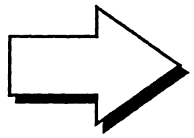
REVOLUTIONS IN STORAGE: PRML CHANNEL AND MR HEAD

PUSHING THE LIMITS

What would you like in your next disk drive?

- **More Capacity?**
- **Higher Performance?**
- **Lower Cost?**

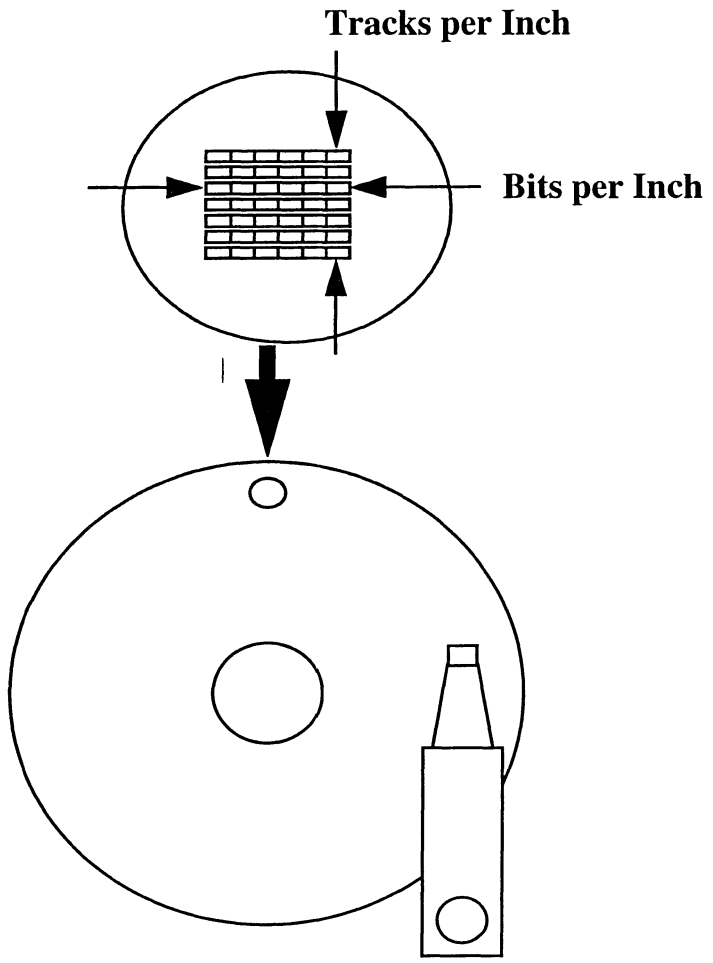


ALL ARE ACHIEVED WITH HIGHER AREAL DENSITY!

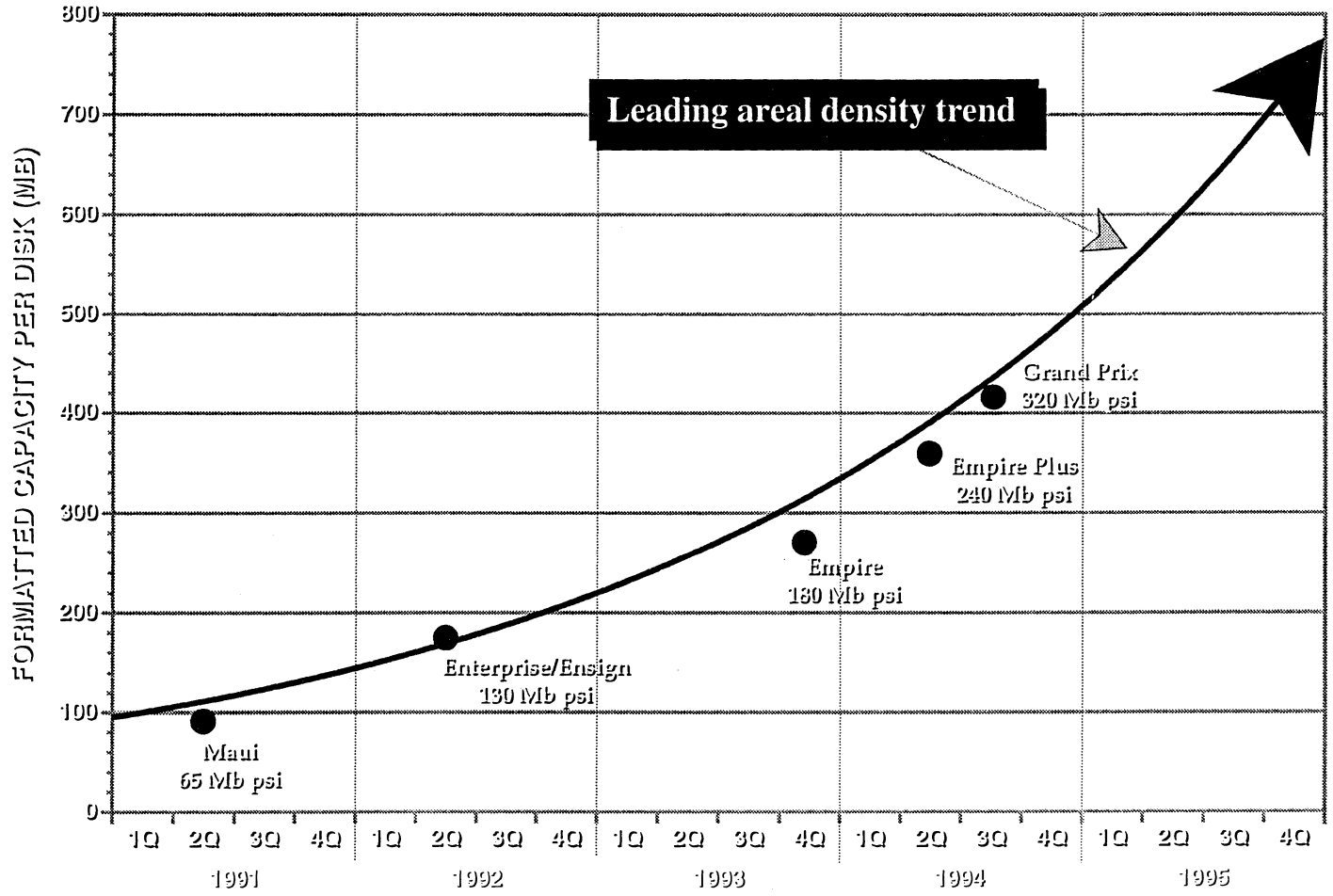
But, how do we do this??

AREAL DENSITY

- **Tracks per Inch X Bits per Inch**
- **More density requires increasing either TPI or BPI**
- **Boosting either parameter is becoming increasingly difficult with current technologies**
- **MR Heads and PRML Channels help with both**

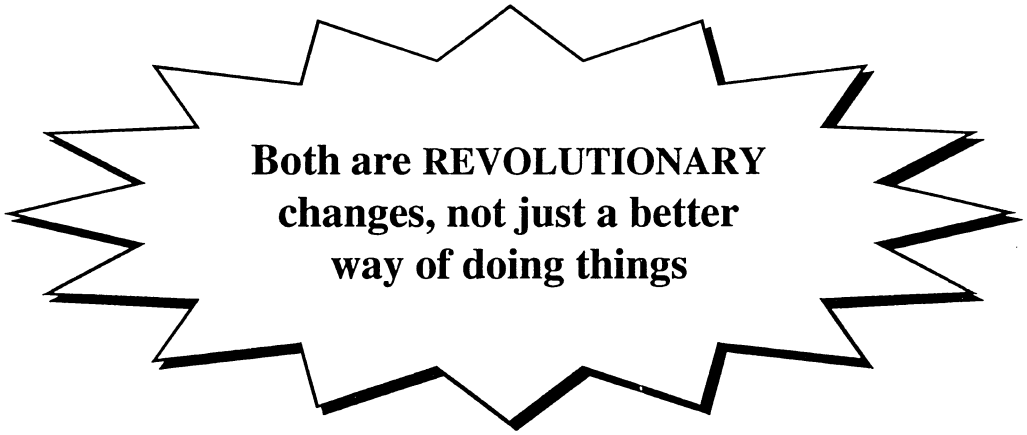


QUANTUM HIGH CAPACITY PRODUCTS VS. CAPACITY/DISK TRENDS



REVOLUTIONARY TECHNOLOGY

- ☆ PRML Channel
- ☆ MR Heads



- The technologies they replace have both been in use since disk drives were invented!

Peak Detect Channel → PRML Channel

Inductive Heads → MR Heads

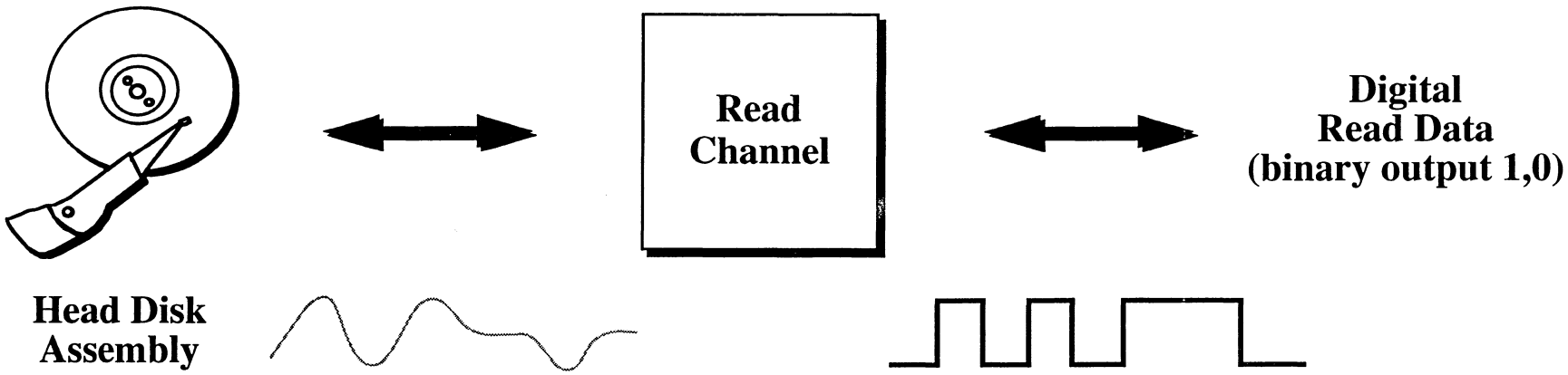
PRML

Partial Response Maximum Likelihood

1970s	Technique first used in digital communications
1990	First-generation PRML for hard disk drives introduced by IBM
1993	Quantum is first independent drive company to ship disk drives with PRML

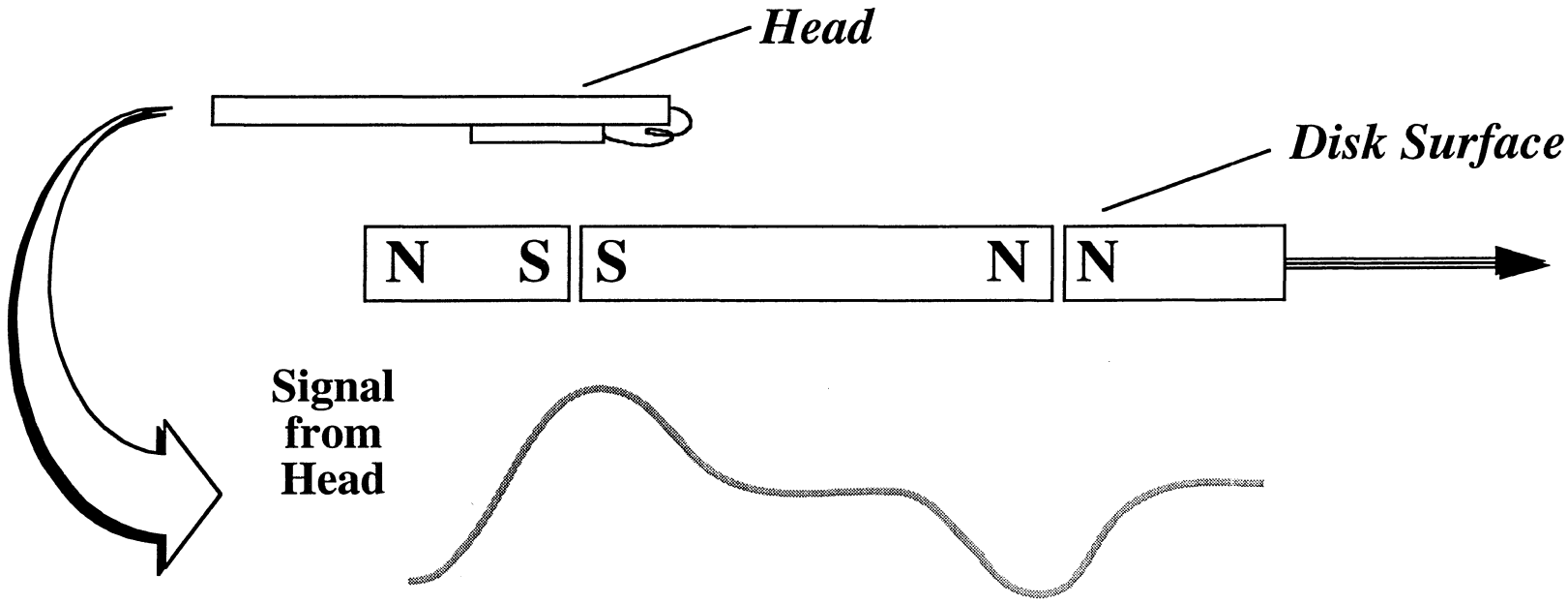
Read Channel Functions in a Hard Drive

- Encodes (writes) data into a series of "magnetic" transitions on the disk
- Retrieves (reads) data from the disk and returns it to the user in digital form



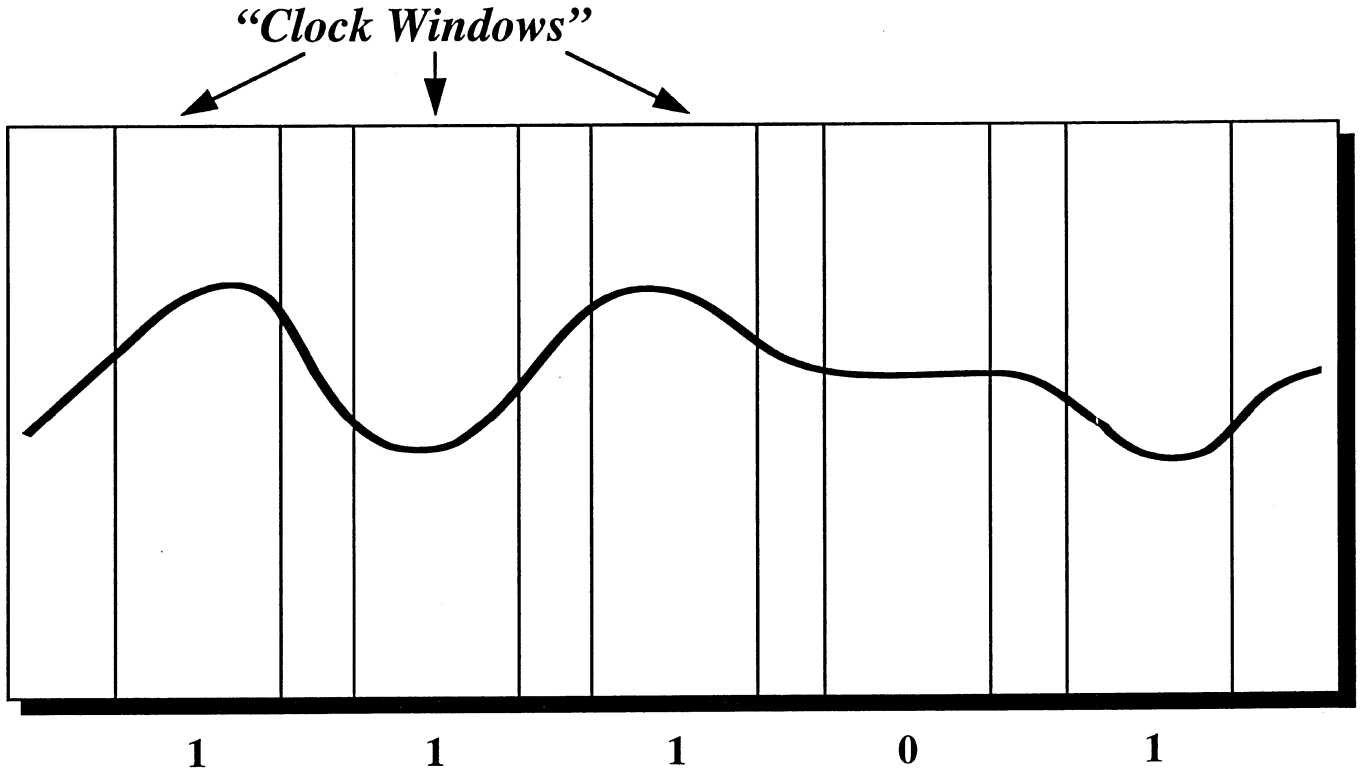
MAGNETIC RECORDING

- **Disk drives do not directly record "0"s and "1"s on the media**
- **It converts data into "flux reversals" which must be decoded to recreate the data**



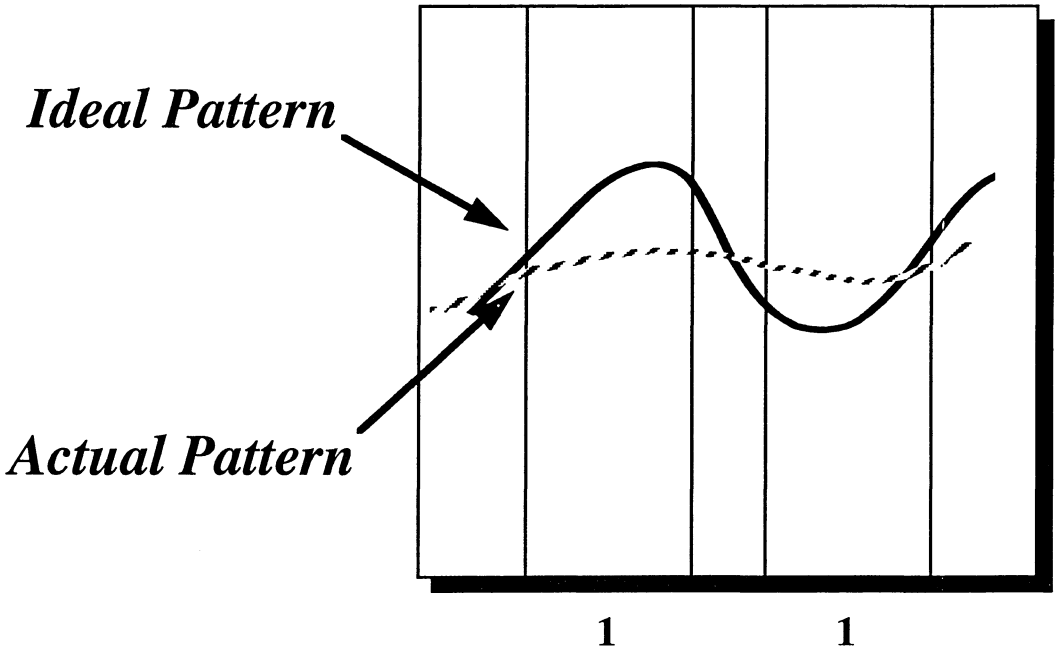
PEAK DETECT RECORDING

- **A transition during a clock window indicates a "1"; the lack of a transition indicates a "0"**



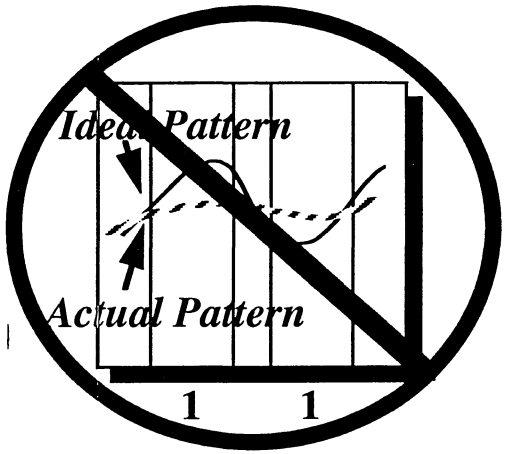
INTER-SYMBOL INTERFERENCE

- **Peak detect recording is complicated by interaction between recorded signals**
- **When reading two adjacent flux changes, signals can nearly cancel each other**



CODING

- Due to inter-symbol interference (ISI), flux changes in adjacent "windows" are not allowed
- User data must be "encoded" in a manner which eliminates adjacent "1"s
- A coded string of data is 50% longer than the uncoded string
- End result: Inefficiency



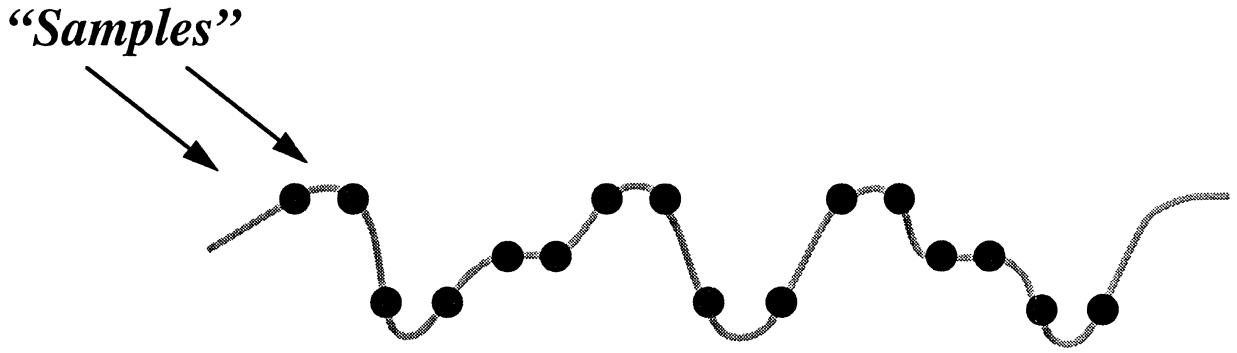
PRML TO THE RESCUE

- PRML recognizes patterns, rather than individual peaks
- Inter-symbol interference is accounted for in the pattern recognition
- Far more efficient coding allows better use of disk space

	Peak Detect	*PRML*
User Data	2 bits	16 bits
Coded Data	3 bits	17 bits

How PRML Works

- Data is recorded in a similar manner as with peak detect
- When read back, the data is digitized, or "sampled," at regular intervals



- This sample pattern is then compared with all possible patterns to find a match

How PRML Works

- Patterns are analyzed in groups which are 6-bits wide
- The maximum number of possible patterns is 2^6, or 64
- Actual number of possible patterns is less than 64 due to coding restrictions
- Sample patterns are compared with known possible patterns using a least-squares technique

PRML CHANNEL

- As a simplified example ...
  - Reduce the group to 3-bits wide
  - Suppose we know the user data is one of two possible patterns
- User data is either ...

1	1	0	0	1	1

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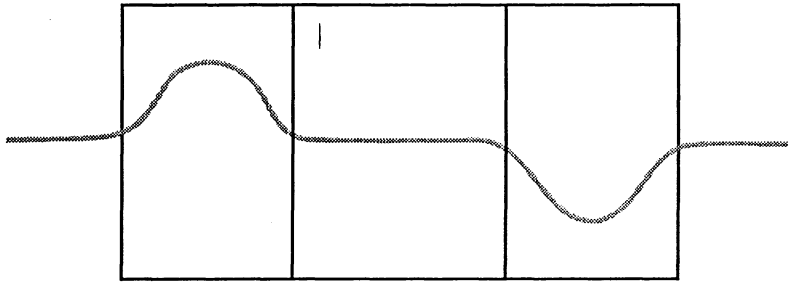

- OR -

0	0	1	1	0	0

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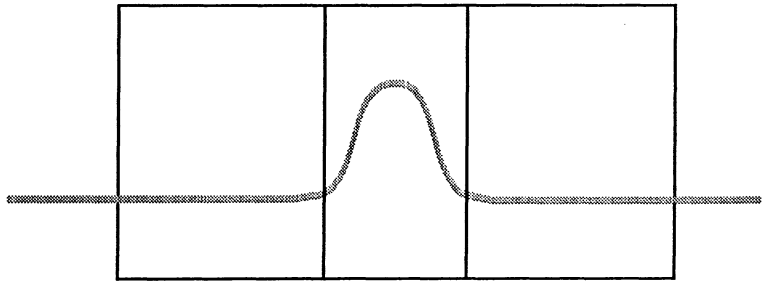
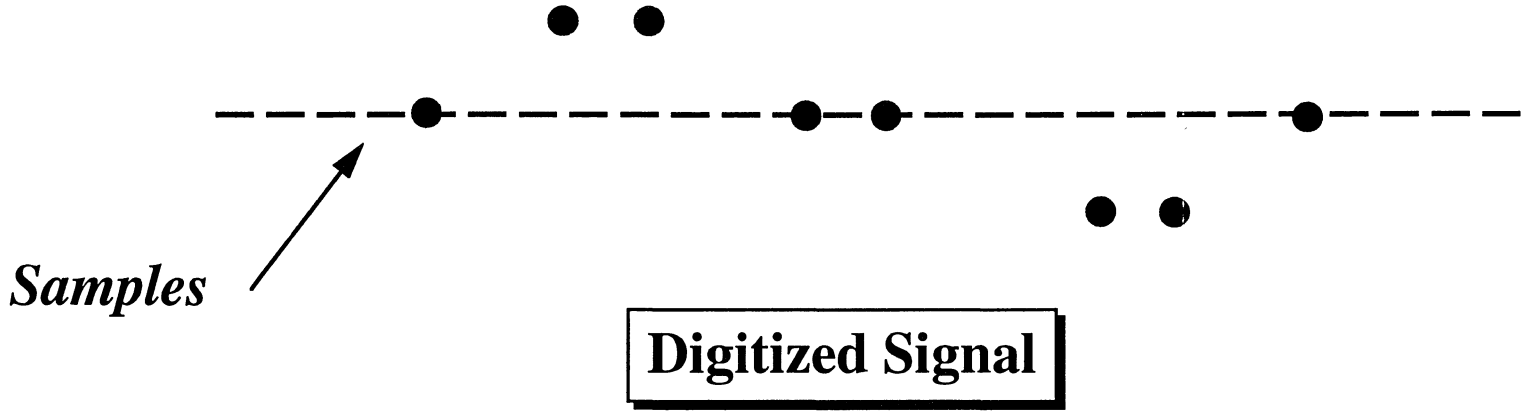
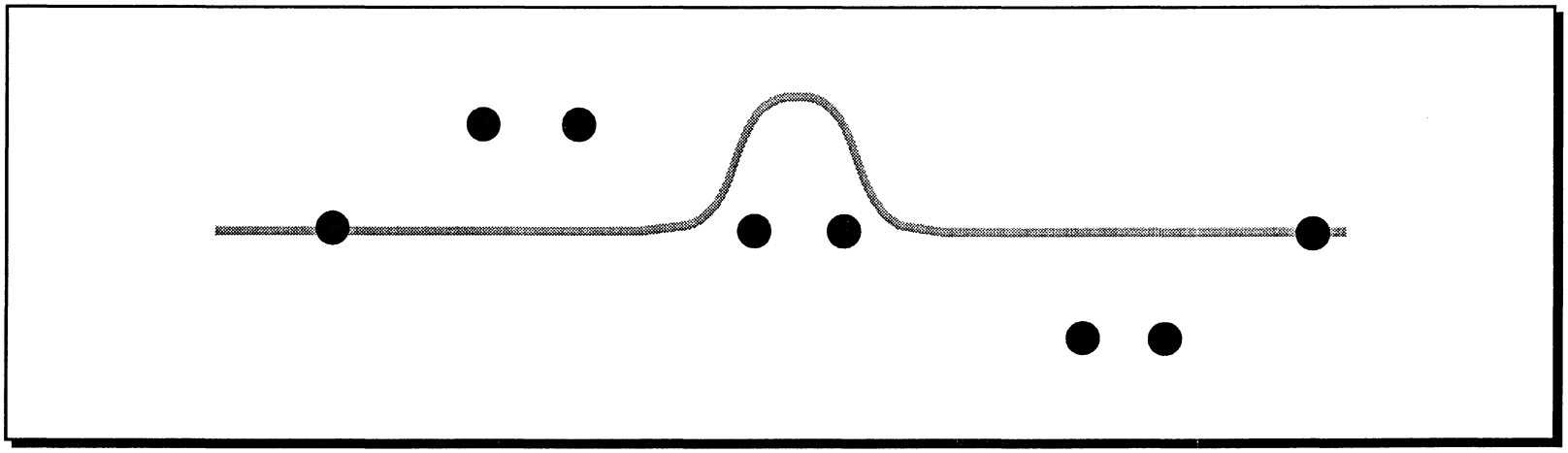


PRML Channel

- **Now suppose that the digitized read signal looks like this ...**

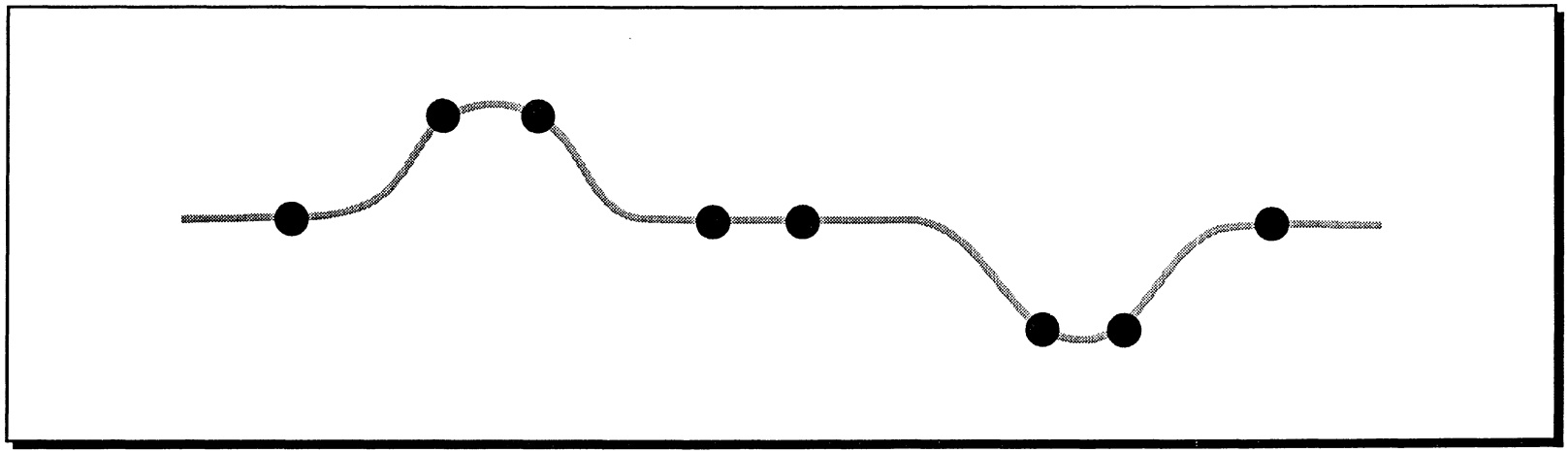


PRML Channel



Poor match with the | 0 | 1 | 0 | **pattern**

PRML Channel



Good fit with | 1 | 1 | 0 | 0 | 1 | 1 | **pattern**

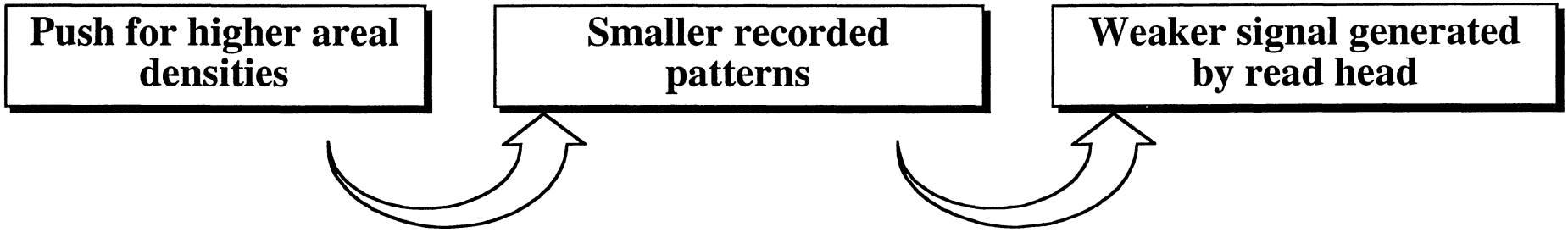
This is the most likely data

PRML Channel

- More efficient coding allows 40% higher data rate for the same clock rate
- Gate count required (≈15,000 gates) is economical with sub-micron manufacturing techniques
- High speed channels (>100 Mb/sec) will soon be possible with conventional CMOS technology

MR Heads

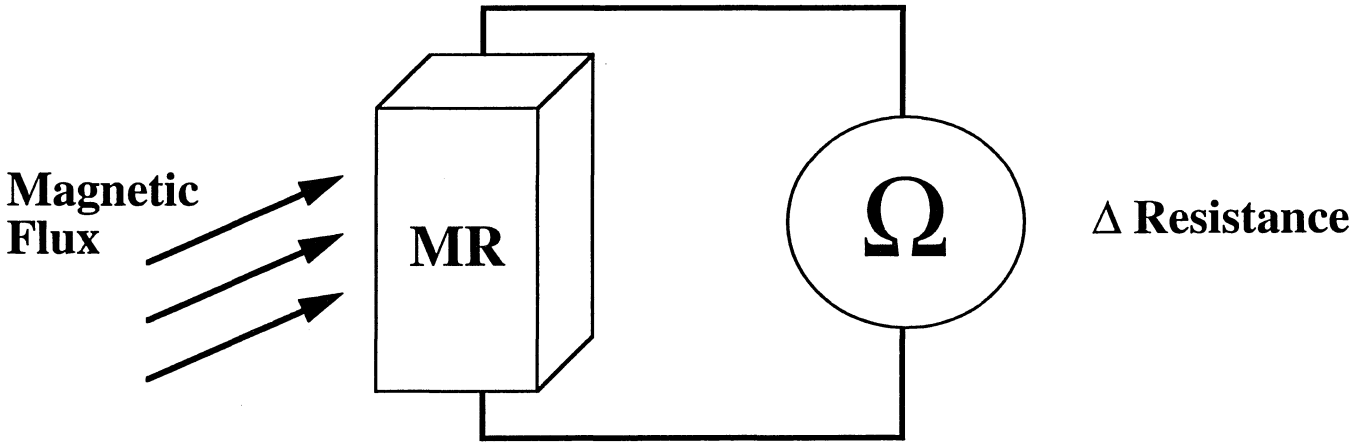
What's driving the need for new head technology?



- We compensate by:
  - Flying heads closer to the disk
  - Adding more inductance to the head
- Both solutions are reaching limits

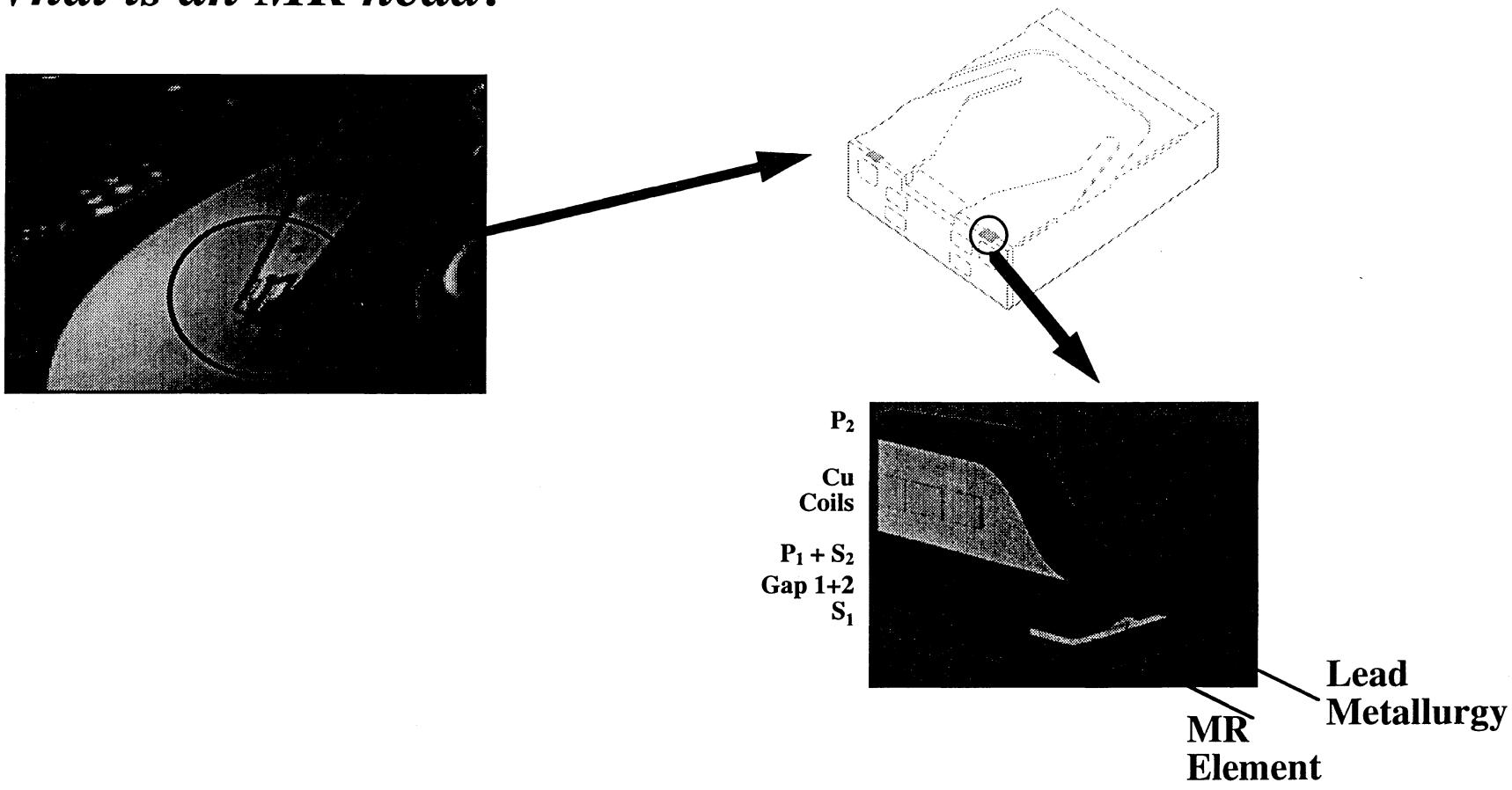
MR Heads

- "MR" stands for "Magneto Resistance"
  - Electrical resistance of certain materials changes when exposed to magnetic field
  - Strip of MR material is embedded in head
  - Change in material's resistance used to detect flux changes on disk



MR HEADS

What is an MR head?



MR Heads

- **Advantages to MR**
  - **High signal output**
  - **Separate read and write elements**
  - **Low noise**
  - **Velocity independent output**

SEPARATE READ/WRITE ELEMENTS

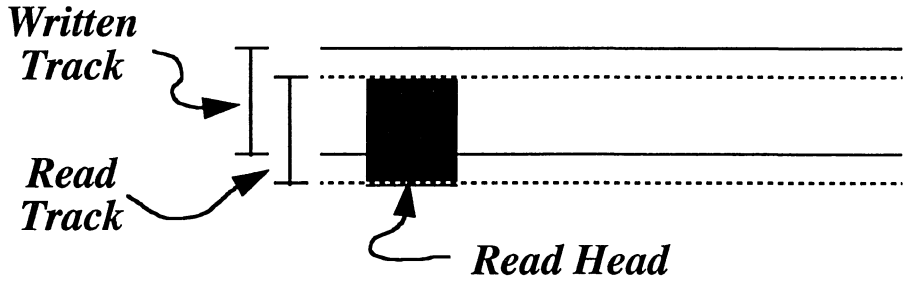
- **Goal of a read/write head:**
  - **High amplitude signal output**
  - **Low noise**
- **When reading data, imperfect alignment with the written track causes:**
  - **Reduced signal levels**
  - **Increased noise from adjacent track**
  - **MR heads help by reading and writing with different elements**

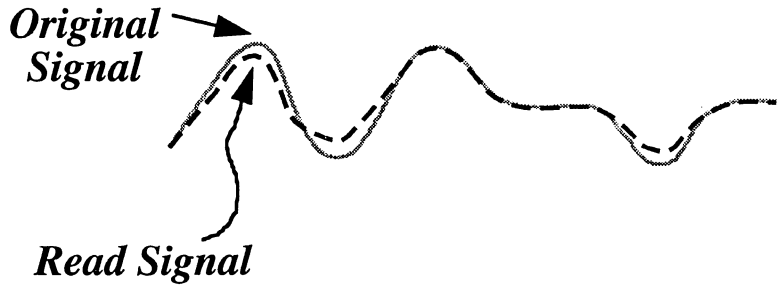
WRITE WIDE/READ NARROW

Inductive Head

When reading, slight misalignment offsets head from written track

This reduces amplitude and adds noise

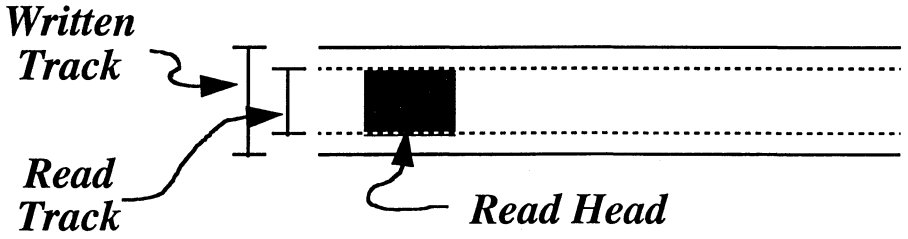


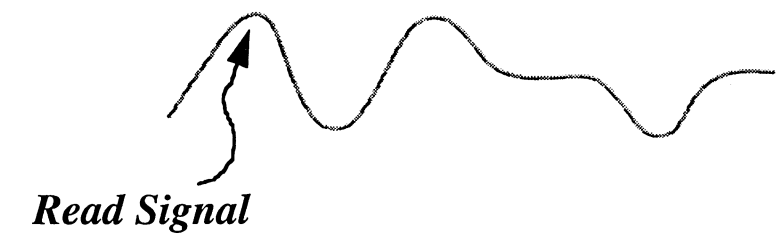


MR Head

Read head is narrow and can remain entirely over written track, even with misalignment

Original amplitude maintained, no noise is added





CONCLUSIONS

- **The market continues to demand advances in storage:**
  - **More capacity, higher performance, and lower cost**
- **Achieving these goals requires increased areal density**
- **MR Head demonstrations have shown areal densities 4X today's leading edge**
- **PRML Channels support the future growth in data transfer rates**

CONCLUSIONS

- **PRML and MR are both significant departures from the past**
- **As they are further refined, we will continue to see rapid advances in magnetic storage capability**