Quick Review over the Last Lecture

Logical conjunctions:
- AND
- OR
- NOT
- NAND
- NOR
- XOR

Notations:
- $\bar{A}$
- $A \land B$
- $A \lor B$
- $A \oplus B$
- $A \lor B$

Venn diagrams:
- [Venn diagrams for AND, OR, NOT, NAND, NOR, XOR]

Logic circuits:
- [Logic circuit diagrams for AND, OR, NOT, NAND, NOR, XOR]
Access Patterns to a Hard Disk Drive

Research on access patterns on network attached storages (NAS): *

Source: University of California, Santa Cruz

* http://www.oracle.com/
Origins of Data Loss

Information storage is required:

* http://www.oracle.com/

Why Tape Storage?

Magnetic tape media:

- times-more data are stored as compared with a hard disk drives (HDD).

Almost EB data are stored in tape media

→ Almost tapes!

* http://home.jeita.or.jp/
Data Transfer Speed

Magnetic tape media:

Without compression, \( \text{MB/sec.} \times \text{GB/h} \).

Almost comparable with a HDD

- 3.5" HDD 15K rpm
- 3.5" HDD 10K rpm
- 3.5" HDD 7.2K rpm
- TS1130
- T10000B
- LTO Ultrium 5
- LTO Ultrium 4
- LTO Ultrium 3
- Blu-ray 12x
- DVD-ROM 16x

Where are Magnetic Storages Used?

World-wide enterprise disk storage consumption:

* http://home.jeita.or.jp/
Energy Consumption

Energy costs:

- Tape media: LTO-5 without compression
- Initial 3 PB data + 45% annual increase for 12 years

→ Total cost of ownership (TCO): 1/15 of HDD
→ Energy cost: 1/238 of HDD

First Magnetic Tape Drive

In 1951, Remington Rand introduced the first tape drive for a computer:

- UNIVAC (Universal automatic computer) I uses a tape drive, UNISEROV.
  - ½-inch wide tape
  - Nickel-plated phosphor bronze (Vicalloy)
  - 1,200 feet long
  - 8 channels (for data, for parity and for timing)
  - inch/sec. (= characters/sec.)

* http://home.jeita.or.jp/
* http://www.wikipedia.org/
Fabrication of Magnetic Tape

Advanced Intelligent Tape

In 1996, Sony introduced Advanced Intelligent Tape (AIT) :

- 8-mm wide tape
- 25 ~ 800 GB (without compression)
- MB / sec. (without compression)
- Memory in cassette (MIC) : 64-kbit
  Electrically erasable programmable read-only memory (EEPROM) stores usage history and data address.
  → Fast operation
- Adaptive lossless data compression (ALDC) :
  Data compression ~ 1/2.6.
  → High recording density

* http://www.youtube.com/watchv=FeKxC8pLTbl

* http://www.wikipedia.org/
In 1987, Sony introduced Digital Audio Tape (DAT): *

Digital Data Storage (DDS) was then developed in 1989.

- 0.15-inch (3.81-mm) or 8-mm wide tape
- 60 ~ 170 m long
- 2 write heads at 6° angle with 9,000 rpm
- ~ mm / sec. ( MB / sec.)

- > 17M units shipped
- ~ 50 % in magnetic tape storage

Minimisation of Bit Errors

2 read / write heads : *

Two adjacent tracks with their azimuth angle at ± 20°

* http://www.itmedia.co.jp/enterprise/articles/0607/13/news034.html
Head Configuration

2 pairs of read/write heads:

- Magnetic ferrite core
- Metal-in-gap layer
- Glass
- Non-magnetic ceramics
- Magnetic lamination
- Gap length
- Data track width (DAT 72 = 5.4 µm)

Development of a DDS

Capacity doubles every 3 year:

* http://www.itmedia.co.jp/enterprise/articles/0607/13/news034.html
In 2000, IBM, HP and Seagate introduced Linear Tape Open (LTO) :

- Based on research at IBM Tucson Laboratory
- DLT and AIT have dominated the market.
- Accelis :
  - 8-mm wide tape
  - 2 reels
  - High access speed
  - Resembles Sony AIT
- Ultrium :
  - ½-inch wide tape
  - 1 reels and linear scan
  - Large storage capacity
  - Resembles Quantum DLT
  - 100 GB capacity (without compression)
  - MB / sec.

*L TO Ultrium Roadmap

* http://www.ultrium.com/
Precise Positioning

Data subsets are repeatedly stored in various tracks:

Surface smoothness

Tape width ~ 1.27 cm

Kagoshima

Distribution in left / right

Sapporo

1,600 km

LTO Tape Media

Track width of LTO tape media:

- 12.65 mm wide tape / tracks
- Track width: \( \mu \text{m} \)

Track width: 8.1 \( \mu \text{m} \)

* http://home.jeita.or.jp/
Recent Development

In order to store 10 TB data:

* http://www.oracle.com/

Bit Size Roadmap

Data subsets are repeatedly stored in various tracks:

* http://www.oracle.com/
Smaller grain sizes required for better signal-to-noise ratios (SNR) :

- Barium ferrites (BaFe$_{12}$O$_{19}$)
  - Hexagonal platelet
  - Naturally stable oxide (no corrosion)

New BaFe$_{12}$O$_{19}$

New tape media is under development : *

* http://www.oracle.com/
Magnetic Degradation

Measuring changes in demagnetisation:


Stability equivalent to -year ambient storage

Head Design

Miniaturisation of the head components:

* http://home.jeita.or.jp/
Areal Density Roadmap

Consistent increase in areal density is anticipated:

* http://www.oracle.com/

Tape Cartridge Capacity Roadmap

Consistent increase in cartridge capacity is anticipated:

* http://www.oracle.com/
Consistent increase in data transfer rate is anticipated:

- Increased linear densities
- Increased number of heads
- Increased tape velocities

In 2010, IBM and Fuji Film announced a record:

IBM Research sets new record in magnetic tape data density

Important milestone in storing, protecting and accessing increasing volumes of data for a smarter planet

Zurich, Switzerland, 22 January 2010—IBM researchers today announced they have demonstrated a world record in areal data density on linear magnetic tape—a significant update to one of the computer industry’s most resilient, reliable and affordable data storage technologies.

This breakthrough proves that tape technology can increase capacity for years to come, which has important implications, as tape storage systems are more energy efficient and cost-effective than hard disk drive storage systems. Businesses and governments use magnetic tape to store, protect and access large volumes of important data, including: data and video archives, back-up files, replicas for disaster recovery, and retention of information required for regulatory compliance.

The scientists at IBM Research – Zurich, in cooperation with the FUJIFILM Corporation of Japan, recorded data onto an advanced prototype tape, at a density of 29.5 billion bits per square inch — about 39 times the areal data density of today’s most popular industry-standard magnetic tape product. To achieve this feat, IBM Research has developed several new critical technologies, and for the past three years worked closely with FUJIFILM to optimize its next-generation dual-coat magnetic tape based on barium ferrite (BaFe) particles.
Tape Storage Can Survive

In order to fill the memory / storage access speed gap:

* [http://home.jeita.or.jp/](http://home.jeita.or.jp/)