Low Level RF and Instrumentation Platform Requirements

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AD/RF Fermilab

VXI Controller Hardware

Technologies of interest:

-Multi-channel ADCs

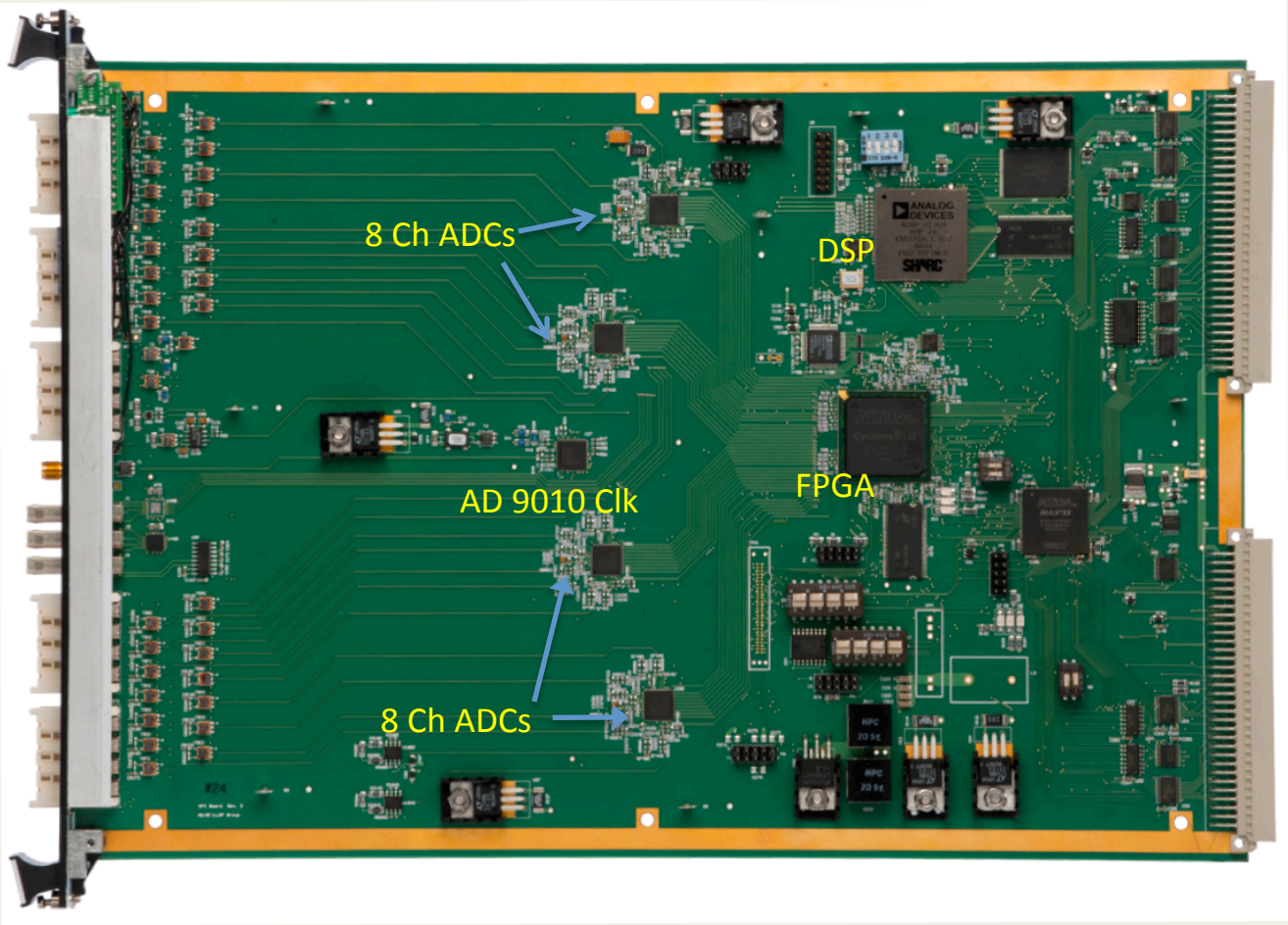
-Low Voltage Differential Signaling (LVDS) high speed serial connections

-Differential IF signal paths

-8 channel coax connectors

-Shielded enclosure

-Low cost per channel

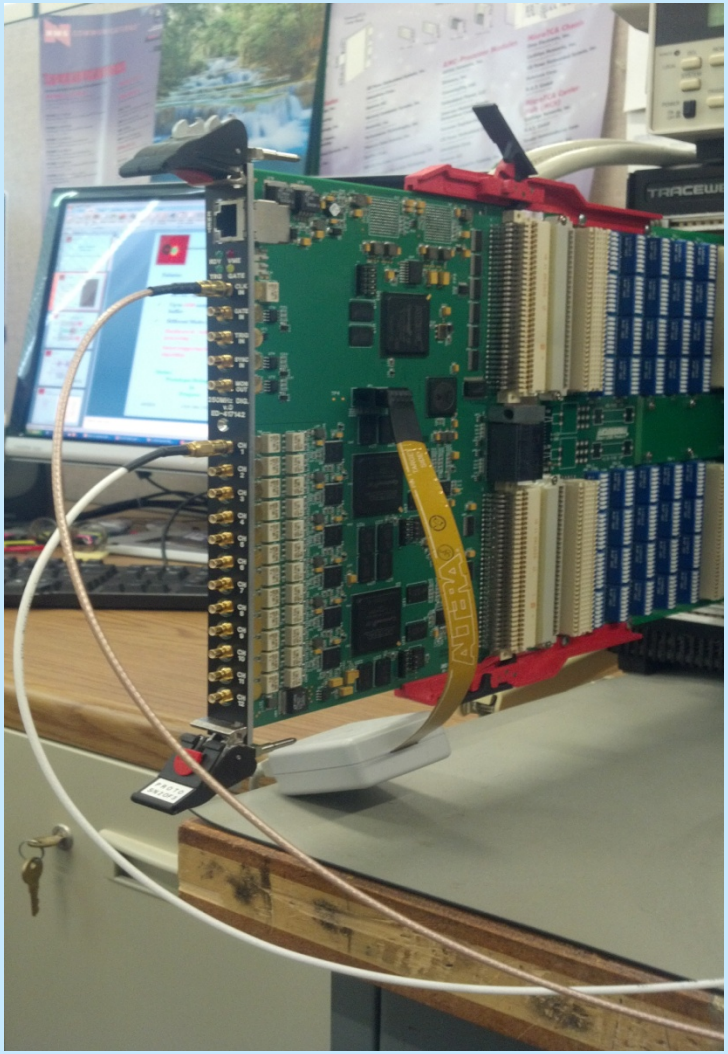


Futures:

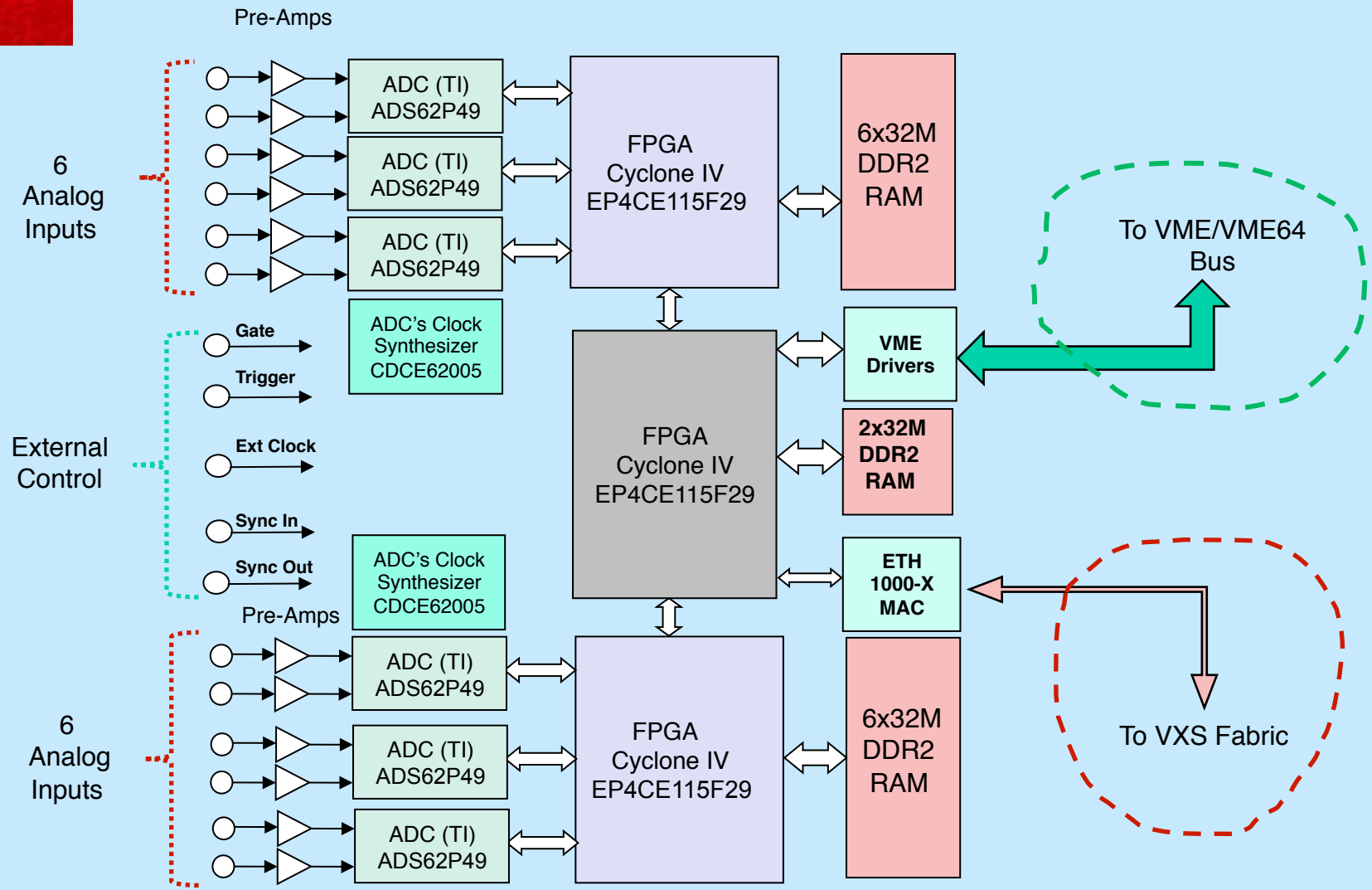
- ✓ *12 channels, 14 bit* at 6U VME Board
- ✓ DC/AC- up to *250MSPS* Operation
- ✓ Up to *64M* sample per channel DDR2 buffer
- ✓ Different Modes (12) of Operation
- ✓ Hardware & Software onboard data processing
- ✓ Smart triggering based on FPGA algorithm

Status:

Prototypes Debugging in Progress

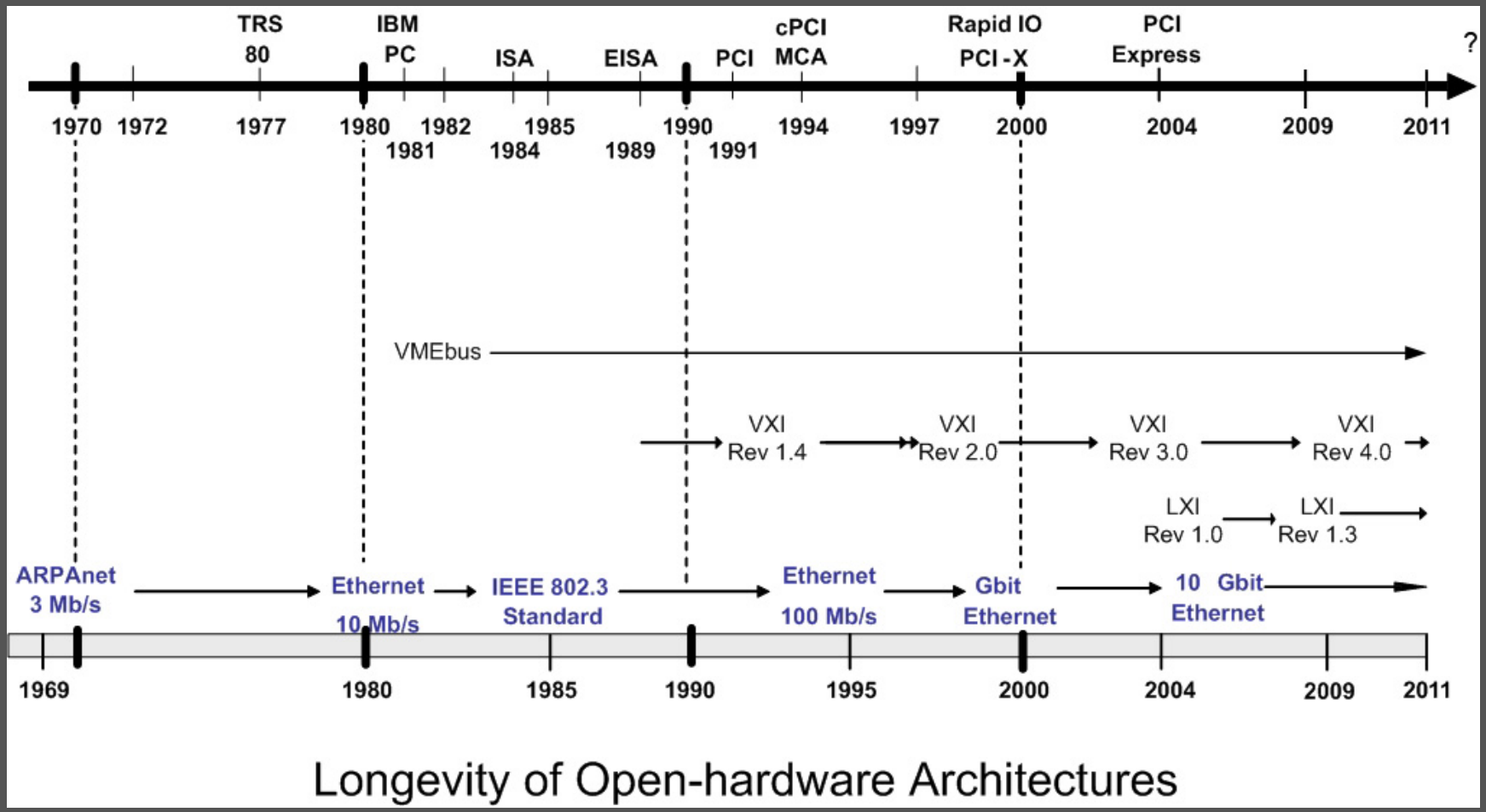


BLOCK DIAGRAM



Desirable Attributes of an Instrumentation Platform for LLRF

- Large (VME or VXI size)
  - board area
  - Front and or rear panel space
  - Pitch for tall components
- Cooling, RFI shielding
- Trigger, interrupt structure, distributed clock
- Low noise environment (attowatts/Hz, femtoseconds)
  - analog and digital voltage power supplies
- High speed (Gbits/s), low noise digital communications to an in system processor
- A common processor supported by our Controls Network
- Reliable operation and easy repair
- Long Life of platform



Ethernet and VME are not going away anytime soon

Technology Choices

- Complete “Turnkey” Systems
- VME, VXI 4.0
- Open VPX
- ACTA, MicroTCA, MicroTCA for Physics
- PXI, Compact PCI
- Stand alone modules
- “Pizza box” or rack chassis

A Benchmark System

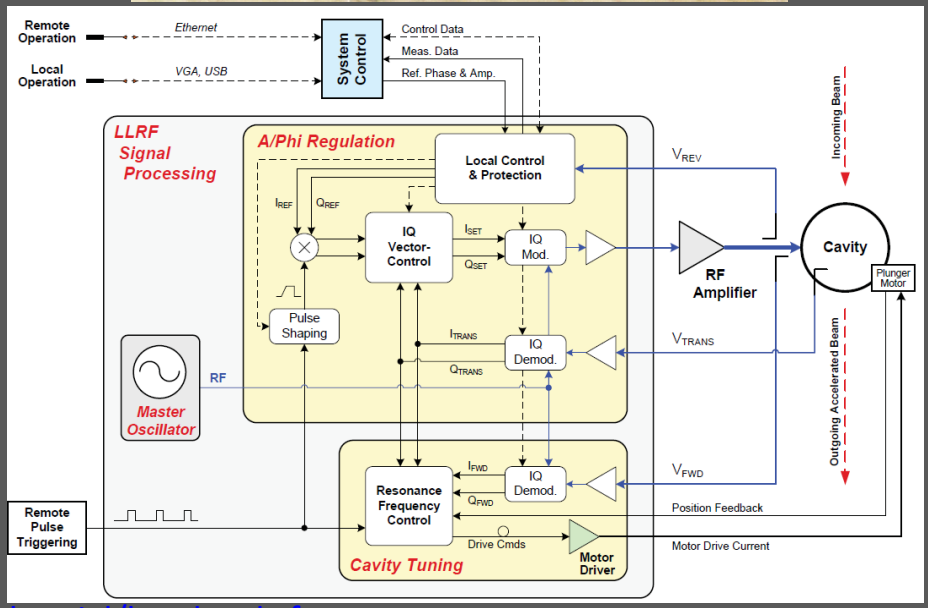
- 8 RF inputs.
- 1 RF output.
- Processor.
- Chassis.
- Some capability of “real time” processing.

Thomson

Low Level RF (LLRF) Systems

Availability, Reliability, and Long Lifetime

Thomson Digital LLRF systems are instrumental in accomplishing amplitude and phase control in the electromagnetic cavities of particle accelerators. They keep amplifiers tuned to the correct frequency no matter how the cavities drift, thus ensuring that particles accelerate and not slow down.



http://www.thomson-broadcast.com/products/scientific-industrial/low-level-rf-systems

Instrumentation Technologies

Libera LLRF stabilizes the accelerator's RF field by applying real-time digital feedback and feed - forward.

- **High reliability with excellent performance**
- superior stability tested on high performance machines: amplitude stability RMS < 0.0001; phase stability RMS < 0.01 º at 1 MHz measurement bandwidth

- **Configurable to specific accelerator's needs**
- based on µTCA and AMC standards
- modular and configurable building blocks
- playground for RF specialists: functional solution is enhanced by modules that enable the RF specialists to further tailor and optimize the system
- up to 12 GHz RF frequencies supported
- pulsed and CW modes of operation

- **Small form factor**
- complete powerful control system is formed in standard 19˝ 2U box

- **Support**
- experienced support from Instrumentation Technologies team

- **Easy to use**
- comprehensive Graphical User Interface (GUI) provides crucial information and commands
-
- **Easy to be integrated into Control System**
- digital system
- network-attached device
- EPICS ready
- High-level Application Programming Interface (API) for the integration in other Control Systems

http://www.i-tech.si/accelerators-instrumentation/libera-llrf/modular-building-blocks_10

Lyrtech RD

ADAC250 FPGA mezzanine card (FMC)

Perseus 601X advanced mezzanine card (AMC) with Virtex-6 FPGA

µDigitizer: 1x Perseus 601x + 1x FMC IO card, uses 1x AMC slot

http://lyrtechrd.com/en/products/view/+udigitizer

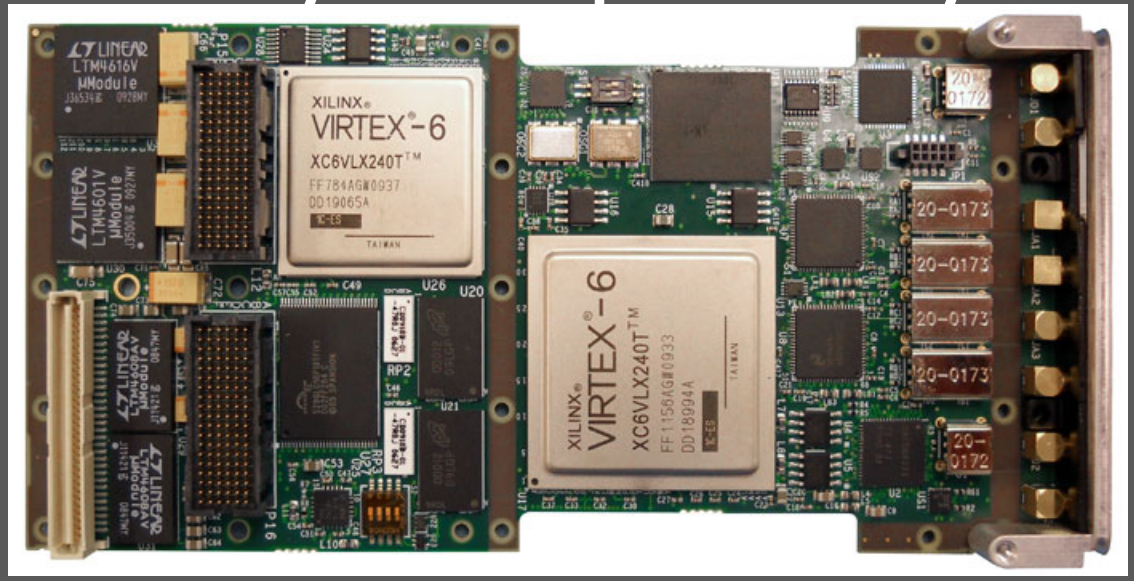
Agilent

Compact PCI

- U1066A-001 Dual-channel,
- 100 MHz/300 MHz, 400MS/s,
- Acqiris DC440
- $11,180.56 ea. x 4 =
- $44,722.24 for 8 input channels

http://www.home.agilent.com/agilent/product.jspx?id=1184900&pid=1184900&lc=eng&ct=PRODUCT&cc=US

Mercury Computer Systems



Open VPX

- DCM-V6-4R160-1T1000-XMC, 4 in, 1 out XMC with V6 FPGA : $18,000 each
- Processor : $10,000 each
- Chassis: $10,000 to $30,000 for commercial grade, more for rugged

Total: $56,000 to $76,000 for 8 input and 2 output channels in chassis.

http://www.mc.com/products/microwave-rf/digital-receivers-and-tuners/

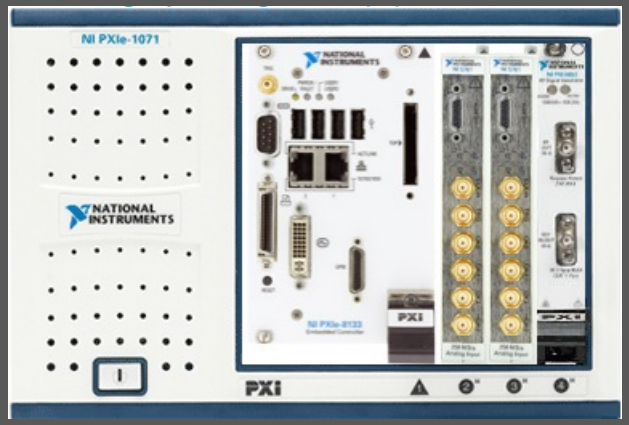
Ztec

ZT8441 digitizer

- IF Digitizer
- Platform: VXI, PCI, PXI and LXI
- Resolution: 16 bit
- Max Analog Bandwidth: 1 GHz
- Max Sample Rate: 400 MS/s
- Real Time Sig. Processing: 100 Hz to 160 MHz FPGA based DDC w/ fractional resampling
- Channel: IF or Dual IQ
- Max Record Length: 512 MB

http://www.ztecinstruments.com/products/rf-test-equipment/series/ZT8440/

National Instruments



National Instruments

- NI PXIe-8133 Core i7-820QM 1.73 GHz Controller, Win 7 (32-Bit), $5,649
- NI 5761 250 MS/s, Digitizer Adapter Module for NI FlexRIO, 2 x $5,149
- NI PXIe-7962R NI FlexRIO FPGA Module (Virtex-5 SX50T, 512MB RAM), 2 x $6,199
- NI PXI-5650 1.3 GHz RF Signal Generators and CW Source, $3,199
- NI PXIe-1071, 4-Slot 3U PXI Express Chassis, $999

Total Price: $ 34,913

http://www.ni.com/pxi/

ThinkRF

ThinkRF WSA4000-108
RF Receiver/Digitizer/Analyzer
Tuning and Bandwidth
Frequency range ..... 100 kHz to 10 GHz
Tuning resolution ..... 1 Hz
Tuning speed ..... < 500 µs
Maximum instantaneous bandwidth ..... 100 MHz
http://www.thinkrf.com/wsa4000.html

RFspace

$3000

SPECIFICATIONS

Frequency Range: 10 KHz - 32 MHz *

Digital Down Converter: Xilinx FPGA

Synchronization : Optional 10 MHz reference input

PC Interface: Ethernet 100 base-T (UDP/TCP/IP)

Filters: 115+ dB 80% alias free BW (Single DDC)

Output IQ Sample Rate: 12.5 KHz to 2 MHz

Output I/Q Bandwidth: 10 KHz to 1.60 MHz *NEW* DDC Flatness: <0.5 dB

Dynamic Range: 105 dB

http://rfspace.com/RFSPACE/NetSDR.html

RFspace

$525

Specifications

- Frequency Range: 500Hz to 30 MHz in 1 Hz steps. (Usable down to 100 Hz)
- Input Impedance: 50 Ohms
- Clipping RF level (Max Gain): -9dBm (Typ)
- Maximum Frequency display BW: 190 KHz
- Sampling Rate: 66.666 MHz
- Sends 16 bits of I/Q Data to the PC via USB. No messy soundcard cables required.

http://rfspace.com/RFSPACE/SDR-IQ.html

Acquitek

ADQ 114, 14-bit resolution, 800 MSPS, 64 MSample of on board memory.

The card has two host interfaces, one high speed USB 2.0 port and an integrated PXI Express bus for high speed data transfer.

Input bandwidth of up to 720 MHz

Two Virtex5 FPGAs (SX50T and LX30T) to give a flexible solution for implementation of customized functionality.

The ADQ114 is delivered either as a single card for implementation in custom designs or as a stand alone DAQ in a robust aluminum case

http://www.acquitek.com/adq114/data-acquisition-card.html

Midwest Microwave Solutions Inc

30-3000MHz

600MHz – 6GHz Dual Channel Phase Coherent RF Digitizer

MSDD-3000-pps - 0.82” x 3” x 6”

- **Miniature VHF/UHF Digitizer with Precision Time Tagged Data Outputs**
- 30-3000MHz, 9-16V, 1pps and 10MHz inputs, Time tagged data outputs, 10/100/1000 Ethernet controlled, Tracking and fixed filter preselector, 12dB NF, +5dBm IP3, 20MHz digitized IF BW, 14bit ADC, TMS320C6455 DSP, Altera Cyclone II FPGA, On-board DDR and Flash memory, <100Hz DDC tuning, 500usec tuning speed, 80dB typical Image/IF rejection, Externally flash-able DSP and FPGA, 12W typical (code dependent)

http://mms-rf.com/rf-digitizers.html

Universal Software Radio Peripheral

- **NI USRP: Software Defined Radio Platform**
  - Tunable center frequency from 50 MHz to 2.2 GHz covering FM radio, GPS, GSM, radar, and ISM bands
  - Up to 20 MHz baseband I/Q bandwidth streaming at 25 MS/s for host-based processing with NI LabVIEW

$3200 ea.
http://www.ni.com/usrp/

Pizza Box

- Evolution from AP2 BPMs, Pbar RF Phase Hop boards, Debuncher BPMs and new Linac BPMs.
- Present technology provides four RF inputs, one DAC out, LVDS bus, Ethernet, USB and power regulation for $250 per channel.
- Moving to Pizza Box format looks to bring the cost down to $150 per input channel (if you need 24 channels in one place).
- Development effort is roughly 1/3 in hardware design and board layout, and 2/3 in firmware. With interruptions for other projects and waiting for funding and parts, the total calendar time from inception to working boards is 12 to 15 months.

uTCA

- The Good
  - Support in the accelerator community
    - DESY, xFEL, SLAC, CERN
  - High speed, quite backplane
  - Expect to have commercial support for some time?
- The Bad
  - Single supply which can be noisy
  - Lots of software overhead for the crate
  - Small board area and front panel –
    - RTMs ?
  - Few instrumentation boards available now

IS ATCA the Future VME?

- At the recent AdvancedTCA Summit, interest in AdvancedTCA extensions or uTCA .4 was minimal. Meanwhile, in a keynote address, Huawei even suggested new architectures that amounted to developing its own proprietary blade servers.
- http://www.atcanewsletter.com/English/Newsletters/2012/Articles/201202_Article_DrewSproul.html
- Technology may be changing too fast for another standard to be dominate

Links

- ACTA, MicroTCA
  - http://www.i-tech.si/accelerators-instrumentation/libera-llrf/modular-building-blocks_10
  - http://lyrtechrd.com/en/products/view/+udigitizer
  - http://www.pt.com/solutions/physics
  - http://www.struck.de/Poster-xTCASummit1111.pdf
- Open VPX
  - http://www.mc.com/products/microwave-rf/digital-receivers-and-tuners/
  - http://www.mouser.com/catalog/specsheets/TE_Vita.pdf
- Compact PCI
  - http://www.home.agilent.com/agilent/product.jspx?id=1184900&pid=1184900&lc=eng&ct=PRODUCT&cc=US
- PXI
  - http://www.pxisa.org/
  - http://www.ztecinstruments.com/products/rf-test-equipment/series/ZT8440/
  - http://www.ni.com/pxi/
- Complete Systems
  - http://www.thomson-broadcast.com/products/scientific-industrial/low-level-rf-systems
  - http://www.i-tech.si/accelerators-instrumentation/libera-llrf/modular-building-blocks_10
  - http://lyrtechrd.com/en/products/view/+udigitizer
- Modules
  - http://www.thinkrf.com/wsa4000.html
  - http://rfspace.com/RFSPACE/NetSDR.html
  - http://rfspace.com/RFSPACE/SDR-IQ.html
  - http://www.acquitek.com/adq114/data-acquisition-card.html
  - http://mms-rf.com/rf-digitizers.html
  - http://www.ni.com/usrp/