Advanced Modular Oscilloscopes & Digitizers
Optimized for Accelerator Applications

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ZTEC Instruments

May 3, 2010
Agenda

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

installed EPICS Oscilloscopes

...at the Beamline

EPICS

...in the Control Room

www.ztecinstruments.com/EPICS

...from Anywhere

ZTEC Instruments
EPICS Oscilloscopes for Particle Accelerators
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
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
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

- **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.
# Digitizers & Oscilloscopes

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

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

Extraction Kicker Monitor

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

![Graph showing PSR Ext Kicker 71+ and Beam Pulse](image)
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

<table>
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<tr>
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<th>Maximum Record Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZT4420-DP Series</td>
<td>12 bit (488 µV)</td>
<td>500 MS/s</td>
<td>300 MHz</td>
<td>PCI, PXI, VXI, LXI</td>
<td>2</td>
<td>2 or 4</td>
</tr>
<tr>
<td>ZT4430-DP Series</td>
<td>13 bit (244 µV)</td>
<td>250 MS/s</td>
<td>300 MHz</td>
<td>PCI, PXI, VXI, LXI</td>
<td>2</td>
<td>2 or 4</td>
</tr>
<tr>
<td>ZT4440-DP Series</td>
<td>14 bit (122 µV)</td>
<td>400 MS/s</td>
<td>300 MHz</td>
<td>PCI, PXI, VXI, LXI</td>
<td>2</td>
<td>2 or 4</td>
</tr>
</tbody>
</table>

**ZTEC Instruments**
EPICS Oscilloscopes for Particle Accelerators
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
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.

Thank you!

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

www.ztecinstruments.com

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