recommends using high precision external reference TI part REF3020/3120 or equivalent for 2.048-V reference.

### 5.10.1 ADC Power-Up Control Bit Timing

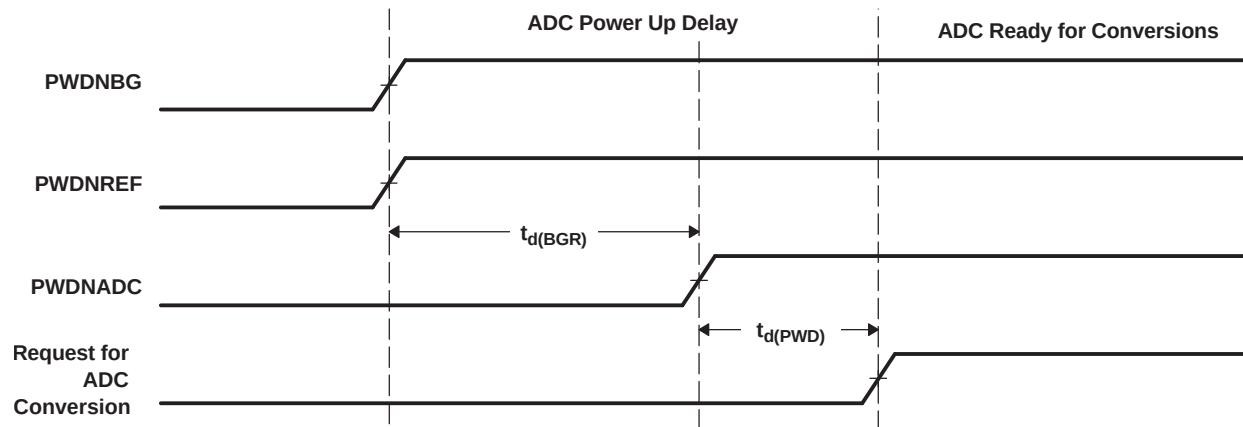


Figure 5-37. ADC Power-Up Control Bit Timing

Table 5-66. ADC Power-Up Delays

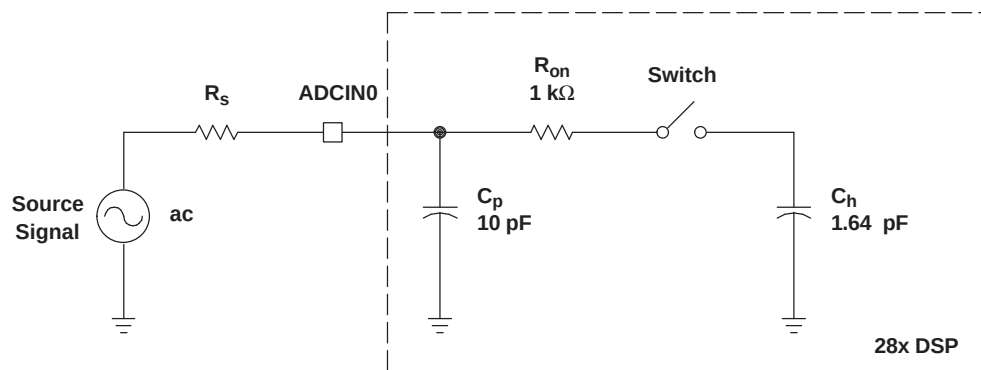
| PARAMETER <sup>(1)</sup> |                                                                                                                                                                                                                                                                                                                | MIN | TYP | MAX | UNIT    |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|---------|
| $t_{d(BGR)}$             | Delay time for band gap reference to be stable. Bits 7 and 6 of the ADCTRL3 register (ADCBGRFDN1/0) must be set to 1 before the PWDNADC bit is enabled.                                                                                                                                                        |     |     | 5   | ms      |
| $t_{d(PWD)}$             | Delay time for power-down control to be stable. Bit delay time for band-gap reference to be stable. Bits 7 and 6 of the ADCTRL3 register (ADCBGRFDN1/0) must be set to 1 before the PWDNADC bit is enabled. Bit 5 of the ADCTRL3 register (PWDNADC) must be set to 1 before any ADC conversions are initiated. | 20  | 50  |     | $\mu$ s |
|                          |                                                                                                                                                                                                                                                                                                                |     |     | 1   | ms      |

(1) Timings maintain compatibility to the 281x ADC module. The 2833x/2823x ADC also supports driving all 3 bits at the same time and waiting  $t_{d(BGR)}$  ms before first conversion.

Table 5-67. Typical Current Consumption for Different ADC Configurations (at 25-MHz ADCCLK)<sup>(1)</sup> (2)

| ADC OPERATING MODE         | CONDITIONS                                                                                                             | V <sub>DDA18</sub> | V <sub>DDA3.3</sub> | UNIT    |
|----------------------------|------------------------------------------------------------------------------------------------------------------------|--------------------|---------------------|---------|
| Mode A (Operational Mode): | <ul style="list-style-type: none"> <li>BG and REF enabled</li> <li>PWD disabled</li> </ul>                             | 30                 | 2                   | mA      |
| Mode B:                    | <ul style="list-style-type: none"> <li>ADC clock enabled</li> <li>BG and REF enabled</li> <li>PWD enabled</li> </ul>   | 9                  | 0.5                 | mA      |
| Mode C:                    | <ul style="list-style-type: none"> <li>ADC clock enabled</li> <li>BG and REF disabled</li> <li>PWD enabled</li> </ul>  | 5                  | 20                  | $\mu$ A |
| Mode D:                    | <ul style="list-style-type: none"> <li>ADC clock disabled</li> <li>BG and REF disabled</li> <li>PWD enabled</li> </ul> | 5                  | 15                  | $\mu$ A |

- (1) Test Conditions:  
 SYSCLKOUT = 150 MHz  
 ADC module clock = 25 MHz  
 ADC performing a continuous conversion of all 16 channels in Mode A
- (2) V<sub>DDA18</sub> includes current into V<sub>DD1A18</sub> and V<sub>DD2A18</sub>. V<sub>DDA3.3</sub> includes current into V<sub>DDA2</sub> and V<sub>DDAIO</sub>.



Typical Values of the Input Circuit Components:

|                                  |              |
|----------------------------------|--------------|
| Switch Resistance ( $R_{on}$ ):  | 1 k $\Omega$ |
| Sampling Capacitor ( $C_h$ ):    | 1.64 pF      |
| Parasitic Capacitance ( $C_p$ ): | 10 pF        |
| Source Resistance ( $R_s$ ):     | 50 $\Omega$  |

**Figure 5-38. ADC Analog Input Impedance Model**

### 5.10.2 Definitions

#### Reference Voltage

The on-chip ADC has a built-in reference, which provides the reference voltages for the ADC.

#### Analog Inputs

The on-chip ADC consists of 16 analog inputs, which are sampled either one at a time or two channels at a time. These inputs are software-selectable.

#### Converter

The on-chip ADC uses a 12-bit four-stage pipeline architecture, which achieves a high sample rate with low power consumption.

#### Conversion Modes

The conversion can be performed in two different conversion modes:

- Sequential sampling mode (SMODE = 0)
- Simultaneous sampling mode (SMODE = 1)

### 5.10.3 Sequential Sampling Mode (Single-Channel) (SMODE = 0)

In sequential sampling mode, the ADC can continuously convert input signals on any of the channels (Ax to Bx). The ADC can start conversions on event triggers from the ePWM, software trigger, or from an external ADCSOC signal. If the SMODE bit is 0, the ADC will do conversions on the selected channel on every Sample/Hold pulse. The conversion time and latency of the Result register update are explained below. The ADC interrupt flags are set a few SYSCLKOUT cycles after the Result register update. The selected channels will be sampled at every falling edge of the Sample/Hold pulse. The Sample/Hold pulse width can be programmed to be 1 ADC clock wide (minimum) or 16 ADC clocks wide (maximum).

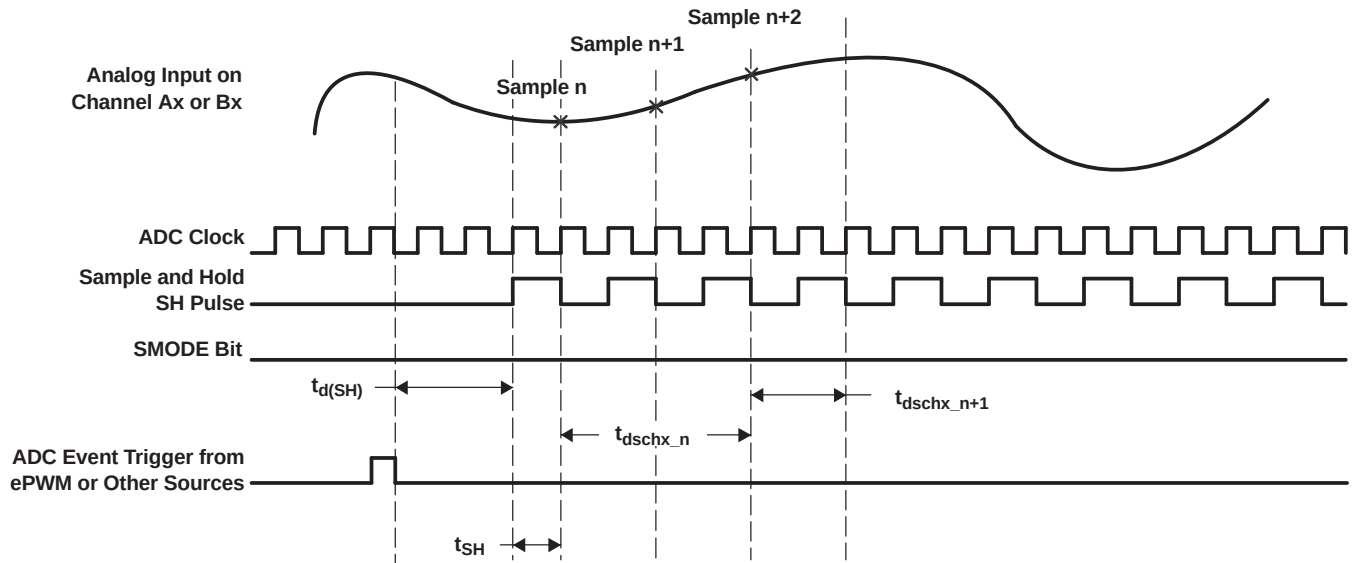


**Figure 5-39. Sequential Sampling Mode (Single-Channel) Timing**

**Table 5-68. Sequential Sampling Mode Timing**

|                    |                                                                | SAMPLE n                             | SAMPLE n + 1                         | AT 25-MHz<br>ADC CLOCK,<br>$t_{c(ADCCLK)} = 40 \text{ ns}$ | REMARKS                             |
|--------------------|----------------------------------------------------------------|--------------------------------------|--------------------------------------|------------------------------------------------------------|-------------------------------------|
| $t_{d(SH)}$        | Delay time from event trigger to sampling                      | $2.5t_{c(ADCCLK)}$                   |                                      |                                                            |                                     |
| $t_{SH}$           | Sample/Hold width/Acquisition Width                            | $(1 + \text{Acqps}) * t_{c(ADCCLK)}$ |                                      | 40 ns with Acqps = 0                                       | Acqps value = 0-15<br>ADCTRL1[8:11] |
| $t_{d(schx\_n)}$   | Delay time for first result to appear in Result register       | $4t_{c(ADCCLK)}$                     |                                      | 160 ns                                                     |                                     |
| $t_{d(schx\_n+1)}$ | Delay time for successive results to appear in Result register |                                      | $(2 + \text{Acqps}) * t_{c(ADCCLK)}$ | 80 ns                                                      |                                     |

#### 5.10.4 Simultaneous Sampling Mode (Dual-Channel) (SMODE = 1)

In simultaneous mode, the ADC can continuously convert input signals on any one pair of channels (A0/B0 to A7/B7). The ADC can start conversions on event triggers from the ePWM, software trigger, or from an external ADCSOC signal. If the SMODE bit is 1, the ADC will do conversions on two selected channels on every Sample/Hold pulse. The conversion time and latency of the result register update are explained below. The ADC interrupt flags are set a few SYSCLKOUT cycles after the Result register update. The selected channels will be sampled simultaneously at the falling edge of the Sample/Hold pulse. The Sample/Hold pulse width can be programmed to be 1 ADC clock wide (minimum) or 16 ADC clocks wide (maximum).

##### NOTE

In simultaneous mode, the ADCIN channel pair select must be A0/B0, A1/B1, ..., A7/B7, and not in other combinations (such as A1/B3, and so on).

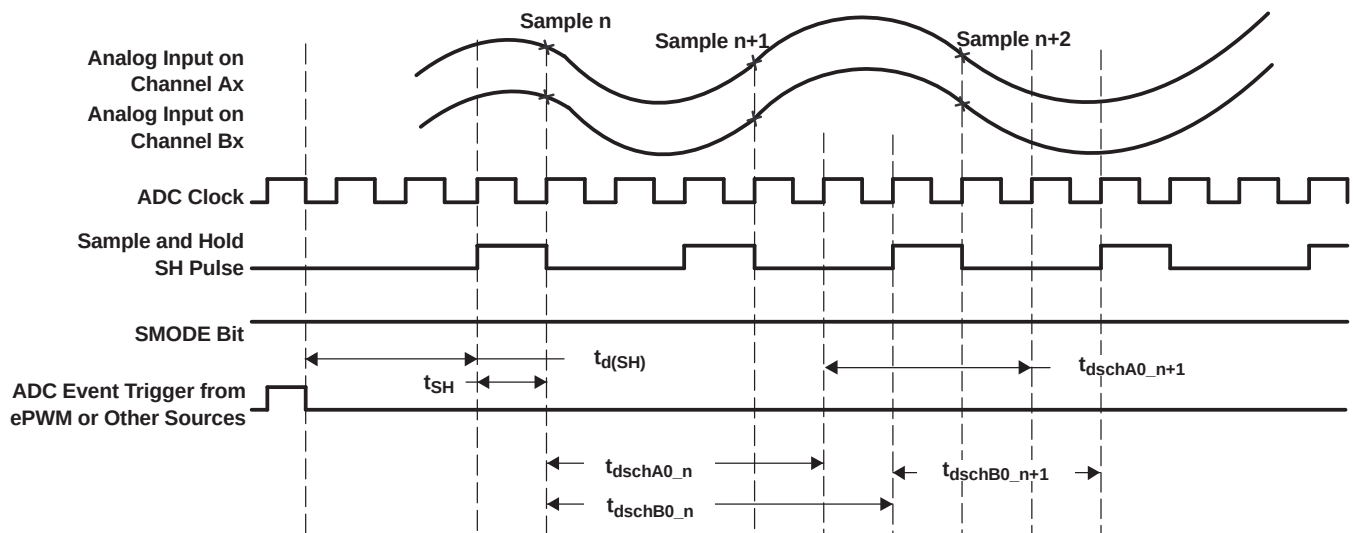


Figure 5-40. Simultaneous Sampling Mode Timing

Table 5-69. Simultaneous Sampling Mode Timing

|                     |                                                                | SAMPLE n                             | SAMPLE n + 1                         | AT 25-MHz<br>ADC CLOCK,<br>$t_{c(ADCCLK)} = 40 \text{ ns}$ | REMARKS                             |
|---------------------|----------------------------------------------------------------|--------------------------------------|--------------------------------------|------------------------------------------------------------|-------------------------------------|
| $t_{d(SH)}$         | Delay time from event trigger to sampling                      | $2.5t_{c(ADCCLK)}$                   |                                      |                                                            |                                     |
| $t_{SH}$            | Sample/Hold width/Acquisition Width                            | $(1 + \text{Acqps}) * t_{c(ADCCLK)}$ |                                      | 40 ns with Acqps = 0                                       | Acqps value = 0-15<br>ADCTRL1[8:11] |
| $t_{d(schA0\_n)}$   | Delay time for first result to appear in Result register       | $4t_{c(ADCCLK)}$                     |                                      | 160 ns                                                     |                                     |
| $t_{d(schB0\_n)}$   | Delay time for first result to appear in Result register       | $5t_{c(ADCCLK)}$                     |                                      | 200 ns                                                     |                                     |
| $t_{d(schA0\_n+1)}$ | Delay time for successive results to appear in Result register |                                      | $(3 + \text{Acqps}) * t_{c(ADCCLK)}$ | 120 ns                                                     |                                     |
| $t_{d(schB0\_n+1)}$ | Delay time for successive results to appear in Result register |                                      | $(3 + \text{Acqps}) * t_{c(ADCCLK)}$ | 120 ns                                                     |                                     |

### 5.10.5 Detailed Descriptions

#### Integral Nonlinearity

Integral nonlinearity refers to the deviation of each individual code from a line drawn from zero through full scale. The point used as zero occurs one-half LSB before the first code transition. The full-scale point is defined as level one-half LSB beyond the last code transition. The deviation is measured from the center of each particular code to the true straight line between these two points.

#### Differential Nonlinearity

An ideal ADC exhibits code transitions that are exactly 1 LSB apart. DNL is the deviation from this ideal value. A differential nonlinearity error of less than  $\pm 1$  LSB ensures no missing codes.

#### Zero Offset

The major carry transition should occur when the analog input is at zero volts. Zero error is defined as the deviation of the actual transition from that point.

#### Gain Error

The first code transition should occur at an analog value one-half LSB above negative full scale. The last transition should occur at an analog value one and one-half LSB below the nominal full scale. Gain error is the deviation of the actual difference between first and last code transitions and the ideal difference between first and last code transitions.

#### Signal-to-Noise Ratio + Distortion (SINAD)

SINAD is the ratio of the rms value of the measured input signal to the rms sum of all other spectral components below the Nyquist frequency, including harmonics but excluding dc. The value for SINAD is expressed in decibels.

#### Effective Number of Bits (ENOB)

For a sine wave, SINAD can be expressed in terms of the number of bits. Using the following formula,  $N = \frac{(\text{SINAD} - 1.76)}{6.02}$  it is possible to get a measure of performance expressed as N, the effective number of bits. Thus, effective number of bits for a device for sine wave inputs at a given input frequency can be calculated directly from its measured SINAD.

#### Total Harmonic Distortion (THD)

THD is the ratio of the rms sum of the first nine harmonic components to the rms value of the measured input signal and is expressed as a percentage or in decibels.

#### Spurious Free Dynamic Range (SFDR)

SFDR is the difference in dB between the rms amplitude of the input signal and the peak spurious signal.

## 5.11 Migrating Between F2833x Devices and F2823x Devices

The principal difference between these two devices is the absence of the floating-point unit (FPU) in the F2823x devices. This section describes how to build an application for each:

- For F2833x devices:
  - Code Composer Studio 3.3 with Service Release 9 or later is required for debug support of C28x + floating-point devices.
  - Use `-v28 --float_support = fpu32` compiler options. The `--float_support` option is available in compiler v5.0.2 or later. In Code Composer Studio, the `--float_support` option is located on the advanced tab of the compiler options (Project → Build\_Options → Compiler → Advanced tab).
  - Include the compiler's run-time support library for native 32-bit floating-point. For example, use `rts2800_fpu32.lib` for C code or `rts2800_fpu32_eh.lib` for C++ code.
  - Consider using the [C28x FPU Fast RTS Library](#) for high-performance floating-point math functions such as `sin`, `cos`, `div`, `sqrt`, and `atan`. The Fast RTS library should be linked in before the normal run-time support library.
- For F2823x devices:
  - Either leave off the `--float_support` switch or use `-v28 --float_support=none`
  - Include the appropriate run-time support library for fixed point code. For example, use `rts2800_ml.lib` for C code or `rts2800_ml_eh.lib` for C++ code.
  - Consider using the [C28x IQmath library - A Virtual Floating Point Engine](#) to achieve a performance boost from math functions such as `sin`, `cos`, `div`, `sqrt`, and `atan`.  
Code built in this manner will also run on F2833x devices, but it will not make use of the on-chip floating-point unit.

In either case, to allow for quick portability between native floating-point and fixed-point devices, TI suggests writing your code using the IQmath macro language described in C28x IQMath Library.

## 6 Detailed Description

### 6.1 Brief Descriptions

#### 6.1.1 C28x CPU

The F2833x (C28x+FPU)/F2823x (C28x) family is a member of the TMS320C2000™ digital signal controller (DSC) platform. The C28x+FPU based controllers have the same 32-bit fixed-point architecture as TI's existing C28x DSCs, but also include a single-precision (32-bit) IEEE 754 floating-point unit (FPU). It is a very efficient C/C++ engine, enabling users to develop their system control software in a high-level language. It also enables math algorithms to be developed using C/C++. The device is as efficient at DSP math tasks as it is at system control tasks that typically are handled by microcontroller devices. This efficiency removes the need for a second processor in many systems. The 32 × 32-bit MAC 64-bit processing capabilities enable the controller to handle higher numerical resolution problems efficiently. Add to this the fast interrupt response with automatic context save of critical registers, resulting in a device that is capable of servicing many asynchronous events with minimal latency. The device has an 8-level-deep protected pipeline with pipelined memory accesses. This pipelining enables it to execute at high speeds without resorting to expensive high-speed memories. Special branch-look-ahead hardware minimizes the latency for conditional discontinuities. Special store conditional operations further improve performance.

The F2823x family is also a member of the TMS320C2000™ digital signal controller (DSC) platform but it does not include a floating-point unit (FPU).

#### 6.1.2 Memory Bus (Harvard Bus Architecture)

As with many DSC type devices, multiple buses are used to move data between the memories and peripherals and the CPU. The C28x memory bus architecture contains a program read bus, data read bus and data write bus. The program read bus consists of 22 address lines and 32 data lines. The data read and write buses consist of 32 address lines and 32 data lines each. The 32-bit-wide data buses enable single cycle 32-bit operations. The multiple bus architecture, commonly termed Harvard Bus, enables the C28x to fetch an instruction, read a data value and write a data value in a single cycle. All peripherals and memories attached to the memory bus will prioritize memory accesses. Generally, the priority of memory bus accesses can be summarized as follows:

|          |                |                                                                          |
|----------|----------------|--------------------------------------------------------------------------|
| Highest: | Data Writes    | (Simultaneous data and program writes cannot occur on the memory bus.)   |
|          | Program Writes | (Simultaneous data and program writes cannot occur on the memory bus.)   |
|          | Data Reads     |                                                                          |
|          | Program Reads  | (Simultaneous program reads and fetches cannot occur on the memory bus.) |
| Lowest:  | Fetches        | (Simultaneous program reads and fetches cannot occur on the memory bus.) |

#### 6.1.3 Peripheral Bus

To enable migration of peripherals between various TI DSC family of devices, the 2833x/2823x devices adopt a peripheral bus standard for peripheral interconnect. The peripheral bus bridge multiplexes the various buses that make up the processor Memory Bus into a single bus consisting of 16 address lines and 16 or 32 data lines and associated control signals. Three versions of the peripheral bus are supported. One version supports only 16-bit accesses (called peripheral frame 2). Another version supports both 16- and 32-bit accesses (called peripheral frame 1). The third version supports DMA access and both 16- and 32-bit accesses (called peripheral frame 3).

### 6.1.4 Real-Time JTAG and Analysis

The 2833x/2823x devices implement the standard IEEE 1149.1 JTAG interface. Additionally, the devices support real-time mode of operation whereby the contents of memory, peripheral and register locations can be modified while the processor is running and executing code and servicing interrupts. The user can also single step through nontime-critical code while enabling time-critical interrupts to be serviced without interference. The device implements the real-time mode in hardware within the CPU. This is a feature unique to the 2833x/2823x device, requiring no software monitor. Additionally, special analysis hardware is provided that allows setting of hardware breakpoint or data/address watch-points and generate various user-selectable break events when a match occurs.

### 6.1.5 External Interface (XINTF)

This asynchronous interface consists of 20 address lines, 32 data lines, and three chip-select lines. The chip-select lines are mapped to three external zones, Zones 0, 6, and 7. Each of the three zones can be programmed with a different number of wait states, strobe signal setup and hold timing and each zone can be programmed for extending wait states externally or not. The programmable wait state, chip-select and programmable strobe timing enables glueless interface to external memories and peripherals.

### 6.1.6 Flash

The F28335/F28333/F28235 devices contain 256K × 16 of embedded flash memory, segregated into eight 32K × 16 sectors. The F28334/F28234 devices contain 128K × 16 of embedded flash memory, segregated into eight 16K × 16 sectors. The F28332/F28232 devices contain 64K × 16 of embedded flash, segregated into four 16K × 16 sectors. All the devices also contain a single 1K × 16 of OTP memory at address range 0x380400–0x3807FF. The user can individually erase, program, and validate a flash sector while leaving other sectors untouched. However, it is not possible to use one sector of the flash or the OTP to execute flash algorithms that erase/program other sectors. Special memory pipelining is provided to enable the flash module to achieve higher performance. The flash/OTP is mapped to both program and data space; therefore, it can be used to execute code or store data information. Note that addresses 0x33FFF0–0x33FFF5 are reserved for data variables and should not contain program code.

#### NOTE

The Flash and OTP wait-states can be configured by the application. This allows applications running at slower frequencies to configure the flash to use fewer wait-states.

Flash effective performance can be improved by enabling the flash pipeline mode in the Flash options register. With this mode enabled, effective performance of linear code execution will be much faster than the raw performance indicated by the wait-state configuration alone. The exact performance gain when using the Flash pipeline mode is application-dependent.

For more information on the Flash options, Flash wait-state, and OTP wait-state registers, see the [TMS320x2833x, 2823x system control and interrupts reference guide](#).

### 6.1.7 M0, M1 SARAMs

All 2833x/2823x devices contain these two blocks of single access memory, each 1K × 16 in size. The stack pointer points to the beginning of block M1 on reset. The M0 and M1 blocks, like all other memory blocks on C28x devices, are mapped to both program and data space. Hence, the user can use M0 and M1 to execute code or for data variables. The partitioning is performed within the linker. The C28x device presents a unified memory map to the programmer. This makes for easier programming in high-level languages.

### 6.1.8 L0, L1, L2, L3, L4, L5, L6, L7 SARAMs

The F28335/F28333/F28235 and F28334/F28234 each contain 32K × 16 of single-access RAM, divided into 8 blocks (L0–L7 with 4K each). The F28332/F28232 contain 24K × 16 of single-access RAM, divided into 6 blocks (L0–L5 with 4K each). Each block can be independently accessed to minimize CPU pipeline stalls. Each block is mapped to both program and data space. L4, L5, L6, and L7 are DMA-accessible.

### 6.1.9 Boot ROM

The Boot ROM is factory-programmed with boot-loading software. Boot-mode signals are provided to tell the bootloader software what boot mode to use on power up. The user can select to boot normally or to download new software from an external connection or to select boot software that is programmed in the internal Flash/ROM. The Boot ROM also contains standard tables, such as SIN/COS waveforms, for use in math related algorithms.

**Table 6-1. Boot Mode Selection**

| MODE | GPIO87/XA15 | GPIO86/XA14 | GPIO85/XA13 | GPIO84/XA12 | MODE <sup>(1)</sup>                   |
|------|-------------|-------------|-------------|-------------|---------------------------------------|
| F    | 1           | 1           | 1           | 1           | Jump to Flash                         |
| E    | 1           | 1           | 1           | 0           | SCI-A boot                            |
| D    | 1           | 1           | 0           | 1           | SPI-A boot                            |
| C    | 1           | 1           | 0           | 0           | I2C-A boot                            |
| B    | 1           | 0           | 1           | 1           | eCAN-A boot                           |
| A    | 1           | 0           | 1           | 0           | McBSP-A boot                          |
| 9    | 1           | 0           | 0           | 1           | Jump to XINTF x16                     |
| 8    | 1           | 0           | 0           | 0           | Jump to XINTF x32                     |
| 7    | 0           | 1           | 1           | 1           | Jump to OTP                           |
| 6    | 0           | 1           | 1           | 0           | Parallel GPIO I/O boot                |
| 5    | 0           | 1           | 0           | 1           | Parallel XINTF boot                   |
| 4    | 0           | 1           | 0           | 0           | Jump to SARAM                         |
| 3    | 0           | 0           | 1           | 1           | Branch to check boot mode             |
| 2    | 0           | 0           | 1           | 0           | Branch to Flash, skip ADC calibration |
| 1    | 0           | 0           | 0           | 1           | Branch to SARAM, skip ADC calibration |
| 0    | 0           | 0           | 0           | 0           | Branch to SCI, skip ADC calibration   |

(1) All four GPIO pins have an internal pullup.

#### NOTE

Modes 0, 1, and 2 in [Table 6-1](#) are for TI debug only. Skipping the ADC calibration function in an application will cause the ADC to operate outside of the stated specifications

### 6.1.9.1 Peripheral Pins Used by the Bootloader

Table 6-2 shows which GPIO pins are used by each peripheral bootloader. Refer to the GPIO mux table to see if these conflict with any of the peripherals you would like to use in your application.

**Table 6-2. Peripheral Bootload Pins**

| BOOTLOADER | PERIPHERAL LOADER PINS                                                                                 |
|------------|--------------------------------------------------------------------------------------------------------|
| SCI-A      | SCIRXDA (GPIO28)<br>SCITXDA (GPIO29)                                                                   |
| SPI-A      | SPISIMOA (GPIO16)<br>SPISOMIA (GPIO17)<br>SPICLKA (GPIO18)<br>SPISTEA (GPIO19)                         |
| I2C        | SDAA (GPIO32)<br>SCLA (GPIO33)                                                                         |
| CAN        | CANRXA (GPIO30)<br>CANTXA (GPIO31)                                                                     |
| McBSP      | MDXA (GPIO20)<br>MDRA (GPIO21)<br>MCLKXA (GPIO22)<br>MFSXA (GPIO23)<br>MCLKRA (GPIO7)<br>MFSRA (GPIO5) |

### 6.1.10 Security

The devices support high levels of security to protect the user firmware from being reverse engineered. The security features a 128-bit password (hardcoded for 16 wait-states), which the user programs into the flash. One code security module (CSM) is used to protect the flash/OTP and the L0/L1/L2/L3 SARAM blocks. The security feature prevents unauthorized users from examining the memory contents via the JTAG port, executing code from external memory or trying to boot-load some undesirable software that would export the secure memory contents. To enable access to the secure blocks, the user must write the correct 128-bit KEY value, which matches the value stored in the password locations within the Flash.

In addition to the CSM, the emulation code security logic (ECSL) has been implemented to prevent unauthorized users from stepping through secure code. Any code or data access to flash, user OTP, L0, L1, L2, or L3 memory while the emulator is connected will trip the ECSL and break the emulation connection. To allow emulation of secure code, while maintaining the CSM protection against secure memory reads, the user must write the correct value into the lower 64 bits of the KEY register, which matches the value stored in the lower 64 bits of the password locations within the flash. Note that dummy reads of all 128 bits of the password in the flash must still be performed. If the lower 64 bits of the password locations are all ones (unprogrammed), then the KEY value does not need to match.

When initially debugging a device with the password locations in flash programmed (that is, secured), the emulator takes some time to take control of the CPU. During this time, the CPU will start running and may execute an instruction that performs an access to a protected ECSL area. If this happens, the ECSL will trip and cause the emulator connection to be cut. Two solutions to this problem exist:

1. The first is to use the Wait-In-Reset emulation mode, which will hold the device in reset until the emulator takes control. The emulator must support this mode for this option.
2. The second option is to use the “Branch to check boot mode” boot option. This will sit in a loop and continuously poll the boot mode select pins. The user can select this boot mode and then exit this mode once the emulator is connected by re-mapping the PC to another address or by changing the boot mode selection pin to the desired boot mode.

---

**NOTE**

- When the code-security passwords are programmed, all addresses from 0x33FF80 to 0x33FFF5 cannot be used as program code or data. These locations must be programmed to 0x0000.
- If the code security feature is not used, addresses 0x33FF80 to 0x33FFEF may be used for code or data. Addresses 0x33FFF0 to 0x33FFF5 are reserved for data and should not contain program code.

The 128-bit password (at 0x33FFF8 to 0x33FFFF) must not be programmed to zeros. Doing so would permanently lock the device.

---

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**Code Security Module Disclaimer**

THE CODE SECURITY MODULE (CSM) INCLUDED ON THIS DEVICE WAS DESIGNED TO PASSWORD PROTECT THE DATA STORED IN THE ASSOCIATED MEMORY (EITHER ROM OR FLASH) AND IS WARRANTED BY TEXAS INSTRUMENTS (TI), IN ACCORDANCE WITH ITS STANDARD TERMS AND CONDITIONS, TO CONFORM TO TI'S PUBLISHED SPECIFICATIONS FOR THE WARRANTY PERIOD APPLICABLE FOR THIS DEVICE.

TI DOES NOT, HOWEVER, WARRANT OR REPRESENT THAT THE CSM CANNOT BE COMPROMISED OR BREACHED OR THAT THE DATA STORED IN THE ASSOCIATED MEMORY CANNOT BE ACCESSED THROUGH OTHER MEANS. MOREOVER, EXCEPT AS SET FORTH ABOVE, TI MAKES NO WARRANTIES OR REPRESENTATIONS CONCERNING THE CSM OR OPERATION OF THIS DEVICE, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

IN NO EVENT SHALL TI BE LIABLE FOR ANY CONSEQUENTIAL, SPECIAL, INDIRECT, INCIDENTAL, OR PUNITIVE DAMAGES, HOWEVER CAUSED, ARISING IN ANY WAY OUT OF YOUR USE OF THE CSM OR THIS DEVICE, WHETHER OR NOT TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO LOSS OF DATA, LOSS OF GOODWILL, LOSS OF USE OR INTERRUPTION OF BUSINESS OR OTHER ECONOMIC LOSS.

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### 6.1.11 Peripheral Interrupt Expansion (PIE) Block

The PIE block serves to multiplex numerous interrupt sources into a smaller set of interrupt inputs. The PIE block can support up to 96 peripheral interrupts. On the 2833x/2823x, 58 of the possible 96 interrupts are used by peripherals. The 96 interrupts are grouped into blocks of 8 and each group is fed into 1 of 12 CPU interrupt lines (INT1 to INT12). Each of the 96 interrupts is supported by its own vector stored in a dedicated RAM block that can be overwritten by the user. The vector is automatically fetched by the CPU on servicing the interrupt. It takes eight CPU clock cycles to fetch the vector and save critical CPU registers. Hence the CPU can quickly respond to interrupt events. Prioritization of interrupts is controlled in hardware and software. Each individual interrupt can be enabled or disabled within the PIE block.

### 6.1.12 External Interrupts (XINT1–XINT7, XNMI)

The devices support eight masked external interrupts (XINT1–XINT7, XNMI). XNMI can be connected to the INT13 or NMI interrupt of the CPU. Each of the interrupts can be selected for negative, positive, or both negative and positive edge triggering and can also be enabled or disabled (including the XNMI). XINT1, XINT2, and XNMI also contain a 16-bit free-running up counter, which is reset to zero when a valid interrupt edge is detected. This counter can be used to accurately time-stamp the interrupt. Unlike the 281x devices, there are no dedicated pins for the external interrupts. XINT1, XINT2, and XNMI interrupts can accept inputs from GPIO0–GPIO31 pins. XINT3–XINT7 interrupts can accept inputs from GPIO32–GPIO63 pins.

### 6.1.13 Oscillator and PLL

The device can be clocked by an external oscillator or by a crystal attached to the on-chip oscillator circuit. A PLL is provided supporting up to 10 input-clock-scaling ratios. The PLL ratios can be changed on-the-fly in software, enabling the user to scale back on operating frequency if lower power operation is desired. Refer to [Section 5.9.4.4](#) for timing details. The PLL block can be set in bypass mode.

### 6.1.14 Watchdog

The devices contain a watchdog timer. The user software must regularly reset the watchdog counter within a certain time frame; otherwise, the watchdog will generate a reset to the processor. The watchdog can be disabled if necessary.

### 6.1.15 Peripheral Clocking

The clocks to each individual peripheral can be enabled or disabled so as to reduce power consumption when a peripheral is not in use. Additionally, the system clock to the serial ports (except I2C and eCAN) and the ADC blocks can be scaled relative to the CPU clock. This enables the timing of peripherals to be decoupled from increasing CPU clock speeds.

### 6.1.16 Low-Power Modes

The devices are full static CMOS devices. Three low-power modes are provided:

- IDLE:** Place CPU into low-power mode. Peripheral clocks may be turned off selectively and only those peripherals that need to function during IDLE are left operating. An enabled interrupt from an active peripheral or the watchdog timer will wake the processor from IDLE mode.
- STANDBY:** Turns off clock to CPU and peripherals. This mode leaves the oscillator and PLL functional. An external interrupt event will wake the processor and the peripherals. Execution begins on the next valid cycle after detection of the interrupt event
- HALT:** Turns off the internal oscillator. This mode basically shuts down the device and places it in the lowest possible power consumption mode. A reset or external signal can wake the device from this mode.

### 6.1.17 Peripheral Frames 0, 1, 2, 3 (PFn)

The device segregates peripherals into four sections. The mapping of peripherals is as follows:

|      |         |                                                                   |
|------|---------|-------------------------------------------------------------------|
| PF0: | PIE:    | PIE Interrupt Enable and Control Registers Plus PIE Vector Table  |
|      | Flash:  | Flash Waitstate Registers                                         |
|      | XINTF:  | External Interface Registers                                      |
|      | DMA     | DMA Registers                                                     |
|      | Timers: | CPU-Timers 0, 1, 2 Registers                                      |
|      | CSM:    | Code Security Module KEY Registers                                |
|      | ADC:    | ADC Result Registers (dual-mapped)                                |
| PF1: | eCAN:   | eCAN Mailbox and Control Registers                                |
|      | GPIO:   | GPIO MUX Configuration and Control Registers                      |
|      | ePWM:   | Enhanced Pulse Width Modulator Module and Registers (dual mapped) |
|      | eCAP:   | Enhanced Capture Module and Registers                             |
|      | eQEP:   | Enhanced Quadrature Encoder Pulse Module and Registers            |
| PF2: | SYS:    | System Control Registers                                          |
|      | SCI:    | Serial Communications Interface (SCI) Control and RX/TX Registers |
|      | SPI:    | Serial Port Interface (SPI) Control and RX/TX Registers           |
|      | ADC:    | ADC Status, Control, and Result Register                          |
|      | I2C:    | Inter-Integrated Circuit Module and Registers                     |
|      | XINT    | External Interrupt Registers                                      |
| PF3: | McBSP   | Multichannel Buffered Serial Port Registers                       |
|      | ePWM:   | Enhanced Pulse Width Modulator Module and Registers (dual mapped) |

### 6.1.18 General-Purpose Input/Output (GPIO) Multiplexer

Most of the peripheral signals are multiplexed with GPIO signals. This enables the user to use a pin as GPIO if the peripheral signal or function is not used. On reset, GPIO pins are configured as inputs. The user can individually program each pin for GPIO mode or peripheral signal mode. For specific inputs, the user can also select the number of input qualification cycles. This is to filter unwanted noise glitches. The GPIO signals can also be used to bring the device out of specific low-power modes.

### 6.1.19 32-Bit CPU-Timers (0, 1, 2)

CPU-Timers 0, 1, and 2 are identical 32-bit timers with presetable periods and with 16-bit clock prescaling. The timers have a 32-bit count down register, which generates an interrupt when the counter reaches zero. The counter is decremented at the CPU clock speed divided by the prescale value setting. When the counter reaches zero, it is automatically reloaded with a 32-bit period value. CPU-Timer 2 is reserved for Real-Time OS (RTOS)/BIOS applications. It is connected to INT14 of the CPU. If DSP/BIOS or SYS/BIOS is not being used, CPU-Timer 2 is available for general use. CPU-Timer 1 is for general use and can be connected to INT13 of the CPU. CPU-Timer 0 is also for general use and is connected to the PIE block.

### 6.1.20 Control Peripherals

The 2833x/2823x devices support the following peripherals which are used for embedded control and communication:

- ePWM: The enhanced PWM peripheral supports independent and complementary PWM generation, adjustable dead-band generation for leading and trailing edges, latched and cycle-by-cycle trip mechanism. Some of the PWM pins support HRPWM features. The ePWM registers are supported by the DMA to reduce the overhead for servicing this peripheral.
- eCAP: The enhanced capture peripheral uses a 32-bit time base and registers up to four programmable events in continuous/one-shot capture modes. This peripheral can also be configured to generate an auxiliary PWM signal.
- eQEP: The enhanced QEP peripheral uses a 32-bit position counter, supports low-speed measurement using capture unit and high-speed measurement using a 32-bit unit timer. This peripheral has a watchdog timer to detect motor stall and input error detection logic to identify simultaneous edge transition in QEP signals.
- ADC: The ADC block is a 12-bit converter, single ended, 16-channels. It contains two sample-and-hold units for simultaneous sampling. The ADC registers are supported by the DMA to reduce the overhead for servicing this peripheral.

### 6.1.21 Serial Port Peripherals

The devices support the following serial communication peripherals:

- eCAN: This is the enhanced version of the CAN peripheral. It supports 32 mailboxes, time-stamping of messages, and is compliant with ISO 11898-1 (CAN 2.0B).
- McBSP: The multichannel buffered serial port (McBSP) connects to E1/T1 lines, phone-quality codecs for modem applications or high-quality stereo audio DAC devices. The McBSP receive and transmit registers are supported by the DMA to significantly reduce the overhead for servicing this peripheral. Each McBSP module can be configured as an SPI as required.
- SPI: The SPI is a high-speed, synchronous serial I/O port that allows a serial bit stream of programmed length (1 to 16 bits) to be shifted into and out of the device at a programmable bit-transfer rate. Normally, the SPI is used for communications between the DSC and external peripherals or another processor. Typical applications include external I/O or peripheral expansion through devices such as shift registers, display drivers, and ADCs. Multidevice communications are supported by the master/slave operation of the SPI. On the 2833x/2823x, the SPI contains a 16-level receive and transmit FIFO for reducing interrupt servicing overhead.
- SCI: The serial communications interface is a 2-wire asynchronous serial port, commonly known as UART. The SCI contains a 16-level receive and transmit FIFO for reducing interrupt servicing overhead.
- I2C: The inter-integrated circuit (I2C) module provides an interface between a DSC and other devices compliant with Philips Semiconductors Inter-IC bus (I2C-bus) specification version 2.1 and connected by way of an I2C-bus. External components attached to this 2-wire serial bus can transmit/receive up to 8-bit data to/from the DSC through the I2C module. On the 2833x/2823x, the I2C contains a 16-level receive and transmit FIFO for reducing interrupt servicing overhead.

## 6.2 Peripherals

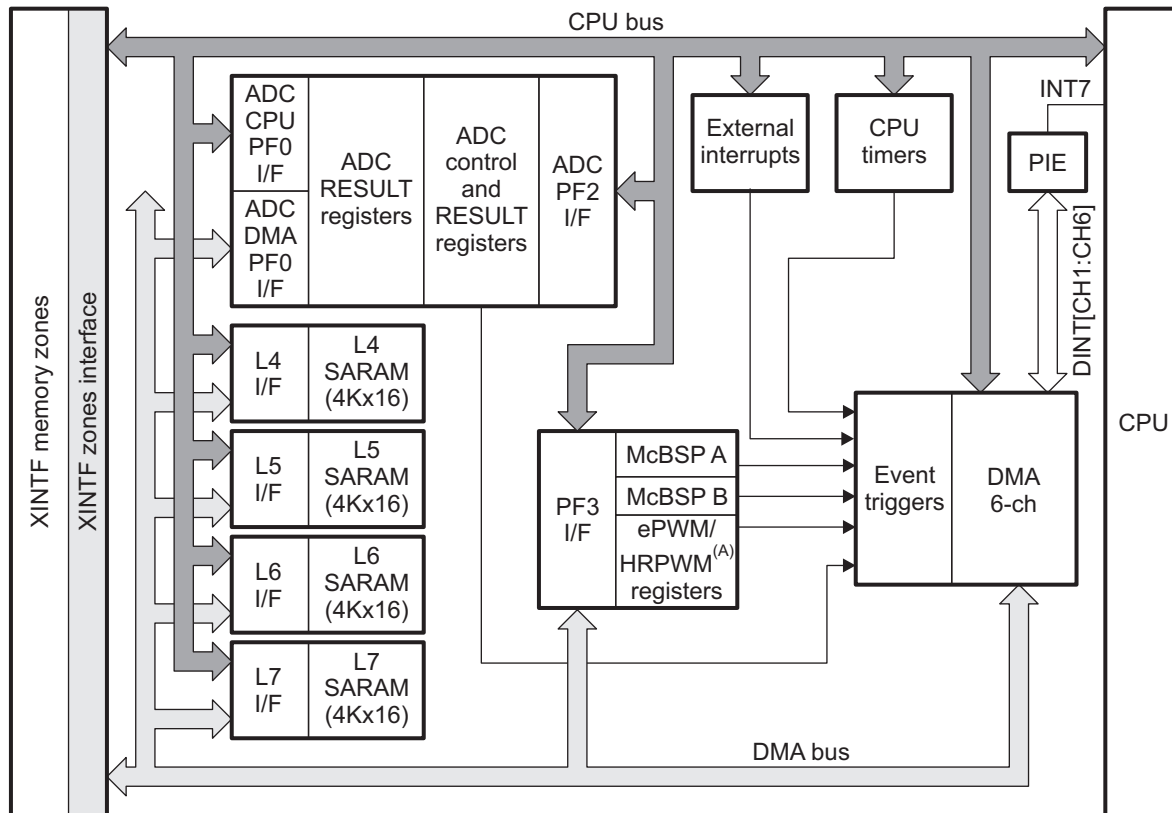
The integrated peripherals of the 2833x and 2823x devices are described in the following subsections:

- 6-channel Direct Memory Access (DMA)
- Three 32-bit CPU-Timers
- Up to six enhanced PWM modules (ePWM1, ePWM2, ePWM3, ePWM4, ePWM5, ePWM6)
- Up to six enhanced capture modules (eCAP1, eCAP2, eCAP3, eCAP4, eCAP5, eCAP6)
- Up to two enhanced QEP modules (eQEP1, eQEP2)
- Enhanced analog-to-digital converter (ADC) module
- Up to two enhanced controller area network (eCAN) modules (eCAN-A, eCAN-B)
- Up to three serial communications interface modules (SCI-A, SCI-B, SCI-C)
- One serial peripheral interface (SPI) module (SPI-A)
- Inter-integrated circuit (I2C) module
- Up to two multichannel buffered serial port (McBSP-A, McBSP-B) modules
- Digital I/O and shared pin functions
- External Interface (XINTF)

### 6.2.1 DMA Overview

Features:

- 6 channels with independent PIE interrupts
- Trigger sources:
  - ePWM SOCA/SOCB
  - ADC Sequencer 1 and Sequencer 2
  - McBSP-A and McBSP-B transmit and receive logic
  - XINT1–7 and XINT13
  - CPU timers
  - Software
- Data sources and destinations:
  - L4–L7 16K × 16 SARAM
  - All XINTF zones
  - ADC Memory Bus mapped RESULT registers
  - McBSP-A and McBSP-B transmit and receive buffers
  - ePWM registers
- Word Size: 16-bit or 32-bit (McBSPs limited to 16-bit)
- Throughput: 4 cycles/word (5 cycles/word for McBSP reads)



- A. The ePWM and HRPWM registers must be remapped to PF3 (through bit 0 of the MAPCNF register) before they can be accessed by the DMA. The ePWM or HRPWM connection to DMA is not present in silicon revision 0.

**Figure 6-1. DMA Functional Block Diagram**

## 6.2.2 32-Bit CPU-Timer 0, CPU-Timer 1, CPU-Timer 2

There are three 32-bit CPU-timers on the devices (CPU-Timer 0, CPU-Timer 1, CPU-Timer 2).

CPU-Timer 2 is reserved for DSP/BIOS or SYS/BIOS. CPU-Timer 0 and CPU-Timer 1 can be used in user applications. These timers are different from the timers that are present in the ePWM modules.

### NOTE

If the application is not using DSP/BIOS or SYS/BIOS, then CPU-Timer 2 can be used in the application.

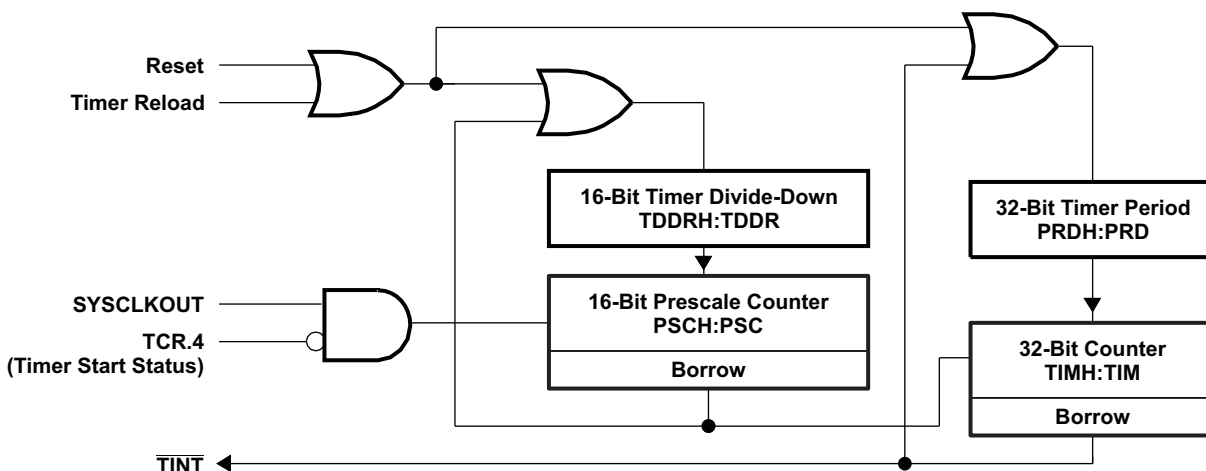
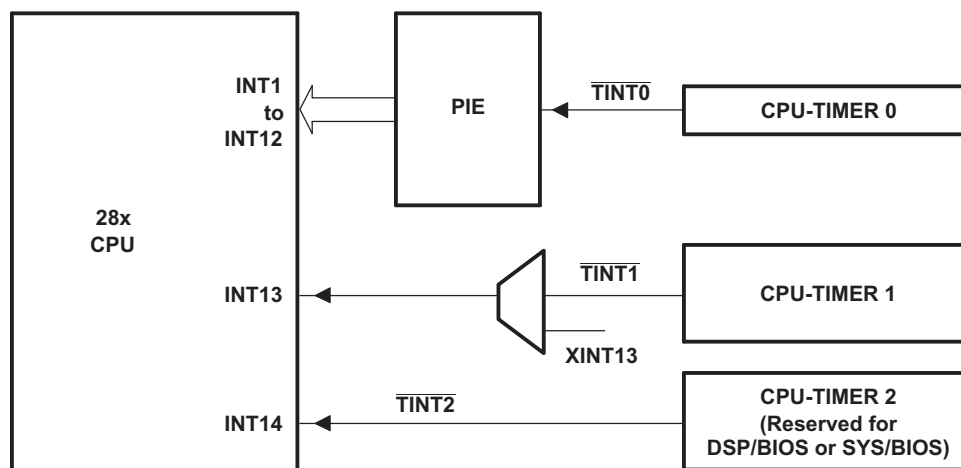


Figure 6-2. CPU-Timers

The timer interrupt signals ( $\overline{TINT0}$ ,  $\overline{TINT1}$ ,  $\overline{TINT2}$ ) are connected as shown in Figure 6-3.



- A. The timer registers are connected to the memory bus of the C28x processor.
- B. The timing of the timers is synchronized to SYSCLKOUT of the processor clock.

Figure 6-3. CPU-Timer Interrupt Signals and Output Signal

The general operation of the timer is as follows: The 32-bit counter register "TIMH:TIM" is loaded with the value in the period register "PRDH:PRD". The counter register decrements at the SYSCLKOUT rate of the C28x. When the counter reaches 0, a timer interrupt output signal generates an interrupt pulse. The registers listed in Table 6-3 are used to configure the timers. For more information, see the [TMS320x2833x, 2823x system control and interrupts reference guide](#).

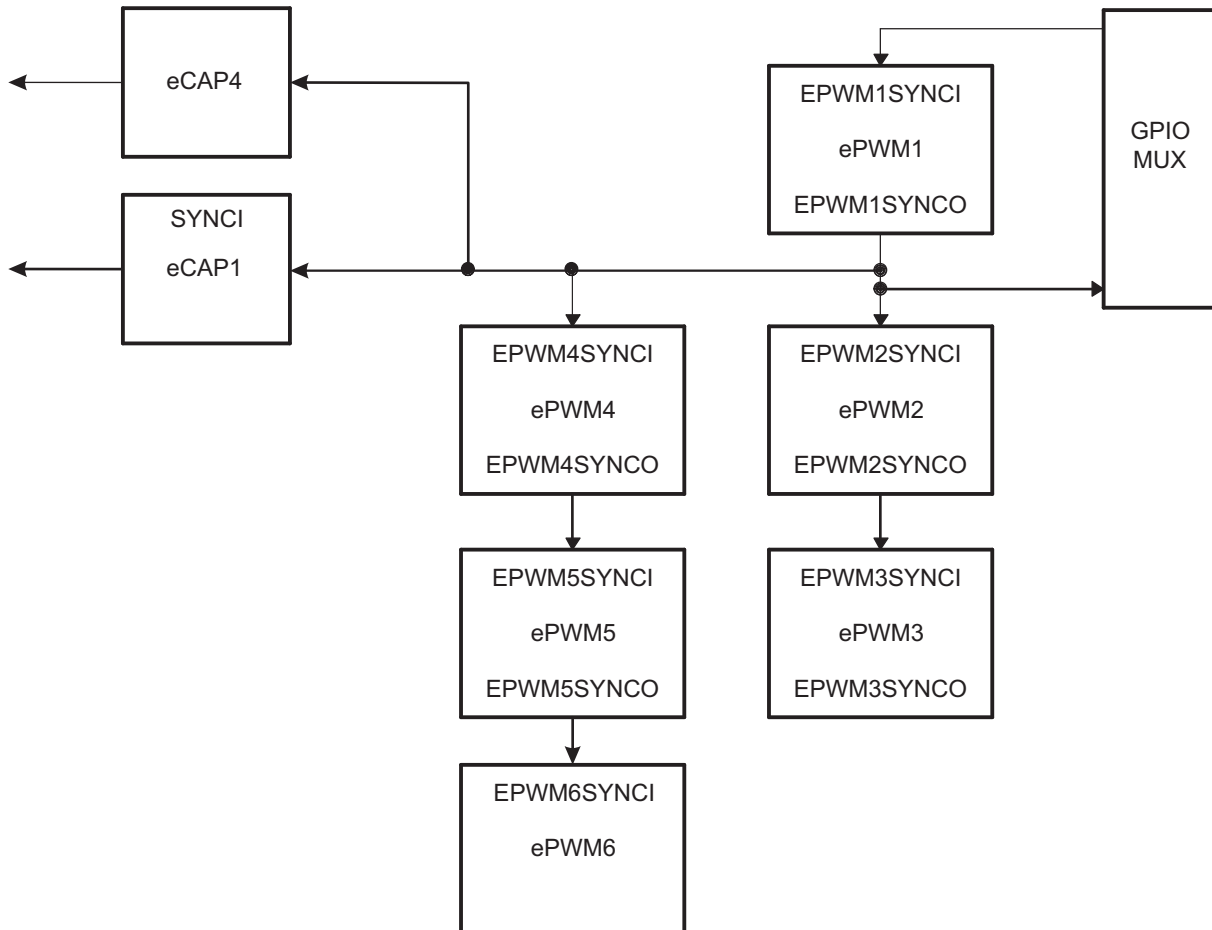
**Table 6-3. CPU-Timers 0, 1, 2 Configuration and Control Registers**

| NAME       | ADDRESS         | SIZE (x16) | DESCRIPTION                         |
|------------|-----------------|------------|-------------------------------------|
| TIMER0TIM  | 0x0C00          | 1          | CPU-Timer 0, Counter Register       |
| TIMER0TIMH | 0x0C01          | 1          | CPU-Timer 0, Counter Register High  |
| TIMER0PRD  | 0x0C02          | 1          | CPU-Timer 0, Period Register        |
| TIMER0PRDH | 0x0C03          | 1          | CPU-Timer 0, Period Register High   |
| TIMER0TCR  | 0x0C04          | 1          | CPU-Timer 0, Control Register       |
| Reserved   | 0x0C05          | 1          |                                     |
| TIMER0TPR  | 0x0C06          | 1          | CPU-Timer 0, Prescale Register      |
| TIMER0TPRH | 0x0C07          | 1          | CPU-Timer 0, Prescale Register High |
| TIMER1TIM  | 0x0C08          | 1          | CPU-Timer 1, Counter Register       |
| TIMER1TIMH | 0x0C09          | 1          | CPU-Timer 1, Counter Register High  |
| TIMER1PRD  | 0x0C0A          | 1          | CPU-Timer 1, Period Register        |
| TIMER1PRDH | 0x0C0B          | 1          | CPU-Timer 1, Period Register High   |
| TIMER1TCR  | 0x0C0C          | 1          | CPU-Timer 1, Control Register       |
| Reserved   | 0x0C0D          | 1          |                                     |
| TIMER1TPR  | 0x0C0E          | 1          | CPU-Timer 1, Prescale Register      |
| TIMER1TPRH | 0x0C0F          | 1          | CPU-Timer 1, Prescale Register High |
| TIMER2TIM  | 0x0C10          | 1          | CPU-Timer 2, Counter Register       |
| TIMER2TIMH | 0x0C11          | 1          | CPU-Timer 2, Counter Register High  |
| TIMER2PRD  | 0x0C12          | 1          | CPU-Timer 2, Period Register        |
| TIMER2PRDH | 0x0C13          | 1          | CPU-Timer 2, Period Register High   |
| TIMER2TCR  | 0x0C14          | 1          | CPU-Timer 2, Control Register       |
| Reserved   | 0x0C15          | 1          |                                     |
| TIMER2TPR  | 0x0C16          | 1          | CPU-Timer 2, Prescale Register      |
| TIMER2TPRH | 0x0C17          | 1          | CPU-Timer 2, Prescale Register High |
| Reserved   | 0x0C18 – 0x0C3F | 40         |                                     |

### 6.2.3 Enhanced PWM Modules

The 2833x/2823x devices contain up to six enhanced PWM (ePWM) modules (ePWM1 to ePWM6). [Figure 6-4](#) shows the time-base counter synchronization scheme 3. [Figure 6-5](#) shows the signal interconnections with the ePWM.

[Table 6-4](#) shows the complete ePWM register set per module and [Table 6-5](#) shows the remapped register configuration.



- A. By default, ePWM and HRPWM registers are mapped to Peripheral Frame 1 (PF1). [Table 6-4](#) shows this configuration. To re-map the registers to Peripheral Frame 3 (PF3) to enable DMA access, bit 0 (MAPEPWM) of MAPCNF register (address 0x702E) must be set to 1. [Table 6-5](#) shows the remapped configuration.

**Figure 6-4. Time-Base Counter Synchronization Scheme 3**

**Table 6-4. ePWM Control and Status Registers (Default Configuration in PF1)**

| NAME    | ePWM1  | ePWM2  | ePWM3  | ePWM4  | ePWM5  | ePWM6  | SIZE (x16) / #SHADOW | DESCRIPTION                                           |
|---------|--------|--------|--------|--------|--------|--------|----------------------|-------------------------------------------------------|
| TBCTL   | 0x6800 | 0x6840 | 0x6880 | 0x68C0 | 0x6900 | 0x6940 | 1 / 0                | Time Base Control Register                            |
| TBSTS   | 0x6801 | 0x6841 | 0x6881 | 0x68C1 | 0x6901 | 0x6941 | 1 / 0                | Time Base Status Register                             |
| TBPHSHR | 0x6802 | 0x6842 | 0x6882 | 0x68C2 | 0x6902 | 0x6942 | 1 / 0                | Time Base Phase HRPWM Register                        |
| TBPHS   | 0x6803 | 0x6843 | 0x6883 | 0x68C3 | 0x6903 | 0x6943 | 1 / 0                | Time Base Phase Register                              |
| TBCTR   | 0x6804 | 0x6844 | 0x6884 | 0x68C4 | 0x6904 | 0x6944 | 1 / 0                | Time Base Counter Register                            |
| TBPRD   | 0x6805 | 0x6845 | 0x6885 | 0x68C5 | 0x6905 | 0x6945 | 1 / 1                | Time Base Period Register Set                         |
| CMPCTL  | 0x6807 | 0x6847 | 0x6887 | 0x68C7 | 0x6907 | 0x6947 | 1 / 0                | Counter Compare Control Register                      |
| CMPAHR  | 0x6808 | 0x6848 | 0x6888 | 0x68C8 | 0x6908 | 0x6948 | 1 / 1                | Time Base Compare A HRPWM Register                    |
| CMPA    | 0x6809 | 0x6849 | 0x6889 | 0x68C9 | 0x6909 | 0x6949 | 1 / 1                | Counter Compare A Register Set                        |
| CMPB    | 0x680A | 0x684A | 0x688A | 0x68CA | 0x690A | 0x694A | 1 / 1                | Counter Compare B Register Set                        |
| AQCTLA  | 0x680B | 0x684B | 0x688B | 0x68CB | 0x690B | 0x694B | 1 / 0                | Action Qualifier Control Register For Output A        |
| AQCTLB  | 0x680C | 0x684C | 0x688C | 0x68CC | 0x690C | 0x694C | 1 / 0                | Action Qualifier Control Register For Output B        |
| AQSFR   | 0x680D | 0x684D | 0x688D | 0x68CD | 0x690D | 0x694D | 1 / 0                | Action Qualifier Software Force Register              |
| AQCSFR  | 0x680E | 0x684E | 0x688E | 0x68CE | 0x690E | 0x694E | 1 / 1                | Action Qualifier Continuous S/W Force Register Set    |
| DBCTL   | 0x680F | 0x684F | 0x688F | 0x68CF | 0x690F | 0x694F | 1 / 1                | Dead-Band Generator Control Register                  |
| DBRED   | 0x6810 | 0x6850 | 0x6890 | 0x68D0 | 0x6910 | 0x6950 | 1 / 0                | Dead-Band Generator Rising Edge Delay Count Register  |
| DBFED   | 0x6811 | 0x6851 | 0x6891 | 0x68D1 | 0x6911 | 0x6951 | 1 / 0                | Dead-Band Generator Falling Edge Delay Count Register |
| TZSEL   | 0x6812 | 0x6852 | 0x6892 | 0x68D2 | 0x6912 | 0x6952 | 1 / 0                | Trip Zone Select Register <sup>(1)</sup>              |
| TZCTL   | 0x6814 | 0x6854 | 0x6894 | 0x68D4 | 0x6914 | 0x6954 | 1 / 0                | Trip Zone Control Register <sup>(1)</sup>             |
| TZEINT  | 0x6815 | 0x6855 | 0x6895 | 0x68D5 | 0x6915 | 0x6955 | 1 / 0                | Trip Zone Enable Interrupt Register <sup>(1)</sup>    |
| TZFLG   | 0x6816 | 0x6856 | 0x6896 | 0x68D6 | 0x6916 | 0x6956 | 1 / 0                | Trip Zone Flag Register                               |
| TZCLR   | 0x6817 | 0x6857 | 0x6897 | 0x68D7 | 0x6917 | 0x6957 | 1 / 0                | Trip Zone Clear Register <sup>(1)</sup>               |
| TZFRC   | 0x6818 | 0x6858 | 0x6898 | 0x68D8 | 0x6918 | 0x6958 | 1 / 0                | Trip Zone Force Register <sup>(1)</sup>               |
| ETSEL   | 0x6819 | 0x6859 | 0x6899 | 0x68D9 | 0x6919 | 0x6959 | 1 / 0                | Event Trigger Selection Register                      |
| ETPS    | 0x681A | 0x685A | 0x689A | 0x68DA | 0x691A | 0x695A | 1 / 0                | Event Trigger Prescale Register                       |
| ETFLG   | 0x681B | 0x685B | 0x689B | 0x68DB | 0x691B | 0x695B | 1 / 0                | Event Trigger Flag Register                           |
| ETCLR   | 0x681C | 0x685C | 0x689C | 0x68DC | 0x691C | 0x695C | 1 / 0                | Event Trigger Clear Register                          |
| ETFRC   | 0x681D | 0x685D | 0x689D | 0x68DD | 0x691D | 0x695D | 1 / 0                | Event Trigger Force Register                          |
| PCCTL   | 0x681E | 0x685E | 0x689E | 0x68DE | 0x691E | 0x695E | 1 / 0                | PWM Chopper Control Register                          |
| HRCNFG  | 0x6820 | 0x6860 | 0x68A0 | 0x68E0 | 0x6920 | 0x6960 | 1 / 0                | HRPWM Configuration Register <sup>(1)</sup>           |

(1) Registers that are EALLOW protected.

**Table 6-5. ePWM Control and Status Registers (Remapped Configuration in PF3 - DMA-Accessible)**

| NAME    | ePWM1  | ePWM2  | ePWM3  | ePWM4  | ePWM5  | ePWM6  | SIZE (x16) / #SHADOW | DESCRIPTION                                           |
|---------|--------|--------|--------|--------|--------|--------|----------------------|-------------------------------------------------------|
| TBCTL   | 0x5800 | 0x5840 | 0x5880 | 0x58C0 | 0x5900 | 0x5940 | 1 / 0                | Time Base Control Register                            |
| TBSTS   | 0x5801 | 0x5841 | 0x5881 | 0x58C1 | 0x5901 | 0x5941 | 1 / 0                | Time Base Status Register                             |
| TBPHSHR | 0x5802 | 0x5842 | 0x5882 | 0x58C2 | 0x5902 | 0x5942 | 1 / 0                | Time Base Phase HRPWM Register                        |
| TBPHS   | 0x5803 | 0x5843 | 0x5883 | 0x58C3 | 0x5903 | 0x5943 | 1 / 0                | Time Base Phase Register                              |
| TBCTR   | 0x5804 | 0x5844 | 0x5884 | 0x58C4 | 0x5904 | 0x5944 | 1 / 0                | Time Base Counter Register                            |
| TBPRD   | 0x5805 | 0x5845 | 0x5885 | 0x58C5 | 0x5905 | 0x5945 | 1 / 1                | Time Base Period Register Set                         |
| CMPCTL  | 0x5807 | 0x5847 | 0x5887 | 0x58C7 | 0x5907 | 0x5947 | 1 / 0                | Counter Compare Control Register                      |
| CMPAHR  | 0x5808 | 0x5848 | 0x5888 | 0x58C8 | 0x5908 | 0x5948 | 1 / 1                | Time Base Compare A HRPWM Register                    |
| CMPA    | 0x5809 | 0x5849 | 0x5889 | 0x58C9 | 0x5909 | 0x5949 | 1 / 1                | Counter Compare A Register Set                        |
| CMPB    | 0x580A | 0x584A | 0x588A | 0x58CA | 0x590A | 0x594A | 1 / 1                | Counter Compare B Register Set                        |
| AQCTLA  | 0x580B | 0x584B | 0x588B | 0x58CB | 0x590B | 0x594B | 1 / 0                | Action Qualifier Control Register For Output A        |
| AQCTLB  | 0x580C | 0x584C | 0x588C | 0x58CC | 0x590C | 0x594C | 1 / 0                | Action Qualifier Control Register For Output B        |
| AQSFR   | 0x580D | 0x584D | 0x588D | 0x58CD | 0x590D | 0x594D | 1 / 0                | Action Qualifier Software Force Register              |
| AQCSFR  | 0x580E | 0x584E | 0x588E | 0x58CE | 0x590E | 0x594E | 1 / 1                | Action Qualifier Continuous S/W Force Register Set    |
| DBCTL   | 0x580F | 0x584F | 0x588F | 0x58CF | 0x590F | 0x594F | 1 / 1                | Dead-Band Generator Control Register                  |
| DBRED   | 0x5810 | 0x5850 | 0x5890 | 0x58D0 | 0x5910 | 0x5950 | 1 / 0                | Dead-Band Generator Rising Edge Delay Count Register  |
| DBFED   | 0x5811 | 0x5851 | 0x5891 | 0x58D1 | 0x5911 | 0x5951 | 1 / 0                | Dead-Band Generator Falling Edge Delay Count Register |
| TZSEL   | 0x5812 | 0x5852 | 0x5892 | 0x58D2 | 0x5912 | 0x5952 | 1 / 0                | Trip Zone Select Register <sup>(1)</sup>              |
| TZCTL   | 0x5814 | 0x5854 | 0x5894 | 0x58D4 | 0x5914 | 0x5954 | 1 / 0                | Trip Zone Control Register <sup>(1)</sup>             |
| TZEINT  | 0x5815 | 0x5855 | 0x5895 | 0x58D5 | 0x5915 | 0x5955 | 1 / 0                | Trip Zone Enable Interrupt Register <sup>(1)</sup>    |
| TZFLG   | 0x5816 | 0x5856 | 0x5896 | 0x58D6 | 0x5916 | 0x5956 | 1 / 0                | Trip Zone Flag Register                               |
| TZCLR   | 0x5817 | 0x5857 | 0x5897 | 0x58D7 | 0x5917 | 0x5957 | 1 / 0                | Trip Zone Clear Register <sup>(1)</sup>               |
| TZFRC   | 0x5818 | 0x5858 | 0x5898 | 0x58D8 | 0x5918 | 0x5958 | 1 / 0                | Trip Zone Force Register <sup>(1)</sup>               |
| ETSEL   | 0x5819 | 0x5859 | 0x5899 | 0x58D9 | 0x5919 | 0x5959 | 1 / 0                | Event Trigger Selection Register                      |
| ETPS    | 0x581A | 0x585A | 0x589A | 0x58DA | 0x591A | 0x595A | 1 / 0                | Event Trigger Prescale Register                       |
| ETFLG   | 0x581B | 0x585B | 0x589B | 0x58DB | 0x591B | 0x595B | 1 / 0                | Event Trigger Flag Register                           |
| ETCLR   | 0x581C | 0x585C | 0x589C | 0x58DC | 0x591C | 0x595C | 1 / 0                | Event Trigger Clear Register                          |
| ETFRC   | 0x581D | 0x585D | 0x589D | 0x58DD | 0x591D | 0x595D | 1 / 0                | Event Trigger Force Register                          |
| PCCTL   | 0x581E | 0x585E | 0x589E | 0x58DE | 0x591E | 0x595E | 1 / 0                | PWM Chopper Control Register                          |
| HRCNFG  | 0x5820 | 0x5860 | 0x58A0 | 0x58E0 | 0x5920 | 0x5960 | 1 / 0                | HRPWM Configuration Register <sup>(1)</sup>           |

(1) Registers that are EALLOW protected.



#### 6.2.4 High-Resolution PWM (HRPWM)

The HRPWM module offers PWM resolution (time granularity) which is significantly better than what can be achieved using conventionally derived digital PWM methods. The key points for the HRPWM module are:

- Significantly extends the time resolution capabilities of conventionally derived digital PWM
- Typically used when effective PWM resolution falls below approximately 9 or 10 bits. This occurs at PWM frequencies greater than approximately 200 kHz when using a CPU/System clock of 100 MHz.
- This capability can be used in both duty cycle and phase-shift control methods.
- Finer time granularity control or edge positioning is controlled through extensions to the Compare A and Phase registers of the ePWM module.
- HRPWM capabilities are offered only on the A signal path of an ePWM module (that is, on the EPWMxA output). EPWMxB output has conventional PWM capabilities.



The eCAP modules are clocked at the SYSCLKOUT rate.

The clock enable bits (ECAP1ENCLK, ECAP2ENCLK, ECAP3ENCLK, ECAP4ENCLK, ECAP5ENCLK, ECAP6ENCLK) in the PCLKCR1 register are used to turn off the eCAP modules individually (for low power operation). Upon reset, ECAP1ENCLK, ECAP2ENCLK, ECAP3ENCLK, ECAP4ENCLK, ECAP5ENCLK, and ECAP6ENCLK are set to low, indicating that the peripheral clock is off.

**Table 6-6. eCAP Control and Status Registers**

| NAME     | eCAP1             | eCAP2             | eCAP3             | eCAP4             | eCAP5             | eCAP6             | SIZE<br>(x16) | DESCRIPTION                         |
|----------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------------|-------------------------------------|
| TSCTR    | 0x6A00            | 0x6A20            | 0x6A40            | 0x6A60            | 0x6A80            | 0x6AA0            | 2             | Timestamp Counter                   |
| CTRPHS   | 0x6A02            | 0x6A22            | 0x6A42            | 0x6A62            | 0x6A82            | 0x6AA2            | 2             | Counter Phase Offset Value Register |
| CAP1     | 0x6A04            | 0x6A24            | 0x6A44            | 0x6A64            | 0x6A84            | 0x6AA4            | 2             | Capture 1 Register                  |
| CAP2     | 0x6A06            | 0x6A26            | 0x6A46            | 0x6A66            | 0x6A86            | 0x6AA6            | 2             | Capture 2 Register                  |
| CAP3     | 0x6A08            | 0x6A28            | 0x6A48            | 0x6A68            | 0x6A88            | 0x6AA8            | 2             | Capture 3 Register                  |
| CAP4     | 0x6A0A            | 0x6A2A            | 0x6A4A            | 0x6A6A            | 0x6A8A            | 0x6AAA            | 2             | Capture 4 Register                  |
| Reserved | 0x6A0C-<br>0x6A12 | 0x6A2C-<br>0x6A32 | 0x6A4C-<br>0x6A52 | 0x6A6C-<br>0x6A72 | 0x6A8C-<br>0x6A92 | 0x6AAC-<br>0x6AB2 | 8             | Reserved                            |
| ECCTL1   | 0x6A14            | 0x6A34            | 0x6A54            | 0x6A74            | 0x6A94            | 0x6AB4            | 1             | Capture Control Register 1          |
| ECCTL2   | 0x6A15            | 0x6A35            | 0x6A55            | 0x6A75            | 0x6A95            | 0x6AB5            | 1             | Capture Control Register 2          |
| ECEINT   | 0x6A16            | 0x6A36            | 0x6A56            | 0x6A76            | 0x6A96            | 0x6AB6            | 1             | Capture Interrupt Enable Register   |
| ECFLG    | 0x6A17            | 0x6A37            | 0x6A57            | 0x6A77            | 0x6A97            | 0x6AB7            | 1             | Capture Interrupt Flag Register     |
| ECCLR    | 0x6A18            | 0x6A38            | 0x6A58            | 0x6A78            | 0x6A98            | 0x6AB8            | 1             | Capture Interrupt Clear Register    |
| ECFRC    | 0x6A19            | 0x6A39            | 0x6A59            | 0x6A79            | 0x6A99            | 0x6AB9            | 1             | Capture Interrupt Force Register    |
| Reserved | 0x6A1A-<br>0x6A1F | 0x6A3A-<br>0x6A3F | 0x6A5A-<br>0x6A5F | 0x6A7A-<br>0x6A7F | 0x6A9A-<br>0x6A9F | 0x6ABA-<br>0x6ABF | 6             | Reserved                            |

## 6.2.6 Enhanced QEP Modules

The device contains up to two enhanced quadrature encoder (eQEP) modules (eQEP1, eQEP2). Figure 6-7 shows the block diagram of the eQEP module.

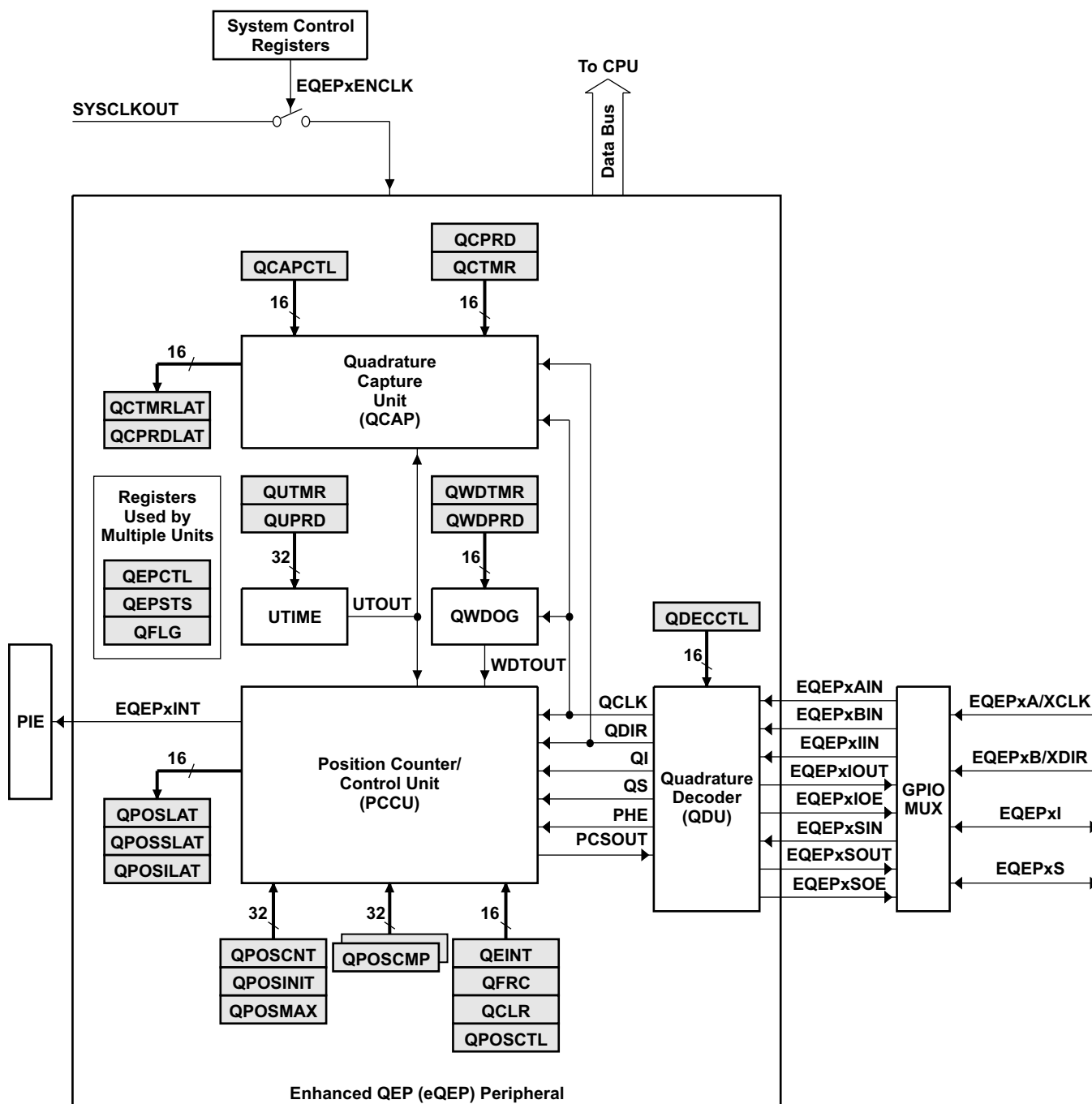


Figure 6-7. eQEP Functional Block Diagram

Table 6-7 provides a summary of the eQEP registers.

**Table 6-7. eQEP Control and Status Registers**

| NAME     | eQEP1 ADDRESS   | eQEP2 ADDRESS   | eQEP1 SIZE(x16)/ #SHADOW | REGISTER DESCRIPTION                   |
|----------|-----------------|-----------------|--------------------------|----------------------------------------|
| QPOSCNT  | 0x6B00          | 0x6B40          | 2/0                      | eQEP Position Counter                  |
| QPOSINIT | 0x6B02          | 0x6B42          | 2/0                      | eQEP Initialization Position Count     |
| QPOSMAX  | 0x6B04          | 0x6B44          | 2/0                      | eQEP Maximum Position Count            |
| QPOSCMP  | 0x6B06          | 0x6B46          | 2/1                      | eQEP Position-compare                  |
| QPOSILAT | 0x6B08          | 0x6B48          | 2/0                      | eQEP Index Position Latch              |
| QPOSSLAT | 0x6B0A          | 0x6B4A          | 2/0                      | eQEP Strobe Position Latch             |
| QPOSLAT  | 0x6B0C          | 0x6B4C          | 2/0                      | eQEP Position Latch                    |
| QUTMR    | 0x6B0E          | 0x6B4E          | 2/0                      | eQEP Unit Timer                        |
| QUPRD    | 0x6B10          | 0x6B50          | 2/0                      | eQEP Unit Period Register              |
| QWDTMR   | 0x6B12          | 0x6B52          | 1/0                      | eQEP Watchdog Timer                    |
| QWDPRD   | 0x6B13          | 0x6B53          | 1/0                      | eQEP Watchdog Period Register          |
| QDECCTL  | 0x6B14          | 0x6B54          | 1/0                      | eQEP Decoder Control Register          |
| QEPCTL   | 0x6B15          | 0x6B55          | 1/0                      | eQEP Control Register                  |
| QCAPCTL  | 0x6B16          | 0x6B56          | 1/0                      | eQEP Capture Control Register          |
| QPOSCTL  | 0x6B17          | 0x6B57          | 1/0                      | eQEP Position-compare Control Register |
| QEINT    | 0x6B18          | 0x6B58          | 1/0                      | eQEP Interrupt Enable Register         |
| QFLG     | 0x6B19          | 0x6B59          | 1/0                      | eQEP Interrupt Flag Register           |
| QCLR     | 0x6B1A          | 0x6B5A          | 1/0                      | eQEP Interrupt Clear Register          |
| QFRC     | 0x6B1B          | 0x6B5B          | 1/0                      | eQEP Interrupt Force Register          |
| QEPSTS   | 0x6B1C          | 0x6B5C          | 1/0                      | eQEP Status Register                   |
| QCTMR    | 0x6B1D          | 0x6B5D          | 1/0                      | eQEP Capture Timer                     |
| QCPRD    | 0x6B1E          | 0x6B5E          | 1/0                      | eQEP Capture Period Register           |
| QCTMRLAT | 0x6B1F          | 0x6B5F          | 1/0                      | eQEP Capture Timer Latch               |
| QCPRDLAT | 0x6B20          | 0x6B60          | 1/0                      | eQEP Capture Period Latch              |
| Reserved | 0x6B21 – 0x6B3F | 0x6B61 – 0x6B7F | 31/0                     |                                        |

## 6.2.7 Analog-to-Digital Converter (ADC) Module

A simplified functional block diagram of the ADC module is shown in [Figure 6-8](#). The ADC module consists of a 12-bit ADC with a built-in sample-and-hold (S/H) circuit. Functions of the ADC module include:

- 12-bit ADC core with built-in S/H
- Analog input: 0.0 V to 3.0 V (Voltages above 3.0 V produce full-scale conversion results.)
- Fast conversion rate: Up to 80 ns at 25-MHz ADC clock, 12.5 MSPS
- 16 dedicated ADC channels. 8 channels multiplexed per Sample/Hold
- Autosequencing capability provides up to 16 "autoconversions" in a single session. Each conversion can be programmed to select any 1 of 16 input channels
- Sequencer can be operated as two independent 8-state sequencers or as one large 16-state sequencer (that is, two cascaded 8-state sequencers)
- Sixteen result registers (individually addressable) to store conversion values
  - The digital value of the input analog voltage is derived by:

Digital Value = 0 , when  $ADCIN \leq ADCLO$

Digital Value =  $\text{floor} \left( 4096 \times \frac{ADCIN - ADCLO}{3} \right)$  , when  $ADCLO < ADCIN < 3 \text{ V}$

Digital Value = 4095 , when  $ADCIN \geq 3 \text{ V}$

- Multiple triggers as sources for the start-of-conversion (SOC) sequence
  - S/W - software immediate start
  - ePWM start of conversion
  - XINT2 ADC start of conversion
- Flexible interrupt control allows interrupt request on every end-of-sequence (EOS) or every other EOS.
- Sequencer can operate in "start/stop" mode, allowing multiple "time-sequenced triggers" to synchronize conversions.
- SOCA and SOCB triggers can operate independently in dual-sequencer mode.
- Sample-and-hold (S/H) acquisition time window has separate prescale control.

The ADC module in the 2833x/2823x devices has been enhanced to provide flexible interface to ePWM peripherals. The ADC interface is built around a fast, 12-bit ADC module with a fast conversion rate of up to 80 ns at 25-MHz ADC clock. The ADC module has 16 channels, configurable as two independent 8-channel modules. The two independent 8-channel modules can be cascaded to form a 16-channel module. Although there are multiple input channels and two sequencers, there is only one converter in the ADC module. [Figure 6-8](#) shows the block diagram of the ADC module.

The two 8-channel modules have the capability to autosequence a series of conversions, each module has the choice of selecting any one of the respective eight channels available through an analog MUX. In the cascaded mode, the autosequencer functions as a single 16-channel sequencer. On each sequencer, once the conversion is complete, the selected channel value is stored in its respective RESULT register. Autosequencing allows the system to convert the same channel multiple times, allowing the user to perform oversampling algorithms. This gives increased resolution over traditional single-sampled conversion results.

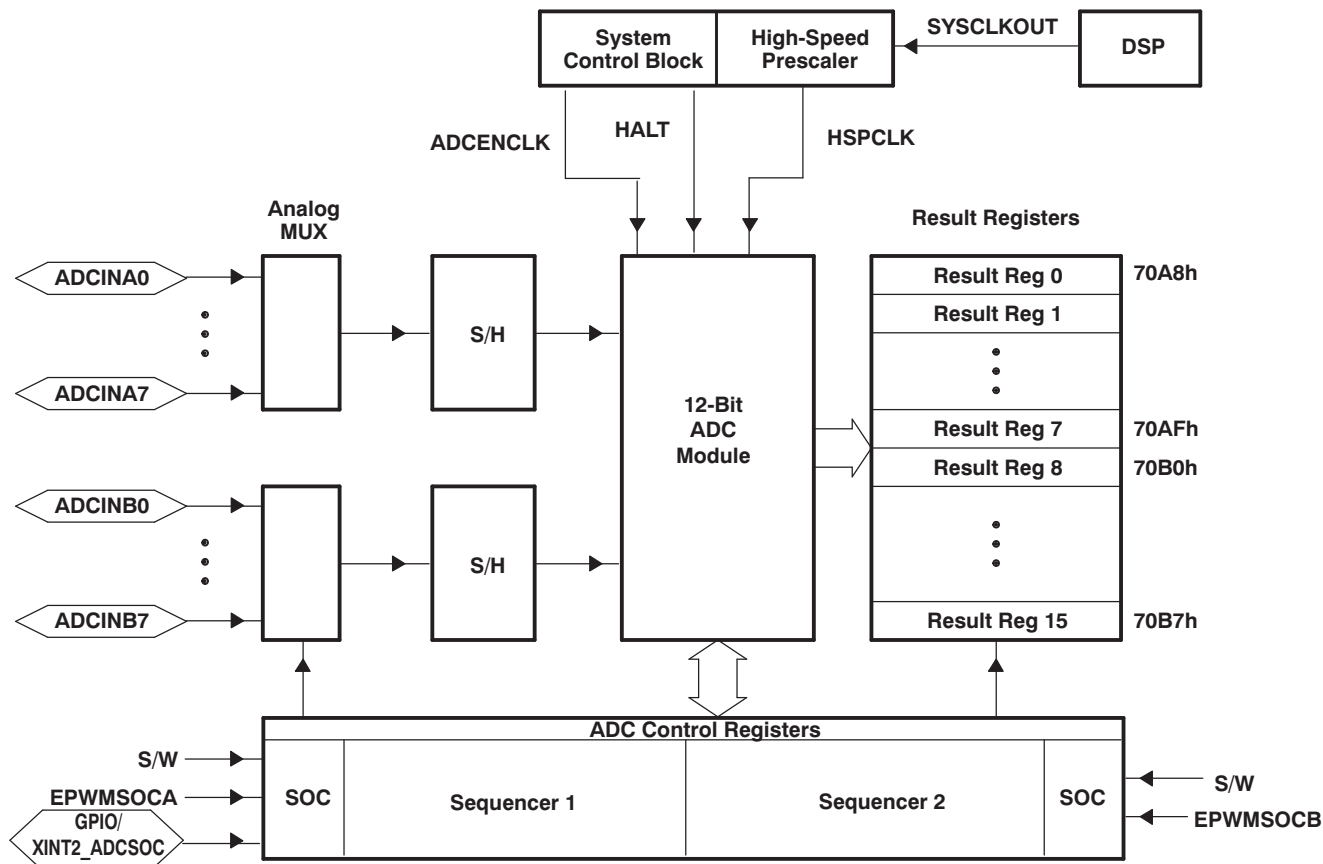


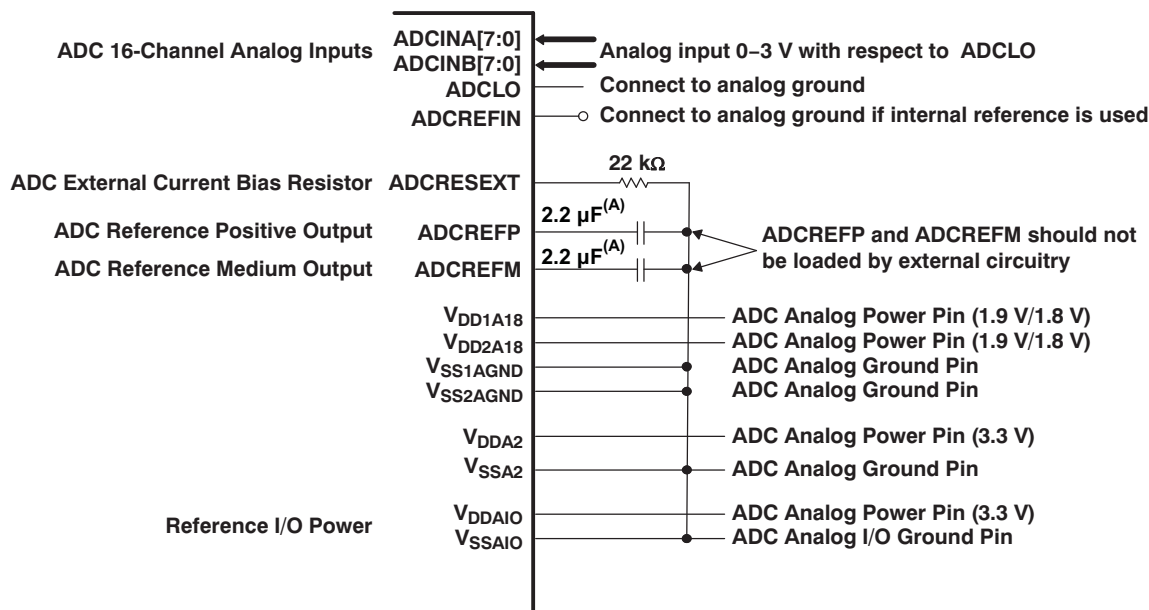
Figure 6-8. Block Diagram of the ADC Module

To obtain the specified accuracy of the ADC, proper board layout is very critical. To the best extent possible, traces leading to the ADCIN pins should not run in close proximity to the digital signal paths. This is to minimize switching noise on the digital lines from getting coupled to the ADC inputs. Furthermore, proper isolation techniques must be used to isolate the ADC module power pins ( $V_{DD1A18}$ ,  $V_{DD2A18}$ ,  $V_{DDA2}$ ,  $V_{DDAIO}$ ) from the digital supply. Figure 6-9 shows the ADC pin connections for the devices.

#### NOTE

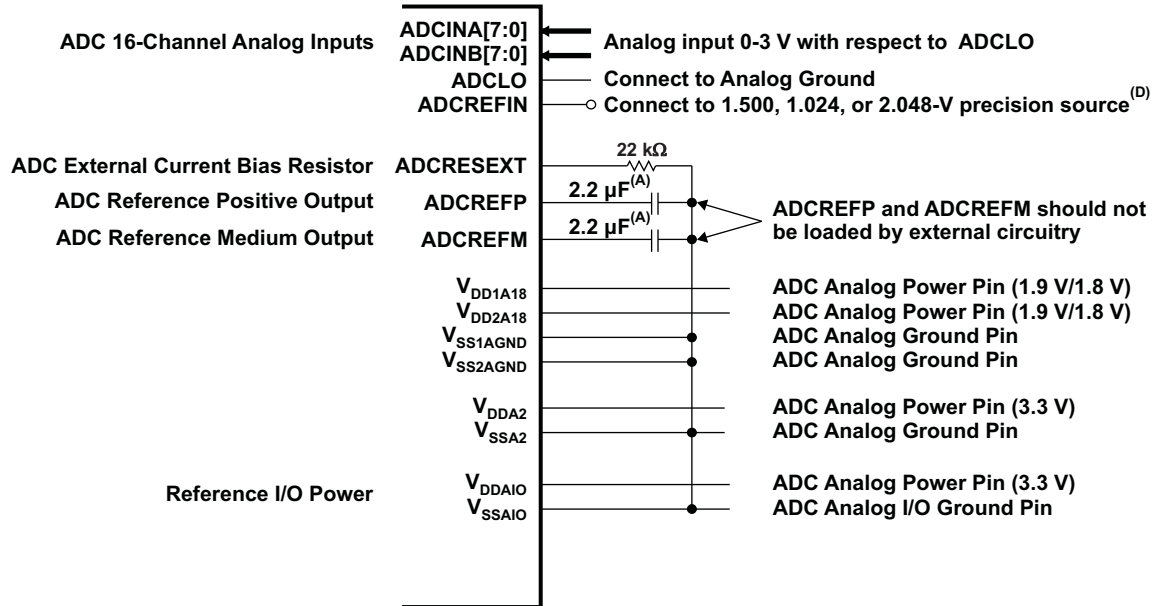
1. The ADC registers are accessed at the SYCLKOUT rate. The internal timing of the ADC module is controlled by the high-speed peripheral clock (HSPCLK).
2. The behavior of the ADC module based on the state of the ADCENCLK and HALT signals is as follows:
  - **ADCENCLK**: On reset, this signal will be low. While reset is active-low ( $\overline{XRS}$ ) the clock to the register will still function. This is necessary to make sure all registers and modes go into their default reset state. The analog module, however, will be in a low-power inactive state. As soon as reset goes high, then the clock to the registers will be disabled. When the user sets the ADCENCLK signal high, then the clocks to the registers will be enabled and the analog module will be enabled. There will be a certain time delay (ms range) before the ADC is stable and can be used.
  - **HALT**: This mode only affects the analog module. It does not affect the registers. In this mode, the ADC module goes into low-power mode. This mode also will stop the clock to the CPU, which will stop the HSPCLK; therefore, the ADC register logic will be turned off indirectly.

Figure 6-9 shows the ADC pin-biasing for internal reference and Figure 6-10 shows the ADC pin-biasing for external reference.



- A. TAIYO YUDEN LMK212BJ225MG-T or equivalent
- B. External decoupling capacitors are recommended on all power pins.
- C. Analog inputs must be driven from an operational amplifier that does not degrade the ADC performance.

**Figure 6-9. ADC Pin Connections With Internal Reference**



- A. TAIYO YUDEN LMK212BJ225MG-T or equivalent
- B. External decoupling capacitors are recommended on all power pins.
- C. Analog inputs must be driven from an operational amplifier that does not degrade the ADC performance.
- D. External voltage on ADCREFIN is enabled by changing bits 15:14 in the ADC Reference Select register depending on the voltage used on this pin. TI recommends TI part REF3020 or equivalent for 2.048-V generation. Overall gain accuracy will be determined by accuracy of this voltage source.

**Figure 6-10. ADC Pin Connections With External Reference**

**NOTE**

The temperature rating of any recommended component must match the rating of the end product.

### 6.2.7.1 ADC Connections if the ADC Is Not Used

It is recommended to keep the connections for the analog power pins, even if the ADC is not used. Following is a summary of how the ADC pins should be connected, if the ADC is not used in an application:

- $V_{DD1A18}/V_{DD2A18}$  – Connect to  $V_{DD}$
- $V_{DDA2}$ ,  $V_{DDAIO}$  – Connect to  $V_{DDIO}$
- $V_{SS1AGND}/V_{SS2AGND}$ ,  $V_{SSA2}$ ,  $V_{SSAIO}$  – Connect to  $V_{SS}$
- $ADCLO$  – Connect to  $V_{SS}$
- $ADCREFIN$  – Connect to  $V_{SS}$
- $ADCREFP/ADCREFM$  – Connect a 100-nF cap to  $V_{SS}$
- $ADCRESEXT$  – Connect a 20-k $\Omega$  resistor (very loose tolerance) to  $V_{SS}$ .
- $ADCINAn$ ,  $ADCINBn$  – Connect to  $V_{SS}$

When the ADC is not used, be sure that the clock to the ADC module is not turned on to realize power savings.

When the ADC module is used in an application, unused ADC input pins should be connected to analog ground ( $V_{SS1AGND}/V_{SS2AGND}$ )

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#### NOTE

ADC parameters for gain error and offset error are specified only if the ADC calibration routine is executed from the Boot ROM. See [Section 6.2.7.3](#) for more information.

---

## 6.2.7.2 ADC Registers

The ADC operation is configured, controlled, and monitored by the registers listed in [Table 6-8](#).

**Table 6-8. ADC Registers<sup>(1)</sup>**

| NAME         | ADDRESS <sup>(1)</sup> | ADDRESS <sup>(2)</sup> | SIZE (x16) | DESCRIPTION                                      |
|--------------|------------------------|------------------------|------------|--------------------------------------------------|
| ADCTRL1      | 0x7100                 |                        | 1          | ADC Control Register 1                           |
| ADCTRL2      | 0x7101                 |                        | 1          | ADC Control Register 2                           |
| ADCMAXCONV   | 0x7102                 |                        | 1          | ADC Maximum Conversion Channels Register         |
| ADCCHSELSEQ1 | 0x7103                 |                        | 1          | ADC Channel Select Sequencing Control Register 1 |
| ADCCHSELSEQ2 | 0x7104                 |                        | 1          | ADC Channel Select Sequencing Control Register 2 |
| ADCCHSELSEQ3 | 0x7105                 |                        | 1          | ADC Channel Select Sequencing Control Register 3 |
| ADCCHSELSEQ4 | 0x7106                 |                        | 1          | ADC Channel Select Sequencing Control Register 4 |
| ADCASEQSR    | 0x7107                 |                        | 1          | ADC Auto-Sequence Status Register                |
| ADCRESULT0   | 0x7108                 | 0x0B00                 | 1          | ADC Conversion Result Buffer Register 0          |
| ADCRESULT1   | 0x7109                 | 0x0B01                 | 1          | ADC Conversion Result Buffer Register 1          |
| ADCRESULT2   | 0x710A                 | 0x0B02                 | 1          | ADC Conversion Result Buffer Register 2          |
| ADCRESULT3   | 0x710B                 | 0x0B03                 | 1          | ADC Conversion Result Buffer Register 3          |
| ADCRESULT4   | 0x710C                 | 0x0B04                 | 1          | ADC Conversion Result Buffer Register 4          |
| ADCRESULT5   | 0x710D                 | 0x0B05                 | 1          | ADC Conversion Result Buffer Register 5          |
| ADCRESULT6   | 0x710E                 | 0x0B06                 | 1          | ADC Conversion Result Buffer Register 6          |
| ADCRESULT7   | 0x710F                 | 0x0B07                 | 1          | ADC Conversion Result Buffer Register 7          |
| ADCRESULT8   | 0x7110                 | 0x0B08                 | 1          | ADC Conversion Result Buffer Register 8          |
| ADCRESULT9   | 0x7111                 | 0x0B09                 | 1          | ADC Conversion Result Buffer Register 9          |
| ADCRESULT10  | 0x7112                 | 0x0B0A                 | 1          | ADC Conversion Result Buffer Register 10         |
| ADCRESULT11  | 0x7113                 | 0x0B0B                 | 1          | ADC Conversion Result Buffer Register 11         |
| ADCRESULT12  | 0x7114                 | 0x0B0C                 | 1          | ADC Conversion Result Buffer Register 12         |
| ADCRESULT13  | 0x7115                 | 0x0B0D                 | 1          | ADC Conversion Result Buffer Register 13         |
| ADCRESULT14  | 0x7116                 | 0x0B0E                 | 1          | ADC Conversion Result Buffer Register 14         |
| ADCRESULT15  | 0x7117                 | 0x0B0F                 | 1          | ADC Conversion Result Buffer Register 15         |
| ADCTRL3      | 0x7118                 |                        | 1          | ADC Control Register 3                           |
| ADCST        | 0x7119                 |                        | 1          | ADC Status Register                              |
| Reserved     | 0x711A –<br>0x711B     |                        | 2          |                                                  |
| ADCREFSSEL   | 0x711C                 |                        | 1          | ADC Reference Select Register                    |
| ADCOFFTRIM   | 0x711D                 |                        | 1          | ADC Offset Trim Register                         |
| Reserved     | 0x711E –<br>0x711F     |                        | 2          |                                                  |

(1) The registers in this column are Peripheral Frame 2 Registers.

(2) The ADC result registers are dual mapped. Locations in Peripheral Frame 2 (0x7108–0x7117) are 2 wait-states and left justified. Locations in Peripheral frame 0 space (0x0B00–0x0B0F) are 1 wait-state for CPU accesses and 0 wait state for DMA accesses and right justified. During high speed/continuous conversion use of the ADC, use the 0 wait-state locations for fast transfer of ADC results to user memory.

### 6.2.7.3 ADC Calibration

The ADC\_cal() routine is programmed into TI reserved OTP memory by the factory. The boot ROM automatically calls the ADC\_cal() routine to initialize the ADCREFSEL and ADCOFFTRIM registers with device specific calibration data. During normal operation, this process occurs automatically and no action is required by the user.

If the boot ROM is bypassed by Code Composer Studio during the development process, then ADCREFSEL and ADCOFFTRIM must be initialized by the application. Methods for calling the ADC\_cal() routine from an application are described in the [TMS320x2833x, F2823x Analog-to-Digital Converter \(ADC\) module reference guide](#).

#### CAUTION

FAILURE TO INITIALIZE THESE REGISTERS WILL CAUSE THE ADC TO FUNCTION OUT OF SPECIFICATION.

If the system is reset or the ADC module is reset using Bit 14 (RESET) from the ADC Control Register 1, the routine must be repeated.

### 6.2.8 Multichannel Buffered Serial Port (McBSP) Module

The McBSP module has the following features:

- Compatible to McBSP in TMS320C54x/TMS320C55x DSP devices
- Full-duplex communication
- Double-buffered data registers that allow a continuous data stream
- Independent framing and clocking for receive and transmit
- External shift clock generation or an internal programmable frequency shift clock
- A wide selection of data sizes including 8, 12, 16, 20, 24, or 32 bits
- 8-bit data transfers with LSB or MSB first
- Programmable polarity for both frame synchronization and data clocks
- Highly programmable internal clock and frame generation
- Direct interface to industry-standard CODECs, Analog Interface Chips (AICs), and other serially connected A/D and D/A devices
- Works with SPI-compatible devices
- The following application interfaces can be supported on the McBSP:
  - T1/E1 framers
  - IOM-2 compliant devices
  - AC97-compliant devices (the necessary multiphase frame synchronization capability is provided.)
  - IIS-compliant devices
  - SPI
- McBSP clock rate,

$$\text{CLKG} = \frac{\text{CLKSRG}}{(1 + \text{CLKGDV})}$$

where CLKSRG source could be LSPCLK, CLKX, or CLKR. Serial port performance is limited by I/O buffer switching speed. Internal prescalers must be adjusted such that the peripheral speed is less than the I/O buffer speed limit.

#### NOTE

See [Section 5](#) for maximum I/O pin toggling speed.

Figure 6-11 shows the block diagram of the McBSP module.

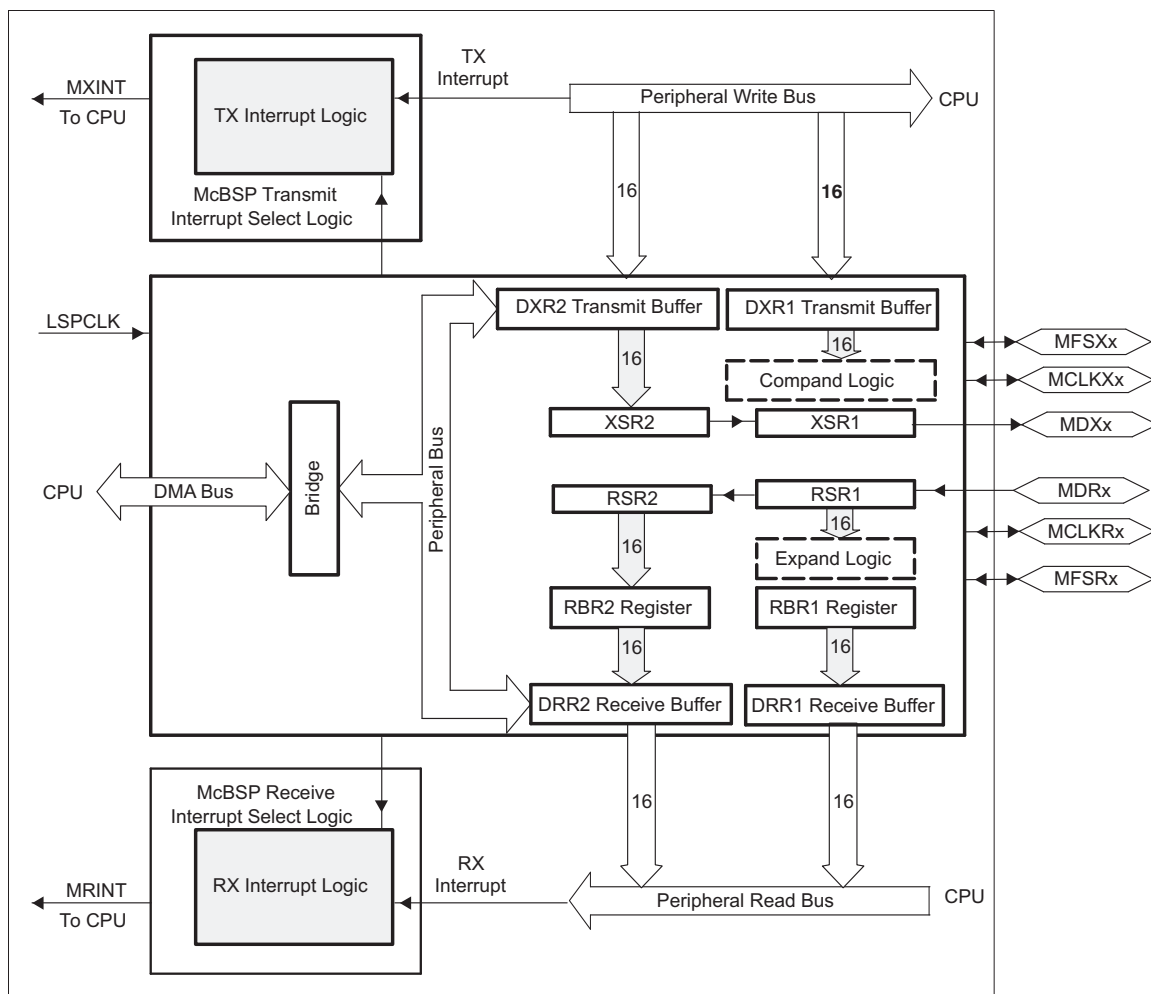


Figure 6-11. McBSP Module

Table 6-9 provides a summary of the McBSP registers.

**Table 6-9. McBSP Register Summary**

| NAME                                     | McBSP-A ADDRESS | McBSP-B ADDRESS | TYPE | RESET VALUE | DESCRIPTION                                        |
|------------------------------------------|-----------------|-----------------|------|-------------|----------------------------------------------------|
| <b>Data Registers, Receive, Transmit</b> |                 |                 |      |             |                                                    |
| DDR2                                     | 0x5000          | 0x5040          | R    | 0x0000      | McBSP Data Receive Register 2                      |
| DDR1                                     | 0x5001          | 0x5041          | R    | 0x0000      | McBSP Data Receive Register 1                      |
| DXR2                                     | 0x5002          | 0x5042          | W    | 0x0000      | McBSP Data Transmit Register 2                     |
| DXR1                                     | 0x5003          | 0x5043          | W    | 0x0000      | McBSP Data Transmit Register 1                     |
| <b>McBSP Control Registers</b>           |                 |                 |      |             |                                                    |
| SPCR2                                    | 0x5004          | 0x5044          | R/W  | 0x0000      | McBSP Serial Port Control Register 2               |
| SPCR1                                    | 0x5005          | 0x5045          | R/W  | 0x0000      | McBSP Serial Port Control Register 1               |
| RCR2                                     | 0x5006          | 0x5046          | R/W  | 0x0000      | McBSP Receive Control Register 2                   |
| RCR1                                     | 0x5007          | 0x5047          | R/W  | 0x0000      | McBSP Receive Control Register 1                   |
| XCR2                                     | 0x5008          | 0x5048          | R/W  | 0x0000      | McBSP Transmit Control Register 2                  |
| XCR1                                     | 0x5009          | 0x5049          | R/W  | 0x0000      | McBSP Transmit Control Register 1                  |
| SRGR2                                    | 0x500A          | 0x504A          | R/W  | 0x0000      | McBSP Sample Rate Generator Register 2             |
| SRGR1                                    | 0x500B          | 0x504B          | R/W  | 0x0000      | McBSP Sample Rate Generator Register 1             |
| <b>Multichannel Control Registers</b>    |                 |                 |      |             |                                                    |
| MCR2                                     | 0x500C          | 0x504C          | R/W  | 0x0000      | McBSP Multichannel Register 2                      |
| MCR1                                     | 0x500D          | 0x504D          | R/W  | 0x0000      | McBSP Multichannel Register 1                      |
| RCERA                                    | 0x500E          | 0x504E          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition A  |
| RCERB                                    | 0x500F          | 0x504F          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition B  |
| XCERA                                    | 0x5010          | 0x5050          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition A |
| XCERB                                    | 0x5011          | 0x5051          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition B |
| PCR                                      | 0x5012          | 0x5052          | R/W  | 0x0000      | McBSP Pin Control Register                         |
| RCERC                                    | 0x5013          | 0x5053          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition C  |
| RCERD                                    | 0x5014          | 0x5054          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition D  |
| XCERC                                    | 0x5015          | 0x5055          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition C |
| XCERD                                    | 0x5016          | 0x5056          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition D |
| RCERE                                    | 0x5017          | 0x5057          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition E  |
| RCERF                                    | 0x5018          | 0x5058          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition F  |
| XCERE                                    | 0x5019          | 0x5059          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition E |
| XCERF                                    | 0x501A          | 0x505A          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition F |
| RCERG                                    | 0x501B          | 0x505B          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition G  |
| RCERH                                    | 0x501C          | 0x505C          | R/W  | 0x0000      | McBSP Receive Channel Enable Register Partition H  |
| XCERG                                    | 0x501D          | 0x505D          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition G |
| XCERH                                    | 0x501E          | 0x505E          | R/W  | 0x0000      | McBSP Transmit Channel Enable Register Partition H |
| MFFINT                                   | 0x5023          | 0x5063          | R/W  | 0x0000      | McBSP Interrupt Enable Register                    |

### 6.2.9 Enhanced Controller Area Network (eCAN) Modules (eCAN-A and eCAN-B)

The CAN module has the following features:

- Fully compliant with ISO 11898-1 (CAN 2.0B)
- Supports data rates up to 1 Mbps
- Thirty-two mailboxes, each with the following properties:
  - Configurable as receive or transmit
  - Configurable with standard or extended identifier
  - Has a programmable receive mask
  - Supports data and remote frame
  - Composed of 0 to 8 bytes of data
  - Uses a 32-bit timestamp on receive and transmit message
  - Protects against reception of new message
  - Holds the dynamically programmable priority of transmit message
  - Employs a programmable interrupt scheme with two interrupt levels
  - Employs a programmable alarm on transmission or reception time-out
- Low-power mode
- Programmable wake-up on bus activity
- Automatic reply to a remote request message
- Automatic retransmission of a frame in case of loss of arbitration or error
- 32-bit local network time counter synchronized by a specific message (communication in conjunction with mailbox 16)
- Self-test mode
  - Operates in a loopback mode receiving its own message. A "dummy" acknowledge is provided, thereby eliminating the need for another node to provide the acknowledge bit.

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#### NOTE

For a SYSCLKOUT of 100 MHz, the smallest bit rate possible is 7.812 kbps.

For a SYSCLKOUT of 150 MHz, the smallest bit rate possible is 11.719 kbps.

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The F2833x/F2823x CAN has passed the conformance test per ISO/DIS 16845. Contact TI for test report and exceptions.

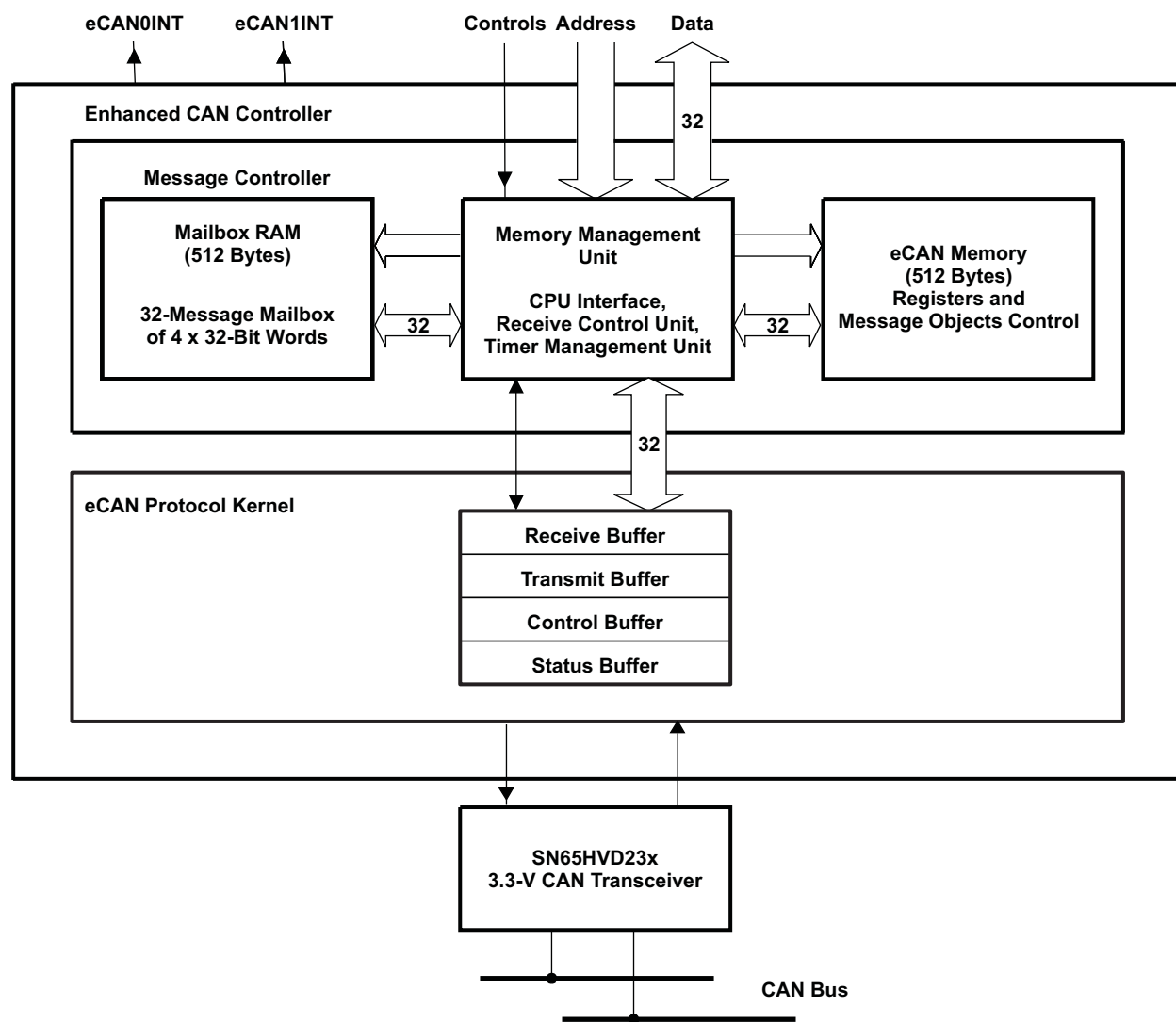


Figure 6-12. eCAN Block Diagram and Interface Circuit

**Table 6-10. 3.3-V eCAN Transceivers**

| PART NUMBER | SUPPLY VOLTAGE | LOW-POWER MODE    | SLOPE CONTROL | VREF | OTHER               | T <sub>A</sub> |
|-------------|----------------|-------------------|---------------|------|---------------------|----------------|
| SN65HVD230  | 3.3 V          | Standby           | Adjustable    | Yes  | –                   | –40°C to 85°C  |
| SN65HVD230Q | 3.3 V          | Standby           | Adjustable    | Yes  | –                   | –40°C to 125°C |
| SN65HVD231  | 3.3 V          | Sleep             | Adjustable    | Yes  | –                   | –40°C to 85°C  |
| SN65HVD231Q | 3.3 V          | Sleep             | Adjustable    | Yes  | –                   | –40°C to 125°C |
| SN65HVD232  | 3.3 V          | None              | None          | None | –                   | –40°C to 85°C  |
| SN65HVD232Q | 3.3 V          | None              | None          | None | –                   | –40°C to 125°C |
| SN65HVD233  | 3.3 V          | Standby           | Adjustable    | None | Diagnostic Loopback | –40°C to 125°C |
| SN65HVD234  | 3.3 V          | Standby and Sleep | Adjustable    | None | –                   | –40°C to 125°C |
| SN65HVD235  | 3.3 V          | Standby           | Adjustable    | None | Autobaud Loopback   | –40°C to 125°C |

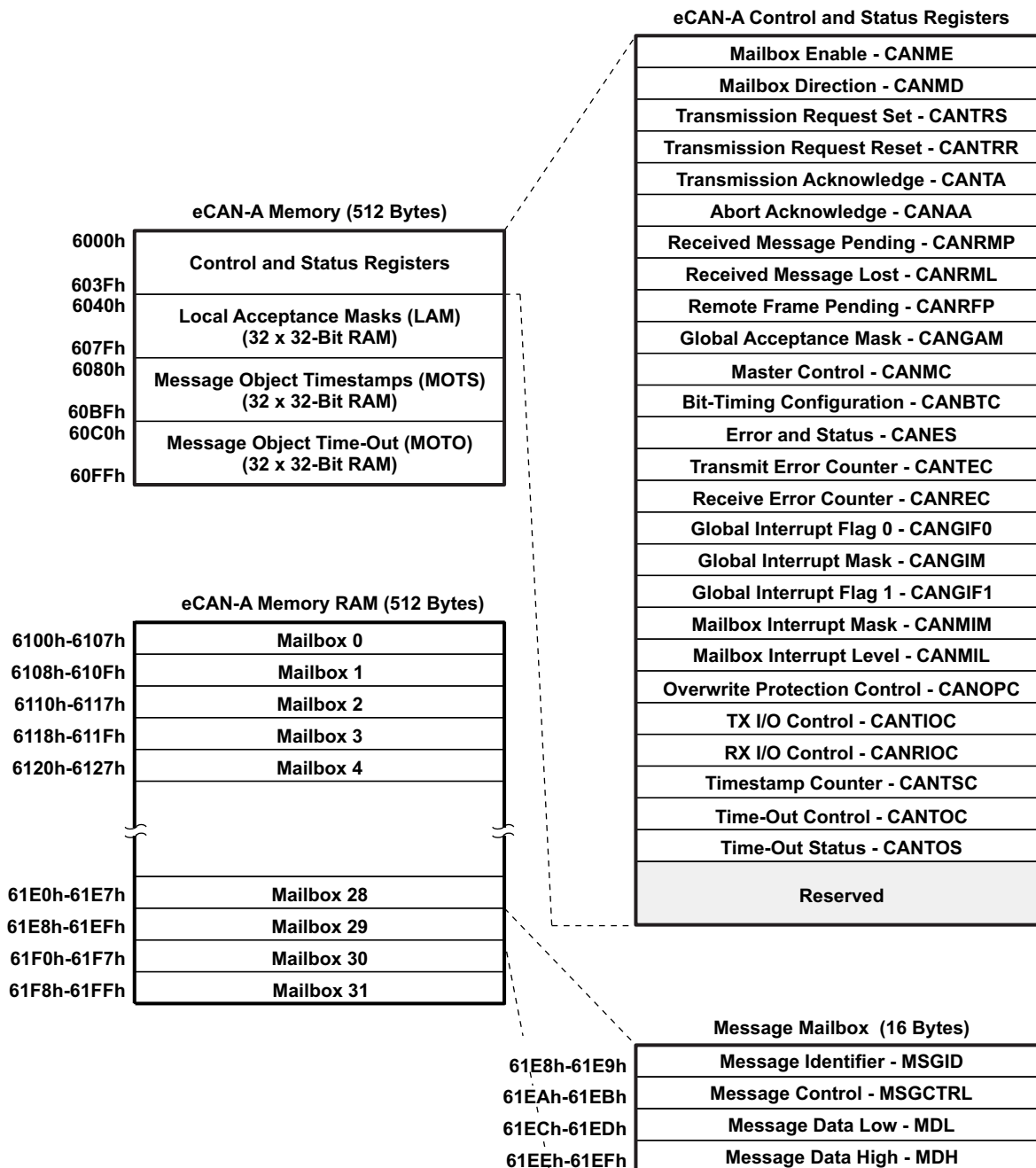


Figure 6-13. eCAN-A Memory Map

**NOTE**

If the eCAN module is not used in an application, the RAM available (LAM, MOTS, MOTO, and mailbox RAM) can be used as general-purpose RAM. The CAN module clock should be enabled for this.

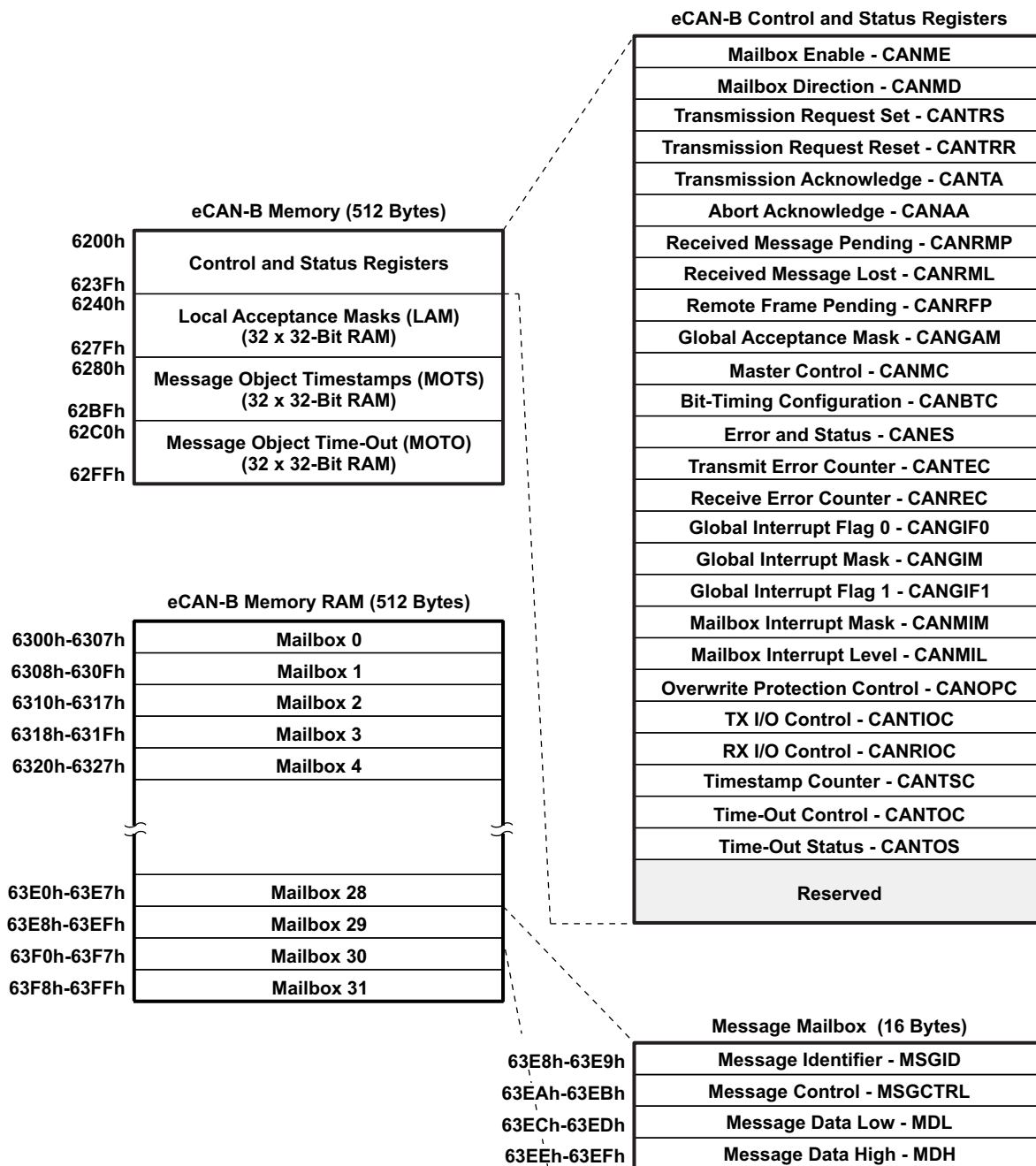


**Figure 6-14. eCAN-B Memory Map**

The CAN registers listed in [Table 6-11](#) are used by the CPU to configure and control the CAN controller and the message objects. eCAN control registers only support 32-bit read/write operations. Mailbox RAM can be accessed as 16 bits or 32 bits. Thirty-two-bit accesses are aligned to an even boundary.

**Table 6-11. CAN Register Map<sup>(1)</sup>**

| REGISTER NAME | eCAN-A ADDRESS | eCAN-B ADDRESS | SIZE (x32) | DESCRIPTION                              |
|---------------|----------------|----------------|------------|------------------------------------------|
| CANME         | 0x6000         | 0x6200         | 1          | Mailbox enable                           |
| CANMD         | 0x6002         | 0x6202         | 1          | Mailbox direction                        |
| CANTRS        | 0x6004         | 0x6204         | 1          | Transmit request set                     |
| CANTRR        | 0x6006         | 0x6206         | 1          | Transmit request reset                   |
| CANTA         | 0x6008         | 0x6208         | 1          | Transmission acknowledge                 |
| CANAA         | 0x600A         | 0x620A         | 1          | Abort acknowledge                        |
| CANRMP        | 0x600C         | 0x620C         | 1          | Receive message pending                  |
| CANRML        | 0x600E         | 0x620E         | 1          | Receive message lost                     |
| CANRFP        | 0x6010         | 0x6210         | 1          | Remote frame pending                     |
| CANGAM        | 0x6012         | 0x6212         | 1          | Global acceptance mask                   |
| CANMC         | 0x6014         | 0x6214         | 1          | Master control                           |
| CANBTC        | 0x6016         | 0x6216         | 1          | Bit-timing configuration                 |
| CANES         | 0x6018         | 0x6218         | 1          | Error and status                         |
| CANTEC        | 0x601A         | 0x621A         | 1          | Transmit error counter                   |
| CANREC        | 0x601C         | 0x621C         | 1          | Receive error counter                    |
| CANGIF0       | 0x601E         | 0x621E         | 1          | Global interrupt flag 0                  |
| CANGIM        | 0x6020         | 0x6220         | 1          | Global interrupt mask                    |
| CANGIF1       | 0x6022         | 0x6222         | 1          | Global interrupt flag 1                  |
| CANMIM        | 0x6024         | 0x6224         | 1          | Mailbox interrupt mask                   |
| CANMIL        | 0x6026         | 0x6226         | 1          | Mailbox interrupt level                  |
| CANOPC        | 0x6028         | 0x6228         | 1          | Overwrite protection control             |
| CANTIOC       | 0x602A         | 0x622A         | 1          | TX I/O control                           |
| CANRIOC       | 0x602C         | 0x622C         | 1          | RX I/O control                           |
| CANTSC        | 0x602E         | 0x622E         | 1          | Timestamp counter (Reserved in SCC mode) |
| CANTOC        | 0x6030         | 0x6230         | 1          | Time-out control (Reserved in SCC mode)  |
| CANTOS        | 0x6032         | 0x6232         | 1          | Time-out status (Reserved in SCC mode)   |

(1) These registers are mapped to Peripheral Frame 1.

### 6.2.10 Serial Communications Interface (SCI) Modules (SCI-A, SCI-B, SCI-C)

The devices include three serial communications interface (SCI) modules. The SCI modules support digital communications between the CPU and other asynchronous peripherals that use the standard nonreturn-to-zero (NRZ) format. The SCI receiver and transmitter are double-buffered, and each has its own separate enable and interrupt bits. Both can be operated independently or simultaneously in the full-duplex mode. To ensure data integrity, the SCI checks received data for break detection, parity, overrun, and framing errors. The bit rate is programmable to more than 65000 different speeds through a 16-bit baud-select register.

Features of each SCI module include:

- Two external pins:
  - SCITXD: SCI transmit-output pin
  - SCIRXD: SCI receive-input pin
- NOTE: Both pins can be used as GPIO if not used for SCI.
- Baud rate programmable to 64K different rates:

$$\text{Baud rate} = \frac{\text{LSPCLK}}{(\text{BRR} + 1) * 8} \quad \text{when BRR} \neq 0$$

$$\text{Baud rate} = \frac{\text{LSPCLK}}{16} \quad \text{when BRR} = 0$$

#### NOTE

See [Section 5](#) for maximum I/O pin toggling speed.

- Data-word format
  - One start bit
  - Data-word length programmable from one to eight bits
  - Optional even/odd/no parity bit
  - One or two stop bits
- Four error-detection flags: parity, overrun, framing, and break detection
- Two wake-up multiprocessor modes: idle-line and address bit
- Half- or full-duplex operation
- Double-buffered receive and transmit functions
- Transmitter and receiver operations can be accomplished through interrupt-driven or polled algorithms with status flags.
  - Transmitter: TXRDY flag (transmitter-buffer register is ready to receive another character) and TX EMPTY flag (transmitter-shift register is empty)
  - Receiver: RXRDY flag (receiver-buffer register is ready to receive another character), BRKDT flag (break condition occurred), and RX ERROR flag (monitoring four interrupt conditions)
- Separate enable bits for transmitter and receiver interrupts (except BRKDT)
- NRZ (nonreturn-to-zero) format

#### NOTE

All registers in this module are 8-bit registers that are connected to Peripheral Frame 2. When a register is accessed, the register data is in the lower byte (7-0), and the upper byte (15-8) is read as zeros. Writing to the upper byte has no effect.

Enhanced features:

- Auto baud-detect hardware logic
- 16-level transmit/receive FIFO

The SCI port operation is configured and controlled by the registers listed in [Table 6-12](#), [Table 6-13](#), and [Table 6-14](#).

**Table 6-12. SCI-A Registers<sup>(1)</sup>**

| NAME                    | ADDRESS | SIZE (x16) | DESCRIPTION                                  |
|-------------------------|---------|------------|----------------------------------------------|
| SCICCR A                | 0x7050  | 1          | SCI-A Communications Control Register        |
| SCICTL1A                | 0x7051  | 1          | SCI-A Control Register 1                     |
| SCIHBAUDA               | 0x7052  | 1          | SCI-A Baud Register, High Bits               |
| SCILBAUDA               | 0x7053  | 1          | SCI-A Baud Register, Low Bits                |
| SCICTL2A                | 0x7054  | 1          | SCI-A Control Register 2                     |
| SCIRXSTA                | 0x7055  | 1          | SCI-A Receive Status Register                |
| SCIRXEMUA               | 0x7056  | 1          | SCI-A Receive Emulation Data Buffer Register |
| SCIRXBUFA               | 0x7057  | 1          | SCI-A Receive Data Buffer Register           |
| SCITXBUFA               | 0x7059  | 1          | SCI-A Transmit Data Buffer Register          |
| SCIFFTXA <sup>(2)</sup> | 0x705A  | 1          | SCI-A FIFO Transmit Register                 |
| SCIFFRXA <sup>(2)</sup> | 0x705B  | 1          | SCI-A FIFO Receive Register                  |
| SCIFFCTA <sup>(2)</sup> | 0x705C  | 1          | SCI-A FIFO Control Register                  |
| SCIPRIA                 | 0x705F  | 1          | SCI-A Priority Control Register              |

(1) Registers in this table are mapped to Peripheral Frame 2 space. This space only allows 16-bit accesses. 32-bit accesses produce undefined results.

(2) These registers are new registers for the FIFO mode.

**Table 6-13. SCI-B Registers<sup>(1) (2)</sup>**

| NAME                    | ADDRESS | SIZE (x16) | DESCRIPTION                                  |
|-------------------------|---------|------------|----------------------------------------------|
| SCICCRB                 | 0x7750  | 1          | SCI-B Communications Control Register        |
| SCICTL1B                | 0x7751  | 1          | SCI-B Control Register 1                     |
| SCIHBAUDB               | 0x7752  | 1          | SCI-B Baud Register, High Bits               |
| SCILBAUDB               | 0x7753  | 1          | SCI-B Baud Register, Low Bits                |
| SCICTL2B                | 0x7754  | 1          | SCI-B Control Register 2                     |
| SCIRXSTB                | 0x7755  | 1          | SCI-B Receive Status Register                |
| SCIRXEMUB               | 0x7756  | 1          | SCI-B Receive Emulation Data Buffer Register |
| SCIRXBUB                | 0x7757  | 1          | SCI-B Receive Data Buffer Register           |
| SCITXBUB                | 0x7759  | 1          | SCI-B Transmit Data Buffer Register          |
| SCIFFTXB <sup>(2)</sup> | 0x775A  | 1          | SCI-B FIFO Transmit Register                 |
| SCIFFRXB <sup>(2)</sup> | 0x775B  | 1          | SCI-B FIFO Receive Register                  |
| SCIFFCTB <sup>(2)</sup> | 0x775C  | 1          | SCI-B FIFO Control Register                  |
| SCIPRIB                 | 0x775F  | 1          | SCI-B Priority Control Register              |

(1) Registers in this table are mapped to Peripheral Frame 2 space. This space only allows 16-bit accesses. 32-bit accesses produce undefined results.

(2) These registers are new registers for the FIFO mode.

**Table 6-14. SCI-C Registers<sup>(1) (2)</sup>**

| NAME                    | ADDRESS | SIZE (x16) | DESCRIPTION                                  |
|-------------------------|---------|------------|----------------------------------------------|
| SCICRC                  | 0x7770  | 1          | SCI-C Communications Control Register        |
| SCICTL1C                | 0x7771  | 1          | SCI-C Control Register 1                     |
| SCIHBAUDC               | 0x7772  | 1          | SCI-C Baud Register, High Bits               |
| SCILBAUDC               | 0x7773  | 1          | SCI-C Baud Register, Low Bits                |
| SCICTL2C                | 0x7774  | 1          | SCI-C Control Register 2                     |
| SCIRXSTC                | 0x7775  | 1          | SCI-C Receive Status Register                |
| SCIRXEMUC               | 0x7776  | 1          | SCI-C Receive Emulation Data Buffer Register |
| SCIRXBUFC               | 0x7777  | 1          | SCI-C Receive Data Buffer Register           |
| SCITXBUFC               | 0x7779  | 1          | SCI-C Transmit Data Buffer Register          |
| SCIFFTXC <sup>(2)</sup> | 0x777A  | 1          | SCI-C FIFO Transmit Register                 |
| SCIFFRXC <sup>(2)</sup> | 0x777B  | 1          | SCI-C FIFO Receive Register                  |
| SCIFFCTC <sup>(2)</sup> | 0x777C  | 1          | SCI-C FIFO Control Register                  |
| SCIPRC                  | 0x777F  | 1          | SCI-C Priority Control Register              |

(1) Registers in this table are mapped to Peripheral Frame 2 space. This space only allows 16-bit accesses. 32-bit accesses produce undefined results.

(2) These registers are new registers for the FIFO mode.

Figure 6-15 shows the SCI module block diagram.

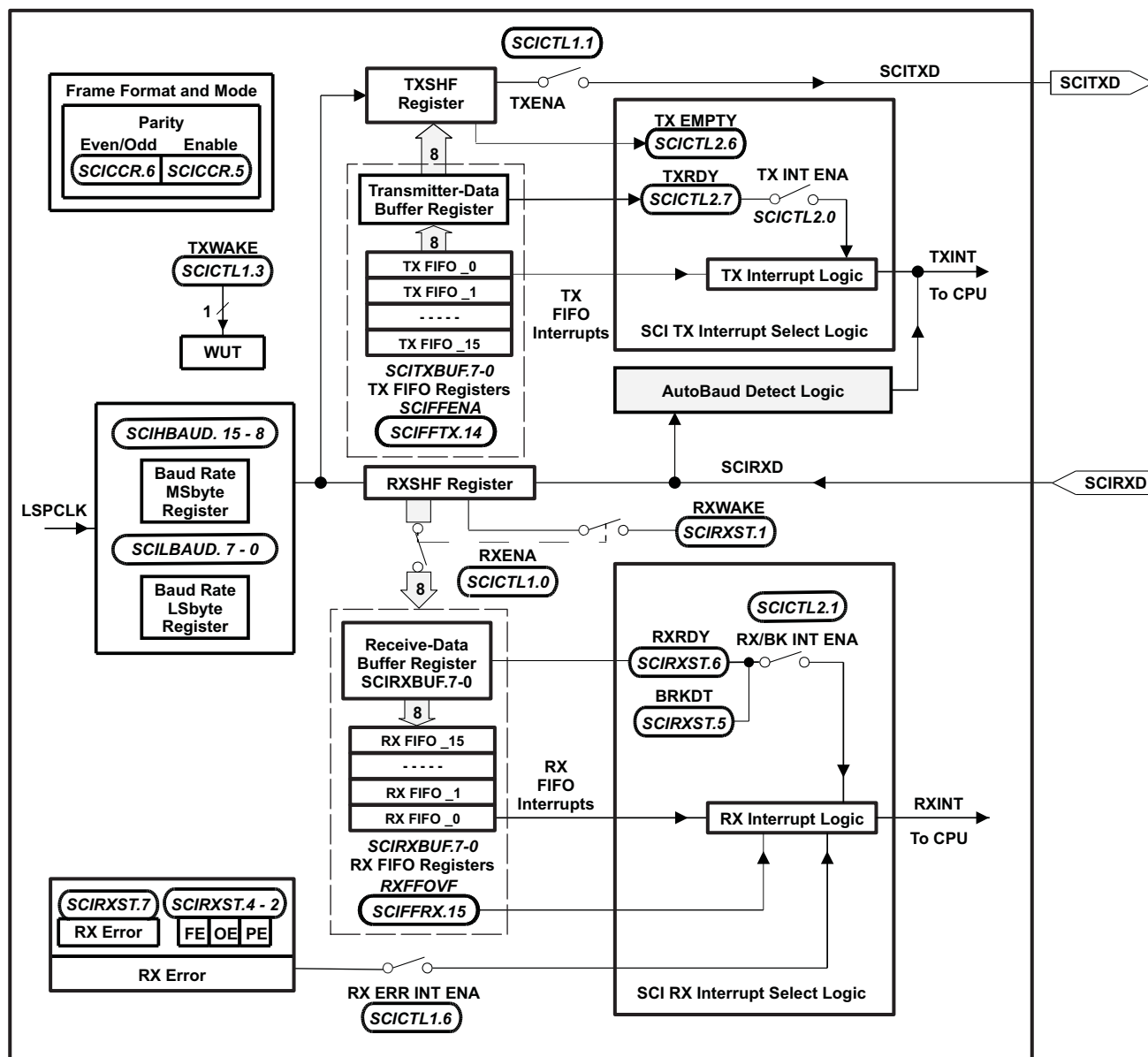


Figure 6-15. Serial Communications Interface (SCI) Module Block Diagram

### 6.2.11 Serial Peripheral Interface (SPI) Module (SPI-A)

The device includes the four-pin serial peripheral interface (SPI) module. One SPI module (SPI-A) is available. The SPI is a high-speed, synchronous serial I/O port that allows a serial bit stream of programmed length (1 to 16 bits) to be shifted into and out of the device at a programmable bit-transfer rate. Normally, the SPI is used for communications between the DSC controller and external peripherals or another processor. Typical applications include external I/O or peripheral expansion through devices such as shift registers, display drivers, and ADCs. Multidevice communications are supported by the master/slave operation of the SPI.

The SPI module features include:

- Four external pins:
  - SPISOMI: SPI slave-output/master-input pin
  - SPISIMO: SPI slave-input/master-output pin
  - $\overline{\text{SPISTE}}$ : SPI slave transmit-enable pin
  - SPICLK: SPI serial-clock pin

---

#### NOTE

All four pins can be used as GPIO if the SPI module is not used.

---

- Two operational modes: master and slave  
Baud rate: 125 different programmable rates.

$$\text{Baud rate} = \frac{\text{LSPCLK}}{(\text{SPIBRR} + 1)} \quad \text{when SPIBRR} = 3 \text{ to } 127$$

$$\text{Baud rate} = \frac{\text{LSPCLK}}{4} \quad \text{when SPIBRR} = 0, 1, 2$$


---

#### NOTE

See [Section 5](#) for maximum I/O pin toggling speed.

---

- Data word length: 1 to 16 data bits
- Four clocking schemes (controlled by clock polarity and clock phase bits) include:
  - Falling edge without phase delay: SPICLK active-high. SPI transmits data on the falling edge of the SPICLK signal and receives data on the rising edge of the SPICLK signal.
  - Falling edge with phase delay: SPICLK active-high. SPI transmits data one half-cycle ahead of the falling edge of the SPICLK signal and receives data on the falling edge of the SPICLK signal.
  - Rising edge without phase delay: SPICLK inactive-low. SPI transmits data on the rising edge of the SPICLK signal and receives data on the falling edge of the SPICLK signal.
  - Rising edge with phase delay: SPICLK inactive-low. SPI transmits data one half-cycle ahead of the rising edge of the SPICLK signal and receives data on the rising edge of the SPICLK signal.
- Simultaneous receive and transmit operation (transmit function can be disabled in software)
- Transmitter and receiver operations are accomplished through either interrupt-driven or polled algorithms.
- Nine SPI module control registers: Located in control register frame beginning at address 7040h.

---

#### NOTE

All registers in this module are 16-bit registers that are connected to Peripheral Frame 2. When a register is accessed, the register data is in the lower byte (7–0), and the upper byte (15–8) is read as zeros. Writing to the upper byte has no effect.

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Enhanced features:

- 16-level transmit/receive FIFO
- Delayed transmit control

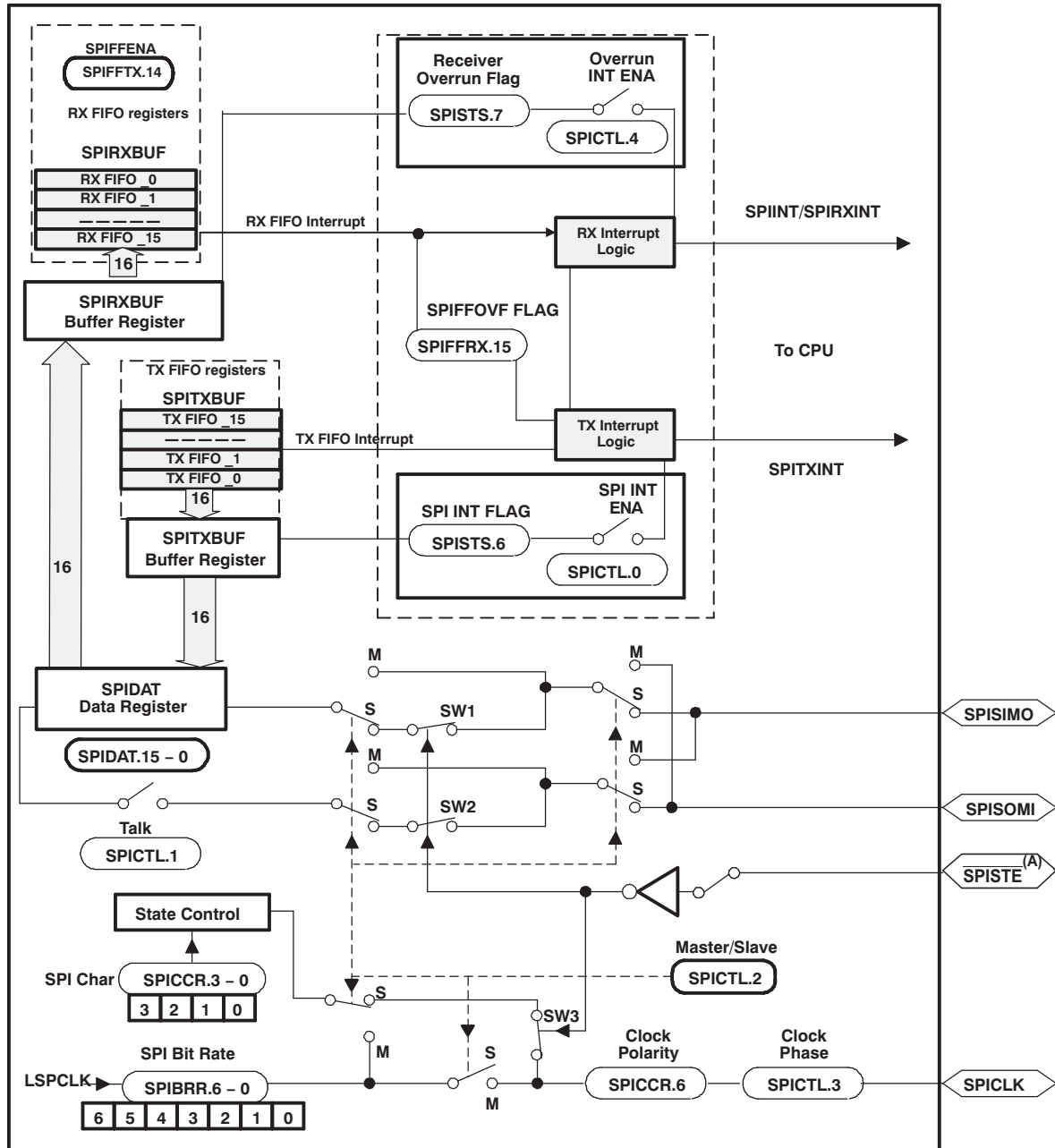
The SPI port operation is configured and controlled by the registers listed in [Table 6-15](#).

**Table 6-15. SPI-A Registers**

| NAME     | ADDRESS | SIZE (x16) | DESCRIPTION <sup>(1)</sup>              |
|----------|---------|------------|-----------------------------------------|
| SPICCR   | 0x7040  | 1          | SPI-A Configuration Control Register    |
| SPICTL   | 0x7041  | 1          | SPI-A Operation Control Register        |
| SPISTS   | 0x7042  | 1          | SPI-A Status Register                   |
| SPIBRR   | 0x7044  | 1          | SPI-A Baud Rate Register                |
| SPIRXEMU | 0x7046  | 1          | SPI-A Receive Emulation Buffer Register |
| SPIRXBUF | 0x7047  | 1          | SPI-A Serial Input Buffer Register      |
| SPITXBUF | 0x7048  | 1          | SPI-A Serial Output Buffer Register     |
| SPIDAT   | 0x7049  | 1          | SPI-A Serial Data Register              |
| SPIFFTX  | 0x704A  | 1          | SPI-A FIFO Transmit Register            |
| SPIFFRX  | 0x704B  | 1          | SPI-A FIFO Receive Register             |
| SPIFFCT  | 0x704C  | 1          | SPI-A FIFO Control Register             |
| SPIPRI   | 0x704F  | 1          | SPI-A Priority Control Register         |

(1) Registers in this table are mapped to Peripheral Frame 2. This space only allows 16-bit accesses. 32-bit accesses produce undefined results.

Figure 6-16 is a block diagram of the SPI in slave mode.

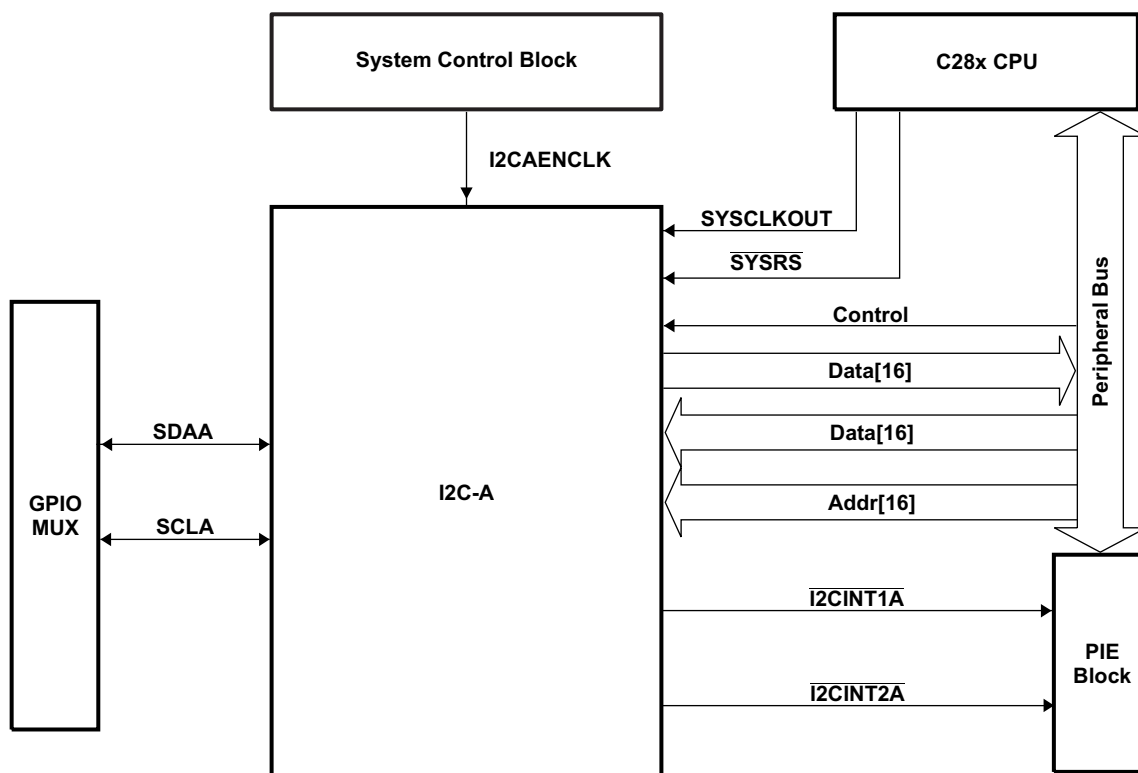


A.  $\overline{\text{SPISTE}}$  is driven low by the master for a slave device.

**Figure 6-16. SPI Module Block Diagram (Slave Mode)**

## 6.2.12 Inter-Integrated Circuit (I2C)

The device contains one I2C Serial Port. Figure 6-17 shows how the I2C peripheral module interfaces within the device.



- The I2C registers are accessed at the SYCLKOUT rate. The internal timing and signal waveforms of the I2C port are also at the SYCLKOUT rate.
- The clock enable bit (I2CAENCLK) in the PCLKCR0 register turns off the clock to the I2C port for low power operation. Upon reset, I2CAENCLK is clear, which indicates the peripheral internal clocks are off.

**Figure 6-17. I2C Peripheral Module Interfaces**

The I2C module has the following features:

- Compliance with the Philips Semiconductors I<sup>2</sup>C-bus specification (version 2.1):
  - Support for 1-bit to 8-bit format transfers
  - 7-bit and 10-bit addressing modes
  - General call
  - START byte mode
  - Support for multiple master-transmitters and slave-receivers
  - Support for multiple slave-transmitters and master-receivers
  - Combined master transmit/receive and receive/transmit mode
  - Data transfer rate from 10 kbps up to 400 kbps (I2C Fast-mode rate)
- One 16-word receive FIFO and one 16-word transmit FIFO
- One interrupt that can be used by the CPU. This interrupt can be generated as a result of one of the following conditions:
  - Transmit-data ready
  - Receive-data ready
  - Register-access ready
  - No-acknowledgment received
  - Arbitration lost
  - Stop condition detected
  - Addressed as slave
- An additional interrupt that can be used by the CPU when in FIFO mode
- Module-enable and module-disable capability
- Free data format mode

The registers in [Table 6-16](#) configure and control the I2C port operation.

**Table 6-16. I2C-A Registers**

| NAME    | ADDRESS | DESCRIPTION                                             |
|---------|---------|---------------------------------------------------------|
| I2COAR  | 0x7900  | I2C own address register                                |
| I2CIER  | 0x7901  | I2C interrupt enable register                           |
| I2CSTR  | 0x7902  | I2C status register                                     |
| I2CCLKL | 0x7903  | I2C clock low-time divider register                     |
| I2CCLKH | 0x7904  | I2C clock high-time divider register                    |
| I2CCNT  | 0x7905  | I2C data count register                                 |
| I2CDRR  | 0x7906  | I2C data receive register                               |
| I2CSAR  | 0x7907  | I2C slave address register                              |
| I2CDXR  | 0x7908  | I2C data transmit register                              |
| I2CMDR  | 0x7909  | I2C mode register                                       |
| I2CISRC | 0x790A  | I2C interrupt source register                           |
| I2CPSC  | 0x790C  | I2C prescaler register                                  |
| I2CFFTX | 0x7920  | I2C FIFO transmit register                              |
| I2CFFRX | 0x7921  | I2C FIFO receive register                               |
| I2CRSR  | –       | I2C receive shift register (not accessible to the CPU)  |
| I2CXSR  | –       | I2C transmit shift register (not accessible to the CPU) |

### 6.2.13 GPIO MUX

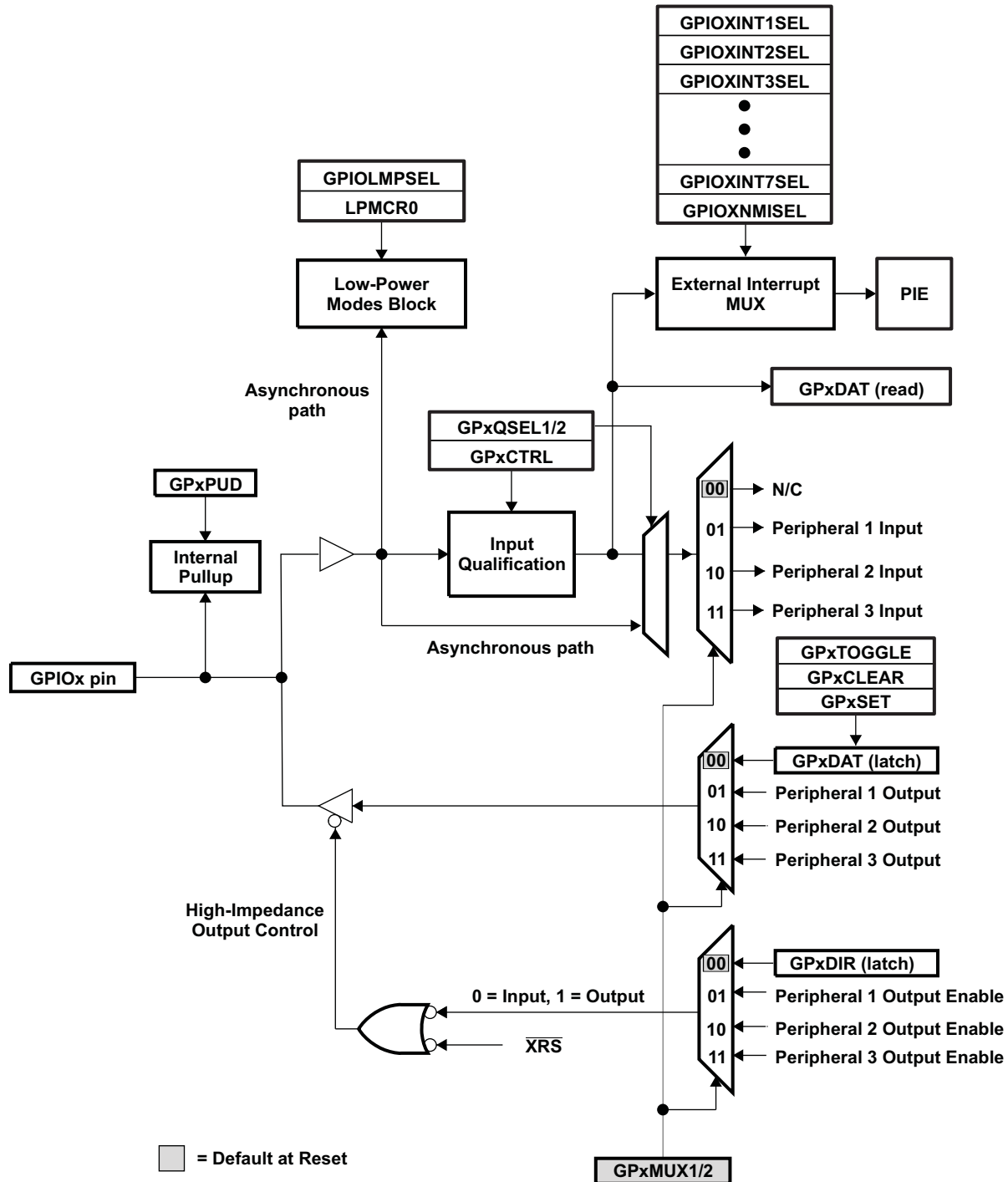
On the 2833x/2823x devices, the GPIO MUX can multiplex up to three independent peripheral signals on a single GPIO pin in addition to providing individual pin bit-banging I/O capability. The GPIO MUX block diagram per pin is shown in [Figure 6-18](#). Because of the open-drain capabilities of the I2C pins, the GPIO MUX block diagram for these pins differ. See the [TMS320x2833x, 2823x system control and interrupts reference guide](#) for details.

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#### NOTE

There is a 2-SYSCLKOUT cycle delay from when the write to the GPxMUXn and GPxQSELn registers occurs to when the action is valid.

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- x stands for the port, either A or B. For example, GPxDIR refers to either the GPADIR and GPBDIR register depending on the particular GPIO pin selected.
- GPxDAT latch/read are accessed at the same memory location.
- This is a generic GPIO MUX block diagram. Not all options may be applicable for all GPIO pins. See the [TMS320x2833x, 2823x system control and interrupts reference guide](#) for pin-specific variations.

**Figure 6-18. GPIO MUX Block Diagram**

The device supports 88 GPIO pins. The GPIO control and data registers are mapped to Peripheral Frame 1 to enable 32-bit operations on the registers (along with 16-bit operations). [Table 6-17](#) shows the GPIO register mapping.

**Table 6-17. GPIO Registers**

| NAME                                                                          | ADDRESS         | SIZE (x16) | DESCRIPTION                                       |
|-------------------------------------------------------------------------------|-----------------|------------|---------------------------------------------------|
| <b>GPIO CONTROL REGISTERS (EALLOW PROTECTED)</b>                              |                 |            |                                                   |
| GPACTRL                                                                       | 0x6F80          | 2          | GPIO A Control Register (GPIO0 to 31)             |
| GPAQSEL1                                                                      | 0x6F82          | 2          | GPIO A Qualifier Select 1 Register (GPIO0 to 15)  |
| GPAQSEL2                                                                      | 0x6F84          | 2          | GPIO A Qualifier Select 2 Register (GPIO16 to 31) |
| GPAMUX1                                                                       | 0x6F86          | 2          | GPIO A MUX 1 Register (GPIO0 to 15)               |
| GPAMUX2                                                                       | 0x6F88          | 2          | GPIO A MUX 2 Register (GPIO16 to 31)              |
| GPADIR                                                                        | 0x6F8A          | 2          | GPIO A Direction Register (GPIO0 to 31)           |
| GPAPUD                                                                        | 0x6F8C          | 2          | GPIO A Pullup Disable Register (GPIO0 to 31)      |
| Reserved                                                                      | 0x6F8E – 0x6F8F | 2          |                                                   |
| GPBCTRL                                                                       | 0x6F90          | 2          | GPIO B Control Register (GPIO32 to 63)            |
| GPBQSEL1                                                                      | 0x6F92          | 2          | GPIO B Qualifier Select 1 Register (GPIO32 to 47) |
| GPBQSEL2                                                                      | 0x6F94          | 2          | GPIOB Qualifier Select 2 Register (GPIO48 to 63)  |
| GPBMUX1                                                                       | 0x6F96          | 2          | GPIO B MUX 1 Register (GPIO32 to 47)              |
| GPBMUX2                                                                       | 0x6F98          | 2          | GPIO B MUX 2 Register (GPIO48 to 63)              |
| GPBDIR                                                                        | 0x6F9A          | 2          | GPIO B Direction Register (GPIO32 to 63)          |
| GPBPUD                                                                        | 0x6F9C          | 2          | GPIO B Pullup Disable Register (GPIO32 to 63)     |
| Reserved                                                                      | 0x6F9E – 0x6FA5 | 8          |                                                   |
| GPCMUX1                                                                       | 0x6FA6          | 2          | GPIO C MUX1 Register (GPIO64 to 79)               |
| GPCMUX2                                                                       | 0x6FA8          | 2          | GPIO C MUX2 Register (GPIO80 to 87)               |
| GPCDIR                                                                        | 0x6FAA          | 2          | GPIO C Direction Register (GPIO64 to 87)          |
| GPCPUD                                                                        | 0x6FAC          | 2          | GPIO C Pullup Disable Register (GPIO64 to 87)     |
| Reserved                                                                      | 0x6FAE – 0x6FBF | 18         |                                                   |
| <b>GPIO DATA REGISTERS (NOT EALLOW PROTECTED)</b>                             |                 |            |                                                   |
| GPADAT                                                                        | 0x6FC0          | 2          | GPIO A Data Register (GPIO0 to 31)                |
| GPASET                                                                        | 0x6FC2          | 2          | GPIO A Data Set Register (GPIO0 to 31)            |
| GPACLEAR                                                                      | 0x6FC4          | 2          | GPIO A Data Clear Register (GPIO0 to 31)          |
| GPATOGGLE                                                                     | 0x6FC6          | 2          | GPIO A Data Toggle Register (GPIO0 to 31)         |
| GPBDAT                                                                        | 0x6FC8          | 2          | GPIO B Data Register (GPIO32 to 63)               |
| GPBSET                                                                        | 0x6FCA          | 2          | GPIO B Data Set Register (GPIO32 to 63)           |
| GPBCLEAR                                                                      | 0x6FCC          | 2          | GPIO B Data Clear Register (GPIO32 to 63)         |
| GPBTOGGLE                                                                     | 0x6FCE          | 2          | GPIOB Data Toggle Register (GPIO32 to 63)         |
| GPCDAT                                                                        | 0x6FD0          | 2          | GPIO C Data Register (GPIO64 to 87)               |
| GPCSET                                                                        | 0x6FD2          | 2          | GPIO C Data Set Register (GPIO64 to 87)           |
| GPCCLEAR                                                                      | 0x6FD4          | 2          | GPIO C Data Clear Register (GPIO64 to 87)         |
| GPCTOGGLE                                                                     | 0x6FD6          | 2          | GPIO C Data Toggle Register (GPIO64 to 87)        |
| Reserved                                                                      | 0x6FD8 – 0x6FDF | 8          |                                                   |
| <b>GPIO INTERRUPT AND LOW-POWER MODES SELECT REGISTERS (EALLOW PROTECTED)</b> |                 |            |                                                   |
| GPIOXINT1SEL                                                                  | 0x6FE0          | 1          | XINT1 GPIO Input Select Register (GPIO0 to 31)    |
| GPIOXINT2SEL                                                                  | 0x6FE1          | 1          | XINT2 GPIO Input Select Register (GPIO0 to 31)    |
| GPIOXNMISEL                                                                   | 0x6FE2          | 1          | XNMI GPIO Input Select Register (GPIO0 to 31)     |
| GPIOXINT3SEL                                                                  | 0x6FE3          | 1          | XINT3 GPIO Input Select Register (GPIO32 to 63)   |
| GPIOXINT4SEL                                                                  | 0x6FE4          | 1          | XINT4 GPIO Input Select Register (GPIO32 to 63)   |
| GPIOXINT5SEL                                                                  | 0x6FE5          | 1          | XINT5 GPIO Input Select Register (GPIO32 to 63)   |
| GPIOXINT6SEL                                                                  | 0x6FE6          | 1          | XINT6 GPIO Input Select Register (GPIO32 to 63)   |
| GPIOINT7SEL                                                                   | 0x6FE7          | 1          | XINT7 GPIO Input Select Register (GPIO32 to 63)   |
| GPIOIPMSEL                                                                    | 0x6FE8          | 2          | LPM GPIO Select Register (GPIO0 to 31)            |
| Reserved                                                                      | 0x6FEA – 0x6FFF | 22         |                                                   |

**Table 6-18. GPIO-A Mux Peripheral Selection Matrix**

| REGISTER BITS                                     |    | PERIPHERAL SELECTION |                         |                                                                        |                                          |                                                     |
|---------------------------------------------------|----|----------------------|-------------------------|------------------------------------------------------------------------|------------------------------------------|-----------------------------------------------------|
| GPADIR<br>GPADAT<br>GPASET<br>GPACLR<br>GPATOGGLE |    | GPAMUX1<br>GPAQSEL1  | GPIOx<br>GPAMUX1 = 0, 0 | PER1<br>GPAMUX1 = 0, 1                                                 | PER2<br>GPAMUX1 = 1, 0                   | PER3<br>GPAMUX1 = 1, 1                              |
| QUALPRD0                                          | 0  | 1, 0                 | GPIO0 (I/O)             | EPWM1A (O)                                                             | Reserved                                 | Reserved                                            |
|                                                   | 1  | 3, 2                 | GPIO1 (I/O)             | EPWM1B (O)                                                             | ECAP6 (I/O)                              | MFSRB (I/O)                                         |
|                                                   | 2  | 5, 4                 | GPIO2 (I/O)             | EPWM2A (O)                                                             | Reserved                                 | Reserved                                            |
|                                                   | 3  | 7, 6                 | GPIO3 (I/O)             | EPWM2B (O)                                                             | ECAP5 (I/O)                              | MCLKRB (I/O)                                        |
|                                                   | 4  | 9, 8                 | GPIO4 (I/O)             | EPWM3A (O)                                                             | Reserved                                 | Reserved                                            |
|                                                   | 5  | 11, 10               | GPIO5 (I/O)             | EPWM3B (O)                                                             | MFSRA (I/O)                              | ECAP1 (I/O)                                         |
|                                                   | 6  | 13, 12               | GPIO6 (I/O)             | EPWM4A (O)                                                             | EPWMSYNCl (I)                            | EPWMSYNCO (O)                                       |
|                                                   | 7  | 15, 14               | GPIO7 (I/O)             | EPWM4B (O)                                                             | MCLKRA (I/O)                             | ECAP2 (I/O)                                         |
| QUALPRD1                                          | 8  | 17, 16               | GPIO8 (I/O)             | EPWM5A (O)                                                             | CANTXB (O)                               | ADC $\overline{\text{SOCA}}\overline{\text{O}}$ (O) |
|                                                   | 9  | 19, 18               | GPIO9 (I/O)             | EPWM5B (O)                                                             | SCITXDB (O)                              | ECAP3 (I/O)                                         |
|                                                   | 10 | 21, 20               | GPIO10 (I/O)            | EPWM6A (O)                                                             | CANRXB (I)                               | ADC $\overline{\text{SOCB}}\overline{\text{O}}$ (O) |
|                                                   | 11 | 23, 22               | GPIO11 (I/O)            | EPWM6B (O)                                                             | SCIRXDB (I)                              | ECAP4 (I/O)                                         |
|                                                   | 12 | 25, 24               | GPIO12 (I/O)            | $\overline{\text{TZ}}\overline{1}$ (I)                                 | CANTXB (O)                               | MDXB (O)                                            |
|                                                   | 13 | 27, 26               | GPIO13 (I/O)            | $\overline{\text{TZ}}\overline{2}$ (I)                                 | CANRXB (I)                               | MDRB (I)                                            |
|                                                   | 14 | 29, 28               | GPIO14 (I/O)            | $\overline{\text{TZ}}\overline{3}$ (I)/ $\overline{\text{XHOLD}}$ (I)  | SCITXDB (O)                              | MCLKXB (I/O)                                        |
|                                                   | 15 | 31, 30               | GPIO15 (I/O)            | $\overline{\text{TZ}}\overline{4}$ (I)/ $\overline{\text{XHOLDA}}$ (O) | SCIRXDB (I)                              | MFSXB (I/O)                                         |
|                                                   |    | GPAMUX2<br>GPAQSEL2  | GPAMUX2 = 0, 0          | GPAMUX2 = 0, 1                                                         | GPAMUX2 = 1, 0                           | GPAMUX2 = 1, 1                                      |
| QUALPRD2                                          | 16 | 1, 0                 | GPIO16 (I/O)            | SPISIMOA (I/O)                                                         | CANTXB (O)                               | $\overline{\text{TZ}}\overline{5}$ (I)              |
|                                                   | 17 | 3, 2                 | GPIO17 (I/O)            | SPISOMIA (I/O)                                                         | CANRXB (I)                               | $\overline{\text{TZ}}\overline{6}$ (I)              |
|                                                   | 18 | 5, 4                 | GPIO18 (I/O)            | SPICLKA (I/O)                                                          | SCITXDB (O)                              | CANRXA (I)                                          |
|                                                   | 19 | 7, 6                 | GPIO19 (I/O)            | $\overline{\text{SPISTEA}}$ (I/O)                                      | SCIRXDB (I)                              | CANTXA (O)                                          |
|                                                   | 20 | 9, 8                 | GPIO20 (I/O)            | EQEP1A (I)                                                             | MDXA (O)                                 | CANTXB (O)                                          |
|                                                   | 21 | 11, 10               | GPIO21 (I/O)            | EQEP1B (I)                                                             | MDRA (I)                                 | CANRXB (I)                                          |
|                                                   | 22 | 13, 12               | GPIO22 (I/O)            | EQEP1S (I/O)                                                           | MCLKXA (I/O)                             | SCITXDB (O)                                         |
|                                                   | 23 | 15, 14               | GPIO23 (I/O)            | EQEP1I (I/O)                                                           | MFSXA (I/O)                              | SCIRXDB (I)                                         |
| QUALPRD3                                          | 24 | 17, 16               | GPIO24 (I/O)            | ECAP1 (I/O)                                                            | EQEP2A (I)                               | MDXB (O)                                            |
|                                                   | 25 | 19, 18               | GPIO25 (I/O)            | ECAP2 (I/O)                                                            | EQEP2B (I)                               | MDRB (I)                                            |
|                                                   | 26 | 21, 20               | GPIO26 (I/O)            | ECAP3 (I/O)                                                            | EQEP2I (I/O)                             | MCLKXB (I/O)                                        |
|                                                   | 27 | 23, 22               | GPIO27 (I/O)            | ECAP4 (I/O)                                                            | EQEP2S (I/O)                             | MFSXB (I/O)                                         |
|                                                   | 28 | 25, 24               | GPIO28 (I/O)            | SCIRXDA (I)                                                            | $\overline{\text{XZCS}}\overline{6}$ (O) |                                                     |
|                                                   | 29 | 27, 26               | GPIO29 (I/O)            | SCITXDA (O)                                                            | XA19 (O)                                 |                                                     |
|                                                   | 30 | 29, 28               | GPIO30 (I/O)            | CANRXA (I)                                                             | XA18 (O)                                 |                                                     |
|                                                   | 31 | 31, 30               | GPIO31 (I/O)            | CANTXA (O)                                                             | XA17 (O)                                 |                                                     |

**Table 6-19. GPIO-B Mux Peripheral Selection Matrix**

| REGISTER BITS                                     |    |                     | PERIPHERAL SELECTION    |                            |                            |                        |
|---------------------------------------------------|----|---------------------|-------------------------|----------------------------|----------------------------|------------------------|
| GPBDIR<br>GPBDAT<br>GPBSET<br>GPBCLR<br>GPBTOGGLE |    | GPBMUX1<br>GPBQSEL1 | GPIOx<br>GPBMUX1 = 0, 0 | PER1<br>GPBMUX1 = 0, 1     | PER2<br>GPBMUX1 = 1, 0     | PER3<br>GPBMUX1 = 1, 1 |
| QUALPRD0                                          | 0  | 1, 0                | GPIO32 (I/O)            | SDAA (I/OC) <sup>(1)</sup> | EPWMSYNCI (I)              | ADCSOAO (O)            |
|                                                   | 1  | 3, 2                | GPIO33 (I/O)            | SCLA (I/OC) <sup>(1)</sup> | EPWMSYNCO (O)              | ADCSOCBO (O)           |
|                                                   | 2  | 5, 4                | GPIO34 (I/O)            | ECAP1 (I/O)                | XREADY (I)                 |                        |
|                                                   | 3  | 7, 6                | GPIO35 (I/O)            | SCITXDA (O)                | XR $\overline{W}$ (O)      |                        |
|                                                   | 4  | 9, 8                | GPIO36 (I/O)            | SCIRXDA (I)                | $\overline{XZCS0}$ (O)     |                        |
|                                                   | 5  | 11, 10              | GPIO37 (I/O)            | ECAP2 (I/O)                | $\overline{XZCS7}$ (O)     |                        |
|                                                   | 6  | 13, 12              | GPIO38 (I/O)            | Reserved                   | $\overline{XWE0}$ (O)      |                        |
|                                                   | 7  | 15, 14              | GPIO39 (I/O)            |                            | XA16 (O)                   |                        |
| QUALPRD1                                          | 8  | 17, 16              | GPIO40 (I/O)            |                            | XA0/ $\overline{XWE1}$ (O) |                        |
|                                                   | 9  | 19, 18              | GPIO41 (I/O)            |                            | XA1 (O)                    |                        |
|                                                   | 10 | 21, 20              | GPIO42 (I/O)            |                            | XA2 (O)                    |                        |
|                                                   | 11 | 23, 22              | GPIO43 (I/O)            |                            | XA3 (O)                    |                        |
|                                                   | 12 | 25, 24              | GPIO44 (I/O)            |                            | XA4 (O)                    |                        |
|                                                   | 13 | 27, 26              | GPIO45 (I/O)            |                            | XA5 (O)                    |                        |
|                                                   | 14 | 29, 28              | GPIO46 (I/O)            |                            | XA6 (O)                    |                        |
|                                                   | 15 | 31, 30              | GPIO47 (I/O)            |                            | XA7 (O)                    |                        |
|                                                   |    | GPBMUX2<br>GPBQSEL2 | GPBMUX2 = 0, 0          | GPBMUX2 = 0, 1             | GPBMUX2 = 1, 0             | GPBMUX2 = 1, 1         |
| QUALPRD2                                          | 16 | 1, 0                | GPIO48 (I/O)            | ECAP5 (I/O)                | XD31 (I/O)                 |                        |
|                                                   | 17 | 3, 2                | GPIO49 (I/O)            | ECAP6 (I/O)                | XD30 (I/O)                 |                        |
|                                                   | 18 | 5, 4                | GPIO50 (I/O)            | EQEP1A (I)                 | XD29 (I/O)                 |                        |
|                                                   | 19 | 7, 6                | GPIO51 (I/O)            | EQEP1B (I)                 | XD28 (I/O)                 |                        |
|                                                   | 20 | 9, 8                | GPIO52 (I/O)            | EQEP1S (I/O)               | XD27 (I/O)                 |                        |
|                                                   | 21 | 11, 10              | GPIO53 (I/O)            | EQEP1I (I/O)               | XD26 (I/O)                 |                        |
|                                                   | 22 | 13, 12              | GPIO54 (I/O)            | SPISIMOA (I/O)             | XD25 (I/O)                 |                        |
|                                                   | 23 | 15, 14              | GPIO55 (I/O)            | SPISOMIA (I/O)             | XD24 (I/O)                 |                        |
| QUALPRD3                                          | 24 | 17, 16              | GPIO56 (I/O)            | SPICLKA (I/O)              | XD23 (I/O)                 |                        |
|                                                   | 25 | 19, 18              | GPIO57 (I/O)            | $\overline{SPISTEA}$ (I/O) | XD22 (I/O)                 |                        |
|                                                   | 26 | 21, 20              | GPIO58 (I/O)            | MCLKRA (I/O)               | XD21 (I/O)                 |                        |
|                                                   | 27 | 23, 22              | GPIO59 (I/O)            | MFSRA (I/O)                | XD20 (I/O)                 |                        |
|                                                   | 28 | 25, 24              | GPIO60 (I/O)            | MCLKRB (I/O)               | XD19 (I/O)                 |                        |
|                                                   | 29 | 27, 26              | GPIO61 (I/O)            | MFSRB (I/O)                | XD18 (I/O)                 |                        |
|                                                   | 30 | 29, 28              | GPIO62 (I/O)            | SCIRXDC (I)                | XD17 (I/O)                 |                        |
|                                                   | 31 | 31, 30              | GPIO63 (I/O)            | SCITXDC (O)                | XD16 (I/O)                 |                        |

(1) Open drain

**Table 6-20. GPIO-C Mux Peripheral Selection Matrix**

| REGISTER BITS |    | PERIPHERAL SELECTION |                                         |                                        |
|---------------|----|----------------------|-----------------------------------------|----------------------------------------|
|               |    | GPCMUX1              | GPIOx or PER1<br>GPCMUX1 = 0, 0 or 0, 1 | PER2 or PER3<br>GPCMUX1 = 1, 0 or 1, 1 |
|               |    |                      |                                         |                                        |
| no qual       | 0  | 1, 0                 | GPIO64 (I/O)                            | XD15 (I/O)                             |
|               | 1  | 3, 2                 | GPIO65 (I/O)                            | XD14 (I/O)                             |
|               | 2  | 5, 4                 | GPIO66 (I/O)                            | XD13 (I/O)                             |
|               | 3  | 7, 6                 | GPIO67 (I/O)                            | XD12 (I/O)                             |
|               | 4  | 9, 8                 | GPIO68 (I/O)                            | XD11 (I/O)                             |
|               | 5  | 11, 10               | GPIO69 (I/O)                            | XD10 (I/O)                             |
|               | 6  | 13, 12               | GPIO70 (I/O)                            | XD9 (I/O)                              |
|               | 7  | 15, 14               | GPIO71 (I/O)                            | XD8 (I/O)                              |
| no qual       | 8  | 17, 16               | GPIO72 (I/O)                            | XD7 (I/O)                              |
|               | 9  | 19, 18               | GPIO73 (I/O)                            | XD6 (I/O)                              |
|               | 10 | 21, 20               | GPIO74 (I/O)                            | XD5 (I/O)                              |
|               | 11 | 23, 22               | GPIO75 (I/O)                            | XD4 (I/O)                              |
|               | 12 | 25, 24               | GPIO76 (I/O)                            | XD3 (I/O)                              |
|               | 13 | 27, 26               | GPIO77 (I/O)                            | XD2 (I/O)                              |
|               | 14 | 29, 28               | GPIO78 (I/O)                            | XD1 (I/O)                              |
|               | 15 | 31, 30               | GPIO79 (I/O)                            | XD0 (I/O)                              |
|               |    | <b>GPCMUX2</b>       | <b>GPCMUX2 = 0, 0 or 0, 1</b>           | <b>GPCMUX2 = 1, 0 or 1, 1</b>          |
| no qual       | 16 | 1, 0                 | GPIO80 (I/O)                            | XA8 (O)                                |
|               | 17 | 3, 2                 | GPIO81 (I/O)                            | XA9 (O)                                |
|               | 18 | 5, 4                 | GPIO82 (I/O)                            | XA10 (O)                               |
|               | 19 | 7, 6                 | GPIO83 (I/O)                            | XA11 (O)                               |
|               | 20 | 9, 8                 | GPIO84 (I/O)                            | XA12 (O)                               |
|               | 21 | 11, 10               | GPIO85 (I/O)                            | XA13 (O)                               |
|               | 22 | 13, 12               | GPIO86 (I/O)                            | XA14 (O)                               |
|               | 23 | 15, 14               | GPIO87 (I/O)                            | XA15 (O)                               |

The user can select the type of input qualification for each GPIO pin through the GPxQSEL1/2 registers from four choices:

- Synchronization To SYSCLKOUT Only (GPxQSEL1/2 = 0, 0): This is the default mode of all GPIO pins at reset and it simply synchronizes the input signal to the system clock (SYSCLKOUT).
- Qualification Using Sampling Window (GPxQSEL1/2 = 0, 1 and 1, 0): In this mode the input signal, after synchronization to the system clock (SYSCLKOUT), is qualified by a specified number of cycles before the input is allowed to change.

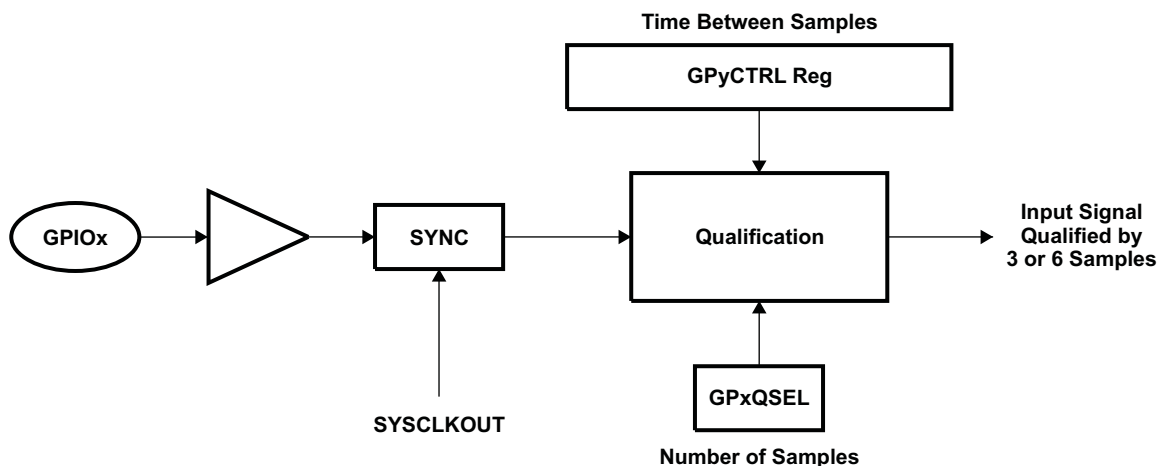


**Figure 6-19. Qualification Using Sampling Window**

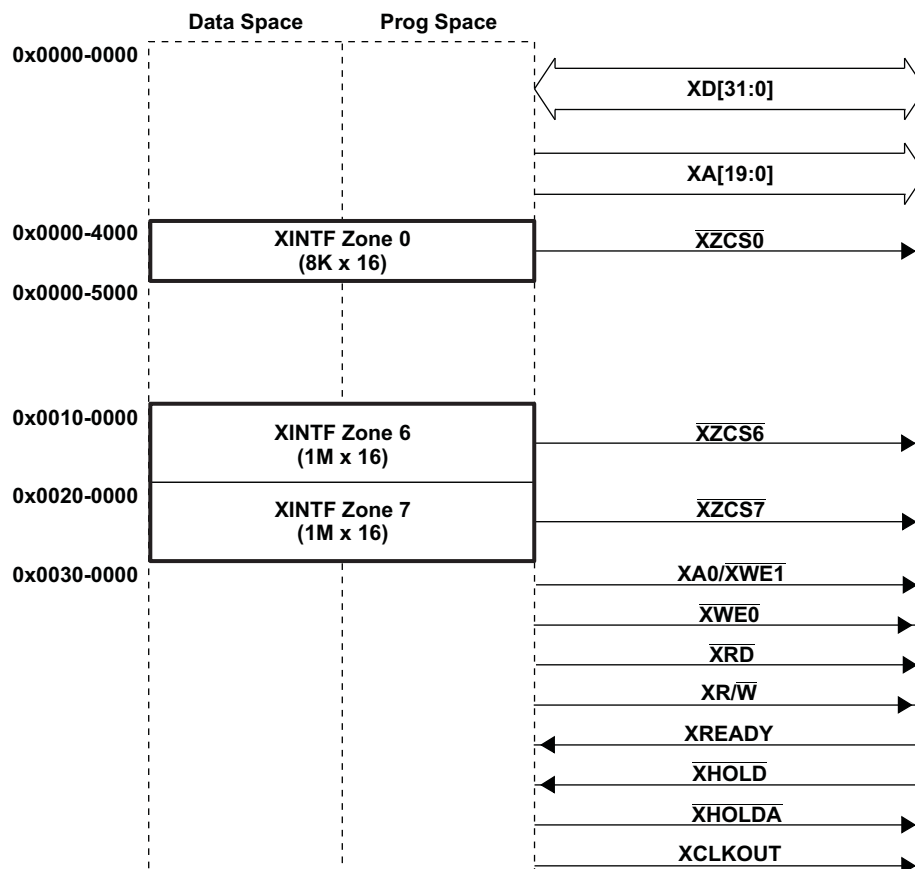
- The sampling period is specified by the QUALPRD bits in the GPxCTRL register and is configurable in groups of 8 signals. It specifies a multiple of SYSCLKOUT cycles for sampling the input signal. The sampling window is either 3-samples or 6-samples wide and the output is only changed when all samples are the same (all 0s or all 1s) as shown in [Figure 6-19](#) (for 6-sample mode).
- No Synchronization (GPxQSEL1/2 = 1,1): This mode is used for peripherals where synchronization is not required (synchronization is performed within the peripheral).

Due to the multilevel multiplexing that is required on the device, there may be cases where a peripheral input signal can be mapped to more than one GPIO pin. Also, when an input signal is not selected, the input signal will default to either a 0 or 1 state, depending on the peripheral.

## 6.2.14 External Interface (XINTF)

This section gives a top-level view of the external interface (XINTF) that is implemented on the 2833x/2823x devices.

The XINTF is a nonmultiplexed asynchronous bus, similar to the 2812 XINTF. The XINTF is mapped into three fixed zones shown in Figure 6-20.



- A. Each zone can be programmed with different wait states, setup and hold timings, and is supported by zone chip selects that toggle when an access to a particular zone is performed. These features enable glueless connection to many external memories and peripherals.
- B. Zones 1 – 5 are reserved for future expansion.
- C. Zones 0, 6, and 7 are always enabled.

**Figure 6-20. External Interface Block Diagram**

Figure 6-21 and Figure 6-22 show typical 16-bit and 32-bit data bus XINTF connections, illustrating how the functionality of the XA0 and XWE1 signals change, depending on the configuration. Table 6-21 defines XINTF configuration and control registers.

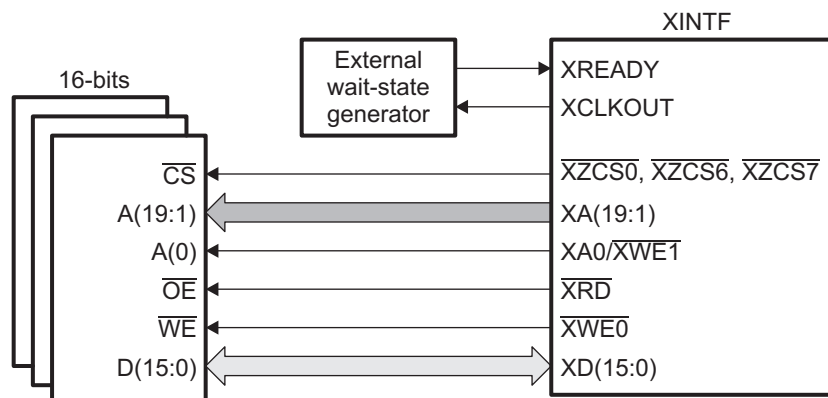


Figure 6-21. Typical 16-Bit Data Bus XINTF Connections

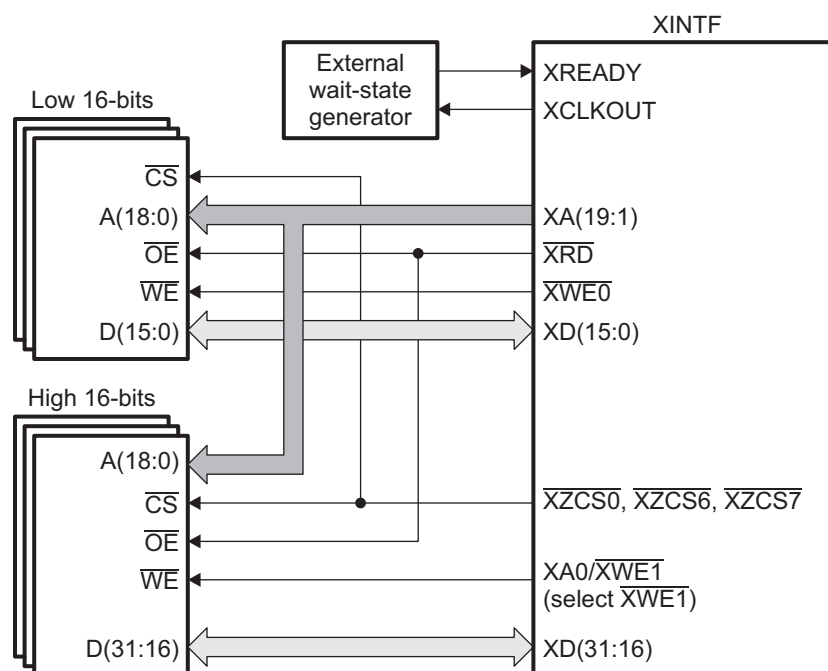


Figure 6-22. Typical 32-Bit Data Bus XINTF Connections

Table 6-21. XINTF Configuration and Control Register Mapping

| NAME                    | ADDRESS   | SIZE (x16) | DESCRIPTION                   |
|-------------------------|-----------|------------|-------------------------------|
| XTIMING0                | 0x00–0B20 | 2          | XINTF Timing Register, Zone 0 |
| XTIMING6 <sup>(1)</sup> | 0x00–0B2C | 2          | XINTF Timing Register, Zone 6 |
| XTIMING7                | 0x00–0B2E | 2          | XINTF Timing Register, Zone 7 |
| XINTCNF2 <sup>(2)</sup> | 0x00–0B34 | 2          | XINTF Configuration Register  |
| XBANK                   | 0x00–0B38 | 1          | XINTF Bank Control Register   |
| XREVISION               | 0x00–0B3A | 1          | XINTF Revision Register       |
| XRESET                  | 0x00–0B3D | 1          | XINTF Reset Register          |

(1) XTIMING1 - XTIMING5 are reserved for future expansion and are not currently used.

(2) XINTCNF1 is reserved and not currently used.

## 6.3 Memory Maps

In [Figure 6-23](#) to [Figure 6-25](#), the following apply:

- Memory blocks are not to scale.
- Peripheral Frame 0, Peripheral Frame 1, Peripheral Frame 2, and Peripheral Frame 3 memory maps are restricted to data memory only. A user program cannot access these memory maps in program space.
- *Protected* means the order of "Write followed by Read" operations is preserved rather than the pipeline order. See the [TMS320x2833x, 2823x system control and interrupts reference guide](#) for more details.
- Certain memory ranges are EALLOW protected against spurious writes after configuration.
- Locations 0x38 0080–0x38 008F contain the ADC calibration routine. It is not programmable by the user.
- If the eCAN module is not used in an application, the RAM available (LAM, MOTS, MOTO, and mailbox RAM) can be used as general-purpose RAM. The CAN module clock should be enabled for this.

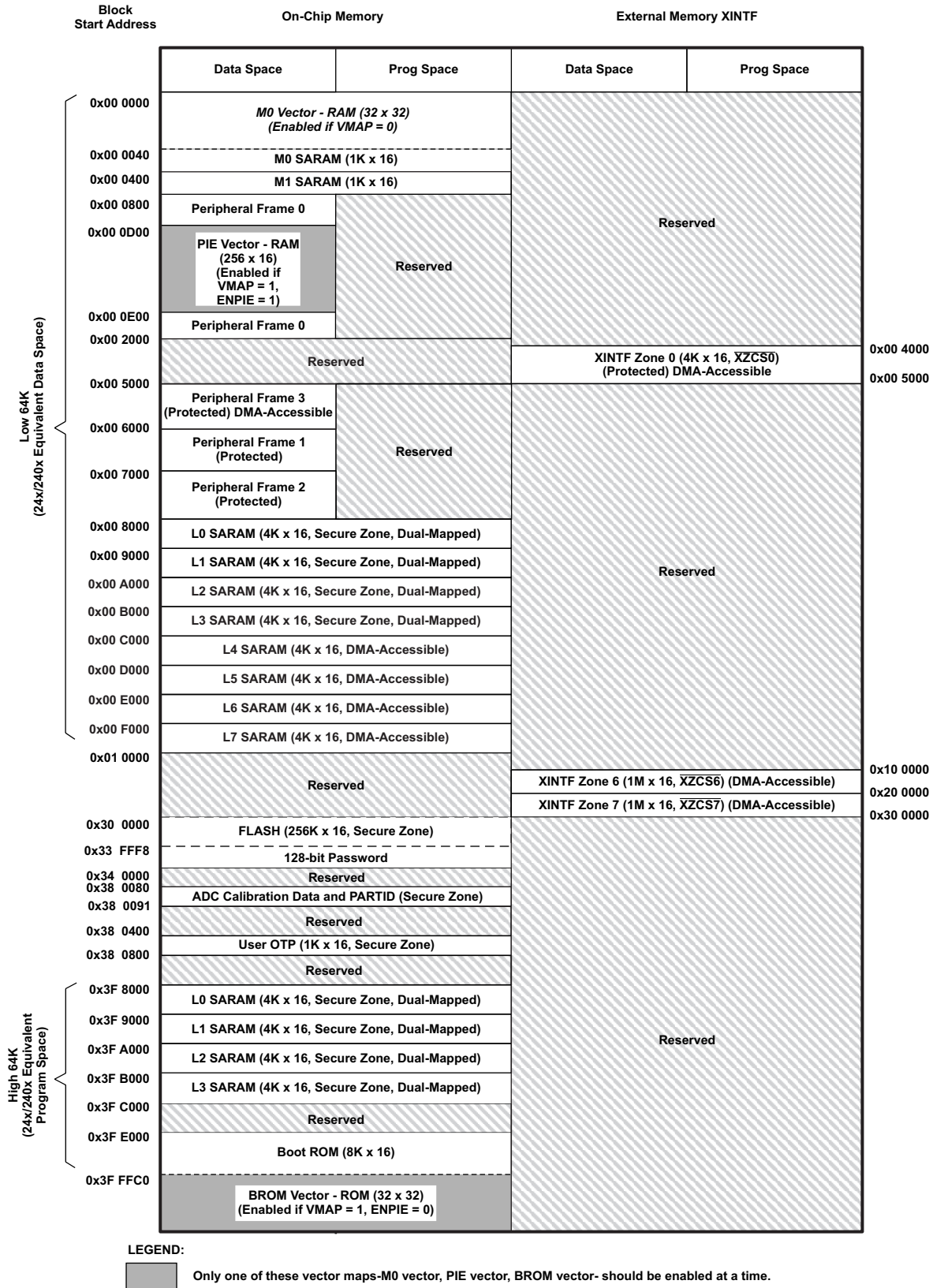
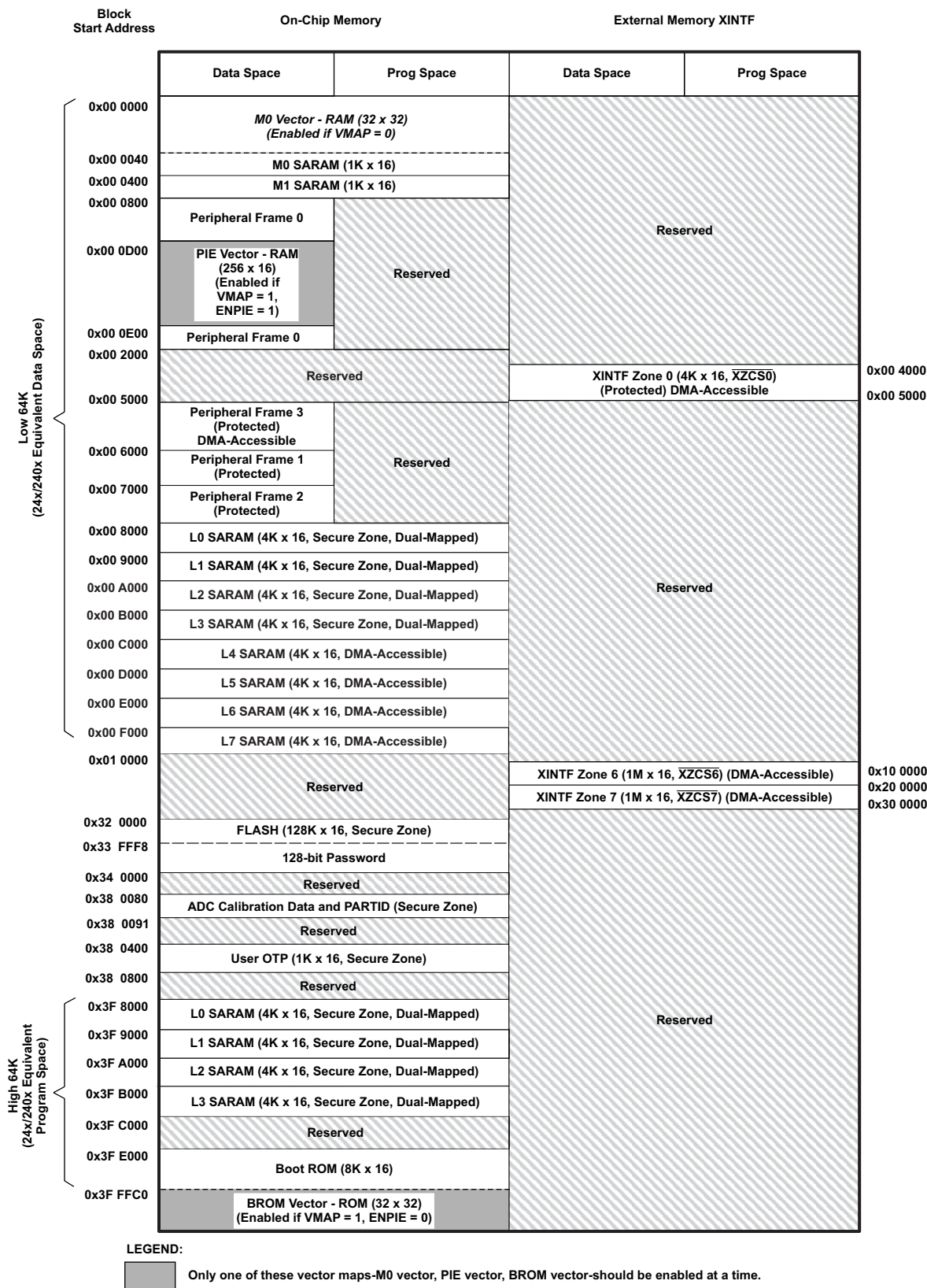


**Figure 6-23. F28335, F28333, F28235 Memory Map**


**Figure 6-24. F28334, F28234 Memory Map**

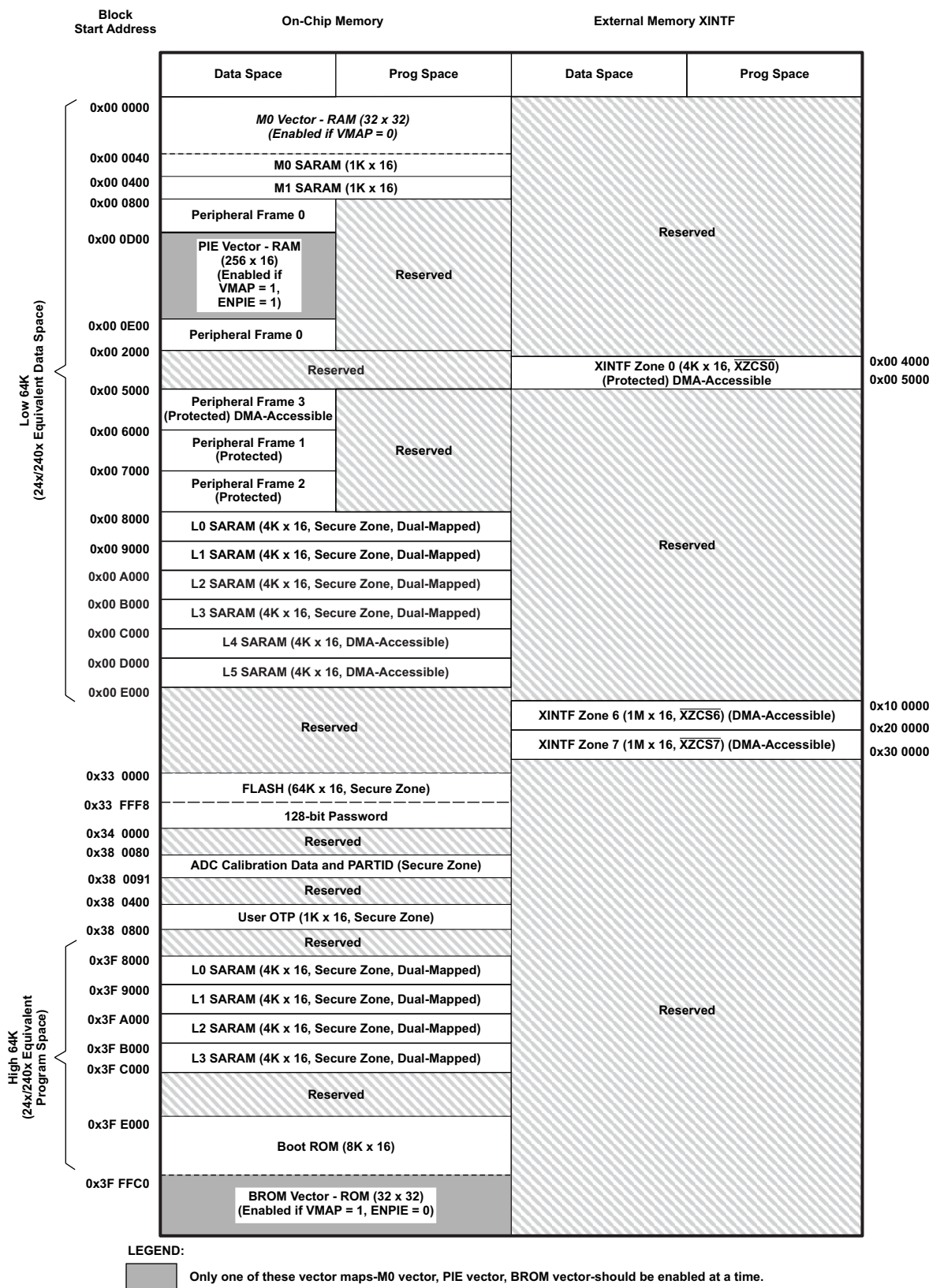


Figure 6-25. F28332, F28232 Memory Map

**Table 6-22. Addresses of Flash Sectors in F28335, F28333, F28235**

| ADDRESS RANGE         | PROGRAM AND DATA SPACE                                      |
|-----------------------|-------------------------------------------------------------|
| 0x30 0000 - 0x30 7FFF | Sector H (32K × 16)                                         |
| 0x30 8000 - 0x30 FFFF | Sector G (32K × 16)                                         |
| 0x31 0000 - 0x31 7FFF | Sector F (32K × 16)                                         |
| 0x31 8000 - 0x31 FFFF | Sector E (32K × 16)                                         |
| 0x32 0000 - 0x32 7FFF | Sector D (32K × 16)                                         |
| 0x32 8000 - 0x32 FFFF | Sector C (32K × 16)                                         |
| 0x33 0000 - 0x33 7FFF | Sector B (32K × 16)                                         |
| 0x33 8000 - 0x33 FF7F | Sector A (32K × 16)                                         |
| 0x33 FF80 - 0x33 FFF5 | Program to 0x0000 when using the Code Security Module       |
| 0x33 FFF6 - 0x33 FFF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x33 FFF8 - 0x33 FFFF | Security Password (128-Bit) (Do Not Program to all zeros)   |

**Table 6-23. Addresses of Flash Sectors in F28334, F28234**

| ADDRESS RANGE         | PROGRAM AND DATA SPACE                                      |
|-----------------------|-------------------------------------------------------------|
| 0x32 0000 - 0x32 3FFF | Sector H (16K × 16)                                         |
| 0x32 4000 - 0x32 7FFF | Sector G (16K × 16)                                         |
| 0x32 8000 - 0x32 BFFF | Sector F (16K × 16)                                         |
| 0x32 C000 - 0x32 FFFF | Sector E (16K × 16)                                         |
| 0x33 0000 - 0x33 3FFF | Sector D (16K × 16)                                         |
| 0x33 4000 - 0x33 7FFF | Sector C (16K × 16)                                         |
| 0x33 8000 - 0x33 BFFF | Sector B (16K × 16)                                         |
| 0x33 C000 - 0x33 FF7F | Sector A (16K × 16)                                         |
| 0x33 FF80 - 0x33 FFF5 | Program to 0x0000 when using the Code Security Module       |
| 0x33 FFF6 - 0x33 FFF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x33 FFF8 - 0x33 FFFF | Security Password (128-Bit) (Do Not Program to all zeros)   |

**Table 6-24. Addresses of Flash Sectors in F28332, F28232**

| ADDRESS RANGE         | PROGRAM AND DATA SPACE                                      |
|-----------------------|-------------------------------------------------------------|
| 0x33 0000 - 0x33 3FFF | Sector D (16K × 16)                                         |
| 0x33 4000 - 0x33 7FFF | Sector C (16K × 16)                                         |
| 0x33 8000 - 0x33 BFFF | Sector B (16K × 16)                                         |
| 0x33 C000 - 0x33 FF7F | Sector A (16K × 16)                                         |
| 0x33 FF80 - 0x33 FFF5 | Program to 0x0000 when using the Code Security Module       |
| 0x33 FFF6 - 0x33 FFF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x33 FFF8 - 0x33 FFFF | Security Password (128-Bit) (Do Not Program to all zeros)   |

### NOTE

- When the code-security passwords are programmed, all addresses from 0x33FF80 to 0x33FFF5 cannot be used as program code or data. These locations must be programmed to 0x0000.
- If the code security feature is not used, addresses 0x33FF80 to 0x33FFEF may be used for code or data. Addresses 0x33FFF0 to 0x33FFF5 are reserved for data and should not contain program code.

[Table 6-25](#) shows how to handle these memory locations.

**Table 6-25. Handling Security Code Locations**

| ADDRESS             | FLASH                 |                           |
|---------------------|-----------------------|---------------------------|
|                     | CODE SECURITY ENABLED | CODE SECURITY DISABLED    |
| 0x33FF80 – 0x33FFEF | Fill with 0x0000      | Application code and data |
| 0x33FFF0 – 0x33FFF5 |                       | Reserved for data only    |

Peripheral Frame 1, Peripheral Frame 2, and Peripheral Frame 3 are grouped together to enable these blocks to be write/read peripheral block protected. The protected mode ensures that all accesses to these blocks happen as written. Because of the C28x pipeline, a write immediately followed by a read, to different memory locations, will appear in reverse order on the memory bus of the CPU. This can cause problems in certain peripheral applications where the user expected the write to occur first (as written). The C28x CPU supports a block protection mode where a region of memory can be protected so as to make sure that operations occur as written (the penalty is extra cycles are added to align the operations). This mode is programmable and by default, it will protect the selected zones.

The wait states for the various spaces in the memory map area are listed in [Table 6-26](#).

**Table 6-26. Wait States**

| AREA               | WAIT STATES (CPU)                                                       | WAIT STATES (DMA) <sup>(1)</sup>                                    | COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M0 and M1 SARAMs   | 0-wait                                                                  |                                                                     | Fixed                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Peripheral Frame 0 | 0-wait (writes)<br>1-wait (reads)                                       | 0-wait (reads)<br>No access (writes)                                |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Peripheral Frame 3 | 0-wait (writes)<br>2-wait (reads)                                       | 0-wait (writes)<br>1-wait (reads)                                   | Assumes no conflicts between CPU and DMA.                                                                                                                                                                                                                                                                                                                                                                                                   |
| Peripheral Frame 1 | 0-wait (writes)<br>2-wait (reads)                                       | No access                                                           | Cycles can be extended by peripheral generated ready.<br>Consecutive (back-to-back) writes to Peripheral Frame 1 registers will experience a 1-cycle pipeline hit (1-cycle delay)                                                                                                                                                                                                                                                           |
| Peripheral Frame 2 | 0-wait (writes)<br>2-wait (reads)                                       | No access                                                           | Fixed. Cycles cannot be extended by the peripheral.                                                                                                                                                                                                                                                                                                                                                                                         |
| L0 SARAM           | 0-wait                                                                  | No access                                                           | Assumes no CPU conflicts                                                                                                                                                                                                                                                                                                                                                                                                                    |
| L1 SARAM           |                                                                         |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| L2 SARAM           |                                                                         |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| L3 SARAM           |                                                                         |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| L4 SARAM           | 0-wait data (reads)                                                     | 0-wait                                                              | Assumes no conflicts between CPU and DMA.                                                                                                                                                                                                                                                                                                                                                                                                   |
| L5 SARAM           | 0-wait data (writes)                                                    |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| L6 SARAM           | 1-wait program (reads)                                                  |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| L7 SARAM           | 1-wait program (writes)                                                 |                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| XINTF              | Programmable<br><br>0-wait minimum writes with write buffer enabled     | Programmable<br><br>0-wait minimum writes with write buffer enabled | Programmed through the XTIMING registers or extendable through external XREADY signal to meet system timing requirements.<br>1-wait is minimum wait states allowed on external waveforms for both reads and writes on XINTF.<br>0-wait minimum for writes assumes write buffer enabled and not full.<br>Assumes no conflicts between CPU and DMA. When DMA and CPU try simultaneously (conflict), a 1-cycle delay is added for arbitration. |
| OTP                | Programmable<br>1-wait minimum                                          | No access                                                           | Programmed via the Flash registers.<br>1-wait is minimum number of wait states allowed. 1-wait-state operation is possible at a reduced CPU frequency.                                                                                                                                                                                                                                                                                      |
| FLASH              | Programmable<br>1-wait Paged min<br>1-wait Random min<br>Random ≥ Paged | No access                                                           | Programmed via the Flash registers.<br>0-wait minimum for paged access is not allowed                                                                                                                                                                                                                                                                                                                                                       |
| FLASH Password     | 16-wait fixed                                                           | No access                                                           | Wait states of password locations are fixed.                                                                                                                                                                                                                                                                                                                                                                                                |
| Boot-ROM           | 1-wait                                                                  | No access                                                           | 0-wait speed is not possible.                                                                                                                                                                                                                                                                                                                                                                                                               |

(1) The DMA has a base of four cycles/word.

## 6.4 Register Map

The devices contain four peripheral register spaces. The spaces are categorized as follows:

Peripheral Frame 0: These are peripherals that are mapped directly to the CPU memory bus.  
See [Table 6-27](#).

Peripheral Frame 1: These are peripherals that are mapped to the 32-bit peripheral bus.  
See [Table 6-28](#).

Peripheral Frame 2: These are peripherals that are mapped to the 16-bit peripheral bus.  
See [Table 6-29](#).

Peripheral Frame 3: These are peripherals that are mapped to the 32-bit DMA-accessible peripheral bus. See [Table 6-30](#).

**Table 6-27. Peripheral Frame 0 Registers<sup>(1)</sup>**

| NAME                                                                 | ADDRESS RANGE         | SIZE (x16) | ACCESS TYPE <sup>(2)</sup> |
|----------------------------------------------------------------------|-----------------------|------------|----------------------------|
| Device Emulation Registers                                           | 0x00 0880 – 0x00 09FF | 384        | EALLOW protected           |
| FLASH Registers <sup>(3)</sup>                                       | 0x00 0A80 – 0x00 0ADF | 96         | EALLOW protected           |
| Code Security Module Registers                                       | 0x00 0AE0 – 0x00 0AEF | 16         | EALLOW protected           |
| ADC registers (dual-mapped)<br>0 wait (DMA), 1 wait (CPU), read only | 0x00 0B00 – 0x00 0B0F | 16         | Not EALLOW protected       |
| XINTF Registers                                                      | 0x00 0B20 – 0x00 0B3F | 32         | EALLOW protected           |
| CPU-Timer 0, CPU-Timer 1, CPU-Timer 2<br>Registers                   | 0x00 0C00 – 0x00 0C3F | 64         | Not EALLOW protected       |
| PIE Registers                                                        | 0x00 0CE0 – 0x00 0CFF | 32         | Not EALLOW protected       |
| PIE Vector Table                                                     | 0x00 0D00 – 0x00 0DFF | 256        | EALLOW protected           |
| DMA Registers                                                        | 0x00 1000 – 0x00 11FF | 512        | EALLOW protected           |

(1) Registers in Frame 0 support 16-bit and 32-bit accesses.

(2) If registers are EALLOW protected, then writes cannot be performed until the EALLOW instruction is executed. The EDIS instruction disables writes to prevent stray code or pointers from corrupting register contents.

(3) The Flash Registers are also protected by the Code Security Module (CSM).

**Table 6-28. Peripheral Frame 1 Registers**

| NAME                     | ADDRESS RANGE         | SIZE (x16) |
|--------------------------|-----------------------|------------|
| eCAN-A Registers         | 0x00 6000 – 0x00 61FF | 512        |
| eCAN-B Registers         | 0x00 6200 – 0x00 63FF | 512        |
| ePWM1 + HRPWM1 Registers | 0x00 6800 – 0x00 683F | 64         |
| ePWM2 + HRPWM2 Registers | 0x00 6840 – 0x00 687F | 64         |
| ePWM3 + HRPWM3 Registers | 0x00 6880 – 0x00 68BF | 64         |
| ePWM4 + HRPWM4 Registers | 0x00 68C0 – 0x00 68FF | 64         |
| ePWM5 + HRPWM5 Registers | 0x00 6900 – 0x00 693F | 64         |
| ePWM6 + HRPWM6 Registers | 0x00 6940 – 0x00 697F | 64         |
| eCAP1 Registers          | 0x00 6A00 – 0x00 6A1F | 32         |
| eCAP2 Registers          | 0x00 6A20 – 0x00 6A3F | 32         |
| eCAP3 Registers          | 0x00 6A40 – 0x00 6A5F | 32         |
| eCAP4 Registers          | 0x00 6A60 – 0x00 6A7F | 32         |
| eCAP5 Registers          | 0x00 6A80 – 0x00 6A9F | 32         |
| eCAP6 Registers          | 0x00 6AA0 – 0x00 6ABF | 32         |
| eQEP1 Registers          | 0x00 6B00 – 0x00 6B3F | 64         |
| eQEP2 Registers          | 0x00 6B40 – 0x00 6B7F | 64         |
| GPIO Registers           | 0x00 6F80 – 0x00 6FFF | 128        |

**Table 6-29. Peripheral Frame 2 Registers**

| NAME                         | ADDRESS RANGE         | SIZE (x16) |
|------------------------------|-----------------------|------------|
| System Control Registers     | 0x00 7010 – 0x00 702F | 32         |
| SPI-A Registers              | 0x00 7040 – 0x00 704F | 16         |
| SCI-A Registers              | 0x00 7050 – 0x00 705F | 16         |
| External Interrupt Registers | 0x00 7070 – 0x00 707F | 16         |
| ADC Registers                | 0x00 7100 – 0x00 711F | 32         |
| SCI-B Registers              | 0x00 7750 – 0x00 775F | 16         |
| SCI-C Registers              | 0x00 7770 – 0x00 777F | 16         |
| I2C-A Registers              | 0x00 7900 – 0x00 793F | 64         |

**Table 6-30. Peripheral Frame 3 Registers**

| NAME                                | ADDRESS RANGE   | SIZE (x16) |
|-------------------------------------|-----------------|------------|
| McBSP-A Registers (DMA)             | 0x5000 – 0x503F | 64         |
| McBSP-B Registers (DMA)             | 0x5040 – 0x507F | 64         |
| ePWM1 + HRPWM1 (DMA) <sup>(1)</sup> | 0x5800 – 0x583F | 64         |
| ePWM2 + HRPWM2 (DMA)                | 0x5840 – 0x587F | 64         |
| ePWM3 + HRPWM3 (DMA)                | 0x5880 – 0x58BF | 64         |
| ePWM4 + HRPWM4 (DMA)                | 0x58C0 – 0x58FF | 64         |
| ePWM5 + HRPWM5 (DMA)                | 0x5900 – 0x593F | 64         |
| ePWM6 + HRPWM6 (DMA)                | 0x5940 – 0x597F | 64         |

- (1) The ePWM and HRPWM modules can be re-mapped to Peripheral Frame 3 where they can be accessed by the DMA module. To achieve this, bit 0 (MAPEPWM) of MAPCNF register (address 0x702E) must be set to 1. This register is EALLOW protected. When this bit is 0, the ePWM and HRPWM modules are mapped to Peripheral Frame 1.

### 6.4.1 Device Emulation Registers

These registers are used to control the protection mode of the C28x CPU and to monitor some critical device signals. The registers are defined in [Table 6-31](#).

**Table 6-31. Device Emulation Registers**

| NAME      | ADDRESS RANGE    | SIZE (x16) | DESCRIPTION                                    |                               |        |
|-----------|------------------|------------|------------------------------------------------|-------------------------------|--------|
| DEVICECNF | 0x0880<br>0x0881 | 2          | Device Configuration Register                  |                               |        |
| PARTID    | 0x380090         | 1          | Part ID Register                               | TMS320F28335                  | 0x00EF |
|           |                  |            |                                                | TMS320F28334                  | 0x00EE |
|           |                  |            |                                                | TMS320F28333                  | 0x00E0 |
|           |                  |            |                                                | TMS320F28332                  | 0x00ED |
|           |                  |            |                                                | TMS320F28235                  | 0x00E8 |
|           |                  |            |                                                | TMS320F28234                  | 0x00E7 |
|           |                  |            |                                                | TMS320F28232                  | 0x00E6 |
| CLASSID   | 0x0882           | 1          | TMS320F2833x<br>Floating-Point<br>Class Device | TMS320F28335                  | 0x00EF |
|           |                  |            |                                                | TMS320F28334                  | 0x00EF |
|           |                  |            |                                                | TMS320F28333                  | 0x00EF |
|           |                  |            |                                                | TMS320F28332                  | 0x00EF |
|           |                  |            | TMS320F2823x<br>Fixed-Point<br>Class Device    | TMS320F28235                  | 0x00E8 |
|           |                  |            |                                                | TMS320F28234                  | 0x00E8 |
|           |                  |            |                                                | TMS320F28232                  | 0x00E8 |
| REVID     | 0x0883           | 1          | Revision ID Register                           | 0x0001 – Silicon Rev. A – TMS |        |
| PROTSTART | 0x0884           | 1          | Block Protection Start Address Register        |                               |        |
| PROTRANGE | 0x0885           | 1          | Block Protection Range Address Register        |                               |        |

## 6.5 Interrupts

Figure 6-26 shows how the various interrupt sources are multiplexed.

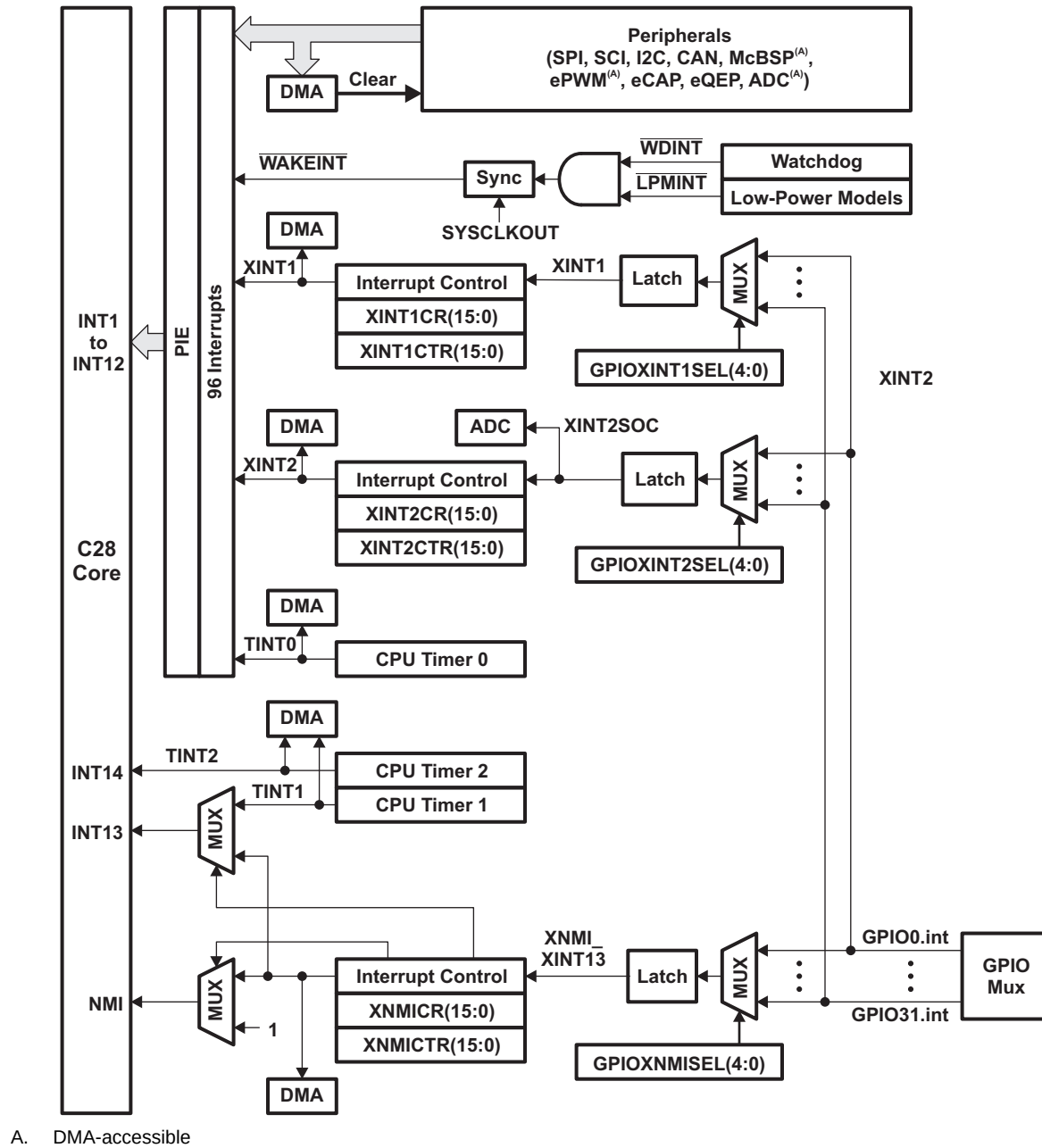


Figure 6-26. External and PIE Interrupt Sources

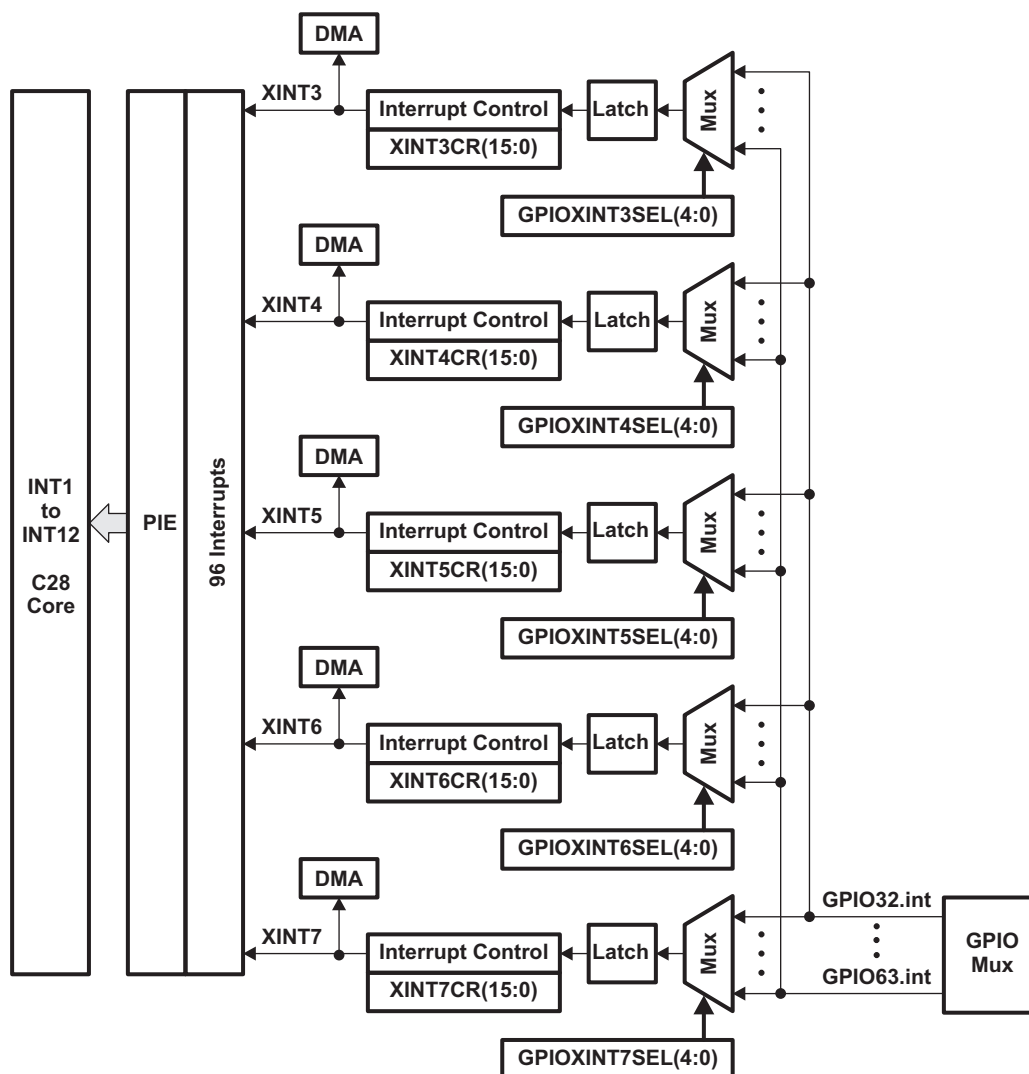


Figure 6-27. External Interrupts

Eight PIE block interrupts are grouped into one CPU interrupt. In total, 12 CPU interrupt groups, with 8 interrupts per group equals 96 possible interrupts. On the 2833x/2823x devices, 58 of these are used by peripherals as shown in Table 6-32.

The TRAP #VectorNumber instruction transfers program control to the interrupt service routine corresponding to the vector specified. TRAP #0 tries to transfer program control to the address pointed to by the reset vector. The PIE vector table does not, however, include a reset vector. Therefore, TRAP #0 should not be used when the PIE is enabled. Doing so will result in undefined behavior.

When the PIE is enabled, TRAP #1 to TRAP #12 will transfer program control to the interrupt service routine corresponding to the first vector within the PIE group. For example: TRAP #1 fetches the vector from INT1.1, TRAP #2 fetches the vector from INT2.1, and so forth.

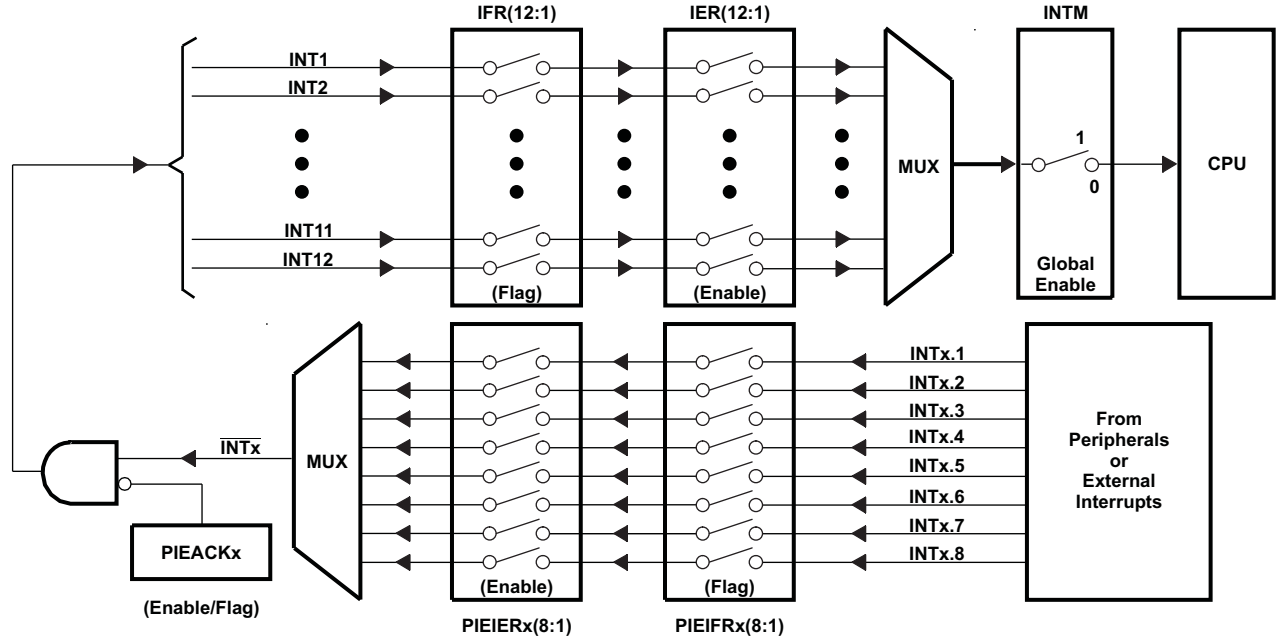


Figure 6-28. Multiplexing of Interrupts Using the PIE Block

Table 6-32. PIE Peripheral Interrupts<sup>(1)</sup>

| CPU INTERRUPTS | PIE INTERRUPTS     |                    |                             |                     |                     |                     |                     |                     |
|----------------|--------------------|--------------------|-----------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|                | INTx.8             | INTx.7             | INTx.6                      | INTx.5              | INTx.4              | INTx.3              | INTx.2              | INTx.1              |
| INT1           | WAKEINT (LPM/WD)   | TINT0 (TIMER 0)    | ADCINT <sup>(2)</sup> (ADC) | XINT2               | XINT1               | Reserved            | SEQ2INT (ADC)       | SEQ1INT (ADC)       |
| INT2           | Reserved           | Reserved           | EPWM6_TZINT (ePWM6)         | EPWM5_TZINT (ePWM5) | EPWM4_TZINT (ePWM4) | EPWM3_TZINT (ePWM3) | EPWM2_TZINT (ePWM2) | EPWM1_TZINT (ePWM1) |
| INT3           | Reserved           | Reserved           | EPWM6_INT (ePWM6)           | EPWM5_INT (ePWM5)   | EPWM4_INT (ePWM4)   | EPWM3_INT (ePWM3)   | EPWM2_INT (ePWM2)   | EPWM1_INT (ePWM1)   |
| INT4           | Reserved           | Reserved           | ECAP6_INT (eCAP6)           | ECAP5_INT (eCAP5)   | ECAP4_INT (eCAP4)   | ECAP3_INT (eCAP3)   | ECAP2_INT (eCAP2)   | ECAP1_INT (eCAP1)   |
| INT5           | Reserved           | Reserved           | Reserved                    | Reserved            | Reserved            | Reserved            | EQEP2_INT (eQEP2)   | EQEP1_INT (eQEP1)   |
| INT6           | Reserved           | Reserved           | MXINTA (McBSP-A)            | MRINTA (McBSP-A)    | MXINTB (McBSP-B)    | MRINTB (McBSP-B)    | SPITXINTA (SPI-A)   | SPIRXINTA (SPI-A)   |
| INT7           | Reserved           | Reserved           | DINTCH6 (DMA)               | DINTCH5 (DMA)       | DINTCH4 (DMA)       | DINTCH3 (DMA)       | DINTCH2 (DMA)       | DINTCH1 (DMA)       |
| INT8           | Reserved           | Reserved           | SCITXINTC (SCI-C)           | SCIRXINTC (SCI-C)   | Reserved            | Reserved            | I2CINT2A (I2C-A)    | I2CINT1A (I2C-A)    |
| INT9           | ECAN1_INTB (CAN-B) | ECAN0_INTB (CAN-B) | ECAN1_INTA (CAN-A)          | ECAN0_INTA (CAN-A)  | SCITXINTB (SCI-B)   | SCIRXINTB (SCI-B)   | SCITXINTA (SCI-A)   | SCIRXINTA (SCI-A)   |
| INT10          | Reserved           | Reserved           | Reserved                    | Reserved            | Reserved            | Reserved            | Reserved            | Reserved            |
| INT11          | Reserved           | Reserved           | Reserved                    | Reserved            | Reserved            | Reserved            | Reserved            | Reserved            |
| INT12          | LUF (FPU)          | LVF (FPU)          | Reserved                    | XINT7               | XINT6               | XINT5               | XINT4               | XINT3               |

- (1) Out of the 96 possible interrupts, 58 interrupts are currently used. The remaining interrupts are reserved for future devices. These interrupts can be used as software interrupts if they are enabled at the PIEIFRx level, provided none of the interrupts within the group is being used by a peripheral. Otherwise, interrupts coming in from peripherals may be lost by accidentally clearing their flag while modifying the PIEIFR. To summarize, there are two safe cases when the reserved interrupts could be used as software interrupts:
- 1) No peripheral within the group is asserting interrupts.
  - 2) No peripheral interrupts are assigned to the group (example PIE group 11).
- (2) ADCINT is sourced as a logical "OR" of both the SEQ1INT and SEQ2INT signals. This is to support backward compatibility with the implementation found on the TMS320F281x series of devices, where SEQ1INT and SEQ2INT did not exist, only ADCINT. For new implementations, TI recommends using SEQ1INT and SEQ2INT and not enabling ADCINT in the PIEIER register.

**Table 6-33. PIE Configuration and Control Registers**

| NAME     | ADDRESS         | SIZE (x16) | DESCRIPTION <sup>(1)</sup>       |
|----------|-----------------|------------|----------------------------------|
| PIECTRL  | 0x0CE0          | 1          | PIE, Control Register            |
| PIEACK   | 0x0CE1          | 1          | PIE, Acknowledge Register        |
| PIEIER1  | 0x0CE2          | 1          | PIE, INT1 Group Enable Register  |
| PIEIFR1  | 0x0CE3          | 1          | PIE, INT1 Group Flag Register    |
| PIEIER2  | 0x0CE4          | 1          | PIE, INT2 Group Enable Register  |
| PIEIFR2  | 0x0CE5          | 1          | PIE, INT2 Group Flag Register    |
| PIEIER3  | 0x0CE6          | 1          | PIE, INT3 Group Enable Register  |
| PIEIFR3  | 0x0CE7          | 1          | PIE, INT3 Group Flag Register    |
| PIEIER4  | 0x0CE8          | 1          | PIE, INT4 Group Enable Register  |
| PIEIFR4  | 0x0CE9          | 1          | PIE, INT4 Group Flag Register    |
| PIEIER5  | 0x0CEA          | 1          | PIE, INT5 Group Enable Register  |
| PIEIFR5  | 0x0CEB          | 1          | PIE, INT5 Group Flag Register    |
| PIEIER6  | 0x0CEC          | 1          | PIE, INT6 Group Enable Register  |
| PIEIFR6  | 0x0CED          | 1          | PIE, INT6 Group Flag Register    |
| PIEIER7  | 0x0CEE          | 1          | PIE, INT7 Group Enable Register  |
| PIEIFR7  | 0x0CEF          | 1          | PIE, INT7 Group Flag Register    |
| PIEIER8  | 0x0CF0          | 1          | PIE, INT8 Group Enable Register  |
| PIEIFR8  | 0x0CF1          | 1          | PIE, INT8 Group Flag Register    |
| PIEIER9  | 0x0CF2          | 1          | PIE, INT9 Group Enable Register  |
| PIEIFR9  | 0x0CF3          | 1          | PIE, INT9 Group Flag Register    |
| PIEIER10 | 0x0CF4          | 1          | PIE, INT10 Group Enable Register |
| PIEIFR10 | 0x0CF5          | 1          | PIE, INT10 Group Flag Register   |
| PIEIER11 | 0x0CF6          | 1          | PIE, INT11 Group Enable Register |
| PIEIFR11 | 0x0CF7          | 1          | PIE, INT11 Group Flag Register   |
| PIEIER12 | 0x0CF8          | 1          | PIE, INT12 Group Enable Register |
| PIEIFR12 | 0x0CF9          | 1          | PIE, INT12 Group Flag Register   |
| Reserved | 0x0CFA – 0x0CFF | 6          | Reserved                         |

(1) The PIE configuration and control registers are not protected by EALLOW mode. The PIE vector table is protected.

## 6.5.1 External Interrupts

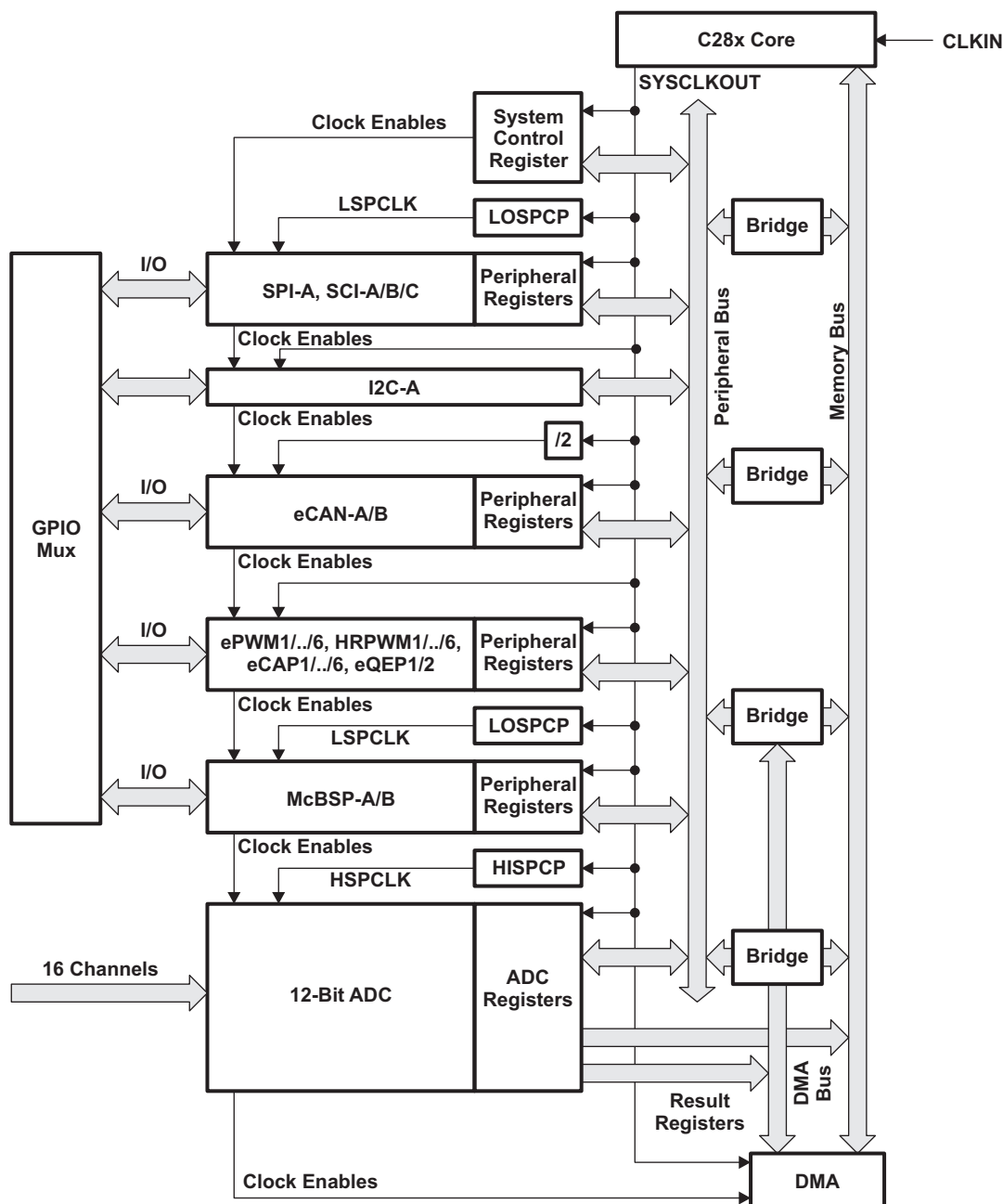
**Table 6-34. External Interrupt Registers**

| NAME     | ADDRESS         | SIZE (x16) | DESCRIPTION                  |
|----------|-----------------|------------|------------------------------|
| XINT1CR  | 0x00 7070       | 1          | XINT1 configuration register |
| XINT2CR  | 0x00 7071       | 1          | XINT2 configuration register |
| XINT3CR  | 0x00 7072       | 1          | XINT3 configuration register |
| XINT4CR  | 0x00 7073       | 1          | XINT4 configuration register |
| XINT5CR  | 0x00 7074       | 1          | XINT5 configuration register |
| XINT6CR  | 0x00 7075       | 1          | XINT6 configuration register |
| XINT7CR  | 0x00 7076       | 1          | XINT7 configuration register |
| XNMICR   | 0x00 7077       | 1          | XNMI configuration register  |
| XINT1CTR | 0x00 7078       | 1          | XINT1 counter register       |
| XINT2CTR | 0x00 7079       | 1          | XINT2 counter register       |
| Reserved | 0x707A – 0x707E | 5          |                              |
| XNMICTR  | 0x00 707F       | 1          | XNMI counter register        |

Each external interrupt can be enabled or disabled or qualified using positive, negative, or both positive and negative edge. For more information, see the [TMS320x2833x, 2823x system control and interrupts reference guide](#).

## 6.6 System Control

This section describes the oscillator, PLL and clocking mechanisms, the watchdog function and the low-power modes. Figure 6-29 shows the various clock and reset domains that will be discussed.



- A. CLKIN is the clock into the CPU. It is passed out of the CPU as SYSCLKOUT (that is, CLKIN is the same frequency as SYSCLKOUT). See Figure 6-30 for an illustration of how CLKIN is derived.

**Figure 6-29. Clock and Reset Domains**

### NOTE

There is a 2-SYSCLKOUT cycle delay from when the write to the PCLKCR0, PCLKCR1, and PCLKCR2 registers (enables peripheral clocks) occurs to when the action is valid. This delay must be considered before trying to access the peripheral configuration registers.

The PLL, clocking, watchdog and low-power modes, are controlled by the registers listed in [Table 6-35](#).

**Table 6-35. PLL, Clocking, Watchdog, and Low-Power Mode Registers**

| NAME     | ADDRESS               | SIZE (x16) | DESCRIPTION                                    |
|----------|-----------------------|------------|------------------------------------------------|
| PLLSTS   | 0x00 7011             | 1          | PLL Status Register                            |
| Reserved | 0x00 7012 – 0x00 7018 | 7          | Reserved                                       |
| Reserved | 0x00 7019             | 1          | Reserved                                       |
| HISPCP   | 0x00 701A             | 1          | High-Speed Peripheral Clock Prescaler Register |
| LOSPCP   | 0x00 701B             | 1          | Low-Speed Peripheral Clock Prescaler Register  |
| PCLKCR0  | 0x00 701C             | 1          | Peripheral Clock Control Register 0            |
| PCLKCR1  | 0x00 701D             | 1          | Peripheral Clock Control Register 1            |
| LPMCR0   | 0x00 701E             | 1          | Low-Power Mode Control Register 0              |
| Reserved | 0x00 701F             | 1          | Reserved                                       |
| PCLKCR3  | 0x00 7020             | 1          | Peripheral Clock Control Register 3            |
| PLLCR    | 0x00 7021             | 1          | PLL Control Register                           |
| SCSR     | 0x00 7022             | 1          | System Control and Status Register             |
| WDCNTR   | 0x00 7023             | 1          | Watchdog Counter Register                      |
| Reserved | 0x00 7024             | 1          | Reserved                                       |
| WDKEY    | 0x00 7025             | 1          | Watchdog Reset Key Register                    |
| Reserved | 0x00 7026 – 0x00 7028 | 3          | Reserved                                       |
| WDCR     | 0x00 7029             | 1          | Watchdog Control Register                      |
| Reserved | 0x00 702A – 0x00 702D | 4          | Reserved                                       |
| MAPCNF   | 0x00 702E             | 1          | ePWM/HRPWM Re-map Register                     |

## 6.6.1 OSC and PLL Block

Figure 6-30 shows the OSC and PLL block.

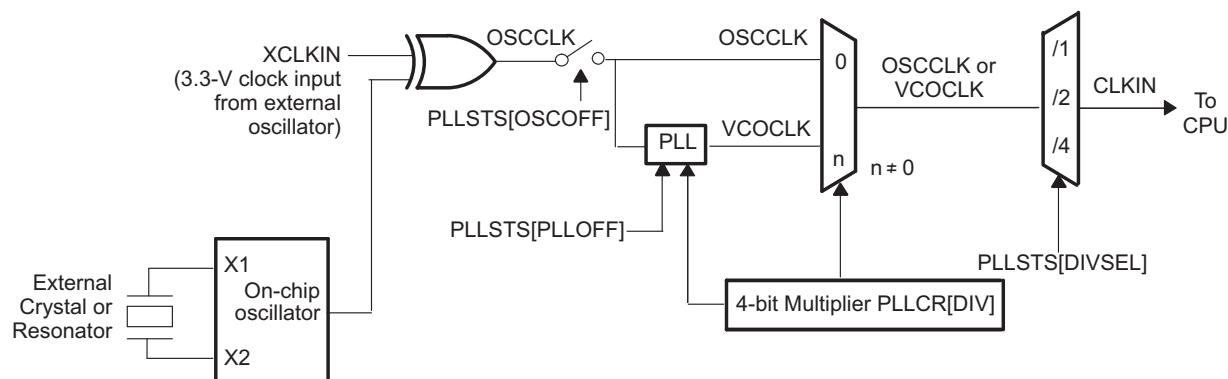


Figure 6-30. OSC and PLL Block Diagram

The on-chip oscillator circuit enables a crystal/resonator to be attached to the 2833x/2823x devices using the X1 and X2 pins. If the on-chip oscillator is not used, an external oscillator can be used in either one of the following configurations:

- A 3.3-V external oscillator can be directly connected to the XCLKIN pin. The X2 pin should be left unconnected and the X1 pin tied low. The logic-high level in this case should not exceed  $V_{DDIO}$ .
- A 1.9-V (1.8-V for 100 MHz devices) external oscillator can be directly connected to the X1 pin. The X2 pin should be left unconnected and the XCLKIN pin tied low. The logic-high level in this case should not exceed  $V_{DD}$ .

The three possible input-clock configurations are shown in Figure 6-31 to Figure 6-33.

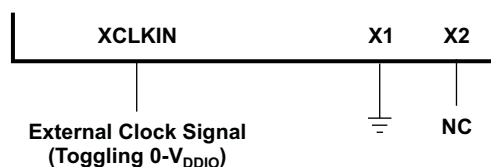


Figure 6-31. Using a 3.3-V External Oscillator

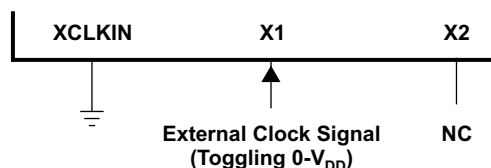


Figure 6-32. Using a 1.9-V External Oscillator

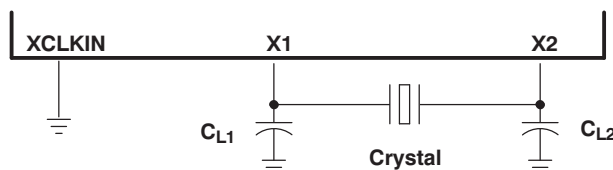


Figure 6-33. Using the Internal Oscillator

### 6.6.1.1 External Reference Oscillator Clock Option

The typical specifications for the external quartz crystal for a frequency of 30 MHz follow:

- Fundamental mode, parallel resonant
- $C_L$  (load capacitance) = 12 pF
- $C_{L1} = C_{L2} = 24$  pF
- $C_{shunt} = 6$  pF
- ESR range = 25 to 40  $\Omega$

TI recommends that customers have the resonator/crystal vendor characterize the operation of their device with the DSC chip. The resonator/crystal vendor has the equipment and expertise to tune the tank circuit. The vendor can also advise the customer regarding the proper tank component values that will produce proper start-up and stability over the entire operating range.

### 6.6.1.2 PLL-Based Clock Module

The devices have an on-chip, PLL-based clock module. This module provides all the necessary clocking signals for the device, as well as control for low-power mode entry. The PLL has a 4-bit ratio control PLLCR[DIV] to select different CPU clock rates. The watchdog module should be disabled before writing to the PLLCR register. It can be re-enabled (if need be) after the PLL module has stabilized, which takes 131072 OSCCLK cycles. The input clock and PLLCR[DIV] bits should be chosen in such a way that the output frequency of the PLL (VCOCLK) does not exceed 300 MHz.

**Table 6-36. PLL Settings<sup>(1)</sup>**

| PLLCR[DIV] VALUE <sup>(2) (3)</sup> | PLLSTS[DIVSEL] = 0 or 1 | SYSCLKOUT (CLKIN)  |                                   |
|-------------------------------------|-------------------------|--------------------|-----------------------------------|
|                                     |                         | PLLSTS[DIVSEL] = 2 | PLLSTS[DIVSEL] = 3 <sup>(4)</sup> |
| 0000 (PLL bypass)                   | OSCCLK/4 (Default)      | OSCCLK/2           | OSCCLK                            |
| 0001                                | (OSCCLK * 1)/4          | (OSCCLK * 1)/2     | –                                 |
| 0010                                | (OSCCLK * 2)/4          | (OSCCLK * 2)/2     | –                                 |
| 0011                                | (OSCCLK * 3)/4          | (OSCCLK * 3)/2     | –                                 |
| 0100                                | (OSCCLK * 4)/4          | (OSCCLK * 4)/2     | –                                 |
| 0101                                | (OSCCLK * 5)/4          | (OSCCLK * 5)/2     | –                                 |
| 0110                                | (OSCCLK * 6)/4          | (OSCCLK * 6)/2     | –                                 |
| 0111                                | (OSCCLK * 7)/4          | (OSCCLK * 7)/2     | –                                 |
| 1000                                | (OSCCLK * 8)/4          | (OSCCLK * 8)/2     | –                                 |
| 1001                                | (OSCCLK * 9)/4          | (OSCCLK * 9)/2     | –                                 |
| 1010                                | (OSCCLK * 10)/4         | (OSCCLK * 10)/2    | –                                 |
| 1011 – 1111                         | Reserved                | Reserved           | Reserved                          |

- (1) By default, PLLSTS[DIVSEL] is configured for /4. (The boot ROM changes this to /2.) PLLSTS[DIVSEL] must be 0 before writing to the PLLCR and should be changed only after PLLSTS[PLLLOCKS] = 1.
- (2) The PLL control register (PLLCR) and PLL Status Register (PLLSTS) are reset to their default state by the  $\overline{XRS}$  signal or a watchdog reset only. A reset issued by the debugger or the missing clock detect logic have no effect.
- (3) This register is EALLOW protected. See the [TMS320x2833x, 2823x system control and interrupts reference guide](#) for more information.
- (4) A divider at the output of the PLL is necessary to ensure correct duty cycle of the clock fed to the core. For this reason, a DIVSEL value of 3 is not allowed when the PLL is active.

**Table 6-37. CLKIN Divide Options**

| PLLSTS [DIVSEL] | CLKIN DIVIDE      |
|-----------------|-------------------|
| 0               | /4                |
| 1               | /4                |
| 2               | /2                |
| 3               | /1 <sup>(1)</sup> |

(1) This mode can be used only when the PLL is bypassed or off.

The PLL-based clock module provides two modes of operation:

- Crystal-operation - This mode allows the use of an external crystal/resonator to provide the time base to the device.
- External clock source operation - This mode allows the internal oscillator to be bypassed. The device clocks are generated from an external clock source input on the X1 or the XCLKIN pin.

**Table 6-38. Possible PLL Configuration Modes**

| PLL MODE   | REMARKS                                                                                                                                                                                                                                                                                                                                                               | PLLSTS[DIVSEL] | CLKIN AND SYSCLOCKOUT            |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------------------------|
| PLL Off    | Invoked by the user setting the PLOFF bit in the PLLSTS register. The PLL block is disabled in this mode. This can be useful to reduce system noise and for low power operation. The PLLCR register must first be set to 0x0000 (PLL Bypass) before entering this mode. The CPU clock (CLKIN) is derived directly from the input clock on either X1/X2, X1 or XCLKIN. | 0, 1<br>2<br>3 | OSCCLK/4<br>OSCCLK/2<br>OSCCLK/1 |
| PLL Bypass | PLL Bypass is the default PLL configuration upon power up or after an external reset (XRS). This mode is selected when the PLLCR register is set to 0x0000 or while the PLL locks to a new frequency after the PLLCR register has been modified. In this mode, the PLL itself is bypassed but the PLL is not turned off.                                              | 0, 1<br>2<br>3 | OSCCLK/4<br>OSCCLK/2<br>OSCCLK/1 |
| PLL Enable | Achieved by writing a nonzero value n into the PLLCR register. Upon writing to the PLLCR the device will switch to PLL Bypass mode until the PLL locks.                                                                                                                                                                                                               | 0, 1<br>2      | OSCCLK*n/4<br>OSCCLK*n/2         |

### 6.6.1.3 Loss of Input Clock

In PLL-enabled and PLL-bypass mode, if the input clock OSCCLK is removed or absent, the PLL will still issue a limp-mode clock. The limp-mode clock continues to clock the CPU and peripherals at a typical frequency of 1–5 MHz. Limp mode is not specified to work from power up, only after input clocks have been present initially. In PLL bypass mode, the limp mode clock from the PLL is automatically routed to the CPU if the input clock is removed or absent.

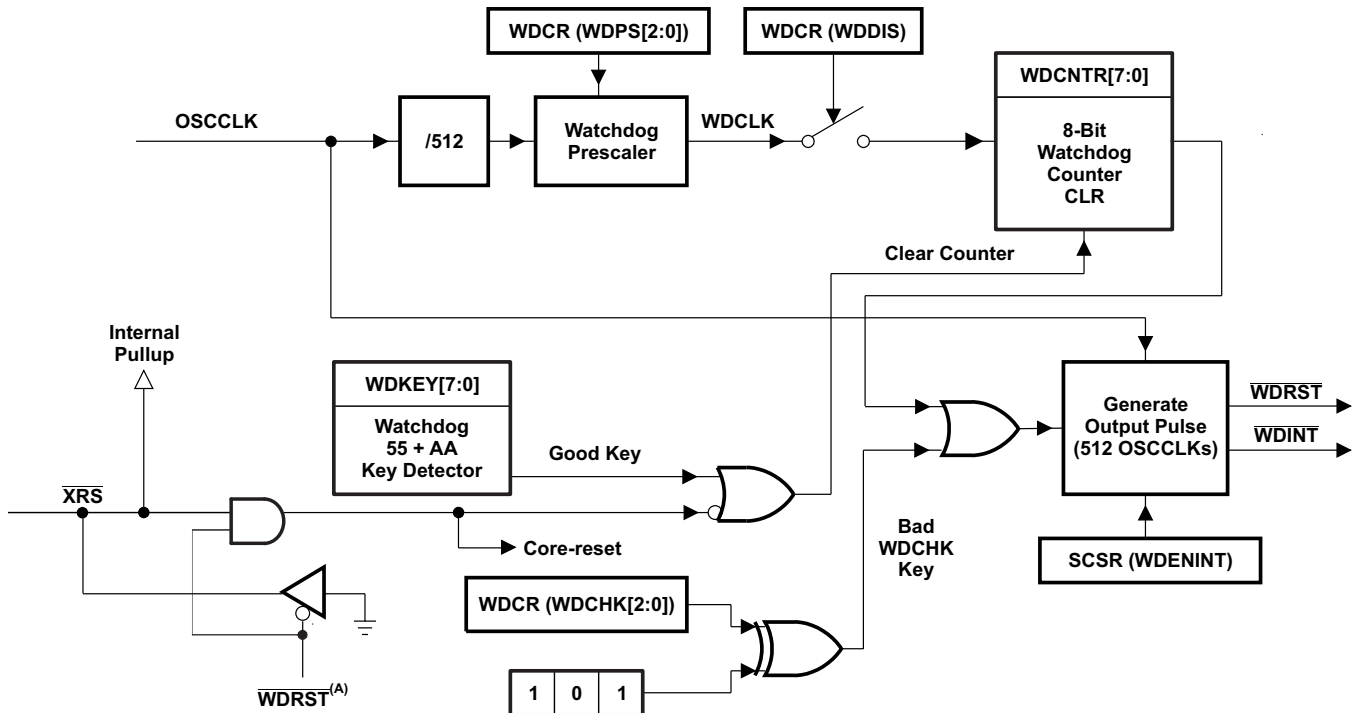
Normally, when the input clocks are present, the watchdog counter decrements to initiate a watchdog reset or WDINT interrupt. However, when the external input clock fails, the watchdog counter stops decrementing (that is, the watchdog counter does not change with the limp-mode clock). In addition to this, the device will be reset and the “Missing Clock Status” (MCLKSTS) bit will be set. These conditions could be used by the application firmware to detect the input clock failure and initiate necessary shut-down procedure for the system.

#### NOTE

Applications in which the correct CPU operating frequency is absolutely critical should implement a mechanism by which the DSC will be held in reset, should the input clocks ever fail. For example, an R-C circuit may be used to trigger the  $\overline{\text{XRS}}$  pin of the DSC, should the capacitor ever get fully charged. An I/O pin may be used to discharge the capacitor on a periodic basis to prevent it from getting fully charged. Such a circuit would also help detect failure of the flash memory and the  $V_{\text{DD3VFL}}$  rail.

## 6.6.2 Watchdog Block

The watchdog block on the 2833x/2823x device is similar to the one used on the 240x and 281x devices. The watchdog module generates an output pulse, 512 oscillator clocks wide (OSCCLK), whenever the 8-bit watchdog up counter has reached its maximum value. To prevent this, the user disables the counter or the software must periodically write a 0x55 + 0xAA sequence into the watchdog key register which will reset the watchdog counter. Figure 6-34 shows the various functional blocks within the watchdog module.



A. The  $\overline{\text{WDRST}}$  signal is driven low for 512 OSCCLK cycles.

Figure 6-34. Watchdog Module

The  $\overline{\text{WDINT}}$  signal enables the watchdog to be used as a wakeup from IDLE/STANDBY mode.

In STANDBY mode, all peripherals are turned off on the device. The only peripheral that remains functional is the watchdog. The WATCHDOG module will run off OSCCLK. The  $\overline{\text{WDINT}}$  signal is fed to the LPM block so that it can wake the device from STANDBY (if enabled). See Section 6.7, Low-Power Modes Block, for more details.

In IDLE mode, the  $\overline{\text{WDINT}}$  signal can generate an interrupt to the CPU, through the PIE, to take the CPU out of IDLE mode.

In HALT mode, this feature cannot be used because the oscillator (and PLL) are turned off and hence so is the WATCHDOG.

## 6.7 Low-Power Modes Block

The low-power modes on the 2833x/2823x devices are similar to the 240x devices. [Table 6-39](#) summarizes the various modes.

**Table 6-39. Low-Power Modes**

| MODE    | LPMCR0(1:0) | OSCCLK                                                             | CLKIN | SYSCCLKOUT        | EXIT <sup>(1)</sup>                                                                              |
|---------|-------------|--------------------------------------------------------------------|-------|-------------------|--------------------------------------------------------------------------------------------------|
| IDLE    | 00          | On                                                                 | On    | On <sup>(2)</sup> | $\overline{\text{XRS}}$ , watchdog interrupt, any enabled interrupt, XNMI                        |
| STANDBY | 01          | On<br>(watchdog still running)                                     | Off   | Off               | $\overline{\text{XRS}}$ , watchdog interrupt, GPIO Port A signal, debugger <sup>(3)</sup> , XNMI |
| HALT    | 1X          | Off<br>(oscillator and PLL turned off,<br>watchdog not functional) | Off   | Off               | $\overline{\text{XRS}}$ , GPIO port A signal, XNMI,<br>debugger <sup>(3)</sup>                   |

- (1) The EXIT column lists which signals or under what conditions the low-power mode will be exited. A low signal, on any of the signals, will exit the low power condition. This signal must be kept low long enough for an interrupt to be recognized by the device. Otherwise, the IDLE mode will not be exited and the device will go back into the indicated low-power mode.
- (2) The IDLE mode on the C28x behaves differently than on the 24x/240x. On the C28x, the clock output from the CPU (SYSCCLKOUT) is still functional while on the 24x/240x the clock is turned off.
- (3) On the C28x, the JTAG port can still function even if the CPU clock (CLKIN) is turned off.

The various low-power modes operate as follows:

- IDLE mode:** This mode is exited by any enabled interrupt or an XNMI that is recognized by the processor. The LPM block performs no tasks during this mode as long as the LPMCR0(LPM) bits are set to 0,0.
- STANDBY mode:** Any GPIO port A signal (GPIO[31:0]) can wake the device from STANDBY mode. The user must select which signal(s) will wake the device in the GPIO\_LPMSEL register. The selected signal(s) are also qualified by the OSCCLK before waking the device. The number of OSCCLKs is specified in the LPMCR0 register.
- HALT mode:** Only the  $\overline{\text{XRS}}$  and any GPIO port A signal (GPIO[31:0]) can wake the device from HALT mode. The user selects the signal in the GPIO\_LPMSEL register.

### NOTE

The low-power modes do not affect the state of the output pins (PWM pins included). They will be in whatever state the code left them in when the IDLE instruction was executed. See the [TMS320x2833x, 2823x system control and interrupts reference guide](#) for more details.

## 7 Applications, Implementation, and Layout

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### 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 their design implementation to confirm system functionality.

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### 7.1 TI Design or Reference Design

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 [TIDesigns](#).

#### [EtherCAT Interface for High Performance MCU Reference Design](#)

This reference design demonstrates how to connect a C2000 Delfino MCU to an EtherCAT® ET1100 slave controller. The interface supports both demultiplexed address/data busses for maximum bandwidth and minimum latency and a SPI mode for low pin-count EtherCAT communication. The slave controller offloads the processing of 100Mbps Ethernet-based fieldbus communication, thereby eliminating CPU overhead for these tasks.

#### [C2000 Resolver to Digital Conversion Kit](#)

This is a motherboard-style Resolver to Digital conversion kit used to experiment with various C2000 microcontrollers for software-based resolver to digital conversion using on-chip ADCs. The Resolver Kit also allows interface to resolvers and inverter control processor.

## 8 Device and Documentation Support

### 8.1 Getting Started

This section gives a brief overview of the steps to take when first developing for a C28x device. For more detail on each of these steps, see the following:

- [C2000 Real-Time Control MCUs – Getting started](#)
- [C2000 Real-Time Control MCUs – Tools & software](#)
- [Motor drive and control](#)
- [Digital power](#)

### 8.2 Device and Development Support Tool Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all TMS320™ DSC devices and support tools. Each TMS320™ DSP commercial family member has one of three prefixes: TMX, TMP, or TMS (for example, **TMS320F28335**). 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 (TMX/TMDX) through fully qualified production devices/tools (TMS/TMDS).

Device development evolutionary flow:

|            |                                                                                                                                      |
|------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>TMX</b> | Experimental device that is not necessarily representative of the final device's electrical specifications                           |
| <b>TMP</b> | Final silicon die that conforms to the device's electrical specifications but has not completed quality and reliability verification |
| <b>TMS</b> | Fully qualified production device                                                                                                    |

Support tool development evolutionary flow:

|             |                                                                                                         |
|-------------|---------------------------------------------------------------------------------------------------------|
| <b>TMDX</b> | Development-support product that has not yet completed Texas Instruments internal qualification testing |
| <b>TMDS</b> | Fully qualified development-support product                                                             |

TMX and TMP devices and TMDX development-support tools are shipped against the following disclaimer:

"Developmental product is intended for internal evaluation purposes."

TMS 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 (TMX or TMP) 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.

TI device nomenclature also includes a suffix with the device family name. This suffix indicates the package type (for example, ZJZ) and temperature range (for example, A). [Figure 8-1](#) provides a legend for reading the complete device name for any family member.

For device part numbers and further ordering information, see the Package Option Addendum of this document, the TI website ([www.ti.com](http://www.ti.com)), or contact your TI sales representative.

For additional description of the device nomenclature markings on the die, see the [TMS320F2833x, TMS320F2823x DSC silicon errata](#).

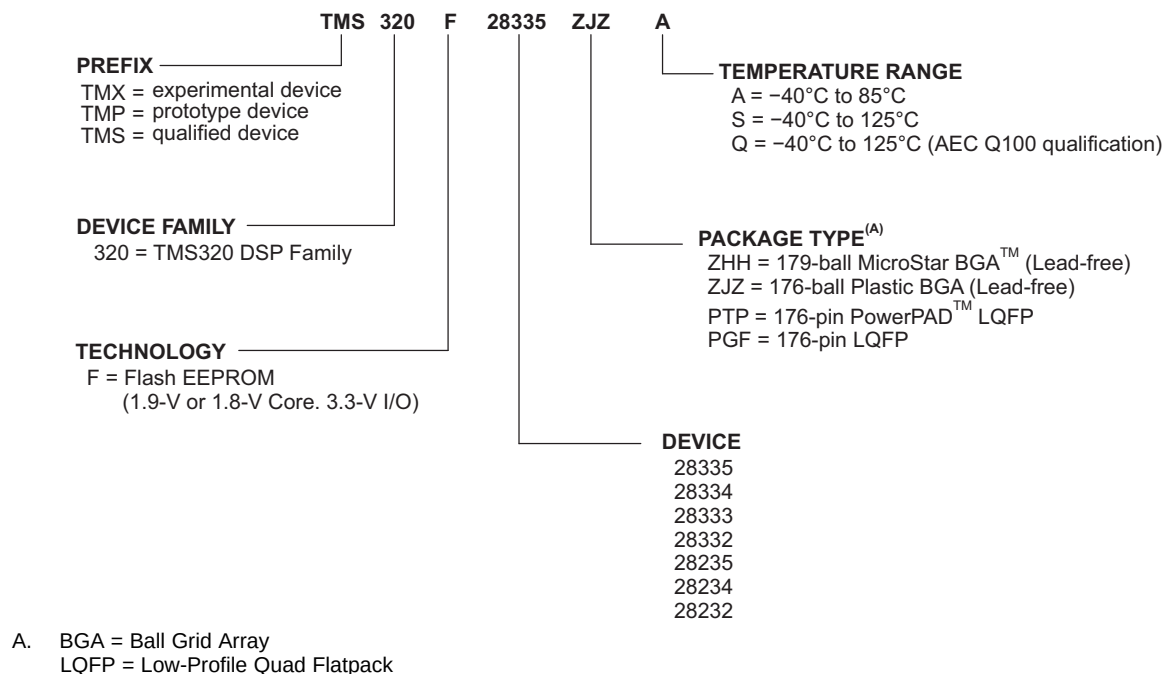


**Figure 8-1. Example of F2833x, F2823x Device Nomenclature**

## 8.3 Tools and Software

TI offers an extensive line of development tools. Some of the tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below. To view all available tools and software for C2000™ real-time control MCUs, visit the [C2000 MCU Tools and Software](#) page.

### Design Kits and Evaluation Modules

#### [C2000 DesignDRIVE Development Kit for Industrial Motor Control](#)

DesignDRIVE is a single hardware and software platform that makes it easy to develop and evaluate solutions for many industrial drive, motor control, and servo topologies. DesignDRIVE offers support for a wide variety of motor types, sensing technologies, encoder standards and communications networks, as well as easy expansion to develop with industrial communications and functional safety topologies, thus enabling more comprehensive, integrated drive system solutions. Based on the real-time control architecture of TI's C2000 microcontrollers (MCUs), DesignDRIVE is ideal for the development of industrial inverter and servo drives used in robotics, computer numerical control machinery (CNC), elevators, materials conveyance and other industrial manufacturing applications.

#### [C2000 Delfino MCUs F28377S LaunchPad Development Kit](#)

The C2000™ Delfino™ MCUs LaunchPad™ development kit is an inexpensive evaluation platform that provides designers with a low-cost development kit for high-performance digital control applications. This tool provides a great starting point for development of many high-end digital control applications such as industrial drives and automation; power line communications; solar inverters; and more.

#### [TMS320F28335 Experimenter Kit](#)

C2000™ MCU Experimenter Kits provide a robust hardware prototyping platform for real-time, closed loop control development with C2000 microcontrollers. This platform is a great tool to customize and prove-out solutions for many common power electronics applications, including motor control, digital power supplies, solar inverters, digital LED lighting, precision sensing, and more.

### Software

#### [C2000 DesignDRIVE Software for Industrial Drives and Motor Control](#)

The DesignDRIVE platform combines software solutions with DesignDRIVE Development Kits to make it easy to develop and evaluate solutions for many industrial drive and servo topologies. DesignDRIVE offers support for a wide variety of motor types, sensing technologies, position sensors and communications networks, including specific examples for vector control of motors, incorporating current, speed and position loops, to help developers jumpstart their evaluation and development. Based on the real-time control architecture of TI's C2000™ microcontrollers (MCUs), DesignDRIVE is ideal for the development of industrial inverter and servo drives used in robotics, computer numerical control machinery (CNC), elevators, materials conveyance and other industrial manufacturing applications.

#### [C2000 SafeTI™ 60730 SW Packages](#)

The C2000 MCU SafeTI-60730 Software package includes UL-certified, as recognized components, SafeTI™ software packages that help make designing for functional safety consumer applications with TI C2000™ real-time control microcontrollers (MCUs) easier and faster. The software in these SafeTI software packages is UL-certified, as recognized components, to the UL 1998:2008 Class 1 standard, and is compliant with IEC 60730-1:2010 Class B, both of which include home appliances, arc detectors, power converters, power tools, e-bikes, and many others. SafeTI software packages are available for select TI C2000 MCUs and can be embedded in applications using these MCUs to help customers simplify certification for functional safety-compliant consumer devices. Because of the similarity of the two standards, the IEC 60730 software libraries can also help assist customers developing consumer applications compliant with the IEC 60335-1:2010 standard.

### [powerSUITE Digital Power Supply Software Frequency Response Analyzer Tool for C2000™ MCUs](#)

The Software Frequency Response Analyzer (SFRA) is one of several tools included in the powerSUITE Digital Power Supply Design Software Tools for C2000™ Microcontrollers. The SFRA includes a software library that enables developers to quickly measure the frequency response of their digital power converter. The SFRA library contains software functions that inject a frequency into the control loop and measure the response of the system using the C2000 MCUs' on-chip analog to digital converter (ADC). This process provides the plant frequency response characteristics and the open loop gain frequency response of the closed loop system. The user can then view the plant and open loop gain frequency response on a PC-based GUI. All of the frequency response data is exported into a CSV file, or optionally an Excel spreadsheet, which can then be used to design the compensation loop using the Compensation Designer.

### [C2000Ware for C2000 MCUs](#)

C2000Ware for C2000™ microcontrollers is a cohesive set of development software and documentation designed to minimize software development time. From device-specific drivers and libraries to device peripheral examples, C2000Ware provides a solid foundation to begin development and evaluation of your product.

## **Development Tools**

### [C2000 Gang Programmer](#)

The C2000 Gang Programmer is a C2000 device programmer that can program up to eight identical C2000 devices at the same time. The C2000 Gang Programmer connects to a host PC using a standard RS-232 or USB connection and provides flexible programming options that allow the user to fully customize the process.

### [Code Composer Studio™ \(CCS\) Integrated Development Environment \(IDE\) for C2000 Microcontrollers](#)

Code Composer Studio is an integrated development environment (IDE) that supports TI's Microcontroller and Embedded Processors portfolio. Code Composer Studio comprises a suite of tools used to develop and debug embedded applications. It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features. The intuitive IDE provides a single user interface taking the user through each step of the application development flow. Familiar tools and interfaces allow users to get started faster than ever before. Code Composer Studio combines the advantages of the Eclipse software framework with advanced embedded debug capabilities from TI resulting in a compelling feature-rich development environment for embedded developers.

### [Uniflash Standalone Flash Tool](#)

CCS Uniflash is a standalone tool used to program on-chip flash memory on TI MCUs.

## **Models**

Various models are available for download from the product Tools & Software pages. These include I/O Buffer Information Specification (IBIS) Models and Boundary-Scan Description Language (BSDL) Models. To view all available models, visit the Models section of the Tools & Software page for each device, which can be found in [Table 8-1](#).

## 8.4 Documentation Support

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://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 current documentation that describes the processor, related peripherals, and other technical collateral is listed below.

### Errata

[TMS320F2833x, TMS320F2823x DSC silicon errata](#) describes the advisories and usage notes for different versions of silicon.

### CPU User's Guides

[TMS320C28x CPU and instruction set reference guide](#) describes the central processing unit (CPU) and the assembly language instructions of the TMS320C28x fixed-point digital signal processors (DSPs). It also describes emulation features available on these DSPs.

[TMS320C28x extended instruction sets technical reference manual](#) describes the architecture, pipeline, and instruction set of the TMU, VCU-II, and FPU accelerators.

### Peripheral Guides

[C2000 real-time control peripherals reference guide](#) describes the peripheral reference guides of the 28x digital signal processors (DSPs).

[TMS320x2833x, 2823x system control and interrupts reference guide](#) describes the various interrupts and system control features of the 2833x and 2823x digital signal controllers (DSCs).

[TMS320x2833x Analog-to-Digital Converter \(ADC\) module reference guide](#) describes how to configure and use the on-chip ADC module, which is a 12-bit pipelined ADC.

[TMS320x2833x, 2823x DSC External Interface \(XINTF\) reference guide](#) describes the XINTF, which is a nonmultiplexed asynchronous bus, as it is used on the 2833x and 2823x devices.

[TMS320x2833x, 2823x Boot ROM reference guide](#) describes the purpose and features of the bootloader (factory-programmed boot-loading software) and provides examples of code. It also describes other contents of the device on-chip boot ROM and identifies where all of the information is located within that memory.

[TMS320F2833x/2823x Multichannel Buffered Serial Port \(McBSP\) reference guide](#) describes the McBSP available on the 2833x and 2823x devices. The McBSPs allow direct interface between a DSP and other devices in a system.

[TMS320x2833x, 2823x Direct Memory Access \(DMA\) module reference guide](#) describes the DMA on the 2833x and 2823x devices.

[TMS320x2833x, 2823x Enhanced Pulse Width Modulator \(ePWM\) module reference guide](#) describes the main areas of the enhanced pulse width modulator that include digital motor control, switch mode power supply control, UPS (uninterruptible power supplies), and other forms of power conversion.

[TMS320x2833x, 2823x High Resolution Pulse Width Modulator \(HRPWM\) reference guide](#) describes the operation of the high-resolution extension to the pulse width modulator (HRPWM).

[TMS320x2833x, 2823x Enhanced Capture \(eCAP\) module reference guide](#) describes the enhanced capture module. It includes the module description and registers.

[TMS320x2833x, 2823x Enhanced Quadrature Encoder Pulse \(eQEP\) module reference guide](#) describes the eQEP module, which is used for interfacing with a linear or rotary incremental encoder to get position, direction, and speed information from a rotating machine in high-performance motion and position control systems. It includes the module description and registers.

[TMS320F2833x, 2823x Enhanced Controller Area Network \(eCAN\) reference guide](#) describes the eCAN that uses established protocol to communicate serially with other controllers in electrically noisy environments.

[TMS320x2833x, 2823x Serial Communications Interface \(SCI\) reference guide](#) describes the SCI, which is a two-wire asynchronous serial port, commonly known as a UART. The SCI modules support digital communications between the CPU and other asynchronous peripherals that use the standard nonreturn-to-zero (NRZ) format.

[TMS320x2833x, 2823x Serial Peripheral Interface \(SPI\) reference guide](#) describes the SPI - a high-speed synchronous serial input/output (I/O) port - that allows a serial bit stream of programmed length (one to sixteen bits) to be shifted into and out of the device at a programmed bit-transfer rate.

[TMS320x2833x, 2823x Inter-Integrated Circuit \(I2C\) module reference guide](#) describes the features and operation of the inter-integrated circuit (I2C) module.

## Tools Guides

[TMS320C28x Assembly language tools v18.12.0.LTS user's guide](#) describes the assembly language tools (assembler and other tools used to develop assembly language code), assembler directives, macros, common object file format, and symbolic debugging directives for the TMS320C28x device.

[TMS320C28x optimizing C/C++ compiler v18.12.0.LTS user's guide](#) describes the TMS320C28x C/C++ compiler. This compiler accepts ANSI standard C/C++ source code and produces TMS320 DSP assembly language source code for the TMS320C28x device.

[TMS320C28x DSP/BIOS 5.x Application Programming Interface \(API\) reference guide](#) describes development using DSP/BIOS.

## Application Reports

The [SMT & packaging application notes](#) website lists documentation on TI's surface mount technology (SMT) and application notes on a variety of packaging-related topics.

[TMS320x281x to TMS320x2833x or 2823x migration overview](#) describes how to migrate from the 281x device design to 2833x or 2823x designs.

[TMS320x280x to TMS320x2833x or 2823x migration overview](#) describes how to migrate from a 280x device design to 2833x or 2823x designs.

[TMS320C28x FPU primer](#) provides an overview of the floating-point unit (FPU) in the C2000™ Delfino microcontroller devices.

[Running an application from internal flash memory on the TMS320F28xxx DSP](#) covers the requirements needed to properly configure application software for execution from on-chip flash memory. Requirements for both DSP/BIOS and non-DSP/BIOS projects are presented. Example code projects are included.

[Programming TMS320x28xx and 28xxx peripherals in C/C++](#) explores a hardware abstraction layer implementation to make C/C++ coding easier on 28x DSPs. This method is compared to traditional #define macros and topics of code efficiency and special case registers are also addressed.

[Using PWM output as a Digital-to-Analog Converter on a TMS320F280x Digital Signal Controller](#) presents a method for using the on-chip pulse width modulated (PWM) signal generators on the TMS320F280x family of digital signal controllers as a digital-to-analog converter (DAC).

[TMS320F280x digital signal controller USB connectivity using the TUSB3410 USB-to-UART bridge chip](#) presents hardware connections as well as software preparation and operation of the development system using a simple communication echo program.

[Using the Enhanced Quadrature Encoder Pulse \(eQEP\) module in TMS320x280x, 28xxx as a dedicated capture](#) provides a guide for the use of the eQEP module as a dedicated capture unit and is applicable to the TMS320x280x, 28xxx family of processors.

[Using the ePWM module for 0% - 100% duty cycle control](#) provides a guide for the use of the ePWM module to provide 0% to 100% duty cycle control and is applicable to the TMS320x280x family of processors.

[TMS320x280x and TMS320F2801x ADC calibration](#) describes a method for improving the absolute accuracy of the 12-bit ADC found on the TMS320x280x and TMS320F2801x devices. Inherent gain and offset errors affect the absolute accuracy of the ADC. The methods described in this report can improve the absolute accuracy of the ADC to levels better than 0.5%. This application report has an option to download an example program that executes from RAM on the F2808 EzDSP.

[Online stack overflow detection on the TMS320C28x DSP](#) presents the methodology for online stack overflow detection on the TMS320C28x DSP. C-source code is provided that contains functions for implementing the overflow detection on both DSP/BIOS and non-DSP/BIOS applications.

[PowerPAD™ thermally enhanced package](#) focuses on the specifics of integrating a PowerPAD™ package into the PCB design.

[Semiconductor packing methodology](#) describes the packing methodologies employed to prepare semiconductor devices for shipment to end users.

[Calculating useful lifetimes of embedded processors](#) provides a methodology for calculating the useful lifetime of TI embedded processors (EPs) under power when used in electronic systems. It is aimed at general engineers who wish to determine if the reliability of the TI EP meets the end system reliability requirement.

[Semiconductor and IC package thermal metrics](#) describes traditional and new thermal metrics and puts their application in perspective with respect to system-level junction temperature estimation.

[An introduction to IBIS \(I/O Buffer Information Specification\) modeling](#) discusses various aspects of IBIS including its history, advantages, compatibility, model generation flow, data requirements in modeling the input/output structures and future trends.

[Serial flash programming of C2000™ microcontrollers](#) discusses using a flash kernel and ROM loaders for serial programming a device.

## 8.5 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 8-1. Related Links**

| PARTS        | PRODUCT FOLDER             | SAMPLE & BUY               | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|--------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| TMS320F28335 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TMS320F28334 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TMS320F28333 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TMS320F28332 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TMS320F28235 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TMS320F28234 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TMS320F28232 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

## 8.6 Community Resources

The following links connect to TI community resources. Linked contents are 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](#).

**TI E2E™ Online Community** The TI engineer-to-engineer (E2E) community was created to foster collaboration among engineers. At [e2e.ti.com](http://e2e.ti.com), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**TI Embedded Processors Wiki** Established to help developers get started with Embedded Processors from Texas Instruments and to foster innovation and growth of general knowledge about the hardware and software surrounding these devices.

## 8.7 Trademarks

Code Composer Studio, DSP/BIOS, MicroStar BGA, TMS320C2000, Delfino, C2000, Piccolo, PowerPAD, E2E are trademarks of Texas Instruments.

EtherCAT is a registered trademark of Beckhoff Automation GmbH, Germany.

All other trademarks are the property of their respective owners.

## 8.8 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.

## 8.9 Glossary

**TI Glossary** This glossary lists and explains terms, acronyms, and definitions.

## 9 Mechanical, Packaging, and Orderable Information

### 9.1 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.

For packages with a thermal pad, the MECHANICAL DATA figure shows a generic thermal pad without dimensions. For the actual thermal pad dimensions that are applicable to this device, see the THERMAL PAD MECHANICAL DATA figure.

To learn more about TI packaging, visit the [Packaging information](#) website.

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type     | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|------------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TMS320F28232PGFA | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28232PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28232PTPQ | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   |              | TMS320<br>F28232PTPQ    | <a href="#">Samples</a> |
| TMS320F28232PTPS | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   |              | TMS320<br>F28232PTPS    | <a href="#">Samples</a> |
| TMS320F28232ZHHA | ACTIVE        | BGA<br>MICROSTAR | ZHH                | 179  | 160            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | F28232ZHHA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28232ZJZA | NRND          | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | 320F28232ZJZA<br>TMS    |                         |
| TMS320F28234PGFA | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28234PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28234PTPQ | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   | -40 to 125   | TMS320<br>F28234PTPQ    | <a href="#">Samples</a> |
| TMS320F28234PTPS | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   | -40 to 125   | TMS320<br>F28234PTPS    | <a href="#">Samples</a> |
| TMS320F28234ZHHA | ACTIVE        | BGA<br>MICROSTAR | ZHH                | 179  | 160            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | F28234ZHHA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28234ZJZA | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | 320F28234ZJZA<br>TMS    | <a href="#">Samples</a> |
| TMS320F28234ZJZQ | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28234ZJZQ<br>TMS    | <a href="#">Samples</a> |
| TMS320F28234ZJZS | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28234ZJZS<br>TMS    | <a href="#">Samples</a> |
| TMS320F28235PGFA | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28235PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28235PTPQ | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   |              | TMS320<br>F28235PTPQ    | <a href="#">Samples</a> |
| TMS320F28235PTPS | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   |              | TMS320<br>F28235PTPS    | <a href="#">Samples</a> |
| TMS320F28235ZJZA | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | 320F28235ZJZA<br>TMS    | <a href="#">Samples</a> |
| TMS320F28235ZJZQ | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28235ZJZQ<br>TMS    | <a href="#">Samples</a> |

| Orderable Device  | Status<br>(1) | Package Type     | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|-------------------|---------------|------------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TMS320F28235ZJZQR | ACTIVE        | BGA              | ZJZ                | 176  | 1000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28235ZJZQ<br>TMS    | <a href="#">Samples</a> |
| TMS320F28235ZJZS  | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28235ZJZS<br>TMS    | <a href="#">Samples</a> |
| TMS320F28332PGFA  | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28332PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28332PTPS  | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   |              | TMS320<br>F28332PTPS    | <a href="#">Samples</a> |
| TMS320F28333PGFA  | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28333PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28334PGFA  | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28334PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28334PTPS  | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   |              | TMS320<br>F28334PTPS    | <a href="#">Samples</a> |
| TMS320F28334ZHHA  | ACTIVE        | BGA<br>MICROSTAR | ZHH                | 179  | 160            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | F28334ZHHA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28334ZJZA  | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | 320F28334ZJZA<br>TMS    | <a href="#">Samples</a> |
| TMS320F28334ZJZQ  | NRND          | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28334ZJZQ<br>TMS    |                         |
| TMS320F28334ZJZS  | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28334ZJZS<br>TMS    | <a href="#">Samples</a> |
| TMS320F28335PGFA  | ACTIVE        | LQFP             | PGF                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 85    | F28335PGFA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28335PTPQ  | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   | -40 to 125   | TMS320<br>F28335PTPQ    | <a href="#">Samples</a> |
| TMS320F28335PTPS  | ACTIVE        | HLQFP            | PTP                | 176  | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-4-260C-72 HR   | -40 to 125   | TMS320<br>F28335PTPS    | <a href="#">Samples</a> |
| TMS320F28335ZHHA  | ACTIVE        | BGA<br>MICROSTAR | ZHH                | 179  | 160            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | F28335ZHHA<br>TMS320    | <a href="#">Samples</a> |
| TMS320F28335ZJZA  | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 85    | 320F28335ZJZA<br>TMS    | <a href="#">Samples</a> |
| TMS320F28335ZJZQ  | ACTIVE        | BGA              | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28335ZJZQ<br>TMS    | <a href="#">Samples</a> |
| TMS320F28335ZJZQR | ACTIVE        | BGA              | ZJZ                | 176  | 1000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28335ZJZQ<br>TMS    | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TMS320F28335ZJZS | ACTIVE        | BGA          | ZJZ                | 176  | 126            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-3-260C-168 HR  | -40 to 125   | 320F28335ZJZS<br>TMS    | <a href="#">Samples</a> |

(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.

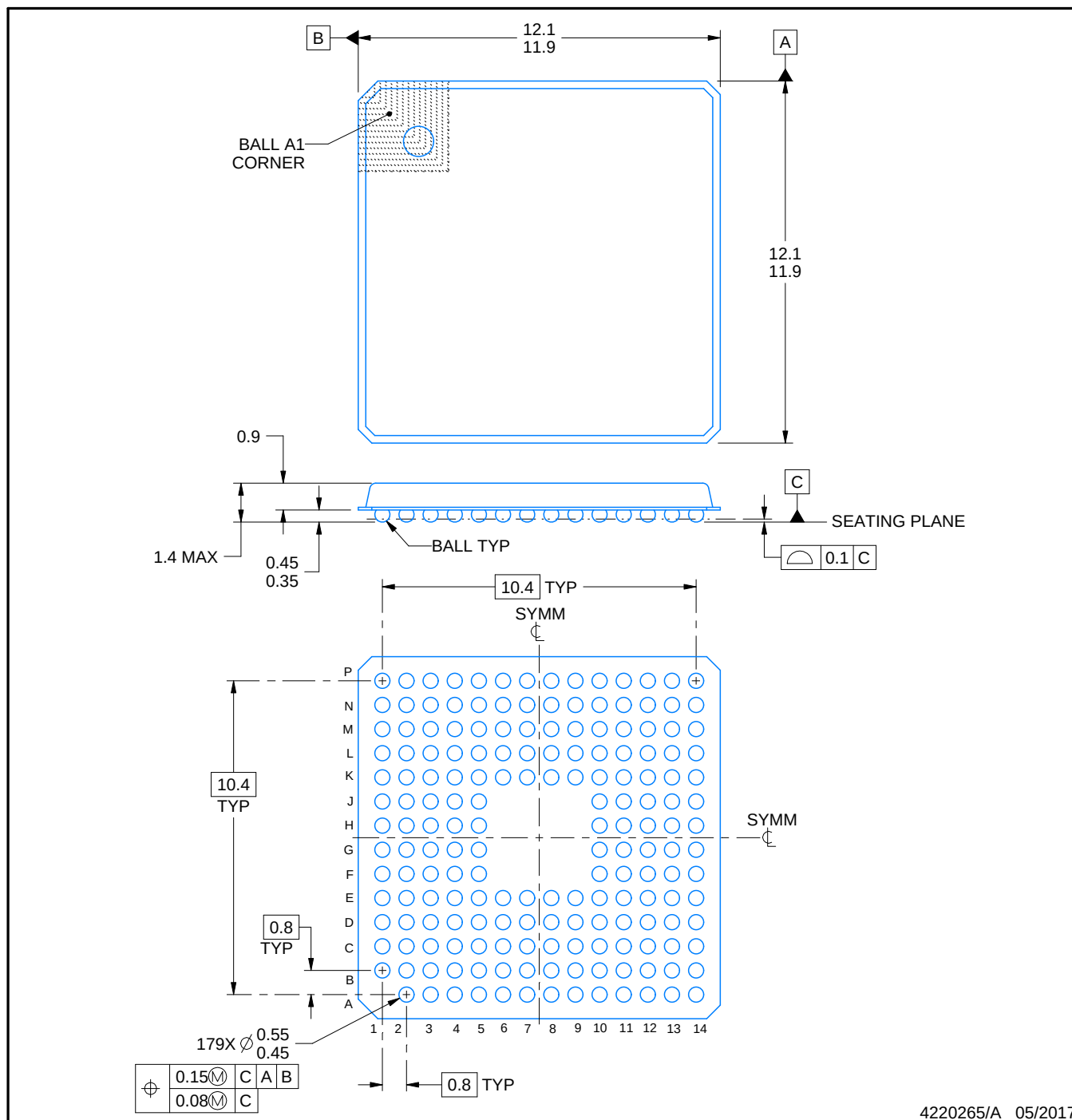
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



**ZHH0179A**

## UBGA - 1.4 mm max height

## BALL GRID ARRAY



NOTES:

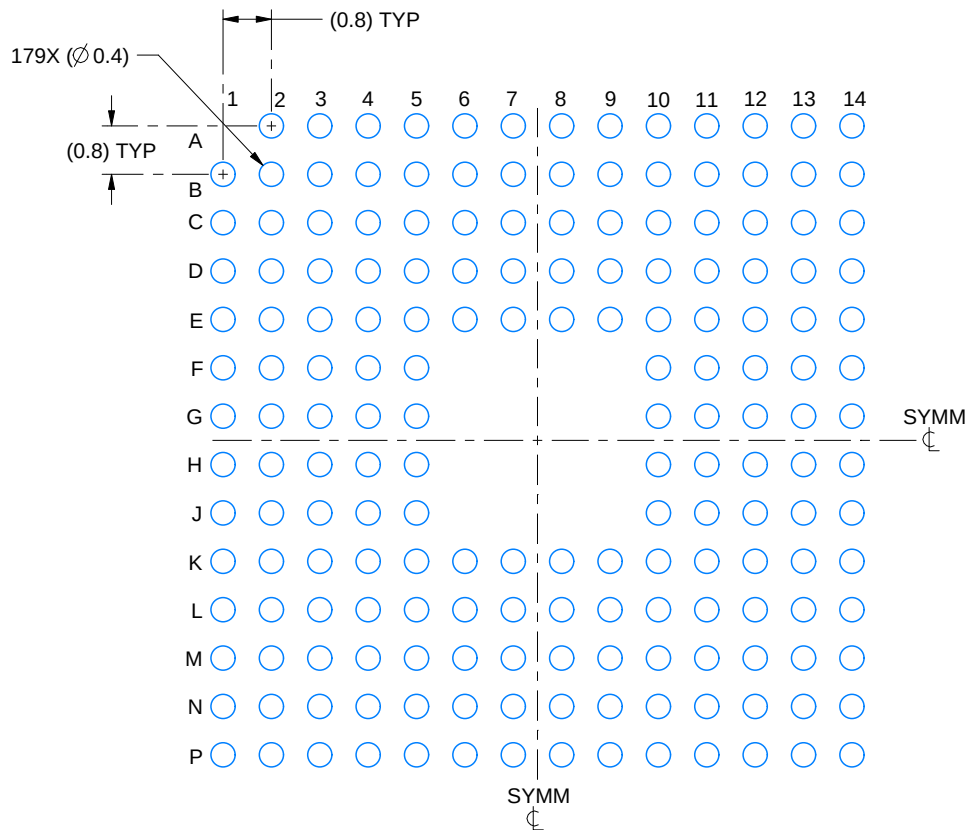
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This is a Pb-free solder ball design.

# EXAMPLE BOARD LAYOUT

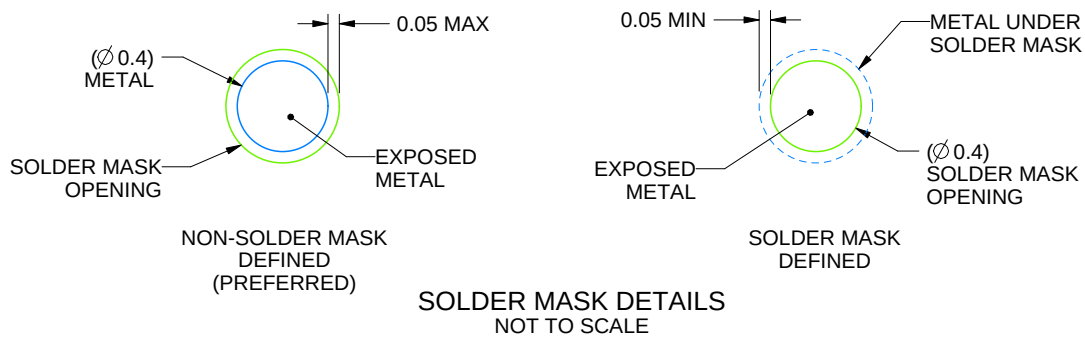
ZHH0179A

UBGA - 1.4 mm max height

BALL GRID ARRAY



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 8X



4220265/A 05/2017

NOTES: (continued)

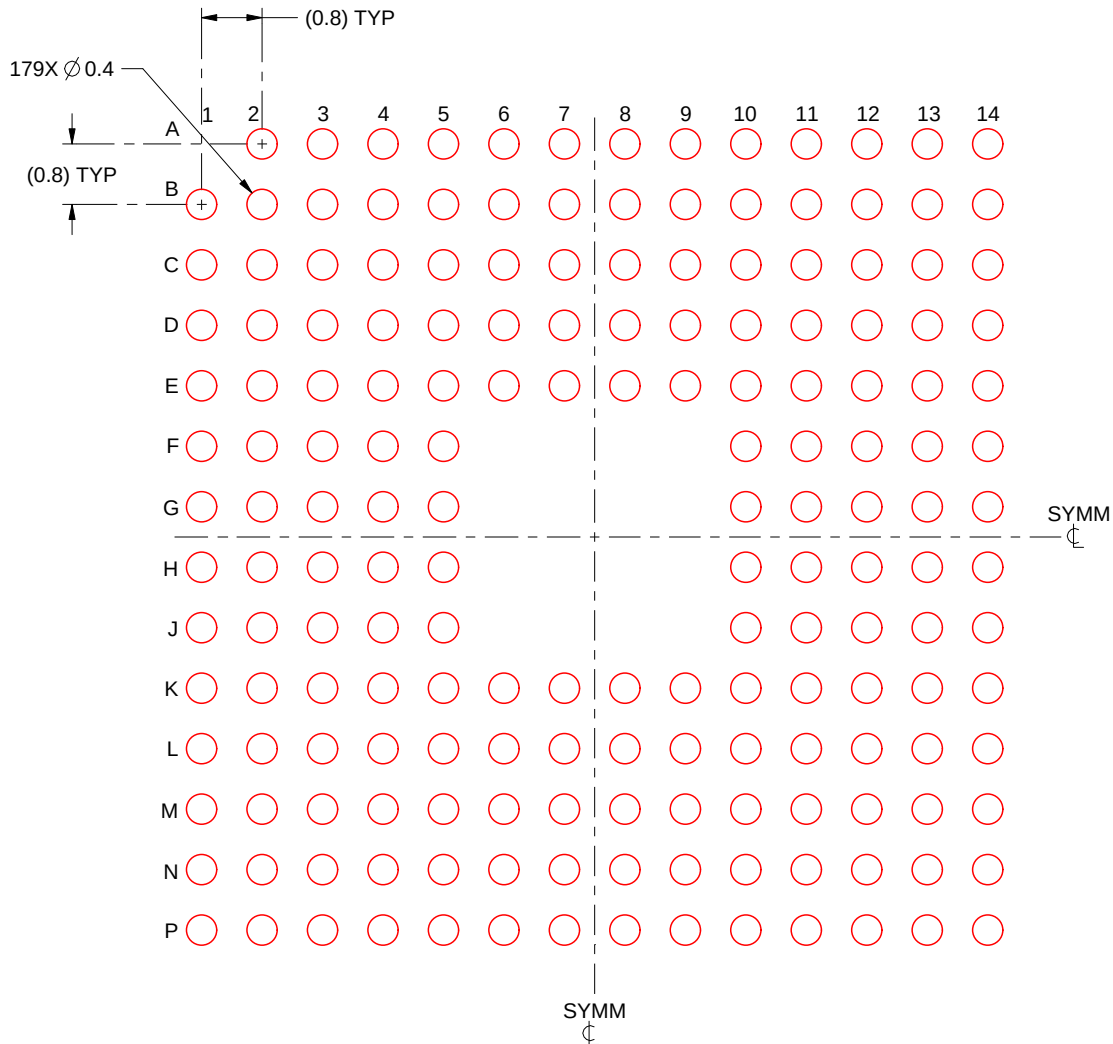
- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. See Texas Instruments Literature No. SSZA002 ([www.ti.com/lit/ssza002](http://www.ti.com/lit/ssza002)).

# EXAMPLE STENCIL DESIGN

ZHH0179A

UBGA - 1.4 mm max height

BALL GRID ARRAY

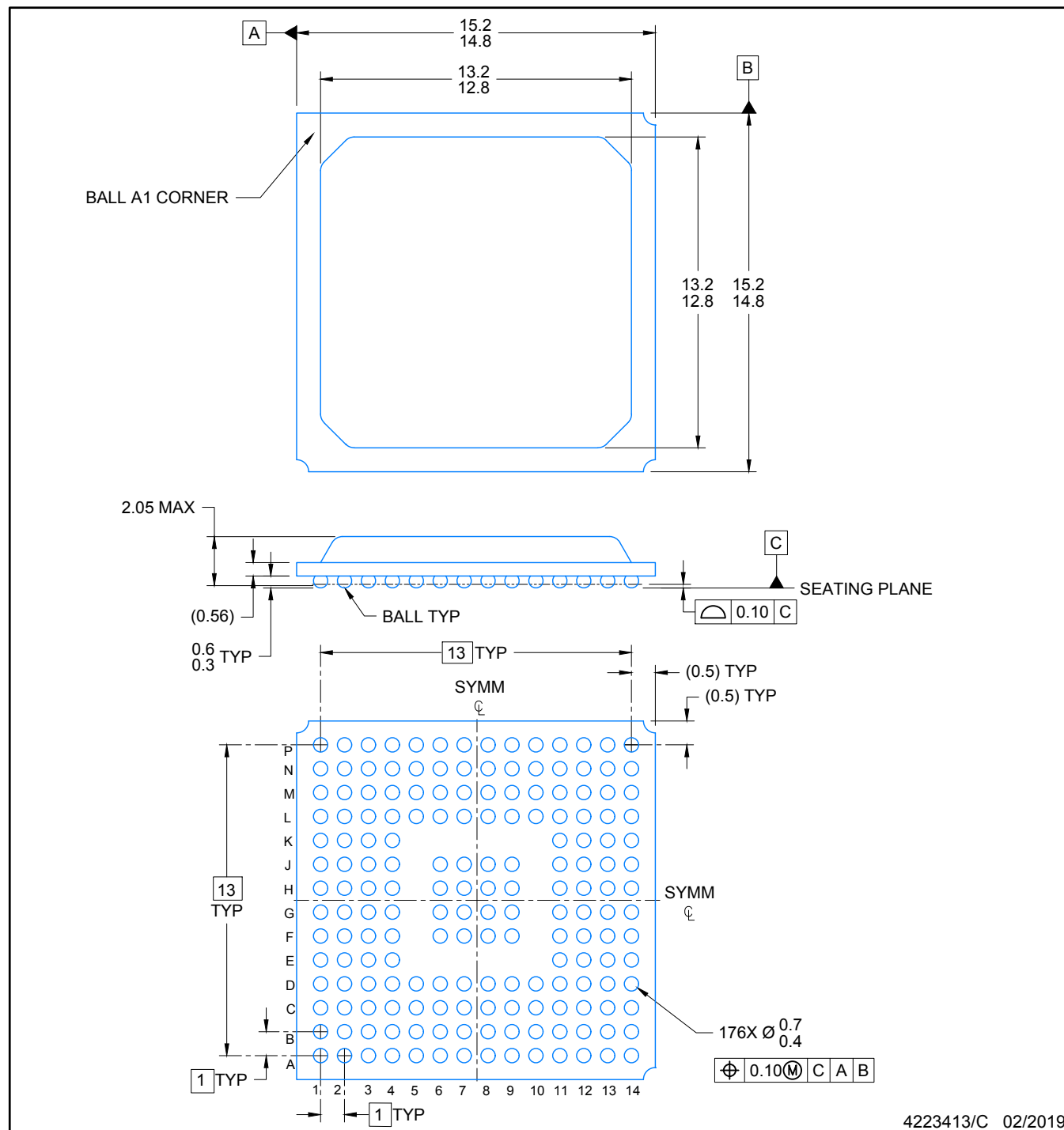


SOLDER PASTE EXAMPLE  
 BASED ON 0.15 mm THICK STENCIL  
 SCALE: 10X

4220265/A 05/2017

NOTES: (continued)

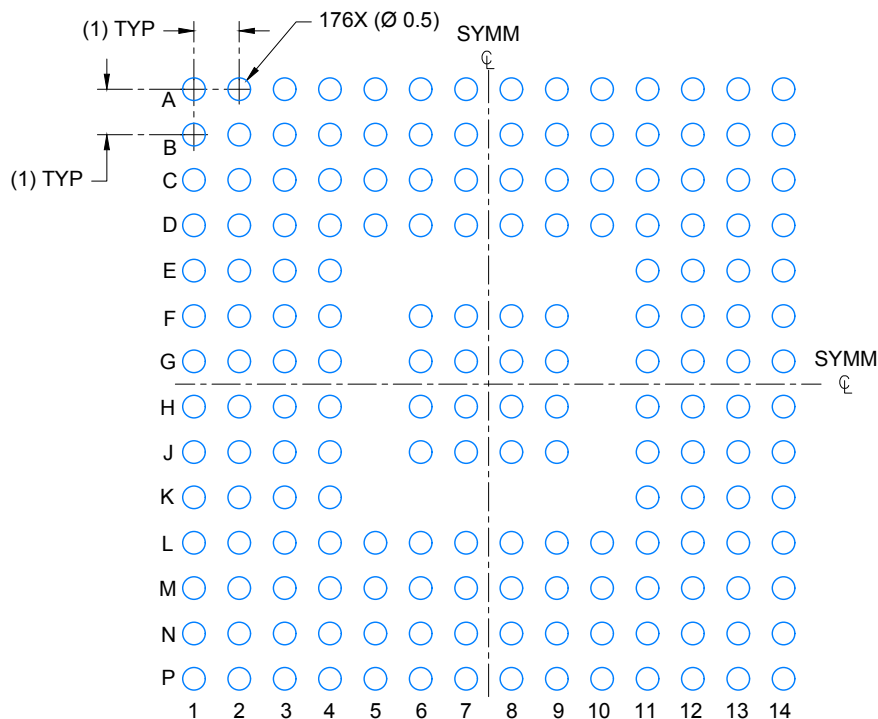
5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.



4223413/C 02/2019

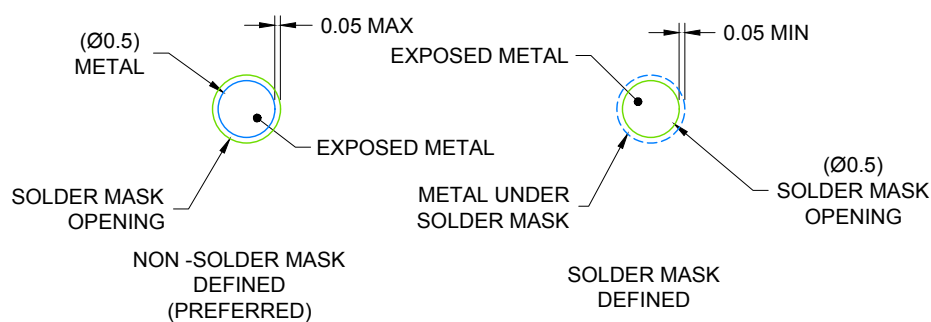
## NOTES:

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. This is a lead-free solder ball design.



LAND PATTERN EXAMPLE

SCALE: 6X



SOLDER MASK DETAILS

NOT TO SCALE

4223413/C 02/2019

NOTES: (continued)

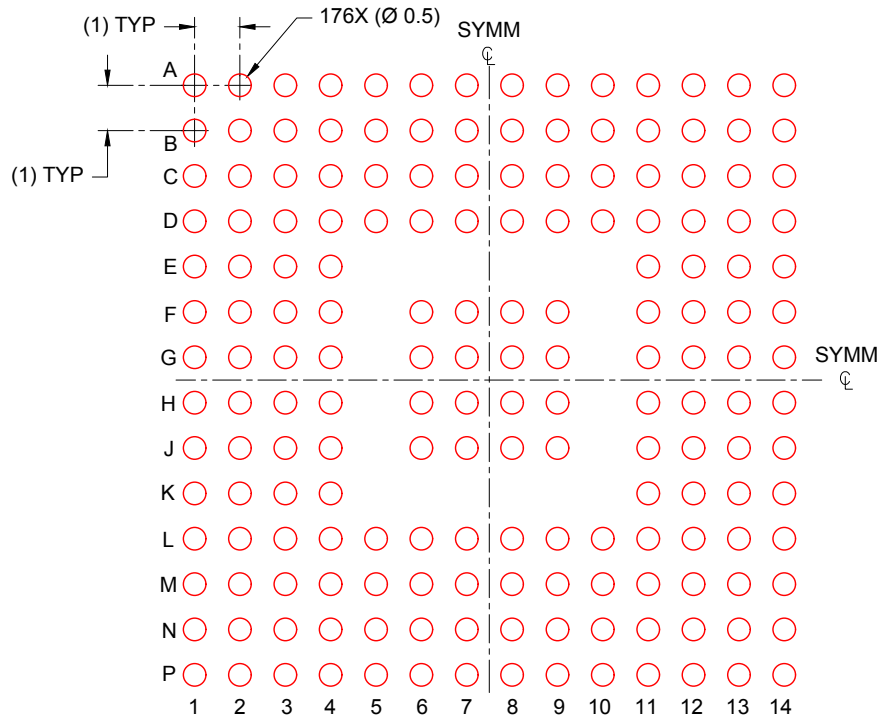
- Final dimension may vary due to manufacturing tolerance considerations and also routing constraints. For information, see Texas Instruments literature number SSZA002 ([www.ti.com/lit/ssza002](http://www.ti.com/lit/ssza002)).

# EXAMPLE STENCIL DESIGN

ZJZ0176A

PBGA - 2.05 mm max height

PLASTIC BALL GRID ARRAY



SOLDER PASTE EXAMPLE  
 BASED ON 0.15 mm THICK STENCIL  
 SCALE: 6X

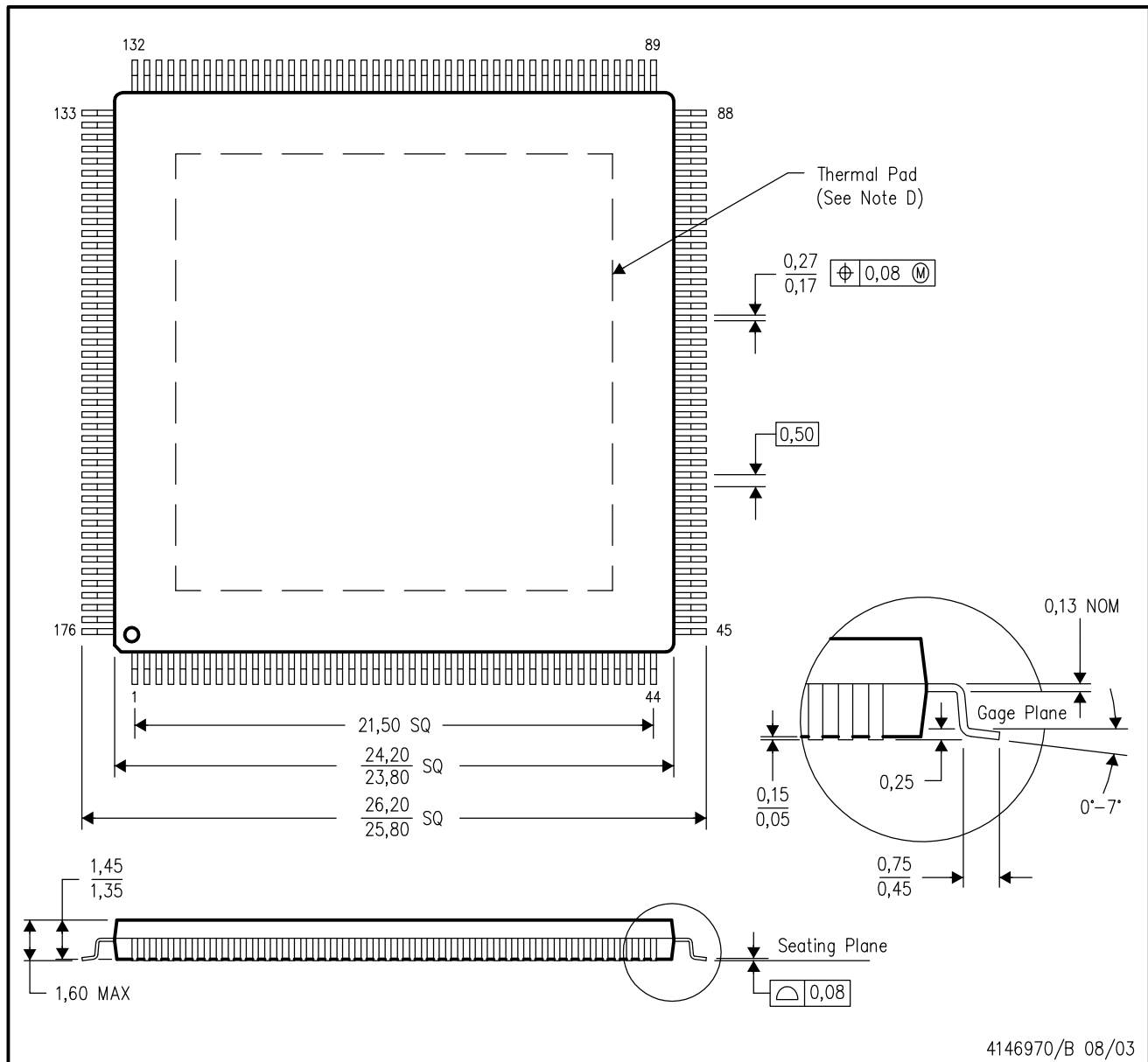
4223413/C 02/2019

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

PTP (S-PQFP-G176)

PowerPAD™ PLASTIC QUAD FLATPACK



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Falls within JEDEC MO-026

PowerPAD is a trademark of Texas Instruments.

PTP (S-PQFP-G176)

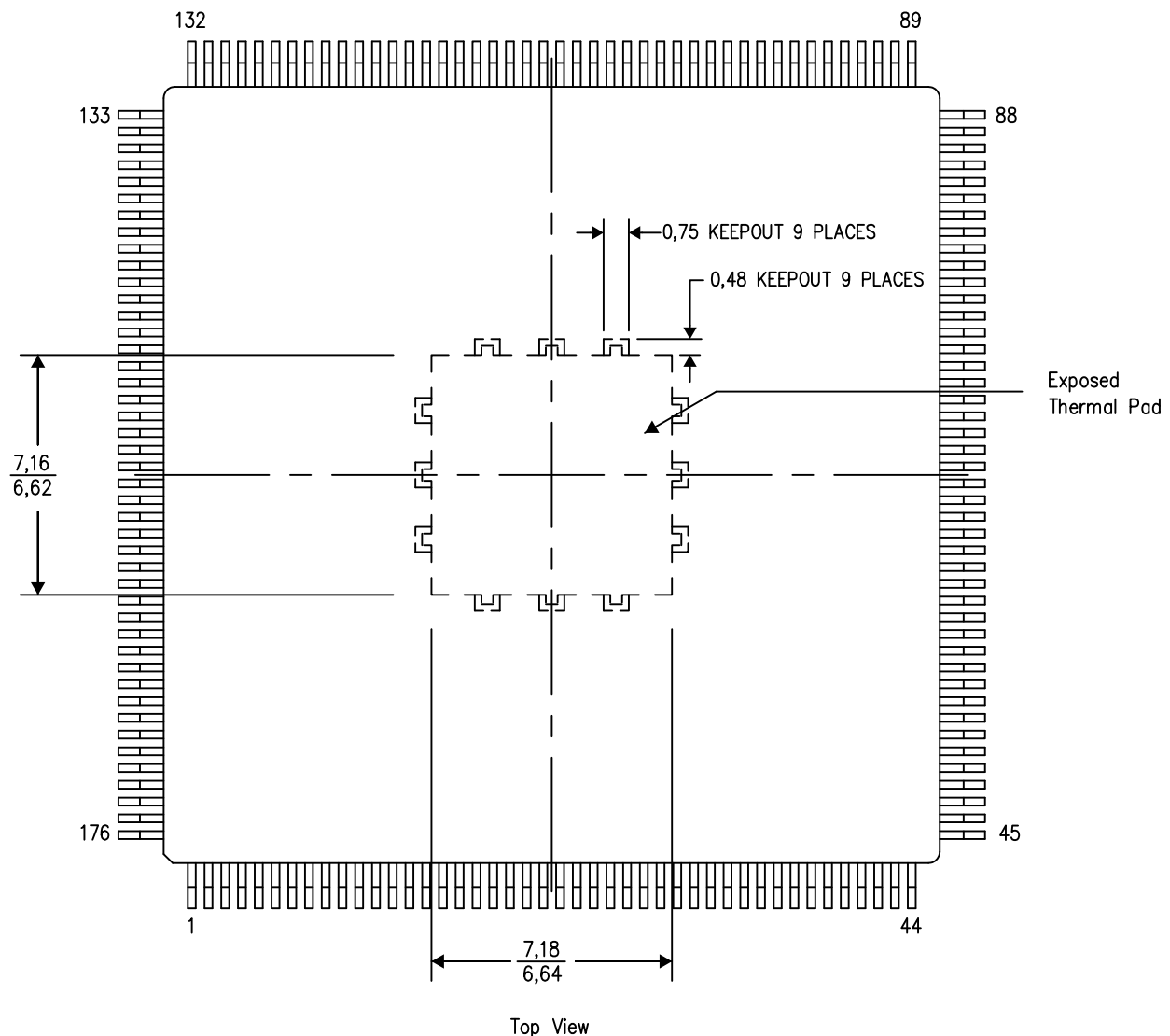
PowerPAD™ PLASTIC QUAD FLATPACK

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

4209350-4/F 04/13

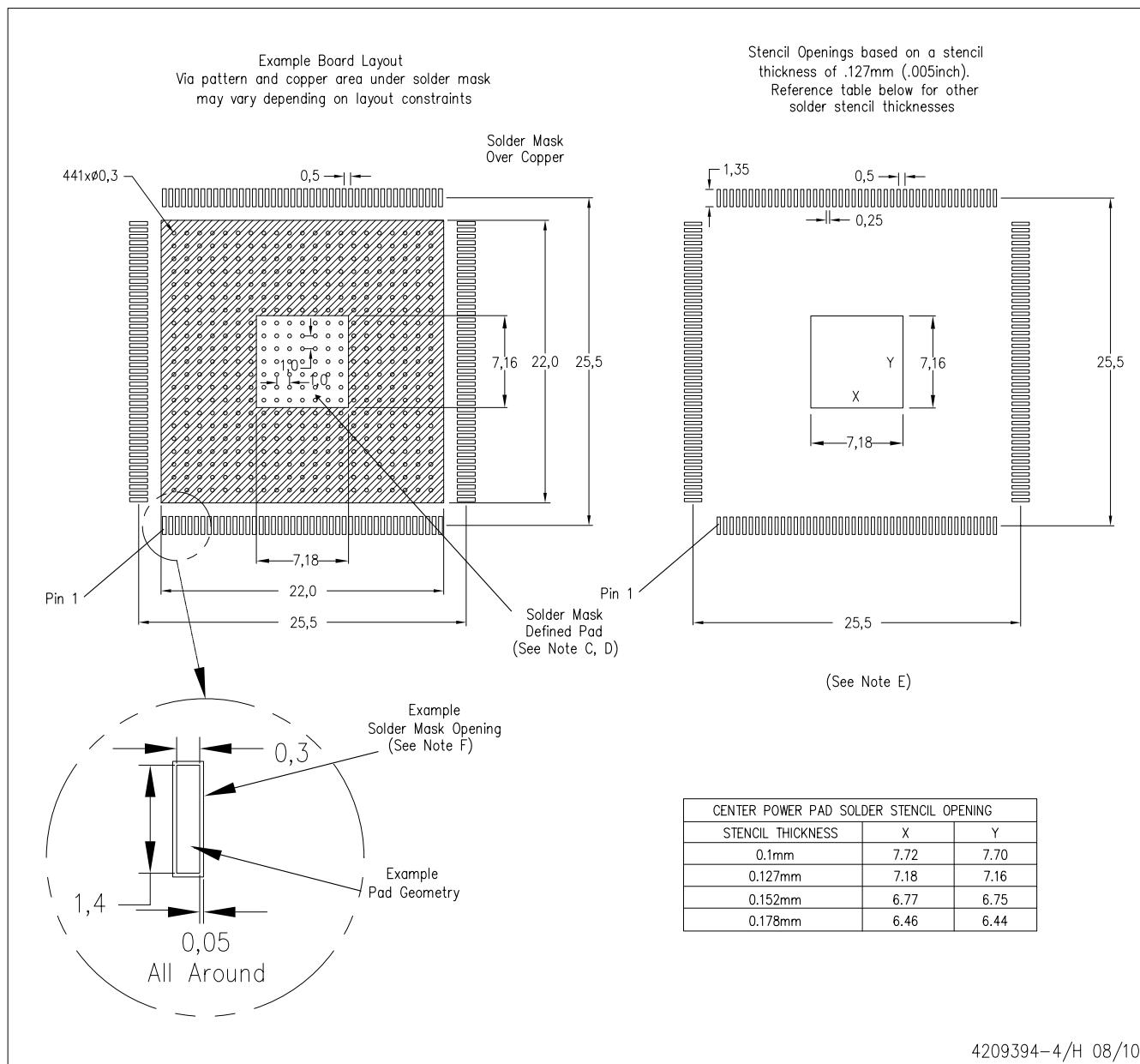
NOTE: All linear dimensions are in millimeters

NOTE: Keep-out features are identified to prevent board routing interference. These exposed metal features may vary within the identified area or be completely absent on some devices.

PowerPAD is a trademark of Texas Instruments

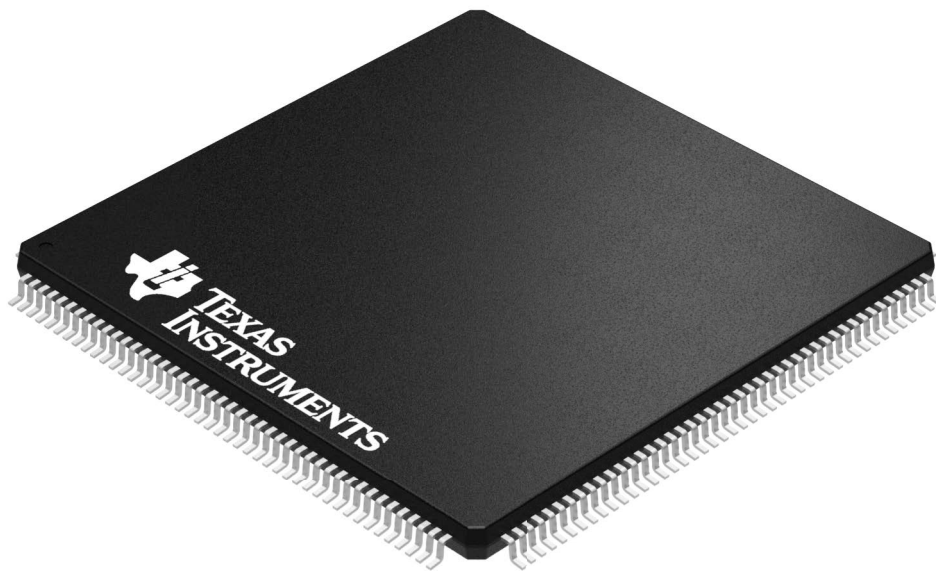
PTP (S-PQFP-G176)

PowerPAD™ PLASTIC QUAD FLATPACK

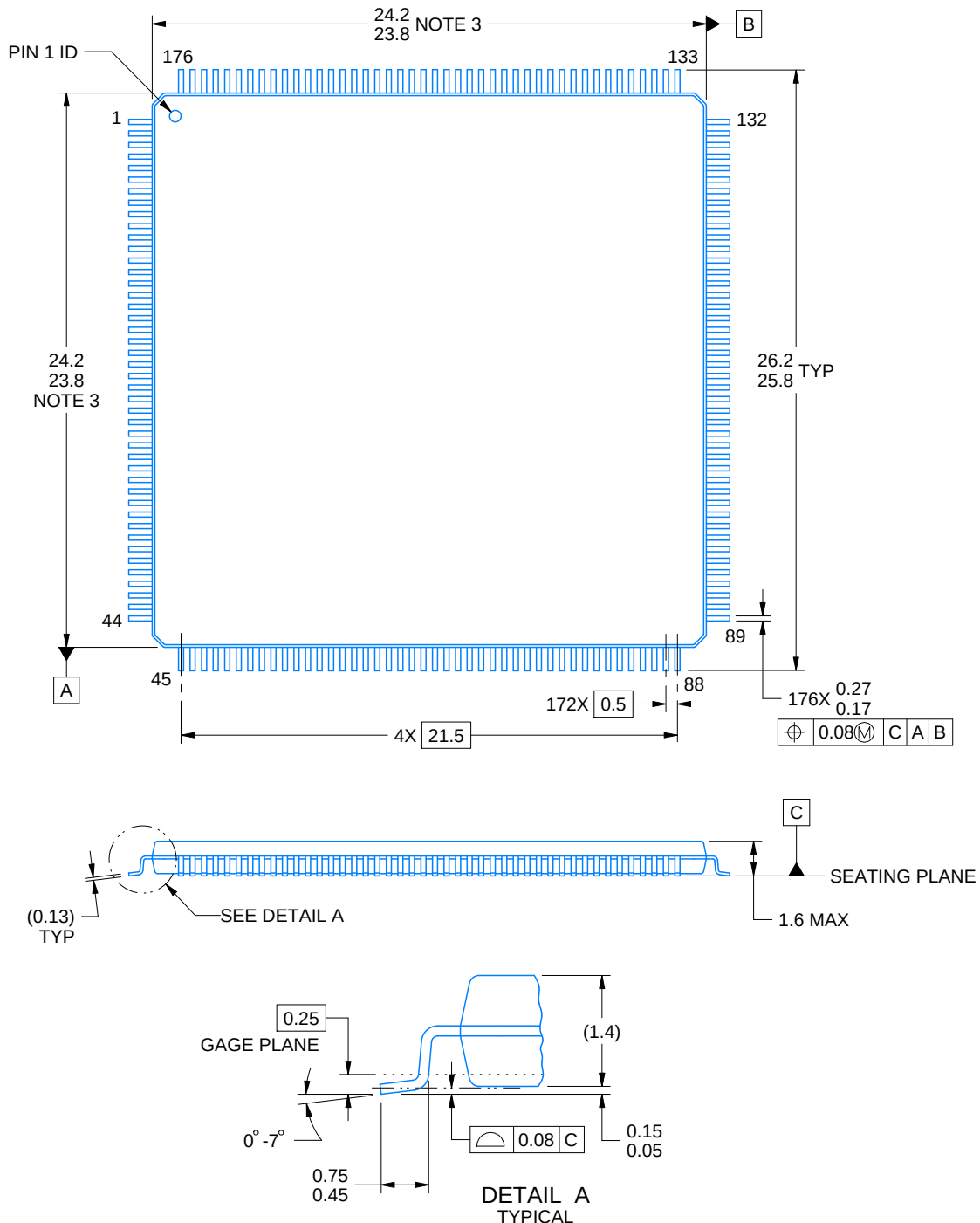
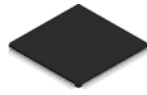


- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>. Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PowerPAD is a trademark of Texas Instruments.



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4215177/A 05/2017

## NOTES:

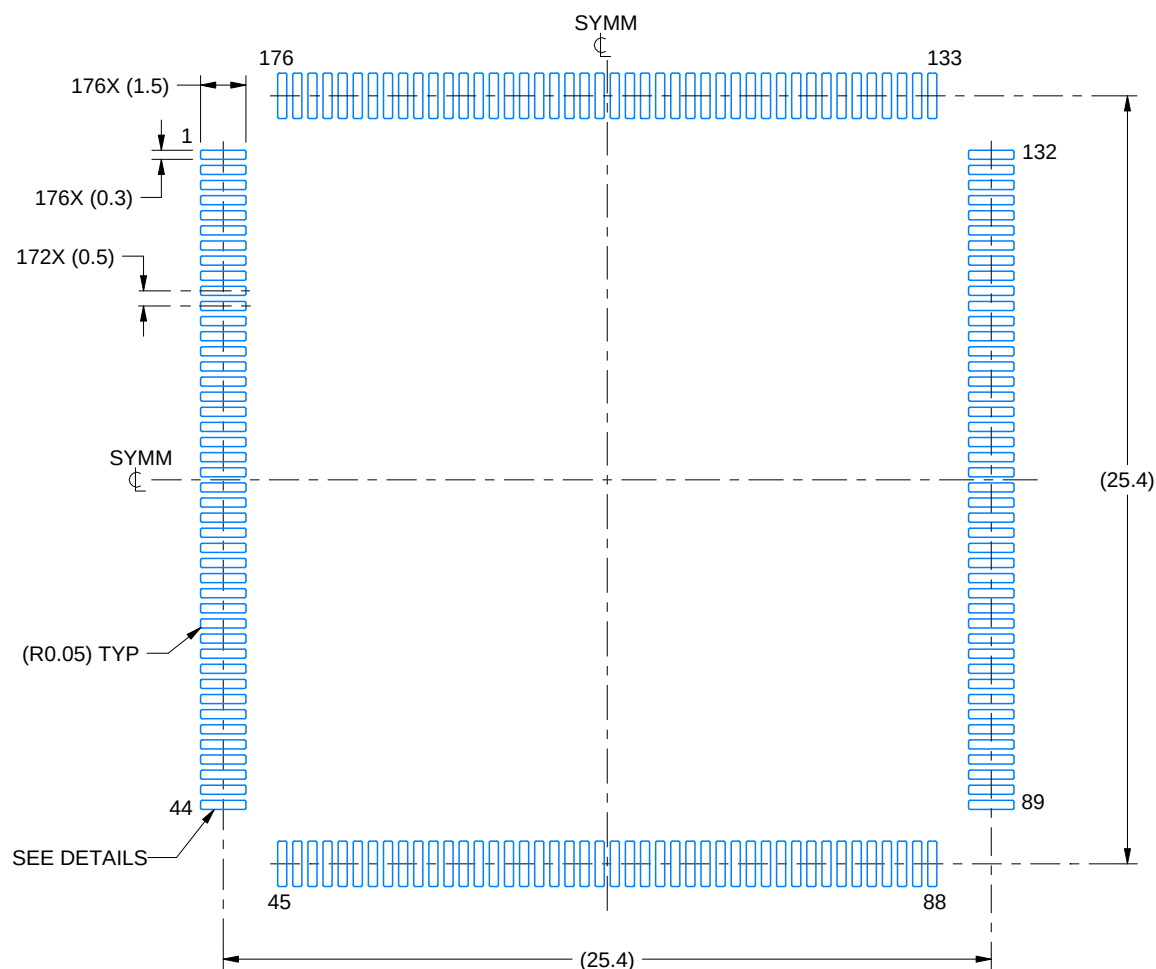
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs.
4. Reference JEDEC registration MS-026.

# EXAMPLE BOARD LAYOUT

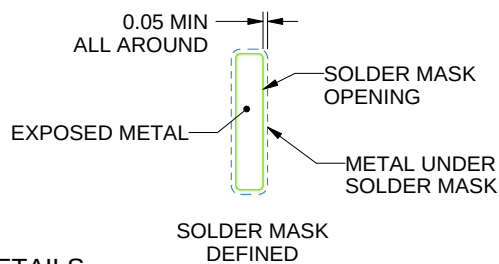
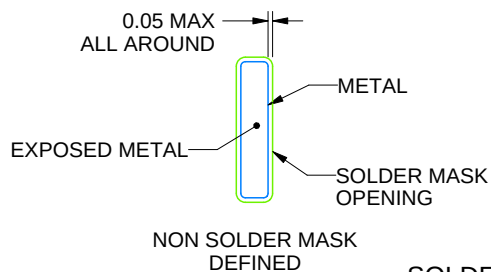
PGF0176A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:4X



SOLDER MASK DETAILS

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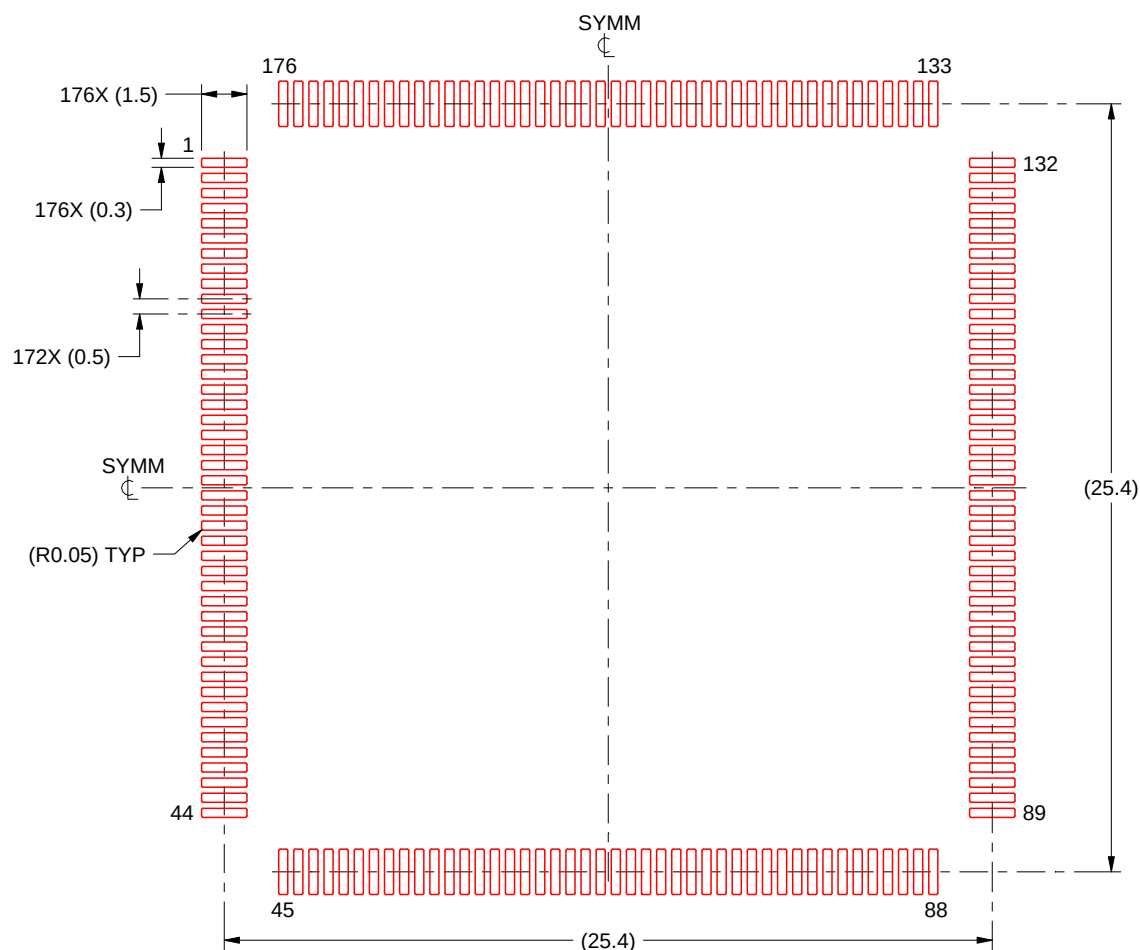
NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

**PGF0176A**

**LQFP - 1.6 mm max height**

## PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:4X

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NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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