Volume 6, No. 9, September 2015

Journal of Global Research in Computer Science

RESEARCH PAPER

http://rroij.com/global-research-in-computer-science.php

ISSN-2229-371X

The Effect of Heat on Processors: A Challenge to Computer Usage in Northern Nigeria Rural Colleges

Barau Nuhu Barnabas Best

Computer Science Department Nasarawa State College of Education, Akwanga Nasarawa State, Nigeria

bestbarau2013.39@gmail.com

Abstract: Central Processing Unit CPU popularly called "Processor" is termed the brain of the computer. This is where all processing of information takes place. Processor a very sensitive part and a determinant of what happens. This article runs a study on how a processor can perform under various degrees of temperature. Nigeria a third world and developing country in West Africa is situated in the sahara region and do experience very high temperature especially in the northern part. The writer saw this as a great setback in using computer systems in the country's rural schools due to inability to acquire special cooling devices, hence affecting the processors (CPU) negatively. The article sought to proffer solution to this issue as the study was able to review on Turbo Booster of Intel and AMD processors as kind of processors capable of withstanding various degrees of temperature change. Experimental test and analysis carried out and possible results are discussed. Recommendations on what schools in the rural areas of northern Nigeria should do were enumerated.

Keywords- Central Processing Unit CPU, Processor, Temperature, Rural schools

INTRODUCTION

A processor is the electronic circuitry within a computer that carries out the instructions of a computer program by performing the basic arithmetic, logical, control and input/output (I/O) operations specified by the instructions [1]. Is a small chip that resides in computers and other electronic devices. Its basic job is to receive input and provide the appropriate output. While this may seem like a simple task, modern processors can handle trillions of calculations per second.

As for the use of terms Rousse, stated that the term processor has generally replaced the term central processing unit (CPU) [2]. The processor in a personal computer or embedded in small devices is often called a microprocessor.

Technically in the article [3] a comprehensive description on the operation of a computer processor is outlaid. It described processor as a collection of billions of off/on switches. The article explains further that these switches use the most basic logic known to man, known as Boolean logic that is, everything is either on, or off, either a one (on) or a zero (off). These switches are of course tiny, around 32nm, depending upon the transistor in question, and have been described as containing "merely a couple of electrons". A single silicon chip can contain thousands of transistors [4]. To clarify on the concept CPU, is necessary to understand the fundamental issues at hand here, the switch; understand this elusive switch; how it works and what it is made of. This switch is a switch whose state as "on" or "off" is governed by voltage; unlike the lighting switch at home, where up perhaps is "on", in the case of the switches we are talking about (High K Metal Gate Transistors), a high voltage is "on", and a low voltage is "off"[5] [3].

BASIC OPERATIONS OF A COMPUTER PROCESSOR

Processors manipulate information in a signal like structure. As earlier stated, these signals are basically collections of binary zeros and ones (0's and 1's) represented in "on" and "off" manner. To understand this operations there are foundational ideas that must be understood as the writer explains;

Clock Cycles-Frequency, Speed:

Clock speed is the rate at which a processor can complete a processing cycle. It is typically measured in megahertz or gigahertz. One megahertz is equal to one million cycles per second, while one gigahertz equals one billion cycles per second. This means a 1.8 GHz processor has twice the clock speed of a 900 MHz processor [6].

The frequency or speed of a processor is, of course, related to the underlying structure of the switch. All of these terms are roundabout ways of describing the rate at which processor's switches can turn on and off, or switch between the high voltage that designates "on" and the low voltage that designates "off" (Vcc and Vss). The rate at which this switching occurs is really, very rapid. This entails that clock speed can be best imagined as a pulse- like signal, switching rapidly back and forth from on to off. The description is shown in Figure 1.

The diagram depict an ideal binary situation showing the voltage at exactly "on" or "off" but in real situation it is not so. In true situation, our switches work on tolerances, accepting anything over some value Vcc as "on," and anything less as "off". It also takes some time to transit from one state to another, as shown in Figure 2.

Overclocking:

Overclocking, means running the CPU at a greater speed than intended by its manufacturer [7]. As previously stated, the clock

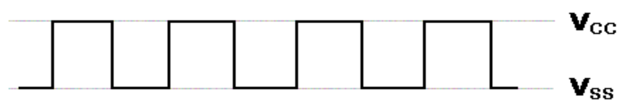

Figure.1. Where Vcc is the high, "on", and Vss is the low "off" voltage. The Y axis here is Voltage, the X axis here is time.

© JGRCS 2015, All Rights Reserved

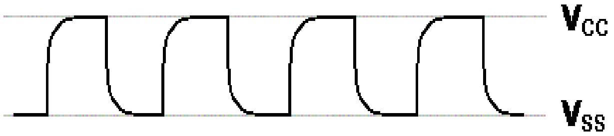

Figure.2

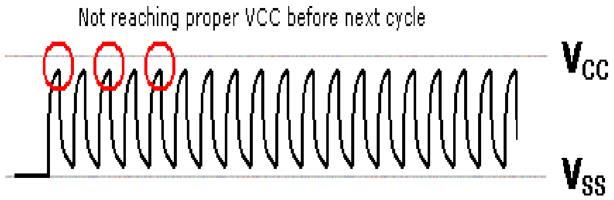

Figure.3

speed is actually the clock frequency, or the number of times that the transistors inside the processor switch from on to off per second. Therefore, when a processor is overclock, it means that it is force to switch between the two states more rapidly, and some problems arise. Referring to diagram 2, there is some time required for the state of a given switch to change from on to off-there is some time required for the voltage to drain from the gate; increasing the number of times the state must switch per second, decreases the amount of time the processor has to transit between the two states. The fact experienced here is the issue associated with the processor being unable to make the transition in the time allotted, this is termed instability.

Here processor cannot tell the difference between on and off, as the voltage never reaches the recognized "on", Vcc and "off" Vss. Figure 3 is clear representation of this state.

Situation encountered in diagram 3 can easily be explained that the voltage cannot switch fast enough between the two states, however there are two solutions. One is to somehow change the value that is recognized as on, or else increase the speed at which that transition occurs. Increasing the speed is a common thing done every time, that is when the voltage of processor is increased in order to maintain stability; while the peak voltage is actually raised, Vcc is effectively moved down in relation to the maximum voltage, providing for the same effect.

Decreasing the time it takes to switch states

Decreasing the switching time is paramount here but before discussing how to alter the time it takes to switch states, is good to first know what governs the rate at which this switching can occur. While current is not technically the rate at which voltage dissipates, it can be related for any given situation, and it can be used as a proxy to describe the rate at which voltage dissipates.

Using the simple current-voltage equation $I = V/R$ [8].

Here two things can be done to increase the value of I (current):

1. Increase the voltage

2. Decrease the resistance

It is more realistic to be concerned with decreasing the resistance. Resistance is the ability of a given material to resist the flow of electricity through it. Resistance is affected by temperature as expressed

$R = kT$ (R is resistance, k is some constant of proportionality, and T is temperature) [8].

Thus considering the random movement of electrons that inhibits the general path of flow, and perhaps mathematically that resistance increases as temperature increases. On the other hand, as temperature decreases, so does resistance, effectively decreasing the time it takes to switch states, from high to low; solving our problem and providing a simple solution.

TEMPERATURE CHALLENGES ON COMPUTER SYSTEMS

The article principally wishes to answer questions raised by computer users and school proprietors in developing countries on equipping their study centers with computer systems. In developing countries like Nigeria, there are so much infrastructural deficiencies in the rural areas; these include inadequate power supply, lack of good roads to reach enthusiastic expecting school children and a lot more [9]. The writer saw the need for such localities to enhance their academic shortfalls with the use of computers, yet so much fears elude them with regards to the following retrospect facts;

• Computers are expensive and require expensive means to keep, use and maintain.

• There is lack of electric power supply enough not just to operate the system but the accessories that can maintain these systems. One of the major fears is their inability to obtain good means of providing desired temperature that will sustain these items.

The writer saw that must of Nigerian localities experience excessive high temperature through the year and without adequate facilities can computers in such areas be sustained? In addition to the problem of excessive heat experienced in such areas ability to purchase cooling systems like electric fans, air conditioners etc. remains impossible, this greatly affect any attempts to acquire computer systems to ease learning among the students.

Nigeria, like the rest of West Africa and other tropical lands, has only two seasons these are the Dry season and the Rainy season. The whole of West Africa is heated intensely as result of the increased insolation received from the sun being overhead over West Africa and temperatures can climb as high as 35°C (95.0 °F) over West Africa during this time. In fact temperatures in the northern part of Nigeria can go as high as 48°C (118.4 °F) in cities like Maiduguri [10].

The dry season of Nigeria is a period of little cloud cover in the southern part of Nigeria to virtually no cloud cover in the northern part of Nigeria. The sun shines through the atmosphere with little obstructions from the clear skies making the dry season in Nigeria a period of warm weather conditions thereby around March to April following the onset of the rainy season, temperatures can go as high as 44°C (111.2°F) in some parts of Nigeria. As for the rainy season especially in the northern part of Nigeria last for only three to four months (June–September) the rest of the year is hot and dry with temperatures climbing as high as 40°C (104.0°F) [11].

The study hence unveils that Nigeria is obviously in a hot temperate region therefore, experiences high temperature over the year. The questions in this article still remain; does heat

© JGRCS 2015, All Rights Reserved

really affects the performance of a computer system? Most likely the computer processor which serves as the heart of the system. Does temperature change determine the life span of computers in excessive hot temperate regions?

STUDY REVIEW

The writer made reviews with regard to how processors perform under temperature change, and the facts from the reviews agreed with reasons why the writer embarked on the study. These reviews are stated thus;

Bates, [7] asserts that room temperature, affects the internal workings of a computer. And further stated that higher room temperatures can affect performance, especially exceeding 80°F/27°C since the computer's internal heat will be greater. Yet Bates concludes that performance though affected but not greatly affected; in fact, mostly, is not noticeable but that does not mean overheating in itself does not have greater consequences.

Another similar view says the ideal operating temperature of a computer's environment ranges from 50 degrees F to 82 degrees, though it should be as close as possible to room temperature, 72 degrees. It says laptops should operate between 50 and 95 degrees [12]. It further explained that excessive heat lowers the electrical resistance of objects, therefore increasing the current. In addition, slowdown is a result of overheating. Components can shut down when overheated and the motherboard temperature sensor instructs hardware such as the hard drive and processor to slow down.

Another study is in a tutorial note [13], it said just like all electronic components, CPU produces heat while it is running. Heat in excess, however, is not good and can even lead CPU to burn or to work in an unstable way. The note further reiterates that Microprocessors heat due to Joule effect, which is the process of transforming electrical energy into heat. Inside the CPU there are several wires (conductors) in charge of its internal interconnections. The Joule effect appears due to the shock between electrons and the conductor ion mesh, leading to an increase in the temperature of the conductor. The heat generated by an electronic device needs to be removed as soon as possible; otherwise its internal temperature will increase. If the device gets too hot internally, its internal circuits can be damaged.

Furthermore, review study by Winde gave this remark "For each ten degrees C, chemical reactions double in their speed. This doubling is roughly accurate when referring to leakage currents. Leakage currents represent heat sources and further increase junction (CPU) temperatures"[14]. In addition Winde explained that with a CPU one will have the following three mechanisms of degradation: Temperature Range, Thermal Cycles that is, degradation due to thermal cycling (turning the computer on and off) and Voltage, meaning when over-volting a CPU, the internal heat generation is considerably greater since increases in voltage normally yield an increase in current flow.

Almost all the studies carried out by the writer agreed that heat is of enormous concern on computer processors hence the computer system. But the writer's intend is to proffer solution to rural schools in Nigeria where excessive heat is a barrier to computer usage in the schools. In these localities as earlier stated, access to cooling rooms with air conditioners and fans is beyond reach while these children are expected to know computer as a prerequisite to their writing examinations to higher schools. Typically in Nigeria, Tertiary school examinations called JAMB (Joint Admission and Matriculation Board) examinations is the only examination that allows every student the opportunity to gain admission into higher college like university and others. The examination today has been computerized. Obviously students in the urban settlement can attempt such examinations while rural students are at disadvantage [15] and [16].

In response to the underlying problem this article looked closely into a study carried out by Bach. The article unveiled a very useful fact that older CPUs would simply fail if they started to overheat, but modern CPUs adjust their frequency based on temperature (among other things) to prevent a dramatic failure [17]. The article seems to give a glimpse of hope to the challenge encountered by the writer. On this view, this work largely depends on Bach findings.

CPUs OPERATIONS AND TEMPERATURE EFFECTS

Findings from Bach revealed that modern CPUs are able to adjust their operating frequencies through a number of technologies in order to either reduce their power consumption or provide maximum power as needed. The first of these modern technologies is Turbo Boost (or Turbo Core for AMD APU/CPUs). According to the overview page for Intel Turbo Boost Technology 2.0, there are five factors that affect the amount of increased frequency an Intel CPU can achieve via Turbo Boost:

- Type of workload
- Number of active cores
- Estimated current consumption
- Estimated power consumption
- Processor temperature

Apart from the four factors, processor temperature is the main factor this work is concerned about. It would be expected that Turbo Boost to slowly stepping back the amount of Turbo Boost as the CPU gets hotter. Bach found that in actuality, an Intel CPU under heavy load will actually run at the maximum Turbo Boost allowed by the other four factors until it hits the CPU's thermal limit.

It is a fact that CPUs also have extremely robust thermal protection, so that if the CPU starts operating above the CPU's thermal limit it will begin to reduce the frequency in order to prevent catastrophic failure. Oddly, is found that the thermal limit for both Turbo Boost and thermal protection on Intel CPUs to be right at 100°C - which makes it very convenient to remember. In other words, it means until the CPU hits 100°C before seeing 100% of the CPUs available performance. Once it starts hitting 100°C, however, the CPU will start throttling back to keep itself from overheating.

As earlier said experience and explicit testing shows that modern Intel CPUs can run at their maximum Turbo Boost frequency all the way up to 100°C. While there may be a tiny performance difference between a CPU running at 30°C and one running at

© JGRCS 2015, All Rights Reserved

95°C, testing has found that the difference is miniscule. In fact, even after running benchmarks dozens of times the difference is so small that it is essentially nonexistent.

A point of interest is what happens once a CPU starts to hit 100°C. To figure this out, Bach took an Intel Core i7 4790 and cooled it with a Gelid Silent Spirit Rev. 2 CPU cooler that was connected to a manual pulse width modulation (PWM) fan speed controller. Linpack software was used; The Linpack Benchmarks are a measure of a system's floating point computing power introduced by Jack Dongarra, they measure how fast a computer solves a dense n by n system of linear equations Ax = b, which is a common task in engineering. The aim is to approximate how fast a computer will perform when solving real problems. It is a simplification, since no single computational task can reflect the overall performance of a computer system [18]. By running Linpack and slowly dialing the fan speed down in careful increments, Bach were able to allow the CPU to overheat by incremental amounts. At each cooling increment they kept a log of the Linpack benchmark results as well as using CoreTemp to record the CPU core temperature and frequency.

Since the Intel CPU thermal limit is 100°C, one can quantify the amount of overheating by measuring the amount of time the CPU temperature was running at > 99°C. This is graphically represented in Figure 4.

It became a surprised when the testing showed that while the minimum CPU load frequency started to drop as soon as the CPU hit 100°C, the average CPU frequency didn't drop by more than .1GHz until the CPU was overheating more than 30% of the time. In fact, Intel CPUs are surprisingly good at being able to handle this much heat with such a small reduction in the average frequency.

As this gave an understanding of what is happening from a frequency standpoint, is also needful to know how this affects

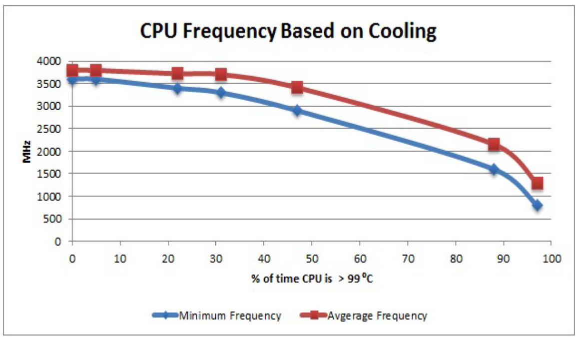

Figure.4. CPU behavior from frequency stand point.

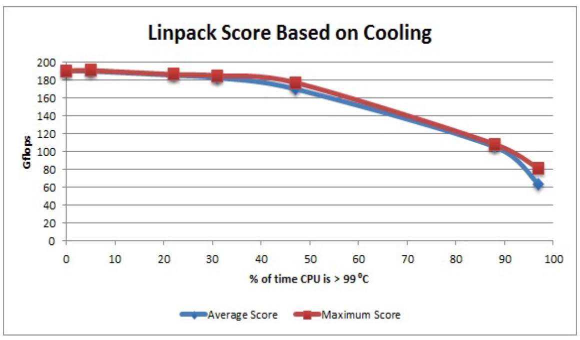

Figure.5. CPU behavior from Actual Performance stand point.

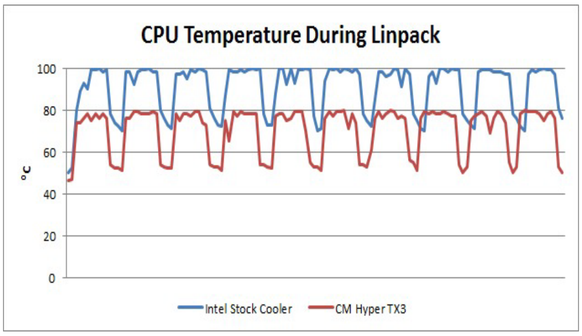

Figure.6. CPU performance using non-manual coolers CM Hyper TX3 and Intel Stock.

real-world performance. To achieve this, Bach in the research recorded the Linpack performance results to see what the actual performance implications of overheating. The outcome is interpreted in Figure 5.

It is evident that Linpack is one of the most consistent CPU benchmarks ever seen and the Intel Core i7 4790 should score right at 190 GFlops with the problem size we used for this testing (30000). What is interesting is that the Linpack results from the testing almost exactly follow the average CPU frequency from the previous graph (diagram 4). While it makes complete sense, this pretty much just confirms that from a strictly CPU performance point of view, the performance of a CPU is directly related to its average frequency.

In discussing the results, beyond the fact that Intel CPUs are impressively stable even while technically overheating it means that one can expect full performance from an Intel CPU as long as it is kept below 100 °C. At the same time, even if the CPU occasionally hits 100°C there will not be more than a minimal drop in performance until it spends a significant amount of time (more than 20% of the time) above 99 °C.

FORMAL IMPLEMENTATION

Depicting from Bach experiment is really interesting, but it may be hard to translate into a real world situation. To accomplish this, the exact same Linpack test is performed except that instead of altering the cooling manually two different CPU coolers were used - the stock cooler that came bundled with the Core i7 4790 and the budget-friendly Cooler Master Hyper TX3 which only costs about $20. To make this as real-world as possible, a test hardware (Asus Sabertooth Z97 Mark II, Intel Core i7 4790, 4x Kingston HyperX LoVo DDR3-1600 4GB, NVIDIA GeForce GTX 980) was installed into a Fractal Design Define R4 chassis with the stock fans running at 5V. Linpack test results is shown in Figures 6 and 7.

The graph on diagram 6 shows that even a very affordable CPU cooler like the CM Hyper TX3 is able to dramatically lower the CPU temperature under load. While the stock cooler is easily hitting 100°C during the benchmark run, the CM Hyper TX3 only ever hits a maximum temperature of 80°C. In terms of how much the CPU was overheating, the stock cooler allowed the CPU to run at > 99°C about 20% of the time.

The graphs (Figures 6 and 7) explain that when comparing the two coolers one should expect a measurable, albeit small, drop in performance with the stock cooler. It is found that using the stock cooler made the CPU perform about 2.5% slower than it

© JGRCS 2015, All Rights Reserved

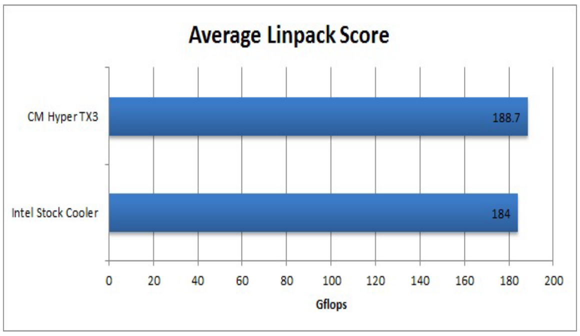

Figure.7. CPU performances from previous graph.

did with the CM Hyper TX3. The neat thing is that this drop in performance almost exactly lines up with the graphs of expected performance.

DISCUSSION OF RESULTS / ANALYSIS

The results of our testing can pretty much be summarized with the following three points:

1. Modern Intel CPUs run at full speed (including the full Turbo Boost allowed based on the number of cores and workload) all the way up to 100°C

2. Even after the CPU hits 100°C, the performance is not greatly affected until the CPU spends about 20% of the time > 99 °C

3. While stock cooling only causes around a 2.5% drop in performance, even a budget after-market cooler will dramatically improve CPU temperatures

Truly, it is a bit surprised at how well modern Intel CPUs dealt with really high temperatures. They manage to run at full speed all the way up to 100 °C, and even then the performance is not greatly affected unless they spend a significant amount of time at that temperature. Certainly no one is advocating letting CPU run at those kinds of temperatures, however.

Therefore considering the writers concern, the results of the experiment carried out has allayed the fears of using computers in rural schools where the average temperature is high. The fears of thinking whether investing on computer systems will be a waste should not be taken serious any more. Majorly caution must be taken in considering the type of systems to acquire. Experiment showed that Turbo boaster processors like Intel are of high reliability therefore in terms of purchase this must be taken into consideration.

Despite the outcome of this experiment by Bach, the article still caution computer users as this article is about performance there are plenty of non-performance based reasons to keep CPU temperature at a more reasonable level. This is because sensitive electronics like CPUs have a finite lifespan and running them at higher temperatures shortens it.

SUMMARY AND CONCLUSION

In summary, is very right to say high temperatures possess great threat to computer systems and it remains unadvisable to subject them to high temperatures unnecessarily. This article tried to solve problem regarding situation where temperature problem serves as a barrier to computer usage meaning on extreme cases. For instance in Nigeria some parts of the country temperature is quite high and access to required facilities to maintain low temperature is unobtainable.

Schools in the rural areas are badly affected whereby having good computer laboratories is difficult for ideal situation. Fears to spend money in purchase of systems has eluded such schools thereby necessitating the need to know if there are systems that can tolerate these situations to a bearable level.

The article was able to come up with a useful solution whereby it discovered that there are processors that can assist to great extend in tolerating this temperature change even though not absolute. Intel processors could be of help provided they are not over stretched beyond recommended level. There are other aided mechanism capable of assisting in maintaining good temperature level; using giant liquid cooling loops, insanely high flow fans, or even things like liquid nitrogen to keep a CPU extremely well cooled. The article already showed that coolers like CM Hyper TX3 or Gelid Tranquillo would be a better match for CPU.

Conclusively, is accepted that CPU could run around 80-85°C when put under full load for an extended period of time. It is found that this gives the CPU plenty of thermal headroom, does not greatly impact the CPU's lifespan, and keeps the system rock stable without overdoing it on cooling. Lower temperatures are, of course, better (within reason) but if you want a target to aim for, 80-85°C is still within safety.

RECOMMENDATION

Having noted that processors are temperature sensitive and despite efforts in making temperature friendly processors like the Intel, there is need for caution. In regards to system usage the writer wishes to encourage users not to over panic rather be precautious minded. In view of these, the following recommendations are necessary.

- Rural schools should be selective when purchasing systems, is recommended by the writer's view that Turbo boaster processors like Intel made should be patronized.
- Since cooling systems like air conditioners are not very much available, time spend on systems should be minimized especially during the dry season as average temperature is normally very high.
- Exposing students to computers should be a necessity as today it is prerequisite to every academic activity.
- Parents and guardians should be encouraged to acquire systems for their wards as this will greatly reduce the usage of school computers hence improving the school systems life span.
- Computer laboratories in rural schools should be sited in positions where temperature is reasonably friendly. Where trees can provide some shed to the computer rooms since for avoidance of dust the doors and windows are not supposed to be left open.

REFERENCES

[1] Wikipedia (2015). https://en.wikipedia.org/wiki/ Central_processing_unit.

© JGRCS 2015, All Rights Reserved

[2] Rousse M, (2006) "Microprocessors glossary: http://whatis.techtarget.com/definition/processor updated in April 2006.

[3] http://www.overclock.net/t/794098/the-effect-of-temperature-on-your-processor-science-warning retrieved on 15th July, 2015.

[4] Zandbergen P, (2015) "Central Processing Unit (CPU): Parts, Definition & Function Chapter 1 / Lesson 2, July, 2015.

[5] Gaudin S, "The transistor: The most important invention of the 20th century? Computerworld, Dec 2007.

[6] techterms.com (2008).

[7] Bates P, "How Heat Affects Your Computer, And Should You Be Worried? Technology Explained", Aug 2014.

[8] Abbott AF (1984) Ordinary Level Physics Published February 27th 1984 by Heinemann Educational Publishers ISBN: 0435670107.

[9] Adomi EE and Kpangban E, "Application of ICTs in Nigerian Secondary Schools Library Philosophy and Practice," 2010.

[10] http://sunday.dailytrust.com/index.php?option=com_content&view =article&id=3565:Maiduguri-residents-how-we-cope-under-harsh-48-degree-celsius&catid=41:latest-news&Itemid=26 Retrieved on 15th July, 2015.

[11] http://www.nigeria-weather.com/ 2015. Retrieved on 15th July, 2015.

[12] Smathers MO, (2014) "How Does Temperature Affect The Performance of Computer Components?," 2014.

[13] Torres G and Lima C (2007) Maximum CPU Temperature Tutorials October 10, 2007 Retrieved on 10th July, 2015.

[14] Winde L, "Overclocking's Impact on CPU Life," 1999, Retrieved on 14th July, 2015.

[15] Federal Republic of Nigeria "Government in action," 2006.

[16] Goshit, T "Nigeria's need for ICT: SP. 259 technology and policy in Africa," 2006.

[17] Bach M, "Impact of Temperature on Intel CPU Performance," Oct 28, 2014.

© JGRCS 2015, All Rights Reserved