



Data Acquisition Trends and Issues

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RADIX / SYSTEMS® 

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

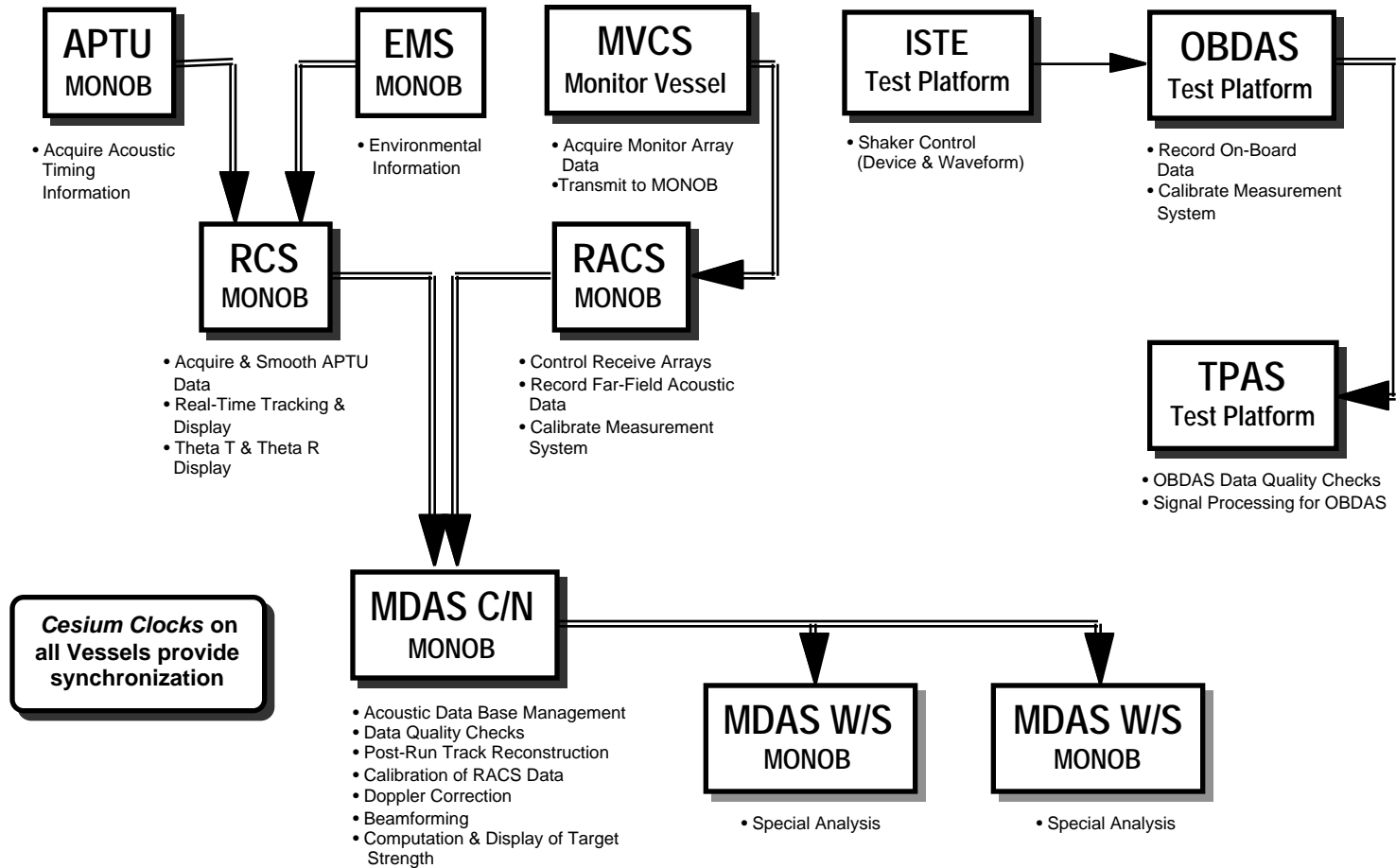
- **MicroVAX Based**
- **Total of Seven Systems with Common Timing and Data Communications:**
 - 25 computers, including 12 VAX, 2 Supercomputers, 6 Array Processors
 - 4 languages and 3 operating systems
 - A/D converters in separate chassis
 - COTS at Chassis Level
 - Largest data acquisition system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



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

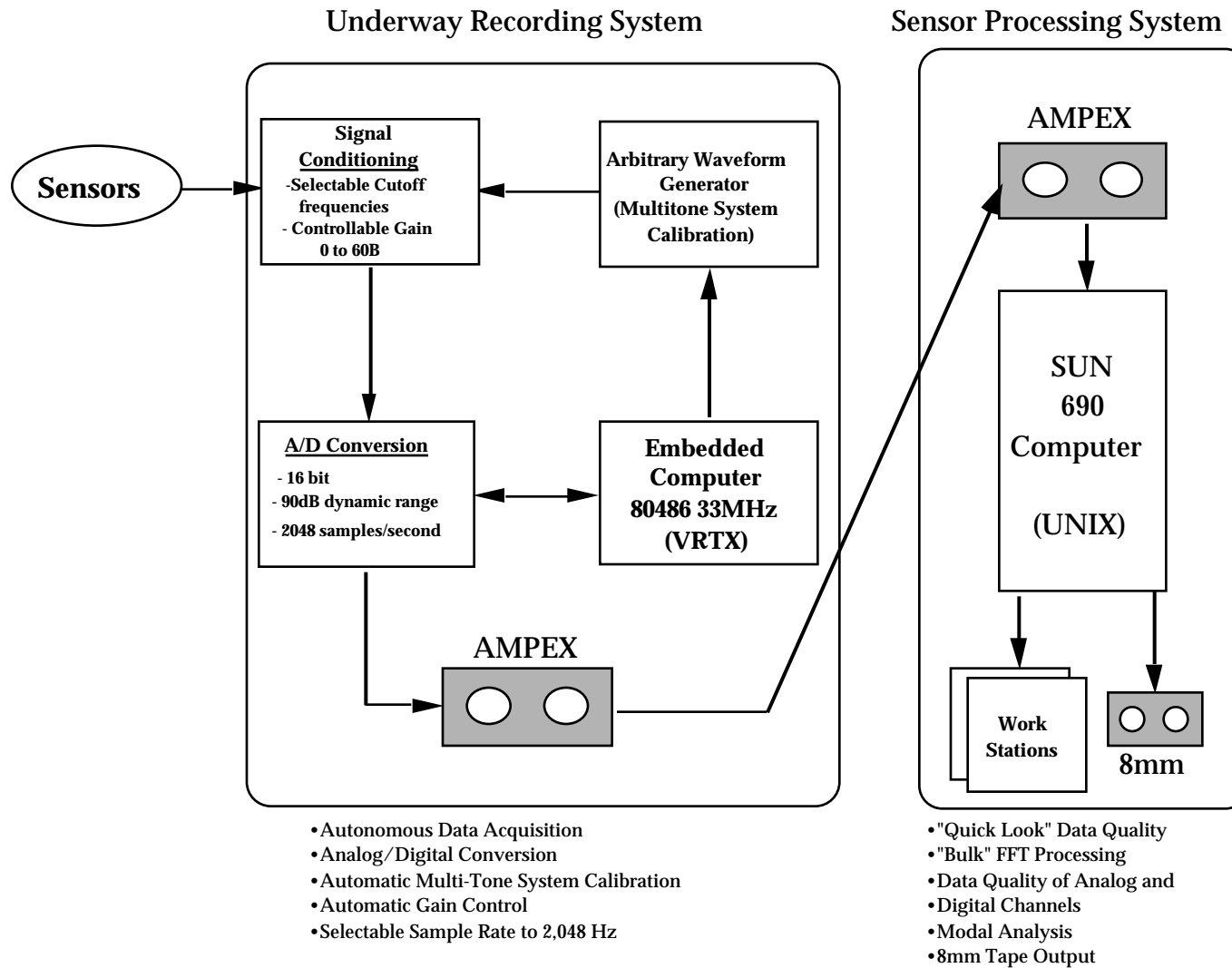
- **URS**

- 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

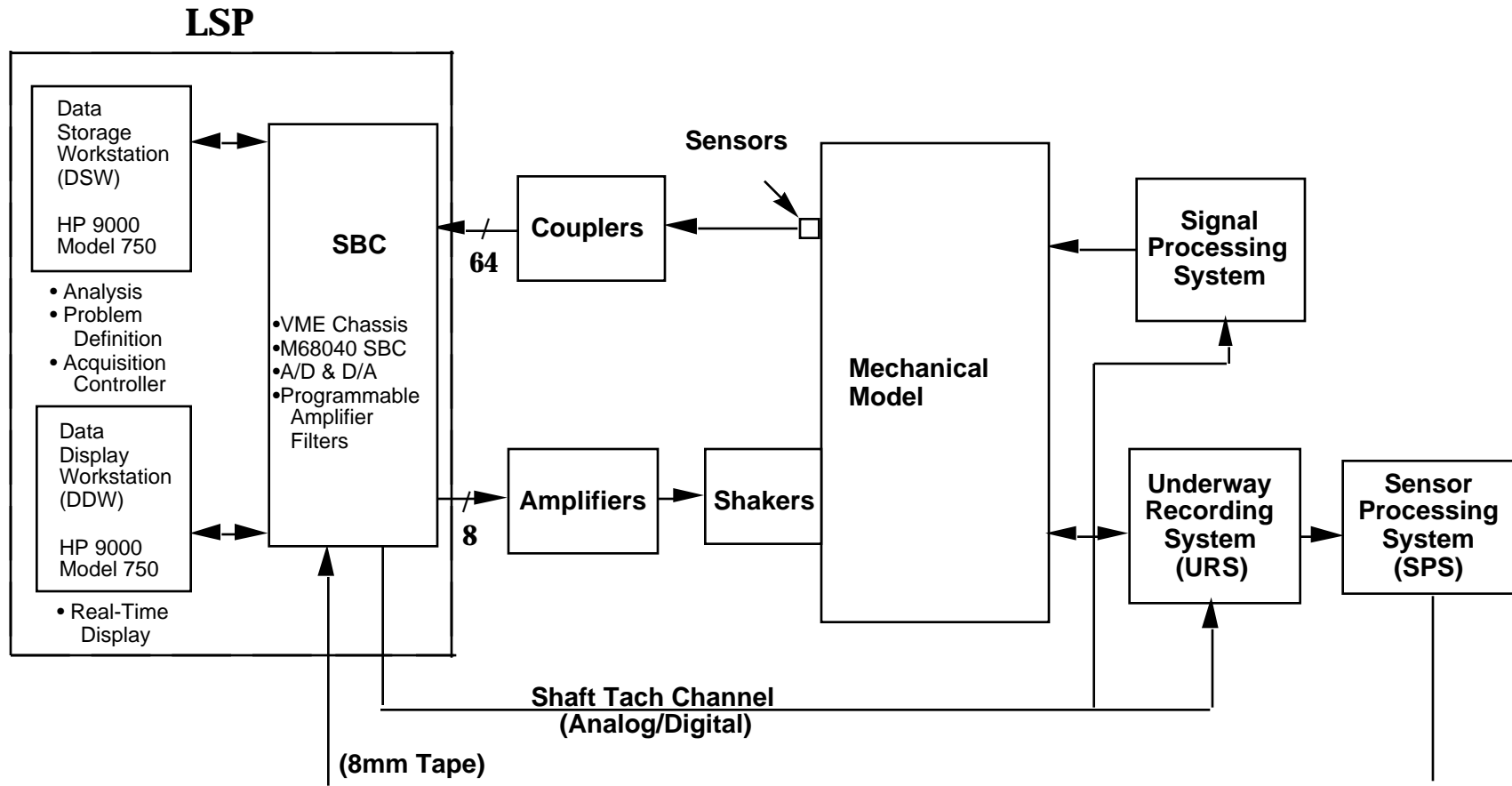
URS and SPS Block Diagram



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**

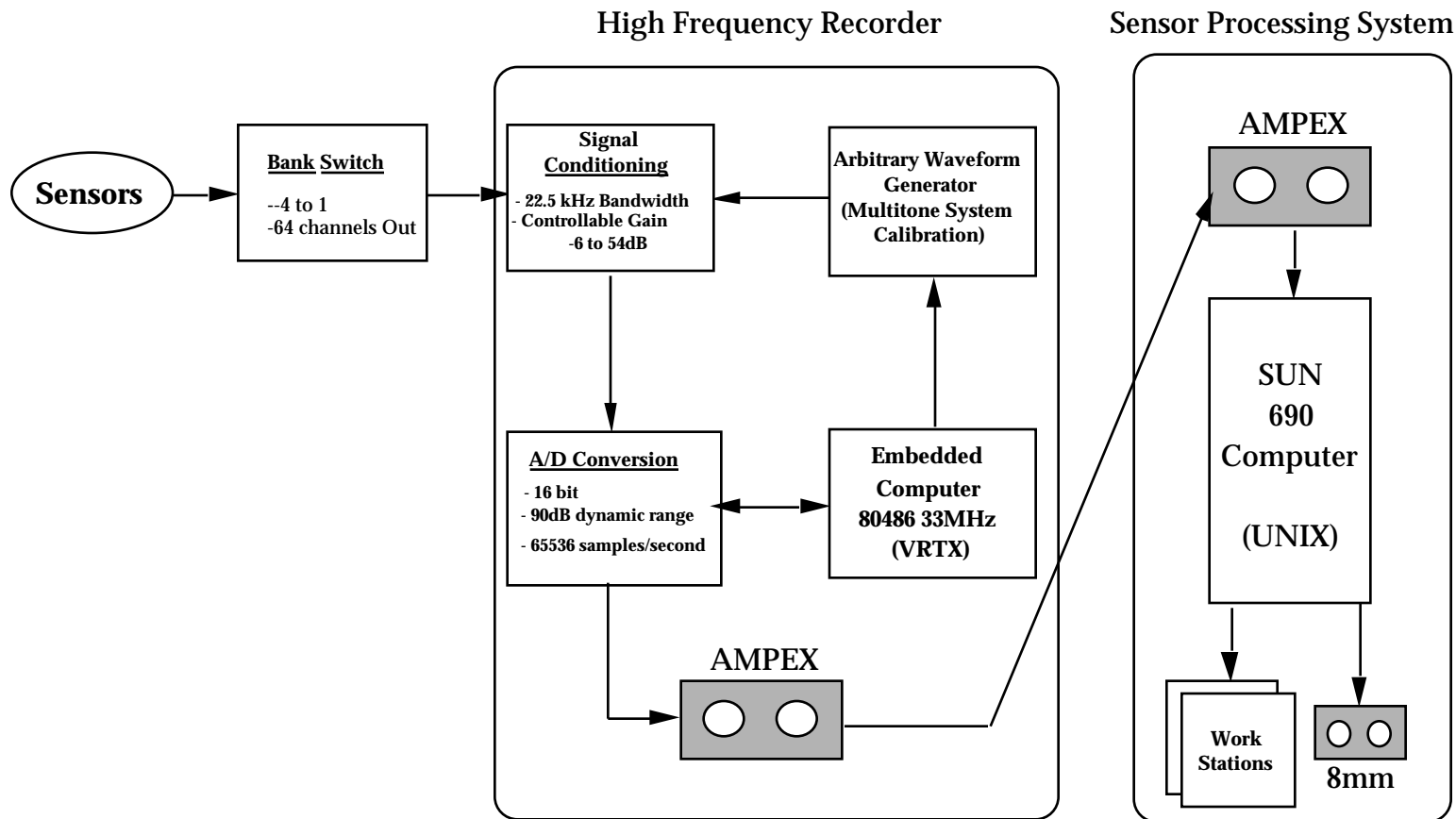
Laboratory Simulator Processor (LSP)



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)



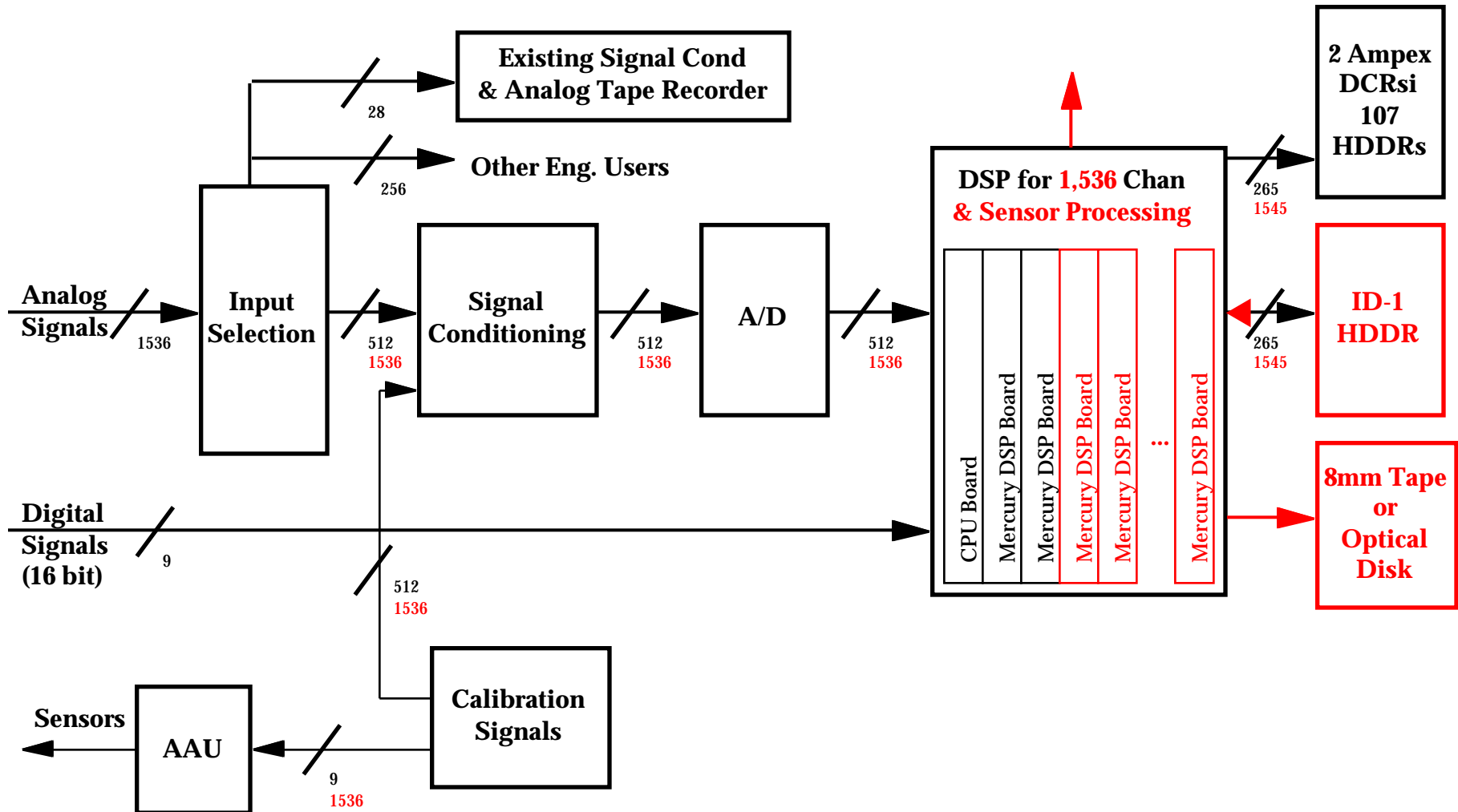
- Autonomous Data Acquisition
- Analog/Digital Conversion
- Automatic Multi-Tone System Calibration
- Selectable Sample Rate to 65,636 Hz
- Bandwidth to 22.5 kHz

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

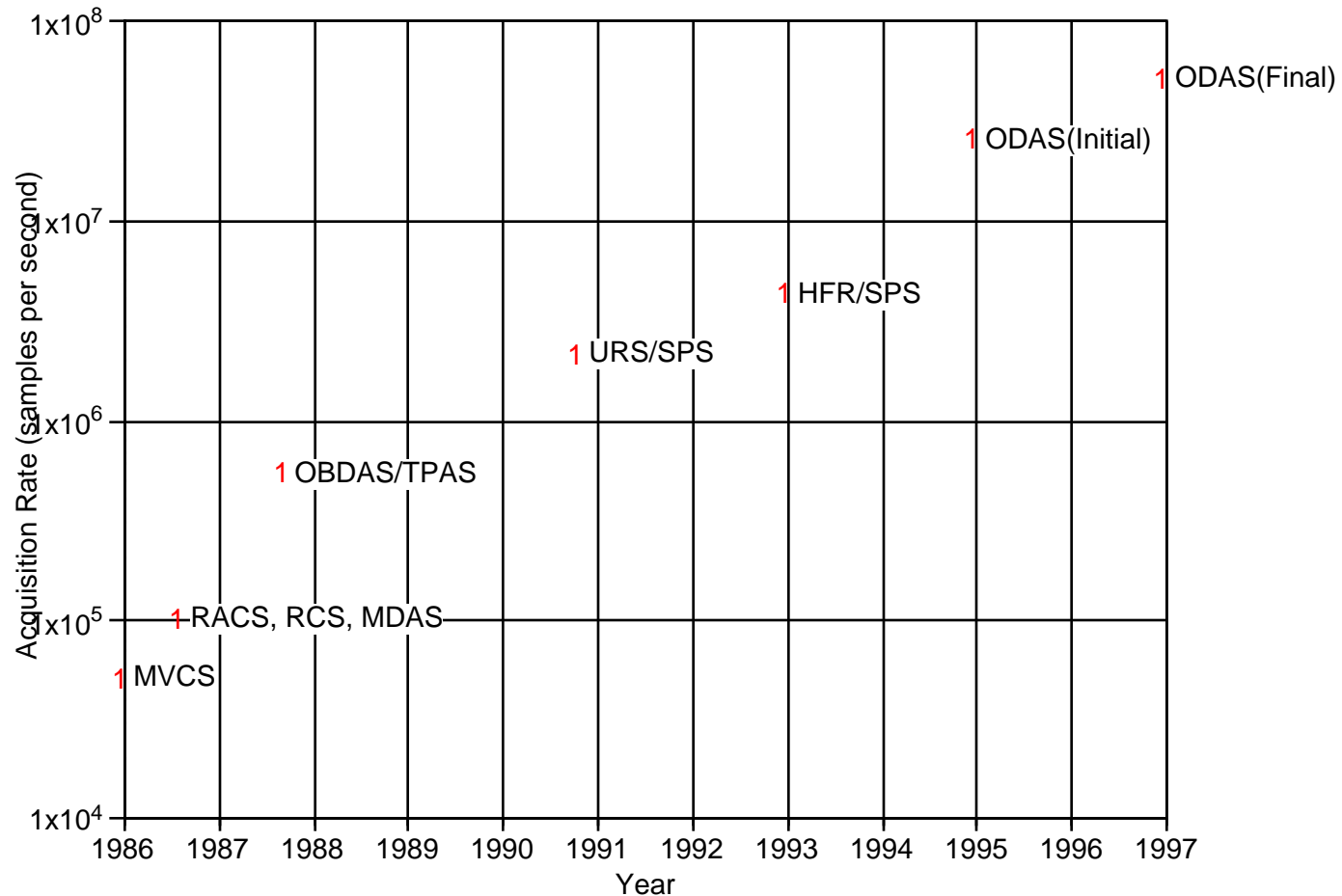
On-Board Data Acquisition System (ODAS)

- **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)



Acquisition System Capabilities



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



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**



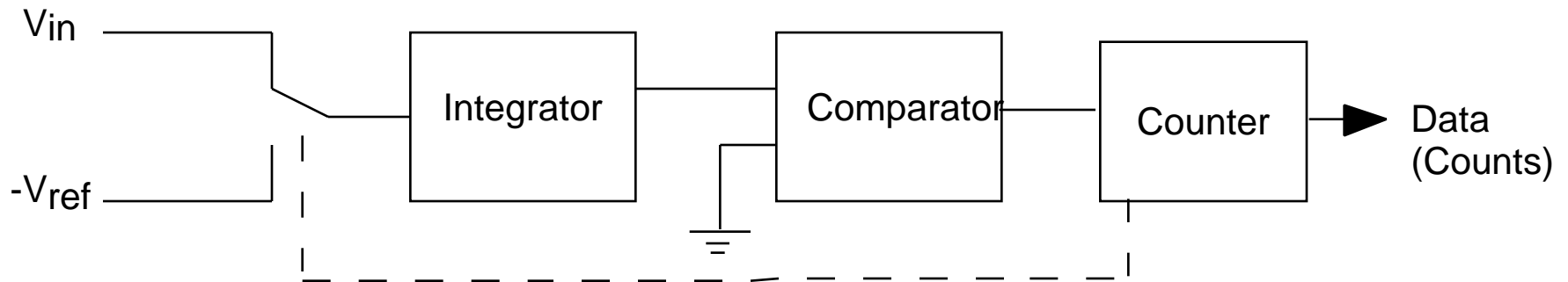
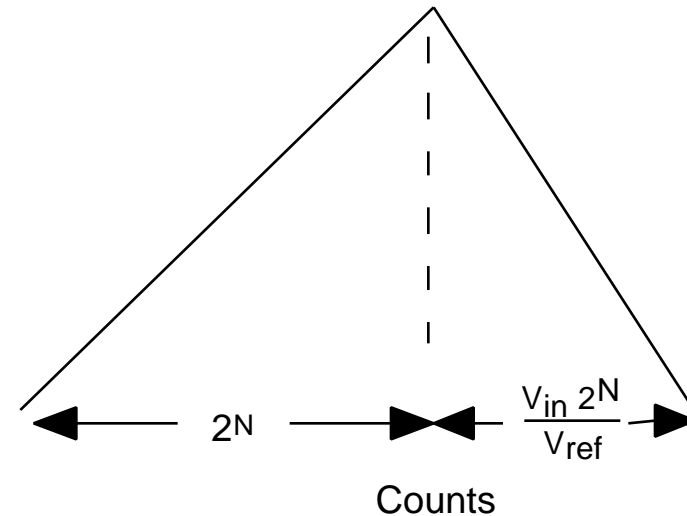
A/D Technology

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**

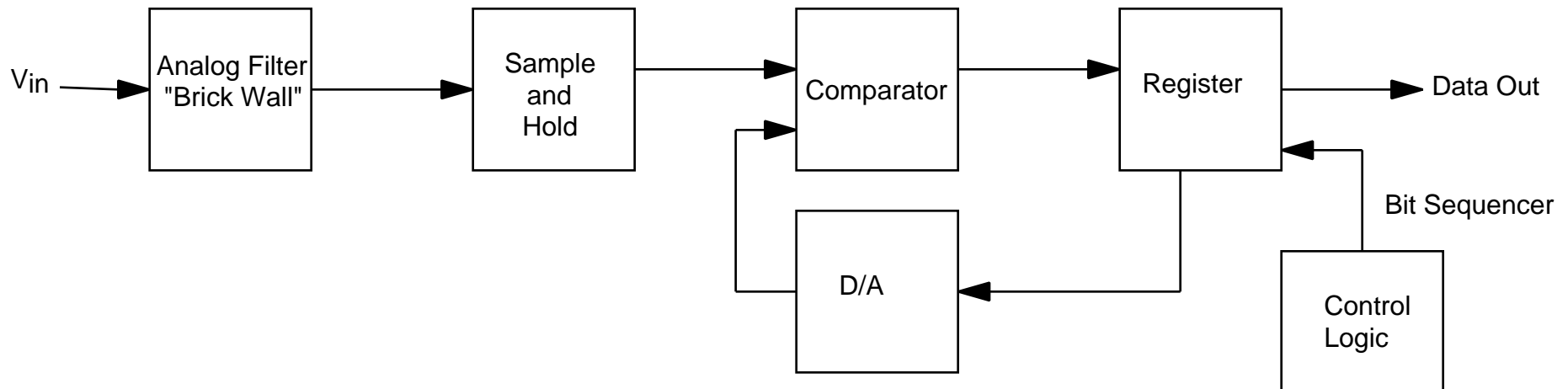
Integrating (Slope) A/D

- 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



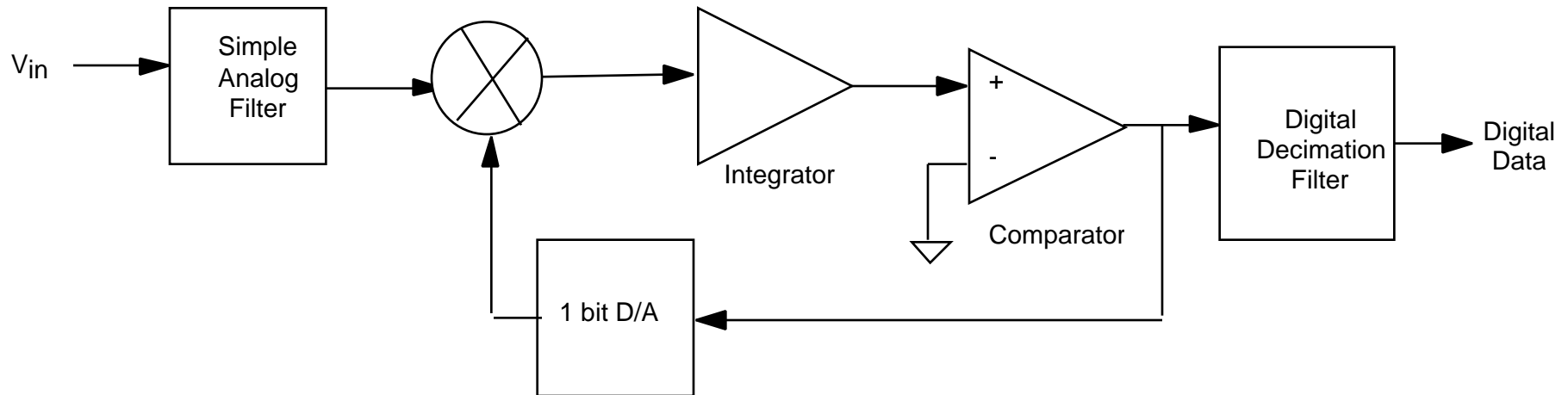
Successive Approximation A/D

- **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

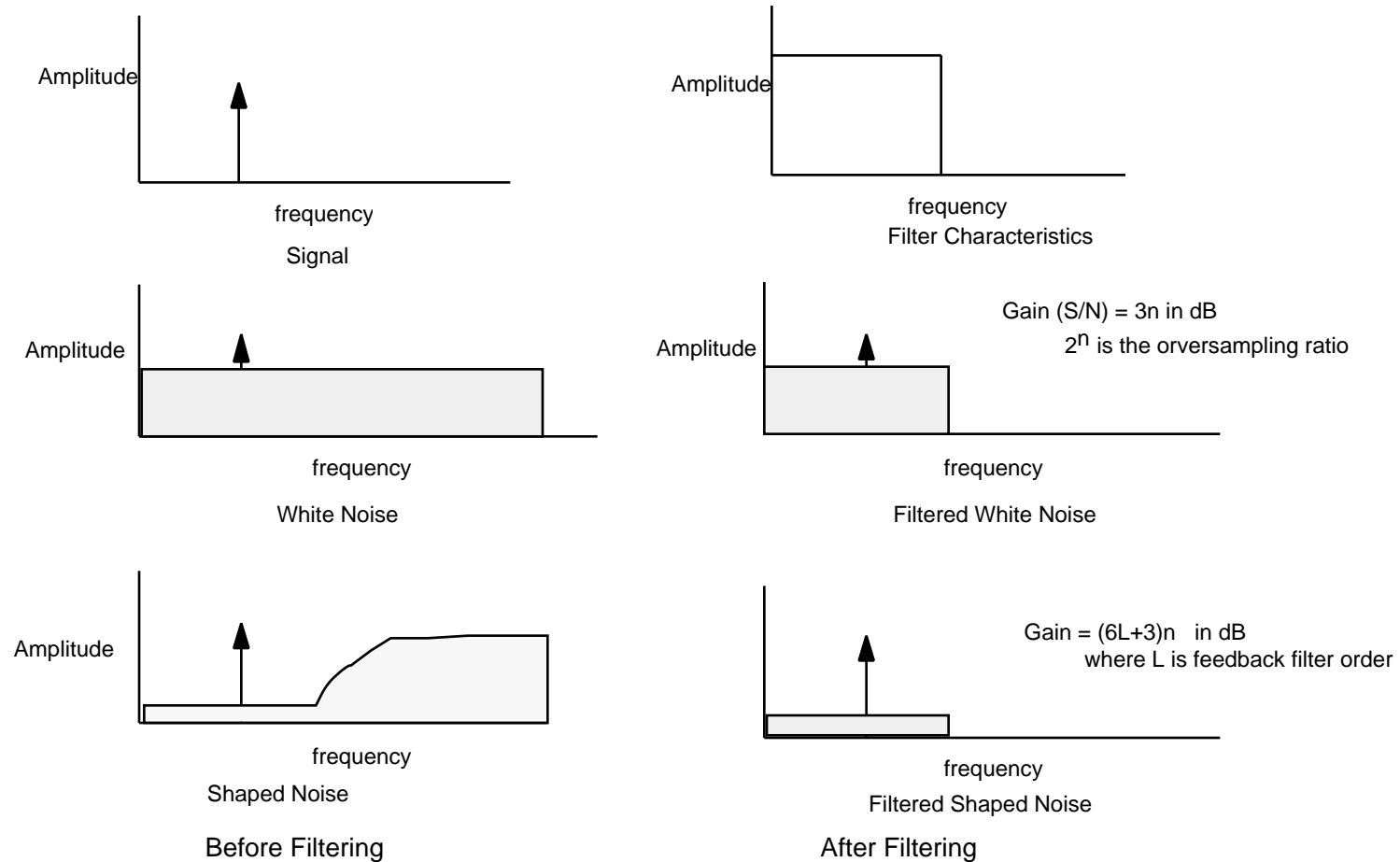


Delta Sigma A/D Converter

- 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



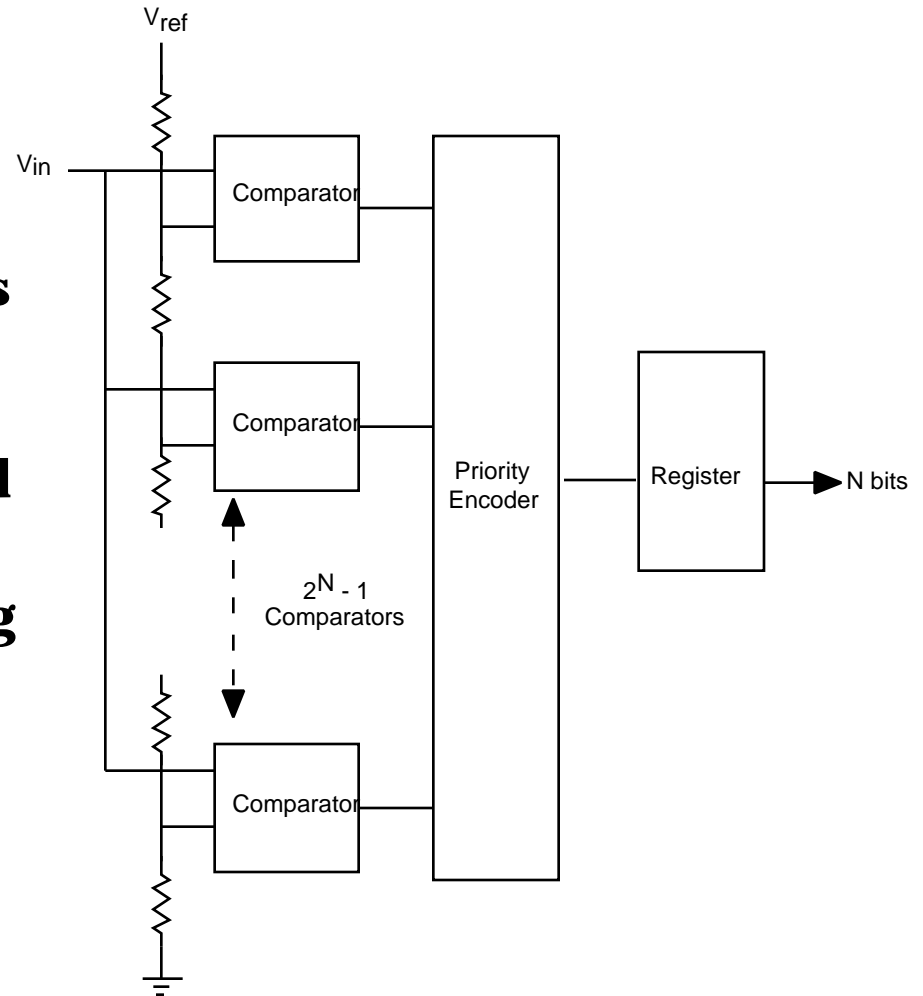
Delta-Sigma Noise Gain



Oversampling Gain on Quantization Noise

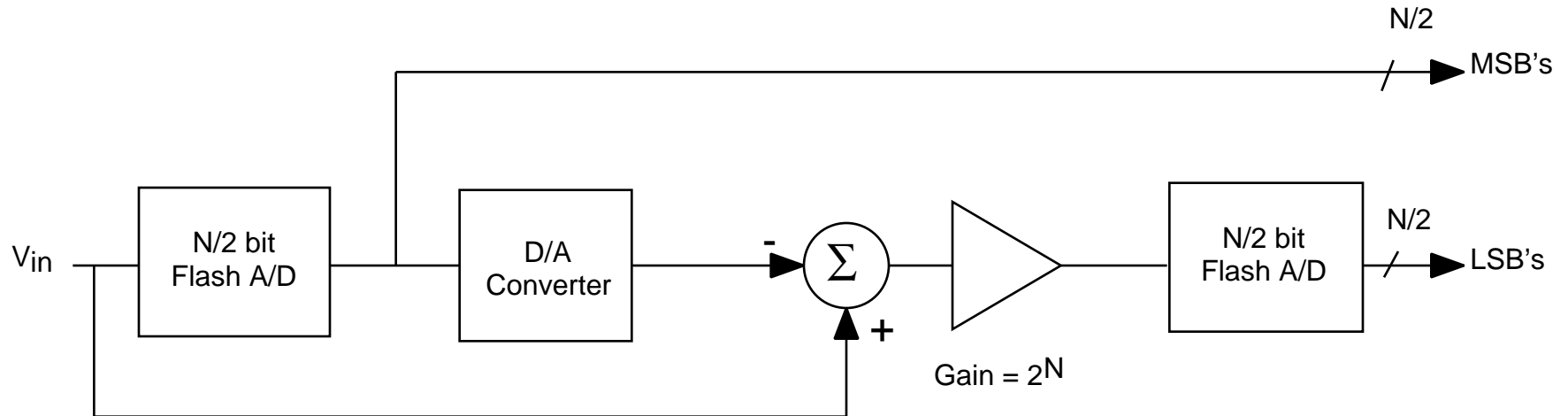
Flash A/D converters

- 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



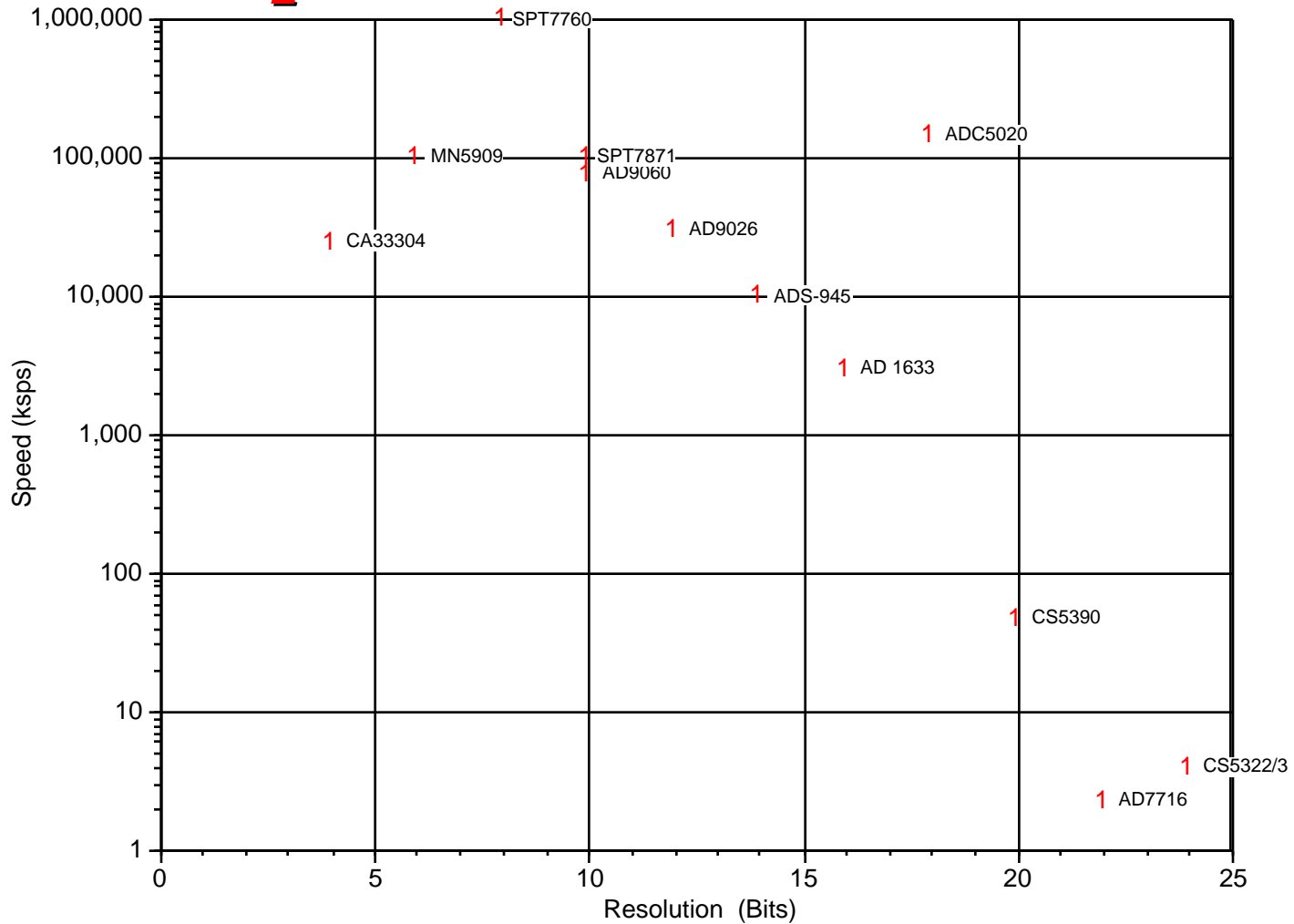
Subranging A/D Converter

- 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





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

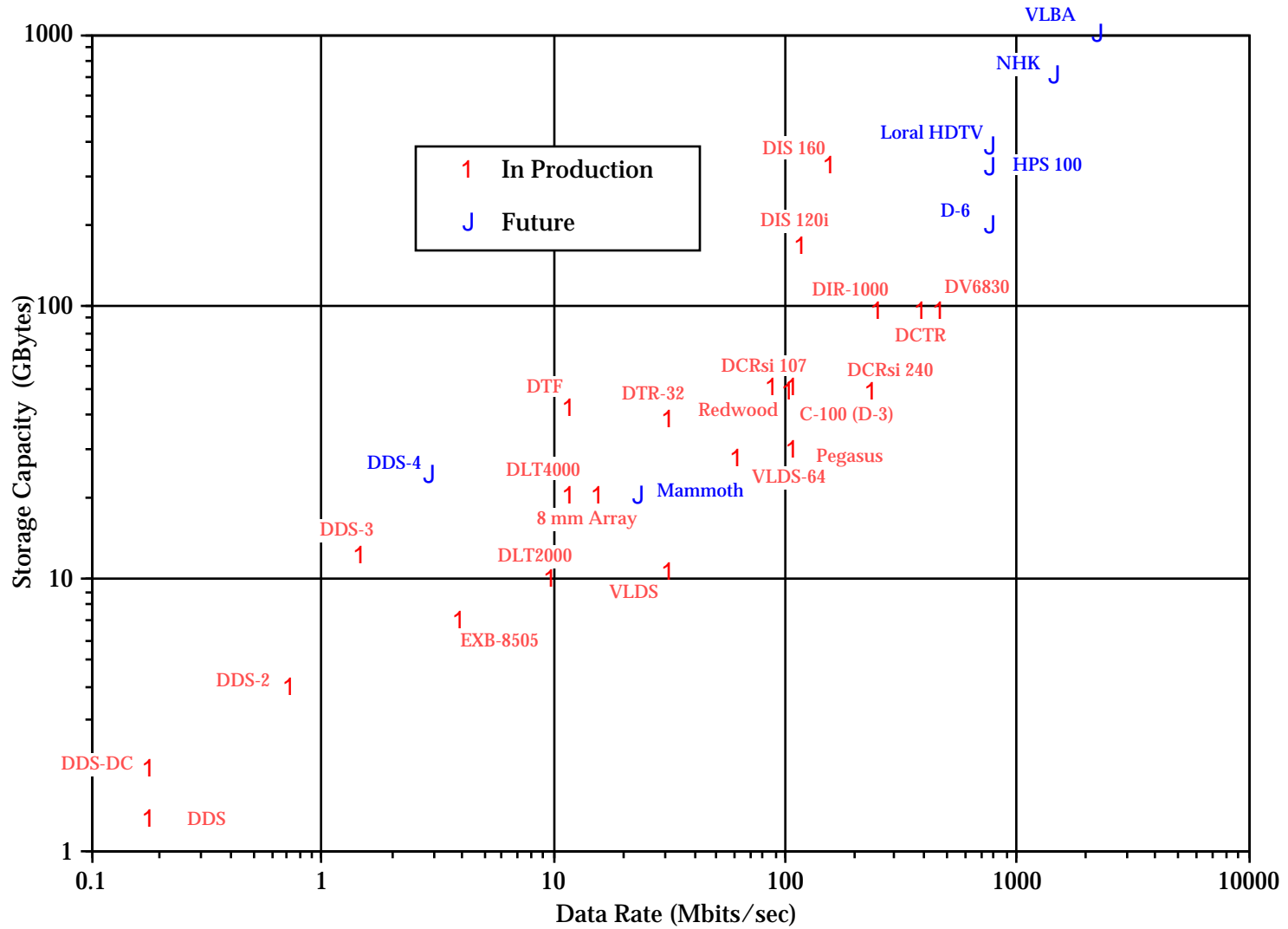
Recording Technology

- **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



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