ieee Southern Minnesota Section Newsletter

Published by the Southern Minnesota Section of the Institute of Electrical and Electronics Engineers *February 1999*

Hard Disk Drives

by Weldon Hanson

Advances in computer processing power, in tandem with bloated software and the advent of multimedia, have led to marked increases in data storage requirements. Keeping pace, storage capacity has increased at a compound growth rate of 60%.

To be competitive in this fast-paced environment, hard disk drive manufacturers must continually speed up product development. The product cycle is now between one and two years long, from design to end of production.

Disk drive storage is used in an ever-growing variety of applications – from traditional mainframe, desktop and laptop computers to emerging consumer applications such as video-on-demand. Miniature disk drives are now being integrated into digital cameras and other handheld devices.

Hard disk drives are available in a variety of physical sizes, including form factors (disk diameters, in inches) of 5.25, 3.5, 2.5, 1.6 and 1.0 – the 1-inch, 340-MB *Microdrive* was recently announced by IBM. Announced drive capacities range as high as 50 GB (a 1.6-inch high, 3.5-inch diameter drive). Most disk drives shipped in 1998 were 3.5-inch drives with capacities of 4 GB to 9 GB.

To achieve these advances in storage capacity, while also improving performance and reducing cost, engineers have improved nearly all aspects of disk drive design. They have implemented new magnetoresistive (MR) read sensor technologies; miniaturized components; tightened component tolerances; increased spindle speed (rpm); integrated electronics for higher-frequency operation; improved data coding techniques and error correction capability; implemented power-saving features; and reduced overall parts counts.

The disk drive is an electromechanical assembly containing several elements:

Casting – an aluminum shell with precision machined surfaces and holes for rigidly mounting and enclosing the other drive components.

Disk pack – an assembly of aluminum or glass disks, clamped rigidly to a precision spindle motor.

Positioning system – an aluminum actuator that is rotated about a bearing pivot by a voice-coil motor; the read/write transducers are mounted in a stainless steel suspension attached to this actuator.

Electronics card – includes a microprocessor, memory, computer interface, spindle and actuator control, and read/write electronics.

(Continued on page 2)

IEEE Section Meeting

Weldon Hanson

Disk Drive Tutorial

Monday, February 15, 7:00 pm
Mayo Medical Sciences Building
(321 3rd Avenue SW, Rochester)

☞ *Pizza & socializing at 6:30 pm* ☜

Weldon Hanson is a Senior Engineer for IBM’s Storage Systems Division at IBM Rochester. A member of the Advanced Channel Development and Integration team, he helps design and evaluate data channels (the integrated circuits that encode data written to the disk and convert the readback signal back into digital data).

Hanson's career at IBM began in 1982, after earning his BSEE at the South Dakota School of Mines and Technology. At IBM, he has worked on process and test equipment for recording head manufacturing, and he was involved in specifying recording component dimensional and magnetic tolerances for the head and disk.

He recently completed a 2½-year assignment at IBM Fujisawa, Japan, where he was instrumental in introducing PRML data channels into IBM’s line of mobile and desktop disk drives.

IBM’s 340-MB Microdrive

(Hard Disk Drives, continued from page 1)

Storing data in the drive and retrieving data from the drive is accomplished by passing commands and data over an interface cable between the drive and computer. Several interface protocols have been defined and implemented as industry standards, including the AT or IDE (Integrated Drive Electronics) interface, SCSI (Small Computer System Interface), SSA (System Serial Architecture), and Fiber Channel.

When the command to write data to the disk is executed, the read/write transducer is positioned by the actuator over the precise location on the rotating disk surface where the specific record is to be written. Data and actuator positioning (servo) information is recorded on the disk surface in concentric tracks. Bursts of servo information separate blocks of "customer" data. Typically there are about 60 equally spaced servo sections, occupying about 10% of the track; the remaining portion of the track contains data and information used for synchronization and error correction.

The disk is typically divided into eight concentric zones between the inner and outer recordable radii. In each zone a single bit frequency is used for recording the servo positioning information, but several different bit frequencies are used in each zone for recording the customer data. Consequently, the linear bit density (kb/inch) is nearly uniform across the surface, except for some relaxation of the density at the outer radii to compensate for SNR (signal to noise ratio) degradation caused by the higher datarate (Mb/s) there.

Data is organized in sectors of 512 customer bytes. Preceding each sector is a synchronization and "sync mark" field. Following the customer data is an error correction code field. This overhead, in addition to the servo information, results in a format efficiency of approximately 75%. In other words, only about 75% of the disk surface contains actual customer data.

To store data, binary data is first encoded. This write signal is then amplified and applied to the write coil in the head (the read/write transducer that flies only a few microinches above the disk surface). The write coil produces a magnetic field that saturates the magnetic coating on the disk directly under the head, leaving binary data recorded as a series of magnetic transitions.

The readback process recovers the binary data from the disk by using the read head to sense the magnetic transitions. The resulting signal is amplified by a nearby preamp to a level suitable for the data channel module on the electronics card. The read portion of the head is made up of a magnetoresistive (MR) layer, a biasing layer, and shields, all designed to produce a linear readback signal via spatial filtering of the magnetic flux transitions on the disk.

The preamp supplies a small bias current to the MR layer, which reacts to the flux transitions by changing its electrical (ohmic) resistance. By this method, the flux transitions are converted to a voltage waveform consisting of a series of positive and negative peaks. This waveform is amplified by the preamp and passed to the read channel to be decoded into customer data.

In the data channel, the amplified readback signal is filtered, normalized for amplitude, and equalized (shaped) to match the expected signal frequency response of the detector. The equalized waveform is then sampled and converted to digital form. This datastream is processed by a "maximum likelihood" detector to extract the encoded customer data that was hidden in the noisy analog readback signal.

Drive manufacturers use "Partial Response Maximum Likelihood" (PRML) channels because such detectors allow higher bit densities. They effectively match the detector's frequency response to the magnetic recording system. The minimum bandwidth requirements of these detection schemes allows lower clocking frequencies. Extended PRML variants include EPRML and EEPRML.

Past predictions of the demise of magnetic recording systems utilizing longitudinal recording technology have been proven incorrect. The industry continues to improve positioning systems, reduce disk noise, reduce head flying height, improve head sensitivity, and design increasingly effective detectors to recover written data. Continued innovation, and the scaling of key parameters in the recording system, should continue to increase drive capacities at present rates in the foreseeable future.

At some point in the future, it is reasonable to expect that recording densities will approach the superparamagnetic limit, where the laws of physics mandate that thermal noise will obscure magnetically recorded information. But even at that point, perpendicular recording techniques may be employed to squeeze out still more gigabits per square inch.

(SCADA, continued from page 4)

With the broadened scope, RPU prepared a specification for the procurement of a combined water and electric SCADA system. Based on vendor reactions, it became evident that such a melding of responsibilities was not routinely done. This is because a water SCADA system is often implemented on platforms suited for process control, such as petroleum production, natural gas or waste treatment.

Such process systems are installed on programmable logic controllers (PLCs), where each controller has a set of tasks to automatically perform while communicating with each other and with a master controller for displaying system conditions.

In contrast, an electric SCADA system is alarm and annunciator based. Here, each remotely controlled station's equipment is wired to a remote terminal unit (RTU) which acts only as an interface with the master station. Very little if any automated control functions are performed. A human operator receives all of the system conditions reported from each RTU, and makes reactive decisions and control changes back through each RTU.

These differences of system operation affected the capability of various vendors to bid the project. Ultimately, four vendors were approved for bid. Proposals were evaluated, and the project was awarded based on vendor experience, comparable project success, and, of course, price.

Valmet Automation of Houston, Texas, was the successful bidder, and this firm has worked closely with RPU technical staff to construct, program and effectively integrate the system.

Computer equipment used for the system is generally available off the shelf. Hewlett-Packard workstations running Windows NT and Digital Equipment Corporation processors running UNIX comprise the master station computing horsepower.

Software is an integrated combination of AutoCAD (for graphics), Sybase (for database management), Windows applications (for some of the user interfaces) and proprietary code.

The system was installed and put on line in February 1998, for electric SCADA operation. Further installations throughout the summer and fall of 1998 brought the water SCADA functions on line. Acceptance testing is currently being performed, involving tests to prove functionality, stability, speed, robustness and reliability.

The first quarter of 1999 will see the finalization of this successful project. Although there have been challenges and difficulties associated with the replacement of two control systems, the operation of one system platform has shown its advantages. The proof of the project's success can be seen in the fact that water and electric services for the citizens and businesses of Rochester have continued nearly seamlessly, from the customer's perspective.

RPU operating staff continue to learn the basic and advanced features of the system. In the near future, these advanced features will allow RPU to customize many data management, reporting and condition-monitoring functions that had not been available before.

A tour of the RPU System Operations Control Center, and a demonstration of the new SCADA system, is scheduled for Monday, February 1, at 7:00 pm. The tour will begin in the Community Room at RPU offices, 4000 East River Road NE, Rochester. The session may last approximately 30-45 minutes, depending on questions from the audience.

Where Have We Been?

Well, you may have noticed that we didn't have any section meetings in November, December or January. You didn't get a newsletter either. What happened?

The short answer is cancellations. For various and reasonable reasons, the speakers we had arranged for these meetings canceled, and we weren't successful in finding replacement speakers on short notice.

It was a string of extraordinarily bad luck, possibly related to *la nina*, that produced this run of three successive cancellations. In the future, we hope to implement a backup plan and keep a stand-in speaker on tap.

IEEE Section Event

Tour of RPU's System Operation Control Center

Monday, February 1, 7:00 pm
Rochester Public Utilities, Community Room
(4000 East River Road NE, Rochester)

This tour of RPU's System Operation Control Center will focus on the System Control and Data Acquisition (SCADA) system.

RPU's SCADA System

By Neil Stiller

For many years, electric utilities have owned and operated computers to remotely manage electric power equipment and the flow of energy using System Control And Data Acquisition (SCADA) systems. Such systems alert the operator of equipment failure and system conditions that call for corrective reaction, and they remotely control switches, circuit breakers and generators. Rochester Public Utilities (RPU) has utilized such equipment for many years. As with any computer system, obsolescence and maintenance are factors governing decisions to replace or upgrade hardware and software.

In October 1995, RPU set into motion a project to replace an electric SCADA system that was purchased in 1983. With an original budget of $400,000, the RPU Engineering department set out to research the current market technology and to determine the project scope.

It was quickly noticed that substantial cost savings and efficiency improvements were available if the SCADA system not only operated the RPU electric system, but also the water distribution system. (The RPU water SCADA system had been purchased in 1984, and it was approaching obsolescence.)

(Continued on page 3)

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