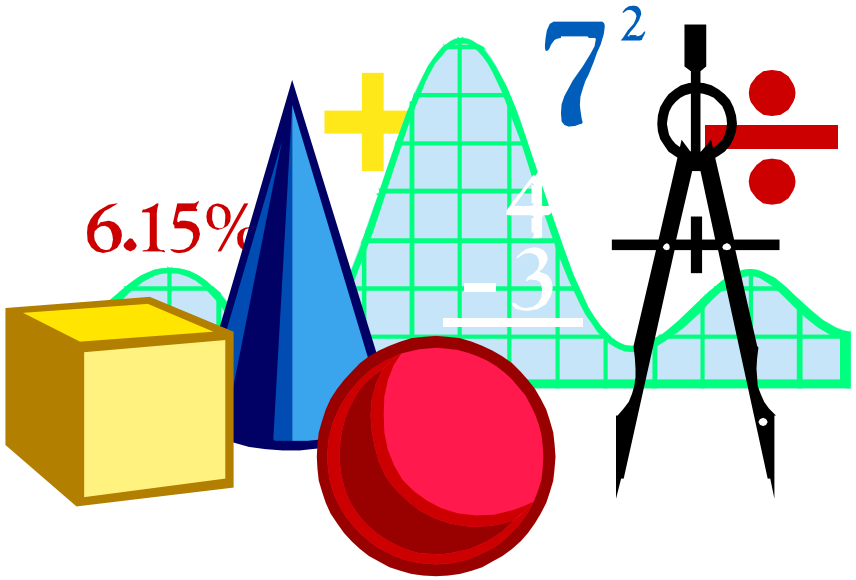
LS4 - A new high performance ADC in VXI



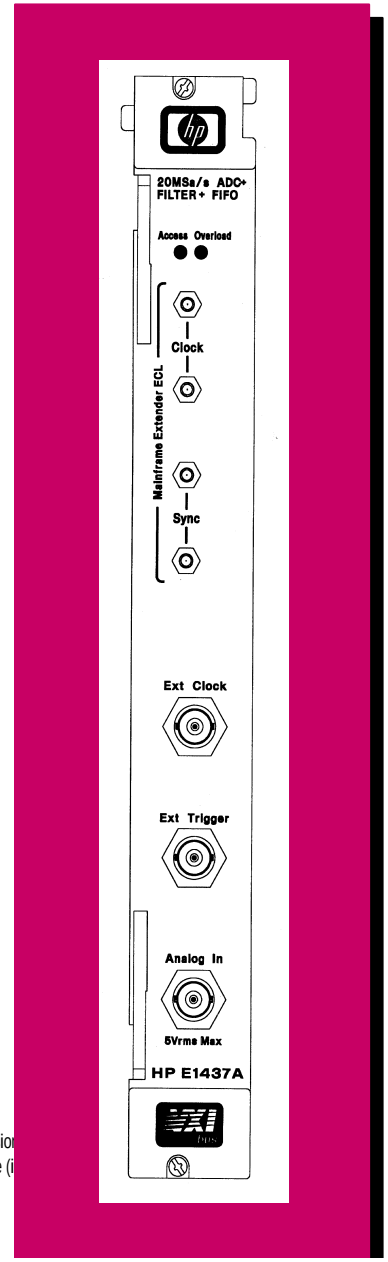
E1437A - more than just an ADC

Sample rate / resolution

- 20 MSa/s, 23 bits

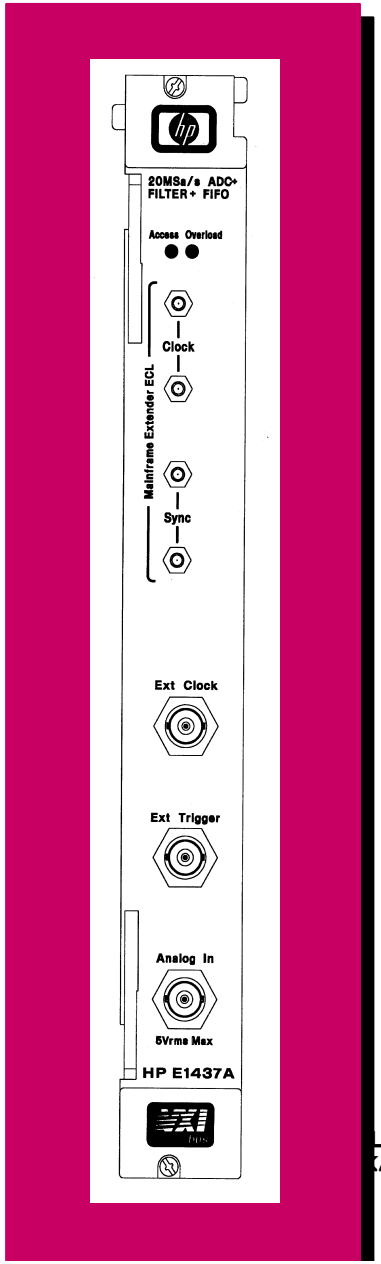
Features

- 8 MHz input (alias protected)
- Filters & LO
- 8 MB FIFO (16/32/64 MB opt)
- Local Bus



HEWLETT PACKARD

E1437A Applications



Aerospace Defense

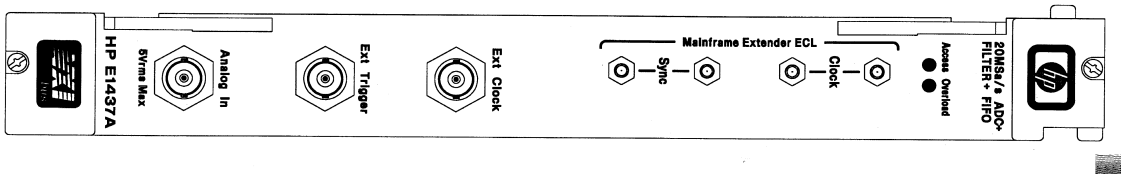
- Modular receiver designers
  Dynamic range
- ATE designers (waveform capture)
  Resolve small changes on large signals

E1437A ADC with DSP

Agenda

- What is it?
  Features and why
- Application
  Modular digital receiver
  Precision waveform capture
- Positioning.
  E1430A
  Other ADCs

E1437A P&D

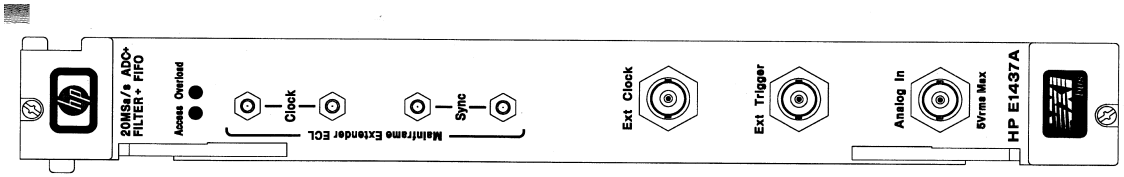


Price:

▸ E1437A	20 MSa/s ADC with filter and FIFO	$16,000 (US)
▸ opt UFC	16 MByte FIFO	$ 750 (US)
▸ opt ANC	32 MByte FIFO	$ 1,500 (US)
▸ opt ANE	64 MByte FIFO	$ 4,000 (US)

Delivery:

- December 1996



E1437A Sales Tools

Literature

- Product Overview Brochure
- Technical Specifications
- FTM

Demo

- Pre-programmed software

Product Notes

LSD web site:

http://bbs.lsid.hp.com:8080/html/products/e1437/prodinfo.html

E1437A ADC features

Sample Rate

- 20 MSa/sec and 20.48 MSa/sec

Input Bandwidth

- 8 MHz, selectable AAF *

Raw resolution

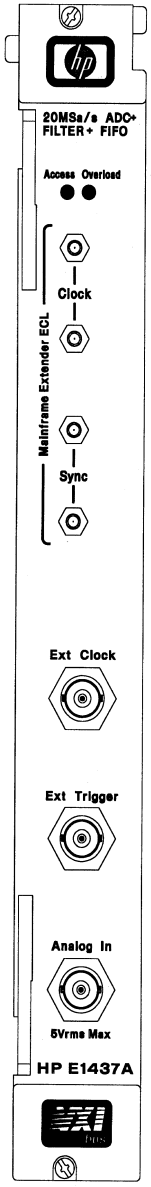
- 23 bits

Distortion

- -80 dBc or -110 dBfs

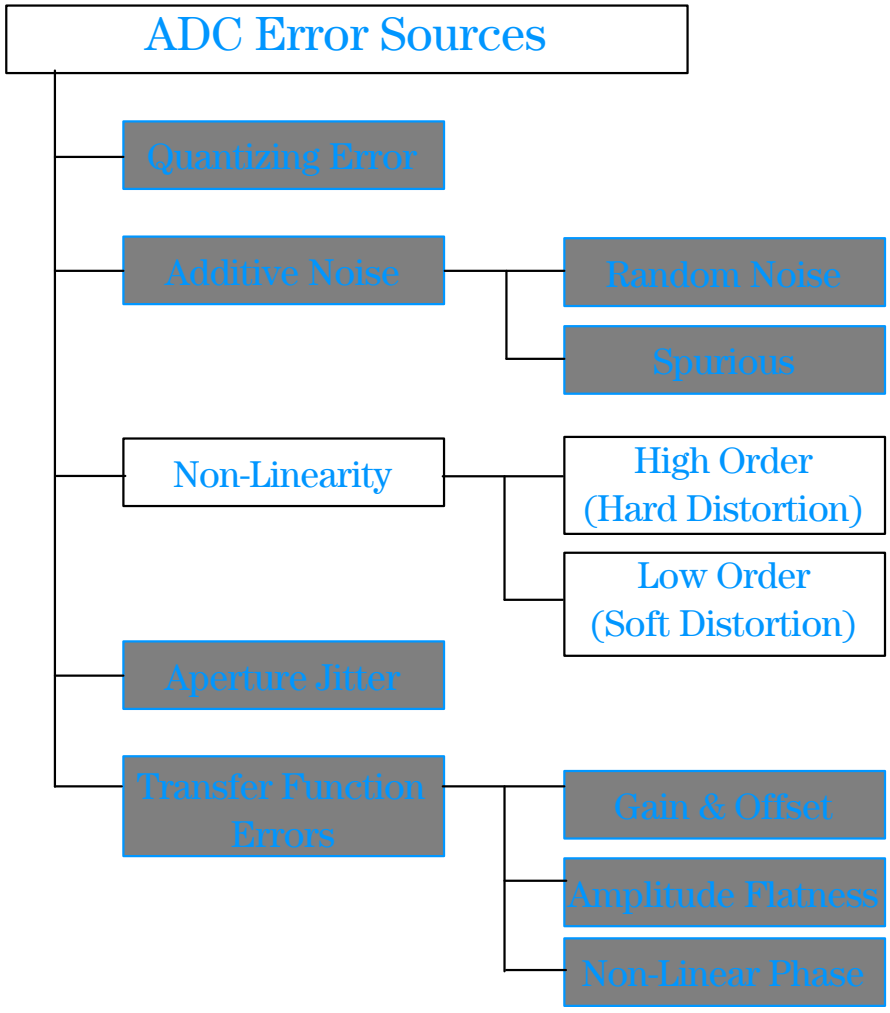
Noise

- -139 dBfs/Hz



* Anti-alias filter

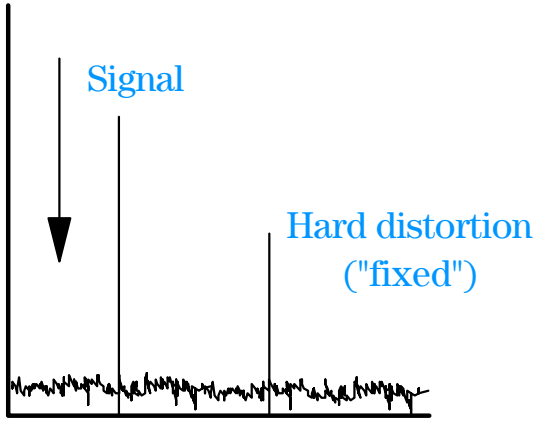
E1437A ADC



Solutions exist for:

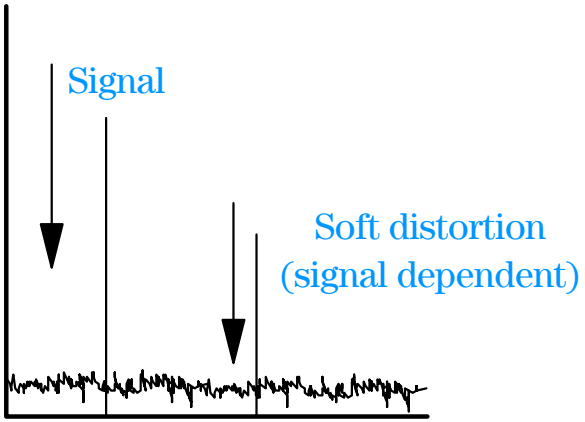
- Quantizing error = dithering
- Random noise = filter, average, FFT, etc.
- Spurious = design, layout
- Aperture jitter = low frequency
- Transfer function = correction tables

E1437A Distortion



High order (hard) distortion

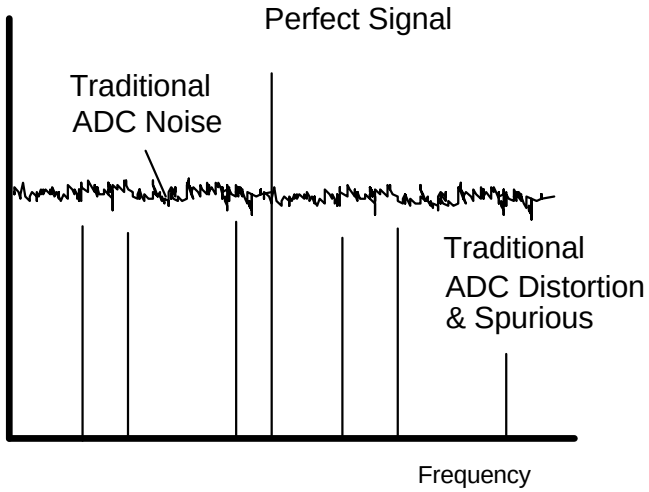
- Discrete
- Uncertain placement
- Numerous
- Fixed level (relatively)



Low order (soft) distortion

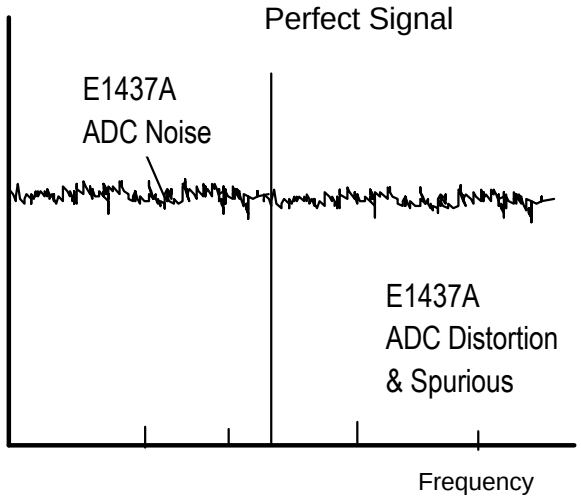
- Discrete
- Uncertain placement
- Less numerous
- Level changes with signal

E1437A Distortion Correction Algorithm



Traditional ADC

Distortion level comparable *to full bandwidth noise level*



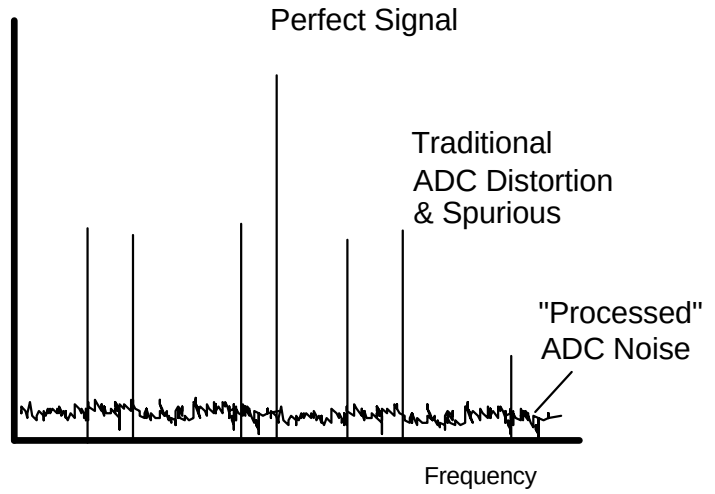
E1437A ADC

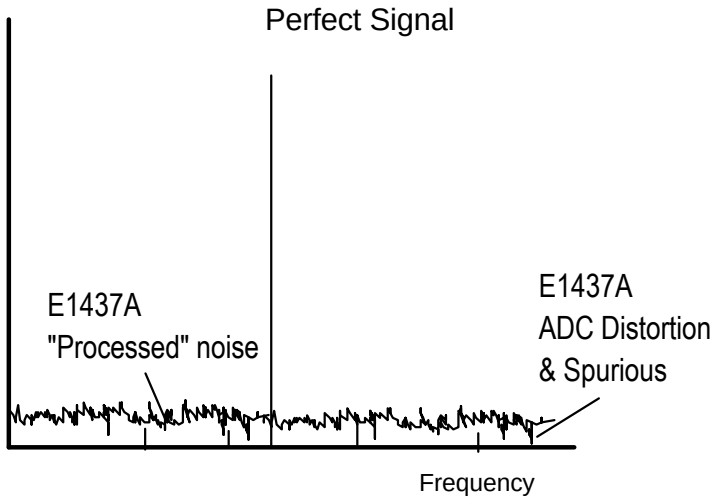
Distortion correction algorithm reduces level well below *the full bandwidth noise level*

Full bandwidth noise: -70 dBFS

Distortion Level: up to -110 dBFS

E1437A Linear Data & DSP

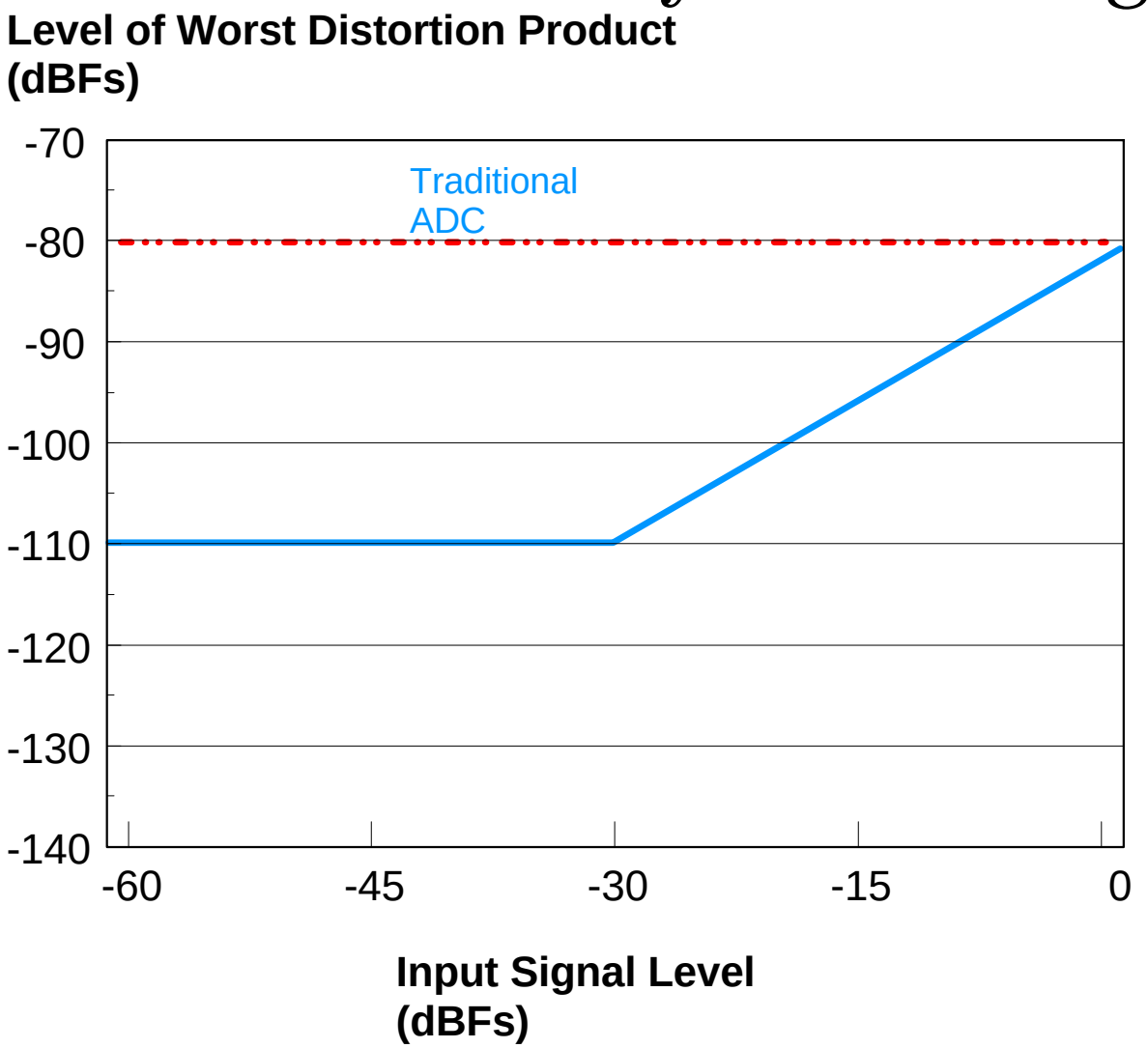




DSP can improve resolution

- Averaging ($1/\sqrt{N}$)
- Filtering
- FFT (10 log (#bins))

E1437A Dynamic Range



Distortion Products

-80 dBc or -110 dBfs *(13 -18 bits)*

E1437A ADC with DSP

"How many of those bits are real ?"

- "*10MHz Analog-to-Digital Converter with 110-dB Linearity*", Howard E. Hilton, HP Journal, October 1993, pg 105-112

- *A Digital Signal Processing Approach to Analog to Digital Converters*, Allen Alexopulos, http://bbs.lsid.hp.com:8080/html/products/e1430/prodinfo.htmo

E1437A Features

Filters

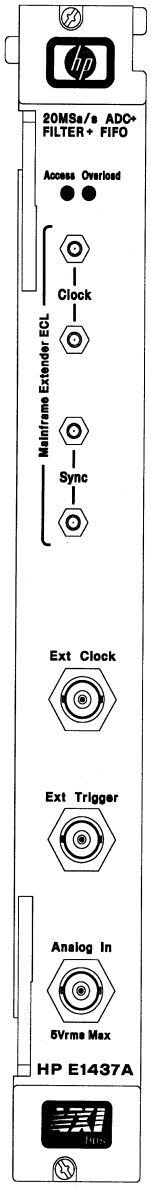
- 8 MHz to 0.95 Hz

Digital LO

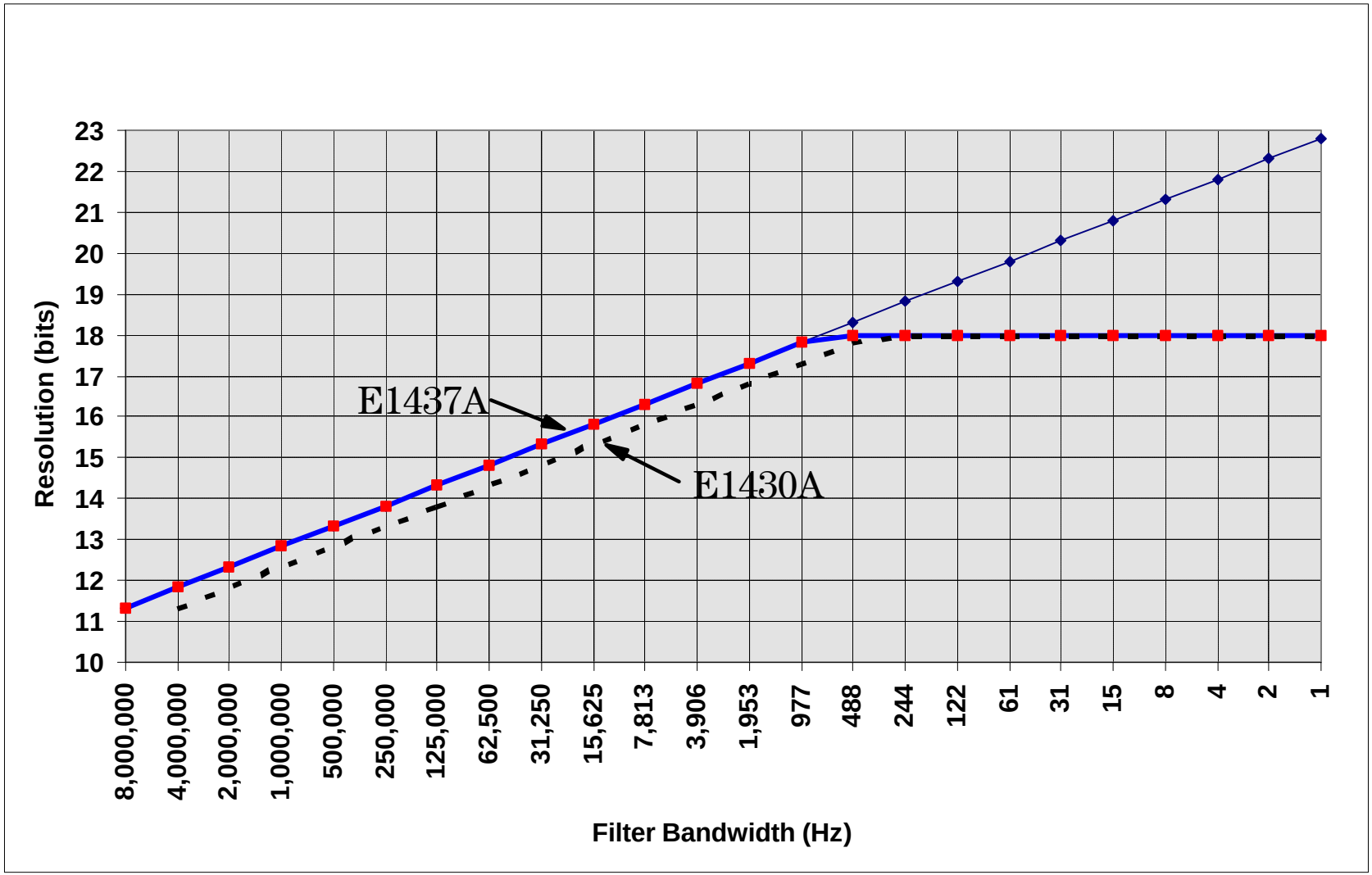
- 20 uHz resolution
- I/Q

FIFO

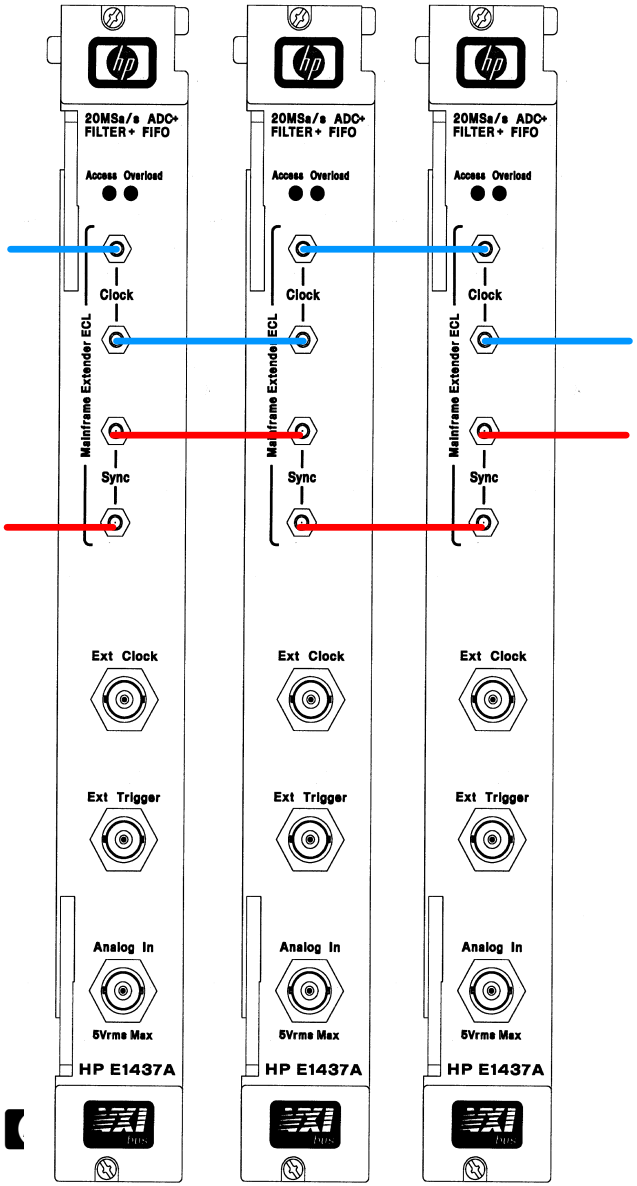
- Standard: 8 MB
- Optional: 16/32/64 MB



E1437A Bandwidth vs Resolution



E1437A Multi-channel features



External Clock

- Phase lock: 20 MHz/N, N<10
- Non-phase lock: DC to 20 MHz
- Signal type: Any > 150 mVrms

Clock Extend

- Front panel
- VXI

External Synch

- Synchronize filters

External Trigger

E1437A Programming

I/O

- Message
- VXI and Local Bus (60 MB/s)
- 16 or 32 bit
- Real, Real & Imaginary (I/Q)

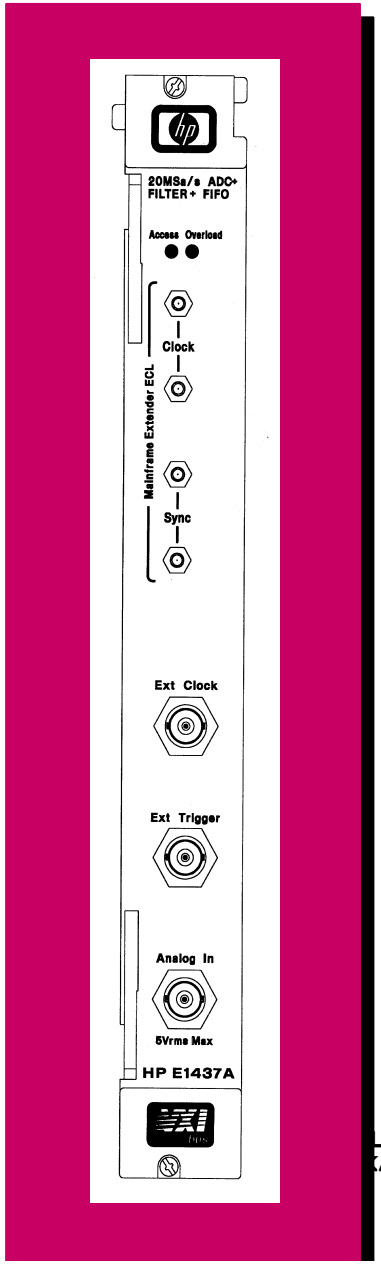
Software

- VXIplug&play compatible
- C library with source
- Demo Program (WIN, UX)
- Example programs
- DSP utilities

E1437A ADC with DSP

"What can you do with it?"

E1437A Applications

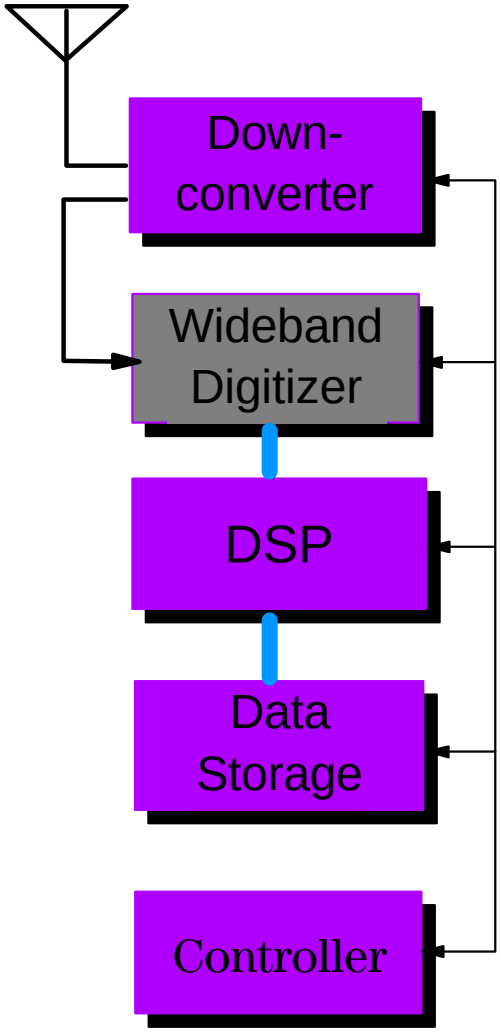


Aerospace Defense

- Modular receiver designers
  Dynamic range
- ATE designers (waveform capture)
  Resolve small changes on large signals

E1437A Digital receiver

(modular, software reconfigurable)



Tuner: HF to UHF, wideband IF

ADC: Digitize wideband IF, maximize tuner performance

DSP: channelize, classify, mod recognize, direction find, demodulate

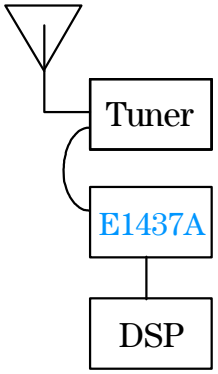
Storage: LAN/satellite buffer, signal archive

Controller: GUI

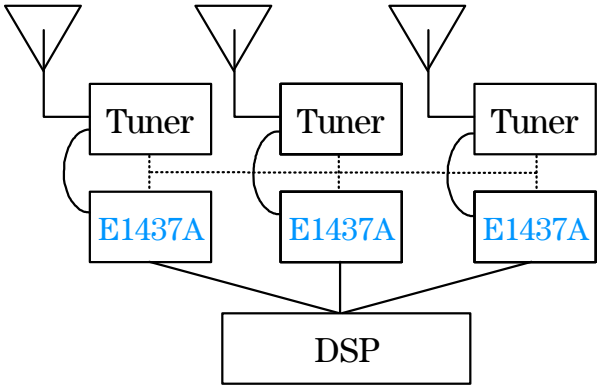
E1437A Modular receivers

Types of modular receivers

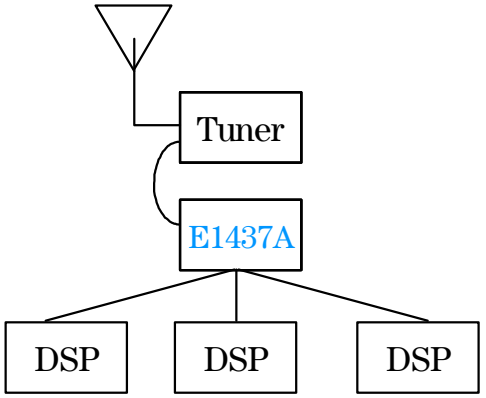
- Single wideband channel (search)
- Multi-wideband channels (direction find)
- Multi-narrowband channels (monitor)



- Search Rx

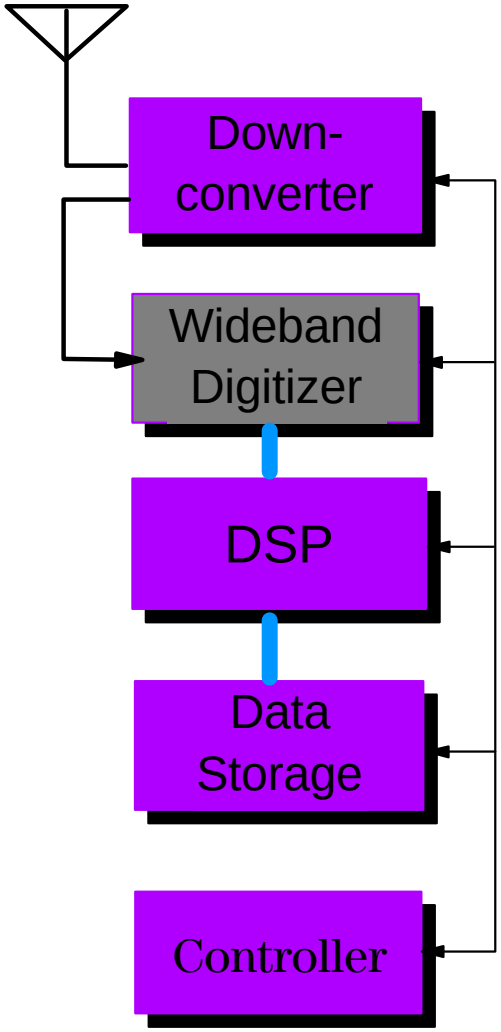


- Direction Find



- Monitor Rx

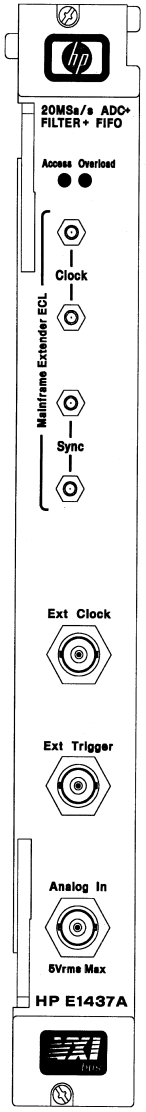
E1437A Modular, wideband, digital receiver



E1437A contribution

- SFDR (110 dBfs)
  ADC no longer limits Rx performance
- Filters
  Match BW to channel
  Reduce DSP load
- Digital LO
  I/Q outputs for digital demod
  Tune filter to signal
- Local Bus
  Fast enough for wideband data
- FIFO
  Buffer for block processes

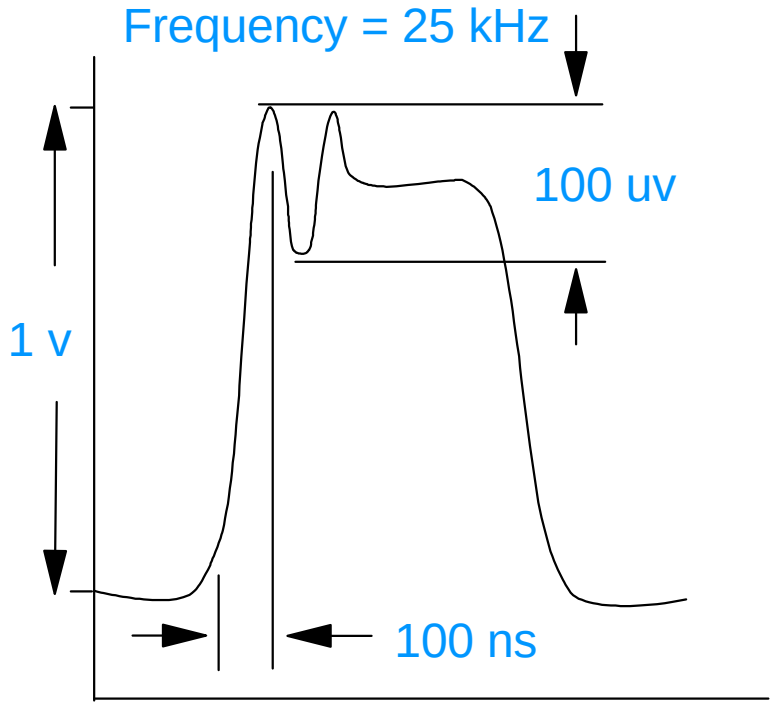
E1437A Waveform Capture



E1437A contribution

- High precision
  resolve small changes on large signals
- Programmable bandwidth
  limit noise, limit data
- Local bus
  keeps up with continuous sampling
- FIFO
  capture buffer

E1437A Waveform capture



E1437A in the Time Domain

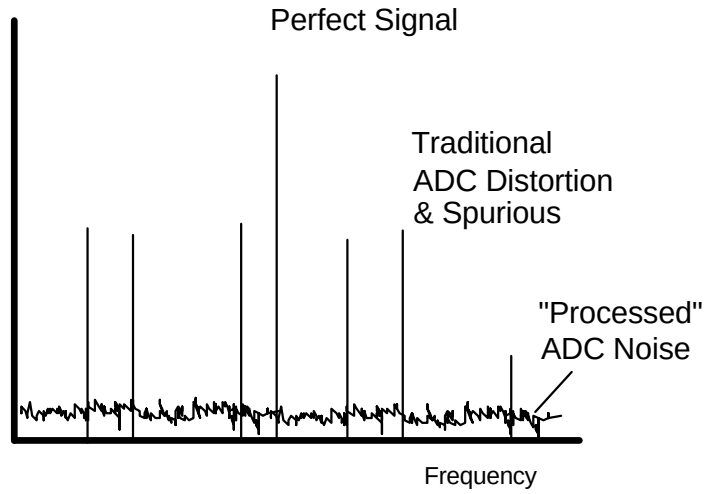
- Resolution: 100 ppm
  (-80 dBc = 20 log (V2/V1))
- Rise time: < 45ns (gaussian)
  (Rise time = 0.35 / 8 MHz)
- Repetitive signal
  (Filter, average, FFT)

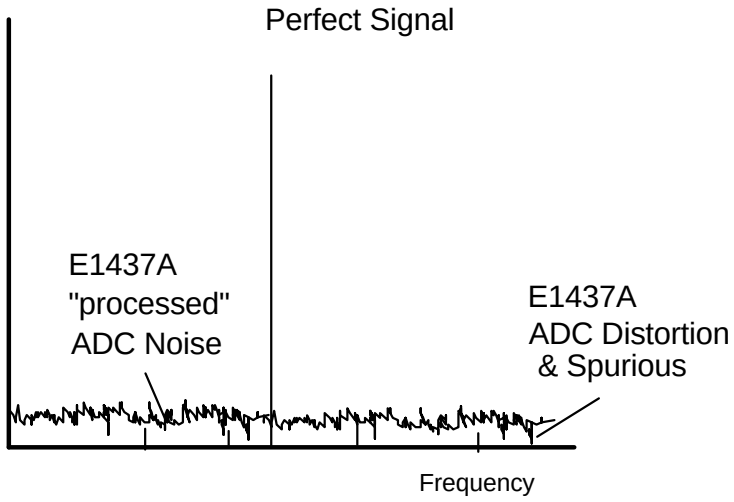
E1437A Comparison

Comparison Chart: HP 20 MSa/s ADCs + a DMM

	E1410A (DMM)	E1437A (ADC)	E1429A (ADC)	E1426A (Scope)
Sample Rate	1450 Sa/s (10 us)	20 MSa/s	20 MSa/s	20 MSa/s
Bandwidth	1 MHz (350 ns)	8 MHz (45 ns)	50 MHz (7 ns)	500 MHz (0.7 ns)
Bits	*11.5 (350 ppm)*	*23 (100 ppm)*	*12 (1400 ppm)*	*8 (1000 ppm)*
Channels	1	1	2	4
Input Z	1M	50	50/75/1M	50/1M
Memory	8 kBytes (est)	FIFO, 8/16/32/64MB	Segment, 512kB/chan	Shared, 64kB
Output Ports	VXI only	VXI, Local Bus	VXI, Local Bus	VXI only
Price	$3995	$16,000	$9,070	$8,110

E1437A Linear data & DSP

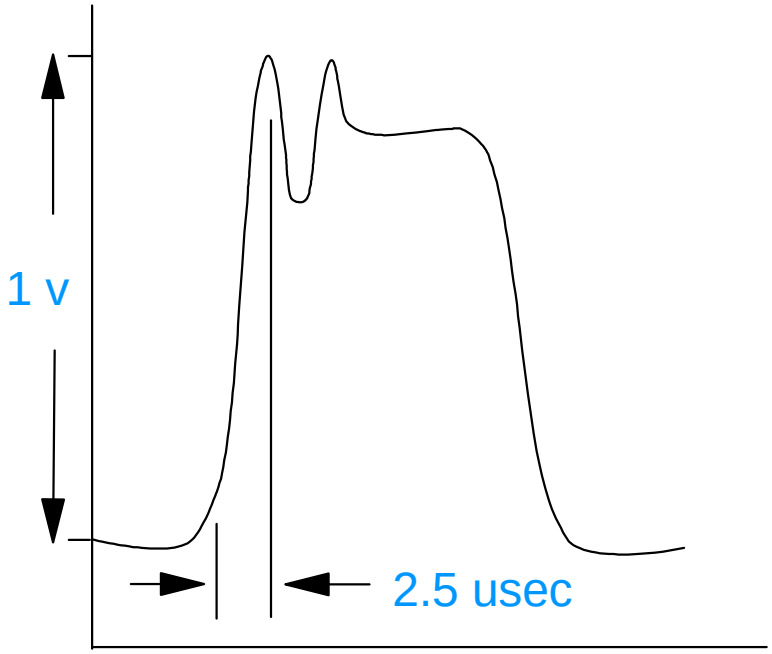




DSP improves resolution by reducing noise

- Averaging
- Filtering
- FFT

E1437A Time Domain with DSP



Averaging

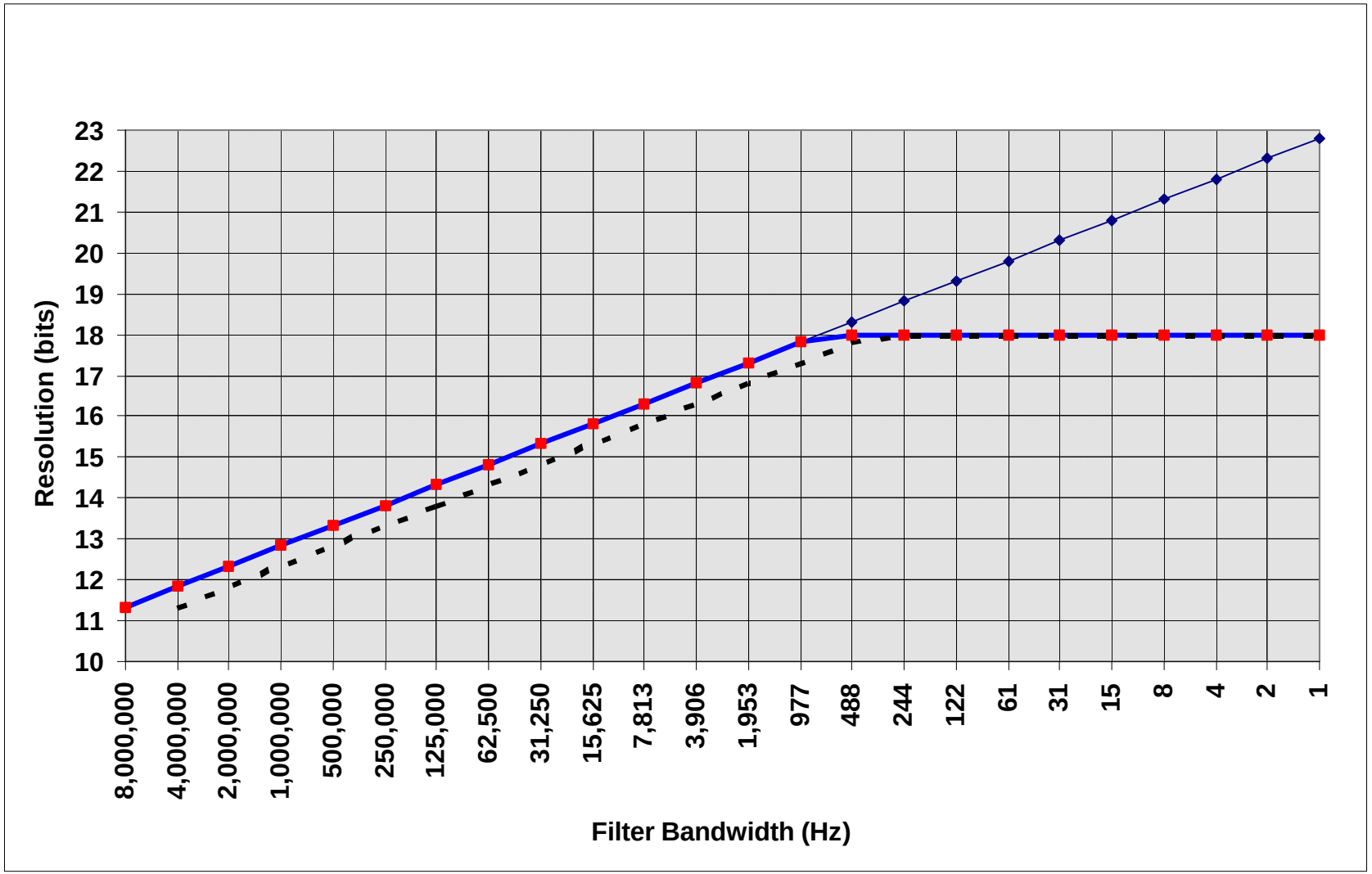
- Resolution improves as $1/\sqrt{N}$*
- Each 2x = 1 bit

Therefore:

- Need 3 bits
- 3 bits = 2^3 improvement
- N = 64

* N = number of averages

E1437A Bandwidth vs Resolution



E1437A Time Domain

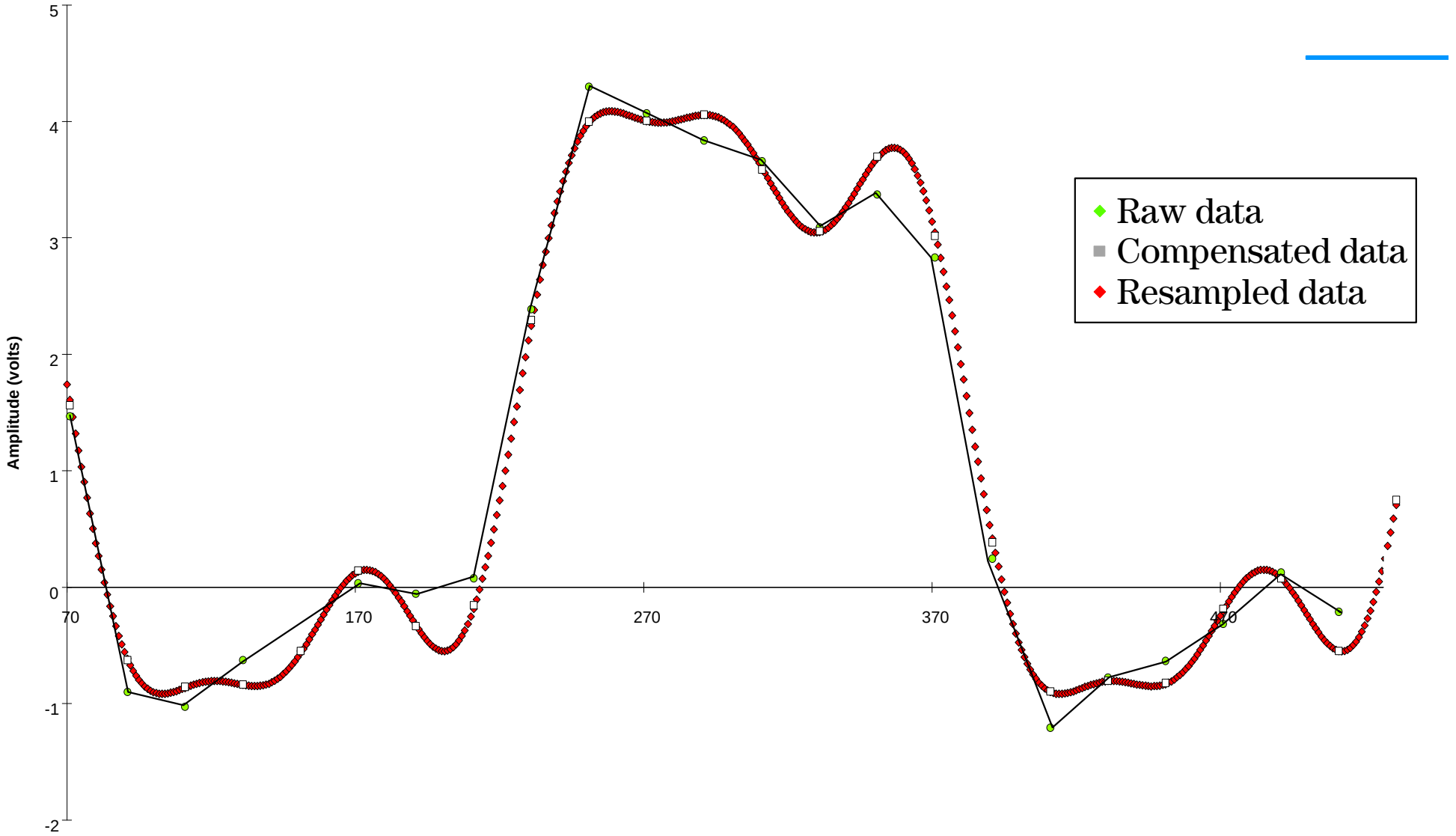
HP DSP: DSP algorithms

- DFT (real, complex, power)
- Window function
- Resample

Resample (curve fit algorithm)

- Plotting data
- Interpolating between sample points

Precision Waveform Capture



E1437A Positioning

	E1437A	E1430A
Sample rate	20 MSa/s	10 MSa/s
Input BW	8 MHz	4 MHz
Broadband Noise Floor	-70 dBfs (8 MHz)	-70 dBfs (4 MHz)
FIFO	8 MB (16/32/64 MB opt)	8 MB
External Clock	Phase lockable	Not phase lockable
Programming	VXIp&p, message	Register
Price	$16,000 (US)	$12,250 (US)

E1430A vs E1437A

- Sample rate
- Input bandwidth
- Noise floor
- FIFO
- External clock
- Programming
- Price

E1437A Comparison

Comparison: HP VXI 20 MSa/s digitizers

	E1410A (DMM)	E1437A (ADC)	E1429A (ADC)	E1426A (Scope)	E1428A (Scope)
Sample Rate	1450 Sa/s (10 us)	20 MSa/s	20 MSa/s	20 MSa/s	1 GSa/s
Bandwidth	1 MHz (350 ns)	8 MHz (45 ns)	50 MHz (7 ns)	500 MHz (0.7 ns)	250 MHz (1.4 ns)
Bits	11.5 (350 ppm)	23 (100 ppm)	12 (1400 ppm)	8 (1000 ppm)	8 (1000 ppm)
Channels	1	1	2	4	2
Input Z	1M	50	50/75/1M	50/1M	50/1M
Memory	8 kBytes (est)	FIFO, 8 - 64MB	Segment, 512kB/chan	Shared, 64kB	Shared, 1MB
Output Ports	VXI only	VXI, Local Bus	VXI, Local Bus	VXI only	VXI only
Price	$3995	$16,000	$9,070	$8,110	$13,200

E1437A Positioning

	E1413A	E1414A	E1433A	E1432A	E1431A	E1430A	E1437A	E1429A
Price	$6,020	$8,060	$11,700	$11,350	$8,160	$12,250	$16,000	$9,070
Sample Rate	100kSa/s	50 kSa/a	196 kSa/s	51.2 kSa/s	25.6 kSa/s	10 MSa/s	20 MSa/s	20 MSa/s
Bits	16	16	16	16	16	23	23	12
Channels	64	512	8	16	8	1	1	2
Input Z	100M		1M	1M	1M	50	50	50/75/1M
Memory	FIFO, 128kB	FIFO, 64kB	FIFO, 4/32MB	FIFO, 4/32MB	FIFO, 32kB/chan	FIFO, 8MB	FIFO, 8 - 64MB	Segment, 512kB/chan
Output Ports	VXI only	VXI only	VXI, Local Bus	VXI, Local Bus	VXI, Local Bus	VXI, Local Bus	VXI, Local Bus	VXI, Local Bus

Scanning A/D

Physical Meas
Data Acq

Digitizers

E1437A Complimentary products

Tuners

- WJ 9119 (HF)
- Raptor (VHF-UHF)

DSP

- E1485A

Data Storage

- E1488A
- E1562A/B/C