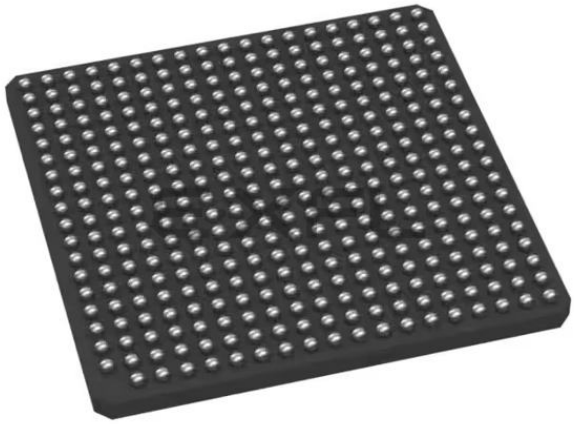

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Understanding Embedded - Microprocessors

Embedded microprocessors are specialized computing chips designed to perform specific tasks within an embedded system. Unlike general-purpose microprocessors found in personal computers, embedded microprocessors are tailored for dedicated functions within larger systems, offering optimized performance, efficiency, and reliability. These microprocessors are integral to the operation of countless electronic devices, providing the computational power necessary for controlling processes, handling data, and managing communications.

Applications of Embedded - Microprocessors

Embedded microprocessors are utilized across a broad spectrum of applications, making them indispensable in

Details	
Product Status	Obsolete
Core Processor	PowerPC G4
Number of Cores/Bus Width	1 Core, 32-Bit
Speed	600MHz
Co-Processors/DSP	Multimedia; SIMD
RAM Controllers	-
Graphics Acceleration	No
Display & Interface Controllers	-
Ethernet	-
SATA	-
USB	-
Voltage - I/O	1.5V, 1.8V, 2.5V
Operating Temperature	0°C ~ 105°C (TA)
Security Features	-
Package / Case	360-CLGA, FCCLGA
Supplier Device Package	360-FCCLGA (25x25)
Purchase URL	https://www.e-xfl.com/product-detail/nxp-semiconductors/mc7448vs600nc

when running a typical benchmark at temperatures in a typical system. The Full-Power Mode–Thermal value is intended to represent the sustained power consumption of the device when running a typical code sequence at high temperature and is recommended to be used as the basis for designing a thermal solution; see Section 9.7, "Power and Thermal Management Information" for more information on thermal solutions. The Full-Power Mode–Maximum value is recommended to be used for power supply design because this represents the maximum peak power draw of the device that a power supply must be capable of sourcing without voltage droop. For information on power consumption when dynamic frequency switching is enabled, see Section 9.7.5, "Dynamic Frequency Switching (DFS)."

Table 7. Power Consumption for MPC7448 at Maximum Rated Frequency

	Die Junction Temperature (T_j)	Maximum Processor Core Frequency (Speed Grade, MHz)				Unit	Notes
		1000 MHz	1420 MHz	1600 MHz	1700 MHz		
Full-Power Mode							
Typical	65 •C	15.0	19.0	20.0	21.0	W	1, 2
Thermal	105 •C	18.6	23.3	24.4	25.6	W	1, 5
Maximum	105 •C	21.6	27.1	28.4	29.8	W	1, 3
Nap Mode							
Typical	105 •C	11.1	11.8	13.0	13.0	W	1, 6
Sleep Mode							
Typical	105 •C	10.8	11.4	12.5	12.5	W	1, 6
Deep Sleep Mode (PLL Disabled)							
Typical	105 •C	10.4	11.0	12.0	12.0	W	1, 6

Notes:

1. These values specify the power consumption for the core power supply (V_{DD}) at nominal voltage and apply to all valid processor bus frequencies and configurations. The values do not include I/O supply power (OV_{DD}) or PLL supply power (AV_{DD}). OV_{DD} power is system dependent but is typically < 5% of V_{DD} power. Worst case power consumption for AV_{DD} < 13 mW. Freescale also offers MPC7448 part numbers that meet lower power consumption specifications; for more information on these devices, see Section 11.2, "Part Numbers Not Fully Addressed by This Document."
2. Typical power consumption is an average value measured with the processor operating at its rated maximum processor core frequency (except for Deep Sleep Mode), at nominal recommended V_{DD} (see Table 4) and 65°C while running the Dhrystone 2.1 benchmark and achieving 2.3 Dhrystone MIPs/MHz. This parameter is not 100% tested but periodically sampled.b
3. Maximum power consumption is the average measured with the processor operating at its rated maximum processor core frequency, at nominal V_{DD} and maximum operating junction temperature (see Table 4) while running an entirely cache-resident, contrived sequence of instructions to keep all the execution units maximally busy.
4. Doze mode is not a user-definable state; it is an intermediate state between full-power and either nap or sleep mode. As a result, power consumption for this mode is not tested.
5. Thermal power consumption is an average value measured at the nominal recommended V_{DD} (see Table 4) and 105 °C while running the Dhrystone 2.1 benchmark and achieving 2.3 Dhrystone MIPs/MHz. This parameter is not 100% tested but periodically sampled.
6. Typical power consumption for these modes is measured at the nominal recommended V_{DD} (see Table 4) and 105 °C in the mode described. This parameter is not 100% tested but is periodically sampled.

5.2 AC Electrical Characteristics

This section provides the AC electrical characteristics for the MPC7448. After fabrication, functional parts are sorted by maximum processor core frequency as shown in Section 5.2.1, “Clock AC Specifications,” and tested for conformance to the AC specifications for that frequency. The processor core frequency, determined by the bus (SYSCLK) frequency and the settings of the PLL_CFG[0:5] signals, can be dynamically modified using dynamic frequency switching (DFS). Parts are sold by maximum processor core frequency; see Section 11, “Part Numbering and Marking,” for information on ordering parts. DFS is described in Section 9.7.5, “Dynamic Frequency Switching (DFS).”

5.2.1 Clock AC Specifications

Table 8 provides the clock AC timing specifications as defined in Figure 3 and represents the tested operating frequencies of the devices. The maximum system bus frequency, f_{SYSCLK}, given in Table 8, is considered a practical maximum in a typical single-processor system. This does not exclude multi-processor systems, but these typically require considerably more design effort to achieve the maximum rated bus frequency. The actual maximum SYSCLK frequency for any application of the MPC7448 will be a function of the AC timings of the microprocessor(s), the AC timings for the system controller, bus loading, circuit board topology, trace lengths, and so forth, and may be less than the value given in Table 8.

Table 8. Clock AC Timing Specifications

At recommended operating conditions. See Table 4.

Characteristic		Symbol	Maximum Processor Core Frequency (Speed Grade)								Unit	Notes
			1000 MHz		1420 MHz		1600 MHz		1700 MHz			
			Min	Max	Min	Max	Min	Max	Min	Max		
Processor core frequency	DFS mode disabled	f_{core}	600	1000	600	1420	600	1600	600	1700	MHz	1, 8
	DFS mode enabled	f_{core_DF}	300	500	300	710	300	800	300	850		9
VCO frequency		f_{VCO}	600	1000	600	1420	600	800	600	1700	MHz	1, 10
SYSCLK frequency		f_{SYSCLK}	33	200	33	200	33	200	33	200	MHz	1, 2, 8
SYSCLK cycle time		t_{SYSCLK}	5.0	30	5.0	30	5.0	30	5.0	30	ns	2
SYSCLK rise and fall time		t_{KR}, t_{KF}	—	0.5	—	0.5	—	0.5	—	0.5	ns	3
SYSCLK duty cycle measured at $OV_{DD}/2$		t_{KHKL}/t_{SYSCLK}	40	60	40	60	40	60	40	60	%	4
SYSCLK cycle-to-cycle jitter			—	150	—	150	—	150	—	150	ps	5, 6
Internal PLL relock time			—	100	—	100	—	100	—	100	µs	7

Notes:

1. **Caution**: The SYSCLK frequency and PLL_CFG[0:5] settings must be chosen such that the resulting SYSCLK (bus) frequency, processor core frequency, and PLL (VCO) frequency do not exceed their respective maximum or minimum operating frequencies. Refer to the PLL_CFG[0:5] signal description in Section 9.1.1, “PLL Configuration,” for valid PLL_CFG[0:5] settings.
2. Actual maximum system bus frequency is system-dependent. See Section 5.2.1, “Clock AC Specifications.”
3. Rise and fall times for the SYSCLK input measured from 0.4 to 1.4 V
4. Timing is guaranteed by design and characterization.
5. Guaranteed by design
6. The SYSCLK driver’s closed loop jitter bandwidth should be less than 1.5 MHz at –3 dB.
7. Relock timing is guaranteed by design and characterization. PLL-relock time is the maximum amount of time required for PLL lock after a stable V_{DD} and SYSCLK are reached during the power-on reset sequence. This specification also applies when the PLL has been disabled and subsequently re-enabled during sleep mode. Also note that $\overline{\text{HRESET}}$ must be held asserted for a minimum of 255 bus clocks after the PLL-relock time during the power-on reset sequence.
8. This reflects the maximum and minimum core frequencies when the dynamic frequency switching feature (DFS) is disabled. f_{core_DFS} provides the maximum and minimum core frequencies when operating in a DFS mode.
9. This specification supports the Dynamic Frequency Switching (DFS) feature and is applicable only when one of the DFS modes (divide-by-2 or divide-by-4) is enabled. When DFS is disabled, the core frequency must conform to the maximum and minimum frequencies stated for f_{core}.
10. Use of the DFS feature does not affect VCO frequency.

Figure 4 provides the AC test load for the MPC7448.

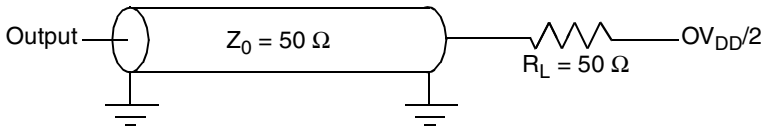


Figure 4. AC Test Load

Figure 5 provides the $\overline{\text{BMODE}}$[0:1] input timing diagram for the MPC7448. These mode select inputs are sampled once before and once after $\overline{\text{HRESET}}$ negation.

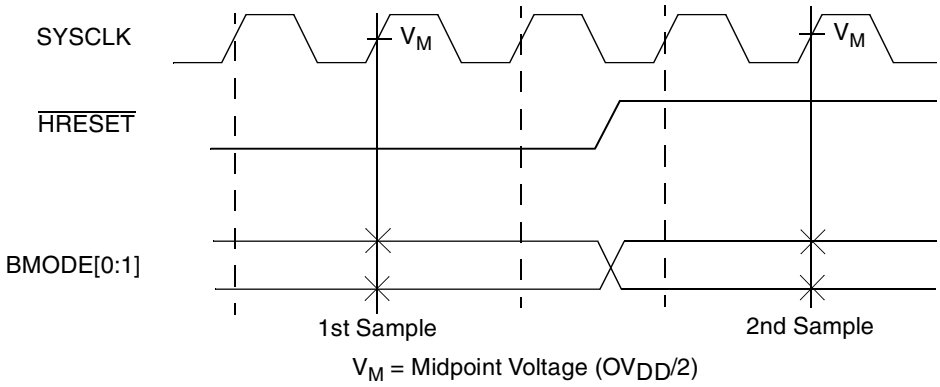
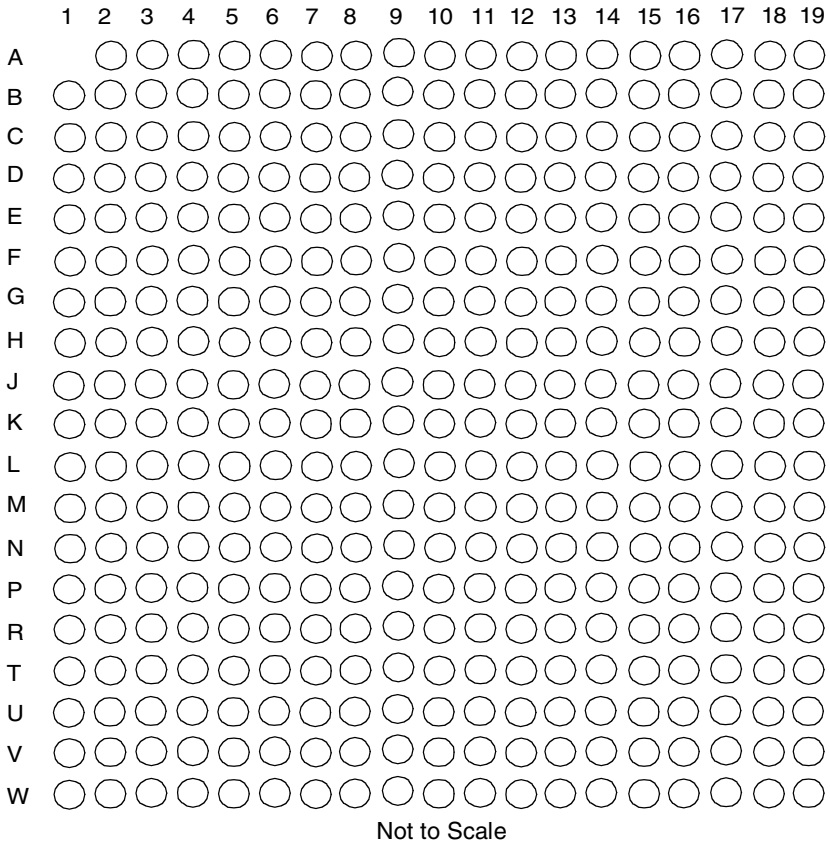


Figure 5. $\overline{\text{BMODE}}$[0:1] Input Sample Timing Diagram

6 Pin Assignments

Figure 12 (in Part A) shows the pinout of the MPC7448, 360 high coefficient of thermal expansion ceramic ball grid array (HCTE) package as viewed from the top surface. Part B shows the side profile of the HCTE package to indicate the direction of the top surface view.

Part A



Part B

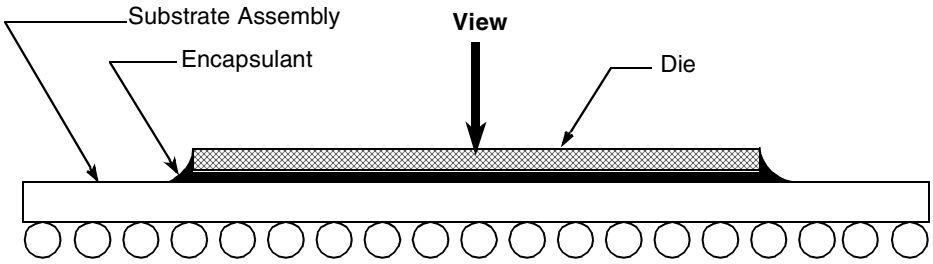


Figure 12. Pinout of the MPC7448, 360 HCTE Package as Viewed from the Top Surface

7 Pinout Listings

Table 11 provides the pinout listing for the MPC7448, 360 HCTE package. The pinouts of the MPC7448 and MPC7447A are compatible, but the requirements regarding the use of the additional power and ground pins have changed. The MPC7448 requires these pins be connected to the appropriate power or ground plane to achieve high core frequencies; see Section 9.3, “Connection Recommendations,” for additional information. As a result, these pins should be connected in all new designs.

Additionally, the MPC7448 may be populated on a board designed for a MPC7447 (or MPC7445 or MPC7441), provided the core voltage can be made to match the requirements in Table 4 and all pins defined as ‘no connect’ for the MPC7447 are unterminated, as required by the *MPC7457 RISC Microprocessor Hardware Specifications*. The MPC7448 uses pins previously marked ‘no connect’ for the temperature diode pins and for additional power and ground connections. The additional power and ground pins are required to achieve high core frequencies and core frequency will be limited if they are not connected; see Section 9.3, “Connection Recommendations,” for additional information. Because these ‘no connect’ pins in the MPC7447 360 pin package are not driven in functional mode, an MPC7447 can be populated in an MPC7448 board.

NOTE

Caution must be exercised when performing boundary scan test operations on a board designed for an MPC7448, but populated with an MPC7447 or earlier device. This is because in the MPC7447 it is possible to drive the latches associated with the former ‘no connect’ pins in the MPC7447, potentially causing contention on those pins. To prevent this, ensure that these pins are not connected on the board or, if they are connected, ensure that the states of internal MPC7447 latches do not cause these pins to be driven during board testing.

For the MPC7448, pins that were defined as the TEST[0:4] factory test signal group on the MPC7447A and earlier devices have been assigned new functions. For most of these, the termination recommendations for the TEST[0:4] pins of the MPC7447A are compatible with the MPC7448 and will allow correct operation with no performance loss. The exception is BVSEL1 (TEST3 on the MPC7447A and earlier devices), which may require a different termination depending which I/O voltage mode is desired; see Table 3 for more information.

NOTE

This pinout is not compatible with the MPC750, MPC7400, or MPC7410 360 BGA package.

Table 11. Pinout Listing for the MPC7448, 360 HCTE Package (continued)

Signal Name	Pin Number	Active	I/O	Notes
$\overline{\text{LVRAM}}$	B10	—	—	12, 20, 22
NC (no connect)	A6, A14, A15, B14, B15, C14, C15, C16, C17, C18, C19, D14, D15, D16, D17, D18, D19, E14, E15, F14, F15, G14, G15, H15, H16, J15, J16, J17, J18, J19, K15, K16, K17, K18, K19, L15, L16, L17, L18, L19	—	—	11
$\overline{\text{LSSD\_MODE}}$	E8	Low	Input	6, 12
$\overline{\text{MCP}}$	C9	Low	Input	
OV_{DD}	B4, C2, C12, D5, F2, H3, J5, K2, L5, M3, N6, P2, P8, P11, R4, R13, R16, T6, T9, U2, U12, U16, V4, V7, V10, V14	—	—	
OVDD_SENSE	E18, G18	—	—	16
PLL_CFG[0:4]	B8, C8, C7, D7, A7	High	Input	
PLL_CFG[5]	D10	High	Input	9, 20
$\overline{\text{PMON\_IN}}$	D9	Low	Input	13
$\overline{\text{PMON\_OUT}}$	A9	Low	Output	
$\overline{\text{QACK}}$	G5	Low	Input	
$\overline{\text{QREQ}}$	P4	Low	Output	
$\overline{\text{SHD}}$[0:1]	E4, H5	Low	I/O	3
$\overline{\text{SMI}}$	F9	Low	Input	
$\overline{\text{SRESET}}$	A2	Low	Input	
SYSCLK	A10	—	Input	
$\overline{\text{TA}}$	K6	Low	Input	
TBEN	E1	High	Input	
$\overline{\text{TBST}}$	F11	Low	Output	
TCK	C6	High	Input	
TDI	B9	High	Input	6
TDO	A4	High	Output	
$\overline{\text{TEA}}$	L1	Low	Input	
TEMP_ANODE	N18	—	—	17
TEMP_CATHODE	N19	—	—	17
TMS	F1	High	Input	6
$\overline{\text{TRST}}$	A5	Low	Input	6, 14
$\overline{\text{TS}}$	L4	Low	I/O	3
TSIZ[0:2]	G6, F7, E7	High	Output	
TT[0:4]	E5, E6, F6, E9, C5	High	I/O	
$\overline{\text{WT}}$	D3	Low	Output	
V_{DD}	H8, H10, H12, J7, J9, J11, J13, K8, K10, K12, K14, L7, L9, L11, L13, M8, M10, M12	—	—	
V_{DD}	A13, A16, A18, B17, B19, C13, E13, E16, F12, F17, F19, G11, G16, H14, H17, H19, M14, M16, M18, N15, N17, P16, P18	—	—	15

8 Package Description

The following sections provide the package parameters and mechanical dimensions for the HCTE package.

8.1 Package Parameters for the MPC7448, 360 HCTE BGA

The package parameters are as provided in the following list. The package type is 25 × 25 mm, 360-lead high coefficient of thermal expansion ceramic ball grid array (HCTE).

Package outline	25 × 25 mm
Interconnects	360 (19 × 19 ball array – 1)
Pitch	1.27 mm (50 mil)
Minimum module height	2.32 mm
Maximum module height	2.80 mm
Ball diameter	0.89 mm (35 mil)
Coefficient of thermal expansion	12.3 ppm/°C

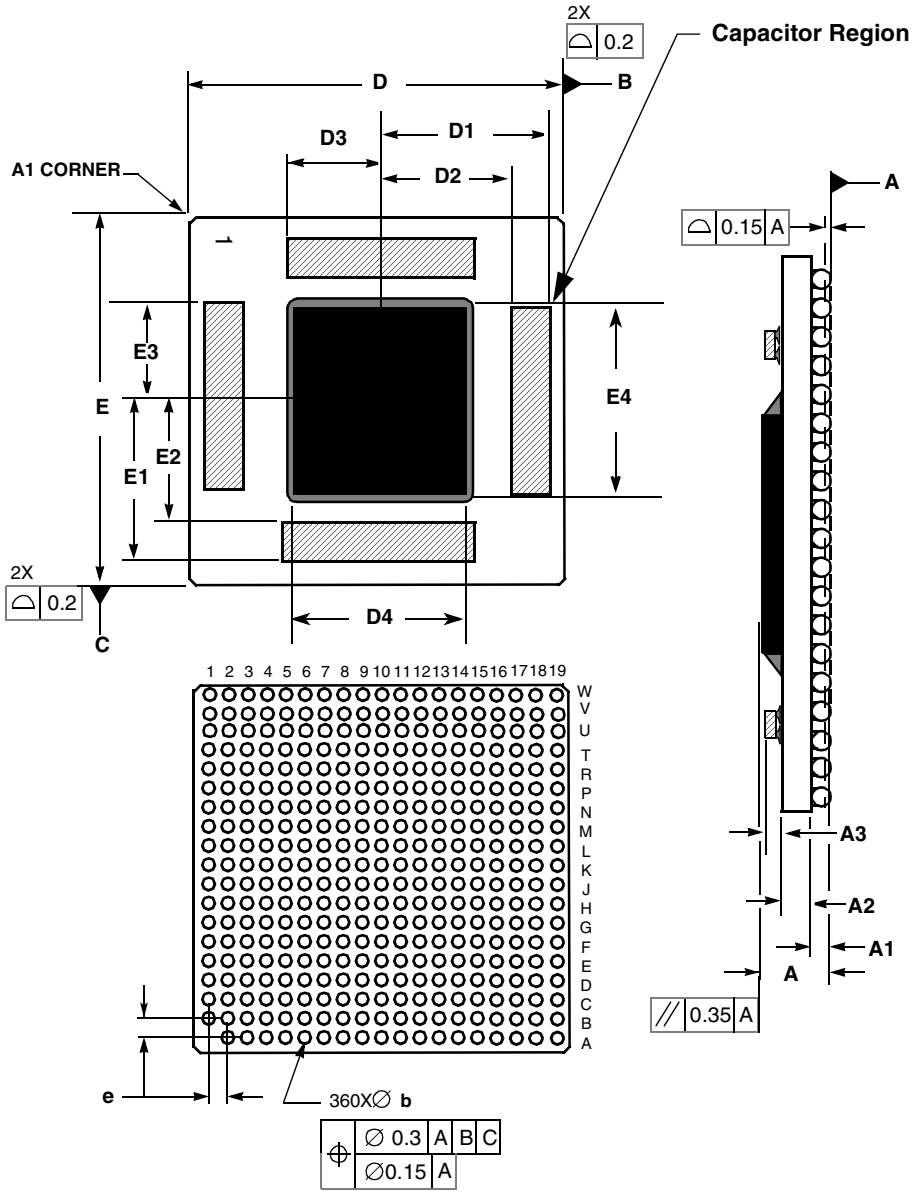
8.5 Package Parameters for the MPC7448, 360 HCTE RoHS-Compliant BGA

The package parameters are as provided in the following list. The package type is 25 × 25 mm, 360-lead high coefficient of thermal expansion ceramic ball grid array (HCTE) with RoHS-compliant lead-free spheres.

Package outline	25 × 25 mm
Interconnects	360 (19 × 19 ball array – 1)
Pitch	1.27 mm (50 mil)
Minimum module height	1.92 mm
Maximum module height	2.40 mm
Ball diameter	0.75 mm (30 mil)
Coefficient of thermal expansion	12.3 ppm/°C

8.6 Mechanical Dimensions for the MPC7448, 360 HCTE RoHS-Compliant BGA

Figure 13 provides the mechanical dimensions and bottom surface nomenclature for the MPC7448, 360 HCTE BGA package with RoHS-compliant lead-free spheres.



NOTES:
1. Dimensioning and tolerancing per ASME Y14.5M, 1994
2. Dimensions in millimeters.
3. Top side A1 corner index is a metalized feature with various shapes. Bottom side A1 corner is designated with a ball missing from the array.
4. Dimension A1 represents the collapsed sphere diameter.

	Millimeters	
Dim	**Min**	**Max**
A	1.92	2.40
A1 [4]	0.40	0.60
A2	0.70	0.90
A3	—	0.6
b	0.60	0.90
D	25.00 BSC	
D1	—	11.3
D2	8.0	—
D3	—	6.5
D4	7.2	7.4
e	1.27 BSC	
E	25.00 BSC	
E1	—	11.3
E2	8.0	—
E3	—	6.5
E4	7.9	8.1

Figure 15. Mechanical Dimensions and Bottom Surface Nomenclature for the MPC7448, 360 HCTE RoHS-Compliant BGA Package

Table 12. MPC7448 Microprocessor PLL Configuration Example (continued)

PLL_CFG[0:5]	Example Core and VCO Frequency in MHz										
	Bus-to-Core Multiplier [5]	Core-to-VCO Multiplier [5]	Bus (SYSCLK) Frequency								
			33.3 MHz	50 MHz	66.6 MHz	75 MHz	83 MHz	100 MHz	133 MHz	167 MHz	200 MHz
100110	11x	1x			733	825	913	1100	1467		
000000	11.5x	1x			766	863	955	1150	1533		
101110	12x	1x		600	800	900	996	1200	1600		
111110	12.5x	1x		625	833	938	1038	1250	1667		
010110	13x	1x		650	865	975	1079	1300			
111000	13.5x	1x		675	900	1013	1121	1350			
110010	14x	1x		700	933	1050	1162	1400			
000110	15x	1x		750	1000	1125	1245	1500			
110110	16x	1x		800	1066	1200	1328	1600			
000010	17x	1x		850	1132	1275	1417	1700			
001010	18x	1x	600	900	1200	1350	1500				
001110	20x	1x	667	1000	1332	1500	1666				
010010	21x	1x	700	1050	1399	1575					
011010	24x	1x	800	1200	1600						
111010	28x	1x	933	1400							
001100	PLL bypass		PLL off, SYSCLK clocks core circuitry directly								
111100	PLL off		PLL off, no core clocking occurs								

Notes:

1. PLL_CFG[0:5] settings not listed are reserved.
2. The sample bus-to-core frequencies shown are for reference only. Some PLL configurations may select bus, core, or VCO frequencies which are not useful, not supported, or not tested for by the MPC7448; see Section 5.2.1, "Clock AC Specifications," for valid SYSCLK, core, and VCO frequencies.
3. In PLL-bypass mode, the SYSCLK input signal clocks the internal processor directly and the PLL is disabled. However, the bus interface unit requires a 2x clock to function. Therefore, an additional signal, EXT_QUAL, must be driven at half the frequency of SYSCLK and offset in phase to meet the required input setup t_{IVKH} and hold time t_{IXKH} (see Table 9). The result will be that the processor bus frequency will be one-half SYSCLK, while the internal processor is clocked at SYSCLK frequency. This mode is intended for factory use and emulator tool use only.
   Note: The AC timing specifications given in this document do not apply in PLL-bypass mode.
4. In PLL-off mode, no clocking occurs inside the MPC7448 regardless of the SYSCLK input.
5. Applicable when DFS modes are disabled. These multipliers change when operating in a DFS mode. See Section 9.7.5, "Dynamic Frequency Switching (DFS)" for more information.
6. Bus-to-core multipliers less than 5x require that assertion of AACK be delayed by one or two bus cycles to allow the processor to generate a response to a snooped transaction. See the *MPC7450 RISC Microprocessor Reference Manual* for more information.

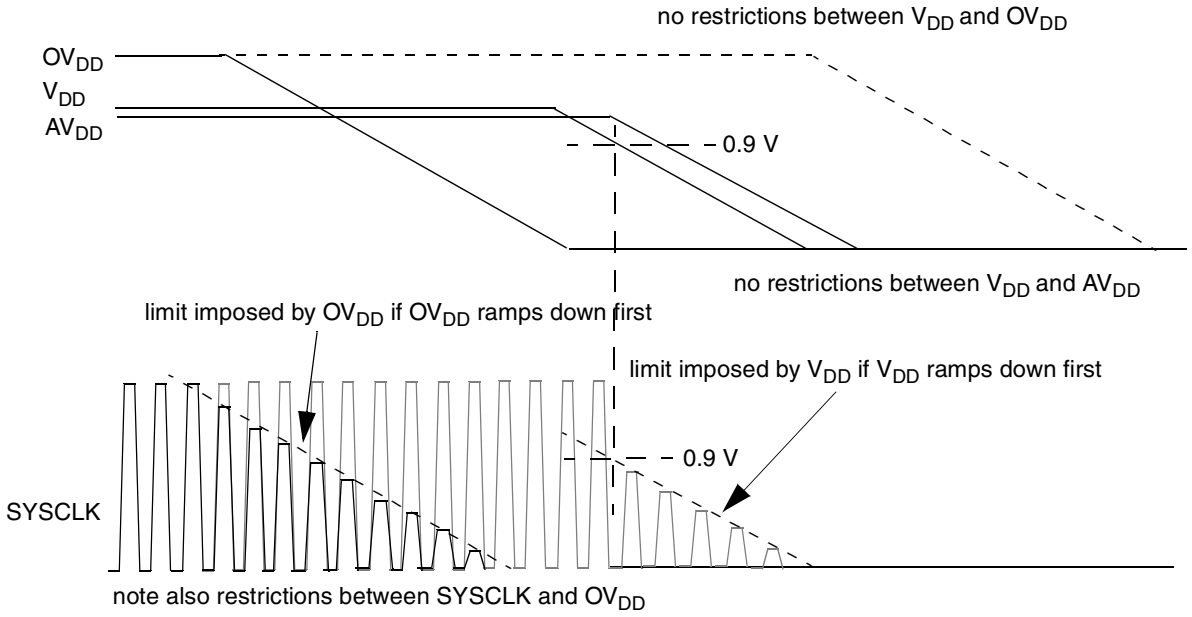


Figure 17. MPC7448 Power Down Sequencing Requirements

There is no requirement regarding AV_{DD} during power down, but it is recommended that AV_{DD} track V_{DD} within the RC time constant of the PLL filter circuit described in Section 9.2.2, "PLL Power Supply Filtering" (nominally 100 µs).

9.2.2 PLL Power Supply Filtering

The AV_{DD} power signal is provided on the MPC7448 to provide power to the clock generation PLL. To ensure stability of the internal clock, the power supplied to the AV_{DD} input signal should be filtered of any noise in the 500-KHz to 10-MHz resonant frequency range of the PLL. The circuit shown in Figure 18 using surface mount capacitors with minimum effective series inductance (ESL) is strongly recommended. In addition to filtering noise from the AV_{DD} input, it also provides the required delay between V_{DD} and AV_{DD} as described in Section 9.2.1, "Power Supply Sequencing."

The circuit should be placed as close as possible to the AV_{DD} pin to minimize noise coupled from nearby circuits. It is often possible to route directly from the capacitors to the AV_{DD} pin, which is on the periphery of the device footprint.

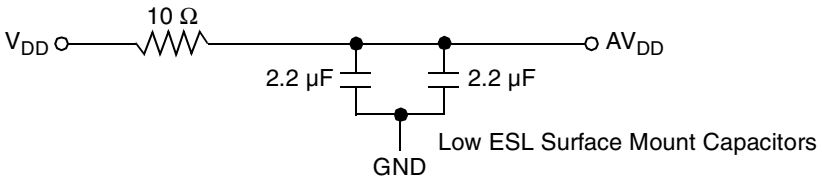


Figure 18. PLL Power Supply Filter Circuit

9.2.4 Decoupling Recommendations

Due to the MPC7448 dynamic power management feature, large address and data buses, and high operating frequencies, the MPC7448 can generate transient power surges and high frequency noise in its power supply, especially while driving large capacitive loads. This noise must be prevented from reaching other components in the MPC7448 system, and the MPC7448 itself requires a clean, tightly regulated source of power. Therefore, it is recommended that the system designer use sufficient decoupling capacitors, typically one capacitor for every V_{DD} pin, and a similar amount for the OV_{DD} pins, placed as close as possible to the power pins of the MPC7448. It is also recommended that these decoupling capacitors receive their power from separate V_{DD}, OV_{DD}, and GND power planes in the PCB, using short traces to minimize inductance.

These capacitors should have a value of 0.01 or 0.1 µF. Only ceramic surface mount technology (SMT) capacitors should be used to minimize lead inductance. Orientations where connections are made along the length of the part, such as 0204, are preferable but not mandatory. Consistent with the recommendations of Dr. Howard Johnson in *High Speed Digital Design: A Handbook of Black Magic* (Prentice Hall, 1993) and contrary to previous recommendations for decoupling Freescale microprocessors, multiple small capacitors of equal value are recommended over using multiple values of capacitance.

In addition, it is recommended that there be several bulk storage capacitors distributed around the PCB, feeding the V_{DD} and OV_{DD} planes, to enable quick recharging of the smaller chip capacitors. These bulk capacitors should have a low equivalent series resistance (ESR) rating to ensure the quick response time necessary. They should also be connected to the power and ground planes through two vias to minimize inductance. Suggested bulk capacitors are 100–330 µF (AVX TPS tantalum or Sanyo OSCON).

9.3 Connection Recommendations

To ensure reliable operation, it is highly recommended to connect unused inputs to an appropriate signal level. Unless otherwise noted, unused active low inputs should be tied to OV_{DD} and unused active high inputs should be connected to GND. All NC (no connect) signals must remain unconnected.

Power and ground connections must be made to all external V_{DD}, OV_{DD}, and GND pins in the MPC7448. For backward compatibility with the MPC7447, MPC7445, and MP7441, or for migrating a system originally designed for one of these devices to the MPC7448, the new power and ground signals (formerly NC, see Table 11) may be left unconnected if the core frequency is 1 GHz or less. Operation above 1 GHz requires that these additional power and ground signals be connected, and it is strongly recommended that all new designs include the additional connections. See also Section 7, “Pinout Listings,” for additional information.

The MPC7448 provides VDD_SENSE, OVDD_SENSE, and GND_SENSE pins. These pins connect directly to the power/ground planes in the device package and are intended to allow an external device to measure the voltage present on the V_{DD}, OV_{DD} and GND planes in the device package. The most common use for these signals is as a feedback signal to a power supply regulator to allow it to compensate for board losses and supply the correct voltage at the device. (Note that all voltage parameters are specified at the pins of the device.) If not used for this purpose, it is recommended that these signals be connected to test points that can be used in the event that an accurate measurement of the voltage at the device is needed during system debug. Otherwise, these signals should be connected to the appropriate power/ground planes on the circuit board or left unconnected.

to fully control the processor. If the target system has independent reset sources, such as voltage monitors, watchdog timers, power supply failures, or push-button switches, then the COP reset signals must be merged into these signals with logic.

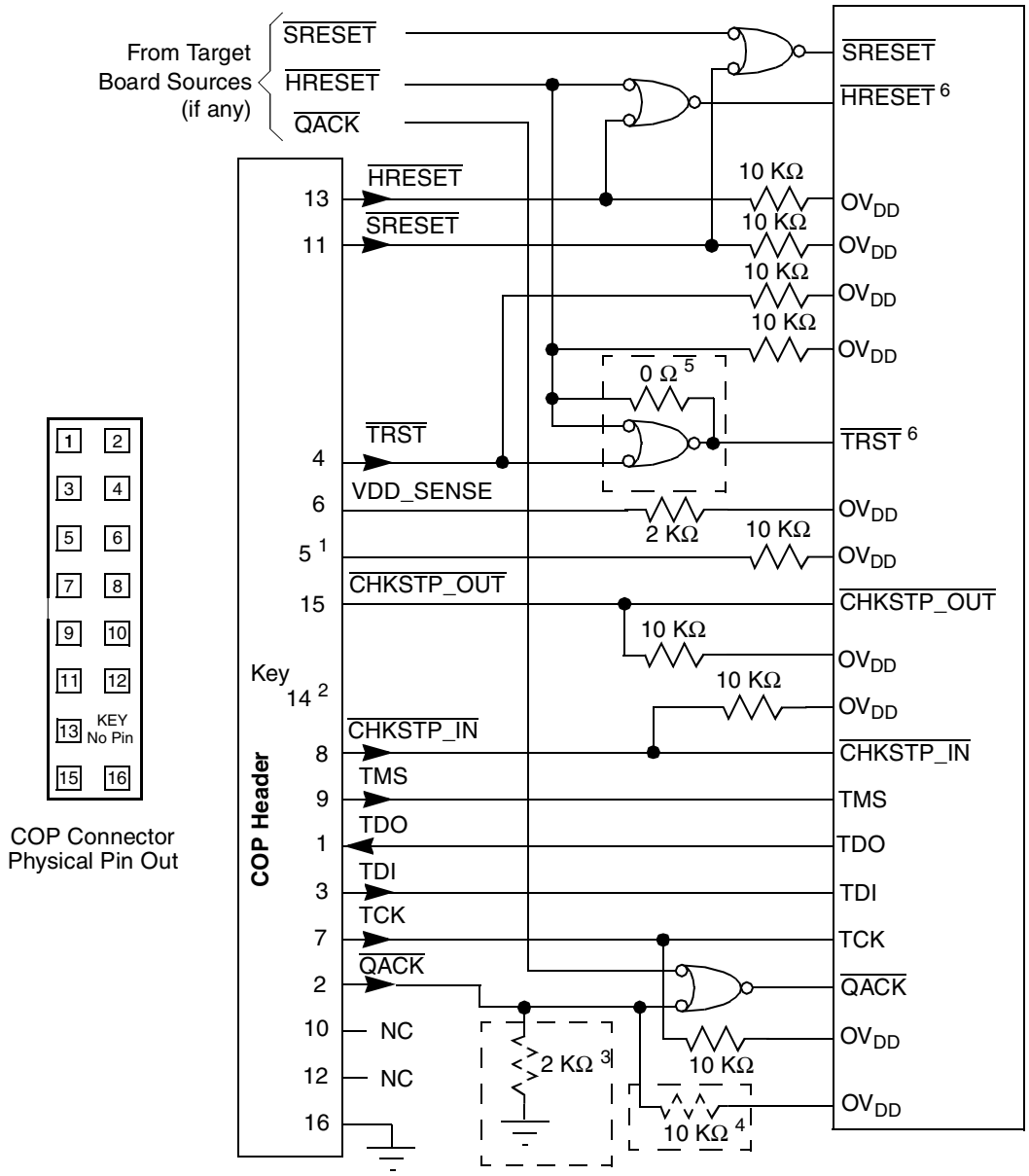
The arrangement shown in Figure 21 allows the COP port to independently assert $\overline{\text{HRESET}}$ or $\overline{\text{TRST}}$, while ensuring that the target can drive $\overline{\text{HRESET}}$ as well. If the JTAG interface and COP header will not be used, $\overline{\text{TRST}}$ should be tied to $\overline{\text{HRESET}}$ through a 0-Ω isolation resistor so that it is asserted when the system reset signal ($\overline{\text{HRESET}}$) is asserted, ensuring that the JTAG scan chain is initialized during power-on. Although Freescale recommends that the COP header be designed into the system as shown in Figure 21, if this is not possible, the isolation resistor will allow future access to $\overline{\text{TRST}}$ in the case where a JTAG interface may need to be wired onto the system in debug situations.

The COP header shown in Figure 21 adds many benefits—breakpoints, watchpoints, register and memory examination/modification, and other standard debugger features are possible through this interface—and can be as inexpensive as an unpopulated footprint for a header to be added when needed.

The COP interface has a standard header for connection to the target system, based on the 0.025" square-post, 0.100" centered header assembly (often called a Berg header). The connector typically has pin 14 removed as a connector key.

There is no standardized way to number the COP header shown in Figure 21; consequently, many different pin numbers have been observed from emulator vendors. Some are numbered top-to-bottom then left-to-right, while others use left-to-right then top-to-bottom, while still others number the pins counter clockwise from pin 1 (as with an IC). Regardless of the numbering, the signal placement recommended in Figure 21 is common to all known emulators.

The $\overline{\text{QACK}}$ signal shown in Figure 21 is usually connected to the bridge chip or other system control logic in a system and is an input to the MPC7448 informing it that it can go into the quiescent state. Under normal operation this occurs during a low-power mode selection. In order for COP to work, the MPC7448 must see this signal asserted (pulled down). While shown on the COP header, not all emulator products drive this signal. If the product does not, a pull-down resistor can be populated to assert this signal. Additionally, some emulator products implement open-drain type outputs and can only drive $\overline{\text{QACK}}$ asserted; for these tools, a pull-up resistor can be implemented to ensure this signal is negated when it is not being driven by the tool. Note that the pull-up and pull-down resistors on the $\overline{\text{QACK}}$ signal are mutually exclusive and it is never necessary to populate both in a system. To preserve correct power-down operation, $\overline{\text{QACK}}$ should be merged through logic so that it also can be driven by the bridge or system logic.



Notes:

1. RUN/$\overline{\text{STOP}}$, normally found on pin 5 of the COP header, is not implemented on the MPC7448. Connect pin 5 of the COP header to OV_{DD} with a 10-KΩ pull-up resistor.
2. Key location; pin 14 is not physically present on the COP header.
3. Component not populated. Populate only if debug tool does not drive $\overline{\text{QACK}}$.
4. Populate only if debug tool uses an open-drain type output and does not actively negate $\overline{\text{QACK}}$.
5. If the JTAG interface is implemented, connect $\overline{\text{HRESET}}$ from the target source to $\overline{\text{TRST}}$ from the COP header though an AND gate to $\overline{\text{TRST}}$ of the part. If the JTAG interface is not implemented, connect $\overline{\text{HRESET}}$ from the target source to $\overline{\text{TRST}}$ of the part through a 0-Ω isolation resistor.
6. The COP port and target board should be able to independently assert $\overline{\text{HRESET}}$ and $\overline{\text{TRST}}$ to the processor in order to fully control the processor as shown above.

Figure 21. JTAG Interface Connection

9.7 Power and Thermal Management Information

This section provides thermal management information for the high coefficient of thermal expansion (HCTE) package for air-cooled applications. Proper thermal control design is primarily dependent on the system-level design—the heat sink, airflow, and thermal interface material. The MPC7448 implements several features designed to assist with thermal management, including DFS and the temperature diode. DFS reduces the power consumption of the device by reducing the core frequency; see Section 9.7.5.1, "Power Consumption with DFS Enabled," for specific information regarding power reduction and DFS. The temperature diode allows an external device to monitor the die temperature in order to detect excessive temperature conditions and alert the system; see Section 9.7.4, "Temperature Diode," for more information.

To reduce the die-junction temperature, heat sinks may be attached to the package by several methods—spring clip to holes in the printed-circuit board or package, and mounting clip and screw assembly (see Figure 22); however, due to the potential large mass of the heat sink, attachment through the printed-circuit board is suggested. In any implementation of a heat sink solution, the force on the die should not exceed ten pounds (45 Newtons).

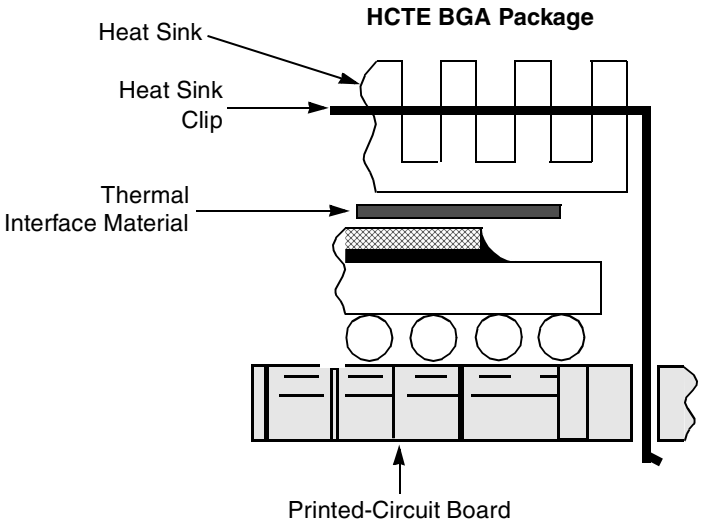


Figure 22. BGA Package Exploded Cross-Sectional View with Several Heat Sink Options

NOTE

A clip on heat sink is not recommended for LGA because there may not be adequate clearance between the device and the circuit board. A through-hole solution is recommended, as shown in Figure 23.

9.7.1 Internal Package Conduction Resistance

For the exposed-die packaging technology described in Table 5, the intrinsic conduction thermal resistance paths are as follows:

- The die junction-to-case thermal resistance (the case is actually the top of the exposed silicon die)
- The die junction-to-board thermal resistance

Figure 24 depicts the primary heat transfer path for a package with an attached heat sink mounted to a printed-circuit board.

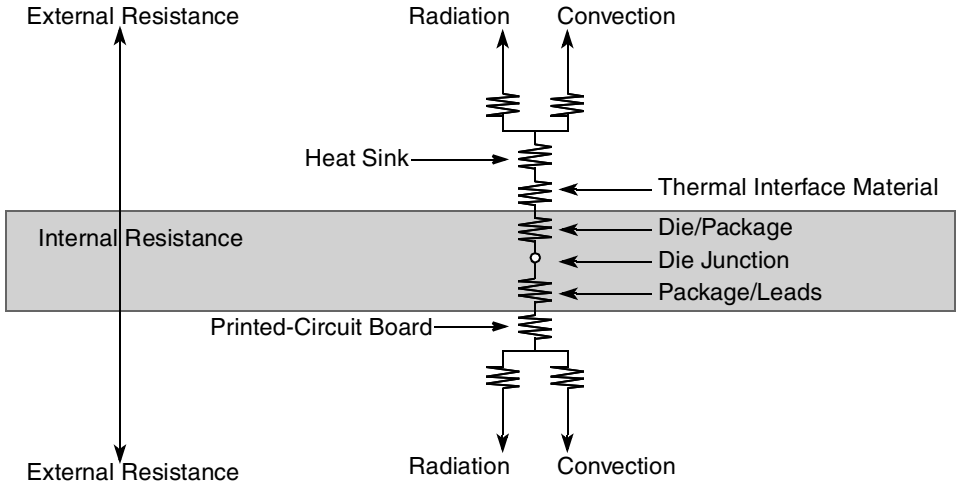


Figure 24. C4 Package with Heat Sink Mounted to a Printed-Circuit Board

Heat generated on the active side of the chip is conducted through the silicon, through the heat sink attach material (or thermal interface material), and, finally, to the heat sink, where it is removed by forced-air convection.

Because the silicon thermal resistance is quite small, the temperature drop in the silicon may be neglected for a first-order analysis. Thus, the thermal interface material and the heat sink conduction/convective thermal resistances are the dominant terms.

9.7.2 Thermal Interface Materials

A thermal interface material is recommended at the package lid-to-heat sink interface to minimize the thermal contact resistance. For those applications where the heat sink is attached by spring clip mechanism, Figure 25 shows the thermal performance of three thin-sheet thermal-interface materials (silicone, graphite/oil, fluoroether oil), a bare joint, and a joint with thermal grease as a function of contact pressure. As shown, the performance of these thermal interface materials improves with increasing contact pressure. The use of thermal grease significantly reduces the interface thermal resistance. That is, the bare joint results in a thermal resistance approximately seven times greater than the thermal grease joint.

Often, heat sinks are attached to the package by means of a spring clip to holes in the printed-circuit board (see Figure 22). Therefore, synthetic grease offers the best thermal performance due to the low interface pressure and is recommended due to the high power dissipation of the MPC7448. Of course, the selection

Shin-Etsu MicroSi, Inc. 10028 S. 51st St. Phoenix, AZ 85044 Internet: www.microsi.com	888-642-7674
Laird Technologies - Thermal (formerly Thermagon Inc.) 4707 Detroit Ave. Cleveland, OH 44102 Internet: www.lairdtech.com	888-246-905

The following section provides a heat sink selection example using one of the commercially available heat sinks.

9.7.3 Heat Sink Selection Example

For preliminary heat sink sizing, the die-junction temperature can be expressed as follows:

$$T_j = T_i + T_r + (R_{\theta JC} + R_{\theta int} + R_{\theta sa}) \times P_d$$

where:

T_j is the die-junction temperature
T_i is the inlet cabinet ambient temperature
T_r is the air temperature rise within the computer cabinet
$R_{\theta JC}$ is the junction-to-case thermal resistance
$R_{\theta int}$ is the adhesive or interface material thermal resistance
$R_{\theta sa}$ is the heat sink base-to-ambient thermal resistance
P_d is the power dissipated by the device

During operation, the die-junction temperatures (T_j) should be maintained less than the value specified in Table 4. The temperature of air cooling the component greatly depends on the ambient inlet air temperature and the air temperature rise within the electronic cabinet. An electronic cabinet inlet-air temperature (T_i) may range from 30□ to 40□C. The air temperature rise within a cabinet (T_r) may be in the range of 5□ to 10□C. The thermal resistance of the thermal interface material ($R_{\theta int}$) is typically about 1.1 □C/W. For example, assuming a T_i of 30□C, a T_r of 5□C, an HCTE package $R_{\theta JC}$ = 0.1, and a power consumption (P_d) of 25.6 W, the following expression for T_j is obtained:

Die-junction temperature: $T_j = 30□C + 5□C + (0.1□C/W + 1.1□C/W + \theta_{sa}) \times 25.6$

For this example, a $R_{\theta sa}$value of 1.53 □C/W or less is required to maintain the die junction temperature below the maximum value of Table 4.

Though the die junction-to-ambient and the heat sink-to-ambient thermal resistances are a common figure-of-merit used for comparing the thermal performance of various microelectronic packaging technologies, one should exercise caution when only using this metric in determining thermal management because no single parameter can adequately describe three-dimensional heat flow. The final die-junction operating temperature is not only a function of the component-level thermal resistance, but the system-level design and its operating conditions. In addition to the component's power consumption, a number of factors affect the final operating die-junction temperature—airflow, board population (local heat flux of adjacent components), heat sink efficiency, heat sink attach, heat sink placement, next-level interconnect technology, system air temperature rise, altitude, and so on.

Due to the complexity and variety of system-level boundary conditions for today's microelectronic equipment, the combined effects of the heat transfer mechanisms (radiation, convection, and conduction) may vary widely. For these reasons, we recommend using conjugate heat transfer models for the board as well as system-level designs.

For system thermal modeling, the MPC7448 thermal model is shown in Figure 26. Four volumes represent this device. Two of the volumes, solder ball-air and substrate, are modeled using the package outline size of the package. The other two, die and bump-underfill, have the same size as the die. The silicon die should be modeled $8.0 \times 7.3 \times 0.86$ mm^3 with the heat source applied as a uniform source at the bottom of the volume. The bump and underfill layer is modeled as $8.0 \times 7.3 \times 0.07$ mm^{3}collapsed in the z-direction with a thermal conductivity of 5.0 W/(m • K) in the z-direction. The substrate volume is $25 \times 25 \times 1.14$ mm^3 and has 9.9 W/(m • K) isotropic conductivity in the xy-plane and 2.95 W/(m • K) in the direction of the z-axis. The solder ball and air layer are modeled with the same horizontal dimensions as the substrate and is 0.8 mm thick. For the LGA package the solder and air layer is 0.1 mm thick, but the material properties are the same. It can also be modeled as a collapsed volume using orthotropic material properties: 0.034 W/(m • K) in the xy-plane direction and 11.2 W/(m • K) in the direction of the z-axis.

Conductivity	Value	Unit
Die ($8.0 \times 7.3 \times 0.86$ mm^3)		
Silicon	Temperature-dependent	W/(m • K)
Bump and Underfill ($8.0 \times 7.3 \times 0.07$ mm^3)		
k_z	5.0	W/(m • K)
Substrate ($25 \times 25 \times 1.14$ mm^3)		
k_x	9.9	W/(m • K)
k_y	9.9	
k_z	2.95	
Solder Ball and Air ($25 \times 25 \times 0.8$ mm^3)		
k_x	0.034	W/(m • K)
k_y	0.034	
k_z	11.2	

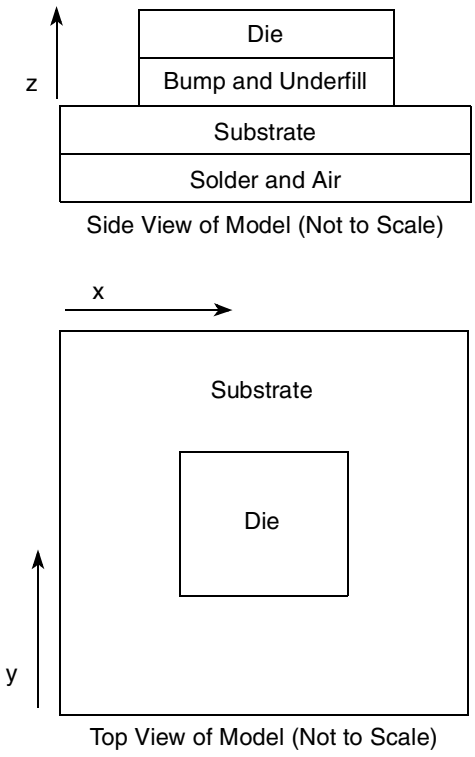


Figure 26. Recommended Thermal Model of MPC7448

Table 16. Valid Divide Ratio Configurations

DFS mode disabled		DFS divide-by-2 mode enabled (HID1[DFS2] = 1 or $\overline{\text{DFS2}}$ = 0)		DFS divide-by-4 mode enabled (HID1[DFS4] = 1 or $\overline{\text{DFS4}}$ = 0)	
Bus-to-Core Multiplier Configured by PLL_CFG[0:5] (see Table 12)	HID1[PC0-5] [3]	Bus-to-Core Multiplier	HID1[PC0-5] [3]	Bus-to-Core Multiplier	HID1[PC0-5] [3]
2x [4]	010000	N/A (unchanged) [1]	unchanged [1]	N/A (unchanged) [1]	unchanged [1]
3x [4]	100000	N/A (unchanged) [1]	unchanged [1]	N/A (unchanged) [1]	unchanged [1]
4x [4]	101000	2x [4]	010000	N/A (unchanged) [1]	unchanged [1]
5x	101100	2.5x [4]	010101	N/A (unchanged) [1]	unchanged [1]
5.5x	100100	2.75x [4]	110101 [2]	N/A (unchanged) [1]	unchanged [1]
6x	110100	3x [4]	100000	N/A (unchanged) [1]	unchanged [1]
6.5x	010100	3.25x [4]	100000 [2]	N/A (unchanged) [1]	unchanged [1]
7x	001000	3.5x [4]	110101	N/A (unchanged) [1]	unchanged [1]
7.5x	000100	3.75x [4]	110101 [2]	N/A (unchanged) [1]	unchanged [1]
8x	110000	4x [4]	101000 [4]	2x [4]	010000
8.5x	011000	4.25x [4]	101000 [2]	N/A (unchanged) [1]	unchanged [1]
9x	011110	4.5x [4]	011101	2.25x [4]	010000 [2]
9.5x	011100	4.75x [4]	011101 [2]	N/A (unchanged) [1]	unchanged [1]
10x	101010	5x	101100	2.5x [4]	010101
10.5x	100010	5.25x	101100 [2]	N/A (unchanged) [1]	unchanged [1]
11x	100110	5.5x	100100	2.75x [4]	010101 [2]
11.5x	000000	5.75x	100100 [2]	N/A (unchanged) [1]	unchanged [1]
12x	101110	6x	110100	3x [4]	100000
12.5x	111110	6.25x	110100 [2]	N/A (unchanged) [1]	unchanged [1]
13x	010110	6.5x	010100	3.25x [4]	100000 [2]
13.5x	111000	6.75	010100 [2]	N/A (unchanged) [1]	unchanged [1]
14x	110010	7x	001000	3.5x [4]	110101
15x	000110	7.5x	000100	3.75x [4]	110101 [2]
16x	110110	8x	110000	4x [4]	101000
17x	000010	8.5x	011000	4.25x [4]	101000 [2]
18x	001010	9x	011110	4.5x [4]	011101
20x	001110	10x	101010	5x	101100
21x	010010	10.5x	100010	5.25x	101100 [2]