

- **Advanced Multibus Architecture With Three Separate 16-Bit Data Memory Buses and One Program Memory Bus**
- **40-Bit Arithmetic Logic Unit (ALU), Including a 40-Bit Barrel Shifter and Two Independent 40-Bit Accumulators**
- **17- × 17-Bit Parallel Multiplier Coupled to a 40-Bit Dedicated Adder for Non-Pipelined Single-Cycle Multiply/Accumulate (MAC) Operation**
- **Compare, Select, and Store Unit (CSSU) for the Add/Compare Selection of the Viterbi Operator**
- **Exponent Encoder to Compute an Exponent Value of a 40-Bit Accumulator Value in a Single Cycle**
- **Two Address Generators With Eight Auxiliary Registers and Two Auxiliary Register Arithmetic Units (ARAUs)**
- **Data Bus With a Bus-Holder Feature**
- **Extended Addressing Mode for 8M × 16-Bit Maximum Addressable External Program Space**
- **16K x 16-Bit On-Chip ROM**
- **32K x 16-Bit Dual-Access On-Chip RAM**
- **Single-Instruction-Repeat and Block-Repeat Operations for Program Code**
- **Block-Memory-Move Instructions for Better Program and Data Management**
- **Instructions With a 32-Bit Long Word Operand**
- **Instructions With Two- or Three-Operand Reads**
- **Arithmetic Instructions With Parallel Store and Parallel Load**
- **Conditional Store Instructions**
- **Fast Return From Interrupt**
- **On-Chip Peripherals**
 - **Software-Programmable Wait-State Generator and Programmable Bank Switching**
 - **On-Chip Phase-Locked Loop (PLL) Clock Generator With Internal Oscillator or External Clock Source**
 - **Three Multichannel Buffered Serial Ports (McBSPs)**
 - **Enhanced 8-Bit Parallel Host-Port Interface With 16-Bit Data/Addressing**
 - **One 16-Bit Timer**
 - **Six-Channel Direct Memory Access (DMA) Controller**
- **Power Consumption Control With IDLE1, IDLE2, and IDLE3 Instructions With Power-Down Modes**
- **CLKOUT Off Control to Disable CLKOUT**
- **On-Chip Scan-Based Emulation Logic, IEEE Std 1149.1[†] (JTAG) Boundary Scan Logic**
- **12.5-ns Single-Cycle Fixed-Point Instruction Execution Time (80 MIPS)**
- **1.8-V Core Power Supply**
- **1.8-V to 3.6-V I/O Power Supply Enables Operation With a Single 1.8-V Supply or With Dual Power Supplies**
- **Available in a 144-Pin Plastic Thin Quad Flatpack (TQFP) (PGE Suffix) and a 144-Pin Ball Grid Array (BGA) (GGU Suffix)**



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[†] IEEE Standard 1149.1-1990 Standard-Test-Access Port and Boundary Scan Architecture.

ADVANCE INFORMATION concerns new products in the sampling or preproduction phase of development. Characteristic data and other specifications are subject to change without notice.



TMS320UC5409 FIXED-POINT DIGITAL SIGNAL PROCESSOR

SPRS101E – APRIL 1999 – REVISED OCTOBER 2008

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REVISION HISTORY

This data sheet revision history highlights the technical changes made to the SPRS101D device-specific data sheet to make it an SPRS101E revision.

Scope: This document has been reviewed for technical accuracy; the technical content is up-to-date as of the specified release date with the following changes.

PAGE(S) NO.	ADDITIONS/CHANGES/DELETIONS
11	Terminal Functions table: – Updated DESCRIPTION of $\overline{\text{TRST}}$ – Added footnote about $\overline{\text{TRST}}$

TMS320UC5409 FIXED-POINT DIGITAL SIGNAL PROCESSOR

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description

The TMS320UC5409 fixed-point, digital signal processor (DSP) (hereafter referred to as the UC5409 unless otherwise specified) is ideal for low-power, high-performance applications. This processor offers very low power consumption and the flexibility to support various system voltage configurations. The wide range of I/O voltage enables it to operate with a single 1.8-V power supply or with dual power supplies for mixed voltage systems. This feature eliminates the need for external level-shifting and reduces power consumption in emerging sub-3V systems.

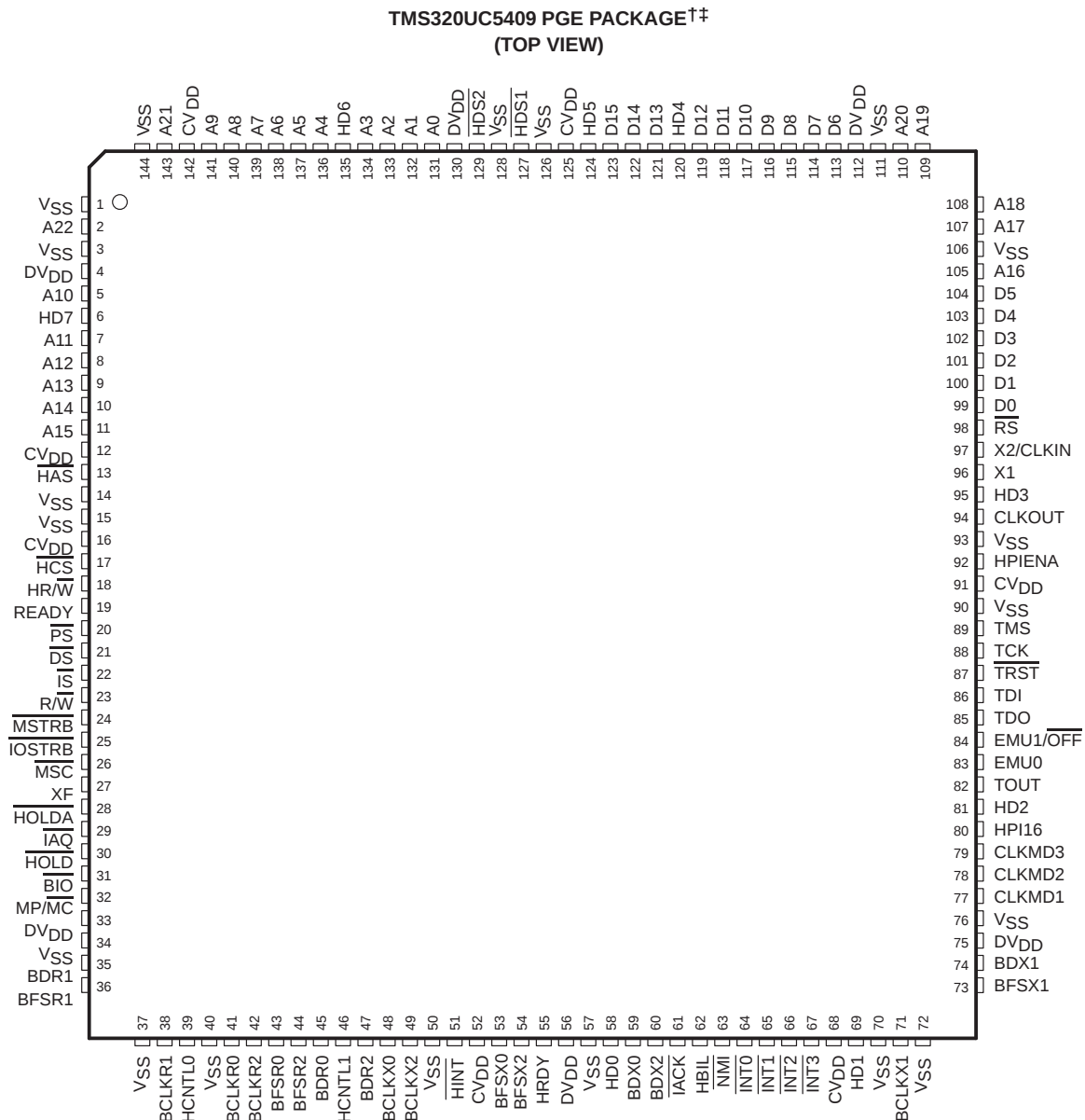
The TMS320UC5409 fixed-point, digital signal processor (DSP) (hereafter referred to as the UC5409 unless otherwise specified) is based on an advanced modified Harvard architecture that has one program memory bus and three data memory buses. This processor provides an arithmetic logic unit (ALU) with a high degree of parallelism, application-specific hardware logic, on-chip memory, and additional on-chip peripherals. The basis of the operational flexibility and speed of this DSP is a highly specialized instruction set.

For detailed information on the architecture of the C5000 family of DSPs, see the *TMS320C54x™ DSP Functional Overview* (literature number SPRU307).

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description (continued)



† NC = No internal connection

‡ DVDD is the power supply for the I/O pins while CVDD is the power supply for the core CPU. VSS is the ground for both the I/O pins and the core CPU.

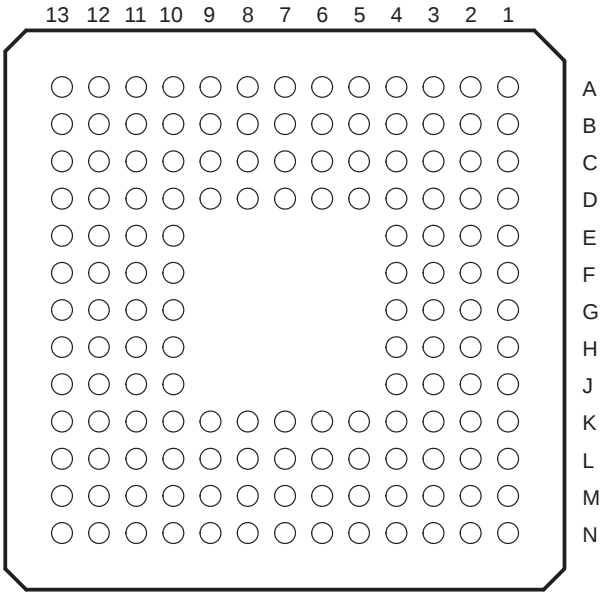
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description (continued)

TMS320UC5409 GGU PACKAGE
(BOTTOM VIEW)



The pin assignments table to follow lists each signal quadrant and BGA ball number for the TMS320UC5409GGU (144-pin BGA package).

description (continued)

Pin Assignments on TMS320UC5409GGU (144-Pin BGA Package)[†]

SIGNAL QUADRANT 1	BGA BALL #	SIGNAL QUADRANT 2	BGA BALL #	SIGNAL QUADRANT 3	BGA BALL #	SIGNAL QUADRANT 4	BGA BALL #
V _{SS}	A1	BFSX1	N13	V _{SS}	N1	A19	A13
A22	B1	BDX1	M13	BCLKR1	N2	A20	A12
V _{SS}	C2	DV _{DD}	L12	HCNTL0	M3	V _{SS}	B11
DV _{DD}	C1	V _{SS}	L13	V _{SS}	N3	DV _{DD}	A11
A10	D4	CLKMD1	K10	BCLKR0	K4	D6	D10
HD7	D3	CLKMD2	K11	BCLKR2	L4	D7	C10
A11	D2	CLKMD3	K12	BFSR0	M4	D8	B10
A12	D1	HPI16	K13	BFSR2	N4	D9	A10
A13	E4	HD2	J10	BDR0	K5	D10	D9
A14	E3	TOUT	J11	HCNTL1	L5	D11	C9
A15	E2	EMU0	J12	BDR2	M5	D12	B9
CV _{DD}	E1	EMU1/OFF	J13	BCLKX0	N5	HD4	A9
HAS	F4	TDO	H10	BCLKX2	K6	D13	D8
V _{SS}	F3	TDI	H11	V _{SS}	L6	D14	C8
V _{SS}	F2	TRST	H12	HINT	M6	D15	B8
CV _{DD}	F1	TCK	H13	CV _{DD}	N6	HD5	A8
HCS	G2	TMS	G12	BFSX0	M7	CV _{DD}	B7
HR/W	G1	V _{SS}	G13	BFSX2	N7	V _{SS}	A7
READY	G3	CV _{DD}	G11	HRDY	L7	HDS1	C7
PS	G4	HPIENA	G10	DV _{DD}	K7	V _{SS}	D7
DS	H1	V _{SS}	F13	V _{SS}	N8	HDS2	A6
IS	H2	CLKOUT	F12	HD0	M8	DV _{DD}	B6
R/W	H3	HD3	F11	BDX0	L8	A0	C6
MSTRB	H4	X1	F10	BDX2	K8	A1	D6
IOSTRB	J1	X2/CLKIN	E13	IACK	N9	A2	A5
MSC	J2	RS	E12	HBIL	M9	A3	B5
XF	J3	D0	E11	NMI	L9	HD6	C5
HOLDA	J4	D1	E10	INT0	K9	A4	D5
IAQ	K1	D2	D13	INT1	N10	A5	A4
HOLD	K2	D3	D12	INT2	M10	A6	B4
BIO	K3	D4	D11	INT3	L10	A7	C4
MP/MC	L1	D5	C13	CV _{DD}	N11	A8	A3
DV _{DD}	L2	A16	C12	HD1	M11	A9	B3
V _{SS}	L3	V _{SS}	C11	V _{SS}	L11	CV _{DD}	C3
BDR1	M1	A17	B13	BCLKX1	N12	A21	A2
BFSR1	M2	A18	B12	V _{SS}	M12	V _{SS}	B2

[†] DV_{DD} is the power supply for the I/O pins while CV_{DD} is the power supply for the core CPU. V_{SS} is the ground for both the I/O pins and the core CPU.

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TMS320UC5409 FIXED-POINT DIGITAL SIGNAL PROCESSOR

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terminal functions

The following table lists each signal, function, and operating mode(s) grouped by function.

Terminal Functions

TERMINAL NAME		I/O†	DESCRIPTION		
DATA SIGNALS					
A22 (MSB)	O/Z	Parallel address bus A22 [most significant bit (MSB)] through A0 [least significant bit (LSB)]. The lower sixteen address pins (A0 to A15) are multiplexed to address all external memory (program, data) or I/O while the upper seven address pins (A16 to A22) are only used to address external program space. These pins are placed in the high-impedance state when the hold mode is enabled, or when <u>OFF</u> is low.			
A21					
A20					
A19					
A18					
A17					
A16					
A15					
A14					
A13					
A12					
A11					
A10					
A9					
A8					
A7					
A6					
A5					
A4					
A3					
A2					
A1					
A0 (LSB)		A15 (MSB)	I	These pins can be used to address internal memory via the HPI when the HPI16 pin is high (A0 – A15).	
		A14			
		A13			
		A12			
		A11			
		A10			
		A9			
		A8			
		A7			
		A6			
		A5			
		A4			
		A3			
		A2			
		A1			
		A0 (LSB)			
D15 (MSB)	I/O/Z	D15 (MSB)	I/O		Parallel data bus D15 (MSB) through D0 (LSB). The sixteen data pins (D0 to D15) are multiplexed to transfer data between the core CPU and external data/program memory or I/O devices. The data bus is placed in the high-impedance state when not outputting or when <u>RS</u> or <u>HOLD</u> is asserted. The data bus also goes into the high-impedance state when <u>OFF</u> is low. The data bus has bus holders to reduce the static power dissipation caused by floating, unused pins. These bus holders also eliminate the need for external bias resistors on unused pins. When the data bus is not being driven by the UC5409, the bus holders keep the pins at the previous logic level. The data bus holders on the UC5409 are disabled at reset and can be enabled/disabled via the BH bit of the bank-switching control register (BSCR).
D14					
D13					
D12					
D11					
D10					
D9					
D8					
D7					
D6					
D5					
D4					
D3					
D2					
D1					
D0 (LSB)			D0 (LSB)		
INITIALIZATION, INTERRUPT, AND RESET OPERATIONS					
<u>IACK</u>	O/Z	Interrupt acknowledge signal. <u>IACK</u> indicates receipt of an interrupt and that the program counter is fetching the interrupt vector location designated by A15–A0. <u>IACK</u> also goes into the high-impedance state when <u>OFF</u> is low.			
<u>INT0</u> <u>INT1</u> <u>INT2</u> <u>INT3</u>	I	External user interrupts. <u>INT0</u> – <u>INT3</u> are prioritized and are maskable by the interrupt mask register and the interrupt mode bit. <u>INT0</u> – <u>INT3</u> can be polled and reset by way of the interrupt flag register.			
<u>NMI</u>	I	Nonmaskable interrupt. <u>NMI</u> is an external interrupt that cannot be masked by way of the INTM or the IMR. When <u>NMI</u> is activated, the processor traps to the appropriate vector location.			

† I = Input, O = Output, Z = High-impedance, S = Supply

‡ Although this pin includes an internal pulldown resistor, a 470- Ω external pulldown is required. If the $\overline{\text{TRST}}$ pin is connected to multiple DSPs, a buffer is recommended to ensure the V_{IL} and V_{IH} specifications are met.

Terminal Functions (Continued)

TERMINAL NAME	I/O†	DESCRIPTION
INITIALIZATION, INTERRUPT, AND RESET OPERATIONS (CONTINUED)		
$\overline{\text{RS}}$	I	Reset. $\overline{\text{RS}}$ causes the digital signal processor (DSP) to terminate execution and causes a reinitialization of the CPU and peripherals. When $\overline{\text{RS}}$ is brought to a high level, execution begins at location 0FF80h of program memory. $\overline{\text{RS}}$ affects various registers and status bits.
$\text{MP}/\overline{\text{MC}}$	I	Microprocessor/microcomputer mode select. If active low at reset, microcomputer mode is selected, and the internal program ROM is mapped into the upper program memory space. If the pin is driven high during reset, microprocessor mode is selected, and the on-chip ROM is removed from program space. $\text{MP}/\overline{\text{MC}}$ is only sampled at reset, and the $\text{MP}/\overline{\text{MC}}$ bit of the PMST register can override the mode that is selected at reset.
MULTIPROCESSING SIGNALS		
$\overline{\text{BIO}}$	I	Branch control. A branch can be conditionally executed when $\overline{\text{BIO}}$ is active. If low, the processor executes the conditional instruction. For the XC instruction, the $\overline{\text{BIO}}$ condition is sampled during the decode phase of the pipeline; all other instructions sample $\overline{\text{BIO}}$ during the read phase of the pipeline.
XF	O/Z	External flag output (latched software-programmable signal). XF is set high by the SSBX XF instruction, set low by the RSBX XF instruction or by loading ST1. XF is used for signaling other processors in multiprocessor configurations or used as a general-purpose output pin. XF goes into the high-impedance state when $\overline{\text{OFF}}$ is low, and is set high at reset.
MEMORY CONTROL SIGNALS		
$\overline{\text{DS}}$ $\overline{\text{PS}}$ $\overline{\text{IS}}$	O/Z	Data, program, and I/O space select signals. $\overline{\text{DS}}$, $\overline{\text{PS}}$, and $\overline{\text{IS}}$ are always high unless driven low for accessing a particular external memory space. Active period corresponds to valid address information. $\overline{\text{DS}}$, $\overline{\text{PS}}$, and $\overline{\text{IS}}$ are placed into the high-impedance state in the hold mode; the signals also go into the high-impedance state when $\overline{\text{OFF}}$ is low.
$\overline{\text{MSTRB}}$	O/Z	Memory strobe signal. $\overline{\text{MSTRB}}$ is always high unless low-level asserted to indicate an external bus access to data or program memory. $\overline{\text{MSTRB}}$ is placed in the high-impedance state in the hold mode; it also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
READY	I	Data ready. READY indicates that an external device is prepared for a bus transaction to be completed. If the device is not ready (READY is low), the processor waits one cycle and checks READY again. Note that the processor performs ready detection if at least two software wait states are programmed. The READY signal is not sampled until the completion of the software wait states.
$\text{R}/\overline{\text{W}}$	O/Z	Read/write signal. $\text{R}/\overline{\text{W}}$ indicates transfer direction during communication to an external device. $\text{R}/\overline{\text{W}}$ is normally in the read mode (high), unless it is asserted low when the DSP performs a write operation. $\text{R}/\overline{\text{W}}$ is placed in the high-impedance state in hold mode; it also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
$\overline{\text{IOSTRB}}$	O/Z	I/O strobe signal. $\overline{\text{IOSTRB}}$ is always high unless low-level asserted to indicate an external bus access to an I/O device. $\overline{\text{IOSTRB}}$ is placed in the high-impedance state in the hold mode; it also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
$\overline{\text{HOLD}}$	I	Hold. $\overline{\text{HOLD}}$ is asserted to request control of the address, data, and control lines. When acknowledged by the C54x, these lines go into the high-impedance state.
$\overline{\text{HOLDA}}$	O/Z	Hold acknowledge. $\overline{\text{HOLDA}}$ indicates that the UC5409 is in a hold state and that the address, data, and control lines are in the high-impedance state, allowing the external memory interface to be accessed by other devices. $\overline{\text{HOLDA}}$ also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
$\overline{\text{MSC}}$	O/Z	Microstate complete. $\overline{\text{MSC}}$ indicates completion of all software wait states. When two or more software wait states are enabled, the $\overline{\text{MSC}}$ pin goes low during the last of these wait states. If connected to the READY input, $\overline{\text{MSC}}$ forces one external wait state after the last internal wait state is completed. $\overline{\text{MSC}}$ also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
$\overline{\text{IAQ}}$	O/Z	Instruction acquisition signal. $\overline{\text{IAQ}}$ is asserted (active low) when there is an instruction address on the address bus. $\overline{\text{IAQ}}$ goes into the high-impedance state when $\overline{\text{OFF}}$ is low.

† I = Input, O = Output, Z = High-impedance, S = Supply

‡ Although this pin includes an internal pulldown resistor, a 470- Ω external pulldown is required. If the $\overline{\text{TRST}}$ pin is connected to multiple DSPs, a buffer is recommended to ensure the V_{IL} and V_{IH} specifications are met.

TMS320UC5409

FIXED-POINT DIGITAL SIGNAL PROCESSOR

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Terminal Functions (Continued)

TERMINAL NAME	I/O†	DESCRIPTION
OSCILLATOR/TIMER SIGNALS		
CLKOUT	O/Z	Master clock output signal. CLKOUT cycles at the machine-cycle rate of the CPU. The internal machine cycle is bounded by rising edges of this signal. CLKOUT also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
CLKMD1 CLKMD2 CLKMD3	I	Clock mode select signals. These inputs select the mode that the clock generator is initialized to after reset. The logic levels of CLKMD1–CLKMD3 are latched when the reset pin is low, and the clock mode register is initialized to the selected mode. After reset, the clock mode can be changed through software, but the clock mode select signals have no effect until the device is reset again.
X2/CLKIN	I	Clock/oscillator input. If the internal oscillator is not being used, X2/CLKIN functions as the clock input.
X1	O	Output pin from the internal oscillator for the crystal. If the internal oscillator is not used, X1 should be left unconnected. X1 does not go into the high-impedance state when $\overline{\text{OFF}}$ is low.
TOUT	O/Z	Timer output. TOUT signals a pulse when the on-chip timer counts down past zero. The pulse is one CLKOUT cycle wide. TOUT also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
MULTICHANNEL BUFFERED SERIAL PORT SIGNALS		
BCLKR0 BCLKR1 BCLKR2	I/O/Z	Receive clock input. BCLKR serves as the serial shift clock for the buffered serial port receiver.
BDR0 BDR1 BDR2	I	Serial data receive input
BFSR0 BFSR1 BFSR2	I/O/Z	Frame synchronization pulse for receive input. The BFSR pulse initiates the receive data process over BDR.
BCLKX0 BCLKX1 BCLKX2	I/O/Z	Transmit clock. BCLKX serves as the serial shift clock for the McBSP transmitter. BCLKX can be configured as an input or an output; it is configured as an input following reset. BCLKX enters the high-impedance state when $\overline{\text{OFF}}$ goes low.
BDX0 BDX1 BDX2	O/Z	Serial data transmit output. BDX is placed in the high-impedance state when not transmitting, when $\overline{\text{RS}}$ is asserted, or when $\overline{\text{OFF}}$ is low.
BFSX0 BFSX1 BFSX2	I/O/Z	Frame synchronization pulse for transmit input/output. The BFSX pulse initiates the transmit data process. BFSX can be configured as an input or an output; it is configured as an input following reset. BFSX goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
HOST-PORT INTERFACE SIGNALS		
A0 – A15	I	These pins can be used to address internal memory via the HPI when the HPI16 pin is high.
D0 – D15	I/O	These pins can be used to read/write internal memory via the HPI when the HPI16 pin is high. The sixteen data pins, D0 to D15, are multiplexed to transfer data between the core CPU and external data/program memory, I/O devices, or HPI in 16-bit mode. The data bus is placed in the high-impedance state when not outputting or when RS or HOLD is asserted. The data bus also goes into the high-impedance state when $\overline{\text{OFF}}$ is low. The data bus includes bus holders to reduce the static power dissipation caused by floating, unused pins. The bus holders also eliminate the need for external bias resistors on unused pins. When the data bus is not being driven by the UC5409, the bus holders keep the pins at the logic level that was most recently driven. The data bus holders of the UC5409 are disabled at reset, and can be enabled/disabled via the BH bit of the BSCR.
HD0 – HD7	I/O/Z	Parallel bidirectional data bus. These pins can also be used as general-purpose I/O pins when the HPI16 pin is high. HD0–HD7 is placed in the high-impedance state when not outputting data or when $\overline{\text{OFF}}$ is low. The HPI data bus includes bus holders to reduce the static power dissipation caused by floating, unused pins. When the HPI data bus is not being driven by the UC5409, the bus holders keep the pins at the logic level that was most recently driven. The HPI data bus holders are disabled at reset and can be enabled/disabled via the HBH bit of the BSCR.

† I = Input, O = Output, Z = High-impedance, S = Supply

‡ Although this pin includes an internal pulldown resistor, a 470- Ω external pulldown is required. If the $\overline{\text{TRST}}$ pin is connected to multiple DSPs, a buffer is recommended to ensure the V_{IL} and V_{IH} specifications are met.



Terminal Functions (Continued)

TERMINAL NAME	I/O†	DESCRIPTION
HOST-PORT INTERFACE SIGNALS (CONTINUED)		
HCNTL0 HCNTL1	I	Control. HCNTL0 and HCNTL1 select a host access to one of the three HPI registers. The control inputs have internal pullup resistors that are only enabled when HPIENA = 0.
HBIL	I	Byte identification. HBIL identifies the first or second byte of transfer. The HBIL input has an internal pullup resistor that is only enabled when HPIENA = 0.
$\overline{\text{HCS}}$	I	Chip select. $\overline{\text{HCS}}$ is the select input for the HPI and must be driven low during accesses. The chip-select input has an internal pullup resistor that is only enabled when HPIENA = 0.
$\overline{\text{HDS1}}$ $\overline{\text{HDS2}}$	I	Data strobe. $\overline{\text{HDS1}}$ and $\overline{\text{HDS2}}$ are driven by the host read and write strobes to control transfers. The strobe inputs have internal pullup resistors that are only enabled when HPIENA = 0.
$\overline{\text{HAS}}$	I	Address strobe. Hosts with multiplexed address and data pins require $\overline{\text{HAS}}$ to latch the address in the HPIA register. HAS has an internal pullup resistor that is only enabled when HPIENA = 0.
HR/ $\overline{\text{W}}$	I	Read/write. HR/ $\overline{\text{W}}$ controls the direction of an HPI transfer. R/ $\overline{\text{W}}$ has an internal pullup resistor that is only enabled when HPIENA = 0.
HRDY	O/Z	Ready. The ready output informs the host when the HPI is ready for the next transfer. HRDY goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
$\overline{\text{HINT}}$	O/Z	Interrupt. This output is used to interrupt the host. When the DSP is in reset, $\overline{\text{HINT}}$ is driven high. The signal goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
HPIENA	I	HPI module select. HPIENA must be driven high during reset to enable the HPI. An internal pulldown resistor is always active and the HPIENA pin is sampled on the rising edge of RS. If HPIENA is left open or is driven low during reset, the HPI module is disabled. Once the HPI is disabled, the HPIENA pin has no effect until the UC5409 is reset.
HPI16	I	HPI 16-bit select pin. HPI16 = 1 selects the non-multiplexed mode. The non-multiplexed mode allows hosts with separate address/data buses to access the HPI address range via the 16 address pins (A0–A15). The 16-bit data is also accessible through pins D0 through D15. Host-to-DSP and DSP-to-Host interrupts are not supported. There are no HPIC and HPIA registers in the non-multiplexed mode since HCNTL0 and HCNTL1 signals are available.
SUPPLY PINS		
CVDD	S	+VDD. Dedicated 1.8-V power supply for the core CPU
DVDD	S	+VDD. Dedicated 3.3-V power supply for the I/O pins
VSS	S	Ground
TEST PINS		
TCK	I	IEEE standard 1149.1 test clock. TCK is normally a free-running clock signal with a 50% duty cycle. The changes on the test access port (TAP) of input signals TMS and TDI are clocked into the TAP controller, instruction register, or selected test data register on the rising edge of TCK. Changes at the TAP output signal (TDO) occur on the falling edge of TCK.
TDI	I	IEEE standard 1149.1 test data input pin with internal pullup device. TDI is clocked into the selected register (instruction or data) on a rising edge of TCK.
TDO	O/Z	IEEE standard 1149.1 test data output. The contents of the selected register (instruction or data) are shifted out of TDO on the falling edge of TCK. TDO is in the high-impedance state except when the scanning of data is in progress. TDO also goes into the high-impedance state when $\overline{\text{OFF}}$ is low.
TMS	I	IEEE standard 1149.1 test mode select. Pin with internal pullup device. This serial control input is clocked into the TAP controller on the rising edge of TCK.
$\overline{\text{TRST}}^\ddagger$	I	IEEE standard 1149.1 test reset. $\overline{\text{TRST}}$, when high, gives the IEEE standard 1149.1 scan system control of the operations of the device. If $\overline{\text{TRST}}$ is driven low, the device operates in its functional mode, and the IEEE standard 1149.1 signals are ignored. Pin with internal pulldown device.

† I = Input, O = Output, Z = High-impedance, S = Supply

‡ Although this pin includes an internal pulldown resistor, a 470- Ω external pulldown is required. If the $\overline{\text{TRST}}$ pin is connected to multiple DSPs, a buffer is recommended to ensure the V_{IL} and V_{IH} specifications are met.

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Terminal Functions (Continued)

TERMINAL NAME	I/O [†]	DESCRIPTION
TEST PINS (CONTINUED)		
EMU0	I/O/Z	Emulator 0 pin. When $\overline{\text{TRST}}$ is driven low, EMU0 must be high for activation of the $\overline{\text{OFF}}$ condition. When $\overline{\text{TRST}}$ is driven high, EMU0 is used as an interrupt to or from the emulator system and is defined as input/output by way of the IEEE standard 1149.1 scan system.
EMU1/ $\overline{\text{OFF}}$	I/O/Z	Emulator 1 pin/disable all outputs. When $\overline{\text{TRST}}$ is driven high, EMU1/ $\overline{\text{OFF}}$ is used as an interrupt to or from the emulator system and is defined as input/output by way of the IEEE standard 1149.1 scan system. When $\overline{\text{TRST}}$ is driven low, EMU1/ $\overline{\text{OFF}}$ is configured as $\overline{\text{OFF}}$. The EMU1/ $\overline{\text{OFF}}$ signal, when active low, puts all output drivers into the high-impedance state. Note that $\overline{\text{OFF}}$ is used exclusively for testing and emulation purposes (not for multiprocessing applications). Therefore, for the $\overline{\text{OFF}}$ feature, the following apply: $\overline{\text{TRST}}$ = low EMU0 = high EMU1/ $\overline{\text{OFF}}$ = low

[†] I = Input, O = Output, Z = High-impedance, S = Supply

[‡] Although this pin includes an internal pulldown resistor, a 470- Ω external pulldown is required. If the $\overline{\text{TRST}}$ pin is connected to multiple DSPs, a buffer is recommended to ensure the V_{IL} and V_{IH} specifications are met.

memory

The UC5409 device provides both on-chip ROM and RAM memories to aid in system performance and integration.

on-chip ROM with bootloader

The 5409 features a 16K-word $\times$ 16-bit on-chip maskable ROM. Customers can arrange to have the ROM of the 5409 programmed with contents unique to any particular application. A security option is available to protect a custom ROM. This security option is described in the *TMS320C54x DSP CPU and Peripherals Reference Set, Volume 1* (literature number SPRU131). Note that only the ROM security option, and not the ROM/RAM option, is available on the 5409.

A bootloader is available in the standard 5409 on-chip ROM. This bootloader can be used to automatically transfer user code from an external source to anywhere in the program memory at power up. If the MP/ $\overline{\text{MC}}$ pin is sampled low during a hardware reset, execution begins at location FF80h of the on-chip ROM. This location contains a branch instruction to the start of the bootloader program. The standard 5409 bootloader provides different ways to download the code to accommodate various system requirements:

- Parallel from 8-bit or 16-bit-wide EPROM
- Parallel from I/O space 8-bit or 16-bit mode
- Serial boot from serial ports 8-bit or 16-bit mode
- Host-port interface boot
- SPI serial EEPROM 8-bit boot mode

on-chip ROM with bootloader (continued)

The standard on-chip ROM layout is shown in Table 1.

Table 1. Standard On-Chip ROM Layout[†]

ADDRESS RANGE	DESCRIPTION
0x0000h – 0xBFFFh	External program space
0xC000h – 0xF7FFh	Reserved
0xF800h – 0xFBFFh	Bootloader
0xFC00h – 0xFEFFh	Reserved
0xFF00h – 0xFF7Fh	Reserved [†]
0xFF80h – 0xFFFFh	Interrupt vector table

[†] In the VC5409 ROM, 128 words are reserved for factory device-testing purposes. Application code to be implemented in on-chip ROM must reserve these 128 words at addresses FF00h–FF7Fh in program space.

on-chip RAM

The UC5409 device contains 32K × 16-bit of on-chip dual-access RAM (DARAM). The DARAM is composed of four blocks of 8K words each. Each block in the DARAM can support two reads in one cycle, or a read and a write in one cycle. The DARAM is located in the address range 0080h–7FFFh in data space, and can be mapped into program/data space by setting the OVLY bit to one.

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memory map

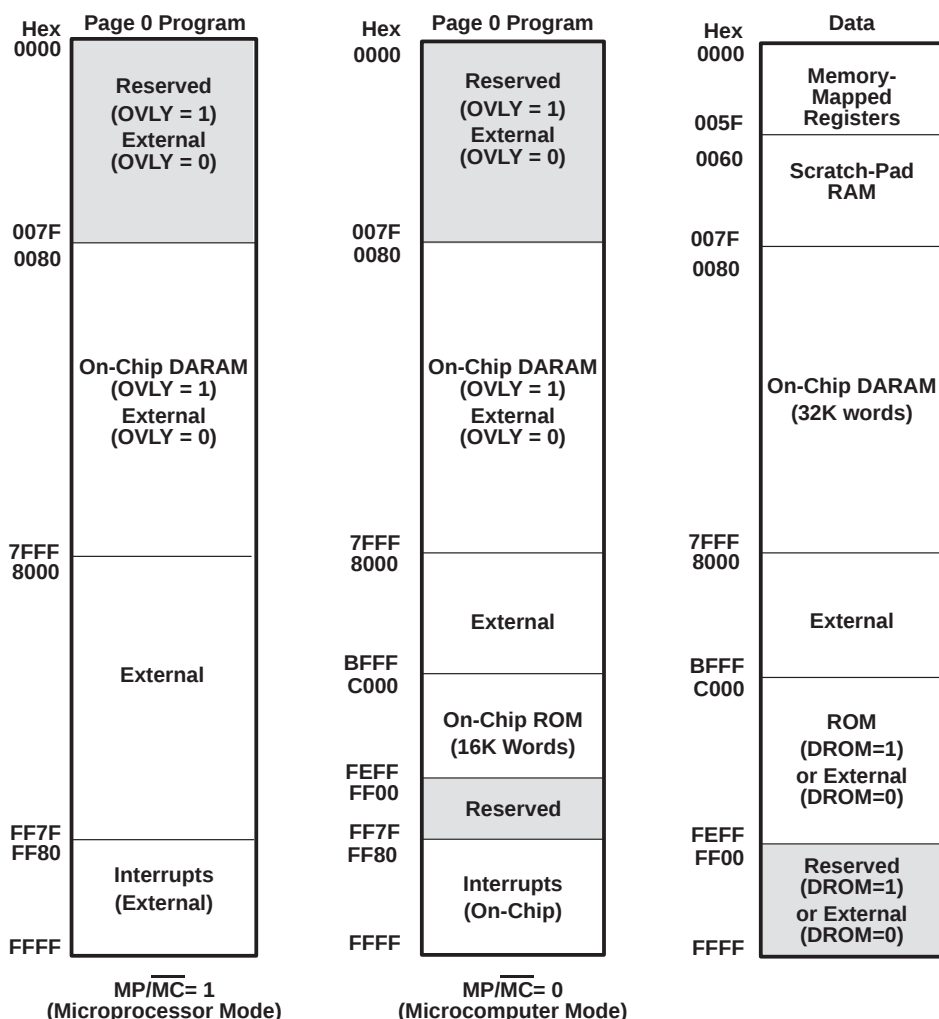


Figure 1. Memory Map

relocatable interrupt vector table

The reset, interrupt, and trap vectors are addressed in program space. These vectors are soft — meaning that the processor, when taking the trap, loads the program counter (PC) with the trap address and executes the code at the vector location. Four words are reserved at each vector location to accommodate a delayed branch instruction, either two 1-word instructions or one 2-word instruction, which allows branching to the appropriate interrupt service routine with minimal overhead.

At device reset, the reset, interrupt, and trap vectors are mapped to address FF80h in program space. However, these vectors can be remapped to the beginning of any 128-word page in program space after device reset. This is done by loading the interrupt vector pointer (IPTR) bits in the PMST register with the appropriate 128-word page boundary address. After loading IPTR, any user interrupt or trap vector is mapped to the new 128-word page.

NOTE: The hardware reset ($\overline{RS}$) vector cannot be remapped because a hardware reset loads the IPTR with 1s. Therefore, the reset vector is always fetched at location FF80h in program space.

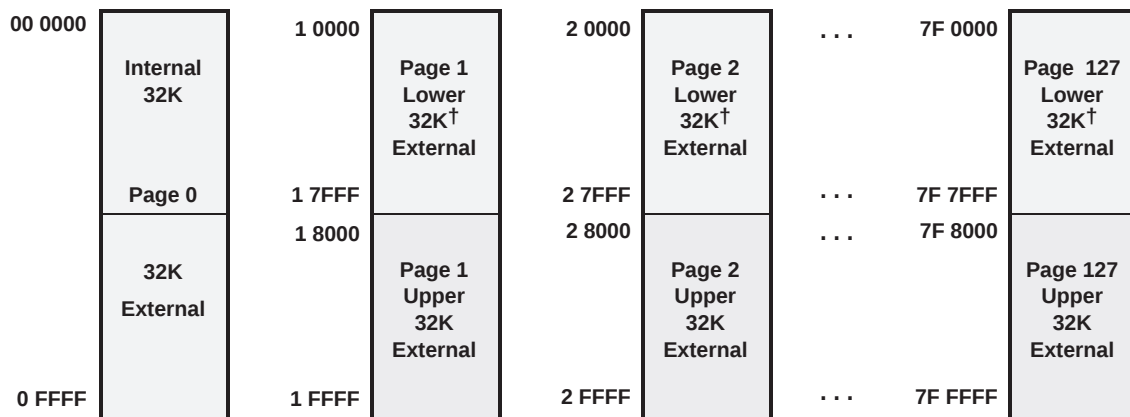
extended program memory

The UC5409 uses a paged extended memory scheme in program space to allow access of up to 8M program memory locations. In order to implement this scheme, the UC5409 includes several features that are also present on the 548/549 devices:

- Twenty-three address lines, instead of sixteen
- An extra memory-mapped register, the XPC register defines the page selection. This register is memory-mapped into data space to address 001Eh. At a hardware reset, the XPC is initialized to 0.
- Six extra instructions for addressing extended program space. These six instructions affect the XPC.
 - *FB[D]* pmad (23 bits) – Far branch
 - *FBACC[D]* Accu[22:0] – Far branch to the location specified by the value in accumulator A or accumulator B
 - *FCALL[D]* pmad (23 bits) – Far call
 - *FCALA[D]* Accu[22:0] – Far call to the location specified by the value in accumulator A or accumulator B
 - *FRET[D]* – Far return
 - *FRETE[D]* – Far return with interrupts enabled
- In addition to these new instructions, two 54x instructions are extended to use 23 bits in the UC5409:
 - *READA* data_memory (using 23-bit accumulator address)
 - *WRITA* data_memory (using 23-bit accumulator address)

All other instructions, software interrupts, and hardware interrupts do not modify the XPC register and access only memory within the current page.

Program memory in the UC5409 is organized into 127 pages that are each 64K in length, as shown in Figure 2.



[†] The lower 32K words of pages 1 through 126 are available only when the OVLY bit is cleared to 0. If the OVLY bit is set to 1, the on-chip RAM is mapped to the lower 32K words of all program space pages.

Figure 2. Extended Program Memory

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on-chip peripherals

The UC5409 device has the following peripherals:

- Software-programmable wait-state generator with programmable bank-switching wait states
- An enhanced 8-bit host-port interface (HPI8/16) with 16-bit data/addressing
- Three multichannel buffered serial ports (McBSPs)
- One hardware timer
- A clock generator with a phase-locked loop (PLL)
- A direct memory access (DMA) controller

software-programmable wait-state generator

The software wait-state generator of the UC5409 is similar to that of the 5410 and it can extend external bus cycles by up to fourteen machine cycles. Devices that require more than fourteen wait states can be interfaced using the hardware READY line. When all external accesses are configured for zero wait states, the internal clocks to the wait-state generator are automatically disabled. Disabling the wait-state generator clocks reduces the power consumption of the UC5409.

The software wait-state register (SWWSR) controls the operation of the wait-state generator. The 14 LSBs of the SWWSR specify the number of wait states (0 to 7) to be inserted for external memory accesses to five separate address ranges. This allows a different number of wait states for each of the five address ranges. Additionally, the software wait-state multiplier (SWSM) bit of the system configuration register (SCR) defines a multiplication factor of 1 or 2 for the number of wait states. At reset, the wait-state generator is initialized to provide seven wait states on all external memory accesses. The SWWSR bit fields are shown in Figure 3 and described in Table 2.

15	14	12	11	9	8	6	5	3	2	0
XPA	I/O	Data	Data	Program	Program					
R/W-0	R/W-111	R/W-111	R/W-111	R/W-111	R/W-111					

LEGEND: R = Read, W = Write

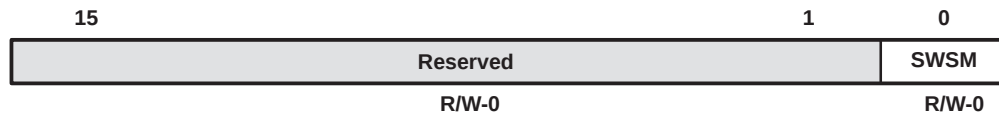
Figure 3. Software Wait-State Register (SWWSR) [Memory-Mapped Register (MMR) Address 0028h]

software-programmable wait-state generator (continued)

Table 2. Software Wait-State Register (SWWSR) Bit Fields

BIT NO.	NAME	RESET VALUE	FUNCTION
15	XPA	0	Extended program address control bit. XPA is used in conjunction with the program space fields (bits 0 through 5) to select the address range for program space wait states.
14–12	I/O	1	I/O space. The field value (0–7) corresponds to the base number of wait states for I/O space accesses within addresses 0000–FFFFh. The SWSM bit of the SWCR defines a multiplication factor of 1 or 2 for the base number of wait states.
11–9	Data	1	Upper data space. The field value (0–7) corresponds to the base number of wait states for external data space accesses within addresses 8000–FFFFh. The SWSM bit of the SWCR defines a multiplication factor of 1 or 2 for the base number of wait states.
8–6	Data	1	Lower data space. The field value (0–7) corresponds to the base number of wait states for external data space accesses within addresses 0000–7FFFh. The SWSM bit of the SWCR defines a multiplication factor of 1 or 2 for the base number of wait states.
5–3	Program	1	Upper program space. The field value (0–7) corresponds to the base number of wait states for external program space accesses within the following addresses: ☐ XPA = 0: x8000 – xFFFFh ☐ XPA = 1: The upper program space bit field has no effect on wait states. The SWSM bit of the SWCR defines a multiplication factor of 1 or 2 for the base number of wait states.
2–0	Program	1	Program space. The field value (0–7) corresponds to the base number of wait states for external program space accesses within the following addresses: ☐ XPA = 0: x0000–x7FFFh ☐ XPA = 1: 00000–FFFFFh The SWSM bit of the SWCR defines a multiplication factor of 1 or 2 for the base number of wait states.

The software wait-state multiplier bit of the software wait-state configuration register is used to extend the base number of wait states selected by the SWWSR. The SWCR bit fields are shown in Figure 4 and described in Table 3.



LEGEND: R = Read, W = Write

Figure 4. Software Wait-State Configuration Register (SWCR) [MMR Address 002Bh]

Table 3. Software Wait-State Configuration Register (SWCR) Bit Fields

PIN NO.	NAME	RESET VALUE	FUNCTION
15–1	Reserved	0	These bits are reserved and are unaffected by writes.
0	SWSM	0	Software wait-state multiplier. Used to multiply the number of wait states defined in the SWWSR by a factor of 1 or 2. ☐ SWSM = 0: wait-state base values are unchanged (multiplied by 1). ☐ SWSM = 1: wait-state base values are multiplied by 2 for a maximum of 14 wait states.

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programmable bank-switching wait states

The programmable bank-switching logic of the UC5409 is functionally equivalent to that of the 548/549 devices. This feature automatically inserts one cycle when accesses cross memory-bank boundaries within program or data memory space. A bank-switching wait state can also be automatically inserted when accesses cross the data space boundary into program space.

The bank-switching control register (BSCR) defines the bank size for bank-switching wait-states. Figure 5 shows the BSCR and its bits are described in Table 4.



LEGEND: R = Read, W = Write

Figure 5. Bank-Switching Control Register (BSCR) [MMR Address 0029h]

Table 4. Bank-Switching Control Register Fields

BIT NO.	BIT NAME	RESET VALUE	FUNCTION
15–12	BNKCMP	1111	Bank compare. BNKCMP determines the external memory-bank size. BNKCMP is used to mask the four MSBs of an address. For example, if BNKCMP = 1111b, the four MSBs (bits 12–15) are compared, resulting in a bank size of 4K words. Bank sizes of 4K words to 64K words are allowed.
11	PS - DS	1	Program read – data read access. PS-DS inserts an extra cycle between consecutive accesses of program read and data read or data read and program read. PS-DS = 0 No extra cycles are inserted by this feature. PS-DS = 1 One extra cycle is inserted between consecutive data and program reads.
10–3	Reserved	0	These bits are reserved and are unaffected by writes.
2	HBH	0	HPI bus holder. HBH controls the HPI bus holder feature. HBH is cleared to 0 at reset. HBH = 0 The bus holder is disabled. HBH = 1 The bus holder is enabled. When not driven, the HPI data bus (HD[7:0]) is held in the previous logic level.
1	BH	0	Bus holder. BH controls the data bus holder feature. BH is cleared to 0 at reset. BH = 0 The bus holder is disabled. BH = 1 The bus holder is enabled. When not driven, the data bus (D[15:0]) is held in the previous logic level.
0	EXIO	0	External bus interface off. The EXIO bit controls the external bus-off function. EXIO = 0 The external bus interface functions as usual. EXIO = 1 The address bus, data bus, and control signals become inactive after completing the current bus cycle. Note that the DROM, MP/MC, and OVLY bits in the PMST and the HM bit of ST1 cannot be modified when the interface is disabled.

parallel I/O ports

The UC5409 has a total of 64K I/O ports. These ports can be addressed by the PORTR instruction or the PORTW instruction. The $\overline{IS}$ signal indicates a read/write operation through an I/O port. The UC5409 can interface easily with external devices through the I/O ports while requiring minimal off-chip address-decoding circuits.

enhanced 8-bit host-port interface (HPI8/16)

The UC5409 host-port interface, also referred to as the HPI8/16, is an enhanced version of the standard 8-bit HPI found on earlier 54x DSPs (542, 545, 548, and 549). The HPI8/16 is an 8-bit parallel port for interprocessor communication. The features of the HPI8/16 include:

Standard features:

- Sequential transfers (with autoincrement) or random-access transfers
- Host interrupt and 54x interrupt capability
- Multiple data strobes and control pins for interface flexibility

Enhanced features of the UC5409 HPI8/16:

- Access to entire on-chip RAM through DMA bus
- Capability to continue transferring during emulation stop
- Capability to transfer 16-bit address and 16-bit data (non-multiplexed mode)

The HPI8/16 functions as a slave and enables the host processor to access the on-chip memory of the UC5409. A major enhancement to the UC5409 HPI over previous versions is that it allows host access to the entire on-chip memory range of the DSP. The HPI8/16 does not have access to external memory. The host and the DSP both have access to the on-chip RAM at all times and host accesses are always synchronized to the DSP clock. If the host and the DSP contend for access to the same location, the host has priority, and the DSP waits for one HPI8/16 cycle. Note that since host accesses are always synchronized to the UC5409 clock, an active input clock (CLKIN) is required for HPI8/16 accesses during IDLE states, and host accesses are not allowed while the UC5409 reset pin is asserted.

In standard 8-bit mode, the HPI8/16 interface consists of an 8-bit bidirectional data bus and various control signals. Sixteen-bit transfers are accomplished in two parts with the HBIL input designating high or low byte. The host communicates with the HPI8/16 through three dedicated registers — HPI address register (HPIA), HPI data register (HPID), and an HPI control register (HPIC). The HPIA and HPID registers are only accessible by the host, and the HPIC register is accessible by both the host and the UC5409.

In 16-bit nonmultiplexed mode (HPI16=1), the HPI8/16 can read and write to internal memory via the external address and data pins, A0 – A15 and D0–D15, respectively. HD0–HD7 can be configured as general-purpose input/output (GPIO). The HPI16 non-multiplexed mode does not support the use of the HPID and HPIA registers. Host-to-DSP and DSP-to-host interrupts are also not supported. See Figure 6 for the HPI memory map.

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enhanced 8-bit host-port interface (HPI8/16) (continued)

0000h	Reserved
005Fh	
0060h	
007Fh	Scratch-Pad RAM
0080h	
7FFFh	On-Chip RAM (32K x 16 Bits)
8000h	
FFFFh	Reserved

Figure 6. UC5409 HPI Memory Map

HPI nonmultiplexed mode

In *nonmultiplexed* mode, a host with separate address/data buses can access the HPI16 data register (HPID) via the HD 16-bit bidirectional data bus, and the address register (HPIA) via the 16-bit HA address bus. The host initiates the access with the strobe signals ($\overline{\text{HDS1}}$, $\overline{\text{HDS2}}$, $\overline{\text{HCS}}$) and controls the direction of the access with the $\overline{\text{HR/W}}$ signal. The HPI16 can stall host accesses via the $\overline{\text{HRDY}}$ signal. Note that the HPIC register is not available in *nonmultiplexed* mode since there are no $\overline{\text{HCNTL}}$ signals available. All host accesses initiate a DMA read or write access. Figure 7 shows a block diagram of the HPI16 in *nonmultiplexed* mode.

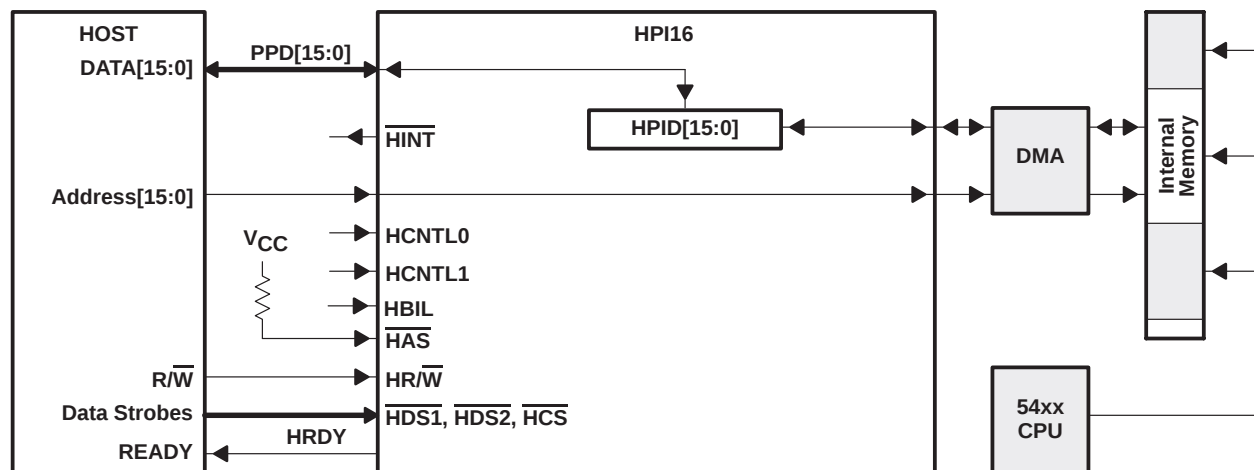


Figure 7. Host-Port Interface — Nonmultiplexed Mode

host access control

Host accesses are controlled by the data strobes ($\overline{\text{HDS1}}$ and $\overline{\text{HDS2}}$), along with chip select ($\overline{\text{HCS}}$), in exactly the same fashion as documented in the *HPI nonmultiplexed mode* section.

host access type

In *nonmultiplexed* mode, only one access type (HPID read/write) is available since the HPIA register is not needed because of direct address inputs, and since the $\overline{\text{HCNTL}}$ pins are not available for access-type selection.

HPI16 control register (HPIC)

In *nonmultiplexed* mode, the HPIC register is not accessible via the host. This precludes DSP-to-host or host-to-DSP interrupts, data prefetch via the FETCH bit, and HRDY polling. Extended addressing capability still exists (even without the XHPIA bit) because the HA bus is 16 bits wide.

HPI16 address register (HPIA)

In *nonmultiplexed* mode, the HPIA register is not needed because direct address inputs A[15:0] are used as HA[15:0]. The DMA address comes directly from the HA pins. Note that the HA bus is still always latched at the end of the host access (on the rising edge of $\overline{\text{HDS}} = \overline{\text{HDS1}} \text{ XNOR } \overline{\text{HDS2}}$) in order to ensure a valid address during the DMA write access.

host data prefetch

Since the HPIA register is not used in *nonmultiplexed* mode, the prefetch mechanism is not supported. Random address accesses in *nonmultiplexed* mode are still faster than those in *multiplexed* mode because of the separate address and data buses.

host ready logic (HRDY)

Hardware HRDY logic operation in *nonmultiplexed* mode is the same as that in *multiplexed* mode. HRDY operation during prefetches and HRDY/FETCH bit interaction are not supported with *nonmultiplexed* mode.

host/DSP interrupts

Host-to-DSP and DSP-to-host interrupts are not supported by HPI16 in *nonmultiplexed* mode.

other HPI system considerations

operation during IDLE2

The HPI can continue to operate during IDLE1 or IDLE2 by using special clock management logic that turns on relevant clocks to perform a synchronous memory access, and then turns the clocks back off to save power. The DSP CPU does not wake up from the IDLE mode during this process.

multichannel buffered serial ports

The UC5409 device has three high-speed, full-duplex multichannel buffered serial ports (McBSPs) that allow direct interface to other C54x/LC54x devices, codecs, and other devices in a system. The McBSPs are based on the standard serial port interface found on other 54x devices. Like its predecessors, the McBSP provides:

- Full-duplex communication
- Double-buffer data registers, which allow a continuous data stream
- Independent framing and clocking for receive and transmit

In addition, the McBSP has the following capabilities:

- Direct interface to:
 - T1/E1 framers
 - MVIP switching-compatible and ST-BUS compliant devices
 - IOM-2 compliant devices
 - AC97-compliant devices
 - Serial peripheral interface (SPI™) devices
- Multichannel transmit and receive of up to 128 channels
- A wide selection of data sizes including 8, 12, 16, 20, 24, or 32 bits
- μ -law and A-law companding
- Programmable polarity for both frame synchronization and data clocks
- Programmable internal clock and frame generation

SPI is a trademark of Motorola Inc.

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multichannel buffered serial ports (continued)

The McBSPs consist of separate transmit and receive channels that operate independently. The external interface of each McBSP consists of the following pins:

- BCLKX Transmit reference clock
- BDX Transmit data
- BFSX Transmit frame synchronization
- BCLKR Receive reference clock
- BDR Receive data
- BFSR Receive frame synchronization

The six pins listed are functionally equivalent to the pins of previous serial port interface pins in the C5000 family of DSPs. On the transmitter, transmit frame synchronization and clocking are indicated by the BFSX and BCLKX pins, respectively. The CPU or DMA can initiate transmission of data by writing to the data transmit register (DXR). Data written to DXR is shifted out on the BDX pin through a transmit shift register (XSR). This structure allows DXR to be loaded with the next word to be sent while the transmission of the current word is in progress.

On the receiver, receive frame synchronization and clocking are indicated by the BFSR and BCLKR pins, respectively. The CPU or DMA can read received data from the data receive register (DRR). Data received on the BDR pin is shifted into a receive shift register (RSR) and then buffered in the receive buffer register (RBR). If the DRR is empty, the RBR contents are copied into the DRR. If not, the RBR holds the data until the DRR is available. This structure allows storage of the two previous words while the reception of the current word is in progress.

The CPU and DMA can move data to and from the McBSPs and can synchronize transfers based on McBSP interrupts, event signals, and status flags. The DMA is capable of handling data movement between the McBSPs and memory with no intervention from the CPU.

In addition to the standard serial port functions, the McBSP provides programmable clock and frame sync generation. Among the programmable functions are:

- Frame synchronization pulse width
- Frame period
- Frame synchronization delay
- Clock reference (internal vs. external)
- Clock division
- Clock and frame sync polarity

The on-chip companding hardware allows compression and expansion of data in either μ -law or A-law format. When companding is used, transmit data is encoded according to specified companding law and received data is decoded to 2s complement format.

The McBSP allows the multiple channels to be independently selected for the transmitter and receiver. When multiple channels are selected, each frame represents a time-division multiplexed (TDM) data stream. In using TDM data streams, the CPU may only need to process a few of them. Thus, to save memory and bus bandwidth, multichannel selection allows independent enabling of particular channels for transmission and reception. Up to 32 channels in a stream of up to 128 channels can be enabled.

The clock-stop mode (CLKSTP) in the McBSP provides compatibility with the serial peripheral interface (SPI) protocol. Clock-stop mode works with only single-phase frames and one word per frame. The word sizes supported by the McBSP are programmable for 8-, 12-, 16-, 20-, 24-, or 32-bit operation. When the McBSP is configured to operate in SPI mode, both the transmitter and the receiver operate together as a master or as a slave.

The McBSP is fully static and operates at arbitrarily low clock frequencies. The maximum frequency is CPU clock frequency divided by 2.

sample rate generator external clock options

Although the CLKS pin is not available on the 5409 PGE and GGU packages, the 5409 is capable of synchronization to external clock sources. CLKX or CLKR can be used by the sample rate generator for external synchronization. The sample rate clock mode extended (SCLKME) bit field is located in the PCR to accommodate this option.

15	14	13	12	11	10	9	8
Reserved		XIOEN	RIOEN	FSXM	FSRM	CLKXM	CLKRM
RW		RW	RW	RW	RW	RW	RW
7	6	5	4	3	2	1	0
SCLKME	CLKS STAT	DX STAT	DR STAT	FSXP	FSRP	CLKXP	CLKRP
RW	RW	RW	RW	RW	RW	RW	RW

Legend: R = Read, W = Write

Figure 8. Pin Control Register (PCR)

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sample rate generator external clock options (continued)

Table 5. Pin Control Register (PCR) Bit Field Description

BITS	NAME	FUNCTION
15 – 14	Reserved	Reserved. Pins are not used.
13	XIOEN	Transmit/Receive general-purpose I/O mode ONLY when $\overline{XRST}=0$ in the SPCR(1/2) XIOEN = 0 DX pin is not a general-purpose output. FSX and CLKX are not general-purpose I/Os. XIOEN = 1 DX pin is a general-purpose output. FSX and CLKX are general-purpose I/Os. These serial port pins do not perform serial port operations.
12	RIOEN	Transmit/Receive general-purpose I/O mode ONLY when $\overline{RRST}=0$ in the SPCR(1/2) RIOEN = 0 DR and CLKS pins are not general-purpose inputs. FSR and CLKR are not general-purpose I/Os. RIOEN = 1 DR and CLKS pins are general-purpose inputs. FSR and CLKR are general-purpose I/Os. These serial port pins do not perform serial port operations. The CLKS pin is affected by a combination of $\overline{RRST}$ and RIOEN signals of the receiver.
11	FSXM	Transmit frame synchronization mode FSRM = 0 Frame synchronization signal derived from an external source. FSRM = 1 Frame synchronization is determined by the sample rate generator frame synchronization mode bit (FSGM) in the SRGR2.
10	FSRM	Receive frame synchronization mode FSRM = 0 Frame synchronization pulses generated by an external device. FSR is an input pin. FSRM = 1 Frame synchronization generated internally by the sample rate generator. FSR is an output pin except when GSYNC=1 in the SRGR.
9	CLKRM	Receiver clock mode Case 1: Digital loop-back mode is not set (CLB=0) in SPCR1. CLKRM = 0 Receive clock (CLKR) is an input pin driven by an external clock. CLKRM = 1 CLKR is an output pin and is driven by the internal sample rate generator Case 2: Digital loop-back mode set (CLB=1) in SPCR1 CLKRM = 0 Receive clock (Not the CLKR pin) is driven by transmit clock (CLKX), which is based on CLKXM bit in the PCR. CLKR pin is in high-impedance mode. CLKRM = 1 CLKR is an output pin and is driven by the transmit clock. The transmit clock is derived based on the CLKXM bit in the PCR.
8	CLKXM	Transmitter clock mode CLKXM = 0 Receiver/transmitter clock is driven by an external clock with CLK(R/X) as an input pin CLKXM = 1 CLK(R/X) is an output pin and is driven by the internal sample rate generator During SPI mode (CLKSTP is a non-zero value): CLKXM = 0 McBSP is a slave and clock (CLKX) is driven by the SPI master in the system. CLKR is internally driven by CLKX. CLKXM = 1 McBSP is a master and generates the clock (CLKX) to drive its receive clock (CLKR) and the shift clock of the SPI-compliant slaves in the system.

sample rate generator external clock options (continued)

Table 5. Pin Control Register (PCR) Bit Field Description (Continued)

BIT	NAME	FUNCTION
7	SCLKME	Sample rate clock mode extended SCLKME = 0 External clock via CLKS or CPU clock is used as a reference by the sample rate generator. SCLKME = 1 External clock via CLKR or CLKX clock is used as a reference by the sample rate generator.
6	CLKS STAT	CLKS pin status. CLKS STAT reflects value on CLKS pin when selected as a general-purpose input.
5	DX STAT	DX pin status. DX STAT reflects value on DX pin when it is selected as a general-purpose output.
4	DR STAT	DR pin status. DR STAT reflects value on DR pin when it is selected as a general-purpose input.
3–2	FSXP FSRP	Receive/Transmit frame synchronization polarity. FS(R/X)P = 0 Frame synchronization pulse FS(R/X) is active high FS(R/X)P = 1 Frame synchronization pulse FS(R/X) is active low
1	CLKXP	Transmit clock polarity CLKXP = 0 Transmit data sampled on rising edge of CLKR CLKXP = 1 Transmit data sampled on falling edge of CLKR
0	CLKRP	Receive clock polarity CLKRP = 0 Receive data sampled on falling edge of CLKR CLKRP = 1 Receive data sampled on rising edge of CLKR

The 5409 sample rate generator has four clock input options that are only available when both the PCR and SRGR2 are used. Table 6 shows the sample rate generator clock input options.

Table 6. Sample Rate Generator Clock Input Options

MODE	SCLKME (PCR.7)	CLKSM (SRGR2.13)
CLKS pin	0	0
CPU	0	1
CLKR pin	1	0
CLKX pin	1	1

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GSYNC	CLKSP	CLKSM	FSGM	FPER											
RW	RW	RW	RW	RW											

Legend: R = Read, W = Write

Figure 9. Sample Rate Generator Register 2 (SRGR2)

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sample rate generator external clock options (continued)

Table 7. Sample Rate Generator Register 2 (SRGR2) Bit Field Descriptions

BIT	NAME	FUNCTION
15	GSYNC	Sample rate generator clock synchronization. Only used when the external clock (CLKS) drives the sample rate generator clock (CLKSM=0) GSYNC = 0 The sample rate generator clock (CLKG) is free-running. GSYNC = 1 The sample rate generator clock (CLKG) is running. But CLKG is resynchronized and frame sync signal (FSG) is generated only after detecting the receive frame synchronization signal (FSR). Also, frame period (FPER) is a don't care because the period is dictated by the external frame sync pulse.
14	CLKSP	CLKS polarity clock edge select. Only used when the external clock (CLKS) drives the sample rate generator clock (CLKSM=0). CLKSP = 0 Rising edge of CLKS generates CLKG and FSG. CLKSP = 1 Falling edge of CLKS generates CLKG and FSG.
13	CLKSM	McBSP sample rate generator clock mode SCLKME = 0 CLKS = 0 Sample rate generator clock derived from the CLKS pin (in PCR) CLKS = 1 Sample rate generator clock derived from CPU clock SCLKME = 1 CLKS = 0 Sample rate generator clock derived from CLKR pin (in PCR) CLKS = 1 Sample rate generator clock derived from CLKX pin
12	FSGM	Sample rate generator transmit frame synchronization mode. Used when FSXM=1 in the PCR. FSGM = 0 Transmit frame sync signal (FSX) due to DXR(1/2) copy FSGN = 1 Transmit frame sync signal driven by the sample rate generator frame sync signal (FSG)
11 – 0	FPER	Frame period. This determines when the next frame sync signal should become active. Range: up to 2 ¹² ; 1 to 4096 CLKG periods.

hardware timer

The UC5409 device features one 16-bit timing circuit with a 4-bit prescaler. The main counter of each timer is decremented by one every CLKOUT cycle. Each time the counter decrements to 0, a timer interrupt is generated. The timer can be stopped, restarted, reset, or disabled by specific control bits.

clock generator

The clock generator provides clocks to the UC5409 device, and consists of an internal oscillator and a phase-locked loop (PLL) circuit. The clock generator requires a reference clock input, which can be provided by using a crystal resonator with the internal oscillator, or from an external clock source. The reference clock input is then divided by two (DIV mode) to generate clocks for the UC5409 device, or the PLL circuit can be used (PLL mode) to generate the device clock by multiplying the reference clock frequency by a scale factor, allowing use of a clock source with a lower frequency than that of the CPU. The PLL is an adaptive circuit that, once synchronized, locks onto and tracks an input clock signal.

When the PLL is initially started, it enters a transitional mode during which the PLL acquires lock with the input signal. Once the PLL is locked, it continues to track and maintain synchronization with the input signal. Then, other internal clock circuitry allows the synthesis of new clock frequencies for use as master clock for the UC5409 device.



clock generator (continued)

This clock generator allows system designers to select the clock source. The sources that drive the clock generator are:

- A crystal resonator circuit. The crystal resonator circuit is connected across the X1 and X2/CLKIN pins of the UC5409 to enable the internal oscillator.
- An external clock. The external clock source is directly connected to the X2/CLKIN pin, and X1 is left unconnected.

The software-programmable PLL features a high level of flexibility, and includes a clock scaler that provides various clock multiplier ratios, capability to directly enable and disable the PLL, and a PLL lock timer that can be used to delay switching to PLL clocking mode of the device until lock is achieved. Devices that have a built-in software-programmable PLL can be configured in one of two clock modes:

- PLL mode. The input clock (X2/CLKIN) is multiplied by 1 of 31 possible ratios. These ratios are achieved using the PLL circuitry.
- DIV (divider) mode. The input clock is divided by 2 or 4. Note that when DIV mode is used, the PLL can be completely disabled in order to minimize power dissipation.

The software-programmable PLL is controlled using the 16-bit memory-mapped (address 0058h) clock mode register (CLKMD). The CLKMD register is used to define the clock configuration of the PLL clock module. Upon reset, the CLKMD register is initialized with a predetermined value dependent only upon the state of the CLKMD1 – CLKMD3 pins as shown in Table 8.

Table 8. Clock Mode Settings at Reset

CLKMD1	CLKMD2	CLKMD3	CLKMD RESET VALUE	CLOCK MODE
0	0	0	E007h	PLL x 15
0	0	1	9007h	PLL x 10
0	1	0	4007h	PLL x 5
1	0	0	1007h	PLL x 2
1	1	0	F007h	PLL x 1
1	1	1	0000h	1/2 (PLL disabled)
1	0	1	F000h	1/4 (PLL disabled)
0	1	1	—	Reserved (Bypass mode)

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DMA controller

The UC5409 direct memory access (DMA) controller transfers data between points in the memory map without intervention by the CPU. The DMA controller allows movements of data to and from internal program/data memory, internal peripherals (such as the McBSPs), and external program/data memory to occur in the background of CPU operation. The DMA has six independent programmable channels allowing six different contexts for DMA operation.

features

The DMA has the following features:

- The DMA has external memory access.
- The DMA operates independently of the CPU.
- The DMA has six channels. The DMA can keep track of the contexts of six independent block transfers.
- The DMA has higher priority than the CPU for internal accesses.
- Each channel has independently programmable priorities.
- Each channel's source and destination address registers can have configurable indexes through memory on each read and write transfer, respectively. The address may remain constant, be post-incremented, post-decremented, or be adjusted by a programmable value.
- Each read or write transfer may be initialized by selected events. (Internally only)
- Each DMA channel is capable of sending interrupts to the CPU.
- The DMA can perform double-word transfers (a 32-bit transfer of two 16-bit words). (Internally only)

DMA external access

The UC5409 DMA supports external accesses to extended program, data memory, and extended I/O memory.

- Only two channels are available for external accesses. (One for external reads/one for external writes.)
- Single-word transfers are supported for external accesses.
- The DMA does not support transfers from peripherals to external memory.
- The DMA does not support transfers from external memory to the peripherals.

DMA external transfer

Unlike the 5410, the 5409 DMA mode control register (DMMCRx) has two additional bits; DLAXS (DMMCRn[5]) and SLAXS (DMMCRn[11]). These new bits specify the on/off-chip memory for the source and destination of the program/data/I/O spaces.

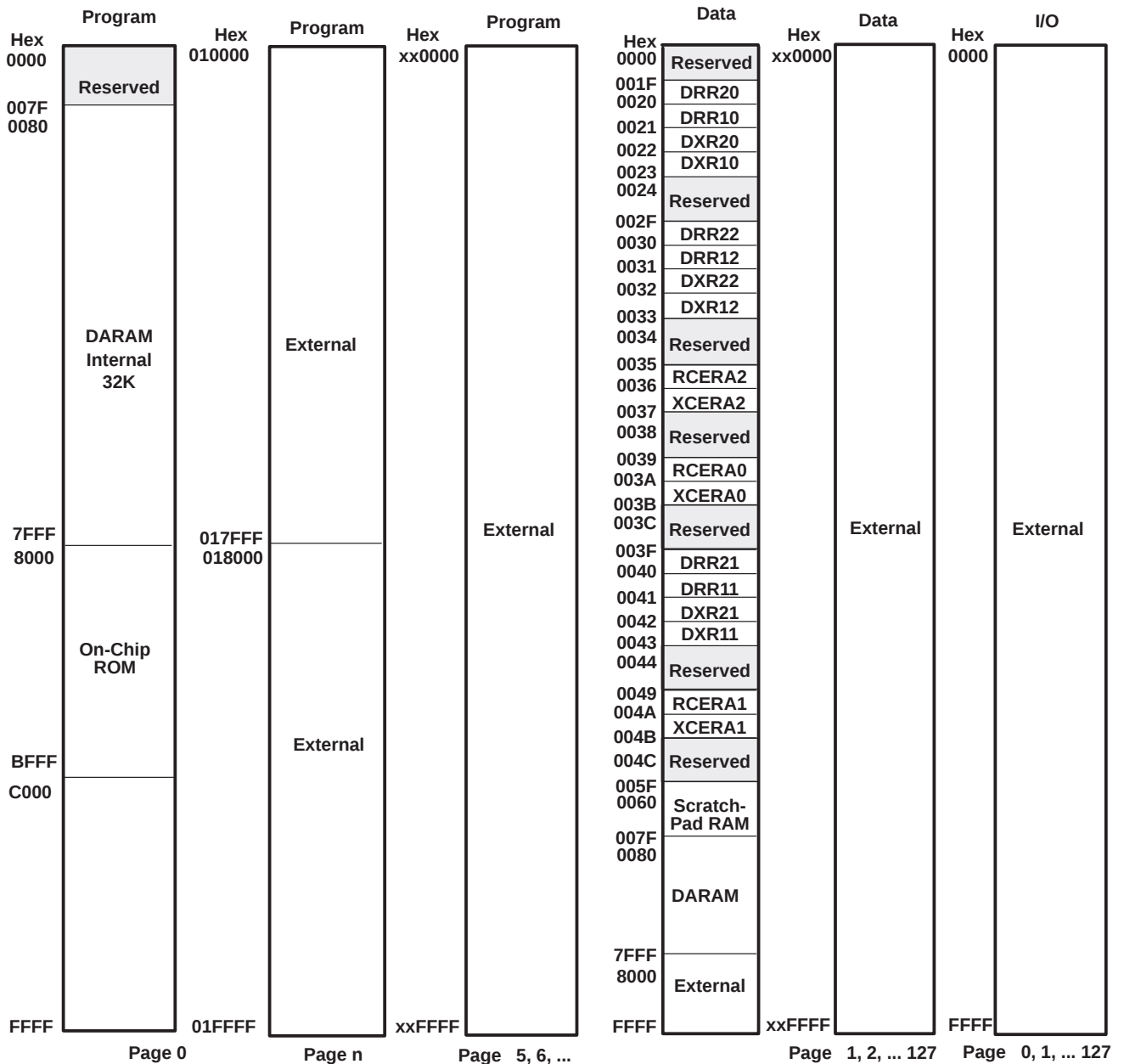
- When DLAXS is set to 0 (default), the DMA does not perform an external access for the destination. When DLAXS is set to 1, the DMA performs an external access to the destination location.
- When SLAXS is set to 0 (default), the DMA does not perform an external access for the source. When DLAXS is set to 1, the DMA performs an external access from the source location.

Two new registers are added to the 5409 DMA to support DMA accesses to/from DMA extended data memory, page 1 to page 127.

- The DMA extended source data page register (XSRCDP[6:0]) is located at subbank address 028h.
- The DMA extended destination data page register (XDSTDP[6:0]) is located at subbank address 029h.

DMA memory map

The DMA memory map, as shown in Figure 10, allows DMA transfers to be unaffected by the status of the MP/MC, DROM, and OVLY bits.



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NOTE A: n = 1, 2, 3, or 4

Figure 10. TMS320UC5409 DMA Memory Map

DMA priority level

Each DMA channel can be independently assigned high priority or low priority relative to each other. Multiple DMA channels that are assigned to the same priority level are handled in a round-robin manner.

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DMA source/destination address modification

The DMA provides flexible address-indexing modes for easy implementation of data management schemes such as autobuffering and circular buffers. Source and destination addresses can be indexed separately and can be post-incremented, post-decremented, or post-incremented with a specified index offset.

DMA in autoinitialization mode

The DMA can automatically reinitialize itself after completion of a block transfer. Some of the DMA registers can be preloaded for the next block transfer through the DMA global reload registers (DMGSA, DMGDA, and DMGCR). Autoinitialization allows:

- Continuous operation: Normally, the CPU would have to reinitialize the DMA immediately after the completion of the current block transfer; but with the global reload registers, it can reinitialize these values for the next block transfer any time after the current block transfer begins.
- Repetitive operation: The CPU does not preload the global reload register with new values for each block transfer but only loads them on the first block transfer.

DMA transfer counting

The DMA channel element count register (DMCTR_x) and the frame count register (DMFRC_x) contain bit fields that represent the number of frames and the number of elements per frame to be transferred.

- Frame count. This 8-bit value defines the total number of frames in the block transfer. The maximum number of frames per block transfer is 128 (FRAME COUNT = 0ffh). The counter is decremented upon the last read transfer in a frame transfer. Once the last frame is transferred, the selected 8-bit counter is reloaded with the DMA global frame reload register (DMGFR) if the AUTOINIT bit is set to 1. A frame count of 0 (default value) means the block transfer contains a single frame.
- Element count. This 16-bit value defines the number of elements per frame. This counter is decremented after the read transfer of each element. The maximum number of elements per frame is 65536 (DMCTR_n = 0FFFFh). In autoinitialization mode, once the last frame is transferred, the counter is reloaded with the DMA global count reload register (DMGCR).

DMA transfers in double-word mode (Internal Only)

Double-word mode allows the DMA to transfer 32-bit words in any index mode. In double-word mode, two consecutive 16-bit transfers are initiated and the source and destination addresses are automatically updated following each transfer. In this mode, each 32-bit word is considered to be one element.

DMA channel index registers

The particular DMA channel index register is selected by way of the SIND and DIND field in the DMA mode control register (DMMCR_x). Unlike basic address adjustment, in conjunction with the frame index DMFRI0 and DMFRI1, the DMA allows different adjustment amounts depending on whether or not the element transfer is the last in the current frame. The normal adjustment value (element index) is contained in the element index registers DMIDX0 and DMIDX1. The adjustment value (frame index) for the end of the frame is determined by the selected DMA frame index register (either DMFRI0 or DMFRI1).

The element index and the frame index affect address adjustment as follows:

- Element index: For all except the last transfer in the frame, the element index determines the amount to be added to the DMA channel for the source/destination address register (DMSRC_x/DMDST_x) as selected by the SIND/DIND bits.
- Frame index: If the transfer is the last in a frame, the frame index is used for address adjustment as selected by the SIND/DIND bits. This occurs in both single-frame and multi-frame transfer.

DMA interrupts

The ability of the DMA to interrupt the CPU based on the status of the data transfer is configurable and is determined by the IMOD and DINM bits in the DMA channel mode control register (DMMCRn). The available modes are shown in Table 9.

Table 9. DMA Interrupts

MODE	DINM	IMOD	INTERRUPT
ABU (non-decrement)	1	0	At full buffer only
ABU (non-decrement)	1	1	At half buffer and full buffer
Multi-Frame	1	0	At block-transfer complete (DMCTRn = DMSEFCn[7:0] = 0)
Multi-Frame	1	1	At end of frame and end of block (DMCTRn = 0)
Either	0	X	No interrupt generated
Either	0	X	No interrupt generated

DMA controller synchronization events

The transfers associated with each DMA channel can be synchronized to one of several events. The DSYN bit field of the DMSEFCn register selects the synchronization event for a channel. The list of possible events and the DSYN values are shown in Table 10.

Table 10. DMA Synchronization Events

DSYN VALUE	DMA SYNCHRONIZATION EVENT
0000b	No synchronization used
0001b	McBSP0 receive event
0010b	McBSP0 transmit event
0011b	McBSP2 receive event
0100b	McBSP2 transmit event
0101b	McBSP1 receive event
0110b	McBSP1 transmit event
0111b	Reserved
1000b	Reserved
1001b	Reserved
1010b	Reserved
1011b	Reserved
1100b	Reserved
1101b	Timer interrupt event
1110b	External interrupt 3
1111b	Reserved

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DMA channel interrupt selection

The DMA controller can generate a CPU interrupt for each of the six channels. However, due to a limit on the number of internal CPU interrupt inputs, channels 0, 1, 2, and 3 are multiplexed with other interrupt sources. DMA channels 0, 1, 2, and 3 share an interrupt line with the receive and transmit portions of the McBSP. When the UC5409 is reset, the interrupts from these three DMA channels are deselected. The INTSEL bit field in the DMPREC register can be used to select these interrupts, as shown in Table 11.

Table 11. DMA Channel Interrupt Selection

INTSEL Value	IMR/IFR[6]	IMR/IFR[7]	IMR/IFR[10]	IMR/IFR[11]
00b (reset)	BRINT2	BXINT2	BRINT1	BXINT1
01b	BRINT2	BXINT2	DMAC2	DMAC3
10b	DMAC0	DMAC1	DMAC2	DMAC3
11b	Reserved			

memory-mapped registers

The UC5409 has 27 memory-mapped CPU registers, which are mapped in data memory space addresses 0h to 1Fh. The device also has a set of memory-mapped registers associated with peripherals. Table 12 gives a list of CPU memory-mapped registers (MMRs) available on UC5409. Table 13 shows additional peripheral MMRs associated with the UC5409.

Table 12. CPU Memory-Mapped Registers

NAME	ADDRESS		DESCRIPTION
	DEC	HEX	
IMR	0	0	Interrupt mask register
IFR	1	1	Interrupt flag register
–	2–5	2–5	Reserved for testing
ST0	6	6	Status register 0
ST1	7	7	Status register 1
AL	8	8	Accumulator A low word (15–0)
AH	9	9	Accumulator A high word (31–16)
AG	10	A	Accumulator A guard bits (39–32)
BL	11	B	Accumulator B low word (15–0)
BH	12	C	Accumulator B high word (31–16)
BG	13	D	Accumulator B guard bits (39–32)
TREG	14	E	Temporary register
TRN	15	F	Transition register
AR0	16	10	Auxiliary register 0
AR1	17	11	Auxiliary register 1
AR2	18	12	Auxiliary register 2
AR3	19	13	Auxiliary register 3
AR4	20	14	Auxiliary register 4
AR5	21	15	Auxiliary register 5
AR6	22	16	Auxiliary register 6
AR7	23	17	Auxiliary register 7
SP	24	18	Stack pointer register
BK	25	19	Circular buffer size register
BRC	26	1A	Block repeat counter
RSA	27	1B	Block repeat start address
REA	28	1C	Block repeat end address
PMST	29	1D	Processor mode status (PMST) register
XPC	30	1E	Extended program page register
–	31	1F	Reserved

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memory-mapped registers (continued)

Table 13. Peripheral Memory-Mapped Registers

NAME	ADDRESS	DESCRIPTION	TYPE
DDR20	20h	Data receive register 2	McBSP #0
DDR10	21h	Data receive register 1	McBSP #0
DXR20	22h	Data transmit register 2	McBSP #0
DXR10	23h	Data transmit register 1	McBSP #0
TIM	24h	Timer register	Timer
PRD	25h	Timer period counter	Timer
TCR	26h	Timer control register	Timer
–	27h	Reserved	
SWWSR	28h	Software wait-state register	External Bus
BSCR	29h	Bank-switching control register	External Bus
–	2Ah	Reserved	
SWCR	2Bh	Software wait-state control register	External Bus
HPIC	2Ch	HPI control register	HPI
–	2Dh–2Fh	Reserved	
DDR22	30h	Data receive register 2	McBSP #2
DDR12	31h	Data receive register 1	McBSP #2
DXR22	32h	Data transmit register 2	McBSP #2
DXR12	33h	Data transmit register 2	McBSP #2
SPSA2	34h	McBSP2 subbank address register	McBSP #2
SPSD2	35h	McBSP2 subbank data register	McBSP #2
–	36–37h	Reserved	
SPSA0	38h	McBSP0 subbank address register	McBSP #0
SPCD0	39h	McBSP0 subbank data register	McBSP #0
–	3Ah–3Bh	Reserved	
GPIOCR	3C	General-purpose I/O pins control register	GPIO
GPIOSR	3D	General-purpose I/O pins status register	GPIO
–	3E–3F	Reserved	
DDR21	40h	Data receive register 1	McBSP #1
DDR11	41h	Data receive register 2	McBSP #1
DXR21	42h	Data transmit register 1	McBSP #1
DXR11	43h	Data transmit register 2	McBSP #1
–	44h–47h	Reserved	
SPSA1	48h	McBSP1 subbank address register	McBSP #1
SPCD1	49h	McBSP1 subbank data register	McBSP #1
–	4Ah–53h	Reserved	
DMPREC	54h	DMA channel priority and enable control register	DMA
DMSA	55h	DMA subbank address register	DMA
DMSDI	56h	DMA subbank data register with autoincrement	DMA
DMSDN	57h	DMA subbank data register	DMA
CLKMD	58h	Clock mode register	PLL
–	59h–5Fh	Reserved	

McBSP control registers and subaddresses

The control registers for the multichannel buffered serial port (McBSP) are accessed using the subbank addressing scheme. This allows a set or subbank of registers to be accessed through a single memory location. The serial port subbank address (SPSA) register is used as a pointer to select a particular register within the subbank. The serial port subbank data (SPSD) register is used to access (read or write) the selected register. Table 14 shows the McBSP control registers and their corresponding subaddresses.

Table 14. McBSP Control Registers and Subaddresses

McBSP0		McBSP1		SUB ADDRESS	DESCRIPTION
NAME	ADDRESS	NAME	ADDRESS		
SPCR10	39h	SPCR11	49h	00h	Serial port control register 1
SPCR20	39h	SPCR21	49h	01h	Serial port control register 2
RCR10	39h	RCR11	49h	02h	Receive control register 1
RCR20	39h	RCR21	49h	03h	Receive control register 2
XCR10	39h	XCR11	49h	04h	Transmit control register 1
XCR20	39h	XCR21	49h	05h	Transmit control register 2
SRGR10	39h	SRGR11	49h	06h	Sample rate generator register 1
SRGR20	39h	SRGR21	49h	07h	Sample rate generator register 2
MCR10	39h	MCR11	49h	08h	Multichannel register 1
MCR20	39h	MCR21	49h	09h	Multichannel register 2
RCERA0	39h	RCERA1	49h	0Ah	Receive channel enable register partition A
RCERB0	39h	RCERB1	49h	0Bh	Receive channel enable register partition B
XCERA0	39h	XCERA1	49h	0Ch	Transmit channel enable register partition A
XCERB0	39h	XCERB1	49h	0Dh	Transmit channel enable register partition B
PCR0	39h	PCR1	49h	0Eh	Pin control register

DMA subbank addressed registers

The direct memory access (DMA) controller has several control registers associated with it. The main control register (DMPREC) is a standard memory mapped register. However, the other registers are accessed using the subbank addressing scheme. This allows a set, or subbank of registers to be accessed through a single memory location. The DMA subbank address (DMSA) register is used as a pointer to select a particular register within the subbank, while the DMA subbank data (DMSDN) register or the DMA subbank data register with autoincrement (DMSDI) is used to access (read or write) the selected register.

When the DMSDI register is used to access the subbank, the subbank address is automatically postincremented so that a subsequent access affects the next register within the subbank. This autoincrement feature is intended for efficient, successive accesses to several control registers. If the autoincrement feature is not required, the DMSDN register should be used to access the subbank. Table 15 shows the DMA controller subbank addressed registers and their corresponding subaddresses.

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DMA subbank addressed registers (continued)

Table 15. DMA Subbank Addressed Registers

DMA		SUB ADDRESS	DESCRIPTION
NAME	ADDRESS		
DMSRC0	56h/57h	00h	DMA channel 0 source address register
DMDST0	56h/57h	01h	DMA channel 0 destination address register
DMCTR0	56h/57h	02h	DMA channel 0 element count register
DMSFC0	56h/57h	03h	DMA channel 0 sync select and frame count register
DMMCR0	56h/57h	04h	DMA channel 0 transfer mode control register
DMSRC1	56h/57h	05h	DMA channel 1 source address register
DMDST1	56h/57h	06h	DMA channel 1 destination address register
DMCTR1	56h/57h	07h	DMA channel 1 element count register
DMSFC1	56h/57h	08h	DMA channel 1 sync select and frame count register
DMMCR1	56h/57h	09h	DMA channel 1 transfer mode control register
DMSRC2	56h/57h	0Ah	DMA channel 2 source address register
DMDST2	56h/57h	0Bh	DMA channel 2 destination address register
DMCTR2	56h/57h	0Ch	DMA channel 2 element count register
DMSFC2	56h/57h	0Dh	DMA channel 2 sync select and frame count register
DMMCR2	56h/57h	0Eh	DMA channel 2 transfer mode control register
DMSRC3	56h/57h	0Fh	DMA channel 3 source address register
DMDST3	56h/57h	10h	DMA channel 3 destination address register
DMCTR3	56h/57h	11h	DMA channel 3 element count register
DMSFC3	56h/57h	12h	DMA channel 3 sync select and frame count register
DMMCR3	56h/57h	13h	DMA channel 3 transfer mode control register
DMSRC4	56h/57h	14h	DMA channel 4 source address register
DMDST4	56h/57h	15h	DMA channel 4 destination address register
DMCTR4	56h/57h	16h	DMA channel 4 element count register
DMSFC4	56h/57h	17h	DMA channel 4 sync select and frame count register
DMMCR4	56h/57h	18h	DMA channel 4 transfer mode control register
DMSRC5	56h/57h	19h	DMA channel 5 source address register
DMDST5	56h/57h	1Ah	DMA channel 5 destination address register
DMCTR5	56h/57h	1Bh	DMA channel 5 element count register
DMSFC5	56h/57h	1Ch	DMA channel 5 sync select and frame count register
DMMCR5	56h/57h	1Dh	DMA channel 5 transfer mode control register
DMSRCP	56h/57h	1Eh	DMA source program page address (common channel)
DMDSTP	56h/57h	1Fh	DMA destination program page address (common channel)
DMIDX0	56h/57h	20h	DMA element index address register 0
DMIDX1	56h/57h	21h	DMA element index address register 1
DMFRI0	56h/57h	22h	DMA frame index register 0
DMFRI1	56h/57h	23h	DMA frame index register 1
DMGSA	56h/57h	24h	DMA global source address reload register
DMGDA	56h/57h	25h	DMA global destination address reload register
DMGCR	56h/57h	26h	DMA global count reload register
DMGFR	56h/57h	27h	DMA global frame count reload register

interrupts

Vector-relative locations and priorities for all internal and external interrupts are shown in Table 16.

Table 16. Interrupt Locations and Priorities

NAME	LOCATION		PRIORITY	FUNCTION
	DECIMAL	HEX		
$\overline{RS}$, SINTR	0	00	1	Reset (hardware and software reset)
$\overline{NMI}$, SINT16	4	04	2	Nonmaskable interrupt
SINT17	8	08	—	Software interrupt #17
SINT18	12	0C	—	Software interrupt #18
SINT19	16	10	—	Software interrupt #19
SINT20	20	14	—	Software interrupt #20
SINT21	24	18	—	Software interrupt #21
SINT22	28	1C	—	Software interrupt #22
SINT23	32	20	—	Software interrupt #23
SINT24	36	24	—	Software interrupt #24
SINT25	40	28	—	Software interrupt #25
SINT26	44	2C	—	Software interrupt #26
SINT27	48	30	—	Software interrupt #27
SINT28	52	34	—	Software interrupt #28
SINT29	56	38	—	Software interrupt #29
SINT30	60	3C	—	Software interrupt #30
$\overline{INT0}$, SINT0	64	40	3	External user interrupt #0
$\overline{INT1}$, SINT1	68	44	4	External user interrupt #1
$\overline{INT2}$, SINT2	72	48	5	External user interrupt #2
TINT, SINT3	76	4C	6	Timer interrupt
BRINT0, SINT4	80	50	7	McBSP #0 receive interrupt (default)
BXINT0, SINT5	84	54	8	McBSP #0 transmit interrupt (default)
BRINT2, SINT7, DMAC0	88	58	9	McBSP #2 receive interrupt (default)
BXINT2, SINT6, DMAC1	92	5C	10	McBSP #2 transmit interrupt (default)
$\overline{INT3}$, SINT8	96	60	11	External user interrupt #3
HINT, SINT9	100	64	12	HPI interrupt
BRINT1, SINT10, DMAC2	104	68	13	McBSP #1 receive interrupt (default)
BXINT1, SINT11, DMAC3	108	6C	14	McBSP #1 transmit interrupt (default)
DMAC4,SINT12	112	70	15	DMA channel 4 interrupt (default)
DMAC5,SINT13	116	74	16	DMA channel 5 interrupt (default)
Reserved	120–127	78–7F	—	Reserved

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interrupts (continued)

The bits of the interrupt flag register (IFR) and interrupt mask register (IMR) are arranged as shown in Figure 11. The function of each bit is described in Table 17.

15-14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RES	DMAC5	DMAC4	BXINT1 DMAC3	BRINT1 DMAC2	HINT	INT3	BXINT2 DMAC1	BRINT2 DMAC0	BXINT0	BRINT0	TINT	INT2	INT1	INT0

Figure 11. IFR and IMR Registers

Table 17. IFR and IMR Register Bit Fields

BIT		FUNCTION
NUMBER	NAME	
15-14	–	Reserved for future expansion
13	DMAC5	DMA channel 5 interrupt flag/mask bit
12	DMAC4	DMA channel 4 interrupt flag/mask bit
11	BXINT1/DMAC3	McBSP1 transmit interrupt flag/mask bit
10	BRINT1/DMAC2	McBSP1 receive interrupt flag/mask bit
9	HINT	Host to 54x interrupt flag/mask
8	INT3	External interrupt 3 flag/mask
7	BXINT2/DMAC1	McBSP2 transmit interrupt flag/mask bit
6	BRINT2/DMAC0	McBSP2 receive interrupt flag/mask bit
5	BXINT0	McBSP0 transmit interrupt flag/mask bit
4	BRINT0	McBSP0 receive interrupt flag/mask bit
3	TINT	Timer interrupt flag/mask bit
2	INT2	External interrupt 2 flag/mask bit
1	INT1	External interrupt 1 flag/mask bit
0	INT0	External interrupt 0 flag/mask bit

device and development-support tool nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all TMS320™ DSP devices and support tools. Each TMS320™ DSP commercial family member has one of three prefixes: TMX, TMP, or TMS. Texas Instruments recommends two of three possible prefix designators for 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:

TMS	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 with appropriate disclaimers describing their limitations and intended uses. Experimental devices (TMX) may not be representative of a final product and Texas Instruments reserves the right to change or discontinue these products without notice.

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.

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documentation support

Extensive documentation supports all TMS320 family generations of devices from product announcement through applications development. The following types of documentation are available to support the design and use of the C5000 family of DSPs:

- *TMS320C54x™ DSP Functional Overview* (literature number SPRU307)
- Device-specific data sheets (such as this document)
- Complete User Guides
- Development-support tools
- Hardware and software application reports

The four-volume *TMS320C54x DSP Reference Set* (literature number SPRU210) consists of:

- *Volume 1: CPU and Peripherals* (literature number SPRU131)
- *Volume 2: Mnemonic Instruction Set* (literature number SPRU172)
- *Volume 3: Algebraic Instruction Set* (literature number SPRU179)
- *Volume 4: Applications Guide* (literature number SPRU173)

The reference set describes in detail the TMS320C54x products currently available, and the hardware and software applications, including algorithms, for fixed-point TMS320 devices.

A series of DSP textbooks is published by Prentice-Hall and John Wiley & Sons to support digital signal processing research and education. The TMS320 newsletter, *Details on Signal Processing*, is published quarterly and distributed to update TMS320 customers on product information.

Information regarding TI DSP products is also available on the Worldwide Web at <http://www.ti.com> uniform resource locator (URL).

absolute maximum ratings over specified temperature range (unless otherwise noted)[†]

Supply voltage I/O range, $DV_{DD}^{\ddagger}$	–0.3 V to 4.0 V
Supply voltage core range, $CV_{DD}^{\ddagger}$	–0.3 V to 2.0 V
Input voltage range, V_I	–0.3 V to 4.5 V
Output voltage range, V_O	–0.3 V to 4.5 V
Operating case temperature range, T_C	–40°C to 100°C
Storage temperature range, T_{Stg}	–55°C to 150°C

[†] 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.

[‡] All voltage values are with respect to V_{SS} .

recommended operating conditions

		MIN	NOM	MAX	UNIT
DV_{DD}	Device supply voltage, I/O	1.71		3.6	V
CV_{DD}	Device supply voltage, core	1.71	1.8	1.98	V
V_{SS}	Supply voltage, GND		0		V
V_{IH}	High-level input voltage, I/O	RS, $\overline{INTn}$, $\overline{NMI}$, X2/CLKIN, $\overline{BIO}$, BCLKR0, BCLKR1, BCLKX0, BCLKX1, $\overline{HCS}$, $\overline{HDS1}$, $\overline{HDS2}$, TCK, CLKMDn, $DV_{DD} = 3.3 \pm 0.3$ V		$DV_{DD} + 0.3$	V
		All other inputs		$DV_{DD} + 0.3$	
V_{IL}	Low-level input voltage	RS, $\overline{INTn}$, $\overline{NMI}$, X2/CLKIN, $\overline{BIO}$, BCLKR0, BCLKR1, BCLKX0, BCLKX1, $\overline{HCS}$, $\overline{HDS1}$, $\overline{HDS2}$, TCK, CLKMDn, $DV_{DD} = 3.3 \pm 0.3$ V		0.6	V
		All other inputs		0.8	
I_{OH}	High-level output current			–300	μA
I_{OL}	Low-level output current			1.5	mA
T_C	Operating case temperature	–40		100	°C

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electrical characteristics over recommended operating case temperature range (unless otherwise noted)

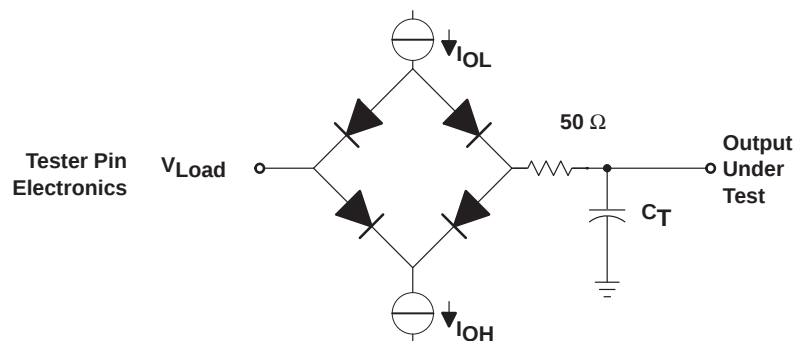
PARAMETER		TEST CONDITIONS		MIN	TYP [†]	MAX	UNIT
V _{OH}	High-level output voltage	I _{OH} = MAX		DV _{DD} – 0.3			V
V _{OL}	Low-level output voltage	DV _{DD} = 1.71 to 1.89 V	I _{OL} = MAX			0.4	V
			CLKOUT				
		DV _{DD} = 1.9 to 3.6 V	I _{OL} = MAX			0.35	
I _{Iz}	Input current for outputs in high impedance	D[15:0], HD[7:0]	Bus holders enabled, DV _{DD} = MAX, V _I = V _{SS} to DV _{DD}			–175	μA
		All other inputs	DV _{DD} = MAX, V _O = V _{SS} to DV _{DD}			–5	
I _I	Input current	X2/CLKIN				–40	μA
		TRST	With internal pulldown			–5	
		HPIENA	With internal pulldown			–5	
		TMS, TCK, TDI, HPI [‡]	With internal pullups, HPIENA = 0			–300	
		All other input-only pins				–5	
I _{DDC}	Supply current, core CPU	CV _{DD} = 1.8 V, f _{clock} = 80 MHz, [§] T _C = 25°C				30	mA
I _{DDP}	Supply current, pins	DV _{DD} = 3.3 V, f _{clock} = 80 MHz, [§] T _C = 25°C				36	mA
I _{DD}	Supply current, standby	IDLE2	PLL × 1 mode, 40 MHz input			5	mA
		IDLE3	Divide-by-two mode, CLKIN stopped			5	μA
C _i	Input capacitance					5	pF
C _o	Output capacitance					5	pF

[†] All values are typical unless otherwise specified.

[‡] HPI input signals except for HPIENA.

[§] Clock mode: PLL × 1 with external source

PARAMETER MEASUREMENT INFORMATION



Where: I_{OL} = 1.5 mA (all outputs)
I_{OH} = 300 μA (all outputs)
V_{Load} = 1.5 V
C_T = 40 pF typical load circuit capacitance

Figure 12. 3.3-V Test Load Circuit

internal oscillator with external crystal

The internal oscillator is enabled by connecting a crystal across X1 and X2/CLKIN. The frequency of CLKOUT is a multiple of the oscillator frequency. The multiply ratio is determined by the bit settings in the CLKMD register. The crystal should be in fundamental-mode operation, and parallel resonant, with an effective series resistance of 30 Ω and power dissipation of 1 mW. The circuit shown in Figure 13 represents fundamental-mode operation.

recommended operating conditions of internal oscillator with external crystal (see Figure 13)

	MIN	NOM	MAX	UNIT
f_{clock} Input clock frequency	10		20	MHz
C1, C2		10		pF

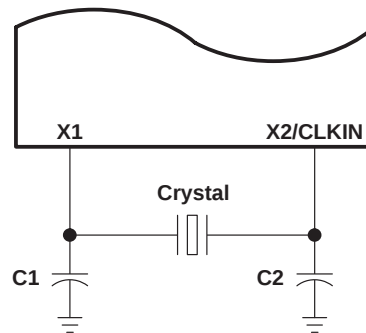


Figure 13. Internal Oscillator With External Crystal

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divide-by-two clock option

The frequency of the external reference clock provided at the X2/CLKIN pin can be divided by a factor of two to generate the internal machine cycle. The selection of the clock mode is described in the clock generator section.

The external frequency injected must conform to specifications listed in the timing requirements table.

switching characteristics over recommended operating conditions [$H = 0.5t_{c(CO)}$][†] (see Figure 13, Figure 14, and the recommended operating conditions table)

PARAMETER	MIN	TYP	MAX	UNIT
$t_{c(CO)}$ Cycle time, CLKOUT	10 [‡]	$2t_{c(CI)}$	†	ns
$t_{d(CIH-CO)}$ Delay time, X2/CLKIN high to CLKOUT high/low	3	6	10	ns
$t_f(CO)$ Fall time, CLKOUT		2		ns
$t_r(CO)$ Rise time, CLKOUT		2		ns
$t_w(COL)$ Pulse duration, CLKOUT low	H-2	H-1	H	ns
$t_w(COH)$ Pulse duration, CLKOUT high	H-2	H-1	H	ns

[†] This device utilizes a fully static design and therefore can operate with $t_{c(CI)}$ approaching ∞ . The device is characterized at frequencies approaching 0 Hz.

[‡] It is recommended that the PLL clocking option be used for maximum frequency operation.

timing requirements (see Figure 14)

	MIN	MAX	UNIT
$t_{c(CI)}$ Cycle time, X2/CLKIN	5	†	ns
$t_f(CI)$ Fall time, X2/CLKIN		1	ns
$t_r(CI)$ Rise time, X2/CLKIN		1	ns

[†] This device utilizes a fully static design and therefore can operate with $t_{c(CI)}$ approaching ∞ . The device is characterized at frequencies approaching 0 Hz.

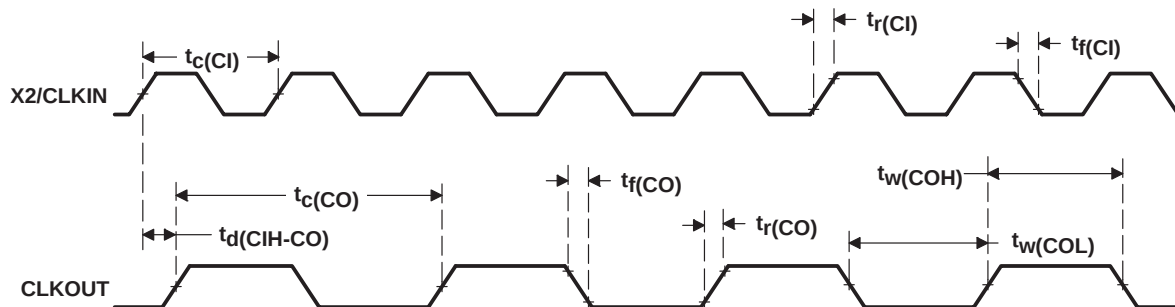


Figure 14. External Divide-by-Two Clock Timing

multiply-by-N clock option

The frequency of the external reference clock provided at the X2/CLKIN pin can be multiplied by a factor of N to generate the internal machine cycle. The selection of the clock mode and the value of N is described in the clock generator section.

The external frequency injected must conform to specifications listed in the timing requirements table.

switching characteristics over recommended operating conditions [$H = 0.5t_{c(CO)}$] (see Figure 13 and Figure 15)

PARAMETER		MIN	TYP	MAX	UNIT
$t_{c(CO)}$	Cycle time, CLKOUT	10	$t_{c(CI)}/N^{\dagger}$		ns
$t_{d(CI-CO)}$	Delay time, X2/CLKIN high/low to CLKOUT high/low	4	10	16	ns
$t_f(CO)$	Fall time, CLKOUT		2		ns
$t_r(CO)$	Rise time, CLKOUT		2		ns
$t_w(COL)$	Pulse duration, CLKOUT low	H-2	H-1	H	ns
$t_w(COH)$	Pulse duration, CLKOUT high	H-2	H-1	H	ns
t_p	Transitory phase, PLL lock up time			–	μs

$\dagger$ N = Multiplication factor

timing requirements (see Figure 15) †

		MIN	MAX	UNIT
t _{c(CI)}	Cycle time, X2/CLKIN	Integer PLL multiplier N (N = 1–15)	10N 200N	ns
		PLL multiplier N = x.5	10N 200N	
		PLL multiplier N = x.25, x.75	10N 100N	
t _{f(CI)}	Fall time, X2/CLKIN	8		ns
t _{r(CI)}	Rise time, X2/CLKIN	8		ns

$\dagger$ N = Multiplication factor

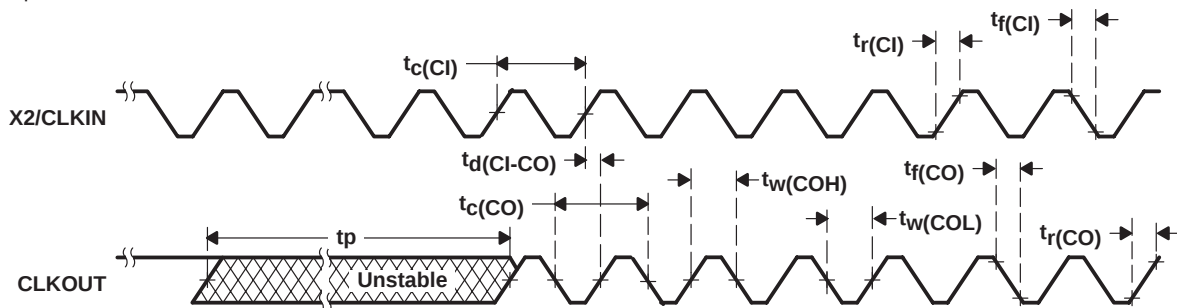


Figure 15. External Multiply-by-One Clock Timing

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memory and parallel I/O interface timing

switching characteristics over recommended operating conditions for a *memory read* ($\overline{MSTRB} = 0$)[†] (see Figure 16)

PARAMETER		MIN	MAX	UNIT
$t_d(\text{CLKL-A})$	Delay time, CLKOUT low to address valid [‡]	0	3	ns
$t_d(\text{CLKH-A})$	Delay time, CLKOUT high (transition) to address valid [§]	0	3	ns
$t_d(\text{CLKL-MSL})$	Delay time, CLKOUT low to $\overline{MSTRB}$ low	0	3	ns
$t_d(\text{CLKL-MSH})$	Delay time, CLKOUT low to $\overline{MSTRB}$ high	0	3	ns
$t_h(\text{CLKL-A})_R$	Hold time, address valid after CLKOUT low [‡]	0	3	ns
$t_h(\text{CLKH-A})_R$	Hold time, address valid after CLKOUT high [§]	0	3	ns

[†] Address, $\overline{PS}$, and $\overline{DS}$ timings are all included in timings referenced as address.

[‡] In the case of a memory read preceded by a memory read

[§] In the case of a memory read preceded by a memory write

timing requirements for a *memory read* ($\overline{MSTRB} = 0$) [$H = 0.5 t_{c(CO)}$][†] (see Figure 16)

		MIN	MAX	UNIT
$t_a(A)_M$	Access time, read data access from address valid		2H-10	ns
$t_a(MSTRBL)$	Access time, read data access from $\overline{MSTRB}$ low		2H-10	ns
$t_{su}(D)_R$	Setup time, read data before CLKOUT low	4		ns
$t_h(D)_R$	Hold time, read data after CLKOUT low	0		ns
$t_h(A-D)_R$	Hold time, read data after address invalid	0		ns
$t_h(D)\overline{MSTRB}H$	Hold time, read data after $\overline{MSTRB}$ high	0		ns

[†] Address, $\overline{PS}$, and $\overline{DS}$ timings are all included in timings referenced as address.

memory and parallel I/O interface timing (continued)

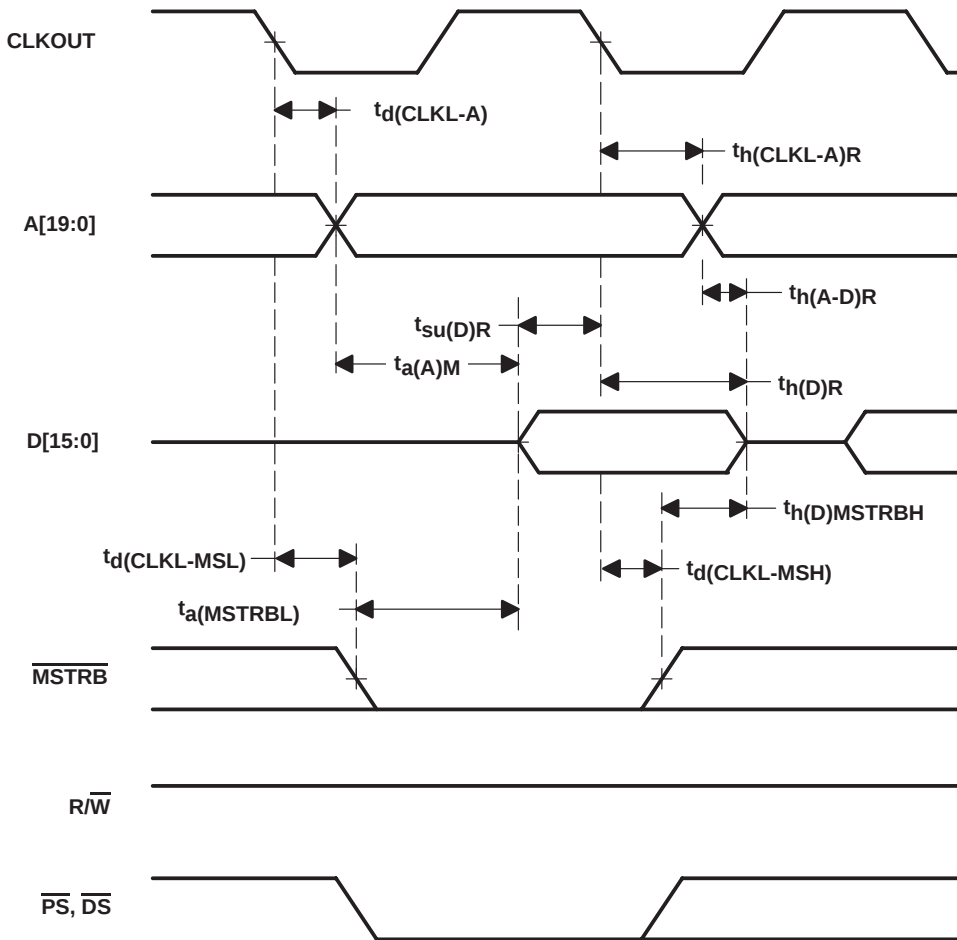


Figure 16. Memory Read ($\overline{\text{MSTRB}} = 0$)

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memory and parallel I/O interface timing (continued)

switching characteristics over recommended operating conditions for a *memory write* ($\overline{\text{MSTRB}} = 0$) [$H = 0.5 t_{c(CO)}$][†] (see Figure 17)

PARAMETER		MIN	MAX	UNIT
$t_d(\text{CLKH-A})$	Delay time, CLKOUT high to address valid [‡]	0	3	ns
$t_d(\text{CLKL-A})$	Delay time, CLKOUT low to address valid [§]	0	3	ns
$t_d(\text{CLKL-MSL})$	Delay time, CLKOUT low to $\overline{\text{MSTRB}}$ low	0	3	ns
$t_d(\text{CLKL-D})_W$	Delay time, CLKOUT low to data valid	0	5	ns
$t_d(\text{CLKL-MSH})$	Delay time, CLKOUT low to $\overline{\text{MSTRB}}$ high	-2	3	ns
$t_d(\text{CLKH-RWL})$	Delay time, CLKOUT high to $\overline{\text{R/W}}$ low	-2	3	ns
$t_d(\text{CLKH-RWH})$	Delay time, CLKOUT high to $\overline{\text{R/W}}$ high	-2	3	ns
$t_d(\text{RWL-MSTRBL})$	Delay time, $\overline{\text{R/W}}$ low to $\overline{\text{MSTRB}}$ low	H-2	H+2	ns
$t_h(\text{A})_W$	Hold time, address valid after CLKOUT high [‡]	0	3	ns
$t_h(\text{D})_{\text{MSH}}$	Hold time, write data valid after $\overline{\text{MSTRB}}$ high	H-3	H+3 [§]	ns
$t_w(\text{SL})_{\text{MS}}$	Pulse duration, $\overline{\text{MSTRB}}$ low	2H-4		ns
$t_{su}(\text{A})_W$	Setup time, address valid before $\overline{\text{MSTRB}}$ low	2H-4		ns
$t_{su}(\text{D})_{\text{MSH}}$	Setup time, write data valid before $\overline{\text{MSTRB}}$ high	2H-5	2H+5 [§]	ns
$t_{en}(\text{D-RWL})$	Enable time, data bus driven after $\overline{\text{R/W}}$ low	H-5		ns
$t_{dis}(\text{RWH-D})$	Disable time, $\overline{\text{R/W}}$ high to data bus high impedance		0	ns

[†] Address, $\overline{\text{PS}}$, and $\overline{\text{DS}}$ timings are all included in timings referenced as address.

[‡] In the case of a memory write preceded by a memory write

[§] In the case of a memory write preceded by an I/O cycle

memory and parallel I/O interface timing (continued)

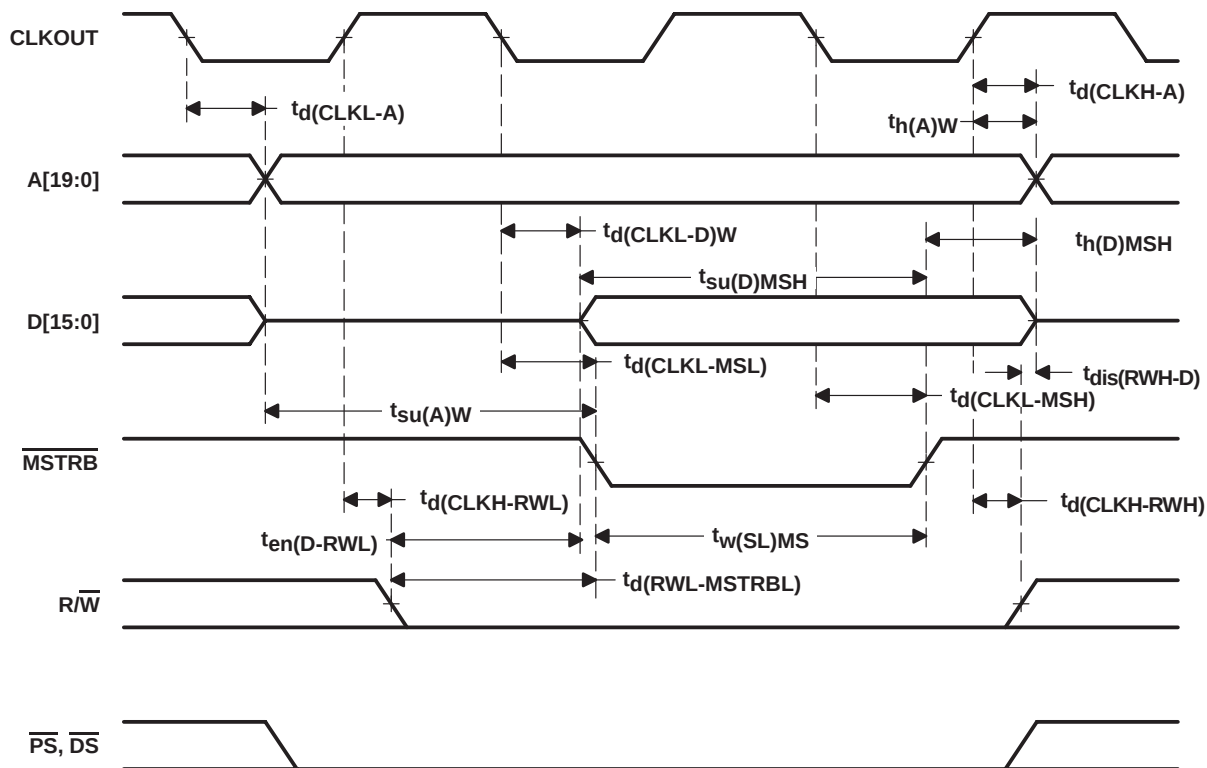


Figure 17. Memory Write ($\overline{\text{MSTRB}} = 0$)

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memory and parallel I/O interface timing (continued)

switching characteristics over recommended operating conditions for a *parallel I/O port read* ($\overline{\text{IOSTRB}} = 0$)[†] (see Figure 18)

PARAMETER	MIN	MAX	UNIT
$t_d(\text{CLKL-A})$ Delay time, CLKOUT low to address valid	0	3	ns
$t_d(\text{CLKH-ISTRBL})$ Delay time, CLKOUT high to $\overline{\text{IOSTRB}}$ low	0	3	ns
$t_d(\text{CLKH-ISTRBH})$ Delay time, CLKOUT high to $\overline{\text{IOSTRB}}$ high	0	3	ns
$t_h(\text{A})\text{IOR}$ Hold time, address after CLKOUT low	0	3	ns

[†] Address and $\overline{\text{IS}}$ timings are included in timings referenced as address.

timing requirements for a *parallel I/O port read* ($\overline{\text{IOSTRB}} = 0$) [$H = 0.5 t_{c(\text{CO})}$][†] (see Figure 18)

	MIN	MAX	UNIT
$t_a(\text{A})\text{IO}$ Access time, read data access from address valid		3H–10	ns
$t_a(\text{ISTRBL})\text{IO}$ Access time, read data access from $\overline{\text{IOSTRB}}$ low		2H–10	ns
$t_{su}(\text{D})\text{IOR}$ Setup time, read data before CLKOUT high	4		ns
$t_h(\text{D})\text{IOR}$ Hold time, read data after CLKOUT high	0		ns
$t_h(\text{ISTRBH-D})\text{R}$ Hold time, read data after $\overline{\text{IOSTRB}}$ high	0		ns

[†] Address and $\overline{\text{IS}}$ timings are included in timings referenced as address.

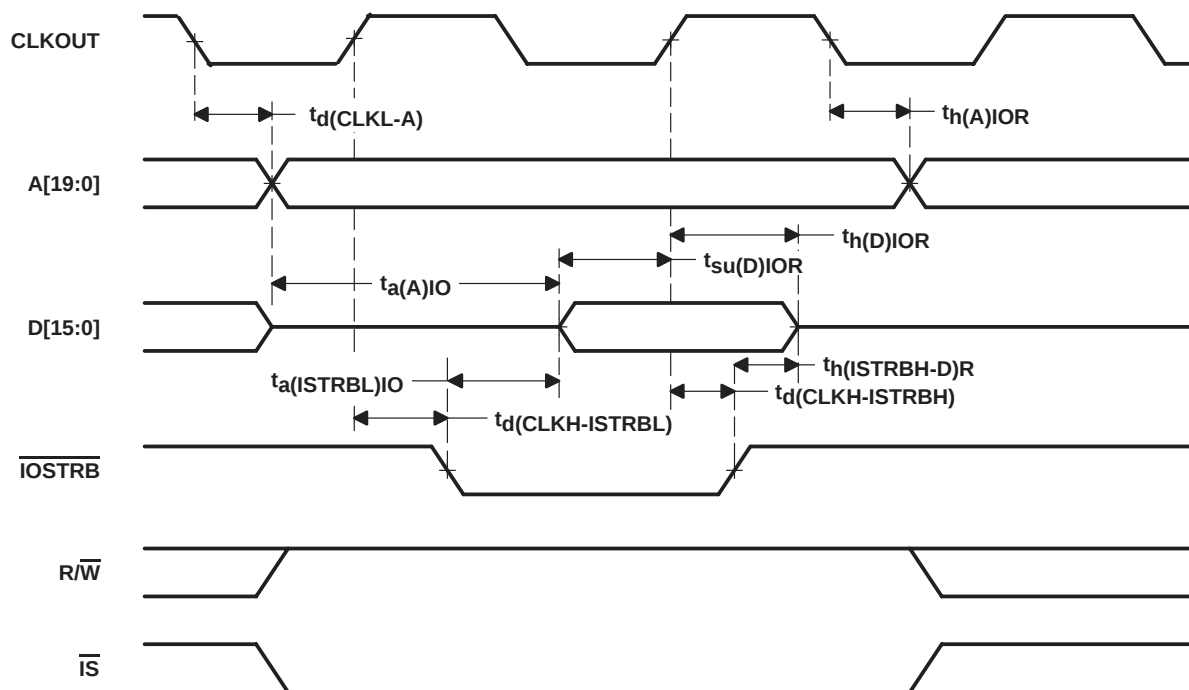


Figure 18. Parallel I/O Port Read ($\overline{\text{IOSTRB}} = 0$)

memory and parallel I/O interface timing (continued)

switching characteristics over recommended operating conditions for a *parallel I/O port write* ($\overline{\text{IOSTRB}} = 0$) [$H = 0.5 t_{c(CO)}$][†] (see Figure 19)

PARAMETER	MIN	MAX	UNIT
$t_d(\text{CLKL-A})$	0	3	ns
$t_d(\text{CLKH-ISTRBL})$	0	3	ns
$t_d(\text{CLKH-D})_{\text{IOW}}$	H-5	H+3	ns
$t_d(\text{CLKH-ISTRBH})$	0	3	ns
$t_d(\text{CLKL-RWL})$	0	3	ns
$t_d(\text{CLKL-RWH})$	0	3	ns
$t_h(\text{A})_{\text{IOW}}$	0	3	ns
$t_h(\text{D})_{\text{IOW}}$	H-3	H+3	ns
$t_{su}(\text{D})_{\text{IOSTRBH}}$	H-3	H+1	ns
$t_{su}(\text{A})_{\text{IOSTRBL}}$	H-3	H+3	ns

[†] Address and IS timings are included in timings referenced as address.

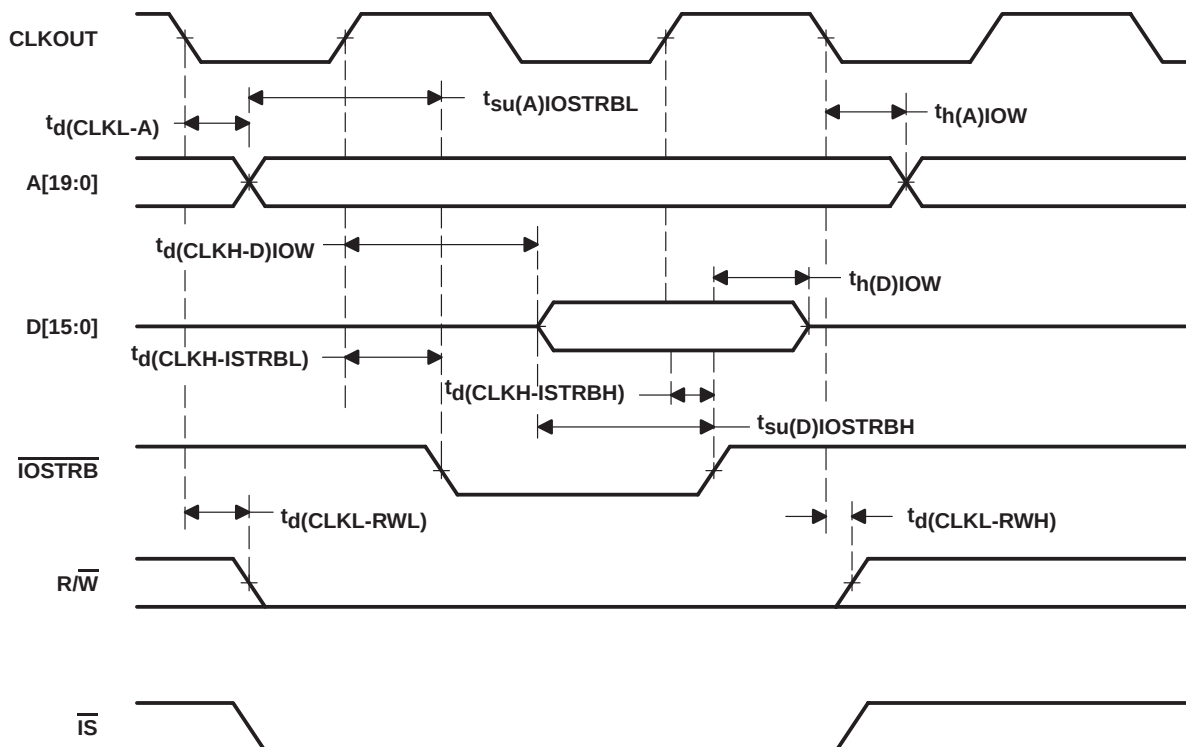


Figure 19. Parallel I/O Port Write ($\overline{\text{IOSTRB}} = 0$)

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ready timing for externally generated wait states

timing requirements for externally generated wait states [$H = 0.5 t_{c(CO)}$][†] (see Figure 20, Figure 21, Figure 22, and Figure 23)

		MIN	MAX	UNIT
$t_{su(RDY)}$	Setup time, READY before CLKOUT low	5		ns
$t_{h(RDY)}$	Hold time, READY after CLKOUT low	0		ns
$t_{v(RDY)MSTRB}$	Valid time, READY after $\overline{MSTRB}$ low [‡]		4H–8	ns
$t_{h(RDY)MSTRB}$	Hold time, READY after $\overline{MSTRB}$ low [‡]	4H		ns
$t_{v(RDY)IOSTRB}$	Valid time, READY after $\overline{IOSTRB}$ low [‡]		5H–8	ns
$t_{h(RDY)IOSTRB}$	Hold time, READY after $\overline{IOSTRB}$ low [‡]	5H		ns
$t_{v(MSCL)}$	Valid time, $\overline{MSC}$ low after CLKOUT low	0	3	ns
$t_{v(MSCH)}$	Valid time, $\overline{MSC}$ high after CLKOUT low	0	3	ns

[†] The hardware wait states can be used only in conjunction with the software wait states to extend the bus cycles. To generate wait states using READY, at least two software wait states must be programmed.

[‡] These timings are included for reference only. The critical timings for READY are those referenced to CLKOUT.

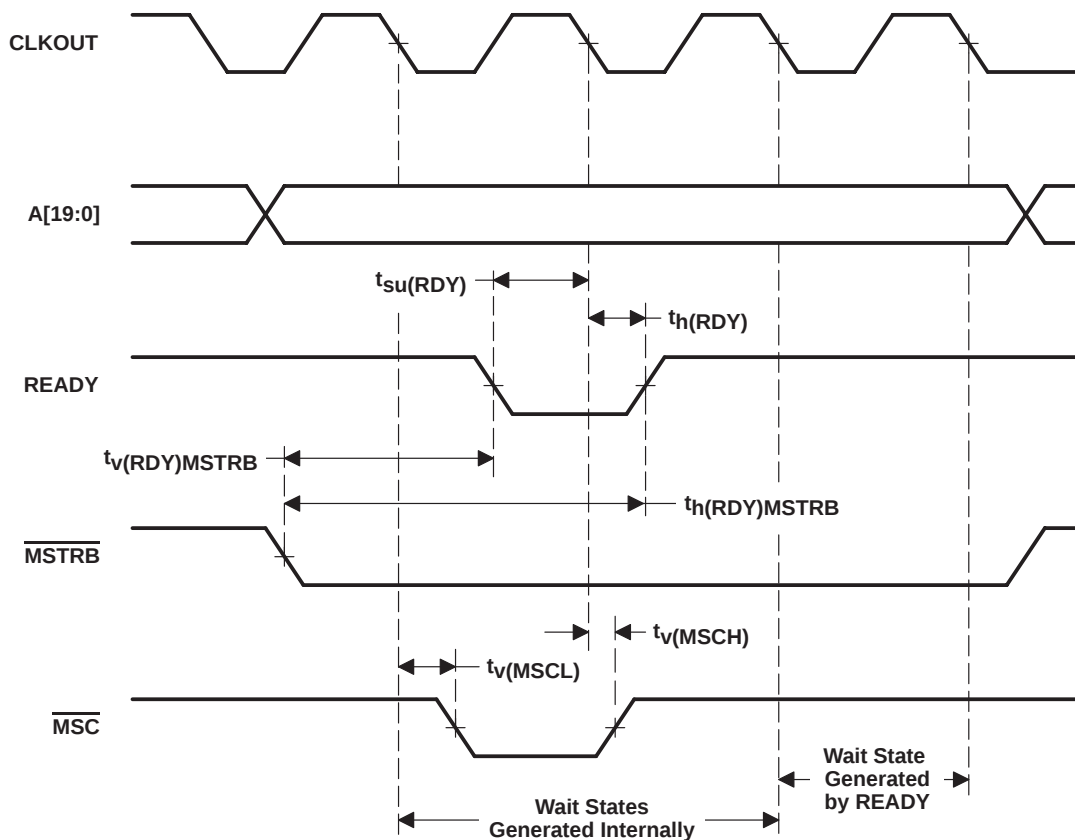


Figure 20. Memory Read With Externally Generated Wait States

ready timing for externally generated wait states (continued)

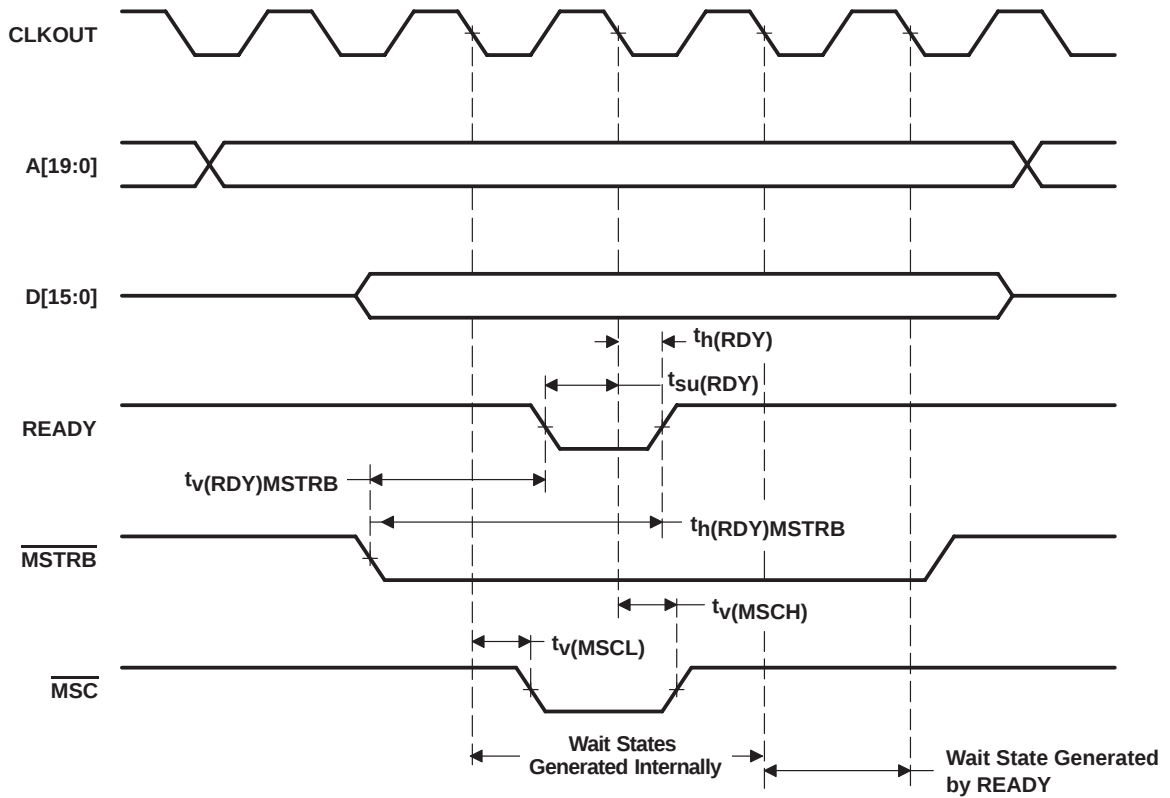


Figure 21. Memory Write With Externally Generated Wait States

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ready timing for externally generated wait states (continued)

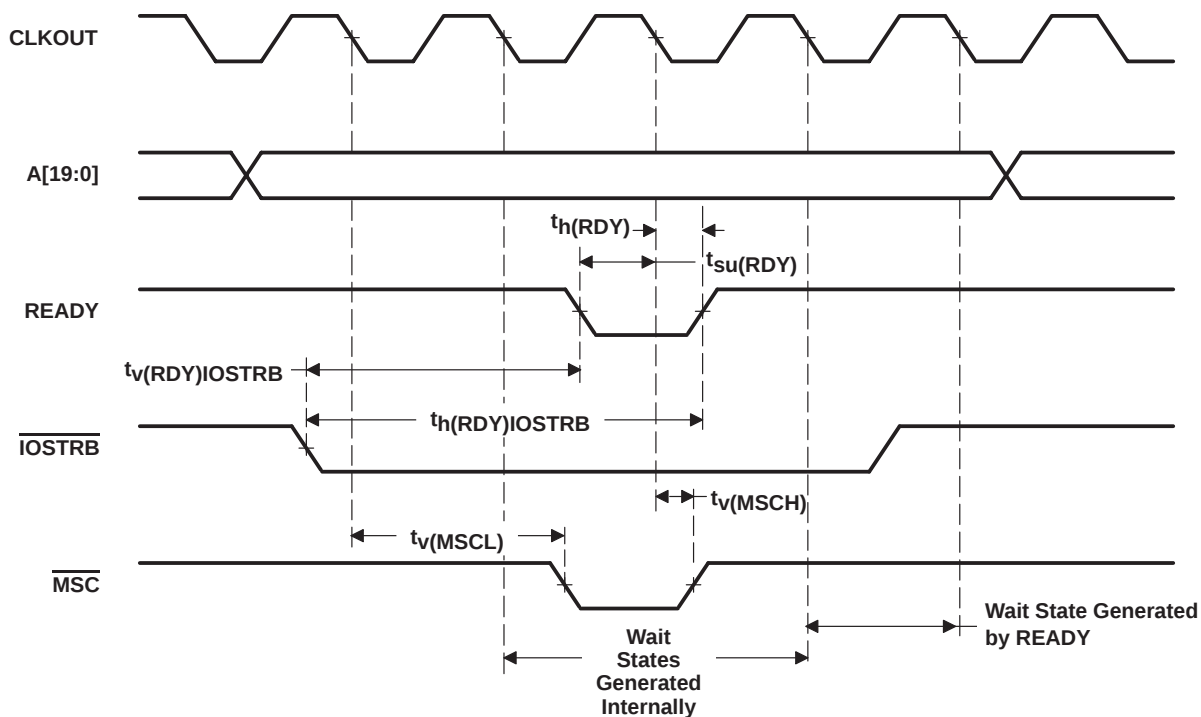


Figure 22. I/O Read With Externally Generated Wait States

ready timing for externally generated wait states (continued)

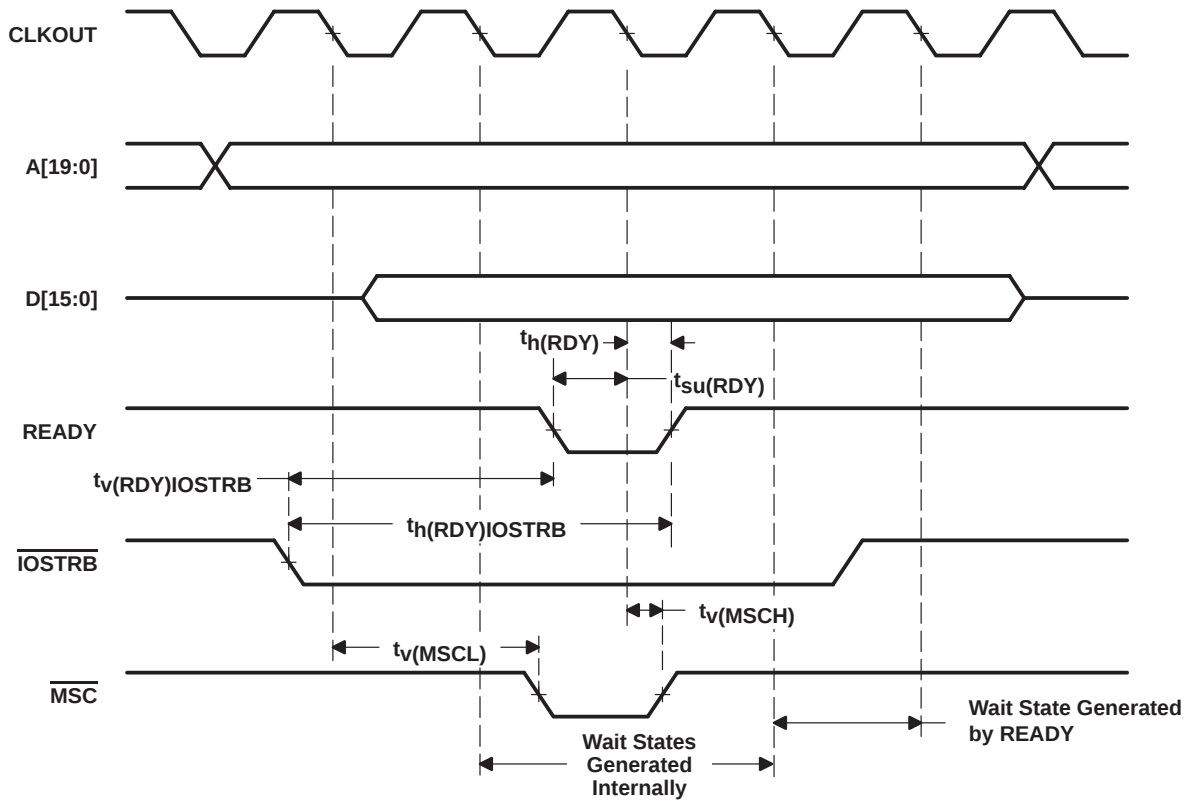


Figure 23. I/O Write With Externally Generated Wait States

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HOLD and HOLDA timings

switching characteristics over recommended operating conditions for memory control signals and HOLDA, [H = 0.5 t_c(CO)] (see Figure 24)

PARAMETER		MIN	MAX	UNIT
t _{dis} (CLKL-A)	Disable time, address, $\overline{\text{PS}}$, $\overline{\text{DS}}$, $\overline{\text{IS}}$ high impedance from CLKOUT low	5		ns
t _{dis} (CLKL-RW)	Disable time, R/ $\overline{\text{W}}$ high impedance from CLKOUT low	5		ns
t _{dis} (CLKL-S)	Disable time, $\overline{\text{MSTRB}}$, $\overline{\text{IOSTRB}}$ high impedance from CLKOUT low	5		ns
t _{en} (CLKL-A)	Enable time, address, $\overline{\text{PS}}$, $\overline{\text{DS}}$, $\overline{\text{IS}}$ from CLKOUT low	2H+5		ns
t _{en} (CLKL-RW)	Enable time, R/ $\overline{\text{W}}$ enabled from CLKOUT low	2H+5		ns
t _{en} (CLKL-S)	Enable time, $\overline{\text{MSTRB}}$, $\overline{\text{IOSTRB}}$ enabled from CLKOUT low	2	2H+5	ns
t _v (HOLDA)	Valid time, $\overline{\text{HOLDA}}$ low after CLKOUT low	0	5	ns
	Valid time, $\overline{\text{HOLDA}}$ high after CLKOUT low	-2	3	ns
t _w (HOLDA)	Pulse duration, $\overline{\text{HOLDA}}$ low duration	2H-3		ns

timing requirements for memory control signals and $\overline{\text{HOLDA}}$, [H = 0.5 t_c(CO)] (see Figure 24)

	MIN	MAX	UNIT
t _w (HOLD)	4H+10		ns
t _{su} (HOLD)	10		ns

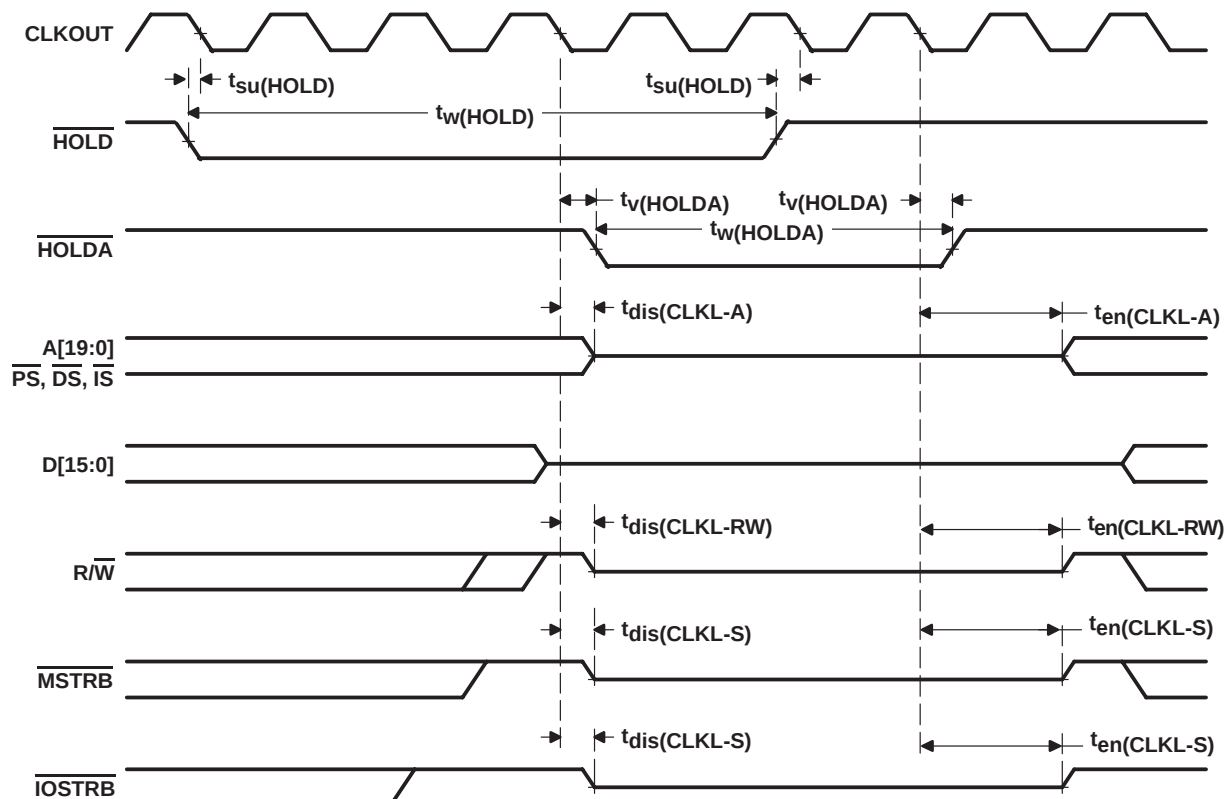


Figure 24. $\overline{\text{HOLD}}$ and $\overline{\text{HOLDA}}$ Timings (HM = 1)

reset, $\overline{\text{BIO}}$, interrupt, and $\text{MP}/\overline{\text{MC}}$ timings

timing requirements for reset, $\overline{\text{BIO}}$, interrupt, and $\text{MP}/\overline{\text{MC}}$ [$H = 0.5 t_{c(\text{CO})}$] (see Figure 25, Figure 26, and Figure 27)

		MIN	MAX	UNIT
$t_{\text{h}}(\text{RS})$	Hold time, $\overline{\text{RS}}$ after CLKOUT low	0		ns
$t_{\text{h}}(\text{BIO})$	Hold time, $\overline{\text{BIO}}$ after CLKOUT low	0		ns
$t_{\text{h}}(\text{INT})$	Hold time, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$, after CLKOUT low [†]	0		ns
$t_{\text{h}}(\text{MPMC})$	Hold time, $\text{MP}/\overline{\text{MC}}$ after CLKOUT low	0		ns
$t_{\text{w}}(\text{RSL})$	Pulse duration, $\overline{\text{RS}}$ low [‡]	4H+5		ns
$t_{\text{w}}(\text{BIO})\text{S}$	Pulse duration, $\overline{\text{BIO}}$ low, synchronous	2H+5		ns
$t_{\text{w}}(\text{BIO})\text{A}$	Pulse duration, $\overline{\text{BIO}}$ low, asynchronous	4H		ns
$t_{\text{w}}(\text{INTH})\text{S}$	Pulse duration, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$ high (synchronous)	2H+7		ns
$t_{\text{w}}(\text{INTH})\text{A}$	Pulse duration, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$ high (asynchronous)	4H		ns
$t_{\text{w}}(\text{INTL})\text{S}$	Pulse duration, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$ low (synchronous)	2H+7		ns
$t_{\text{w}}(\text{INTL})\text{A}$	Pulse duration, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$ low (asynchronous)	4H		ns
$t_{\text{w}}(\text{INTL})\text{WKP}$	Pulse duration, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$ low for IDLE2/IDLE3 wakeup	8		ns
$t_{\text{su}}(\text{RS})$	Setup time, $\overline{\text{RS}}$ before X2/CLKIN low [¶]	5		ns
$t_{\text{su}}(\text{BIO})$	Setup time, $\overline{\text{BIO}}$ before CLKOUT low	8	10	ns
$t_{\text{su}}(\text{INT})$	Setup time, $\overline{\text{INTn}}$, $\overline{\text{NMI}}$, $\overline{\text{RS}}$ before CLKOUT low	8	10	ns
$t_{\text{su}}(\text{MPMC})$	Setup time, $\text{MP}/\overline{\text{MC}}$ before CLKOUT low	8		ns

[†] The external interrupts ($\overline{\text{INT0}}$ – $\overline{\text{INT3}}$, $\overline{\text{NMI}}$) are synchronized to the core CPU by way of a two-flip-flop synchronizer which samples these inputs with consecutive falling edges of CLKOUT. The input to the interrupt pins is required to represent a 1-0-0 sequence at the timing that is corresponding to three CLKOUT sampling sequences.

[‡] If the PLL mode is selected, then at power-on sequence, or at wakeup from IDLE3, $\overline{\text{RS}}$ must be held low for at least 50 μs to ensure synchronization and lock-in of the PLL.

[§] Note that $\overline{\text{RS}}$ may cause a change in clock frequency, therefore changing the value of H.

[¶] Divide-by-two mode

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reset, $\overline{\text{BIO}}$, interrupt, and $\text{MP}/\overline{\text{MC}}$ timings (continued)

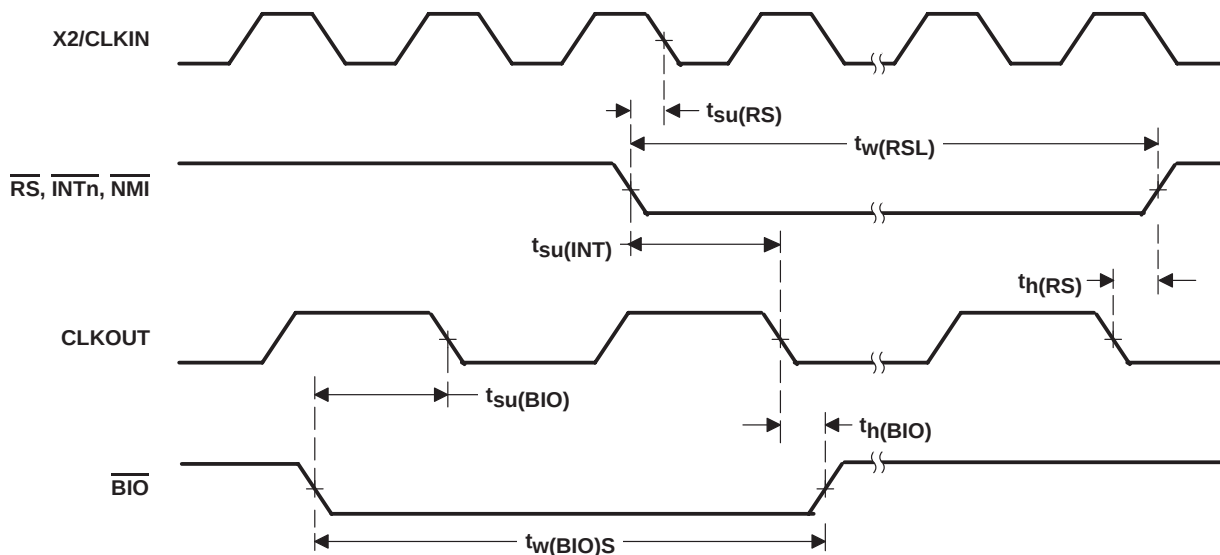


Figure 25. Reset and $\overline{\text{BIO}}$ Timings

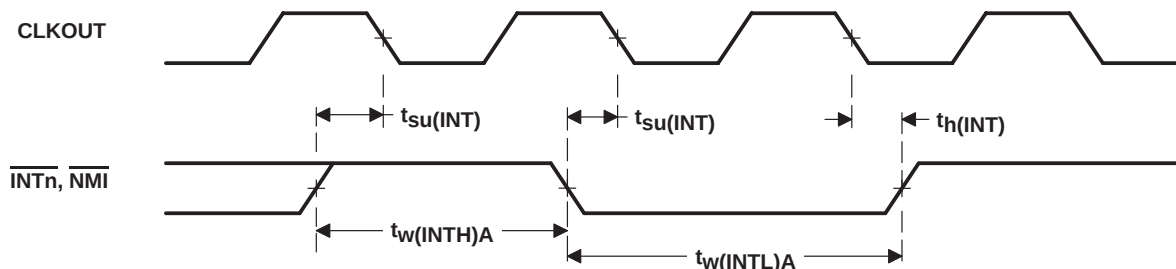


Figure 26. Interrupt Timing

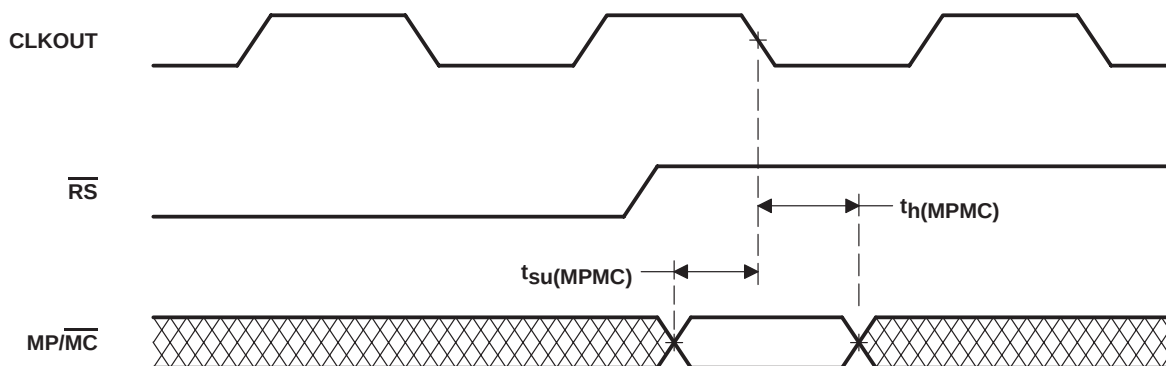


Figure 27. $\text{MP}/\overline{\text{MC}}$ Timing

instruction acquisition ($\overline{\text{IAQ}}$), interrupt acknowledge ($\overline{\text{IACK}}$), external flag (XF), and TOUT timings

switching characteristics over recommended operating conditions for $\overline{\text{IAQ}}$ and $\overline{\text{IACK}}$ [$H = 0.5 t_{c(CO)}$] (see Figure 28)

PARAMETER		MIN	MAX	UNIT
$t_d(\text{CLKL-IAQL})$	Delay time, CLKOUT low to $\overline{\text{IAQ}}$ low	0	3	ns
$t_d(\text{CLKL-IAQH})$	Delay time, CLKOUT low to $\overline{\text{IAQ}}$ high	0	3	ns
$t_d(A)\text{IAQ}$	Delay time, address valid to $\overline{\text{IAQ}}$ low		4	ns
$t_d(\text{CLKL-IACKL})$	Delay time, CLKOUT low to $\overline{\text{IACK}}$ low	0	3	ns
$t_d(\text{CLKL-IACKH})$	Delay time, CLKOUT low to $\overline{\text{IACK}}$ high	0	3	ns
$t_d(A)\text{IACK}$	Delay time, address valid to $\overline{\text{IACK}}$ low		3	ns
$t_h(A)\text{IAQ}$	Hold time, $\overline{\text{IAQ}}$ high after address invalid	0		ns
$t_h(A)\text{IACK}$	Hold time, $\overline{\text{IACK}}$ high after address invalid	0		ns
$t_w(\text{IAQL})$	Pulse duration, $\overline{\text{IAQ}}$ low	2H-5		ns
$t_w(\text{IACKL})$	Pulse duration, $\overline{\text{IACK}}$ low	2H-5		ns

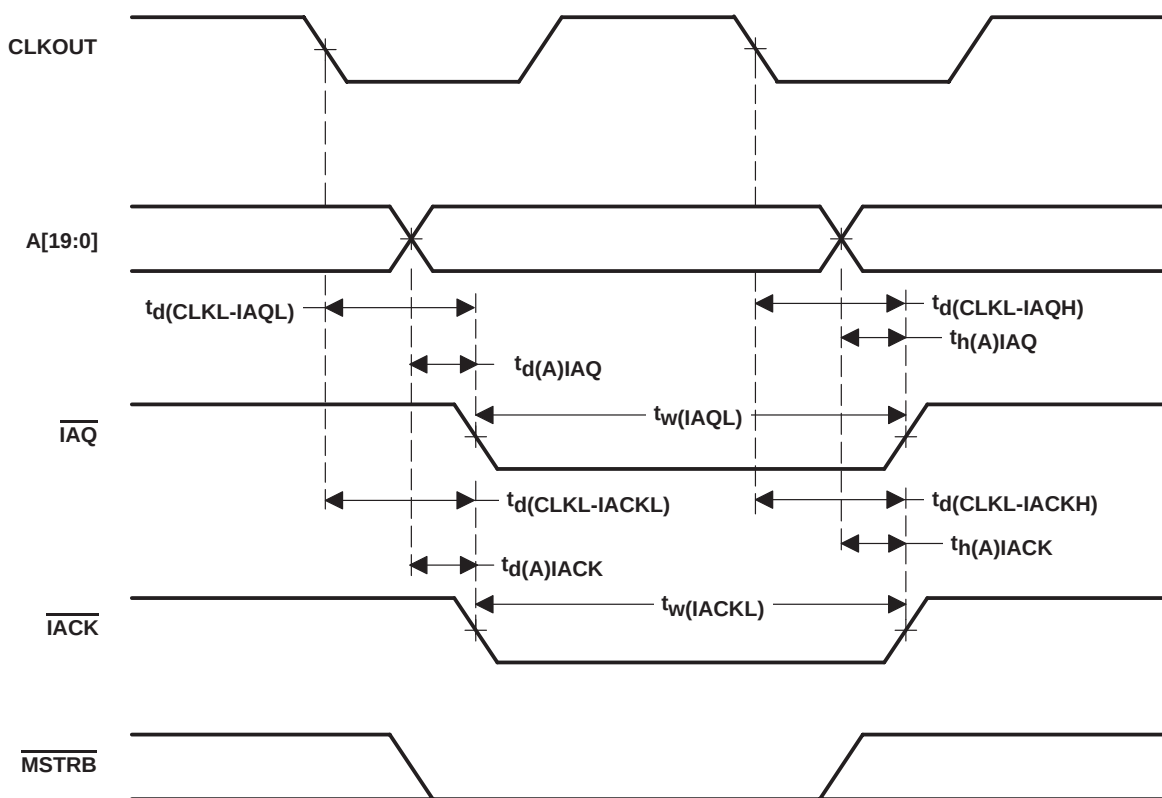


Figure 28. $\overline{\text{IAQ}}$ and $\overline{\text{IACK}}$ Timings

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instruction acquisition ($\overline{\text{IAQ}}$), interrupt acknowledge ($\overline{\text{IACK}}$), external flag (XF), and TOUT timings (continued)

switching characteristics over recommended operating conditions for XF and TOUT [H = 0.5 $t_{\text{c(CO)}}$] (see Figure 29 and Figure 30)

PARAMETER		MIN	MAX	UNIT
$t_{\text{d(XF)}}$	Delay time, CLKOUT low to XF high	0	3	ns
	Delay time, CLKOUT low to XF low	0	3	
$t_{\text{d(TOUTH)}}$	Delay time, CLKOUT low to TOUT high	0	3	ns
$t_{\text{d(TOCTL)}}$	Delay time, CLKOUT low to TOUT low	0	3	ns
$t_{\text{w(TOUT)}}$	Pulse duration, TOUT	2H	10	ns

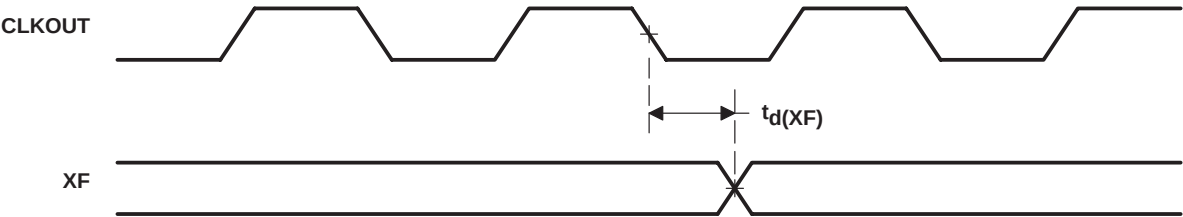


Figure 29. XF Timing

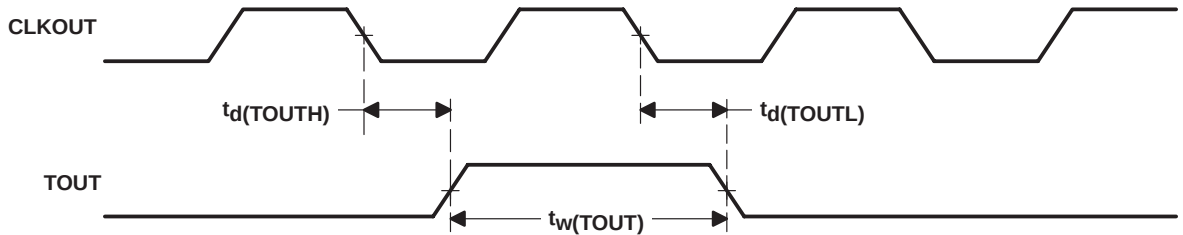


Figure 30. TOUT Timing

multichannel buffered serial port timing

timing requirements for McBSP [$H=0.5t_{c(CO)}$][†] (see Figure 31 and Figure 32)

			MIN	MAX	UNIT
$t_c(\text{BCKRX})$	Cycle time, BCLKR/X	BCLKR/X ext	4H		ns
$t_w(\text{BCKRX})$	Pulse duration, BCLKR/X high or BCLKR/X low	BCLKR/X ext	2H–1		ns
$t_{su}(\text{BFRH-BCKRL})$	Setup time, external BFSR high before BCLKR low	BCLKR int	8		ns
		BCLKR ext	1		
$t_h(\text{BCKRL-BFRH})$	Hold time, external BFSR high after BCLKR low	BCLKR int	0		ns
		BCLKR ext	3		
$t_{su}(\text{BDRV-BCKRL})$	Setup time, BDR valid before BCLKR low	BCLKR int	5		ns
		BCLKR ext	0		
$t_h(\text{BCKRL-BDRV})$	Hold time, BDR valid after BCLKR low	BCLKR int	0		ns
		BCLKR ext	4		
$t_{su}(\text{BFXH-BCKXL})$	Setup time, external BFSX high before BCLKX low	BCLKX int	7		ns
		BCLKX ext	0		
$t_h(\text{BCKXL-BFXH})$	Hold time, external BFSX high after BCLKX low	BCLKX int	0		ns
		BCLKX ext	3		
$t_r(\text{BCKRX})$	Rise time, BCKR/X	BCLKR/X ext		8	ns
$t_f(\text{BCKRX})$	Fall time, BCKR/X	BCLKR/X ext		8	ns

[†] CLKRP = CLKXP = FSRP = FSXP = 0. If the polarity of any of the signals is inverted, then the timing references of that signal are also inverted.

switching characteristics for McBSP [$H=0.5t_{c(CO)}$][†] (see Figure 31 and Figure 32)

PARAMETER			MIN	MAX	UNIT
$t_c(\text{BCKRX})$	Cycle time, BCLKR/X	BCLKR/X int	4H		ns
$t_w(\text{BCKRXH})$	Pulse duration, BCLKR/X high	BCLKR/X int	$D - 2^{\ddagger}$	$D + 2^{\ddagger}$	ns
$t_w(\text{BCKRXL})$	Pulse duration, BCLKR/X low	BCLKR/X int	$C - 2^{\ddagger}$	$C + 2^{\ddagger}$	ns
$t_d(\text{BCKRH-BFRV})$	Delay time, BCLKR high to internal BFSR valid	BCLKR int	–2	2	ns
		BCLKR ext	3	9	ns
$t_d(\text{BCKXH-BFXV})$	Delay time, BCLKX high to internal BFSX valid	BCLKX int	0	4	ns
		BCLKX ext	8	11	
$t_{dis}(\text{BCKXH-BDXHZ})$	Disable time, BCLKX high to BDX high impedance following last data bit of transfer	BCLKX int	–1	4	ns
		BCLKX ext	3	9	
$t_d(\text{BCKXH-BDXV})$	Delay time, BCLKX high to BDX valid	BCLKX int	0 [§]	7	ns
		BCLKX ext	3	11	
$t_d(\text{BFXH-BDXV})$	Delay time, BFSX high to BDX valid ONLY applies when in data delay 0 (XDATDLY = 00b) mode	BFSX int	–1 [§]	3	ns
		BFSX ext	3	13	

[†] CLKRP = CLKXP = FSRP = FSXP = 0. If the polarity of any of the signals is inverted, then the timing references of that signal are also inverted.

[‡] $T = \text{BCLKRX period} = (1 + \text{CLKGDV}) * 2H$

$C = \text{BCLKRX low pulse width} = T/2$ when CLKGDV is odd or zero and $= (\text{CLKGDV}/2) * 2H$ when CLKGDV is even

$D = \text{BCLKRX high pulse width} = T/2$ when CLKGDV is odd or zero and $= (\text{CLKGDV}/2 + 1) * 2H$ when CLKGDV is even

[§] Minimum delay times also represent minimum output hold times.

The diagram illustrates the timing for the BDR read operation across three different RDATDLY settings: 00b, 01b, and 10b. The signals involved are BCLKR, BFSR (int), BFSR (ext), and BDR. The BCLKR signal is a periodic clock. The BFSR (int) and BFSR (ext) signals are active-low, indicating the start and end of the read operation. The BDR signal shows the data being read, with bits (n-1), (n-2), (n-3), and (n-4) for RDATDLY=00b, and bits (n-1), (n-2), and (n-3) for RDATDLY=01b and 10b. The timing parameters are defined as follows:

- $t_c(\text{BCKRX})$: BCLKR period.
- $t_w(\text{BCKRXH})$: BCLKR high pulse width.
- $t_w(\text{BCKRXL})$: BCLKR low pulse width.
- $t_r(\text{BCKRX})$: BCLKR rise/fall time.
- $t_d(\text{BCKRH-BFRV})$: Delay from BCLKR high to BFSR (int) high.
- $t_d(\text{BCKRH-BFRV})$: Delay from BCLKR high to BFSR (ext) high.
- $t_r(\text{BCKRX})$: Delay from BCLKR low to BFSR (int) low.
- $t_r(\text{BCKRX})$: Delay from BCLKR low to BFSR (ext) low.
- $t_{su}(\text{BFRH-BCKRL})$: Setup time from BFSR (int) high to BCLKR low.
- $t_h(\text{BCKRL-BFRH})$: Hold time from BCLKR low to BFSR (int) high.
- $t_{su}(\text{BDRV-BCKRL})$: Setup time from BFSR (ext) high to BCLKR low.
- $t_h(\text{BCKRL-BDRV})$: Hold time from BCLKR low to BFSR (ext) high.
- $t_{su}(\text{BDRV-BCKRL})$: Setup time from BDR high to BCLKR low.
- $t_h(\text{BCKRL-BDRV})$: Hold time from BCLKR low to BDR high.

Figure 32. McBSP Transmit Timings

multichannel buffered serial port timing (continued)

timing requirements for McBSP general-purpose I/O (see Figure 33)

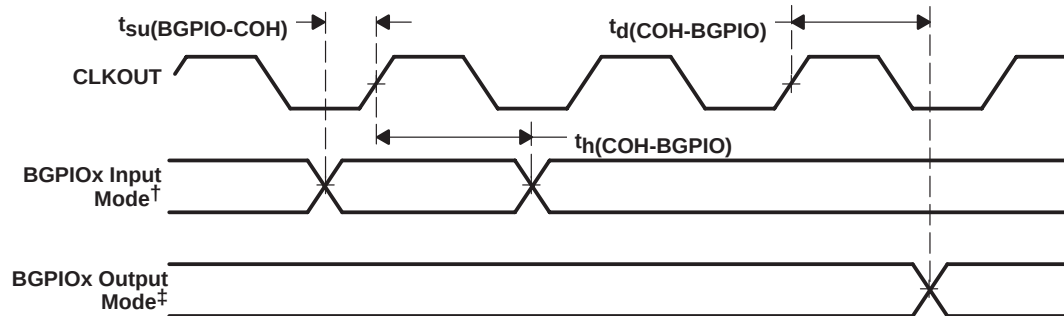
	MIN	MAX	UNIT
$t_{su}(BGPIO-COH)$ Setup time, BGPIOx input mode before CLKOUT high [†]	9		ns
$t_h(COH-BGPIO)$ Hold time, BGPIOx input mode after CLKOUT high [†]	0		ns

[†] BGPIOx refers to BCLKRx, BFSRx, BDRx, BCLKXx, or BFSXx when configured as a general-purpose input.

switching characteristics for McBSP general-purpose I/O (see Figure 33)

PARAMETER	MIN	MAX	UNIT
$t_d(COH-BGPIO)$ Delay time, CLKOUT high to BGPIOx output mode [‡]	0	5	ns

[‡] BGPIOx refers to BCLKRx, BFSRx, BCLKXx, BFSXx, or BDXX when configured as a general-purpose output.



[†] BGPIOx refers to BCLKRx, BFSRx, BDRx, BCLKXx, or BFSXx when configured as a general-purpose input.

[‡] BGPIOx refers to BCLKRx, BFSRx, BCLKXx, BFSXx, or BDXX when configured as a general-purpose output.

Figure 33. McBSP General-Purpose I/O Timings

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multichannel buffered serial port timing (continued)

timing requirements for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 10b, CLKXP = 0[†] (see Figure 34)

		MASTER		SLAVE		UNIT
		MIN	MAX	MIN	MAX	
$t_{su}(BDRV-BCKXL)$	Setup time, BDR valid before BCLKX low	9		-	12H	ns
$t_h(BCKXL-BDRV)$	Hold time, BDR valid after BCLKX low	0		5	+ 12H	ns
$t_{su}(BFXL-BCKXL)$	Setup time, BFSX low before BCLKX low			10		ns
$t_c(BCKX)$	Cycle time, BCLKX			32H		ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

switching characteristics for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 10b, CLKXP = 0[†] (see Figure 34)

PARAMETER		MASTER [‡]		SLAVE		UNIT
		MIN	MAX	MIN	MAX	
$t_h(BCKXL-BFXL)$	Hold time, BFSX low after BCLKX low [§]	T - 3	T + 4			ns
$t_d(BFXL-BCKXH)$	Delay time, BFSX low to BCLKX high [¶]	C - 5	C + 3			ns
$t_d(BCKXH-BDXV)$	Delay time, BCLKX high to BDX valid	-2	4	6H + 54	10H + 15	ns
$t_{dis}(BCKXL-BDXHZ)$	Disable time, BDX high impedance following last data bit from BCLKX low	C - 2	C + 3			ns
$t_{dis}(BFXH-BDXHZ)$	Disable time, BDX high impedance following last data bit from BFSX high			2H + 4	6H + 17	ns
$t_d(BFXL-BDXV)$	Delay time, BFSX low to BDX valid			4H + 2	8H + 17	ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

[‡] T = BCLKX period = $(1 + CLKGDV) * 2H$

C = BCLKX low pulse width = T/2 when CLKGDV is odd or zero and = $(CLKGDV/2) * 2H$ when CLKGDV is even

[§] FSRP = FSXP = 1. As a SPI master, BFSX is inverted to provide active-low slave-enable output. As a slave, the active-low signal input on BFSX and BFSR is inverted before being used internally.

CLKXM = FSXM = 1, CLKRM = FSRM = 0 for master McBSP

CLKXM = CLKRM = FSXM = FSRM = 0 for slave McBSP

[¶] BFSX should be low before the rising edge of clock to enable slave devices and then begin a SPI transfer at the rising edge of the master clock (BCLKX).

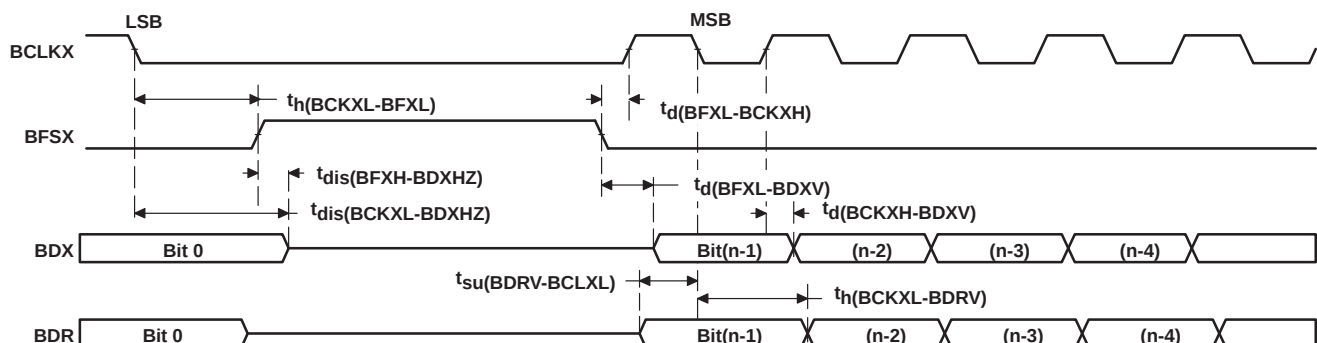


Figure 34. McBSP Timing as SPI Master or Slave: CLKSTP = 10b, CLKXP = 0

multichannel buffered serial port timing (continued)

timing requirements for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 11b, CLKXP = 0[†] (see Figure 35)

		MASTER		SLAVE		UNIT
		MIN	MAX	MIN	MAX	
$t_{su}(BDRV-BCKXL)$	Setup time, BDR valid before BCLKX low	12		2 – 12H		ns
$t_h(BCKXH-BDRV)$	Hold time, BDR valid after BCLKX high	4		5 + 12H		ns
$t_{su}(BFXL-BCKXH)$	Setup time, BFSX low before BCLKX high			10		ns
$t_c(BCKX)$	Cycle time, BCLKX			32H		ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

switching characteristics for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 11b, CLKXP = 0[†] (see Figure 35)

PARAMETER		MASTER [‡]		SLAVE		UNIT
		MIN	MAX	MIN	MAX	
$t_h(BCKXL-BFXL)$	Hold time, BFSX low after BCLKX low [§]	C – 3	C + 43			ns
$t_d(BFXL-BCKXH)$	Delay time, BFSX low to BCLKX high [¶]	T – 5	T + 3			ns
$t_d(BCKXL-BDXV)$	Delay time, BCLKX low to BDX valid	–2	6	6H + 5	10H + 15	ns
$t_{dis}(BCKXL-BDXHZ)$	Disable time, BDX high impedance following last data bit from BCLKX low	–2	4	6H + 3	10H + 17	ns
$t_d(BFXL-BDXV)$	Delay time, BFSX low to BDX valid	D – 2	D + 4	4H – 2	8H + 17	ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

[‡] T = BCLKX period = (1 + CLKGDV) * 2H

C = BCLKX low pulse width = T/2 when CLKGDV is odd or zero and = (CLKGDV/2) * 2H when CLKGDV is even

D = BCLKX high pulse width = T/2 when CLKGDV is odd or zero and = (CLKGDV/2 + 1) * 2H when CLKGDV is even

[§] FSRP = FSXP = 1. As a SPI master, BFSX is inverted to provide active-low slave-enable output. As a slave, the active-low signal input on BFSX and BFSR is inverted before being used internally.

CLKXM = FSXM = 1, CLKRM = FSRM = 0 for master McBSP

CLKXM = CLKRM = FSXM = FSRM = 0 for slave McBSP

[¶] BFSX should be low before the rising edge of clock to enable slave devices and then begin a SPI transfer at the rising edge of the master clock (BCLKX).

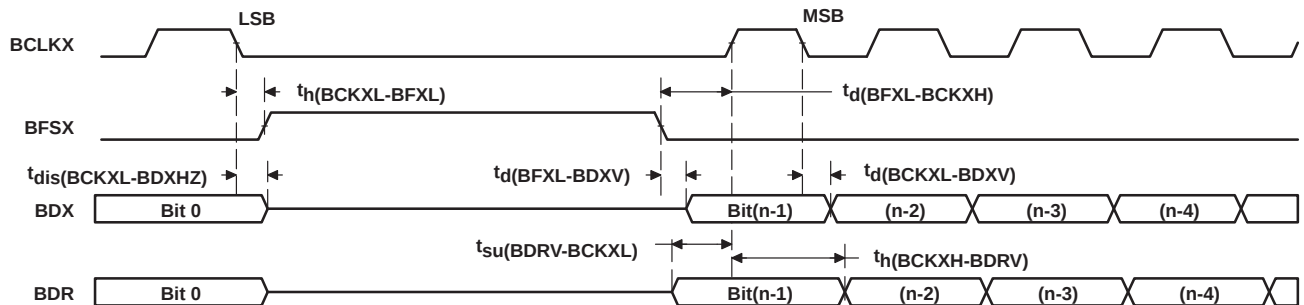


Figure 35. McBSP Timing as SPI Master or Slave: CLKSTP = 11b, CLKXP = 0

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multichannel buffered serial port timing (continued)

timing requirements for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 10b, CLKXP = 1[†] (see Figure 36)

	MASTER		SLAVE		UNIT
	MIN	MAX	MIN	MAX	
$t_{su}(BDRV-BCKXH)$ Setup time, BDR valid before BCLKX high	12		2 – 12H		ns
$t_h(BCKXH-BDRV)$ Hold time, BDR valid after BCLKX high	4		5 + 12H		ns
$t_{su}(BFXL-BCKXL)$ Setup time, BFSX low before BCLKX low			10		ns
$t_c(BCKX)$ Cycle time, BCLKX			32H		ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

switching characteristics for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 10b, CLKXP = 1[†] (see Figure 36)

PARAMETER	MASTER [‡]		SLAVE		UNIT
	MIN	MAX	MIN	MAX	
$t_h(BCKXH-BFXL)$ Hold time, BFSX low after BCLKX high [§]	T – 3	T + 4			ns
$t_d(BFXL-BCKXL)$ Delay time, BFSX low to BCLKX low [¶]	D – 5	D + 3			ns
$t_d(BCKXL-BDXV)$ Delay time, BCLKX low to BDX valid	–2	6	6H + 5	10H + 15	ns
$t_{dis}(BCKXH-BDXHZ)$ Disable time, BDX high impedance following last data bit from BCLKX high	D – 2	D + 3			ns
$t_{dis}(BFXH-BDXHZ)$ Disable time, BDX high impedance following last data bit from BFSX high			2H + 3	6H + 17	ns
$t_d(BFXL-BDXV)$ Delay time, BFSX low to BDX valid			4H – 2	8H + 17	ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

[‡] T = BCLKX period = (1 + CLKGDV) * 2H

D = BCLKX high pulse width = T/2 when CLKGDV is odd or zero and = (CLKGDV/2 + 1) * 2H when CLKGDV is even

[§] FSRP = FSXP = 1. As a SPI master, BFSX is inverted to provide active-low slave-enable output. As a slave, the active-low signal input on BFSX and BFSR is inverted before being used internally.

CLKXM = FSXM = 1, CLKRM = FSRM = 0 for master McBSP

CLKXM = CLKRM = FSXM = FSRM = 0 for slave McBSP

[¶] BFSX should be low before the rising edge of clock to enable slave devices and then begin a SPI transfer at the rising edge of the master clock (BCLKX).

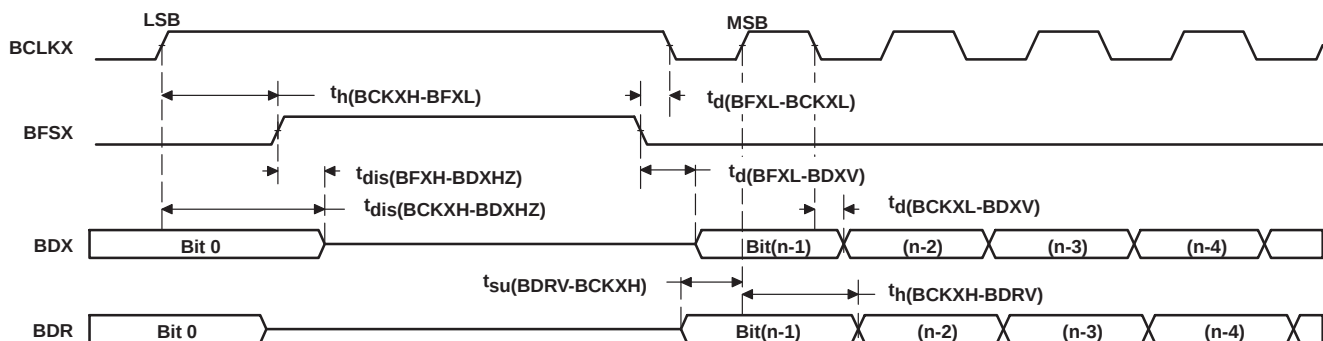


Figure 36. McBSP Timing as SPI Master or Slave: CLKSTP = 10b, CLKXP = 1

multichannel buffered serial port timing (continued)

timing requirements for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 11b, CLKXP = 1[†] (see Figure 37)

		MASTER		SLAVE		UNIT
		MIN	MAX	MIN	MAX	
$t_{su}(BDRV-BCKXL)$	Setup time, BDR valid before BCLKX low	9		- 12H		ns
$t_h(BCKXL-BDRV)$	Hold time, BDR valid after BCLKX low	0		5 + 12H		ns
$t_{su}(BFXL-BCKXL)$	Setup time, BFSX low before BCLKX low			10		ns
$t_c(BCKX)$	Cycle time, BCLKX			32H		ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

switching characteristics for McBSP as SPI master or slave: $[H=0.5t_{c(CO)}]$ CLKSTP = 11b, CLKXP = 1[†] (see Figure 37)

PARAMETER		MASTER [‡]		SLAVE		UNIT
		MIN	MAX	MIN	MAX	
$t_h(BCKXH-BFXL)$	Hold time, BFSX low after BCLKX high [§]	D - 3	D + 4			ns
$t_d(BFXL-BCKXL)$	Delay time, BFSX low to BCLKX low [¶]	T - 5	T + 3			ns
$t_d(BCKXH-BDXV)$	Delay time, BCLKX high to BDX valid	-2	6	6H + 5	10H + 15	ns
$t_{dis}(BCKXH-BDXHZ)$	Disable time, BDX high impedance following last data bit from BCLKX high	-2	4	6H + 3	10H + 17	ns
$t_d(BFXL-BDXV)$	Delay time, BFSX low to BDX valid	C - 2	C + 4	4H - 2	8H + 17	ns

[†] For all SPI slave modes, CLKG is programmed as 1/2 of the CPU clock by setting CLKSM = CLKGDV = 1.

[‡] T = BCLKX period = (1 + CLKGDV) * 2H

C = BCLKX low pulse width = T/2 when CLKGDV is odd or zero and = (CLKGDV/2) * 2H when CLKGDV is even

D = BCLKX high pulse width = T/2 when CLKGDV is odd or zero and = (CLKGDV/2 + 1) * 2H when CLKGDV is even

[§] FSRP = FSXP = 1. As a SPI master, BFSX is inverted to provide active-low slave-enable output. As a slave, the active-low signal input on BFSX and BFSR is inverted before being used internally.

CLKXM = FSXM = 1, CLKRM = FSRM = 0 for master McBSP

CLKXM = CLKRM = FSXM = FSRM = 0 for slave McBSP

[¶] BFSX should be low before the rising edge of clock to enable slave devices and then begin a SPI transfer at the rising edge of the master clock (BCLKX).

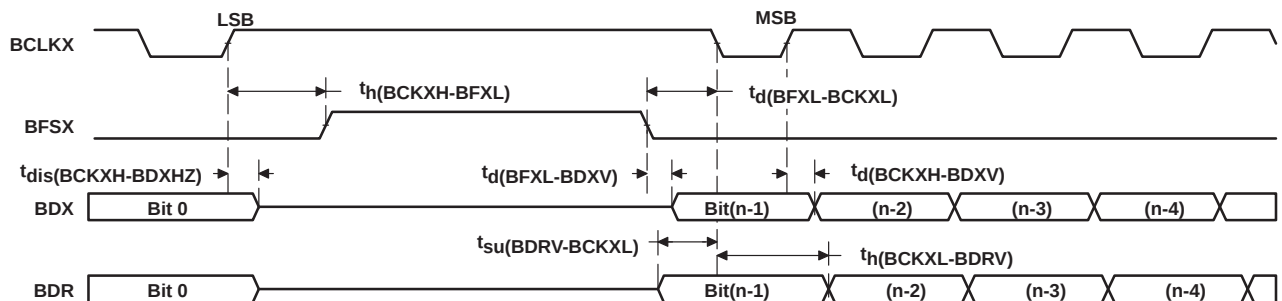


Figure 37. McBSP Timing as SPI Master or Slave: CLKSTP = 11b, CLKXP = 1

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HPI8 timing

switching characteristics over recommended operating conditions^{†‡§¶} [H = 0.5t_{c(CO)}]
(see Figure 38, Figure 39, Figure 40, and Figure 41)

PARAMETER		MIN	MAX	UNIT
t _{en} (DSL-HD)	Enable time, HD driven from DS low	2	17	ns
t _d (DSL-HDV1)	Delay time, DS low to HDx valid for first byte of an HPI read	Case 1a: Memory accesses when DMAC is active in 16-bit mode and t _w (DSH) < 18H	18H+18 – t _w (DSH)	ns
		Case 1b: Memory accesses when DMAC is active in 16-bit mode and t _w (DSH) ≥ 18H	18	
		Case 1c: Memory access when DMAC is active in 32-bit mode and t _w (DSH) < 26H	26H+18 – t _w (DSH)	
		Case 1d: Memory access when DMAC is active in 32-bit mode and t _w (DSH) ≥ 26H	18	
		Case 2a: Memory accesses when DMAC is inactive and t _w (DSH) < 10H	10H+18 – t _w (DSH)	
		Case 2b: Memory accesses when DMAC is inactive and t _w (DSH) ≥ 10H	18	
		Case 3: Register accesses	18	
t _d (DSL-HDV2)	Delay time, DS low to HDx valid for second byte of an HPI read		18	ns
t _h (DSH-HDV) _R	Hold time, HDx valid after DS high, for a HPI read	3	5	ns
t _v (HYH-HDV)	Valid time, HDx valid after HRDY high		5	
t _d (DSH-HYL)	Delay time, DS high to HRDY low (see Note 1)		10	ns
t _d (DSH-HYH)	Delay time, DS high to HRDY high	Case 1a: Memory accesses when DMAC is active in 16-bit mode	18H+10	ns
		Case 1b: Memory accesses when DMAC is active in 32-bit mode	26H+10	ns
		Case 2: Memory accesses when DMAC is inactive	10H+10	ns
		Case 3: Write accesses to HPIC register (see Note 2)	6H+10	
t _d (HCS-HRDY)	Delay time, <u>HCS</u> low/high to HRDY low/high		8	ns
t _d (COH-HYH)	Delay time, CLKOUT high to HRDY high		8	ns
t _d (COH-HTX)	Delay time, CLKOUT high to <u>HINT</u> change		10	ns
t _d (COH-GPIO)	Delay time, CLKOUT high to HDx output change. HDx is configured as a general-purpose output.		6	ns

NOTES: 1. The HRDY output is always high when the $\overline{\text{HCS}}$ input is high, regardless of DS timings.
2. This timing applies when writing a one to the DSPINT bit or HINT bit of the HPIC register. All other writes to the HPIC occur asynchronously, and do not cause HRDY to be deasserted.

[†] DS refers to the logical OR of HCS, HDS1, and HDS2.

[‡] HDx refers to any of the HPI data bus pins (HD0, HD1, HD2, etc.).

[§] DMAC stands for direct memory access (DMA) controller. The HPI8 shares the internal DMA bus with the DMAC, thus HPI8 access times are affected by DMAC activity.

[¶] GPIO refers to the HD pins when they are configured as general-purpose input/outputs.

HPI8 timing (continued)

timing requirements^{†‡§} (see Figure 38, Figure 39, Figure 40, and Figure 41)

		MIN	MAX	UNIT
$t_{su}(HBV-DSL)$	Setup time, HBIL valid before DS low	10		ns
$t_h(DSL-HBV)$	Hold time, HBIL valid after DS low	5		ns
$t_{su}(HSL-DSL)$	Setup time, $\overline{HAS}$ low before DS low	5		ns
$t_w(DSL)$	Pulse duration, DS low	20		ns
$t_w(DSH)$	Pulse duration, DS high	10		ns
$t_{su}(HDV-DSH)$	Setup time, HDx valid before DS high, HPI write	5		ns
$t_h(DSH-HDV)W$	Hold time, HDx valid after DS high, HPI write	3		ns
$t_{su}(GPIO-COH)$	Setup time, HDx input valid before CLKOUT high, HDx configured as general-purpose input	3		ns
$t_h(GPIO-COH)$	Hold time, HDx input valid after CLKOUT high, HDx configured as general-purpose input	0		ns

[†] DS refers to the logical OR of $\overline{HCS}$, $\overline{HDS1}$, and $\overline{HDS2}$.

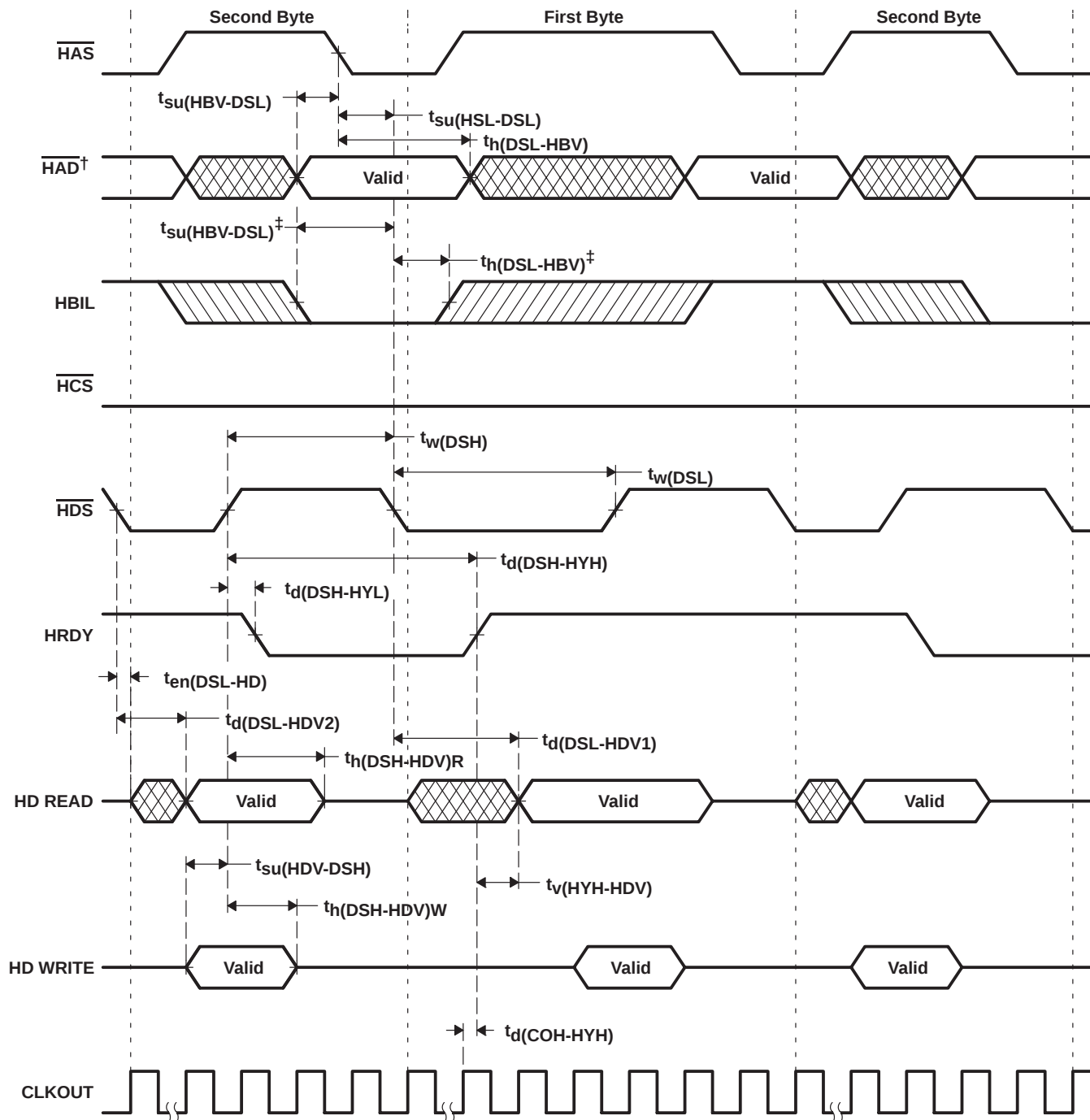
[‡] HDx refers to any of the HPI data bus pins (HD0, HD1, HD2, etc.).

[§] GPIO refers to the HD pins when they are configured as general-purpose input/outputs.

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HPI8 timing (continued)



† $\overline{\text{HAD}}$ refers to HCNTL0 , HCNTL1 , and $\text{HR}/\overline{\text{W}}$.

‡ When $\overline{\text{HAS}}$ is not used ($\overline{\text{HAS}}$ always high)

Figure 38. Using $\overline{\text{HDS}}$ to Control Accesses ($\overline{\text{HCS}}$ Always Low)

HPI8 timing (continued)

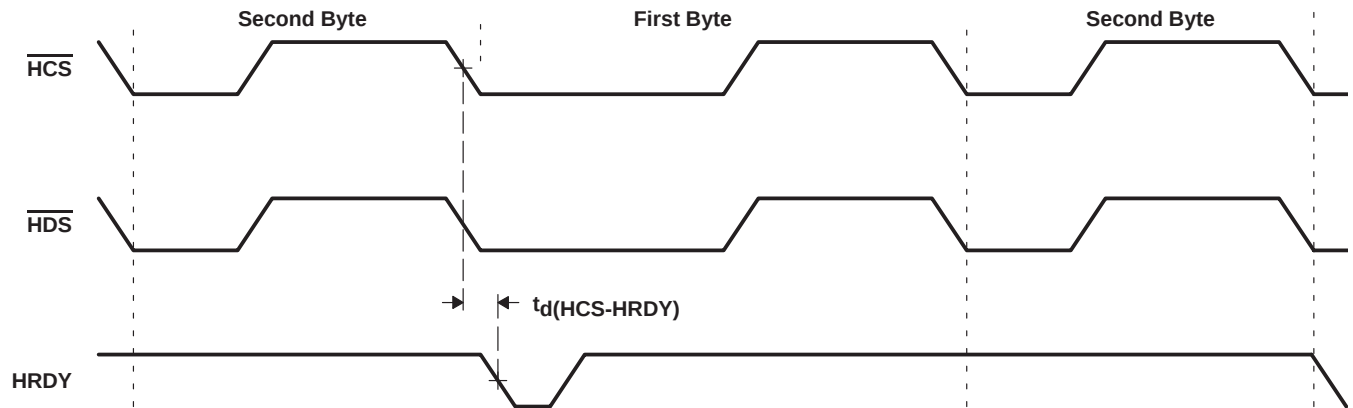


Figure 39. Using $\overline{\text{HCS}}$ to Control Accesses

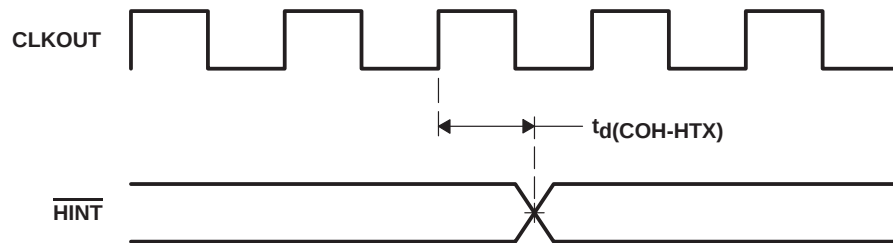
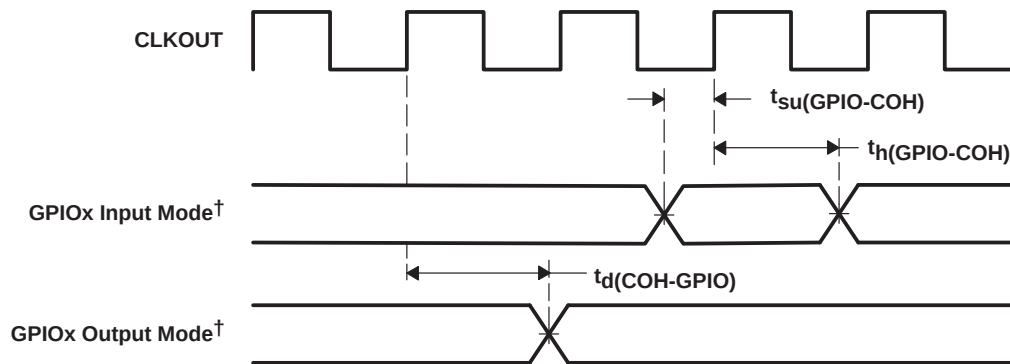


Figure 40. $\overline{\text{HINT}}$ Timing



† GPIOx refers to HD0, HD1, HD2, ...HD7, when the HD bus is configured for general-purpose input/output (I/O).

Figure 41. GPIOx[†] Timings

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HPI16 timing

switching characteristics over recommended operating conditions^{†‡§¶} [$H = 0.5t_{c(CO)}$]
(see Figure 42 and Figure 43)

PARAMETER		MIN	MAX	UNIT
$t_{en}(DSL-HD)$	Enable time, Dx driven from DS low	7	17	ns
$t_d(DSL-HDV1)$	Delay time, DS low to Dx valid for an HPI read	Case 1a: Memory accesses when DMAC is active in 16-bit mode and $t_{w(DSH)} < 18H$		$18H+22 - t_{w(DSH)}$
		Case 1b: Memory accesses when DMAC is active in 16-bit mode and $t_{w(DSH)} \geq 18H$		22
		Case 2a: Memory accesses when DMAC is inactive and $t_{w(DSH)} < 10H$		$10H+22 - t_{w(DSH)}$
		Case 2b: Memory accesses when DMAC is inactive and $t_{w(DSH)} \geq 10H$		22
		Case 3: Register accesses		22
$t_h(DSH-HDV)R$	Hold time, Dx valid after DS rising edge, read [§]	1	8	ns
$t_{su}(HDV-HYH)$	Setup time, Dx valid before HRDY rising edge			ns
$t_d(DSH-HYL)$	Delay time, DS or $\overline{HCS}$ high to HRDY low [‡]		10	ns
$t_d(DSH-HYH)$	Delay time, DS high to HRDY high [§] (writes and autoincrement reads)	Case 1: Memory access when DMAC is active in 16-bit mode		$18H+10$
		Case 2: Memory access when DMAC is inactive		$10H+10$
$t_d(DSL-HYL)$	Delay time, HDS or $\overline{HCS}$ low/high to HRDY low/high		8	ns
$t_d(COH-HTH)$	Delay time, CLKOUT high to HRDY high		8	ns
$t_d(COH-GPIO)$	Delay time, CLKOUT rising edge to HDx output change. HDx is configured as a general-purpose output.		6	ns

NOTE: The HRDY output is always high when the $\overline{HCS}$ input is high, regardless of DS timings.

[†] DS refers to the logical OR of $\overline{HCS}$, HDS1, or HDS2.

[‡] Dx refers to any of the DPI data bus pins (D0, D1, D2, etc.).

[§] DMAC stands for direct memory access (DMA) controller. The HPI16 shares the internal DMA bus with the DMAC, thus HPI16 access times are affected by DMAC activity.

[¶] GPIO refers to the HD pins when they are configured as general-purpose input/outputs.

ADVANCE INFORMATION



HPI16 timing (continued)

timing requirements^{†‡§} [$H = 0.5t_{c(CO)}$] (see Note 1, Figure 42, and Figure 43)

		MIN	MAX	UNIT
$t_{su}(HBV-DSL)$	Setup time, HAD valid before DS falling edge ^{†‡}	10		ns
$t_h(DSL-HBV)$	Hold time, HAD valid after DS falling edge ^{†‡}	5		ns
$t_{su}(HAV-DSL)$	Setup time, HAD valid before DS falling edge [†]			ns
$t_h(DSH-HAV)$	Hold time, address valid after DS rising edge [†]			ns
$t_{su}(HDV-DSH)$	Setup time, Dx valid before DS high (HPI write)			ns
$t_h(DSH-HDV)W$	Hold time, Dx valid after DS high (HPI write)	3		ns
$t_w(DSL)$	Pulse duration, DS low [‡]	20		ns
$t_w(DSH)$	Pulse duration, DS high [‡]	10		ns
$t_{su}(GPIO-COH)$	Setup time, Dx input valid before CLKOUT high, HDx configured as general-purpose input	2		ns
$t_h(GPIO-COH)$	Hold time, Dx input valid after CLKOUT high, HDx configured as general-purpose input	0		ns
$t_c(DSH-DSH)$	Cycle time, DS rising edge to next DS rising edge [‡] (Minimum timings represent WRITES while maximum timings represent READS)	Nonmultiplexed mode (no increment) with no DMA activity.		ns
		Nonmultiplexed mode (no increment) with 16-bit DMA activity.		ns

[†] DS refers to the logical OR of $\overline{HCS}$ and $\overline{HDS1}$ and $\overline{HDS2}$.

[‡] Dx refers to any of the HPI data bus pins (D0, D1, D2, etc.).

[§] GPIO refers to the HD pins when they are configured as general-purpose input/outputs.

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HPI16 timing (continued)

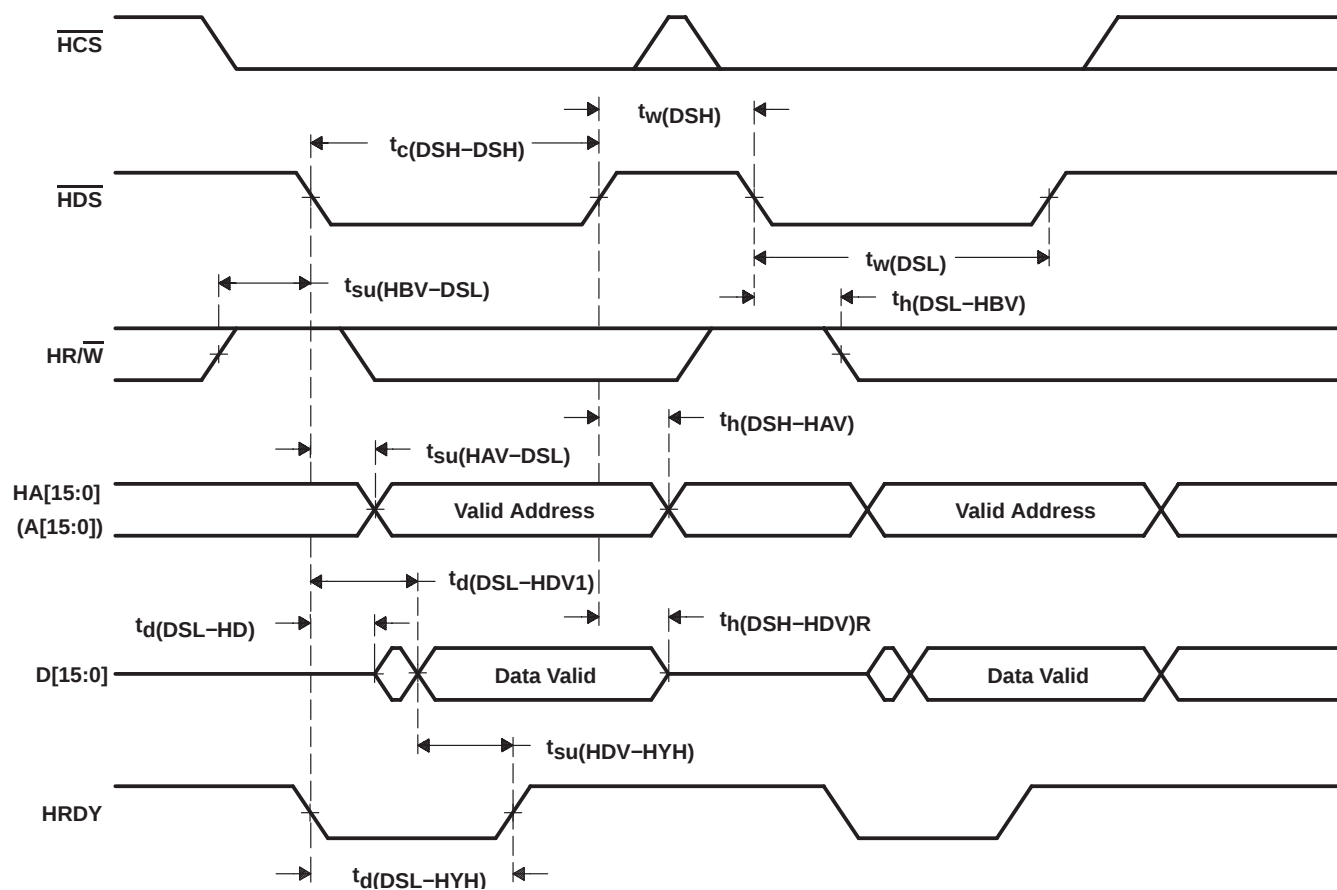


Figure 42. Nonmultiplexed Read Timings

HPI16 timing (continued)

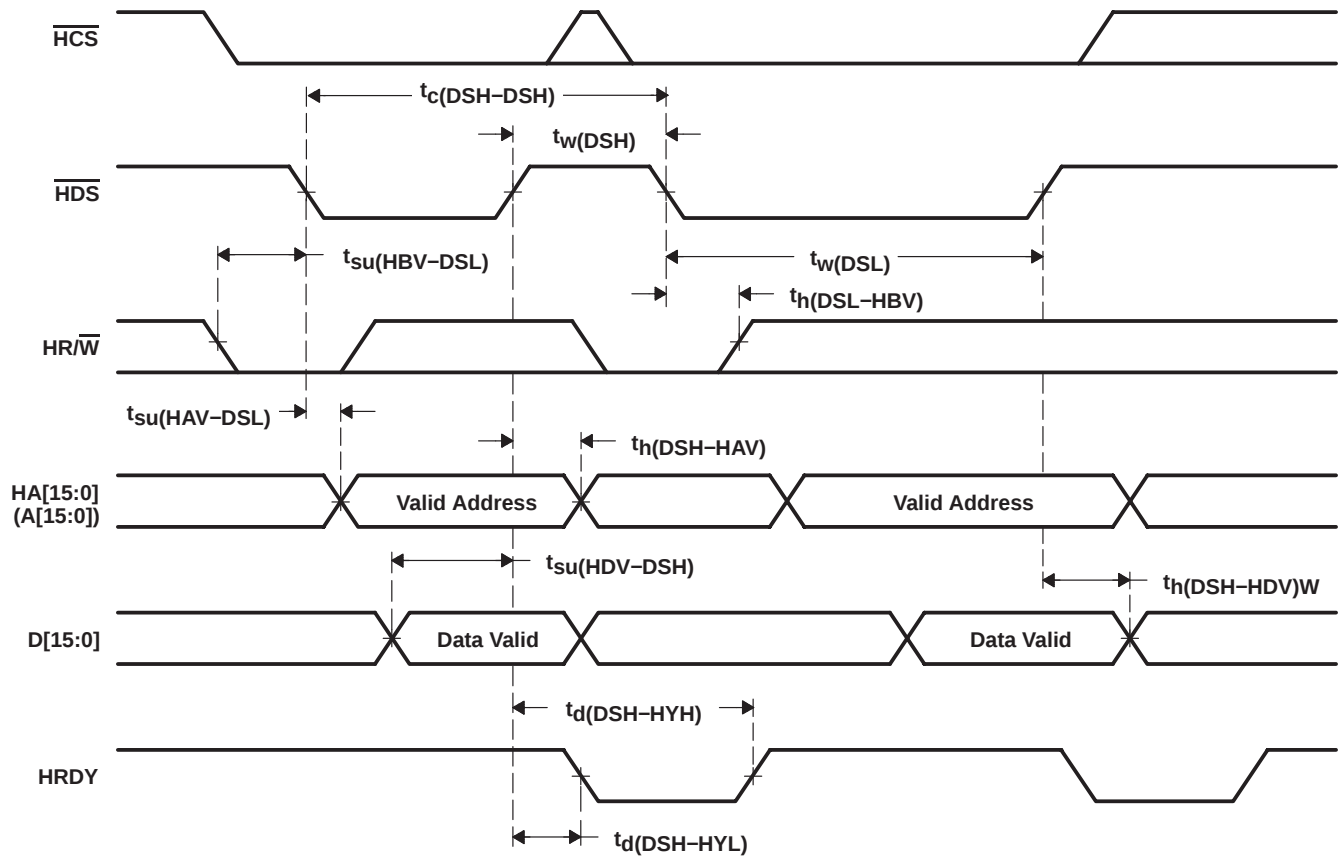


Figure 43. Nonmultiplexed Write Timings

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MECHANICAL DATA

package thermal resistance characteristics

Table 18 and Table 19 provide the thermal resistance characteristics for the recommended package types used on the TMS320UC5409 DSP.

Table 18. Thermal Resistance Characteristics of PGE Package

PARAMETER	°C/W
$R_{\theta JA}$	56
$R_{\theta JC}$	5

Table 19. Thermal Resistance Characteristics of GGU Package

PARAMETER	°C/W
$R_{\theta JA}$	38
$R_{\theta JC}$	5

packaging information

The following packaging information reflects the most current released data available for the designated device(s). This data is subject to change without notice and without revision of this document.

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TMS320UC5409GGU-80	ACTIVE	BGA MI CROSTAR	GGU	144	160	TBD	SNPB	Level-3-220C-168 HR
TMS320UC5409GGUR80	OBSOLETE	BGA MI CROSTAR	GGU	144		TBD	Call TI	Call TI
TMS320UC5409PGE-80	ACTIVE	LQFP	PGE	144	60	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

⁽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⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

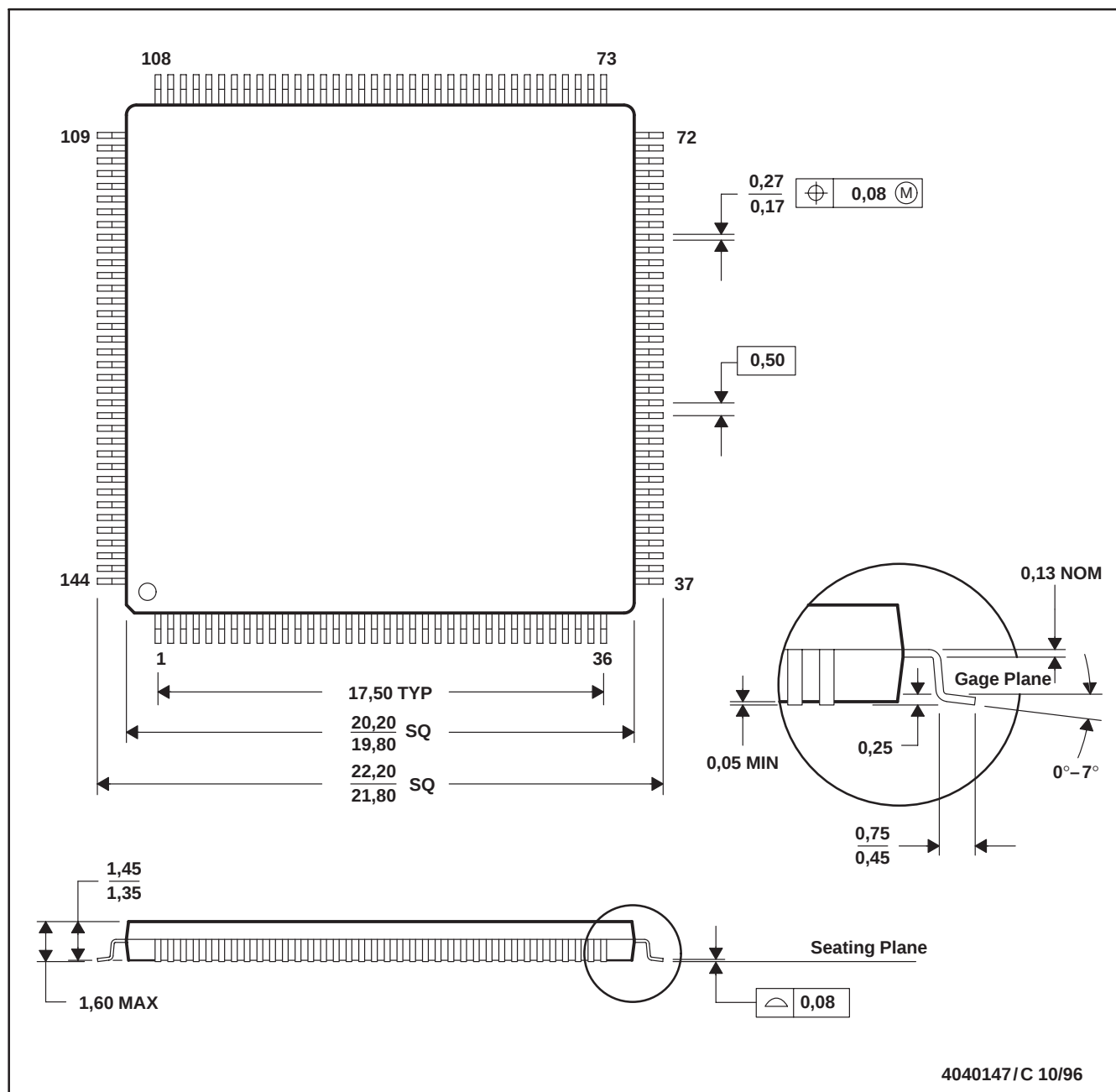
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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PGE (S-PQFP-G144)

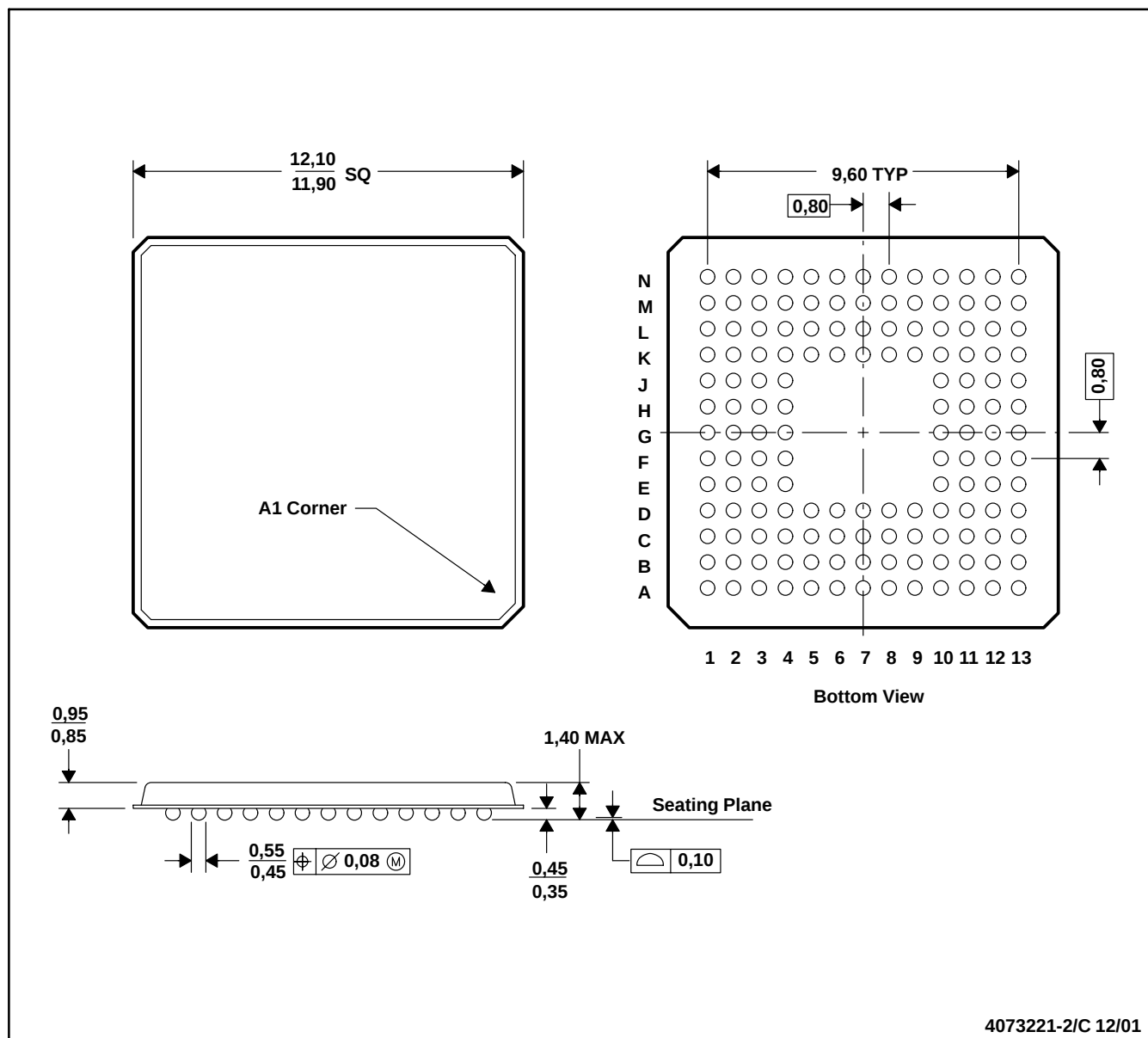
PLASTIC QUAD FLATPACK



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

GGU (S-PBGA-N144)

PLASTIC BALL GRID ARRAY



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 B. This drawing is subject to change without notice.
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