System Board Component and Peripheral Device Temperature Measurements of Personal Computers with the IBM 6x86 Microprocessor

Application Note

Author: Janak Patel

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Introduction

The IBM 6x86 processor’s superscalar, superpipelined architecture provides superior performance for IBM PC-compatible software. It is capable of executing a wide range of operating systems and application software such as DOS, Windows, OS/2, UNIX, Windows 95, Windows NT, Novell and many others. The superpipelined architecture allows the IBM 6x86 to operate at an internal clock frequency of 100 MHz and above.

Since the IBM 6x86 processor runs at higher internal clock frequency and provides superior performance, it requires more power to operate steady and stable. IBM 6x86 processors operate at the supply voltage range of 3.3 to 3.6 volts. This, however, requires the IBM 6x86 processor to draw additional current. The required power to operate the IBM 6x86 processor is not an issue since the currently available system board for an IBM PC compatible personal computer can provide the power needed. For more detail on the power requirement for the IBM 6x86 processor, refer to application note #40215: *Proper Decoupling Solutions for the IBM 6x86 Microprocessor* and #40211: *Voltage Regulators for the IBM 6x86 Microprocessor*. Refer to #40217 *Solution Pak for the IBM 6x86 Microprocessor* for available system boards for the IBM 6x86 microprocessor. These documents can be ordered by calling the IBM Microelctronics Division Faxback service at (415) 855-4121 or they can be downloaded from the World Wide Web at **http://www.chips.ibm.com/products/x86/doclist.html**.

The consumed power in the microprocessor generates the heat. The IBM 6x86 processor at 150 MHz internal clock frequency generates about 20 watts power in typical condition and an absolute maximum of 25 watts in a worst case situation. If this heat is not removed efficiently, the temperature of the microprocessor can rise significantly. Each electronic device has a specific operating temperature limit. The device may not operate properly beyond the operating temperature limit. The case temperature of the IBM 6x86 processor must not exceed 75^{o} C. An external heatsinking device, such as a heatsink, air flow or combination, is required to keep the IBM 6x86 microprocessor within the operating temperature limit. If the proper thermal solution is not implemented for the IBM 6x86 microprocessor, it may not operate consistently or not function at all. However, there are thermal solutions available for all IBM 6x86 microprocessors for up to 150 MHz internal clock frequency to keep the IBM 6x86 microprocessor's case temperature within 75^{o} C limit. Refer to application note #40214: *Heatsink and Fan/Heatsink for IBM 6x86 Microprocessor* for a thermal solution for a specific internal clock frequency IBM 6x86. The user may also refer to application notes #40209: *Selection of Appropriate Thermal Solution for IBM 6x86 Microprocessors* and #40216: *System Level Design Considerations for IBM 6x86 Microprocessor Thermal Management* for more details.

Although the thermal solutions for IBM 6x86 processor up to 150 MHz internal clock frequency are available, the system integrator may have concern about the heating of system board components, such as the chipset, SRAM, memory module, and peripheral devices, such as hard disk drives, in the vicinity of the IBM 6x86 microprocessor. This is a valid concern since up to 25 watts of power is generated in the microprocessor as well as additional heat is generated in the voltage regulator due to higher output current.

The intent of this application note is to present empirical evidence that indicates there is no adverse impact on the other system board components and peripheral devices due to higher power dissipation in the IBM 6x86 processor and voltage regulator. Two case studies are presented to show that temperatures of concerned components and peripheral devices are well within their operating temperature limits in the industry standard desk-mounted personal computer with the IBM 6x86 processor operating at 150 MHz internal clock frequency in worst case condition (i.e., generating about 25 watts power in the microprocessor.) In case one, an appropriate thermal solution for the IBM 6x86 processor was used; in the second case, a marginal thermal solution for the processor was employed. The temperatures of concerned system board components and peripheral devices were well within their operating limits despite the marginal thermal solution for the processor in the second case. This application note also shows how to evaluate an individual system for the heating concerns of system board components and peripheral devices in the vicinity of the IBM 6x86 microprocessor.

System Configuration

As shown in Figure 1, an industry standard desk-mount personal computer chassis, usually recognized as a desktop, was used to measure all the temperatures in both case studies. However, Figure 1 shows the first case study where a full AT style system board was used while in the second case study, a baby AT style system board was used. The baby AT style system board is smaller than the full AT style board. The baby AT style system board has the same width as full AT style, but its length does not stretch all the way up to the speaker as shown in Figure 1. The baby AT style system board extends up to the hard disk drive's back edge . As shown in Figure 1, air vents were provided in the front bottom panel for the room air to enter the system. Air vents, in the circular form at the right rear of the desktop and where the power supply unit exhaust fan is mounted, were provided to exhaust the warm system air to the room.

In Figure 1, the Socket 5 shows the location of the IBM 6x86 processor with respect to other system components. The location of socket 5 in the second case study was right behind the socket 5 as shown in the Figure 1. In both cases, the video adapter card was plugged in the fourth ISA adapter connector which is next to the PCI adapter connector as shown in Figure 2. The sound, fax/modem and network adapter cards were not installed in the desktop in either case. The sound, fax/modem and network adapter cards dissipate some power, however, the power generated (usually in the range of 4 to 8 watts) in these adapter cards can be easily dissipated with mass of the card and venting system in the system chassis. In addition to that, not all cards dissipate the power at the same time so these cards may not be active but may help dissipate the system board heat. Hence, these adapter cards were not installed to simulate the worst possible thermal configuration to cover other unknown configurations too. Similarly, the hard disk drive of 1037 MB size was mounted alone to simulate the worst possible thermal configuration as shown in Figure 1. The floppy diskette drive is usually stacked on top of the hard disk drive. The floppy drive is usually not active all the time and may help dissipate the heat from the hard disk drive and hence it was mounted where CD-ROM drive and 5.25" floppy drive or other drives are usually mounted in the front right hand side of the desktop as shown in the Figure 1. The CD-ROM was also not installed because its presence does not affect the thermal configuration

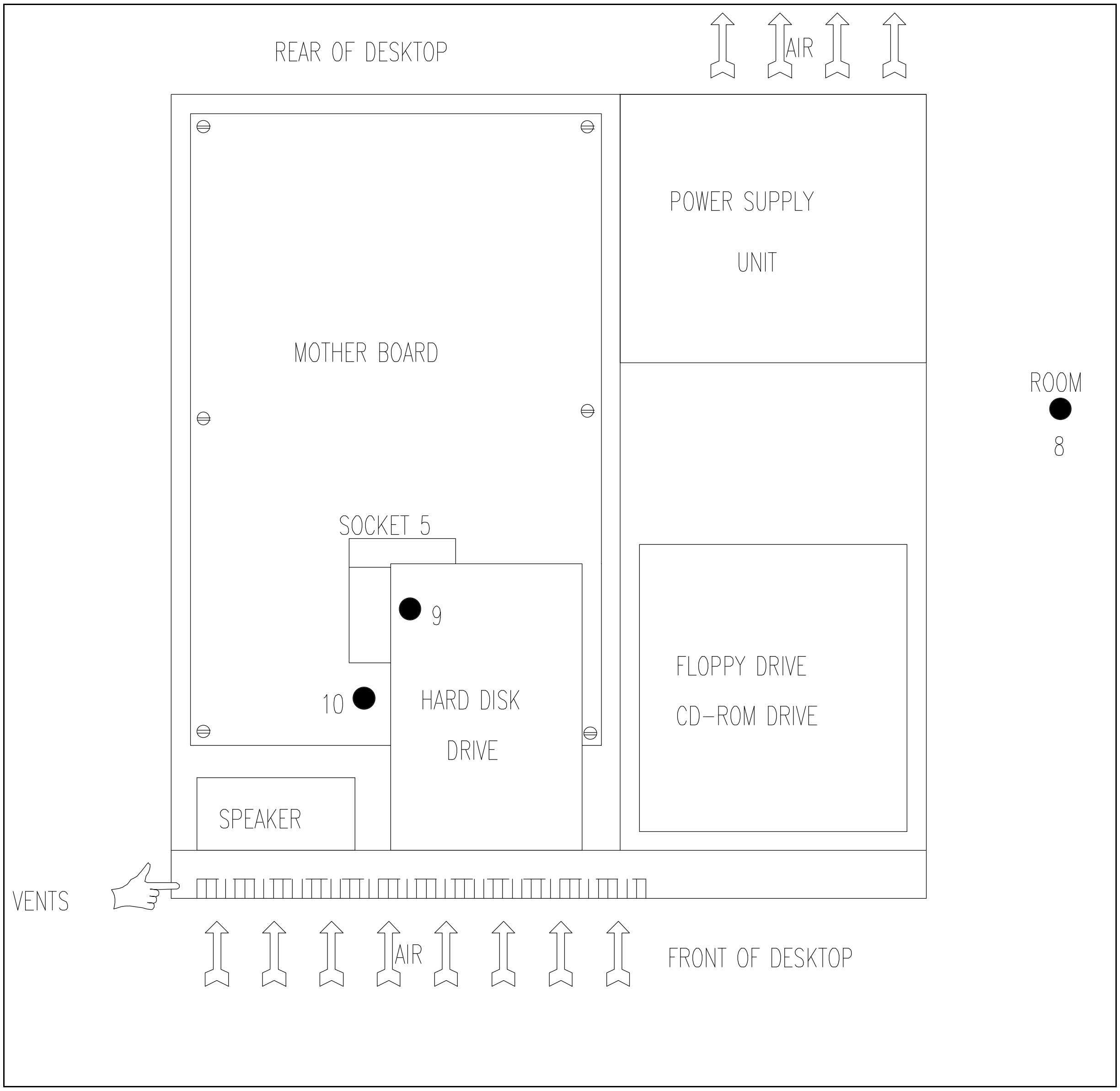

Figure 1. Industry Standard Desk Mount Personal Computer Chassis with System Components.

due to a partition in the system, low power, and it is located relatively far from the microprocessor. The IBM 6x86 microprocessor has an internal cache of 16KB and the on board secondary cache was 256KB in both case studies.

In both case studies, no additional fan or blower has been employed except the power supply unit exhaust fan and the one used in the thermal solution for the processor.

Case Study One

An IBM 6x86 microprocessor in a 296 pin ceramic pin grid array package with copper-tungsten integrated heat slug and spreader was plugged into socket 5 of the system board as shown in Figure 2. All four memory SIMMS were populated with a total of 16 MB of RAM. The jumpers on the system board were set up for 1) 3.5 volts supply to the microprocessor, 2) system bus frequency at 50 MHz and 3) internal clock frequency at 150 MHz. It may be noted that running the system bus frequency at 75 MHz improves the system performance but the amount of the power drawn by the IBM 6x86 processor depends upon the internal clock frequency regardless of the system bus frequency. A convoluted fan/sink of Wakefield Engineering**, part number 979L-100AB121, was attached on top of the IBM 6x86 processor using thermal grease with thermal conductivity of 0.5 watts per meter - (^{o}) degrees C. The fan/sink assembly usually includes the clip to be attached to the socket 5 tabs for mechanical strength and proper thermal contact with the microprocessor, however, the clip was not attached to the tabs of socket 5 to create a worst case thermal configuration. The 12 volts dc power to the fan of fan/sink assembly was fed through the system power supply unit.

Five mil diameter (36 gauge) J type thermocouple wires, part number 5SC-TT-J-36-72 of Omega Engineering Inc.**, with open bead were attached to the various components of the system board in the vicinity of the microprocessor and voltage regulator as shown in Figure 2. Any other type of thermocouple, such as T and K, can also be used to record the temperature. The case temperature of IBM 6x86 processor has to be measured at the top center of package. However, a thermocouple was attached to the center of bottom lid of IBM 6x86 processor so as not to interfere with the fan/sink attachment to the microprocessor. In a separate study, it was concluded that at a steady state condition, the temperature difference between the center of the bottom lid and center of the top case of the IBM 6x86 processor is about 5^o C. The thermocouple at location 2 was attached to the printed circuit board surface between the socket 5 and voltage regulator due to the expected hot surface at this point. A thermocouple was also hung at location 6 in the air about 1" away from the microprocessor and about 1" over the PCB to detect the system ambient temperature rise. Care must be taken to ensure that exhaust air flow from the fan/sink does not influence the system ambient temperature rise. All other components were selected near and around the microprocessor to evaluate the influence of microprocessor heat dissipation on these components. The measured temperatures of these components were at the top center of their cases. No heatsink was attached to the chipset in this case. A small piece of copper tape was used to attach the thermocouple to the case to ensure that the bead makes good contact with the case. Any other thermal cement can also be used to attach the thermocouple to the components. A thermocouple was hung out side the system chassis in the room to monitor the room temperature. A thermocouple on the hard disk drive case was attached as shown in the Figure 1. It was determined by touch and feel that the outer skin of system chassis right above the microprocessor and voltage regulator locations was the warmest spot on the whole chassis. A thermocouple was attached at the warmest spot of skin to monitor the worst skin temperature of the system chassis as shown in Figure 1. The location of the warmest spot on the skin in an individual system may be different depending upon the locations of the microprocessor, voltage regulator, air vents, etc.

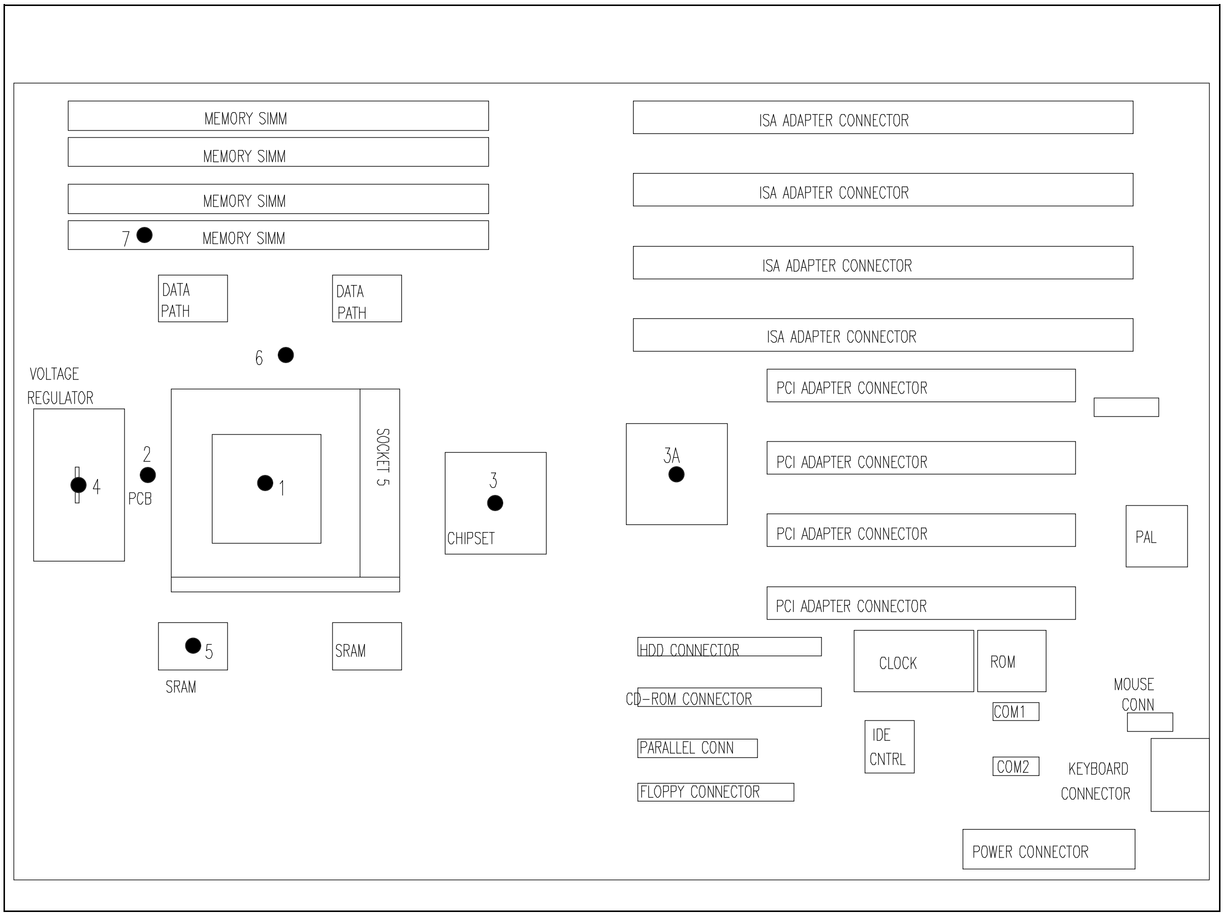

Figure 2. Full AT Style System Board with Major Components Employed in Case Study One.

It was determined previously that Landmark's Speed200 Version 2.0 execution under DOS drew the maximum amount of current in the IBM 6x86 processor. The PUZZLE program, which can be down loaded from the WWW http://www.chips.ibm.com/products/x86/doclist.html, was also executed to ensure that internal clock frequency jumper settings were correct. Table 1 below provides time in seconds to execute the puzzle for various internal clock frequencies of the IBM 6x86 processor. It may be noted that some variation in time may occur due to variation in the video card selection.

Internal Clock Frequency of IBM 6x86 processor in MHz	Time Required to complete Puzzle in Seconds
100	1.05/1.10
120	0.88
133	0.77/0.82
150	0.72/0.77

Table 1. Time Required to Run Puzzle for the IBM 6x86 Processor at Various Internal Clock Frequency.

The Speed200 execution was carried out for 5 hours. The actual steady state thermal condition, however, exists within a couple of hours. The other ends of thermocouple wires were attached to a PC based data acquisition system where data were logged in at 15 minute interval for five hours. The highest reading for each location during 5 hour test is tabulated in Table 2 below.

Location Number	Description	Temp. in C	Temp. Extrapolated for 35 C Room Temp. in C	Comments
1	IBM 6x86 processor Case Bottom	61	70	Case Top will be 66 and 75
2	PCB	57	66	
3	Chipset	60	69	Near IBM 6x86
3A	Chipset	53	62	Away from IBM 6x86
4	Voltage Regulator	83	92	Specification: Tc = 118 C
5	SRAM	38	47	
6	System Ambient	38	47	
7	Memory module	42	51	
8	Room	26	35	
9	Hard Disk Drive	48	57	
10	Skin	35	44	

Table 2. Temperatures of System Board Components and Peripherals with IBM 6x86 processor.

As you can see from above Table 2 that all the temperatures are below 85^{o} C at normal room temperature of 26^{o} C. The extrapolated temperatures for 35^{o} C room temperature are also below 85^{o} C for all components except the voltage regulator. However, the case temperature limit specification for most of the voltage regulators is above 100^{o} C. The warmest skin temperature of the system chassis at a room temperature of 35^{o} C is well below 50^{o} C safety limit. The IBM 6x86 processor at 150 MHz internal clock frequency and 3.5 volts supply voltage meets the case temperature specification of 75^{o} C at maximum room temperature of 35^{o} C. The specifications for the hard disk drive operating environment is 5^{o} to 55^{o} C; at a room temperature of 35^{o} C, that maximum system ambient temperature is 47^{o} C.

Case Study Two

The set up for this case was the same as case one with a few changes. The first change is the size of the system board. The second change is a thermal solution used for the IBM 6x86 microprocessor. The thermal solution selected for the IBM 6x86 processor in this case can keep the case temperature of the IBM 6x86 processor within 75^{o} C limit at a maximum room temperature of 27^{o} C. The thermal solution for the IBM 6x86 processor in this case cannot keep the case temperature of microprocessor within a 75^o C specification limit for room temperature exceeding 27^o C. However, the intent of selecting the marginal thermal solution for the IBM 6x86 processor in this case was to show that there was no adverse heating effect on the system board components and peripheral devices. The same software tools and procedures as the previous case were used to record the temperature data. The highest recorded temperature for each location is tabulated in Table 3 below.

Location Number	Description	Temp. in C	Temp. Extrapolated for 35 C Room Temp. in C	Comments
1	IBM 6x86 Case Bottom	69	78	Case Top will be 74 and 83
2	PCB	55	64	
3	Chipset	65	74	Measured at top of heatsink
4	Voltage Regulator 1	79	88	Specification: Tc = 118 C
4A	Voltage Regulator 2	80	89	Specification: Tc = 118 C
5	SRAM	35	44	
6	System Ambient	39	48	
7	Memory module	37	46	Located near Power Supply
8	Room	26	35	
9	Hard Disk Drive	47	56	
10	Skin	36	45	

Table 3. Temperatures of System Board Components and Peripherals with IBM 6x86 processor.

As you can see from Table 3 above, the case temperature (top) of the IBM 6x86 processor is 83^{o}C, 8^o C over the specification limit of 75^o C at 35^o C room temperature. The case temperatures of all other components at room temperature are below 85^o C. The chipset uses a small pin fin aluminum green anodized heatsink. The temperature of the chipset was measured on the top center of the pin fin heatsink. The chipset specifications for operation are a system environment temperature up to 70^o C; this system’s extrapolated ambient temperature is 48^o C. The extrapolated temperatures for all components for 35^o C room temperature are within 85^o C except the voltage regulators. The case temperature specification for most of the voltage regulators is above 100^o C.

Summary

The IBM 6x86 microprocessor provides superior performance for IBM PC-compatible software. The high internal clock frequencies needed to achieve this greater performance require more power to allow the processor to operate soundly. Appropriate system board voltage regulators and decoupling capacitors provide the power needed by the IBM 6x86 processor. The magnified power in turn increases the system ambient temperature. The thermal solutions to dissipate up to 25 watts of power generated in the processor are also available. **This application note provides the important information for the system integrator. For the test environments described here, there is no adverse heating effect on system board components and peripheral devices due to the higher power dissipation of the IBM 6x86 processor.** This application note also provides procedures to monitor temperatures of various system board components and peripherals for a specific individual system. No additional fan or blower is required for a comparable system with the processor in the Industry Standard desktop or floor mount tower type chassis except the one used for a thermal solution of the IBM 6x86 processor. The Industry Standard desktop or floor mount tower type chassis comes with an integral power supply fan unit.