- **Controlled Baseline**
  - **One Assembly/Test Site, One Fabrication Site**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product Change Notification**
- **Qualification Pedigree†**
- **Operating Temperature Ranges:**
  - **Military (M) −55°C to 125°C**
- **High-Performance Floating-Point Digital Signal Processor (DSP):**
  - **SM320LC31-40EP (3.3 V)**
    50-ns Instruction Cycle Time
    220 MOPS, 40 MFLOPS, 20 MIPS
- **32-Bit High-Performance CPU**
- **16-/32-Bit Integer and 32-/40-Bit Floating-Point Operations**
- **32-Bit Instruction and Data Words, 24-Bit Addresses**
- **Two 1K Word × 32-Bit Single-Cycle Dual-Access On-Chip RAM Blocks**
- **Boot-Program Loader**
- **64-Word × 32-Bit Instruction Cache**
- **Eight Extended-Precision Registers**
- **Two Address Generators With Eight Auxiliary Registers and Two Auxiliary Register Arithmetic Units (ARAUs)**
- **Two Low-Power Modes**
- **On-Chip Memory-Mapped Peripherals:**
  - **One Serial Port Supporting 8-/16-/24-/32-Bit Transfers**
  - **Two 32-Bit Timers**
  - **One-Channel Direct Memory Access (DMA) Coprocessor for Concurrent I/O and CPU Operation**
- **Fabricated Using Enhanced Performance Implanted CMOS (EPIC™) Technology by Texas Instruments (TI)**
- **Two- and Three-Operand Instructions**
- **40 / 32-Bit Floating-Point / Integer Multiplier and Arithmetic Logic Unit (ALU)**
- **Parallel ALU and Multiplier Execution in a Single Cycle**
- **Block-Repeat Capability**
- **Zero-Overhead Loops With Single-Cycle Branches**
- **Conditional Calls and Returns**
- **Interlocked Instructions for Multiprocessing Support**
- **Bus-Control Registers Configure Strobe-Control Wait-State Generation**
- **Validated Ada Compiler**
- **Integer, Floating-Point, and Logical Operations**
- **32-Bit Barrel Shifter**
- **One 32-Bit Data Bus (24-Bit Address)**
- **Packaging**
  - **132-Lead Plastic Quad Flatpack (PQ Suffix)**

description

The SM320LC31-EP digital signal processor (DSP) is a 32-bit, floating-point processor manufactured in 0.6-µm triple-level-metal CMOS technology. The device is part of the SMJ320C3x generation of DSPs from Texas Instruments.

The SM320LC31-EP internal busing and special digital-signal-processing instruction set have the speed and flexibility to execute up to 60 MFLOPS. The SM320LC31-EP optimizes speed by implementing functions in hardware that other processors implement through software or microcode. This hardware-intensive approach provides performance previously unavailable on a single chip.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

† Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over an extended temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.

EPIC is a trademark of Texas Instruments Incorporated.
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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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description (continued)

The SM320LC31-EP can perform parallel multiply and ALU operations on integer or floating-point data in a single cycle. Each processor also possesses a general-purpose register file, a program cache, dedicated ARAUs, internal dual-access memories, one DMA channel supporting concurrent I/O, and a short machine-cycle time. High performance and ease of use are results of these features.

General-purpose applications are greatly enhanced by the large address space, multiprocessor interface, internally and externally generated wait states, one external interface port, two timers, one serial port, and multiple-interrupt structure. The SM320LC31-EP supports a wide variety of system applications from host processor to dedicated coprocessor.

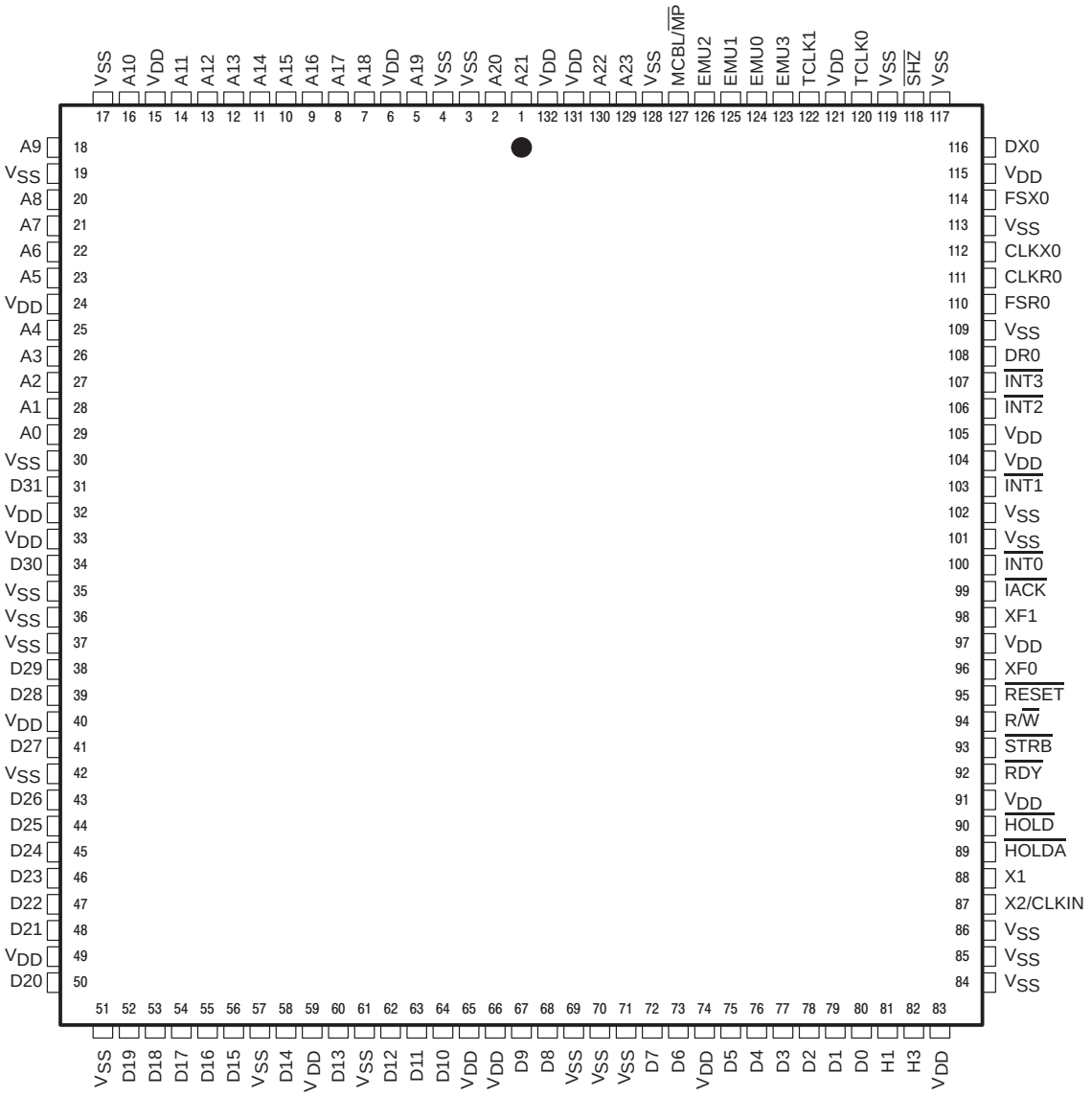
High-level-language support is easily implemented through a register-based architecture, large address space, powerful addressing modes, flexible instruction set, and well-supported floating-point arithmetic.

For additional information when designing for cold temperature operation, please see Texas Instruments application report *320C3x, 320C4x and 320MCM42x Power-up Sensitivity at Cold Temperature*, literature number SGUA001.

SM320LC31-EP pinout (top view)

The SM320LC31-EP device is packaged in a132-pin plastic quad flatpack (PQ Suffix). The full part number is SM320LC31PQM40EP.

PQ PACKAGE
(TOP VIEW)



Terminal Assignments (PQ Package)

PIN NUMBER	PIN NAME	PIN NUMBER	PIN NAME	PIN NUMBER	PIN NAME	PIN NUMBER	PIN NAME
29	A0	64	D10	103	$\overline{\text{INT1}}$	30	V_{SSL}†
28	A1	63	D11	106	$\overline{\text{INT2}}$	35	V_{SSL}†
27	A2	62	D12	107	$\overline{\text{INT3}}$	36	DV_{SS}
26	A3	60	D13	127	MCBL/$\overline{\text{MP}}$	37	IV_{SS}†
25	A4	58	D14	92	R/$\overline{\text{W}}$	42	DV_{SS}
23	A5	56	D15	95	$\overline{\text{RDY}}$	51	CV_{SS}†
22	A6	55	D16	94	$\overline{\text{RESET}}$	57	IV_{SS}†
21	A7	54	D17	118	$\overline{\text{SHZ}}$	61	DV_{SS}
20	A8	53	D18	93	$\overline{\text{STRB}}$	69	V_{SSL}†
18	A9	52	D19	120	TCLK0	70	V_{SSL}†
16	A10	50	D20			71	DV_{SS}
14	A11	48	D21			84	CV_{SS}†
13	A12	47	D22	6	AV_{DD}‡	85	IV_{SS}†
12	A13	46	D23	15	AV_{DD}‡	86	DV_{SS}
11	A14	45	D24	24	V_{DDL}	101	V_{SSL}†
10	A15	44	D25	32	V_{DDL}	102	CV_{SS}†
9	A16	43	D26	33	DV_{DD}‡	109	IV_{SS}†
8	A17	41	D27	40	DV_{DD}‡	113	V_{SUBS}§
7	A18	39	D28	49	DV_{DD}‡	117	DV_{SS}
5	A19	38	D29	59	V_{DDL}	119	CV_{SS}†
2	A20	34	D30	65	V_{DDL}	128	X1
1	A21	31	D31	66	DV_{DD}‡	88	X2/CLKIN
130	A22	108	DR0	74	DV_{DD}‡	87	XF0
129	A23	116	DX0	83	CV_{DD}‡	96	XF1
111	CLKR0	124	EMU0	91	CV_{DD}‡	98	No Connect
112	CLKX0	125	EMU1	97	V_{DDL}		
80	D0	126	EMU2	104	V_{DDL}		
79	D1	123	EMU3	105	PV_{DD}‡		
78	D2	110	FSR0	115	PV_{DD}‡		
77	D3	114	FSX0	121	V_{DDL}		
76	D4	81	$\overline{\text{HOLD}}$	131	V_{DDL}		
75	D5	82	$\overline{\text{HOLDA}}$	132	V_{SSL}†		
73	D6	90	H1	3	DV_{SS}		
72	D7	89	H3	4	CV_{SS}†		
68	D8	99	$\overline{\text{IACK}}$	17	DV_{SS}		
67	D9	100	$\overline{\text{INT0}}$	19	CV_{SS}†		

† CV_{SS}, V_{SSL}, and IV_{SS} are on the same plane.
‡ AV_{DD}, DV_{DD}, CV_{DD}, and PV_{DD} are on the same plane.
§ V_{SUBS} connects to die metallization. Tie this pin to clean ground.

Terminal Functions

TERMINAL NAME	QTY	TYPE†	DESCRIPTION	CONDITIONS WHEN SIGNAL IS Z TYPE‡		
PRIMARY-BUS INTERFACE						
D31−D0	32	I/O/Z	32-bit data port	S	H	R
A23−A0	24	O/Z	24-bit address port	S	H	R
R/$\overline{W}$	1	O/Z	Read/write. R/$\overline{W}$ is high when a read is performed and low when a write is performed over the parallel interface.	S	H	R
$\overline{STRB}$	1	O/Z	External-access strobe	S	H	
$\overline{RDY}$	1	I	Ready. $\overline{RDY}$ indicates that the external device is prepared for a transaction completion.			
$\overline{HOLD}$	1	I	Hold. When $\overline{HOLD}$ is a logic low, any ongoing transaction is completed. A23−A0, D31−D0, $\overline{STRB}$, and R/$\overline{W}$ are placed in the high-impedance state and all transactions over the primary-bus interface are held until $\overline{HOLD}$ becomes a logic high or until the NOHOLD bit of the primary-bus-control register is set.			
$\overline{HOLDA}$	1	O/Z	Hold acknowledge. $\overline{HOLDA}$ is generated in response to a logic low on $\overline{HOLD}$. $\overline{HOLDA}$ indicates that A23−A0, D31−D0, $\overline{STRB}$, and R/$\overline{W}$ are in the high-impedance state and that all transactions over the bus are held. $\overline{HOLDA}$ is high in response to a logic high of $\overline{HOLD}$ or the NOHOLD bit of the primary-bus-control register is set.	S		
CONTROL SIGNALS						
$\overline{RESET}$	1	I	Reset. When $\overline{RESET}$ is a logic low, the device is in the reset condition. When $\overline{RESET}$ becomes a logic high, execution begins from the location specified by the reset vector.			
$\overline{INT3}$−$\overline{INT0}$	4	I	External interrupts			
$\overline{IACK}$	1	O/Z	Interrupt acknowledge. $\overline{IACK}$ is generated by the IACK instruction. $\overline{IACK}$ can be used to indicate the beginning or the end of an interrupt-service routine.	S		
MCBL/$\overline{MP}$	1	I	Microcomputer boot-loader/microprocessor mode-select			
$\overline{SHZ}$	1	I	Shutdown high impedance. When active, $\overline{SHZ}$ shuts down the device and places all pins in the high-impedance state. $\overline{SHZ}$ is used for board-level testing to ensure that no dual-drive conditions occur. **CAUTION:** A low on $\overline{SHZ}$ corrupts the device memory and register contents. Reset the device with $\overline{SHZ}$ high to restore it to a known operating condition.			
XF1, XF0	2	I/O/Z	External flags. XF1 and XF0 are used as general-purpose I/Os or to support interlocked processor instruction.	S		R
SERIAL PORT 0 SIGNALS						
CLKR0	1	I/O/Z	Serial port 0 receive clock. CLKR0 is the serial shift clock for the serial port 0 receiver.	S		R
CLKX0	1	I/O/Z	Serial port 0 transmit clock. CLKX0 is the serial shift clock for the serial port 0 transmitter.	S		R
DR0	1	I/O/Z	Data-receive. Serial port 0 receives serial data on DR0.	S		R
DX0	1	I/O/Z	Data-transmit output. Serial port 0 transmits serial data on DX0.	S		R
FSR0	1	I/O/Z	Frame-synchronization pulse for receive. The FSR0 pulse initiates the data-receive process using DR0.	S		R
FSX0	1	I/O/Z	Frame-synchronization pulse for transmit. The FSX0 pulse initiates the data-transmit process using DX0.	S		R
TIMER SIGNALS						
TCLK0	1	I/O/Z	Timer clock 0. As an input, TCLK0 is used by timer 0 to count external pulses. As an output, TCLK0 outputs pulses generated by timer 0.	S		
TCLK1	1	I/O/Z	Timer clock 1. As an input, TCLK0 is used by timer 1 to count external pulses. As an output, TCLK1 outputs pulses generated by timer 1.	S		

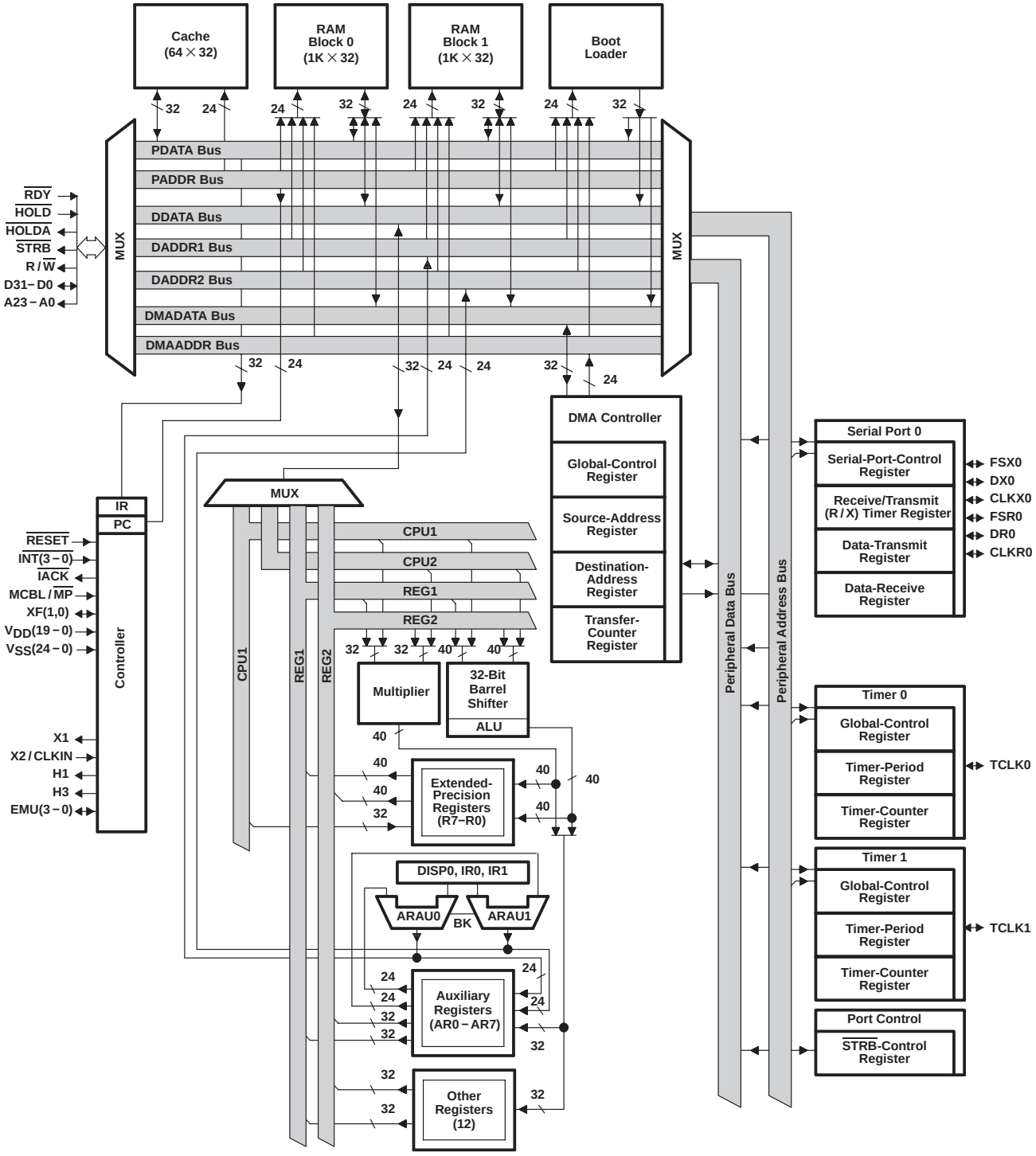
† I = input, O = output, Z = high-impedance state
‡ S = $\overline{SHZ}$ active, H = $\overline{HOLD}$ active, R = $\overline{RESET}$ active

Terminal Functions (Continued)

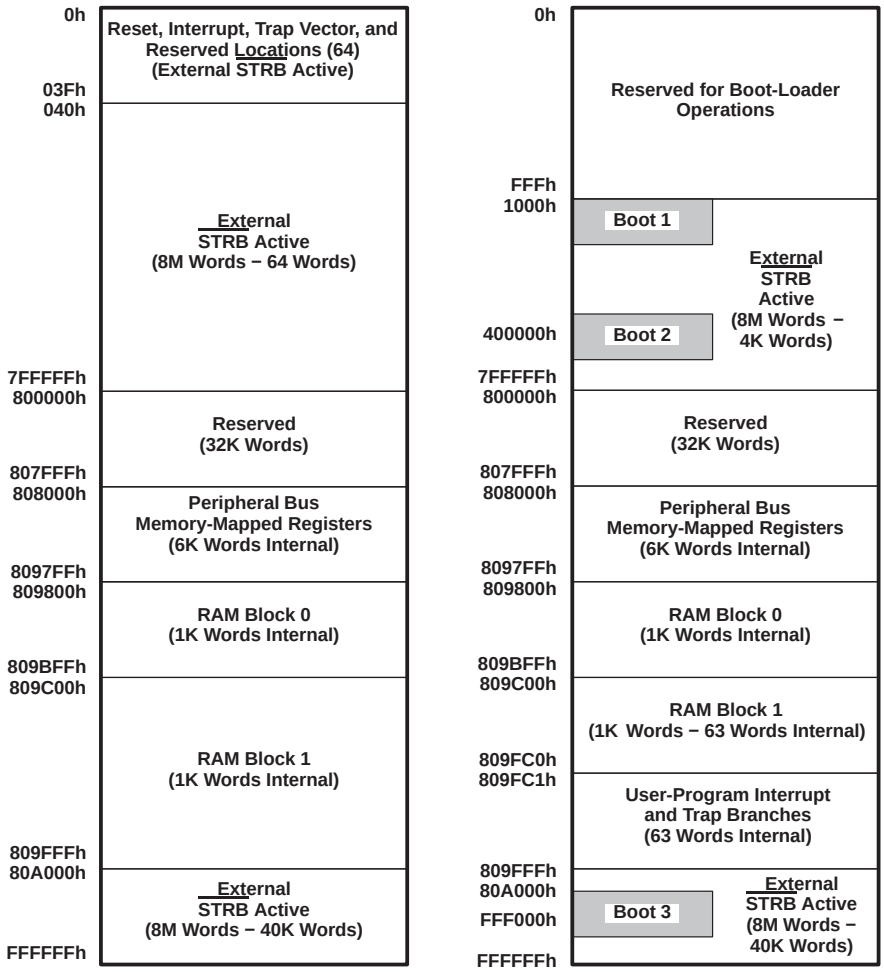
TERMINAL NAME	TERMINAL QTY	TYPE†	DESCRIPTION	CONDITIONS WHEN SIGNAL IS Z TYPE‡
SUPPLY AND OSCILLATOR SIGNALS				
H1	1	O/Z	External H1 clock. H1 has a period equal to twice CLKIN.	S
H3	1	O/Z	External H3 clock. H3 has a period equal to twice CLKIN.	S
V_{DD}	20	I	5-V supply for C31 devices and 3.3-V supply for LC31 devices. All must be connected to a common supply plane.§	
V_{SS}	25	I	Ground. All grounds must be connected to a common ground plane.	
X1	1	O	Output from the internal-crystal oscillator. If a crystal is not used, X1 should be left unconnected.	
X2/CLKIN	1	I	Internal-oscillator input from a crystal or a clock	
RESERVED¶				
EMU2−EMU0	3	I	Reserved for emulation. Use pullup resistors to V_{DD}	
EMU3	1	O/Z	Reserved for emulation	S

† I = input, O = output, Z = high-impedance state
‡ S = $\overline{SHZ}$ active, H = HOLD active, R = $\overline{RESET}$ active
§ Recommended decoupling capacitor value is 0.1 μF.
¶ Follow the connections specified for the reserved pins. Use 18-kΩ−22-kΩ pullup resistors for best results. All V_{DD} supply pins must be connected to a common supply plane, and all ground pins must be connected to a common ground plane.

functional block diagram



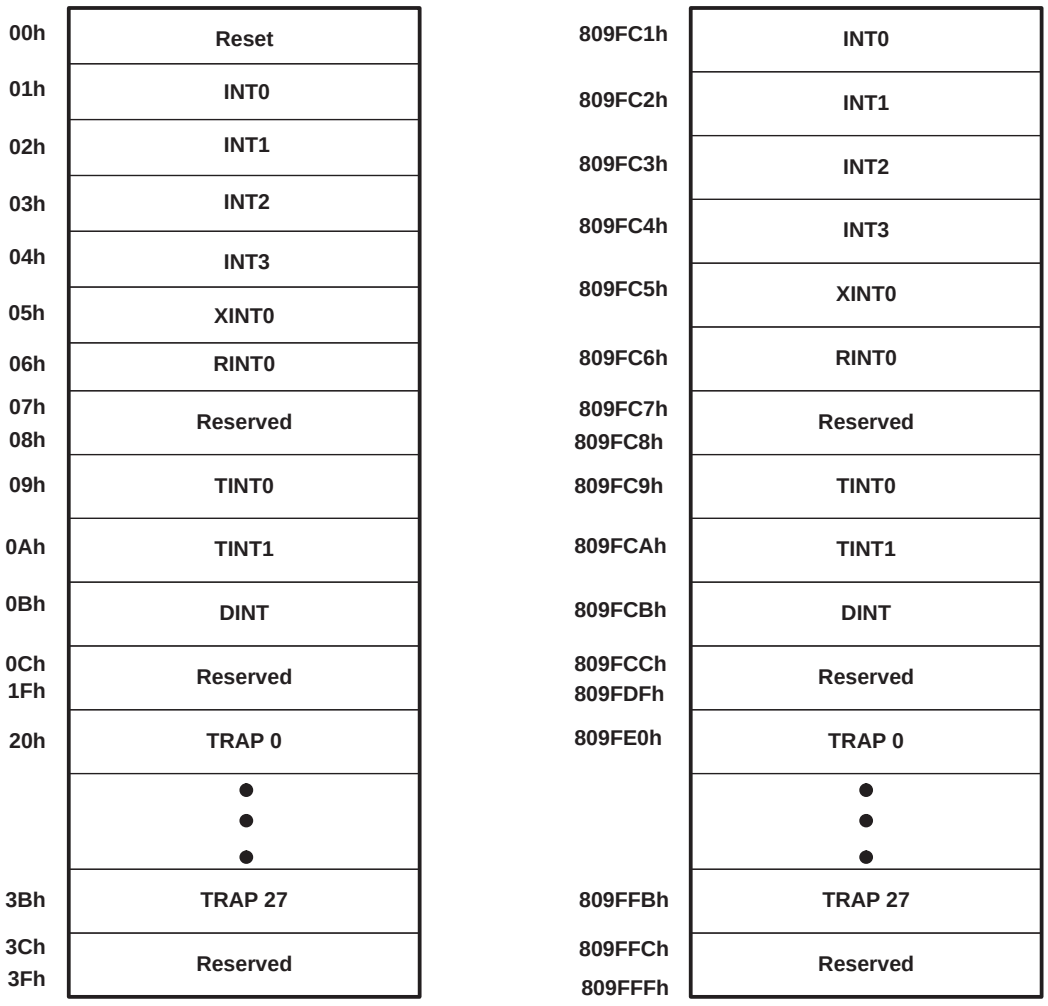
memory map†



† Figure 1 depicts the memory map for the SMJ320C31. See the *TMS320C3x Users Guide* (literature number SPRU031) for a detailed description of this memory mapping.

Figure 1. SM320C31-EP Memory Map

memory map (continued)



(a) Microprocessor Mode

(b) Microcomputer / Boot-Loader Mode

Figure 2. Reset, Interrupt, and Trap Vector/Branches Memory-Map Locations

memory map (continued)

808000h	DMA Global Control
808004h	DMA Source Address
808006h	DMA Destination Address
808008h	DMA Transfer Counter
808020h	Timer 0 Global Control
808024h	Timer 0 Counter
808028h	Timer 0 Period Register
808030h	Timer 1 Global Control
808034h	Timer 1 Counter
808038h	Timer 1 Period Register
808040h	Serial Global Control
808042h	FSX/DX/CLKX Serial Port Control
808043h	FSR/DR/CLKR Serial Port Control
808044h	Serial R/X Timer Control
808045h	Serial R/X Timer Counter
808046h	Serial R/X Timer Period Register
808048h	Data-Transmit
80804Ch	Data-Receive
808064h	Primary-Bus Control

†Shading denotes reserved address locations

Figure 3. Peripheral Bus Memory-Mapped Registers†

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

Supply voltage, V_{DD} (see Note 1) . . . . . −0.3 V to 5 V
Input voltage, V_I . . . . . −0.3 V to 5 V
Output voltage, V_O . . . . . −0.3 V to 5 V
Continuous power dissipation (worst case) (see Note 2) . . . . . 850 mW
Operating case temperature, T_C . . . . . −55°C to 125°C
Storage temperature, T_{stg} . . . . . −65°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.

NOTES: 1. All voltage values are with respect to V_{SS}.
2. Actual operating power is less. This value was obtained under specially produced worst-case test conditions for the TMS320C31-33 and the TMS320LC31-40, which are not sustained during normal device operation. These conditions consist of continuous parallel writes of a checkerboard pattern to both primary and extension buses at the maximum rate possible. See normal (I_{CC}) current specification in the electrical characteristics table and also read *Calculation of TMS320C30 Power Dissipation Application Report* (literature number SPRA020).

recommended operating conditions (see Note 3)

		MIN	NOM	MAX	UNIT
V_{DD}	Supply voltage (DV_{DD}, etc.)	3.13	3.3	3.47	V
V_{SS}	Supply voltage (CV_{SS}, etc.)		0		V
V_{IH}	High-level input voltage (except $\overline{\text{RESET}}$)	1.8		V_{DD} + 0.3*	V
	High-level input voltage ($\overline{\text{RESET}}$)	2.2		V_{DD} + 0.3*	V
V_{IL}	Low-level input voltage	− 0.3*		0.6	V
I_{OH}	High-level output current			− 300	µA
I_{OL}	Low-level output current			2	mA
T_C	Operating case temperature	−55		125	°C
V_{TH}	High-level input voltage for CLKIN	2.5		V_{DD} + 0.3*	V

* This parameter is not production tested.

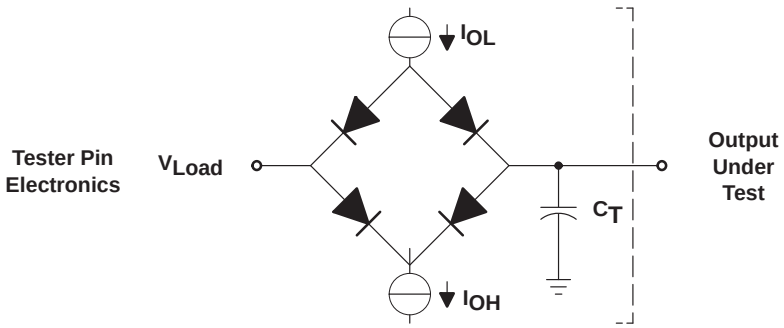
NOTE 3: All voltage values are with respect to V_{SS}. All input and output voltage levels are TTL-compatible. CLKIN can be driven by a CMOS clock.

electrical characteristics over recommended ranges of supply voltage (unless otherwise noted) (see Note 3)†

PARAMETER		TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
V_{OH}	High-level output voltage	V_{DD} = MIN, I_{OH} = MAX		2			V
V_{OL}	Low-level output voltage	V_{DD} = MIN, I_{OH} = MAX				0.4	V
I_Z	High-impedance current	V_{DD} = MAX		− 20		+ 20	µA
I_I	Input current	V_I = V_{SS} to V_{DD}		− 10		+ 10	µA
I_{IP}	Input current (with internal pullup)	Inputs with internal pullups§		− 600		10	µA
I_{CC}	Supply current¶#	T_A = 25°C, V_{DD} = MAX	f_x = 40 MHz		150	300	mA
I_{DD}	Supply current	Standby, IDLE2, Clocks shut off			20		µA
C_i	Input capacitance	All inputs except CLKIN				15*	pF
		CLKIN				25	
C_o	Output capacitance					20*	pF

† All input and output voltage levels are TTL compatible.
‡ For LC31, all typical values are at V_{DD} = 3.3 V, T_A = 25°C.
§ Pins with internal pullup devices: INT3–INT0, MCBL/MP.
¶ Actual operating current is less than this maximum value. This value was obtained under specially produced worst-case test conditions, which are not sustained during normal device operation. These conditions consist of continuous parallel writes of a checkerboard pattern to both primary and expansion buses at the maximum rate possible. See *Calculation of TMS320C30 Power Dissipation Application Report* (literature number SPRA020).
# f_x is the input clock frequency.
* This parameter is not production tested.
NOTE 3: All voltage values are with respect to V_{SS}. All input and output voltage levels are TTL-compatible. CLKIN can be driven by a CMOS clock.

PARAMETER MEASUREMENT INFORMATION



Where: I_{OL} = 2 mA (all outputs)
I_{OH} = 300 µA (all outputs)
V_{LOAD} = 2.15 V
C_T = 80-pF typical load-circuit capacitance

Figure 4. SM320LC31-EP Test Load Circuit

PARAMETER MEASUREMENT INFORMATION

signal transition levels for LC31 (see Figure 5 and Figure 6)

Outputs are driven to a minimum logic-high level of 2 V and to a maximum logic-low level of 0.4 V. Output transition times are specified as follows:

- For a high-to-low transition on an output signal, the level at which the output is said to be no longer high is 2 V and the level at which the output is said to be low is 1 V.
- For a low-to-high transition, the level at which the output is said to be no longer low is 1 V and the level at which the output is said to be high is 2 V.

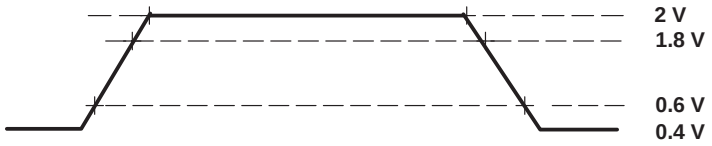


Figure 5. LC31 Output Levels

Transition times for inputs are specified as follows:

- For a high-to-low transition on an input signal, the level at which the input is said to be no longer high is 1.8 V and the level at which the input is said to be low is 0.6 V.
- For a low-to-high transition on an input signal, the level at which the input is said to be no longer low is 0.6 V and the level at which the input is said to be high is 1.8 V.

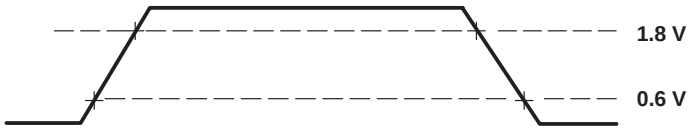


Figure 6. LC31 Input Levels

PARAMETER MEASUREMENT INFORMATION

timing parameter symbology

Timing parameter symbols used herein were created in accordance with JEDEC Standard 100-A. In order to shorten the symbols, some of the pin names and other related terminology have been abbreviated as follows, unless otherwise noted:

A	A23−A0	H	H1 and H3
ASYNCH	Asynchronous reset signals	HOLD	$\overline{\text{HOLD}}$
C	CLKX0	HOLDA	$\overline{\text{HOLDA}}$
CI	CLKIN	IACK	$\overline{\text{IACK}}$
CLKR	CLKR0	INT	$\overline{\text{INT3}}$−$\overline{\text{INT0}}$
CONTROL	Control signals	RDY	$\overline{\text{RDY}}$
D	D31−D0	RW	R/$\overline{\text{W}}$
DR	DR	RESET	$\overline{\text{RESET}}$
DX	DX	S	$\overline{\text{STRB}}$
FS	FSX/R	SCK	CLKX/R
FSX	FSX0	SHZ	$\overline{\text{SHZ}}$
FSR	FSR0	TCLK	TCLK0, TCLK1, or TCLKx
GPI	General-purpose input	XF	XF0, XF1, or XFx
GPIO	General-purpose input/output; peripheral pin	XFIO	XFx switching from input to output
GPO	General-purpose output		

timing

Timing specifications apply to the SM320LC31-EP.

X2/CLKIN, H1, and H3 timing

The following table defines the timing parameters for the X2/CLKIN, H1, and H3 interface signals.

timing parameters for X2/CLKIN, H1, H3 (see Figure 7, Figure 8, and Figure 9)

NO.			MIN	MAX	UNIT
1	$t_{f(CI)}$	Fall time, CLKIN		5*	ns
2	$t_{w(CIL)}$	Pulse duration, CLKIN low $t_{c(CI)}$ = min	9		ns
3	$t_{w(CIH)}$	Pulse duration, CLKIN high $t_{c(CI)}$ = min	9		ns
4	$t_{r(CI)}$	Rise time, CLKIN		5*	ns
5	$t_{c(CI)}$	Cycle time, CLKIN	25	303	ns
6	$t_{f(H)}$	Fall time, H1 and H3		3	ns
7	$t_{w(HL)}$	Pulse duration, H1 and H3 low	P−5†		ns
8	$t_{w(HH)}$	Pulse duration, H1 and H3 high	P−6†		ns
9	$t_{r(H)}$	Rise time, H1 and H3		3	ns
10	$t_{d(HL-HH)}$	Delay time. from H1 low to H3 high or from H3 low to H1 high	0	4	ns
11	$t_{c(H)}$	Cycle time, H1 and H3	50	606	ns

† P = $t_{c(CI)}$
* This parameter is not production tested.

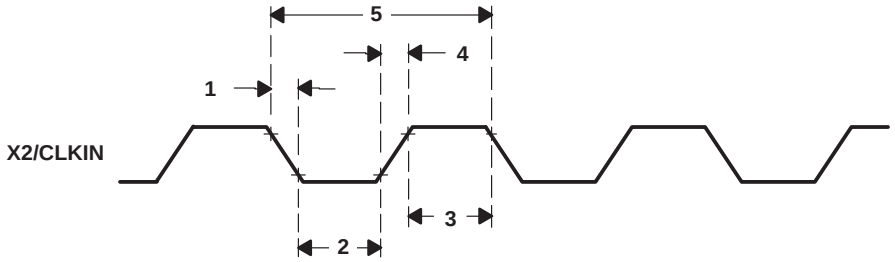


Figure 7. Timing for X2/CLKIN

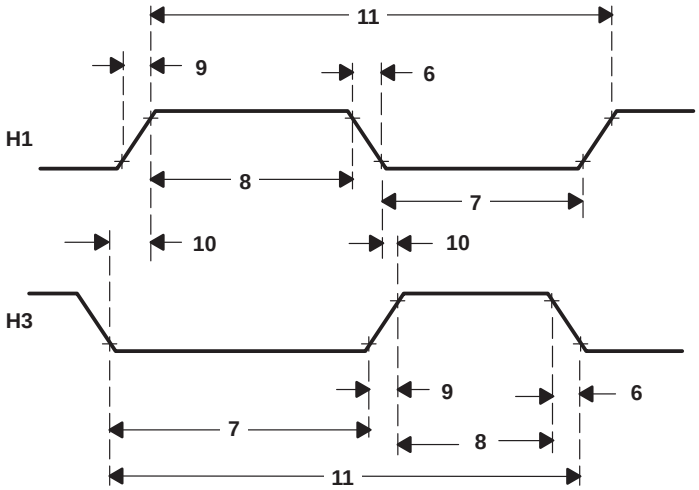


Figure 8. Timing for H1 and H3

X2/CLKIN, H1, and H3 timing (continued)

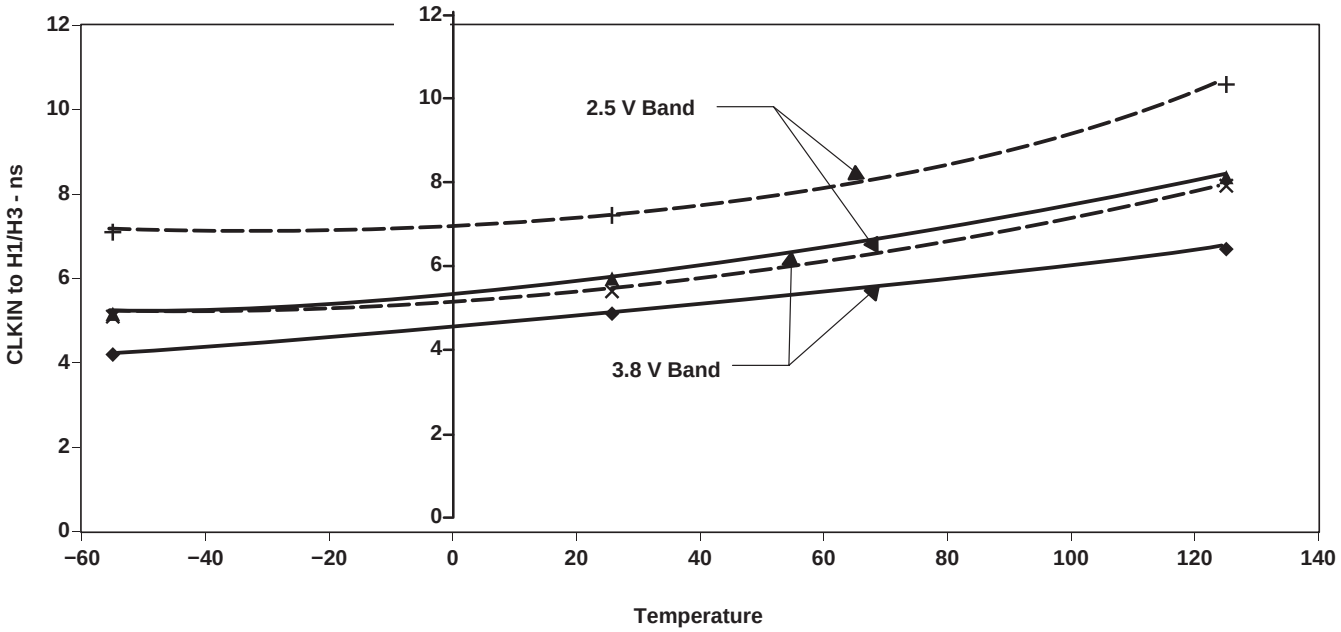


Figure 9. SM320LC31-EP CLKIN to H1/H3 as a Function of Temperature (Typical)

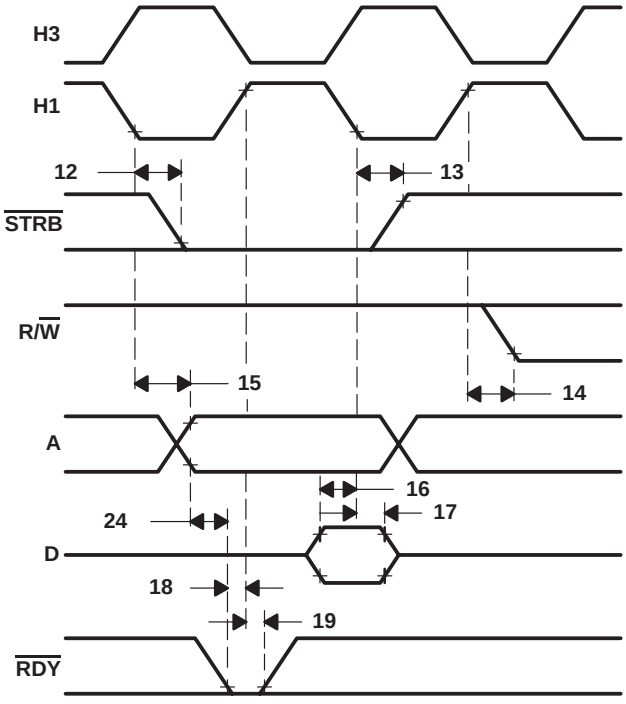
memory read/write timing

The following table defines memory read/write timing parameters for $\overline{\text{STRB}}$.

timing parameters for memory ($\overline{\text{STRB}}$ = 0) read/write (see Figure 10 and Figure 11)†

NO.			MIN	MAX	UNIT
12	$t_{d(H1L-SL)}$	Delay time, H1 low to $\overline{\text{STRB}}$ low	0*	6	ns
13	$t_{d(H1L-SH)}$	Delay time, H1 low to $\overline{\text{STRB}}$ high	0*	6	ns
14	$t_{d(H1H-RWL)R}$	Delay time, H1 high to R/$\overline{\text{W}}$ low (read)	0*	9	ns
15	$t_{d(H1L-A)}$	Delay time, H1 low to A valid	0*	10	ns
16	$t_{su(D-H1L)R}$	Setup time, D before H1 low (read)	14		ns
17	$t_{h(H1L-D)R}$	Hold time, D after H1 low (read)	0		ns
18	$t_{su(RDY-H1H)}$	Setup time, $\overline{\text{RDY}}$ before H1 high	8		ns
19	$t_{h(H1H-RDY)}$	Hold time, $\overline{\text{RDY}}$ after H1 high	0		ns
20	$t_{d(H1H-RWH)W}$	Delay time, H1 high to R/$\overline{\text{W}}$ high (write)		9	ns
21	$t_{v(H1L-D)W}$	Valid time, D after H1 low (write)		17	ns
22	$t_{h(H1H-D)W}$	Hold time, D after H1 high (write)	0		ns
23	$t_{d(H1H-A)W}$	Delay time, H1 high to A valid on back-to-back write cycles (write)		15	ns
24	$t_{d(A-RDY)}$	Delay time, $\overline{\text{RDY}}$ from A valid		7*	ns

† See Figure 12 for address bus timing variation with load capacitance greater than typical load-circuit capacitance (C_T = 80 pF).
* This parameter is not production tested.



NOTE A: $\overline{\text{STRB}}$ remains low during back-to-back read operations.

Figure 10. Timing for Memory ($\overline{\text{STRB}}$ = 0) Read

memory read/write timing (continued)

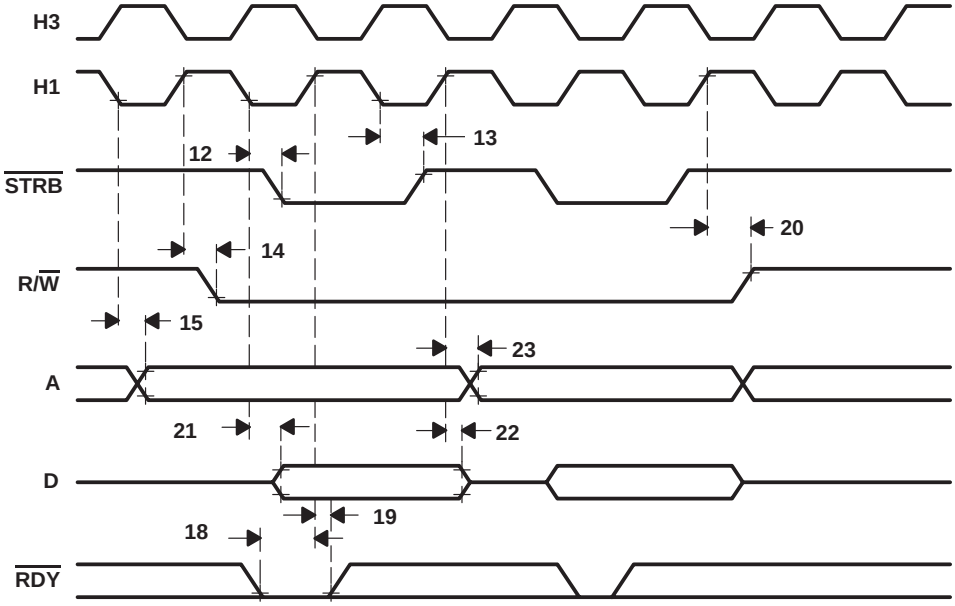
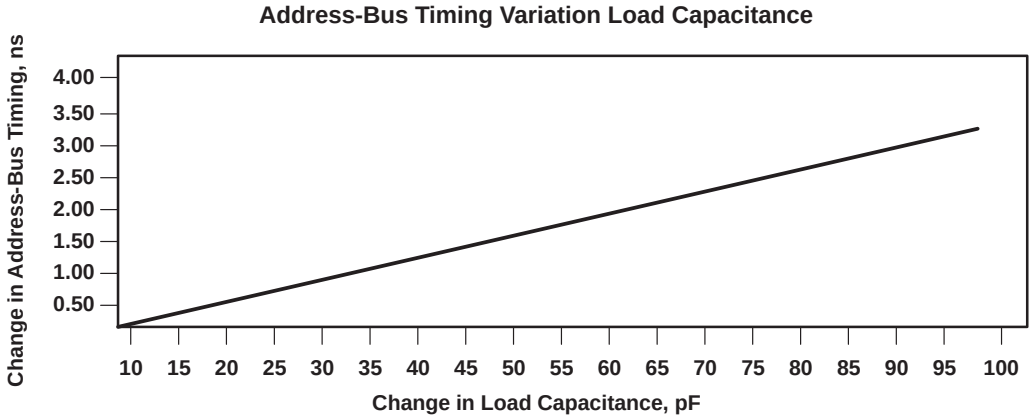


Figure 11. Timing for Memory ($\overline{\text{STRB}}$ = 0) Write



NOTE A: 30 pF/ns slope

Figure 12. Address-Bus Timing Variation With Load Capacitance (see Note A)

XF0 and XF1 timing when executing LDFI or LDII

The following table defines the timing parameters for XF0 and XF1 during execution of LDFI or LDII.

timing for XF0 and XF1 when executing LDFI or LDII (see Figure 13)

NO.			MIN	MAX	UNIT
25	$t_{d(H3H-XF0L)}$	Delay time, H3 high to XF0 low		13	ns
26	$t_{su(XF1-H1L)}$	Setup time, XF1 before H1 low	10		ns
27	$t_{h(H1L-XF1)}$	Hold time, XF1 after H1 low	0		ns

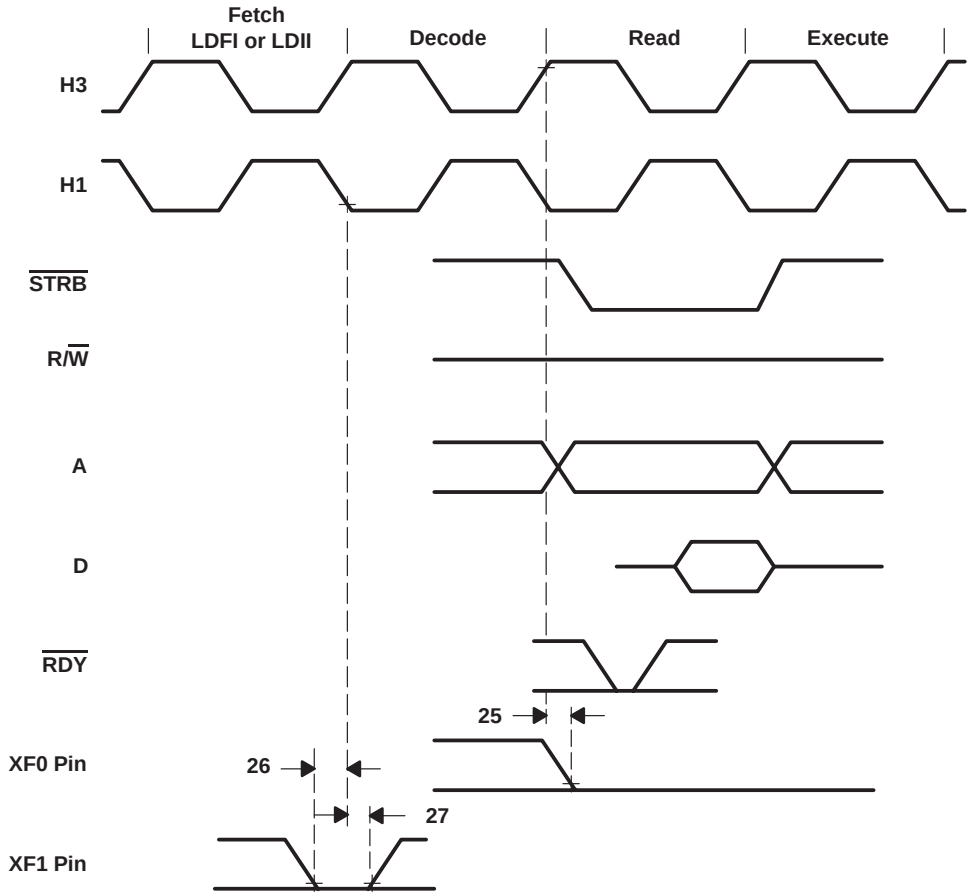


Figure 13. Timing for XF0 and XF1 When Executing LDFI or LDII

XF0 timing when executing STFI and STII†

The following table defines the timing parameters for the XF0 pin during execution of STFI or STII.

timing for XF0 when executing STFI or STII (see Figure 14)

NO.			MIN	MAX	UNIT
28	$t_{d(H3H-XF0H)}$	Delay time, H3 high to XF0 high		13	ns

† XF0 is always set high at the beginning of the execute phase of the interlock-store instruction. When no pipeline conflicts occur, the address of the store is also driven at the beginning of the execute phase of the interlock-store instruction. However, if a pipeline conflict prevents the store from executing, the address of the store will not be driven until the store can execute.

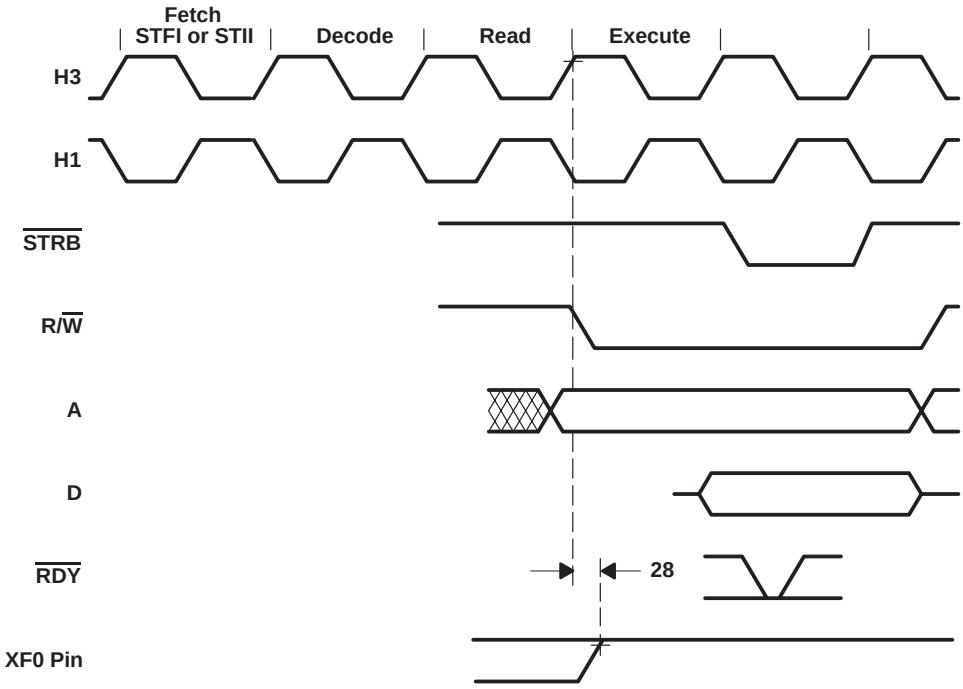


Figure 14. Timing for XF0 When Executing an STFI or STII

XF0 and XF1 timing when executing SIGI

The following table defines the timing parameters for the XF0 and XF1 pins during execution of SIGI.

timing for XF0 and XF1 when executing SIGI (see Figure 15)

NO.			MIN	MAX	UNIT
29	$t_{d(H3H-XF0L)}$	Delay time, H3 high to XF0 low		13	ns
30	$t_{d(H3H-XF0H)}$	Delay time, H3 high to XF0 high		13	ns
31	$t_{su(XF1-H1L)}$	Setup time, XF1 before H1 low	10		ns
32	$t_{h(H1L-XF1)}$	Hold time, XF1 after H1 low	0		ns

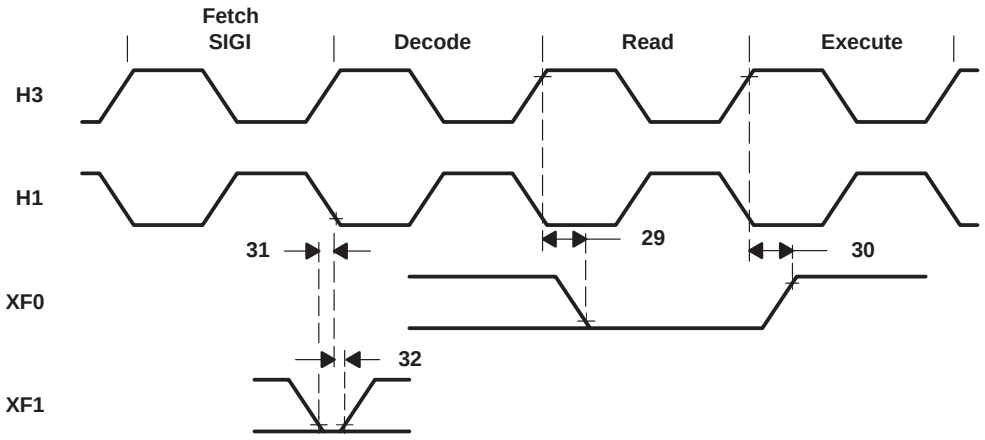


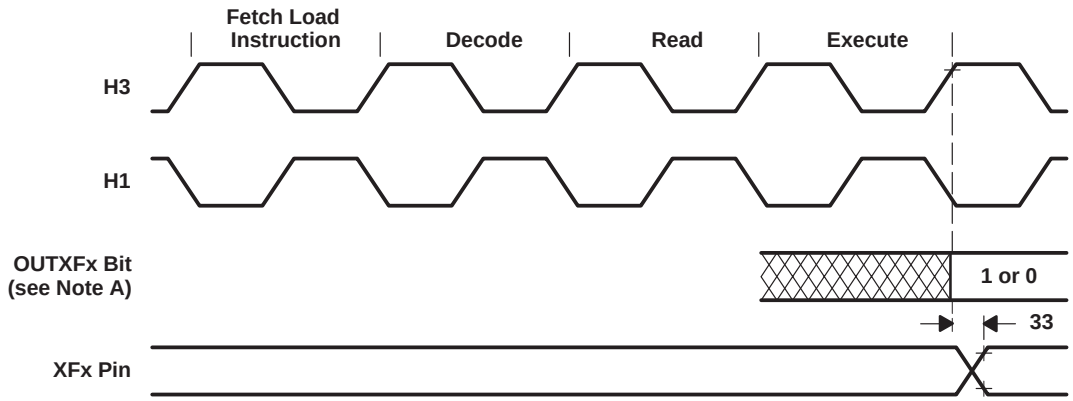
Figure 15. Timing for XF0 and XF1 When Executing SIGI

loading when XF is configured as an output

The following table defines the timing parameter for loading the XF register when the XFx pin is configured as an output.

timing for loading the XF register when configured as an output pin (see Figure 16)

NO.			MIN	MAX	UNIT
33	$t_{v(H3H-XF)}$	Valid time, H3 high to XFx		13	ns



NOTE A: OUTXFx represents either bit 2 or 6 of the IOF register.

Figure 16. Timing for Loading XF Register When Configured as an Output Pin

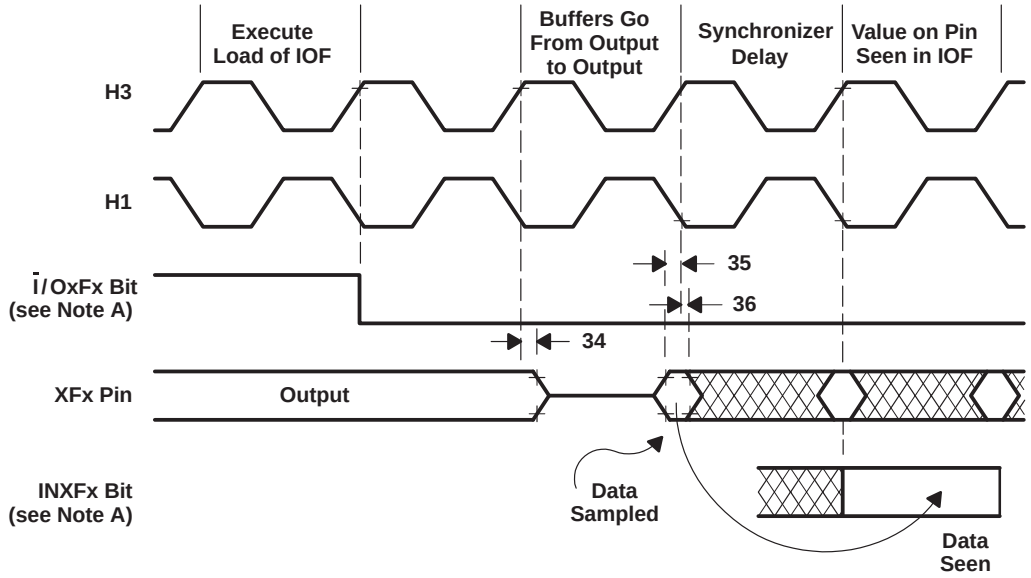
changing XFx from an output to an input

The following table defines the timing parameters for changing the XFx pin from an output pin to an input pin.

timing of XFx changing from output to input mode (see Figure 17)

NO.			MIN	MAX	UNIT
34	$t_{h(H3H-XF)}$	Hold time, XFx after H3 high		13*	ns
35	$t_{su(XF-H1L)}$	Setup time, XFx before H1 low	10		ns
36	$t_{h(H1L-XF)}$	Hold time, XFx after H1 low	0		ns

* This parameter is not production tested.



NOTE A: $\overline{I}$/OxFx represents either bit 1 or bit 5 of the IOF register, and INXFx represents either bit 3 or bit 7 of the IOF register.

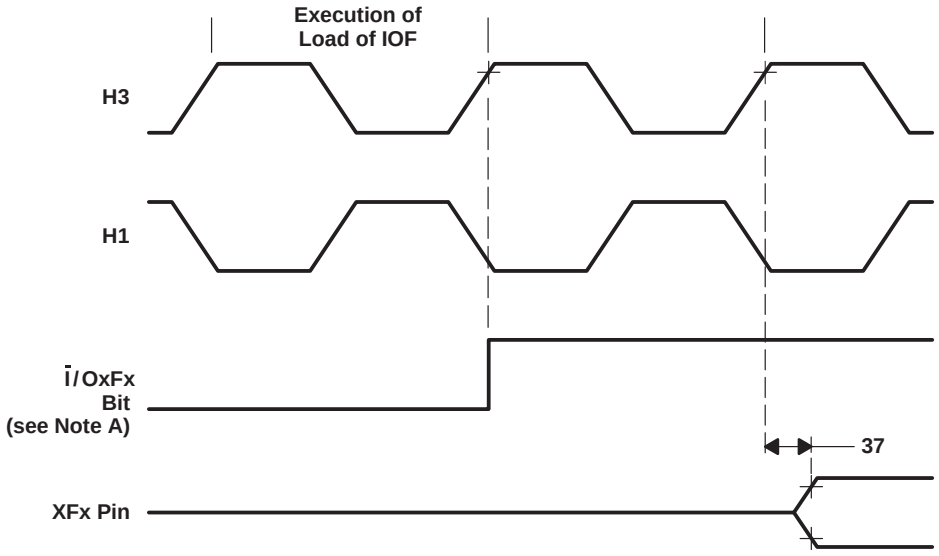
Figure 17. Timing for Change of XFx From Output to Input Mode

changing XFx from an input to an output

The following table defines the timing parameter for changing the XFx pin from an input pin to an output pin.

timing for XFx changing from input to output mode (see Figure 18)

NO.			MIN	MAX	UNIT
37	$t_{d(H3H-XFIO)}$	Delay time, H3 high to XFx switching from input to output		17	ns



NOTE A: I/OxFx represents either bit 1 or bit 5 of the IOF register.

Figure 18. Timing for Change of XFx From Input to Output Mode

reset timing

RESET is an asynchronous input that can be asserted at any time during a clock cycle. If the specified timings are met, the exact sequence shown in Figure 19 occurs; otherwise, an additional delay of one clock cycle is possible.

The asynchronous reset signals include XF0/1, CLKX0, DX0, FSX0, CLKR0, DR0, FSR0, and TCLK0/1.

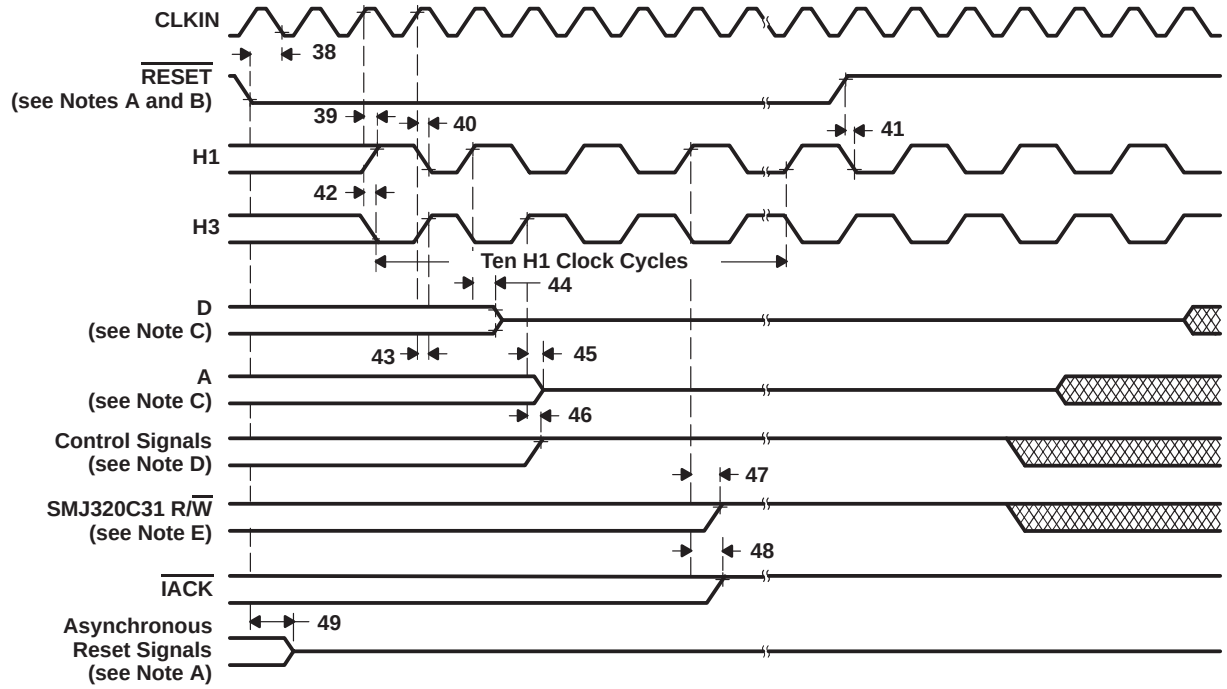
Resetting the device initializes the primary- and expansion-bus control registers to seven software wait states and therefore results in slow external accesses until these registers are initialized.

HOLD is an asynchronous input and can be asserted during reset.

$\overline{\text{RESET}}$ timing (see Figure 19)

NO.			MIN	MAX	UNIT
38	$t_{su(RESET-CIL)}$	Setup time, $\overline{\text{RESET}}$ before CLKIN low	10	P†*	ns
39	$t_{d(CLKINH-H1H)}$	Delay time, CLKIN high to H1 high (see Note 4)	2	14	ns
40	$t_{d(CLKINH-H1L)}$	Delay time, CLKIN high to H1 low (see Note 4)	2	14	ns
41	$t_{su(RESETH-H1L)}$	Setup time, $\overline{\text{RESET}}$ high before H1 low and after ten H1 clock cycles	9		ns
42	$t_{d(CLKINH-H3L)}$	Delay time, CLKIN high to H3 low (see Note 4)	2	14	ns
43	$t_{d(CLKINH-H3H)}$	Delay time, CLKIN high to H3 high (see Note 4)	2	14	ns
44	$t_{dis(H1H-DZ)}$	Disable time, H1 high to D (high impedance)		13*	ns
45	$t_{dis(H3H-AZ)}$	Disable time, H3 high to A (high impedance)		9*	ns
46	$t_{d(H3H-CONTROLH)}$	Delay time, H3 high to control signals high		9*	ns
47	$t_{d(H1H-RWH)}$	Delay time, H1 high to R/$\overline{\text{W}}$ high		9*	ns
48	$t_{d(H1H-IACKH)}$	Delay time, H1 high to $\overline{\text{IACK}}$ high		9*	ns
49	$t_{dis(RESETL-ASYNCH)}$	Disable time, $\overline{\text{RESET}}$ low to asynchronous reset signals disabled (high impedance)		21*	ns

† P = $t_{c(CI)}$
* This parameter is not production tested.
NOTE 4: See Figure 9 for typical temperature dependence.



NOTES: A. Asynchronous reset signals include XF0/1, CLKX0, DX0, FSX0, CLKR0, DR0, FSR0, and TCLK0/1.
B. $\overline{\text{RESET}}$ is an asynchronous input and can be asserted at any point during a clock cycle. If the specified timings are met, the exact sequence shown occurs; otherwise, an additional delay of one clock cycle is possible.
C. In microprocessor mode, the reset vector is fetched twice, with seven software wait states each time. In microcomputer mode, the reset vector is fetched twice, with no software wait states.
D. Control signals include $\overline{\text{STRB}}$.
E. The R/$\overline{\text{W}}$ outputs are placed in a high-impedance state during reset and can be provided with a resistive pullup, nominally 18−22 kΩ, if undesirable spurious writes are caused when these outputs go low.

Figure 19. Timing for $\overline{\text{RESET}}$

interrupt response timing

The following table defines the timing parameters for the $\overline{INT}$ signals.

timing for $\overline{INT3}$−$\overline{INT0}$ response (see Figure 20)

NO.			MIN	MAX	UNIT
50	$t_{su(INT-H1L)}$	Setup time, $\overline{INT3}$−$\overline{INT0}$ before H1 low	15		ns
51	$t_{w(INT)}$	Pulse duration, interrupt to ensure only one interrupt	P	2P†*	ns

† $P = t_{c(H)}$
* This parameter is not production tested.

The interrupt ($\overline{INT}$) pins are asynchronous inputs that can be asserted at any time during a clock cycle. The SM320LC31-EP interrupts are level-sensitive, not edge-sensitive. Interrupts are detected on the falling edge of H1. Therefore, interrupts must be set up and held to the falling edge of H1 for proper detection. The CPU and DMA respond to detected interrupts on instruction-fetch boundaries only.

For the processor to recognize only one interrupt on a given input, an interrupt pulse must be set up and held to:

- A minimum of one H1 falling edge
- No more than two H1 falling edges

The SM320LC31-EP can accept an interrupt from the same source every two H1 clock cycles.

If the specified timings are met, the exact sequence shown in Figure 20 occurs; otherwise, an additional delay of one clock cycle is possible.

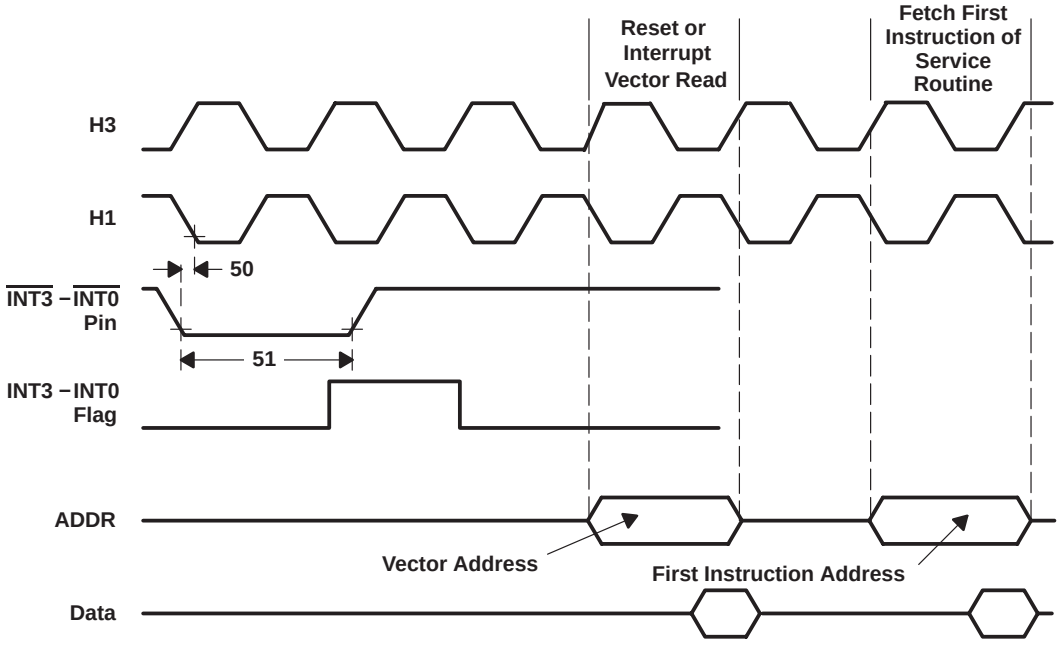


Figure 20. Timing for $\overline{INT3}$−$\overline{INT0}$ Response

interrupt-acknowledge timing

The $\overline{\text{IACK}}$ output goes active on the first half-cycle (HI rising) of the decode phase of the IACK instruction and goes inactive at the first half-cycle (HI rising) of the read phase of the IACK instruction.

timing for $\overline{\text{IACK}}$ (see Note 5 and Figure 21)

NO.			MIN	MAX	UNIT
52	$t_{d(H1H-IACKL)}$	Delay time, H1 high to $\overline{\text{IACK}}$ low		9	ns
53	$t_{d(H1H-IACKH)}$	Delay time, H1 high to $\overline{\text{IACK}}$ high		9	ns

NOTE 5: $\overline{\text{IACK}}$ goes active on the first half-cycle (H1 rising) of the decode phase of the IACK instruction and goes inactive at the first half-cycle (H1 rising) of the read phase of the IACK instruction. Because of pipeline conflicts, $\overline{\text{IACK}}$ remains low for one cycle even if the decode phase of the IACK instruction is extended.

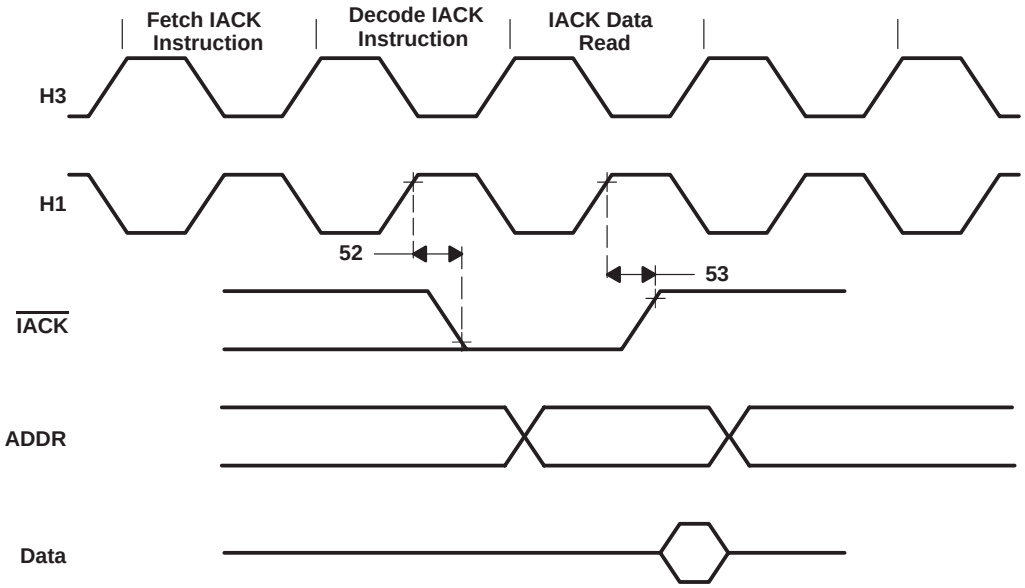


Figure 21. Timing for $\overline{\text{IACK}}$

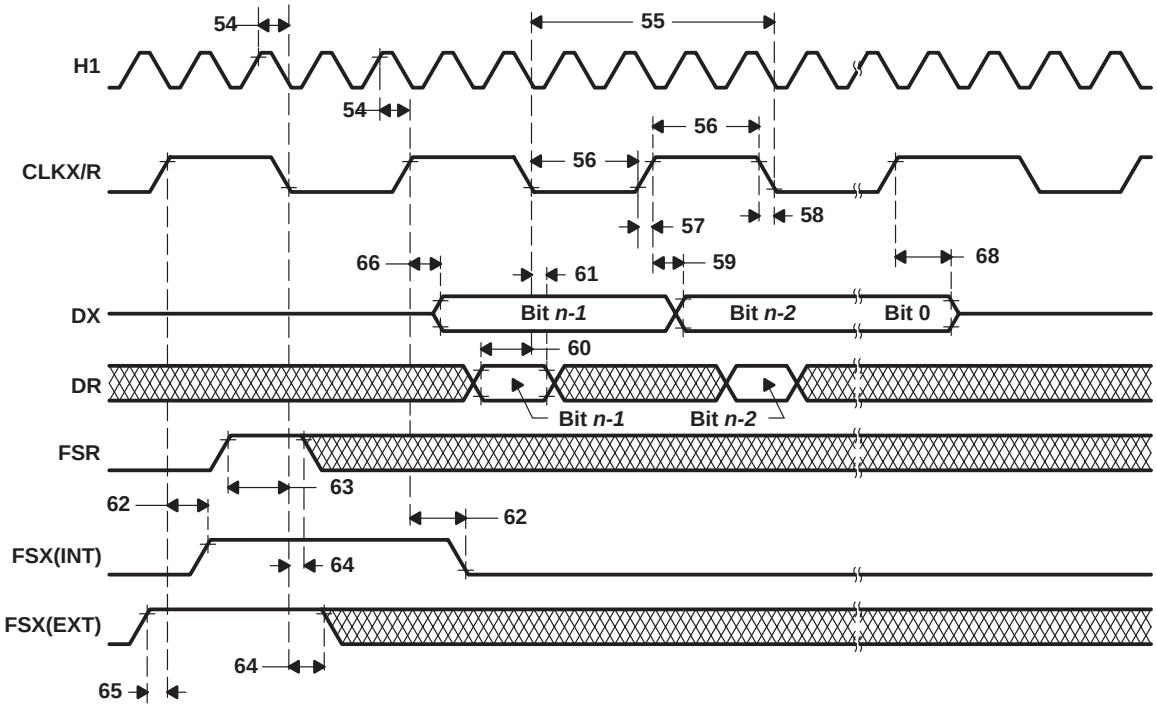
serial-port timing (see Figure 22 and Figure 23)

NO.				MIN	MAX	UNIT
54	$t_{d(H1H-SCK)}$	Delay time, H1 high to internal CLKX/R			13	ns
55	$t_{c(SCK)}$	Cycle time, CLKX/R	CLKX/R ext	$t_{c(H)}$x2.6		ns
			CLKX/R int	$t_{c(H)}$x2	$t_{c(H)}$x2^{32}	
56	$t_{w(SCK)}$	Pulse duration, CLKX/R high/low	CLKX/R ext	$t_{c(H)}$+10		ns
			CLKX/R int	[$t_{c(SCK)}$/2]−5	[$t_{c(SCK)}$/2]+5	
57	$t_{r(SCK)}$	Rise time, CLKX/R			7	ns
58	$t_{f(SCK)}$	Fall time, CLKX/R			7	ns
59	$t_{d(C-DX)}$	Delay time, CLKX to DX valid	CLKX ext		30	ns
			CLKX int		17	
60	$t_{su(DR-CLKRL)}$	Setup time, DR before CLKR low	CLKR ext	9		ns
			CLKR int	21		
61	$t_{h(CLKRL-DR)}$	Hold time, DR from CLKR low	CLKR ext	9		ns
			CLKR int	0		
62	$t_{d(C-FSX)}$	Delay time, CLKX to internal FSX high/low	CLKX ext		27	ns
			CLKX int		15	
63	$t_{su(FSR-CLKRL)}$	Setup time, FSR before CLKR low	CLKR ext	9		ns
			CLKR int	9		
64	$t_{h(SCKL-FS)}$	Hold time, FSX/R input from CLKX/R low	CLKX/R ext	9		ns
			CLKX/R int	0		
65	$t_{su(FSX-C)}$	Setup time, external FSX before CLKX	CLKX ext	−[$t_{c(H)}$−8]*	[$t_{c(SCK)}$/2]−10*	ns
			CLKX int	[$t_{c(H)}$−21]*	$t_{c(SCK)}$/2*	
66	$t_{d(CH-DX)V}$	Delay time, CLKX to first DX bit, FSX precedes CLKX high	CLKX ext		30*	ns
			CLKX int		18*	
67	$t_{d(FSX-DX)V}$	Delay time, FSX to first DX bit, CLKX precedes FSX			30*	ns
68	$t_{d(CH-DXZ)}$	Delay time, CLKX high to DX high impedance following last data bit			17*	ns

* This parameter is not production tested.

data-rate timing modes

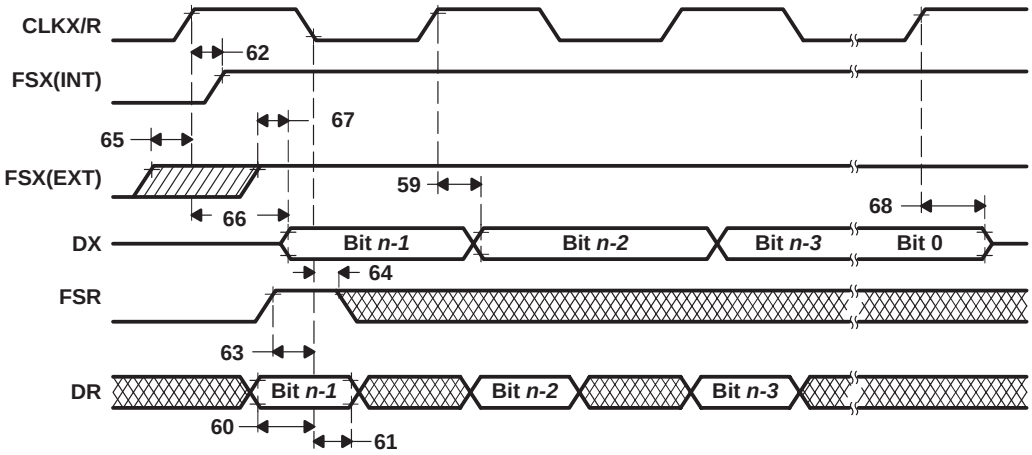
Unless otherwise indicated, the data-rate timings shown in Figure 22 and Figure 23 are valid for all serial-port modes, including handshake. For a functional description of serial-port operation, see the *TMS320C3x User's Guide* (literature number SPRU031).



NOTES: A. Timing diagrams show operations with CLKXP = CLKRP = FSXP = FSRP = 0.
B. Timing diagrams depend on the length of the serial-port word, where n = 8, 16, 24, or 32 bits, respectively.

Figure 22. Timing for Fixed Data-Rate Mode

data-rate timing modes (continued)



NOTES: A. Timing diagrams show operation with CLKXP = CLKRP = FSXP = FSRP = 0.
B. Timing diagrams depend on the length of the serial-port word, where n = 8, 16, 24, or 32 bits, respectively.
C. The timings that are not specified expressly for the variable data-rate mode are the same as those that are specified for the fixed data-rate mode.

Figure 23. Timing for Variable Data-Rate Mode

$\overline{\text{HOLD}}$ timing

$\overline{\text{HOLD}}$ is an asynchronous input that can be asserted at any time during a clock cycle. If the specified timings are met, the exact sequence shown in Figure 27 occurs; otherwise, an additional delay of one clock cycle is possible.

The NOHOLD bit of the primary-bus control register overrides the $\overline{\text{HOLD}}$ signal. When this bit is set, the device comes out of hold and prevents future hold cycles.

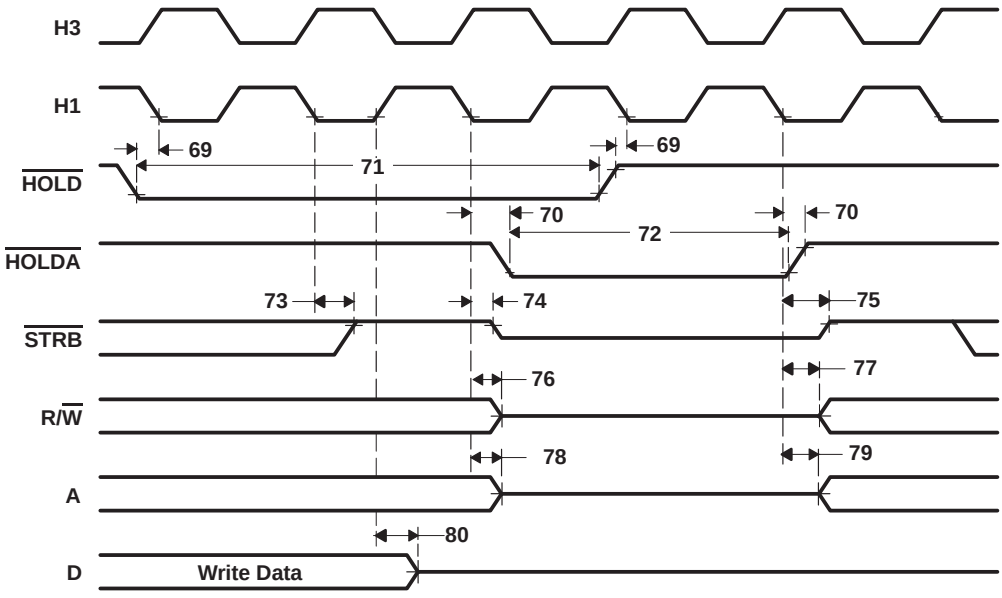
Asserting $\overline{\text{HOLD}}$ prevents the processor from accessing the primary bus. Program execution continues until a read from or a write to the primary bus is requested. In certain circumstances, the first write is pending, thus allowing the processor to continue until a second write is encountered.

timing for $\overline{\text{HOLD}}$/$\overline{\text{HOLDA}}$ (see Figure 24)

NO.			MIN	MAX	UNIT
69	$t_{su(HOLD-H1L)}$	Setup time, $\overline{\text{HOLD}}$ before H1 low	13		ns
70	$t_{v(H1L-HOLDA)}$	Valid time, $\overline{\text{HOLDA}}$ after H1 low	0*	9	ns
71	$t_{w(HOLD)}$†	Pulse duration, $\overline{\text{HOLD}}$ low	$2t_{c(H)}$		ns
72	$t_{w(HOLDA)}$	Pulse duration, $\overline{\text{HOLDA}}$ low	$t_{cH}-5$*		ns
73	$t_{d(H1L-SH)H}$	Delay time, H1 low to $\overline{\text{STRB}}$ high for a $\overline{\text{HOLD}}$	0*	9	ns
74	$t_{dis(H1L-S)}$	Disable time, H1 low to $\overline{\text{STRB}}$ to the high-impedance state	0*	9*	ns
75	$t_{en(H1L-S)}$	Enable time, H1 low to $\overline{\text{STRB}}$ enabled (active)	0*	9	ns
76	$t_{dis(H1L-RW)}$	Disable time, H1 low to R/$\overline{\text{W}}$ to the high-impedance state	0*	9*	ns
77	$t_{en(H1L-RW)}$	Enable time, H1 low to R/$\overline{\text{W}}$ enabled (active)	0*	9	ns
78	$t_{dis(H1L-A)}$	Disable time, H1 low to address to the high-impedance state	0*	10*	ns
79	$t_{en(H1L-A)}$	Enable time, H1 low to address enabled (valid)	0*	13	ns
80	$t_{dis(H1H-D)}$	Disable time, H1 high to data to the high-impedance state	0*	9*	ns

† $\overline{\text{HOLD}}$ is an asynchronous input and can be asserted at any point during a clock cycle. If the specified timings are met, the exact sequence shown in Figure 24 occurs; otherwise, an additional delay of one clock cycle is possible.

* This parameter is not production tested.



NOTE A: $\overline{\text{HOLDA}}$ goes low in response to $\overline{\text{HOLD}}$ going low and continues to remain low until one H1 cycle after $\overline{\text{HOLD}}$ goes back high.

Figure 24. Timing for $\overline{\text{HOLD}}$/$\overline{\text{HOLDA}}$

general-purpose I/O timing

Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1. The contents of the internal control registers associated with each peripheral define the modes for these pins.

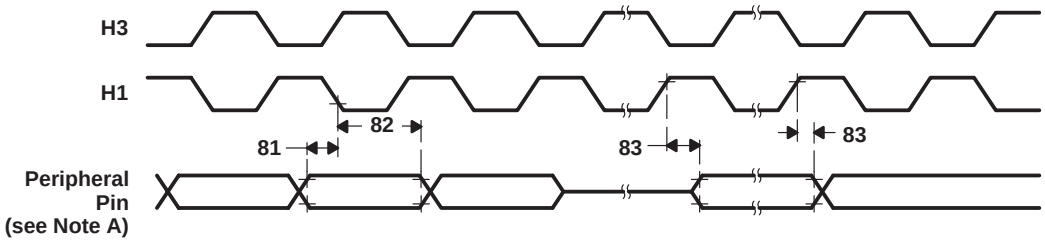
peripheral pin I/O timing

The table, timing parameters for peripheral pin general-purpose I/O, defines peripheral pin general-purpose I/O timing parameters.

timing requirements for peripheral pin general-purpose I/O (see Note 6 and Figure 25)

NO.			MIN	MAX	UNIT
81	$t_{su(GPIO-H1L)}$	Setup time, general-purpose input before H1 low	10		ns
82	$t_{h(H1L-GPIO)}$	Hold time, general-purpose input after H1 low	0		ns
83	$t_{d(H1H-GPIO)}$	Delay time, general-purpose output after H1 high		13	ns

NOTE 6: Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1. The modes of these pins are defined by the contents of internal-control registers associated with each peripheral.



NOTE A: Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1.

Figure 25. Timing for Peripheral Pin General-Purpose I/O

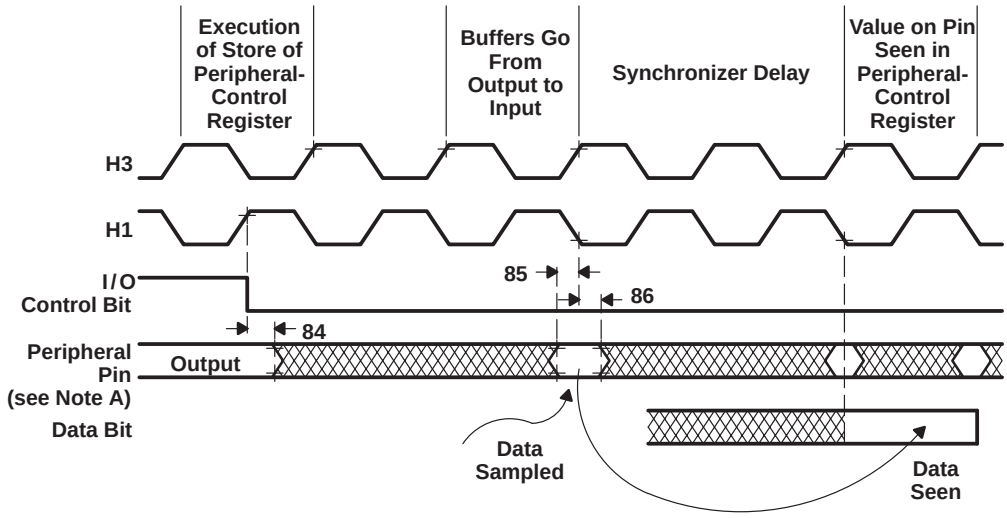
changing the peripheral pin I/O modes

The following tables show the timing parameters for changing the peripheral pin from a general-purpose output pin to a general-purpose input pin and vice versa.

timing requirements for peripheral pin changing from general-purpose output to input mode (see Note 6 and Figure 26)

NO.			MIN	MAX	UNIT
84	$t_{h(H1H)}$	Hold time, peripheral pin after H1 high		13	ns
85	$t_{su(GPIO-H1L)}$	Setup time, peripheral pin before H1 low	9		ns
86	$t_{h(H1L-GPIO)}$	Hold time, peripheral pin after H1 low	0		ns

NOTE 6: Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1. The modes of these pins are defined by the contents of internal-control registers associated with each peripheral.



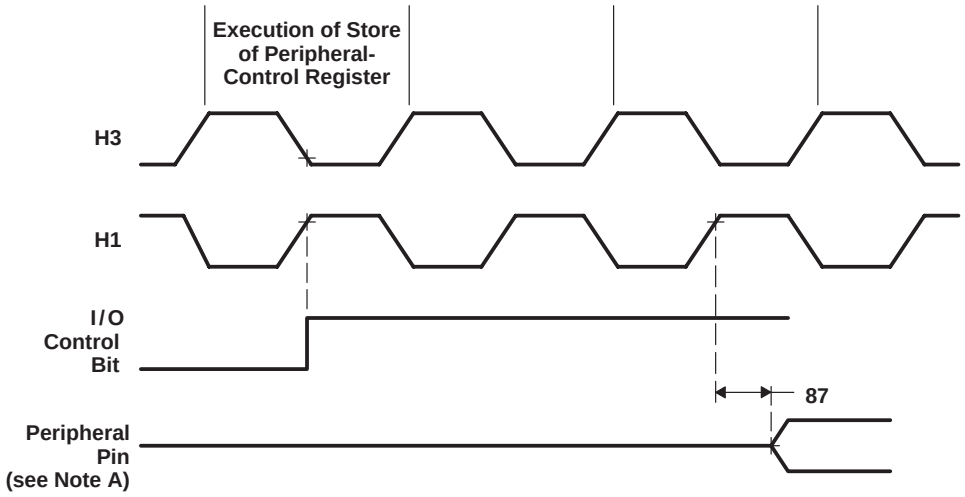
NOTE A: Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1.

Figure 26. Timing for Change of Peripheral Pin From General-Purpose Output to Input Mode

timing for peripheral pin changing from general-purpose input to output mode (see Note 6 and Figure 27)

NO.			MIN	MAX	UNIT
87	$t_{d(H1H-GPIO)}$	Delay time, H1 high to peripheral pin switching from input to output		13	ns

NOTE 6: Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1. The modes of these pins are defined by the contents of internal-control registers associated with each peripheral.



NOTE A: Peripheral pins include CLKX0, CLKR0, DX0, DR0, FSX0, FSR0, and TCLK0/1.

Figure 27. Timing for Change of Peripheral Pin From General-Purpose Input to Output Mode

timer pin timing

Valid logic-level periods and polarity are specified by the contents of the internal control registers.

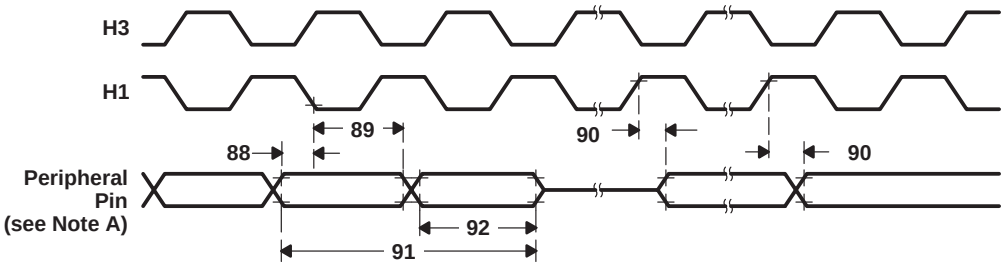
The following tables define the timing requirements for the timer pin.

timing for timer pin (see Note 7 and Figure 28)

NO.				MIN	MAX	UNIT
88	$t_{su(TCLK-H1L)}$	Setup time, TCLK external before H1 low		10		ns
89	$t_{h(H1L-TCLK)}$	Hold time, TCLK external after H1 low		0		ns
90	$t_{d(H1H-TCLK)}$	Delay time, H1 high to TCLK internal valid			9	ns
91	$t_{c(TCLK)}$	Cycle time, TCLK	TCLK ext	$t_{C(H)}\times 2.6$		ns
			TCLK int	$t_{C(H)}\times 2$	$t_{C(H)}\times 2^{32}$*	
92	$t_{w(TCLK)}$	Pulse duration, TCLK high/low	TCLK ext	$t_{C(H)}+10$		ns
			TCLK int	$[t_{C(TCLK)}/2]-5$	$[t_{C(TCLK)}/2]+5$	

* This parameter is not production tested.

NOTE 7: Numbers 88 and 89 are applicable for a synchronous input clock. Timing parameters 91 and 92 are applicable for an asynchronous input clock.



NOTE A: $\overline{\text{HOLDA}}$ goes low in response to $\overline{\text{HOLD}}$ going low and continues to remain low until one H1 cycle after $\overline{\text{HOLD}}$ goes back high.

Figure 28. Timing for Timer Pin

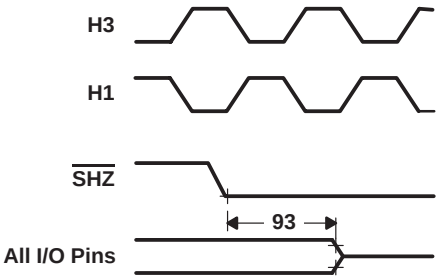
$\overline{\text{SHZ}}$ pin timing

The following table defines the timing parameter for the $\overline{\text{SHZ}}$ pin.

timing parameters for $\overline{\text{SHZ}}$ (see Figure 29)

NO.			MIN	MAX	UNIT
93	$t_{dis(SHZ)}$	Disable time, $\overline{\text{SHZ}}$ low to all O, I/O pins disabled (high impedance)	0*	2P†*	ns

† P = $t_{c(CI)}$
* This parameter is not production tested.

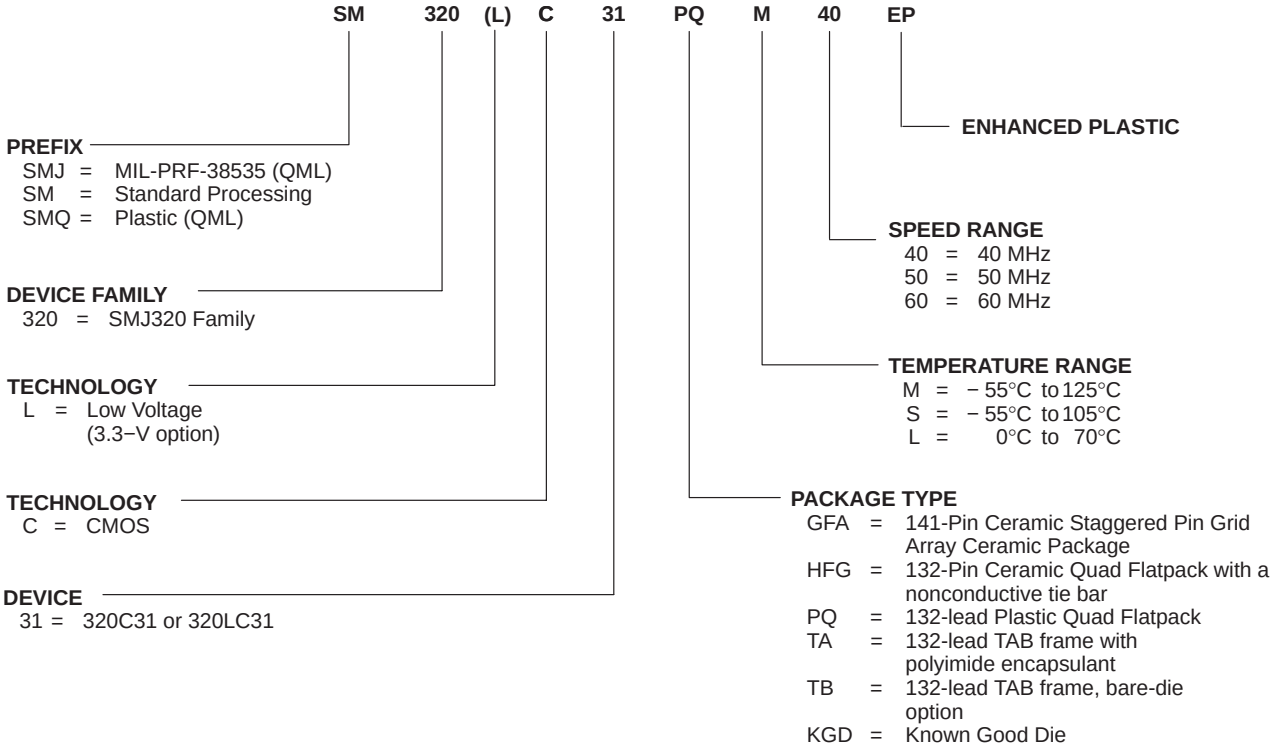


NOTE A: Enabling $\overline{\text{SHZ}}$ destroys SM320LC31-EP register and memory contents. Assert $\overline{\text{SHZ}}$ = 1 and reset the SM320LC31-EP to restore it to a known condition.

Figure 29. Timing for $\overline{\text{SHZ}}$

part order information

DEVICE	TECHNOLOGY	POWER SUPPLY	OPERATING FREQUENCY	PACKAGE TYPE	PROCESSING LEVEL
SM320LC31PQM40EP	0.72-µm CMOS	3.3 V ± 5%	40 MHz	Plastic 132-lead good flatpack	EP



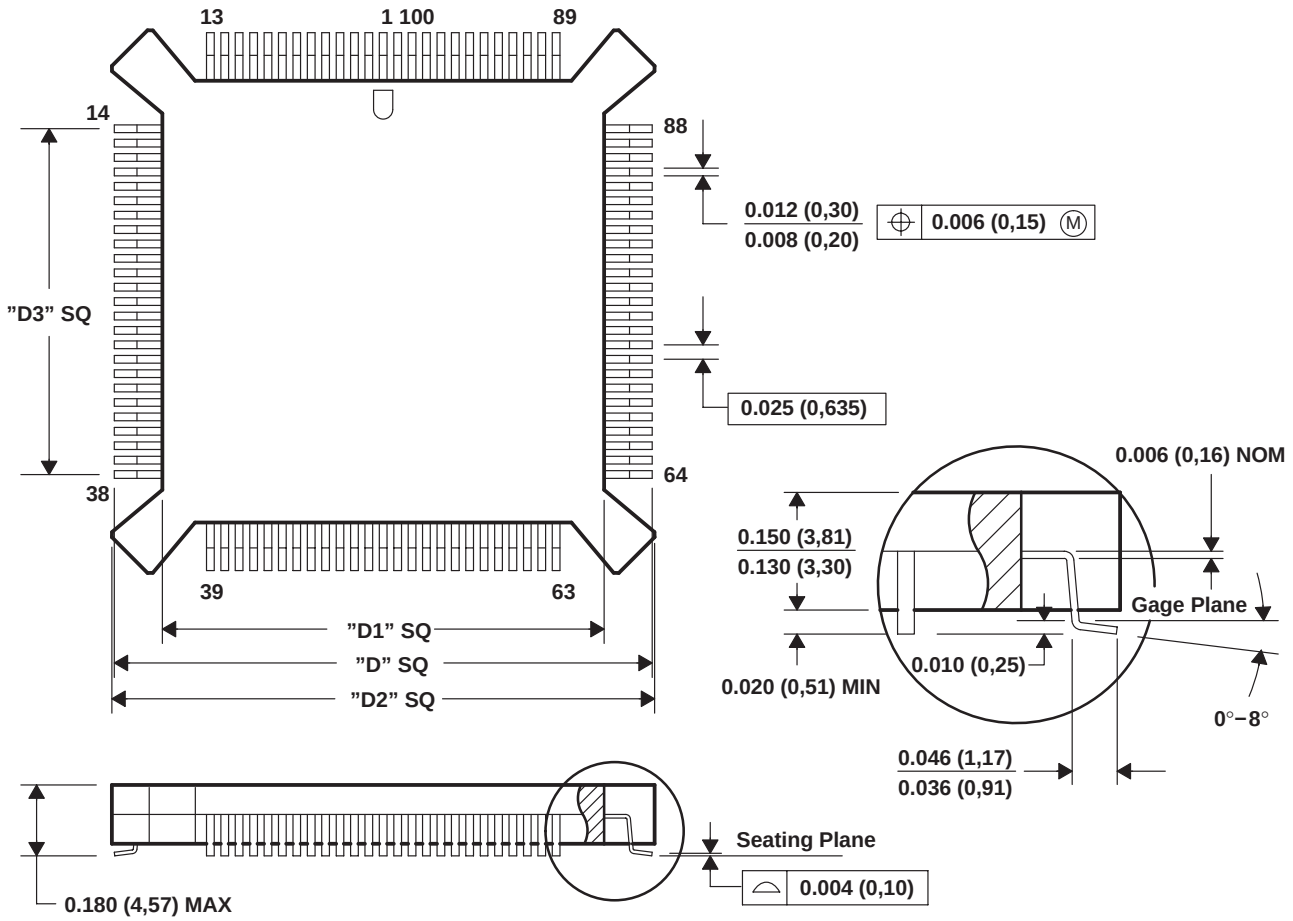
Note: Not all speed, package, process, or temperature combinations are available.

Figure 30. Device Nomenclature

MECHANICAL DATA

PQ (S-PQFP-G*)** **PLASTIC QUAD FLATPACK**

100 LEAD SHOWN



DIM \ LEADS ***		100	132
"D"	MAX	0.890 (22,61)	1.090 (27,69)
	MIN	0.870 (22,10)	1.070 (27,18)
"D1"	MAX	0.766 (19,46)	0.966 (24,54)
	MIN	0.734 (18,64)	0.934 (23,72)
"D2"	MAX	0.912 (23,16)	1.112 (28,25)
	MIN	0.888 (22,56)	1.088 (27,64)
"D3"	NOM	0.600 (15,24)	0.800 (20,32)

4040045/C 11/95

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MO-069

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