WHITE PAPER ULINK Technology

NCQ for Power Efficiency

February 10, 2006
By Yun Wang

Preface

Power usage has been a major issue in the recent personal computer designs. In order for a desktop to obtain the green machine, power usage has been very critical. On average the desktop PC consumes 100 to 200 Watts of power, which is the equivalent of the power usage of lighting for a living room. In addition to the power used by the components, the PC requires a fan to cool the system down. This cooling takes an additional toll of the power usage. The more power the system uses, the higher fan speed it requires to cool it off. This escalates the power usage while the fan noise roars on the quiet computer desk. Modern desktop design has to solve the power usage problem while keeping the system cooler and quieter. That's a challenge.

HDD Power Consumption Study

For notebooks and hand held computers, this issue has become even more critical. The battery life for the notebook always is the major design criteria. Some notebook computers last longer while others only have useful usage for up to 2 or 3 hours. Ironically, it is not that the designer cannot add more usable hour for the notebook by adding more battery power, but the weight that the users dictate cannot allow for more battery power. A notebook PC supposedly is used like a notebook, weighing less than 6.5 pounds. In reality the weight including a carry on charger is more than 8 pounds. This weight has prevented users from using it as a notebook, rather it like a brick or some heavy object. Some notebook PCs have turned into sub-notebooks with reduced weight; however, the usable time is also sacrificed. Many sub-notebooks weigh for less than 5 pounds, but they cannot last for more than 2.5 hours.

By examining the power usage the major consumption of power comes from many areas such as CPU, memory, LCD display and Hard Disk Drive (HDD). Each area of function makes up the total power usage. In the calculation of power, the battery is usually rated as Watt-Hour, or Wh. This is a more accurate unit to show the power capacity than Amp-Hour (Ah) that was used before. The Watt-Hour unit means the wattage that the battery can provide within one hour. The higher Wh the larger capacity the battery is. Normally a notebook computer uses Lithium-Ion battery for higher capacity of power per measured weight. Lithium-Ion battery also has benefit of longer life and little memory effect.

To achieve longer operating hour by a giving battery weight, the power of the notebook PC has to be reduced. On average the hard drive in a notebook PC consumes 20% of the power. The hard drive utilizes rotational media that is mechanically mounted on a pivot. In order to read/write the media, not only the media has to spin at high speed, the actuator has to move the read/write heads to the target track. This mechanical system requires substantial power to maintain its moving and operation. Due to the physics of momentum and friction, the HDD power consumption has a big impact on the overall system power usage.

NCQ Power Optimizations

Initially command queuing was aimed for improving HDD performance. By allowing the hard drive reorder, the command sequence hard disk engineer hopes to obtain better performance. This is how it works: for a giving number of random commands, the distance of traveling the media and head are reduced when the sequence of data accesses order is optimized. In real life application, for example, if someone delivers pizza to three locations, one can follow the sequence of which pizza was ordered. But a smart delivery person may want to start from the nearest location and drive to the next location which is near to the first location. Potentially one can save much time in delivering pizza, and in turn it will save gas.

The hard drive receives commands from the host system and accesses the media to record or retrieve the data. Before the Serial ATA (SATA) was introduced, most of the notebook PC's use Parallel interface, or PATA. Because the PATA interface limitation, the queuing feature has never been widely implemented. The complicated interface protocol and the higher command overhead, and the difficult driver handling made the PATA queuing harder to deploy. Most systems were built on non-queue operation until the SATA Native Command Queuing (NCQ) was introduced. SATA NCQ solved the problem of queuing efficiency by streamlining the command delivery sequences and command response protocol. In addition the promoter of SATA NCQ designed a standard host interface called AHCI (Advanced Host Controller Interface) that has standardized the host command delivery scheme and unified the host device driver interface. With this the SATA NCQ system can operate on an efficient queuing model.

Measurement of Power

By reordering the command queue it not only improves the hard dive performance but also reduces the power consumption. This study measures the power usage of a 60GB 2.5 inch HDD used in notebook PC. The measurement is based on a random command sequence. The current is taken on a current meter and recorded on a computer. The testing system is configured as follows:

1. A 2.5 inch notebook drive is connected to the test station.
2. The drive is connected with SATA cable.
3. A Fluke 189 current meter is connected to the drive's 5V power supply.

4. Drive Master 2006 Pro is running on the test system.

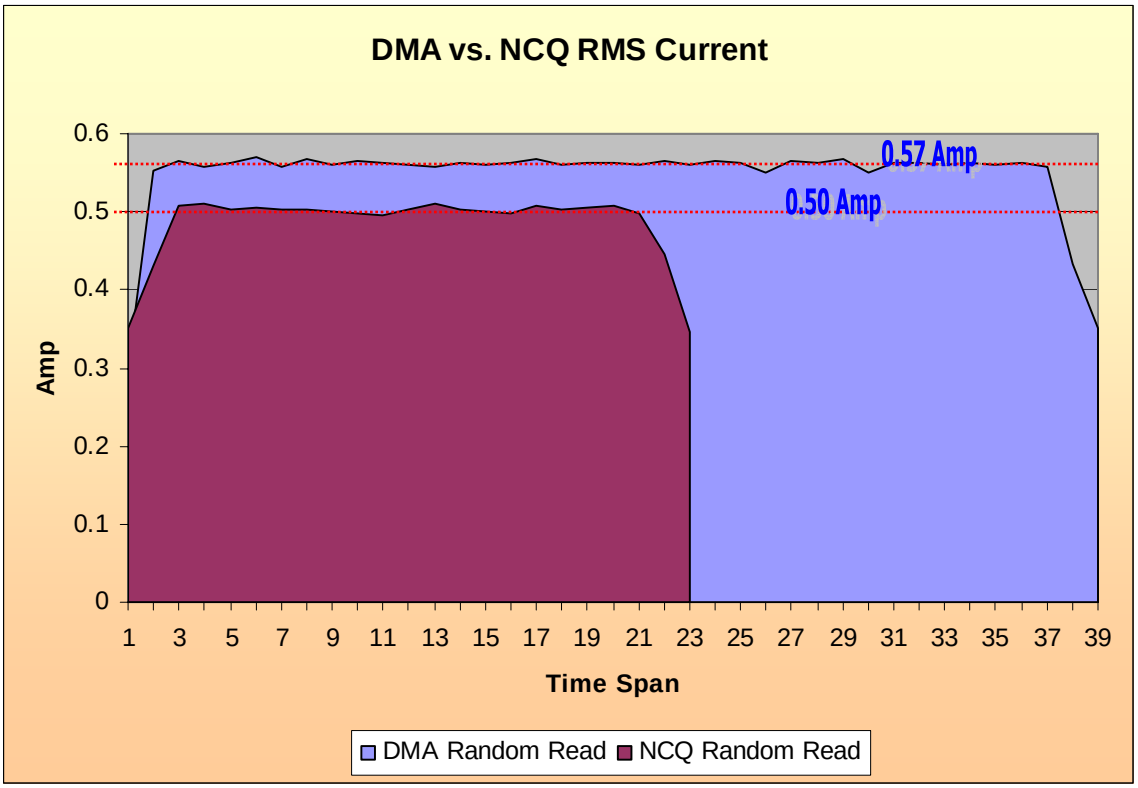
Drive Master 2006 Pro is software from ULINK Technology which is used to send NCQ commands to the hard drive. In this test Drive Master 2006 Pro stimulates the command sequence and the computer connected to the Fluke current meter records RMS current every second. The data of the current consumption is then analyzed and compared.

Drive Master 2006 Pro issues a group of random Read DMA command first. This DMA command does not have queue reordering. Drive Master 2006 Pro then issues another group of random NCQ Read commands. The computer records current going through 5V power supply and stores it on a file.

We found two facts:

1. When operating on NCQ the average current consumption is reduced.
2. The amount of time used for the same number of random read commands is reduced with NCQ Read.

The reason for the time reduction was understood by the efficiency of NCQ reordering. In addition, the average current (power consumption) is also reduced because the travel distance was reduced. To explain this we can go back to the pizza delivery scenario, when recording the delivery sequence: the total time of delivery is shortened, and the total gas usage is also reduced.



The total power measurement in this test is shown on the chart. A DMA Read consumes 0.57 Amp while the NCQ Read consumes 0.50 Amp. This is a 14% lower current consumption. In addition, by integrating the area, the power wattage DMA and NCQ consumed are 27.264 mW and 18.118 mW, respectively. In other words, NCQ consumes 66.45% of the DMA power usage.

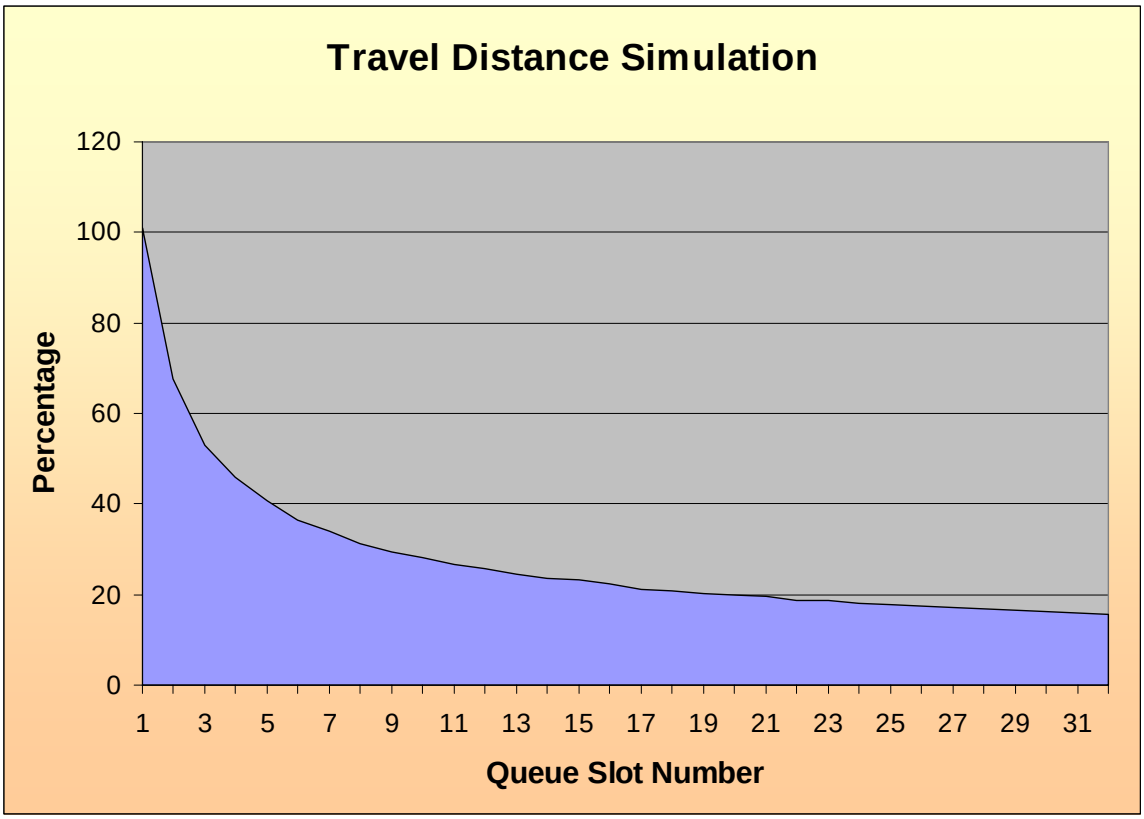
This calculation is based on full usage on queue, at 32 queue depth. Many applications with Intel NCQ driver under Windows operating system show queue slots been fully utilized, reaching the maximum of 32 slots. The burst NCQ commands conserve much power with very fast accesses.

Acoustics

NCQ commands not only increase the performance and power efficiency of a drive, but also cause the drive to emit less noise. The noise on hard disc drives (HDD) has become annoying for many PC users, especially in a quiet environment such as a library. The noise is generated by the rotating spindle and the read/write head movements. The read/write head contributes to most of the noise when a HDD is running because the acceleration or deceleration of its actuator makes the abrupt pitch noticeable from the base audible spectrum.

On NCQ commands, because the access order is sorted, the travel distance of the given group of command becomes shorter. This moving reduction is simulated by the ULINK's Drive Master program. The simulation shows the total number of tracks needed to be

crossed with a given number of random read commands. Assuming the DMA has only one slot, and NCQ has 1 to 32 slots, the simulation calculates the track number for each case, from 1 slot to 32 slots. The result is displayed on the chart.



As it shows on the simulated chart, the travel distance is reduced when the slot number increased. When the Queue depth reaches 32, the travel distance becomes 18% of the total distance compare with the 1 slot. This track crossing number reduction can greatly reduce the read/write head movement, and results in a much quieter drive.

This simulation considers the best sorting possible condition; in real life, we usually still drive far from the targeted number. However, with less than optimum sorting, the benefit of acoustic noise reduction still very clear. It has been very obviously noticeable by simply running a drive with DMA read random command, and then running the same drive with NCQ read. The drive makes more noise in the DMA than in the NCQ.

Summary

In summary the NCQ introduction has revolutionize the storage devices. The benefit can be felt and measured from the device. It is believed that most system will reap the benefit and most devices will continue to improve to achieve faster speed, lower power, and quieter noise. Ultimately, the user can enjoy bigger, better, and more reliable computing experience.

