Editor's Note: PDF version of slides from Beam Instrumentation Workshop 2010, Santa Fe, NM

2010 Beam Instrumentation Workshop

BIW10 14th Beam Instrumentation Workshop May 2-6, 2010

Advanced Modular Oscilloscopes & Digitizers Optimized for Accelerator Applications

Chris Ziomek & Boyd Shaw
ZTEC Instruments

May 3, 2010

Agenda

1. ZTEC story
2. Accelerator instrumentation
3. Oscilloscope & digitizer applications
4. What did we miss?

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ZTEC Story

My Background

- 1986 – 1993: LANL
  - GTA, SSC, APS, Twente FEL, AFEL, …
  - Digital & Controls Engineer
  - LLRF Section Leader

- 1993 – 1996: SLAC
  - PEP-II, NLCTA
  - Microwave Engineer

- 1996 – present: ZTEC
  - Founder & President

Modular Instruments for ATE

PCI LOCAL BUS

PXI Systems Alliance

VXI bus

LXI

Key ATE Design Wins

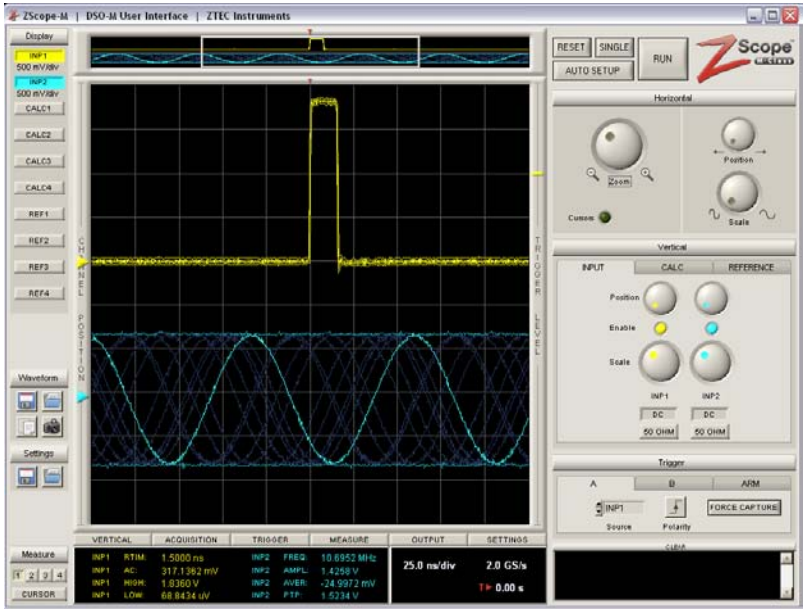
Military – Aerospace Test

- USN RTCASS
- USMC VIPER/T
- USAF TISS/TTIP
- USN ADEPT
- USN AVITS
- MoD Bowman Tester
- Honeywell F15J Tester
- BAE Korean F15 Tester
- Raytheon MK698 & Presidio Testers
- EADS-NA Test & Services Tester
- General Dynamics FOROPS/ELINT

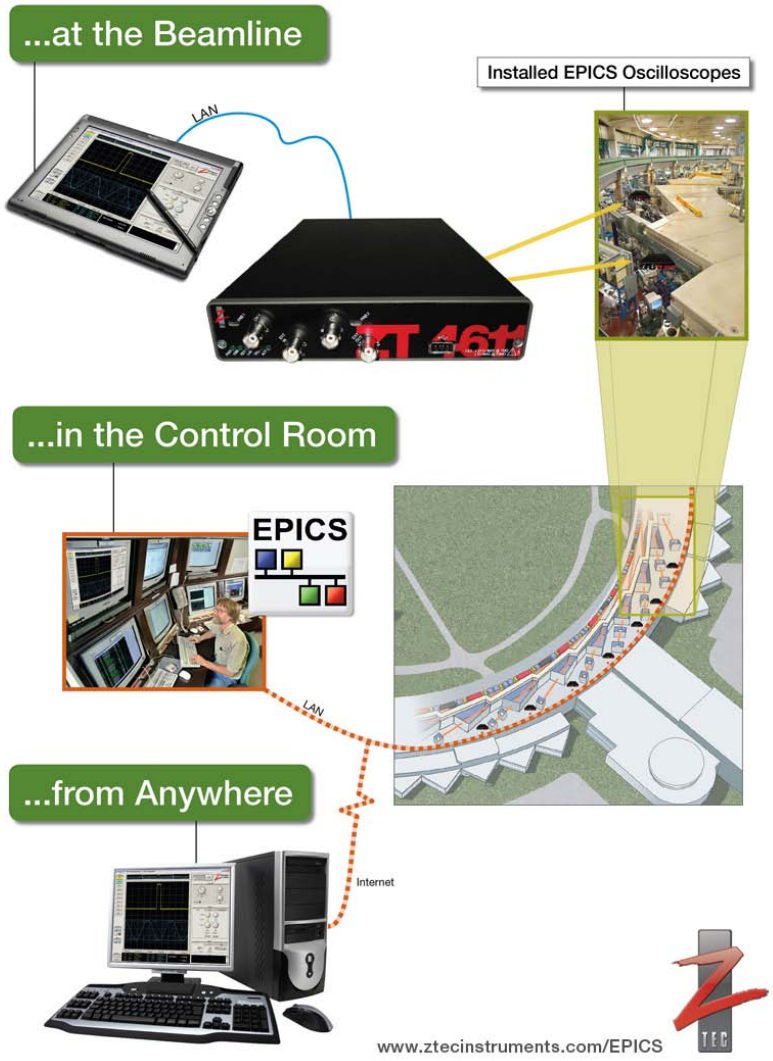
Semiconductor Parametric Test

- Keithley 4200
- Auriga AU4750

Portable Instruments for Remote Access



LXI



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Accelerator Instrumentation

Invention & Experimentation

- The mission of Particle Accelerator Laboratories is to push the technology envelope.
- What you do will not be done by private industry.
- You are early adopters of new technology.
- Invention and experimentation are your focus.

Historical Perspective

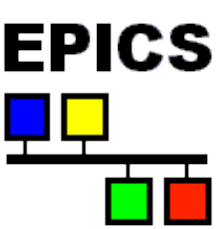
My experience as early adopter in 1980s

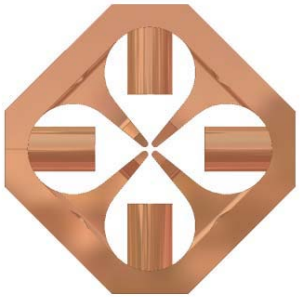
- VXI
- PLDs
- LabVIEW
- Quadrature-sampled IF
- Adaptive feedforward control
- DSP-based control

Historical Perspective

Other inventions

- EPICS, CA, EDM, MEDM, …
- RF amplifiers, cavities & electronics
- Timing & synchronization methods
- FGPA-based fast parallel processing
- Advanced magnetic materials and field sources
- Beam diagnostic techniques & instrumentation
- Beam damping control systems





32-channel Faraday-cup array

Present Day

Beam Instrumentation Requirements

- More dynamic range
- More analog bandwidth
- Many synchronized channels
- Lots of data
  - High download throughput or
  - On-board data processing & reduction
- Low-latency signal processing
- Ease of integration
- Open source software

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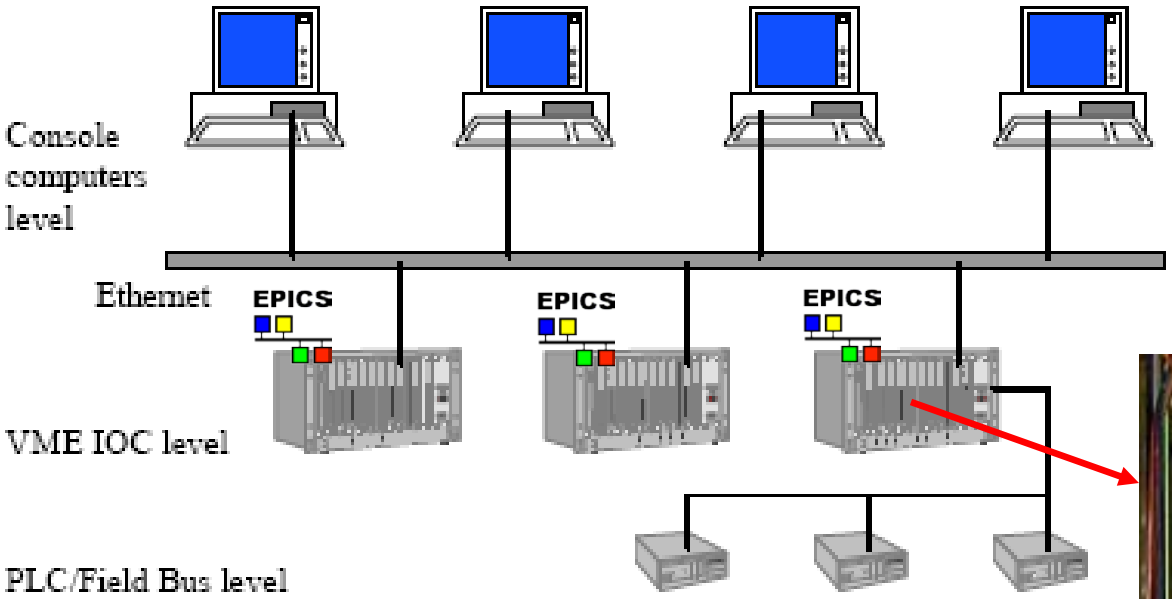
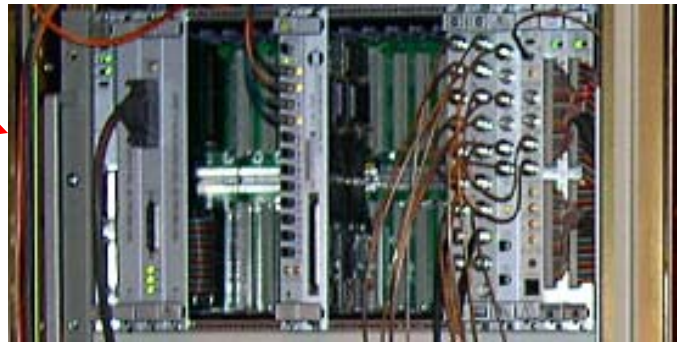
Oscilloscope & Digitizer Applications

Traditional Digitizer Implementations





- **Advantage**: high channel density
- **Disadvantages**: requires embedded controllers ($$), requires EPICS drivers and integration, shared-controller data bottleneck

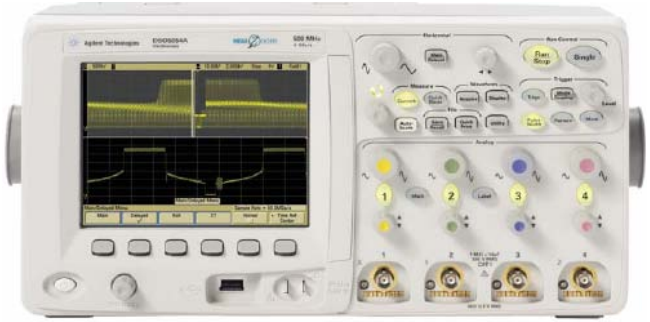
Traditional Oscilloscope Implementations

+

EPICS

(custom EPICS drivers for each oscilloscope model)

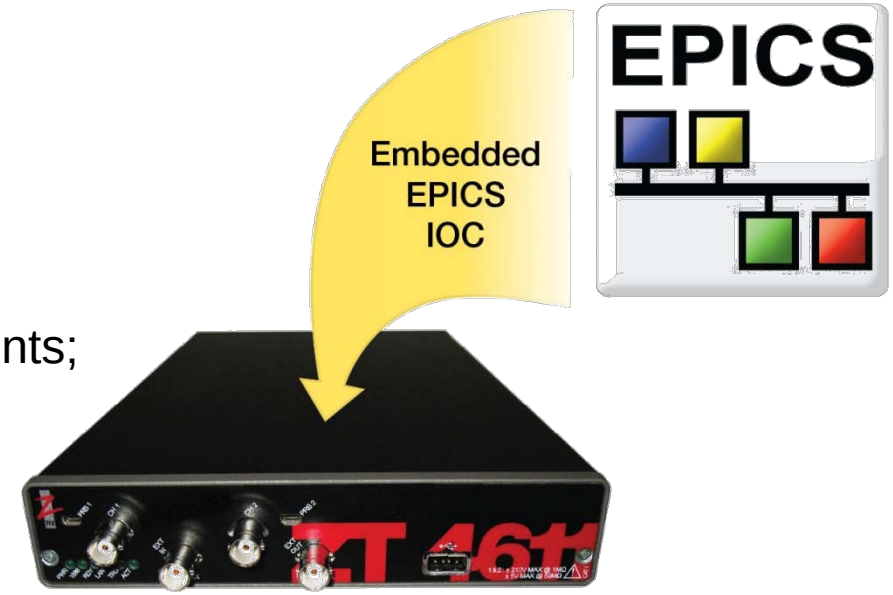
+



- **Advantage**: many benchtop oscilloscopes in use
- **Disadvantages**: requires PC controller ($), slow throughput, requires EPICS drivers and integration, models change often, low channel density

EPICS Oscilloscopes

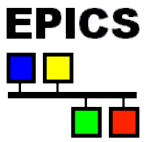
- Full Performance Oscilloscopes
  Benchtop oscilloscope capabilities;
  more functionality than digitizers
- Embedded EPICS IOC
  No external IOC required;
  no EPICS drivers or integration
- Fast Onboard Processing
  Fast waveform math and measurements;
  no IOC bottlenecks;
- Compact
  Up to 8 channels in 1U of rack space
- ZTEC Knowledge & Support
  Excellent product and EPICS knowledge
  and support.



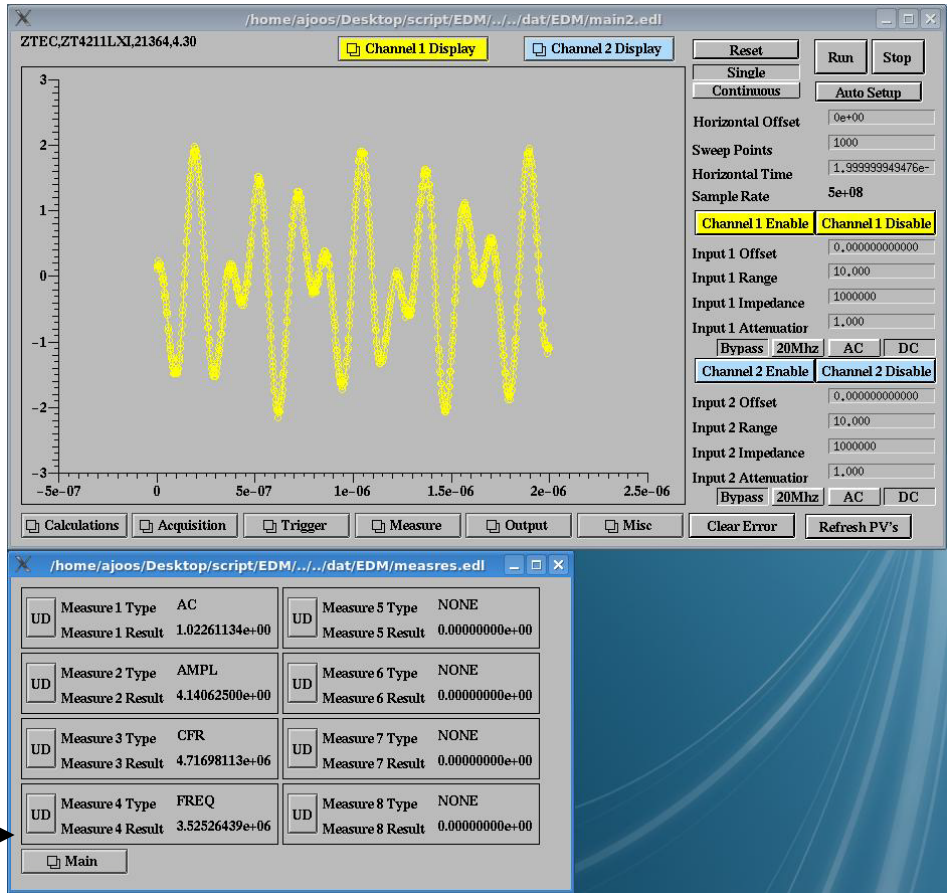
EPICS Oscilloscopes

Remote Monitoring & Control
in the control room & at the beamline

- Embedded IOC publishes ~900 PVs using Channel Access
- Responsive remote interface
- EDM & MEDM displays included
- Export data to MATLAB, LabVIEW, etc.



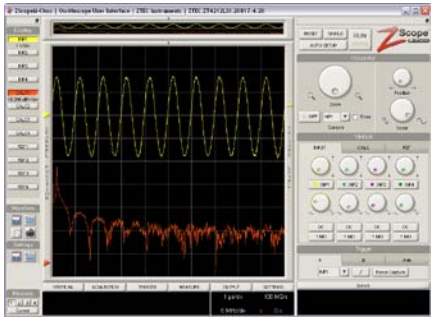
Channel Access



EDM and MEDM Control & Display Panels

Digitizers & Oscilloscopes

Series	Resolution	Maximum Sample Rate	Analog Bandwidth	Platform	Channels			Maximum Record Length
					PCI/PXI	VXI	LXI	
ZT4610	8 bit	4 GS/s	1 GHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	64M samples
ZT4210	8 bit	1 GS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	256M samples
ZT450	8 bit	2.5 GS/s	750 MHz	PCI, PXI, VXI	2	4	-	32M samples
	8 bit	2 GS/s	500 MHz	PCI, PXI, VXI	2	4	-	32M samples
	8 bit	1 GS/s	500 MHz	PCI, PXI, VXI	2	4	-	32M samples
ZT430	12 bit	200 MS/s	90 MHz	PCI, PXI, VXI	2	4	-	4M samples
ZT4420	12 bit	1 GS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	256M samples
ZT4430	13 bit	500 MS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	256M samples
ZT4440	14 bit	800 MS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	256M samples
ZT410	14 bit	500 MS/s	250 MHz	PCI, PXI, VXI	2	4	-	16M samples
	16 bit	400 MS/s	250 MHz	PCI, PXI, VXI	2	4	-	16M samples



Deployed at Facilities Around the World

US

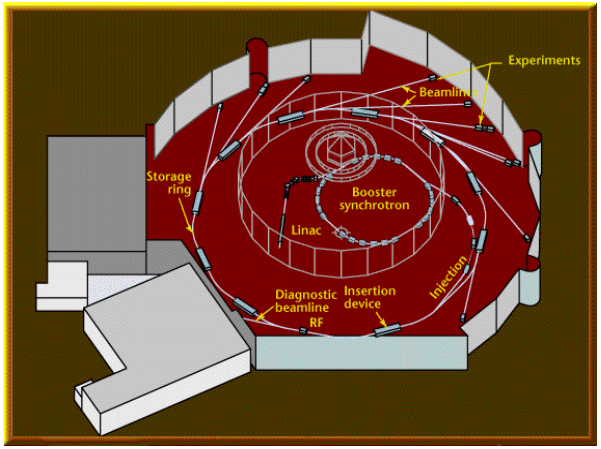
- Lawrence Berkeley
- SLAC
- Los Alamos
- Argonne
- Fermi
- Oak Ridge
- Jefferson Lab
- Lawrence Livermore
- Indiana University Cyclotron

International

- NSRRC - Taiwan
- BESSY, DESY - Germany
- Royal Halloway, Diamond Light - UK
- J-PARC - Japan
- CNRS - France
- CERN - Switzerland

Remote monitoring via EPICS

- Monitor a variety of signals around the synchrotron
  - DCCT and ICT
  - BPM
  - Kicker
  - Klystron
- Continuous capture of up to four 25,000 point waveforms on each instrument for 500 ms
- Download and re-arm in time to capture next waveform at 1Hz
- Multiple applications using same data
  - EDM for display
  - MATLAB for analysis



High Dynamic Range Digitizers

LANSCE
Los Alamos Neutron Science Center

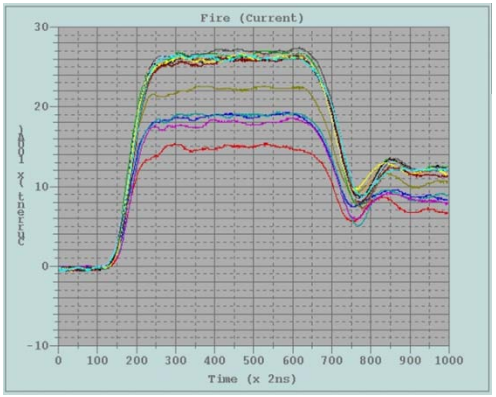
PXI digitizers for Chi-Nu experiment

- 14-bit, 400 MS/s digitizers with <0.35 mV RMS noise (2 Vpp range)
- Star trigger to tightly synchronize multiple cards and multiple chassis
- Fiducial adds analog marker to waveform for absolute time reference across system
- On-board data analysis and reduction

Machine Protection

Real-time monitoring of injection/extraction waveforms for machine protection

- Key Benefits of EPICS Oscilloscope Solution for SNS
  - **Embedded EPICS IOC**
    - Dedicated processor for EPICS/CA
  - **Fast Mask testing**
    - Test 4 channels at 60Hz
    - Displays last failed waveform while monitoring
    - Test entire or partial waveform
    - Fast protection OK pulse output
  - **Powers-on to specified instrument state**

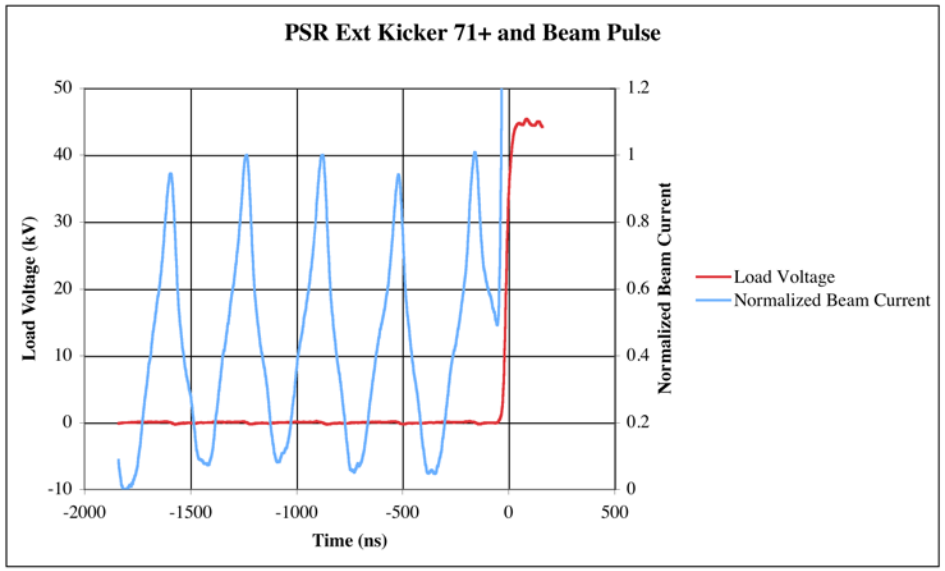


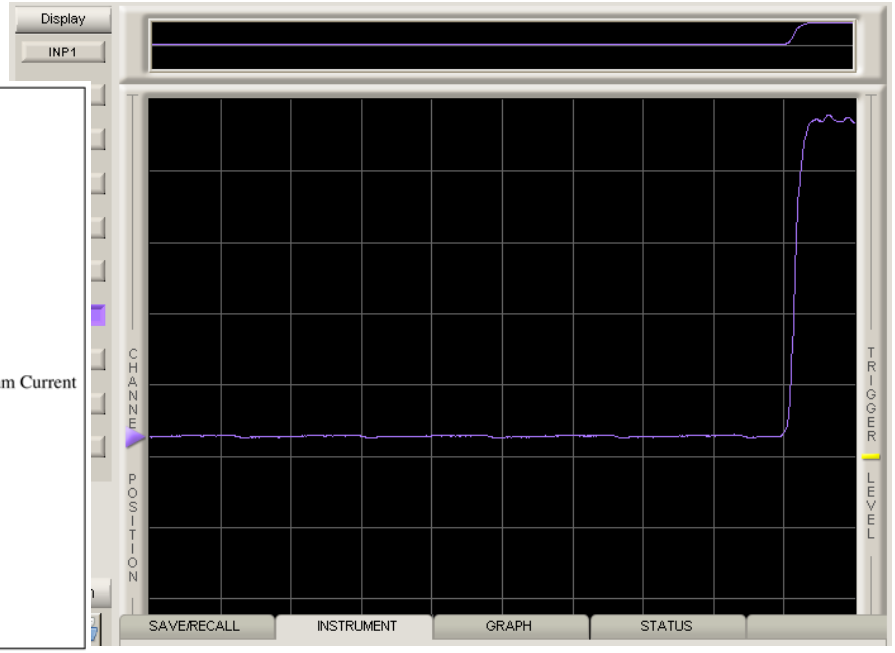
Remote monitoring via EPICS

LANSCE
Los Alamos Neutron Science Center

Extraction Kicker Monitor

- Replace bench oscilloscopes monitored via video feed
- Remote control via EPICS/EDM
- Adds quantitative analysis of waveforms

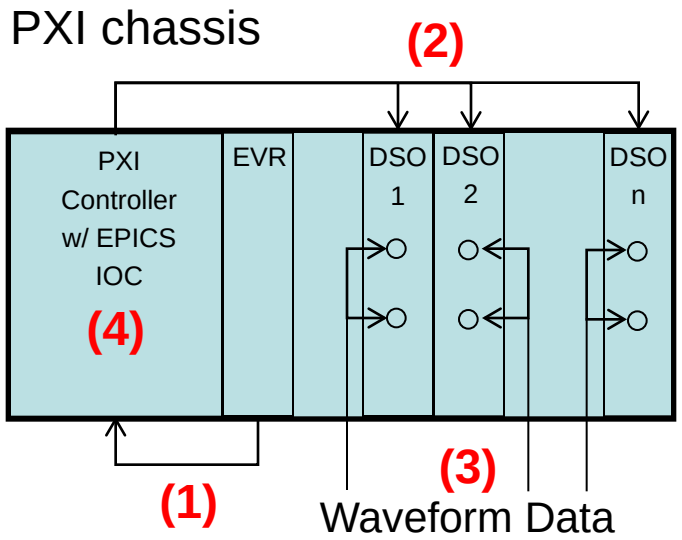




Beam Synchronous Acquisitions

ZTEC EPICS IOC in PXI

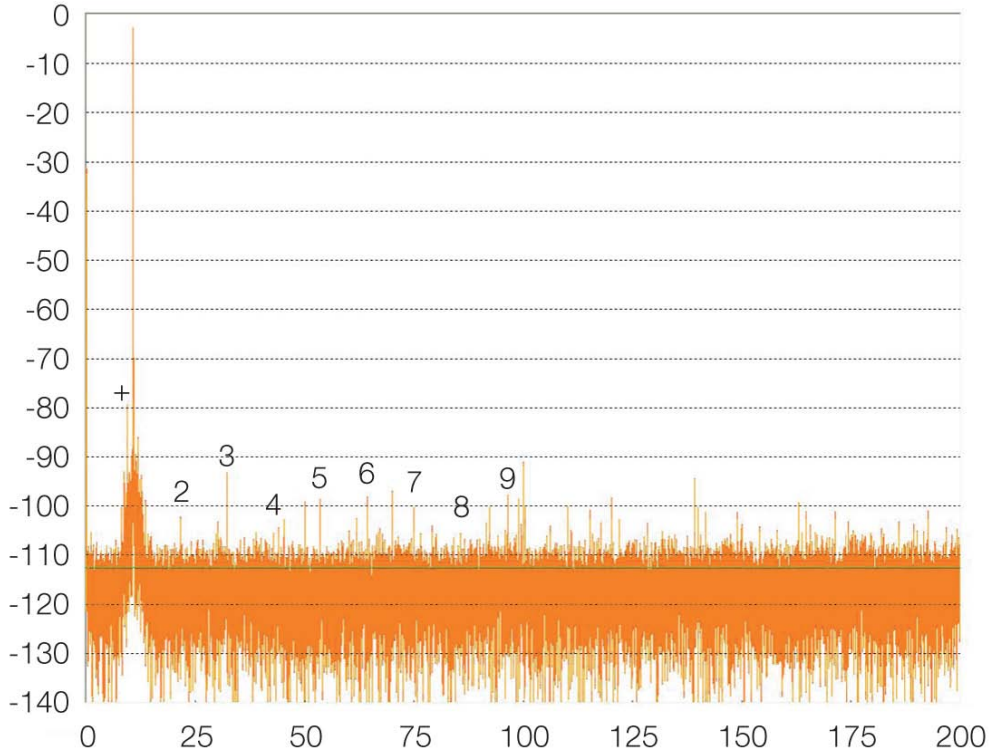
1. PXI controller or STAR card receives trigger from timing EVR card (Micro Research Finland)
2. ZTEC PXI oscilloscopes (DSO) receive trigger over backplane
3. Oscilloscopes capture waveforms and download waveform PVs to controller
4. Waveform PVs receive TSEL field from timing EVR card



* EPICS driver & service source code provides user customization

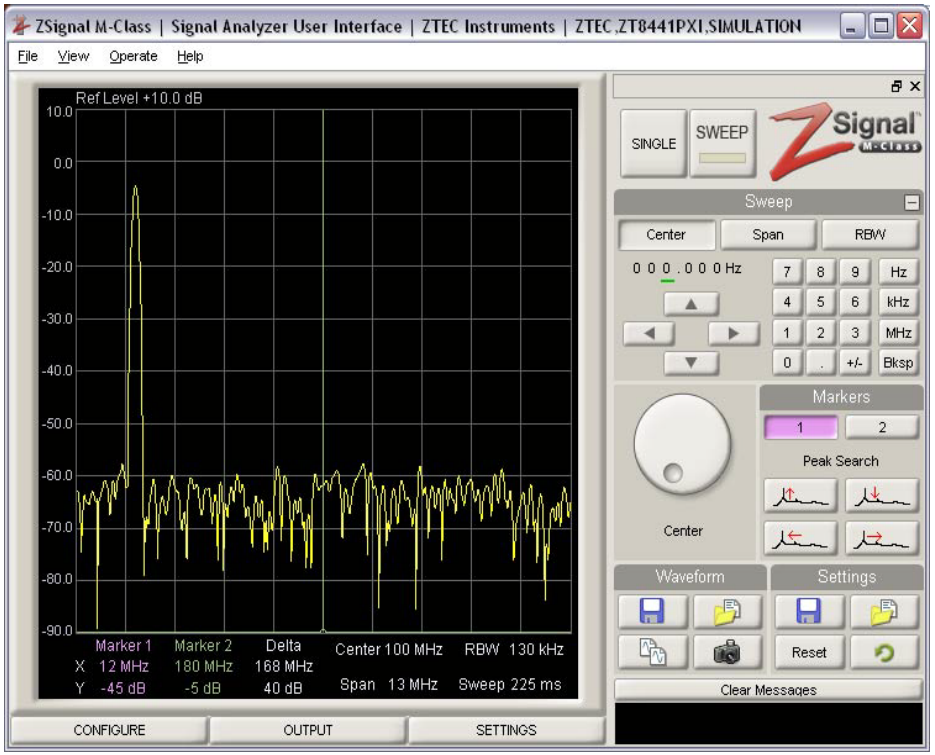
High Dynamic Range Digitizers

Product	Resolution	Maximum Sample Rate	Maximum Analog Bandwidth	Platform	Channels			Maximum Record Length
					PCI PXI	VXI	LXI	
ZT4420-DP Series	12 bit (488 µV)	500 MS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	128 MS
ZT4430-DP Series	13 bit (244 µV)	250 MS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	128 MS
ZT4440-DP Series	14 bit (122 µV)	400 MS/s	300 MHz	PCI, PXI, VXI, LXI	2	2 or 4	2 or 4	128 MS



Product	SNR	THD	SINAD	SFDR
ZT4420-DP Series	62.6 dBc	-86.7 dBc	62.5 dBc	81.5 dBc
ZT4430-DP Series	64.1 dBc	-86.7 dBc	64.0 dBc	81.5 dBc
ZT4440-DP Series	65.1 dBc	-86.7 dBc	65.0 dBc	81.5 dBc

Signal & Spectrum Analyzer



ZT8441 PXI RF/IF Digitizer

Frequency Range:
DC to 1GHz

Instantaneous IF Bandwidth:
100 Hz to 150 MHz

Real-Time Signal Processing:
FPGA-based digital down conversion (DDC)

Alias-Free Sample Rate:
100 S/s to 400 MS/s

ADC:
Dual 400 MS/s 14-bit

Spurious-Free Dynamic Range:
> 80 dBc

Inputs:
RF or Dual I/Q

Memory:
512 MiB or 128 MiSamples of I/Q data pairs

ZTEC Knowledge & Support

- ZTEC Instruments has the desire and the expertise to help with your accelerator instrumentation applications:
  - Application engineering support for EPICS
  - Quality and responsive pre-sales and post-sales support
  - Customized solutions to meet specific requirements

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What did we miss?

Conclusion

1. Particle Accelerator Laboratories are at the forefront of technology.

2. We strive to understand your needs & perspective.

3. We innovate to meet your objectives.

4. What did we miss? Challenge us.

Thank you!

For questions, or to setup an *remote EPICS oscilloscope demonstration*, please contact:

www.ztecinstruments.com

Chris Ziomek
(505) 924-0589
cziomek@ztec-inc.com

ZTEC Instruments
7715 Tiburon St. NE
Albuquerque, NM 87109
Phone: (505) 342-0132
Fax: (505) 342-0222