

TMS320F280x、TMS320C280x、TMS320F2801x 数字信号处理器

1 器件概述

1.1 特性

- 高性能静态 CMOS 技术
 - 100MHz (10ns 周期时间)
 - 60MHz (16.67ns 周期时间)
 - 低功耗 (1.8V 内核, 3.3V I/O) 设计
- 支持 JTAG 边界扫描
 - IEEE 标准 1149.1-1990 标准测试访问端口和边界扫描架构
- 高性能 32 位 CPU (TMS320C28x)
 - 16 × 16 和 32 × 32 MAC 操作
 - 16 × 16 双 MAC
 - 哈佛 (Harvard) 总线架构
 - 连动运算
 - 快速中断响应和处理
 - 统一存储器编程模型
 - 高效代码 (使用 C/C++ 和汇编语言)
- 片上存储器
 - F2809: 128K × 16 闪存, 18K × 16 SARAM
 - F2808: 64K × 16 闪存, 18K × 16 SARAM
 - F2806: 32K × 16 闪存, 10K × 16 SARAM
 - F2802: 32K × 16 闪存, 6K × 16 SARAM
 - F2801: 16K × 16 闪存, 6K × 16 SARAM
 - F2801x: 16K × 16 闪存, 6K × 16 SARAM
 - 1K × 16 OTP ROM (仅适用于闪存器件)
 - C2802: 32K × 16 ROM, 6K × 16 SARAM
 - C2801: 16K × 16 ROM, 6K × 16 SARAM
- 引导 ROM (4K × 16)
 - 具有软件引导模式 (通过 SCI、SPI、CAN、I2C 和并行 I/O)
 - 标准数学表
- 时钟和系统控制
 - 片上振荡器
 - 看门狗计时器模块
- 任一 GPIO A 引脚可连接至三个外部内核中断之一
- 可支持全部 43 个外设中断的外设中断扩展 (PIE) 块
- 字节序: 小端字节序
- 128 位安全密钥/锁
 - 保护闪存/OTP/L0/L1 块
 - 防止固件逆向工程
- 3 个 32 位 CPU 计时器
- 增强型控制外设
 - 高达 16 个 PWM 输出
 - 在 150ps MEP 分辨率下高达 6 个 HRPWM 输出
 - 多达 4 个捕获输入
 - 多达 2 个正交编码器接口
 - 多达 6 个 32 位/6 个 16 位计时器
- 串行端口外设
 - 多达 4 个 SPI 模块
 - 多达 2 个 SCI (UART) 模块
 - 多达 2 个 CAN 模块
 - 1 条内部集成电路 (I2C) 总线
- 12 位 ADC, 16 通道
 - 2 × 8 通道输入多路复用器
 - 两个采样保持
 - 单个/同步转换
 - 快速转换率:
 - 80ns - 12.5MSPS (仅 F2809)
 - 160ns - 6.25MSPS (280x)
 - 267ns - 3.75MSPS (F2801x)
 - 内部或外部基准
- 多达 35 个具有输入滤波功能且可单独编程的多路复用 GPIO 引脚
- 高级仿真 特性
 - 分析和断点功能
 - 通过硬件的实时调试
- 开发支持包括
 - ANSI C/C++ 编译器/汇编器/连接器
 - Code Composer Studio™IDE 项目示例的源代码
 - SYS/BIOS
 - 数字电机控制和数字电源软件库
- 低功耗模式, 节省能耗
 - 支持闲置、待机、停机模式
 - 禁用单独的外设时钟
- 封装选项
 - 薄型四方扁平封装 (PZ)
 - MicroStar BGA™(GGM, ZGM)
- 温度选项
 - A: -40°C 至 85°C (PZ, GGM, ZGM)
 - S: -40°C 至 125°C (PZ, GGM, ZGM)
 - Q: -40°C 至 125°C (PZ)
 - (通过针对汽车 应用的 AEC-Q100 认证)

1.2 应用



- 电机驱动与控制
- 数字电源

1.3 说明

TMS320F2809、TMS320F2808、TMS320F2806、TMS320F2802、TMS320F2801、TMS320F28015、TMS320F28016、TMS320C2802 和 TMS320C2801 器件均属于 TMS320C28x DSP 系列器件，是适用于高要求控制应用的高度集成和高性能解决方案。

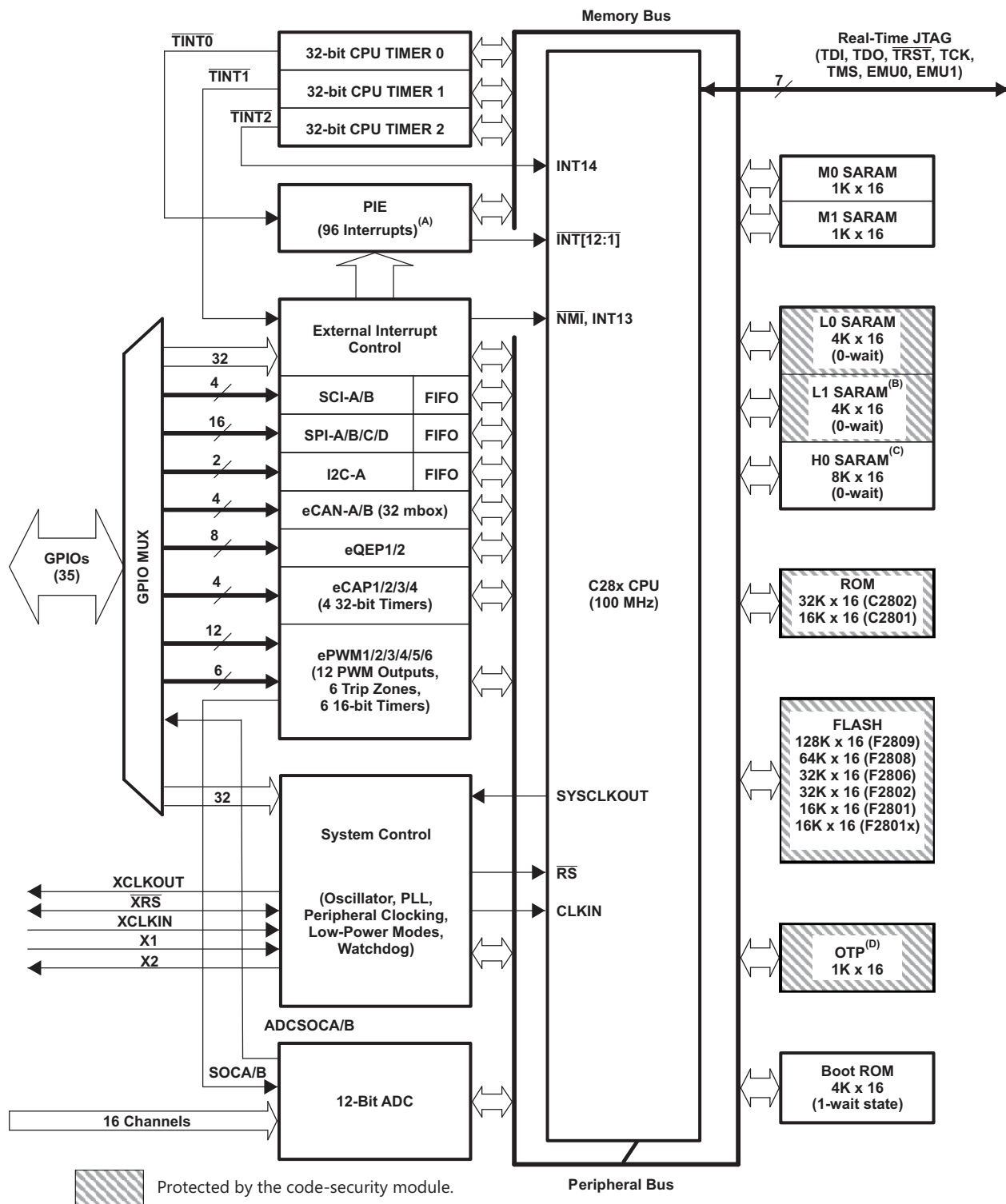
在整个文档中，TMS320F2809、TMS320F2808、TMS320F2806、TMS320F2802、TMS320F2801、TMS320C2802、TMS320C2801、TMS320F28015 和 TMS320F28016 分别简写为 F2809、F2808、F2806、F2802、F2801、C2802、C2801、F28015 和 F28016。TMS320F28015 和 TMS320F28016 均简写为 F2801x。 [器件比较（100MHz 器件）](#) 和 [器件比较（60MHz 器件）](#) 提供了各款器件的特性摘要。

器件信息⁽¹⁾

| 器件型号 | 封装 | 封装尺寸 |
|-----------------|---------------------|-----------------|
| TMS320F2809ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2808ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2806ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2802ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2801ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320C2802ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320C2801ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F28016ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F28015ZGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2809GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2808GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2806GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2802GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2801GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320C2802GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320C2801GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F28016GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F28015GGM | BGA MicroStar (100) | 10.0mm × 10.0mm |
| TMS320F2809PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320F2808PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320F2806PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320F2802PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320F2801PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320C2802PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320C2801PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320F28016PZ | LQFP (100) | 14.0mm × 14.0mm |
| TMS320F28015PZ | LQFP (100) | 14.0mm × 14.0mm |

(1) 有关这些器件的更多信息，请参阅[机械、封装和可订购信息](#)。

1.4 功能方框图



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- 96 个可能中断中的 43 个用在器件上。
- 在 F2802, F2801, C2802, 和 C2801 上不可用。
- 在 F2806, F2802, F2801, C2802, 和 C2801 上不可用。
- 对于 C280x 器件, 1K x 16 OTP 已经被 1K x 16 ROM 取代。

图 1-1. 功能方框图

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2 修订历史记录

| Changes from May 31, 2012 to March 11, 2019 (from N Revision (May 2012) to O Revision) | Page |
|---|------|
| <ul style="list-style-type: none"> 全局：文档结构已经过重新编排。 1 全局：将“DSP/BIOS”替换为“SYS/BIOS” 1 全局：将“CAN 2.0B”更改为“ISO11898-1 (CAN 2.0B)” 1 全局：删除了对应用报告 《TMS320LF24xx 和 TMS320F28xx 器件的可靠性数据》(SPRA963) 的引用 1 节 1 (器件概述)：将章节标题从“F280x、F2801x、C280x DSP”更改为“器件概述” 1 节 1.1 (特性)：删除了“支持动态 PLL 比率变化”特性 1 节 1.1：向 Q 温度选项添加了“(通过针对汽车 应用的 AEC-Q100 认证)” 1 节 1.2 (应用：添加了此部分 1 节 1.3 (说明：添加了此部分 2 节 1.4 (功能方框图)：添加了此部分 3 Section 3 (Device Comparison): Added section. 7 Table 3-1 (Device Comparison (100-MHz Devices)): Changed title from "Hardware Features (100-MHz Devices)" to "Device Comparison (100-MHz Devices)". 7 Table 3-1: Changed "PWM outputs" to "PWM channels". 7 Table 3-1: Added "(AEC-Q100 Qualification)" after Q temperature range. 7 Table 3-1: Removed "Product status" row. 7 Table 3-2 (Device Comparison (60-MHz Devices)): Changed title from "Hardware Features (60-MHz Devices)" to "Device Comparison (60-MHz Devices)". 8 Table 3-2: Changed "PWM outputs" to "PWM channels". 8 Table 3-2: Added "(AEC-Q100 Qualification)" after Q temperature range. 8 Table 3-2: Removed "Product status" row. 8 Section 3.1 (Related Products): Added section. 9 Section 4 (Terminal Configuration and Functions): Added section. 10 Section 4.1 (Pin Diagrams): Changed section title from "Pin Assignments" to "Pin Diagrams". 10 Table 4-1 (Signal Descriptions): Updated DESCRIPTION of $\overline{\text{XRS}}$. 15 Section 5.2 (ESD Ratings – Automotive): Added section. 22 Section 5.3 (ESD Ratings – Commercial): Added section. 22 Section 5.4 (Recommended Operating Conditions): Changed "Q version (Q100 Qualification)" to "Q version (AEC-Q100 Qualification)". 22 Section 5.5 (Power Consumption Summary): Changed section title from "Current Consumption" to "Power Consumption Summary". 23 Section 5.13 (Thermal Design Considerations): Added section. 33 Section 5.14 (Timing and Switching Characteristics): Added section. 34 Section 5.14.2 (Power Sequencing): Updated "No voltage larger than a diode drop ..." paragraph. 36 Section 5.14.2: Removed "Power Management and Supervisory Circuit Solutions" section. 36 Figure 5-12 (General-Purpose Input Timing): Changed XCLKOUT to SYSCLK. 44 Figure 5-16 (PWM Hi-Z Characteristics): Changed XCLKOUT to SYSCLK. 48 Table 5-24 (High-Resolution PWM Characteristics at SYSCLKOUT = 60–100 MHz): Updated footnote. 49 Section 5.14.4.5.1 (SPI Master Mode Timing): Updated section. 52 Section 5.14.4.5.2 (SPI Slave Mode Timing): Updated section. 55 Table 5-39 (Flash Parameters at 100-MHz SYSCLKOUT): Added MAX Program Time values and MAX Erase Time values. Updated and added footnotes. 58 Table 5-41 (Flash Data Retention Duration): Added table. 59 Section 5.16.1 (Migration Issues): Added NOTE about ROM versions of F280x device not being accepted by TI anymore. 66 Section 6 (Detailed Description): Changed section title from "Functional Overview" to "Detailed Description". 68 Section 6.1.6 (ROM): Added NOTE. 69 Section 6.2.6 (Enhanced Analog-to-Digital Converter (ADC) Module): Updated equations by which the digital value of the input analog voltage is derived. 85 Section 6.2.9 (Serial Peripheral Interface (SPI) Modules (SPI-A, SPI-B, SPI-C, SPI-D)): Updated "Rising edge with phase delay" clockng scheme 99 Table 6-27 (Device Emulation Registers): Updated REVID: Added Silicon rev. A for F2809 only. 119 Table 6-28 (PIE Peripheral Interrupts): Added footnote about ADCINT. 122 Figure 6-30 (Watchdog Module): Updated figure. 130 | |

| | |
|---|---------------------|
| • Section 7 (Applications, Implementation, and Layout): Added section. | 132 |
| • 节 8 (器件和文档支持)：添加了此部分 | 133 |
| • 图 8-1 (TMS320x280x/2801x 器件命名规则示例)：将“(Q100 认证)”更改为“(AEC-Q100 认证)”..... | 134 |
| • 节 8.3 (工具和软件)：添加了此部分 | 135 |
| • 节 8.4 (文档支持)：更新了该部分。 | 136 |
| • 节 8.5 (相关链接)：添加了此部分 | 138 |

3 Device Comparison

Table 3-1. Device Comparison (100-MHz Devices)

| FEATURE | | TYPE ⁽¹⁾ | F2809 | F2808 | F2806 | F2802 | F2801 | C2802 | C2801 |
|--|--|-----------------------|-----------------------------|-----------------------------|-------------------------|--------------------|--------------------|--------------------|--------------------|
| Instruction cycle (at 100 MHz) | | – | 10 ns | 10 ns | 10 ns | 10 ns | 10 ns | 10 ns | 10 ns |
| Single-access RAM (SARAM) (16-bit word) | | – | 18K (L0, L1, M0, M1, H0) | 18K (L0, L1, M0, M1, H0) | 10K (L0, L1, M0, M1) | 6K (L0, M0, M1) | 6K (L0, M0, M1) | 6K (L0, M0, M1) | 6K (L0, M0, M1) |
| 3.3-V on-chip flash (16-bit word) | | – | 128K | 64K | 32K | 32K | 16K | – | – |
| On-chip ROM (16-bit word) | | – | – | – | – | – | – | 32K | 16K |
| Code security for on-chip flash/SARAM/OTP blocks | | – | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Boot ROM (4K x 16) | | – | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| One-time programmable (OTP) ROM (16-bit word) | | – | 1K | 1K | 1K | 1K | 1K | – | – |
| PWM channels | | 0 | ePWM1/2/3/4/5/6 | ePWM1/2/3/4/5/6 | ePWM1/2/3/4/5/6 | ePWM1/2/3 | ePWM1/2/3 | ePWM1/2/3 | ePWM1/2/3 |
| HRPWM channels | | 0 | ePWM1A/2A/3A/4A/5A/6A | ePWM1A/2A/3A/4A | ePWM1A/2A/3A/4A | ePWM1A/2A/3A | ePWM1A/2A/3A | ePWM1A/2A/3A | ePWM1A/2A/3A |
| 32-bit CAPTURE inputs or auxiliary PWM outputs | | 0 | eCAP1/2/3/4 | eCAP1/2/3/4 | eCAP1/2/3/4 | eCAP1/2 | eCAP1/2 | eCAP1/2 | eCAP1/2 |
| 32-bit QEP channels (four inputs/channel) | | 0 | eQEP1/2 | eQEP1/2 | eQEP1/2 | eQEP1 | eQEP1 | eQEP1 | eQEP1 |
| Watchdog timer | | – | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 12-Bit, 16-channel ADC conversion time | | 1 | 80 ns | 160 ns | 160 ns | 160 ns | 160 ns | 160 ns | 160 ns |
| 32-Bit CPU timers | | – | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Serial Peripheral Interface (SPI) | | 0 | SPI-A/B/C/D | SPI-A/B/C/D | SPI-A/B/C/D | SPI-A/B | SPI-A/B | SPI-A/B | SPI-A/B |
| Serial Communications Interface (SCI) | | 0 | SCI-A/B | SCI-A/B | SCI-A/B | SCI-A | SCI-A | SCI-A | SCI-A |
| Enhanced Controller Area Network (eCAN) | | 0 | eCAN-A/B | eCAN-A/B | eCAN-A | eCAN-A | eCAN-A | eCAN-A | eCAN-A |
| Inter-Integrated Circuit (I2C) | | 0 | I2C-A | I2C-A | I2C-A | I2C-A | I2C-A | I2C-A | I2C-A |
| Digital I/O pins (shared) | | – | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| External interrupts | | – | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Supply voltage | | 1.8-V Core, 3.3-V I/O | – | Yes | Yes | Yes | Yes | Yes | Yes |
| Packaging | 100-Pin PZ | – | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | 100-Ball GGM, ZGM | – | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Temperature options | A: –40°C to 85°C | – | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) |
| | S: –40°C to 125°C | – | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) |
| | Q: –40°C to 125°C (AEC-Q100 Qualification) | – | (PZ) | (PZ) | (PZ) | (PZ) | (PZ) | (PZ) | (PZ) |

(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. Device Comparison (60-MHz Devices)

| FEATURE | | TYPE ⁽¹⁾ | F2802-60 | F2801-60 | F28016 | F28015 |
|--|---|---------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Instruction cycle (at 60 MHz) | | – | 16.67 ns | 16.67 ns | 16.67 ns | 16.67 ns |
| Single-access RAM (SARAM) (16-bit word) | | – | 6K (L0, M0, M1) | 6K (L0, M0, M1) | 6K (L0, M0, M1) | 6K (L0, M0, M1) |
| 3.3-V on-chip flash (16-bit word) | | – | 32K | 16K | 16K | 16K |
| On-chip ROM (16-bit word) | | – | – | – | – | – |
| Code security for on-chip flash/SARAM/OTP blocks | | – | Yes | Yes | Yes | Yes |
| Boot ROM (4K x 16) | | – | Yes | Yes | Yes | Yes |
| One-time programmable (OTP) ROM (16-bit word) | | – | 1K | 1K | 1K | 1K |
| PWM channels | | 0 | ePWM1/2/3 | ePWM1/2/3 | ePWM1/2/3/4 | ePWM1/2/3/4 |
| HRPWM channels | | 0 | ePWM1A/2A/3A | ePWM1A/2A/3A | ePWM1A/2A/3A/4A | ePWM1A/2A/3A/4A |
| 32-bit CAPTURE inputs or auxiliary PWM outputs | | 0 | eCAP1/2 | eCAP1/2 | eCAP1/2 | eCAP1/2 |
| 32-bit QEP channels (four inputs/channel) | | 0 | eQEP1 | eQEP1 | – | – |
| Watchdog timer | | – | Yes | Yes | Yes | Yes |
| 12-Bit ADC | No. of channels | 1 | 16 | 16 | 16 | 16 |
| | MSPS | | 3.75 | 3.75 | 3.75 | 3.75 |
| | Conversion time | | 267 ns | 267 ns | 267 ns | 267 ns |
| 32-Bit CPU timers | | – | 3 | 3 | 3 | 3 |
| Serial Peripheral Interface (SPI) | | 0 | SPI-A/B | SPI-A/B | SPI-A | SPI-A |
| Serial Communications Interface (SCI) | | 0 | SCI-A | SCI-A | SCI-A | SCI-A |
| Enhanced Controller Area Network (eCAN) | | 0 | eCAN-A | eCAN-A | eCAN-A | – |
| Inter-Integrated Circuit (I2C) | | 0 | I2C-A | I2C-A | I2C-A | I2C-A |
| Digital I/O pins (shared) | | – | 35 | 35 | 35 | 35 |
| External interrupts | | – | 3 | 3 | 3 | 3 |
| Supply voltage | | – | 1.8-V Core, 3.3-V I/O | 1.8-V Core, 3.3-V I/O | 1.8-V Core, 3.3-V I/O | 1.8-V Core, 3.3-V I/O |
| Packaging | 100-Pin PZ | – | Yes | Yes | Yes | Yes |
| | 100-Ball GGM, ZGM | – | Yes | Yes | Yes | Yes |
| Temperature options | A: –40°C to 85°C | – | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) |
| | S: –40°C to 125°C | – | (PZ GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) | (PZ, GGM, ZGM) |
| | Q: –40°C to 125°C (AEC-Q100 Qualification) | – | (PZ) | (PZ) | (PZ) | (PZ) |

(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 this family of products, see the following links:

[TMS320F2837xS Delfino™ Microcontrollers](#)

The Delfino™ TMS320F2837xS is a powerful 32-bit floating-point microcontroller unit (MCU) designed for advanced closed-loop control applications such as industrial drives and servo motor control; solar inverters and converters; digital power; transportation; and power line communications. Complete development packages for digital power and industrial drives are available as part of the powerSUITE and DesignDRIVE initiatives.

4 Terminal Configuration and Functions

4.1 Pin Diagrams

The TMS320F2809, TMS320F2808, TMS320F2806, TMS320F2802, TMS320F2801, TMS320C2802, TMS320C2801, TMS320F28015, and TMS320F28016 100-pin PZ low-profile quad flatpack (LQFP) pin assignments are shown in Figure 4-1, Figure 4-2, Figure 4-3, and Figure 4-4. The 100-ball GGM and ZGM ball grid array (BGA) terminal assignments are shown in Figure 4-5. Table 4-1 describes the function(s) of each pin.

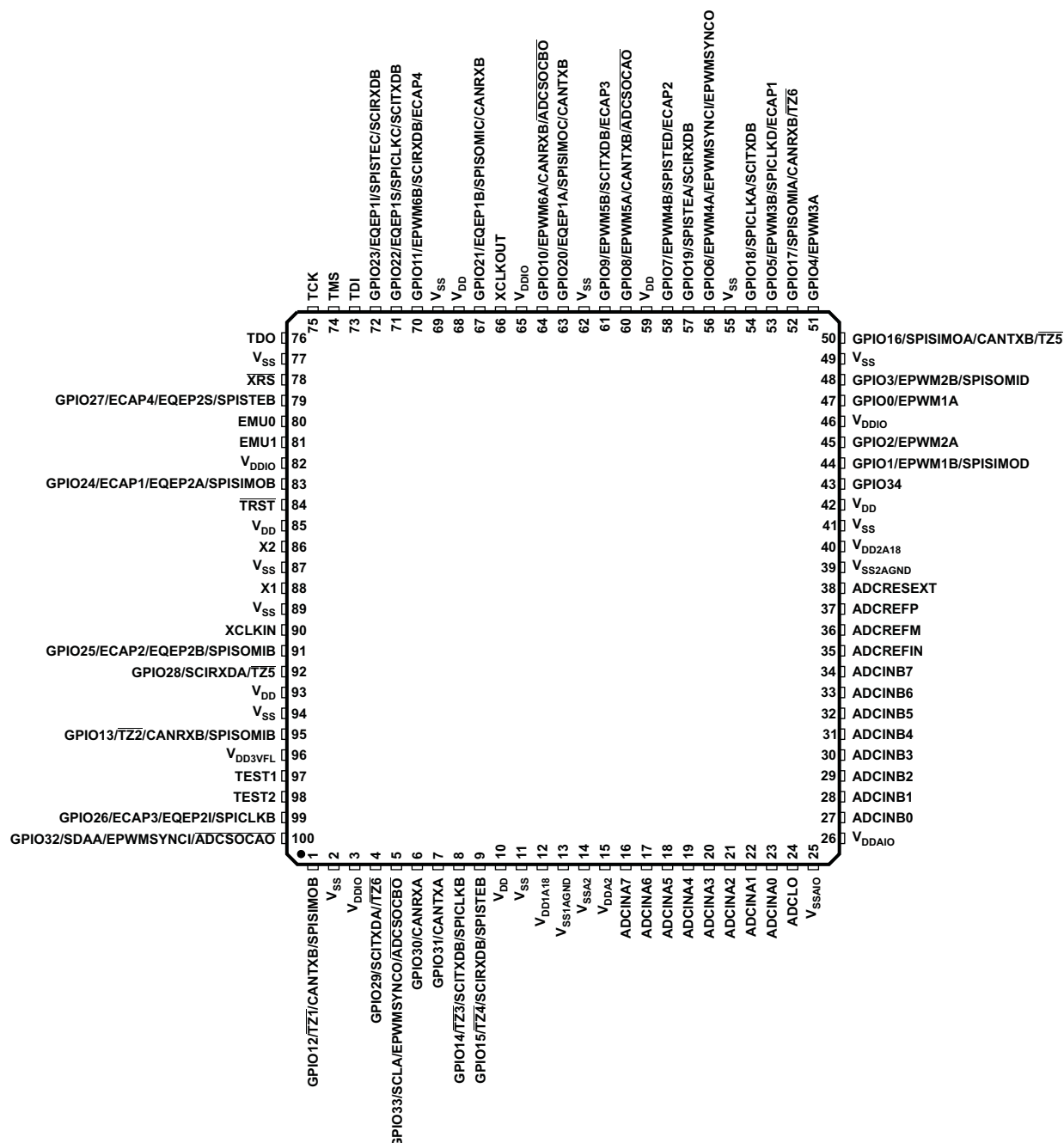


Figure 4-1. TMS320F2809, TMS320F2808 100-Pin PZ LQFP (Top View)

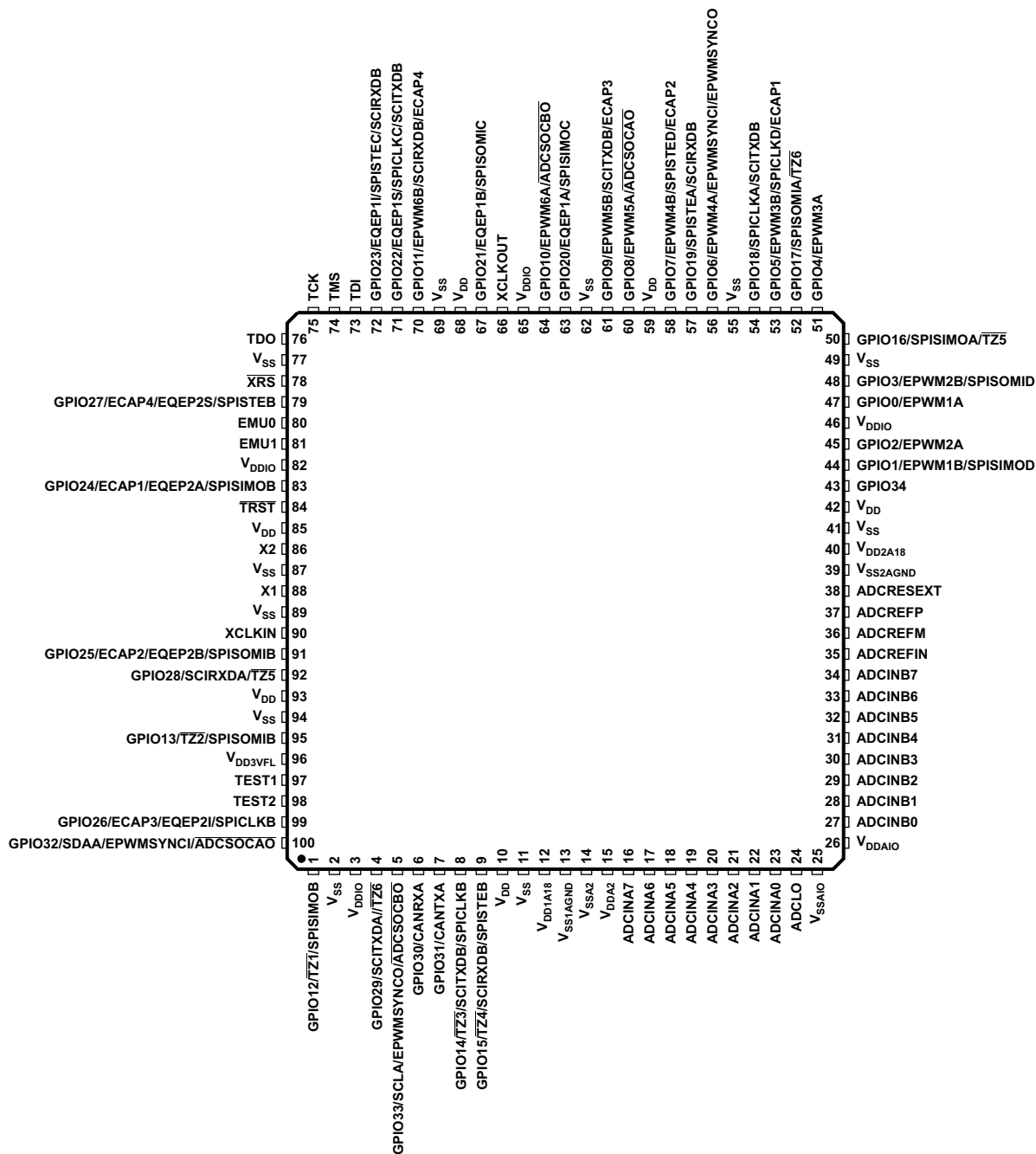


Figure 4-2. TMS320F2806 100-Pin PZ LQFP (Top View)

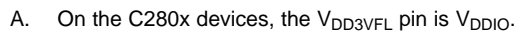
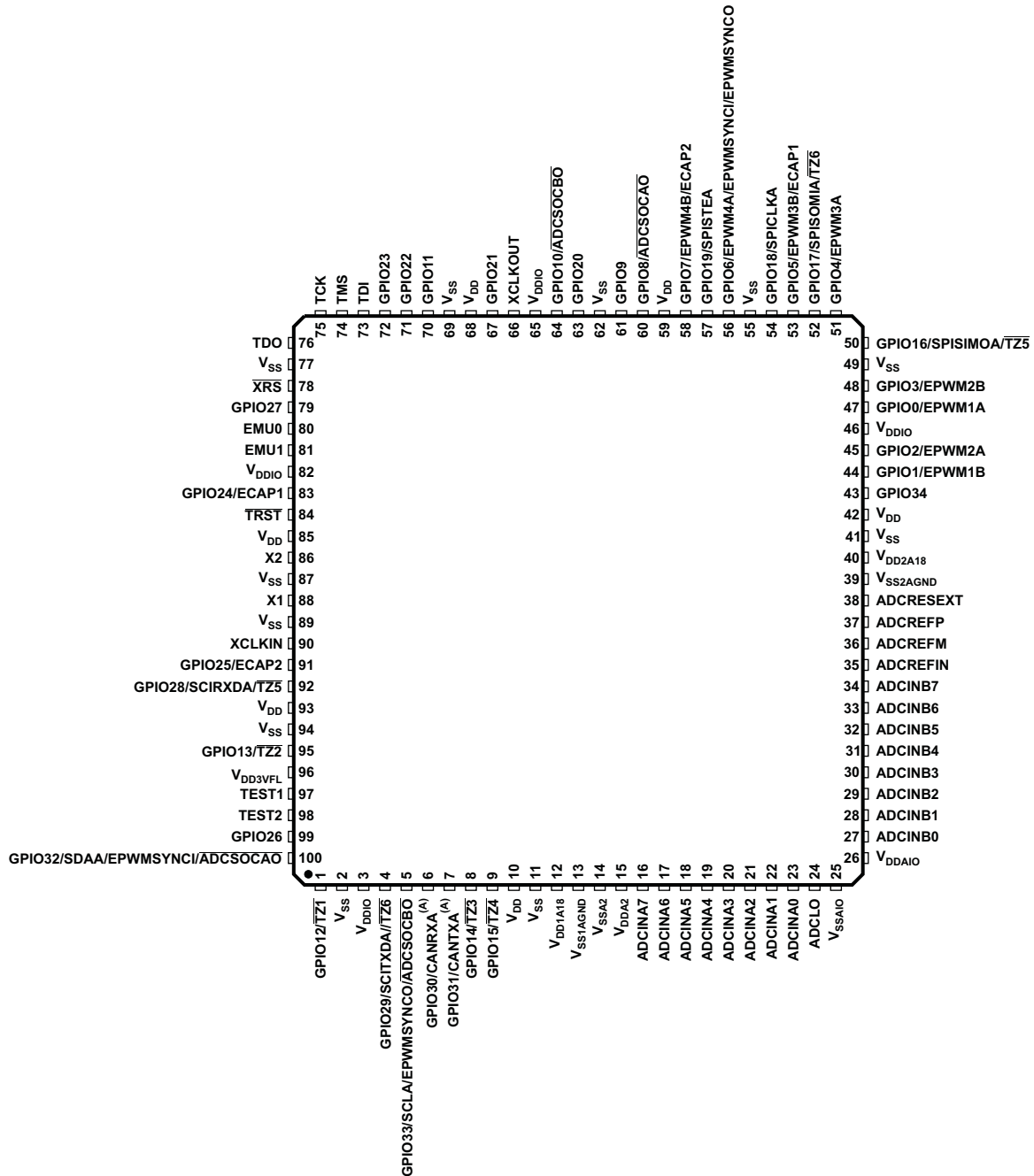
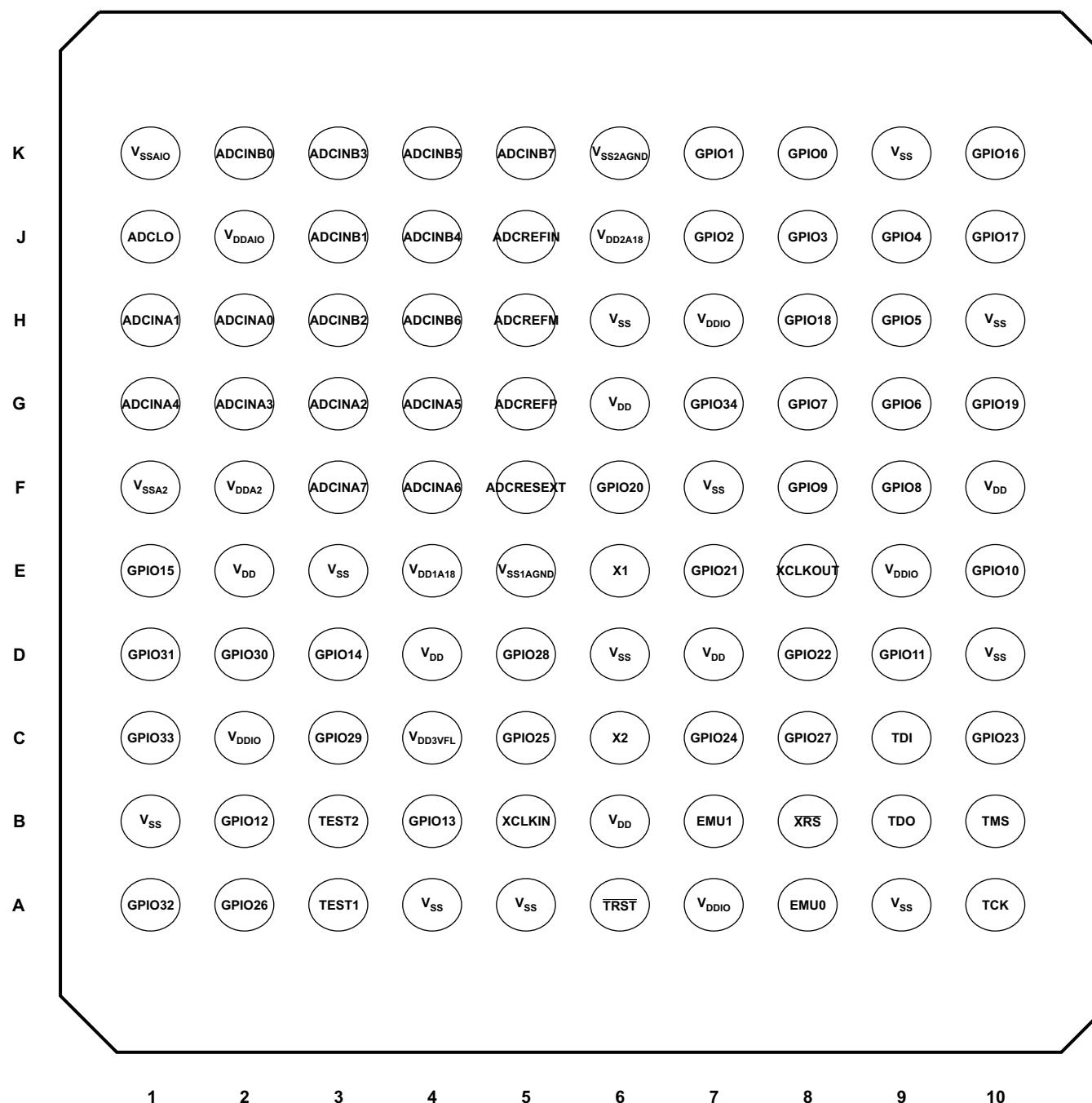


Figure 4-3. TMS320F2802, TMS320F2801, TMS320C2802, TMS320C2801 100-Pin PZ LQFP (Top View)



A. CANTXA (pin 7) and CANRXA (pin 6) pins are not applicable for the TMS320F28015.

Figure 4-4. TMS320F2801x 100-Pin PZ LQFP (Top View)



Bottom View

Figure 4-5. TMS320F2809, TMS320F2808, TMS320F2806, TMS320F2802, TMS320F2801,
TMS320F28016, TMS320F28015, TMS320C2802, TMS320C2801
100-Ball GGM and ZGM MicroStar BGA™ (Bottom View)

4.2 Signal Descriptions

Table 4-1 describes the signals. All digital inputs are TTL-compatible. All outputs are 3.3 V with CMOS levels. Inputs are not 5-V tolerant.

Table 4-1. Signal Descriptions

| NAME | PIN NO. | | DESCRIPTION ⁽¹⁾ |
|--------------------------|-------------|-----------------------|---|
| | PZ PIN # | GGM/ ZGM BALL # | |
| JTAG | | | |
| $\overline{\text{TRST}}$ | 84 | A6 | 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. NOTE: Do not use pullup resistors on $\overline{\text{TRST}}$; it has an internal pull-down device. $\overline{\text{TRST}}$ 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 Ω resistor generally offers adequate protection. Since this is application-specific, it is recommended that each target board be validated for proper operation of the debugger and the application. (I, \downarrow) |
| TCK | 75 | A10 | JTAG test clock with internal pullup (I, \uparrow) |
| TMS | 74 | B10 | 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 | 73 | C9 | 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 | 76 | B9 | 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 | 80 | A8 | 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) NOTE: An external pullup resistor is recommended 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 Ω to 4.7-k Ω resistor is generally adequate. Since this is application-specific, it is recommended that each target board be validated for proper operation of the debugger and the application. |
| EMU1 | 81 | B7 | 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) NOTE: An external pullup resistor is recommended 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 Ω to 4.7-k Ω resistor is generally adequate. Since this is application-specific, it is recommended that each target board be validated for proper operation of the debugger and the application. |
| FLASH | | | |
| V _{DD3VFL} | 96 | C4 | 3.3-V Flash Core Power Pin. This pin should be connected to 3.3 V at all times. On the ROM parts (C280x), this pin should be connected to V _{DDIO} . |
| TEST1 | 97 | A3 | Test Pin. Reserved for TI. Must be left unconnected. (I/O) |
| TEST2 | 98 | B3 | Test Pin. Reserved for TI. Must be left unconnected. (I/O) |
| CLOCK | | | |
| XCLKOUT | 66 | E8 | 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 the bits 1, 0 (XCLKOUTDIV) in the XCLK register. At reset, XCLKOUT = SYSCLKOUT/4. The XCLKOUT signal can be turned off by setting XCLKOUTDIV to 3. Unlike other GPIO pins, the XCLKOUT pin is not placed in high-impedance state during a reset. (O/Z, 8 mA drive). |
| XCLKIN | 90 | B5 | External Oscillator Input. This pin is used to feed a clock from an external 3.3-V oscillator. In this case, tie the X1 pin to GND. Alternately, when a crystal/resonator is used (or if an external 1.8-V oscillator is fed into the X1 pin), tie the XCLKIN pin to GND. (I) |

(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 ⁽¹⁾ |
|-------------------------|-------------|-----------------------|--|
| | PZ PIN # | GGM/ ZGM BALL # | |
| X1 | 88 | E6 | 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 1.8-V core digital power supply. A 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 | 86 | C6 | 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 | | | |
| $\overline{\text{XRS}}$ | 78 | B8 | Device Reset (in) and Watchdog Reset (out). 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 DSP 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) 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 | 16 | F3 | ADC Group A, Channel 7 input (I) |
| ADCINA6 | 17 | F4 | ADC Group A, Channel 6 input (I) |
| ADCINA5 | 18 | G4 | ADC Group A, Channel 5 input (I) |
| ADCINA4 | 19 | G1 | ADC Group A, Channel 4 input (I) |
| ADCINA3 | 20 | G2 | ADC Group A, Channel 3 input (I) |
| ADCINA2 | 21 | G3 | ADC Group A, Channel 2 input (I) |
| ADCINA1 | 22 | H1 | ADC Group A, Channel 1 input (I) |
| ADCINA0 | 23 | H2 | ADC Group A, Channel 0 input (I) |
| ADCINB7 | 34 | K5 | ADC Group B, Channel 7 input (I) |
| ADCINB6 | 33 | H4 | ADC Group B, Channel 6 input (I) |
| ADCINB5 | 32 | K4 | ADC Group B, Channel 5 input (I) |
| ADCINB4 | 31 | J4 | ADC Group B, Channel 4 input (I) |
| ADCINB3 | 30 | K3 | ADC Group B, Channel 3 input (I) |
| ADCINB2 | 29 | H3 | ADC Group B, Channel 2 input (I) |
| ADCINB1 | 28 | J3 | ADC Group B, Channel 1 input (I) |
| ADCINB0 | 27 | K2 | ADC Group B, Channel 0 input (I) |
| ADCLO | 24 | J1 | Low Reference (connect to analog ground) (I) |
| ADCRESEXT | 38 | F5 | ADC External Current Bias Resistor. Connect a 22-k Ω resistor to analog ground. |
| ADCREFIN | 35 | J5 | External reference input (I) |
| ADCREFP | 37 | G5 | Internal Reference Positive Output. Requires a low ESR (under 1.5 Ω) ceramic bypass capacitor of 2.2 μF to analog ground. (O) NOTE: Use the ADC Clock rate to derive the ESR specification from the capacitor data sheet that is used in the system. |
| ADCREFM | 36 | H5 | Internal Reference Medium Output. Requires a low ESR (under 1.5 Ω) ceramic bypass capacitor of 2.2 μF to analog ground. (O) NOTE: Use the ADC Clock rate to derive the ESR specification from the capacitor data sheet that is used in the system. |

Table 4-1. Signal Descriptions (continued)

| NAME | PIN NO. | | DESCRIPTION ⁽¹⁾ |
|--|-------------|-----------------------|--|
| | PZ PIN # | GGM/ ZGM BALL # | |
| CPU AND I/O POWER PINS | | | |
| V _{DDA2} | 15 | F2 | ADC Analog Power Pin (3.3 V) |
| V _{SSA2} | 14 | F1 | ADC Analog Ground Pin |
| V _{DDAIO} | 26 | J2 | ADC Analog I/O Power Pin (3.3 V) |
| V _{SSAIO} | 25 | K1 | ADC Analog I/O Ground Pin |
| V _{DD1A18} | 12 | E4 | ADC Analog Power Pin (1.8 V) |
| V _{SS1AGND} | 13 | E5 | ADC Analog Ground Pin |
| V _{DD2A18} | 40 | J6 | ADC Analog Power Pin (1.8 V) |
| V _{SS2AGND} | 39 | K6 | ADC Analog Ground Pin |
| V _{DD} | 10 | E2 | CPU and Logic Digital Power Pins (1.8 V) |
| V _{DD} | 42 | G6 | |
| V _{DD} | 59 | F10 | |
| V _{DD} | 68 | D7 | |
| V _{DD} | 85 | B6 | |
| V _{DD} | 93 | D4 | |
| V _{DDIO} | 3 | C2 | Digital I/O Power Pin (3.3 V) |
| V _{DDIO} | 46 | H7 | |
| V _{DDIO} | 65 | E9 | |
| V _{DDIO} | 82 | A7 | |
| V _{SS} | 2 | B1 | Digital Ground Pins |
| V _{SS} | 11 | E3 | |
| V _{SS} | 41 | H6 | |
| V _{SS} | 49 | K9 | |
| V _{SS} | 55 | H10 | |
| V _{SS} | 62 | F7 | |
| V _{SS} | 69 | D10 | |
| V _{SS} | 77 | A9 | |
| V _{SS} | 87 | D6 | |
| V _{SS} | 89 | A5 | |
| V _{SS} | 94 | A4 | |
| GPIOA AND PERIPHERAL SIGNALS ⁽²⁾⁽³⁾ | | | |
| GPIO0 EPWM1A - - | 47 | K8 | General-purpose input/output 0 (I/O/Z) ⁽⁴⁾ Enhanced PWM1 Output A and HRPWM channel (O) - - |
| GPIO1 EPWM1B SPISIMOD - | 44 | K7 | General-purpose input/output 1 (I/O/Z) ⁽⁴⁾ Enhanced PWM1 Output B (O) SPI-D slave in, master out (I/O) (not available on 2801, 2802) - |
| GPIO2 EPWM2A - - | 45 | J7 | General-purpose input/output 2 (I/O/Z) ⁽⁴⁾ Enhanced PWM2 Output A and HRPWM channel (O) - - |

(2) Some peripheral functions may not be available in TMS320F2801x devices. See [Table 3-2](#) for details.

(3) All GPIO pins are I/O/Z, 4-mA drive typical (unless otherwise indicated), and have an internal pullup, which can be selectively enabled/disabled on a per-pin basis. This feature only applies to the GPIO pins. The GPIO function (shown in Italics) is the default at reset. The peripheral signals that are listed under them are alternate functions.

(4) The pullups on GPIO0-GPIO11 pins are not enabled at reset.

Table 4-1. Signal Descriptions (continued)

| NAME | PIN NO. | | DESCRIPTION ⁽¹⁾ |
|---|-------------|-----------------------|---|
| | PZ PIN # | GGM/ ZGM BALL # | |
| GPIO3 EPWM2B SPISOMID - | 48 | J8 | General-purpose input/output 3 (I/O/Z) ⁽⁴⁾ Enhanced PWM2 Output B (O) SPI-D slave out, master in (I/O) (not available on 2801, 2802) - |
| GPIO4 EPWM3A - - | 51 | J9 | General-purpose input/output 4 (I/O/Z) ⁽⁴⁾ Enhanced PWM3 output A and HRPWM channel (O) - - |
| GPIO5 EPWM3B SPICLKD ECAP1 | 53 | H9 | General-purpose input/output 5 (I/O/Z) ⁽⁴⁾ Enhanced PWM3 output B (O) SPI-D clock (I/O) (not available on 2801, 2802) Enhanced capture input/output 1 (I/O) |
| GPIO6 EPWM4A EPWMSYNCl EPWMSYNCO | 56 | G9 | General-purpose input/output 6 (I/O/Z) ⁽⁴⁾ Enhanced PWM4 output A and HRPWM channel (O) (not available on 2801, 2802) External ePWM sync pulse input (I) External ePWM sync pulse output (O) |
| GPIO7 EPWM4B SPISTED ECAP2 | 58 | G8 | General-purpose input/output 7 (I/O/Z) ⁽⁴⁾ Enhanced PWM4 output B (O) (not available on 2801, 2802) SPI-D slave transmit enable (I/O) (not available on 2801, 2802) Enhanced capture input/output 2 (I/O) |
| GPIO8 EPWM5A CANTXB ADCSOCAO | 60 | F9 | General-purpose input/output 8 (I/O/Z) ⁽⁴⁾ Enhanced PWM5 output A and HRPWM channel (O) (not available on 2801, 2802) Enhanced CAN-B transmit (O) (not available on 2801, 2802, F2806) ADC start-of-conversion A (O) |
| GPIO9 EPWM5B SCITXDB ECAP3 | 61 | F8 | General-purpose input/output 9 (I/O/Z) ⁽⁴⁾ Enhanced PWM5 output B (O) (not available on 2801, 2802) SCI-B transmit data (O) (not available on 2801, 2802) Enhanced capture input/output 3 (I/O) (not available on 2801, 2802) |
| GPIO10 EPWM6A CANRXB ADCSOCBO | 64 | E10 | General-purpose input/output 10 (I/O/Z) ⁽⁴⁾ Enhanced PWM6 output A and HRPWM channel (O) (not available on 2801, 2802) Enhanced CAN-B receive (I) (not available on 2801, 2802, F2806) ADC start-of-conversion B (O) |
| GPIO11 EPWM6B SCIRXDB ECAP4 | 70 | D9 | General-purpose input/output 11 (I/O/Z) ⁽⁴⁾ Enhanced PWM6 output B (O) (not available on 2801, 2802) SCI-B receive data (I) (not available on 2801, 2802) Enhanced CAP Input/Output 4 (I/O) (not available on 2801, 2802) |
| GPIO12 TZ1 CANTXB SPISIMOB | 1 | B2 | General-purpose input/output 12 (I/O/Z) ⁽⁵⁾ Trip Zone input 1 (I) Enhanced CAN-B transmit (O) (not available on 2801, 2802, F2806) SPI-B Slave in, Master out (I/O) |
| GPIO13 TZ2 CANRXB SPISOMIB | 95 | B4 | General-purpose input/output 13 (I/O/Z) ⁽⁵⁾ Trip zone input 2 (I) Enhanced CAN-B receive (I) (not available on 2801, 2802, F2806) SPI-B slave out, master in (I/O) |
| GPIO14 TZ3 SCITXDB SPICLKB | 8 | D3 | General-purpose input/output 14 (I/O/Z) ⁽⁵⁾ Trip zone input 3 (I) SCI-B transmit (O) (not available on 2801, 2802) SPI-B clock input/output (I/O) |
| GPIO15 TZ4 SCIRXDB SPISTEB | 9 | E1 | General-purpose input/output 15 (I/O/Z) ⁽⁵⁾ Trip zone input 4 (I) SCI-B receive (I) (not available on 2801, 2802) SPI-B slave transmit enable (I/O) |
| GPIO16 SPISIMOA CANTXB TZ5 | 50 | K10 | General-purpose input/output 16 (I/O/Z) ⁽⁵⁾ SPI-A slave in, master out (I/O) Enhanced CAN-B transmit (O) (not available on 2801, 2802, F2806) Trip zone input 5 (I) |

(5) The pullups on GPIO12-GPIO34 are enabled upon reset.

Table 4-1. Signal Descriptions (continued)

| NAME | PIN NO. | | DESCRIPTION ⁽¹⁾ |
|--|-------------|-----------------------|---|
| | PZ PIN # | GGM/ ZGM BALL # | |
| GPIO17 SPISOMIA CANRXB TZ6 | 52 | J10 | General-purpose input/output 17 (I/O/Z) ⁽⁵⁾ SPI-A slave out, master in (I/O) Enhanced CAN-B receive (I) (not available on 2801, 2802, F2806) Trip zone input 6 (I) |
| GPIO18 SPICLKA SCITXDB - - | 54 | H8 | General-purpose input/output 18 (I/O/Z) ⁽⁵⁾ SPI-A clock input/output (I/O) SCI-B transmit (O) (not available on 2801, 2802) - - |
| GPIO19 SPISTEA SCIRXDB - - | 57 | G10 | General-purpose input/output 19 (I/O/Z) ⁽⁵⁾ SPI-A slave transmit enable input/output (I/O) SCI-B receive (I) (not available on 2801, 2802) - - |
| GPIO20 EQEP1A SPISIMOC CANTXB | 63 | F6 | General-purpose input/output 20 (I/O/Z) ⁽⁵⁾ Enhanced QEP1 input A (I) SPI-C slave in, master out (I/O) (not available on 2801, 2802) Enhanced CAN-B transmit (O) (not available on 2801, 2802, F2806) |
| GPIO21 EQEP1B SPISOMIC CANRXB | 67 | E7 | General-purpose input/output 21 (I/O/Z) ⁽⁵⁾ Enhanced QEP1 input A (I) SPI-C master in, slave out (I/O) (not available on 2801, 2802) Enhanced CAN-B receive (I) (not available on 2801, 2802, F2806) |
| GPIO22 EQEP1S SPICLKC SCITXDB | 71 | D8 | General-purpose input/output 22 (I/O/Z) ⁽⁵⁾ Enhanced QEP1 strobe (I/O) SPI-C clock (I/O) (not available on 2801, 2802) SCI-B transmit (O) (not available on 2801, 2802) |
| GPIO23 EQEP1I SPISTEC SCIRXDB | 72 | C10 | General-purpose input/output 23 (I/O/Z) ⁽⁵⁾ Enhanced QEP1 index (I/O) SPI-C slave transmit enable (I/O) (not available on 2801, 2802) SCI-B receive (I) (not available on 2801, 2802) |
| GPIO24 ECAP1 EQEP2A SPISIMOB | 83 | C7 | General-purpose input/output 24 (I/O/Z) ⁽⁵⁾ Enhanced capture 1 (I/O) Enhanced QEP2 input A (I) (not available on 2801, 2802) SPI-B slave in, master out (I/O) |
| GPIO25 ECAP2 EQEP2B SPISOMIB | 91 | C5 | General-purpose input/output 25 (I/O/Z) ⁽⁵⁾ Enhanced capture 2 (I/O) Enhanced QEP2 input B (I) (not available on 2801, 2802) SPI-B master in, slave out (I/O) |
| GPIO26 ECAP3 EQEP2I SPICLKB | 99 | A2 | General-purpose input/output 26 (I/O/Z) ⁽⁵⁾ Enhanced capture 3 (I/O) (not available on 2801, 2802) Enhanced QEP2 index (I/O) (not available on 2801, 2802) SPI-B clock (I/O) |
| GPIO27 ECAP4 EQEP2S SPISTEB | 79 | C8 | General-purpose input/output 27 (I/O/Z) ⁽⁵⁾ Enhanced capture 4 (I/O) (not available on 2801, 2802) Enhanced QEP2 strobe (I/O) (not available on 2801, 2802) SPI-B slave transmit enable (I/O) |
| GPIO28 SCIRXDA - TZ5 | 92 | D5 | General-purpose input/output 28. This pin has an 8-mA (typical) output buffer. (I/O/Z) ⁽⁵⁾ SCI receive data (I) - Trip zone input 5 (I) |
| GPIO29 SCITXDA - TZ6 | 4 | C3 | General-purpose input/output 29. This pin has an 8-mA (typical) output buffer. (I/O/Z) ⁽⁵⁾ SCI transmit data (O) - Trip zone 6 input (I) |

Table 4-1. Signal Descriptions (continued)

| NAME | PIN NO. | | DESCRIPTION ⁽¹⁾ |
|---|-------------|-----------------------|---|
| | PZ PIN # | GGM/ ZGM BALL # | |
| GPIO30 CANRXA - - | 6 | D2 | General-purpose input/output 30. This pin has an 8-mA (typical) output buffer. (I/O/Z) ⁽⁵⁾ Enhanced CAN-A receive data (I) - - |
| GPIO31 CANTXA - - | 7 | D1 | General-purpose input/output 31. This pin has an 8-mA (typical) output buffer. (I/O/Z) ⁽⁵⁾ Enhanced CAN-A transmit data (O) - - |
| GPIO32 SDAA EPWMSYNCI ADCSOCAO | 100 | A1 | General-purpose input/output 32 (I/O/Z) ⁽⁵⁾ I2C data open-drain bidirectional port (I/OD) Enhanced PWM external sync pulse input (I) ADC start-of-conversion (O) |
| GPIO33 SCLA EPWMSYNCO ADCSOCBO | 5 | C1 | General-Purpose Input/Output 33 (I/O/Z) ⁽⁵⁾ I2C clock open-drain bidirectional port (I/OD) Enhanced PWM external synch pulse output (O) ADC start-of-conversion (O) |
| GPIO34 - - - | 43 | G7 | General-Purpose Input/Output 34 (I/O/Z) ⁽⁵⁾ - - - |

NOTE

Some peripheral functions may not be available in TMS320F2801x devices. See [Table 3-2](#) for details.

5 Specifications

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

5.1 Absolute Maximum Ratings⁽¹⁾⁽²⁾

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 $V_{IN} > V_{DDIO}$) ⁽³⁾ | −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 (GGM, ZGM, PZ) ⁽⁴⁾ | −40 | 85 | °C |
| | S version (GGM, ZGM, PZ) ⁽⁴⁾ | −40 | 125 | |
| | Q version (PZ) ⁽⁴⁾ | −40 | 125 | |
| Junction temperature | T_J ⁽⁴⁾ | −40 | 150 | °C |
| Storage temperature | T_{stg} ⁽⁴⁾ | −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 ± 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) Long-term high-temperature storage and/or extended use at maximum temperature conditions may result in a reduction of overall device life. For additional information, see [Semiconductor and IC package thermal metrics](#).

5.2 ESD Ratings – Automotive

| | | | VALUE | UNIT |
|--|---|---|-------|------|
| TMS320F2809, TMS320F2808, TMS320F2806, TMS320F2802, TMS320F2801, TMS320C2802, TMS320C2801, TMS320F28016, and TMS320F28015 in 100-pin PZ package | | | | |
| $V_{(ESD)}$ Electrostatic discharge | Human body model (HBM), per AEC-Q100-002 ⁽¹⁾ | | ±2000 | V |
| | Charged device model (CDM), per AEC-Q100-011 | All pins | ±500 | |
| | | Corner pins on 100-pin PZ: 1, 25, 26, 50, 51, 75, 76, 100 | ±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 |
|---|--|--|-------|------|
| TMS320F2809, TMS320F2808, TMS320F2806, TMS320F2802, TMS320F2801, TMS320C2802, TMS320C2801, TMS320F28016, and TMS320F28015 in 100-ball ZGM package | | | | |
| V _(ESD) Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | | ±2000 | V |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | | ±500 | |
| TMS320F2809, TMS320F2808, TMS320F2806, TMS320F2802, TMS320F2801, TMS320C2802, TMS320C2801, TMS320F28016, and TMS320F28015 in 100-ball GGM package | | | | |
| V _(ESD) Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | | ±2000 | V |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | | ±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} | | 3.14 | 3.3 | 3.47 | V |
| Device supply voltage CPU, V_{DD} | | 1.71 | 1.8 | 1.89 | V |
| Supply ground, V_{SS} , V_{SSIO} | | | 0 | | V |
| ADC supply voltage (3.3 V), V_{DDA2} , V_{DDAIO} | | 3.14 | 3.3 | 3.47 | V |
| ADC supply voltage (1.8 V), V_{DD1A18} , V_{DD2A18} | | 1.71 | 1.8 | 1.89 | V |
| Flash supply voltage, V_{DD3VFL} | | 3.14 | 3.3 | 3.47 | V |
| Device clock frequency (system clock), $f_{SYSCLKOUT}$ | 100-MHz devices | 2 | | 100 | MHz |
| | 60-MHz devices | 2 | | 60 | MHz |
| High-level input voltage, V_{IH} | All inputs except X1 | 2 | | $V_{DDIO} + 0.3$ | V |
| | X1 | $0.7 * V_{DD} - 0.05$ | | V_{DD} | |
| Low-level input voltage, V_{IL} | All inputs except X1 | $V_{SS} - 0.3$ | | 0.8 | V |
| | X1 | | | $0.3 * V_{DD} + 0.05$ | |
| High-level output source current, $V_{OH} = 2.4$ V, I_{OH} | All I/Os except Group 2 | | | –4 | mA |
| | Group 2 ⁽¹⁾ | | | –8 | |
| Low-level output sink current, $V_{OL} = V_{OL MAX}$, I_{OL} | All I/Os except Group 2 | | | 4 | mA |
| | Group 2 ⁽¹⁾ | | | 8 | |
| Ambient temperature, T_A | A version | –40 | | 85 | °C |
| | S version | –40 | | 125 | |
| | Q version (AEC-Q100 Qualification) | –40 | | 125 | |

(1) Group 2 pins are as follows: GPIO28, GPIO29, GPIO30, GPIO31, TDO, XCLKOUT, EMU0, and EMU1

5.5 Power Consumption Summary

Table 5-1. TMS320F2809, TMS320F2808 Current Consumption by Power-Supply Pins at 100-MHz SYSCLKOUT

| MODE | TEST CONDITIONS | I _{DD} | | I _{DDIO} ⁽¹⁾ | | I _{DD3VFL} ⁽²⁾ | | I _{DDA18} ⁽³⁾ | | I _{DDA33} ⁽⁴⁾ | |
|---------------------|--|--------------------|--------------------|----------------------------------|--------------------|------------------------------------|--------------------|-----------------------------------|--------------------|-----------------------------------|--------------------|
| | | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ |
| Operational (Flash) | The following peripheral clocks are enabled: <ul style="list-style-type: none"> ePWM1/2/3/4/5/6 eCAP1/2/3/4 eQEP1/2 eCAN-A SCI-A/B SPI-A ADC I2C All PWM pins are toggled at 100 kHz. All I/O pins are left unconnected. Data is continuously transmitted out of the SCI-A, SCI-B, and eCAN-A ports. The hardware multiplier is exercised. Code is running out of flash with 3 wait-states. XCLKOUT is turned off. | 195 mA | 230 mA | 15 mA | 27 mA | 35 mA | 40 mA | 30 mA | 38 mA | 1.5 mA | 2 mA |
| IDLE | Flash is powered down. XCLKOUT is turned off. The following peripheral clocks are enabled: <ul style="list-style-type: none"> eCAN-A SCI-A SPI-A I2C | 75 mA | 90 mA | 500 μ A | 2 mA | 2 μ A | 10 μ A | 5 μ A | 50 μ A | 15 μ A | 30 μ A |
| STANDBY | Flash is powered down. Peripheral clocks are off. | 6 mA | 12 mA | 100 μ A | 500 μ A | 2 μ A | 10 μ A | 5 μ A | 50 μ A | 15 μ A | 30 μ A |
| HALT | Flash is powered down. Peripheral clocks are off. Input clock is disabled. | 70 μ A | | 60 μ A | 120 μ A | 2 μ A | 10 μ A | 5 μ A | 50 μ A | 15 μ A | 30 μ 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 5-39](#). 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. In order 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) TYP numbers are applicable over room temperature and nominal voltage.
- (6) MAX numbers are at 125°C and MAX voltage.

NOTE

The peripheral - I/O multiplexing implemented in the 280x devices 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. TMS320F2806 Current Consumption by Power-Supply Pins at 100-MHz SYSCLKOUT

| MODE | TEST CONDITIONS | I _{DD} | | I _{DDIO} ⁽¹⁾ | | I _{DD3VFL} ⁽²⁾ | | I _{DDA18} ⁽³⁾ | | I _{DDA33} ⁽⁴⁾ | |
|---------------------|--|--------------------|--------------------|----------------------------------|--------------------|------------------------------------|--------------------|-----------------------------------|--------------------|-----------------------------------|--------------------|
| | | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ |
| Operational (Flash) | The following peripheral clocks are enabled: <ul style="list-style-type: none"> ePWM1/2/3/4/5/6 eCAP1/2/3/4 eQEP1/2 eCAN-A SCI-A/B SPI-A ADC I2C All PWM pins are toggled at 100 kHz. All I/O pins are left unconnected. Data is continuously transmitted out of the SCI-A, SCI-B, and eCAN-A ports. The hardware multiplier is exercised. Code is running out of flash with 3 wait-states. XCLKOUT is turned off | 195 mA | 230 mA | 15 mA | 27 mA | 35 mA | 40 mA | 30 mA | 38 mA | 1.5 mA | 2 mA |
| IDLE | Flash is powered down. XCLKOUT is turned off. The following peripheral clocks are enabled: <ul style="list-style-type: none"> eCAN-A SCI-A SPI-A I2C | 75 mA | 90 mA | 500 µA | 2 mA | 2 µA | 10 µA | 5 µA | 50 µA | 15 µA | 30 µA |
| STANDBY | Flash is powered down. Peripheral clocks are off. | 6 mA | 12 mA | 100 µA | 500 µA | 2 µA | 10 µA | 5 µA | 50 µA | 15 µA | 30 µA |
| HALT | Flash is powered down. Peripheral clocks are off. Input clock is disabled. | 70 µA | | 60 µA | 120 µA | 2 µA | 10 µA | 5 µA | 50 µA | 15 µA | 30 µA |

- (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 5-39](#). 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. In order 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) TYP numbers are applicable over room temperature and nominal voltage.
- (6) MAX numbers are at 125°C and MAX voltage.

NOTE

The peripheral - I/O multiplexing implemented in the 280x devices 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 5-3. TMS320F2802, TMS320F2801 Current Consumption by Power-Supply Pins at 100-MHz SYSCLKOUT

| MODE | TEST CONDITIONS | I _{DD} | | I _{DDIO} ⁽¹⁾ | | I _{DD3VFL} ⁽²⁾ | | I _{DDA18} ⁽³⁾ | | I _{DDA33} ⁽⁴⁾ | |
|---------------------|--|--------------------|--------------------|----------------------------------|--------------------|------------------------------------|--------------------|-----------------------------------|--------------------|-----------------------------------|--------------------|
| | | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ | TYP ⁽⁵⁾ | MAX ⁽⁶⁾ |
| Operational (Flash) | The following peripheral clocks are enabled: <ul style="list-style-type: none"> ePWM1/2/3 eCAP1/2 eQEP1 eCAN-A SCI-A SPI-A ADC I2C All PWM pins are toggled at 100 kHz. All I/O pins are left unconnected. Data is continuously transmitted out of the SCI-A, SCI-B, and eCAN-A ports. The hardware multiplier is exercised. Code is running out of flash with 3 wait-states. XCLKOUT is turned off. | 180 mA | 210 mA | 15 mA | 27 mA | 35 mA | 40 mA | 30 mA | 38 mA | 1.5 mA | 2 mA |
| IDLE | Flash is powered down. XCLKOUT is turned off. The following peripheral clocks are enabled: <ul style="list-style-type: none"> eCAN-A SCI-A SPI-A I2C | 75 mA | 90 mA | 500 µA | 2 mA | 2 µA | 10 µA | 5 µA | 50 µA | 15 µA | 30 µA |
| STANDBY | Flash is powered down. Peripheral clocks are off. | 6 mA | 12 mA | 100 µA | 500 µA | 2 µA | 10 µA | 5 µA | 50 µA | 15 µA | 30 µA |
| HALT | Flash is powered down. Peripheral clocks are off. Input clock is disabled. | 70 µA | | 60 µA | 120 µA | 2 µA | 10 µA | 5 µA | 50 µA | 15 µA | 30 µA |

- (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 5-39](#). 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. In order 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) TYP numbers are applicable over room temperature and nominal voltage.
(6) MAX numbers are at 125°C and MAX voltage.

NOTE

The peripheral - I/O multiplexing implemented in the 280x devices 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 5-4. TMS320C2802, TMS320C2801 Current Consumption by Power-Supply Pins at 100-MHz SYSCLKOUT

| MODE | TEST CONDITIONS | I_{DD} | | $I_{DDIO}^{(1)}$ | | $I_{DDA18}^{(2)}$ | | $I_{DDA33}^{(3)}$ | |
|-------------------|---|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | | TYP ⁽⁴⁾ | MAX ⁽⁵⁾ | TYP ⁽⁴⁾ | MAX ⁽⁵⁾ | TYP ⁽⁴⁾ | MAX ⁽⁵⁾ | TYP ⁽⁴⁾ | MAX ⁽⁵⁾ |
| Operational (ROM) | The following peripheral clocks are enabled: <ul style="list-style-type: none"> ePWM1/2/3 eCAP1/2 eQEP1 eCAN-A SCI-A SPI-A ADC I2C All PWM pins are toggled at 100 kHz. All I/O pins are left unconnected. Data is continuously transmitted out of the SCI-A, SCI-B, and eCAN-A ports. The hardware multiplier is exercised. Code is running out of ROM with 3 wait-states. XCLKOUT is turned off. | 150 mA | 165 mA | 5 mA | 10 mA | 30 mA | 38 mA | 1.5 mA | 2 mA |
| IDLE | XCLKOUT is turned off. The following peripheral clocks are enabled: <ul style="list-style-type: none"> eCAN-A SCI-A SPI-A I2C | 75 mA | 90 mA | 500 μ A | 2 mA | 5 μ A | 50 μ A | 15 μ A | 30 μ A |
| STANDBY | Peripheral clocks are off. | 6 mA | 12 mA | 100 μ A | 500 μ A | 5 μ A | 50 μ A | 15 μ A | 30 μ A |
| HALT | Peripheral clocks are off. Input clock is disabled. | 70 μ A | | 80 μ A | 120 μ A | 5 μ A | 50 μ A | 15 μ A | 30 μ A |

(1) I_{DDIO} current is dependent on the electrical loading on the I/O pins.

(2) I_{DDA18} includes current into V_{DD1A18} and V_{DD2A18} pins. In order 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.

(3) I_{DDA33} includes current into V_{DDA2} and V_{DDAIO} pins.

(4) TYP numbers are applicable over room temperature and nominal voltage.

(5) MAX numbers are at 125°C and MAX voltage.

NOTE

The peripheral - I/O multiplexing implemented in the 280x devices 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.

5.5.1 Reducing Current Consumption

280x devices have a richer peripheral mix compared to the 281x family. While the McBSP has been removed, the following new peripherals have been added on the 280x:

- 3 SPI modules
- 1 CAN module
- 1 I2C module

The two event manager modules of the 281x have been enhanced and replaced with separate ePWM (6), eCAP (4) and eQEP (2) modules, providing tremendous flexibility in applications. Like 281x, 280x DSPs incorporate a unique method to reduce the device current consumption. Since each peripheral unit has an individual clock-enable bit, significant 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 5-5](#) indicates the typical reduction in current consumption achieved by turning off the clocks.

Table 5-5. Typical Current Consumption by Various Peripherals (at 100 MHz)⁽¹⁾

| PERIPHERAL MODULE | I _{DD} CURRENT REDUCTION (mA) ⁽²⁾ |
|----------------------|--|
| ADC | 8 ⁽³⁾ |
| I2C | 5 |
| eQEP | 5 |
| ePWM | 5 |
| eCAP | 2 |
| SCI | 4 |
| SPI | 5 |
| eCAN | 11 |

(1) All peripheral clocks are disabled upon reset. Writing to/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_{DDA18}) as well.

NOTE

I_{DDIO} current consumption is reduced by 15 mA (typical) when XCLKOUT is turned off.

NOTE

The baseline I_{DD} current (current when the core is executing a dummy loop with no peripherals enabled) is 110 mA, typical. To arrive at the I_{DD} current for a given application, the current-drawn by the peripherals (enabled by that application) must be added to the baseline I_{DD} current.

5.5.2 Current Consumption Graphs

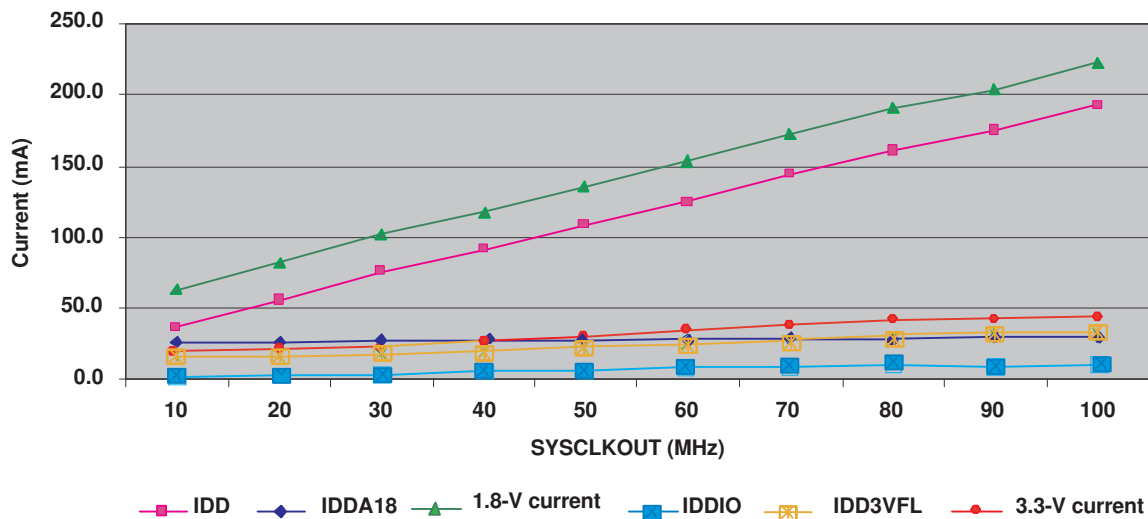


Figure 5-1. Typical Operational Current Versus Frequency (F2808)

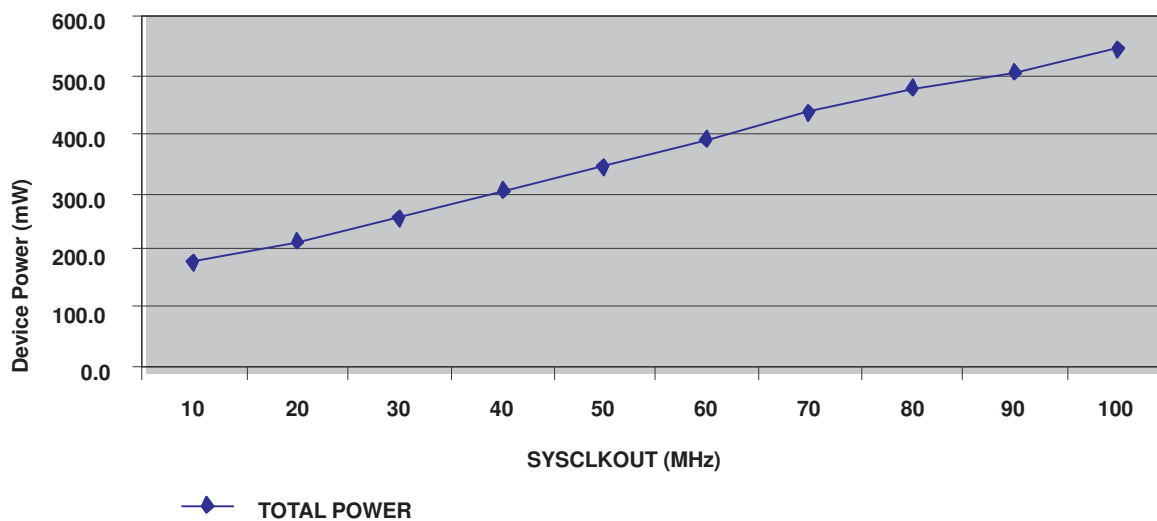


Figure 5-2. Typical Operational Power Versus Frequency (F2808)

NOTE

Typical operational current for 60-MHz devices can be estimated from Figure 5-1. For I_{DD} current alone, subtract the current contribution of non-existent peripherals after scaling the peripheral currents for 60 MHz. For example, to compute the current of F2801-60 device, the contribution by the following peripherals must be subtracted from I_{DD} : ePWM4/5/6, eCAP3/4, eQEP2, SCI-B.

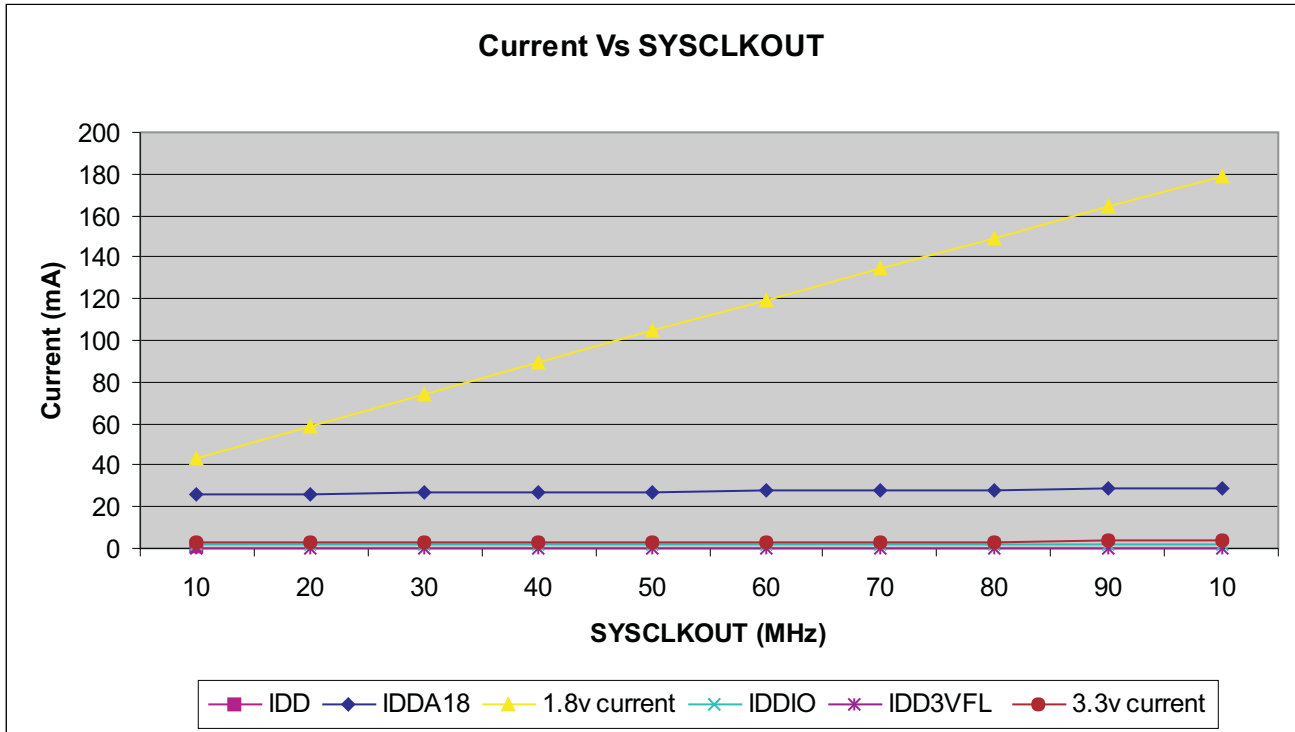


Figure 5-3. Typical Operational Current Versus Frequency (C280x)

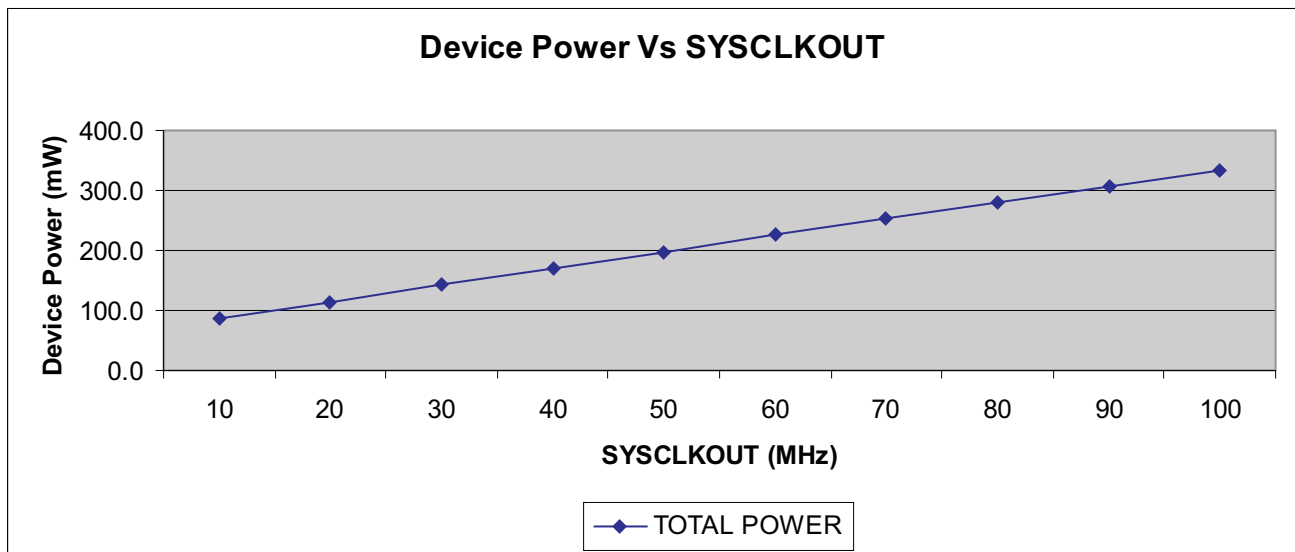


Figure 5-4. Typical Operational Power Versus Frequency (C280x)

5.6 Electrical Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|-----------------|---|---------------------------|--|--|-------------------------|------|------|------|
| V _{OH} | High-level output voltage | | I _{OH} = I _{OH} MAX | | 2.4 | | | V |
| | | | I _{OH} = 50 μA | | V _{DDIO} − 0.2 | | | |
| V _{OL} | Low-level output voltage | | I _{OL} = I _{OL} MAX | | 0.4 | | | V |
| I _{IL} | Input current (low level) | Pin with pullup enabled | V _{DDIO} = 3.3 V, V _{IN} = 0 V | All I/Os (including \overline{XRS}) | −80 | −140 | −190 | μA |
| | | Pin with pulldown enabled | V _{DDIO} = 3.3 V, V _{IN} = 0 V | | | | | |
| I _{IH} | Input current (high level) | Pin with pullup enabled | V _{DDIO} = 3.3 V, V _{IN} = V _{DDIO} | | ±2 | | | μA |
| | | Pin with pulldown enabled | V _{DDIO} = 3.3 V, V _{IN} = V _{DDIO} (F280x) | | 28 | 50 | 80 | |
| | | Pin with pulldown enabled | V _{DDIO} = 3.3 V, V _{IN} = V _{DDIO} (C280x) | | 80 | 140 | 190 | |
| I _{OZ} | Output current, pullup or pulldown disabled | | V _O = V _{DDIO} or 0 V | | ±2 | | | μA |
| C _I | Input capacitance | | | | 2 | | | pF |

5.7 Thermal Resistance Characteristics for F280x 100-Ball GGM Package

| | | °C/W ⁽¹⁾ | AIR FLOW (lfm) ⁽²⁾ |
|----------------------------------|---|---------------------|-------------------------------|
| R _{θJC} | Junction-to-case thermal resistance | 12.08 | N/A |
| R _{θJB} | Junction-to-board thermal resistance | 16.46 | N/A |
| R _{θJA} (High k PCB) | Junction-to-free air thermal resistance | 30.58 | 0 |
| | | 29.31 | 150 |
| | | 28.09 | 250 |
| | | 26.62 | 500 |
| Psi _{JT} | Junction-to-package top | 0.4184 | 0 |
| | | 0.32 | 150 |
| | | 0.3725 | 250 |
| | | 0.4887 | 500 |

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [R_{θJC}] 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*

(2) lfm = linear feet per minute

5.8 Thermal Resistance Characteristics for F280x 100-Pin PZ Package

| | | °C/W ⁽¹⁾ | AIR FLOW (lfm) ⁽²⁾ |
|----------------------------------|---|---------------------|-------------------------------|
| R _{θJC} | Junction-to-case thermal resistance | 12.89 | N/A |
| R _{θJB} | Junction-to-board thermal resistance | 29.58 | N/A |
| R _{θJA} (High k PCB) | Junction-to-free air thermal resistance | 48.16 | 0 |
| | | 40.06 | 150 |
| | | 37.96 | 250 |
| | | 35.17 | 500 |
| Psi _{JT} | Junction-to-package top | 0.3425 | 0 |
| | | 0.85 | 150 |
| | | 1.0575 | 250 |
| | | 1.410 | 500 |

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [R_{θJC}] 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*

(2) lfm = linear feet per minute

5.9 Thermal Resistance Characteristics for C280x 100-Ball GGM Package

| | | °C/W ⁽¹⁾ | AIR FLOW (lfm) ⁽²⁾ |
|---------------------------------|---|---------------------|-------------------------------|
| R θ_{JC} | Junction-to-case thermal resistance | 14.18 | N/A |
| R θ_{JB} | Junction-to-board thermal resistance | 21.36 | N/A |
| R θ_{JA} (High k PCB) | Junction-to-free air thermal resistance | 36.33 | 0 |
| | | 35.01 | 150 |
| | | 33.81 | 250 |
| | | 32.31 | 500 |
| Psi $_{JT}$ | Junction-to-package top | 0.57 | 0 |
| | | 0.43 | 150 |
| | | 0.52 | 250 |
| | | 0.67 | 500 |

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [R θ_{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*

(2) lfm = linear feet per minute

5.10 Thermal Resistance Characteristics for C280x 100-Pin PZ Package

| | | °C/W ⁽¹⁾ | AIR FLOW (lfm) ⁽²⁾ |
|---------------------------------|---|---------------------|-------------------------------|
| R θ_{JC} | Junction-to-case thermal resistance | 13.52 | N/A |
| R θ_{JB} | Junction-to-board thermal resistance | 54.78 | N/A |
| R θ_{JA} (High k PCB) | Junction-to-free air thermal resistance | 69.81 | 0 |
| | | 60.34 | 150 |
| | | 57.46 | 250 |
| | | 53.63 | 500 |
| Psi $_{JT}$ | Junction-to-package top | 0.42 | 0 |
| | | 1.23 | 150 |
| | | 1.54 | 250 |
| | | 2.11 | 500 |

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [R θ_{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*

(2) lfm = linear feet per minute

5.11 Thermal Resistance Characteristics for F2809 100-Ball GGM Package

| | | °C/W ⁽¹⁾ | AIR FLOW (lfm) ⁽²⁾ |
|----------------------------------|---|---------------------|-------------------------------|
| R _{θJC} | Junction-to-case thermal resistance | 10.36 | N/A |
| R _{θJB} | Junction-to-board thermal resistance | 13.3 | N/A |
| R _{θJA} (High k PCB) | Junction-to-free air thermal resistance | 28.15 | 0 |
| | | 26.89 | 150 |
| | | 25.68 | 250 |
| | | 24.22 | 500 |
| Psi _{JT} | Junction-to-package top | 0.38 | 0 |
| | | 0.35 | 150 |
| | | 0.33 | 250 |
| | | 0.44 | 500 |

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [R_{θJC}] 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*

(2) lfm = linear feet per minute

5.12 Thermal Resistance Characteristics for F2809 100-Pin PZ Package

| | | °C/W ⁽¹⁾ | AIR FLOW (lfm) ⁽²⁾ |
|----------------------------------|---|---------------------|-------------------------------|
| R _{θJC} | Junction-to-case thermal resistance | 7.06 | N/A |
| R _{θJB} | Junction-to-board thermal resistance | 28.76 | N/A |
| R _{θJA} (High k PCB) | Junction-to-free air thermal resistance | 44.02 | 0 |
| | | 28.34 | 150 |
| | | 36.28 | 250 |
| | | 33.68 | 500 |
| Psi _{JT} | Junction-to-package top | 0.2 | 0 |
| | | 0.56 | 150 |
| | | 0.7 | 250 |
| | | 0.95 | 500 |

(1) These values are based on a JEDEC defined 2S2P system (with the exception of the Theta JC [R_{θJC}] 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*

(2) lfm = linear feet per minute

5.13 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.

5.14 Timing and Switching Characteristics

5.14.1 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) | | |

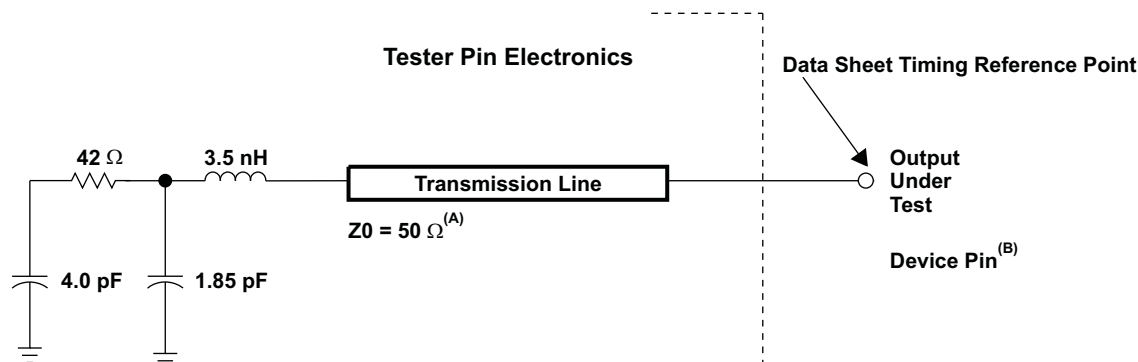
5.14.1.1 General Notes on Timing Parameters

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.

5.14.1.2 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 5-5. 3.3-V Test Load Circuit

5.14.1.3 Device Clock Table

This section provides the timing requirements and switching characteristics for the various clock options available on the 280x DSPs. [Table 5-6](#) and [Table 5-7](#) list the cycle times of various clocks.

Table 5-6. TMS320x280x Clock Table 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 ⁽¹⁾ | $t_{c(CI)}$, 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 ⁽²⁾ | $t_{c(HCO)}$, Cycle time | 10 | 20 ⁽³⁾ | | ns |
| | Frequency | | 50 ⁽³⁾ | 100 | MHz |
| LSPCLK ⁽²⁾ | $t_{c(LCO)}$, Cycle time | 10 | 40 ⁽³⁾ | | ns |
| | Frequency | | 25 ⁽³⁾ | 100 | MHz |
| ADC clock | $t_{c(ADCCLK)}$, Cycle time (All devices except F2809) | 80 | | | ns |
| | Frequency (All devices except F2809) | | | 12.5 | MHz |
| | $t_{c(ADCCLK)}$, Cycle time (F2809) | 40 | | | ns |
| | Frequency (F2809) | | | 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 reset value if SYSCLKOUT = 100 MHz.

Table 5-7. TMS320x280x/2801x Clock Table and Nomenclature (60-MHz Devices)

| | | MIN | NOM | MAX | UNIT |
|--------------------------|------------------------------|--------|---------------------|------|------|
| On-chip oscillator clock | $t_{c(OSC)}$, Cycle time | 28.6 | | 50 | ns |
| | Frequency | 20 | | 35 | MHz |
| XCLKIN ⁽¹⁾ | $t_{c(CI)}$, Cycle time | 16.67 | | 250 | ns |
| | Frequency | 4 | | 60 | MHz |
| SYSCLKOUT | $t_{c(SCO)}$, Cycle time | 16.67 | | 500 | ns |
| | Frequency | 2 | | 60 | MHz |
| XCLKOUT | $t_{c(XCO)}$, Cycle time | 16.67 | | 2000 | ns |
| | Frequency | 0.5 | | 60 | MHz |
| HSPCLK ⁽²⁾ | $t_{c(HCO)}$, Cycle time | 16.67 | 33.3 ⁽³⁾ | | ns |
| | Frequency | | 30 ⁽³⁾ | 60 | MHz |
| LSPCLK ⁽²⁾ | $t_{c(LCO)}$, Cycle time | 16.67 | 66.7 ⁽³⁾ | | ns |
| | Frequency | | 15 ⁽³⁾ | 60 | MHz |
| ADC clock | $t_{c(ADCCLK)}$, Cycle time | 133.33 | | | ns |
| | Frequency | | | 7.5 | 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 reset value if SYSCLKOUT = 60 MHz.

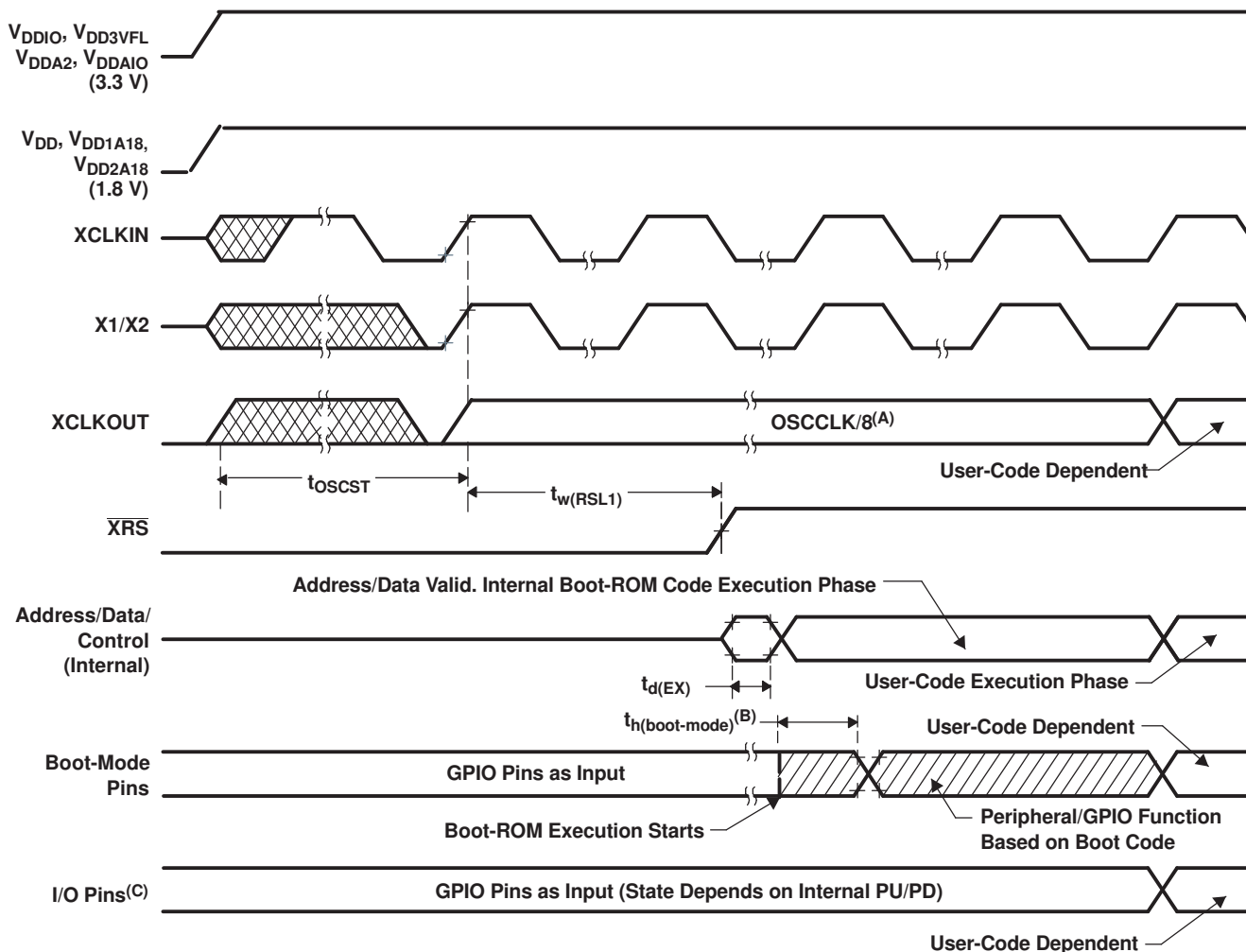
5.14.2 Power Sequencing

No requirements are placed on the power up/down sequence 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 1.8-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} (core voltage) pins prior to or simultaneously with the V_{DDIO} (input/output voltage) 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 5-8](#)). 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 μ s prior to V_{DD} reaching 1.5 V. This is to enhance flash reliability.

No voltage larger than a diode drop (0.7 V) above V_{DDIO} should be applied to any digital pin (for analog pins, it is 0.7 V above V_{DDA}) prior to powering up the device. Voltages applied to pins on an unpowered device can bias internal p-n junctions in unintended ways and produce unpredictable results.



- Upon power up, SYSCLKOUT is OSCCLK/2. Since the XCLKOUTDIV bits in the XCLK register come up with a reset state of 0, SYSCLKOUT is further divided by 4 before it appears at XCLKOUT. This explains why XCLKOUT = 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 5.14.2](#) for requirements to ensure a high-impedance state for GPIO pins during power-up.

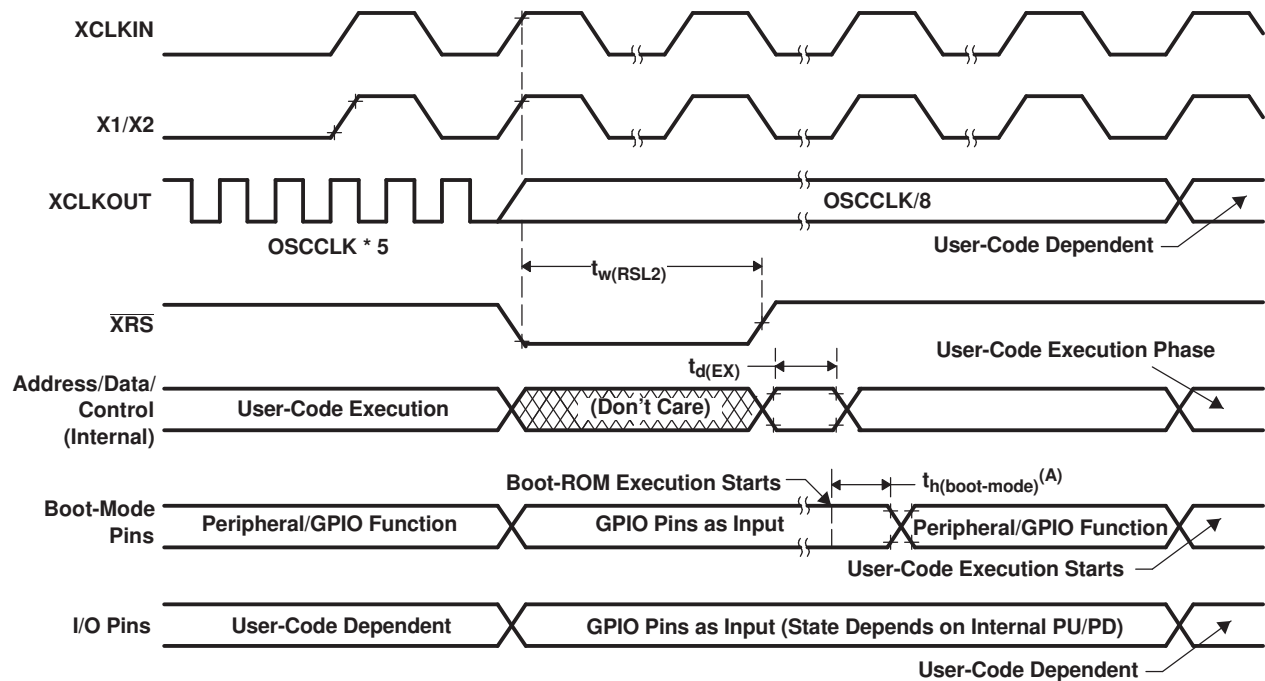
Figure 5-6. Power-on Reset

Table 5-8. Reset ($\overline{\text{XRS}}$) Timing Requirements

| | | | MIN | NOM | MAX | UNIT |
|-------------------------------------|---|------------|---------------------------|---------------------------|-----|--------|
| $t_{w(\text{RSL1})}$ ⁽¹⁾ | Pulse duration, stable XCLKIN to $\overline{\text{XRS}}$ high | | $8t_{c(\text{OSCCLK})}$ | | | cycles |
| $t_{w(\text{RSL2})}$ | Pulse duration, $\overline{\text{XRS}}$ low | Warm reset | $8t_{c(\text{OSCCLK})}$ | | | 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_{OSCST} ⁽²⁾ | 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, $\overline{\text{XRS}}$ has to be low at least for 1 ms after V_{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 5-7. Warm Reset

Figure 5-8 shows an example for the effect of writing into PLLCR register. In the first phase, PLLCR = 0x0004 and $\text{SYSCLKOUT} = \text{OSCCLK} \times 2$. The PLLCR is then written with 0x0008. Right after the PLLCR register is written, the PLL lock-up phase begins. During this phase, $\text{SYSCLKOUT} = \text{OSCCLK}/2$. After the PLL lock-up is complete (which takes 131072 OSCCLK cycles), SYSCLKOUT reflects the new operating frequency, $\text{OSCCLK} \times 4$.

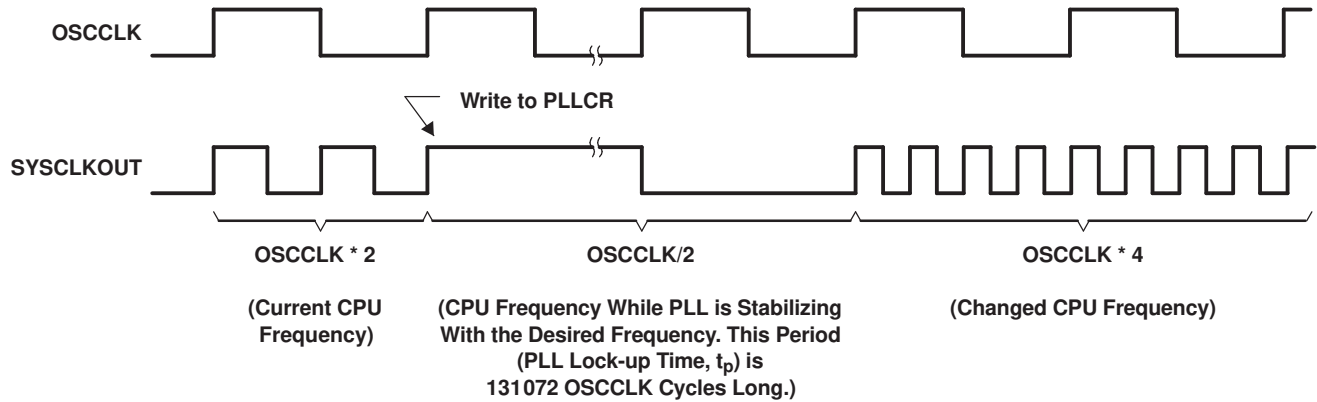


Figure 5-8. Example of Effect of Writing Into PLLCR Register

5.14.3 Clock Requirements and Characteristics

Table 5-9. Input Clock Frequency

| PARAMETER | | | | MIN | TYP | MAX | UNIT |
|----------------|---|---|----------------|-----|-----|-----|------|
| f _x | Input clock frequency | Resonator (X1/X2) | | 20 | | 35 | MHz |
| | | Crystal (X1/X2) | | 20 | | 35 | |
| | | External oscillator/clock source (XCLKIN or X1 pin) | 100-MHz device | 4 | | 100 | |
| | | | 60-MHz device | 4 | | 60 | |
| f _l | Limp mode SYSCLKOUT frequency range (with /2 enabled) | | | 1–5 | | | MHz |

Table 5-10. XCLKIN⁽¹⁾ 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 | | 6 | ns |
| C10 | $t_{r(CI)}$ Rise time, XCLKIN | | 6 | ns |
| C11 | $t_{w(CIL)}$ Pulse duration, XCLKIN low as a percentage of $t_{c(OSCCLK)}$ | 45% | 55% | |
| C12 | $t_{w(CIH)}$ Pulse duration, XCLKIN high as a percentage of $t_{c(OSCCLK)}$ | 45% | 55% | |

(1) This applies to the X1 pin also.

Table 5-11. XCLKIN⁽¹⁾ Timing Requirements - PLL Disabled

| NO. | | | MIN | MAX | UNIT | |
|-----|---------------------|---|-------------------|-------|------|----|
| C8 | t _{c(CI)} | Cycle time, XCLKIN | 100-MHz device | 10 | 250 | ns |
| | | | 60-MHz device | 16.67 | 250 | |
| C9 | t _{f(CI)} | Fall time, XCLKIN | Up to 20 MHz | | 6 | ns |
| | | | 20 MHz to 100 MHz | | 2 | ns |
| C10 | t _{r(CI)} | Rise time, XCLKIN | Up to 20 MHz | | 6 | ns |
| | | | 20 MHz to 100 MHz | | 2 | ns |
| C11 | t _{w(CIL)} | Pulse duration, XCLKIN low as a percentage of t _{c(OSCCLK)} | | 45% | 55% | |
| C12 | t _{w(CIH)} | Pulse duration, XCLKIN high as a percentage of t _{c(OSCCLK)} | | 45% | 55% | |

(1) This applies to the X1 pin also.

The possible configuration modes are shown in [Table 6-33](#).

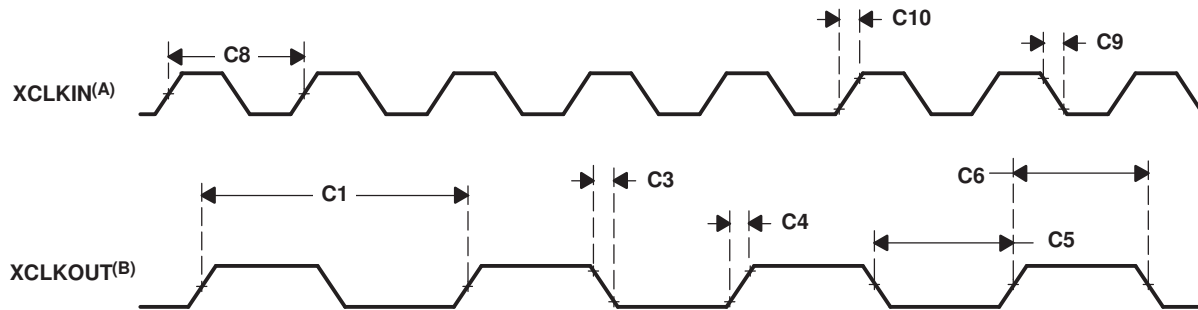
Table 5-12. XCLKOUT Switching Characteristics (PLL Bypassed or Enabled)^{(1) (2)}

| NO. | PARAMETER | | MIN | TYP | MAX | UNIT |
|-----|--|----------------|-------|--------|--------------------------------|--------|
| C1 | $t_{c(XCO)}$ Cycle time, XCLKOUT | 100-MHz device | 10 | | | ns |
| | | 60-MHz device | 16.67 | | | |
| 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 | $t_{c(OSCCLK)}$ ⁽³⁾ | 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 5-9. Clock Timing

5.14.4 Peripherals

5.14.4.1 General-Purpose Input/Output (GPIO)

5.14.4.1.1 GPIO - Output Timing

Table 5-13. 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 |

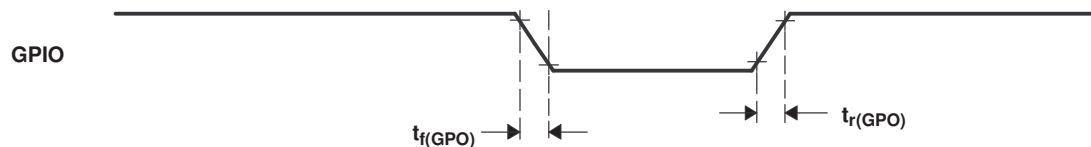


Figure 5-10. General-Purpose Output Timing

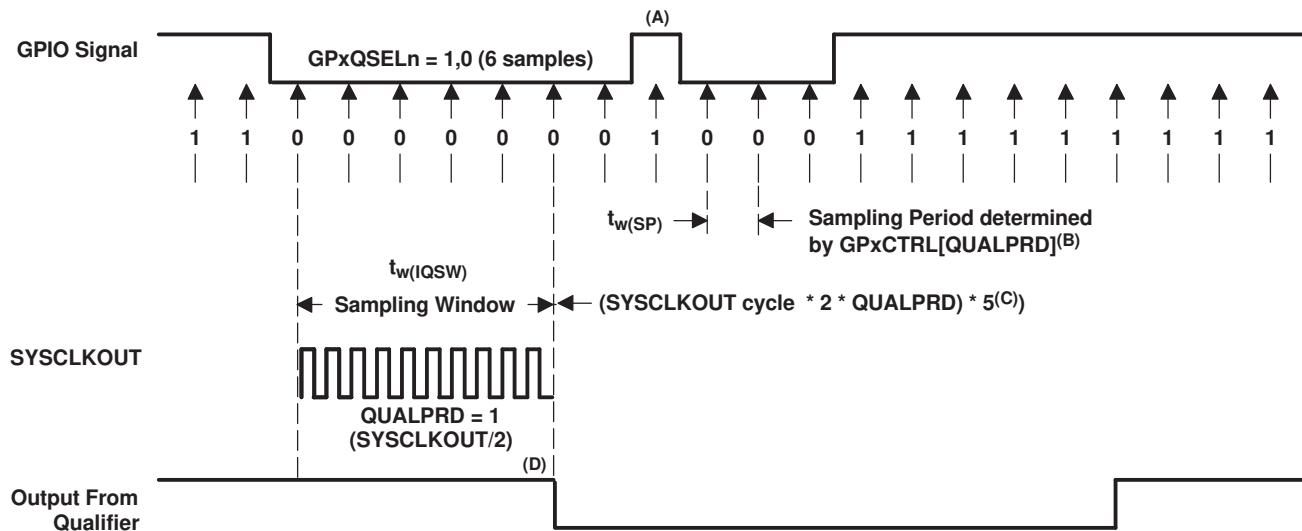
5.14.4.1.2 GPIO - Input Timing

Table 5-14. General-Purpose Input Timing Requirements

| | | | MIN | MAX | UNIT |
|--------------------|---------------------------------|----------------------|---|-----|--------|
| $t_{w(SP)}$ | Sampling period | QUALPRD = 0 | $1t_{c(SCO)}$ | | cycles |
| | | QUALPRD \neq 0 | $2t_{c(SCO)} * \text{QUALPRD}$ | | cycles |
| $t_{w(IQSW)}$ | 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 | $t_{w(IQSW)} + t_{w(SP)} + 1t_{c(SCO)}$ | | cycles |

(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 via 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. Since external signals are driven asynchronously, a 13-SYSCLKOUT-wide pulse ensures reliable recognition.

Figure 5-11. Sampling Mode

5.14.4.1.3 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 = 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 = 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 3 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 6 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 $\text{QUALPRD} = 0$

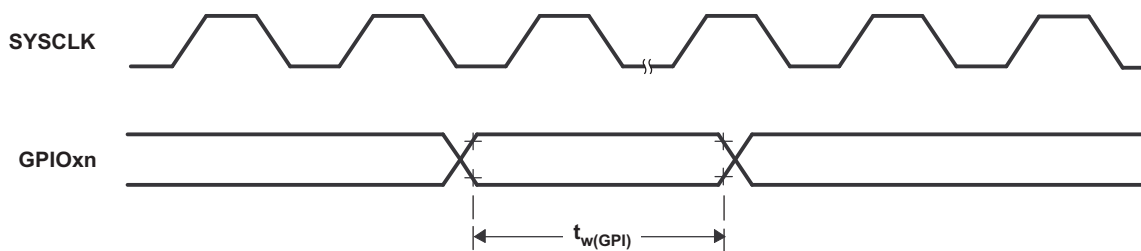


Figure 5-12. General-Purpose Input Timing

NOTE

The pulse-width requirement for general-purpose input is applicable for the XINT2_ADCSOC signal as well.

5.14.4.1.4 Low-Power Mode Wakeup Timing

Table 5-15 shows the timing requirements, Table 5-16 shows the switching characteristics, and Figure 5-13 shows the timing diagram for IDLE mode.

Table 5-15. IDLE Mode Timing Requirements⁽¹⁾

| | | | MIN | MAX | UNIT |
|-------------------|---|-------------------------|-----------------------------|-----|--------|
| $t_{w(WAKE-INT)}$ | Pulse duration, external wake-up signal | Without input qualifier | $2t_{c(SCO)}$ | | cycles |
| | | With input qualifier | $5t_{c(SCO)} + t_{w(IQSW)}$ | | |

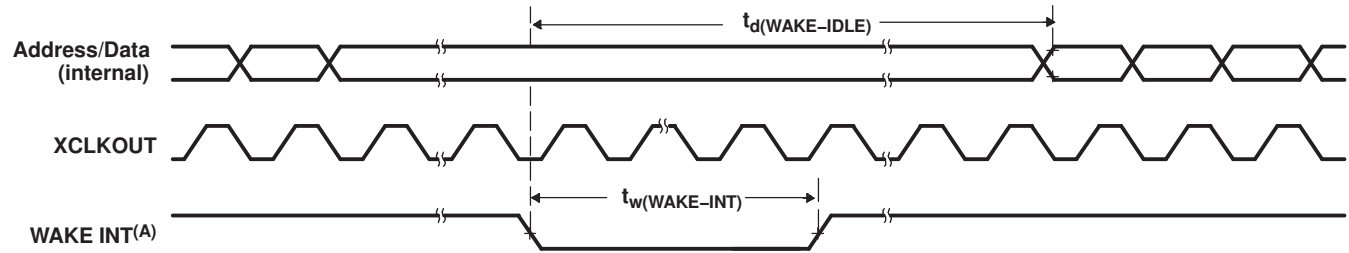
(1) For an explanation of the input qualifier parameters, see Table 5-14.

Table 5-16. IDLE Mode Switching Characteristics⁽¹⁾

| | PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|--------------------|--|-------------------------|-----|--------------------------------|--------|
| $t_{d(WAKE-IDLE)}$ | Delay time, external wake signal to program execution resume ⁽²⁾ | | | | |
| | <ul style="list-style-type: none"> Wake-up from Flash – Flash module in active state | Without input qualifier | | $20t_{c(SCO)}$ | cycles |
| | | With input qualifier | | $20t_{c(SCO)} + t_{w(IQSW)}$ | |
| | <ul style="list-style-type: none"> Wake-up from Flash – Flash module in sleep state | Without input qualifier | | $1050t_{c(SCO)}$ | cycles |
| | | With input qualifier | | $1050t_{c(SCO)} + t_{w(IQSW)}$ | |
| | <ul style="list-style-type: none"> Wake-up from SARAM | Without input qualifier | | $20t_{c(SCO)}$ | cycles |
| | | With input qualifier | | $20t_{c(SCO)} + t_{w(IQSW)}$ | |

(1) For an explanation of the input qualifier parameters, see Table 5-14.

(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} .

Figure 5-13. IDLE Entry and Exit Timing

Table 5-17. STANDBY Mode Timing Requirements

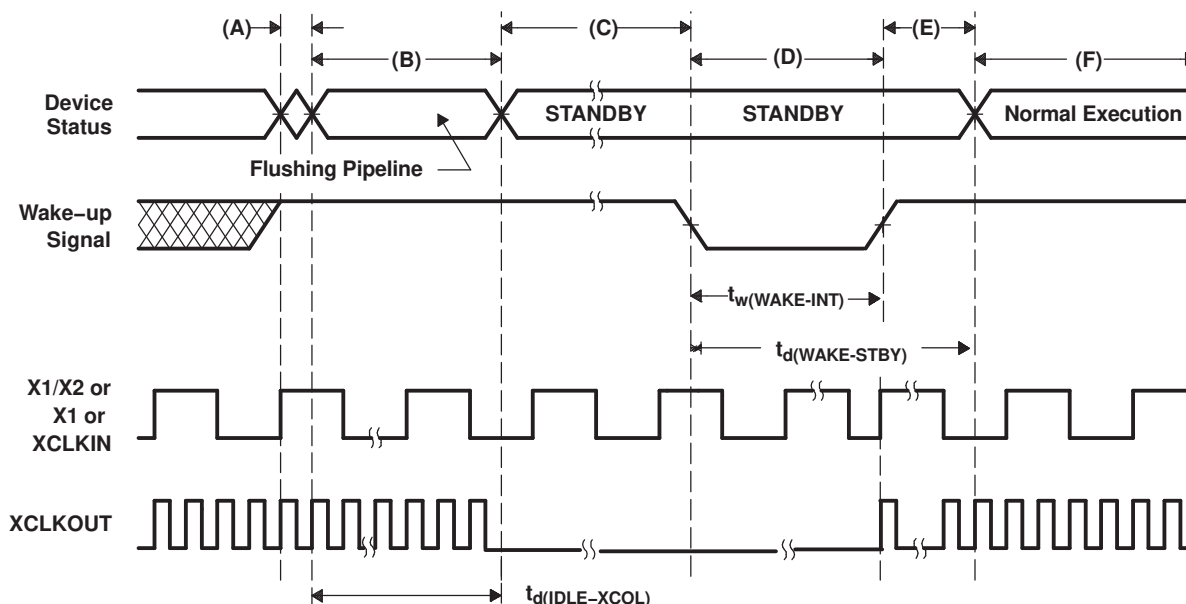
| | | TEST CONDITIONS | MIN | MAX | UNIT |
|-------------------|---|---|-----|-----------------------------------|--------|
| $t_{w(WAKE-INT)}$ | Pulse duration, external wake-up signal | Without input qualification | | $3t_{c(OSCCLK)}$ | cycles |
| | | With input qualification ⁽¹⁾ | | $(2 + QUALSTDBY) * t_{c(OSCCLK)}$ | |

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

Table 5-18. STANDBY Mode Switching Characteristics

| PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|--------------------|--|-------------------------|------------------------------------|--------|
| $t_{d(IDLE-XCOL)}$ | Delay time, IDLE instruction executed to XCLKOUT low | $32t_{c(SCO)}$ | $45t_{c(SCO)}$ | cycles |
| $t_{d(WAKE-STBY)}$ | Delay time, external wake signal to program execution resume ⁽¹⁾ | | | |
| | <ul style="list-style-type: none"> Wake up from flash – Flash module in active state | Without input qualifier | $100t_{c(SCO)}$ | cycles |
| | | With input qualifier | $100t_{c(SCO)} + t_{w(WAKE-INT)}$ | |
| | <ul style="list-style-type: none"> Wake up from flash – Flash module in sleep state | Without input qualifier | $1125t_{c(SCO)}$ | cycles |
| | | With input qualifier | $1125t_{c(SCO)} + t_{w(WAKE-INT)}$ | |
| | <ul style="list-style-type: none"> Wake up from SARAM | Without input qualifier | $100t_{c(SCO)}$ | cycles |
| | | With input qualifier | $100t_{c(SCO)} + t_{w(WAKE-INT)}$ | |

(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.



- IDLE instruction is executed to put the device into STANDBY mode.
- The PLL block responds to the STANDBY signal. SYSCLKOUT is held for approximately 32 cycles (if CLKINDIV = 0) or 64 cycles (if CLKINDIV = 1) before being turned off. This delay enables the CPU pipe and any other pending operations to flush properly.
- Clock to the peripherals are turned off. However, the PLL and watchdog are not shut down. The device is now in STANDBY mode.
- The external wake-up signal is driven active.
- After a latency period, the STANDBY mode is exited.
- Normal execution resumes. The device will respond to the interrupt (if enabled).

Figure 5-14. STANDBY Entry and Exit Timing Diagram

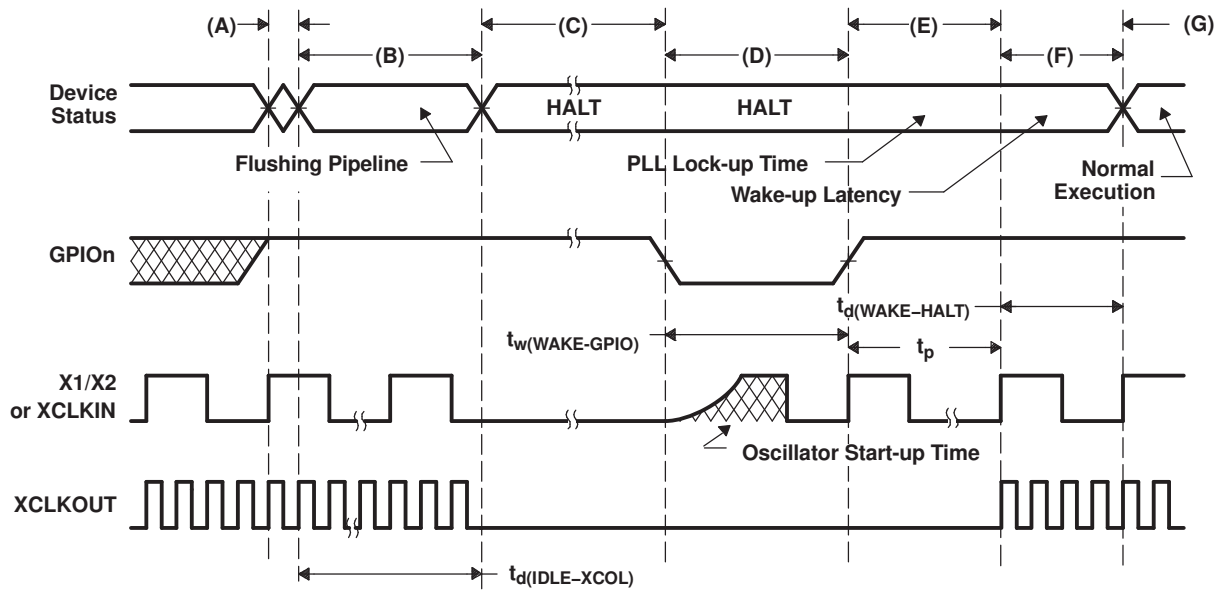
Table 5-19. HALT Mode Timing Requirements

| | | 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 5-8 for an explanation of t_{oscst} .

Table 5-20. 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 | | | |
| | • Wake up from flash – Flash module in sleep state | | $1125t_{c(SCO)}$ | cycles |
| $t_{d(WAKE-HALT)}$ | • Wake up from SARAM | | $35t_{c(SCO)}$ | cycles |



- IDLE instruction is executed to put the device into HALT mode.
- The PLL block responds to the HALT signal. SYSCLKOUT is held for approximately 32 cycles (if CLKINDIV = 0) or 64 cycles (if CLKINDIV = 1) before the oscillator is turned off and the CLKIN to the core is stopped. This delay enables the CPU pipe and any other pending operations to flush properly.
- 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.
- When the GPIO 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. Since 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.
- 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).
- 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.
- Normal operation resumes.

Figure 5-15. HALT Wake-Up Using GPIO

5.14.4.2 Enhanced Control Peripherals

5.14.4.2.1 Enhanced Pulse Width Modulator (ePWM) Timing

PWM refers to PWM outputs on ePWM1–6. Table 5-21 shows the PWM timing requirements and Table 5-22, switching characteristics.

Table 5-21. ePWM Timing Requirements⁽¹⁾

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

(1) For an explanation of the input qualifier parameters, see Table 5-14.

Table 5-22. 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 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 |

5.14.4.2.2 Trip-Zone Input Timing

Table 5-23. Trip-Zone input Timing Requirements⁽¹⁾

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

(1) For an explanation of the input qualifier parameters, see Table 5-14.

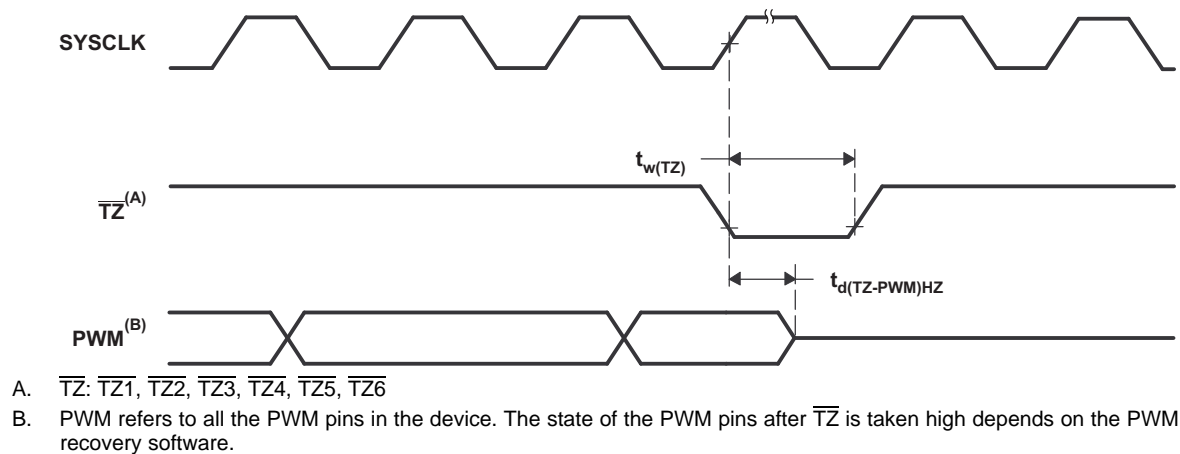


Figure 5-16. PWM Hi-Z Characteristics

5.14.4.2.3 High-Resolution PWM Timing

Table 5-24 shows the high-resolution PWM switching characteristics.

Table 5-24. High-Resolution PWM Characteristics at SYSCLKOUT = 60–100 MHz

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

- (1) The MEP step size will be largest at high temperature and minimum voltage on V_{DD}. 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.

5.14.4.2.4 Enhanced Capture (eCAP) Timing

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

Table 5-25. Enhanced Capture (eCAP) Timing Requirement⁽¹⁾

| | TEST CONDITIONS | 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 5-14.

Table 5-26. eCAP Switching Characteristics

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

5.14.4.2.5 Enhanced Quadrature Encoder Pulse (eQEP) Timing

Table 5-27 shows the eQEP timing requirement and Table 5-28 shows the eQEP switching characteristics.

Table 5-27. Enhanced Quadrature Encoder Pulse (eQEP) Timing Requirements⁽¹⁾

| | TEST CONDITIONS | MIN | MAX | UNIT |
|---|--|--------------------------------|-----|--------|
| $t_{w(QEPP)}$ QEP input period | Asynchronous ⁽²⁾ /synchronous | $2t_{c(SCO)}$ | | cycles |
| | With input qualifier | $2[1t_{c(SCO)} + t_{w(IQSW)}]$ | | |
| $t_{w(INDEXH)}$ QEP Index Input High time | Asynchronous ⁽²⁾ /synchronous | $2t_{c(SCO)}$ | | cycles |
| | With input qualifier | $2t_{c(SCO)} + t_{w(IQSW)}$ | | |
| $t_{w(INDEXL)}$ QEP Index Input Low time | Asynchronous ⁽²⁾ /synchronous | $2t_{c(SCO)}$ | | cycles |
| | With input qualifier | $2t_{c(SCO)} + t_{w(IQSW)}$ | | |
| $t_{w(STROBH)}$ QEP Strobe High time | Asynchronous ⁽²⁾ /synchronous | $2t_{c(SCO)}$ | | cycles |
| | With input qualifier | $2t_{c(SCO)} + t_{w(IQSW)}$ | | |
| $t_{w(STROBL)}$ QEP Strobe Input Low time | Asynchronous ⁽²⁾ /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 5-14.
(2) Refer to the [TMS320F280x](#), [TMS320C280x](#), [TMS320F2801x DSPs silicon errata](#) for limitations in the asynchronous mode.

Table 5-28. 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 |

5.14.4.2.6 ADC Start-of-Conversion Timing

Table 5-29. External ADC Start-of-Conversion Switching Characteristics

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

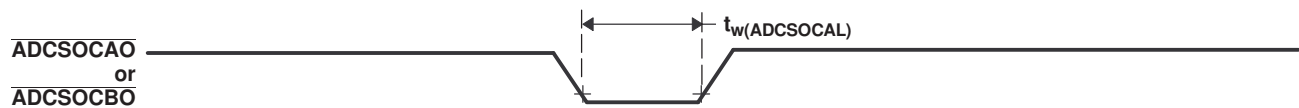


Figure 5-17. ADCSOCAL or ADCSOCBO Timing

5.14.4.3 External Interrupt Timing

Table 5-30. External Interrupt Timing Requirements⁽¹⁾

| | | MIN | MAX | UNIT |
|--|----------------|-----------------------------|-----|--------|
| $t_{w(INT)}$ ⁽²⁾ 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 5-14](#).

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

Table 5-31. External Interrupt Switching Characteristics⁽¹⁾

| 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 5-14](#).

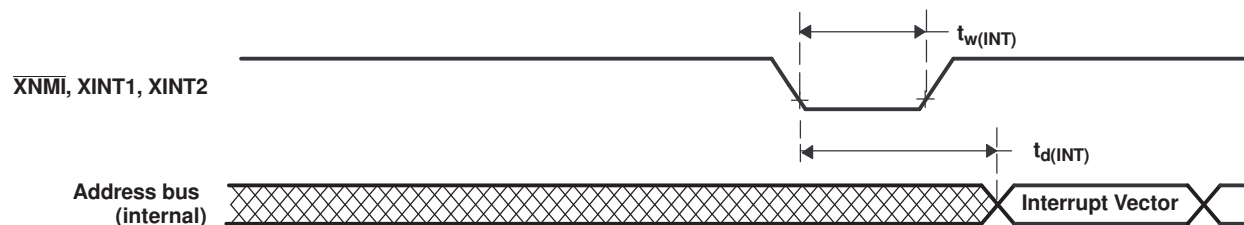


Figure 5-18. External Interrupt Timing

5.14.4.4 I2C Electrical Specification and Timing

Table 5-32. 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 | | μs |
| 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 | | μs |
| I_I | Input current with an input voltage between $0.1 V_{DDIO}$ and $0.9 V_{DDIO}$ MAX | | –10 | 10 | μA |

5.14.4.5 Serial Peripheral Interface (SPI) Timing

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

5.14.4.5.1 SPI Master Mode Timing

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

Table 5-33. SPI Master Mode External Timing (Clock Phase = 0)⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾

| 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).

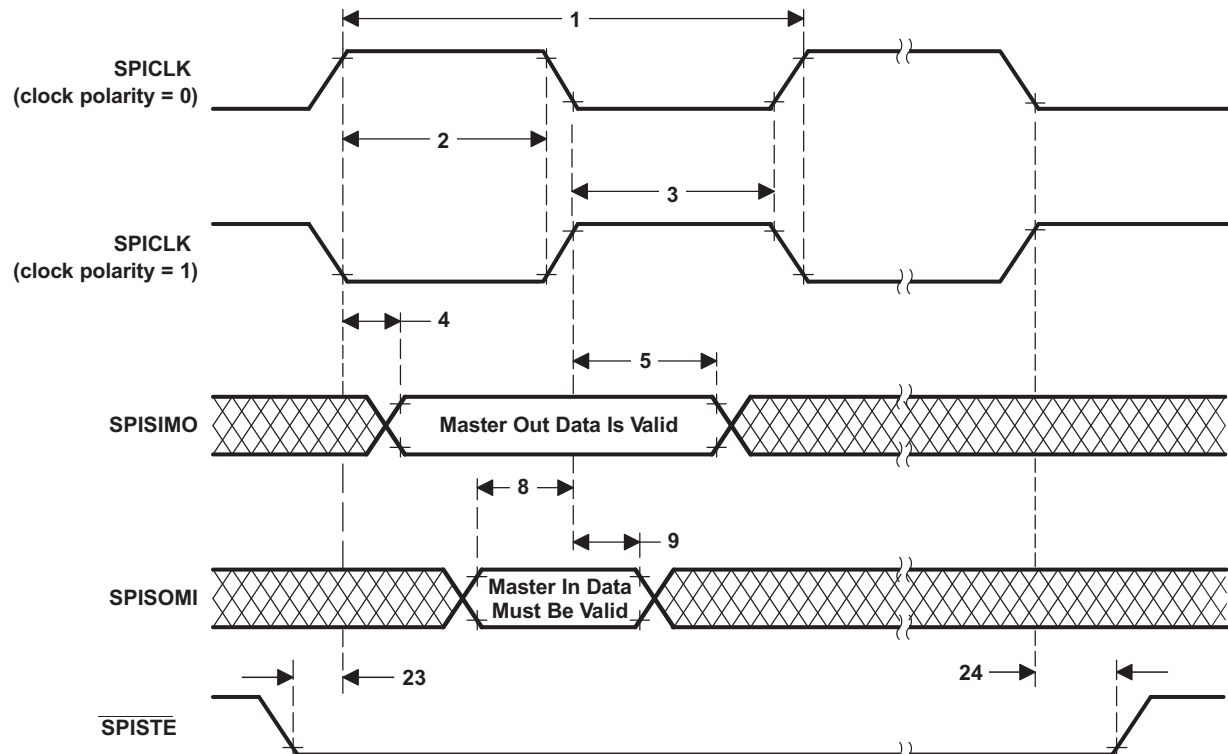


Figure 5-19. SPI Master Mode External Timing (Clock Phase = 0)

Table 5-34. SPI Master Mode External Timing (Clock Phase = 1)⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾

| 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).

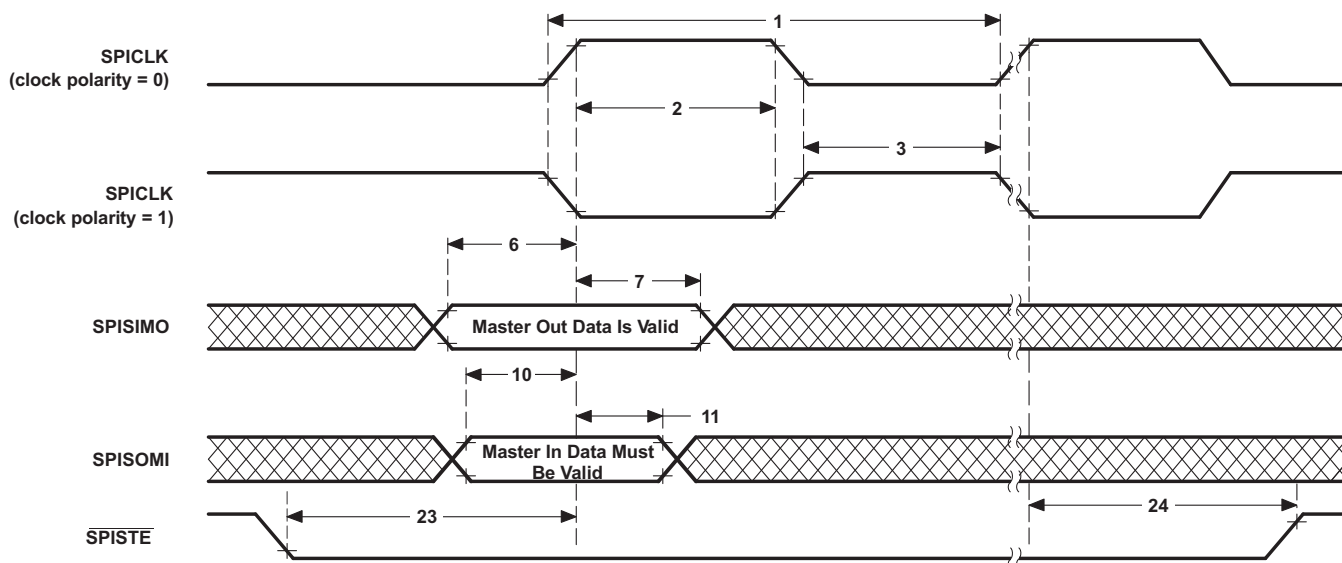


Figure 5-20. SPI Master Mode External Timing (Clock Phase = 1)

5.14.4.5.2 SPI Slave Mode Timing

Table 5-35 lists the slave mode timing (clock phase = 0) and Table 5-36 lists the slave mode timing (clock phase = 1). Figure 5-21 and Figure 5-22 show the timing waveforms.

Table 5-35. SPI Slave Mode External Timing (Clock Phase = 0)⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾

| 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).

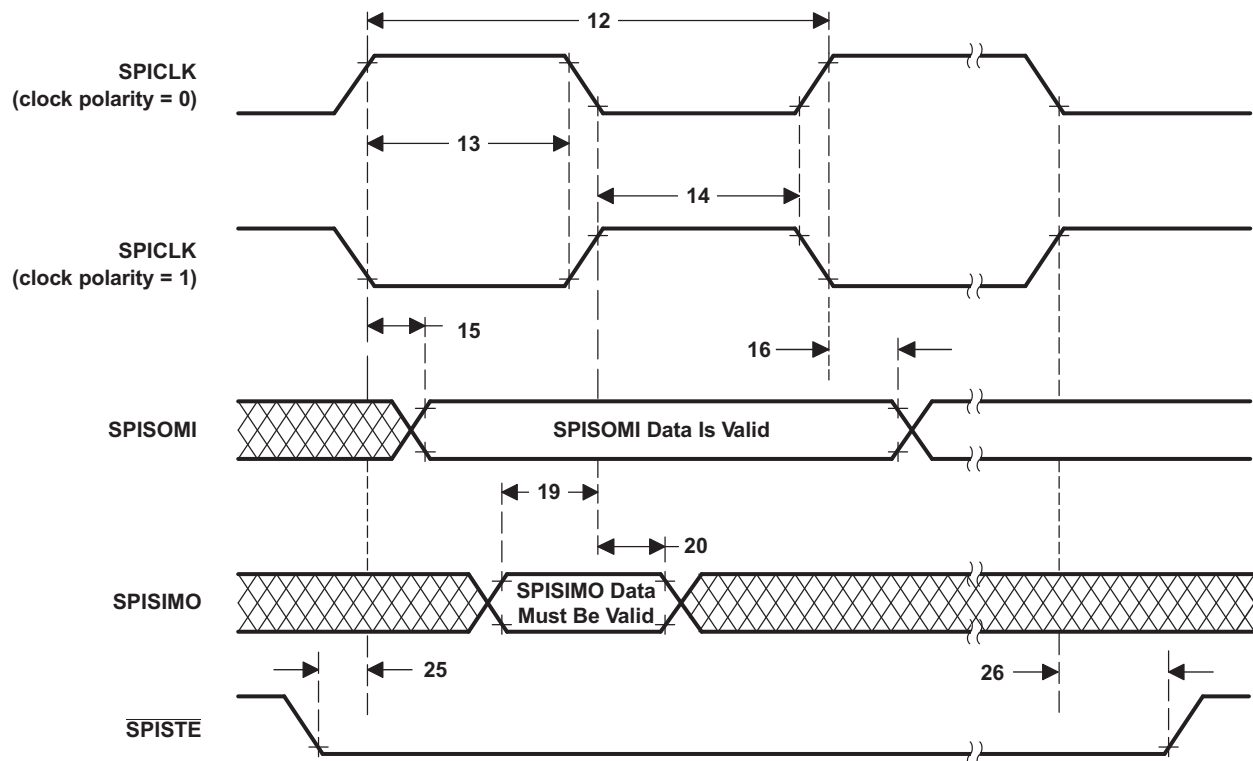


Figure 5-21. SPI Slave Mode External Timing (Clock Phase = 0)

Table 5-36. SPI Slave Mode External Timing (Clock Phase = 1)⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾

| NO. | PARAMETER | MIN | MAX | UNIT |
|-----|---|---------------------|-----|------|
| 12 | $t_{c(SPC)}S$ Cycle time, SPICLK | $4t_{c(SYSC)}S$ | | ns |
| 13 | $t_{w(SPC1)}S$ Pulse duration, SPICLK first pulse | $2t_{c(SYSC)}S - 1$ | | ns |
| 14 | $t_{w(SPC2)}S$ Pulse duration, SPICLK second pulse | $2t_{c(SYSC)}S - 1$ | | 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 | $1.5t_{c(SYSC)}S$ | | ns |
| 22 | $t_{h(SIMO)}S$ Hold time, SPISIMO data valid after SPICLK | $1.5t_{c(SYSC)}S$ | | ns |
| 25 | $t_{su(STE)}S$ Setup time, \overline{SPISTE} active before SPICLK | $1.5t_{c(SYSC)}S$ | | ns |
| 26 | $t_{h(STE)}S$ Hold time, \overline{SPISTE} inactive after SPICLK | $1.5t_{c(SYSC)}S$ | | 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 is controlled by the CLOCK POLARITY bit (SPICCR.6).

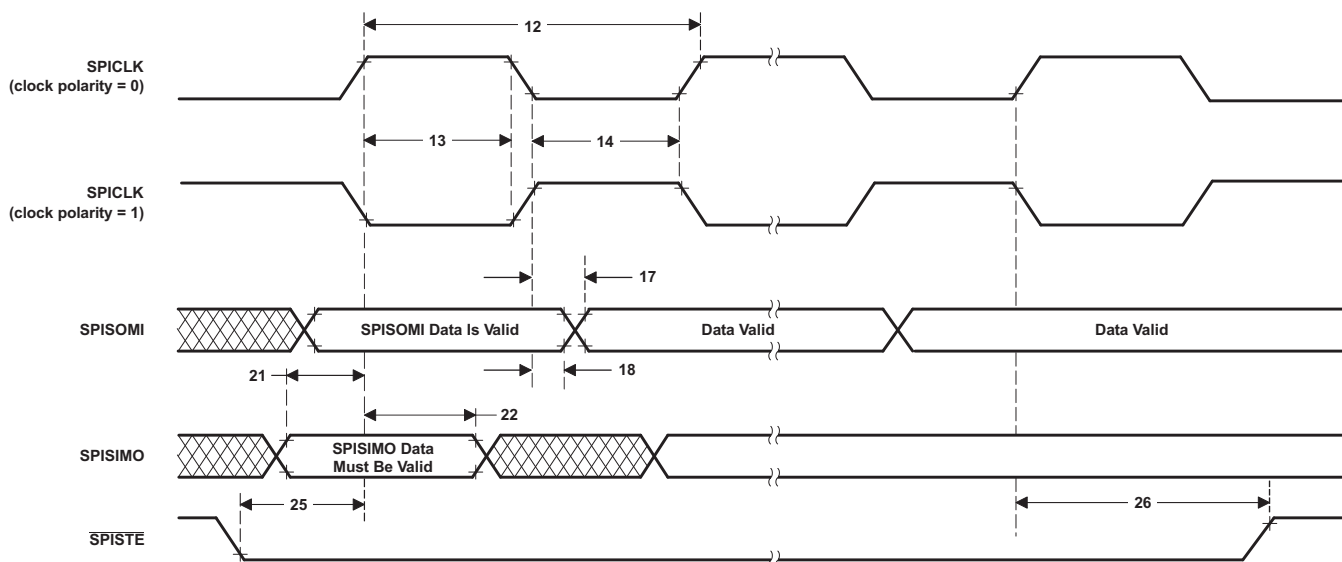


Figure 5-22. SPI Slave Mode External Timing (Clock Phase = 1)

5.14.5 Emulator Connection Without Signal Buffering for the DSP

Figure 5-23 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 5-23 shows the simpler, no-buffering situation. For the pullup/pulldown resistor values, see Section 4.2.

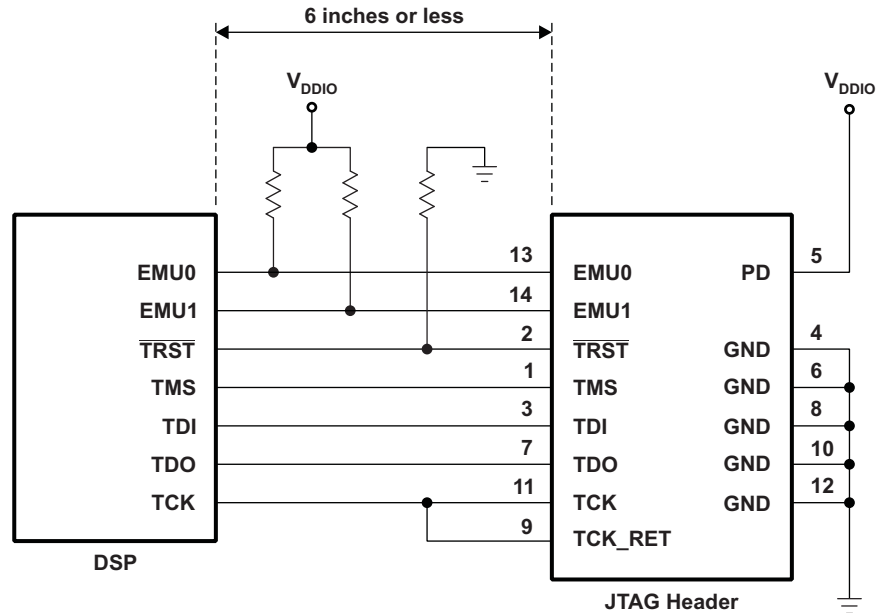


Figure 5-23. Emulator Connection Without Signal Buffering for the DSP

5.14.6 Flash Timing

Table 5-37. Flash Endurance for A and S Temperature Material⁽¹⁾

| | | ERASE/PROGRAM TEMPERATURE | MIN | TYP | MAX | UNIT |
|------------------|--|------------------------------|-------|-------|-----|--------|
| N _f | Flash endurance for the array (write/erase cycles) | 0°C to 85°C (ambient) | 20000 | 50000 | | cycles |
| N _{OTP} | 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 5-38. Flash Endurance for Q Temperature Material⁽¹⁾

| | | ERASE/PROGRAM TEMPERATURE | MIN | TYP | MAX | UNIT |
|------------------|--|------------------------------|-------|-------|-----|--------|
| N _f | Flash endurance for the array (write/erase cycles) | –40°C to 125°C (ambient) | 20000 | 50000 | | cycles |
| N _{OTP} | 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 5-39. Flash Parameters at 100-MHz SYSCLKOUT

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------------------|--|-----------------|-----|-----|---------------------|------|
| Program Time ⁽¹⁾ | 16-Bit Word | | | 50 | | μs |
| | 16K Sector | | | 500 | 2000 ⁽²⁾ | ms |
| | 8K Sector | | | 250 | 2000 ⁽²⁾ | ms |
| | 4K Sector | | | 125 | 2000 ⁽²⁾ | ms |
| Erase Time ⁽³⁾ | 16K Sector | | | 2 | 15 ⁽²⁾ | s |
| | 8K Sector | | | 2 | 15 ⁽²⁾ | s |
| | 4K Sector | | | 2 | 15 ⁽²⁾ | s |
| I _{DD3VFLP} ⁽⁴⁾ | V _{DD3VFL} current consumption during the Erase/Program cycle | Erase | | 75 | | mA |
| | | Program | | 35 | | mA |
| I _{DDP} ⁽⁴⁾ | V _{DD} current consumption during Erase/Program cycle | | | 140 | | mA |
| I _{DDIOP} ⁽⁴⁾ | V _{DDIO} 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) The parameters mentioned in the MAX column are for the first 100 Erase/Program 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 before 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_{MIN} on the supply rails at all times, as specified in the Recommended Operating Conditions of the data sheet. Any brownout 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 5-40. Flash/OTP Access Timing

| PARAMETER | | MIN | MAX | UNIT |
|---------------------|--------------------------|-----|-----|------|
| t _{a(fp)} | Paged flash access time | 36 | | ns |
| t _{a(fr)} | Random flash access time | 36 | | ns |
| t _{a(OTP)} | OTP access time | 60 | | ns |

Table 5-41. 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 5-42. Minimum Required Flash/OTP Wait-States at Different Frequencies

| SYSCLKOUT (MHz) | SYSCLKOUT (ns) | FLASH PAGE WAIT-STATE | FLASH RANDOM WAIT-STATE ⁽¹⁾ | OTP WAIT-STATE |
|-----------------|----------------|-----------------------|--|----------------|
| 100 | 10 | 3 | 3 | 5 |
| 75 | 13.33 | 2 | 2 | 4 |
| 60 | 16.67 | 2 | 2 | 3 |
| 50 | 20 | 1 | 1 | 2 |
| 30 | 33.33 | 1 | 1 | 1 |
| 25 | 40 | 0 | 1 | 1 |
| 15 | 66.67 | 0 | 1 | 1 |
| 4 | 250 | 0 | 1 | 1 |

(1) Random wait-state must be greater than or equal to 1.

Equations to compute the Flash page wait-state and random wait-state in [Table 5-42](#) are as follows:

$$\text{Flash Page Wait-State} = \left\lceil \left(\frac{t_{a(fp)}}{t_{c(SCO)}} \right) - 1 \right\rceil \text{ (round up to the next highest integer) or 0, whichever is larger}$$

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

Equation to compute the OTP wait-state in [Table 5-42](#) is as follows:

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

5.15 On-Chip Analog-to-Digital Converter

Table 5-43. ADC Electrical Characteristics⁽¹⁾⁽²⁾

over recommended operating conditions

| PARAMETER | | MIN | TYP | MAX | UNIT |
|--|-----------------------------------|-------|-------|------|--------|
| DC SPECIFICATIONS | | | | | |
| Resolution | | 12 | | | Bits |
| ADC clock | 60-MHz device | 0.001 | | 7.5 | MHz |
| | 100-MHz device | 0.001 | | 12.5 | |
| | 100-MHz device (F2809 only) | 0.001 | | 25 | |
| ACCURACY | | | | | |
| 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 | |
| DNL (Differential nonlinearity) ⁽³⁾ | | | | ±1 | LSB |
| Offset error ⁽⁴⁾ | | –60 | | +60 | LSB |
| Offset error with hardware trimming | | | ±4 | | LSB |
| Overall gain error with internal reference ⁽⁵⁾ | | –60 | | +60 | LSB |
| Overall gain error with external reference | | –60 | | +60 | LSB |
| Channel-to-channel offset variation | | | ±4 | | LSB |
| Channel-to-channel gain variation | | | ±4 | | LSB |
| ANALOG INPUT | | | | | |
| Analog input voltage (ADCINx to ADCLO) ⁽⁶⁾ | | 0 | | 3 | V |
| ADCLO | | –5 | 0 | 5 | mV |
| Input capacitance | | | 10 | | pF |
| Input leakage current | | | | ±5 | μA |
| INTERNAL VOLTAGE REFERENCE ⁽⁵⁾ | | | | | |
| V _{ADCREFP} - ADCREFP output voltage at the pin based on internal reference | | | 1.275 | | V |
| V _{ADCREFM} - 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 |
| EXTERNAL VOLTAGE REFERENCE ^{(5) (7)} | | | | | |
| V _{ADCREFIN} - 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 |
| AC SPECIFICATIONS | | | | | |
| 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 12.5 MHz ADCCLK.

(2) All voltages listed in this table are with respect to V_{SSA2}.

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

(4) 1 LSB has the weighted value of 3.0/4096 = 0.732 mV.

(5) 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.

(6) Voltages above V_{DDA} + 0.3 V or below V_{SS} - 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.

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

5.15.1 ADC Power-Up Control Bit Timing

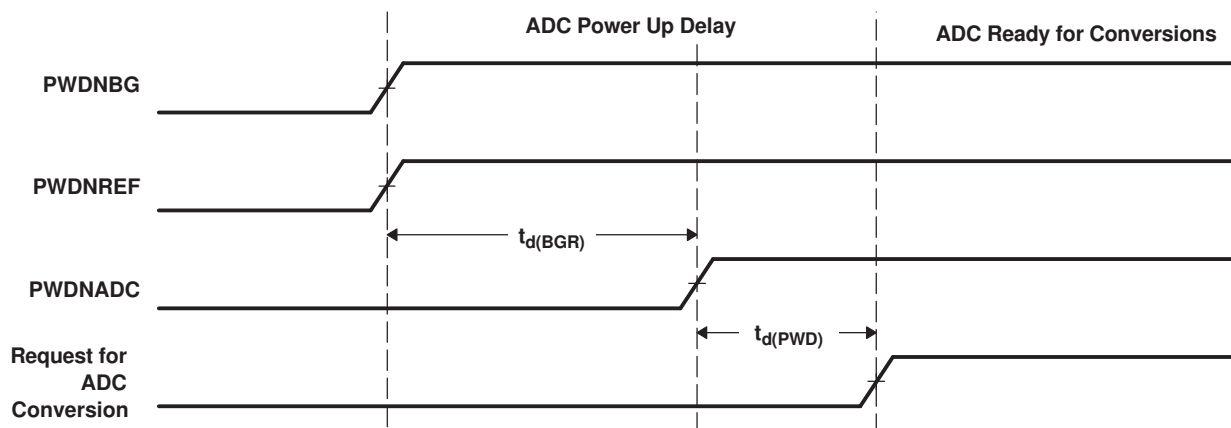


Figure 5-24. ADC Power-Up Control Bit Timing

Table 5-44. ADC Power-Up Delays

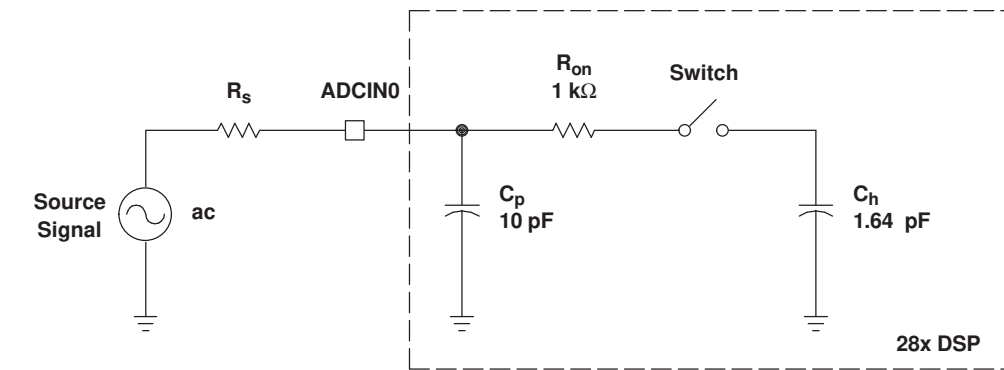
| PARAMETER ⁽¹⁾ | | MIN | TYP | MAX | UNIT |
|--------------------------|--|-----|-----|-----|---------|
| $t_{d(BGR)}$ | Delay time for band gap reference to be stable. Bits 7 and 6 of the ADCTRL3 register (ADCBGRFDN1/0) must be set to 1 before the PWDNADC bit is enabled. | | | 5 | ms |
| $t_{d(PWD)}$ | 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 | | μ s |
| | | | | 1 | ms |

- (1) Timings maintain compatibility to the 281x ADC module. The 280x ADC also supports driving all 3 bits at the same time and waiting $t_{d(BGR)}$ ms before first conversion.

Table 5-45. Current Consumption for Different ADC Configurations (at 12.5-MHz ADCCLK)⁽¹⁾ ⁽²⁾

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

- (1) Test Conditions:
 SYSCLKOUT = 100 MHz
 ADC module clock = 12.5 MHz
 ADC performing a continuous conversion of all 16 channels in Mode A
- (2) V_{DDA18} includes current into V_{DD1A18} and V_{DD2A18}. V_{DDA3.3} includes current into V_{DDA2} and V_{DDAIO}.



Typical Values of the Input Circuit Components:

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

Figure 5-25. ADC Analog Input Impedance Model

5.15.2 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)

5.15.3 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).

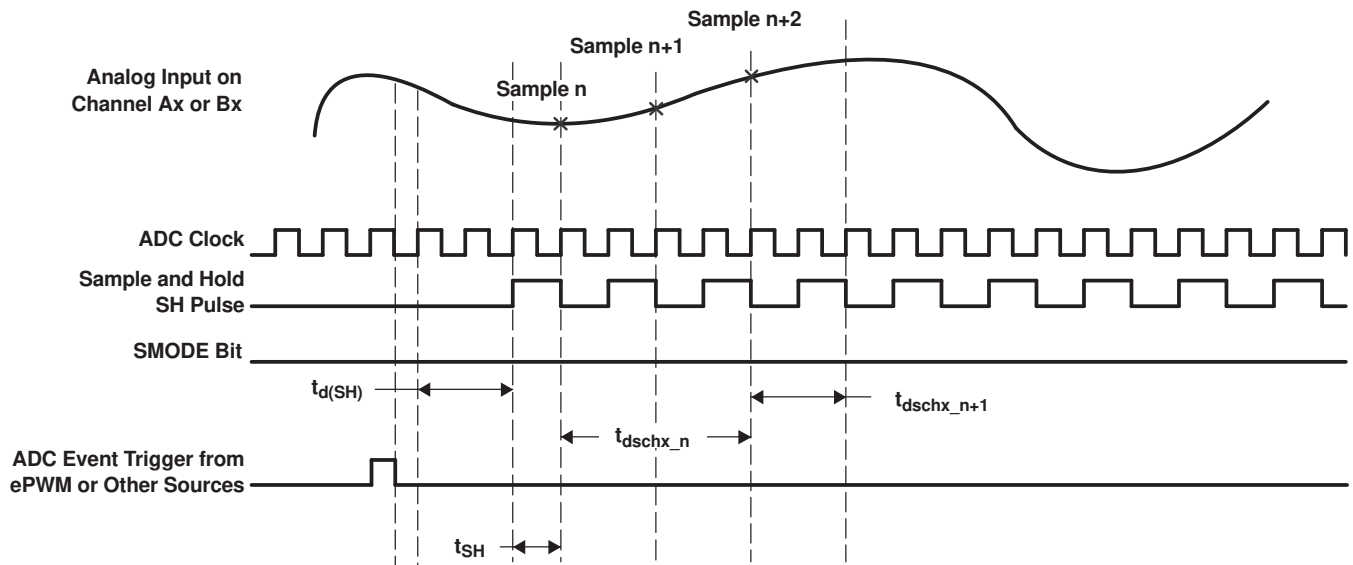


Figure 5-26. Sequential Sampling Mode (Single-Channel) Timing

Table 5-46. Sequential Sampling Mode Timing

| | | SAMPLE n | SAMPLE n + 1 | AT 12.5 MHz ADC CLOCK, $t_{c(ADCCLK)} = 80 \text{ ns}$ | REMARKS |
|--------------------|--|--------------------------------------|--------------------------------------|--|-------------------------------------|
| $t_{d(SH)}$ | Delay time from event trigger to sampling | $2.5t_{c(ADCCLK)}$ | | | |
| t_{SH} | Sample/Hold width/Acquisition Width | $(1 + \text{Acqps}) * t_{c(ADCCLK)}$ | | 80 ns with Acqps = 0 | Acqps value = 0–15 ADCTRL1[8:11] |
| $t_{d(schx_n)}$ | Delay time for first result to appear in Result register | $4t_{c(ADCCLK)}$ | | 320 ns | |
| $t_{d(schx_n+1)}$ | Delay time for successive results to appear in Result register | | $(2 + \text{Acqps}) * t_{c(ADCCLK)}$ | 160 ns | |

5.15.4 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 has to be A0/B0, A1/B1, ..., A7/B7, and not in other combinations (such as A1/B3, and so forth).

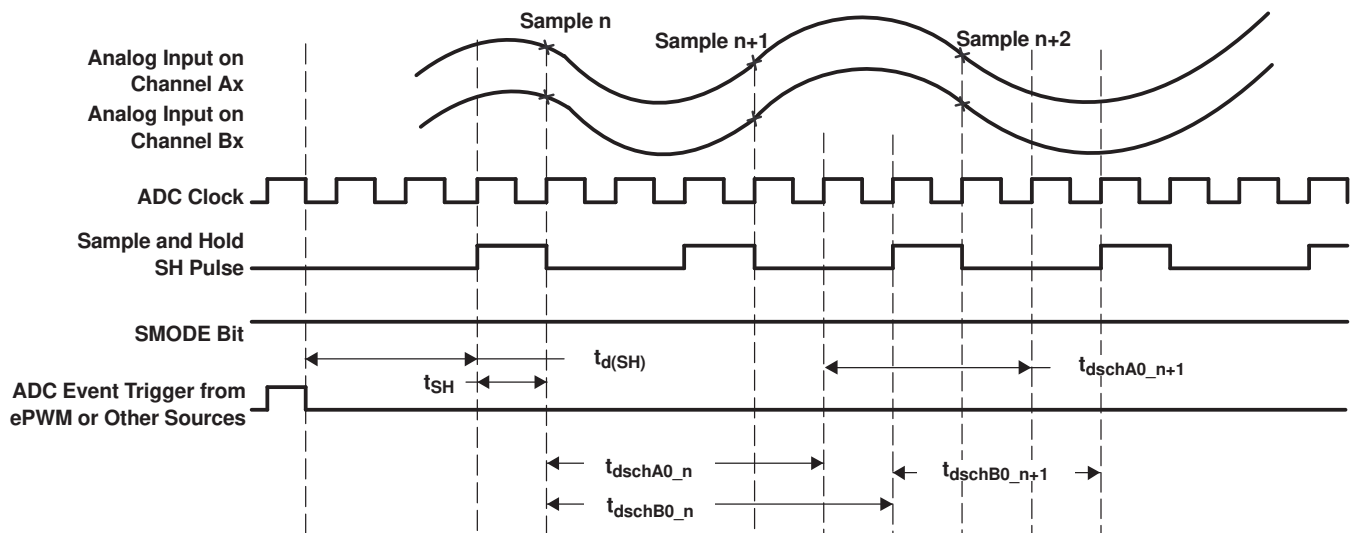


Figure 5-27. Simultaneous Sampling Mode Timing

Table 5-47. Simultaneous Sampling Mode Timing

| | | SAMPLE n | SAMPLE n + 1 | AT 12.5 MHz ADC CLOCK, $t_c(ADCCCLK) = 80 \text{ ns}$ | REMARKS |
|---------------------|--|-------------------------------------|-------------------------------------|---|-------------------------------------|
| $t_{d(SH)}$ | Delay time from event trigger to sampling | $2.5t_c(ADCCCLK)$ | | | |
| t_{SH} | Sample/Hold width/Acquisition Width | $(1 + \text{Acqps}) * t_c(ADCCCLK)$ | | 80 ns with Acqps = 0 | Acqps value = 0–15 ADCTRL1[8:11] |
| $t_{d(schA0_n)}$ | Delay time for first result to appear in Result register | $4t_c(ADCCCLK)$ | | 320 ns | |
| $t_{d(schB0_n)}$ | Delay time for first result to appear in Result register | $5t_c(ADCCCLK)$ | | 400 ns | |
| $t_{d(schA0_n+1)}$ | Delay time for successive results to appear in Result register | | $(3 + \text{Acqps}) * t_c(ADCCCLK)$ | 240 ns | |
| $t_{d(schB0_n+1)}$ | Delay time for successive results to appear in Result register | | $(3 + \text{Acqps}) * t_c(ADCCCLK)$ | 240 ns | |

5.15.5 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 ± 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.

5.16 Migrating From F280x Devices to C280x Devices

5.16.1 Migration Issues

The migration issues to be considered while migrating from the F280x devices to C280x devices are as follows:

- The 1K OTP memory available in F280x devices has been replaced by 1K ROM C280x devices.
- Current consumption differs for F280x and C280x devices for all four possible modes. See the appropriate electrical section for exact numbers.
- The V_{DD3VFL} pin is the 3.3-V Flash core power pin in F280x devices but is a V_{DDIO} pin in C280x devices.
- F280x and C280x devices are pin-compatible and code-compatible; however, they are electrically different with different EMI/ESD profiles. Before ramping production with C280x devices, evaluate performance of the hardware design with both devices.
- Addresses 0x3D 7BFC through 0x3D 7BFF in the OTP and addresses 0x3F 7FF0 through 0x3F 7FF5 in the main ROM array are reserved for ROM part-specific information and are not available for user applications.
- The paged and random wait-state specifications for the Flash and ROM parts are different. While migrating from Flash to ROM parts, the same wait-state values must be used for best-performance compatibility (for example, in applications that use software delay loops or where precise interrupt latencies are critical).
- The analog input switch resistance is smaller in C280x devices compared to F280x devices. While migrating from a Flash to a ROM device care should be taken to design the analog input circuits to meet the application performance required by the sampling network.
- The PART-ID register value is different for Flash and ROM parts.
- From a silicon functionality/errata standpoint, rev A ROM devices are equivalent to rev C flash devices. See the errata applicable to 280x devices for details.
- As part of the ROM code generation process, all unused memory locations in the customer application are automatically filled with 0xFFFF. Unused locations should not be manually filled with any other data.

NOTE

Requests for ROM versions of the F280x device are not accepted by TI anymore.

For errata applicable to 280x devices, see the [TMS320F280x](#), [TMS320C280x](#), [TMS320F2801x DSPs silicon errata](#).

5.17 ROM Timing (C280x only)

Table 5-48. ROM/OTP Access Timing

| PARAMETER | | MIN | MAX | UNIT |
|--------------|---|-----|-----|------|
| $t_{a(rp)}$ | Paged ROM access time | 19 | | ns |
| $t_{a(rr)}$ | Random ROM access time | 19 | | ns |
| $t_{a(ROM)}$ | ROM (OTP area) access time ⁽¹⁾ | 60 | | ns |

(1) In C280x devices, a 1K X 16 ROM block replaces the OTP block found in Flash devices.

Table 5-49. ROM/ROM (OTP area) Minimum Required Wait-States at Different Frequencies

| SYSCLKOUT (MHz) | SYSCLKOUT (ns) | PAGE WAIT- STATE | RANDOM WAIT- STATE ⁽¹⁾ |
|--------------------|-------------------|---------------------|--------------------------------------|
| 100 | 10 | 1 | 1 |
| 75 | 13.33 | 1 | 1 |
| 50 | 20 | 0 | 1 |
| 30 | 33.33 | 0 | 1 |
| 25 | 40 | 0 | 1 |
| 15 | 66.67 | 0 | 1 |
| 4 | 250 | 0 | 1 |

(1) Random wait-state must be greater than or equal to 1.

Equations to compute the page wait-state and random wait-state in [Table 5-49](#) are as follows:

$$\text{ROM Page Wait-State} = \left\lceil \left(\frac{t_{a(rp)}}{t_{c(SCO)}} \right) - 1 \right\rceil \text{ (round up to the next highest integer) or 0, whichever is larger}$$

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

6 Detailed Description

6.1 Brief Descriptions

6.1.1 C28x CPU

The C28x DSP generation is the newest member of the TMS320C2000™ DSP platform. The C28x is a very efficient C/C++ engine, enabling users to develop not only their system control software in a high-level language, but also enables math algorithms to be developed using C/C++. The C28x is as efficient in DSP math tasks as it is in system control tasks that typically are handled by microcontroller devices. This efficiency removes the need for a second processor in many systems. The 32 x 32-bit MAC capabilities of the C28x and its 64-bit processing capabilities, enable the C28x to efficiently handle higher numerical resolution problems that would otherwise demand a more expensive floating-point processor solution. 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 C28x has an 8-level-deep protected pipeline with pipelined memory accesses. This pipelining enables the C28x 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.

6.1.2 Memory Bus (Harvard Bus Architecture)

As with many DSP type devices, multiple busses 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 busses consist of 32 address lines and 32 data lines each. The 32-bit-wide data busses 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 Texas Instruments (TI) DSP family of devices, the 280x devices adopt a peripheral bus standard for peripheral interconnect. The peripheral bus bridge multiplexes the various busses 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. Two versions of the peripheral bus are supported on the 280x. One version only supports 16-bit accesses (called peripheral frame 2). The other version supports both 16- and 32-bit accesses (called peripheral frame 1).

6.1.4 Real-Time JTAG and Analysis

The 280x implements the standard IEEE 1149.1 JTAG interface. Additionally, the 280x supports 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 non-time critical code while enabling time-critical interrupts to be serviced without interference. The 280x implements the real-time mode in hardware within the CPU. This is a unique feature to the 280x, no software monitor is required. Additionally, special analysis hardware is provided which allows the user to set hardware breakpoint or data/address watch-points and generate various user-selectable break events when a match occurs.

6.1.5 Flash

The F2809 contains 128K x 16 of embedded flash memory, segregated into eight 16K x 16 sectors. The F2808 contains 64K x 16 of embedded flash memory, segregated into four 16K x 16 sectors. The F2806 and F2802 have 32K x 16 of embedded flash, segregated into four 8K x 16 sectors. The F2801 device contains 16K x 16 of embedded flash, segregated into four 4K x 16 sectors. All five devices also contain a single 1K x 16 of OTP memory at address range 0x3D 7800 – 0x3D 7BFF. 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 0x3F7FF0 – 0x3F7FF5 are reserved for data variables and should not contain program code.

NOTE

The F2809/F2808/F2806/F2802/F2801 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 [TMS320x280x, 2801x, 2804x DSP system control and interrupts reference guide](#).

6.1.6 ROM

The C2802 contains 32K x 16 of ROM, while the C2801 contains 16K x 16 of ROM.

NOTE

Requests for ROM devices are not accepted by TI anymore.

6.1.7 M0, M1 SARAMs

All 280x devices contain these two blocks of single-access memory, each 1K x 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, H0 SARAMs

The F2809 and F2808 each contain an additional 16K x 16 of single-access RAM, divided into three blocks (L0-4K, L1-4K, H0-8K). The F2806 contains an additional 8K x 16 of single-access RAM, divided into two blocks (L0-4K, L1-4K). The F2802, F2801, C2802, and C2801 each contain an additional 4K x 16 of single-access RAM (L0-4K). Each block can be independently accessed to minimize CPU pipeline stalls. Each block is mapped to both program and data space.

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 | DESCRIPTION | GPIO18 SPICLK SCITXDB | GPIO29 SCITXDA | GPIO34 |
|-------------------|---|-----------------------------|-------------------|--------|
| Boot to Flash/ROM | Jump to Flash/ROM address 0x3F 7FF6 You must have programmed a branch instruction here prior to reset to redirect code execution as desired. | 1 | 1 | 1 |
| SCI-A Boot | Load a data stream from SCI-A | 1 | 1 | 0 |
| SPI-A Boot | Load from an external serial SPI EEPROM on SPI-A | 1 | 0 | 1 |
| I2C Boot | Load data from an external EEPROM at address 0x50 on the I2C bus | 1 | 0 | 0 |
| eCAN-A Boot | Call CAN_Boot to load from eCAN-A mailbox 1. | 0 | 1 | 1 |
| Boot to M0 SARAM | Jump to M0 SARAM address 0x00 0000. | 0 | 1 | 0 |
| Boot to OTP | Jump to OTP address 0x3D 7800 | 0 | 0 | 1 |
| Parallel I/O Boot | Load data from GPIO0 - GPIO15 | 0 | 0 | 0 |

6.1.10 Security

The 280x 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 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.

NOTE

The 128-bit password (at 0x3F 7FF8 – 0x3F 7FFF) must not be programmed to zeros. Doing so would permanently lock the device.

DISCLAIMER

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.

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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 280x, 43 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 8 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/disabled within the PIE block.

6.1.12 External Interrupts (XINT1, XINT2, XNMI)

The 280x supports three masked external interrupts (XINT1, XINT2, 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/disabled (including the XNMI). The masked interrupts 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. Rather, any Port A GPIO pin can be configured to trigger any external interrupt.

6.1.13 Oscillator and PLL

The 280x 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. See [Section 5](#) for timing details. The PLL block can be set in bypass mode.

6.1.14 Watchdog

The 280x 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/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 280x 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 (PFn)

The 280x segregate peripherals into three sections. The mapping of peripherals is as follows:

| | | |
|------|---------|---|
| PF0: | PIE: | PIE Interrupt Enable and Control Registers Plus PIE Vector Table |
| | Flash: | Flash Control, Programming, Erase, Verify Registers |
| | Timers: | CPU-Timers 0, 1, 2 Registers |
| | CSM: | Code Security Module KEY Registers |
| PF1: | ADC: | ADC Result Registers (dual-mapped) |
| | eCAN: | eCAN Mailbox and Control Registers |
| | GPIO: | GPIO MUX Configuration and Control Registers |
| | ePWM: | Enhanced Pulse Width Modulator Module and Registers |
| | eCAP: | Enhanced Capture Module and Registers |
| PF2: | eQEP: | Enhanced Quadrature Encoder Pulse Module and Registers |
| | 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 |

6.1.18 General-Purpose Input/Output (GPIO) Multiplexer

Most of the peripheral signals are multiplexed with general-purpose input/output (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 the SYS/BIOS Real-Time OS, and is connected to INT14 of the CPU. If 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 280x devices support the following peripherals which are used for embedded control and communication:

- ePWM: The enhanced PWM peripheral supports independent/complementary PWM generation, adjustable dead-band generation for leading/trailing edges, latched/cycle-by-cycle trip mechanism. Some of the PWM pins support HRPWM features.
- 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.

6.1.21 Serial Port Peripherals

The 280x 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 ISO11898-1 (CAN 2.0B).
- SPI: The SPI is a high-speed, synchronous serial 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 programmable bit-transfer rate. Normally, the SPI is used for communications between the DSP 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. Multi-device communications are supported by the master/slave operation of the SPI. On the 280x, the SPI contains a 16-level receive and transmit FIFO for reducing interrupt servicing overhead.
- SCI: The serial communications interface is a two-wire asynchronous serial port, commonly known as UART. On the 280x, 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 DSP 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 DSP through the I2C module. On the 280x, the I2C contains a 16-level receive and transmit FIFO for reducing interrupt servicing overhead.

6.2 Peripherals

The integrated peripherals of the 280x are described in the following subsections:

- Three 32-bit CPU-Timers
- Up to six enhanced PWM modules (ePWM1, ePWM2, ePWM3, ePWM4, ePWM5, ePWM6)
- Up to four enhanced capture modules (eCAP1, eCAP2, eCAP3, eCAP4)
- 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 two serial communications interface modules (SCI-A, SCI-B)
- Up to four serial peripheral interface (SPI) modules (SPI-A, SPI-B, SPI-C, SPI-D)
- Inter-integrated circuit module (I2C)
- Digital I/O and shared pin functions

6.2.1 32-Bit CPU-Timers 0/1/2

There are three 32-bit CPU-timers on the 280x devices (CPU-TIMER0/1/2).

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

NOTE

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

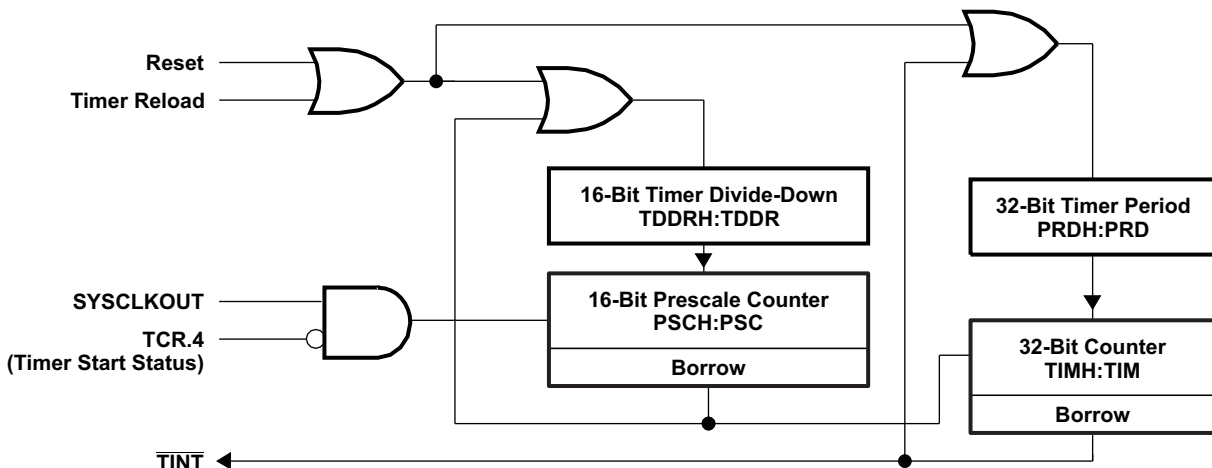
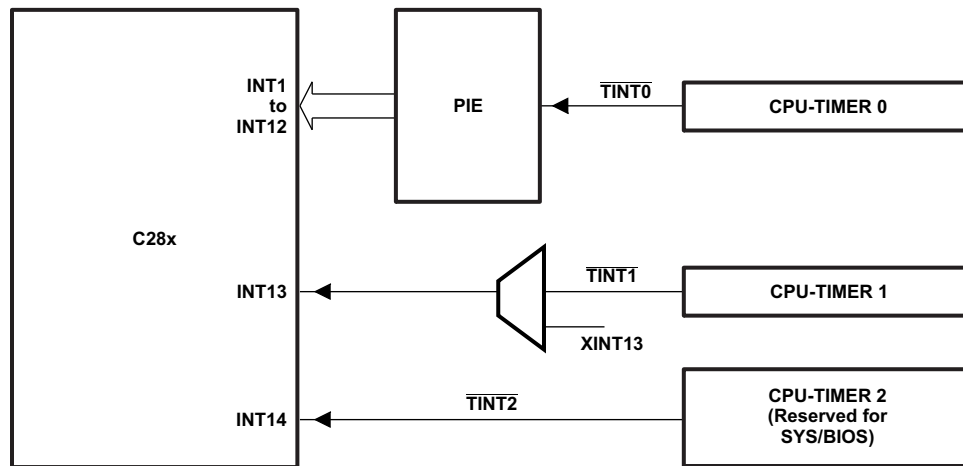


Figure 6-1. CPU-Timers

In the 280x devices, the timer interrupt signals ($\overline{\text{TINT0}}$, $\overline{\text{TINT1}}$, $\overline{\text{TINT2}}$) are connected as shown in Figure 6-2.



- 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 6-2. 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 6-2 are used to configure the timers. For more information, see the [TMS320x280x, 2801x, 2804x DSP system control and interrupts reference guide](#).

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

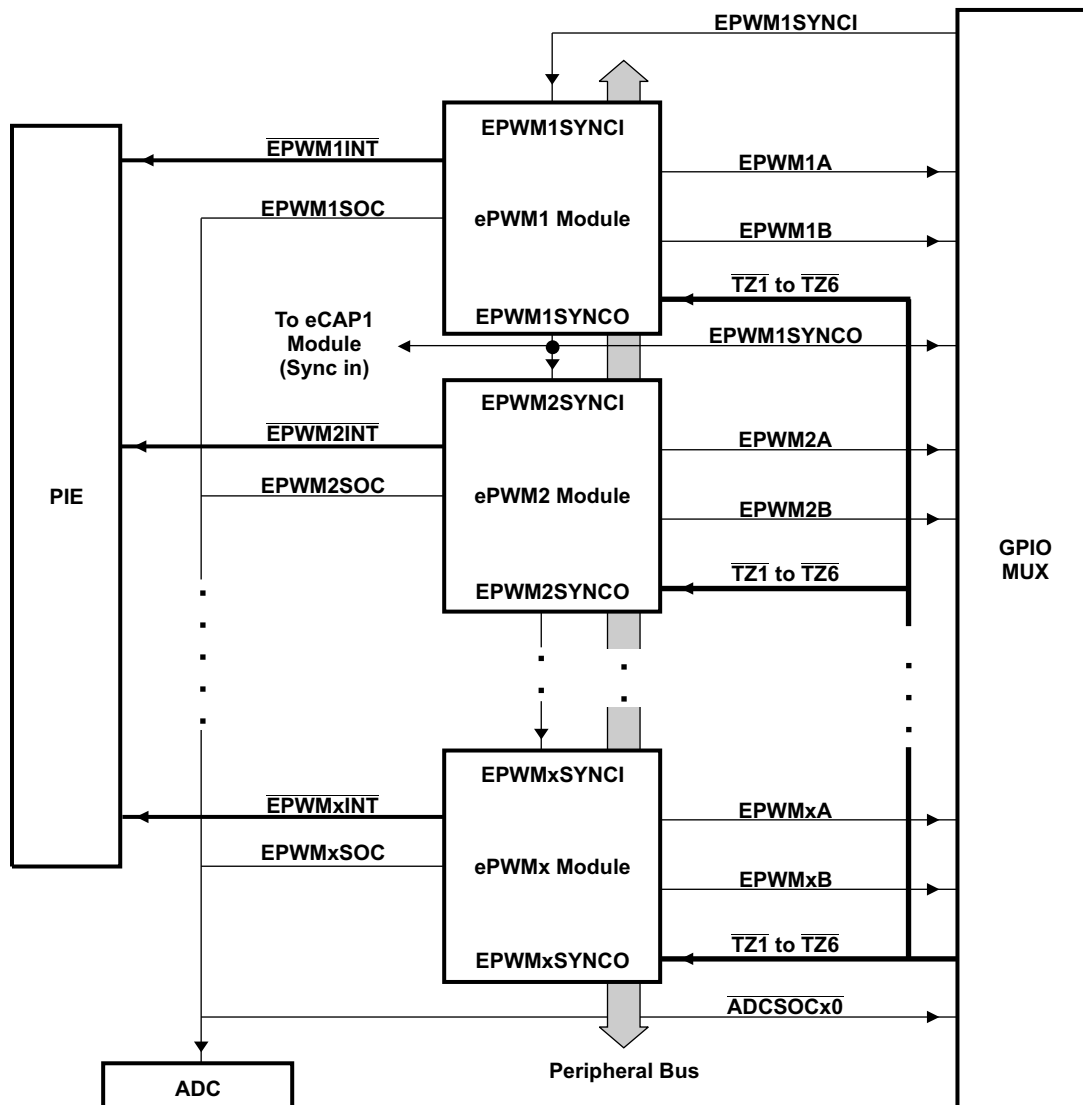
| NAME | ADDRESS | SIZE (x16) | DESCRIPTION |
|------------|---------|------------|-------------------------------------|
| TIMER0TIM | 0x0C00 | 1 | CPU-Timer 0, Counter Register |
| TIMER0TIMH | 0x0C01 | 1 | CPU-Timer 0, Counter Register High |
| TIMER0PRD | 0x0C02 | 1 | CPU-Timer 0, Period Register |
| TIMER0PRDH | 0x0C03 | 1 | CPU-Timer 0, Period Register High |
| TIMER0TCR | 0x0C04 | 1 | CPU-Timer 0, Control Register |
| Reserved | 0x0C05 | 1 | Reserved |
| 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 | Reserved |
| 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 | Reserved |

Table 6-2. CPU-Timers 0, 1, 2 Configuration and Control Registers (continued)

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION |
|------------|-----------------|------------|-------------------------------------|
| TIMER2TPR | 0x0C16 | 1 | CPU-Timer 2, Prescale Register |
| TIMER2TPRH | 0x0C17 | 1 | CPU-Timer 2, Prescale Register High |
| Reserved | 0x0C18 – 0x0C3F | 40 | Reserved |

6.2.2 Enhanced PWM Modules (ePWM1/2/3/4/5/6)

The 280x device contains up to six enhanced PWM modules (ePWM). [Figure 6-3](#) shows a block diagram of multiple ePWM modules. [Figure 6-4](#) shows the signal interconnections with the ePWM. See the [TMS320x280x, 2801x, 2804x Enhanced Pulse Width Modulator \(ePWM\) module reference guide](#) for more details.



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Figure 6-3. Multiple PWM Modules in a 280x System

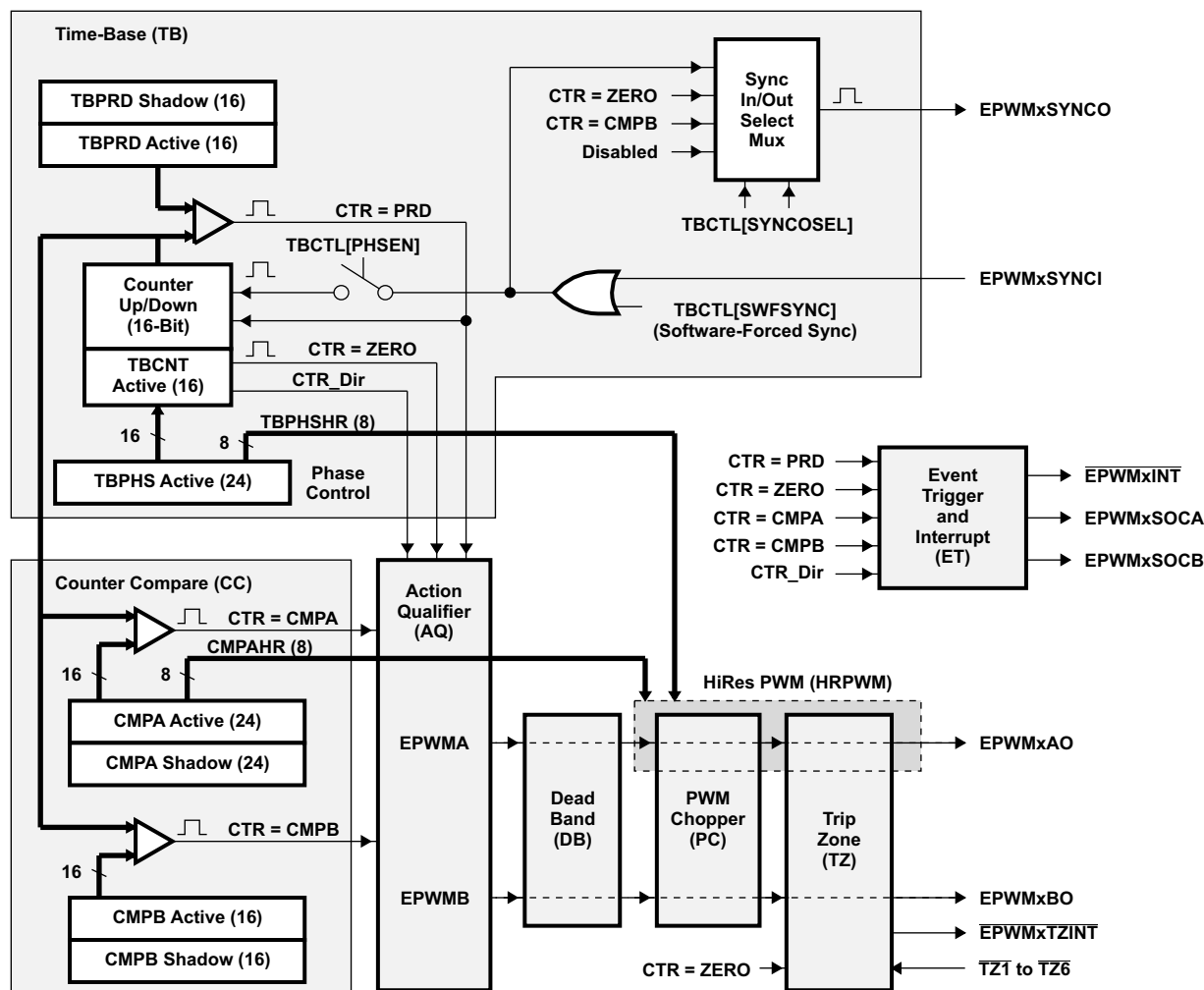
[Table 6-3](#) shows the complete ePWM register set per module.

Table 6-3. ePWM Control and Status Registers

| 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 | N/A | N/A | 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 | N/A | N/A | 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 ⁽¹⁾ |
| TZCTL | 0x6814 | 0x6854 | 0x6894 | 0x68D4 | 0x6914 | 0x6954 | 1 / 0 | Trip Zone Control Register ⁽¹⁾ |
| TZEINT | 0x6815 | 0x6855 | 0x6895 | 0x68D5 | 0x6915 | 0x6955 | 1 / 0 | Trip Zone Enable Interrupt Register ⁽¹⁾ |
| 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 ⁽¹⁾ |
| TZFRC | 0x6818 | 0x6858 | 0x6898 | 0x68D8 | 0x6918 | 0x6958 | 1 / 0 | Trip Zone Force Register ⁽¹⁾ |
| 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 ⁽²⁾ | 0x6960 ⁽²⁾ | 1 / 0 | HRPWM Configuration Register ⁽¹⁾ |

(1) Registers that are EALLOW protected.

(2) Applicable to F2809 only



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Figure 6-4. ePWM Sub-Modules Showing Critical Internal Signal Interconnections

6.2.3 Hi-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 ~ 9–10 bits. This occurs at PWM frequencies greater than ~200 kHz when using a CPU/System clock of 100 MHz.
- This capability can be utilized in both duty cycle and phase-shift control methods.
- Finer time granularity control or edge positioning is controlled via 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 (ECAP1/2/3/4ENCLK) in the PCLKCR1 register are used to turn off the eCAP modules individually (for low power operation). Upon reset, ECAP1ENCLK, ECAP2ENCLK, ECAP3ENCLK, and ECAP4ENCLK are set to low, indicating that the peripheral clock is off.

Table 6-4. eCAP Control and Status Registers

| NAME | eCAP1 | eCAP2 | eCAP3 | eCAP4 | SIZE (x16) | DESCRIPTION |
|----------|--------------------|--------------------|--------------------|--------------------|---------------|-------------------------------------|
| TSCTR | 0x6A00 | 0x6A20 | 0x6A40 | 0x6A60 | 2 | Time-Stamp Counter |
| CTRPHS | 0x6A02 | 0x6A22 | 0x6A42 | 0x6A62 | 2 | Counter Phase Offset Value Register |
| CAP1 | 0x6A04 | 0x6A24 | 0x6A44 | 0x6A64 | 2 | Capture 1 Register |
| CAP2 | 0x6A06 | 0x6A26 | 0x6A46 | 0x6A66 | 2 | Capture 2 Register |
| CAP3 | 0x6A08 | 0x6A28 | 0x6A48 | 0x6A68 | 2 | Capture 3 Register |
| CAP4 | 0x6A0A | 0x6A2A | 0x6A4A | 0x6A6A | 2 | Capture 4 Register |
| Reserved | 0x6A0C – 0x6A12 | 0x6A2C – 0x6A32 | 0x6A4C – 0x6A52 | 0x6A6C – 0x6A72 | 8 | Reserved |
| ECCTL1 | 0x6A14 | 0x6A34 | 0x6A54 | 0x6A74 | 1 | Capture Control Register 1 |
| ECCTL2 | 0x6A15 | 0x6A35 | 0x6A55 | 0x6A75 | 1 | Capture Control Register 2 |
| ECEINT | 0x6A16 | 0x6A36 | 0x6A56 | 0x6A76 | 1 | Capture Interrupt Enable Register |
| ECFLG | 0x6A17 | 0x6A37 | 0x6A57 | 0x6A77 | 1 | Capture Interrupt Flag Register |
| ECCLR | 0x6A18 | 0x6A38 | 0x6A58 | 0x6A78 | 1 | Capture Interrupt Clear Register |
| ECFRC | 0x6A19 | 0x6A39 | 0x6A59 | 0x6A79 | 1 | Capture Interrupt Force Register |
| Reserved | 0x6A1A – 0x6A1F | 0x6A3A – 0x6A3F | 0x6A5A – 0x6A5F | 0x6A7A – 0x6A7F | 6 | Reserved |

Table 6-5 provides a summary of the eQEP registers.

Table 6-5. 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 | Reserved |

6.2.6 Enhanced Analog-to-Digital Converter (ADC) Module

A simplified functional block diagram of the ADC module is shown in [Figure 6-7](#). 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-channel, MUXed inputs
- Autosequencing capability provides up to 16 "autoconversions" in a single session. Each conversion can be programmed to select anyone of 16 input channels
- Sequencer can be operated as two independent 8-channel sequencers or as one large 16-channel sequencer (that is, two cascaded 8-channel sequencers)
- Sixteen result registers (individually addressable) to store conversion values
 - The digital value of the input analog voltage is derived by:

$$\text{Digital Value} = 0 \quad , \text{ when } \text{ADCIN} \leq \text{ADCLO}$$

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

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

A. All fractional values are truncated.

- 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 280x 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 a 16-channel sequencer, configurable as two independent 8-channel sequencers. The two independent 8-channel sequencers can be cascaded to form a 16-channel sequencer. Although there are multiple input channels and two sequencers, there is only one converter in the ADC module. [Figure 6-7](#) shows the block diagram of the ADC module.

The two 8-channel sequencer 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.

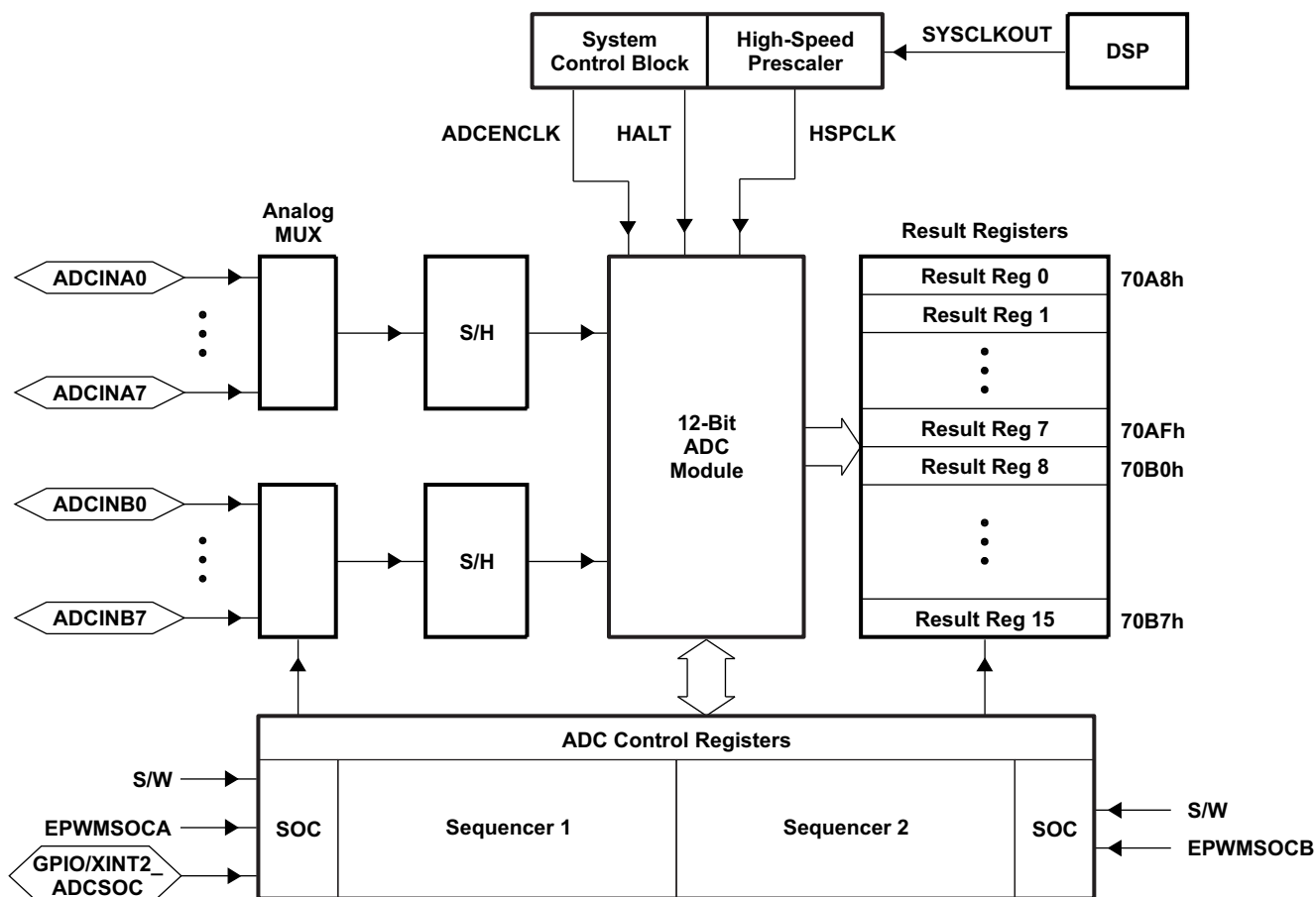


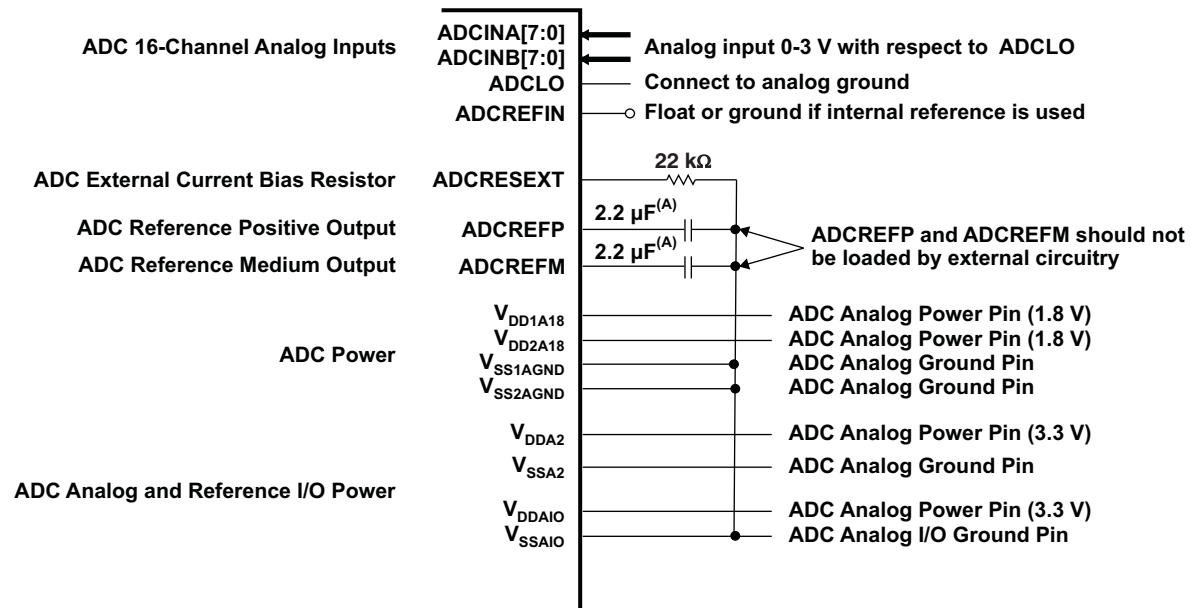
Figure 6-7. Block Diagram of the ADC Module

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_{DDA10}) from the digital supply. Figure 6-8 and Figure 6-9 show the ADC pin connections for the 280x devices.

NOTE

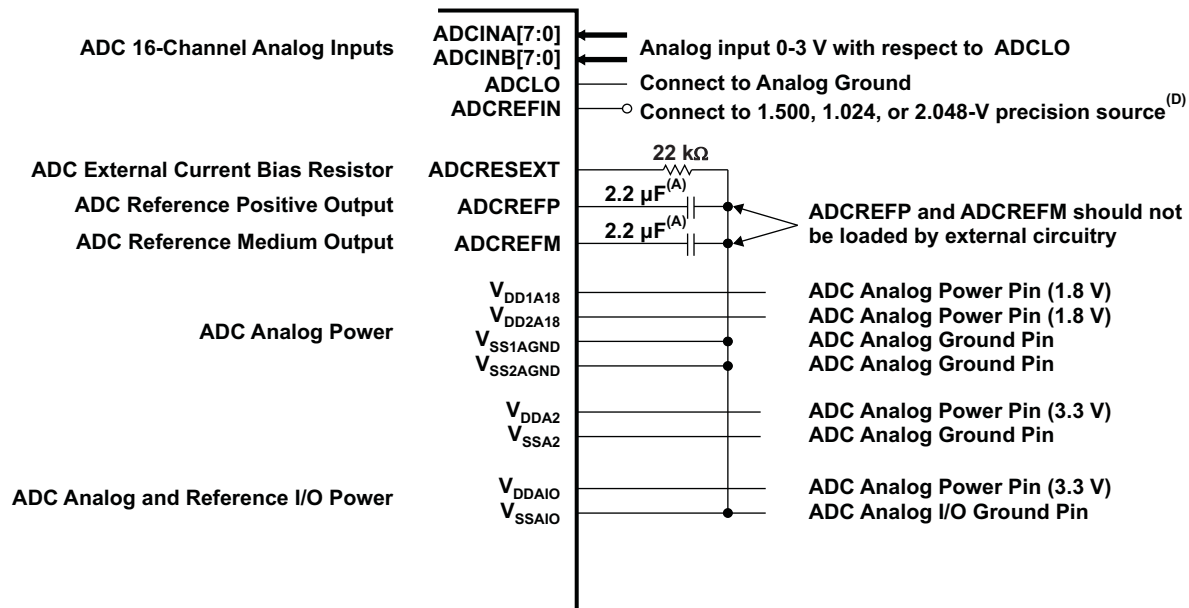
- The ADC registers are accessed at the SYSCCLKOUT rate. The internal timing of the ADC module is controlled by the high-speed peripheral clock (HSPCLK).
- The behavior of the ADC module based on the state of the ADCENCLK and HALT signals is as follows:
 - ADCENCLK:** On reset, this signal will be low. 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 6-8 shows the ADC pin-biasing for internal reference and Figure 6-9 shows the ADC pin-biasing for external reference.



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

Figure 6-8. ADC Pin Connections With Internal Reference



- TAIYO YUDEN LMK212BJ225MG-T or equivalent
- External decoupling capacitors are recommended on all power pins.
- Analog inputs must be driven from an operational amplifier that does not degrade the ADC performance.
- 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 6-9. ADC Pin Connections With External Reference

NOTE

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

6.2.6.1 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 Ω 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 ($V_{SS1AGND}/V_{SS2AGND}$)

6.2.6.2 ADC Registers

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

Table 6-6. ADC Registers⁽¹⁾

| NAME | ADDRESS ⁽¹⁾ | ADDRESS ⁽²⁾ | 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 – 0x711B | | 2 | Reserved |
| ADCREFSSEL | 0x711C | | 1 | ADC Reference Select Register |
| ADCOFFTRIM | 0x711D | | 1 | ADC Offset Trim Register |
| Reserved | 0x711E – 0x711F | | 2 | Reserved |

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

(2) The ADC result registers are dual mapped in the 280x DSP. Locations in Peripheral Frame 2 (0x7108-0x7117) are 2 wait-states and left justified. Locations in Peripheral frame 0 space (0x0B00-0x0B0F) are 0 wait states 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 Enhanced Controller Area Network (eCAN) Modules (eCAN-A and eCAN-B)

The CAN module has the following features:

- Fully compliant with CAN protocol, version 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 time stamp 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.

NOTE

For a SYSCLKOUT of 100 MHz, the smallest bit rate possible is 15.625 kbps.

For a SYSCLKOUT of 60 MHz, the smallest bit rate possible is 9.375 kbps.

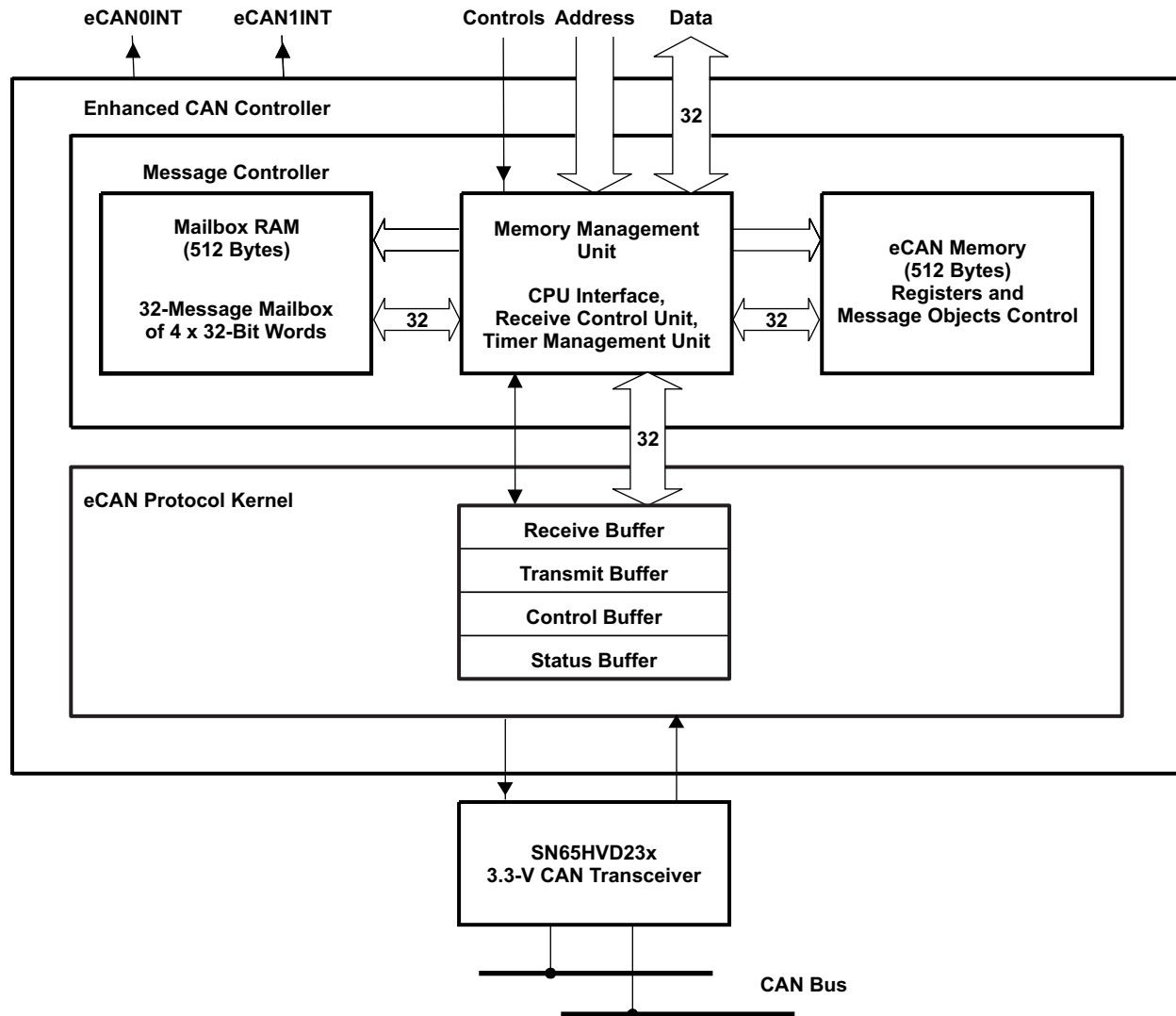


Figure 6-10. eCAN Block Diagram and Interface Circuit

Table 6-7. 3.3-V eCAN Transceivers

| PART NUMBER | SUPPLY VOLTAGE | LOW-POWER MODE | SLOPE CONTROL | VREF | OTHER | T _A |
|-------------|----------------|-----------------|---------------|------|---------------------|----------------|
| 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 & Sleep | Adjustable | None | – | –40°C to 125°C |
| SN65HVD235 | 3.3 V | Standby | Adjustable | None | Autobaud Loopback | –40°C to 125°C |

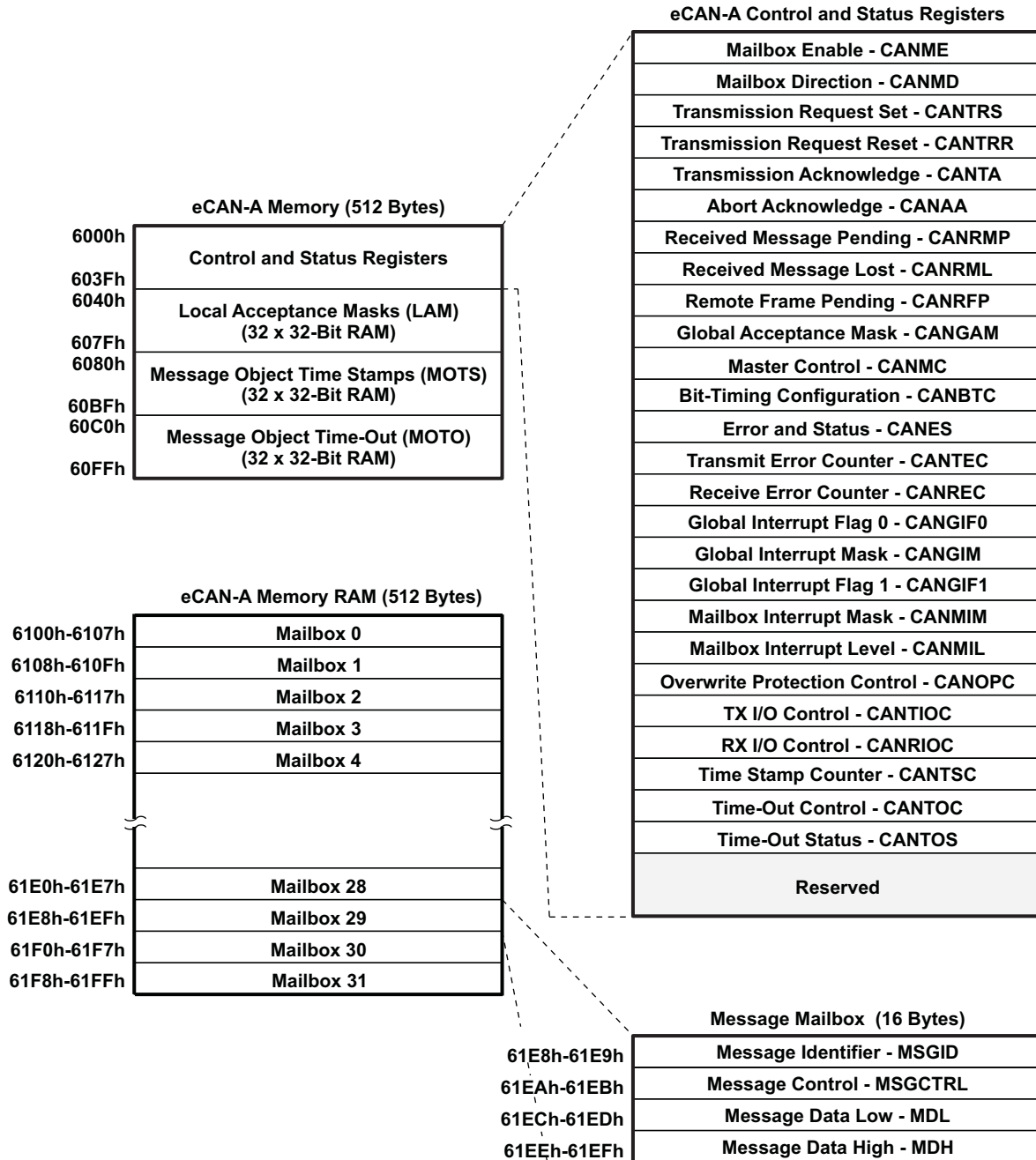


Figure 6-11. eCAN-A Memory Map

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.

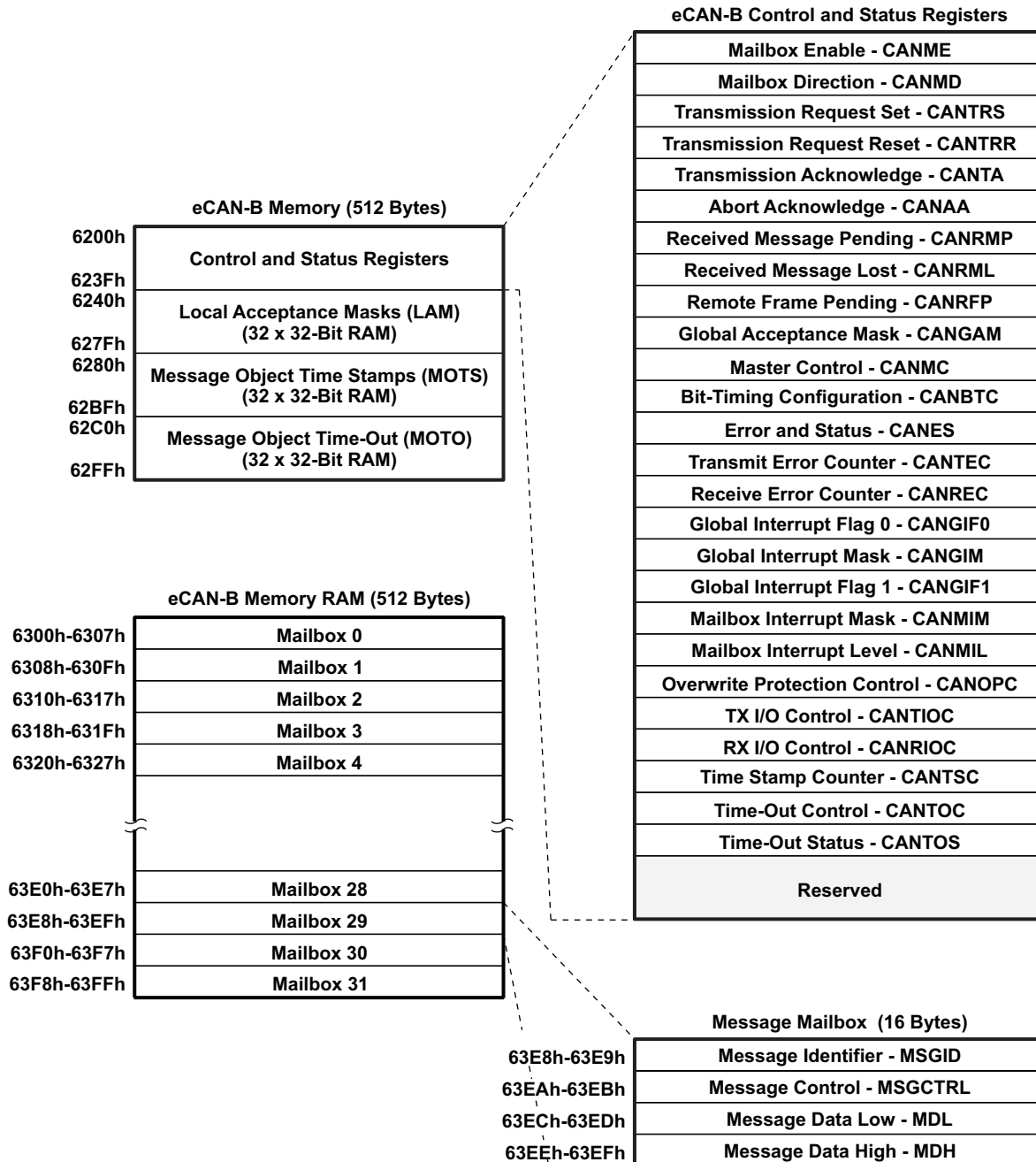


Figure 6-12. eCAN-B Memory Map

The CAN registers listed in [Table 6-8](#) 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. 32-bit accesses are aligned to an even boundary.

Table 6-8. CAN Register Map⁽¹⁾

| 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 | Time stamp 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.

6.2.8 Serial Communications Interface (SCI) Modules (SCI-A, SCI-B)

The 280x devices include two serial communications interface (SCI) modules. The SCI modules support digital communications between the CPU and other asynchronous peripherals that use the standard non-return-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 over 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:

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

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

- 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)
- Max bit rate = $\frac{100 \text{ MHz}}{16} = 6.25 \times 10^6 \text{ b/s}$ (for 100-MHz devices)
- Max bit rate = $\frac{60 \text{ MHz}}{16} = 3.75 \times 10^6 \text{ b/s}$ (for 60-MHz devices)
- NRZ (non-return-to-zero) format
- Ten SCI module control registers located in the control register frame beginning at address 7050h

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 6-9](#) and [Table 6-10](#).

Table 6-9. SCI-A Registers⁽¹⁾

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION |
|-------------------------|---------|------------|--|
| SCICCRRA | 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 ⁽²⁾ | 0x705A | 1 | SCI-A FIFO Transmit Register |
| SCIFFRXA ⁽²⁾ | 0x705B | 1 | SCI-A FIFO Receive Register |
| SCIFFCTA ⁽²⁾ | 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 6-10. SCI-B Registers^{(1) (2)}

| 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 |
| SCIRXBUFB | 0x7757 | 1 | SCI-B Receive Data Buffer Register |
| SCITXBUFB | 0x7759 | 1 | SCI-B Transmit Data Buffer Register |
| SCIFFTXB ⁽²⁾ | 0x775A | 1 | SCI-B FIFO Transmit Register |
| SCIFFRXB ⁽²⁾ | 0x775B | 1 | SCI-B FIFO Receive Register |
| SCIFFCTB ⁽²⁾ | 0x775C | 1 | SCI-B FIFO Control Register |
| SCIPRIB | 0x775F | 1 | SCI-B Priority Control Register |

(1) Registers in this table are mapped to peripheral bus 16 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 6-13 shows the SCI module block diagram.

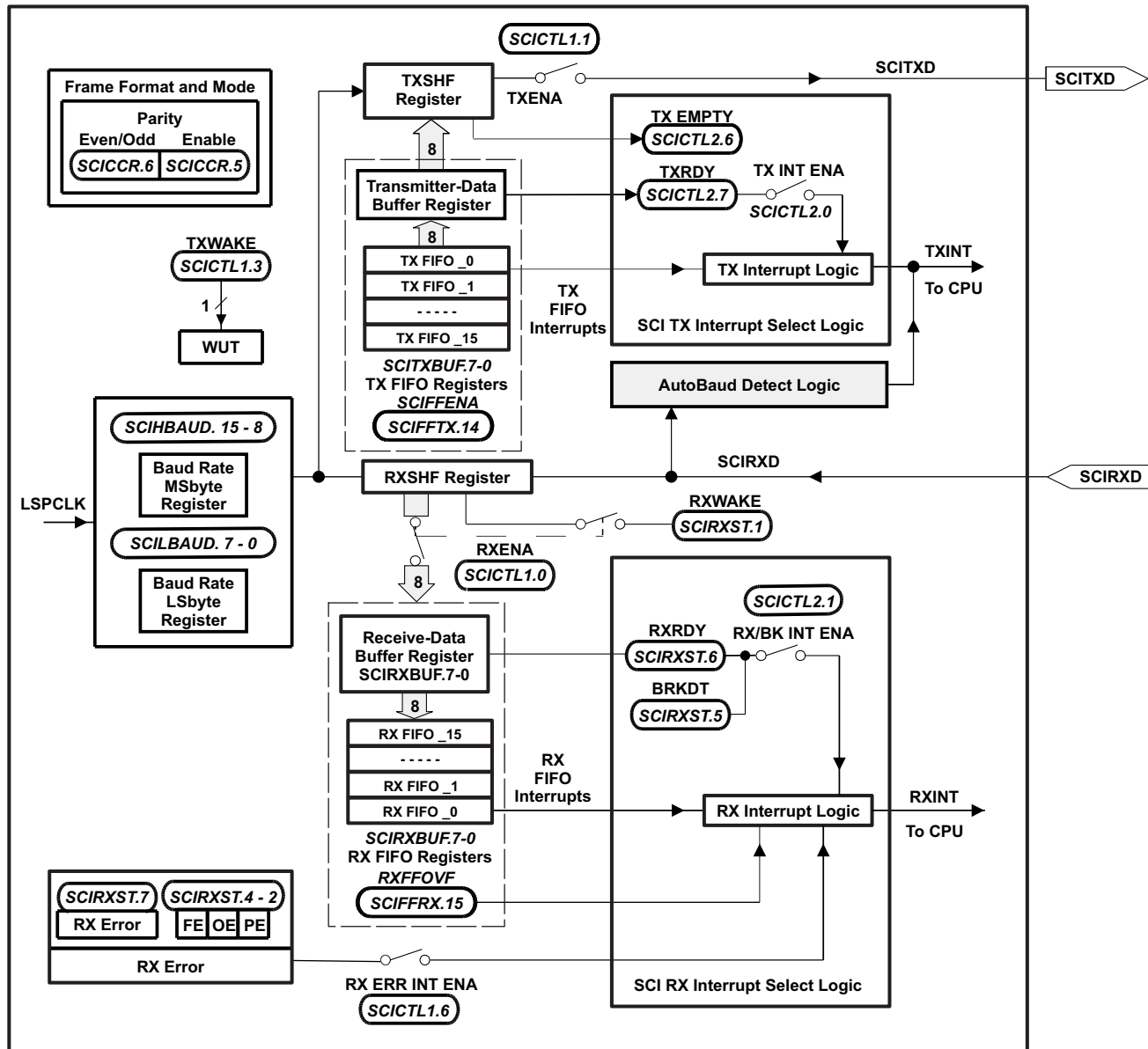


Figure 6-13. Serial Communications Interface (SCI) Module Block Diagram

6.2.9 Serial Peripheral Interface (SPI) Modules (SPI-A, SPI-B, SPI-C, SPI-D)

The 280x devices include the four-pin serial peripheral interface (SPI) module. Up to four SPI modules (SPI-A, SPI-B, SPI-C, and SPI-D) are available. The SPI is a high-speed, synchronous serial 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 programmable bit-transfer rate. Normally, the SPI is used for communications between the DSP 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.

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

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

- Data word length: one to sixteen 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.

Enhanced feature:

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

The SPI port operation is configured and controlled by the registers listed in [Table 6-11](#) through [Table 6-14](#).

Table 6-11. SPI-A Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION ⁽¹⁾ |
|----------|---------|------------|---|
| 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.

Table 6-12. SPI-B Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION ⁽¹⁾ |
|----------|---------|------------|---|
| SPICCR | 0x7740 | 1 | SPI-B Configuration Control Register |
| SPICTL | 0x7741 | 1 | SPI-B Operation Control Register |
| SPISTS | 0x7742 | 1 | SPI-B Status Register |
| SPIBRR | 0x7744 | 1 | SPI-B Baud Rate Register |
| SPIRXEMU | 0x7746 | 1 | SPI-B Receive Emulation Buffer Register |
| SPIRXBUF | 0x7747 | 1 | SPI-B Serial Input Buffer Register |
| SPITXBUF | 0x7748 | 1 | SPI-B Serial Output Buffer Register |
| SPIDAT | 0x7749 | 1 | SPI-B Serial Data Register |
| SPIFFTX | 0x774A | 1 | SPI-B FIFO Transmit Register |
| SPIFFRX | 0x774B | 1 | SPI-B FIFO Receive Register |
| SPIFFCT | 0x774C | 1 | SPI-B FIFO Control Register |
| SPIPRI | 0x774F | 1 | SPI-B 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.

Table 6-13. SPI-C Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION ⁽¹⁾ |
|----------|---------|------------|---|
| SPICCR | 0x7760 | 1 | SPI-C Configuration Control Register |
| SPICTL | 0x7761 | 1 | SPI-C Operation Control Register |
| SPISTS | 0x7762 | 1 | SPI-C Status Register |
| SPIBRR | 0x7764 | 1 | SPI-C Baud Rate Register |
| SPIRXEMU | 0x7766 | 1 | SPI-C Receive Emulation Buffer Register |
| SPIRXBUF | 0x7767 | 1 | SPI-C Serial Input Buffer Register |
| SPITXBUF | 0x7768 | 1 | SPI-C Serial Output Buffer Register |
| SPIDAT | 0x7769 | 1 | SPI-C Serial Data Register |
| SPIFFTX | 0x776A | 1 | SPI-C FIFO Transmit Register |
| SPIFFRX | 0x776B | 1 | SPI-C FIFO Receive Register |
| SPIFFCT | 0x776C | 1 | SPI-C FIFO Control Register |
| SPIPRI | 0x776F | 1 | SPI-C 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.

Table 6-14. SPI-D Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION ⁽¹⁾ |
|----------|---------|------------|---|
| SPICCR | 0x7780 | 1 | SPI-D Configuration Control Register |
| SPICTL | 0x7781 | 1 | SPI-D Operation Control Register |
| SPISTS | 0x7782 | 1 | SPI-D Status Register |
| SPIBRR | 0x7784 | 1 | SPI-D Baud Rate Register |
| SPIRXEMU | 0x7786 | 1 | SPI-D Receive Emulation Buffer Register |
| SPIRXBUF | 0x7787 | 1 | SPI-D Serial Input Buffer Register |
| SPITXBUF | 0x7788 | 1 | SPI-D Serial Output Buffer Register |
| SPIDAT | 0x7789 | 1 | SPI-D Serial Data Register |
| SPIFFTX | 0x778A | 1 | SPI-D FIFO Transmit Register |
| SPIFFRX | 0x778B | 1 | SPI-D FIFO Receive Register |
| SPIFFCT | 0x778C | 1 | SPI-D FIFO Control Register |
| SPIPRI | 0x778F | 1 | SPI-D 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 6-14 is a block diagram of the SPI in slave mode.

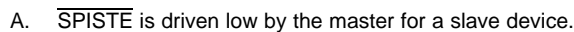


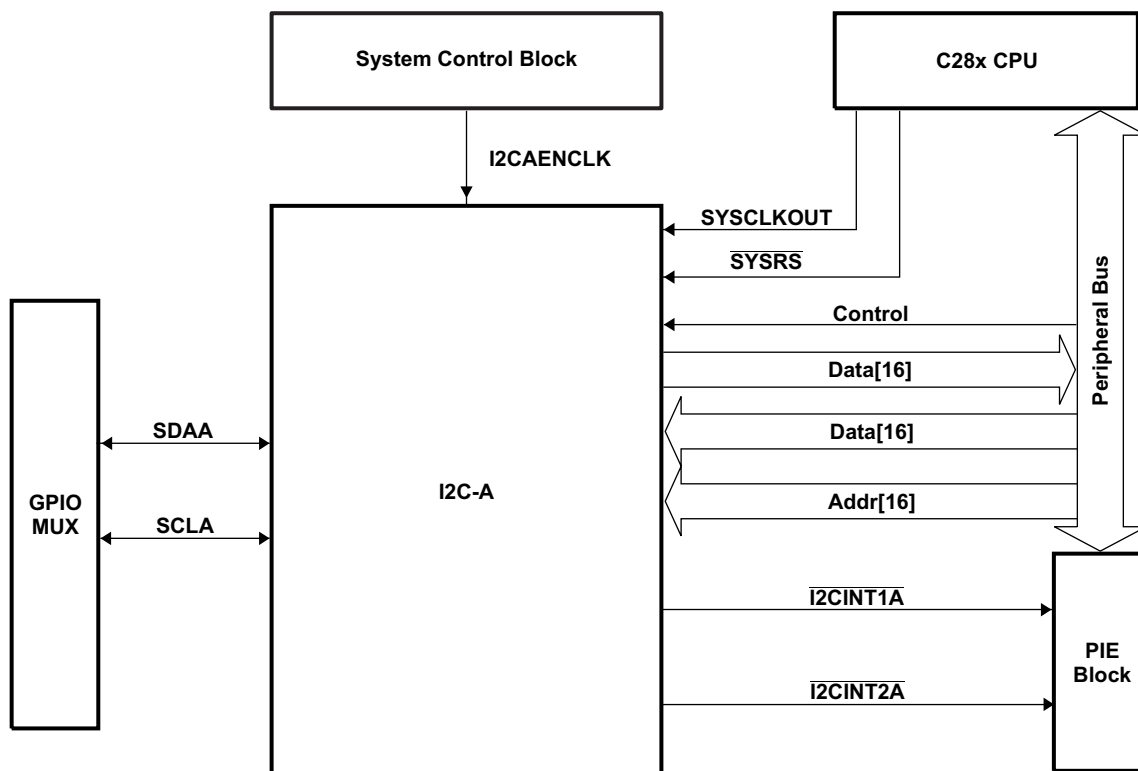
Figure 6-14. SPI Module Block Diagram (Slave Mode)

6.2.10 Inter-Integrated Circuit (I2C)

The 280x device contains one I2C Serial Port. [Figure 6-15](#) shows how the I2C peripheral module interfaces within the 280x device.

The I2C module has the following features:

- Compliance with the Philips Semiconductors I2C-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 of 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/disable capability
- Free data format mode



- The I2C registers are accessed at the SYSCLKOUT rate. The internal timing and signal waveforms of the I2C port are also at the SYSCLKOUT rate.
- The clock enable bit (I2CAENCLK) in the PCLKCRO 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 6-15. I2C Peripheral Module Interfaces

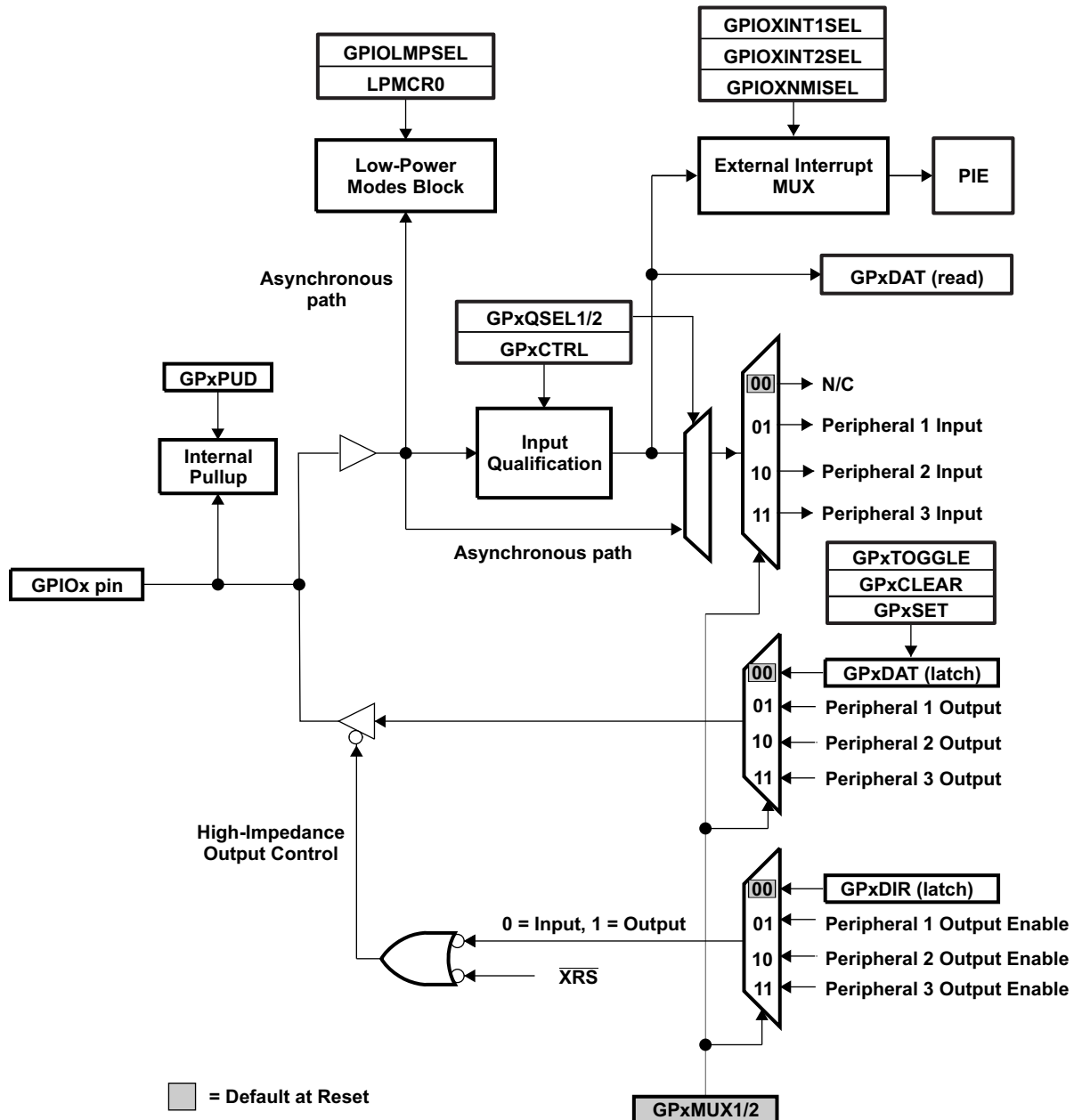
The registers in [Table 6-15](#) configure and control the I2C port operation.

Table 6-15. 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 |
| I2CMR | 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) |

6.2.11 GPIO MUX

On the 280x, the GPIO MUX can multiplex up to three independent peripheral signals on a single GPIO pin in addition to providing individual pin bit-banging IO capability. The GPIO MUX block diagram per pin is shown in Figure 6-16. Because of the open-drain capabilities of the I2C pins, the GPIO MUX block diagram for these pins differ. See the [TMS320x280x, 2801x, 2804x DSP system control and interrupts reference guide](#) for details.



- A. 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.
- B. GPxDAT latch/read are accessed at the same memory location.

Figure 6-16. GPIO MUX Block Diagram

The 280x supports 34 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 6-16](#) shows the GPIO register mapping.

Table 6-16. GPIO Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION |
|---|--------------------|------------|---|
| GPIO CONTROL REGISTERS (EALLOW PROTECTED) | | | |
| 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 Pull Up Disable Register (GPIO0 to 31) |
| Reserved | 0x6F8E – 0x6F8F | 2 | Reserved |
| GPBCTRL | 0x6F90 | 2 | GPIO B Control Register (GPIO32 to 35) |
| GPBQSEL1 | 0x6F92 | 2 | GPIO B Qualifier Select 1 Register (GPIO32 to 35) |
| GPBQSEL2 | 0x6F94 | 2 | Reserved |
| GPBMUX1 | 0x6F96 | 2 | GPIO B MUX 1 Register (GPIO32 to 35) |
| GPBMUX2 | 0x6F98 | 2 | Reserved |
| GPBDIR | 0x6F9A | 2 | GPIO B Direction Register (GPIO32 to 35) |
| GPBPUD | 0x6F9C | 2 | GPIO B Pull Up Disable Register (GPIO32 to 35) |
| Reserved | 0x6F9E – 0x6F9F | 2 | Reserved |
| Reserved | 0x6FA0 – 0x6FBF | 32 | Reserved |
| GPIO DATA REGISTERS (NOT EALLOW PROTECTED) | | | |
| GPADAT | 0x6FC0 | 2 | GPIO Data Register (GPIO0 to 31) |
| GPASET | 0x6FC2 | 2 | GPIO Data Set Register (GPIO0 to 31) |
| GPACLEAR | 0x6FC4 | 2 | GPIO Data Clear Register (GPIO0 to 31) |
| GPATOGGLE | 0x6FC6 | 2 | GPIO Data Toggle Register (GPIO0 to 31) |
| GPBDAT | 0x6FC8 | 2 | GPIO Data Register (GPIO32 to 35) |
| GPBSET | 0x6FCA | 2 | GPIO Data Set Register (GPIO32 to 35) |
| GPBCLEAR | 0x6FCC | 2 | GPIO Data Clear Register (GPIO32 to 35) |
| GPBTOGGLE | 0x6FCE | 2 | GPIO Data Toggle Register (GPIO32 to 35) |
| Reserved | 0x6FD0 – 0x6FDF | 16 | Reserved |
| GPIO INTERRUPT AND LOW POWER MODES SELECT REGISTERS (EALLOW PROTECTED) | | | |
| 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) |
| Reserved | 0x6FE3 – 0x6FE7 | 5 | Reserved |
| GPIO_LPMSEL | 0x6FE8 | 2 | LPM GPIO Select Register (GPIO0 to 31) |
| Reserved | 0x6FEA – 0x6FFF | 22 | Reserved |

Table 6-17. F2808 GPIO MUX Table

| GPAMUX1/2 ⁽¹⁾ REGISTER BITS | DEFAULT AT RESET PRIMARY I/O FUNCTION (GPxMUX1/2 BITS = 0,0) | PERIPHERAL SELECTION 1 ⁽²⁾ (GPxMUX1/2 BITS = 0,1) | PERIPHERAL SELECTION 2 (GPxMUX1/2 BITS = 1,0) | PERIPHERAL SELECTION 3 (GPxMUX1/2 BITS = 1,1) |
|--|--|--|---|---|
| GPAMUX1 | | | | |
| 1–0 | GPIO0 | EPWM1A (O) | Reserved ⁽³⁾ | Reserved ⁽³⁾ |
| 3–2 | GPIO1 | EPWM1B (O) | SPISIMOD (I/O) | Reserved ⁽³⁾ |
| 5–4 | GPIO2 | EPWM2A (O) | Reserved ⁽³⁾ | Reserved ⁽³⁾ |
| 7–6 | GPIO3 | EPWM2B (O) | SPISOMID (I/O) | Reserved ⁽³⁾ |
| 9–8 | GPIO4 | EPWM3A (O) | Reserved ⁽³⁾ | Reserved ⁽³⁾ |
| 11–10 | GPIO5 | EPWM3B (O) | SPICLKD (I/O) | ECAP1 (I/O) |
| 13–12 | GPIO6 | EPWM4A (O) | EPWMSYNCl (I) | EPWMSYNCO (O) |
| 15–14 | GPIO7 | EPWM4B (O) | SPISTED (I/O) | ECAP2 (I/O) |
| 17–16 | GPIO8 | EPWM5A (O) | CANTXB (O) | ADCSOCAO (O) |
| 19–18 | GPIO9 | EPWM5B (O) | SCITXDB (O) | ECAP3 (I/O) |
| 21–20 | GPIO10 | EPWM6A (O) | CANRXB (I) | ADCSOCBO (O) |
| 23–22 | GPIO11 | EPWM6B (O) | SCIRXDB (I) | ECAP4 (I/O) |
| 25–24 | GPIO12 | TZ1 (I) | CANTXB (O) | SPISIMOB (I/O) |
| 27–26 | GPIO13 | TZ2 (I) | CANRXB (I) | SPISOMIB (I/O) |
| 29–28 | GPIO14 | TZ3 (I) | SCITXDB (O) | SPICLKB (I/O) |
| 31–30 | GPIO15 | TZ4 (I) | SCIRXDB (I) | SPISTEB (I/O) |
| GPAMUX2 | | | | |
| 1–0 | GPIO16 | SPISIMOA (I/O) | CANTXB (O) | TZ5 (I) |
| 3–2 | GPIO17 | SPISOMIA (I/O) | CANRXB (I) | TZ6 (I) |
| 5–4 | GPIO18 | SPICLKA (I/O) | SCITXDB (O) | Reserved ⁽³⁾ |
| 7–6 | GPIO19 | SPISTEA (I/O) | SCIRXDB (I) | Reserved ⁽³⁾ |
| 9–8 | GPIO20 | EQEP1A (I) | SPISIMOC (I/O) | CANTXB (O) |
| 11–10 | GPIO21 | EQEP1B (I) | SPISOMIC (I/O) | CANRXB (I) |
| 13–12 | GPIO22 | EQEP1S (I/O) | SPICLKC (I/O) | SCITXDB (O) |
| 15–14 | GPIO23 | EQEP1I (I/O) | SPISTEC (I/O) | SCIRXDB (I) |
| 17–16 | GPIO24 | ECAP1 (I/O) | EQEP2A (I) | SPISIMOB (I/O) |
| 19–18 | GPIO25 | ECAP2 (I/O) | EQEP2B (I) | SPISOMIB (I/O) |
| 21–20 | GPIO26 | ECAP3 (I/O) | EQEP2I (I/O) | SPICLKB (I/O) |
| 23–22 | GPIO27 | ECAP4 (I/O) | EQEP2S (I/O) | SPISTEB (I/O) |
| 25–24 | GPIO28 | SCIRXDA (I) | Reserved ⁽³⁾ | TZ5 (I) |
| 27–26 | GPIO29 | SCITXDA (O) | Reserved ⁽³⁾ | TZ6 (I) |
| 29–28 | GPIO30 | CANRXA (I) | Reserved ⁽³⁾ | Reserved ⁽³⁾ |
| 31–30 | GPIO31 | CANTXA (O) | Reserved ⁽³⁾ | Reserved ⁽³⁾ |
| GPBMUX1 | | | | |
| 1–0 | GPIO32 | SDAA (I/OC) | EPWMSYNCl (I) | ADCSOCAO (O) |
| 3–2 | GPIO33 | SCLA (I/OC) | EPWMSYNCO (O) | ADCSOCBO (O) |
| 5–4 | GPIO34 | Reserved ⁽³⁾ | Reserved ⁽³⁾ | Reserved ⁽³⁾ |

(1) GPxMUX1/2 refers to the appropriate MUX register for the pin; GPAMUX1, GPAMUX2 or GPBMUX1.

(2) This table pertains to the 2808 device. Some peripherals may not be available in the 2809, 2806, 2802, or 2801 devices. See the pin descriptions for more detail.

(3) The word "Reserved" means that there is no peripheral assigned to this GPxMUX1/2 register setting. Should it be selected, the state of the pin will be undefined and the pin may be driven. This selection is a reserved configuration for future expansion.

The user can select the type of input qualification for each GPIO pin via 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.

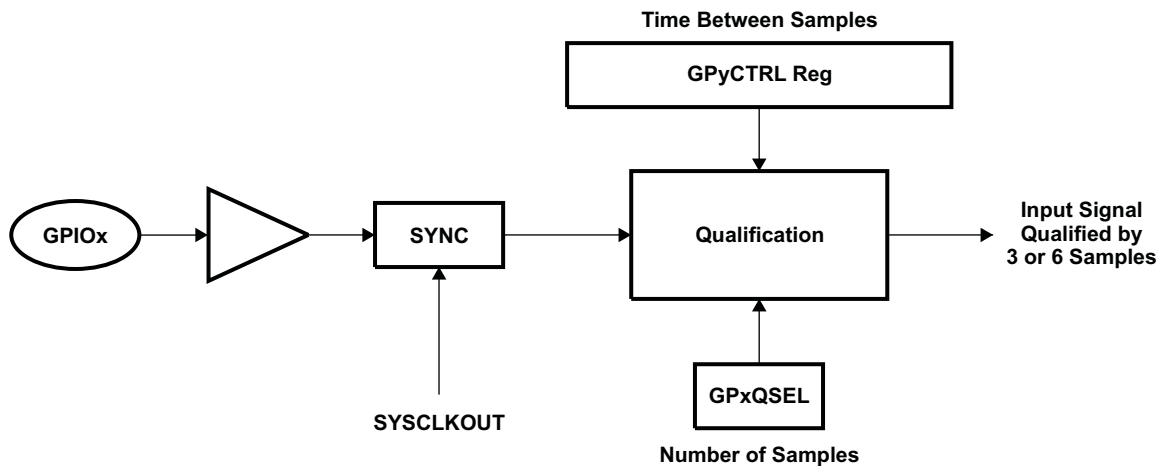


Figure 6-17. Qualification Using Sampling Window

- 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 5-11](#) (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 multi-level multiplexing that is required on the 280x 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.

6.3 Memory Maps

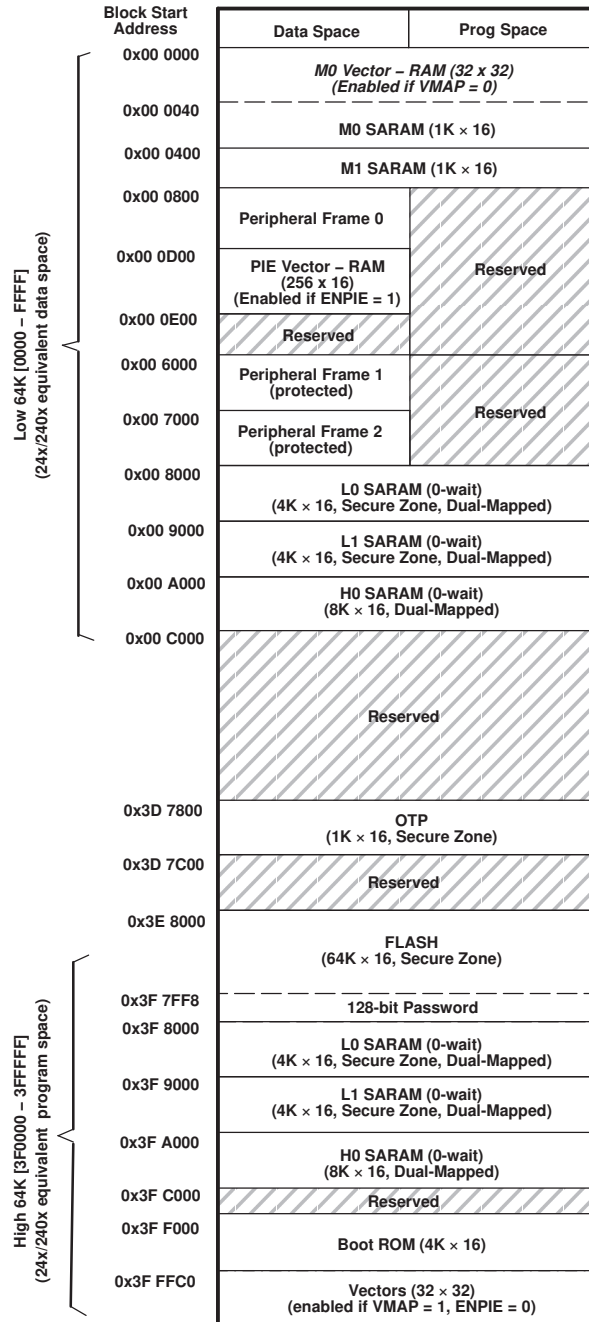
| Block Start Address | Data Space | Prog Space |
|---------------------|--|------------|
| 0x00 0000 | M0 Vector – RAM (32 x 32) (Enabled if VMAP = 0) | |
| 0x00 0040 | M0 SARAM (1K x 16) | |
| 0x00 0400 | M1 SARAM (1K x 16) | |
| 0x00 0800 | Peripheral Frame 0 | Reserved |
| 0x00 0D00 | PIE Vector – RAM (256 x 16) (Enabled if ENPIE = 1) | |
| 0x00 0E00 | Reserved | |
| 0x00 6000 | Peripheral Frame 1 (protected) | Reserved |
| 0x00 7000 | Peripheral Frame 2 (protected) | |
| 0x00 8000 | L0 SARAM (0-wait) (4K x 16, Secure Zone, Dual-Mapped) | |
| 0x00 9000 | L1 SARAM (0-wait) (4K x 16, Secure Zone, Dual-Mapped) | |
| 0x00 A000 | H0 SARAM (0-wait) (8K x 16, Dual-Mapped) | |
| 0x00 C000 | Reserved | |
| 0x3D 7800 | OTP (1K x 16, Secure Zone) | |
| 0x3D 7C00 | Reserved | |
| 0x3D 8000 | FLASH (128K x 16, Secure Zone) | |
| 0x3F 7FF8 | 128-bit Password | |
| 0x3F 8000 | L0 SARAM (0-wait) (4K x 16, Secure Zone, Dual-Mapped) | |
| 0x3F 9000 | L1 SARAM (0-wait) (4K x 16, Secure Zone, Dual-Mapped) | |
| 0x3F A000 | H0 SARAM (0-wait) (8K x 16, Dual-Mapped) | |
| 0x3F C000 | Reserved | |
| 0x3F F000 | Boot ROM (4K x 16) | |
| 0x3F FFC0 | Vectors (32 x 32) (enabled if VMAP = 1, ENPIE = 0) | |

Low 64K [0000 – FFFF]
(24x/240x equivalent data space)

High 64K [3F0000 – 3FFFFFFF]
(24x/240x equivalent program space)

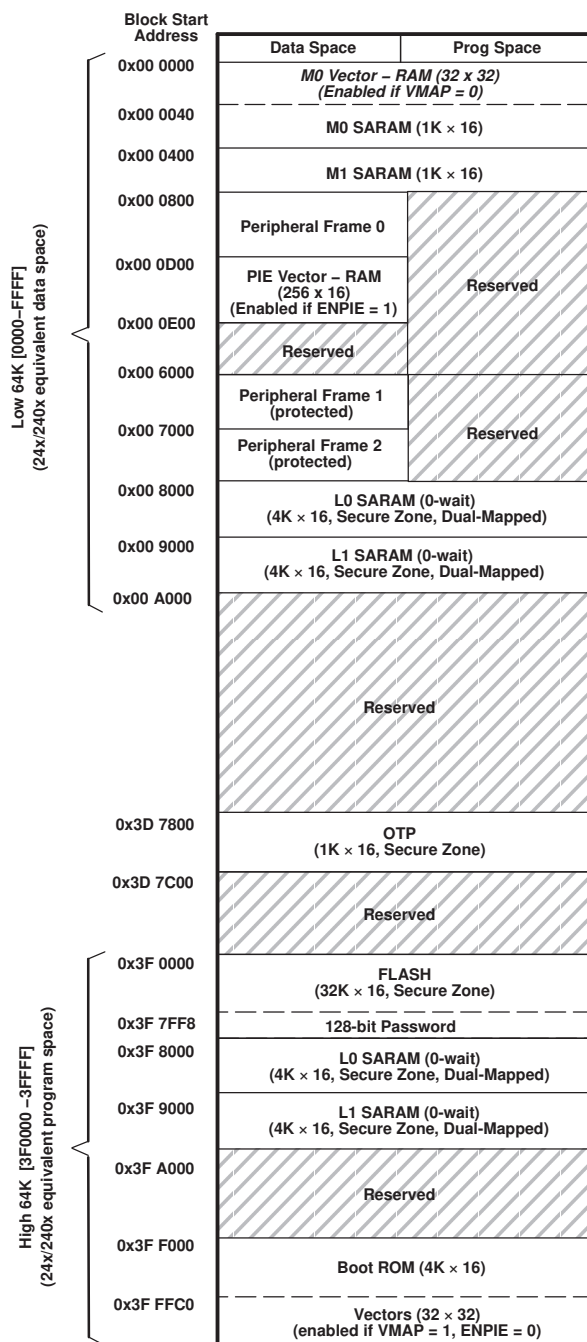
- A. Memory blocks are not to scale.
- B. Peripheral Frame 0, Peripheral Frame 1, and Peripheral Frame 2 memory maps are restricted to data memory only. User program cannot access these memory maps in program space.
- C. *Protected* means the order of Write followed by Read operations is preserved rather than the pipeline order.
- D. Certain memory ranges are EALLOW protected against spurious writes after configuration.

Figure 6-18. F2809 Memory Map



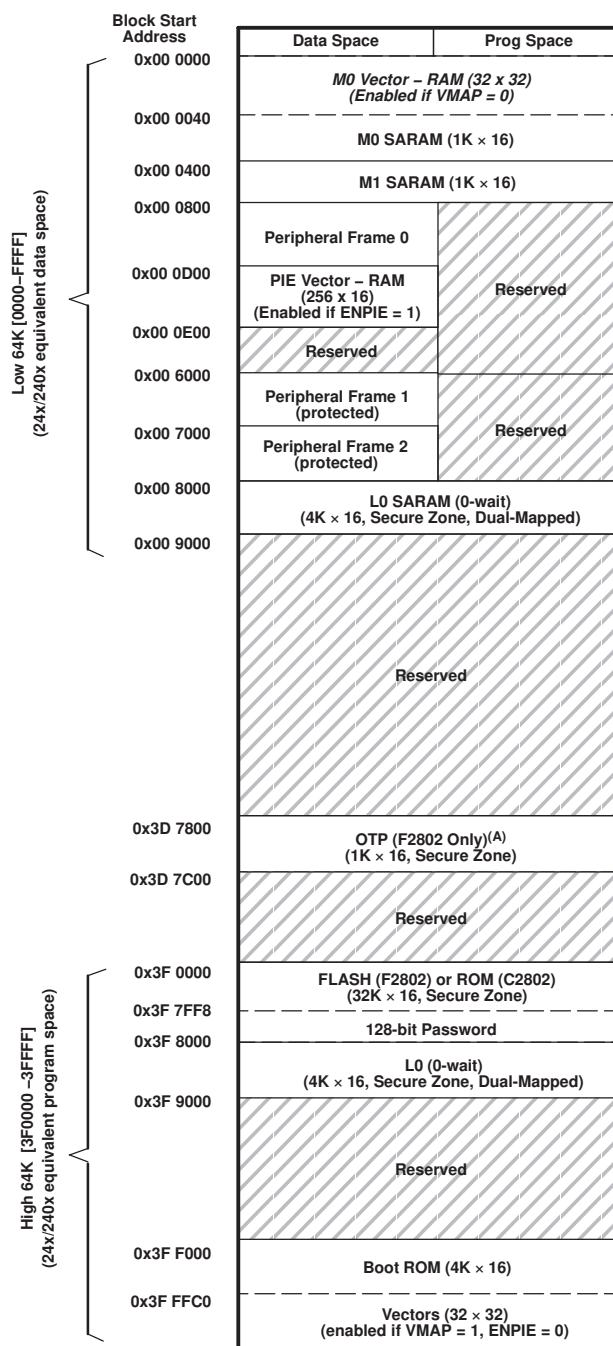
- Memory blocks are not to scale.
- Peripheral Frame 0, Peripheral Frame 1, and Peripheral Frame 2 memory maps are restricted to data memory only. User program cannot access these memory maps in program space.
- Protected* means the order of Write followed by Read operations is preserved rather than the pipeline order.
- Certain memory ranges are EALLOW protected against spurious writes after configuration.

Figure 6-19. F2808 Memory Map



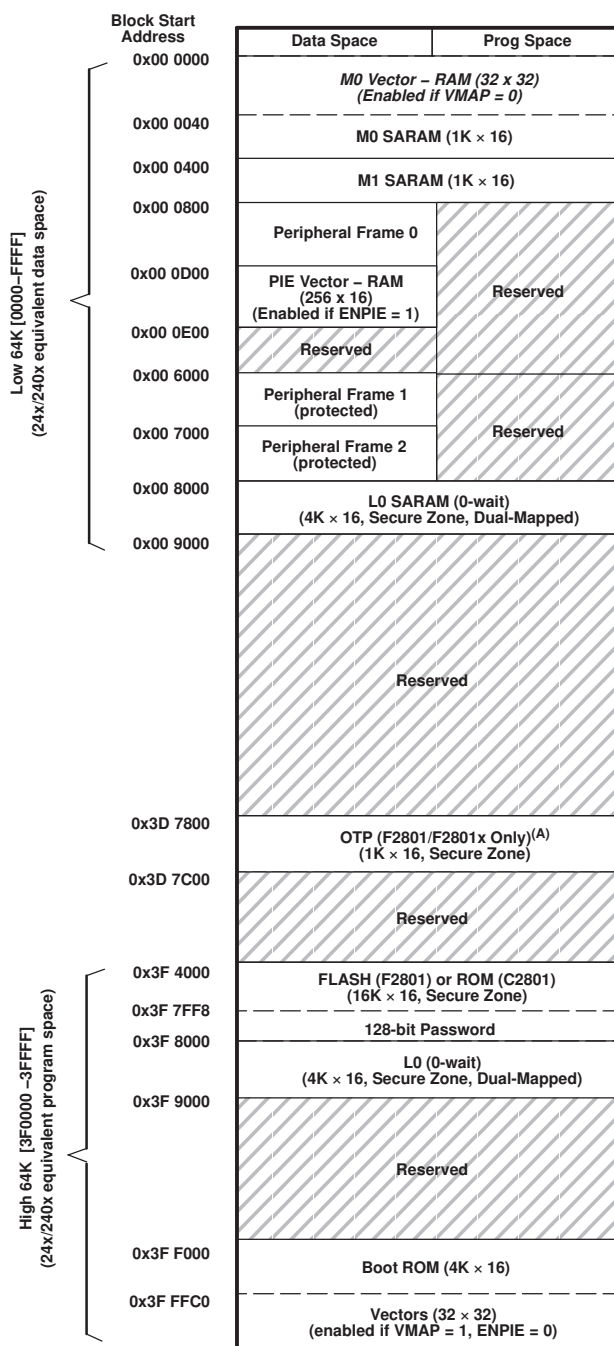
- Memory blocks are not to scale.
- Peripheral Frame 0, Peripheral Frame 1, and Peripheral Frame 2 memory maps are restricted to data memory only. User program cannot access these memory maps in program space.
- Protected* means the order of Write followed by Read operations is preserved rather than the pipeline order.
- Certain memory ranges are EALLOW protected against spurious writes after configuration.

Figure 6-20. F2806 Memory Map



- The 1K x 16 OTP has been replaced with 1K x 16 ROM in C2802.
- Memory blocks are not to scale.
- Peripheral Frame 0, Peripheral Frame 1, and Peripheral Frame 2 memory maps are restricted to data memory only. 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.
- Certain memory ranges are EALLOW protected against spurious writes after configuration.
- Some locations in ROM are reserved for TI. See [Table 6-22](#) for more information.

Figure 6-21. F2802, C2802 Memory Map



- A. The 1K x 16 OTP has been replaced with 1K x 16 ROM in C2801.
- B. Memory blocks are not to scale.
- C. Peripheral Frame 0, Peripheral Frame 1, and Peripheral Frame 2 memory maps are restricted to data memory only. User program cannot access these memory maps in program space.
- D. *Protected* means the order of Write followed by Read operations is preserved rather than the pipeline order.
- E. Certain memory ranges are EALLOW protected against spurious writes after configuration.
- F. Some locations in ROM are reserved for TI. See [Table 6-22](#) for more information.

Figure 6-22. F2801, F28015, F28016, C2801 Memory Map

Table 6-18. Addresses of Flash Sectors in F2809

| ADDRESS RANGE | PROGRAM AND DATA SPACE |
|-----------------------|--|
| 0x3D 8000 – 0x3D BFFF | Sector H (16K x 16) |
| 0x3D C000 – 0x3D FFFF | Sector G (16K x 16) |
| 0x3E 0000 – 0x3E 3FFF | Sector F (16K x 16) |
| 0x3E 4000 – 0x3E 7FFF | Sector E (16K x 16) |
| 0x3E 8000 – 0x3E BFFF | Sector D (16K x 16) |
| 0x3E C000 – 0x3E FFFF | Sector C (16K x 16) |
| 0x3F 0000 – 0x3F 3FFF | Sector B (16K x 16) |
| 0x3F 4000 – 0x3F 7F7F | Sector A (16K x 16) |
| 0x3F 7F80 – 0x3F 7FF5 | Program to 0x0000 when using the Code Security Module |
| 0x3F 7FF6 – 0x3F 7FF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x3F 7FF8 – 0x3F 7FFF | Security Password (128-Bit) (Do not program to all zeros) |

Table 6-19. Addresses of Flash Sectors in F2808

| ADDRESS RANGE | PROGRAM AND DATA SPACE |
|-----------------------|--|
| 0x3E 8000 – 0x3E BFFF | Sector D (16K x 16) |
| 0x3E C000 – 0x3E FFFF | Sector C (16K x 16) |
| 0x3F 0000 – 0x3F 3FFF | Sector B (16K x 16) |
| 0x3F 4000 – 0x3F 7F7F | Sector A (16K x 16) |
| 0x3F 7F80 – 0x3F 7FF5 | Program to 0x0000 when using the Code Security Module |
| 0x3F 7FF6 – 0x3F 7FF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x3F 7FF8 – 0x3F 7FFF | Security Password (128-Bit) (Do not program to all zeros) |

Table 6-20. Addresses of Flash Sectors in F2806, F2802

| ADDRESS RANGE | PROGRAM AND DATA SPACE |
|-----------------------|--|
| 0x3F 0000 – 0x3F 1FFF | Sector D (8K x 16) |
| 0x3F 2000 – 0x3F 3FFF | Sector C (8K x 16) |
| 0x3F 4000 – 0x3F 5FFF | Sector B (8K x 16) |
| 0x3F 6000 – 0x3F 7F7F | Sector A (8K x 16) |
| 0x3F 7F80 – 0x3F 7FF5 | Program to 0x0000 when using the Code Security Module |
| 0x3F 7FF6 – 0x3F 7FF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x3F 7FF8 – 0x3F 7FFF | Security Password (128-Bit) (Do not program to all zeros) |

Table 6-21. Addresses of Flash Sectors in F2801, F28015, F28016

| ADDRESS RANGE | PROGRAM AND DATA SPACE |
|-----------------------|--|
| 0x3F 4000 – 0x3F 4FFF | Sector D (4K x 16) |
| 0x3F 5000 – 0x3F 5FFF | Sector C (4K x 16) |
| 0x3F 6000 – 0x3F 6FFF | Sector B (4K x 16) |
| 0x3F 7000 – 0x3F 7F7F | Sector A (4K x 16) |
| 0x3F 7F80 – 0x3F 7FF5 | Program to 0x0000 when using the Code Security Module |
| 0x3F 7FF6 – 0x3F 7FF7 | Boot-to-Flash Entry Point (program branch instruction here) |
| 0x3F 7FF8 – 0x3F 7FFF | Security Password (128-Bit) (Do not program to all zeros) |

NOTE

- When the code-security passwords are programmed, all addresses between 0x3F7F80 and 0x3F7FF5 cannot be used as program code or data. These locations must be programmed to 0x0000.
- If the code security feature is not used, addresses 0x3F7F80 through 0x3F7FEF may be used for code or data. Addresses 0x3F7FF0 – 0x3F7FF5 are reserved for data and should not contain program code.
- On ROM devices, addresses 0x3F7FF0 – 0x3F7FF5 and 0x3D7BFC – 0x3D7BFF are reserved for TI, irrespective of whether code security has been used or not. User application should not use these locations in any way.

Table 6-22 shows how to handle these memory locations.

Table 6-22. Impact of Using the Code Security Module

| ADDRESS | FLASH | | ROM | |
|-----------------------|---------------------------|---------------------------|------------------------------|---------------------------|
| | Code security enabled | Code security disabled | Code security enabled | Code security disabled |
| 0x3F 7F80 – 0x3F 7FEF | Fill with 0x0000 | Application code and data | Fill with 0x0000 | Application code and data |
| 0x3F 7FF0 – 0x3F 7FF5 | | Reserved for data only | | |
| 0x3D 7BFC – 0x3D 7BFF | Application code and data | | Reserved for TI. Do not use. | |

Peripheral Frame 1 and Peripheral Frame 2 are grouped together so as 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 6-23](#).

Table 6-23. Wait-states

| AREA | WAIT-STATES | COMMENTS |
|--------------------|-----------------------------------|---|
| M0 and M1 SARAMs | 0-wait | Fixed |
| Peripheral Frame 0 | 0-wait | Fixed |
| Peripheral Frame 1 | 0-wait (writes) 2-wait (reads) | Fixed. The eCAN peripheral can extend a cycle as needed. Back-to-back writes will introduce a 1-cycle delay. |
| Peripheral Frame 2 | 0-wait (writes) 2-wait (reads) | Fixed |
| L0 and L1 SARAMs | 0-wait | |
| OTP | Programmable, 1-wait minimum | Programmed via the Flash registers. 1-wait-state operation is possible at a reduced CPU frequency. See Section 6.1.5 for more information. |
| Flash | Programmable, 0-wait minimum | Programmed via the Flash registers. 0-wait-state operation is possible at reduced CPU frequency. The CSM password locations are hardwired for 16 wait-states. See Section 6.1.5 for more information. |
| H0 SARAM | 0-wait | Fixed |
| Boot-ROM | 1-wait | Fixed |

6.4 Register Map

The 280x devices contain three 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 6-24 . |
| Peripheral Frame 1 | These are peripherals that are mapped to the 32-bit peripheral bus. See Table 6-25 . |
| Peripheral Frame 2: | These are peripherals that are mapped to the 16-bit peripheral bus. See Table 6-26 . |

Table 6-24. Peripheral Frame 0 Registers^{(1) (2)}

| NAME | ADDRESS RANGE | SIZE (x16) | ACCESS TYPE ⁽³⁾ |
|------------------------------------|-----------------|------------|-----------------------------------|
| Device Emulation Registers | 0x0880 – 0x09FF | 384 | EALLOW protected |
| FLASH Registers ⁽⁴⁾ | 0x0A80 – 0x0ADF | 96 | EALLOW protected CSM Protected |
| Code Security Module Registers | 0x0AE0 – 0x0AEF | 16 | EALLOW protected |
| ADC Result Registers (dual-mapped) | 0x0B00 – 0x0B0F | 16 | Not EALLOW protected |
| CPU-TIMER0/1/2 Registers | 0x0C00 – 0x0C3F | 64 | Not EALLOW protected |
| PIE Registers | 0x0CE0 – 0x0CFF | 32 | Not EALLOW protected |
| PIE Vector Table | 0x0D00 – 0x0DFF | 256 | EALLOW protected |

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

(2) Missing segments of memory space are reserved and should not be used in applications.

(3) 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.

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

Table 6-25. Peripheral Frame 1 Registers^{(1) (2)}

| NAME | ADDRESS RANGE | SIZE (x16) | ACCESS TYPE |
|---|-----------------|------------|---|
| eCANA Registers | 0x6000 – 0x60FF | 256 | Some eCAN control registers (and selected bits in other eCAN control registers) are EALLOW-protected. |
| eCANA Mailbox RAM | 0x6100 – 0x61FF | 256 | Not EALLOW-protected |
| eCANB Registers | 0x6200 – 0x62FF | 256 | Some eCAN control registers (and selected bits in other eCAN control registers) are EALLOW-protected. |
| eCANB Mailbox RAM | 0x6300 – 0x63FF | 256 | Not EALLOW-protected |
| ePWM1 Registers | 0x6800 – 0x683F | 64 | Some ePWM registers are EALLOW protected. See Table 6-3 . |
| ePWM2 Registers | 0x6840 – 0x687F | 64 | |
| ePWM3 Registers | 0x6880 – 0x68BF | 64 | |
| ePWM4 Registers | 0x68C0 – 0x68FF | 64 | |
| ePWM5 Registers | 0x6900 – 0x693F | 64 | |
| ePWM6 Registers | 0x6940 – 0x697F | 64 | |
| eCAP1 Registers | 0x6A00 – 0x6A1F | 32 | Not EALLOW protected |
| eCAP2 Registers | 0x6A20 – 0x6A3F | 32 | |
| eCAP3 Registers | 0x6A40 – 0x6A5F | 32 | |
| eCAP4 Registers | 0x6A60 – 0x6A7F | 32 | |
| eQEP1 Registers | 0x6B00 – 0x6B3F | 64 | |
| eQEP2 Registers | 0x6B40 – 0x6B7F | 64 | |
| GPIO Control Registers | 0x6F80 – 0x6FBF | 128 | EALLOW protected |
| GPIO Data Registers | 0x6FC0 – 0x6FDF | 32 | Not EALLOW protected |
| GPIO Interrupt and LPM Select Registers | 0x6FE0 – 0x6FFF | 32 | EALLOW protected |

(1) The eCAN control registers only support 32-bit read/write operations. All 32-bit accesses are aligned to even address boundaries.

(2) Missing segments of memory space are reserved and should not be used in applications.

Table 6-26. Peripheral Frame 2 Registers^{(1) (2)}

| NAME | ADDRESS RANGE | SIZE (x16) | ACCESS TYPE |
|------------------------------|-----------------|------------|----------------------|
| System Control Registers | 0x7010 – 0x702F | 32 | EALLOW Protected |
| SPI-A Registers | 0x7040 – 0x704F | 16 | Not EALLOW Protected |
| SCI-A Registers | 0x7050 – 0x705F | 16 | |
| External Interrupt Registers | 0x7070 – 0x707F | 16 | |
| ADC Registers | 0x7100 – 0x711F | 32 | |
| SPI-B Registers | 0x7740 – 0x774F | 16 | |
| SCI-B Registers | 0x7750 – 0x775F | 16 | |
| SPI-C Registers | 0x7760 – 0x776F | 16 | |
| SPI-D Registers | 0x7780 – 0x778F | 16 | |
| I2C Registers | 0x7900 – 0x792F | 48 | |

(1) Peripheral Frame 2 only allows 16-bit accesses. All 32-bit accesses are ignored (invalid data may be returned or written).

(2) Missing segments of memory space are reserved and should not be used in applications.

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 6-27](#).

Table 6-27. Device Emulation Registers

| NAME | ADDRESS RANGE | SIZE (x16) | DESCRIPTION | |
|-----------|------------------|------------|---|---|
| DEVICECNF | 0x0880 0x0881 | 2 | Device Configuration Register | |
| PARTID | 0x0882 | 1 | Part ID Register | 0x002C ⁽¹⁾ - F2801 0x0024 - F2802 0x0034 - F2806 0x003C - F2808 0x00FE - F2809 0x0014 - F28016 0x001C - F28015 0xFF2C - C2801 0xFF24 - C2802 |
| REVID | 0x0883 | 1 | Revision ID Register | 0x0000 - Silicon Rev. 0 - TMX 0x0001 - Silicon Rev. A - TMX 0x0002 - Silicon Rev. B - TMS 0x0003 - Silicon Rev. C - TMS |
| | | | Revision ID Register | 0x0000 - Silicon rev. 0 - TMS (F2809 only) 0x0001 - Silicon rev. A - TMS (F2809 only) |
| PROTSTART | 0x0884 | 1 | Block Protection Start Address Register | |
| PROTRANGE | 0x0885 | 1 | Block Protection Range Address Register | |

(1) The first byte (00) denotes flash devices. FF denotes ROM devices. Other values are reserved for future devices.

6.5 Interrupts

[Figure 6-23](#) shows how the various interrupt sources are multiplexed within the 280x devices.

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 280x, 43 of these are used by peripherals as shown in [Table 6-28](#).

The TRAP #VectorNumber instruction transfers program control to the interrupt service routine corresponding to the vector specified. TRAP #0 attempts 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 through 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.

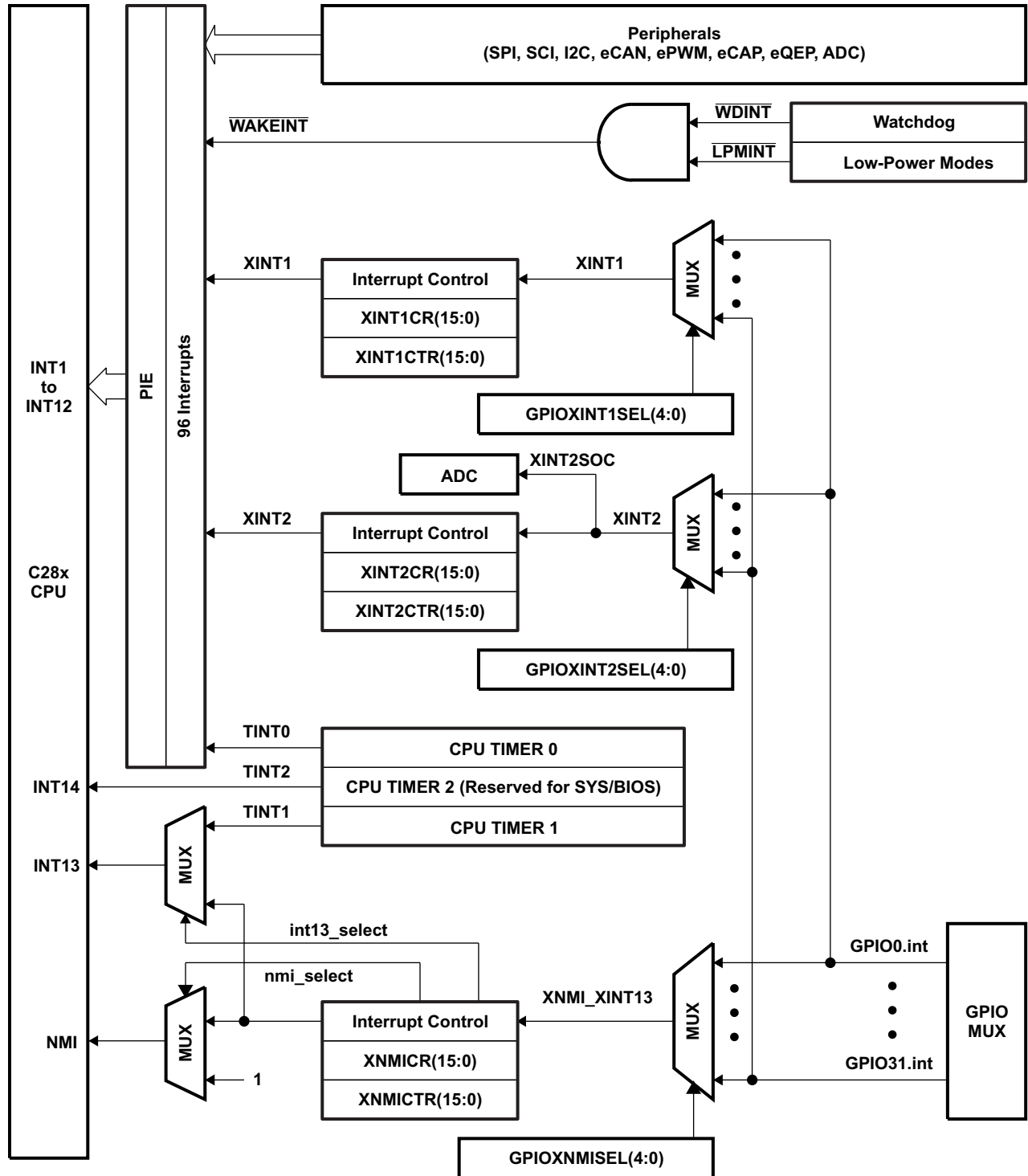


Figure 6-23. External and PIE Interrupt Sources

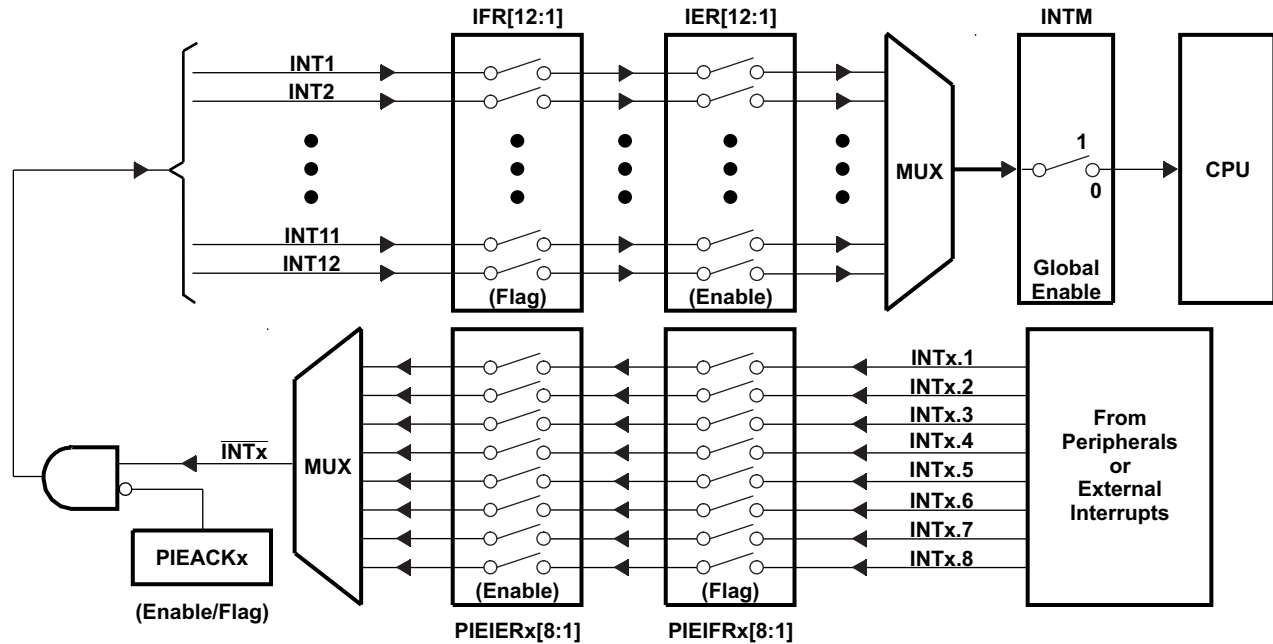


Figure 6-24. Multiplexing of Interrupts Using the PIE Block

Table 6-28. PIE Peripheral Interrupts⁽¹⁾

| 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 ⁽²⁾ (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 | Reserved | Reserved | 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 | SPITXINTD (SPI-D) | SPIRXINTD (SPI-D) | SPITXINTC (SPI-C) | SPIRXINTC (SPI-C) | SPITXINTB (SPI-B) | SPIRXINTB (SPI-B) | SPITXINTA (SPI-A) | SPIRXINTA (SPI-A) |
| INT7 | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved |
| INT8 | Reserved | Reserved | Reserved | Reserved | 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 | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved |

- (1) Out of the 96 possible interrupts, 43 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 12).
- (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 6-29. PIE Configuration and Control Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION ⁽¹⁾ |
|----------|--------------------|------------|----------------------------------|
| 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

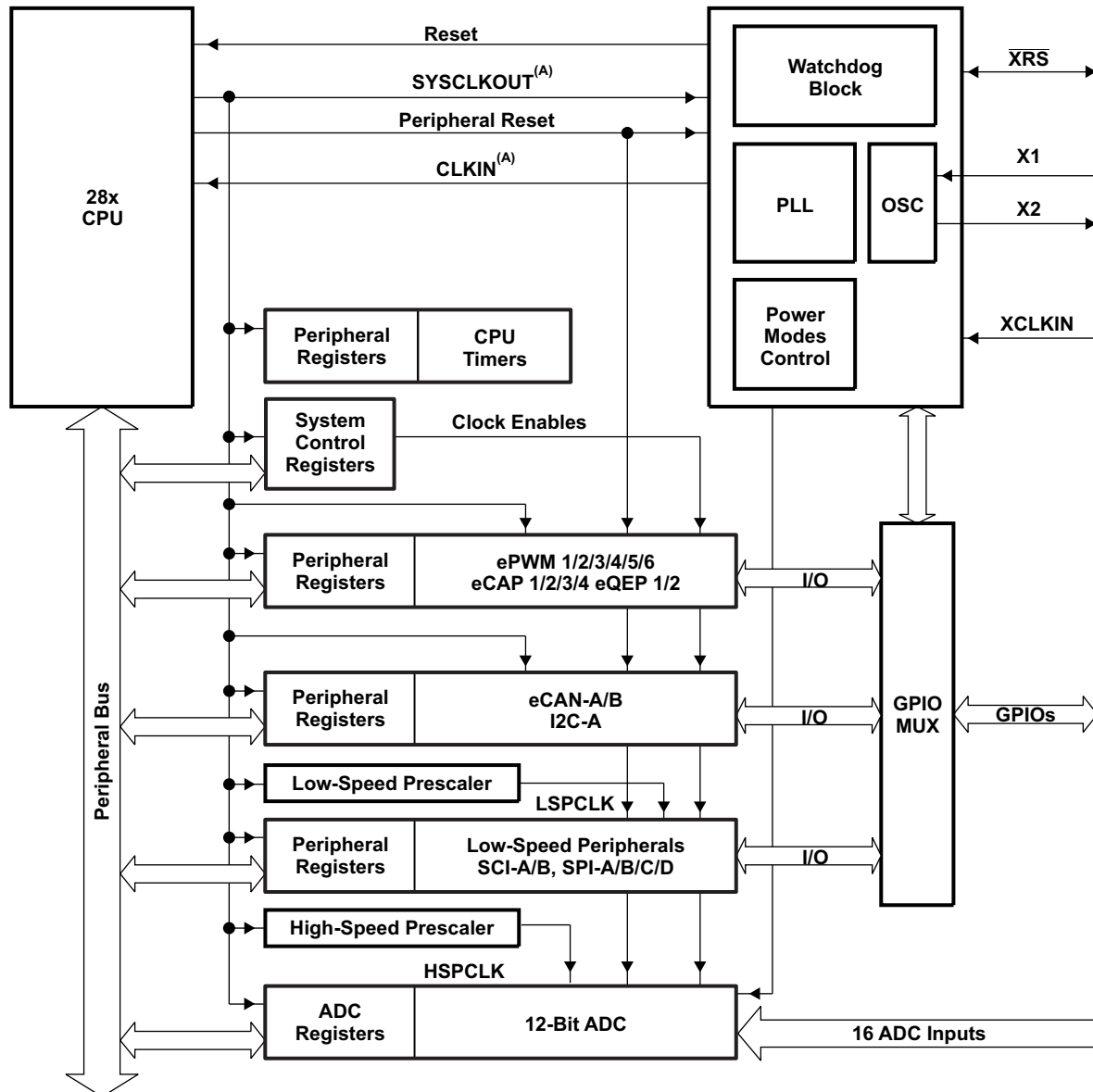
Table 6-30. External Interrupt Registers

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION |
|----------|-----------------|------------|------------------------|
| XINT1CR | 0x7070 | 1 | XINT1 control register |
| XINT2CR | 0x7071 | 1 | XINT2 control register |
| Reserved | 0x7072 – 0x7076 | 5 | Reserved |
| XNMICR | 0x7077 | 1 | XNMI control register |
| XINT1CTR | 0x7078 | 1 | XINT1 counter register |
| XINT2CTR | 0x7079 | 1 | XINT2 counter register |
| Reserved | 0x707A – 0x707E | 5 | Reserved |
| XNMICTR | 0x707F | 1 | XNMI counter register |

Each external interrupt can be enabled/disabled or qualified using positive, negative, or both positive and negative edge. For more information, see the [TMS320x280x, 2801x, 2804x DSP system control and interrupts reference guide](#).

6.6 System Control

This section describes the 280x oscillator, PLL and clocking mechanisms, the watchdog function and the low power modes. Figure 6-25 shows the various clock and reset domains in the 280x devices 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).

Figure 6-25. Clock and Reset Domains

The PLL, clocking, watchdog and low-power modes, are controlled by the registers listed in [Table 6-31](#).

Table 6-31. PLL, Clocking, Watchdog, and Low-Power Mode Registers⁽¹⁾

| NAME | ADDRESS | SIZE (x16) | DESCRIPTION |
|----------|-----------------|------------|---|
| XCLK | 0x7010 | 1 | XCLKOUT Pin Control, X1 and XCLKIN Status Register |
| PLLSTS | 0x7011 | 1 | PLL Status Register |
| Reserved | 0x7012 – 0x7019 | 8 | Reserved |
| HISPCP | 0x701A | 1 | High-Speed Peripheral Clock Prescaler Register (for HSPCLK) |
| LOSPCP | 0x701B | 1 | Low-Speed Peripheral Clock Prescaler Register (for LSPCLK) |
| PCLKCR0 | 0x701C | 1 | Peripheral Clock Control Register 0 |
| PCLKCR1 | 0x701D | 1 | Peripheral Clock Control Register 1 |
| LPMCR0 | 0x701E | 1 | Low-Power Mode Control Register 0 |
| Reserved | 0x701F – 0x7020 | 1 | Reserved |
| PLLCR | 0x7021 | 1 | PLL Control Register |
| SCSR | 0x7022 | 1 | System Control and Status Register |
| WDCNTR | 0x7023 | 1 | Watchdog Counter Register |
| Reserved | 0x7024 | 1 | Reserved |
| WDKEY | 0x7025 | 1 | Watchdog Reset Key Register |
| Reserved | 0x7026 – 0x7028 | 3 | Reserved |
| WDCR | 0x7029 | 1 | Watchdog Control Register |
| Reserved | 0x702A – 0x702F | 6 | Reserved |

(1) All of the registers in this table are EALLOW protected.

6.6.1 OSC and PLL Block

Figure 6-26 shows the OSC and PLL block on the 280x.

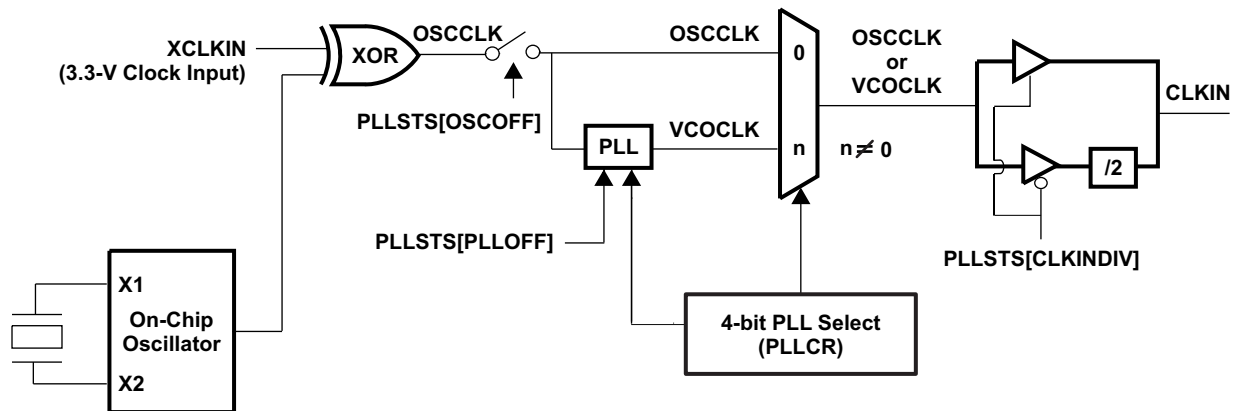


Figure 6-26. OSC and PLL Block Diagram

The on-chip oscillator circuit enables a crystal/resonator to be attached to the 280x 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:

1. 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} .
2. A 1.8-V 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 6-27 through Figure 6-29.

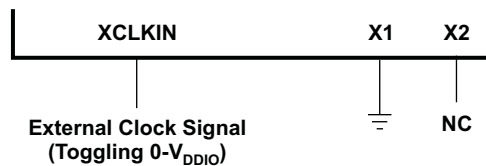


Figure 6-27. Using a 3.3-V External Oscillator

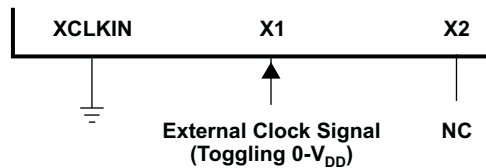


Figure 6-28. Using a 1.8-V External Oscillator

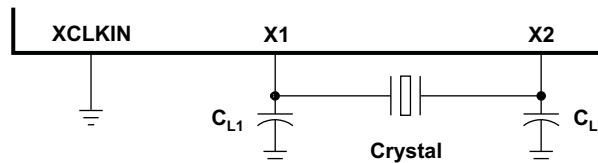


Figure 6-29. Using the Internal Oscillator

6.6.1.1 External Reference Oscillator Clock Option

The typical specifications for the external quartz crystal for a frequency of 20 MHz are listed below:

- Fundamental mode, parallel resonant
- C_L (load capacitance) = 12 pF
- $C_{L1} = C_{L2} = 24$ pF
- $C_{shunt} = 6$ pF
- ESR range = 30 to 60 Ω

TI recommends that customers have the resonator/crystal vendor characterize the operation of their device with the DSP 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 280x 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.

Table 6-32. PLLCR Register Bit Definitions

| PLLCR[DIV] ⁽¹⁾ | SYSCLKOUT (CLKIN) ⁽²⁾ |
|---------------------------|----------------------------------|
| 0000 (PLL bypass) | OSCCLK/n |
| 0001 | (OSCCLK*1)/n |
| 0010 | (OSCCLK*2)/n |
| 0011 | (OSCCLK*3)/n |
| 0100 | (OSCCLK*4)/n |
| 0101 | (OSCCLK*5)/n |
| 0110 | (OSCCLK*6)/n |
| 0111 | (OSCCLK*7)/n |
| 1000 | (OSCCLK*8)/n |
| 1001 | (OSCCLK*9)/n |
| 1010 | (OSCCLK*10)/n |
| 1011–1111 | Reserved |

(1) This register is EALLOW protected.

(2) CLKIN is the input clock to the CPU. SYSCLKOUT is the output clock from the CPU. The frequency of SYSCLKOUT is the same as CLKIN. If CLKINDIV = 0, n = 2; if CLKINDIV = 1, n = 1.

NOTE

PLLSTS[CLKINDIV] enables or bypasses the divide-by-two block before the clock is fed to the core. This bit must be 0 before writing to the PLLCR and must only be set after PLLSTS[PLLLOCKS] = 1.

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 6-33. Possible PLL Configuration Modes

| PLL MODE | REMARKS | PLLSTS[CLKINDIV] | SYSCCLKOUT (CLKIN) |
|------------|--|------------------|--------------------|
| PLL Off | Invoked by the user setting the PLLOFF 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 | OSCCLK/2 |
| | | 1 | OSCCLK |
| 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 | OSCCLK/2 |
| | | 1 | OSCCLK |
| PLL Enable | Achieved by writing a non-zero value n into the PLLCR register. Upon writing to the PLLCR the device will switch to PLL Bypass mode until the PLL locks. | 0 | 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.

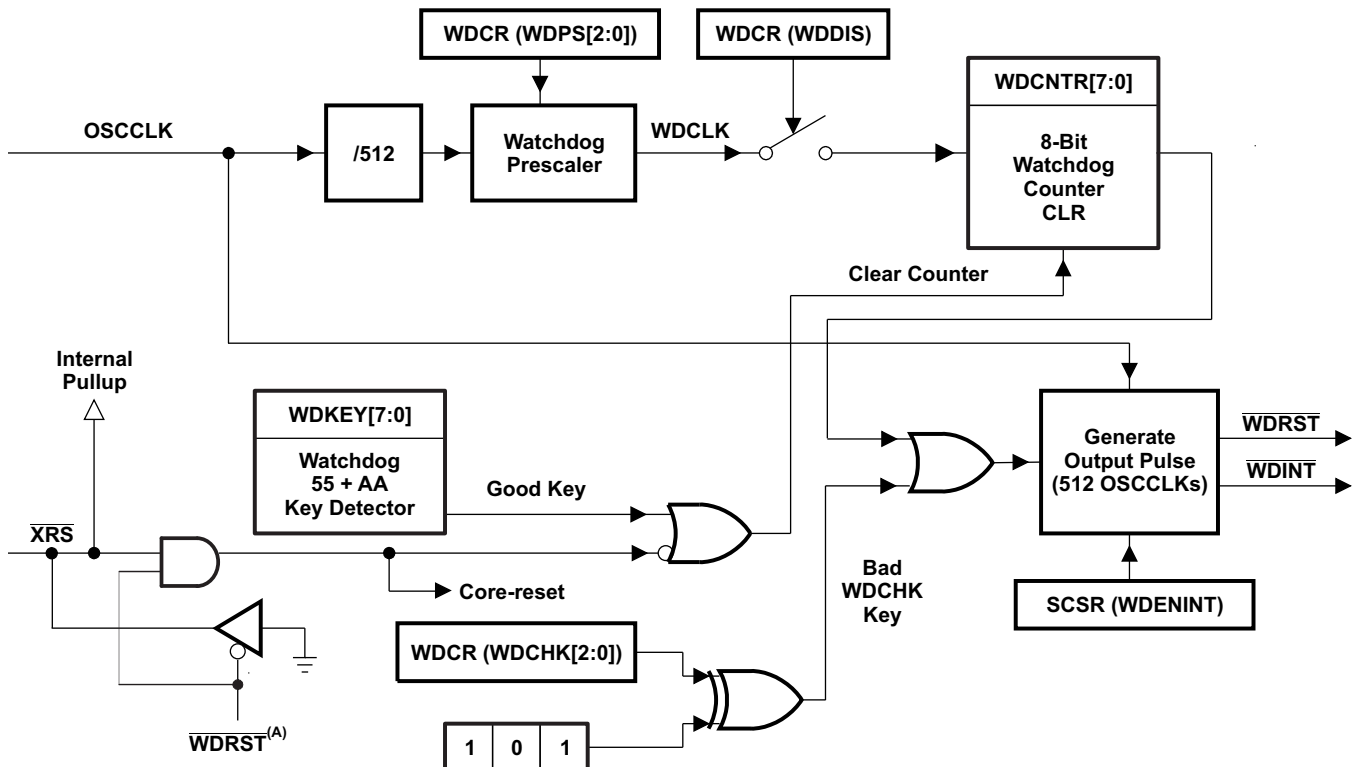
Normally, when the input clocks are present, the watchdog counter decrements to initiate a watchdog reset or WDINT interrupt. However, when the external input clock fails, the watchdog counter stops decrementing (that is, the watchdog counter does not change with the limp-mode clock). In addition to 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 DSP will be held in reset, should the input clocks ever fail. For example, an R-C circuit may be used to trigger the XRS pin of the DSP, 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 in detecting failure of the flash memory and the V_{DD3VFL} rail.

6.6.2 Watchdog Block

The watchdog block on the 280x 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 6-30](#) shows the various functional blocks within the watchdog module.



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

Figure 6-30. 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 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, via 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 280x are similar to the 240x devices. [Table 6-34](#) summarizes the various modes.

Table 6-34. Low-Power Modes

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

- (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 GPIOLPMSEL 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 GPIOLPMSEL 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 [TMS320x280x, 2801x, 2804x DSP system control and interrupts reference guide](#) for more details.

7 Applications, Implementation, and Layout

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

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](#).

8 器件和文档支持

8.1 开始使用

这一部分提供了当为一个 C28x 器件进行首次开发时所采取步骤的简要概括。有关这些步骤的详细情况，请参阅：

- [C2000 实时控制 MCU – 入门](#)
- [C2000 实时控制 MCU – 工具与软件](#)

步骤 1. 获得合适的开发工具

使用一个 C28x 器件开始工作的最快速的方法就是获得一个 eZdsp™ 套件来进行初始开发，此套件，在一个包装内包括：

- 借助 USB 或者并行端口实现的板载 JTAG 仿真
- 合适的仿真驱动器
- Code Composer Studio™ 用于 eZdsp 的 IDE

一旦您已经熟悉此器件并在您自己的硬件上开始开发时，请分别购买 Code Composer Studio™ IDE 用于软件开发和一个 JTAG 仿真工具来启动您的项目。

步骤 2. 下载入门软件

为了简化 C28x 器件的编程，建议用户下载并使用 C/C++ 头文件和示例来开始下载用于 C28x 和它们外设的软件。

为您的器件下载合适的头文件包之后，参考以下资源来获得分步指令以指导您如何为您自己的软件运行外设示例和使用头文件结构。

- /doc 目录下内的快速启动请先读我文件来运行您的第一个应用。
- [《使用 C/C++ 对 TMS320x28xx 和 28xxx 外设进行编程》应用报告](#)

步骤 3. 下载闪存编程软件

很多 C28x 器件包括片上闪存存储器和工具，此工具允许您使用您的软件 IP 来编辑闪存。

- 闪存工具：C28xx 闪存工具
- [《TMS320F281x™ 闪存编程解决方案》](#)
- [《在 TMS320F28xxx DSP 上运行来自内部闪存存储器的应用》](#)

步骤 4. 转到更多高级主题

如需了解更多应用软件和其他高级主题，请访问 [C2000 实时控制 MCU – 工具和软件](#)。

8.2 器件和开发支持工具命名规则

为了标明产品开发周期的阶段，TI 为所有 TMS320™DSP 器件和支持工具的部件号指定了前缀。每一个 TMS2808™ DSP 商用系列成员产品具有以下三个前缀中的一个：TMX，TMP，或者 TMS（例如，TMS320F2808）。德州仪器（TI）建议为其支持的工具使用三个可能前缀指示符中的两个：TMDX 和 TMDS。这些前缀代表了产品开发的发展阶段，即从工程原型（TMX/TMDX）直到完全合格的生产器件/工具（TMS/TMDS）。

器件开发进化流程：

- TMX** 试验器件，不一定代表最终器件的电气规格
- TMP** 最终硅片，符合器件的电气规格，但是未完成质量和可靠性验证
- TMS** 完全合格的生产器件

支持工具开发发展流程：

- TMDX** 还未经完整的德州仪器（TI）内部质量测试的开发支持工具
- TMDS** 完全合格的开发支持产品

TMX 和 TMP 器件和 TMDX 开发支持工具出货时带有如下的免责声明：
“开发产品用于内部评估用途。”

TMS 器件和 TMDS 开发支持工具已进行完全特性描述，并且器件的质量和可靠性已经完全论证。TI 的标准保修证书适用。

预测显示原型器件（TMX 或者 TMP）的故障率大于标准生产器件。由于它们的预计的最终使用故障率仍未定义，德州仪器建议不要将这些器件用于任何生产系统。只有合格的产品器件将被使用。

TI 器件的命名规则还包括一个带有器件系列名称的后缀。这个后缀表明封装类型（例如，PZ）和温度范围（如，S）。图 8-1 提供了解读任一系列产品成员的完整器件名称的图例。

有关器件部件号和详细的订购信息，请参阅封装选项附录、访问 TI 网站 (www.ti.com.cn) 或联系您的 TI 销售代表。

有关裸片器件命名规则标记的其他说明，请参阅 [TMS320F280x](#)、[TMS320C280x](#)、[TMS320F2801x](#) DSP 器件勘误表。

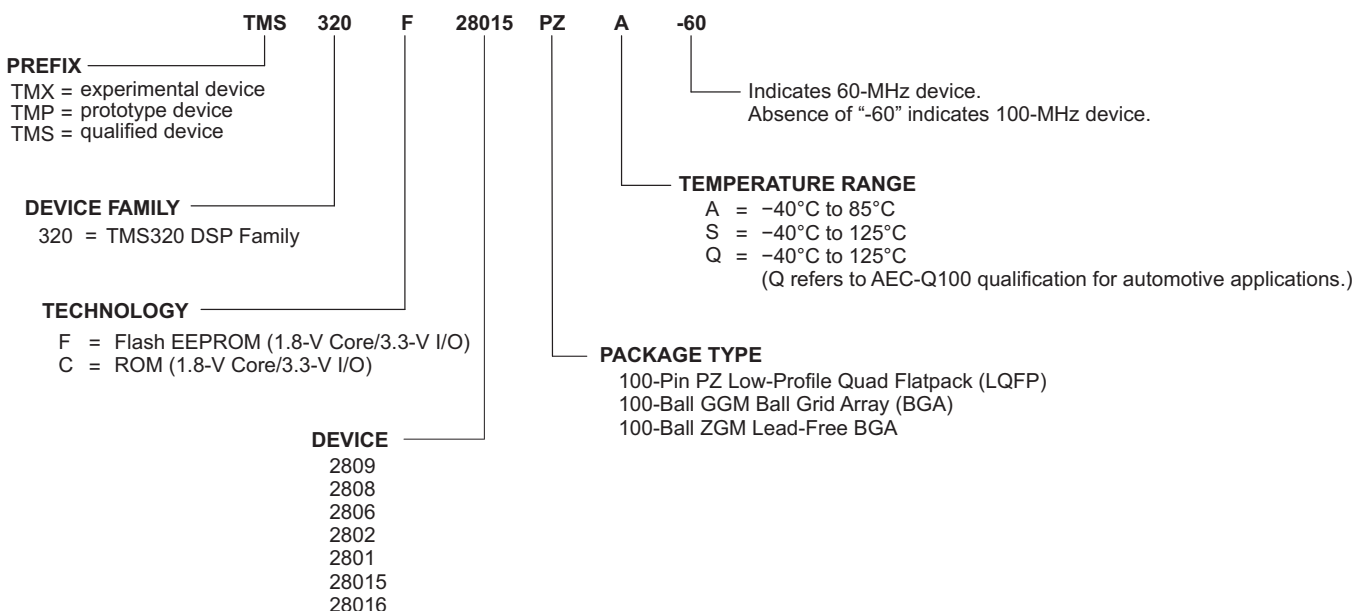


图 8-1. TMS320x280x/2801x 器件命名规则示例

8.3 工具与软件

TI 提供大量的开发工具。下面列出了部分用于评估器件性能、生成代码和开发解决方案的工具和软件。要查看所有可用的工具和软件，请访问每个器件的“工具与软件”页面，见表 8-1。

软件

C28x IQMath 库 - 虚拟浮点引擎

德州仪器 (TI) 的 TMS320C28x IQmath 库是经过高度优化的高精度数学函数集合，能让 C/C++ 编程人员将浮点算法无缝嵌入 TMS320C28x 器件上的定点代码中。这些例程通常用于计算密集型实时应用，而优化的执行速度和高精度是影响这些实时应用的关键因素。通过使用这些例程，您可以获得比使用标准 ANSI C 语言编写的等效代码更快的执行速度。另外，通过提供即用型高精度函数，TI IQmath 库可以显著缩短 DSP 应用开发时间。（在解压和安装该文件后，请在 /docs 文件夹中找到 IQMath 用户指南）。

C280x、C2801x C/C++ 头文件和外设示例

此实用工具包括适用于 TMS320x280x 和 TMS320x280xx DSP 器件的硬件抽象层 (HAL)。该 HAL 使用“C”语言简化了外设配置。它还包含适用于每个外设的简单测试计划，用于说明如何使用 HAL 对片上外设进行控制和配置。

开发工具

C2000 Gang 编程器

C2000 Gang 编程器是一款 C2000 器件编程器，可同时对多达 8 个相同的 C2000 器件进行编程。C2000 Gang 编程器可使用标准的 RS-232 或 USB 连接与主机 PC 相连，并提供灵活的编程选项，允许用户完全自定义流程。

用于 C2000 微控制器的 Code Composer Studio™ (CCS) 集成开发环境 (IDE)

Code Composer Studio 是支持 TI 的微控制器和嵌入式处理器产品系列的集成开发环境 (IDE)。Code Composer Studio 包含一整套用于开发和调试嵌入式应用的工具的工具。它包含了优化的 C/C++ 编译器、源代码编辑器、项目构建环境、调试器、描述器以及其他多种功能。直观的 IDE 提供了单一用户界面，可帮助用户完成应用开发流程的每个步骤。熟悉的工具和界面使用户能够比以前更快地入手。Code Composer Studio 将 Eclipse 软件框架的优点和 TI 先进的嵌入式调试功能相结合，为嵌入式开发人员提供了一种功能丰富的优异开发环境。

Uniflash 独立闪存工具

CCS Uniflash 是一个独立的工具，用于在 TI MCU 上对片上闪存存储器进行编程。

模型

您可以从产品的“工具与软件”页面下载各种模型。这些模型包括 I/O 缓冲器信息规范 (IBIS) 模型和边界扫描说明语言 (BSDL) 模型。要查看所有可用的模型，请访问每个器件的“工具与软件”页面的“模型”部分，具体链接见表 8-1。

8.4 文档支持

如需接收文档更新通知, 请访问 ti.com.cn 上的器件产品文件夹。单击右上角的通知我进行注册, 即可每周接收产品信息更改摘要。有关更改的详细信息, 请查看任何已修订文档中包含的修订历史记录。

下面列出了介绍处理器、相关外设以及其他配套技术资料的最新文档。

勘误表

[TMS320F280x、TMS320C280x、TMS320F2801x DSP 器件勘误表](#) 针对不同版本的器件提供了报告和使用说明。

CPU 用户指南

《[TMS320C28x CPU 和指令集参考指南](#)》介绍了 TMS320C28x 定点数字信号处理器 (DSP) 的中央处理器 (CPU) 和汇编语言指令。它还介绍了这些 DSP 上提供的仿真特性。

《[TMS320x280x、2801x、2804x DSP 系统控制和中断参考指南](#)》介绍了 280x 数字信号处理器 (DSP) 的各种中断和系统控制特性。

外设指南

《[C2000 实时控制外设参考指南](#)》介绍了 28x 数字信号处理器 (DSP) 的外设参考指南。

《[TMS320x280x、2801x、2804x DSP 模数转换器 \(ADC\) 参考指南](#)》介绍了如何配置和使用片上 ADC 模块 (12 位管线型 ADC)。

《[TMS320x280x、2801x、2804x 增强型脉宽调制器 \(ePWM\) 模块参考指南](#)》介绍了增强型脉宽调制器的主要应用领域, 包括数字电机控制、开关模式电源控制、UPS (不间断电源) 和其它形式的电力转换。

《[TMS320x280x、2801x、2804x 增强型正交编码器脉冲 \(eQEP\) 模块参考指南](#)》介绍了 eQEP 模块, 该模块用于连接线性或旋转增量编码器, 以便从高性能运动和位置控制系统的旋转机器中获得位置、方向和速度信息。它包含模块说明和寄存器。

《[TMS320x280x、2801x、2804x 增强型捕捉 \(eCAP\) 模块参考指南](#)》介绍了增强型捕捉模块。它包含模块说明和寄存器。

《[TMS320x280x、2801x、2804x 高分辨率脉宽调制器 \(HRPWM\) 参考指南](#)》介绍了脉宽调制器高分辨率扩展件 (HRPWM) 的操作。

《[TMS320x280x/2801x 增强型控制器局域网 \(eCAN\) 参考指南](#)》介绍了 x280x 和 x2801x 器件上的增强型控制器局域网 (eCAN)。

《[TMS320x280x、2801x、2804x 串行通信接口 \(SCI\) 参考指南](#)》介绍了 TMS320x280x、2801x、2804x 器件上串行通信接口 (SCI) 模块的特性和操作。

《[TMS320x280x、2801x、2804x 串行外设接口参考指南](#)》介绍了串行外设接口如何工作。

《[TMS320x280x、2801x、2804x 内部集成电路 \(I2C\) 模块参考指南](#)》介绍了内部集成电路 (I2C) 模块的特性与操作。

《[TMS320x280x、2801x、2804x 引导 ROM 参考指南](#)》介绍了引导加载程序 (工厂编程的引导加载软件) 的作用和特性。它还介绍了器件的片上引导 ROM 的其它内容, 并识别了所有信息在该存储器内的位置。

工具指南

《[TMS320C28x 汇编语言工具 v18.12.0.LTS 用户指南](#)》介绍了用于 TMS320C28x 器件的汇编语言工具（用于开发汇编语言代码的汇编程序和其他工具）、汇编器指令、宏、通用目标文件格式和符号调试指令。

《[TMS320C28x 优化 C/C++ 编译器 v18.12.0.LTS 用户指南](#)》介绍了 TMS320C28x C/C++ 编译器。此编译器接受 ANSI 标准 C/C++ 源代码，并为 TMS320C28x 器件生成 TMS320 DSP 汇编语言源代码。

《[TMS320C28x DSP/BIOS 5.x 应用编程接口 \(API\) 参考指南](#)》介绍了如何使用 DSP/BIOS 进行开发。

应用报告

《[TMS320x281x 至 TMS320x2833x 或 2823x 的迁移概述](#)》介绍了如何从 281x 器件设计迁移至 2833x 或 2823x 设计。

《[TMS320x280x 至 TMS320x2833x 或 2823x 的迁移概述](#)》介绍了如何从 280x 器件设计迁移至 2833x 或 2823x 设计。

《[TMS320C28x FPU 入门](#)》概括介绍了 2000™ Delfino 微控制器器件中的浮点单元 (FPU)。

《[在 TMS320F28xxx DSP 上运行一个来自内部闪存存储器的应用](#)》介绍了要对来自片上闪存存储器的应用程序进行正确的执行配置所需达到的要求。提供了对 DSP/BIOS 和非 DSP/BIOS 项目的要求。包括示例代码项目。

《[使用 C/C++ 来对 TMS320x28xx 和 28xxx 外设进行编程](#)》介绍了一种硬件抽象层实施，这可以使在 28x DSP 上进行 C/C++ 编码变得更简单。文中将此方法与传统的 #define 宏进行了比较，还提到了代码效率和特例寄存器方面的问题。

《[在 TMS320F280x 数字信号控制器上将 PWM 输出用作数模转换器](#)》介绍了一种将 TMS320F280x 系列数字信号控制器上的片上脉宽调制 (PWM) 信号生成器用作数模转换器 (DAC) 的方法。

《[使用 TUSB3410 USB 转 UART 桥接芯片实现的 TMS320F280x 数字信号控制器 USB 连接](#)》介绍了如何使用简单的通信回传程序实现开发系统的硬件连接和软件准备与运行。

《[将 TMS320x280x/28xxx 中的增强型正交编码器脉冲 \(eQEP\) 模块用作专用捕捉单元](#)》介绍了如何将 eQEP 模块用作专用捕捉单元且该操作适用于 TMS320x280x/28xxx 系列处理器。

《[使用 ePWM 模块实现 0% - 100% 占空比控制](#)》介绍了如何使用 ePWM 模块提供 0% 至 100% 占空比控制且该操作适用于 TMS320x280x 系列处理器。

《[TMS320x280x 和 TMS320F2801x ADC 校准](#)》介绍了一种提高 TMS320x280x 和 TMS320F2801x 器件上的 12 位 ADC 的绝对精度的方法。固有增益和偏移误差会影响 ADC 的绝对精度。这份报告中描述的方法能够改进 ADC 的绝对精度到好于 0.5% 的水平。这份应用报告有一个选项来下载一个示例程序，此程序从 F2808 EzDSP 上的 RAM 执行。

《[在 TMS320C28x DSP 上进行在线堆栈溢出检测](#)》介绍了在 TMS320C28x DSP 上进行在线堆栈溢出检测的方法。文中提供了 C 源代码，包括在 DSP/BIOS 和非 DSP/BIOS 应用上实施溢出检测的函数。

《[TMS320x281x 至 TMS320x280x 迁移概述](#)》介绍了德州仪器 (TI) TMS320x281x 和 TMS320x280x/2801x/2804x DSP 之间的差异，以帮助用户进行应用迁移。

《[半导体封装方法](#)》介绍了准备向最终用户发货时半导体器件所用的封装方法。

《[IBIS \(I/O 缓冲器信息规范\) 建模简介](#)》讨论了 IBIS 的各个方面，包括其历史、优势、兼容性、模型生成流程、输入/输出结构建模中的数据要求以及未来趋势。

《[计算嵌入式处理器的有效使用寿命](#)》介绍了如何计算 TI 嵌入式处理器 (EP) 在电子系统中运行时的有效使用寿命。本文档的目标读者为希望确定 TI EP 的可靠性是否符合终端系统可靠性要求的总工程师。

《[半导体和 IC 封装热指标](#)》介绍了传统和全新的热指标，并将它们应用于系统级结温估算方面。

《[计算任务剖面的 FIT](#)》说明了如何使用 TI 的可靠性降额工具计算系统任务剖面在加电条件下的组件级 FIT。

《[C2000™ 微控制器串行闪存编程](#)》介绍了如何使用闪存内核和 ROM 加载程序对器件进行串行编程。

8.5 相关链接

下表列出了快速访问链接。类别包括技术文档、支持和社区资源、工具和软件，以及立即订购快速访问。

表 8-1. 相关链接

| 器件 | 产品文件夹 | 立即订购 | 技术文档 | 工具与软件 | 支持和社区 |
|--------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| TMS320F2809 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320F2808 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320F2806 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320F2802 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320F2801 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320C2802 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320C2801 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320F28016 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |
| TMS320F28015 | 单击此处 | 单击此处 | 单击此处 | 单击此处 | 单击此处 |

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, 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 商标

Code Composer Studio, MicroStar BGA, Delfino, TMS320C2000, TMS320, 用于 C2000 微控制器的 Code Composer Studio, E2E are trademarks of Texas Instruments.
eZdsp is a trademark of Spectrum Digital.
All other trademarks are the property of their respective owners.

8.8 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

8.9 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

9 机械、封装和可订购信息

9.1 封装信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此数据表的浏览器版本，请查阅左侧的导航栏。

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|-------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TMS320C2801PZA | NRND | LQFP | PZ | 100 | | TBD | Call TI | Call TI | | | |
| TMS320C2802PZA | NRND | LQFP | PZ | 100 | | TBD | Call TI | Call TI | | | |
| TMS320F28015NMFA | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | TMS320 F28015NMFA | Samples |
| TMS320F28015PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F28015PZA TMS | Samples |
| TMS320F28015PZQ | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F28015PZQ TMS | Samples |
| TMS320F28015PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F28015PZS TMS | Samples |
| TMS320F28015PZSR | ACTIVE | LQFP | PZ | 100 | 1000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F28015PZS TMS | Samples |
| TMS320F28016PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F28016PZA TMS | Samples |
| TMS320F28016PZQ | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F28016PZQ TMS | Samples |
| TMS320F28016PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F28016PZS TMS | Samples |
| TMS320F2801NMFA | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | TMS320 F2801NMFA | Samples |
| TMS320F2801PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2801PZA TMS | Samples |
| TMS320F2801PZA-60 | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2801PZA-60 TMS | Samples |
| TMS320F2801PZQ | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2801PZQ TMS | Samples |
| TMS320F2801PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2801PZS TMS | Samples |
| TMS320F2801PZS-60 | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2801PZS-60 TMS | Samples |
| TMS320F2802PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2802PZA TMS | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|-------------------|---------------|--------------|--------------------|------|----------------|---------------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TMS320F2802PZA-60 | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2802PZA-60 TMS | Samples |
| TMS320F2802PZQ | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2802PZQ TMS | Samples |
| TMS320F2802PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2802PZS TMS | Samples |
| TMS320F2802PZS-60 | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2802PZS-60 TMS | Samples |
| TMS320F2806NMFA | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | TMS320 F2806NMFA | Samples |
| TMS320F2806NMFAR | ACTIVE | NFBGA | NMF | 100 | 1000 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | TMS320 F2806NMFA | Samples |
| TMS320F2806NMFS | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 125 | TMS320 F2806NMFS | Samples |
| TMS320F2806PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2806PZA TMS | Samples |
| TMS320F2806PZQ | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2806PZQ TMS | Samples |
| TMS320F2806PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2806PZS TMS | Samples |
| TMS320F2808GBAA | ACTIVE | NFBGA | GBA | 100 | 184 | Non-RoHS & Green | SNPB | Level-3-220C-168 HR | -40 to 85 | TMS320 F2808GBAA | Samples |
| TMS320F2808GBAS | ACTIVE | NFBGA | GBA | 100 | 184 | Non-RoHS & Green | SNPB | Level-3-220C-168 HR | -40 to 125 | TMS320 F2808GBAS | Samples |
| TMS320F2808NMFA | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | TMS320 F2808NMFA | Samples |
| TMS320F2808NMFS | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 125 | TMS320 F2808NMFS | Samples |
| TMS320F2808PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2808PZA TMS | Samples |
| TMS320F2808PZAR | ACTIVE | LQFP | PZ | 100 | 1000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2808PZA TMS | Samples |
| TMS320F2808PZQ | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2808PZQ TMS | Samples |
| TMS320F2808PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2808PZS | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| | | | | | | | | | | TMS | |
| TMS320F2809NMFA | ACTIVE | NFBGA | NMF | 100 | 184 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | TMS320 F2809NMFA | Samples |
| TMS320F2809PZA | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | 320F2809PZA TMS | Samples |
| TMS320F2809PZS | ACTIVE | LQFP | PZ | 100 | 90 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 320F2809PZS TMS | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBsolete: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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OTHER QUALIFIED VERSIONS OF TMS320F2801, TMS320F2801-Q1, TMS320F28015, TMS320F28015-Q1, TMS320F28016, TMS320F28016-Q1, TMS320F2802, TMS320F2802-Q1, TMS320F2806, TMS320F2806-Q1, TMS320F2808, TMS320F2808-Q1, TMS320F2809 :

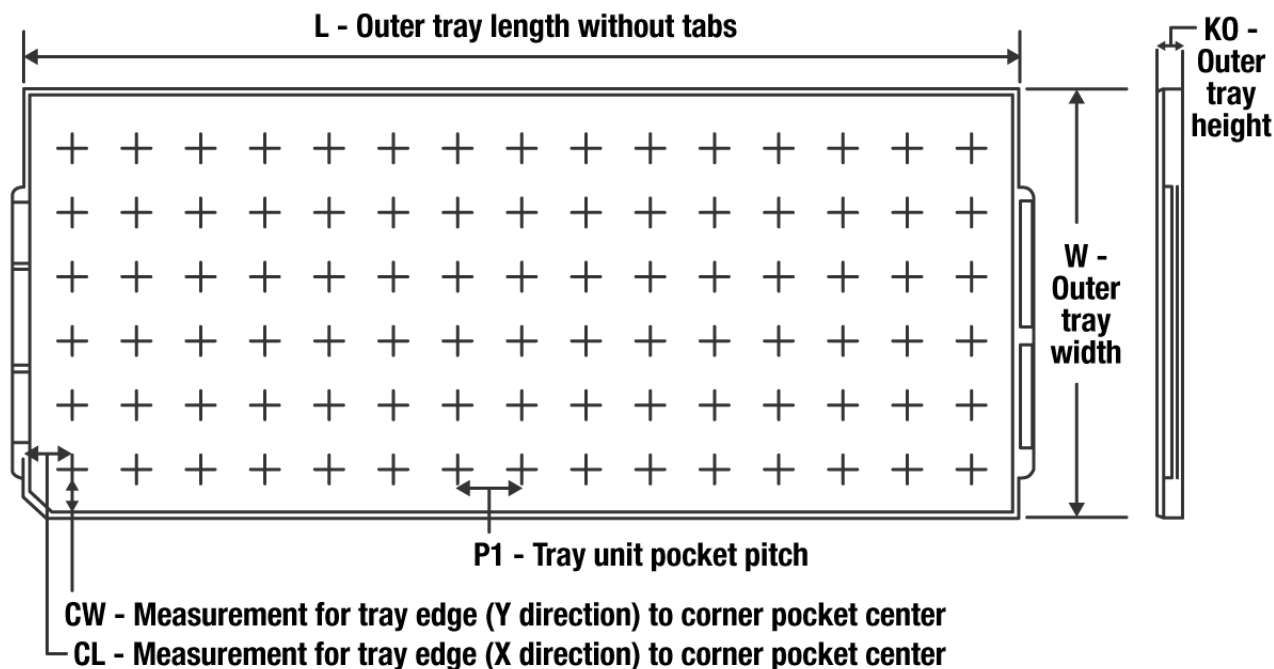
- Catalog : [TMS320F2801](#), [TMS320F28015](#), [TMS320F28016](#), [TMS320F2802](#), [TMS320F2806](#), [TMS320F2808](#)

- Automotive : [TMS320F2801-Q1](#), [TMS320F28015-Q1](#), [TMS320F28016-Q1](#), [TMS320F2802-Q1](#), [TMS320F2806-Q1](#), [TMS320F2808-Q1](#), [TMS320F2809-Q1](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TRAY



Chamfer on Tray corner indicates Pin 1 orientation of packed units.

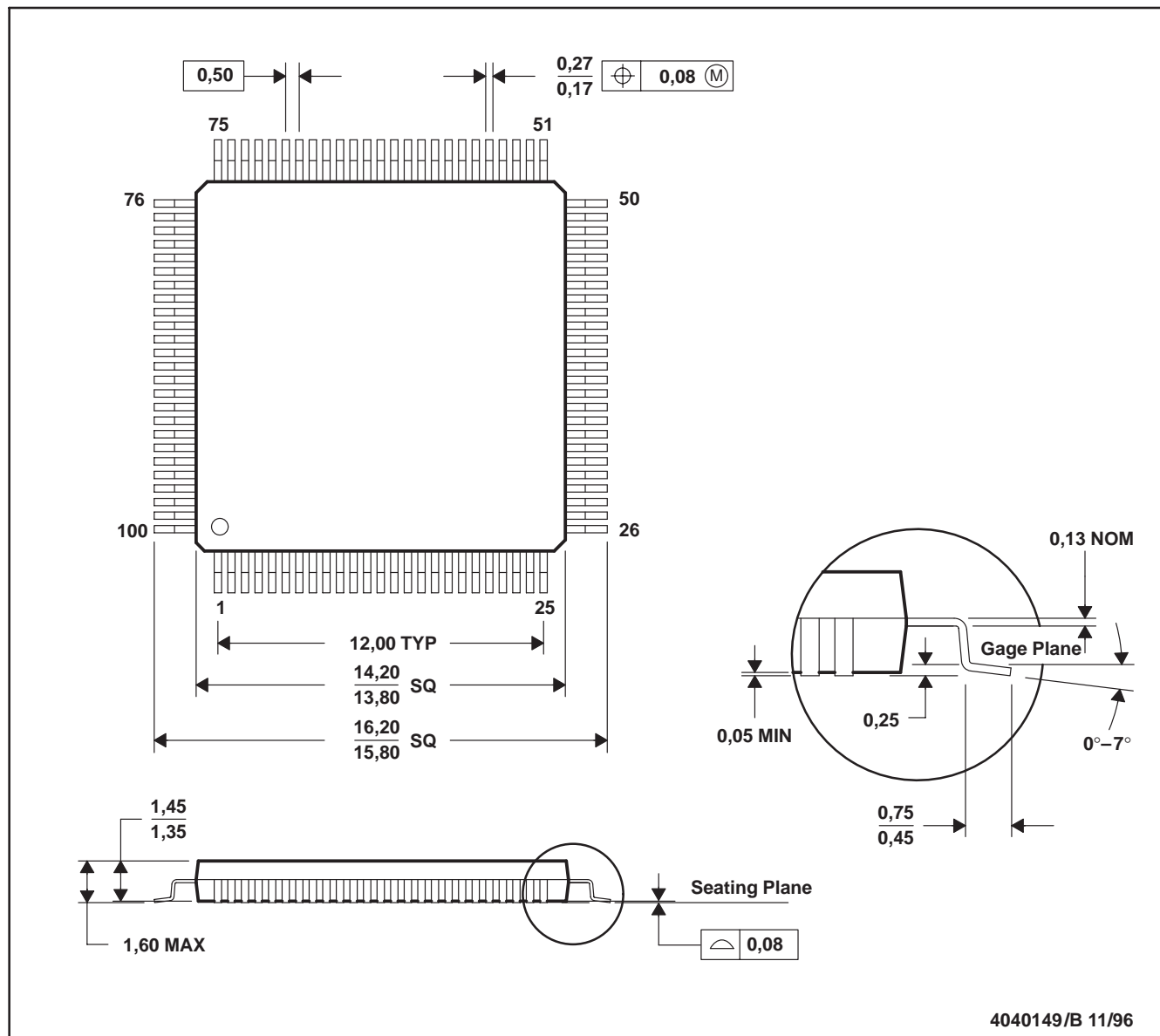
*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (μm) | P1 (mm) | CL (mm) | CW (mm) |
|-------------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| TMS320F28015NMFA | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F28015PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F28015PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F28016PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F28016PZQ | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F28016PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2801NMFA | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2801PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2801PZA-60 | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2801PZQ | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2801PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2801PZS-60 | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2802PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2802PZA-60 | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2802PZQ | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2802PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2802PZS-60 | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |

| Device | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (μm) | P1 (mm) | CL (mm) | CW (mm) |
|-----------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| TMS320F2806NMFA | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2806NMFS | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2806PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2806PZQ | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2806PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2808GBAA | GBA | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2808GBAS | GBA | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2808NMFA | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2808NMFS | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2808PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2808PZQ | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2808PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2809NMFA | NMF | NFBGA | 100 | 184 | 8 x 23 | 150 | 315 | 135.9 | 7620 | 13.4 | 10.1 | 19.65 |
| TMS320F2809PZA | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |
| TMS320F2809PZS | PZ | LQFP | 100 | 90 | 6 x 15 | 150 | 315 | 135.9 | 7620 | 20.3 | 15.4 | 15.4 |

PZ (S-PQFP-G100)

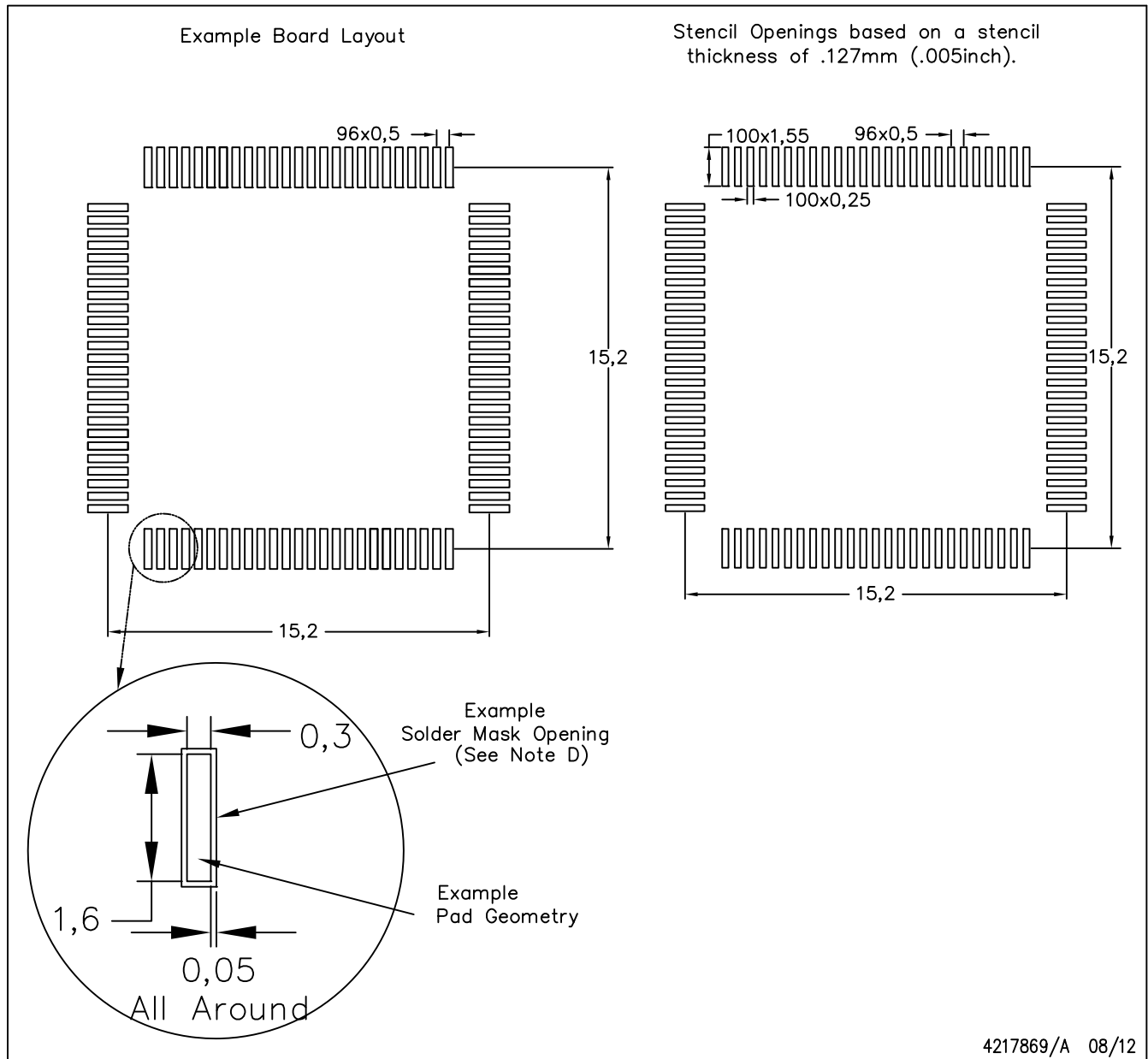
PLASTIC QUAD FLATPACK



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-026

PZ (S-PQFP-G100)

PLASTIC QUAD FLAT PACK

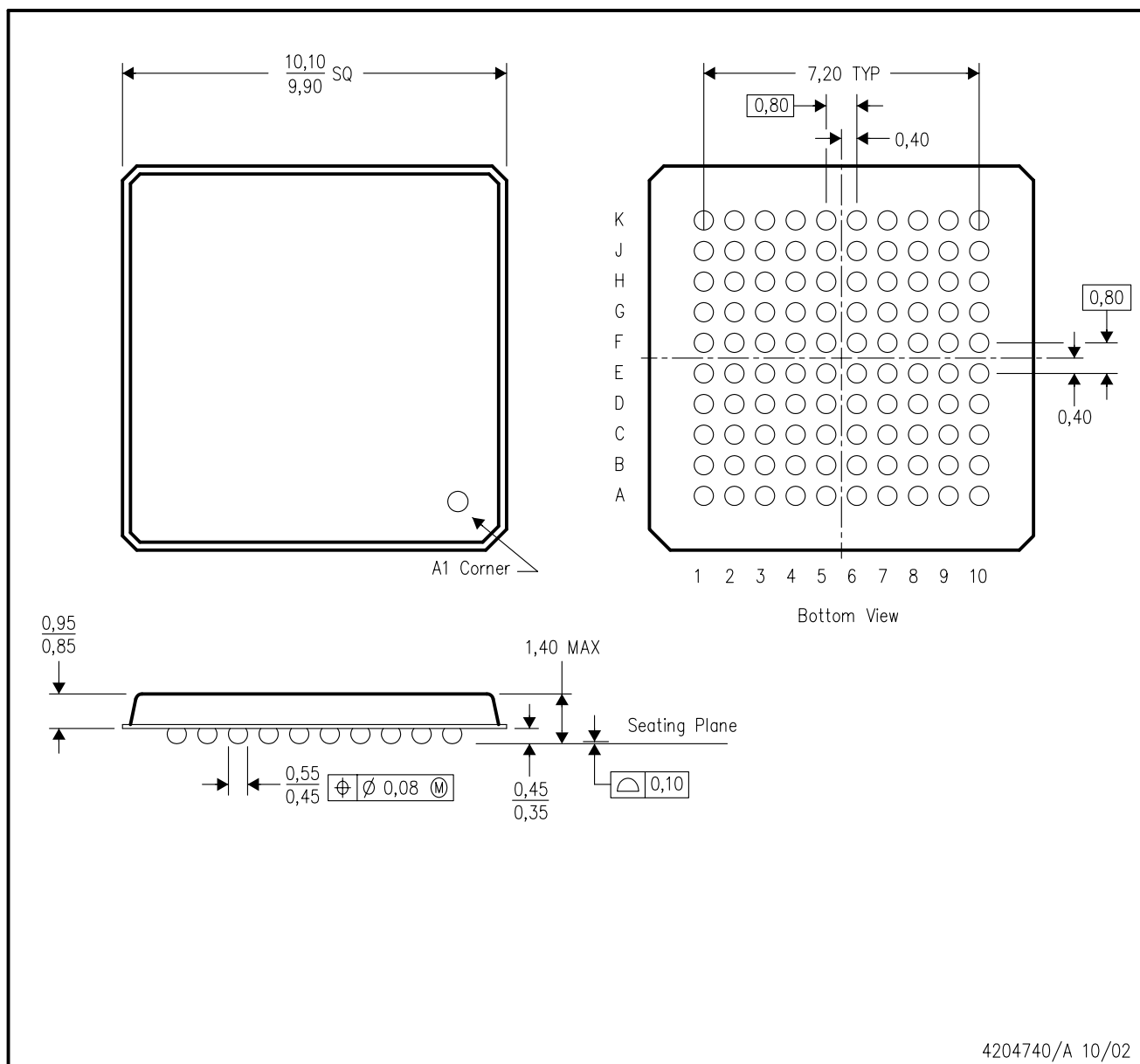


NOTES:

- All linear dimensions are in millimeters.
- This drawing is subject to change without notice.
- 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.

ZGM (S-PBGA-N100)

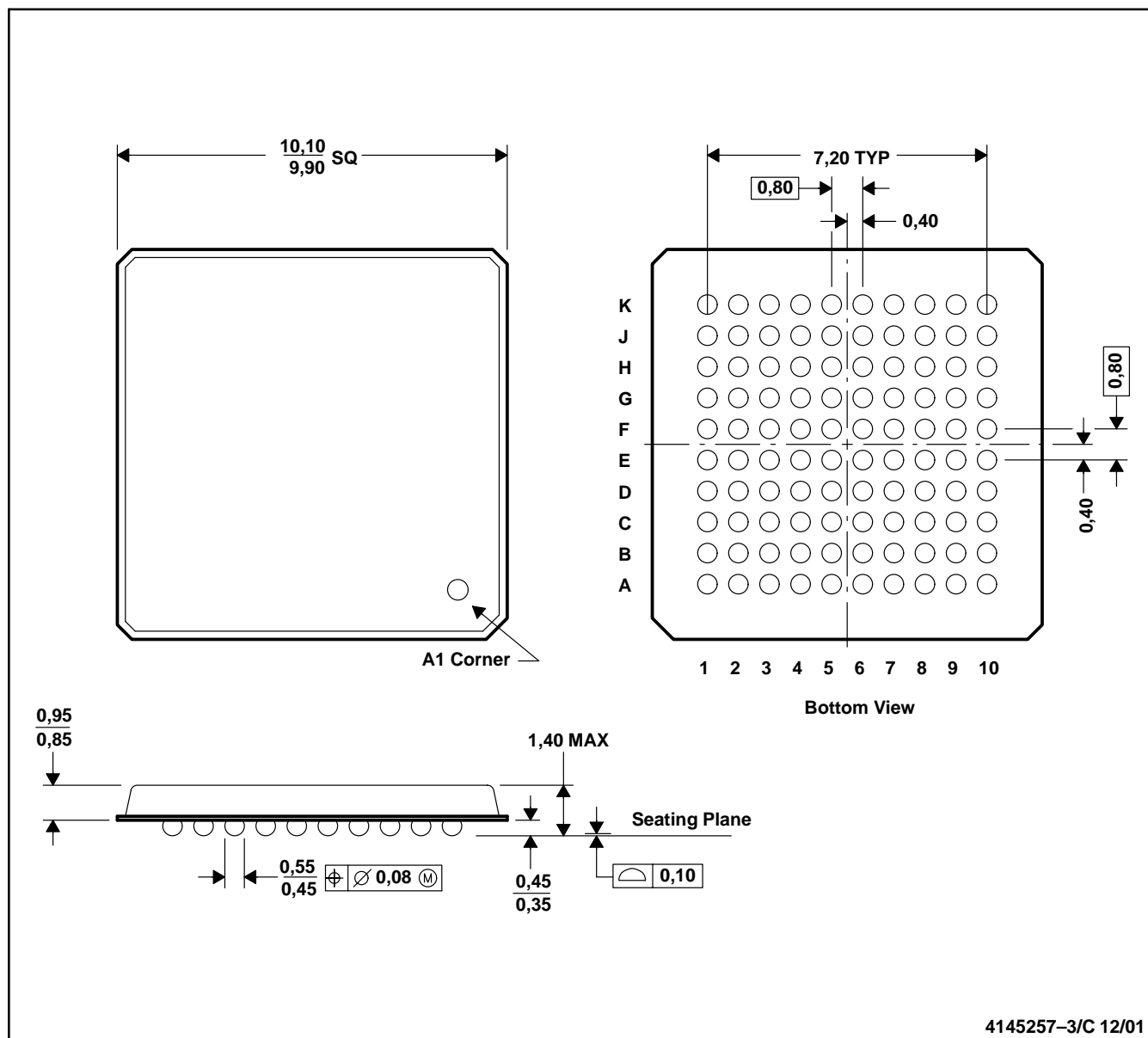
PLASTIC BALL GRID ARRAY



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. MicroStar BGA™ configuration.
 - D. This package is lead-free.

GGM (S-PBGA-N100)

PLASTIC BALL GRID ARRAY



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. MicroStar BGA configuration.

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