Analysis of the Power Usage of an Acer Aspire One Pro Netbook

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***Abstract*—This report presents the results of a preliminary experiment carried out to find out how much power is used by the components in a netbook. We tested the screen, hard drive, wireless interface and processor to obtain data which showed how much power they consumed under different conditions. We found that the screen and the hard drive consumed the most power.**

I. Introduction

The Acer Aspire One Pro P531h is a 10.1 inch netbook which entered the market in August 2009. It has an Intel Atom N270 twin-core processor which runs at a maximum of 1.6 GHz. It has 1 GB of DDR2 RAM and 160 GB of Hard disk space. What makes this netbook interesting is the implementation of a recent generation of Intel Atom processors. These processors have been designed to work at low power as compared to their Core 2 Duo counterparts. They have a Thermal Design Power (TDP)[1] of only 2.5 W at maximum load and have been manufactured using a 45 nm process.[1]

As these devices have gained an important share of the laptop market[2], it becomes interesting to analyse what makes them such successful devices - their portability and more so their long battery life. The power pack shipped with the netbook has a rating of 19V and maximum current draw of 1.58A. This means that under maximum load the netbook will use no more than 30 W of power.

In this report, we present the findings of a preliminary research work carried out to investigate how components in the Acer Aspire One Pro P531h consume power. The rest of the report is structured as follows. Section II explains how the experiment was set up and Section III provides a discussion of the results. Section IV concludes the report by providing an insight into future work that will be done.

[1]TDP refers to the maximum amount of power the cooling system in a computer is required to dissipate.

TABLE I
EQUIPMENT SPECIFICATION

Hardware	**Specifications**
Client PC	Intel Atom N270 1.6 GHz 1GB RAM Ubuntu Netbook Remix 9.10 Filezilla FTP Client
Server PC / Data Logger	Intel Core 2 Duo 2.33 GHz 4GB RAM WindowsVista Home Basic Filezilla FTP Server
Instek Power Supply	Provides DC Power
TDS2014 Oscilloscope	Used to measure the voltage

II. Experiment

This section explains how the experiment was set up and the tools used. It also defines the terms used in this report.

The equipment used for this experiment is listed in Table I. All tests were carried out more than once to make sure that the results obtained matched the previous set of results. Figure 1 illustrates the layout of the testbed used to measure the power used by the netbook. The mean voltages V1 and V2 were obtained by probing the oscilloscope at regular intervals via an RS232 connection using python scripts. The power was calculated using

$$Power = \frac{(V1 - V2) \times V2}{R} \quad (1)$$

The netbook was powered without a battery docked to ensure that no power was being used for charging.

The *Idle State* is defined as the state where the OS is loaded with the default settings, the screen set to maximum brightness and the network interfaces -

bluetooth, ethernet and wireless LAN - are off. It is to be noted that the hard disk drive is active during the idle state and could do random, uncontrolled read/write cycles. This behaviour has not been omitted from the results obtained in this experiment.

A. BIOS and Bootloader Measurements

The BIOS and BootLoader measurements, as demonstrated in Figure 2, were performed to get a baseline of how much power is drawn by the system before the OS is loaded. The BIOS and Bootloader do nothing more than wait for user input. Knowing how much power is used while in these two states allowed us to compare how the OS manages power.

B. Screen Measurements

Screen measurements involved checking how much power is used by the screen at maximum brightness. This was done by setting the power options in the OS to completely blank the screen when the lid was closed. The power usage was recorded over a period of 30 minutes to compare with the Idle State. Another series of tests compared the power usage between a mainly black screen and a mainly white screen. The black and white screens were displayed by changing the colour settings of a terminal window. Various reports have previously stated that a white screen (brighter) consumes more power than a black screen (dimmer). Our results show that this is not the case with the LCD display we tested.

C. Wireless Measurements

The wireless module was first tested by measuring how much power it uses when it is on and not associated to any access points. The second series of tests verified the power usage when it was connected to an access point and the last tests determined how much power was used while transmitting and receiving data over a wireless network. An FTP server was set up to allow for the exchange of data between a server and the netbook. The wireless modulation scheme used was 802.11g, allowing a raw data rate of 54 Mbps.

D. Hard Disk Drive Measurements

The idle state accounts for the power used by the HDD. The HDD was removed from the netbook to measure how much power was being drawn as compared to the Idle State. The netbook was booted with a USB Flash drive with the same Operating System - Ubuntu Netbook Remix 9.10. Measurements were taken during the same interval to determine the difference in power usage. Removing the HDD and running the OS from the USB drive gives us an idea of how much power draw the HDD contributes to in the Idle State. Only the power used by the HDD when in the idle state was tested for. No controlled read/write tests were done in any of the scenarios.

TABLE II
INSTALLING CPUFREQUTILS

Distribution	Terminal/Konsole commmand
Ubuntu	sudo apt-get install cpufrequtils
Fedora	su -c 'yum -y install cpufrequtils'

TABLE III
POWER STATISTICS : BIOS AND BOOTLOADER

Power (W)	Bios	Bootloader
Minimum	5.79	6.077
Maximum	6.44	6.63
Average	6.04	6.34
Std Dev.	0.09	0.08

E. Processor Measurements

The Intel Atom processor that powered our netbook allowed four different clock speeds to be set; 800 MHz, 1.07 GHz, 1.33 GHz and 1.60 GHz. We ran a series of tests at different clock speeds to determine the power levels at each setting. Both cores were set at the same speed and a program was run to keep each fully loaded. To observe changes in power, measurements were taken with the processor:

1) At Idle
2) One core at full load
3) Both cores at full load

The "top" utility was used to confirm the processor was 50% loaded with one core running and 100% loaded with both cores running. To set the speed of the cores the "cpufrequtils" utility was used. Cpufrequtils is freely available for all major Linux distributions. It allows dynamic CPU clock speed scaling via the use of governors. Users can also define their own custom settings.[3]

TABLE IV
POWER STATISTICS : SCREEN

Power (W)	Idle	Screen Off	MinBr	White	Black
Minimum	5.90	2.98	4.58	4.31	4.93
Maximum	6.89	3.57	5.21	9.68	6.29
Average	6.31	3.28	4.89	5.08	5.35
Std Dev.	0.12	0.07	0.09	0.25	0.16

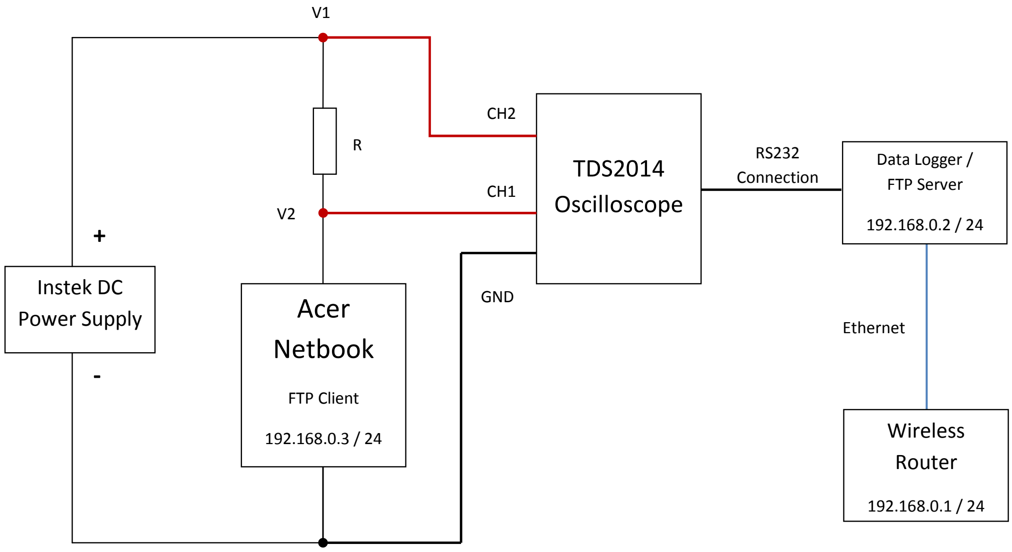


Fig. 1. Testbed for getting power used by devices

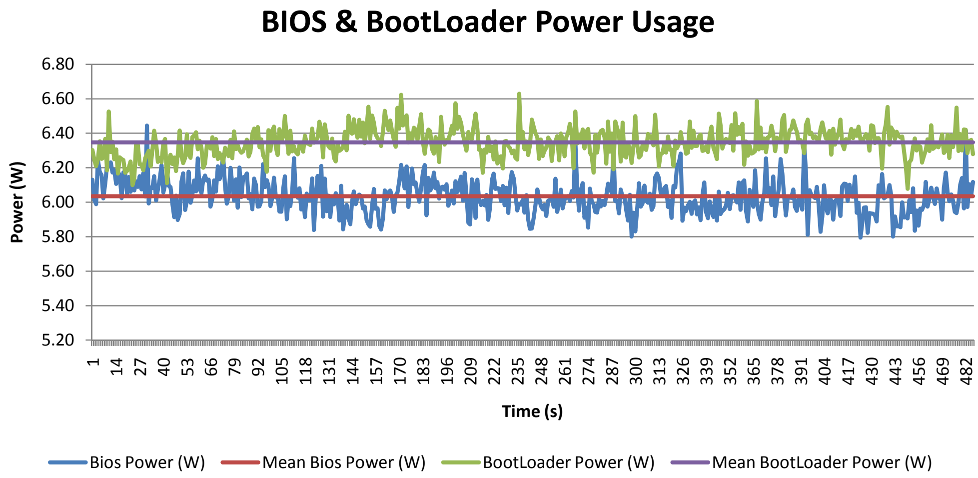


Fig. 2. Power used by the BIOS and BootLoader

TABLE V
POWER STATISTICS : CONNECTION TO ACCESS POINT WITH UNSTABLE DRIVERS

WiFi Power (W)	Associated	dis-Associated
Minimum	3.34	4.52
Maximum	9.69	10.07
Average	4.85	6.39
Std Dev.	0.76	0.14

TABLE VI
POWER STATISTICS : CONNECTION TO ACCESS POINT WITH NEWER DRIVERS

WiFi Power (W)	Associated	dis-Associated
Minimum	6.64	4.85
Maximum	7.97	10.60
Average	7.24	6.64
Std Dev.	0.16	0.29

TABLE VII
POWER STATISTICS : FILE TRANSFER

WiFi Power (W)	Receive	Transmit
Minimum	5.55	5.54
Maximum	13.07	12.69
Average	8.96	7.60
Std Dev.	1.12	1.02
Throughput	3.2 MB/s	523 KB/s
Goodput	3.16 MB/s	447 KB/s

TABLE VIII
POWER STATISTICS : IDLE USAGE WITH AND WITHOUT HDD

Power (W)	HDD	USB
Minimum	5.90	3.68
Maximum	6.89	6.51
Average	6.31	3.97
Std Dev.	0.12	0.13

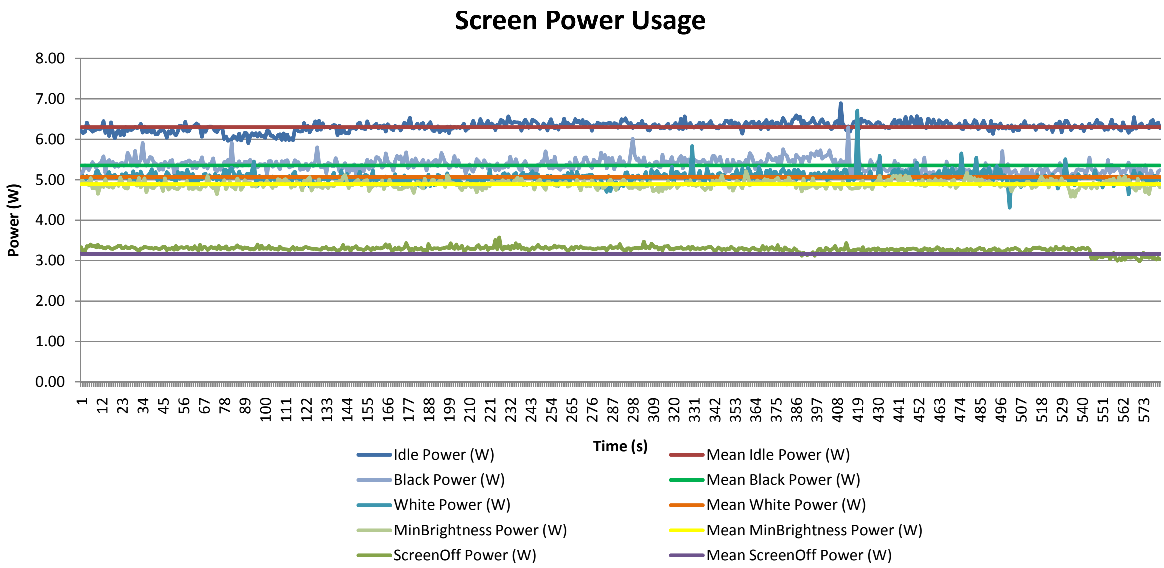


Fig. 3. Transmit and Receive Power Levels

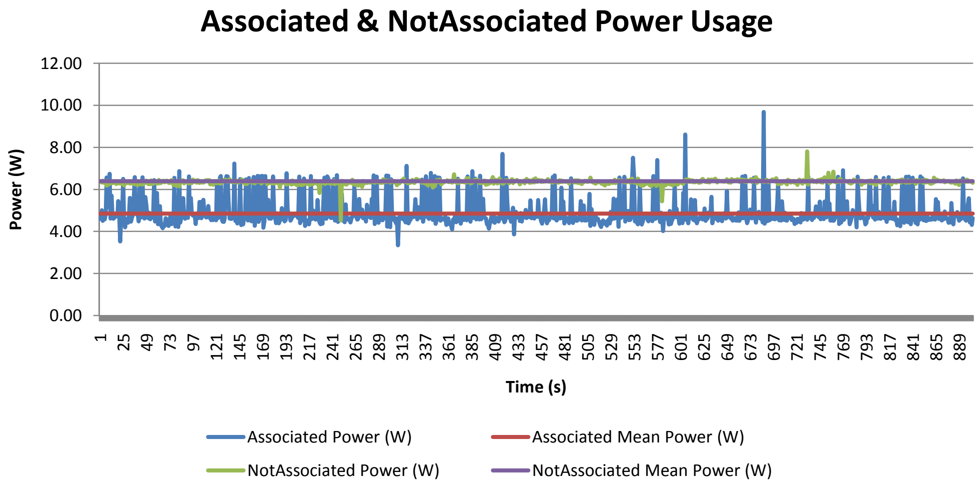


Fig. 4. Associated and Not-Associated Power Usage with old drivers

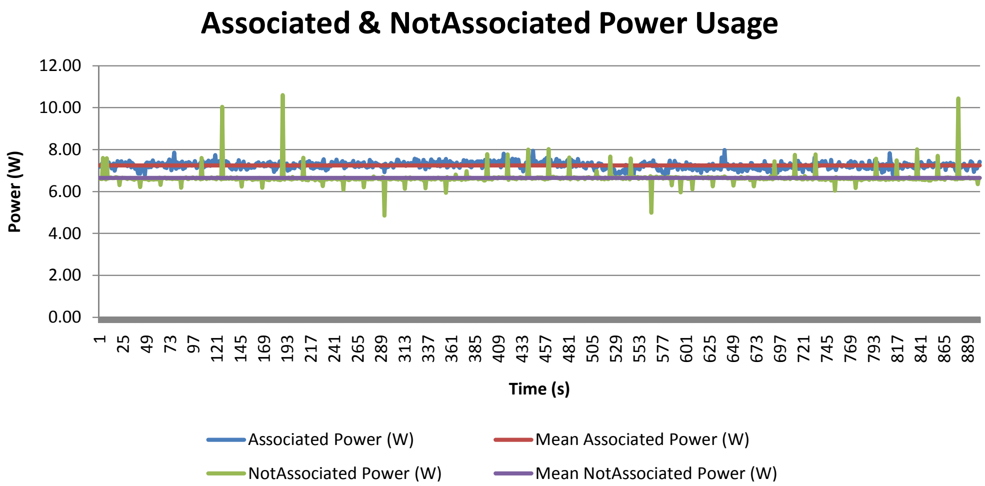


Fig. 5. Associated and Not-Associated Power Usage with new drivers

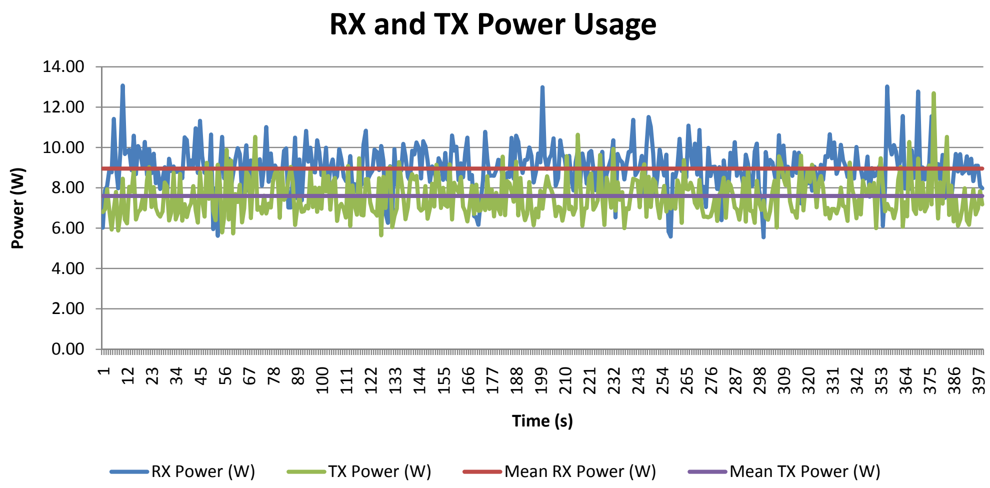
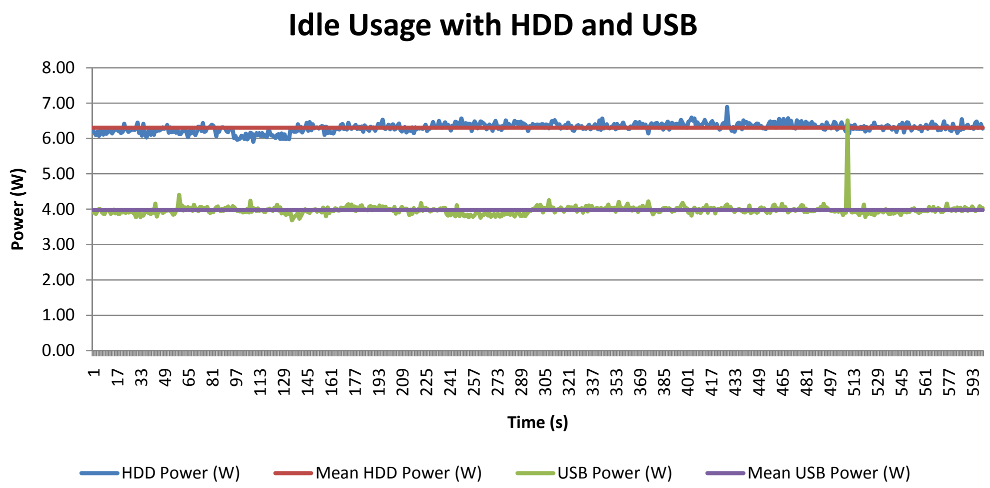
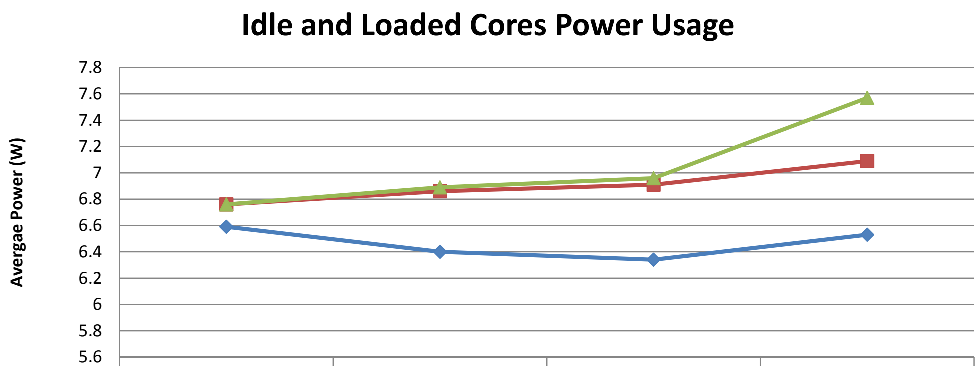


Fig. 6. Transmit and Receive Power Levels





	800	1070	1330	1600
Idle	6.59	6.4	6.34	6.53
1 Core	6.76	6.86	6.91	7.09
2 Cores	6.76	6.89	6.96	7.57

Fig. 7. Booting OS from HDD and USB Power Levels

Fig. 8. Processor Power Levels at different clock speeds

TABLE IX
PROCESSOR IDLE USAGE AT DIFFERENT CLOCK SPEEDS

IDLE Power Usage (W)				
Speed (MHz)	Min	Max	**Mean**	Std Dev.
800	6.35	7.75	**6.59**	0.08
1070	6.08	7.57	**6.40**	0.12
1330	6.08	6.92	**6.34**	0.11
1600	6.01	8.83	**6.53**	0.18

TABLE X
PROCESSOR WITH 1 CORE LOADED AT DIFFERENT CLOCK SPEEDS

1 Core Power Usage (W)				
Speed (MHz)	Min	Max	**Mean**	Std Dev.
800	5.75	9.59	**6.76**	0.24
1070	6.11	9.37	**6.86**	0.33
1330	6.26	10.63	**6.91**	0.30
1600	6.42	11.56	**7.09**	0.34

III. RESULTS

This section details and explains the results obtained from the various tests done on each component outlined in the Experiment section.

A. BIOS and Bootloader

Figure 2 plots the power usage of the BIOS and Bootloader over time. Table III summarises the power usage while in these states. The data demonstrates that while waiting for user input, the Bootloader consumes more power than the BIOS on average. We can also see from Table IV that the Bootloader consumes more power than the OS at the Idle State. This could be due to the processor running at maximum power with power saving mechanisms only activated after the kernel is loaded.

B. Screen

The results for the screen test are illustrated in Figure 3. The Idle State had an average power draw of 6.3 W. We observed that closing the lid brought the power down to 3.17 W. As previously mentioned, closing the lid switches off the display while keeping the computer running. From this result, we can deduce that the screen draws approximately 3.13 W of power - almost half of the total power consumption in the Idle State. We also found out that a mostly black screen uses more power than a predominantly white screen. The mean power draw for the black screen was 5.35 W while that of the white screen was 5.06 W. We discovered that LCD screens manufactured using the *twisted nematic* process could be the cause of this.[4] [Refer to Appendix] So, having a darker background or using “dark” search engines, like Blackle, does not really help save power with these LCD displays. At minimum brightness, the netbook used an average of 4.89 W of power - a saving of 1.42 W from the Idle State. Table IV details the statistics obtained from testing the screen.[2] Although we have repeated the tests several times to find the cause of the discrepancy between the Idle and Black states, the results were similar everytime. Further investigation is required to ascertain why there is more than 1 W difference between those two states.

TABLE XI
PROCESSOR WITH 2 CORES LOADED AT DIFFERENT CLOCK SPEEDS

2 Core Power Usage (W)				
Speed (MHz)	Min	Max	**Mean**	Std Dev.
800	5.76	9.37	**6.76**	0.22
1070	6.35	9.76	**6.89**	0.18
1330	6.48	10.42	**6.96**	0.2
1600	7.27	9.63	**7.57**	0.19

C. Wireless

Tables V through VII contain the tests carried out on the wireless module of the netbook. The Association tests were carried out using two different versions of the wireless NIC driver. The default driver would occasionally cause the device to disconnect from any network while transmitting or receiving data or it would freeze the netbook. Only a reboot permitted us to connect back to a network. The newer drivers functioned correctly. Comparing Tables V and VI, we see that drivers play an important role in the power consumption. The discrepancy between the two sets of results are considerable. Being associated to an access point also draws slightly more power than being just on (not-associated). This response was contrary to the one obtained with the old drivers. We can observe that with the new drivers the power levels are more stable as compared in figures 4 and 5.

The transmit and receive tests were performed using a 1.7 GB file. Table VII shows the statistics recorded while figure 6 displays the behaviour of the transfer. We believe that receiving data requires more power as the transfer rate was higher hence requiring the processor to work harder to filter out the downloaded packets. The transmit rate was small compared to the receive rate. Figure 6 has been truncated to plot these results over the same time period for ease of comparison. Download

[2][MinBr in Table IV stands for Minimum Brightness]

(receive) time for the file was 538 seconds while the upload (transmit) time was 3847 seconds.

D. HDD and USB

Figure 7 demonstrates the change in power usage while using the OS from the HDD and the USB. The test tells us that the hard drive consumes on average 2.34 W of power when it is plugged in. This would make it the second most power-draining component in the system. This test also reveals that the other components in the system draw approximately 0.84 W of power in the Idle State, including the power drawn by the USB Flash drive. Table VIII summarises the results obtained for the HDD and USB test.

E. Processor

Table IX demonstrates the results acquired in the Idle state at different processor speeds. Analysing the mean column, we can observe that the average power at 800 MHz is higher than those at 1070 MHz and 1330 MHz. It could be due a process being triggered or just a spin in or a read/write sequence to the hard drive. Further analysis will be required to determine why that happened.

The graphs presented in figure 8 illustrate how the power varies when one core and both cores are fully loaded. As expected, when the clock speeds are increased we observe a greater power draw. And the power drawn when both cores are busy are higher than with only one core. The results are reviewed in Tables X and XI. Although there is an increase in power when using two cores instead of one, we can observe that the power savings are negligible when the speed is in the range of 800 to 1300 MHz. But the power savings that can be realised while using the processor at the maximum speed of 1600 HHz are considerable. The difference in average power draw between using one core and both cores was nearly 500 mW.

We devised another test to see what happens when each core is configured to run at different speeds simultaneously. We programmed one core to run at the minimum speed of 800 MHz and the other at the maximum speed of 1.6 GHz. These results are plotted in Figure 9 while Table XII provides an overview of the main statistics. The outcome is not as expected, that is at power usage levels somewhere between 800 MHz and 1.6 GHz. It is higher than the results obtained for 1.6 GHz. Our hypothesis for this behaviour would be the extra amount of work the system has to do to keep the cores synchronized. Since both cores are on the same die, they have to share the same bus with each of them sending data to the bus at different rates. We have repeated this test several times and the data obtained was conclusive with the first set of results. To further scrutinize what is happening, we would have to study how the Intel Atom processor architecture works.

TABLE XII
POWER USAGE WITH 1 CORE AT 800MHZ AND THE OTHER AT 1.6 GHZ

Power (W)	Idle	1 Core	2 Cores
Min	6.29	5.88	6.27
Max	7.99	12.35	12.56
Mean	6.56	7.83	8.20
Std Dev	0.10	0.37	0.40

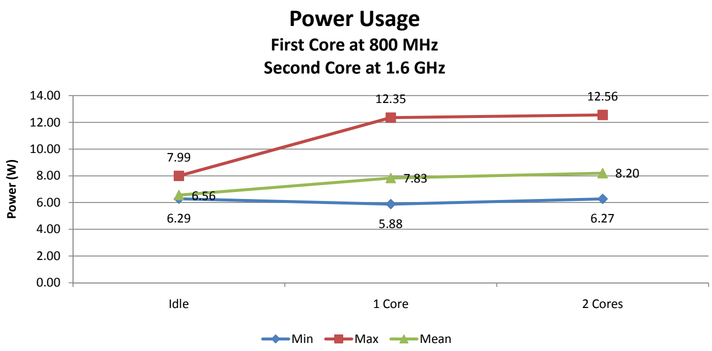


Fig. 9. Processor Power Levels with each core at a different clock speed

IV. Conclusion

The results obtained in this experiment have shown that the screen and hard disk drive use the bulk of the power required to run the netbook (in the Idle State), contributing to 49% and 37% respectively. We also found out that a black screen consumed slightly more power than a white screen. The power used by the wireless module depended largely on the transfer rate and was also affected by how the drivers which controlled it were implemented. The processor's power was as expected; increasing with higher clock speeds. Using the default CPU Frequency scaling set by the OS would save a considerable amount of power as it dynamically switches from 800 MHz to 1.6 GHz depending on usage requirements.

Further work needs to be done to examine how much power the Hard Disk consumes when doing read/write operations. Analysing how the processor adapts to read/write cycles and the power it uses should also prove useful. The ethernet and bluetooth interfaces should also be tested in a similar fashion to that of the wireless module. The power usage of the graphics card and processor will be looked at by comparing the Idle State to playing a movie or a 3D game. The same experiment will be performed under a Microsoft Windows OS to see how it manages power as compared to Ubuntu Linux. The processor would be further stressed by running a software which calculates large prime numbers. The program which loads the processor would be tweaked to allow it to take advantage of specific processor instructions. We would also analyse the benefits of cleverly managing processor speeds - by tweaking the existing governors or writing new ones.

APPENDIX

This section gives a brief explanation of why a black screen consumes more power than a white screen in LCD displays.

Depending on the temperature and particular nature of a substance, liquid crystals can be in one of several distinct phases. Liquid crystals which are in the *Nematic Phase* make Liquid Crystal Displays (LCDs) possible. One of the distinguishing features of liquid displays is that they are affected by electric current. A particular sort of nematic liquid crystal, called twisted nematics (TN), is naturally twisted. Applying an electric current to these liquid crystals will untwist them to varying degrees, depending on the current's voltage. LCDs use these liquid crystals because they react predictably to electric current enabling the control of the amount of light going through. For TN displays, when an electric charge is applied, the liquid molecules untwist changing the angle of light passing through them. This in turn causes affected areas to become darker as no light gets through. This is why LCD displays consume more power when they generate darker images as compared to their CRT counterparts.[5] For more information, refer to http://electronics.howstuffworks.com/lcd1.htm.

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