

**PENTEK**



# Techniques for Wideband RF/IF Signal Recording

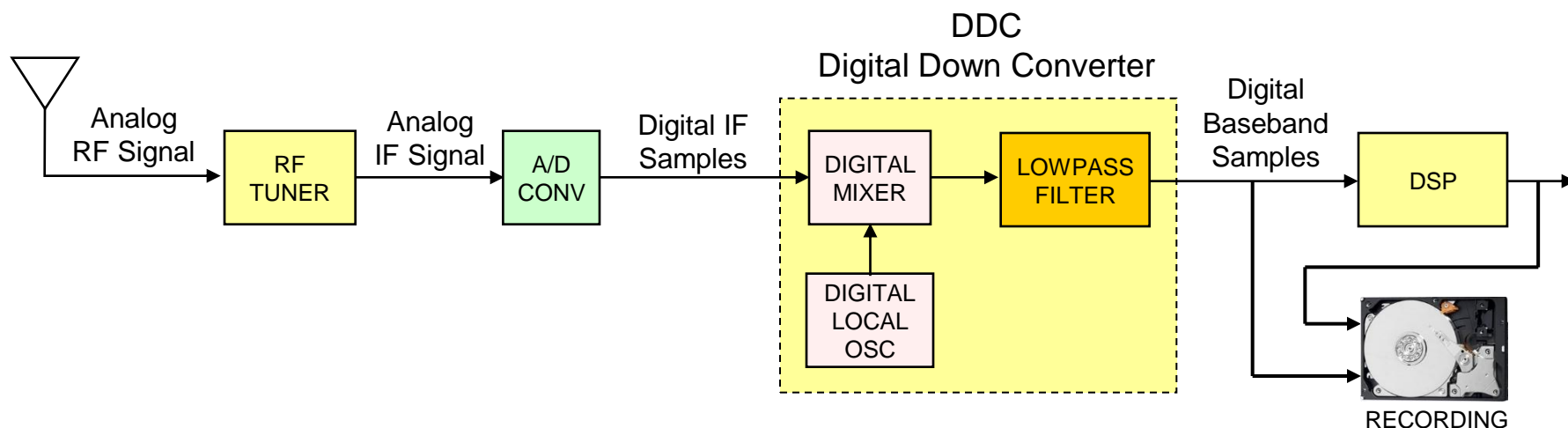
Rodger H. Hosking





# Software Radio Recorder System

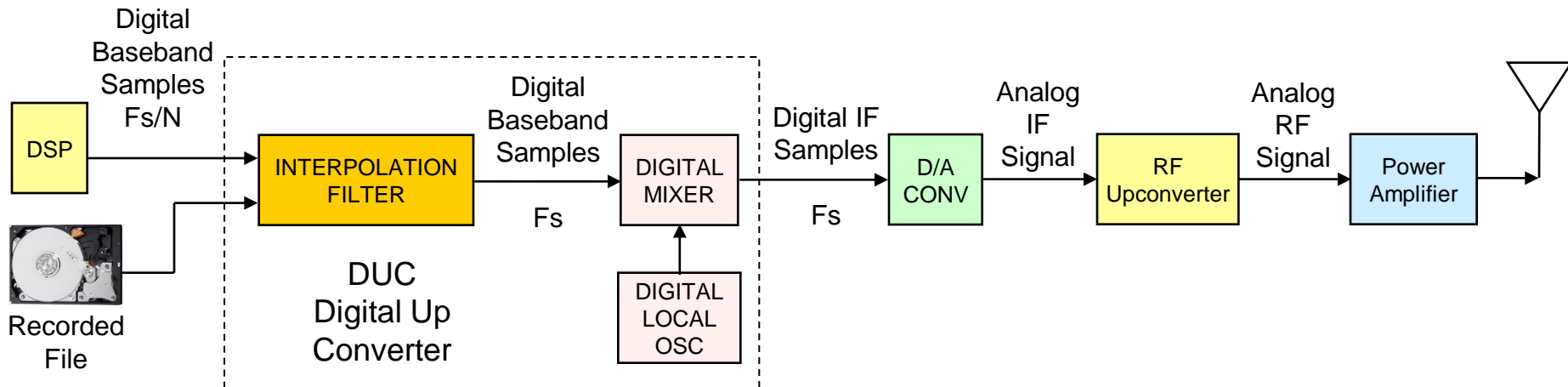
- RF Tuner down converts analog RF signals to analog IF frequencies
- A/D converter digitizes the IF signal to digital samples
- Digital Mixer and Local Oscillator translate digital IF to baseband
- Digital FIR low pass filter limits the digital IF signal bandwidth
- DDC = Mixer + Local Oscillator + Decimating Low Pass Filter
- Baseband DDC samples are stored, forwarded, or processed
- DSP stage performs signal demodulation, etc. with possible storage





# Software Radio Playback System

- Disk Drive or DSP stage generates baseband digital signal
- Digital Up Converter translates digital baseband to IF
- D/A converter converts digital IF samples to analog IF signal
- RF Upconverter translates analog IF signals to analog RF frequencies
- Power amplifier boosts signal energy to antenna

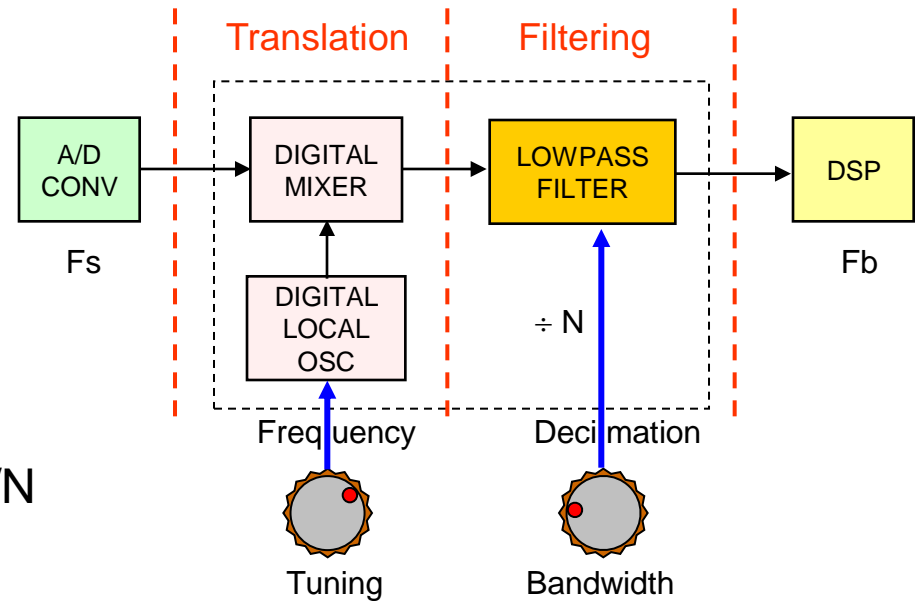




# DDC and DUC: Two-Step Signal Processors

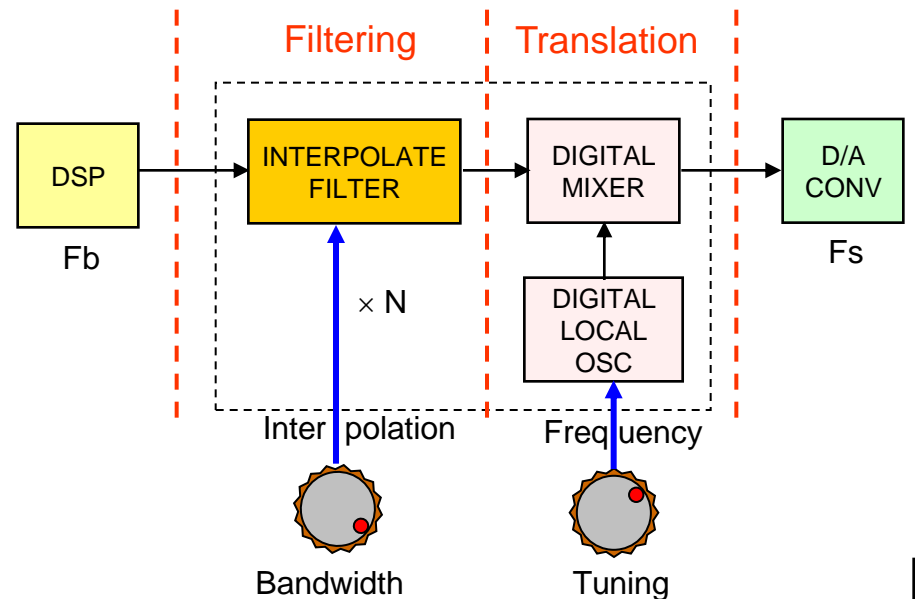
## Digital Down Conversion - DDC

- Frequency Translation
  - Local Oscillator Setting
- Low Pass Filtering
  - Decimation Setting
  - Baseband Sample Rate  $F_b = F_s/N$
  - Baseband Bandwidth =  $0.8 \times F_b$



## Digital Up Conversion - DUC

- Interpolation Filtering
  - Interpolation Setting
  - Baseband Bandwidth =  $0.8 \times F_b$
  - Output Sample Rate  $F_s = F_b \times N$
- Frequency Translation
  - Local Oscillator Setting







# High Speed Recorder Objectives

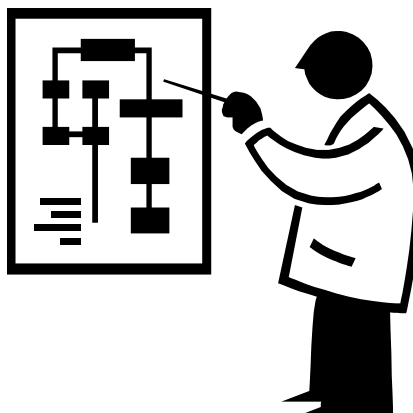
- Digitize, Store and Playback Wideband Analog Signals
  - Signal frequencies above 3 GHz
  - Bandwidths up to 1 GHz
- Multi-channel Synchronous Operation
  - Continuous or Triggered Capture
- Store High-speed Digital Signals
  - 1 GbE, 10 GbE, LVDS, and SerialFPDP
- Time and GPS Location Stamping
- Guaranteed Zero Data Loss
  - Disk Fault-tolerance for High-reliability
- Operation in Lab, Field and Severe Environments
- Tens of Terabytes of Storage
- Exploit Server Class PC Hardware Technology and Costs
  - Removable Storage
- Easy to Use
- Flexible Architecture





# Challenges for High-Speed Recorders

- Signal acquisition and digitization
- Maintain signal integrity
- Synchronization across multiple channels
- Triggering and capturing accuracy
- Hardware data flow bottlenecks
- Disk drive speeds
- Optimize disk storage space
- RAID controller limitations
- Operating system overhead
- Buffering and latency issues
- Shock, vibration and temperature
- Ensuring zero data loss





# Advanced Technology for Recorders

## ■ High-Performance Data Acquisition & Software Radio Modules

- PCIe, XMC and VPX form factors
- 90 dB SFDR signal integrity
- Multi-channel synchronization, triggering and gating
- Hardware DMA controllers - up to 8 GB/sec across PCIe



## ■ Server Class PCs with PCIe Links

- Multi-core CPUs with clock speeds to 4 GHz
- Advanced PCIe Chipsets, Switch and Bridges
- Fast DDR3 SDRAMs operating at 10 GB/sec

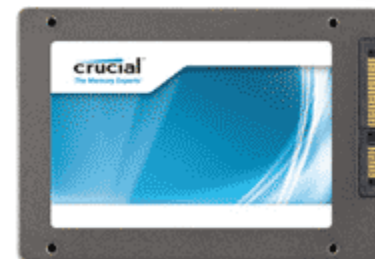


## ■ RAID controllers delivering over 900 MB/sec

- PCIe system interface and SATA III disk interfaces

## ■ Solid State Drives

- Immune to vibration and shock
- SATA III transfer rates to 500 MB/sec or more

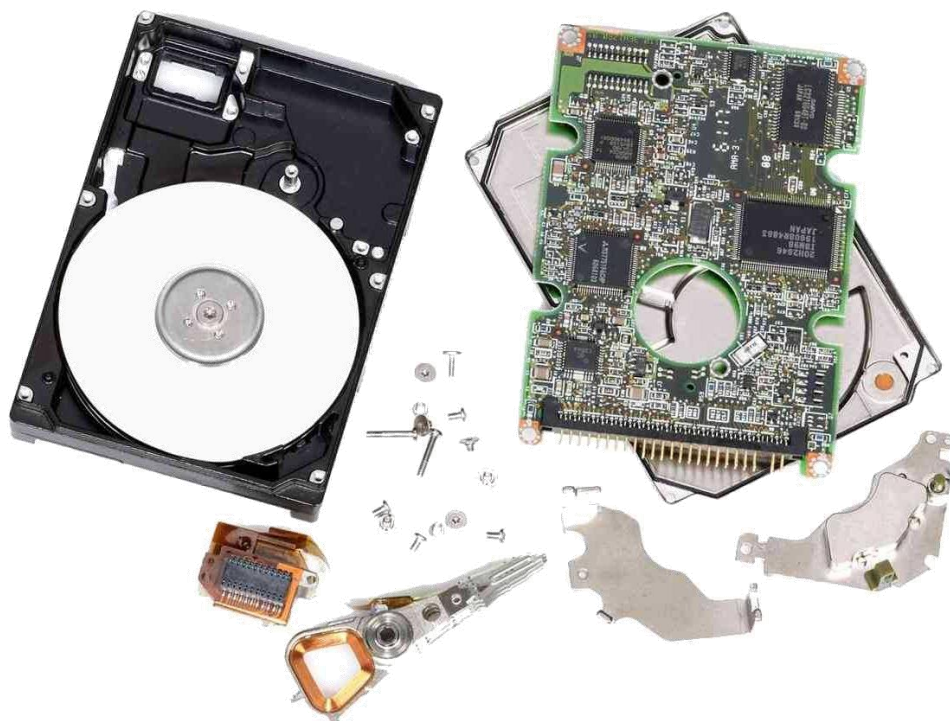




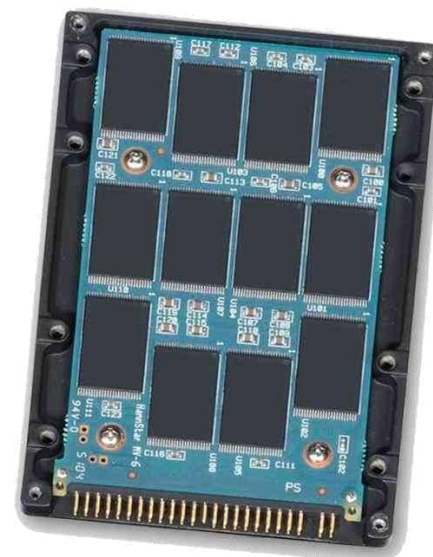
# Magnetic Drives – Solid State Drives

- Magnetic drives use a spinning platter and numerous moving mechanical parts
- SSDs use silicon devices with no moving parts

Inside a Magnetic 2.5" Drive



Inside an SSD







# Comparing Disk Drive Technologies

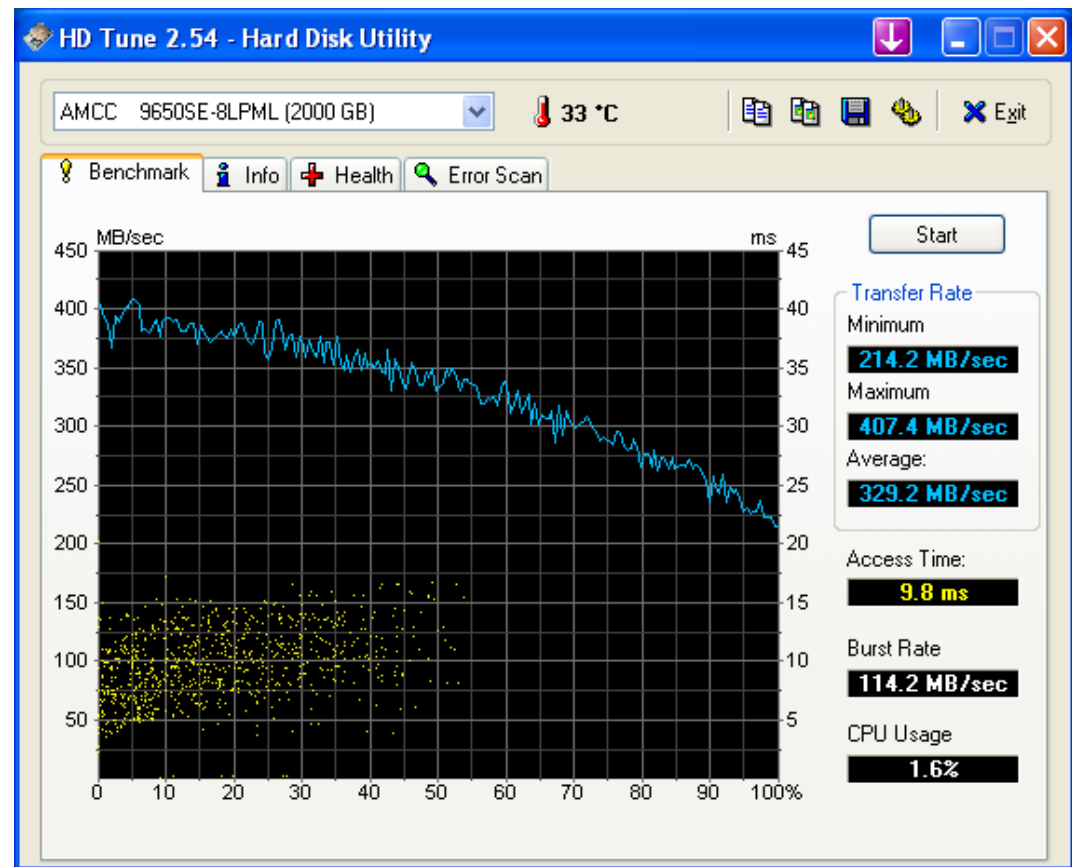
- Typical disk drives used in high speed recorders

Feature	3.5" Magnetic	2.5" Magnetic	2.5" MLC Solid State
Capacity (high end)	2 TB	500 GB	500 GB
Read Transfers	138 MB/sec	150 MB/sec	415 MB/sec
Write Transfers	138 MB/sec	150 MB/sec	260 MB/sec
Weight	750 gm	111 gm	75 gm
Power	10.7 W	1.75 W	0.28 W
Operational Shock	30 G	350 G	1500 G
Operating Temp	5 to 55 °C	0 to 60 °C	0 to 70 °C
Cost	\$275	\$150	\$1100
Cost / GB	\$0.14	\$0.30	\$2.20
Lifetime Write Cycles	∞	∞	74 TB



# Magnetic Drive Characteristics

- An empty magnetic drive starts writing data on the outer tracks of the disk platter and then works towards the center track
- The outer tracks are longer (larger diameters), and the disk rotates at a constant speed
- So, the linear speed of the head against the platter decreases as the disk begins to fill
- The read/write transfer rate is proportional to the linear speed
- This characteristic must be considered when designing for guaranteed read/write rates
- Virtually unlimited number of write cycles (endurance)

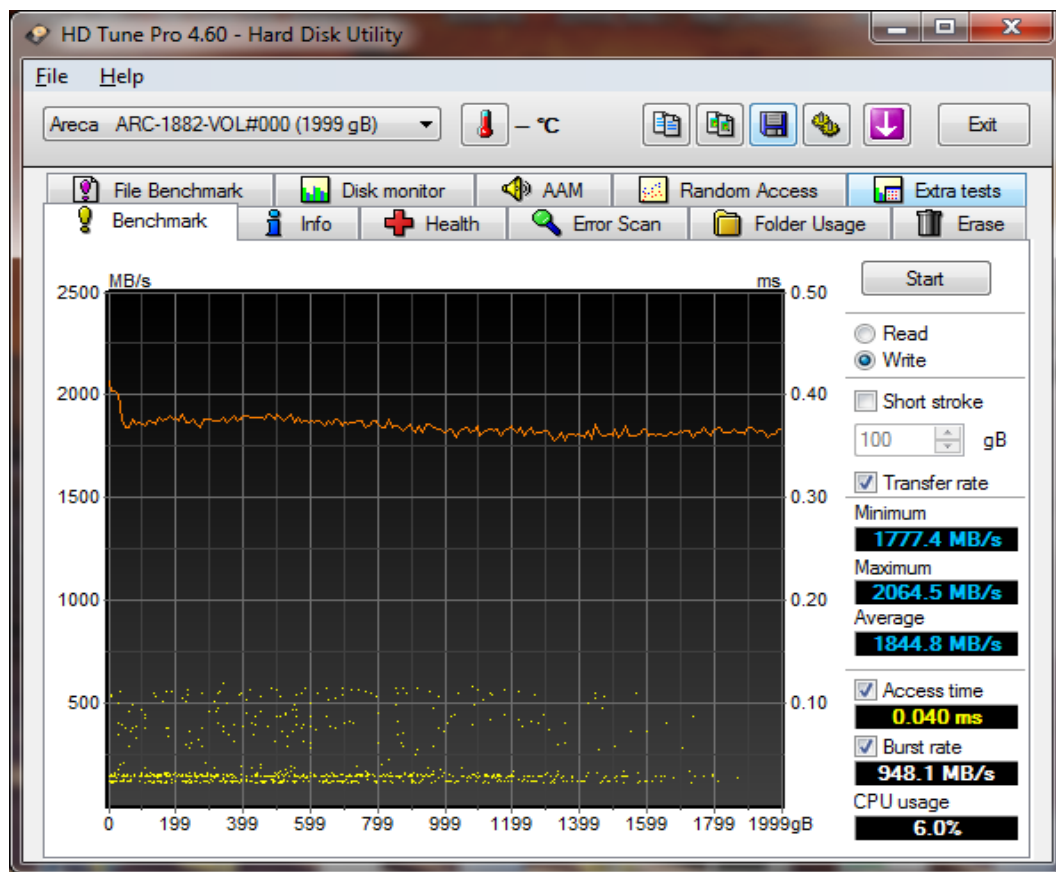


5 Drive RAID 0 – 500 GB WD RE3 – Magnetic 3.5"



# Solid State Drive Characteristics

- Solid state drives have no physical dimensional or rotational effects
- Array of non-volatile solid-state memories
- So, the read/write transfer speeds are uniform across the drive capacity
- Endurance: SSDs have a limited number of write cycles optimized through a wear-leveling controller managing block reads and write to the NAND cells
- JEDEC standards for SSD endurance: [JESD218A](#)
  - Endurance is expressed in TBW (tera bytes written)
  - 72 TBW = 40 GB/day for 5 years
- Sequential file writing in recorders make SSDs excellent candidates!



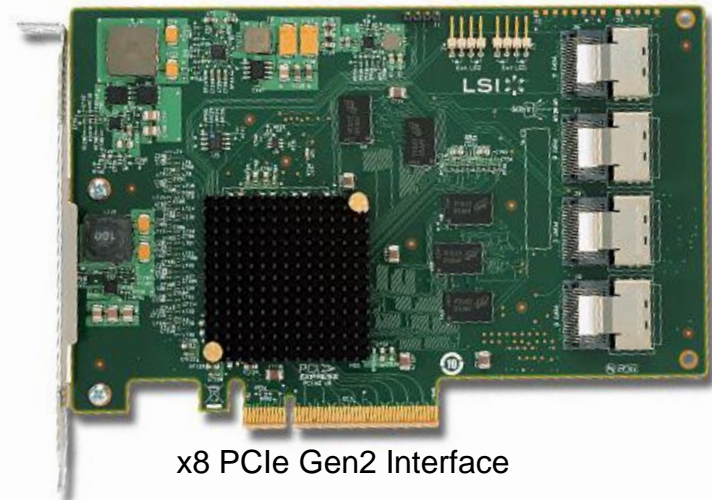
8-Drive RAID 0 – Crucial 256 GB M4 - SSD 2.5"



# RAID Controllers (Host Bus Adapters)

- **Redundant Array of Independent Drives**
- Aggregates storage capacity of multiple disk drives
- Aggregates transfer speed of multiple disk drives
- Provides levels of fault tolerance for critical, high-reliability applications

16-port PCIe Gen2 SATA-2 RAID Controller



Four SATA-II Ports

Four SATA-II Ports

Four SATA-II Ports

Four SATA-II Ports

x8 PCIe Gen2 Interface

LEVEL	Description	Number of Drives*	Capacity Efficiency	Fault Tolerance	Write Speed Improvement
RAID 0	Block level striping	2	100%	none	200%
RAID 1	Mirroring (duplicating)	2	50%	1 drive	100%
RAID 5	Block striping + parity	3	66%	1 drive	200%
RAID 6	Block striping + 2x parity	4	33%	2 drives	100%
RAID 10	Block striping + double mirrors	4	25%	2 drives	200%

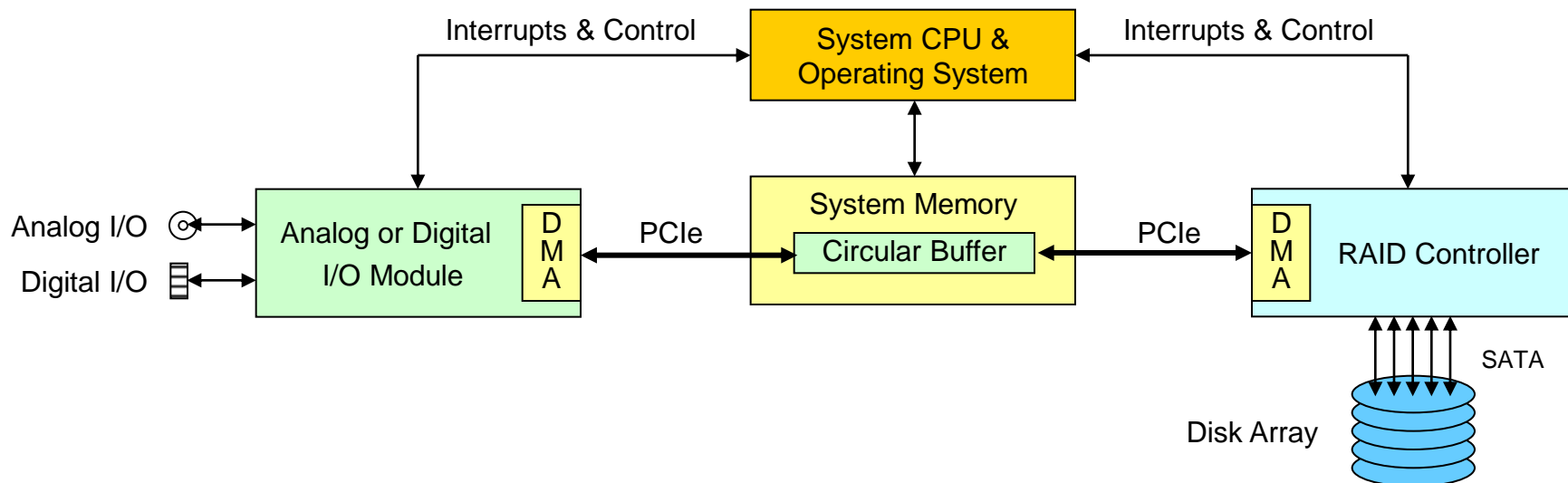
\* Minimum number of drives shown. Benefits shown for that minimum number of drives.





# Recording System Signal Flow

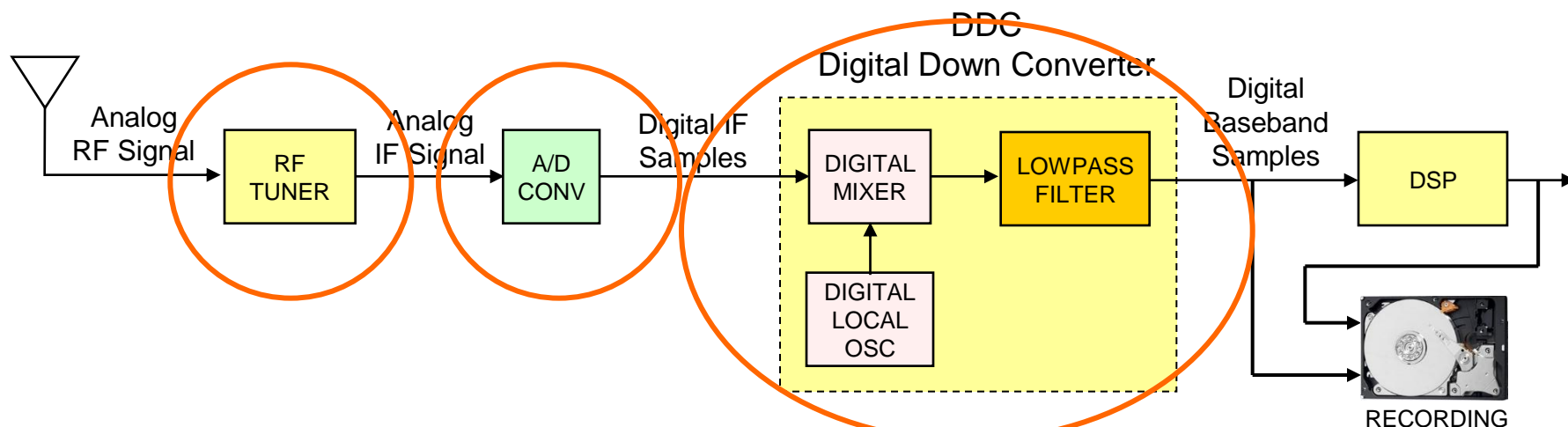
- Hardware DMA controllers handle all critical, real-time data transfers
  - PCIe Links eliminate data flow bottlenecks
  - Between I/O module and system memory
  - Between system memory and RAID controller
- System CPU & Operating System
  - Does not “touch” the real-time data
  - Initializes the I/O modules, RAID controller, and DMA engines
  - Manages performance through interrupts





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# Talon™ Recorder Overview

- High-speed recording and playback systems
  - Analog and Digital I/O Interfaces
  - Programmable bandwidth and tuning frequencies
- Ready to use instrument
  - Ready to record out of the box
  - Intuitive control panel and user interface
  - No software development required
- Multiple form factors
  - Lab, portable and rugged versions
- Windows 7 Operating system
- NTFS file system
  - Allows the user to work with files immediately after capture
  - Supports all Windows signal analysis and processing tools (Matlab)





# Talon™ Recorder Key Features

- Handles wideband analog recording and playback
  - Sustained recording rates up to 2.66 GB/sec in a single 4U chassis
  - Real time signal bandwidths up to 500 MHz (1 GHz A/D Supported)
  - Synchronous and asynchronous multi-channel operation
- Playback Capabilities
  - Recorded files can be reproduced through D/A
- Data Transport Capabilities
  - Removable Drive Bays/Drive Modules included with all systems
- Integrated Signal Viewer
  - Virtual oscilloscope (time) and spectrum analyzer (frequency)
  - Multiple cursors, zooming and panning
  - Signal parameter calculators: harmonic detection, SINAD, and THD
  - Recorded files can be analyzed on Signal Viewer





# Talon's Latest Recorder Technology

- Pentek Cobalt Series Modules
  - Native x8 PCIe interface, Gen 1 (2 GB/sec) and Gen 2 (4 GB/sec)
- Solid State Drives - SSDs
  - 2.5 inch form factor – lightweight, low power
  - Up to 1 TB capacity
  - Read/write rates up to 500 MB/sec (SATA-III)
  - Immune to shock and vibration
  - Eliminates head-seek penalty for multi-channel operation
- High-performance PCIe RAID Controllers
  - Over 1400 MB/sec transfer rates per controller
  - Over 3.2 GB/sec aggregate read/write rates within a single chassis
  - Single high-speed channel can be striped across multiple RAIDs
- Intel Core i7 CPU and Chipsets
  - Maximum throughput from PCIe buses to system memory

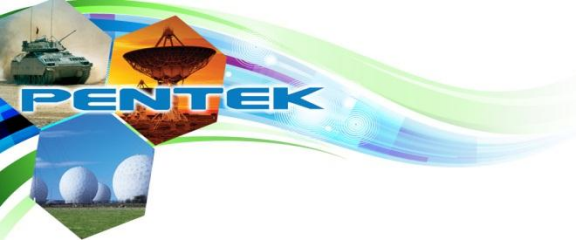


# Talon™ RTS Recorder Form Factors

## ■ RTS Commercial Systems

- PC Server Configuration
- Designed For Use Within Office/Lab Based Environments
- Magnetic Drives
- Models 2701 & 2706
- 19" Rackmountable Chassis
- Model 2721
- Portable Small Briefcase Style Chassis' with Integrated Monitor and Keyboard





# Talon™ RTR Recorder Form Factors

## ■ RTR Rugged Systems

- Designed For Use Within Harsh Environments
- Air cooled
- Solid State Drives - immune to shock and vibration

### • Model 2746

- 19" Rackmount Chassis
- Transit Case available



### Model 2726

- Portable Small Briefcase Style Chassis' with Integrated Monitor and Keyboard
- Operates on moving vehicles & aircraft



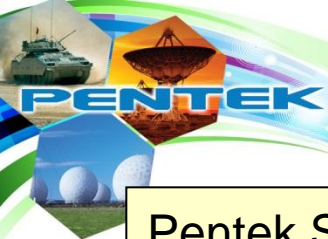


# Talon™ RTX Recorder Form Factors

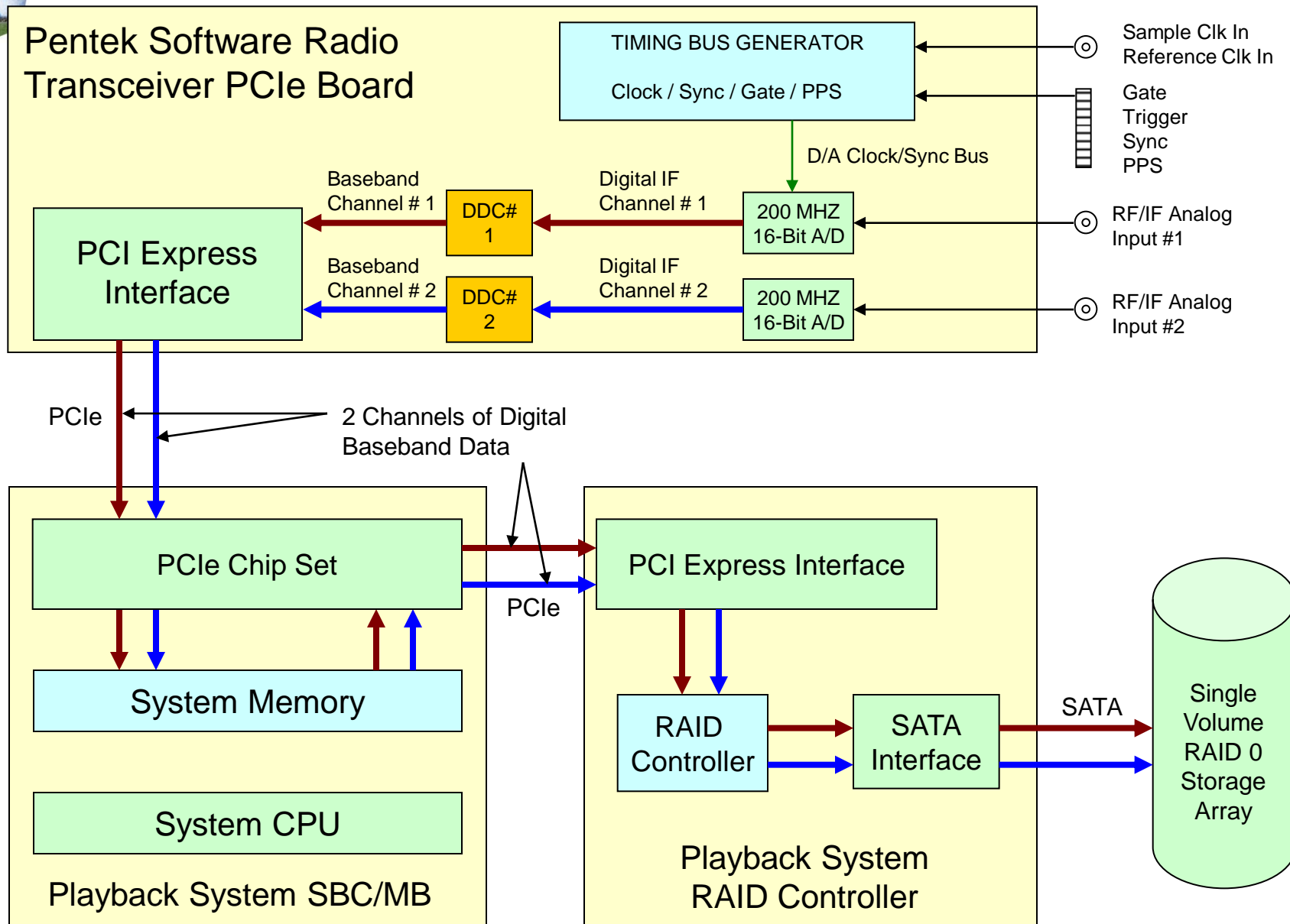
- RTX Extreme Systems
  - SBC Server Configuration
  - Designed For Use Within Extremely Harsh Environments
  - Solid State Drives
  - Typically Sealed & Conduction Cooled
- Model 2786
  - ATR Style, 3U VPX
- Model 2766
  - Other SFF Chassis





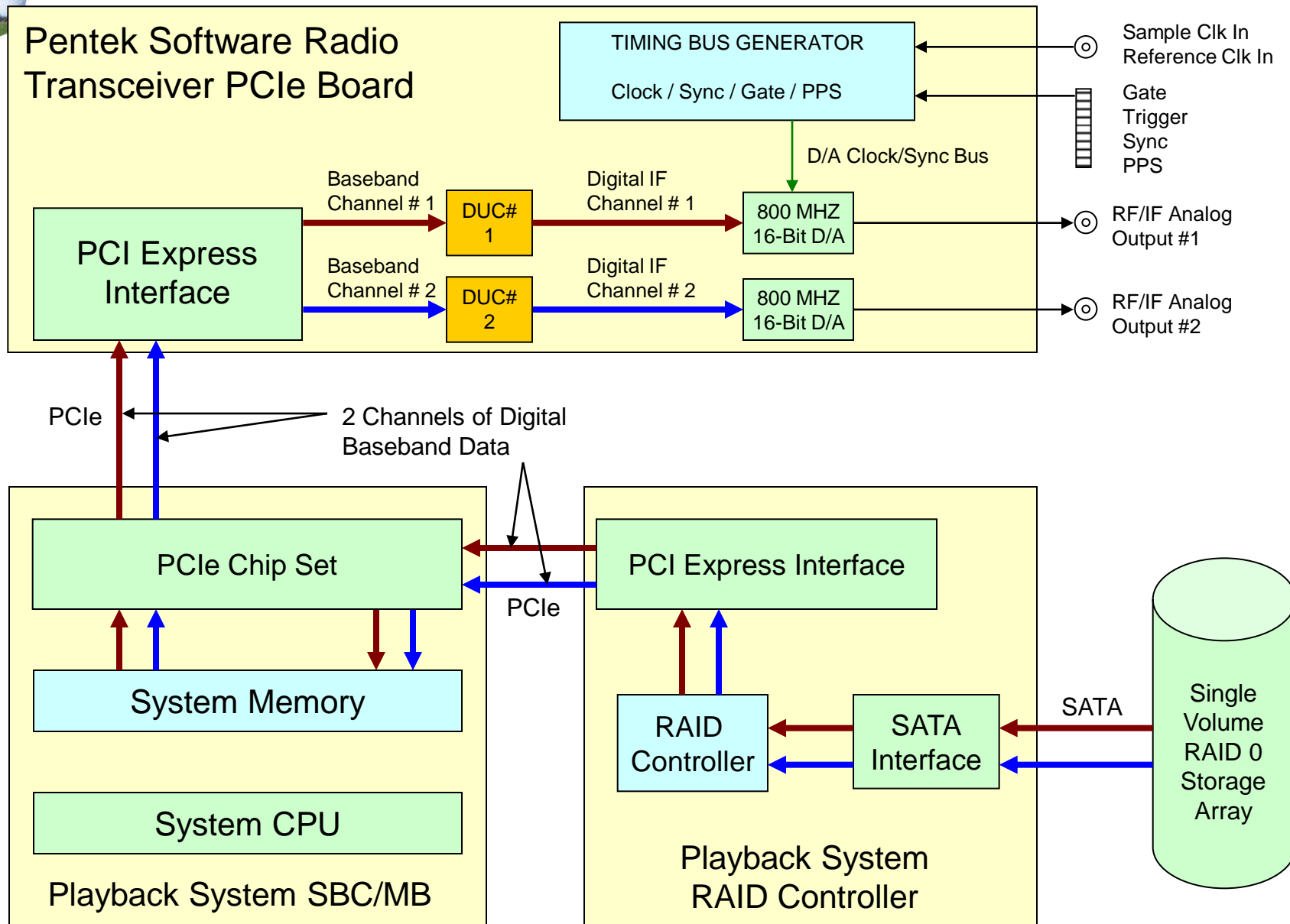


# Record Mode Data Flow



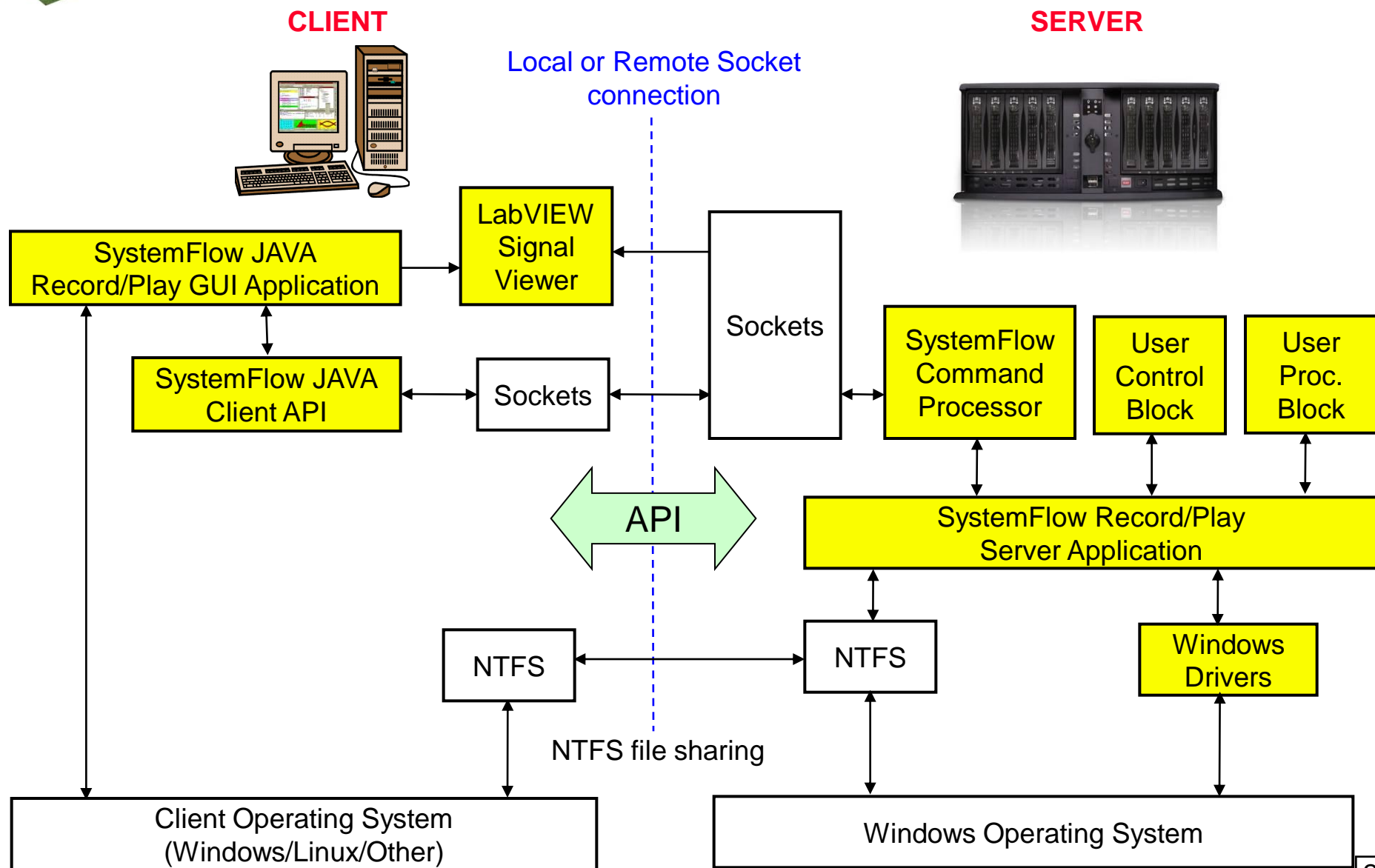


# Playback Mode Data Flow





# Talon SystemFlow Software Architecture



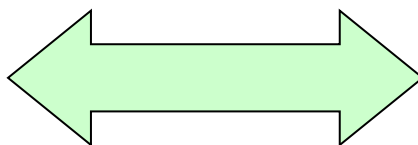


# Talon Remote Client/Server Operation

- Talon client installed on machine in a SIGINT facility
- Talon server installed on machine at a remote location
- Supports remote control from facility
- Supports file transfers back to facility



API Control  
Commands  
via Ethernet  
or Internet

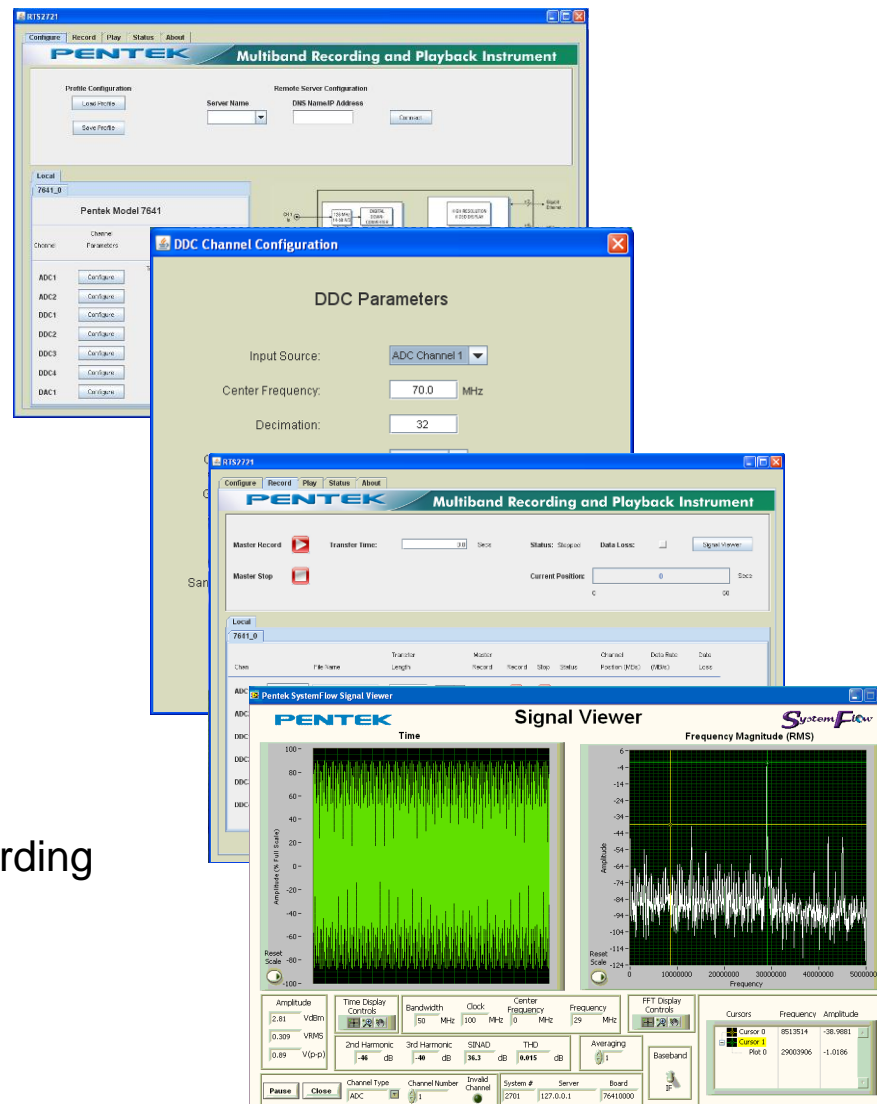






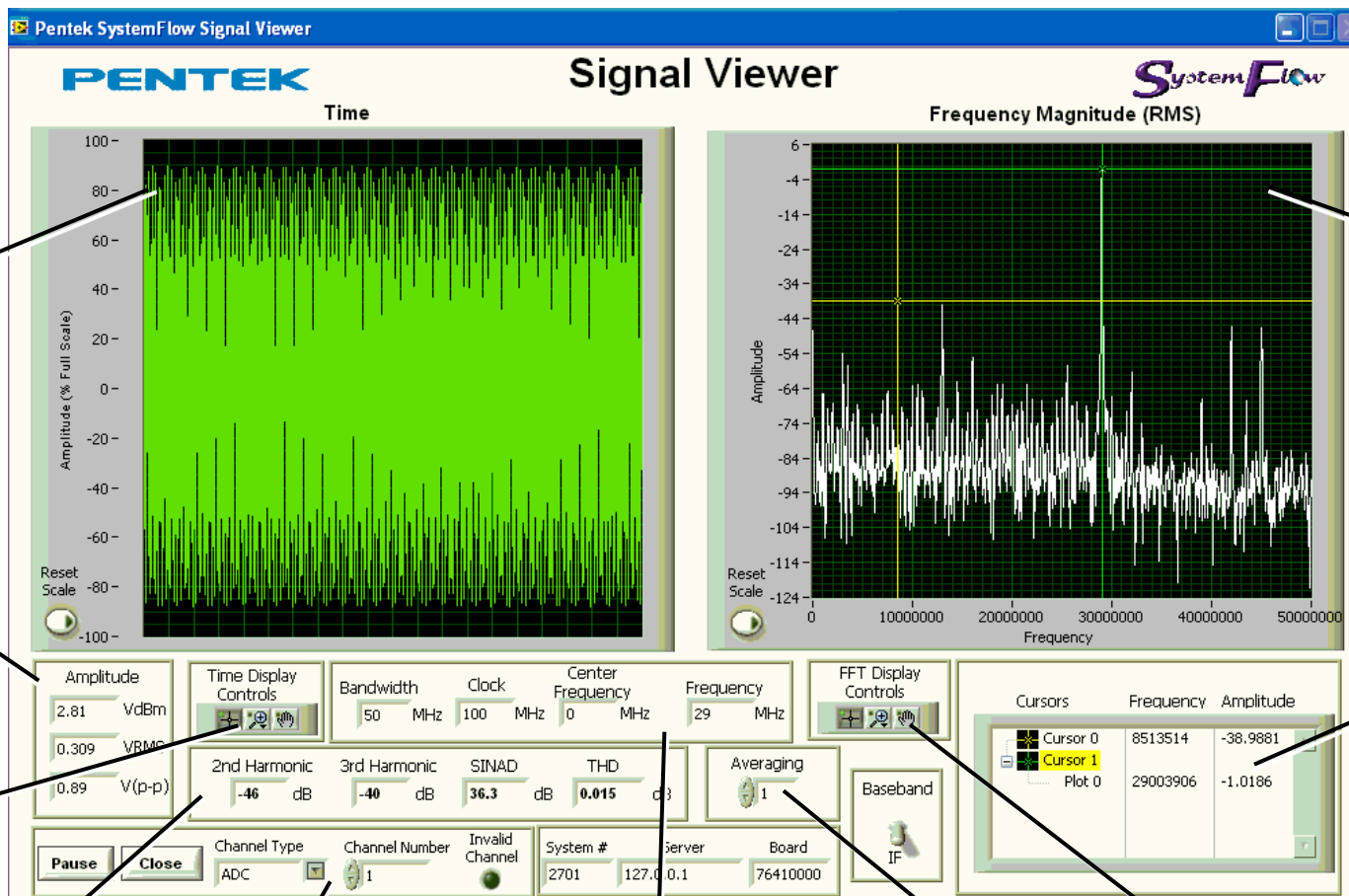
# SystemFlow Graphical User Interface

- Standard GUI Built from API
  - Forms a complete, ready-to-use real-time record/play instrument
  - Configures and initializes real-time hardware
- Record/Play Client API Functions
  - Controls and monitors real-time hardware operations
  - Records from A/D to file
  - Plays back from file to D/A
  - Easy-to-use screen buttons and keyboard parameters entries
- Signal Viewer
  - Previews live signals before & during recording
  - Views recorded files after recording





# SystemFlow Signal Viewer & File Viewer



Time Domain Window

Frequency Domain Window

Voltage Calculator

Time Scale Pan & Zoom

Multiple Annotated Cursors

Signal Analysis Measurements

Channel Selector or File Selector

Frequency Calculator and Parameters

Spectral Averaging

Frequency Scale Pan, Zoom, & Cursors



# ADC/DDC Parameters Screen

Tuning Frequency Used To  
For Translating  
The Sampled A/D Signal  
Down to Baseband

Gate or Trigger Mode  
Polarity

**ADC/DDC 1 Parameters**

☒ Bandwidth: 40.0 MHz

☐ Decimation: 4

Downconversion: ☒

Input Source: ADC 1

Center Frequency: 70.0 MHz

Gate / Trigger Mode: None

Gate / Trigger Polarity: Negative

A/D Sampling Rate: 200.0 MHz

Disk Data Rate: 200.0 MB/s

OK Cancel Apply

Signal Bandwidth  
(Nyquist or Real)

Decimation Factor

Digital Down Conversion  
Enable

Gate or Trigger Mode  
Enable



# SystemFlow GUI Record Screen

Master  
Transfer Length/  
Record Duration

Master Start  
Record Button

Master Stop  
Record Button

A/D Channel  
File Name

Transfer Length/  
Record Duration

Signal Viewer  
Button

Channel	File Name	Transfer Length	Master Record	Record	Stop	Status	Channel Position (MBs)	Data Rate (MB/s)	Data Loss
ADC/DDC 1	E:\BB_Test1.dat	0.0	<input type="checkbox"/>			Recording	107680	400.0	
ADC/DDC 2		0.0	<input type="checkbox"/>			Stopped	0	0.00	

Master Record/  
Multi-channel Simultaneous  
Record Check Box

Independent  
Channel  
Start Record  
Button

Independent  
Channel  
Stop Record  
Button



# SystemFlow GUI Play Screen

Master  
Transfer Length/  
Playback Duration

Master Start  
Playback Button

Master Stop  
Playback Button

File Viewer  
Button

D/A Channel  
File Name

Playback Start  
Position

Transfer Length/  
Playback Duration

The screenshot shows the 'RTS2706' window with tabs for 'Configure', 'Record', 'Play', 'Status', and 'About'. The 'Play' tab is active, displaying the 'PENTEK Multiband Recording and Playback Instrument' interface. The top section contains Master playback controls: 'Master Play' (green play button), 'Transfer Time: 0.0 Secs', 'Status: Stopped', 'Data Loss' (checkbox), 'Signal Viewer' button, 'Master Stop' (green stop button), 'Start Position: 0.0 Secs', 'Current Position: 0 Secs', and 'File Viewer' button. The bottom section shows a table for 'Local' channels with columns: Channel, File Name, Start Position, Transfer Length, Loop, Master Play, Play, Stop, Status, Channel Position (MBs), Data Rate (MB/s), and Data Loss. The first row is for 'DAC 1' with a 'Browse' button, '0.0 Secs', '0.0 Secs', a 'Loop' checkbox, and playback buttons. The status is 'Stopped'.

Channel	File Name	Start Position	Transfer Length	Loop	Master Play	Play	Stop	Status	Channel Position (MBs)	Data Rate (MB/s)	Data Loss
DAC 1	<input type="text" value="Browse"/>	0.0	0.0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="button" value="Play"/>	<input type="button" value="Stop"/>	Stopped	0	0.00	<input type="checkbox"/>

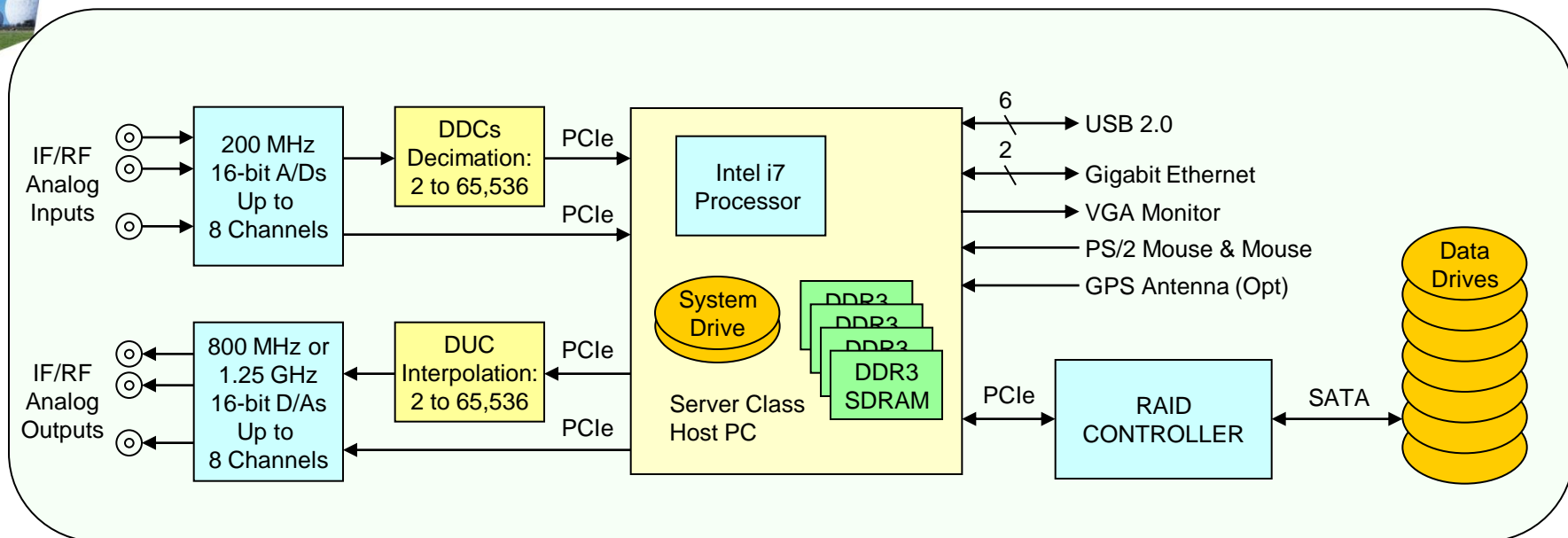
Master Playback/  
Multi-channel Simultaneous  
Playback Check Box

Independent  
Channel  
Start Playback  
Button

Independent  
Channel  
Stop Playback  
Button



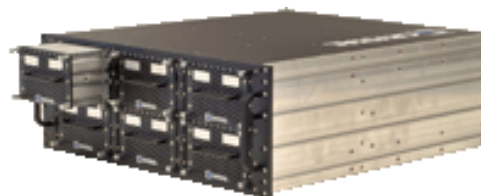
# 200 MHz 16-bit A/D Systems



**RTS 2726 Portable**  
Solid State Drives



**RTS 2726 Lab System**  
3.5" High Capacity Drives  
24 TB Storage



**RTR 2726 Rugged**  
Solid State Drives  
Harsh Environment



**RTX 2786 3U VPX**  
Solid State Drives  
Conduction Cooled

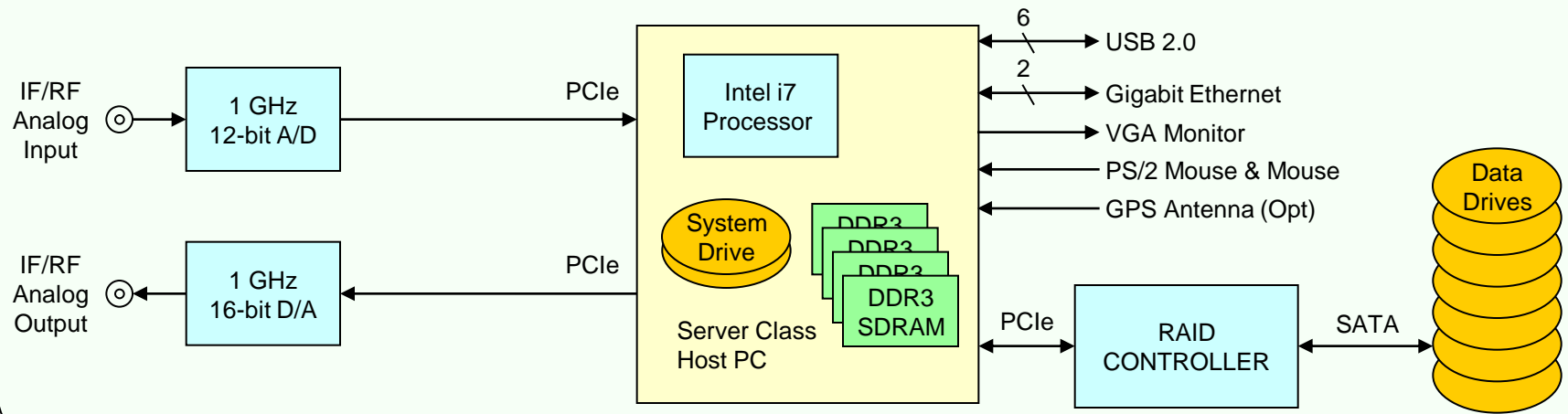




# Other Analog RF/IF Recorders

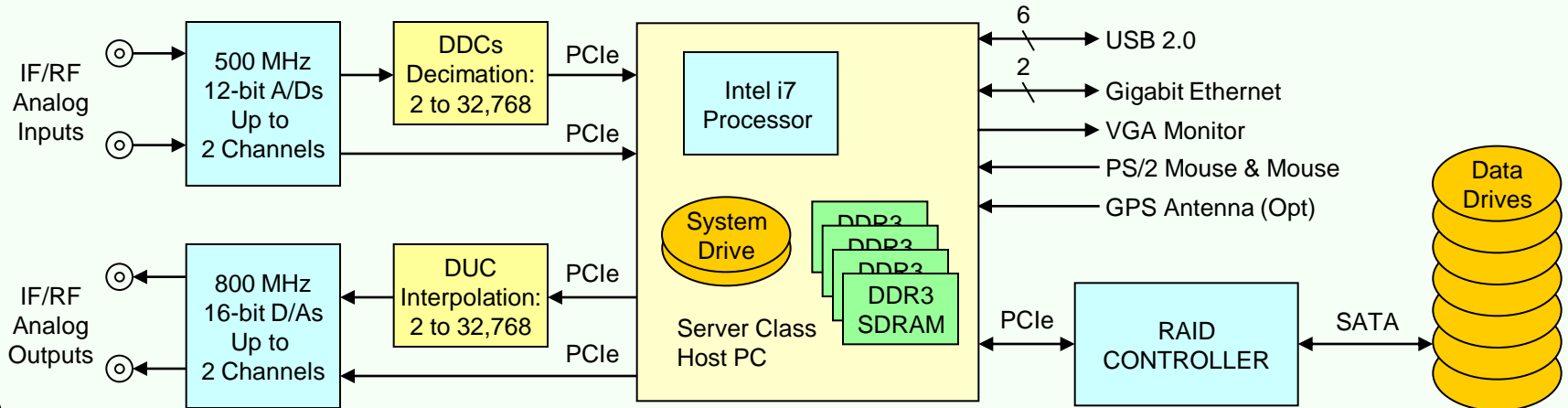
1 GHz 12-bit A/D & 1 GHz 16 bit D/A

**RTS 2708**



Dual Ch 500 MHz 12-bit A/D & 800 MHz 16-bit D/A

**RTS 2711**

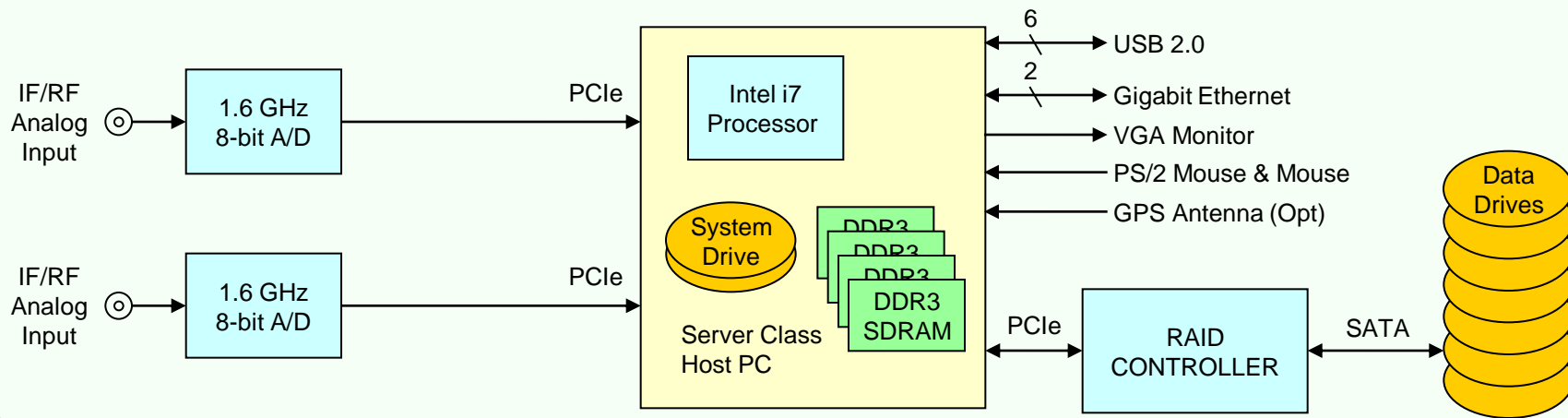




# Extremely Wideband I/O Recorders

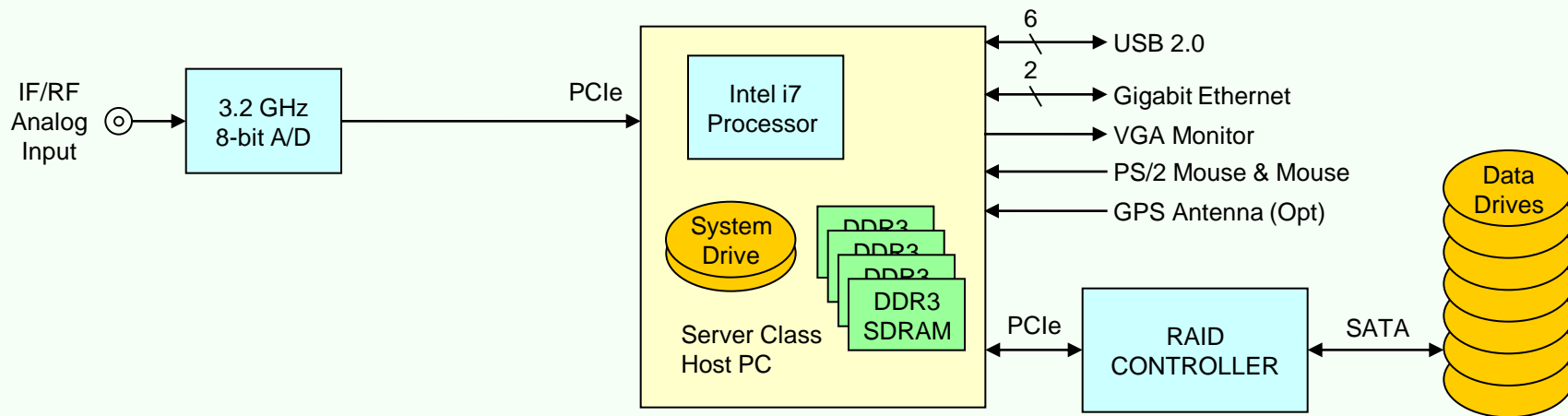
2 Channel 1.6 GHz 8-bit A/D (3.2 GB/sec)

**RTS 2709**



1 Channel 3.2 GHz 8-bit A/D (3.2 GB/sec)

**RTS 2709**





# Wideband Recording Systems Summary

- Multiple form factors
  - Lab, portable, rugged and extreme versions
- Complete High-Speed Recording and Playback Instrument
  - Analog and Digital Interfaces
  - Programmable bandwidth and tuning frequencies
  - Ready to use out of the box
  - No software development required
  - Powerful Signal Viewer with Time and Frequency analysis tools
  - API Library for software integration
  - Multichannel Synchronization
- NTFS File System
  - Files are immediately after capture
  - Supports Windows signal analysis & processing tools (e.g., Matlab)

