Heatsink and Fan/Heatsink for IBM 6x86L Microprocessors

Application Note

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Introduction

The IBM 6x86 and 6x86L microprocessors[1] both have a 296 I/O Pin Grid Array package which is compatible with Sockets 5 and 7. Although both the IBM 6x86 and 6x86L processors have the same foot print packages, there are a few differences between them. The main difference between these processors is the power supply scheme used to operate them. A single level of voltage is supplied to both the core and the I/O of the IBM 6x86 processor. This supply voltage can be either 3.3 volts or 3.5 volts. In the IBM 6x86L processor, two separate levels of voltages are supplied to the core and the I/O. The supply voltage to the I/O is usually fixed at 3.3 volts. The supply voltage to the core can be in the range of 2.7 to 2.9 volts. The lower core supply voltage results in the lower power consumption for the IBM 6x86L processor.

This application note provides the values of maximum power generated in the IBM 6x86L processor at various internal clock frequencies for a proper thermal design. The case-to-ambient or external thermal resistance in degrees Celsius (°C) per watt for various system ambient environments and internal clock frequencies are provided so that the user can select an appropriate thermal solution. Several thermal solutions, such as heatsink and fan/heatsink, are characterized for various operating room temperatures and air flow conditions including a natural convection condition.

Power

The generated power in the IBM 6x86L processor was measured with a specially designed socket. This socket blocks the system board power supply to the microprocessor. An external power supply unit provided the precisely measured separate supply voltages to the core and the I/O of the processor. The currents drawn by the core and the I/O of the IBM 6x86L processor were measured with tapped ammeters. The sense lines were incorporated from the processor's voltage pins to the external power supply unit to compensate for the voltage drops in the lines from the external power supply unit to the microprocessor's voltage pins. It was previously determined that Landmark's** Speed200 Version 2.0** drew the maximum amount of current during its execution.

The supply voltage to the I/O of the IBM 6x86L processor in each measurement was set at 3.3 volts. The amount of current drawn by the I/O during the Speed200 execution was very low. Table 1 below provides the values of the maximum generated power in watts for various internal clock frequencies (in MHz) of the IBM 6x86L processor. The typical or average power generated in the IBM 6x86L processor is about 15% less than the maximum power generated during Speed200 execution. The value of the typical power generated in the microprocessor was calculated by running 20 typical application software packages, such as word-processing, spreadsheet, database, business graphics and utility, in the typical operating systems. However, the thermal solution must be designed for the maximum power dissipation.

[1] The IBM 6x86 and 6x86L Microprocessors are designed by Cyrix Corp., and manufactured by IBM Microelectronics

Internal Clock Frequency (MHz)	Max. Generated Power (Watts) when Core Supply Voltage at 2.7 - 2.9 Volts
100	11.15
120	12.63
133	13.60
150	14.85

Table 1. Max. Generated Power of the IBM 6x86L processor at Various Internal Clock Frequencies.

Case-to-System Ambient Thermal Resistance

The case-to-system ambient or external thermal resistance is obtained by first subtracting the system ambient temperature in °C from the case temperature of the IBM 6x86L processor in °C and then dividing the resultant difference by the maximum generated power in watts. Thus, the unit of the thermal resistance would be °C per watt. The case temperature is measured at the center of the top surface of the package and the system ambient temperature is the temperature of the air surrounding the microprocessor. The ambient temperature referred in this application is the same as the system ambient temperature. The case temperature of the IBM 6x86L processor must not exceed 70° C during its operation. The following table provides the values of the required case-to-ambient thermal resistance for various system ambient temperatures to meet 70° C case temperature specification of the IBM 6x86L processor.

Internal Clock Frequency (MHz)	System Ambient Temperatures:				
	at 35°C	at 40°C	at 45°C	at 50°C	at 55°C
100	3.13	2.69	2.24	1.79	1.34
120	2.77	2.37	1.98	1.58	1.18
133	2.57	2.2	1.83	1.47	1.10
150	2.35	2.02	1.68	1.34	1.01

Table 2. Required Case-to-Ambient Thermal Resistance at Various System Ambient Temp. and Internal Clock Freq. at 2.7 - 2.9 V Core Supply Voltage to the IBM 6x86L Processor.

When an external heat sinking device (such as a heatsink or fan/heatsink) is used to achieve the required case-to-ambient thermal resistance, the external heat sinking device is attached to the top surface of the IBM 6x86L processor. The case-to-ambient thermal resistance is now the sum of the case-to-sink thermal resistance and the sink-to-ambient thermal resistance. The value of the case-to-sink thermal resistance depends on attachment parameters such as thermal conductivity of the bonding material, the thickness of the bond, the effective area of bonding and the contact pressure applied to the bond. Neither the top surface of the IBM 6x86L processor nor the bottom surface of the heat sinking device is perfectly flat. Hence, a small amount of thermally conductive grease is dispensed between these surfaces to fill the air gap and to create a proper thermal path from the case to the sink. The mechanical fastening device, such as a clip or a spring, is employed to provide contact pressure to the bond and the mechanical strength to the assembly to sustain shock and vibration.

The typical value for the case-to-sink thermal resistance for the IBM 6x86L processor can usually range from 0.1 to 0.2 °C per watt. The subtraction of this case-to-sink thermal resistance from the

given value of the case-to-ambient thermal resistance in Table 2 yields a required sink-to-ambient thermal resistance for a given internal clock frequency and a core supply voltage of the microprocessor. Although the thermally conductive grease with a mechanical retention clip method is suggested here for the heatsink attachment to the IBM 6x86L processor, the user may employ any other method, such as thermally conductive epoxy or the double sided adhesive tape, to attach the heatsink to the IBM 6x86L processor.

It may be noted that the system ambient temperature is usually 5-10^{o} C higher than the room temperature and 10-15^{o} C higher than the room temperature in a natural convection environment.

Heatsinks

The heatsink is characterized by the sink-to-ambient thermal resistance in ^{o}C per watt. The smaller the value of the sink-to-ambient thermal resistance of a heatsink, the better the heat dissipation capacity of the heatsink. A smaller value of the sink-to-ambient thermal resistance of a heatsink can be achieved by increasing either the surface area of the heatsink or the air flow over the heatsink surface area.

The amount of air flowing over the IBM 6x86L processor's heatsink surface area depends on many parameters such as the number, location and air flow capacity of system fan, the number and the location of air vents, etc.. Since the amount of air flowing over the processor's heatsink surface area differs from system to system, no air flow (natural convection) can be considered as a worst case situation.

It is obvious that the amount of surface area of a heatsink is a function of the volume it occupies. Increased volume provides an increase of surface area of the heatsink. The available volume for the heatsink varies from system to system depending upon the layout of system components. Since the IBM 6x86L processor would be plugged into a socket 7, the area of the socket 7 can be considered as the best available area for the heatsink in a worst case situation. The socket 7 has a minimum area of 55 mm (2.16") X 62 mm (2.44"). Thus, the best available area for the heatsink would be 55 mm (2.16") X 62 mm (2.44"). The available height can vary from system to system depending on the layout of the system components. However, it cannot simply be set to zero for a worst case situation. The heatsink suppliers usually provide the various heights for a given area of an extruded or a pin fin heatsink.

The required sink-to-ambient thermal resistance spreads from 1.01 to 3.13 ^{o}C per watt for the IBM 6x86L processors, as shown in Table 2.

Once the information on the required sink-to-ambient thermal resistance, air flow and available volume for a heatsink are determined for the IBM 6x86L processor, the search for the suitable heatsink can be performed through the heatsink suppliers' catalogs. The heatsink suppliers provide the sink-to-ambient thermal resistance and the mechanical specifications for their products. An appropriate heatsink can be chosen from any heatsink suppliers' catalogs. A few heatsinks were found through suppliers' catalogs based on the information provided on the thermal resistance and the mechanical specification. These heatsinks were further analyzed and presented here so that the user can gain benefit from the collected data. The intent of providing this information is not to

endorse or qualify the supplier or their products, but an attempt to show the user how to proceed to select an appropriate thermal solution for the microprocessor.

A six-by-eight configuration pin fin heatsink, IERC** p/n PS519 (see Table 3) was selected from the supplier's catalog on the basis that is had the best available area of the heatsink in a worst case situation. The supplier provided the values of the sink-to-ambient thermal resistance of this heatsink at 200 and 400 linear feet per minute (LFPM) air flows are 1.6 and 1.0° C per watt respectively. A retention clip, IERC's SA54-2 or SC5, which latches to the tabs of the socket 7, can be used to attach the heatsink to the IBM 6x86L processor. The length and width of the heatsink are 57.9 mm (2.28") and 54.3 mm (2.138") respectively and the area of the heatsink contains within the best available area envelope in a worst case situation. The height of the heatsink is 31.77 mm (1.25") and may interfere with the full size expansion adapter cards or the hard disk drive bays in some systems. The heatsink was characterized in the industry standard desktop type system chassis with the typical personal computer configuration for a natural convection environment and several air flow conditions. The following table summarizes the characteristics of the heatsink in terms of its ability to dissipate the maximum power at a given room temperature and at a minimum air flow condition based upon the data collected in a laboratory study. The charateristics of heatsink may vary depending upon the system configuration. It is the user's responsibility to carry out verification run in their particular system by monitoring the case temperature of the microprocessor.

Min. Air Flow Over Heatsink in LFPM	Maximum Operating Room Temperature:			
	at 25° C (77° F)	at 30° C (86° F)	at 35° C (95° F)	at 40° C (104° F)
0	12	10.75	9.25	8
100	13.5	12	10.5	9
200	17.5	16	14.25	12.25

Table 3. Max. Power Dissipation Capability (Watts) of IERC's PS519B Heatsink at Various Room Temperatures and Air Flows.

As you can see from Tables 1 and 3, the PS519B heatsink can be used for the IBM 6x86L processor in a lower operating room temperature and with some air flow. This heatsink may not perform well for the IBM 6x86L processor at higher operating room temperature and lower air flow environment. For example, at 25° C operating room temperature and at least 200 feet per minute air flow environment, this heatsink can be used for an internal clock frequency up to 150 MHz. However, at 40° C operating room temperature, this heatsink can be used for 100 MHz.

A pin fin heatsink, Thermalloy** p/n 20995B (250B), w/ attachment clip p/n CLP-70000, was also analyzed but not extensively. This heatsink can be used for up to 100 MHz IBM 6x86L processor and for maximum room temperature of 35°C. It is 10-by-13 pin fin matrix; overall dimension of the heatsink is 51.7mm x 68mm x 31.75mm. Although the overall dimension of the heatsink is slightly larger than sockets 5 and 7, the heatsink overhangs just slightly on one side of the socket.

A slightly larger 10 parallel fins heatsink was also tested, Wakefield Engineering**, p/n 779L-150AB (see Table 4) as an option for higher operating room temperatures and lower air flow environments. The supplier provided the values of the sink-to-ambient thermal resistance of this heatsink in a graphical representation for an air flow range from 200 to 700 linear feet per minute. The value of the sink-to-ambient thermal resistance for a 200 LFPM air flow is about 0.88° C per watt per supplier data. The provision for the heatsink attachment is included in the heatsink assembly. A spring type of configuration latches to the tabs of the socket 7. The length and width of the heatsink are 67.6 mm (2.66") and 63.1 mm (2.484") respectively. Since the length and the width of the heatsink are larger than the length and the width of the socket 7, the heatsink overhangs the socket 7 by not more than 5 mm (.127") on each side of the socket 7. However, due to the shape of the retention mechanism used to secure the heatsink attachment, a clearance envelope of 65 mm (2.56") X 88 mm (3.465") is required to secure the heatsink attachment. The height of the heatsink is 38.1 mm (1.5") and may likely interfere with the full size expansion adapter cards or the hard disk drive bays in some system layouts. The heatsink was characterized in the industry standard desktop type system chassis with the typical personal computer configuration for a natural convection environment as well as several air flow conditions. Table 4 summarizes the characteristics of the heatsink in terms of its ability to dissipate the maximum power at a given room temperature and at a minimum air flow condition based upon the data collected in the a laboratory study. The characteristics of heatsinks may vary depending upon the system configuration and other thermal variables. It is the user's responsibility to carry out verification run by monitoring case temperature of the microprocessor.

Min. Air Flow Over Heatsink in LFPM	Maximum Operating Room Temperature:			
	at 25° C (77° F)	at 30° C (86° F)	at 35° C (95° F)	at 40° C (104° F)
0	13.75	12.25	10.75	9.25
100	20	17.75	15.5	13.25
200	22.5	20	17.5	15

Table 4. Max. Power Dissipation Capability (Watts) of Wakefiled Engineering (p/n779L-150AB) Heatsink at Various Room Temperatures and Air Flows.

As you can see from Tables 1 and 4, the heatsink 779L-150AB from Wakefield Engineering can be used for the IBM 6x86L processor having an internal clock frequency up to 150 MHz in an operating room temperature not exceeding 40° C with at least 200 LFPM air flow. However, this heatsink may not perform well even for lower operating room temperatures when the air flow is reduced from 100 LFPM to a lower value for higher internal clock frequency. For instance, at 35° C room temperature in a natural convection environment, this heatsink is not capable of dissipating 11.15 watts power of the IBM 6x86L processor at 120 MHz. This heatsink may not fit in all the system configurations due to its overall size. The user may contact the suppliers for the detailed mechanical specifications, availability and cost of the heatsinks.

When a heatsink solution is selected for the IBM 6x86L processor, a care must be taken to ensure that an appropriate heatsink for the voltage regulator be implemented. An inadequate heatsink for the voltage regulator may result in exceeding the junction temperature limit. This may cause the shut down of the voltage regulator.

Fan/Heatsinks

A fan/heatsink solution is usually sought when the maximum generated power exceeds 18 watts and the allowable operating room temperature approaches 40° C in a zero air flow environment. In some cases, even for less than 18 watts power and the controlled lower operating room temp. less than 40° C, a fan/heatsink solution is sought. This is because either the required heatsink volume is not available to dissipate the heat or the required air flow over the heatsink surface area does not exist.

Table 5 below provides the information on some selected fan/heatsink assemblies from the major suppliers. The area of all these selected fan/heatsinks contains within the socket 7 area envelope to avoid the interference with components beside the socket 7. Since the clearance above the socket 7 varies from system to system, the height of the fan/heatsink assemblies are selected in the range from 12.6 mm to 25.6 mm. The case-to-ambient thermal resistance of these fan/ heatsink assemblies spread from 1.1 to 1.9° C per watt. The user may select any one from Table 5 or any other comparable fan/heatsink which fits in their system layout. As you can see from the Table 2, the lowest required case-to-ambient thermal resistance is 1.34° C per watt at an internal clock frequency of 150 MHz and at a system ambient temperature of 50° C.

Vendor	Part Number	Overall Size of Assembly LxWxH in mm (inch)	Case-to- Ambient Therm. Resist. (c/w)
Aavid	355455F00267	49.8 (1.96) X 50.1 (1.97) X 17.0 (0.67)	1.55
ACT-RX	ACC 5856-06HW	54.85 (2.16) X 54.75 (2.15) X 12.6 (0.50)	1.85
Oryx	TI5-4515SB7C1(C2)	49.78 (1.96) X 49.78 (1.96) X 25.6 (1.01)	1.1
Oryx	TI5-4010SB7C1(C2)	49.78 (1.96) X 52.50 (2.07) X 20.5 (0.81)	1.5
Chip Coolers	HTS108B	50.8 (2.00) X 50.8 (2.00) X 23.62 (0.93)	1.35
Sanyo Denki	109P5412H8026	54.25 (2.14) X 54.85 (2.16) X 18 (0.71)	1.6
Thermalloy	2325B-TCM42S-PF33	51.18 (2.02) X 53.34 (2.10) X 20.2 (0.80)	1.2
Thermalloy	2321B-TCM42S-PF33	41.28 (1.63) X 43.18 (1.70) X 18.9 (0.75)	1.7
Wakefield	709-100AB121	49.53 (1.95) X 45.50 (1.79) X 25.4 (1.0)	1.5
Wakefield	709-80AB121	49.53 (1.95) X 45.50 (1.79) X 20.3 (0.80)	1.9

Table 5. Specifics on Fan/heatsinks for the IBM 6x86L processor.

The fan of the selected fan/heatsink must be ball bearing type for longer fan life. It is imperative that the clearance of at least 0.4" on the top of fan for the intake air and the clearance of at least 0.2" on the sides of heatsink for the exhaust air so that the fan can perform efficiently.

Thermal Solutions

The following table provides thermal solutions for an operating room temperature not exceeding 35 °C for various internal clock frequencies and air flows. The second column and the third columns of Table 6 provide heatsink solution in a zero and a minimum of 100 LFPM air flow

environments respectively. The fourth column of Table 6 also provides the fan/heatsink solution in a zero air flow environment.

Internal Clock Freq. of IBM 6x86L processor in MHz	Core Supply Voltage at 2.7-2.9 Volts and No System Airflow	Core Supply Voltage at 2.7 - 2.9 V and Min. 100 LFPM System Airflow	Fan/Heatsink for Core Supply Voltage at 2.7 - 2.9 V and no System Airflow.
100	C[3]	C[3]	Any of Table 5
120	N[3]	B[2]	
133	N[3]	B[2]	
150	N[3]	B[2]	

Table 6. ThermalSolutions for the IBM 6x86L fir a Maximum Room Temperature of 35ºC

B[2] Heatsink - 2.66" (67.6) x 2.484" (63.1) x 1.5" (38.1) from Wakefield p/n 779L-150AB
C[3] Heatsink - 2.04" (51.7) x 2.677" (68.0) x 1.25" (31.77) from Thermalloy p/n 2502 B
N[3] Not available due to larger heatsink surface area reaquired for higher power dissipation

Summary

The intent of providing this information is not to endorse or qualify the supplier or their products but to assist one in selecting a solution for the IBM 6x86L microprocessor. It is beyond our scope to present each supplier's product. A list of major heatsink and fan/heatsink suppliers is provided in the Appendix for reference. Other fan/heatsink suppliers not listed here may offer products better suited to your needs. It is the user's responsibility to perform the final verification test in their particular system configuration.

This application note provids you with the power values of the IBM 6x86L processor and the required case-to-ambient thermal resistance for the thermal solutions of the processor at various internal clock frequencies. The thermal and mechanical characteristics of some heatsinks and fan/heatsinks are presented. The passive heatsink solutions as well as active fan/heatsink solutions are identified for various internal clock frequencies in different operating room environments as well as different air flow conditions including a natural convection environment. Although the information to implement a thermal solution for the IBM 6x86L processor was presented in this application note, it is strongly recommended that the final verification of a chosen thermal solution be carried out by monitoring the case temperature of the processor in the user's system. The case temperature of the IBM 6x86L processor must not exceed 75^{o} C.

References

1. The IBM 6x86L Microprocessor Databook
2. Application note #40209: *Selection of Appropriate Thermal Solution for IBM 6x86 Microprocessors*
3. Application note #40214: *Heatsink and Fan/heatsink For IBM 6x86 Microprocessor*
4. Application note #40216: *System Level Design Considerations for IBM 6x86 Microprocessor Thermal Management*
5. Application note #40223 *System Board Component and Peripheral Device Temperature Measurements of Personal Computers with the IBM 6x86 Microprocessor*

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Appendix: Heatsink and Fan/heatsink Suppliers

Aavid Thermal Technologies**
One Kool Path
P.O. Box 400
Laconia, NH 03247
Telephone (603)528-3400
Fax (603)528-1478
http://www.aavid.com

Chip Coolers**
333 Strawberry Field Road
Warwick, RI 02887
Telephone (401)739-7600
Fax (401)732-6119
http://www.chipcoolers.com

IERC
135 W. Magnolia Blvd.
Burbank, CA 91502
Telephone (818)842-7277
Fax (818)848-8872
http://iercdya.com

Oryx International Ltd.**
7F., No. 5, Alley 16, Lane 235
Pao Chiao Road, Hsintien City
Taipei, Taiwan. R.O.C.
Telephone 886-2-9141400
Fax 886-2-9142283

Sanyo Denki America**
2612A South Miami Blvd.
Durham, NC 27703
Telephone (919)598-1680
Fax (919)598-1744

Cooler Master, Inc.**
115 Fourier Avenue
Fremont, CA 94538
Telephone (510)770-8566
Fax (510)770-0855
http://www.coolermaster.com

Thermalloy Inc.
2021 W. Valley View
Dallas, TX 75234
Telephone (214)243-4321
Fax (214)241-4656
http://www.thermalloy.com

Wakefield Engineering
60 Audubon Road
Wakefield, MA 01880
Telephone (617)245-5900
Fax (617)246-0874
http://www.wakefield.com

Web Automation, Ltd**
11411 Plano Road
Dallas, TX 75243
Telephone (214)348-8678
Fax (214)343-8958

ACT-RX Technology Corporation**
10F, No. 525, Chung Cheng Road
Hsin Tien City
Taipei Hsien, Taiwan, R.O.C.
Telephone 886-2-218-8000
Fax 886-2-218-8800

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