



**THE DATASHEET OF
TMS470R1A384PZ-T**



16/32-Bit RISC Flash Microcontroller

FEATURES

- High-Performance Static CMOS Technology
- TMS470R1x 16/32-Bit RISC Core (ARM7TDMI™)
 - 24-MHz System Clock (48-MHz Pipeline)
 - Independent 16/32-Bit Instruction Set
 - Open Architecture With Third-Party Support
 - Built-In Debug Module
- Integrated Memory
 - 384K-Byte Program Flash
 - Three Banks With 18 Contiguous Sectors
 - 32K-Byte Static RAM (SRAM)
- Operating Features
 - Core Supply Voltage (V_{CC}): 1.71 V to 2.05 V
 - I/O Supply Voltage (V_{CCIO}): 3.0 V to 3.6 V
 - Low-Power Modes: STANDBY and HALT
 - Extended Industrial Temperature Range
- 470+ System Module
 - 32-Bit Address Space Decoding
 - Bus Supervision for Memory/Peripherals
 - Analog Watchdog (AWD) Timer
 - Enhanced Real-Time Interrupt (RTI)
 - Interrupt Expansion Module (IEM)
 - System Integrity and Failure Detection
- Direct Memory Access (DMA) Controller
 - 32 Control Packets and 16 Channels
- Zero-Pin Phase-Locked Loop (ZPLL)-Based Clock Module With Prescaler
 - Multiply-by-4 or -8 Internal ZPLL Option
 - ZPLL Bypass Mode
- Expansion Bus Module (EBM) (PGE Package)
 - Supports 8- and 16-Bit Expansion Bus Memory Interface Mappings
 - 40 I/O Expansion Bus Pins
- Ten Communication Interfaces:
 - Two Serial Peripheral Interfaces (SPIs)
 - 255 Programmable Baud Rates
 - Two Serial Communication Interfaces (SCIs)
 - 2²⁴ Selectable Baud Rates
 - Asynchronous/Isosynchronous Modes
 - Two Standard CAN Controllers (SCC)
 - 16-Mailbox Capacity
 - Fully Compliant With CAN Protocol, Version 2.0B
 - Class II Serial Interface B (C2SIb)
 - Normal 10.4 Kbps and 4X Mode 41.6 Kbps
 - Three Inter-Integrated Circuit (I2C) Modules (See I2C Notes in *TMS470R1A384 Silicon Errata*, Literature Number [SPNZ148](#))
 - Multi-Master and Slave Interfaces
 - Up to 400 Kbps (Fast Mode)
 - 7- and 10-Bit Address Capability
- High-End Timer (HET)
 - 12 Programmable I/O Channels:
 - 12 High-Resolution Pins
 - High-Resolution Share Feature (XOR)
 - High-End Timer RAM
 - 64-Instruction Capacity
- External Clock Prescale (ECP) Module
 - Programmable Low-Frequency External Clock (CLK)
- 12-Channel 10-Bit Multi-Buffered Analog-to-Digital Converter (MibADC)
 - 32-Word FIFO Buffer
 - Single- or Continuous-Conversion Modes
 - 1.55- μ s Minimum Sample/Conversion Time
 - Calibration Mode and Self-Test Features
- 55 Dedicated General-Purpose I/O (GIO) Pins and 39 Additional Peripheral I/Os (PGE)
- 14 Dedicated General-Purpose I/O (GIO) Pins and 39 Additional Peripheral I/Os (PZ)
- Flexible Interrupt Handling
- Eight External Interrupts



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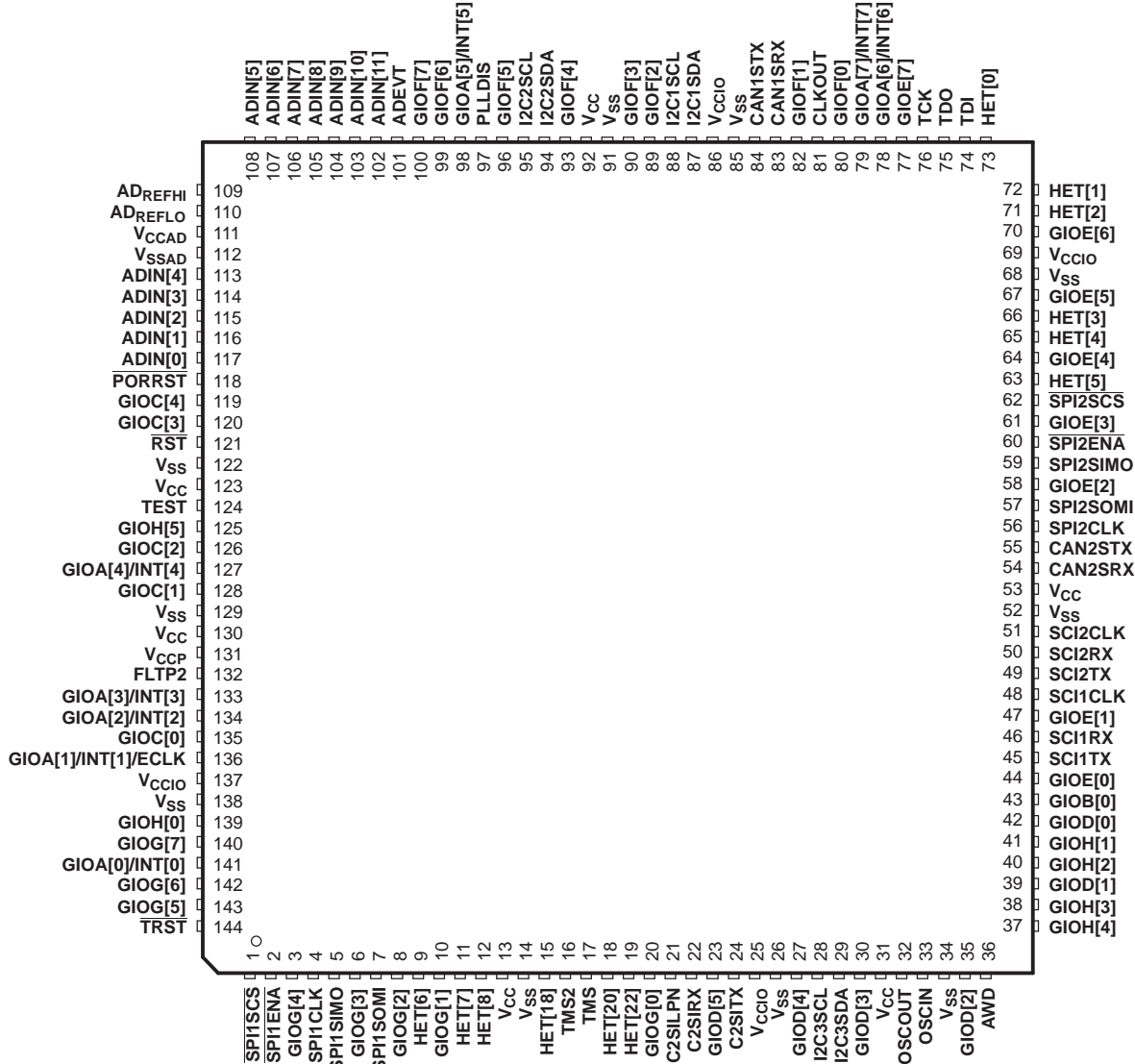
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- On-Chip Scan-Base Emulation Logic, IEEE Standard 1149.1⁽¹⁾ (JTAG) Test-Access Port
- 144-Pin Plastic Low-Profile Quad Flatpack (PGE Suffix)

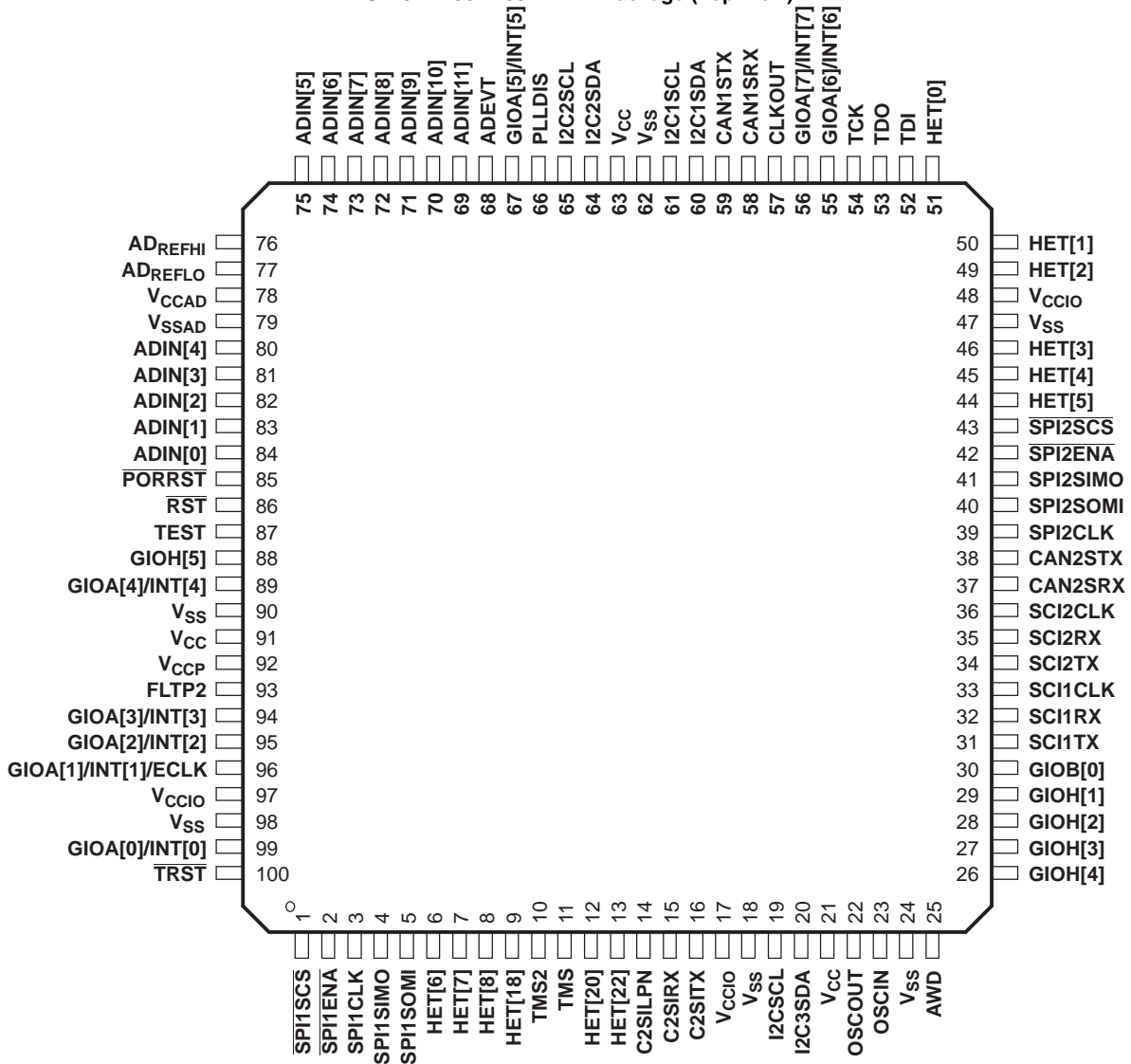
- 100-Pin Plastic Low-Profile Quad Flatpack (PZ Suffix)

(1) The test-access port is compatible with the IEEE Standard 1149.1-1990, IEEE Standard Test-Access Port and Boundary Scan Architecture specification. Boundary scan is not supported on this device.

TMS470R1A384 144-Pin PGE Package (Top View) (Without Expansion Bus)



TMS470R1A384 100-Pin PZ Package (Top View)



DESCRIPTION

The TMS470R1A384⁽¹⁾ devices are members of the Texas Instruments TMS470R1x family of general-purpose 16/32-bit reduced instruction set computer (RISC) microcontrollers. The A384 microcontroller offers high performance utilizing the high-speed ARM7TDMI 16/32-bit RISC central processing unit (CPU), resulting in a high instruction throughput while maintaining greater code efficiency. The ARM7TDMI 16/32-bit RISC CPU views memory as a linear collection of bytes numbered upwards from zero. The A384 utilizes the big-endian format where the most significant byte of a word is stored at the lowest-numbered byte and the least significant byte at the highest-numbered byte.

High-end embedded control applications demand more performance from their controllers while maintaining low costs. The A384 RISC core architecture offers solutions to these performance and cost demands while maintaining low power consumption.

The A384 devices contain the following:

- ARM7TDMI 16/32-bit RISC CPU
- TMS470R1x system module (SYS) with 470+ enhancements
- 384K-byte flash
- 32K-byte SRAM
- Zero-pin phase-locked loop (ZPLL) clock module
- Analog watchdog (AWD) timer
- Enhanced real-time interrupt (RTI) module
- Interrupt expansion module (IEM)
- Two serial peripheral interface (SPI) modules
- Two serial communications interface (SCI) modules
- Two standard CAN controllers (SCC)
- Three inter-integrated circuit (I2C) modules
- Class II serial interface B (C2S1b) module
- 10-bit multi-buffered analog-to-digital converter (MibADC), with 12 input channels
- High-end timer (HET) controlling 12 I/Os
- External clock prescale (ECP)
- Expansion bus module (EBM)
- Up to 87 I/O pins and 1 input-only pin (PGE suffix only), up to 51 I/O pins and 1 input-only pin (PZ suffix only)

The functions performed by the 470+ system module (SYS) include:

- Address decoding
- Memory protection
- Memory and peripherals bus supervision
- Reset and abort exception management
- Prioritization for all internal interrupt sources
- Device clock control
- Parallel signature analysis (PSA)

The enhanced real-time interrupt (RTI) module on the A384 has the option to be driven by the oscillator clock. This data sheet includes device-specific information such as memory and peripheral select assignment, interrupt priority, and a device memory map. For a more detailed functional description of the SYS module, see the *TMS470R1x System Module Reference Guide* (literature number SPNU189).

The A384 memory includes general-purpose SRAM supporting single-cycle read/write accesses in byte, half-word, and word modes.

The flash memory on this device is a nonvolatile, electrically erasable and programmable memory implemented with a 32-bit-wide data bus interface. The flash operates with a system clock frequency of up to 24 MHz. When in pipeline mode, the flash operates with a system clock frequency of up to 48 MHz. For more detailed information on the flash, see the *Flash* section of this data sheet and the *TMS470R1x F05 Flash Reference Guide* (literature number SPNU213).

(1) Throughout the remainder of this document, the TMS470R1A384 is referred to as either the full device name or as A384.

The A384 device has ten communication interfaces: two SPIs, two SCIs, two SCCs, a C2SI, and three I2Cs. The SPI provides a convenient method of serial interaction for high-speed communications between similar shift-register type devices. The SCI is a full-duplex, serial I/O interface intended for asynchronous communication between the CPU and other peripherals using the standard non-return-to-zero (NRZ) format. The SCC uses a serial, multimaster communication protocol that efficiently supports distributed real-time control with robust communication rates of up to 1 megabit per second (Mbps). The SCC is ideal for applications operating in noisy and harsh environments (e.g., industrial fields) that require reliable serial communication or multiplexed wiring. The C2SIb allows the A384 to transmit and receive messages on a class II network following an SAE J1850⁽²⁾ standard. The I2C module is a multi-master communication module providing an interface between the A384 microcontroller and an I2C-compatible device via the I2C serial bus. The I2C supports both 100 Kbps and 400 Kbps speeds. For more detailed functional information on the SPI, SCI, and CAN peripherals, see the specific reference guides (literature numbers [SPNU195](#), [SPNU196](#), and [SPNU197](#)). For more detailed functional information on the I2C, see the *TMS470R1x Inter-Integrated Circuit (I2C) Reference Guide* (literature number SPNU223). For more detailed functional information on the C2SI, see the *TMS470R1x Class II Serial Interface B (C2SIb) Reference Guide* (literature number [SPNU214](#)).

The HET is an advanced intelligent timer that provides sophisticated timing functions for real-time applications. The timer is software-controlled, using a reduced instruction set, with a specialized timer micromachine and an attached I/O port. The HET can be used for compare, capture, or general-purpose I/O. It is especially well suited for applications requiring multiple sensor information and drive actuators with complex and accurate time pulses. The HET used in this device is the high-end timer lite. It has fewer I/Os than the usual 32 in a standard HET. For more detailed functional information on the HET, see the *TMS470R1x High-End Timer (HET) Reference Guide* (literature number SPNU199).

The A384 HET peripheral contains the XOR-share feature. This feature allows two adjacent HET high-resolution channels to be XORed together, making it possible to output smaller pulses than a standard HET. For more detailed information on the HET XOR-share feature, see the *TMS470R1x High-End Timer (HET) Reference Guide* (literature number [SPNU199](#)).

The A384 device has one 10-bit-resolution sample-and-hold MibADC. Each of the MibADC channels can be converted individually or can be grouped by software for sequential conversion sequences. There are three separate groupings, two of which can be triggered by an external event. Each sequence can be converted once when triggered or configured for continuous conversion mode. For more detailed functional information on the MibADC, see the *TMS470R1x Multi-Buffered Analog-to-Digital Converter (MibADC) Reference Guide* (literature number [SPNU206](#)).

The zero-pin phase-locked loop (ZPLL) clock module contains a phase-locked loop, a clock-monitor circuit, a clock-enable circuit, and a prescaler (with prescale values of 1–8). The function of the ZPLL is to multiply the external frequency reference to a higher frequency for internal use. The ZPLL provides ACLK to the system (SYS) module. The SYS module subsequently provides system clock (SYSCLK), real-time interrupt clock (RTICLK), CPU clock (MCLK), and peripheral interface clock (ICLK) to all other A384 device modules. For more detailed functional information on the ZPLL, see the *TMS470R1x Zero-Pin Phase-Locked Loop (ZPLL) Clock Module Reference Guide* (literature number [SPNU212](#)).

NOTE:

ACLK should not be confused with the MibADC internal clock, ADCLK. ACLK is the continuous system clock from an external resonator/crystal reference.

The expansion bus module (EBM) is a stand-alone module that supports the multiplexing of the GIO functions and the expansion bus interface. For more information on the EBM, see the *TMS470R1x Expansion Bus Module (EBM) Reference Guide* (literature number [SPNU222](#)).

The A384 device also has an external clock prescaler (ECP) module that, when enabled, outputs a continuous external clock (ECLK) on a specified GIO pin. The ECLK frequency is a user-programmable ratio of the peripheral interface clock (ICLK) frequency. For more detailed functional information on the ECP, see the *TMS470R1x External Clock Prescaler (ECP) Reference Guide* (literature number [SPNU202](#)).

(2) SAE Standard J1850 Class B Data Communication Network Interface.

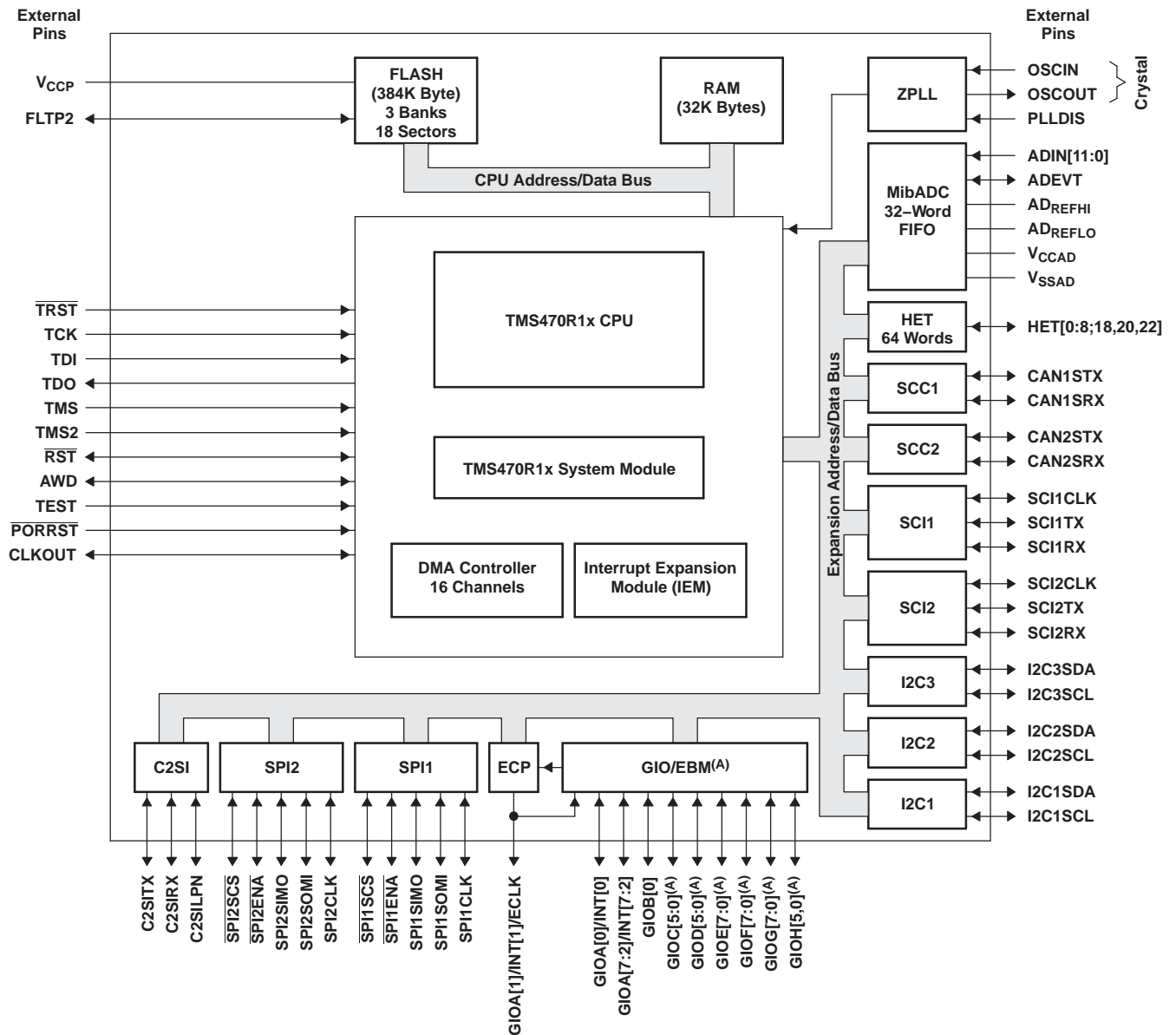
Device Characteristics

The A384 device is a derivative of the F05 system emulation device SE470R1VB8AD. [Table 1](#) identifies all the characteristics of the A384 device except the SYSTEM and CPU, which are generic.

Table 1. Device Characteristics

| CHARACTERISTICS | TMS470R1A384 DEVICE DESCRIPTION | COMMENTS |
|---|---|---|
| MEMORY | | |
| For the number of memory selects on this device, see Table 3 , <i>TMS470R1A384 Memory Selection Assignment</i> . | | |
| Internal Memory | Pipeline/non-pipeline 384K-byte flash 32K-byte SRAM | Flash is pipeline capable. The A384 RAM is implemented in one 16K-byte array selected by two memory-select signals (see Table 3 , <i>TMS470R1A384 Memory Selection Assignment</i>). |
| PERIPHERALS | | |
| For the device-specific interrupt priority configurations, see Table 6 , <i>Interrupt Priority (IEM and CIM)</i> . For the 1K-byte peripheral address ranges and their peripheral selects, see Table 4 , <i>A384 Peripherals, System Module, and Flash Base Addresses</i> . | | |
| CLOCK | ZPLL | Zero-pin PLL has no external loop filter pins. |
| Expansion Bus | EBM | Expansion bus module with 40 pins. Supports 8- and 16-bit memories, PGE package only. See Table 7 for details. |
| General-Purpose I/Os | 55 I/O (PGE suffix) 14 I/O (PZ suffix) | In the PGE package, Port A has 8 external pins; Port B has only 1 external pin; Ports C, D, E, F, and G each have 8 external pins; and Port H has 6 external pins. In the PZ package, Port A has 8 external pins, Port B has 1 external pin, and Port H has 5 external pins. |
| ECP | Yes | |
| SCI | 2 (3-pin) | |
| CAN (HECC and/or SCC) | 2 SCC | Two standard CAN controllers |
| SPI (5 pin, 4 pin, or 3 pin) | 2 (5-pin) | |
| C2S1b | 1 | |
| I2C | 3 | |
| HET with XOR Share | 12 I/O | The high-resolution (HR) Share feature allows even-numbered HR pins to share the next higher odd-numbered HR pin structures. This HR sharing is independent of whether or not the odd pin is available externally. If an odd pin is available externally and shared, then the odd pin can only be used as a general-purpose I/O. For more information on HR SHARE, see the <i>TMS470R1x High-End Timer (HET) Reference Guide</i> (literature number SPNU199). |
| HET RAM | 64-instruction capacity | |
| MibADC | 10-bit 12-channel 64-word FIFO | Both the logic and registers for a full 16-channel MibADC are present. |
| Core Voltage | 1.8 V | |
| I/O Voltage | 3.3 V | |
| Pins | 144/100 | |
| Packages | PGE/PZ | |

Functional Block Diagram



- A. GIOC[4:0], GIOD[5:0], GIOE[5:0], GIOF[7:0], and GIOH[0], which are multiplexed with EBM, are not available on the PZ package. See Table 7 for EBM-to-GIO mapping.

Table 2. Terminal Functions

| TERMINAL | | | INPUT VOLTAGE ⁽¹⁾⁽²⁾ | OUTPUT CURRENT ⁽³⁾ | INTERNAL PULLUP/PULLDOWN | DESCRIPTION |
|--|----|-----|---------------------------------|-------------------------------|--------------------------|--|
| NAME | PZ | PGE | | | | |
| HIGH-END TIMER (HET) | | | | | | |
| HET[0] | 51 | 73 | 3.3 V | 2 mA | | <p>Timer input capture or output compare. The HET[8:0,18,20,22] applicable pins can be programmed as general-purpose input/output (GIO) pins. All are high-resolution pins.</p> <p>The high-resolution (HR) SHARE feature allows even HR pins to share the next higher odd HR pin structures. This HR sharing is independent of whether or not the odd pin is available externally. If an odd pin is available externally and shared, then the odd pin can only be used as a general-purpose I/O. For more information on HR SHARE, see the <i>TMS470R1x High-End Timer (HET) Reference Guide</i> (literature number SPNU199).</p> |
| HET[1] | 50 | 72 | | | | |
| HET[2] | 49 | 71 | | | | |
| HET[3] | 46 | 66 | | | | |
| HET[4] | 45 | 65 | | | | |
| HET[5] | 44 | 63 | | | | |
| HET[6] | 6 | 9 | | | | |
| HET[7] | 7 | 11 | | | | |
| HET[8] | 8 | 12 | | | | |
| HET[18] | 9 | 15 | | | | |
| HET[20] | 12 | 18 | | | | |
| HET[22] | 13 | 19 | | | | |
| STANDARD CAN CONTROLLER (SCC) | | | | | | |
| CAN1SRX | 58 | 83 | 5-V tolerant | 4 mA | | SCC1 receive pin or GIO pin |
| CAN1STX | 59 | 84 | 3.3 V | 2 mA | | SCC1 transmit pin or GIO pin |
| CAN2SRX | 37 | 54 | 5-V tolerant | 4 mA | | SCC2 receive pin or GIO pin |
| CAN2STX | 38 | 55 | 3.3 V | 2 mA | | SCC 2 transmit pin or GIO pin |
| CLASS II SERIAL INTERFACE (C2SIB) | | | | | | |
| C2SILPN | 14 | 21 | 3.3 V | 2 mA | | C2Sib module loopback enable pin or GIO pin |
| C2SIRX | 15 | 22 | 5-V tolerant | 4 mA | | C2Sib module receive data input pin or GIO pin |
| C2SITX | 16 | 24 | 3.3 V | 2 mA | | C2Sib module transmit data output pin or GIO pin |
| GENERAL-PURPOSE I/O (GIO) | | | | | | |
| GIOA[0]/INT[0] | 99 | 141 | 5-V tolerant | 4 mA | | <p>General-purpose input/output pins. GIOA[7:0]/INT[7:0] are interrupt-capable pins. GIOA[1]/INT[1]/ECLK pin is multiplexed with the external clock-out function of the external clock prescale (ECP) module.</p> |
| GIOA[1]/INT[1]/ECLK | 96 | 136 | | | | |
| GIOA[2]/INT[2] | 95 | 134 | | | | |
| GIOA[3]/INT[3] | 94 | 133 | | | | |
| GIOA[4]/INT[4] | 89 | 127 | | | | |
| GIOA[5]/INT[5] | 67 | 98 | | | | |
| GIOA[6]/INT[6] | 55 | 78 | | | | |
| GIOA[7]/INT[7] | 56 | 79 | | | | |
| GIOB[0]/DMAREQ[0] | 30 | 43 | 3.3 V | 2 mA | IPD (20 µA) | <p>GIOB[0], GIOC[4:0], GIOD[5:0], GIOE[7:0:], GIOF[7:0], GIOG[7:0], and GIOH[5:0] are multiplexed with the expansion bus module. See Table 7.</p> |
| GIOC[0]/EBOE | - | 135 | | | | |
| GIOC[1]/EBWR[0] | - | 128 | | | | |
| GIOC[2]/EBWR[1] | - | 126 | | | | |
| GIOC[3]/EBCS[5] | - | 120 | | | | |
| GIOC[4]/EBCS[6] | - | 119 | | | | |

(1) PWR = power, GND = ground, REF = reference voltage, NC = no connect

(2) All I/O pins, except RST, are configured as inputs while PORRST is low and immediately after PORRST goes high.

(3) IPD = internal pulldown, IPU = internal pullup (all internal pullups and pulldowns are active on input pins, independent of the PORRST state.)

Table 2. Terminal Functions (continued)

| TERMINAL | | | INPUT VOLTAGE ⁽¹⁾⁽²⁾ | OUTPUT CURRENT ⁽³⁾ | INTERNAL PULLUP/ PULLDOWN | DESCRIPTION |
|--|----|-----|------------------------------------|----------------------------------|---------------------------------|---|
| NAME | PZ | PGE | | | | |
| GENERAL-PURPOSE I/O (GIO) (CONTINUED) | | | | | | |
| GIOD[0]/EBADDR[0] | - | 42 | 3.3 V | 2 mA | IPD (20 μ A) | GIOB[0], GIOC[4:0], GIOD[5:0], GIOE[7:0:], GIOF[7:0], GIOG[7:0], AND GIOH[5:0] are multiplexed with the expansion bus module. See Table 7 . |
| GIOD[1]/EBADDR[1] | - | 39 | | | | |
| GIOD[2]/EBADDR[2] | - | 35 | | | | |
| GIOD[3]/EBADDR[3] | - | 30 | | | | |
| GIOD[4]/EBADDR[4] | - | 27 | | | | |
| GIOD[5]/EBADDR[5] | - | 23 | | | | |
| GIOE[0]/EBDATA[0] | - | 44 | | | | |
| GIOE[1]/EBDATA[1] | - | 47 | | | | |
| GIOE[2]/EBDATA[2] | - | 58 | | | | |
| GIOE[3]/EBDATA[3] | - | 61 | | | | |
| GIOE[4]/EBDATA[4] | - | 64 | | | | |
| GIOE[5]/EBDATA[5] | - | 67 | | | | |
| GIOE[6]/EBDATA[6] | - | 70 | | | | |
| GIOE[7]/EBDATA[7] | - | 77 | | | | |
| GIOF[0]/EBADDR[6]/ EBDATA[8] | - | 80 | | | | |
| GIOF[1]/EBADDR[7]/ EBDATA[9] | - | 82 | | | | |
| GIOF[2]/EBADDR[8]/ EBDATA[10] | - | 89 | | | | |
| GIOF[3]/EBADDR[9]/ EBDATA[11] | - | 90 | | | | |
| GIOF[4]/EBADDR[10]/ EBDATA[12] | - | 93 | | | | |
| GIOF[5]/EBADDR[11]/ EBDATA[13] | - | 96 | | | | |
| GIOF[6]/EBADDR[12]/ EBDATA[14] | - | 99 | | | | |
| GIOF[7]/EBADDR[13]/ EBDATA[15] | - | 100 | | | | |
| GIOG[0]/EBADDR[14]/ EBADDR[6] | - | 20 | | | | |
| GIOG[1]/EBADDR[15]/ EBADDR[7] | - | 10 | | | | |
| GIOG[2]/EBADDR[16]/ EBADDR[8] | - | 8 | | | | |
| GIOG[3]/EBADDR[17]/ EBADDR[9] | - | 6 | | | | |

Table 2. Terminal Functions (continued)

| TERMINAL | | | INPUT VOLTAGE ⁽¹⁾⁽²⁾ | OUTPUT CURRENT ⁽³⁾ | INTERNAL PULLUP/ PULLDOWN | DESCRIPTION |
|--|----|-----|------------------------------------|----------------------------------|---------------------------------|--|
| NAME | PZ | PGE | | | | |
| GENERAL-PURPOSE I/O (GIO) (CONTINUED) | | | | | | |
| GIOG[4]/EBADDR[18]/ EBADDR[10] | - | 3 | 3.3 V | 2 mA | IPD (20 μ A) | GIOB[0], GIOC[4:0], GIOD[5:0], GIOE[7:0:], GIOF[7:0], GIOG[7:0], AND GIOH[5:0] are multiplexed with the expansion bus module. See Table 7 . |
| GIOG[5]/EBADDR[19]/ EBADDR[11] | - | 143 | | | | |
| GIOG[6]/EBADDR[20]/ EBADDR[12] | - | 142 | | | | |
| GIOG[7]/EBADDR[21]/ EBADDR[13] | - | 140 | | | | |
| GIOH[0]/EBADDR[22]/ EBADDR[14] | - | 139 | | | | |
| GIOH[1]/EBADDR[23]/ EBADDR[15] | 29 | 41 | | | | |
| GIOH[2]/EBADDR[24]/ EBADDR[16] | 28 | 40 | | | | |
| GIOH[3]/EBADDR[25]/ EBADDR[17] | 27 | 38 | | | | |
| GIOH[4]/EBADDR[26]/ EBADDR[18] | 26 | 37 | | | | |
| GIOH[5]/EBHOLD | 88 | 125 | | | | |
| MULTI-BUFFERED ANALOG-TO-DIGITAL CONVERTER (MibADC) | | | | | | |
| ADEVT | 68 | 101 | 3.3 V | 2 mA | | MibADC event input. Can be programmed as a GIO pin. |
| ADIN[0] | 84 | 117 | 3.3 V | | | MibADC analog input pins |
| ADIN[1] | 83 | 116 | | | | |
| ADIN[2] | 82 | 115 | | | | |
| ADIN[3] | 81 | 114 | | | | |
| ADIN[4] | 80 | 113 | | | | |
| ADIN[5] | 75 | 108 | | | | |
| ADIN[6] | 74 | 107 | | | | |
| ADIN[7] | 73 | 106 | | | | |
| ADIN[8] | 72 | 105 | | | | |
| ADIN[9] | 71 | 104 | | | | |
| ADIN[10] | 70 | 103 | | | | |
| ADIN[11] | 69 | 102 | | | | |
| AD _{REFHI} | 76 | 109 | 3.3-V REF | | | MibADC module high-voltage reference input |
| AD _{REFLO} | 77 | 110 | GND REF | | | MibADC module low-voltage reference input |
| V _{CCAD} | 78 | 111 | 3.3-V PWR | | | MibADC analog supply voltage |
| V _{SSAD} | 79 | 112 | GND | | | MibADC analog ground reference |

Table 2. Terminal Functions (continued)

| TERMINAL | | | INPUT VOLTAGE ⁽¹⁾⁽²⁾ | OUTPUT CURRENT ⁽³⁾ | INTERNAL PULLUP/ PULLDOWN | DESCRIPTION |
|---|----|-----|------------------------------------|----------------------------------|---------------------------------|--|
| NAME | PZ | PGE | | | | |
| SERIAL PERIPHERAL INTERFACE 1 (SPI1) | | | | | | |
| SPI1CLK | 3 | 4 | 5-V tolerant | 4 mA | | SPI1 clock. SPI1CLK can be programmed as a GIO pin. |
| $\overline{\text{SPI1ENA}}$ | 2 | 2 | | | | SPI1 chip enable. Can be programmed as a GIO pin. |
| $\overline{\text{SPI1SCS}}$ | 1 | 1 | | | | SPI1 slave chip select. Can be programmed as a GIO pin. |
| SPI1SIMO | 4 | 5 | | | | SPI1 data stream. Slave in/master out. Can be programmed as a GIO pin. |
| SPI1SOMI | 5 | 7 | | | | SPI1 data stream. Slave out/master in. Can be programmed as a GIO pin. |
| SERIAL PERIPHERAL INTERFACE 2 (SPI2) | | | | | | |
| SPI2CLK | 39 | 56 | 5-V tolerant | 4 mA | | SPI2 clock. Can be programmed as a GIO pin. |
| $\overline{\text{SPI2ENA}}$ | 42 | 60 | | | | SPI2 chip enable. Can be programmed as a GIO pin. |
| $\overline{\text{SPI2SCS}}$ | 43 | 62 | | | | SPI2 slave chip select. Can be programmed as a GIO pin. |
| SPI2SIMO | 41 | 59 | | | | SPI2 data stream. Slave in/master out. Can be programmed as a GIO pin. |
| SPI2SOMI | 40 | 57 | | | | SPI2 data stream. Slave out/master in. Can be programmed as a GIO pin. |
| INTER-INTEGRATED CIRCUIT (I2C) | | | | | | |
| I2C1SDA | 60 | 87 | 5-V tolerant | 4 mA | | I2C1 serial data pin or GIO pin |
| I2C1SCL | 61 | 88 | | | | I2C1 serial clock pin or GIO pin |
| I2C2SDA | 64 | 94 | | | | I2C2 serial data pin or GIO pin |
| I2C2SCL | 65 | 95 | | | | I2C2 serial clock pin or GIO pin |
| I2C3SDA | 20 | 29 | | | | I2C3 serial data pin or GIO pin |
| I2C3SCL | 19 | 28 | | | | I2C3 serial clock pin or GIO pin |
| ZERO-PIN PHASE-LOCKED LOOP (ZPLL) | | | | | | |
| OSCIN | 23 | 33 | 1.8 V | | | Crystal connection pin or external clock input |
| OSCOU | 22 | 32 | | 2 mA | | External crystal connection pin |
| PLLDIS | 66 | 97 | 3.3 V | | IPD (20 μ A) | Enable/disable the ZPLL. The ZPLL can be bypassed and the oscillator becomes the system clock. |
| SERIAL COMMUNICATIONS INTERFACE 1 (SCI1) | | | | | | |
| SCI1CLK | 33 | 48 | 3.3 V | 2 mA | | SCI1 clock. SCI1CLK can be programmed as a GIO pin. |
| SCI1RX | 32 | 46 | 5-V tolerant | 4 mA | | SCI1 data receive. SCI1RX can be programmed as a GIO pin. |
| SCI1TX | 31 | 45 | 3.3 V | 2 mA | | SCI1 data transmit. SCI1TX can be programmed as a GIO pin. |
| SERIAL COMMUNICATIONS INTERFACE 2 (SCI2) | | | | | | |
| SCI2CLK | 36 | 51 | 3.3 V | 2 mA | | SCI2 clock. SCI2CLK can be programmed as a GIO pin. |
| SCI2RX | 35 | 50 | 5-V tolerant | 4 mA | | SCI2 data receive. SCI2RX can be programmed as a GIO pin. |
| SCI2TX | 34 | 49 | 3.3 V | 2 mA | | SCI2 data transmit. SCI2TX can be programmed as a GIO pin. |

Table 2. Terminal Functions (continued)

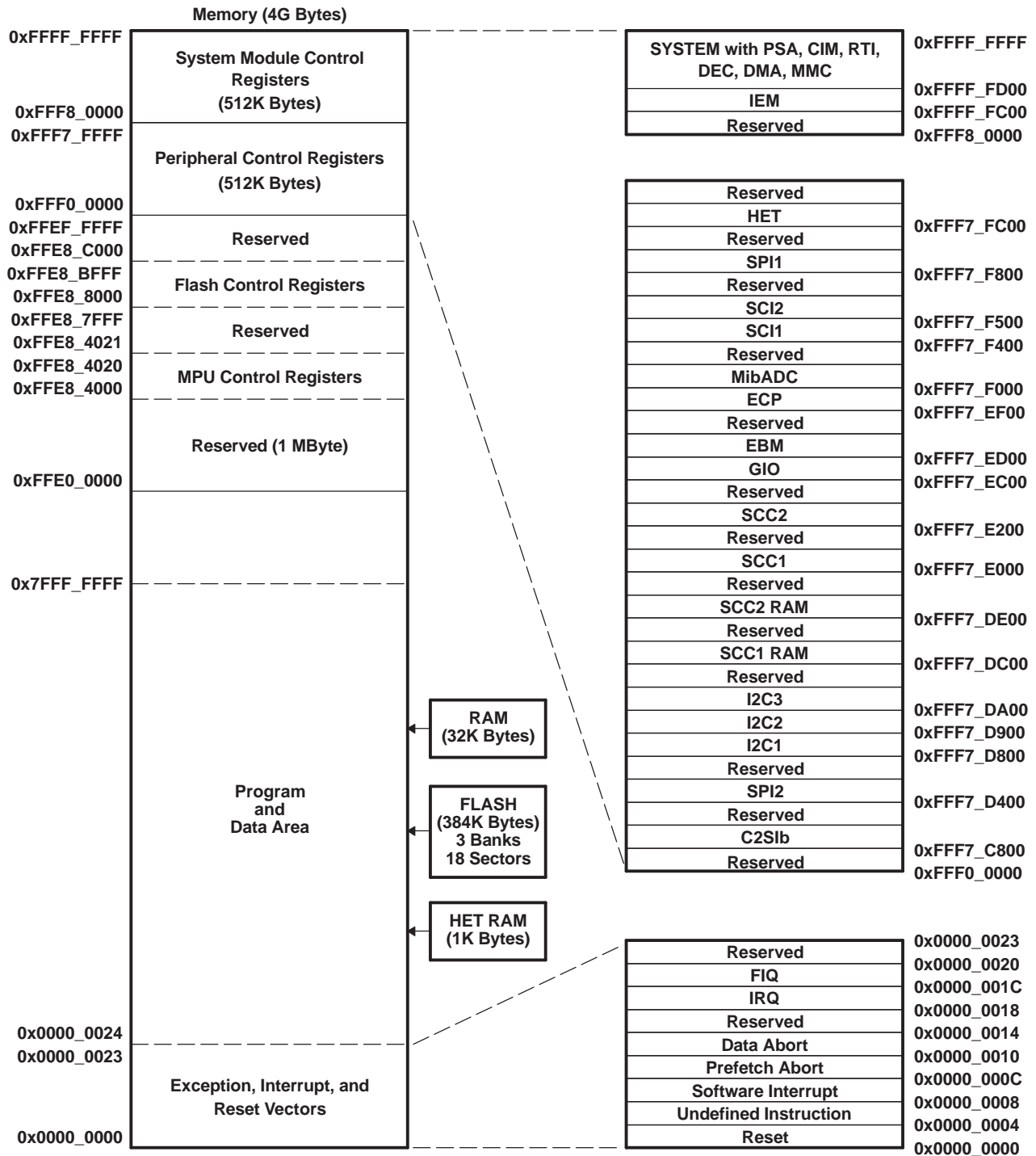
| TERMINAL | | | INPUT VOLTAGE ⁽¹⁾⁽²⁾ | OUTPUT CURRENT ⁽³⁾ | INTERNAL PULLUP/ PULLDOWN | DESCRIPTION |
|--|-----|-----|------------------------------------|----------------------------------|---|--|
| NAME | PZ | PGE | | | | |
| SYSTEM MODULE (SYS) | | | | | | |
| CLKOUT | 57 | 81 | 3.3 V | 4 mA | | Bidirectional clock out. CLKOUT can be programmed as a GIO pin or the output of SYSCLK, ICLK, or MCLK. |
| $\overline{\text{PORRST}}$ | 85 | 118 | 3.3 V | | IPD (20 μ A) | Input master chip power-up reset. External V_{CC} monitor circuitry must assert a power-on reset. |
| $\overline{\text{RST}}$ | 86 | 121 | 3.3 V | 4 mA | IPU (20 μ A) | Bidirectional reset. The internal circuitry can assert a reset, and an external system reset can assert a device reset. On this pin, the output buffer is implemented as an open drain (drives low only). To ensure an external reset is not arbitrarily generated, TI recommends that an external pullup resistor be connected to this pin. |
| WATCHDOG/REAL-TIME INTERRUPT (WD/RTI) | | | | | | |
| AWD | 25 | 36 | 3.3 V | 4 mA | | Analog watchdog reset. The AWD pin provides a system reset if the WD KEY is not written in time by the system, providing an external RC network circuit is connected. If the user is not using AWD, TI recommends that this pin be connected to ground or pulled down to ground by an external resistor. For more details on the external RC network circuit, see the <i>TMS470R1x System Module Reference Guide</i> (literature number SPNU189). |
| TEST/DEBUG (T/D) | | | | | | |
| TCK | 54 | 76 | 3.3 V | 2 mA | IPD (20 μ A) | Test clock. TCK controls the test hardware (JTAG). |
| TDI | 52 | 74 | | 2 mA | IPU (20 μ A) | Test data in. TDI inputs serial data to the test instruction register, test data register, and programmable test address (JTAG). |
| TDO | 53 | 75 | | 4 mA | IPD (20 μ A) | Test data out. TDO outputs serial data from the test instruction register, test data register, identification register, and programmable test address (JTAG). |
| TEST | 87 | 124 | | IPD (20 μ A) | Test enable. Reserved for internal use only. TI recommends that this pin be connected to ground or pulled down to ground by an external resistor. | |
| TMS | 11 | 17 | | 2 mA | IPU (20 μ A) | Serial input for controlling the state of the CPU test access port (TAP) controller (JTAG). |
| TMS2 | 10 | 16 | | 2 mA | IPU (20 μ A) | Serial input for controlling the second TAP. TI recommends that this pin be connected to V_{CCIO} or pulled up to V_{CCIO} by an external resistor. |
| $\overline{\text{TRST}}$ | 100 | 144 | | IPD (20 μ A) | Test hardware reset to TAP1 and TAP2. IEEE Std 1149.1 (JTAG) Boundary-Scan Logic. TI recommends that this pin be pulled down to ground by an external resistor. | |

Table 2. Terminal Functions (continued)

| TERMINAL | | | INPUT VOLTAGE ⁽¹⁾⁽²⁾ | OUTPUT CURRENT ⁽³⁾ | INTERNAL PULLUP/ PULLDOWN | DESCRIPTION |
|---|----|-----|------------------------------------|----------------------------------|---------------------------------|--|
| NAME | PZ | PGE | | | | |
| FLASH | | | | | | |
| FLTP2 | 93 | 132 | NC | NC | | Flash test pad 2. For proper operation, this pin must not be connected [no connect (NC)]. |
| V _{CCP} | 92 | 131 | 3.3-V PWR | | | Flash external pump voltage (3.3 V) |
| SUPPLY VOLTAGE CORE (1.8 V) | | | | | | |
| V _{CC} | 21 | 13 | 1.8-V PWR | | | Core logic supply voltage |
| | 63 | 31 | | | | |
| | 91 | 53 | | | | |
| | - | 92 | | | | |
| | - | 123 | | | | |
| | - | 130 | | | | |
| SUPPLY VOLTAGE DIGITAL I/O (3.3 V) | | | | | | |
| V _{CCIO} | 17 | 25 | 3.3-V PWR | | | Digital I/O supply voltage |
| | 48 | 69 | | | | |
| | - | 86 | | | | |
| | 97 | 137 | | | | |
| SUPPLY GROUND CORE | | | | | | |
| V _{SS} | 90 | 14 | GND | | | Core supply ground reference |
| | 98 | 26 | | | | |
| | - | 34 | | | | |
| | - | 52 | | | | |
| | - | 68 | | | | |
| | 47 | 85 | | | | |
| | - | 91 | | | | |
| | 62 | 122 | | | | |
| | 24 | 129 | | | | |
| | 18 | 138 | | | | |

TMS470R1A384 DEVICE-SPECIFIC INFORMATION

Memory



- A. Memory addresses are configurable by the system (SYS) module within the range of 0x0000_0000 to 0xFFE0_0000.
- B. The CPU registers are not a part of the memory map.

Figure 1. TMS470R1A384 Memory Map

Memory Selects

Memory selects allow the user to address memory arrays (i.e., flash, RAM, and HET RAM) at user-defined addresses. Each memory select has its own set (low and high) of memory base address registers (MFBALRx and MFBALRx) that, together, define the array's starting (base) address, block size, and protection.

The base address of each memory select is configurable to any memory address boundary that is a multiple of the decoded block size. For more information on how to control and configure these memory select registers, see the bus structure and memory sections of the *TMS470R1x System Module Reference Guide* (literature number SPNU189).

For the memory selection assignments and the memory selected, see [Table 3](#).

Table 3. TMS470R1A384 Memory Selection Assignment

| MEMORY SELECT | MEMORY SELECTED (ALL INTERNAL) | MEMORY SIZE ⁽¹⁾ | MPU | MEMORY BASE ADDRESS REGISTER | STATIC MEM CTL REGISTER |
|---------------|-----------------------------------|----------------------------|-----|------------------------------|-------------------------|
| 0 (fine) | FLASH | 384K | NO | MFBALR0 and MFBALR0 | |
| 1 (fine) | FLASH | | NO | MFBALR1 and MFBALR1 | |
| 2 (fine) | RAM | 32K ⁽²⁾ | YES | MFBALR2 and MFBALR2 | |
| 3 (fine) | RAM | | YES | MFBALR3 and MFBALR3 | |
| 4 (fine) | HET RAM | 1K | NO | MFBALR4 and MFBALR4 | SMCR1 |
| 5 (fine) | $\overline{CS}[5]/\text{GIOC}[3]$ | 4MB (x8) 1MB (x16) | NO | MCBALR2 and MCBALR2 | SMCR5 |
| 6 (fine) | $\overline{CS}[6]/\text{GIOC}[4]$ | 4MB (x8) 1MB (x16) | NO | MCBALR3 and MCBALR3 | SMCR6 |

(1) x8 refers to size of memory in 8-bits; x16 refers to size of memory in 16-bits.

(2) The starting addresses for both RAM memory-select signals cannot be offset from each other by a multiple of the user-defined block size in the memory-base address register.

RAM

The A384 device contains 32K-bytes of internal static RAM configurable by the SYS module to be addressed within the range of 0x0000_0000 to 0xFFE0_0000. This A384 RAM is implemented in one 32K-byte array selected by two memory-select signals.

NOTE:

This A384 configuration imposes an additional constraint on the memory map for RAM; the starting addresses for both RAM memory selects cannot be offset from each other by the multiples of the size of the physical RAM (i.e., 32K bytes for the A384 device). The A384 RAM is addressed through memory selects 2 and 3.

The RAM can be protected by the memory protection unit (MPU) portion of the SYS module, allowing the user finer blocks of memory protection than is allowed by the memory selects. The MPU is ideal for protecting an operating system while allowing access to the current task. For more detailed information on the MPU portion of the SYS module and memory protection, see the memory section of the *TMS470R1x System Module Reference Guide* (literature number SPNU189).

F05 Flash

The F05 flash memory is a nonvolatile electrically erasable and programmable memory implemented with a 32-bit-wide data bus interface. The F05 flash has an external state machine for programming and erase functions. See the *Flash Read* and *Flash Program and Erase* sections.

Flash Protection Keys

The A384 device provides flash protection keys. These four 32-bit protection keys prevent program/erase/compaction operations from occurring until after the four protection keys have been matched by the CPU loading the correct user keys into the FMPKEY control register. The protection keys on the A384 are located in the last 4 words of the first 8K sector. For more detailed information on the flash protection keys and the FMPKEY control register, see the "Optional Quadruple Protection Keys" and "Programming the Protection Keys" portions of the *TMS470R1x F05 Flash Reference Guide* (literature number SPNU213).

Flash Read

The A384 flash memory is configurable by the SYS module to be addressed within the range of 0x0000_0000 to 0xFFE0_0000. The flash is addressed through memory selects 0 and 1.

NOTE:

The flash external pump voltage (V_{CCP}) is required for all operations (program, erase, and read).

Flash Pipeline Mode

When in pipeline mode, the flash operates with a system clock frequency of up to 48 MHz (versus a system clock frequency of 24 MHz in normal mode). Flash in pipeline mode is capable of accessing 64-bit words and provides two 32-bit pipelined words to the CPU. Also, in pipeline mode the flash can be read with no wait states when memory addresses are contiguous (after the initial 1- or 2-wait-state reads).

NOTE:

After a system reset, pipeline mode is disabled (FMREGOPT[0] = 0). In other words, the A384 device powers up and comes out of reset in non-pipeline mode. Furthermore, setting the flash configuration mode bit (GBLCTRL[4]) overrides pipeline mode.

Flash Program and Erase

The A384 device flash contains three 128K-byte memory arrays (or banks), for a total of 384K-bytes of flash, and consists of 18 sectors. These 18 sectors are sized as follows:

| SECTOR NO. | SEGMENT | LOW ADDRESS | HIGH ADDRESS | MEMORY ARRAYS (OR BANKS) |
|------------|-----------|-------------|--------------|--------------------------|
| 0 | 8K Bytes | 0x0000_0000 | 0x0000_1FFF | BANK0 (128K Bytes) |
| 1 | 8K Bytes | 0x0000_2000 | 0x0000_3FFF | |
| 2 | 16K Bytes | 0x0000_4000 | 0x0000_7FFF | |
| 3 | 16K Bytes | 0x0000_8000 | 0x0000_BFFF | |
| 4 | 16K Bytes | 0x0000_C000 | 0x0000_FFFF | |
| 5 | 16K Bytes | 0x0001_0000 | 0x0001_3FFF | |
| 6 | 16K Bytes | 0x0001_4000 | 0x0001_7FFF | |
| 7 | 16K Bytes | 0x0001_8000 | 0x0001_BFFF | |
| 8 | 8K Bytes | 0x0001_C000 | 0x0001_DFFF | |
| 9 | 8K bytes | 0x0001_E000 | 0x0001_FFFF | |
| 0 | 32K Bytes | 0x0002_0000 | 0x0002_7FFF | BANK1 (128K Bytes) |
| 1 | 32K Bytes | 0x0002_8000 | 0x0002_FFFF | |
| 2 | 32K Bytes | 0x0003_0000 | 0x0003_7FFF | |
| 3 | 32K Bytes | 0x0003_8000 | 0x0003_FFFF | |
| 0 | 32K Bytes | 0x0004_0000 | 0x0004_7FFF | BANK2 (128K Bytes) |
| 1 | 32K Bytes | 0x0004_8000 | 0x0004_FFFF | |
| 2 | 32K Bytes | 0x0005_0000 | 0x0005_7FFF | |
| 3 | 32K Bytes | 0x0005_8000 | 0x0005_FFFF | |

The minimum size for an erase operation is one sector. The maximum size for a program operation is one 16-bit word.

NOTE:

The flash external pump voltage (V_{CCP}) is required for all operations (program, erase, and read).

Execution can occur from one bank while programming/erasing any or all sectors of another bank. However, execution cannot occur from any sector within a bank that is being programmed or erased.

NOTE:

When the OTP sector is enabled, the rest of the flash memory is disabled. The OTP memory can only be read or programmed from code executed out of RAM.

For more detailed information on flash program and erase operations, see the *TMS470R1x F05 Flash Reference Guide* (literature number SPNU213).

HET RAM

The A384 device contains HET RAM. The HET RAM has a 64-instruction capability. The HET RAM is configurable by the SYS module to be addressed within the range of 0x0000_0000 to 0xFFE0_0000. The HET RAM is addressed through memory select 4.

Peripheral Selects and Base Addresses

The A384 device uses 10 of the 16 peripheral selects to decode the base addresses of the peripherals. These peripheral selects are fixed and transparent to the user because they are part of the decoding scheme used by the SYS module.

Control registers for the peripherals, SYS module, and flash begin at the base addresses shown in [Table 4](#).

Table 4. A384 Peripherals, System Module, and Flash Base Addresses

| CONNECTING MODULE | ADDRESS RANGE | | PERIPHERAL SELECTS |
|-------------------------|---------------|----------------|--------------------|
| | BASE ADDRESS | ENDING ADDRESS | |
| SYSTEM | 0xFFFF_FFCC | 0xFFFF_FFFF | N/A |
| Reserved | 0xFFFF_FF60 | 0xFFFF_FFCB | N/A |
| PSA | 0xFFFF_FF40 | 0xFFFF_FF5F | N/A |
| CIM | 0xFFFF_FF20 | 0xFFFF_FF3F | N/A |
| RTI | 0xFFFF_FF00 | 0xFFFF_FF1F | N/A |
| DMA | 0xFFFF_FE80 | 0xFFFF_FEFF | N/A |
| DEC | 0xFFFF_FE00 | 0xFFFF_FE7F | N/A |
| MMC | 0xFFFF_FD00 | 0xFFFF_FD7F | N/A |
| IEM | 0xFFFF_FC00 | 0xFFFF_FCFE | N/A |
| Reserved | 0xFFFF_FB00 | 0xFFFF_FBF7 | N/A |
| Reserved | 0xFFFF_FA00 | 0xFFFF_FAFF | N/A |
| DMA CMD BUFFER | 0xFFFF_F800 | 0xFFFF_F9FF | N/A |
| Reserved | 0xFFFF8_0000 | 0xFFFF_F7FF | N/A |
| HET | 0xFFF7_FC00 | 0xFFF7_FFFF | PS[0] |
| SPI1 | 0xFFF7_F800 | 0xFFF7_FBF7 | PS[1] |
| SCI2 | 0xFFF7_F500 | 0xFFF7_F7FF | PS[2] |
| SCI1 | 0xFFF7_F400 | 0xFFF7_F4FF | |
| MibADC | 0xFFF7_F000 | 0xFFF7_F3FF | PS[3] |
| ECP | 0xFFF7_EF00 | 0xFFF7_EFFF | PS[4] |
| Reserved | 0xFFF7_EE00 | 0xFFF7_EEFF | |
| EBM | 0xFFF7_ED00 | 0xFFF7_EDFF | |
| GIO | 0xFFF7_EC00 | 0xFFF7_ECFE | |
| Reserved | 0xFFF7_E400 | 0xFFF7_EBFF | PS[5]–PS[6] |
| Reserved | 0xFFF7_E300 | 0xFFF7_E3FF | PS[7] |
| SCC2 | 0xFFF7_E200 | 0xFFF7_E2FF | |
| Reserved | 0xFFF7_E100 | 0xFFF7_E1FF | |
| SCC1 | 0xFFF7_E000 | 0xFFF7_E0FF | |
| Reserved | 0xFFF7_DF00 | 0xFFF7_DFFF | PS[8] |
| SCC2 RAM | 0xFFF7_DE00 | 0xFFF7_DEFF | |
| Reserved | 0xFFF7_DD00 | 0xFFF7_DDFF | |
| SCC1 RAM | 0xFFF7_DC00 | 0xFFF7_DCFE | |
| Reserved | 0xFFF7_DB00 | 0xFFF7_DBFF | PS[9] |
| I2C3 | 0xFFF7_DA00 | 0xFFF7_DAFF | |
| I2C2 | 0xFFF7_D900 | 0xFFF7_D9FF | |
| I2C1 | 0xFFF7_D800 | 0xFFF7_D8FF | |
| SPI2 | 0xFFF7_D400 | 0xFFF7_D7FF | PS[10] |
| Reserved | 0xFFF7_CC00 | 0xFFF7_D3FF | PS[11]–PS[12] |
| C2S1b | 0xFFF7_C800 | 0xFFF7_CBFF | PS[13] |
| Reserved | 0xFFF7_C000 | 0xFFF7_C7FF | PS[14]–PS[15] |
| Reserved | 0xFFF0_0000 | 0xFFF7_BFFF | N/A |
| Flash Control Registers | 0xFFE8_8000 | 0xFFE8_BFFF | N/A |
| MPU Control Registers | 0xFFE8_4000 | 0xFFE8_4023 | N/A |

Direct Memory Access (DMA)

The DMA controller transfers data to and from any specified location in the A384 memory map (except for restricted memory locations like the system control registers area). The DMA manages up to 16 channels, and supports data transfer for both on-chip and off-chip memories and peripherals. The DMA controller is connected to both the CPU and peripheral buses, enabling these data transfers to occur in parallel with CPU activity and, thus, maximizing overall system performance.

Although the DMA controller has two possible configurations for the A384 device, the DMA controller configuration is 32 control packets and 16 channels.

For the A384 DMA request hardwired configuration, see [Table 5](#).

Table 5. DMA Request Lines Connections⁽¹⁾

| MODULES | DMA REQUEST INTERRUPT SOURCES | | DMA CHANNEL |
|------------|-------------------------------|-------------------|-------------|
| EBM | Expansion bus DMA request | EBDMAREQ0 | DMAREQ[0] |
| SPI1 | SPI1 end-receive | SPI1DMA0 | DMAREQ[1] |
| SPI1 | SPI1 end-transmit | SPI1DMA1 | DMAREQ[2] |
| I2C1 | I2C1 read | I2C1DMA0 | DMAREQ[3] |
| SCI1 | SCI1 end-receive | SCI1DMA0 | DMAREQ[4] |
| SCI1 | SCI1 end-transmit | SCI1DMA1 | DMAREQ[5] |
| I2C1 | I2C1 write | I2C1DMA1 | DMAREQ[6] |
| SPI2 | SPI2 end-receive | SPI2DMA0 | DMAREQ[7] |
| SPI2 | SPI2 end-transmit | SPI2DMA1 | DMAREQ[8] |
| I2C2/C2SIb | I2C2 read/C2SIb end-receive | I2C2DMA0/C2SIDMA0 | DMAREQ[9] |
| I2C2/C2SIb | I2C2 write/C2SIb end-transmit | I2C2DMA1/C2SIDMA1 | DMAREQ[10] |
| I2C3 | I2C3 read | I2C3DMA0 | DMAREQ[11] |
| I2C3 | I2C3 write | I2C3DMA1 | DMAREQ[12] |
| Reserved | | | DMAREQ[13] |
| SCI2/SPI3 | SCI2 end-receive | SCI2DMA0 | DMAREQ[14] |
| SCI2/SPI3 | SCI2 end-transmit | SCI2DMA1 | DMAREQ[15] |

(1) For DMA channels with more than one assigned request source (I2C2/C2SIb), only one of the sources listed can be the DMA request generator in a given application. The device has software control to ensure that there are no conflicts between requesting modules.

Each channel has two control packets attached to it, allowing the DMA to continuously load RAM and generate periodic interrupts so that the data can be read by the CPU. The control packets allow for the interrupt enable, and the channels determine the priority level of the interrupt.

DMA transfers occur in one of two modes:

- Non-request mode (used when transferring from memory to memory)
- Request mode (used when transferring from memory to peripheral)

For more detailed functional information on the DMA controller, see the *TMS470R1x Direct Memory Access (DMA) Controller Reference Guide* (literature number SPNU194).

Interrupt Priority (IEM to CIM)

Interrupt requests originating from the A384 peripheral modules (i.e., SPI1 or SPI2, SCI1 or SCI2, RTI, etc.) are assigned to channels within the 48-channel interrupt expansion module (IEM) where, via programmable register mapping, these channels are then mapped to the 32-channel central interrupt manager (CIM) portion of the SYS module.

Programming multiple interrupt sources in the IEM to the same CIM channel effectively shares the CIM channel between sources.

The CIM request channels are maskable so that individual channels can be selectively disabled. All interrupt requests can be programmed in the CIM to be of either type:

- Fast interrupt request (FIQ)
- Normal interrupt request (IRQ)

The CIM prioritizes interrupts. The precedences of request channels decrease with ascending channel order in the CIM [0 (highest) and 31 (lowest) priority]. For IEM-to-CIM default mapping, channel priorities, and their associated modules, see [Table 6](#).

Table 6. Interrupt Priority (IEM and CIM)

| MODULES | INTERRUPT SOURCES | DEFAULT CIM INTERRUPT LEVEL/CHANNEL | IEM CHANNEL |
|-----------|------------------------------|-------------------------------------|-------------|
| SPI1 | SPI1 end-transfer/overrun | 0 | 0 |
| RTI | COMP2 interrupt | 1 | 1 |
| RTI | COMP1 interrupt | 2 | 2 |
| RTI | TAP interrupt | 3 | 3 |
| SPI2 | SPI2 end-transfer/overrun | 4 | 4 |
| GIO | GIO interrupt A | 5 | 5 |
| Reserved | | 6 | 6 |
| HET | HET interrupt 1 | 7 | 7 |
| I2C1 | I2C1 interrupt | 8 | 8 |
| SCI1/SCI2 | SCI1 or SCI2 error interrupt | 9 | 9 |
| SCI1 | SCI1 receive interrupt | 10 | 10 |
| C2SIb | C2SIb interrupt | 11 | 11 |
| I2C2 | I2C2 interrupt | 12 | 12 |
| SCC2 | SCC2 interrupt A | 13 | 13 |
| SCC1 | SCC1 interrupt A | 14 | 14 |
| Reserved | | 15 | 15 |
| MibADC | MibADC end event conversion | 16 | 16 |
| SCI2 | SCI2 receive interrupt | 17 | 17 |
| DMA | DMA interrupt 0 | 18 | 18 |
| I2C3 | I2C3 interrupt | 19 | 19 |
| SCI1 | SCI1 transmit interrupt | 20 | 20 |
| System | SW interrupt (SSI) | 21 | 21 |
| Reserved | | 22 | 22 |
| HET | HET interrupt 2 | 23 | 23 |
| SCC2 | SCC2 interrupt B | 24 | 24 |
| SCC1 | SCC1 interrupt B | 25 | 25 |
| SCI2 | SCI2 transmit interrupt | 26 | 26 |
| MibADC | MibADC end group1 conversion | 27 | 27 |
| DMA | DMA Interrupt 1 | 28 | 28 |
| GIO | GIO interrupt B | 29 | 29 |
| MibADC | MibADC end group2 conversion | 30 | 30 |
| Reserved | | 31 | 31 |

Table 6. Interrupt Priority (IEM and CIM) (continued)

| MODULES | INTERRUPT SOURCES | DEFAULT CIM INTERRUPT LEVEL/CHANNEL | IEM CHANNEL |
|----------------|--------------------------|--|--------------------|
| Reserved | | 31 | 32 |
| Reserved | | 31 | 33 |
| Reserved | | 31 | 34 |
| Reserved | | 31 | 35 |
| Reserved | | 31 | 36 |
| Reserved | | 31 | 37 |
| Reserved | | 31 | 38 |
| Reserved | | 31 | 39 |
| Reserved | | 31 | 40 |
| Reserved | | 31 | 41 |
| Reserved | | 31 | 42 |
| Reserved | | 31 | 43 |
| Reserved | | 31 | 44 |
| Reserved | | 31 | 45 |
| Reserved | | 31 | 46 |
| Reserved | | 31 | 47 |

For more detailed functional information on the IEM, see the *TMS470R1x Interrupt Expansion Module (IEM) Reference Guide* (literature number SPNU211). For more detailed functional information on the CIM, see the *TMS470R1x System Module Reference Guide* (literature number SPNU189).

Expansion Bus Module (EBM)

The expansion bus module (EBM) is a standalone module used to bond out both general-purpose input/output pins and expansion bus interface pins. The module supports 8- and 16-bit expansion bus memory interface mappings, as well as mapping of the following expansion bus signals:

- 22-bit address bus (EBADDR[21:0]) for x8, 19-bit address bus (EBADDR[18:0]) for x16
- 8- or 16-bit data bus (EBDATA[7:0] or EBDATA[15:0])
- Two write strobes ($\overline{\text{EBWR}}[1:0]$)
- Two memory chip selects ($\overline{\text{EBCS}}[6:5]$)
- One output enable ($\overline{\text{EBOE}}$)
- One external hold signal for interfacing to slow memories ($\overline{\text{EBHOLD}}$)

Table 7 shows the multiplexing of I/O signals with the expansion bus interface signals. The mapping of these pins varies depending on the memory mode.

Table 7. Expansion Bus Multiplex Mapping⁽¹⁾

| GIO | EXPANSION BUS MODULE PINS ⁽²⁾ | |
|-----------|--|-------------------------------|
| | x8 | x16 |
| GIOB[0] | EBDMAREQ[0] | EBDMAREQ[0] |
| GIOC[0] | $\overline{\text{EBOE}}$ | $\overline{\text{EBOE}}$ |
| GIOC[2:1] | $\overline{\text{EBWR}}[1:0]$ | $\overline{\text{EBWR}}[1:0]$ |
| GIOC[4:3] | $\overline{\text{EBCS}}[6:5]$ | $\overline{\text{EBCS}}[6:5]$ |
| GIOD[5:0] | EBADDR[5:0] | EBADDR[5:0] |
| GIOE[7:0] | EBDATA[7:0] | EBDATA[7:0] |
| GIOF[7:0] | EBADDR[13:6] | EBDATA[15:8] |
| GIOG[7:0] | EBADDR[21:14] | EBADDR[13:6] |
| GIOH[4:0] | – | EBADDR[18:14] |
| GIOH[5] | $\overline{\text{EBHOLD}}$ | $\overline{\text{EBHOLD}}$ |

(1) These mappings are controlled by the EBM mux control registers B–H (EBMXCRB–EBMXCRH) and the EBM control register 1 (EBMCR1). For GPIO functions, use GIODIRx, GIODINx, GIODOUTx, GIODSETx, and GIODCLR. For more detailed information, see the *TMS470R1x General-Purpose Input/Output (GIO) Reference Guide* (literature number SPNU192) and the *TMS470R1x Expansion Bus Module (EBM) Reference Guide* (literature number SPNU222).

(2) x8 refers to size of memory in 8-bits; x16 refers to size of memory in 16-bits.

Table 8 lists the names of the expansion bus interface signals and their functions.

Table 8. Expansion Bus Pins

| PIN | DESCRIPTION |
|----------------------------|--|
| EBDMAREQ | Expansion bus DMA request |
| $\overline{\text{EBOE}}$ | Expansion bus output enable |
| $\overline{\text{EBWR}}$ | Expansion bus write strobe. $\overline{\text{EBWR}}[1]$ controls EBDATA[15:8] and $\overline{\text{EBWR}}[0]$ controls EBDATA[7:0]. |
| $\overline{\text{EBCS}}$ | Expansion bus chip select |
| EBADDR | Expansion bus address |
| EBDATA | Expansion bus data |
| $\overline{\text{EBHOLD}}$ | Expansion bus hold: an external device connected to the expansion bus may assert this signal to add wait states to an expansion bus transaction. |

MibADC

The multi-buffered analog-to-digital converter (MibADC) accepts an analog signal and converts the signal to a 10-bit digital value.

The A384 MibADC module can function in two modes: compatibility mode, where its programmer's model is compatible with the TMS470R1x ADC module and its digital results are stored in digital result registers; or in buffered mode, where the digital result registers are replaced with three FIFO buffers, one for each conversion group [event, group1 (G1), and group2 (G2)]. In buffered mode, the MibADC buffers can be serviced by interrupts or by the DMA.

NOTE:

The MibADC on this device does not support the DMA.

MibADC Event Trigger Enhancements

The MibADC includes two major enhancements over the event-triggering capability of the TMS470R1x ADC.

- Both group1 and the event group can be configured for event-triggered operation, providing up to two event-triggered groups.
- The trigger source and polarity can be selected individually for both group1 and the event group from the options identified in [Table 9](#).

Table 9. MibADC Event Hookup Configuration

| EVENT NO. | SOURCE SELECT BITS FOR G1 OR EVENT (G1SRC[1:0] OR EVSRC[1:0]) | SIGNAL PIN NAME |
|-----------|--|-----------------|
| EVENT1 | 00 | ADEVT |
| EVENT2 | 01 | HET18 |
| EVENT3 | 10 | Reserved |
| EVENT4 | 11 | Reserved |

For group1, these event-triggered selections are configured via the group1 source select bits (G1SRC[1:0]) in the AD event source register (ADEVTSRC[5:4]). For the event group, these event-triggered selections are configured via the event group source select bits (EVSRC[1:0]) in the AD event source register (ADEVTSRC[1:0]).

For more detailed functional information on the MibADC, see the *TMS470R1x Multi-Buffered Analog-to-Digital Converter (MibADC) Reference Guide* (literature number SPNU206).

JTAG Interface

There are two main test access ports (TAPs) on the device:

- TMS470R1x CPU TAP
- Device TAP for factory test

Some of the JTAG pins are shared among these two TAPs. The connection is shown in [Figure 2](#).

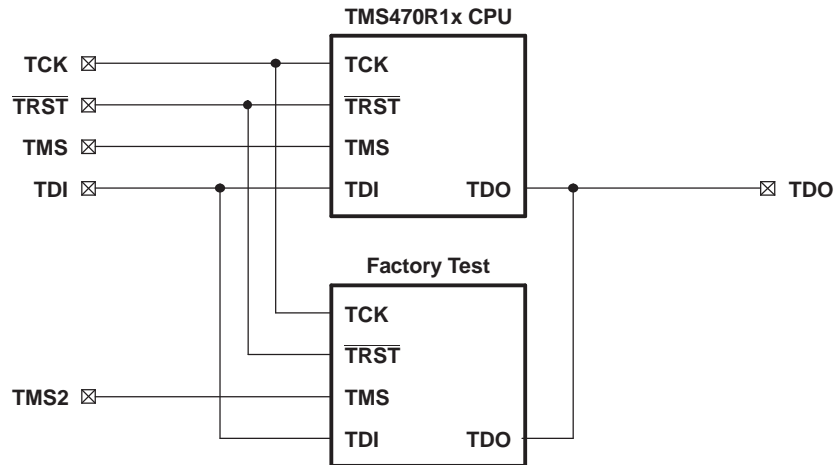


Figure 2. JTAG Interface

Documentation Support

Extensive documentation supports all of the TMS470 microcontroller family generation of devices. The types of documentation available include data sheets with design specifications, complete user's guides for all devices and development support tools, and hardware and software applications. Useful reference documentation includes:

- Bulletin
 - *TMS470 Microcontroller Family Product Bulletin* (literature number SPNB086)
- User's Guides
 - *TMS470R1x System Module Reference Guide* (literature number SPNU189)
 - *TMS470R1x General Purpose Input/Output (GPIO) Reference Guide* (literature number SPNU192)
 - *TMS470R1x Direct Memory Access (DMA) Controller Reference Guide* (literature number SPNU194)
 - *TMS470R1x Serial Peripheral Interface (SPI) Reference Guide* (literature number SPNU195)
 - *TMS470R1x Serial Communication Interface (SCI) Reference Guide* (literature number SPNU196)
 - *TMS470R1x Controller Area Network (CAN) Reference Guide* (literature number SPNU197)
 - *TMS470R1x High End Timer (HET) Reference Guide* (literature number SPNU199)
 - *TMS470R1x External Clock Prescale (ECP) Reference Guide* (literature number SPNU202)
 - *TMS470R1x MultiBuffered Analog to Digital (MibADC) Reference Guide* (literature number SPNU206)
 - *TMS470R1x Zero Pin Phase-Locked Loop (ZPLL) Clock Module Reference Guide* (literature number SPNU212)
 - *TMS470R1x F05 Flash Reference Guide* (literature number SPNU213)
 - *TMS470R1x Class II Serial Interface B (C2S1b) Reference Guide* (literature number SPNU214)
 - *TMS470R1x Class II Serial Interface A (C2S1a) Reference Guide* (literature number SPNU218)
 - *TMS470R1x JTAG Security Module (JSM) Reference Guide* (literature number SPNU245)
 - *TMS470R1x Memory Security Module (MSM) Reference Guide* (literature number SPNU246)
 - *TMS470 Peripherals Overview Reference Guide* (literature number SPNU248)
- Errata Sheet
 - *TMS470R1A384 TMS470 Microcontrollers Silicon Errata* (literature number SPNZ148)

Device and Development-Support Tool Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all DSP devices and support tools. Each DSP commercial family member has one of three prefixes: TMX, TMP, or TMS (e.g., **TMS470R1A384**). Texas Instruments recommends two of three possible prefix designators for its support tools: TMDX and TMDS. These prefixes represent evolutionary stages of product development from engineering prototypes (TMX/TMDX) through fully qualified production devices/tools (TMS/TMDS).

Device development evolutionary flow:

TMX Experimental device that is not necessarily representative of the final device's electrical specifications

TMP Final silicon die that conforms to the device's electrical specifications but has not completed quality and reliability verification

TMS Fully qualified production device

Support tool development evolutionary flow:

TMDX Development-support product that has not yet completed Texas Instruments internal qualification testing.

TMDS Fully qualified development-support product

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

"Developmental product is intended for internal evaluation purposes."

TMS devices and TMDS development-support tools have been characterized fully, and the quality and reliability of the device have been demonstrated fully. TI's standard warranty applies.

Predictions show that prototype devices (TMX or TMP) have a greater failure rate than the standard production devices. Texas Instruments recommends that these devices not be used in any production system because their expected end-use failure rate still is undefined. Only qualified production devices are to be used.

[Figure 3](#) illustrates the numbering and symbol nomenclature for the TMS470R1x family.

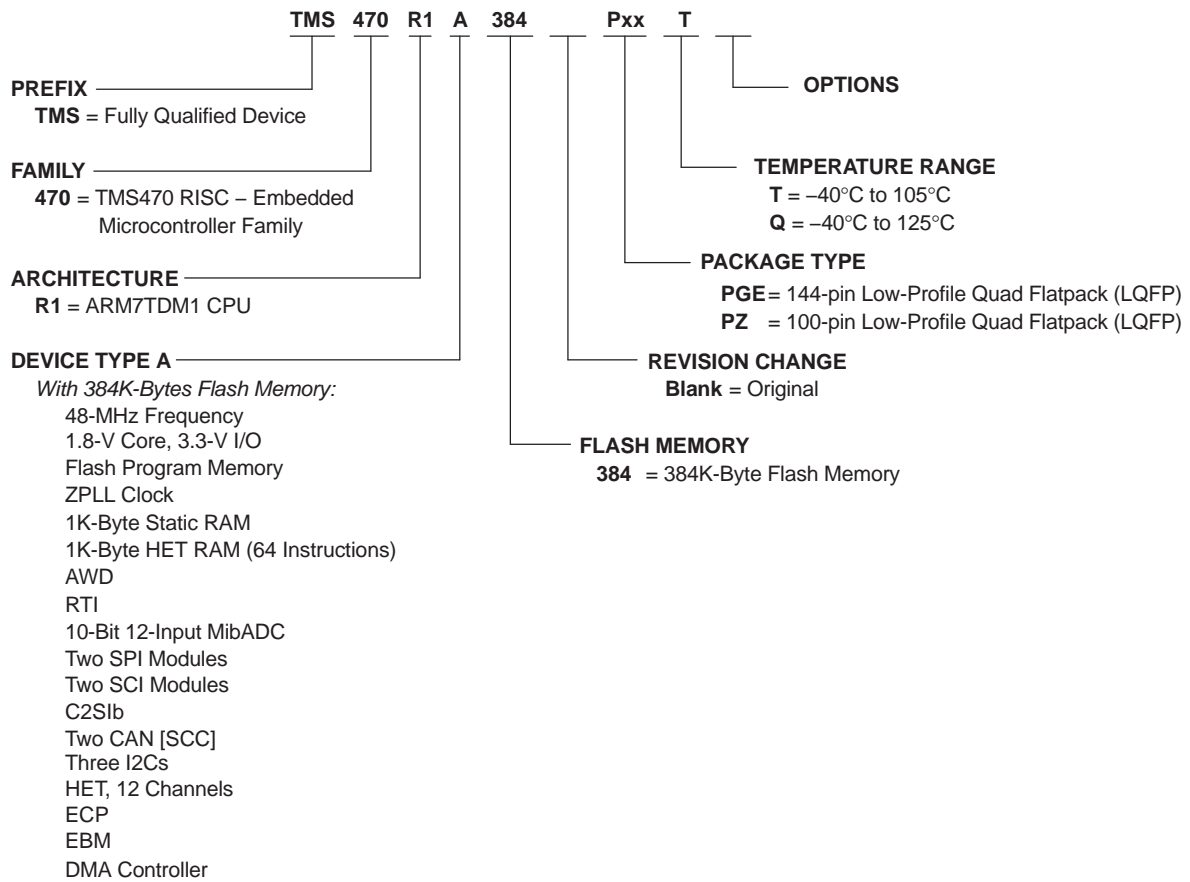
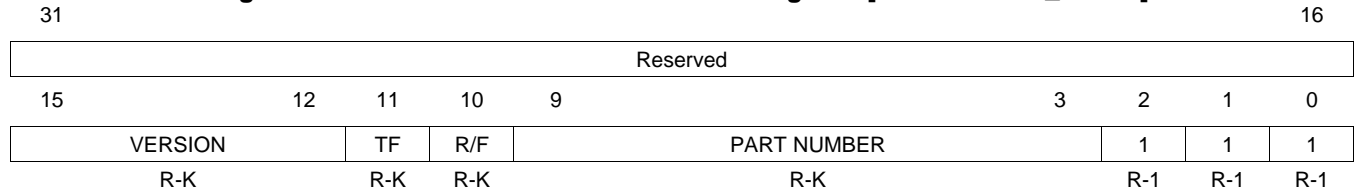


Figure 3. TMS470R1x Family Nomenclature

Device Identification Code Register

The device identification code register identifies the silicon version, the technology family (TF), a ROM or flash device, and an assigned device-specific part number (see [Figure 4](#)). The A384 device identification code register value is 0x096F.

Figure 4. TMS470 Device ID Bit Allocation Register [offset = FFFF_FFF0h]



LEGEND:

R = Read only, -K = Value constant after **RESET**; -n = Value after **RESET**

Table 10. TMS470 Device ID Bit Allocation Register Field Descriptions

| Bit | Field | Value | Description |
|-------|-------------|--------|---|
| 31–16 | Reserved | | Reads are undefined and writes have no effect. |
| 15–12 | VERSION | | Silicon version (revision) bits These bits identify the silicon version of the device. Initial device version numbers start at 0000. |
| 11 | TF | 0 1 | Technology family bit This bit distinguishes the technology family core power supply: 3.3 V for F10/C10 devices 1.8 V for F05/C05 devices |
| 10 | R/F | 0 1 | ROM/flash bit This bit distinguishes between ROM and flash devices: Flash device ROM device |
| 9–3 | PART NUMBER | | Device-specific part number bits These bits identify the assigned device-specific part number. The assigned device-specific part number for the A384 device is 0101101. |
| 2–0 | 1 | | Mandatory High Bits 2, 1, and 0 are tied high by default. |

Device Electrical Specifications and Timing Parameters

Absolute Maximum Ratings

over operating free-air temperature range⁽¹⁾

| | | |
|---|--|-----------------------|
| Supply voltage range: | V_{CC} ⁽²⁾ | –0.5 V to 2.5 V |
| Supply voltage range: | V_{CCIO} , V_{CCAD} , V_{CCP} (flash pump) ⁽²⁾ | –0.5 V to 4.1 V |
| Input voltage range: | All 5-V- tolerant input pins | –0.5 V to 6.0 V |
| | All other input pins | –0.5 V to 4.1 V |
| Input clamp current, I_{IK} : | All 5-V tolerant pins, \overline{PORRST} , \overline{TRST} , TEST, and TCK ($V_I < 0$) | –20 mA ⁽³⁾ |
| | ADIN[0:11] ($V_I < 0$ or $V_I > V_{CCAD}$) | ±10 mA |
| | All other pins ($V_I < 0$ or $V_I > V_{CCAD}$) | ±20 mA |
| Operating free-air temperature range, T_A | T version | –40°C to 105°C |
| | Q version | –40°C to 125°C |
| Operating junction temperature range, T_J | | –40°C to 150°C |
| Storage temperature range, T_{stg} | | –40°C to 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 "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to their associated grounds.

(3) These pins do not have an internal clamp diode to a positive supply voltage.

Device Recommended Operating Conditions⁽¹⁾

| | | MIN | NOM | MAX | UNIT |
|------------|-------------------------------------|-----------|-----|------|------|
| V_{CC} | Digital logic supply voltage (Core) | 1.71 | | 2.05 | V |
| V_{CCIO} | Digital logic supply voltage (I/O) | 3 | 3.3 | 3.6 | V |
| V_{CCAD} | MibADC supply voltage | 3 | 3.3 | 3.6 | V |
| V_{CCP} | Flash pump supply voltage | 3 | 3.3 | 3.6 | V |
| V_{SS} | Digital logic supply ground | | 0 | | V |
| V_{SSAD} | MibADC supply ground | –0.1 | | 0.1 | V |
| T_A | Operating free-air temperature | T version | | 105 | °C |
| | | Q version | –40 | 125 | |
| T_J | Operating junction temperature | –40 | | 150 | °C |

(1) All voltages are with respect to V_{SS} , except V_{CCAD} , which is with respect to V_{SSAD} .

Electrical Characteristics

 over recommended operating free-air temperature range⁽¹⁾

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|------------|---|--|--------------------------------------|-----|------------------|---------|---------|
| V_{hys} | Input hysteresis | | 0.15 | | | V | |
| V_{IL} | Low-level input voltage | All inputs ⁽²⁾ except OSCIN | -0.3 | | 0.8 | V | |
| | | OSCIN only | -0.3 | | $0.35 V_{CC}$ | | |
| V_{IH} | High-level input voltage | All inputs except OSCIN | 2 | | $V_{CCIO} + 0.3$ | V | |
| | | OSCIN only | $0.65 V_{CC}$ | | $V_{CC} + 0.3$ | | |
| V_{th} | Input threshold voltage | AWD only | 1.35 | | 1.8 | V | |
| RDS_{ON} | Drain to source on resistance | AWD only ⁽³⁾ | $V_{OL} - 0.35 V$ at $I_{OL} = 4 mA$ | | 90 | | |
| V_{OL} | Low-level output voltage ⁽⁴⁾ | $I_{OL} = I_{OL MAX}$ | | | $0.2 V_{CCIO}$ | V | |
| | | $I_{OL} = 3 mA$ | | | 0.4 | | |
| V_{OH} | High-level output voltage ⁽⁴⁾ | $I_{OH} = I_{OH MIN}$ | $0.8 V_{CCIO}$ | | | V | |
| | | $I_{OH} = 250 \mu A$ | 2.7 | | | | |
| I_{IC} | Input clamp current (I/O pins) ⁽⁵⁾ | $V_I < V_{SSIO} - 0.3$ or $V_I > V_{CCIO} + 0.3$ | -2 | | 2 | mA | |
| I_i | Input current (3.3-V input pins) | I_{IL} Pulldown | $V_I = V_{SS}$ | -1 | | 1 | μA |
| | | I_{IH} Pulldown | $V_I = V_{CCIO}$ | 5 | | 40 | |
| | | I_{IL} Pullup | $V_I = V_{SS}$ | -40 | | -5 | |
| | | I_{IH} Pullup | $V_I = V_{CCIO}$ | -1 | | 1 | |
| | | All other pins | No pullup or pulldown | -1 | | 1 | |
| | Input current (5-V tolerant input pins) | $V_I = V_{SS}$ | -1 | | 1 | μA | |
| | | $V_I = V_{CCIO}$ | -1 | | 1 | | |
| | | $V_I = 5 V$ | 0.5 | | 20 | | |
| | | $V_I = 5.5 V$ | 1 | | 40 | | |
| I_{OL} | Low-level output current | RST, CLKOUT, AWD, TDO | $V_{OL} = V_{OL MAX}$ | | | 4 | mA |
| | | All other 3.3 V I/O ⁽⁶⁾ | | | | 2 | |
| | | 5-V tolerant | | | | 4 | |
| I_{OH} | High-level output current | RST, CLKOUT, TDO | $V_{OH} = V_{OH MIN}$ | | | -4 | mA |
| | | All other 3.3 V I/O ⁽⁶⁾ | | | | -2 | |
| | | 5 V tolerant | | | | -4 | |

(1) Source currents (out of the device) are negative, while sink currents (into the device) are positive.

(2) This does not apply to the \overline{PORRST} pin. For \overline{PORRST} exceptions, see the *RST and \overline{PORRST} Timings* section.

(3) These values help to determine the external RC network circuit. For more details, see the *TMS470R1x System Module Reference Guide* (literature number SPNU189).

(4) V_{OL} and V_{OH} are linear with respect to the amount of load current (I_{OL}/I_{OH}) applied.

(5) Parameter does not apply to input-only or output-only pins.

(6) The 2-mA buffers on this device are called zero-dominant buffers. If two of these buffers are shorted together and one is outputting a low level and the other is outputting a high level, the resulting value is always low.

Electrical Characteristics (continued)

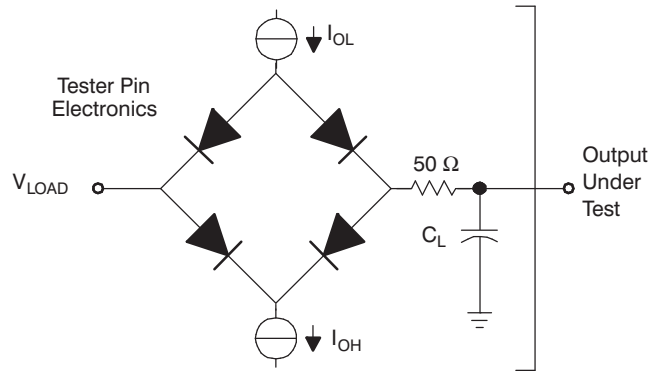
over recommended operating free-air temperature range

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|--|--|-------------------|-----|-----|------|------|
| I _{CC} | V _{CC} digital supply current (operating mode) | SYSCLK = 24 MHz, ICLK = 15 MHz, V _{CC} = 2.05 V | | | | 90 | mA |
| | | SYSCLK = 48 MHz, ICLK = 24 MHz, V _{CC} = 2.05 V | | | | 115 | |
| | V _{CC} digital supply current (standby mode) ⁽⁷⁾ | OSCIN = 4 MHz, V _{CC} = 2.05 V | T version (105°C) | | | 1 | mA |
| | | | Q version (125°C) | | | 1.25 | |
| V _{CC} digital supply current (halt mode) ⁽⁷⁾ | 30°C version, V _{CC} = 2.05 V | | | | 30 | μA | |
| | T version (105°C), V _{CC} = 2.05 V | | | | 365 | | |
| | Q version (125°C), V _{CC} = 2.05 V | | | | 550 | | |
| I _{CCIO} | V _{CCIO} digital supply current (operating mode) | No DC load, V _{CCIO} = 3.6 V ⁽⁸⁾ | | | | 10 | mA |
| | V _{CCIO} digital supply current (standby mode) | No DC load, V _{CCIO} = 3.6 V ⁽⁸⁾ | | | | 15 | μA |
| | V _{CCIO} digital supply current (halt mode) | No DC load, V _{CCIO} = 3.6 V ⁽⁸⁾ | | | | 5 | μA |
| I _{CCAD} | V _{CCAD} supply current (operating mode) | All frequencies, V _{CCAD} = 3.6 V | | | | 25 | mA |
| | V _{CCAD} supply current (standby mode) | No DC load, V _{CCAD} = 3.6 V ⁽⁸⁾ | | | | 10 | μA |
| | V _{CCAD} supply current (halt mode) | V _{CCAD} = 3.6 V | | | | 5 | μA |
| I _{CCP} | V _{CCP} pump supply current | V _{CCP} = 3.6 V read operation | | | | 25 | mA |
| | | V _{CCP} = 3.6 V program and erase | | | | 70 | mA |
| | | V _{CCP} = 3.6 V standby mode operation ⁽⁷⁾ | | | | 10 | μA |
| | | V _{CCP} = 3.6 V halt mode operation ⁽⁷⁾ | | | | 5 | μA |
| C _I | Input capacitance | | | | 2 | pF | |
| C _O | Output capacitance | | | | 3 | pF | |

(7) For flash banks/pumps in sleep mode.

(8) I/O pins configured as inputs or outputs with no load. All pulldown inputs ≤ 0.2 V. All pullup inputs ≥ V_{CCIO} – 0.2 V.

Parameter Measurement Information



Where: I_{OL} = I_{OL} MAX for the respective pin ^(A)
 I_{OH} = I_{OH} MIN for the respective pin ^(A)
 V_{LOAD} = 1.5 V
 C_L = 150-pF typical load-circuit capacitance ^(B)

- A. For these values, see the "Electrical Characteristics over Recommended Operating Free-Air Temperature Range" table.
- B. All timing parameters measured using an external load capacitance of 150 pF unless otherwise noted.

Figure 5. Test Load Circuit

Timing Parameter Symbolology

Timing parameter symbols have been 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:

| | | | |
|-----------|------------------------|------|--------------------------------|
| CM | Compaction, CMPCT | RD | Read |
| CO | CLKOUT | RST | Reset, $\overline{\text{RST}}$ |
| ER | Erase | RX | SCInRX |
| ICLK | Interface clock | S | Slave mode |
| M | Master mode | SCC | SCInCLK |
| OSC, OSC1 | OSCIN | SIMO | SPInSIMO |
| OSCO | OSCOU | SOMI | SPInSOMI |
| P | Program, PROG | SPC | SPInCLK |
| R | Ready | SYS | System clock |
| R0 | Read margin 0, RDMRGN0 | TX | SCInTX |
| R1 | Read margin 1, RDMRGN1 | | |

Lowercase subscripts and their meanings are:

| | | | |
|---|---------------------|----|------------------------|
| a | access time | r | rise time |
| c | cycle time (period) | su | setup time |
| d | delay time | t | transition time |
| f | fall time | v | valid time |
| h | hold time | w | pulse duration (width) |

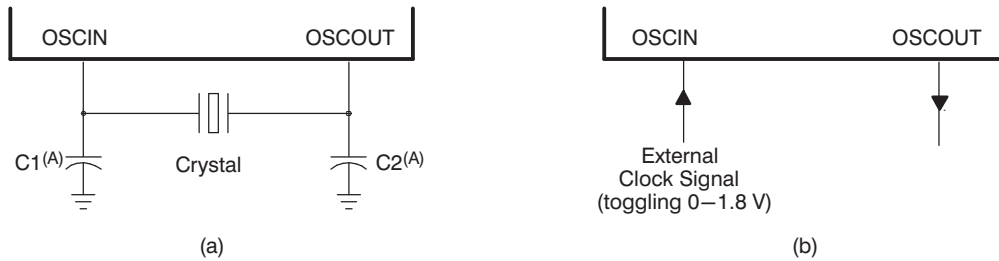
The following additional letters are used with these meanings:

| | | | |
|---|-------|---|--|
| H | High | X | Unknown, changing, or don't care level |
| L | Low | Z | High impedance |
| V | Valid | | |

External Reference Resonator/Crystal Oscillator Clock Option

The oscillator is enabled by connecting the appropriate fundamental 4-20 MHz resonator/crystal and load capacitors across the external OSCIN and OSCOUT pins as shown in Figure 6a. The oscillator is a single-stage inverter held in bias by an integrated bias resistor. This resistor is disabled during leakage test measurement and HALT mode. **TI strongly encourages each customer to submit samples of the device to the resonator/crystal vendors for validation.** The vendors are equipped to determine what load capacitors will best tune their resonator/crystal to the microcontroller device for optimum start-up and operation over temperature/voltage extremes.

An external oscillator source can be used by connecting a 1.8-V clock signal to the OSCIN pin and leaving the OSCOUT pin unconnected (open) as shown in Figure 6b.



- A. The values of C1 and C2 should be provided by the resonator/crystal vendor.

Figure 6. Crystal/Clock Connection

ZPLL AND CLOCK SPECIFICATIONS

Timing Requirements for ZPLL Circuits Enabled or Disabled

| | | MIN | TYP | MAX | UNIT |
|-----------------|-----------------------------------|-----|-----|-----|------|
| $f_{(OSC)}$ | Input clock frequency | 4 | | 20 | MHz |
| $t_{c(O SC)}$ | Cycle time, OSCIN | 50 | | | ns |
| $t_{w(O SCIL)}$ | Pulse duration, OSCIN low | 15 | | | ns |
| $t_{w(O SCIH)}$ | Pulse duration, OSCIN high | 15 | | | ns |
| $f_{(OSCRST)}$ | OSC FAIL frequency ⁽¹⁾ | | 53 | | kHz |

- (1) Causes a device reset (specifically a clock reset) by setting the RST OSC FAIL (GLBCTRL.15) and the OSC FAIL flag (GLBSTAT.1) bits equal to 1. For more detailed information on these bits and device resets, see the *TMS470R1x System Module Reference Guide* (literature number SPNU189).

Switching Characteristics Over Recommended Operating Conditions for Clocks⁽¹⁾⁽²⁾

| PARAMETER | | TEST CONDITIONS ⁽³⁾ | MIN | MAX | UNIT |
|-----------------|--|--------------------------------|------|-----|------|
| $f_{(SYS)}$ | System clock frequency ⁽⁴⁾ | Pipeline mode enabled | | 48 | MHz |
| | | Pipeline mode disabled | | 24 | MHz |
| $f_{(CONFIG)}$ | System clock frequency - flash config mode | | | 24 | MHz |
| $f_{(ICLK)}$ | Interface clock frequency | | | 24 | MHz |
| $f_{(ECLK)}$ | External clock output frequency for ECP module | | | 24 | MHz |
| $t_{c(SYS)}$ | Cycle time, system clock | Pipeline mode enabled | 20.8 | | ns |
| | | Pipeline mode disabled | 41.6 | | ns |
| $t_{c(CONFIG)}$ | Cycle time, system clock - flash config mode | | 41.6 | | ns |
| $t_{c(ICLK)}$ | Cycle time, interface clock | | 41.6 | | ns |
| $t_{c(ECLK)}$ | Cycle time, ECP module external clock output | | 41.6 | | ns |

- (1) $f_{(SYS)} = M \times f_{(OSC)}/R$, where $M = \{8\}$, $R = \{1,2,3,4,5,6,7,8\}$ when $PLLDIS = 0$. R is the system-clock divider determined by the CLKDIVPRE [2:0] bits in the global control register (GLBCTRL[2:0]) and M is the PLL multiplier determined by the MULT4 bit also in the GLBCTRL register (GLBCTRL.3).
 $f_{(SYS)} = f_{(OSC)}/R$, where $R = \{1,2,3,4,5,6,7,8\}$ when $PLLDIS = 1$.
 $f_{(ICLK)} = f_{(SYS)}/X$, where $X = \{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16\}$. X is the interface clock divider ratio determined by the PCR0[4:1] bits in the SYS module.
- (2) $f_{(ECLK)} = f_{(ICLK)}/N$, where $N = \{1 \text{ to } 256\}$. N is the ECP prescale value defined by the ECPCTRL[7:0] register bits in the ECP module.
- (3) Pipeline mode enabled or disabled is determined by the ENPIPE bit (FMREGOPT.0).
- (4) Flash Vread must be set to 5 V to achieve maximum system clock frequency.

Switching Characteristics Over Recommended Operating Conditions for External Clocks⁽¹⁾⁽²⁾⁽³⁾
(see [Figure 7](#) and [Figure 8](#))

| PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|--------------|-----------------------------|---|--|------|
| $t_{w(COL)}$ | Pulse duration, CLKOUT low | SYSCLK or MCLK ⁽⁴⁾ | $0.5t_{c(SYS)} - t_f$ | ns |
| | | ICLK: X is even or 1 ⁽⁵⁾ | $0.5t_{c(ICK)} - t_f$ | |
| | | ICLK: X is odd and not 1 ⁽⁵⁾ | $0.5t_{c(ICK)} + 0.5t_{c(SYS)} - t_f$ | |
| $t_{w(COH)}$ | Pulse duration, CLKOUT high | SYSCLK or MCLK ⁽⁴⁾ | $0.5t_{c(SYS)} - t_r$ | ns |
| | | ICLK: X is even or 1 ⁽⁵⁾ | $0.5t_{c(ICK)} - t_r$ | |
| | | ICLK: X is odd and not 1 ⁽⁵⁾ | $0.5t_{c(ICK)} - 0.5t_{c(SYS)} - t_r$ | |
| $t_{w(EOL)}$ | Pulse duration, ECLK low | N is even and X is even or odd | $0.5t_{c(ECLK)} - t_f$ | ns |
| | | N is odd and X is even | $0.5t_{c(ECLK)} - t_f$ | |
| | | N is odd and X is odd and not 1 | $0.5t_{c(ECLK)} + 0.5t_{c(SYS)} - t_f$ | |
| $t_{w(EOH)}$ | Pulse duration, ECLK high | N is even and X is even or odd | $0.5t_{c(ECLK)} - t_r$ | ns |
| | | N is odd and X is even | $0.5t_{c(ECLK)} - t_r$ | |
| | | N is odd and X is odd and not 1 | $0.5t_{c(ECLK)} - 0.5t_{c(SYS)} - t_r$ | |

- (1) X = {1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16}. X is the interface clock divider ratio determined by the PCR0[4:1] bits in the SYS module.
- (2) N = {1 to 256}. N is the ECP prescale value defined by the ECPCTRL[7:0] register bits in the ECP module.
- (3) CLKOUT/ECLK pulse durations (low/high) are a function of the OSCIN pulse durations when PLLDIS is active.
- (4) Clock source bits are selected as either SYSCLK (CLKCNTL[6:5] = 11 binary) or MCLK (CLKCNTL[6:5] = 10 binary).
- (5) Clock source bits are selected as ICLK (CLKCNTL[6:5] = 01 binary).

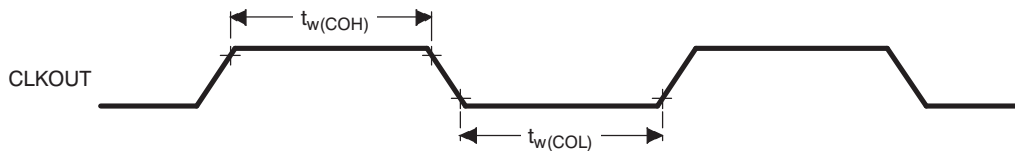


Figure 7. CLKOUT Timing Diagram

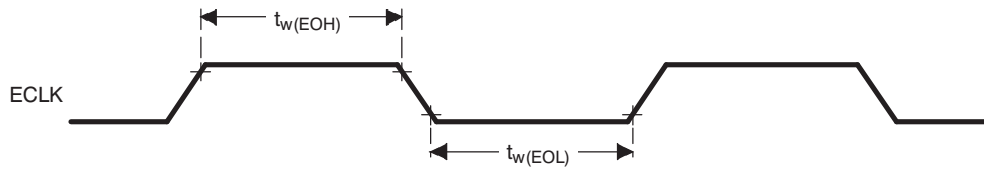


Figure 8. ECLK Timing Diagram

RST AND PORRST TIMINGS

Timing Requirements for PORRST

(see Figure 9)

| | | MIN | MAX | UNIT |
|----------------------------|--|------|-----------------------|------|
| V _{CCPORL} | V _{CC} low supply level when $\overline{\text{PORRST}}$ must be active during power up | | 0.6 | V |
| V _{CCPORH} | V _{CC} high supply level when $\overline{\text{PORRST}}$ must remain active during power up and become active during power down | 1.5 | | V |
| V _{CCIOPORL} | V _{CCIO} low supply level when $\overline{\text{PORRST}}$ must be active during power up | | 1.1 | V |
| V _{CCIOPORH} | V _{CCIO} high supply level when $\overline{\text{PORRST}}$ must remain active during power up and become active during power down | 2.75 | | V |
| V _{IL} | Low-level input voltage after V _{CCIO} > V _{CCIOPORH} | | 0.2 V _{CCIO} | V |
| V _{IL(PORRST)} | Low-level input voltage of $\overline{\text{PORRST}}$ before V _{CCIO} > V _{CCIOPORL} | | 0.5 | V |
| t _{su(PORRST)r} | Setup time, $\overline{\text{PORRST}}$ active before V _{CCIO} > V _{CCIOPORL} during power up | 0 | | ms |
| t _{su(VCCIO)r} | Setup time, V _{CCIO} > V _{CCIOPORL} before V _{CC} > V _{CCPORL} | 0 | | ms |
| t _{h(PORRST)r} | Hold time, $\overline{\text{PORRST}}$ active after V _{CC} > V _{CCPORH} | 1 | | ms |
| t _{su(PORRST)f} | Setup time, $\overline{\text{PORRST}}$ active before V _{CC} ≤ V _{CCPORH} during power down | 8 | | μs |
| t _{h(PORRST)rio} | Hold time, $\overline{\text{PORRST}}$ active after V _{CC} > V _{CCIOPORH} | 1 | | ms |
| t _{h(PORRST)d} | Hold time, $\overline{\text{PORRST}}$ active after V _{CC} < V _{CCPORL} | 0 | | ms |
| t _{su(PORRST)rio} | Setup time, $\overline{\text{PORRST}}$ active before V _{CC} ≤ V _{CCIOPORH} during power down | 0 | | ns |
| t _{su(VCCIO)f} | Setup time, V _{CC} < V _{CCPORL} before V _{CCIO} < V _{CCIOPORL} | 0 | | ns |

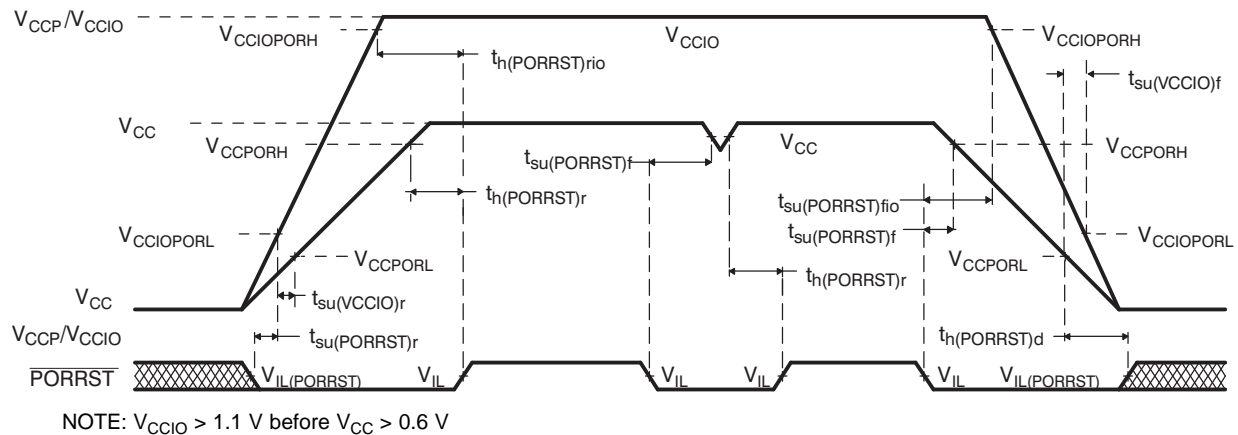


Figure 9. $\overline{\text{PORRST}}$ Timing Diagram

Switching Characteristics Over Recommended Operating Conditions for RST⁽¹⁾

| PARAMETER | | MIN | MAX | UNIT |
|---------------------|---|-------------------------|-----|------|
| t _{v(RST)} | Valid time, $\overline{\text{RST}}$ active after $\overline{\text{PORRST}}$ inactive | 4112t _{c(OSC)} | | ns |
| | Valid time, $\overline{\text{RST}}$ active (all others) | 8t _{c(SYS)} | | |
| t _{fsu} | Flash start-up time, from $\overline{\text{RST}}$ inactive to fetch of first instruction from flash (flash pump stabilization time) | 360t _{c(OSC)} | | ns |

(1) Specified values do NOT include rise/fall times. For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.

JTAG SCAN INTERFACE TIMING

(JTAG Clock Specification 10-MHz and 50-pF Load on TDO Output)

| | | MIN | MAX | UNIT |
|--------------------------|---|-----|-----|------|
| $t_{c(JTAG)}$ | Cycle time, JTAG low and high period | 50 | | ns |
| $t_{su(TDI/TMS - TCKr)}$ | Setup time, TDI, TMS before TCK rise (TCKr) | 15 | | ns |
| $t_h(TCKr - TDI/TMS)$ | Hold time, TDI, TMS after TCKr | 15 | | ns |
| $t_h(TCKf - TDO)$ | Hold time, TDO after TCKf | 10 | | ns |
| $t_d(TCKf - TDO)$ | Delay time, TDO valid after TCK fall (TCKf) | | 45 | ns |

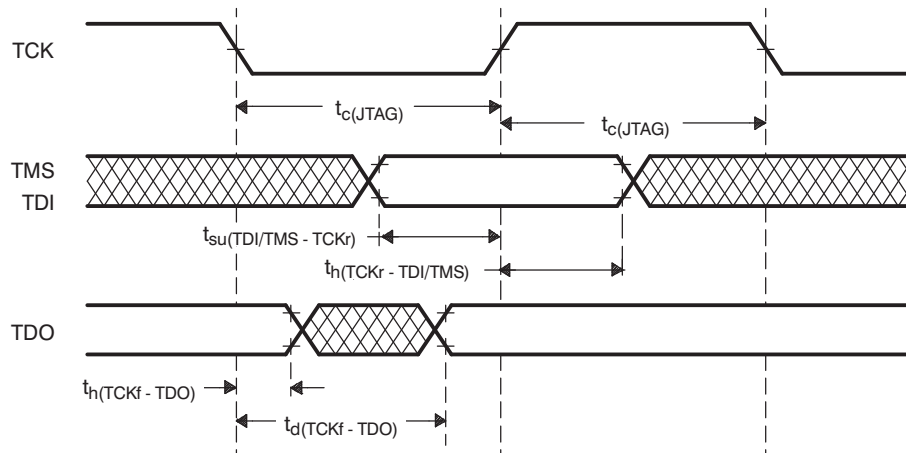


Figure 10. JTAG Scan Timings

OUTPUT TIMINGS

Switching Characteristics for Output Timings versus Load Capacitance (C_L)

(see [Figure 11](#))

| PARAMETER | | MIN | MAX | UNIT | |
|-----------|--|-----------------------|-----|------|----|
| t_r | Rise time, AWD, CLKOUT, \overline{RST} , TD0/GIOC[6] | $C_L = 15\text{ pF}$ | 2.5 | 8 | ns |
| | | $C_L = 50\text{ pF}$ | 5 | 14 | |
| | | $C_L = 100\text{ pF}$ | 9 | 23 | |
| | | $C_L = 150\text{ pF}$ | 13 | 32 | |
| t_f | Fall time, AWD, CLKOUT, TD0/GIOC[6] | $C_L = 15\text{ pF}$ | 2.5 | 8 | ns |
| | | $C_L = 50\text{ pF}$ | 5 | 14 | |
| | | $C_L = 100\text{ pF}$ | 9 | 23 | |
| | | $C_L = 150\text{ pF}$ | 13 | 32 | |
| t_r | Rise time, 4-mA 5-V tolerant pins | $C_L = 15\text{ pF}$ | 3 | 10 | ns |
| | | $C_L = 50\text{ pF}$ | 3.5 | 12 | |
| | | $C_L = 100\text{ pF}$ | 7 | 21 | |
| | | $C_L = 150\text{ pF}$ | 9 | 28 | |
| t_f | Fall time, 4-mA 5-V tolerant pins | $C_L = 15\text{ pF}$ | 2 | 8 | ns |
| | | $C_L = 50\text{ pF}$ | 2.5 | 9 | |
| | | $C_L = 100\text{ pF}$ | 8 | 25 | |
| | | $C_L = 150\text{ pF}$ | 11 | 35 | |
| t_r | Rise time, all other output pins | $C_L = 15\text{ pF}$ | 2.5 | 10 | ns |
| | | $C_L = 50\text{ pF}$ | 6.0 | 25 | |
| | | $C_L = 100\text{ pF}$ | 12 | 45 | |
| | | $C_L = 150\text{ pF}$ | 18 | 65 | |
| t_f | Fall time, all other output pins | $C_L = 15\text{ pF}$ | 3 | 10 | ns |
| | | $C_L = 50\text{ pF}$ | 8.5 | 25 | |
| | | $C_L = 100\text{ pF}$ | 16 | 45 | |
| | | $C_L = 150\text{ pF}$ | 23 | 65 | |

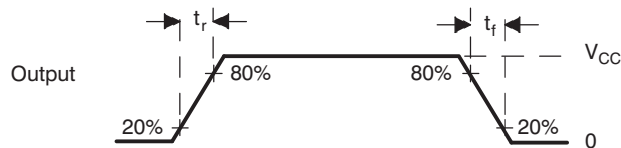


Figure 11. CMOS-Level Outputs

INPUT TIMINGS

Timing Requirements for Input Timings⁽¹⁾

(see Figure 12)

| | | MIN | MAX | UNIT |
|----------|---------------------------|--------------------|-----|------|
| t_{pw} | Input minimum pulse width | $t_{c(ICKL)} + 10$ | | ns |

(1) $t_{c(ICKL)} = \text{interface clock cycle time} = 1/f_{(ICKL)}$

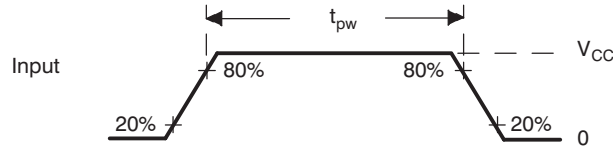


Figure 12. CMOS-Level Inputs

FLASH TIMINGS

Timing Requirements for Program Flash⁽¹⁾

| | | MIN | TYP | MAX | UNIT |
|---------------------|--|-------|----------------|-----|---------------|
| $t_{prog(16-bit)}$ | Half word (16-bit) programming time | 4 | 16 | 200 | μs |
| $t_{prog(Total)}$ | 384K-byte programming time ⁽²⁾ | | 3 | 10 | s |
| $t_{erase(sector)}$ | Sector erase time | | 1.7 | | s |
| t_{wec} | Write/erase cycles at $T_A = -40^\circ\text{C}$ to 125°C | 50000 | | | cycles |
| $t_{fp(RST)}$ | Flash pump settling time from \overline{RST} to SLEEP | | $72t_{c(SYS)}$ | | ns |
| $t_{fp(SLEEP)}$ | Initial flash pump settling time from SLEEP to STANDBY | | $72t_{c(SYS)}$ | | |
| $t_{fp(STANDBY)}$ | Initial flash pump settling time from STANDBY to ACTIVE | | $36t_{c(SYS)}$ | | |

(1) For more detailed information on the flash core sectors, see the *flash program and erase* section of this data sheet.

(2) The 384K-byte programming time includes overhead of state machine.

SPI_n MASTER MODE TIMING PARAMETERS

SPI_n Master Mode External Timing Parameters

(CLOCK PHASE = 0, SPI_nCLK = output, SPI_nSIMO = output, and SPI_nSOMI = input)⁽¹⁾⁽²⁾⁽³⁾ (see Figure 13)

| NO. | | | MIN | MAX | UNIT |
|------------------|----------------------|---|-------------------------|----------------------|------|
| 1 | $t_{c(SPC)M}$ | Cycle time, SPI _n CLK ⁽⁴⁾ | 100 | $256t_{c(ICLK)}$ | ns |
| 2 ⁽⁵⁾ | $t_{w(SPCH)M}$ | Pulse duration, SPI _n CLK high (clock polarity = 0) | $0.5t_{c(SPC)M} - t_r$ | $0.5t_{c(SPC)M} + 5$ | ns |
| | $t_{w(SPCL)M}$ | Pulse duration, SPI _n CLK low (clock polarity = 1) | $0.5t_{c(SPC)M} - t_f$ | $0.5t_{c(SPC)M} + 5$ | |
| 3 ⁽⁵⁾ | $t_{w(SPCL)M}$ | Pulse duration, SPI _n CLK low (clock polarity = 0) | $0.5t_{c(SPC)M} - t_f$ | $0.5t_{c(SPC)M} + 5$ | ns |
| | $t_{w(SPCH)M}$ | Pulse duration, SPI _n CLK high (clock polarity = 1) | $0.5t_{c(SPC)M} - t_r$ | $0.5t_{c(SPC)M} + 5$ | |
| 4 ⁽⁵⁾ | $t_{d(SPCH-SIMO)M}$ | Delay time, SPI _n CLK high to SPI _n SIMO valid (clock polarity = 0) | | 10 | ns |
| | $t_{d(SPCL-SIMO)M}$ | Delay time, SPI _n CLK low to SPI _n SIMO valid (clock polarity = 1) | | 10 | |
| 5 ⁽⁵⁾ | $t_{v(SPCL-SIMO)M}$ | Valid time, SPI _n SIMO data valid after SPI _n CLK low (clock polarity = 0) | $t_{c(SPC)M} - 5 - t_f$ | | ns |
| | $t_{v(SPCH-SIMO)M}$ | Valid time, SPI _n SIMO data valid after SPI _n CLK high (clock polarity = 1) | $t_{c(SPC)M} - 5 - t_r$ | | |
| 6 ⁽⁵⁾ | $t_{su(SOMI-SPCL)M}$ | Setup time, SPI _n SOMI before SPI _n CLK low (clock polarity = 0) | 6 | | ns |
| | $t_{su(SOMI-SPCH)M}$ | Setup time, SPI _n SOMI before SPI _n CLK high (clock polarity = 1) | 6 | | |
| 7 ⁽⁵⁾ | $t_{v(SPCL-SOMI)M}$ | Valid time, SPI _n SOMI data valid after SPI _n CLK low (clock polarity = 0) | 4 | | ns |
| | $t_{v(SPCH-SOMI)M}$ | Valid time, SPI _n SOMI data valid after SPI _n CLK high (clock polarity = 1) | 4 | | |

- (1) The MASTER bit (SPI_nCTRL2.3) is set and the CLOCK PHASE bit (SPI_nCTRL2.0) is cleared.
- (2) $t_{c(ICLK)}$ = interface clock cycle time = $1/f_{(ICLK)}$
- (3) For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.
- (4) When the SPI is in master mode, the following must be true:
For PS values from 1 to 255: $t_{c(SPC)M} \geq (PS + 1)t_{c(ICLK)} \geq 100$ ns, where PS is the prescale value set in the SPI_nCTL1[12:5] register bits.
For PS values of 0: $t_{c(SPC)M} = 2t_{c(ICLK)} \geq 100$ ns.
- (5) The active edge of the SPI_nCLK signal referenced is controlled by the CLOCK POLARITY bit (SPI_nCTRL2[1]).

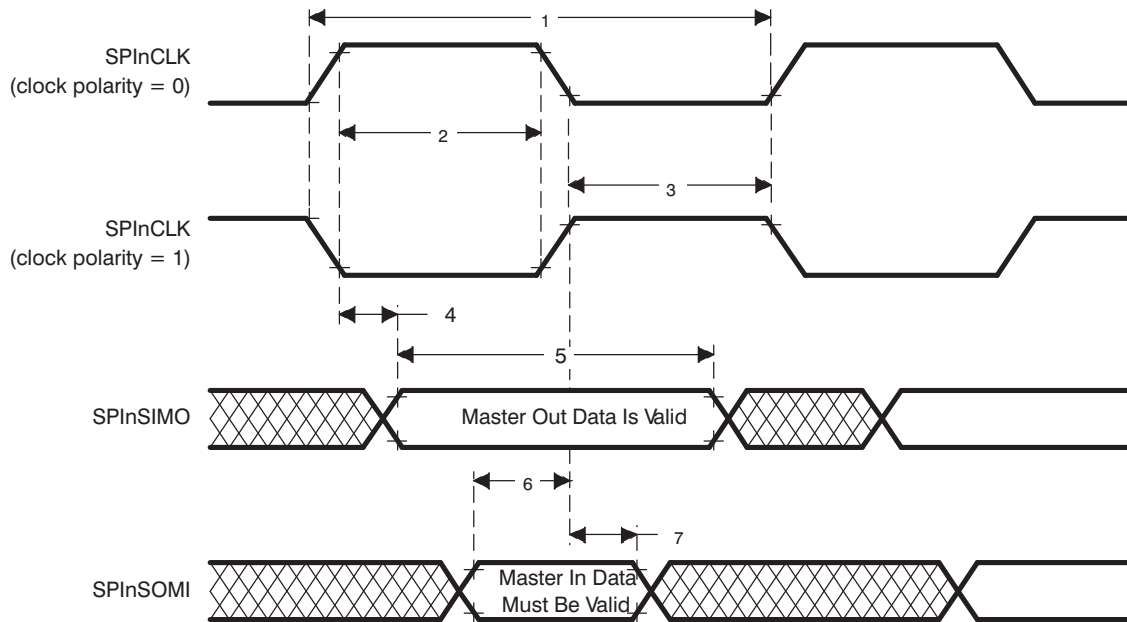


Figure 13. SPI_n Master Mode External Timing (CLOCK PHASE = 0)

SPIn Master Mode External Timing Parameters

(CLOCK PHASE = 1, SPInCLK = output, SPInSIMO = output, and SPInSOMI = input)⁽¹⁾⁽²⁾⁽³⁾ (see Figure 14)

| NO. | | | MIN | MAX | UNIT |
|------------------|----------------------|---|----------------------------|----------------------|------|
| 1 | $t_{c(SPC)M}$ | Cycle time, SPInCLK ⁽⁴⁾ | 100 | $256t_{c(ICLK)}$ | ns |
| 2 ⁽⁵⁾ | $t_{w(SPCH)M}$ | Pulse duration, SPInCLK high (clock polarity = 0) | $0.5t_{c(SPC)M} - t_f$ | $0.5t_{c(SPC)M} + 5$ | ns |
| | $t_{w(SPCL)M}$ | Pulse duration, SPInCLK low (clock polarity = 1) | $0.5t_{c(SPC)M} - t_f$ | $0.5t_{c(SPC)M} + 5$ | |
| 3 ⁽⁵⁾ | $t_{w(SPCL)M}$ | Pulse duration, SPInCLK low (clock polarity = 0) | $0.5t_{c(SPC)M} - t_f$ | $0.5t_{c(SPC)M} + 5$ | ns |
| | $t_{w(SPCH)M}$ | Pulse duration, SPInCLK high (clock polarity = 1) | $0.5t_{c(SPC)M} - t_f$ | $0.5t_{c(SPC)M} + 5$ | |
| 4 ⁽⁵⁾ | $t_{v(SIMO-SPCH)M}$ | Valid time, SPInCLK high after SPInSIMO data valid (clock polarity = 0) | $0.5t_{c(SPC)M} - 10$ | | ns |
| | $t_{v(SIMO-SPCL)M}$ | Valid time, SPInCLK low after SPInSIMO data valid (clock polarity = 1) | $0.5t_{c(SPC)M} - 10$ | | |
| 5 ⁽⁵⁾ | $t_{v(SPCH-SIMO)M}$ | Valid time, SPInSIMO data valid after SPInCLK high (clock polarity = 0) | $0.5t_{c(SPC)M} - 5 - t_f$ | | ns |
| | $t_{v(SPCL-SIMO)M}$ | Valid time, SPInSIMO data valid after SPInCLK low (clock polarity = 1) | $0.5t_{c(SPC)M} - 5 - t_f$ | | |
| 6 ⁽⁵⁾ | $t_{su(SOMI-SPCH)M}$ | Setup time, SPInSOMI before SPInCLK high (clock polarity = 0) | 6 | | ns |
| | $t_{su(SOMI-SPCL)M}$ | Setup time, SPInSOMI before SPInCLK low (clock polarity = 1) | 6 | | |
| 7 ⁽⁵⁾ | $t_{v(SPCH-SOMI)M}$ | Valid time, SPInSOMI data valid after SPInCLK high (clock polarity = 0) | 4 | | ns |
| | $t_{v(SPCL-SOMI)M}$ | Valid time, SPInSOMI data valid after SPInCLK low (clock polarity = 1) | 4 | | |

- (1) The MASTER bit (SPInCTRL2.3) is set and the CLOCK PHASE bit (SPInCTRL2.0) is set.
- (2) $t_{c(ICLK)}$ = interface clock cycle time = $1/f_{ICLK}$
- (3) For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.
- (4) When the SPI is in master mode, the following must be true:
For PS values from 1 to 255: $t_{c(SPC)M} \geq (PS + 1)t_{c(ICLK)} \geq 100$ ns, where PS is the prescale value set in the SPInCTL1[12:5] register bits.
For PS values of 0: $t_{c(SPC)M} = 2t_{c(ICLK)} \geq 100$ ns.
- (5) The active edge of the SPInCLK signal referenced is controlled by the CLOCK POLARITY bit (SPInCTRL2[1]).

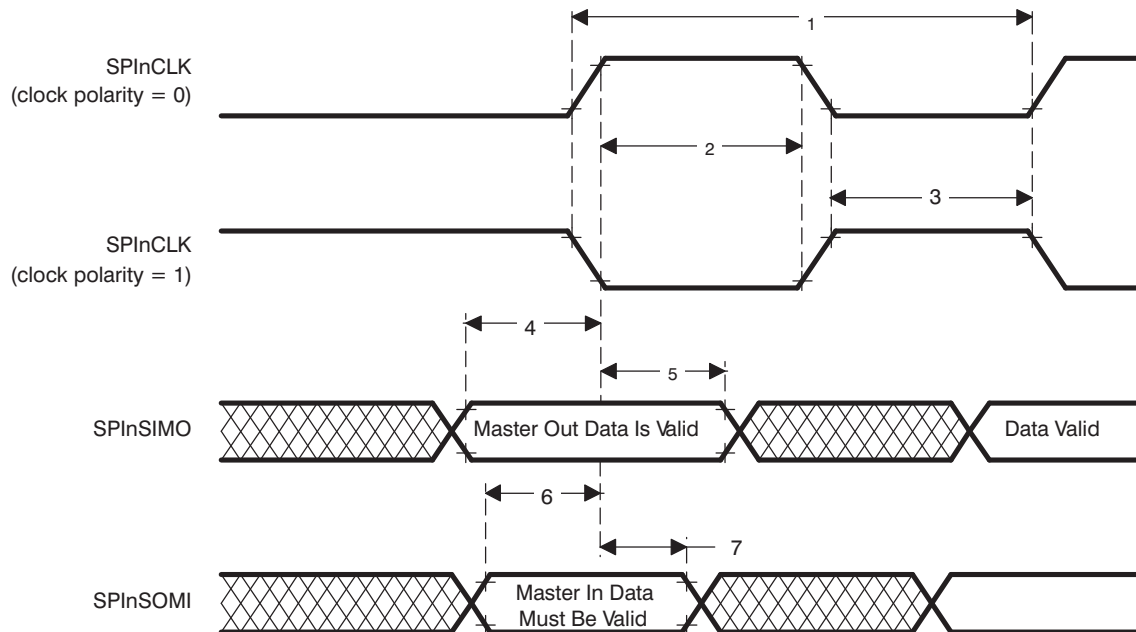


Figure 14. SPIn Master Mode External Timing (CLOCK PHASE = 1)

SPI_n SLAVE MODE TIMING PARAMETERS

SPI_n Slave Mode External Timing Parameters

(CLOCK PHASE = 0, SPI_nCLK = input, SPI_nSIMO = input, and SPI_nSOMI = output)⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾ (see Figure 15)

| NO. | | | MIN | MAX | UNIT |
|------------------|----------------------|---|------------------------------------|------------------------------------|------|
| 1 | $t_{c(SPC)S}$ | Cycle time, SPI _n CLK ⁽⁵⁾ | 100 | $256t_{c(I)CLK}$ | ns |
| 2 ⁽⁶⁾ | $t_{w(SPCH)S}$ | Pulse duration, SPI _n CLK high (clock polarity = 0) | $0.5t_{c(SPC)S} - 0.25t_{c(I)CLK}$ | $0.5t_{c(SPC)S} + 0.25t_{c(I)CLK}$ | ns |
| | $t_{w(SPCL)S}$ | Pulse duration, SPI _n CLK low (clock polarity = 1) | $0.5t_{c(SPC)S} - 0.25t_{c(I)CLK}$ | $0.5t_{c(SPC)S} + 0.25t_{c(I)CLK}$ | |
| 3 ⁽⁶⁾ | $t_{w(SPCL)S}$ | Pulse duration, SPI _n CLK low (clock polarity = 0) | $0.5t_{c(SPC)S} - 0.25t_{c(I)CLK}$ | $0.5t_{c(SPC)S} + 0.25t_{c(I)CLK}$ | ns |
| | $t_{w(SPCH)S}$ | Pulse duration, SPI _n CLK high (clock polarity = 1) | $0.5t_{c(SPC)S} - 0.25t_{c(I)CLK}$ | $0.5t_{c(SPC)S} + 0.25t_{c(I)CLK}$ | |
| 4 ⁽⁶⁾ | $t_{d(SPCH-SOMI)S}$ | Delay time, SPI _n CLK high to SPI _n SOMI valid (clock polarity = 0) | | $6 + t_f$ | ns |
| | $t_{d(SPCL-SOMI)S}$ | Delay time, SPI _n CLK low to SPI _n SOMI valid (clock polarity = 1) | | $6 + t_f$ | |
| 5 ⁽⁶⁾ | $t_{v(SPCH-SOMI)S}$ | Valid time, SPI _n SOMI data valid after SPI _n CLK high (clock polarity = 0) | $t_{c(SPC)S} - 6 - t_f$ | | ns |
| | $t_{v(SPCL-SOMI)S}$ | Valid time, SPI _n SOMI data valid after SPI _n CLK low (clock polarity = 1) | $t_{c(SPC)S} - 6 - t_f$ | | |
| 6 ⁽⁶⁾ | $t_{su(SIMO-SPCL)S}$ | Setup time, SPI _n SIMO before SPI _n CLK low (clock polarity = 0) | 6 | | ns |
| | $t_{su(SIMO-SPCH)S}$ | Setup time, SPI _n SIMO before SPI _n CLK high (clock polarity = 1) | 6 | | |
| 7 ⁽⁶⁾ | $t_{v(SPCL-SIMO)S}$ | Valid time, SPI _n SIMO data valid after SPI _n CLK low (clock polarity = 0) | 6 | | ns |
| | $t_{v(SPCH-SIMO)S}$ | Valid time, SPI _n SIMO data valid after SPI _n CLK high (clock polarity = 1) | 6 | | |

- (1) The MASTER bit (SPI_nCTRL2.3) is cleared and the CLOCK PHASE bit (SPI_nCTRL2.0) is cleared.
- (2) If the SPI is in slave mode, the following must be true: $t_{c(SPC)S} \geq (PS + 1) t_{c(I)CLK}$, where PS = prescale value set in SPI_nCTL1[12:5].
- (3) For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.
- (4) $t_{c(I)CLK} = \text{interface clock cycle time} = 1/f_{(I)CLK}$
- (5) When the SPI_n is in slave mode, the following must be true:
For PS values from 1 to 255: $t_{c(SPC)S} \geq (PS + 1)t_{c(I)CLK} \geq 100$ ns, where PS is the prescale value set in the SPI_nCTL1[12:5] register bits.
For PS values of 0: $t_{c(SPC)S} = 2t_{c(I)CLK} \geq 100$ ns.
- (6) The active edge of the SPI_nCLK signal referenced is controlled by the CLOCK POLARITY bit (SPI_nCTRL2[1]).

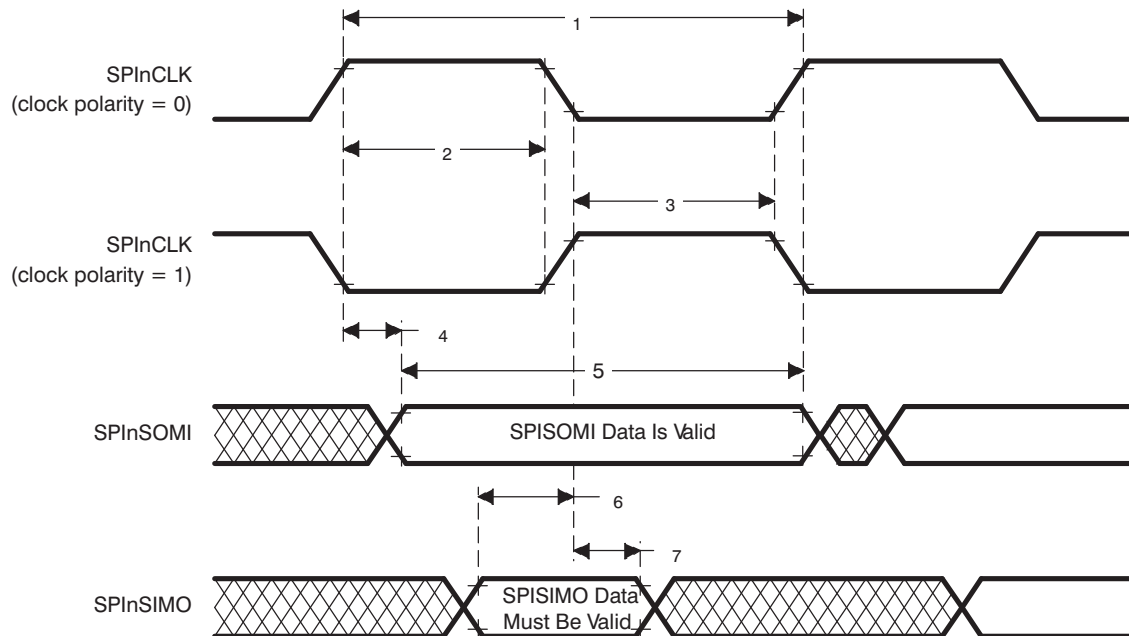


Figure 15. SPI_n Slave Mode External Timing (CLOCK PHASE = 0)

SPIn Slave Mode External Timing Parameters

(CLOCK PHASE = 1, SPInCLK = input, SPInSIMO = input, and SPInSOMI = output)⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾ (see Figure 16)

| NO. | | | MIN | MAX | UNIT |
|------------------|----------------------|---|------------------------------------|------------------------------------|------|
| 1 | $t_{c(SPC)S}$ | Cycle time, SPInCLK ⁽⁵⁾ | 100 | $256t_{c(ICLK)}$ | ns |
| 2 ⁽⁶⁾ | $t_{w(SPCH)S}$ | Pulse duration, SPInCLK high (clock polarity = 0) | $0.5t_{c(SPC)S} - 0.25t_{c(ICLK)}$ | $0.5t_{c(SPC)S} + 0.25t_{c(ICLK)}$ | ns |
| | $t_{w(SPCL)S}$ | Pulse duration, SPInCLK low (clock polarity = 1) | $0.5t_{c(SPC)S} - 0.25t_{c(ICLK)}$ | $0.5t_{c(SPC)S} + 0.25t_{c(ICLK)}$ | |
| 3 ⁽⁶⁾ | $t_{w(SPCL)S}$ | Pulse duration, SPInCLK low (clock polarity = 0) | $0.5t_{c(SPC)S} - 0.25t_{c(ICLK)}$ | $0.5t_{c(SPC)S} + 0.25t_{c(ICLK)}$ | ns |
| | $t_{w(SPCH)S}$ | Pulse duration, SPInCLK high (clock polarity = 1) | $0.5t_{c(SPC)S} - 0.25t_{c(ICLK)}$ | $0.5t_{c(SPC)S} + 0.25t_{c(ICLK)}$ | |
| 4 ⁽⁶⁾ | $t_{v(SOMI-SPCH)S}$ | Valid time, SPInCLK high after SPInSOMI data valid (clock polarity = 0) | $0.5t_{c(SPC)S} - 6 - t_r$ | | ns |
| | $t_{v(SOMI-SPCL)S}$ | Valid time, SPInCLK low after SPInSOMI data valid (clock polarity = 1) | $0.5t_{c(SPC)S} - 6 - t_f$ | | |
| 5 ⁽⁶⁾ | $t_{v(SPCH-SOMI)S}$ | Valid time, SPInSOMI data valid after SPInCLK high (clock polarity = 0) | $0.5t_{c(SPC)S} - 6 - t_r$ | | ns |
| | $t_{v(SPCL-SOMI)S}$ | Valid time, SPInSOMI data valid after SPInCLK low (clock polarity = 1) | $0.5t_{c(SPC)S} - 6 - t_f$ | | |
| 6 ⁽⁶⁾ | $t_{su(SIMO-SPCH)S}$ | Setup time, SPInSIMO before SPInCLK high (clock polarity = 0) | 6 | | ns |
| | $t_{su(SIMO-SPCL)S}$ | Setup time, SPInSIMO before SPInCLK low (clock polarity = 1) | 6 | | |
| 7 ⁽⁶⁾ | $t_{v(SPCH-SIMO)S}$ | Valid time, SPInSIMO data valid after SPInCLK high (clock polarity = 0) | 6 | | ns |
| | $t_{v(SPCL-SIMO)S}$ | Valid time, SPInSIMO data valid after SPInCLK low (clock polarity = 1) | 6 | | |

- (1) The MASTER bit (SPInCTRL2.3) is cleared and the CLOCK PHASE bit (SPInCTRL2.0) is set.
- (2) If the SPI is in slave mode, the following must be true: $t_{c(SPC)S} \geq (PS + 1) t_{c(ICLK)}$, where PS = prescale value set in SPInCTL1[12:5].
- (3) For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.
- (4) $t_{c(ICLK)}$ = interface clock cycle time = $1/f_{(ICLK)}$
- (5) When the SPIn is in slave mode, the following must be true:
For PS values from 1 to 255: $t_{c(SPC)S} \geq (PS + 1)t_{c(ICLK)} \geq 100$ ns, where PS is the prescale value set in the SPInCTL1[12:5] register bits.
For PS values of 0: $t_{c(SPC)S} = 2t_{c(ICLK)} \geq 100$ ns.
- (6) The active edge of the SPInCLK signal referenced is controlled by the CLOCK POLARITY bit (SPInCTRL2[1]).

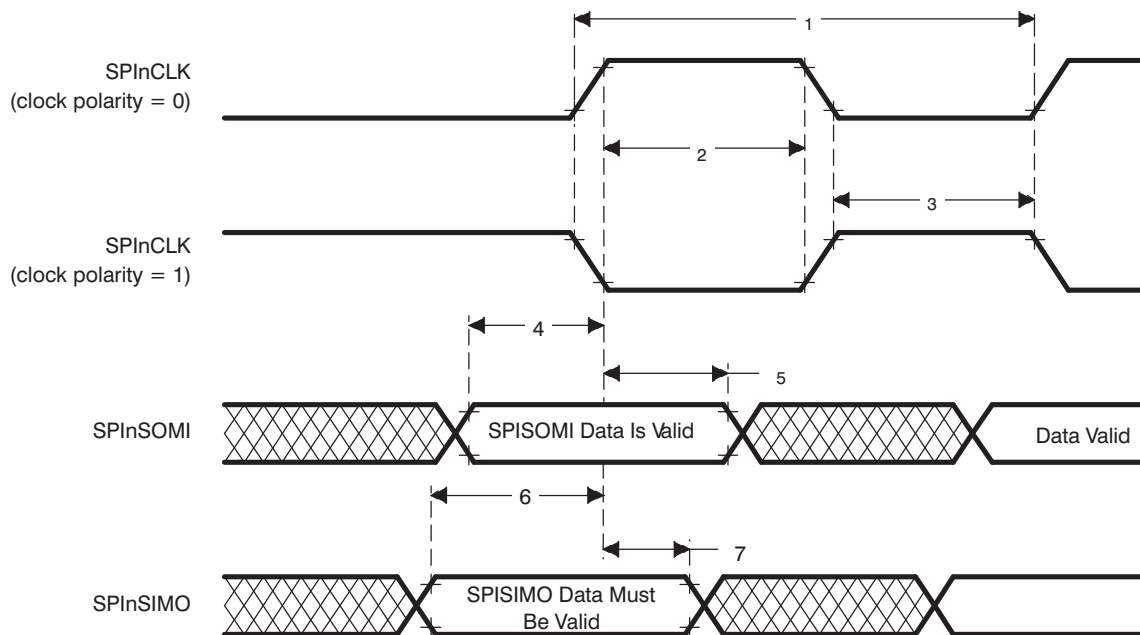


Figure 16. SPIn Slave Mode External Timing (CLOCK PHASE = 1)

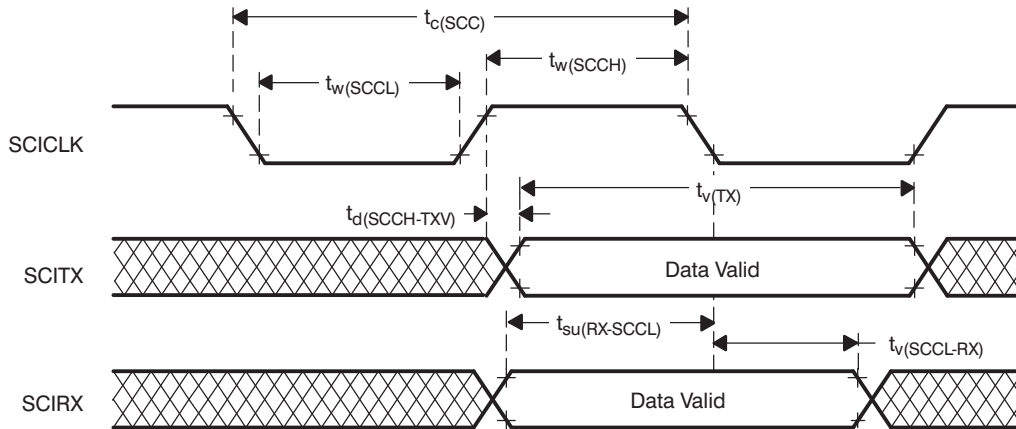
SCI_n ISOSYNCHRONOUS MODE TIMINGS INTERNAL CLOCK

Timing Requirements for Internal Clock SCI_n Isosynchronous Mode⁽¹⁾⁽²⁾⁽³⁾

(see Figure 17)

| | | (BAUD + 1) IS EVEN OR BAUD = 0 | | (BAUD + 1) IS ODD AND BAUD ≠ 0 | | UNIT |
|-------------------|---|-----------------------------------|----------------------|--|----------------------------------|------|
| | | MIN | MAX | MIN | MAX | |
| $t_{c(SCC)}$ | Cycle time, SCI _n CLK | $2t_{c(ICLK)}$ | $2^{24} t_{c(ICLK)}$ | $3t_{c(ICLK)}$ | $(2^{24} - 1) t_{c(ICLK)}$ | ns |
| $t_w(SCCL)$ | Pulse duration, SCI _n CLK low | $0.5t_{c(SCC)} - t_f$ | $0.5t_{c(SCC)} + 5$ | $0.5t_{c(SCC)} + 0.5t_{c(ICLK)} - t_f$ | $0.5t_{c(SCC)} + 0.5t_{c(ICLK)}$ | ns |
| $t_w(SCCH)$ | Pulse duration, SCI _n CLK high | $0.5t_{c(SCC)} - t_f$ | $0.5t_{c(SCC)} + 5$ | $0.5t_{c(SCC)} - 0.5t_{c(ICLK)} - t_f$ | $0.5t_{c(SCC)} - 0.5t_{c(ICLK)}$ | ns |
| $t_d(SCCH-TXV)$ | Delay time, SCI _n CLK high to SCI _n TX valid | | 10 | | 10 | ns |
| $t_v(TX)$ | Valid time, SCI _n TX data after SCI _n CLK low | $t_{c(SCC)} - 10$ | | $t_{c(SCC)} - 10$ | | ns |
| $t_{su}(RX-SCCL)$ | Setup time, SCI _n RX before SCI _n CLK low | $t_{c(ICLK)} + t_f + 20$ | | $t_{c(ICLK)} + t_f + 20$ | | ns |
| $t_v(SCCL-RX)$ | Valid time, SCI _n RX data after SCI _n CLK low | $-t_{c(ICLK)} + t_f + 20$ | | $-t_{c(ICLK)} + t_f + 20$ | | ns |

- (1) BAUD = 24-bit concatenated value formed by the SCI[H,M,L]BAUD registers.
- (2) $t_{c(ICLK)}$ = interface clock cycle time = $1/f_{(ICLK)}$
- (3) For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.



- A. Data transmission/reception characteristics for isosynchronous mode with internal clocking are similar to the asynchronous mode. Data transmission occurs on the SCICLK rising edge, and data reception occurs on the SCICLK falling edge.

Figure 17. SCI_n Isosynchronous Mode Timing Diagram for Internal Clock

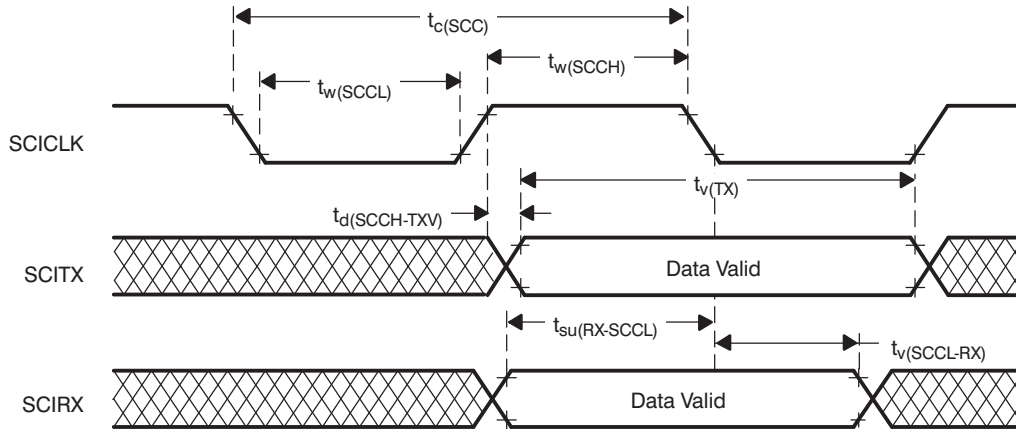
SCIn ISOSYNCHRONOUS MODE TIMINGS EXTERNAL CLOCK

Timing Requirements for External Clock SCIn Isosynchronous Mode⁽¹⁾⁽²⁾

(see Figure 18)

| | | MIN | MAX | UNIT |
|-------------------|---|----------------------------------|----------------------------------|------|
| $t_{c(SCC)}$ | Cycle time, SCInCLK ⁽³⁾ | $8t_{c(ICK)}$ | | ns |
| $t_w(SCCH)$ | Pulse duration, SCInCLK high | $0.5t_{c(SCC)} - 0.25t_{c(ICK)}$ | $0.5t_{c(SCC)} + 0.25t_{c(ICK)}$ | ns |
| $t_w(SCCL)$ | Pulse duration, SCInCLK low | $0.5t_{c(SCC)} - 0.25t_{c(ICK)}$ | $0.5t_{c(SCC)} + 0.25t_{c(ICK)}$ | ns |
| $t_d(SCCH-TXV)$ | Delay time, SCInCLK high to SCInTX valid | | $2t_{c(ICK)} + 12 + t_r$ | ns |
| $t_v(TX)$ | Valid time, SCInTX data after SCInCLK low | $2t_{c(SCC)} - 10$ | | ns |
| $t_{su}(RX-SCCL)$ | Setup time, SCInRX before SCInCLK low | 0 | | ns |
| $t_v(SCCL-RX)$ | Valid time, SCInRX data after SCInCLK low | $2t_{c(ICK)} + 10$ | | ns |

- (1) $t_{c(ICK)}$ = interface clock cycle time = $1/f_{(ICK)}$
- (2) For rise and fall timings, see the "Switching Characteristics for Output Timings versus Load Capacitance" table.
- (3) When driving an external SCInCLK, the following must be true: $t_{c(SCC)} \geq 8t_{c(ICK)}$.



- A. Data transmission / reception characteristics for isosynchronous mode with external clocking are similar to the asynchronous mode. Data transmission occurs on the SCICLK rising edge, and data reception occurs on the SCICLK falling edge.

Figure 18. SCIn Isosynchronous Mode Timing Diagram for External Clock

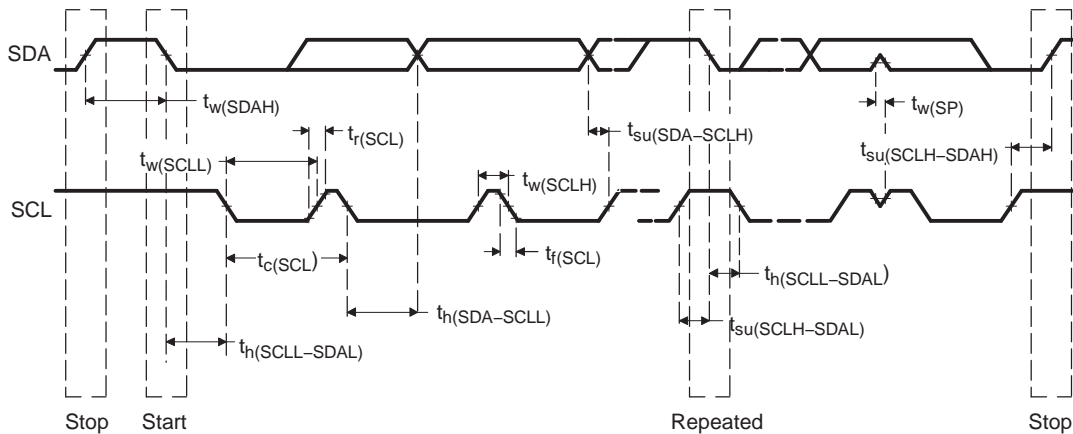
I2C TIMING

Table 11 below assumes testing over recommended operating conditions.

Table 11. I2C Signals (SDA and SCL) Switching Characteristics⁽¹⁾

| PARAMETER | | STANDARD MODE | | FAST MODE | | UNIT |
|----------------------|--|---------------|---------------------|-----------|-----|---------|
| | | MIN | MAX | MIN | MAX | |
| $t_{c(I2CCLK)}$ | Cycle time, I2C module clock | 75 | 150 | 75 | 150 | ns |
| $t_{c(SCL)}$ | Cycle time, SCL | 10 | | 2.5 | | μ s |
| $t_{su(SCLH-SDAL)}$ | Setup time, SCL high before SDA low (for a repeated START condition) | 4.7 | | 0.6 | | μ s |
| $t_h(SCLL-SDAL)$ | Hold time, SCL low after SDA low (for a repeated START condition) | 4 | | 0.6 | | μ s |
| $t_w(SCLL)$ | Pulse duration, SCL low | 4.7 | | 1.3 | | μ s |
| $t_w(SCLH)$ | Pulse duration, SCL high | 4 | | 0.6 | | μ s |
| $t_{su(SDA-SCLH)}$ | Setup time, SDA valid before SCL high | 250 | | 100 | | ns |
| $t_h(SDA-SCLL)$ | Hold time, SDA valid after SCL low | 0 | 3.45 ⁽²⁾ | 0 | 0.9 | μ s |
| $t_w(SDAH)$ | Pulse duration, SDA high between STOP and START conditions | 4.7 | | 1.3 | | μ s |
| $t_{su(SCLH-SDAH)}$ | Setup time, SCL high before SDA high (for STOP condition) | 4.0 | | 0.6 | | μ s |
| $t_w(SP)$ | Pulse duration, spike (must be suppressed) | | | 0 | 50 | ns |
| C_b ⁽³⁾ | Capacitive load for each bus line | | 400 | | 400 | pF |

- (1) The I2C pins SDA and SCL do not feature fail-safe I/O buffers. These pins could potentially draw current when the device is powered down.
- (2) The maximum $t_h(SDA-SCLL)$ for I2C bus devices needs to be met only if the device does not stretch the low period ($t_w(SCLL)$) of the SCL signal.
- (3) C_b = The total capacitance of one bus line in pF.



- A. A device must internally provide a hold time of at least 300 ns for the SDA signal (referred to the V_{IHmin} of the SCL signal) to bridge the undefined region of the falling edge of SCL.
- B. The maximum $t_h(SDA-SCLL)$ needs only be met if the device does not stretch the LOW period ($t_w(SCLL)$) of the SCL signal.
- C. A fast-mode I2C-bus device can be used in a standard-mode I2C-bus system, but the requirement $t_{su(SDA-SCLH)} \geq 250$ ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line $t_r \max + t_{su(SDA-SCLH)}$.
- D. C_b = total capacitance of one bus line in pF. If mixed with HS-mode devices, faster fall-times are allowed.

Figure 19. I2C Timings

STANDARD CAN CONTROLLER (SCC) MODE TIMINGS

Dynamic Characteristics for the CANSTX and CANSRX Pins

| PARAMETER | | MIN | MAX | UNIT |
|-----------------|--|-----|-----|------|
| $t_{d(CANSTX)}$ | Delay time, transmit shift register to CANSTX pin ⁽¹⁾ | | 15 | ns |
| $t_{d(CANSRX)}$ | Delay time, CANSRX pin to receive shift register | | 5 | ns |

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

EXPANSION BUS MODULE TIMING

Expansion Bus Timing Parameters, $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$, $3.0\text{ V} \leq V_{CC} \leq 3.6\text{ V}$

(see [Figure 20](#) and [Figure 21](#))

| | | MIN | MAX | UNIT |
|------------------------|---|------|---------|------|
| $t_{c(CO)}$ | Cycle time, CLKOUT | 20.8 | | ns |
| $t_{d(COH-EBADV)}$ | Delay time, CLKOUT high to EBADDR valid | | 21.4 | ns |
| $t_{h(COH-EBADIV)}$ | Hold time, EBADDR invalid after CLKOUT high | | 12.4 | ns |
| $t_{d(COH-EBOE)}$ | Delay time, CLKOUT high to $\overline{\text{EBOE}}$ fall | | 11.4 | ns |
| $t_{h(COH-EBOEH)}$ | Hold time, $\overline{\text{EBOE}}$ rise after CLKOUT high | | 11.4 | ns |
| $t_{d(COL-EBWR)}$ | Delay time, CLKOUT low to write strobe ($\overline{\text{EBWR}}$) low | | 11.3 | ns |
| $t_{h(COL-EBWRH)}$ | Hold time, $\overline{\text{EBWR}}$ high after CLKOUT low | | 11.6 | ns |
| $t_{su(EBRDATV-COH)}$ | Setup time, EBDATA valid before CLKOUT high (READ) ⁽¹⁾ | 15.2 | | ns |
| $t_{h(COH-EBRDATIV)}$ | Hold time, EBDATA invalid after CLKOUT high (READ) | | (-14.7) | ns |
| $t_{d(COL-EBWDATV)}$ | Delay time, CLKOUT low to EBDATA valid (WRITE) ⁽²⁾ | | 16.1 | ns |
| $t_{h(COL-EBWDATIV)}$ | Hold time, EBDATA invalid after CLKOUT low (WRITE) | | 14.7 | ns |
| SECONDARY TIMES | | | | |
| $t_{d(COH-EBCS0)}$ | Delay, CLKOUT high to $\overline{\text{EBCS0}}$ fall | | 13.6 | ns |
| $t_{h(COH-EBCS0H)}$ | Hold, $\overline{\text{EBCS0}}$ rise after CLKOUT high | | 13.2 | ns |
| $t_{su(COH-EBHOLDL)}$ | Setup time, $\overline{\text{EBHOLD}}$ low to CLKOUT high ⁽¹⁾ | 10.9 | | ns |
| $t_{su(COH-EBHOLDH)}$ | Setup time, $\overline{\text{EBHOLD}}$ high to CLKOUT high ⁽¹⁾ | 10.5 | | ns |

(1) Setup time is the minimum time under worst case conditions. Data with less setup time does not work.

(2) Valid after CLKOUT goes low for write cycles.

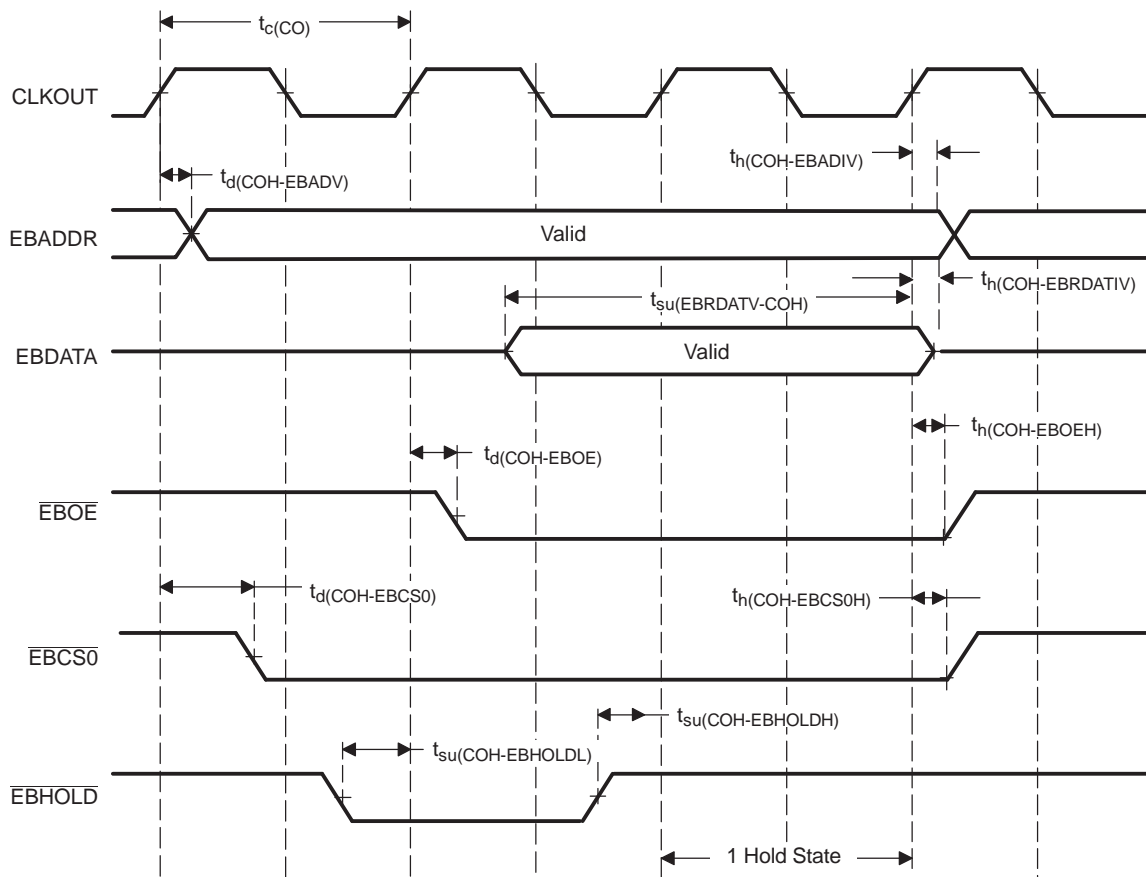


Figure 20. Expansion Memory Signal Timing - Reads

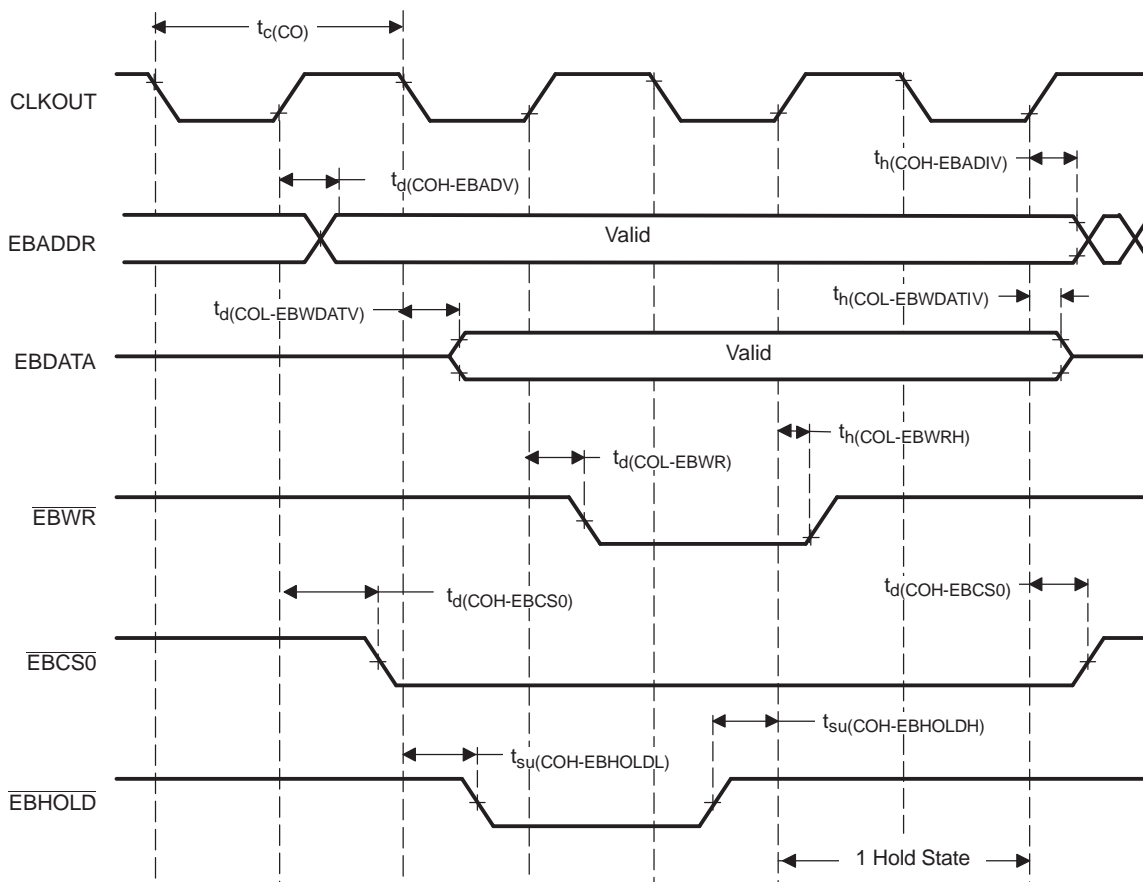


Figure 21. Expansion Memory Signal Timing - Writes

CLASS 2 SERIAL INTERFACE B (C2SIb) VARIABLE PULSE WIDTH (VPW) MODULATION

VPW Timing Requirements

See [Figure 22](#).

| PARAMETER | | NORMAL MODE (10.4 KBPS) | | | | 4X MODE (41.6 KBPS) | | | | UNIT |
|-------------|---------------------------|-------------------------|-----|-----|-----|---------------------|-----|-----|-----|------|
| | | TX | | RX | | TX | | RX | | |
| | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| SOF | Start of frame | 192 | 208 | 163 | 239 | 48 | 52 | 41 | 60 | ns |
| Short Pulse | Low = 0 | 60 | 68 | 34 | 96 | 14 | 18 | 9 | 24 | ns |
| | High = 1 | | | | | | | | | |
| Long Pulse | Low = 0 | 122 | 134 | 97 | 163 | 30 | 34 | 24 | 41 | ns |
| | High = 1 | | | | | | | | | |
| EOD | End of data | 193 | 207 | 164 | 239 | 48 | 52 | 41 | 60 | ns |
| NB | Normalization bit (long) | 122 | 134 | 97 | 163 | 30 | 34 | 24 | 41 | ns |
| | Normalization bit (short) | 60 | 68 | 34 | 96 | 14 | 18 | 9 | 24 | |
| EOF | End of frame | 271 | 289 | 240 | 320 | 67 | 73 | 60 | 80 | ns |
| Break | Short | 290 | - | 239 | - | 290 | - | 60 | - | ns |
| | Long | 758 | - | 239 | - | 758 | - | 60 | - | |

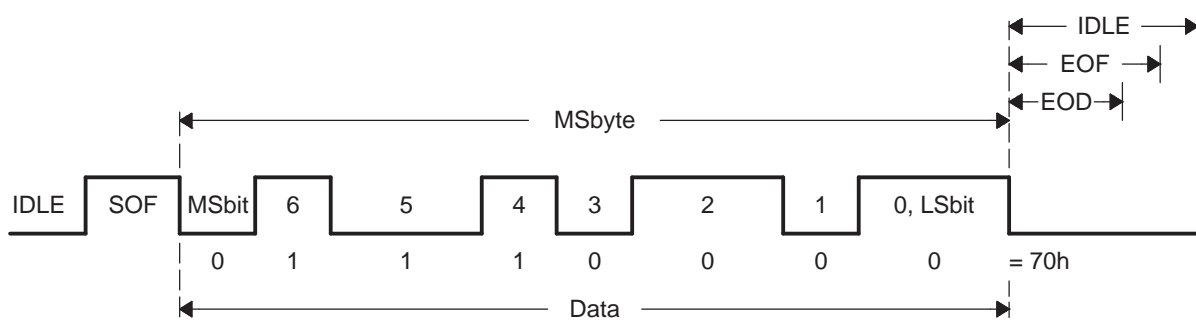


Figure 22. C2SIb Timing Diagram

HIGH-END TIMER (HET) TIMINGS

Minimum PWM Output Pulse Width:

This is equal to one high resolution clock period (HRP). The HRP is defined by the 6-bit high resolution prescale factor (hr), which is user defined, giving prescale factors of 1 to 64, with a linear increment of codes.

Therefore, the minimum PWM output pulse width = $HRP(\min) = hr(\min)/SYSCLK = 1/SYSCLK$

For example, for a SYSCLK of 30 MHz, the minimum PWM output pulse width = $1/30 = 33.33\text{ns}$

Minimum Input Pulses that Can Be Captured:

The input pulse width must be greater or equal to the low resolution clock period (LRP), i.e., the HET loop (the HET program must fit within the LRP). The LRP is defined by the 3-bit loop-resolution prescale factor (lr), which is user defined, with a power of 2 increment of codes. That is, the value of lr can be 1, 2, 4, 8, 16, or 32.

Therefore, the minimum input pulse width = $LRP(\min) = hr(\min) * lr(\min)/SYSCLK = 1 * 1/SYSCLK$

For example, with a SYSCLK of 30 MHz, the minimum input pulse width = $1 * 1/30 = 33.33 \text{ ns}$

NOTE:

Once the input pulse width is greater than LRP, the resolution of the measurement is still HRP. (That is, the captured value gives the number of HRP clocks inside the pulse.)

Abbreviations:

hr = HET high resolution divide rate = 1, 2, 3,...63, 64

lr = HET low resolution divide rate = 1, 2, 4, 8, 16, 32

High resolution clock period = $HRP = hr/SYSCLK$

Loop resolution clock period = $LRP = hr*lr/SYSCLK$

MULTI-BUFFERED A-TO-D CONVERTER (MibADC)

The multi-buffered A-to-D converter (MibADC) has a separate power bus for its analog circuitry that enhances the A-to-D performance by preventing digital switching noise on the logic circuitry, which could be present on V_{SS} and V_{CC} , from coupling into the A-to-D analog stage. All A-to-D specifications are given with respect to AD_{REFLO} unless otherwise noted.

| | |
|------------------------|--|
| Resolution | 10 bits (1024 values) |
| Monotonic | Assured |
| Output conversion code | 00h to 3FFh [00 for $V_{AI} \leq AD_{REFLO}$; 3FFh for $V_{AI} \geq AD_{REFHI}$] |

Table 12. MibADC Recommended Operating Conditions⁽¹⁾

| | | MIN | MAX | UNIT |
|--------------|---|------------------|------------------|------|
| AD_{REFHI} | A-to-D high-voltage reference source | V_{SSAD} | V_{CCAD} | V |
| AD_{REFLO} | A-to-D low-voltage reference source | V_{SSAD} | V_{CCAD} | V |
| V_{AI} | Analog input voltage | $V_{SSAD} - 0.3$ | $V_{CCAD} + 0.3$ | V |
| I_{AIC} | Analog input clamp current ⁽²⁾ ($V_{AI} < V_{SSAD} - 0.3$ or $V_{AI} > V_{CCAD} + 0.3$) | -2 | 2 | mA |

(1) For V_{CCAD} and V_{SSAD} recommended operating conditions, see the "Device Recommended Operating Conditions" table.

(2) Input currents into any ADC input channel outside the specified limits could affect conversion results of other channels.

Table 13. Operating Characteristics Over Full Ranges of Recommended Operating Conditions⁽¹⁾⁽²⁾

| PARAMETER | DESCRIPTION/CONDITIONS | MIN | TYP | MAX | UNIT | |
|---------------|--|--|-----|---------|----------|---|
| R_i | Analog input resistance | | 250 | 500 | Ω | |
| C_i | Analog input capacitance | | | 10 | pF | |
| | | Conversion | | 30 | pF | |
| I_{AIL} | Analog input leakage current | | -1 | 1 | μ A | |
| $I_{ADREFHI}$ | AD_{REFHI} input current | $AD_{REFHI} = 3.6$ V, $AD_{REFLO} = V_{SSAD}$ | | 5 | mA | |
| CR | Conversion range over which specified accuracy is maintained | $AD_{REFHI} - AD_{REFLO}$ | | 3 | 3.6 | V |
| E_{DNL} | Differential nonlinearity error | Difference between the actual step width and the ideal value. See Figure 24 . | | ± 2 | LSB | |
| E_{INL} | Integral nonlinearity error | Maximum deviation from the best straight line through the MibADC. MibADC transfer characteristics, excluding the quantization error. See Figure 25 . | | ± 2 | LSB | |
| E_{TOT} | Total error/absolute accuracy | Maximum value of the difference between an analog value and the ideal midstep value. See Figure 26 . | | ± 2 | LSB | |

(1) $V_{CCAD} = AD_{REFHI}$

(2) $1 \text{ LSB} = (AD_{REFHI} - AD_{REFLO})/2^{10}$ for the MibADC

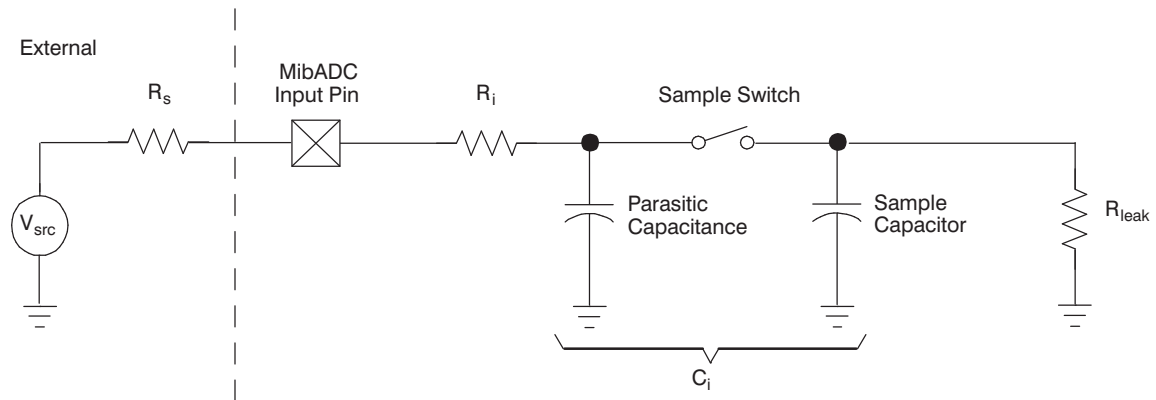


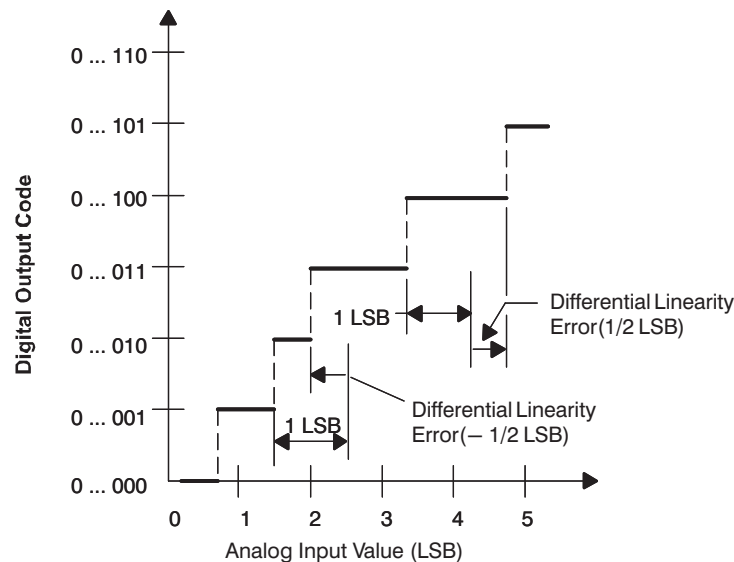
Figure 23. MibADC Input Equivalent Circuit

Multi-Buffer ADC Timing Requirements

| | | MIN | NOM | MAX | UNIT |
|--------------------|---|------|-----|-----|---------------|
| $t_{c(ADCLK)}$ | Cycle time, MibADC clock | 0.05 | | | μs |
| $t_{d(SH)}$ | Delay time, sample and hold time | 1 | | | μs |
| $t_{d(C)}$ | Delay time, conversion time | 0.55 | | | μs |
| $t_{d(SHC)}^{(1)}$ | Delay time, total sample/hold and conversion time | 1.55 | | | μs |

(1) This is the minimum sample/hold and conversion time that can be achieved. These parameters are dependent on many factors; for more details, see the *TMS470R1x Multi-Buffered Analog-to-Digital Converter (MibADC) Reference Guide* (literature number SPNU206).

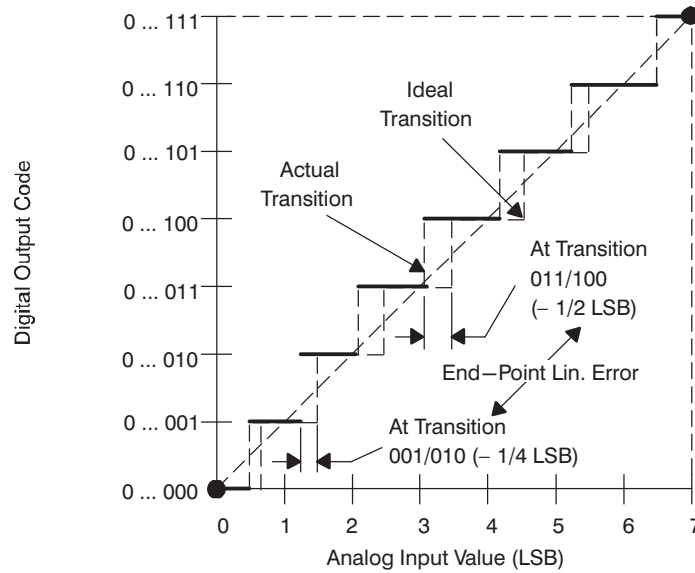
The differential nonlinearity error shown in Figure 24 (sometimes referred to as differential linearity) is the difference between an actual step width and the ideal value of 1 LSB.



A. $1 \text{ LSB} = (AD_{REFHI} - AD_{REFLO})/2^{10}$

Figure 24. Differential Nonlinearity (DNL)

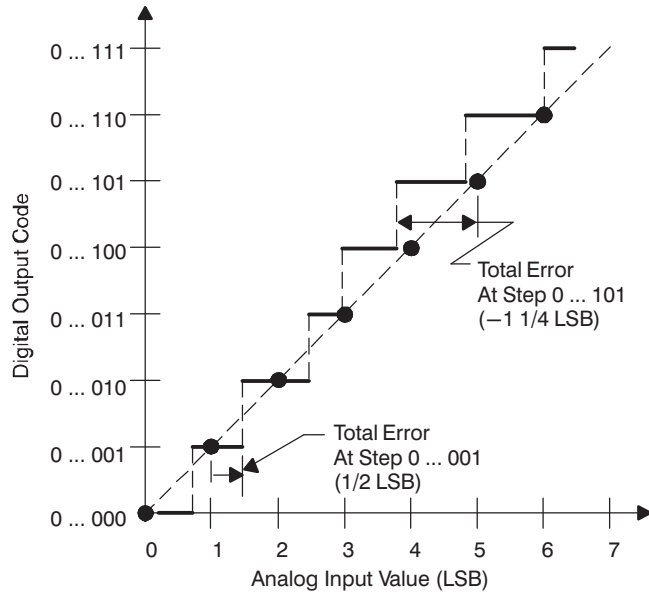
The integral nonlinearity error shown in [Figure 25](#) (sometimes referred to as linearity error) is the deviation of the values on the actual transfer function from a straight line.



A. $1 \text{ LSB} = (AD_{REFHI} - AD_{REFLO})/2^{10}$

Figure 25. Integral Nonlinearity (INL) Error

The absolute accuracy or total error of an MibADC as shown in [Figure 26](#) is the maximum value of the difference between an analog value and the ideal midstep value.



A. $1 \text{ LSB} = (AD_{REFHI} - AD_{REFLO})/2^{10}$

Figure 26. Absolute Accuracy (Total) Error

PGE Thermal Resistance Characteristics

| PARAMETER | °C/W |
|-----------------|------|
| $R_{\theta JA}$ | 43 |
| $R_{\theta JC}$ | 5 |

PZ Thermal Resistance Characteristics

| PARAMETER | °C/W |
|-----------------|------|
| $R_{\theta JA}$ | 48 |
| $R_{\theta JC}$ | 5 |

Revision History

This revision history highlights the changes made to the device-specific datasheet SPNS110.

Table 14. Revision History

| |
|---|
| SPNS110D to SPNS110E |
| Corrected the device-specific part number from 0100001 to 0101101 in Table 10 . |
| SPNS110C to SPNS110D |
| Removed reference to GIOH[5:0] in Terminal Functions table. |
| Changed Output Current for AWD terminal from 8 mA to 4 mA in Terminal Functions table. |
| Changed beginning address for Peripheral Control Registers to 0xFFFF0_0000 in Figure 1 . |
| Changed register value in Device Identification Code Register |
| Changed unit for "V _{CC} digital supply current (standby mode)" from μ A to mA in Electrical Characteristics . |
| SPNS110B to SPNS110C |
| Removed references to digital watchdog (DWD) on page 5. |
| SPNS110A to SPNS110B |
| Revised the Family Nomenclature drawing to add Q version of the temperature range. |
| Revised "Absolute Maximum Ratings" table to add Q version of the temperature range. |
| Revised "Device Recommended Operating Conditions" table to add Q version of the temperature range. |
| Revised "Electrical Characteristics" table to add T and Q temperature versions to I _{CC} specification. Changed T version I _{CC} , standby mode, max to 1. Added Q version I _{CC} standby mode, max of 1.25. Changed T version I _{CC} , halt mode, max to 365. Added Q version I _{CC} halt mode, max of 550. |
| Added note to $\overline{\text{PORRST}}$ Timing Diagram. |
| Changed T _A range to –40°C to 125°C on t _{wec} in "Timing Requirements for Program Flash" table. |
| Added t _{wec} MIN value of 50000 and deleted TYP value in "Timing Requirements for Program Flash" table. |
| Changed t _{erase(sector)} TYP value to 1.7 and removed MAX value in "Timing Requirements for Program Flash" table. |
| SPNS110 to SPNS110A |
| Corrected max value for I _{CC} standby and halt modes in Electrical Characteristics table. |

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|---------|
| TMS470R1A384PGET | NRND | LQFP | PGE | 144 | 60 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR | | 470R1A384PGET TMS | |
| TMS470R1A384PZ-T | NRND | LQFP | PZ | 100 | 90 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR | | 470R1A384PZ-T TMS | |

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

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

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

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

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

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

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

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

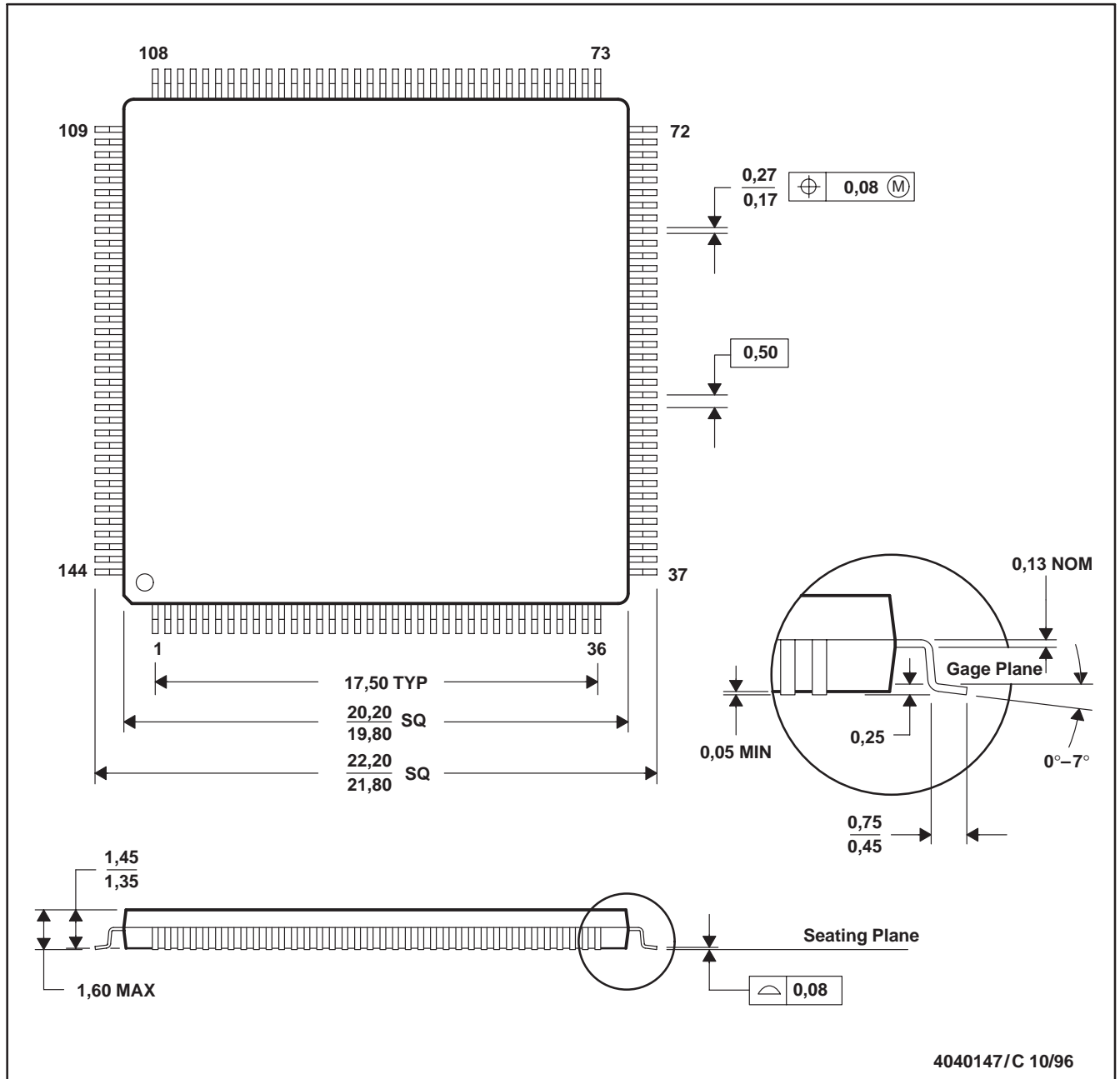
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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PGE (S-PQFP-G144)

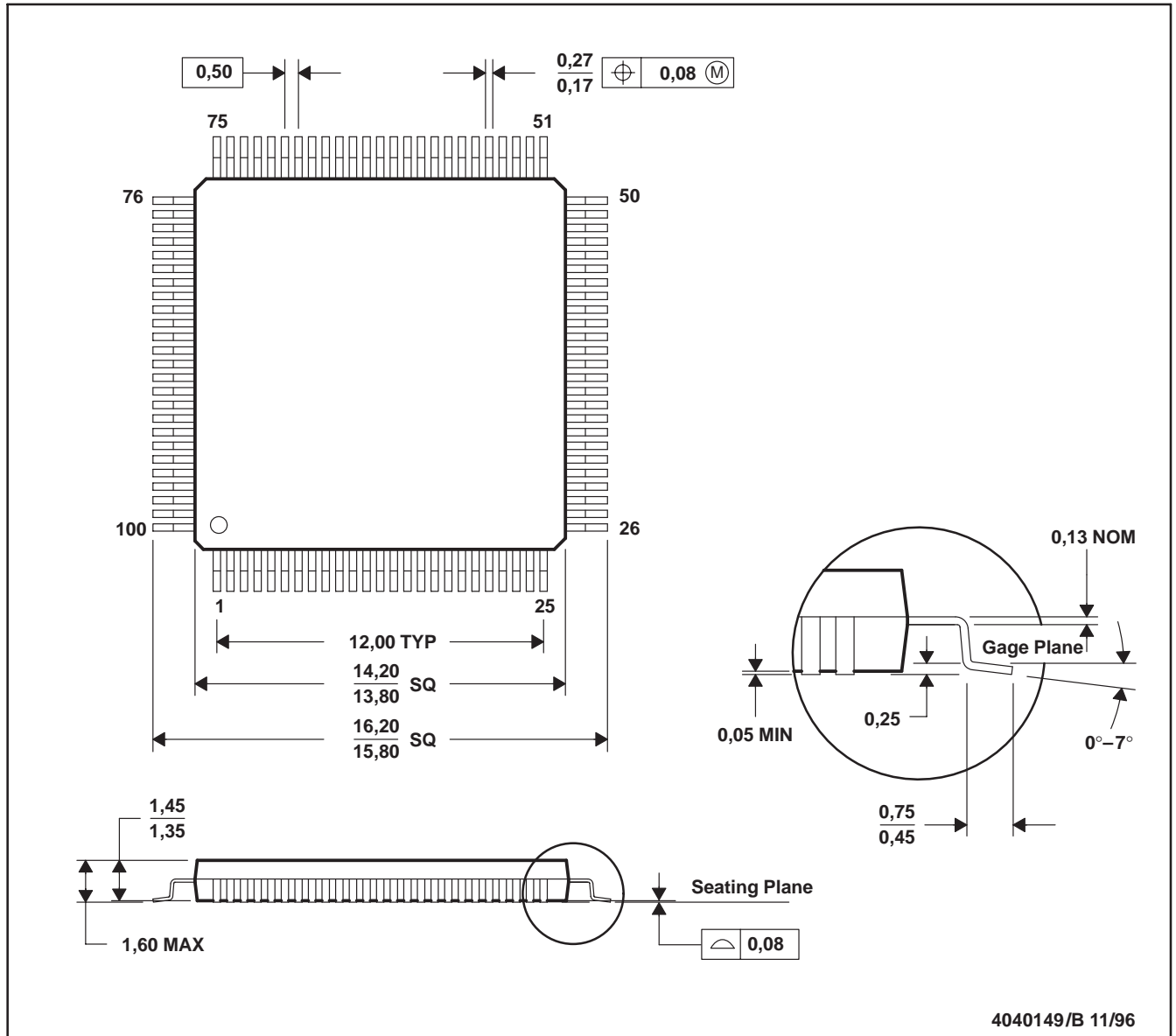
PLASTIC QUAD FLATPACK



- 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)

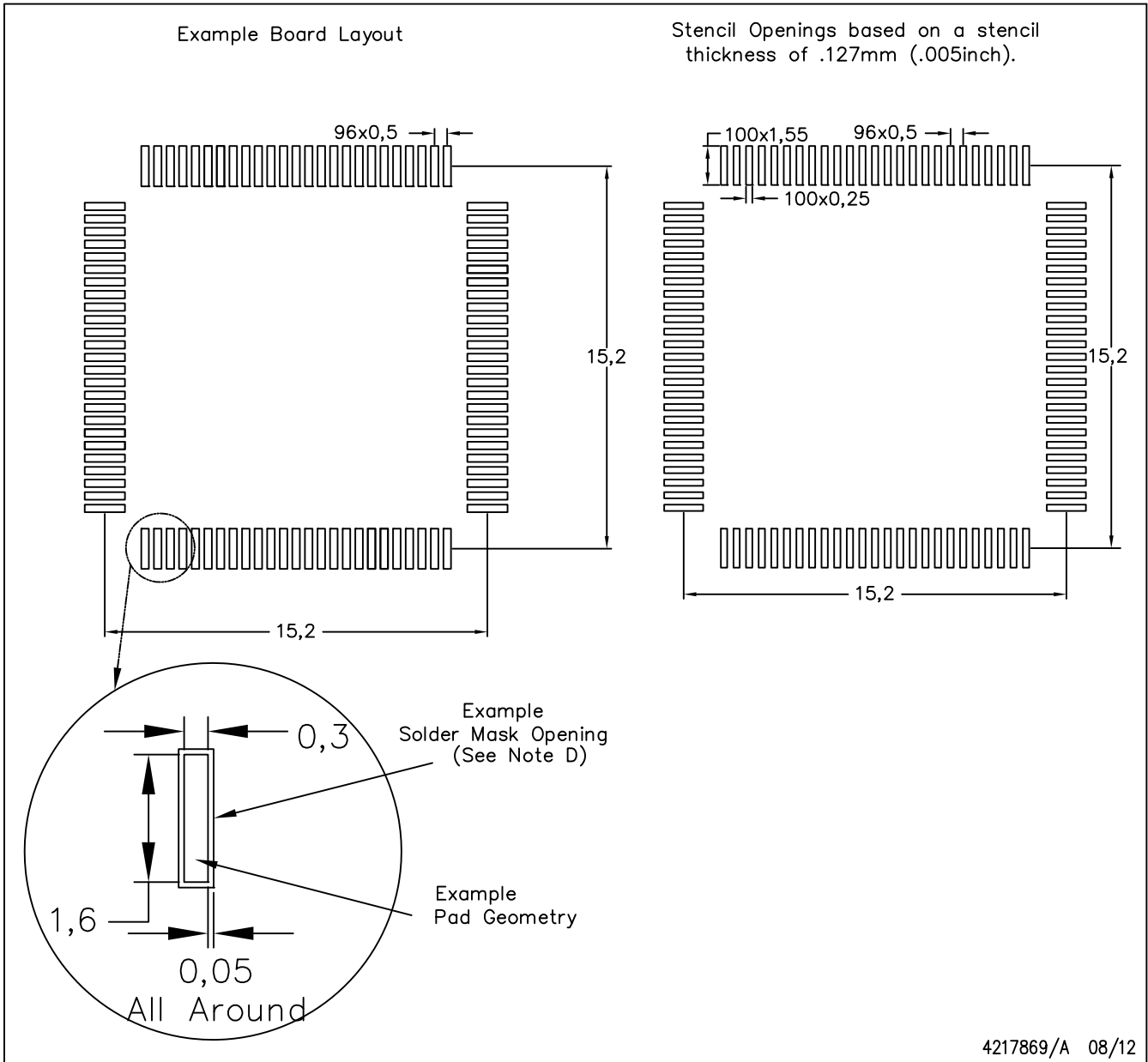
PLASTIC QUAD FLATPACK



- 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.

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