Heat Dissipation in a Computer

Amollo T.A*, Kirui M.S.K, Golicha H.S.A, Kemei S.K, Nyakan P.O
Faculty of Science, Department of Physics, Egerton University, P.O BOX 536-20115, Egerton , Njoro, Kenya.
*Email of the corresponding author: tebymg@gmail.com

Abstract
Computers use electric current to process information. Heat is dissipated in a computer component whenever current flows through it and the heat dissipation causes unavoidable heat buildup and a subsequent temperature rise at and around the component. High operating temperatures is dangerous to the safety and reliability of components since the failure rate of computer components increases almost exponentially with the increase in operating temperatures. Computer industries are building smaller and denser circuits to improve the computing power and portability. The main drawback of this miniaturization is the increase in the amount of heat produced per unit area of the components, so huge amount of money in the semiconductor industry is put towards thermal management. This study sought to determine the amount of heat dissipated by computers. Compaq P4, Compaq P3 and Dell P4 desktop computers were used for the study. The heat dissipation of the desktop computers under varying processor workload was found by measuring the current and voltage from the PSU to the motherboard and HDD of the computers using a digital multimeter. Results show that computers dissipate a lot of heat; in the order of hundreds of joules per second. The heat dissipation was found to increase with an increase in the processor workload.
Keywords; Heat dissipation, Computer, Power consumption

1 Introduction

Computer components depend on the passage of electric current to process information. The current flow through the resistive elements of the computer components is accompanied by heat dissipation of magnitude I^2R (where I is the current through it and R is the resistance of the components).The essence of thermal design is the safe removal of this internally generated heat which result in high operating temperatures which jeopardizes the components safety and reliability (Çengel, 1998). The computer components which produce heat and are susceptible to performance loss and damage due to the heating are integrated circuits. The amount of heat given off by a computer depends on type and speed of the CPU, stype, size and efficiency of the CPU cooler, cleanliness of the CPU cooler, the number of PC cards installed, the type of PC cards installed, case design and number/ type of case fans fitted, the processes the CPU is running, the type of graphic cards makes and the design of the motherboard (Sergei, 2010).Cooling techniques used in personal desktop computers include air cooling, liquid cooling, heat pipe, conduction and radiation cooling (Mudawar and Sund, 2008).

All substances whose temperature is above absolute zero continuously emit thermal radiation which includes the entire visible and infrared (IR) as well as a portion of the ultraviolet (UV) radiation. This radiation is by virtue of the molecular and atomic agitation associated with the internal energy of the material. In the equilibrium state this internal energy is proportional to the temperature of the substance (Howell and Siegel, 1981).Heat dissipation in the computer components causes a heat build up and a subsequent temperature rise at and around the component thus the computer emits thermal radiation as their temperature rises.

Heat transfer in computer components occurs simultaneously by conduction (heat sink), convection (fan) and radiation (Çengel, 1998). For conduction and convection the heat transfer between two locations depends on the temperature difference of the locations to approximately the first power and a physical medium must be present to carry the energy with the convective flow or to transport it by means of thermal conduction. The transfer of energy by thermal radiation between two bodies depends on the difference of the individual absolute temperature of the bodies each raised to a power in the range of about four or five and no medium need to be present between to locations for radiant interchange to occur (Howell and Siegel, 1981).

The amount of radiation energy emitted from a surface depends on the material of the body and the condition of its surface as well as the surface temperature. A black body is a perfect emitter and absorber of radiation. The radiation energy emitted by a black body per unit time and per unit surface area is given by $E = \sigma T^4$ Where $\sigma = 5\cdot 67\times 10^{-8}\frac{W}{m^2}\cdot k^4$ is the Stefan –Boltzmann constant and T is the absolute temperature of the surface (Dutta, 2006). The resistive elements in the computer start radiating heat soon after the computer is plugged in and we can feel the emitted radiation energy by holding our hands against the computer. This emitted radiation is entirely in the infrared region (Çengel, 1998).

2 Methods

2.1 Materials

Dell desktop computer (P4:2.8GHZ, RAM: 5.2MB, HDD: 40GB), Compaq desktop (P3:976MHZ, RAM: 256MB, HDD: 20GB), Compaq desktop computer (P4:2.0 dual core processor, RAM: 2GB, HDD: 250GB), Compaq CRT monitor, digital multimeter and a resistance box were used for the study.

2.2 Heat dissipation measurement

The first law of thermodynamics requires that in steady operation, the energy input into a system equals the energy output from the system. Considering that the only form of energy leaving the computer device is heat dissipated as the current flows through the resistive elements, the heat dissipation in the computer is equal to its power consumption. The voltage V and current I from the PSU to the motherboard and HDD of the desktop computers under varying processor workloads was measured using a digital multimeter. However, the voltage V and current I from the PSU to the HDD of the Compaq P4 computer could not be measured owing to its location in the CPU. A resistance of 10Ω was connected in series with the components when taking the current measurements. The processor workload was varied as follows: one process - windows media player, two processes - windows media player and scanning, three processes - windows media player, VLC media player and scanning, four processes - double scanning, windows media player and VLC media player as shown in table 5**.** These processes were chosen because they are frequently used in personal computers.

3 Results

Heat dissipation = Power consumption i.e. $Q = VI$

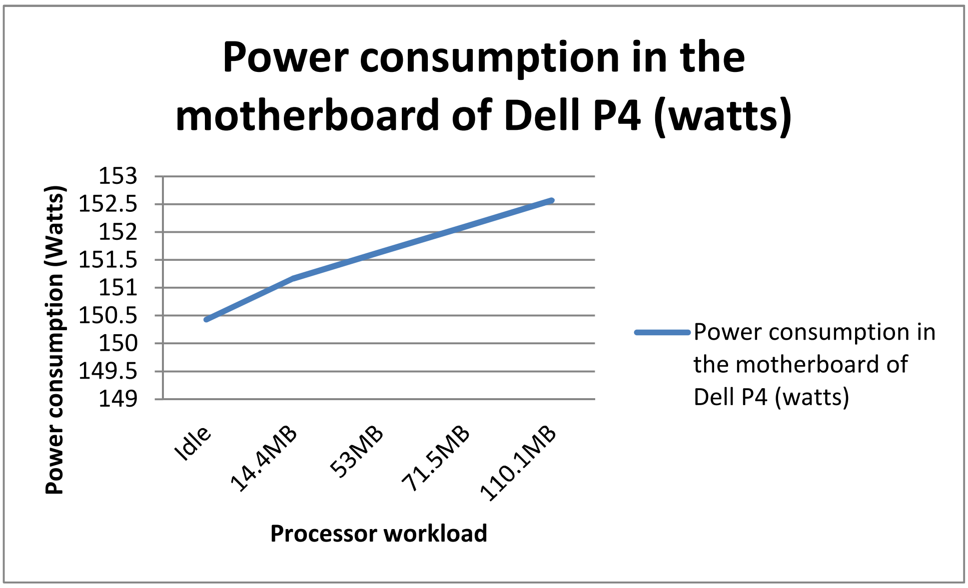

Fig 1: Increase in power consumption with the number of processes in the motherboard of the Dell desktop computer.

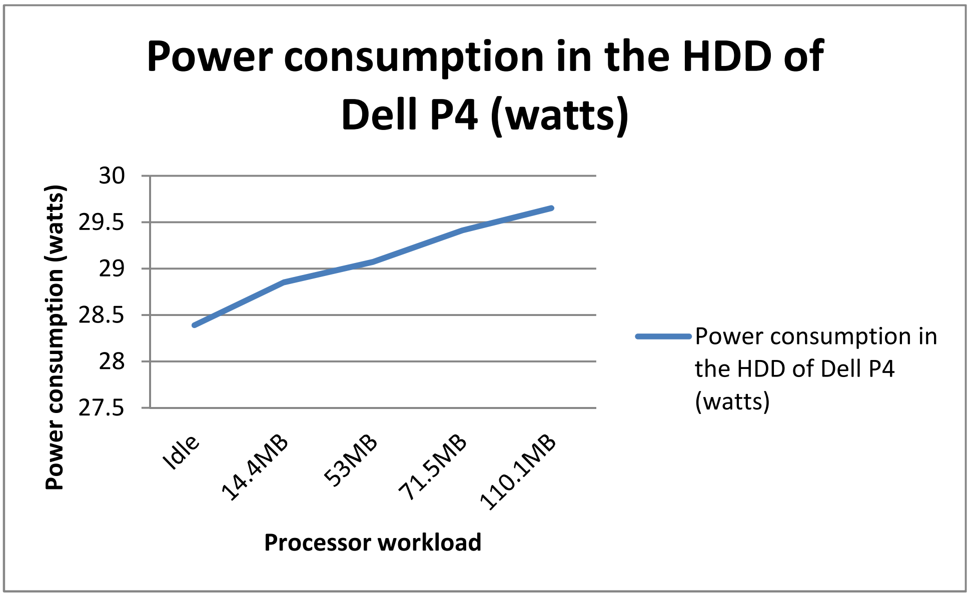

Fig 2: Increase in power consumption with the number of processes in the HDD of the Dell desktop computer**.**

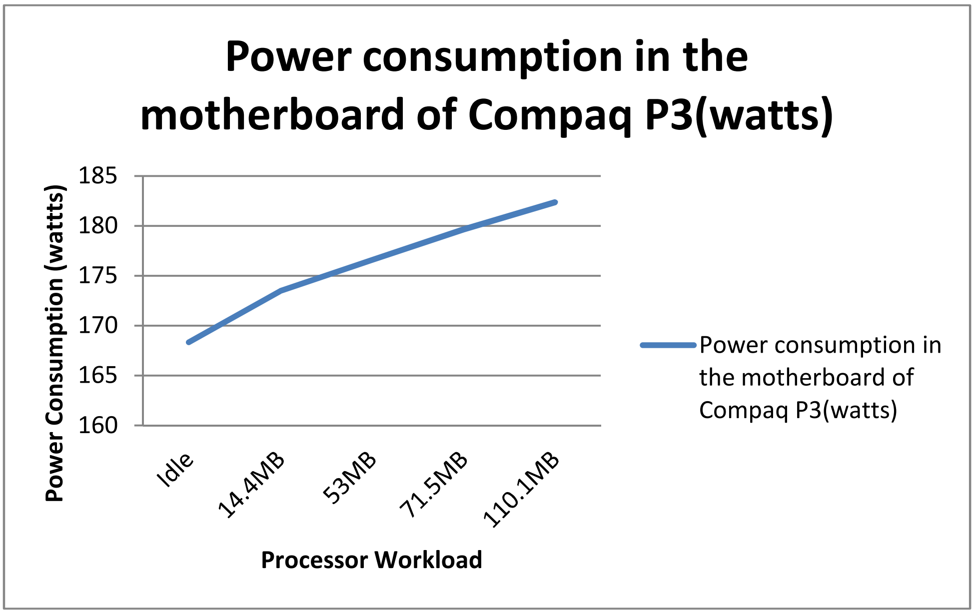

Fig 3: Increase in power consumption with the number of processes in the motherboard of the Compaq P3 desktop computer

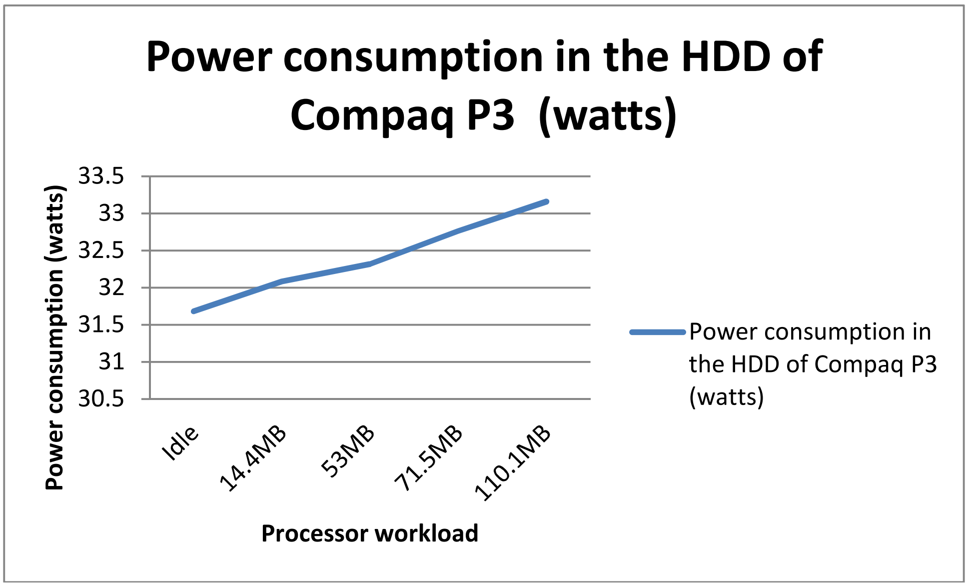

Fig 4: Increase in power consumption with the number of processes in the HDD of the Compaq P3 desktop computer.

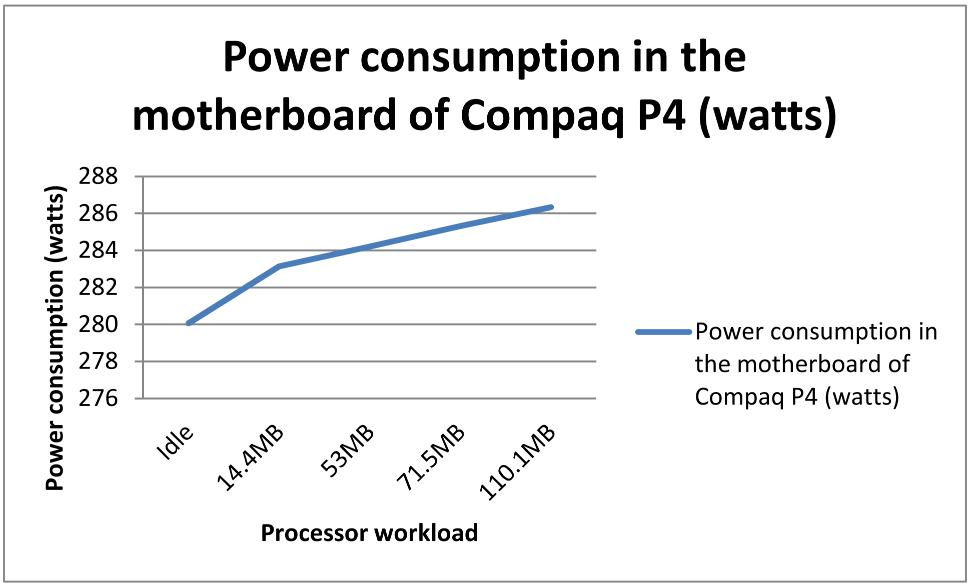

Fig 5: Increase in power consumption with the number of processes in the motherboard of the Compaq P4 desktop computer.

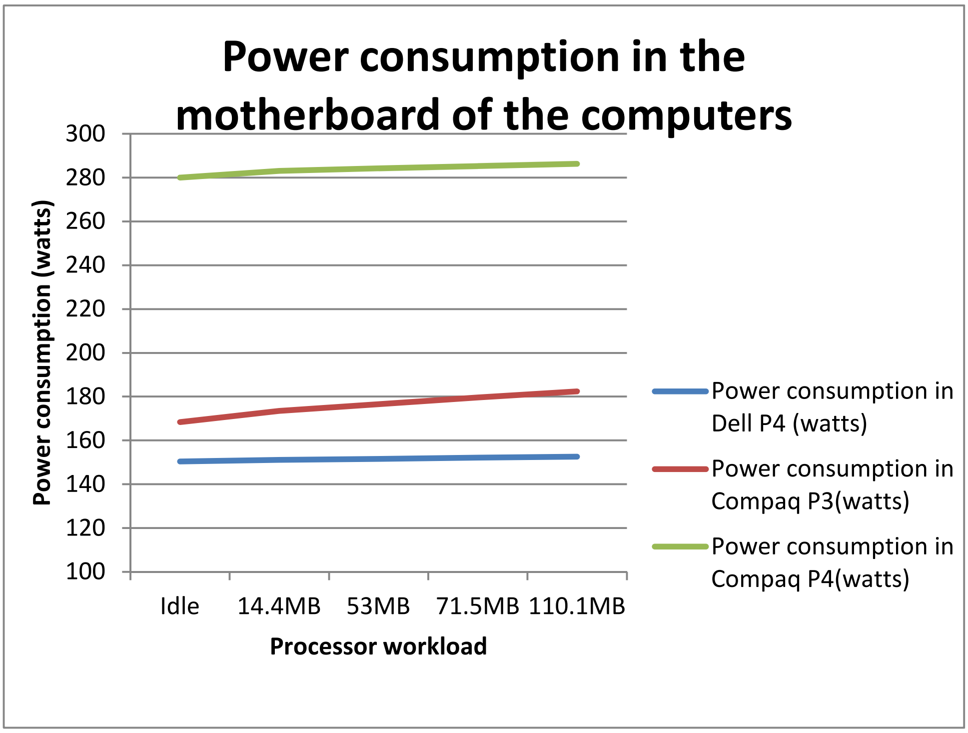

Fig 6: Comparison of power consumption in motherboard of the desktop computers

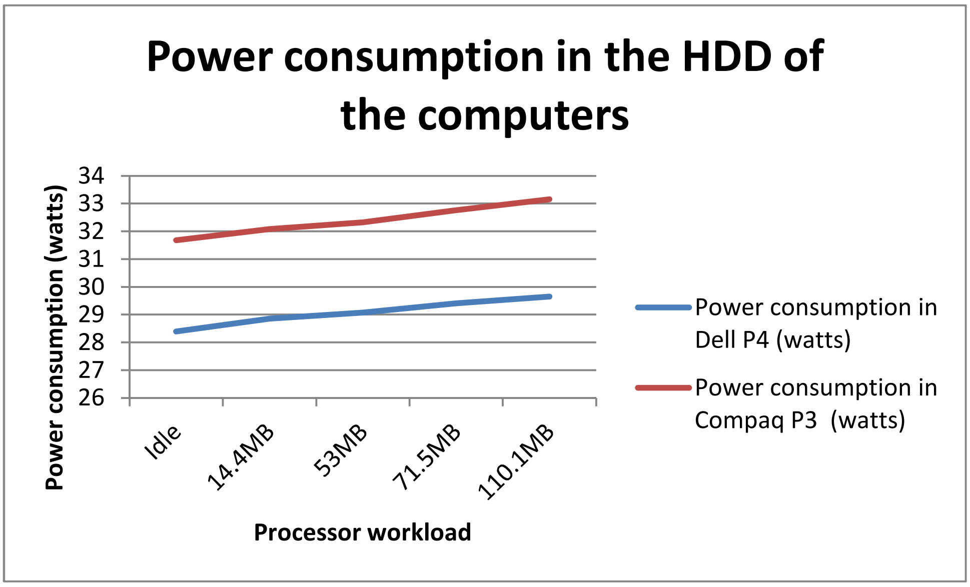

Fig 7: Comparison of power consumption in the HDD of the desktop computers

4 Discussion

Figures 1-5 show that the power consumption of the computers increases with an increase in the number of processes the computers run. Because computer components depend on the flow of electric current to process information, an increase in the workload implies that more current will be used. The graphs in figures 1-5 shows an almost linear relation after an idle mode because in idle state the processor goes into a low power mode, video output is turned off and the hard disks spin down then the power consumption thereafter is mainly dependent on the processor workload. The power consumption of the Compaq P3 computer was found to be higher than that of the Dell P4 computer for the various workloads while the power consumption of the Compaq P4 computer was observed to be much higher than both of the Compaq P3 and Dell P4 computers for the various workloads as shown in figures 6 and 7. The gradient of graphs in figures 1, 3 and 5 are 0.522, 3.422 and 1.475 $\frac{watts}{MB}$ respectively and that of figures 2 and 4 are 0.308 and 0.364 $\frac{watts}{MB}$. The gradients show that Compaq P3 has the highest power consumption per megabyte of load followed by Compaq P4 and lastly Dell P4 computer; this is attributed to the make of the components and the number of components. Heat dissipation therefore was highest in the Compaq P4 computer followed by the Compaq P3 computer and lastly Dell P4 computer. However, computational power was observed to be highest in Compaq P4 computer followed by Dell P4 and lastly Compaq P3. The Compaq P4 computer which had the highest computational power of the three computers equally had the highest power consumption/heat dissipation. The higher heat dissipation in Compaq P3 compared to Dell P4 can only be attributed to its components make because a comparison of the components of the computers as shown in table 4 implies higher heat dissipation in Dell P4 computer. The higher heat dissipation in Compaq P4 computer compared to the Dell P4 computer is attributed to both the computational power and the components make of the computers while the higher heat dissipation in Compaq P4 computer compared to the Compaq P3 computer is attributed to the number of components computational power of the computers.

Conclusion

- Computers dissipate a lot of heat; in the order of hundreds of joules per second.
- Heat dissipation in computers increases with an increase in the number of processes the computer runs.
- High computational power in computers implies high heat dissipation.

.

REFERENCES

Çengel, Y.A., (1998*), Heat transfer: A practical approach*, McGraw-Hill Companies, New York, United States of America, PP 497-506, 864-923.

Dutta, B.K., (2006), *Heat transfer: Principals and applications*, Prentice-Hall of India private ltd, New Delhi, India, PP 207-222.

Howell, J.R. and Siegel, R., (1981), *Thermal radiation heat transfer*, McGraw-Hill Book Company, New York, London, PP 384-408.

Mudawar, I., Sund, M. K., (2008), Single phase and two phase hybrid cooling scheme for high heat flux: Thermal management of defense electronics*, Thermal and thermo chemical phenomena in electronics systems,* **30**, 121-131.

Sergei, L., (2010), *Heat pipe direct touch; XIGMATEK HDT-S963 processor cooler* http://www.xbitlabs.com/articles/coolers/display/xigmatek-hdt-s963-3html accessed on 26/04/2011 at 1400hrs

Table 1: *Power consumption (watts) in the Dell desktop computer (P4:2.8GHZ, RAM: 5.2MB, HDD: 40GB) under various workload*

	Motherboard			HDD		
Processor workload	Voltage (V)	Current (A)	Power consumption (watts)	Voltage (V)	Current (A)	Power consumption (watts)
Idle	38.87	3.87	150.43	16.90	1.68	28.39
One Process	38.96	3.88	151.16	17.07	1.69	28.85
Two processes	38.98	3.89	151.63	17.10	1.70	29.07
Three processes	39.00	3.90	152.10	17.20	1.71	29.41
Four processes	39.02	3.91	152.57	17.24	1.72	29.65

Table 2: Power consumption (watts) in the Compaq desktop (P3:976MHZ, RAM: 256MB, HDD: 20GB) computer under various workloads

	Motherboard			HDD		
Processor workload	Voltage (V)	Current (A)	Power consumption (watts)	Voltage (V)	Current (A)	Power consumption (watts)
Idle	41.06	4.10	168.35	17.90	1.77	31.68
One Process	41.7	4.16	173.47	18.02	1.78	32.08
Two processes	42.04	4.20	176.57	18.06	1.79	32.32
Three processes	42.37	4.24	179.65	18.10	1.81	32.76
Four processes	42.71	4.27	182.37	18.22	1.82	33.16

Table 3: Power consumption (watts) in a Compaq desktop computer (P4:2.0 dual core processor, RAM: 2GB, HDD: 250GB) under various workloads.

	Motherboard		
Processor workload	Voltage (V)	Current (A)	Power consumption (watts)
Idle	52.94	5.29	280.05
One process	53.22	5.32	283.13
Two processes	53.32	5.33	284.20
Three processes	53.43	5.34	285.32
Four processes	53.52	5.35	286.33

Table 4: Comparison of components of the computers.

Components	Compaq P3	Dell P4	Compaq P4
No of capacitors	19	47	42
No of major transistors	6	9	12
No of ICs	3	4	4
No of USB ports	3	8	6
No of expansion slots	1	5	4
No of display slots	4	5	2
No of HDD slots	2	4	4
Processor speed	1.4Hz	2.8GHz	2.0 dual core

Table 5: Type of process and the corresponding processor workload

Number of processes	Type of process and Process load	Processor workload
Idle		
One process	Window media player (14.4MB)	14.4MB
Two processes	Window media player (14.4MB) and scanning (Avast antivirus-38.6MB)	53MB
Three processes	Window media player (14.4MB), scanning (Avast antivirus-38.6MB) and VLC media player(18.5MB)	71.5MB
Four processes	Window media player (14.4MB), double scanning (Avast antivirus- 38.6MB) and VLC media player(18.5MB)	110.1MB