INTEGRATING HARD DISK TECHNOLOGY: ENABLING INTERACTIVE TV

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Abstract

The introduction of Hard Drives into the "Home Gateway" space will change the way people watch TV. This paper addresses some of the engineering issues associated with introducing this technology, and also some of the benefits it will bring.

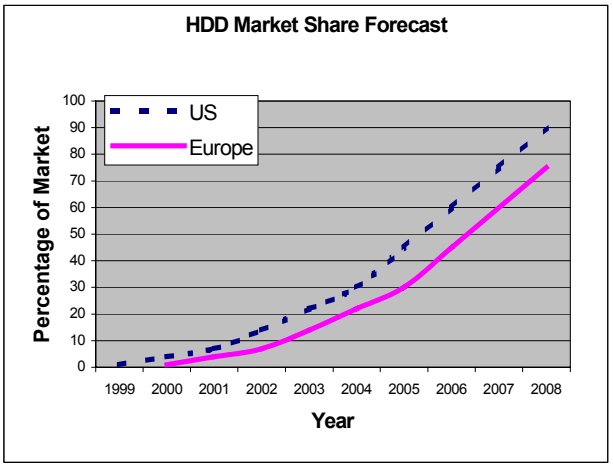
OVERVIEW

Definitions

DVR: This will refer to the basic set of functions that can be associated with the standard VCR today, such as Fast Forward (FF), Rewind (Rew), Pause, Record and Play.

PVR: This will refer to the enhanced personal features such as recording individuals favorite programs, or actors, movies etc.

Pay PVR: This will refer to push services that will earn additional revenue for the MSO, such as downloading the top 5 PPV movies or video games.



Market Forecasts

Market studies predict that by 2005 approximately 40% of the Home Gateway market will be for products with an integrated HDD. For this to happen the hardware and software designers need to work to make the products affordable and to have a perceived market value. There are a number of products that have launched to date that can only be seen as the first in a long range of products and educating the consumer to the benefits of the new technology will be one of the major challenges for the market forecasts to be met.

THE ENVIROMENTAL CHALLENGES

The consumer environment has to be considered as one of the harshest environments for the HDD to live. A consumer will demand high reliability while treating the product in a similar way to any other consumer piece of equipment. The box can regularly be seen in a A/V cabinet with a number of other heat generating pieces of equipment such as VCR's, DVD's and Home Theater Amplifiers, it may also be seen positioned next to or on top of a speaker or even worse a sub woofer and also has to remain totally silent during those quiet points in the latest movie. These issues all need addressing if the product is to be successful.

Heat

Today HDD's are generally designed to operate at a maximum operating temperature of 55 deg C. While this can be seen as acceptable in the PC environment it demands attention in the Home Gateway space. Most consumer products are specified to work in an ambient of up to 45 deg C and are still expected to maintain a mean time to failure of

300,000 to 500,000 hours. On average the ambient within a gateway is between 10 and 15 deg C above the external ambient, hence simple addition shows we instantly hit the maximum operating temperature of the drive. This is being addressed in two ways, firstly as drives become common in the consumer environment drive manufacturers will start to design their drives for this rather than just the PC market. This has started and we will soon see drives with 65deg C max operating temperatures. Secondly today we find that most products require forced cooling of the drive. Fitting a fan, which in turn has its own design problems of noise and reliability, performs this in most cases. Careful design of the airflow in the enclosure to maximize the airflow around the drive gives maximum cooling for minimum fan usage. The fan should also be controlled to be at least software switchable so that its only used as the temperature rises, and preferably speed controlled as this helps to extend the mean time to failure of the fan and also limit the audible noise generated.

Vibration

The design of the mechanical mounting for the drive is one of the most important aspects to consider. It's true to say that a drive that performs well in one product will not necessarily perform well in another. This can be attributed to the mechanical mounting. Vibration due to the disk spinning or the heads seeking, as well as external vibration from speakers or even people walking across the floor can all cause data to be miss read which in turn instigates another read cycle which introduces a time delay. This can be acceptable in the data world but will automatically cause a disruption of the picture, and hence a consumer complaint.

Noise

There are three main sources of noise to consider, rotational noise from the disk spinning, noise generated by the heads seeking, and noise generated by the fan introduced to maintain the operating temperature of the drive. The rotational source can be attributed to the quality of the drive but also the quality of the mounting discussed early. Noise generated by the heads seeking can also be attributed to the drive quality but can be minimized by the software drivers and file management system if designed to minimize the amount of seeks required. The fan noise can be addressed by choosing one with a good quality bearing and by having control over it's speed in software, which keeps the noise generated to the minimum necessary for temperature control.

TECHNICAL CHALLANGES

Analogue vs. Digital

Storing compressed MPEG2 video takes many gigabytes of memory. Recording a single broadcast quality program requires 2Gbytes for every hour (based on an average bit rate of 4.55Mbits/sec for all components of a program). A HDD therefore requires a minimum of 6Gbytes for a 3 hour film and realistically a minimum of 20Gbytes to be useful. Today we see 40Gbytes becoming the standard size this will reach 80Gbytes by the end of 2001 and 150Gbytes by the end of 2002.

Existing stand-alone DVR boxes today take in analogue video and audio and compress the signals to MPEG before they're recorded to the drive. This allows the picture quality or resolution to be controlled by the user in a similar way to VCR's today where the user can select SP (standard play) or LP (long play). This is not possible in the digital world as the video source is already in the MPEG format when transmitted hence the record

resolution is always the same as the broadcast source. This adds complexity to the user interface and the scenario below becomes an issue.
A 2-hour event can take up different amounts of drive space depending on the resolution and hence a 2-hour film on one channel may fit into the remaining drive space whereas a 1 1/2 hour football game may not. Its therefore not possible to directly compare a standalone DVR box today that is specified to record 20 hours of content with an HDD integrated into a product that receives MPEG content directly.

Maximum data rates on HDD's today

Regardless of bus interface, HDD's all fundamentally work in the same way. They're organized as a stack of 1-6 coated metal or glass platters that rotate together. Each platter has 1 or 2 recording surfaces. There is a head assembly with one read /write head for each recording surface and all heads move together. A disk surface is organized as thousands of concentric tracks each divided into a number of individually addressable sectors. Consecutively addressed sectors lie next to each other on the disk, either on the same track on a different surface or on the immediately adjacent track. When a command arrives, the heads seek to the correct track and waits until the first sector rotates under the head (rotational latency). Data transfer then happens to/ from the disk for some consecutive number of sectors. It should be noted that during a data transfer operation the seek rotational latency times are overheads no media data transfer is actually taking place. Once the heads are on the track data transfers happen very quickly with almost no overhead. This media transfer is the ultimate bandwidth limit for HDD's. For small transfer sizes the seek and rotational latency overheads dominate. Therefore to get high sustainable bandwidths you must do large sequential accesses. This means transferring the data in the maximum block sizes allowed to minimize the overheads.

Today's hard drives have basically two standard interfaces, SCSI and ATA. SCSI is aimed at high-end devices hence costs too much for consumer products, hence ATA is favored. ATA is also commonly known as an IDE interface which is a cheap efficient interface over a 40 pin connector. ATA is both an electrical and command specification. ATA comes in a variety of headline speeds, PIO mode, multiword DMA, UDMA/33 (33MB/s), UDMA/66 (66MB/s) and soon UDMA/100 (ATA100 – 100Mb/s). For streaming content these "headline" rates mean nothing, they're just peak transfer rates to and from the HDD cache across the interface, sustainable bandwidth is limited by the media transfer rate which is today an maximum of approximately 25Mbytes/s or 200Mbit/s. Therefore UDMA/33 interface is sufficient for DVR.

As mentioned the sequential transfer size is very important for streaming video. The current ATA4 specification has a maximum limit of 128Kbytes for a single transfer. ATA5/6 will address this limit and increase it up to 32Mbytes.

As the main market for HDD's today is the PC market they're designed to maintain data integrity. This means that there is a very high upper limit for the time a command will take to complete. Unfortunately this makes it very difficult to schedule real time data transfer for video recording and playback. Currently we must use a sledgehammer approach and switch off almost all error correction. ATA5 and 6 will address this issue and provide methods for to control the maximum time taken for executing a command. This will allow the HDD to dynamically adjust the amount of error correction that it performs

whilst still allowing hard real time scheduling. In either case if a non-correctable error occurs for the file system access (i.e. data not video) the HDD driver software must take actions to retry that block again. This is an example of how the consumer DVR market is beginning to steer the HDD manufacturers.

The cost and complexity of legacy analogue support

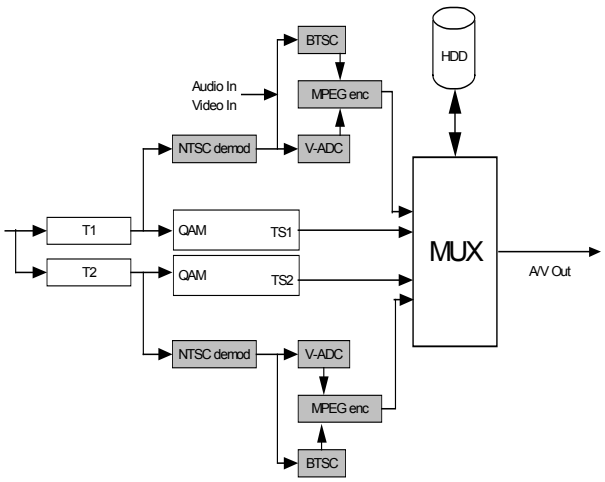


Figure 1

If we were to list the most wanted features for a DVR product the so-called *trick modes* would be near the top as would to watch one channel while recording from another. This should be seamless to the consumer therefore there needs to be two full paths for the video delivery, as shown in fig 1. The analogue channels need to digitized and MPEG encoded before being stored to the drive, which means supporting two real time MPEG encoders, 2 BTSC decoders, 2 video digitizers and 2 full band tuners capable of receiving both analogue and digital channels. The shaded sections in fig 1 represent this. If there were any one thing that would simplify the hardware architecture and improve the overall experience of an integrated digital cable DVR product it would have to be a digital only solution. This may mean carrying all analogue channels in the digital domain also which brings additional head end cost, complexity and inefficient use of cable bandwidth but the overall improvement may be worth the investment.

Network vs. Local storage

VOD could be regarded as a form of DVR and in many ways would appear transparent to the consumer. It can support FF, Rew, Pause and Play, however some of these have more bandwidth implications to the system. For instance assume that you had paid to watch a film and halfway through you needed to pause for an hour for some reason. If the storage were local in the box then no problem, assuming that there's space on the drive the film would be recorded and would start to play from the pause point after the hour.

In a VOD (networked storage) system this would mean that the session would need to be extended by an hour which in turn would impact all the assumptions made for the VOD system bandwidth calculations, plus as DVR becomes more and more heavily deployed this loading would probably increase at a greater rate as the consumer became more familiar with the DVR features. This session could be further extended if the user decided to rewind the film halfway through so that a second person could watch it. There are some policy decisions that need to be taken by the MSO to control this or the sessions can become longer and longer causing serious bandwidth issues.

The answer may lie in a hybrid model where the local storage could buffer the VOD content to limit the session to the length of the film, and as a next step it could be used to reduce the VOD session further by allowing the content to be downloaded at a much faster rate, up to 38Mbits/s which could mean a 2 hour film could be downloaded in approximately 15 mins. The hybrid model

would also allow for the amount of storage to be more readily upgraded on the network side and hence would extend the life of the local storage product. There will no doubt be a sweet spot that justifies the business model that will allow mass deployment of HDD enabled boxes but that can be future proofed by network upgrades.

FUNCTIONAL CHALLENGES

Moving from DVR to PVR

To gain the advantages of PVR there's a requirement for enhanced or extended guide data (metadata) and a software module sometimes referred to as a preference engine that filters the guide data to find the user or multiple users preferences such as, all John Wayne movies, or all new episodes of Friends. This then extends down to the file management system to manage the drive. The user interface then has to deal with the remaining drive space and how much drive space each user may have access to for instance do I record football for dad or Friends for mum? The quality of the PVR experience will heavily depend on the quality of the additional guide information and the preference engine, which in turn will drive the data providers to create this enhanced data.

Moving from PVR to PayPVR

PayPVR brings the additional challenge of how to pay for the drive in the box. While DVR and PVR both give the user an enhanced experience neither justify significant additional revenue for the MSO. Only when services can be downloaded or "pushed" to the drive can additional revenues be generated such as downloading the top 5 PPV movies to the drive to help smooth out the peak demands on a VOD, home shopping catalogues or video games. The addition of PayPVR adds conditional access issues to resolve such as does the user get billed when the movie is downloaded or when its watched. This is an important issue as today most conditional access systems were designed before this became a reality.

Archiving

There will always be the desire by the consumer to archive the content on the drive to some other form of storage. This today would most likely be VHS Tape but in the future may be Digital–Tape, DVD or even a second HDD. While the content is stored in its analogue form this is deemed acceptable to the MPAA but once the content is stored in its original digital format then the MPAA will require a form of copy protection, this is commonly referred to as Digital Rights Management or DRM. Most silicon providers are now incorporating a mechanism to allow for the content to be encrypted before being stored on the HDD. While there's no official standard today this must be addressed or the advantages of HDD will not reach their full potential.

IN SUMMARY

The integration of HDD's into consumer products is inevitable and the technical issues discussed above have or are being addressed and in the future we will see a wider variety of consumer products with HDD's becoming available. This will drive down the cost of the products, which in turn will drive the deployment and encourage new interactive applications that can take advantage of the technology.