Data Acquisition Trends and Issues

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Introduction

- **This paper presents a history of data acquisition systems developed by Radix and a view of where the data acquisition systems are headed in the future.**
- **Subjects to be covered are**
  - Past Systems
  - Open System architecture
  - A/D Technology
  - Digital Signal Processing
  - Recording Technology

Radix Developed Systems

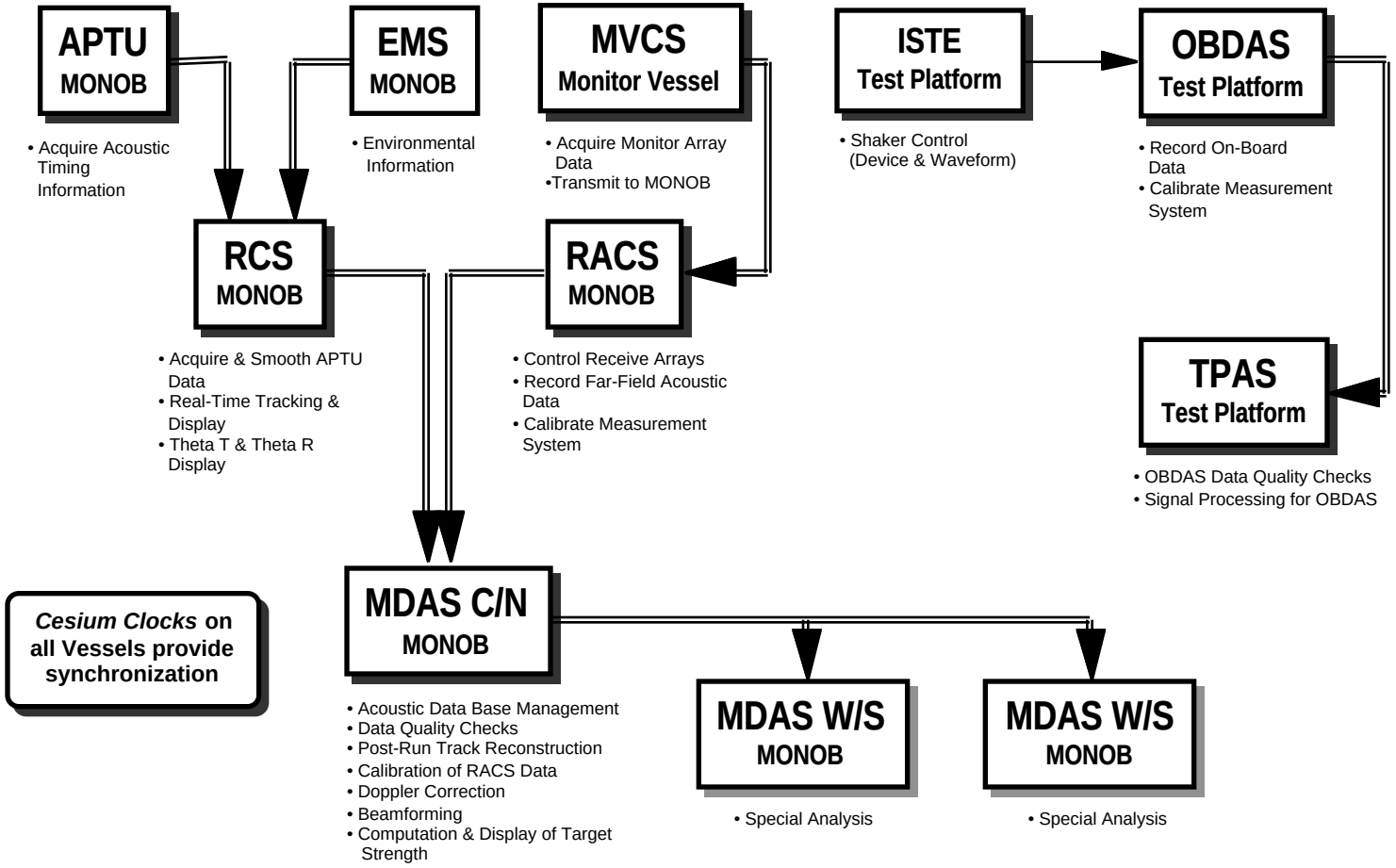
Target Strength Data Acquisition Systems

- **MicroVAX Based**
- **Total of Seven Systems with Common Timing and Data Communications:**
  - 25 computers, including 12 VAX, 2 Supercomputers, 6 Array Processors
  - 4 languages and 3 operating systems
  - A/D converters in separate chassis
  - COTS at Chassis Level
  - Largest data acquisition system had 256 channels
  - Record to tape/hard disk

Target Strength Data Acquisition Systems

- **Seven Systems Integrated by Common Timing, Data Communications:**
  - **Receive Array Collection System (RACS)**
  - **MONOB (now HAYES) Data Analysis System (MDAS)**
  - **Range Control System (RCS)**
    - **Acoustic Pulse Timing Unit (APTU)**
    - **Environmental Monitoring Subsystem (EMS)**
  - **Monitor Vessel Collection System (MVCS)**
  - **Independent Ship Test Equipment (ISTE)**
  - **On-Board Data Acquisition System (OBDAS)**
  - **Test Platform Analysis System (TPAS)**

Target Strength Data Acquisition Systems



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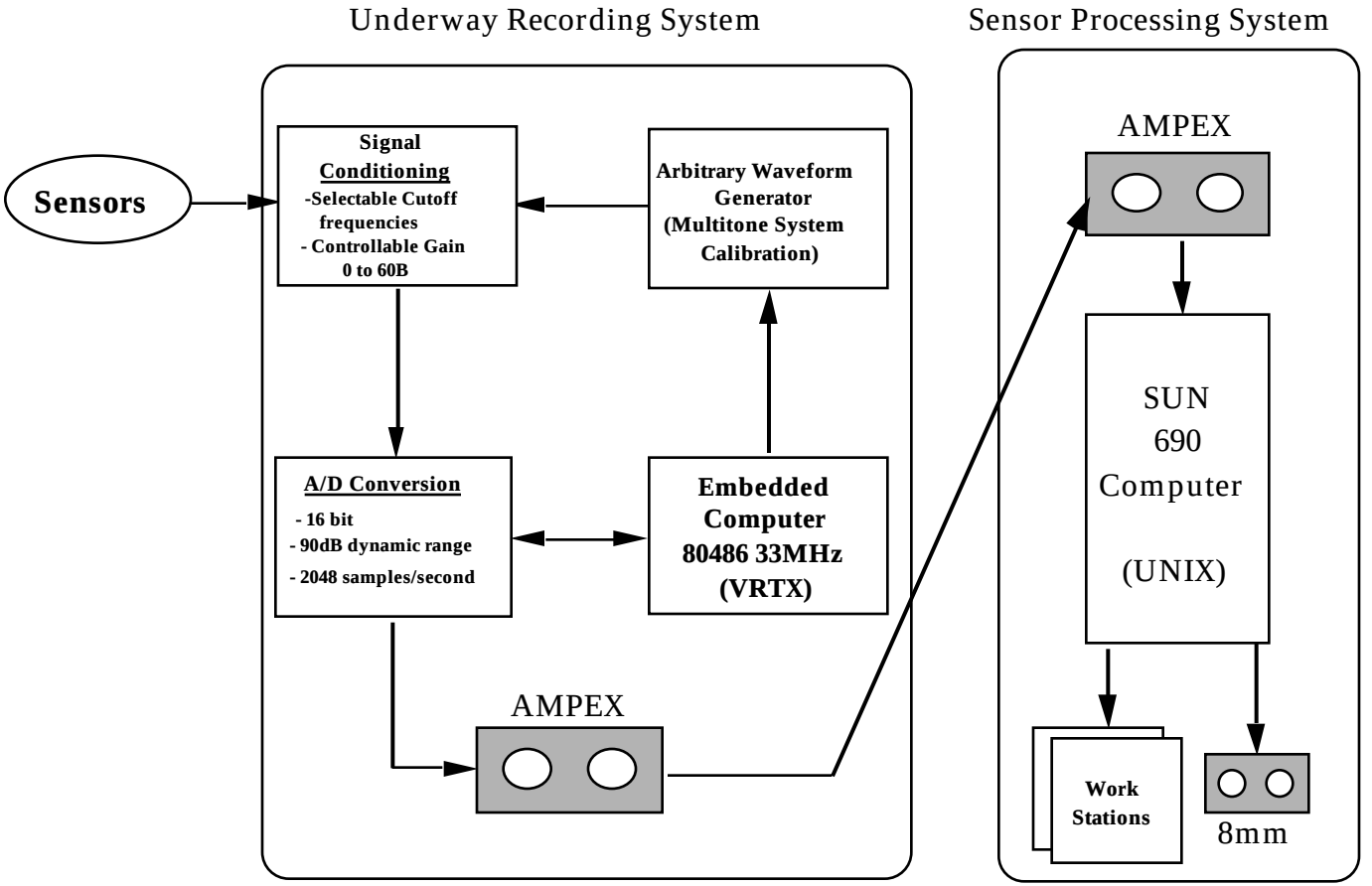
Underway Recording System (URS) and Sensor Processing System (SPS)

- **URS**
  - VXI Based
  - Characteristics
    - 1024 channels, 2048 samples/sec
    - Automatic multitone system calibration
    - Automatic Gain Control
    - Record on Ampex DCRsi recorder
- **SPS**
  - For analysis of recorded data with Playback Ampex DCRsi tapes
  - Sun workstation based
  - “Quick Look” data quality and “Bulk” FFT processing
  - Special DSP based board for processing
  - Transfer of data to low cost 8mm tapes

URS and SPS Block Diagram



- Autonomous Data Acquisition
- Analog / Digital Conversion
- Automatic Multi-Tone System Calibration
- Automatic Gain Control
- Selectable Sample Rate to 2,048 Hz

- "Quick Look" Data Quality
- "Bulk" FFT Processing
- Data Quality of Analog and
- Digital Channels
- Modal Analysis
- 8mm Tape Output

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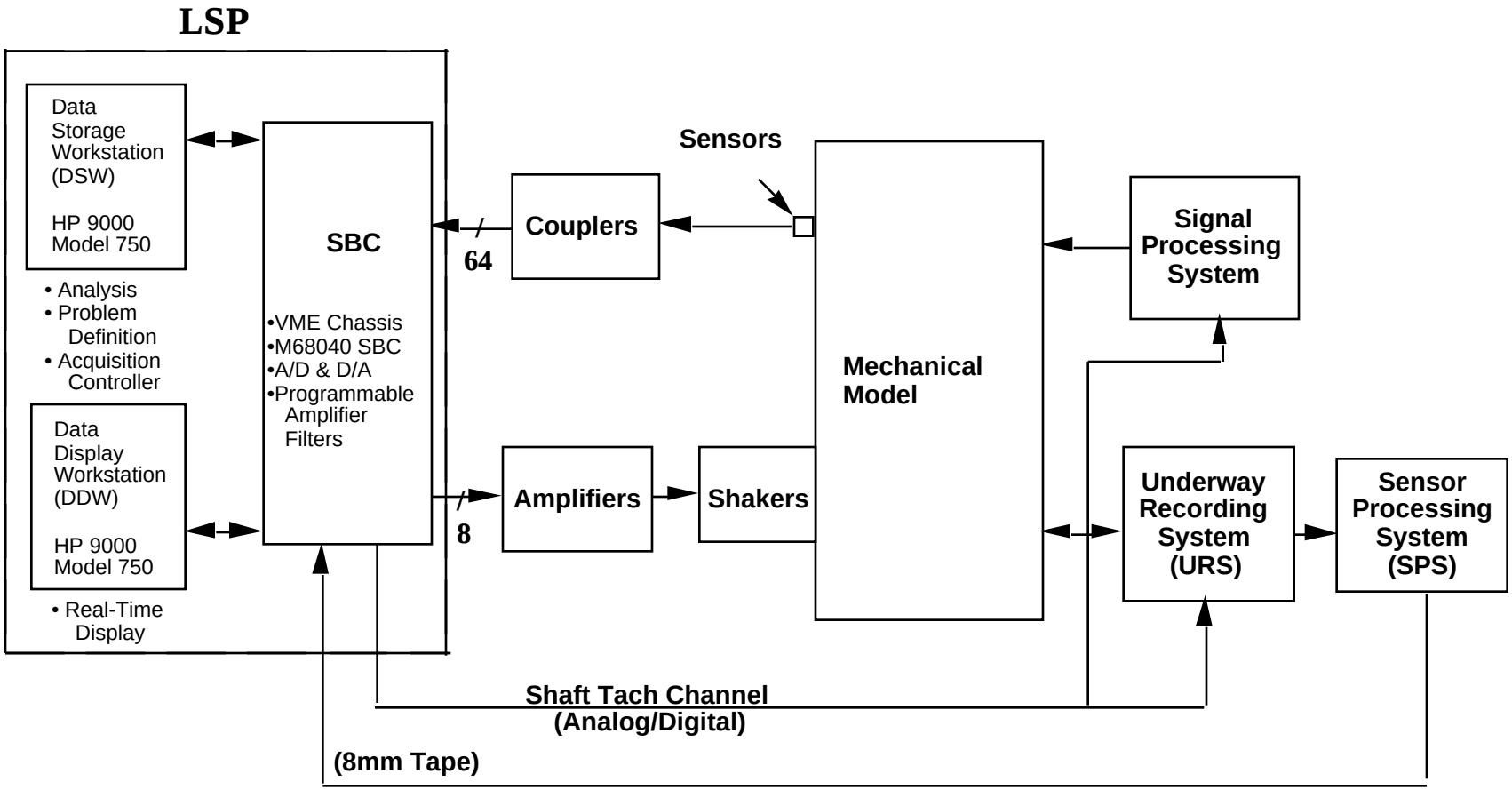
Laboratory Simulator Processor (LSP)

- **VME Based**
  - HP workstations for analysis
- **Characteristics**
  - 64 input channels/ 8 output
  - Sampling Rates to 2048 sps with 16 bits
  - Real-Time and On-Line Displays
- **Real-Time Generation of Stimulation / Data Acquisition to Support T & E**

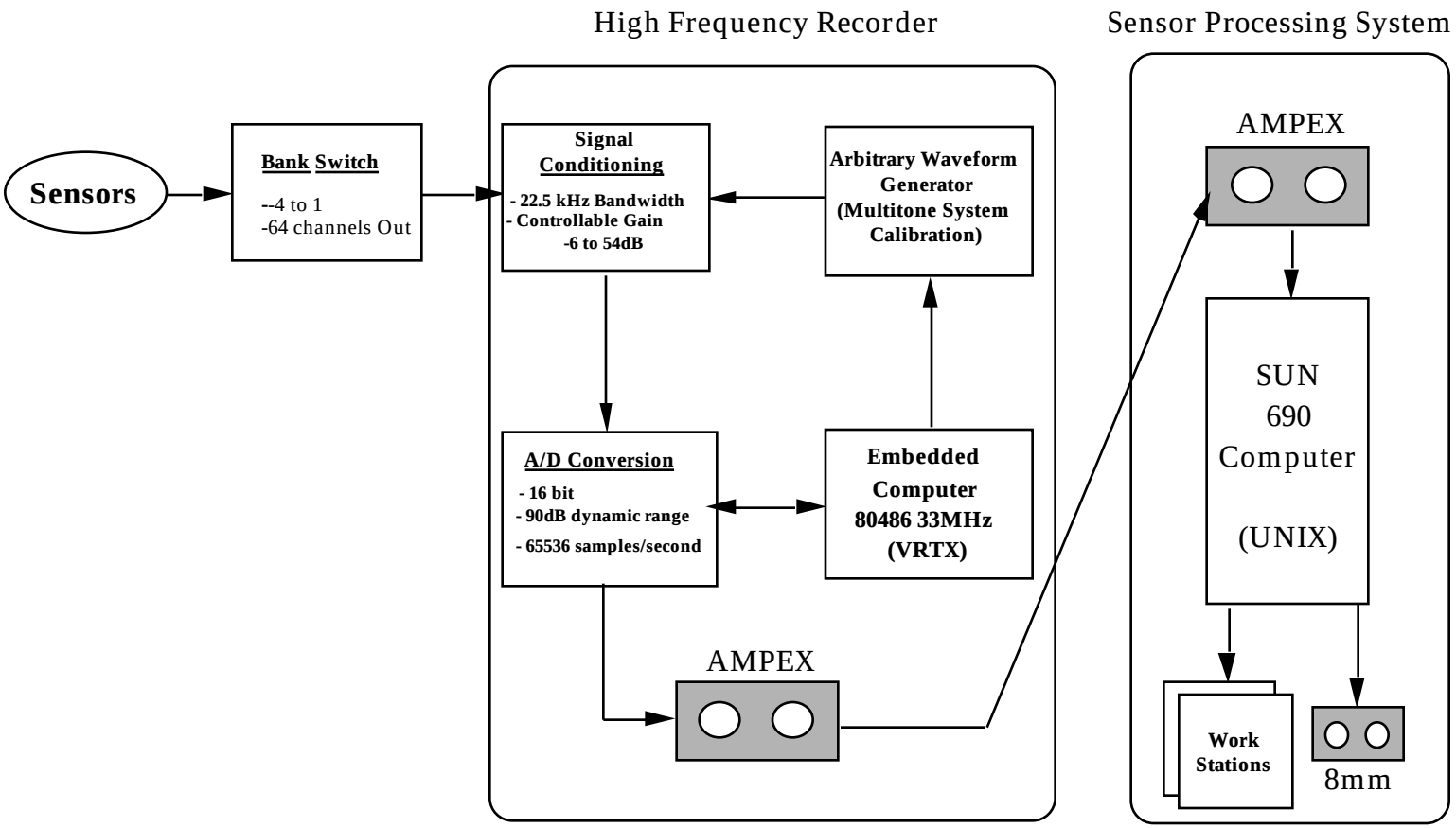
Laboratory Simulator Processor (LSP)



High Frequency Recorder (HFR)

- **VME based**
- **Characteristics**
  - Analog Bank Switch to select between four banks of 64 channels
  - 64 16-bit successive approximation converters sampling at 65536 sps
  - Analog Bandwidth to 22.5 kHz
  - Automatic Multitone System Calibration
  - Data Recorded on High Speed Ampex Tape
- **Accomplishments**
  - Increased bandwidth
  - Six month development cycle

High Frequency Recorder (HFR)



- Autonomous Data Acquisition
- Analog / Digital Conversion
- Automatic Multi-Tone System Calibration
- Selectable Sample Rate to 65,636 Hz
- Bandwidth to 22.5 kHz

- "Quick Look" Data Quality
- "Bulk" FFT Processing
- Data Quality of Analog and
- Digital Channels
- Modal Analysis
- 8mm Tape Output

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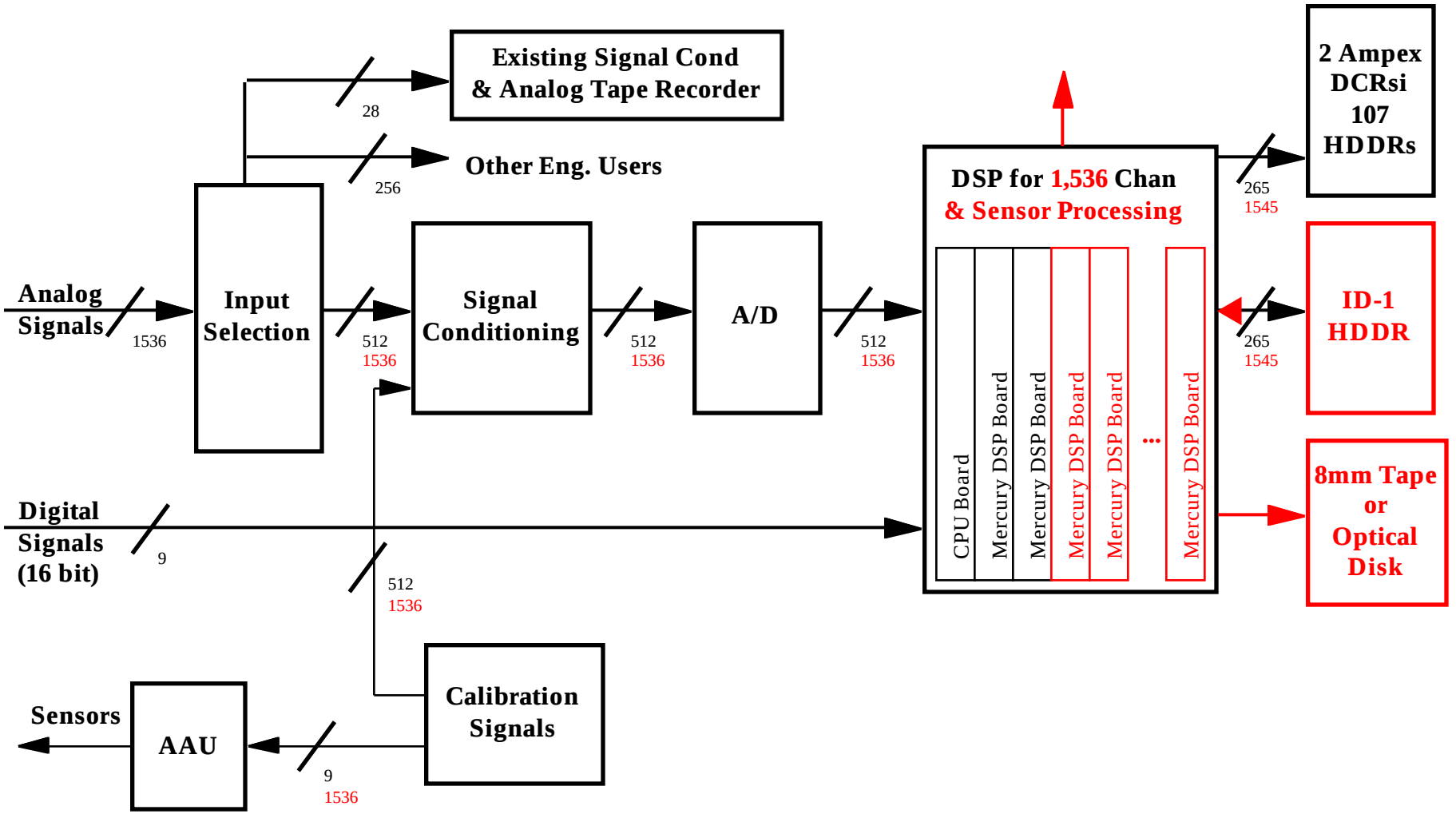
On-Board Data Acquisition System (ODAS)

- **VME Based**
- **Characteristics**
  - 512 channels expandable to 1536 channels
  - 16-bit A/D's sample at 98304 with simultaneous samples
  - DSP to reduce the rate to 64536, 32768, 16384, 8192, 4096, or 2048 (2^{16} to 2^{11}) sps on any subset of channels
  - Different channels recorded at different rates
  - Max. data rate determined by recorder not system
- **Advances**
  - delta-sigma converters to eliminate analog "brickwall" filters
  - decimation filtering to maximize the use of recorder bandwidth (true variable rate recording).
  - Channel selection is done digitally

On-Board Data Acquisition System (ODAS)



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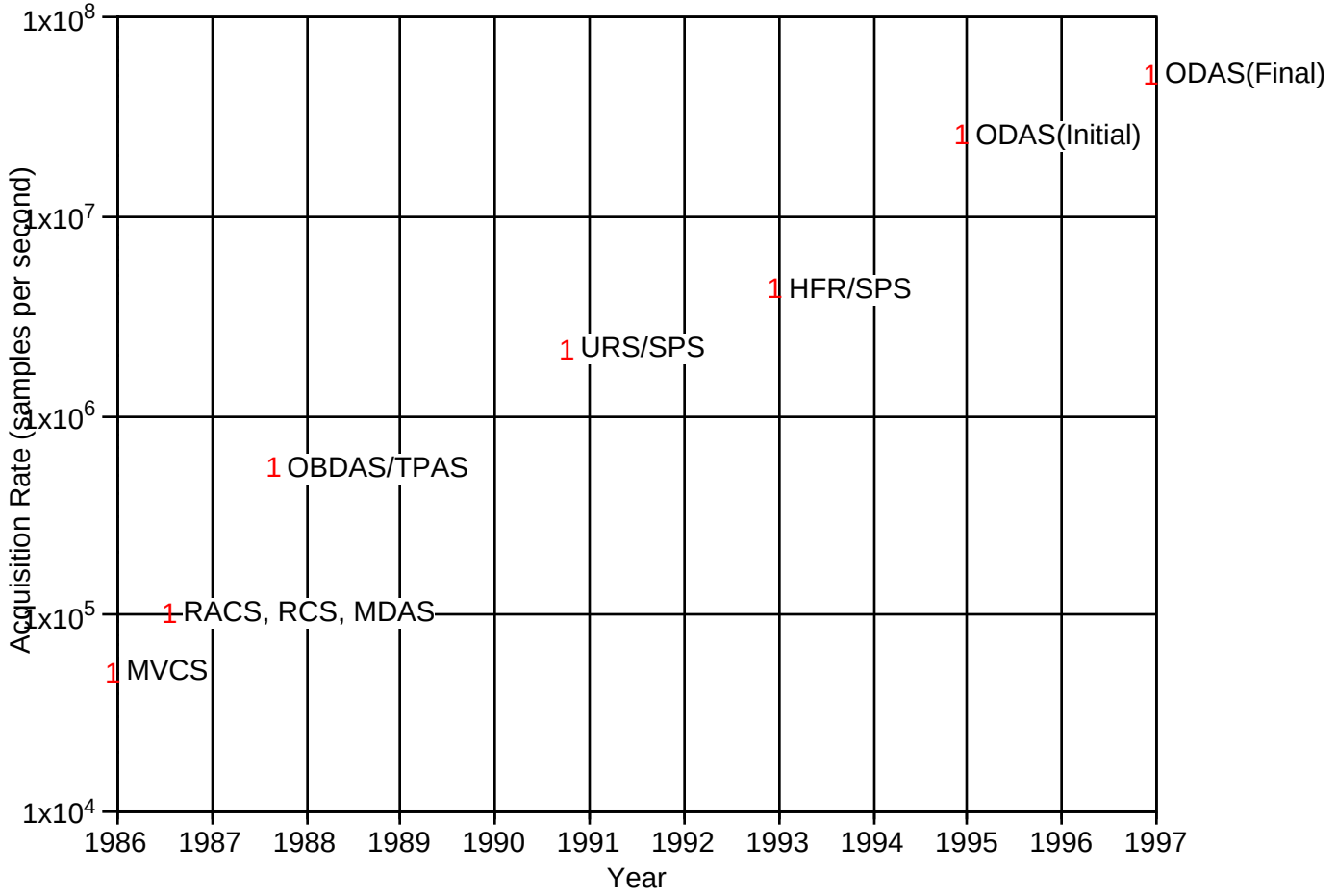
Acquisition System Capabilities



- **Data Acquisition Rates have Increased Over the Past Eight Years**

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Open System architecture

Open System Architecture

- **Use of Open System Architecture enables use of COTS**
  - Standard Backplane (VME-64)
  - Boards from Multiple Vendors (over 100 VME vendors)
  - Upgrade at the board or module level as technology and requirements change
- **Open System Architecture Also Implies an Industry Standard Software Operating System**

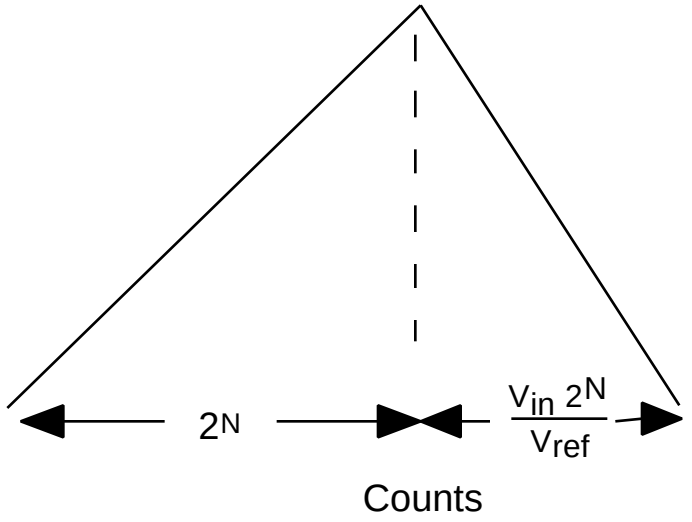
A/D Technology

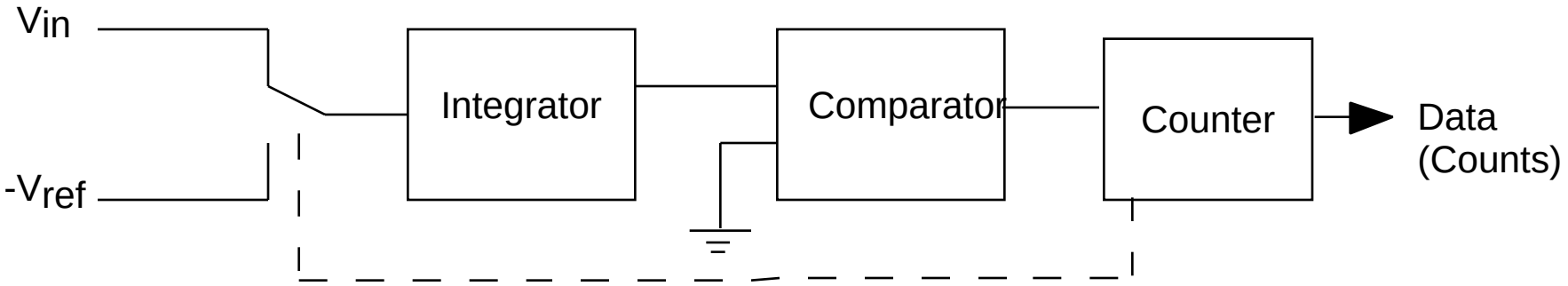
A/D Trends

- **Move the A/D as close to the sensor as possible**
  - Digital data is easier to move than analog data
  - Less noise and pickup problems once information is digitized
  - Can decrease cable mass and even use fiber optics
  - Enables distributed system with A/D at the sensor and display and recording at a central location.
- **The resolution versus speed is always improving**
- **For portable requirements the power consumption versus the resolution is being greatly improved**

Integrating (Slope) A/D

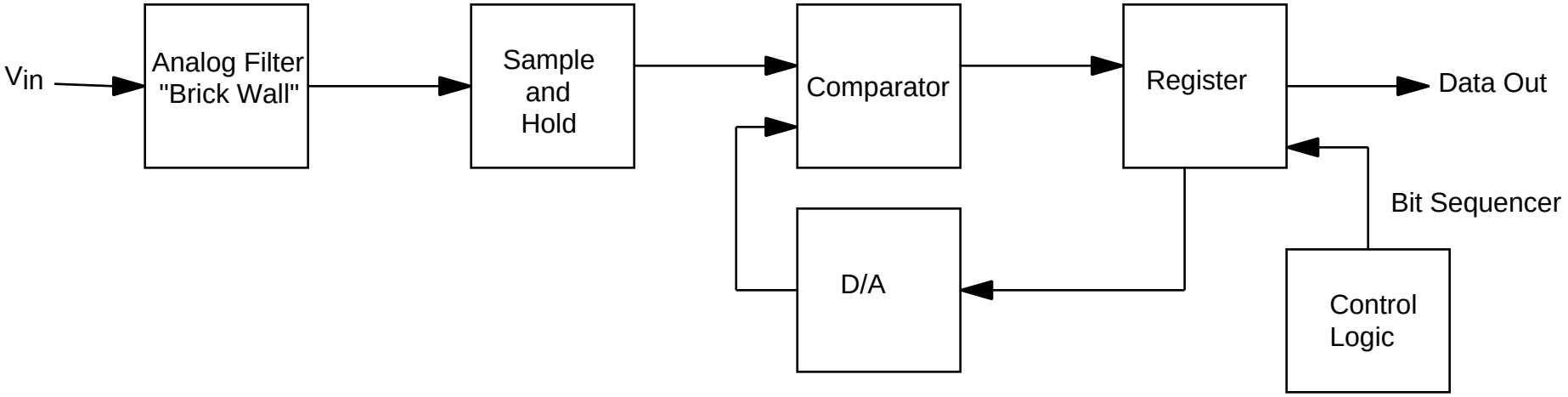
- **Measures time to charge or discharge a capacitor**
- **Slowest due to needing to clock up to 2^n times for each sample**
  - dc or close to dc signals
- **Highest Resolution**





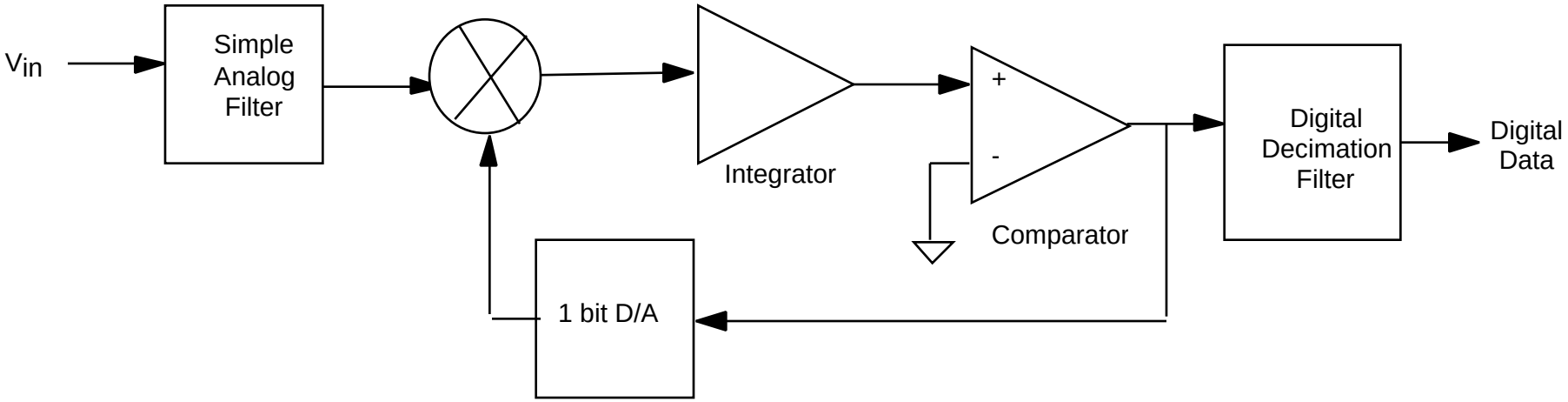
Successive Approximation A/D

- Traditional audio frequency converter
- Requires a sample and hold (S/H)
- Tests one bit at a time starting with the MSB
- Quantization noise is “white”
- Requires complex analog anti-aliasing filter
- Can use analog multiplier in front of sample and hold
  - require multiple S/H's for simultaneous samples

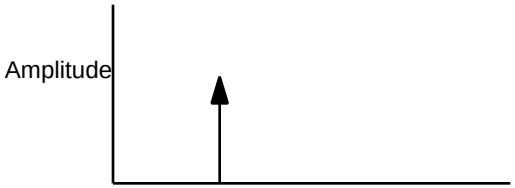


Delta Sigma A/D Converter

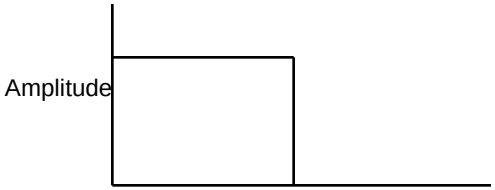
- Uses a high speed converter to compare the input to feed back value
- Filter in feedback loop shapes noise so that it is lower at the lowest frequencies and higher at higher frequencies
- Digital filter removes noise before decimation (decreasing sample rate) to final sample rate.
- Enables using a very simple analog anti-aliasing filter



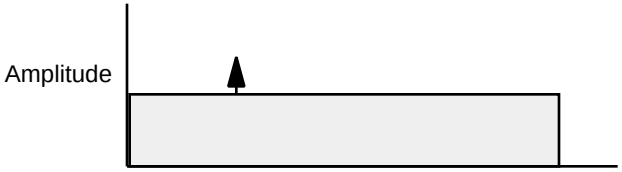
Delta-Sigma Noise Gain



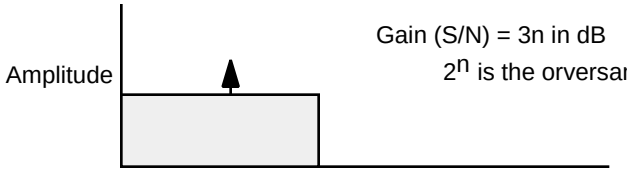
Signal



Filter Characteristics



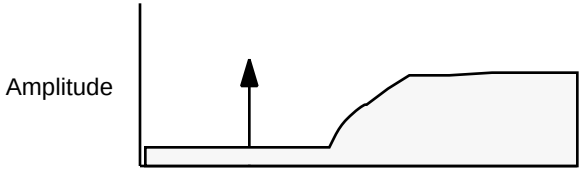
White Noise



Gain (S/N) = 3n in dB

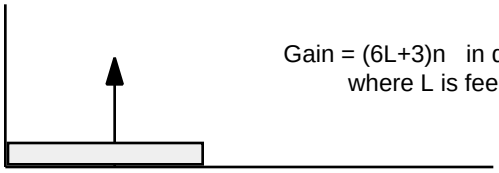
2^n is the orversampling ratio

Filtered White Noise



Shaped Noise

Before Filtering



Gain = (6L+3)n in dB

where L is feedback filter order

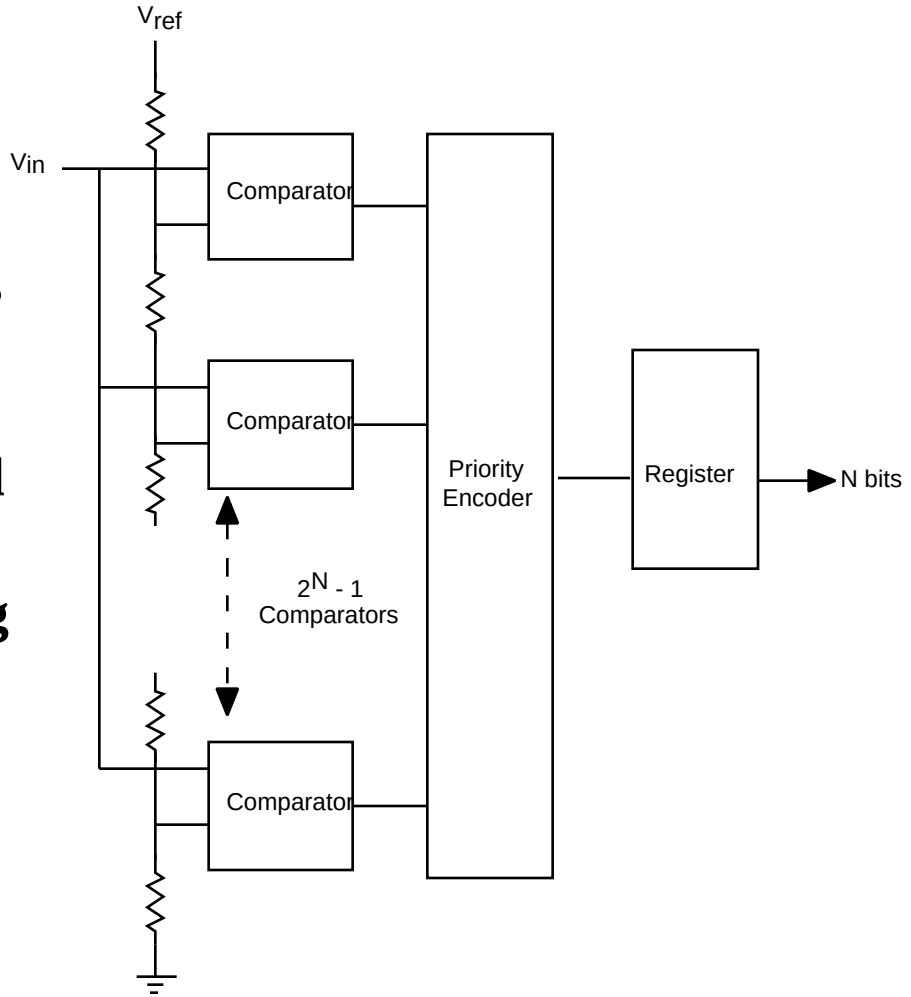
Filtered Shaped Noise

After Filtering

Oversampling Gain on Quantization Noise

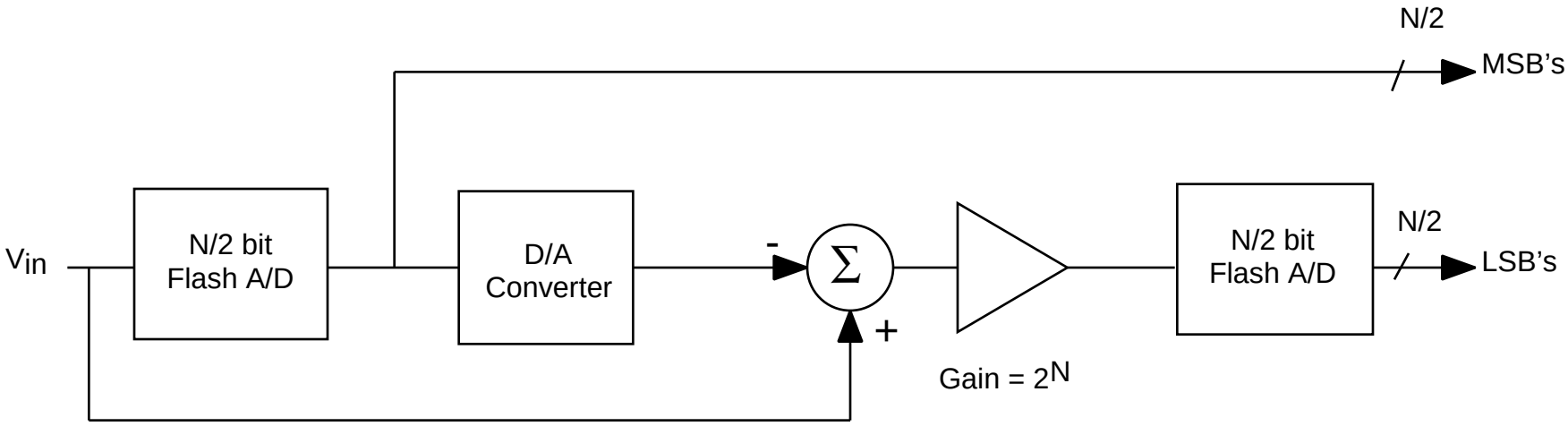
Flash A/D converters

- Uses an analog comparator for each level
- Requires $2^n - 1$ comparators where n equals the number of bits of resolution
- Becomes very expensive and large for large n
- Requires complicated analog anti-aliasing filter

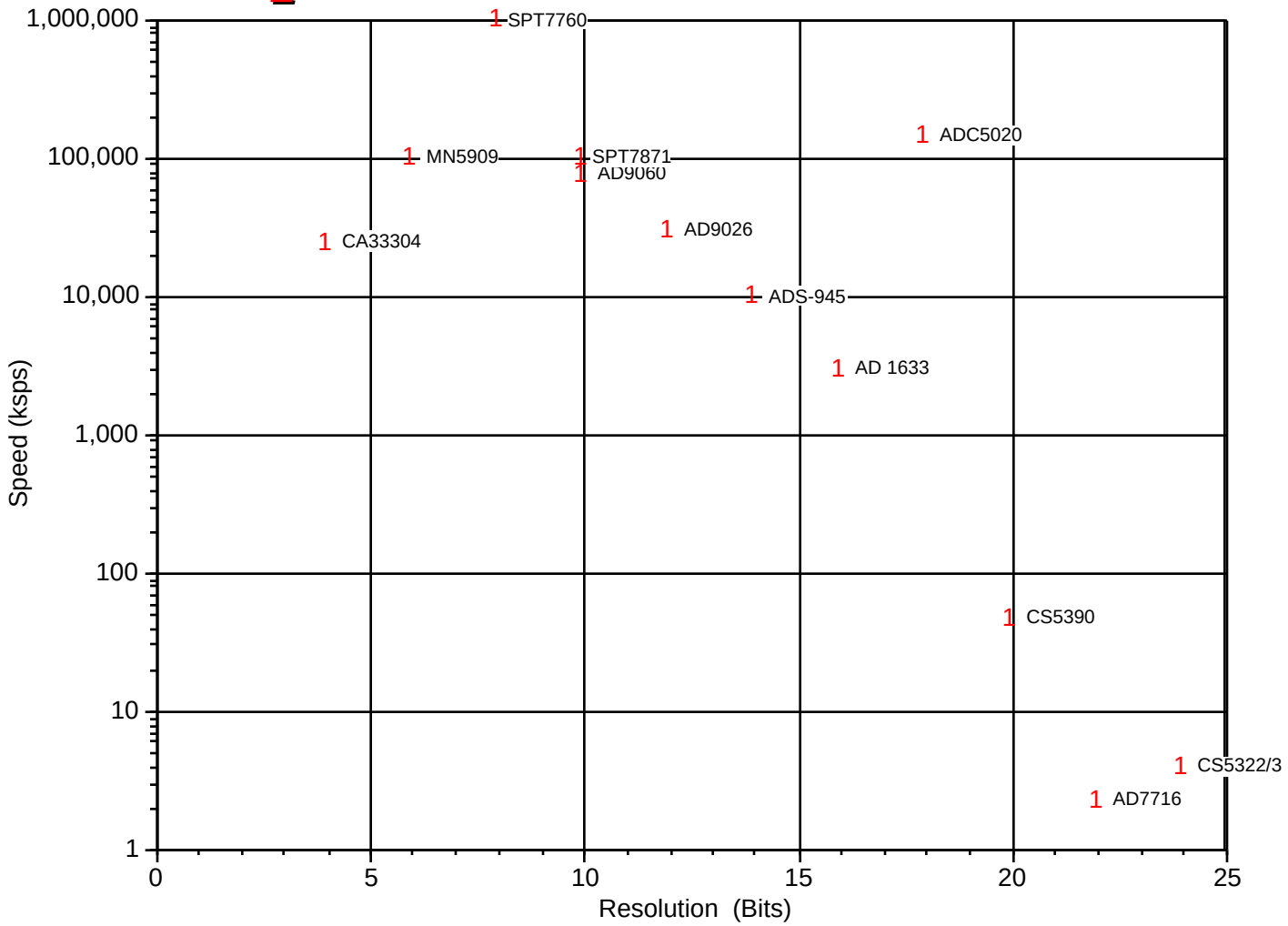


Subranging A/D Converter

- Uses multiple stages of flash converters
- Second stage subtracts first stage answer from signal and converts difference.
- Sample and holds after each stage
- Lower cost than flash



A/D Converters
Sample Rate - Resolution



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Digital Signal Processing

Digital Signal Processing (DSP)

- **Used to replace Analog Signal Processing**
  - A/D conversion at RF or IF level and then detect signals digitally
  - Can make “brickwall” filters a lot easier in digital world than in analog world
- **Decrease Data Rate to Recorder**
  - Record only required information
  - ODAS (Filter and Decimate)
  - Can use to select sub-band and then convert that to a baseband before recording

Software Trends

Software Trends

- **Use standard operating system**
  - Windows 95/Window NT/MacOS
  - Sun OS (UNIX)
  - VxWorks (real time UNIX)
  - PSOS
- **Use of Commercial off-the-shelf (COTS) Software packages**
  - Labview
  - Matlab
- **Language**
  - C or C++ are the most popular

Recording Technology

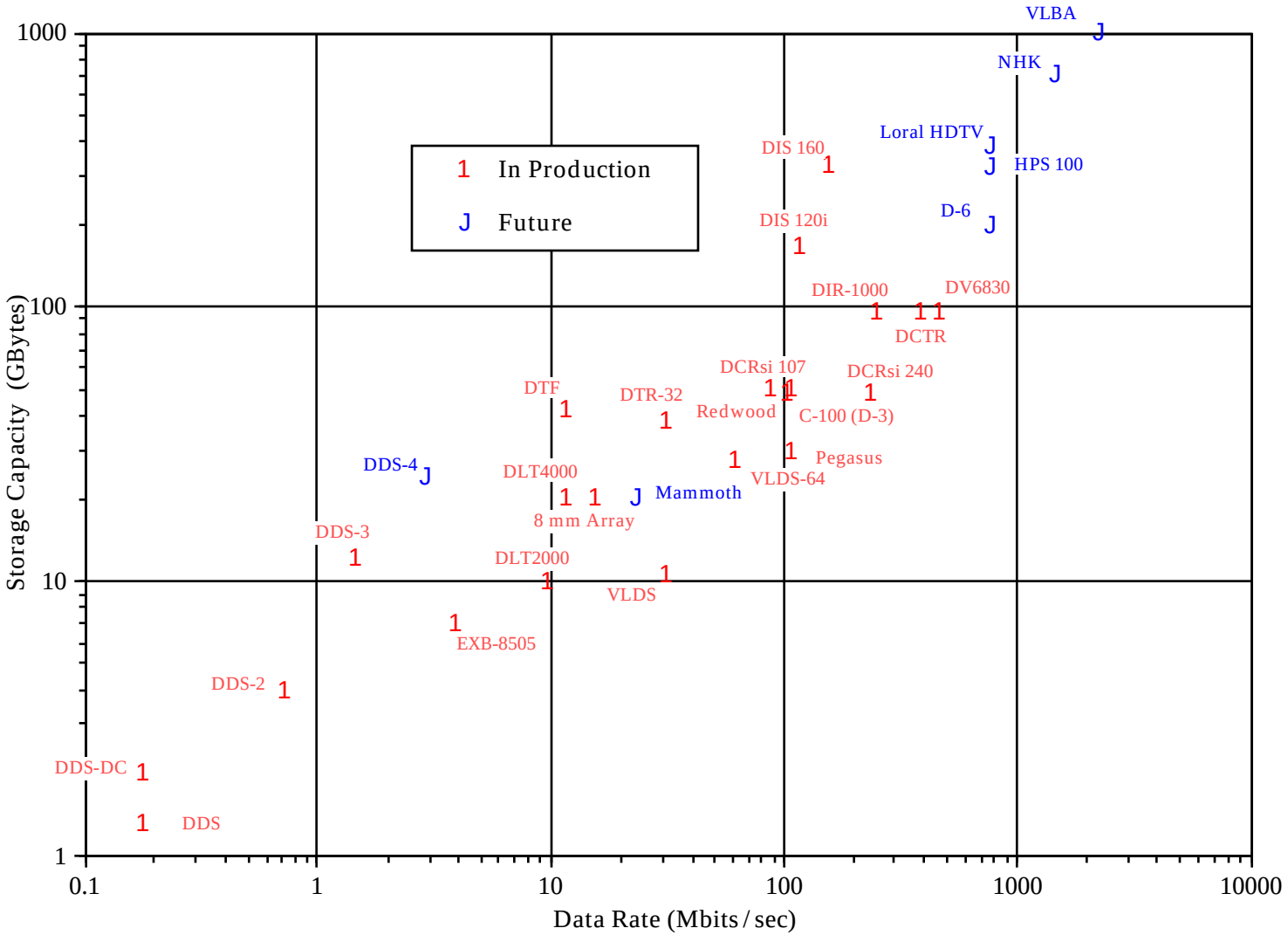
Recording Technology

- **Record with a special system - Playback on standard workstation for analysis**
- **Have seen requirements up to 800 Mbit/sec**
- **Recorder should look transparent to user**
  - Standard interface
    - SCSI n, Fibre Channel
    - Software Drivers for standard operating systems
    - Interface boards for open system
  - Continuously Variable rate
    - Buffer in recorder so user does not have to synchronize to the recorder
    - Rates zero to maximum rate
- **Desire standard interchangeable format between vendors**
  - Do not have to depend on the future plans of one vendor
  - ID-1 is a good example of standard format

Recording Options

- Record to hard disk and then archive to low cost tape
- Record directly to magnetic tape
- Magnetic tape is still the lowest cost with large density
- Optical tape may become competitor in a few years with same data rates and higher density

Magnetic Recorder Data Rates



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Summary

- **Data rates are forever increasing**
- **A/D converters are being moved as close to the sensor as practical**
- **Open system and COTS hardware and software enable rapid design and upgrading**
- **Recording technology**
  - Make transparent to the user with standard interfaces and variable rate
  - Demand is for high rates and more storage