AP-825

APPLICATION NOTE

Mobile Pentium® II Processor and Pentium II Processor Mobile Module Thermal Sensor Interface Specifications

April 1998

Order Number: 243724-001

CONTENTS

1.0. INTRODUCTION

1.1 About This Document

This document describes the key features of the integrated thermal sensor within the Mobile Pentium® II Processor and Pentium II processor Mobile Module. It provides a specification for the programming interface and describes the key registers needed in order to program the thermal sensor.

User may need to refer to SMBus specification for SMBus definition and implementation related issues. SMBus specification is available to general public at the following web address: www.sbs-forum.org

1.2. Thermal Sensor Features

The thermal sensor in the Mobile Pentium II Processor and the Pentium II processor Mobile Module provides the means of measuring the temperature with greater accuracy than any other previous Intel architecture processor products.

The thermal sensor is composed of control electronics, SMBus interface electronics, a precision analog-to-digital convertor and a precision current source. The thermal sensor drives a small current through a silicon diode located on the processor core and measures the voltage generated across the diode by the current. With this information, the thermal sensor computes the temperature of the processor die. Software running on the processor or the microcontroller can use the thermal sensor to thermally manage the system.

Besides the above described remote thermal diode, the thermal sensor also contains an internal thermal diode that can compute the locale temperature of the sensor.

The thermal sensor implements the SMBALERT# signal described in the SMBus specification. It can be programmed to assert SMBALERT# if the temperature of the processor core thermal diode or internal thermal diode exceeds an upper or lower threshold. The thresholds are individually programmable for either thermal diode. The temperature of either thermal diode can be digitally read using an SMBus read command.

The temperature data format is seven-bit plus sign, with each bit corresponding to 1°C, in twos-complement format. Measurements can be done automatically and autonomously, with the conversion rate programmed by the user or programmed to operate in a single-shot mode.

The thermal sensor detects when power is applied to the processor and resets itself at power-up.

1.3. Major Usage Model Differences between Mobile Pentium® II Processor and the Pentium II processor Mobile Module

It is recommended that only the remote diode be used to measure the processor core temperature in the Mobile Pentium II Processor, as the local diode reading is less accurate. The readout during the processor suspend state may not be accurate.

In Pentium II processor Mobile Module, the remote diode is used to measure the processor core temperature, while the locale diode is used to monitor the temperature in the 440BX area.

Please note, the SMBus address is 1001 101 for the Mobile Pentium II Processor, and 1001 110 for Pentium II processor Mobile Module.

2.0. SMBUS INTERFACE

The thermal sensor implements the clock, data and alert signals of the SMBus specification. It does not implement the SMBSUS# suspend signal. The seven bit SMBus address of the thermal sensor is 1001101. The thermal sensor responds to just five of the SMBus packet types: write byte, read byte, send byte, receive byte, and ARA (Alert Response Address). The send byte packet is used for sending one-shot commands only. The receive byte packet accesses the register commanded by the last read byte packet. If a receive byte packet is preceded by a write byte or send byte packet more recently than a read byte packet, then the behavior is undefined. Figure 1 through Figure 5 illustrate the five packet types. In these figures, 'S' represents the SMBus start bit, 'P' represents a stop bit, 'Ack' represents an acknowledge, and '///' represents a negative acknowledge. The shaded bits are transmitted by the thermal sensor and the unshaded bits are transmitted by the SMBus host controller. Table 1 shows the encoding of the command byte.

Please note, the SMBus address is 1001 101 for the Mobile Pentium II Processor, and 1001 110 for Pentium II processor Mobile Module.

The term "device address" in the ARA packet is defined as the SMBus address (7 bit), with a 8th don't care bit.

S	Address	Write	Ack	Command	Ack	Data	Ack	P
	7 bits			8 bits		8 bits		

Figure 1. Write Byte SMBus Packet

S	Address	Write	Ack	Command	Ack	S	Address	Read	Ack	Data	///	P
	7 bits			8 bits			7 bits			8 bits		

Figure 2. Read Byte SMBus Packet

S	Address	Write	Ack	Command	Ack	P
	7 bits			8 bits		

Figure 3. Send Byte SMBus Packet

S	Address	Read	Ack	Data	///	P
	7 bits			8 bits		

Figure 4. Receive Byte SMBus Packet

S	ARA	Read	Ack	Device Address	///	P
	0001 100			8 bits		

Figure 5. ARA SMBus Packet

Table 1. Command Byte Bit Assignments

Register	Command	Reset State	Function
RLT	00H	00000000B	Read internal diode temperature
RRT	01H	00000000B	Read processor core diode temperature
RS	02H	N/A	Read status byte (flags, busy signal)
RC	03H	00000000B	Read configuration byte
RCR	04H	00000010B	Read conversion rate byte
RLHL	05H	01111111B	Read internal diode T_{HIGH} limit
RLLL	06H	11001001B	Read internal diode T_{LOW} limit
RRHL	07H	01111111B	Read processor core diode T_{HIGH} limit
RRLL	08H	11001001B	Read processor core diode T_{LOW} limit
WC	09H	N/A	Write configuration byte
WCR	0AH	N/A	Write conversion rate byte
WLHL	0BH	N/A	Write internal diode T_{HIGH} limit
WLLL	0CH	N/A	Write internal diode T_{LOW} limit
WRHL	0DH	N/A	Write processor core diode T_{HIGH} limit
WRLL	0EH	N/A	Write processor core diode T_{LOW} limit
OSHT	0FH	N/A	One shot command (use send byte packet)
N/A	10H – FFH	N/A	Reserved for future use (don't care)

Note: All RFU bits should be treated as " don't care bits for programming purpose.

All of the commands are for reading or writing registers in the thermal sensor except the one-shot command (OSHT). The one-shot command forces the immediate start of a new conversion cycle. If a conversion is in progress when the one-shot command is received, then the command is ignored. If the thermal sensor is in Standby mode when the one-shot command is received, then a conversion is performed and the sensor returns to Standby mode. If the thermal sensor is in auto-convert mode and it is between conversions, then the conversion rate timer resets and the next automatic conversion takes place after a full delay elapses.

The default command after reset is 00h (RLT). After reset, receive byte packets will return the local temperature until another command is sent to the thermal sensor.

3.0. THERMAL SENSOR REGISTERS

3.1. Thermal Sensor Temperature Registers

The internal and processor core temperature registers contain the temperature of the thermal sensor and the processor core diodes in degrees centigrade, rounded to the nearest integer. The temperature is stored in an eight-bit, two's-complement format, ranges from +127°C to -128°C. These registers are saturating: temperatures above +127°C are represented as +127°C and temperatures below -128°C are represented as -128°C. Table 2 shows the encoding of a number of temperatures.

3.2. Thermal Sensor Limit Registers

The thermal sensor has four temperature limit registers, which define high and low limits for both the internal and processor core diodes. The encoding for these registers is the same as for the temperature registers. If either measured diode temperature equals or exceeds one of its limits, then its alarm is triggered. If the SMBALERT# signal is not masked and any of the temperature limit alarms is triggered, then SMBALERT# will be asserted. The SMBALERT# signal will remain asserted until the thermal sensor receives an ARA packet.

Table 2. Thermal Sensor Temperature Encoding

Temperature (°C)	Rounded	Register Contents
+130.00	+127	01111111B
+127.00	+127	01111111B
+126.50	+127	01111111B
+126.00	+126	01111110B
+25.25	+25	00011001B
+0.50	+1	00000001B
+0.25	0	00000000B
0.00	0	00000000B
-0.25	0	00000000B
-0.50	0	00000000B
-0.75	-1	11111111B
-1.00	-1	11111111B
-25.00	-25	11100111B
-25.50	-25	11100111B
-54.75	-55	11001001B
-55.00	-55	11001001B
-65.00	-65	10111111B

Table 3. Reed Format for Alert Response Address

Bit	Name	Definition
7 (MSB)	ADD7	Thermal Sensor Address Bit 7
6	ADD6	Thermal Sensor Address Bit 6
5	ADD5	Thermal Sensor Address Bit 5
4	ADD4	Thermal Sensor Address Bit 4
3	ADD3	Thermal Sensor Address Bit 3
2	ADD2	Thermal Sensor Address Bit 2
1	ADD1	Thermal Sensor Address Bit 1
0(LSB)	Don’t Care	Don’t Care

Note: All RFU bits should be treated as “ don’t care” bits for programming purpose.

3.3. THERMAL SENSOR STATUS REGISTER

The status register shown in Table 3 indicates which (if any) temperature thresholds have been exceeded. It also indicates if a conversion is in progress or if an open circuit has been detected in the processor core diode connection. Once set, alarm bits stay set until they are cleared by a status register read. A successful read to the status register will clear all the alarm bits. If any alarm conditions persist then the corresponding bits will be set again. Clearing alarm bits does not clear the SMBALERT# latch, only the ARA packet does that.

Table 4. Thermal Sensor Status-Byte Register

Bit	Name	Function
7 (MSB)	BUSY	A one indicates that the analog-to-digital converter is busy converting.
6	LHIGH	A one indicates that the internal diode high temperature alarm has activated.
5	LLOW	A one indicates that the internal diode low temperature alarm has activated.
4	RHIGH	A one indicates that the processor core diode high temperature alarm has activated.
3	RLOW	A one indicates that the processor core diode low temperature alarm has activated.
2	OPEN	A one indicates an open fault in the connection to the processor core diode.
1	RFU	Reserved for future use.
0 (LSB)	RFU	Reserved for future use, and should be read as“ don’t care”.

Note: All RFU bits should be treated as “ don’t care” bits for programming purpose.

3.4. Thermal Sensor Configuration Register

The configuration register controls the SMBALERT# signal and the operating mode (Standby vs. Auto-convert) of the thermal sensor. Table 4 shows the format of the configuration register. If the MASK bit is set high then the SMBALERT# signal is forced inactive (high), regardless of any pending alarm condition. If the RUN/STOP bit is set high, then the thermal sensor immediately stops converting and enters Standby mode. The thermal sensor will still perform temperature conversions in Standby mode when it receives a one-shot command. If the RUN/STOP bit is low, then the thermal sensor enters auto-conversion mode.

Table 5. Thermal Sensor Configuration Register

Bit	Name	Reset State	Function
7 (MSB)	MASK	0	Masks SMBALERT# when high.
6	RUN/STOP	0	Standby mode control bit. If high, the device immediately stops converting, and enters standby mode. If low, the device converts in either one-shot or timer mode
5 – 0	RFU	0	Reserved for future use.

Note: All RFU bits should bee treated as "don't care" bits for programming purpose.

3.5. Conversion Rate Register

The contents of the conversion rate register determines the rate at which temperature conversions happen when the thermal sensor is in auto-convert mode. Table 5 shows the mapping between conversion rate register values and the conversion rate. As indicated in Table 5, the conversion rate register is set to its default state of 02H (0.25Hz) when the thermal sensor is powered up. There is a ±25% error tolerance between the conversion rate indicated in the conversion rate register and the actual conversion rate.

Table 6.Conversion Rate Register Encoding

Register Contents	Conversion Rate (Hz)
00H	0.0625
01H	0.125
02H	0.25
03H	0.5
04H	1
05H	2
06H	4
07H	8
08H – FFH	RFU

Note: All RFU bits should be treated as " don't care" bits for programming purpose.

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