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Freescale Semiconductor
Data Sheet: Technical Data

Document Number: DSP56724EC
Rev. 2, 3/2009

DSP56724/DSP56725

Symphony™ DSP56724/ DSP56725 Multi-Core Audio Processors

DSP56724
144-Pin LQFP
20 mm × 20 mm
0.5 mm pitch

DSP56725
80-Pin LQFP
14 mm × 14 mm
0.65 mm pitch

See Table 19.

The Symphony DSP56724/DSP56725 Multi-Core Audio Processors are part of the DSP5672x family of programmable CMOS DSPs, designed using dual DSP56300 24-bit cores.

The DSP56724 is intended for consumer and professional audio applications that require high performance for audio processing. In addition, the DSP56724 is ideally suited for applications that need the capability to expand memory off-chip or to interface to external parallel peripherals. Potential applications include A/V receivers, DVD Receivers, Home Theater in a Box (HTIB), and professional audio equipment including portable recording equipment, musical instruments, guitar amplifiers and pedals. The DSP56724 offers customers flexibility in their designs by providing a more cost-effective alternative to the DSP56720 while maintaining pin compatibility.

The DSP56725 is intended for automotive and audio applications that require high performance for audio processing. Potential applications include A/V receivers, DVD Receivers, Home Theater in a Box (HTIB), and automotive amplifiers and entertainment systems. The DSP56725 offers customers flexibility in their designs by providing a more cost-effective alternative to the DSP56721 while maintaining pin compatibility.

The DSP56724/DSP56725 devices provide a wealth of on-chip audio processing functions, via a plug and play software architecture system that supports audio decoding algorithms, various equalization algorithms, compression, signal generator, tone control, fade/balance, level meter/spectrum analyzer, among others. The DSP56724/DSP56725 devices also support various matrix decoders and sound field processing algorithms.

With two DSP56300 cores, a single DSP56724/ DSP56725 device can replace dual-DSP designs, saving costs while meeting high MIPs requirements. Legacy peripherals from the previous DSP5636x/37x families are included, as are a variety of new modules available in the DSP5672x family. Modules from the DSP56720 are included, such as an Asynchronous Sample Rate Converter (ASRC), an Inter-Core Communication (ICC) module, an External Memory Controller (EMC) to support SDRAM (DSP56724 only), and a Sony/Philips Digital Interface (S/PDIF) transceiver.

The DSP56724/DSP56725 devices offer up to 250 million instructions per second (MIPs) per core using an internal 250 MHz clock. The DSP56724/ DSP56725 products are high density CMOS devices with 3.3 V inputs and outputs.

The DSP56724 block diagram is shown in Figure 1; the DSP56725 block diagram is shown in Figure 2.

NOTE

This document contains information on a new product. Specifications and information herein are subject to change without notice. Finalized specifications may be published after further characterization and device qualifications are completed.

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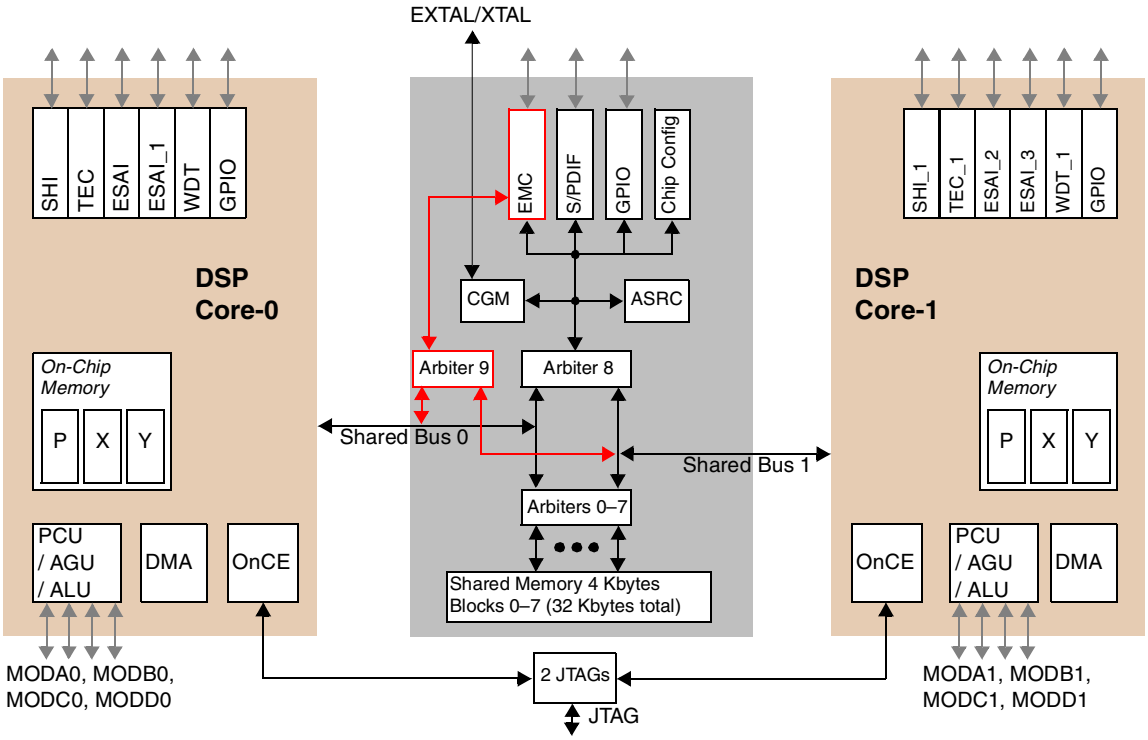


Figure 1. DSP56724 Block Diagram

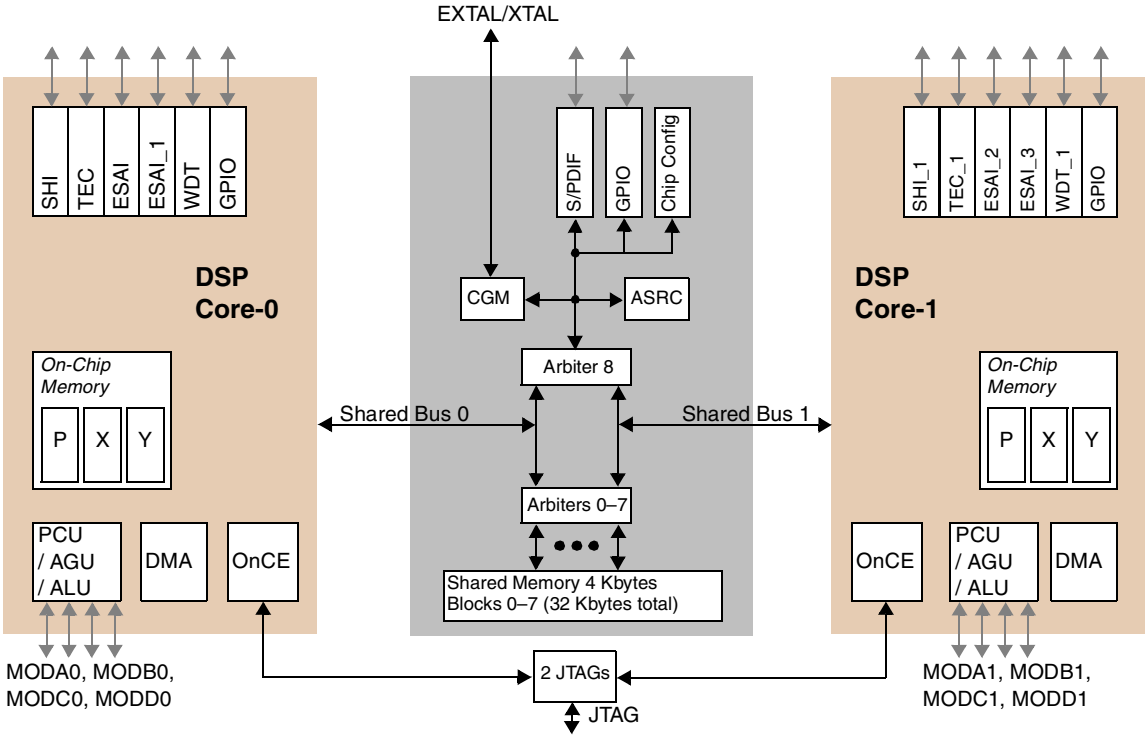


Figure 2. DSP56725 Block Diagram

1 Electrical Characteristics

1.1 Chip-Level Conditions

Table 1 provides a quick reference to the subsections in this section.

Table 1. Chip-Level Conditions

For	See
Section 1.1.1, “Maximum Ratings”	on page 4
Section 1.1.2, “Thermal Characteristics”	on page 6
Section 1.1.3, “Power Requirements”	on page 6
Section 1.1.5, “DC Electrical Characteristics”	on page 8
Section 1.1.6, “AC Electrical Characteristics”	on page 9
Section 1.1.7, “Internal Clocks”	on page 9
Section 1.1.8, “External Clock Operation”	on page 10
Section 1.1.9, “Reset, Stop, Mode Select, and Interrupt Timing”	on page 11

1.1.1 Maximum Ratings

CAUTION

This device contains circuitry protecting against damage due to high static voltage or electrical fields. However, normal precautions should be taken to avoid exceeding maximum voltage ratings. Reliability of operation is enhanced if unused inputs are pulled to an appropriate logic voltage level (for example, either GND or V_{DD}). The suggested value for a pull-up or pull-down resistor is 4.7 kΩ.

NOTE

In the calculation of timing requirements, adding a maximum value of one specification to a minimum value of another specification does not yield a reasonable sum. A maximum specification is calculated using a worst case variation of process parameter values in one direction. The minimum specification is calculated using the worst case for the same parameters in the opposite direction. Therefore, a “maximum” value for a specification will never occur in the same device that has a “minimum” value for another specification; adding a maximum to a minimum represents a condition that can never exist.

Table 2 lists the maximum ratings.

Table 2. Maximum Ratings

Rating[1]	Symbol	Value[1, 2]	Unit
Supply Voltage	V_{CORE_VDD}, V_{PLLD_VDD}	–0.3 to + 1.26	V
	V_{PLLP_VDD}, V_{IO_VDD}, $V_{IO\_VDD\_25}$, V_{PLLA_VDD}	–0.3 to + 4.0	V
Maximum CORE_VDD power supply ramp time	Tr	10	ms
Input Voltage per pin excluding VDD and GND	V_{IN}	GND – 0.3 to 5.5 V	V
Current drain per pin excluding V_{DD} and GND (Except for pads listed below)	I	12	mA
LSYNC_OUT	I_{lsync_out}	5	mA
LCLK	I_{lclk}	5	mA
LALE	I_{ale}	5	mA
TDO	I_{JTAG}	12	mA
Operating temperature range • Fsys < 200 MHz • Fsys < 250 MHz	T_J	 –40 to +100 0 to 90	°C
Storage temperature	T_{STG}	–65 to +150	°C
ESD protected voltage (Human Body Model)	—	2000	V
ESD protected voltage (Charged Device Model) • All pins • Corner pins	—	 500 750	V

Note:

1. GND = 0 V, T_J = –40° C to 100° C, CL = 50 pF
2. Absolute maximum ratings are stress ratings only, and functional operation at the maximum is not guaranteed. Stress beyond the maximum rating may affect device reliability or cause permanent damage to the device.

1.1.2 Thermal Characteristics

Table 3 lists the thermal characteristics.

Table 3. Thermal Characteristics

Characteristic		Symbol	LQFP Values	Unit
Natural Convection, Junction-to-ambient thermal resistance[1,2]	Single layer board (1s)	$R_{\theta JA}$ or θ_{JA}	57 for 80 QFP 49 for 144 QFP	°C/W
	Four layer board (2s2p)		44 for 80 QFP 40 for 144 QFP	°C/W
Junction-to-case thermal resistance[3]	—	$R_{\theta JC}$ or θ_{JC}	10 for 80 QFP 9 for 144 QFP	°C/W

Note:

1. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance.
2. Per SEMI G38-87 and JEDEC JESD51-2 with the single layer board horizontal.
3. Thermal resistance between the die and the case top surface as measured by the cold plate method (MIL SPEC-883 Method 1012.1).

1.1.3 Power Requirements

To prevent high current conditions due to possible improper sequencing of the power supplies, use an external Schottky diode as shown in Figure 3, connected between the DSP56724/DSP56725 IO_VDD and Core_VDD power pins.

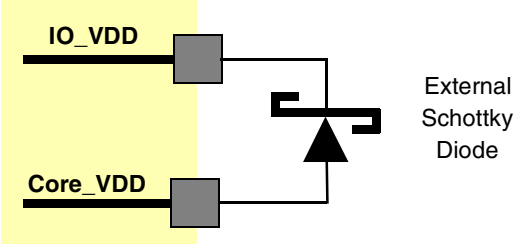


Figure 3. Prevent High Current Conditions by Using External Schottky Diode

If an external Schottky diode is not used (to prevent a high current condition at power-up), then IO_VDD must be applied ahead of Core_VDD, as shown in Figure 4.

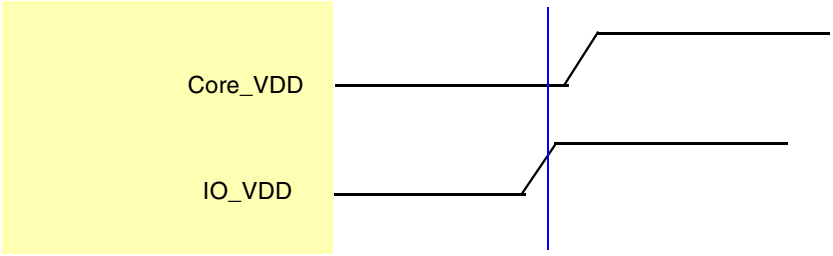


Figure 4. Prevent High Current Conditions by Applying IO_VDD Before Core_VDD

For correct operation of the internal power-on reset logic, the Core_VDD ramp rate (Tr) to full supply must be less than 10 ms, as shown in Figure 4.

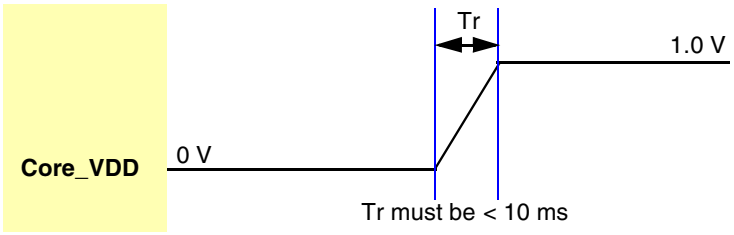


Figure 5. Ensure Correct Operation of Power-On Reset with Fast Ramp of Core_VDD

1.1.4 Power Consumption Considerations

Power dissipation is a key issue in portable DSP applications. Some of the factors which affect current consumption are described in this section. Most of the current consumed by CMOS devices is alternating current (ac), which is charging and discharging the capacitances of the pins and internal nodes.

Current consumption is described by the following formula:

$$I = C \times V \times f \qquad \textit{Eqn. 1}$$

where C=node/pin capacitance
V=voltage swing
f=frequency of node/pin toggle

Example 1. Power Consumption Example

For a GPIO address pin loaded with 50 pF capacitance, operating at 3.3 V, and with a 150 MHz clock, toggling at its maximum possible rate (75 MHz), the current consumption is

$$I = 50x10^{-12}x3.3x75x10^{6} = 12.375mA \qquad \textit{Eqn. 2}$$

The maximum internal current (I_{CCI}max) value reflects the typical possible switching of the internal buses on best-case operation conditions, which is not necessarily a real application case. The typical internal current (I_{CCItyp}) value reflects the average switching of the internal buses on typical operating conditions.

For applications that require very low current consumption, do the following:

- Minimize the number of pins that are switching.
- Minimize the capacitive load on the pins.

One way to evaluate power consumption is to use a current per MIPS measurement methodology to minimize specific board effects (for example, to compensate for measured board current not caused by the DSP). Use the test algorithm, specific test current measurements, and the following equation to derive the current per MIPS value.

$$\mathbf{I/MIPS = I/MHz = (I_{typF2} - I_{typF1})/(F2 - F1)} \qquad \textit{Eqn. 3}$$

where : I_{typF2}=current at F2
I_{typF1}=current at F1
F2=high frequency (any specified operating frequency)
F1=low frequency (any specified operating frequency lower than F2)

NOTE

F1 should be significantly less than F2. For example, F2 could be 66 MHz and F1 could be 33 MHz. The degree of difference between F1 and F2 determines the amount of precision with which the current rating can be determined for an application.

1.1.5 DC Electrical Characteristics

Table 4. DC Electrical Characteristics

Characteristics	Symbol	Min	Typ	Max	Unit
Core Supply voltages • Fsys < 200 MHz • Fsys < 250 MHz	 V_{CORE_VDD}, V_{PLLD_VDD}	 0.95 1.14	 1.0 1.2	 1.05 1.26	V
IO Supply voltages	V_{IO_VDD}, V_{PLLP_VDD}, V_{PLLA_VDD}	3.14	3.3	3.45	V
Input high voltage	V_{IH}	2.0	—	V_{IO_VDD} + 2V	V
Note: To avoid a high current condition and possible system damage, all 3.3-V and 2.5-V supplies must rise before the 1.0-V supplies rise.					
Input low voltage	V_{IL}	–0.3	—	0.8	V
Input leakage current	I_{IN}	—	—	± 80	μA
Clock pin Input Capacitance (EXTAL)	C_{IN}	—	2.057	—	pF
High impedance (off-state) input current (@ 3.3 V or 0 V)	I_{TSI}	–10	—	10	μA
Output high voltage I_{OH} = –12 mA LSYNC_OUT, LALE, LCLK Pins I_{OH} = –16 mA, TDO Pin I_{OH} = –24 mA	V_{OH}	2.4	—	—	V
Output low voltage I_{OL} = 12 mA LSYNC_OUT, LALE, LCLK Pins I_{OL} = 16 mA, TDO Pins I_{OL} = 24 mA	V_{OL}	—	—	0.4	V
Internal pull-up resistor	R_{PU}	63	92	142	kΩ
Internal pull-down resistor	R_{PD}	57	91	159	kΩ
Internal supply current[1] (core only) operating at Fsys < 200 MHz • In Normal mode	 I_{CCI}	 —	 90	 280	mA
• In Wait mode	I_{CCW}	—	60	250	mA
• In Stop mode[2]	I_{CCS}	—	30	220	mA

Table 4. DC Electrical Characteristics (Continued)

Characteristics	Symbol	Min	Typ	Max	Unit
Internal supply current[1] (core only) operating at Fsys < 250 MHz					
• In Normal mode	I_{CCI}	—	140	340	mA
• In Wait mode	I_{CCW}	—	90	290	mA
• In Stop mode[2]	I_{CCS}	—	40	240	mA
Input capacitance	C_{IN}	—	—	10	pF

Note:

1. The Current Consumption section provides a formula to compute the estimated current requirements in Normal mode. In order to obtain these results, all inputs must be terminated (for example, not allowed to float). Measurements are based on synthetic intensive DSP benchmarks. The power consumption numbers in this specification are 90% of the measured results of this benchmark. This reflects typical DSP applications. Typical internal supply current with Fsys < 200 MHz is measured with V_{CORE_VDD} = 1.0 V, V_{DD_IO} = 3.3 V at T_J = 25° C. Maximum internal supply current is measured with V_{CORE_VDD} = 1.05 V, $V_{IO\_VDD)}$ = 3.6 V at T_J = 100° C. Typical internal supply current with Fsys < 250 MHz is measured with V_{CORE_VDD} = 1.2 V, V_{DD_IO} = 3.3 V at T_J = 25° C. Maximum internal supply current is measured with V_{CORE_VDD} = 1.26 V, $V_{IO\_VDD)}$ = 3.6 V at T_J = 90° C.
2. In order to obtain these results, all inputs, which are not disconnected at Stop mode, must be terminated (that is, not allowed to float).

1.1.6 AC Electrical Characteristics

The timing waveforms shown in the AC electrical characteristics section are tested with a V_{IL} maximum of 0.8 V and a V_{IH} minimum of 2.0 V for all pins. AC timing specifications, which are referenced to a device input signal, are measured in production with respect to the 50% point of the respective input signal's transition. For all pins, output levels are measured with the production test machine V_{OL} and V_{OH} reference levels set at 0.4 V and 2.4 V, respectively.

1.1.7 Internal Clocks

Table 5 lists the internal clocks.

Table 5. Internal Clocks

No.	Characteristics	Symbol	Min	Typ	Max	Unit	Condition
1	Comparison Frequency	Fref	2	—	8	MHz	Fref = Fin/NR
2	Input Clock Frequency • with PLL enabled • with PLL disabled	Fin	 2 —	—	 248 200	MHz	—

Table 5. Internal Clocks (Continued)

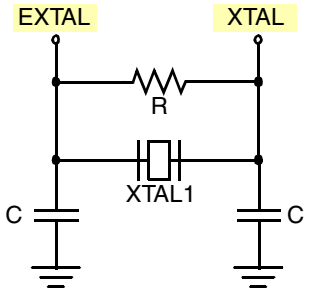
No.	Characteristics	Symbol	Min	Typ	Max	Unit	Condition
3	PLL VCO Frequency	Fvco	200	—	500	MHz	Fvco = (Fin * NF)/NR
4	Output Clock Frequency [1] [2] • with PLL enabled • with PLL disabled	Fout	 25 —	—	 200 or 250 200 or 250	MHz	 Fout = Fvco/NO Fout = Fin
5	System Clock Frequency • with PLL enabled[2] • with PLL disabled	Fsys	 0.195 0	—	 200 or 250 200	MHz	 Fsys = Fout/2^{DF} Fsys = Fout

Note:

1. Fin = External frequency
   NF = Multiplication Factor
   NR = Predivision Factor
   NO = Output Divider
   DF = Division Factor
2. Maximum frequency of 200 MHz supported at 0.95 V < V_{VDD_CORE} < 1.05 V and –40 < Tj < 100° C
   Maximum frequency of 250 MHz supported at 1.14 V < V_{VDD_CORE} < 1.26 V and 0 < Tj < 90° C

1.1.8 External Clock Operation

The DSP56724/DSP56725 system clock is derived from the on-chip oscillator or is externally supplied. To use the on-chip oscillator, connect a crystal and associated resistor/capacitor components to EXTAL and XTAL; see Figure 6.



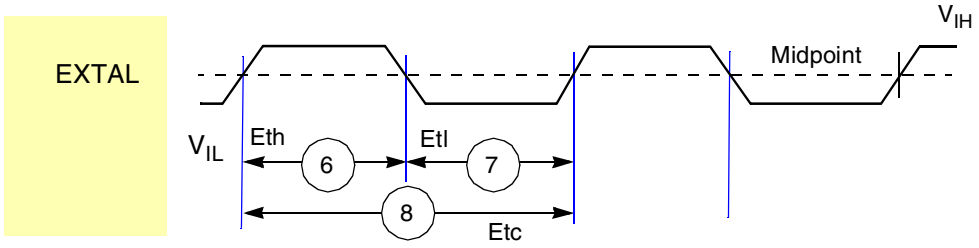
Suggested component values:

f_{osc} = 24.576 MHz
R = 1 M ±10%
C (EXTAL)= 18 pF
C (XTAL) = 18 pF

Calculations are for a 5–30 MHz crystal with the following parameters:
- shunt capacitance (C_0) of 10 pq–F12 pF
- series resistance 40 Ohm
- drive level of 10 µW

Figure 6. Using the On-Chip Oscillator

If the DSP56724/DSP56725 system clock is an externally supplied square wave voltage source, it is connected to EXTAL (Figure 7). When the external square wave source is connected to EXTAL, the XTAL pin is not used.



Note: The midpoint is 0.5 (V_{IH} + V_{IL}).

Figure 7. External Clock Timing

Table 6 lists the clock operation.

Table 6. Clock Operation

No.	Characteristics	Symbol	Min	Max	Units
6	EXTAL input high [1] (40% to 60% duty cycle) • Crystal oscillator • Square wave input	Eth	 16.67 2.5	 100 inf	ns
7	EXTAL input low[1] (40% to 60% duty cycle) • Crystal oscillator • Square wave input	Etl	 16.67 2.5	 100 inf	ns
8	EXTAL cycle time • With PLL disabled • With PLL enabled	Etc	 5 33.3	 inf 500	ns
9	Instruction cycle time • With PLL disabled • With PLL enabled	Tc	 5 4[4]	 inf 5120	ns

Note:

1. Measured at 50% of the input transition.
2. The indicated duty cycle is for the specified maximum frequency for which a part is rated. The minimum clock high or low time required for correct operation, however, remains the same at lower operating frequencies; therefore, when a lower clock frequency is used, the signal symmetry may vary from the specified duty cycle as long as the minimum high time and low time requirements are met.
3. Maximum frequency of 200 MHz supported at 0.95 V < V_{VDD_CORE} < 1.05 V and –40 < Tj < 100° C
   Maximum frequency of 250 MHz supported at 1.14 V < V_{VDD_CORE} < 1.26 V and 0 < Tj < 90° C
4. PLL_{LOCK} = 200 µs.

1.1.9 Reset, Stop, Mode Select, and Interrupt Timing

Table 7 lists the reset, stop, mode select, and interrupt timing.

Table 7. Reset, Stop, Mode Select, and Interrupt Timing

No.	Characteristics	Expression	Min	Max	Unit
10	Delay from $\overline{\text{RESET}}$ assertion to all pins at reset value[3]	—	—	11	ns
11	Required $\overline{\text{RESET}}$ duration[4] • Power on, external clock generator, PLL disabled • Power on, external clock generator, PLL enabled	 $2 \times T_C$ $2 \times T_C$	 10 10	 — —	 ns ns
13	Syn reset deassert delay time • Minimum • Maximum (PLL enabled)	 $2 \times T_C$ $(2xT_C)+PLL_{LOCK}$	 10 200	 — —	 ns us
14	Mode select setup time	—	10	—	ns
15	Mode select hold time	—	12	—	ns
16	Minimum edge-triggered interrupt request assertion width	—	7	—	ns
17	Minimum edge-triggered interrupt request deassertion width	—	4	—	ns
18	Delay from interrupt trigger to interrupt code execution	$10 \times T_{C+4}$	54	—	ns

Table 7. Reset, Stop, Mode Select, and Interrupt Timing (Continued)

No.	Characteristics	Expression	Min	Max	Unit
19	Duration of level sensitive $\overline{\text{IRQA}}$ assertion to ensure interrupt service (when exiting Stop)[1, 2, 3]				
	• PLL is active during Stop and Stop delay is enabled (OMR Bit 6 = 0)	(128 Kbytes × $T_{C)}$	655	—	µs
	• PLL is active during Stop and Stop delay is not enabled (OMR Bit 6 = 1)	25 × T_C	125	—	ns
	• PLL is not active during Stop and Stop delay is enabled (OMR Bit 6 = 0)	(128K x T_C) + PLL_{LOCK}	855	—	µs
	• PLL is not active during Stop and Stop delay is not enabled (OMR Bit 6 = 1)	(25 × T_C) + PLL_{LOCK}	200	—	µs
20	• Delay from $\overline{\text{IRQA}}$, $\overline{\text{IRQB}}$, $\overline{\text{IRQC}}$, $\overline{\text{IRQD}}$, $\overline{\text{NMI}}$ assertion to general-purpose transfer output valid caused by first interrupt instruction execution[1]	10 × T_C + 3.8	—	53.8	ns
21	Interrupt Requests Rate[1]				
	• ESAI, ESAI_1, ESAI_2, ESAI_3, SHI, SHI_1, Timer, Timer_1	12 × T_C	—	60.0	ns
	• DMA	8 × T_C	—	40.0	ns
	• $\overline{\text{IRQ}}$, $\overline{\text{NMI}}$ (edge trigger)	8 × T_C	—	40.0	ns
	• $\overline{\text{IRQ}}$ (level trigger)	12 × T_C	—	60.0	ns
22	DMA Requests Rate				
	• Data read from ESAI, ESAI_1, ESAI_2, ESAI_3, SHI, SHI_1	6 × T_C	—	30.0	ns
	• Data write to ESAI, ESAI_1, ESAI_2, ESAI_3, SHI, SHI_1	7 × T_C	—	35.0	ns
	• Timer, Timer_1	2 × T_C	—	10.0	ns
	• $\overline{\text{IRQ}}$, $\overline{\text{NMI}}$ (edge trigger)	3 × T_C	—	15.0	ns

Note:

1. When using fast interrupts and when $\overline{\text{IRQA}}$, $\overline{\text{IRQB}}$, $\overline{\text{IRQC}}$, and $\overline{\text{IRQD}}$ are defined as level-sensitive, timings 19 through 21 apply to prevent multiple interrupt service. To avoid these timing restrictions, the Edge-triggered mode is recommended when using fast interrupts. Long interrupts are recommended when using Level-sensitive mode.
2. For PLL disable, if using an external clock (PCTL Bit 13 = 1), no stabilization delay is required and recovery time will be defined by the OMR Bit 6 settings.
   For PLL enable, (if bit 12 of the PCTL register is 0), the PLL is shut down during Stop. Recovering from Stop requires the PLL to get locked. The PLL lock procedure duration, PLL Lock Cycles (PLC), may be in the range of 200 us.
3. Periodically sampled and not 100% tested.
4. $\overline{\text{RESET}}$ duration is measured during the time in which $\overline{\text{RESET}}$ is asserted, V_{DD} is valid, and the EXTAL input is active and valid. When V_{DD} is valid, but the other "required $\overline{\text{RESET}}$ duration" conditions (as specified above) have not been yet met, the device circuitry will be in an uninitialized state that can result in significant power consumption and heat-up. Designs should minimize this state to the shortest possible duration.

Figure 8 shows the reset timing diagram.

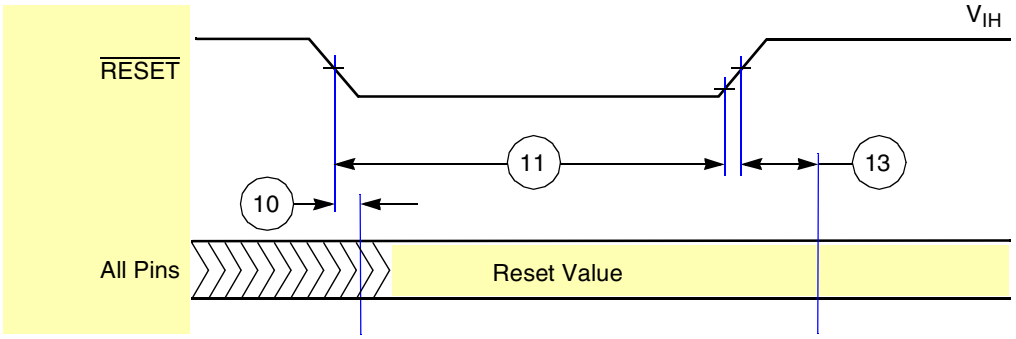


Figure 8. Reset Timing

Figure 9 shows external fast interrupt timing diagram.

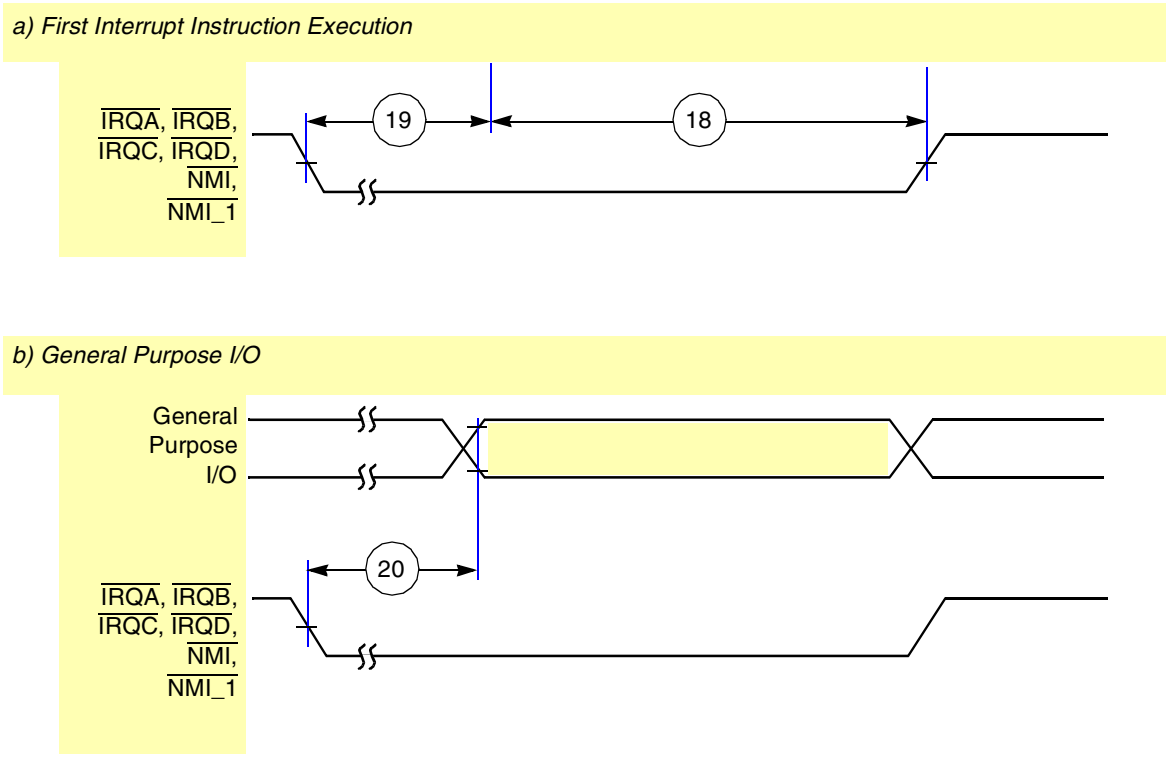


Figure 9. External Fast Interrupt Timing

Figure 10 shows external interrupt timing (negative edge-triggered).

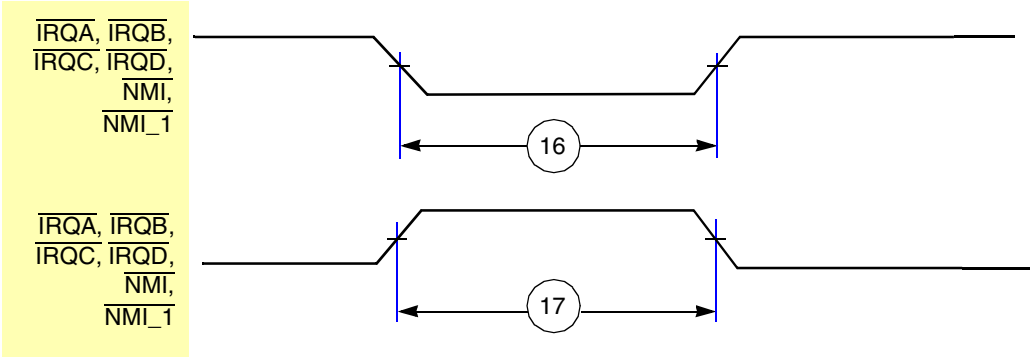


Figure 10. External Interrupt Timing (Negative Edge-Triggered)

Figure 11 shows MODE select set-up and hold time diagram.

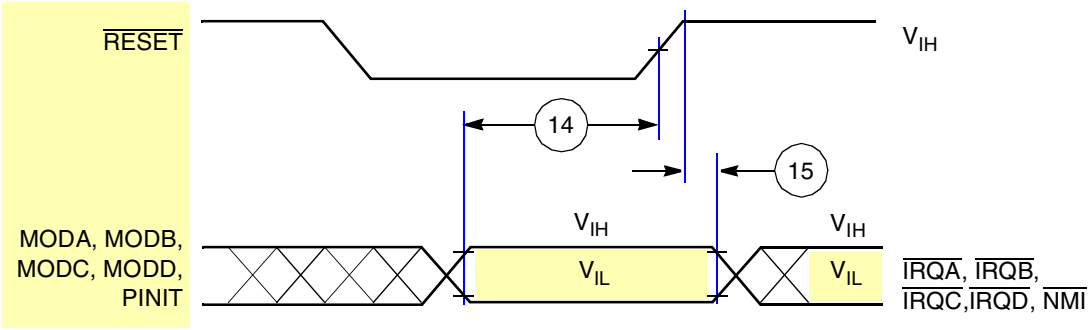


Figure 11. MODE Select Set-Up and Hold Time

1.2 Module-Level Specifications

Table 8 provides a quick reference to the subsections of this section.

Table 8. Module-Level Specifications

For	See
Section 1.2.1, “Serial Host Interface SPI Protocol Timing”	on page 4
Section 1.2.2, “Serial Host Interface (SHI) I2C Protocol Timing”	on page 6
Section 1.2.3, “Programming the SHI I2C Serial Clock”	on page 6
Section 1.2.4, “Enhanced Serial Audio Interface Timing”	on page 8
Section 1.2.5, “GPIO Timing”	on page 29
Section 1.2.6, “JTAG Timing”	on page 30
Section 1.2.7, “Watchdog Timer Timing”	on page 32
Section 1.2.8, “S/PDIF Timing”	on page 33
Section 1.2.9, “EMC Timing Specifications—DSP56724”	on page 34

1.2.1 Serial Host Interface SPI Protocol Timing

Table 9 lists the serial host interface SPI protocol timing.

Table 9. Serial Host Interface SPI Protocol Timing

No.	Characteristics[1,3,4]	Mode	Filter Mode	Expression	Min	Max	Unit
23	Minimum serial clock cycle = t_{SPICC}(min)	Master/Slave	Bypassed	$10 \times T_C + 9$	59.0	—	ns
			Very Narrow	$10 \times T_C + 9$	59.0	—	ns
			Narrow	$10 \times T_C + 133$	183.0	—	ns
			Wide	$10 \times T_C + 333$	383.0	—	ns
XX	Tolerable Spike width on data or clock in.	—	Bypassed	—	—	0	ns
			Very Narrow	—	—	10	ns
			Narrow	—	—	50	ns
			Wide	—	—	100	ns
24	Serial clock high period	Master	Bypassed	$0.5 \times (t_{SPICC})$	29.5	—	ns
			Very Narrow	$0.5 \times (t_{SPICC})$	29.5	—	ns
			Narrow	$0.5 \times (t_{SPICC})$	91.5	—	ns
			Wide	$0.5 \times (t_{SPICC})$	191.5	—	ns
		Slave	Bypassed	$2.0 \times T_C + 19.6$	29.6	—	ns
			Very Narrow	$2.0 \times T_C + 19.6$	29.6	—	ns
			Narrow	$2.0 \times T_C + 86.6$	96.6	—	ns
			Wide	$2.0 \times T_C + 186.6$	196.6	—	ns
25	Serial clock low period	Master	Bypassed	$0.5 \times (t_{SPICC})$	29.5	—	ns
			Very Narrow	$0.5 \times (t_{SPICC})$	29.5	—	ns
			Narrow	$0.5 \times (t_{SPICC})$	91.5	—	ns
			Wide	$0.5 \times t_{SPICC})$	191.5	—	ns
		Slave	Bypassed	$2.0 \times T_C + 19.6$	29.6	—	ns
			Very Narrow	$2.0 \times T_C + 19.6$	29.6	—	ns
			Narrow	$2.0 \times T_C + 86.6$	96.6	—	ns
			Wide	$2.0 \times T_C + 186.6$	196.6	—	ns
26	Serial clock rise/fall time	Master Slave	— —	— —	— —	— 5	ns ns

Table 9. Serial Host Interface SPI Protocol Timing (Continued)

No.	Characteristics[1,3,4]	Mode	Filter Mode	Expression	Min	Max	Unit
27	$\overline{SS}$ assertion to first SCK edge CPHA = 0	Slave	Bypassed	$2.0 \times T_C + 2$	35	—	ns
			Very Narrow	$2.0 \times T_C + 1$	25	—	ns
			Narrow	—	0	—	ns
			Wide	—	0	—	ns
	CPHA = 1	Slave	Bypassed	—	10	—	ns
			Very Narrow	—	0	—	ns
			Narrow	—	0	—	ns
			Wide	—	0	—	ns
28	Last SCK edge to $\overline{SS}$ not asserted	Slave	Bypassed	—	12	—	ns
			Very Narrow	—	22	—	ns
			Narrow	—	100	—	ns
			Wide	—	200	—	ns
29	Data input valid to SCK edge (data input set-up time)	Master /Slave	Bypassed	—	0	—	ns
			Very Narrow	—	0	—	ns
			Narrow	—	0	—	ns
			Wide	—	0	—	ns
30	SCK last sampling edge to data input not valid	Master /Slave	Bypassed	$2 \times T_C + 10$	20	—	ns
			Very Narrow	$2 \times T_C + 30$	40	—	ns
			Narrow	$2 \times T_C + 60$	70	—	ns
			Wide	—	100.0	—	ns
31	$\overline{SS}$ assertion to data out active	Slave	—	—	5	—	ns
32	$\overline{SS}$ deassertion to data high impedance[2]	Slave	—	—	—	9	ns
33	SCK edge to data out valid (data out delay time)	Master /Slave	Bypassed	—	—	45	ns
			Very Narrow	—	—	110	ns
			Narrow	—	—	135	ns
			Wide	—	—	225	ns
34	SCK edge to data out not valid (data out hold time)	Master /Slave	Bypassed	—	10	—	ns
			Very Narrow	—	15	—	ns
			Narrow	—	55	—	ns
			Wide	—	105	—	ns
35	$\overline{SS}$ assertion to data out valid (CPHA = 0)	Slave	—	—	—	14.0	ns

Table 9. Serial Host Interface SPI Protocol Timing (Continued)

No.	Characteristics[1,3,4]	Mode	Filter Mode	Expression	Min	Max	Unit
36	First SCK sampling edge to $\overline{\text{HREQ}}$ output deassertion	Slave	Bypassed	—	45	—	ns
			Very Narrow	—	55	—	ns
			Narrow	—	95	—	ns
			Wide	—	145	—	ns
37	Last SCK sampling edge to $\overline{\text{HREQ}}$ output not deasserted (CPHA = 1)	Slave	Bypassed	—	50.0	—	ns
			Very Narrow	—	60.0	—	ns
			Narrow	—	100.0	—	ns
			Wide	—	150.0	—	ns
38	$\overline{\text{SS}}$ deassertion to $\overline{\text{HREQ}}$ output not deasserted (CPHA = 0)	Slave	—	—	45.0	—	ns
39	$\overline{\text{SS}}$ deassertion pulse width (CPHA = 0)	Slave	—	$2 \times T_C$	0	—	ns
40	$\overline{\text{HREQ}}$ in deassertion to last SCK sampling edge ($\overline{\text{HREQ}}$ in set-up time) (CPHA = 1)	Master	—	—	0	—	ns
41	First SCK edge to $\overline{\text{HREQ}}$ in not asserted ($\overline{\text{HREQ}}$ in hold time)	Master	—	—	0	—	ns
42	$\overline{\text{HREQ}}$ assertion width	Master	—	$3.0 \times T_C$	15	—	ns

Note:

1. 0.95 V < V_{VDD_CORE} < 1.05 V and T_J < 100° C, C_L = 50 pF
2. Periodically sampled, not 100% tested
3. All times assume noise free inputs.
4. All times assume internal clock frequency of 200 MHz.
5. SHI_1 specs match those of SHI
6. Slave timings should equal the serial clock high period + the serial clock low period.

Figure 12 shows the SPI master timing (CPHA = 0).

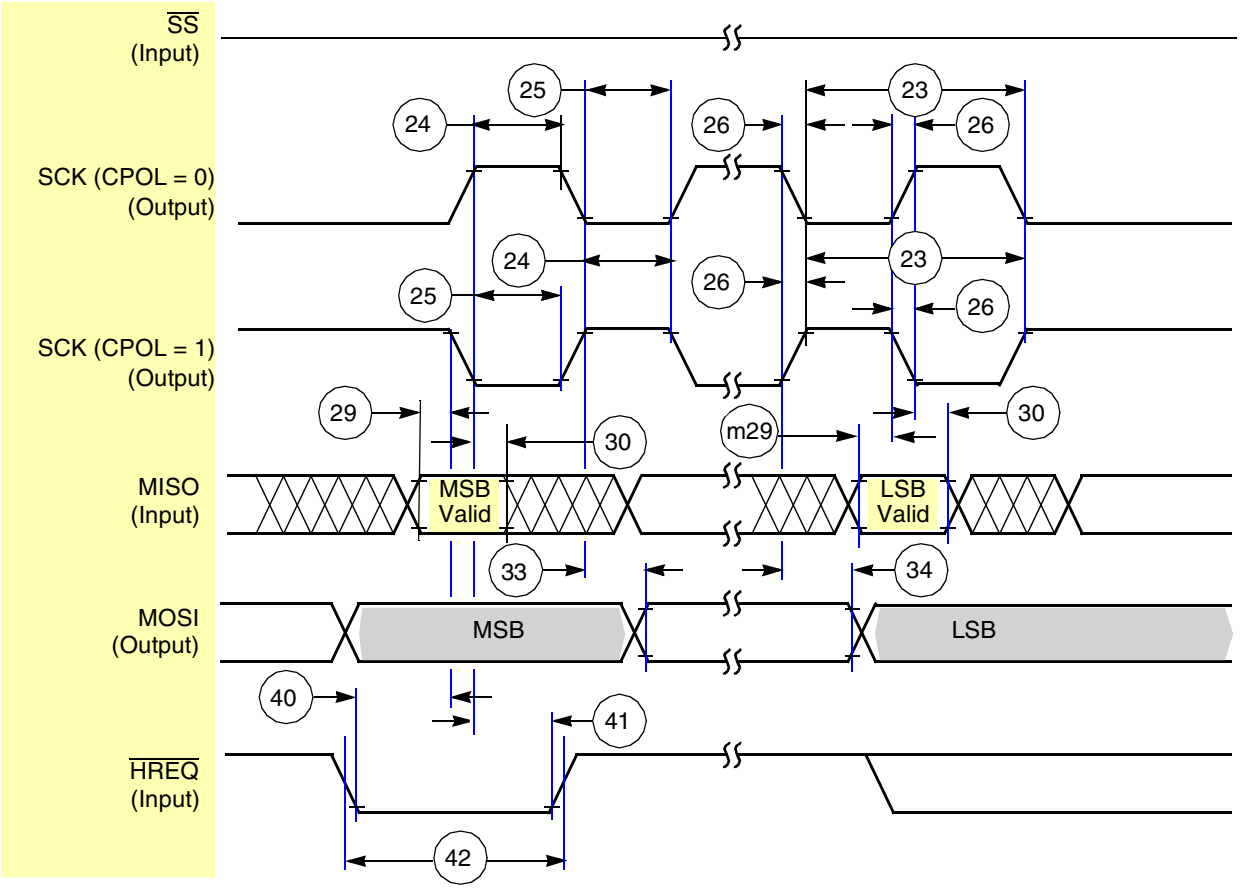


Figure 12. SPI Master Timing (CPHA = 0)

Figure 13 shows the SPI master timing (CPHA = 1).

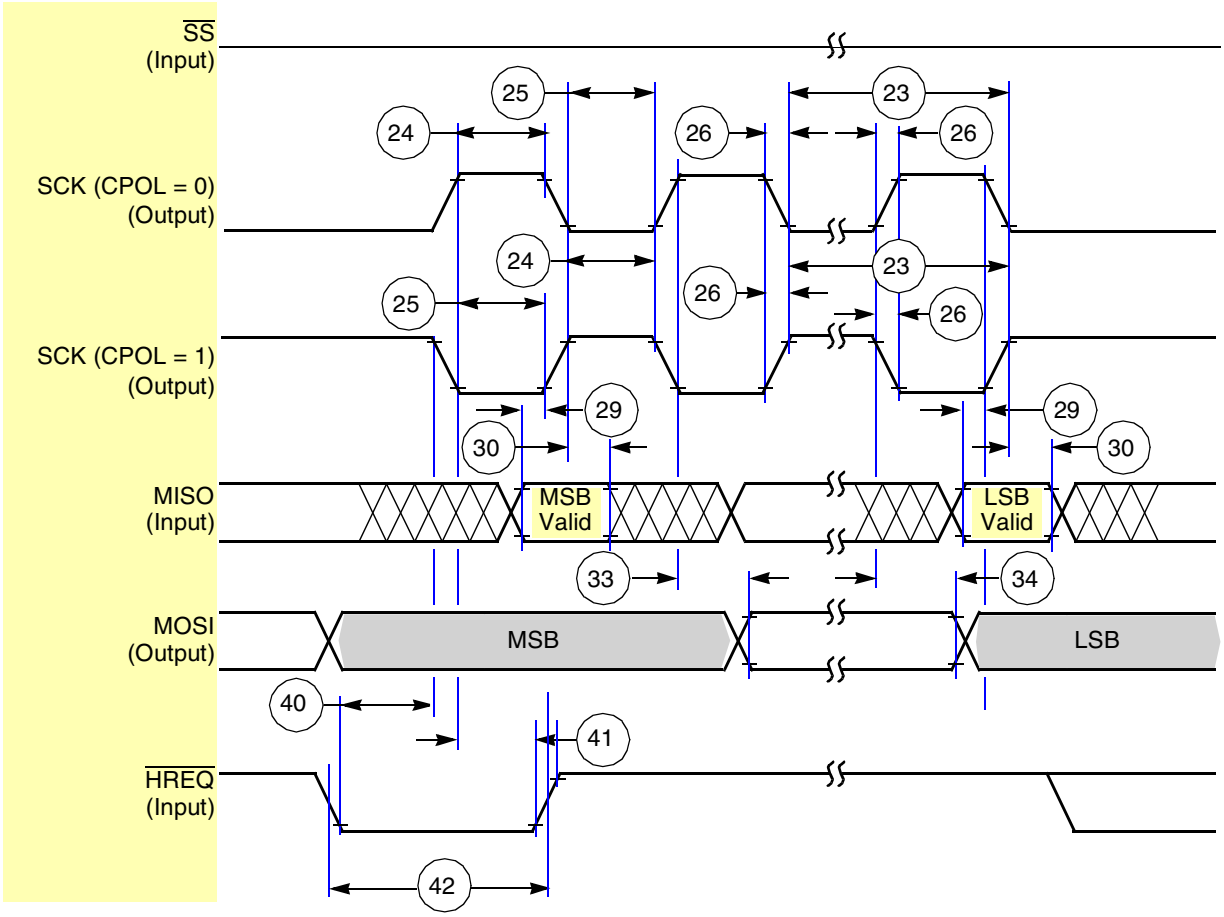


Figure 13. SPI Master Timing (CPHA = 1)

Figure 14 shows the SPI slave timing (CPHA = 0).

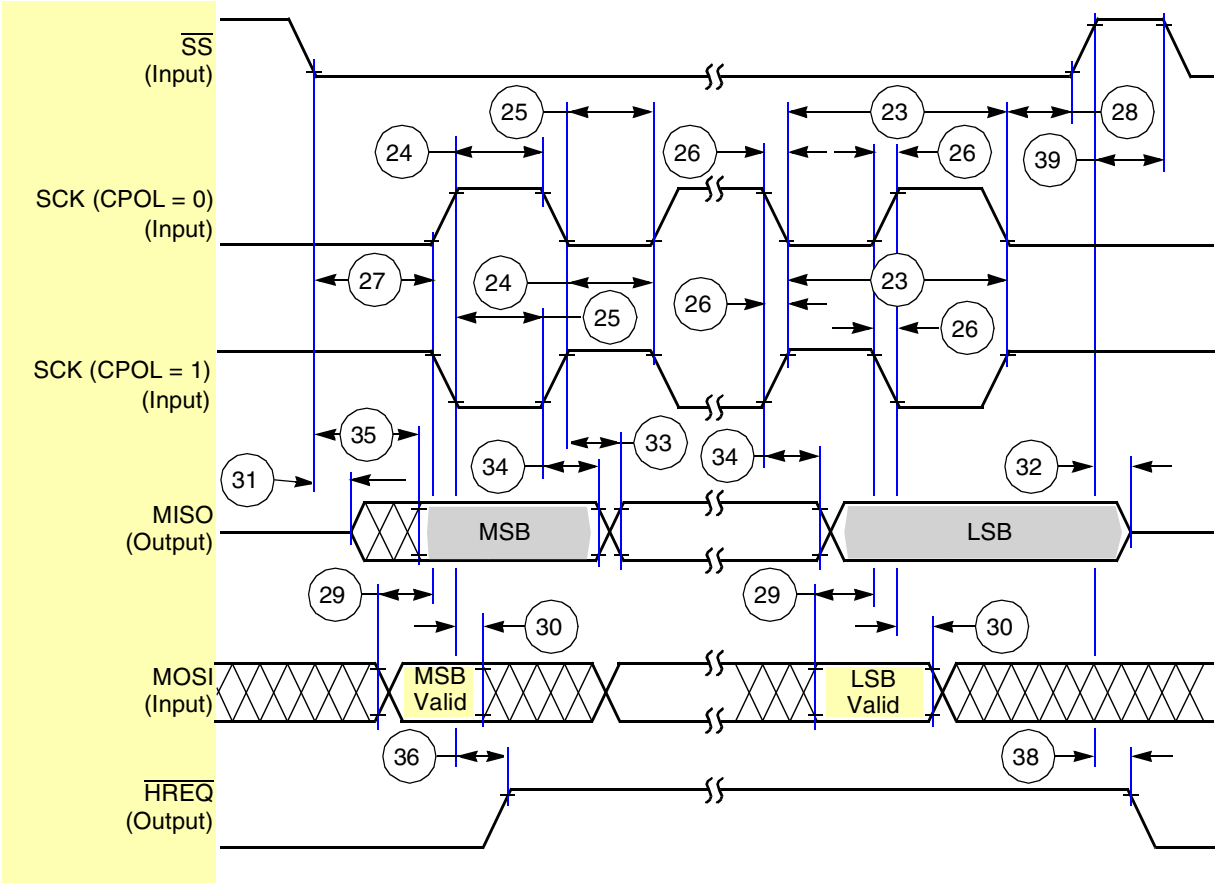


Figure 14. SPI Slave Timing (CPHA = 0)

Figure 15 shows the SPI slave timing (CPHA = 1).

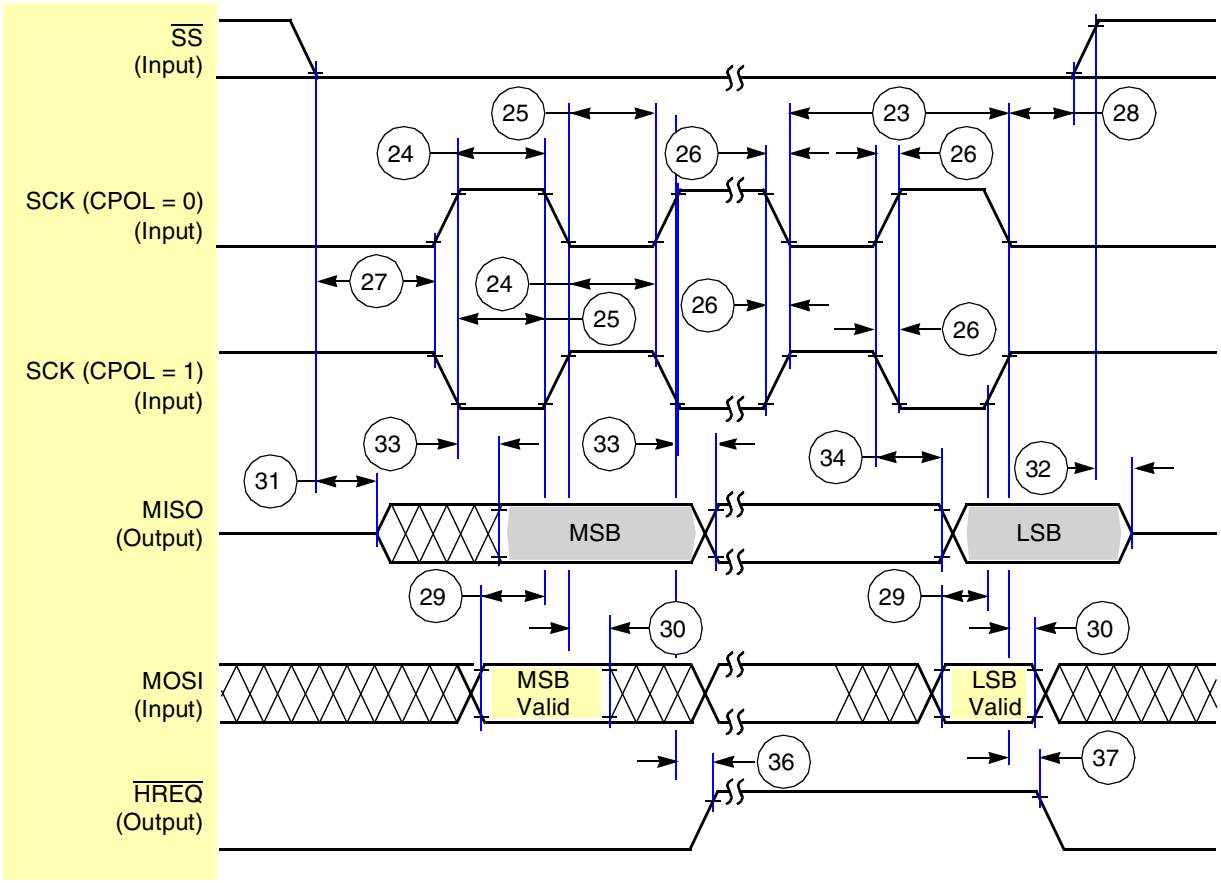


Figure 15. SPI Slave Timing (CPHA = 1)

1.2.2 Serial Host Interface (SHI) I²C Protocol Timing

Table 10 lists the SHI I²C protocol timing diagram.

Table 10. SHI I²C Protocol Timing

Standard I²C							
No.	Characteristics[1,2,3,4,5]	Symbol/ Expression	Standard		Fast-Mode		Unit
			Min	Max	Min	Max	
XX	Tolerable Spike Width on SCL or SDA Filters Bypassed Very Narrow Filters enabled Narrow Filters enabled Wide Filters enabled.	—	 — — — —	 0 10 50 100	 — — — —	 0 10 50 100	 ns ns ns ns
44	SCL clock frequency	F_{SCL}	—	100	—	400	kHz
44	SCL clock cycle	T_{SCL}	10	—	2.5	—	µs
45	Bus free time	T_{BUF}	4.7	—	1.3	—	µs
46	Start condition set-up time	T_{SUSTA}	4.7	—	0.6	—	µs

Table 10. SHI I^2C Protocol Timing (Continued)

Standard I^2C							
No.	**Characteristics[1,2,3,4,5]**	**Symbol/ Expression**	**Standard**		**Fast-Mode**		**Unit**
			Min	**Max**	**Min**	**Max**	
47	Start condition hold time	$T_{HD;STA}$	4.0	—	0.6	—	µs
48	SCL low period	T_{LOW}	4.7	—	1.3	—	µs
49	SCL high period	T_{HIGH}	4.0	—	1.3	—	µs
50	SCL and SDA rise time[7]	T_R	—	1000	—	300	ns
51	SCL and SDA fall time[7]	T_F	—	5.0	—	5.0	ns
52	Data set-up time	$T_{SU;DAT}$	250	—	100	—	ns
53	Data hold time	$T_{HD;DAT}$	0.0	—	0.0	0.9	µs
54	DSP clock frequency • Filters bypassed • Very Narrow filters enabled • Narrow filters enabled • Wide filters enabled	F_{OSC}	 10.6 10.6 11.8 13.1	 — — — —	 28.5 28.5 39.7 61.0	 — — — —	 MHz MHz MHz MHz
55	SCL low to data out valid	$T_{VD;DAT}$	—	3.4	—	0.9	µs
56	Stop condition setup time	$T_{SU;STO}$	4.0	—	0.6	—	µs
57	$\overline{HREQ}$ in deassertion to last SCL edge ($\overline{HREQ}$ in set-up time)	$t_{SU;RQI}$	0.0	—	0.0	—	ns
58	First SCL sampling edge to $\overline{HREQ}$ output deassertion[2] • Filters bypassed • Very Narrow filters enabled • Narrow filters enabled • Wide filters enabled	$T_{NG;RQO}$ $4 \times T_C + 30$ $4 \times T_C + 50$ $4 \times T_C + 130$ $4 \times T_C + 230$	 — — — —	 50.0 70.0 250.0 150.0	 — — — —	 50.0 70.0 150.0 250.0	 ns ns ns ns
59	Last SCL edge to $\overline{HREQ}$ output not deasserted[2] • Filters bypassed • Very Narrow filters enabled • Narrow filters enabled • Wide filters enabled	$T_{AS;RQO}$ $2 \times T_C + 30$ $2 \times T_C + 40$ $2 \times T_C + 80$ $2 \times T_C + 130$	 40 50 90 140	 — — — —	 40 50 90 140	 — — — —	 ns ns ns ns

Table 10. SHI I²C Protocol Timing (Continued)

Standard I²C							
No.	Characteristics[1,2,3,4,5]	Symbol/ Expression	Standard		Fast-Mode		Unit
			Min	Max	Min	Max	
60	$\overline{\text{HREQ}}$ in assertion to first SCL edge • Filters bypassed • Very Narrow filters enabled • Narrow filters enabled • Wide filters enabled	$T_{AS;RQI}$	 4327 4317 4282 4227	 — — — —	 927 917 877 827	 — — — —	 ns ns ns ns
61	First SCL edge to $\overline{\text{HREQ}}$ is not asserted ($\overline{\text{HREQ}}$ in hold time.)	$t_{HO;RQI}$	0.0	—	0.0	—	ns

Note:

1. V_{CORE_VDD} = 1.00± 0.05 V; T_J = –40° C to 100° C, C_L = 50 pF
2. Pull-up resistor: R_P (min) = 1.5 kΩ
3. Capacitive load: C_b (max) = 50 pF
5. All times assume noise free inputs
5. All times assume internal clock frequency of 200 MHz
6. SHI_1 specs match those of SHI
7. The numbers listed are based on the module/pad design and its characteristics during output. The module is compliant with I²C standard, so the module should receive I²C bus compliant signal without any issue.

1.2.3 Programming the SHI I²C Serial Clock

The programmed serial clock cycle, T_{I^2CCP}, is specified by the value of the HDM[7:0] and HRS bits of the HCKR (SHI clock control register).

The expression for T_{I^2CCP} is

$$T_{I^2CCP} = [T_C \times 2 \times (HDM[7:0] + 1) \times (7 \times (1 - HRS) + 1)] \quad \textit{Eqn. 4}$$

where

— HRS is the prescaler rate select bit. When HRS is cleared, the fixed divide-by-eight prescaler is operational. When HRS is set, the prescaler is bypassed.

— HDM[7:0] are the divider modulus select bits. A divide ratio from 1 to 256 (HDM[7:0] = $00 to $FF) may be selected.

In I²C mode, the user may select a value for the programmed serial clock cycle from

$$6 \times T_C \quad \text{(if HDM[7:0] = \$02 and HRS = 1)} \quad \textit{Eqn. 5}$$

to

$$4096 \times T_C \quad \text{(if HDM[7:0] = \$FF and HRS = 0)} \quad \textit{Eqn. 6}$$

The programmed serial clock cycle (T_{I^2CCP}) should be chosen in order to achieve the desired SCL serial clock cycle (T_{SCL}), as shown in next.

$$T_{I^2CCP} + 3 \times T_C + 45ns + T_R \quad \text{(Nominal, SCL Serial Clock Cycle (TSCL) generated as master)} \quad \textit{Eqn. 7}$$

Figure 16 shows the I²C timing diagram.

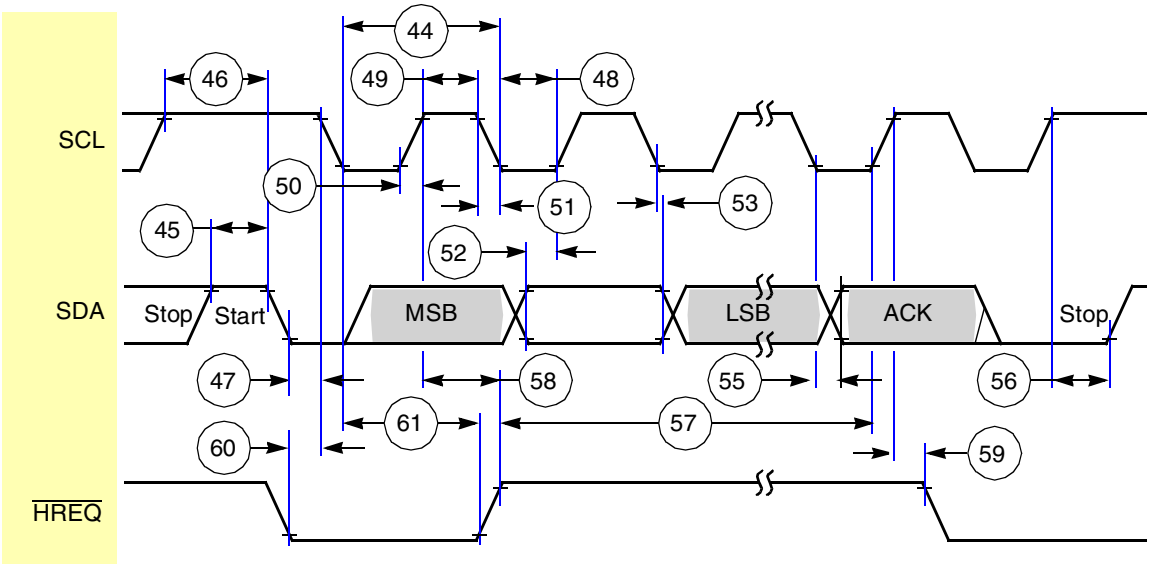


Figure 16. I²C Timing

1.2.4 Enhanced Serial Audio Interface Timing

Table 11 lists the enhanced serial audio interface timing.

Table 11. Enhanced Serial Audio Interface Timing

No.	Characteristics[1, 2, 3]	Symbol	Expression[3]	Min	Max	Condition[4]	Unit
62	Clock cycle[5]	t_{SSICC}	$4 \times T_C$ $4 \times T_C$	20.0 20.0	— —	i ck i ck	ns
63	Clock high period • For internal clock • For external clock	 — —	 $2 \times T_C$ $2 \times T_C$	 10 10	 — —	 — —	ns
64	Clock low period • For internal clock • For external clock	 — —	 $2 \times T_C$ $2 \times T_C$	 10 10	 — —	 — —	ns
65	SCKR rising edge to FSR out (bl) high	—	—	— —	17.0 7.0	x ck i ck a	ns
66	SCKR rising edge to FSR out (bl) low	—	—	— —	17.0 7.0	x ck i ck a	ns
67	SCKR rising edge to FSR out (wr) high[6]	—	—	— —	19.0 9.0	x ck i ck a	ns
68	SCKR rising edge to FSR out (wr) low[6]	—	—	— —	19.0 9.0	x ck i ck a	ns
69	SCKR rising edge to FSR out (wl) high	—	—	— —	16.0 6.0	x ck i ck a	ns
70	SCKR rising edge to FSR out (wl) low	—	—	— —	17.0 7.0	x ck i ck a	ns

Table 11. Enhanced Serial Audio Interface Timing (Continued)

No.	Characteristics[1, 2, 3]	Symbol	Expression[3]	Min	Max	Condition[4]	Unit
71	Data in setup time before SCKR (SCK in synchronous mode) falling edge	—	—	0.0 19.0	— —	x ck i ck	ns
72	Data in hold time after SCKR falling edge	—	—	3.5 9.0	— —	x ck i ck	ns
73	FSR input (bl, wr) high before SCKR falling edge [6]	—	—	2.0 12.0	— —	x ck i ck a	ns
74	FSR input (wl) high before SCKR falling edge	—	—	2.0 12.0	— —	x ck i ck a	ns
75	FSR input hold time after SCKR falling edge	—	—	2.5 8.5	— —	x ck i ck a	ns
76	Flags input setup before SCKR falling edge	—	—	0.0 19.0	— —	x ck i ck s	ns
77	Flags input hold time after SCKR falling edge	—	—	6.0 0.0	— —	x ck i ck s	ns
78	SCKT rising edge to FST out (bl) high	—	—	— —	18.0 8.0	x ck i ck	ns
79	SCKT rising edge to FST out (bl) low	—	—	— —	20.0 10.0	x ck i ck	ns
80	SCKT rising edge to FST out (wr) high[6]	—	—	— —	20.0 10.0	x ck i ck	ns
81	SCKT rising edge to FST out (wr) low[6]	—	—	— —	22.0 12.0	x ck i ck	ns
82	SCKT rising edge to FST out (wl) high	—	—	— —	15.0 9.0	x ck i ck	ns
83	SCKT rising edge to FST out (wl) low	—	—	— —	15.0 10.0	x ck i ck	ns
84	SCKT rising edge to data out enable from high impedance	—	—	— —	22.0 17.0	x ck i ck	ns
85	SCKT rising edge to transmitter #0 drive enable assertion	—	—	— —	17.0 11.0	x ck i ck	ns
86	SCKT rising edge to data out valid	—	—	— —	25.0 13.0	x ck i ck	ns
87	SCKT rising edge to data out high impedance[7]	—	—	— —	25.0 16.0	x ck i ck	ns
88	SCKT rising edge to transmitter #0 drive enable deassertion[7]	—	—	— —	14.0 9.0	x ck i ck	ns
89	FST input (bl, wr) setup time before SCKT falling edge[6]	—	—	2.0 18.0	— —	x ck i ck	ns
90	FST input (wl) setup time before SCKT falling edge	—	—	2.0 18.0	— —	x ck i ck	ns
91	FST input hold time after SCKT falling edge	—	—	4.0 5.0	— —	x ck i ck	ns