Embedded Controller combines Machine Control and Data Acquisition using EPICS and MDSplus

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Applications such as pulse magnet power supply control and power supply monitoring require data capture on many simultaneous inputs.

In a short pulse machine, it has been convenient to run the data acquisition in a high-speed transient mode, capture all the data per shot in a one-shot capture, and then to store this data to a data archive system such as MDSplus. However as machine cycles become longer, and tending towards continuous operation, this approach becomes impractical. Existing continuous operating plants such as particle accelerators, typically use a continuous operating plant control system such as EPICS, and process variables are generally scanned at a lower rate. We propose a hybrid approach where a networked intelligent digitizer captures data continuously at high speed to local memory.

An onboard EPICS IOC publishes a smoothed and decimated version of the analog input data for each channel at a low subrate. When the digitizer is triggered by an external event, eg a power supply trip, full-rate data is then uploaded to a data archiver, either EPICS, or especially for longer data sets, MDSplus. The digitizer is also capable of acting as an embedded controller, managing a number of off the shelf expansion cards, resulting in a compact control system with a very large number of analog, digital IO's and optionally timing highway access.

MDSplus or EPICS? - a quick comparison

- MDSplus – primarily used to control and archive data in shot-based systems. Primary strength is in archiving self-describing data, very good with large data sets with complex relationships captured in expressions. Supports pre-shot configuration.
- EPICS – primarily used as a SCADA system for continuous control. Primary strength is distributing Process Variables on a network. Supports huge numbers of PV's from multiple controllers. While a waveform type is supported, this is generally of shorter length, and most PV's can be viewed as scalars. Supports sequences, easy to use feedback.
- Both systems work well in a distributed network based system, and D-TACQ intelligent digitizers can support both systems, either separately or concurrently.
- There are a number of applications that can be handled by either system, choice of implementation is down to site preference / capability.

Intelligent Digitizer becomes Programmable Automation Controller

ACQ196, ACQ132, ACQ216 digitizers feature an array of simultaneous analog inputs, high capacity FPGA device and high bandwidth path to memory.

They also feature an embedded microprocessor, running an open standard, memory protected operating system... Linux

Running Linux means that it is simple to connect the digitizer to a TCP/IP network, default: Ethernet. Using Ethernet means that systems are highly scalable, data transfer is low cost, and standardized.

Running Linux means that we can leverage open source, open standard control and data management software such as MDSplus and EPICS. Large on-board memory makes it possible to run the software natively on the embedded processor. This makes it simple to connect to other units running the same software. “No Driver Required”.

Compact PCI System Slot functionality means that it is possible to control other third party cards, where additional features or connectivity are required. This is generally easy to do if the devices are provided with Open Source device drivers, less easy if proprietary.

Short Pulse: AI, AO, DO and Timing

- Application requires simultaneous analog input => ACQ196
- also requires AWG to drive amplifiers
- and DO outputs – 64 bit programmable pulse generator
- multiple DI, DO using third party DIO module
- links to system timing using a third party timing module

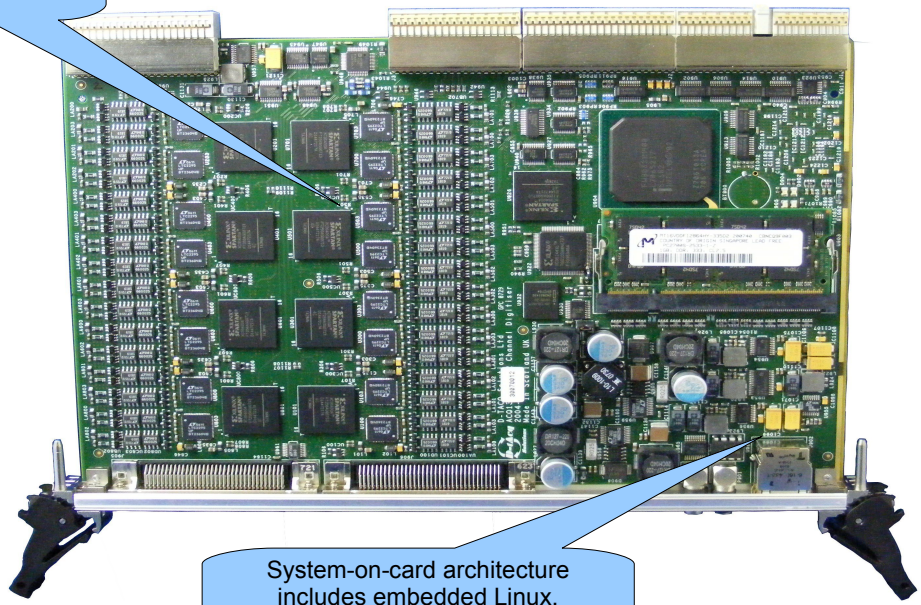
- 4 slot solution with ACQ196 as the networked master computer.
- It's all payload – no bus extension to PC or embedded Pentium required.

Slot	Make	Model	Function	IO
1	D-TACQ	ACQ196CPCI	System Controller	96AI
2	D-TACQ	AO32CPCI	AWG	32 AO, 64 DO
3	Third Party	DIO2	Timing	CLK, TRG
4	Third Party	cp7452	DIO	128DI, 128 DO

Typical MDSplus application:
MDSplus can be used to pre-configure the AWG, DO. Post shot upload of AI, DI data.

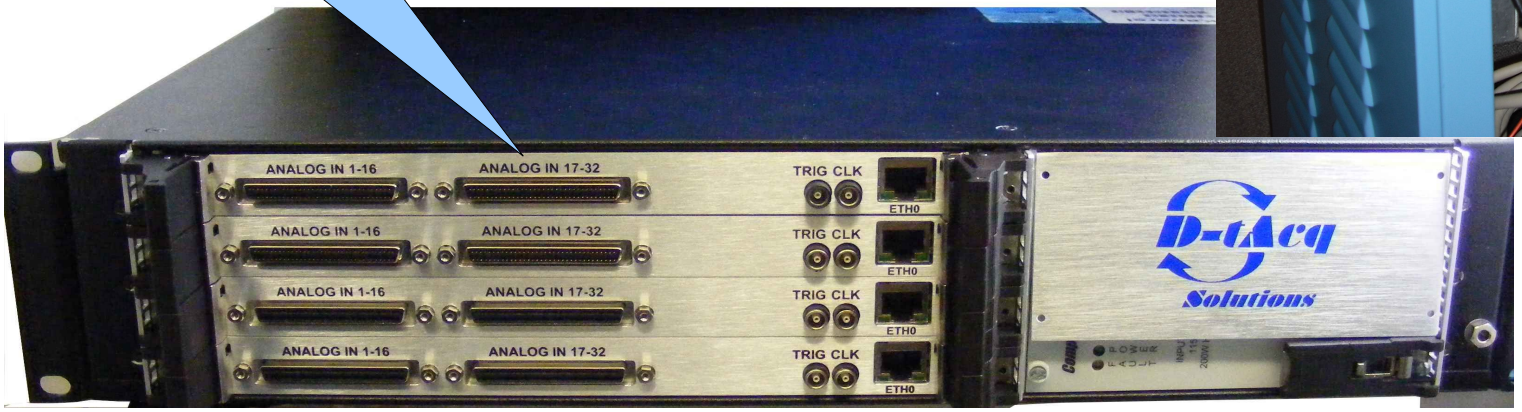
Physical Characteristics

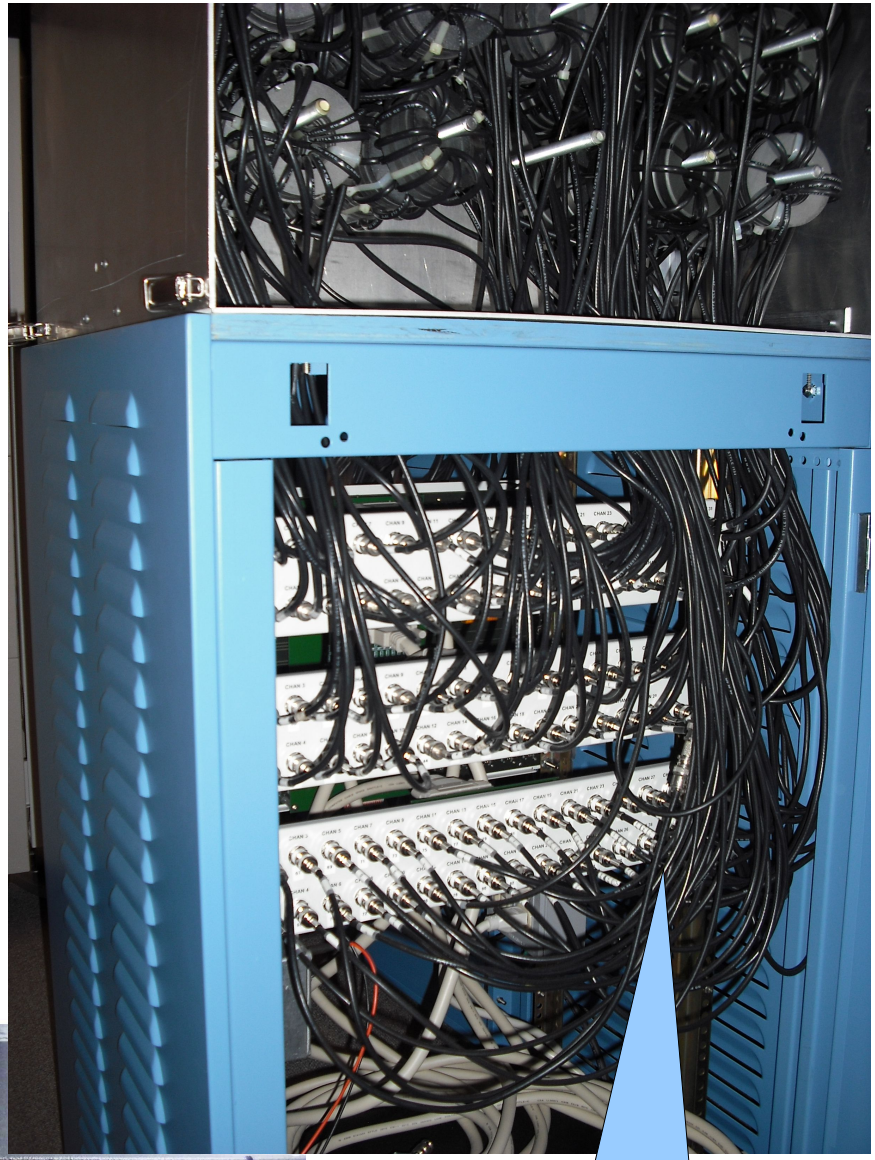
Large Formfactor Card:
High Channel Density



System-on-card architecture includes embedded Linux, gigabyte memory and Ethernet

Horizontal “Slimbox” Chassis makes for compact systems





In the real world, wiring hundreds of signals dominates space available

Power Supply Fault Monitoring

- ACQ196 monitors data
- Third party DIO module

Dual-Rate monitoring

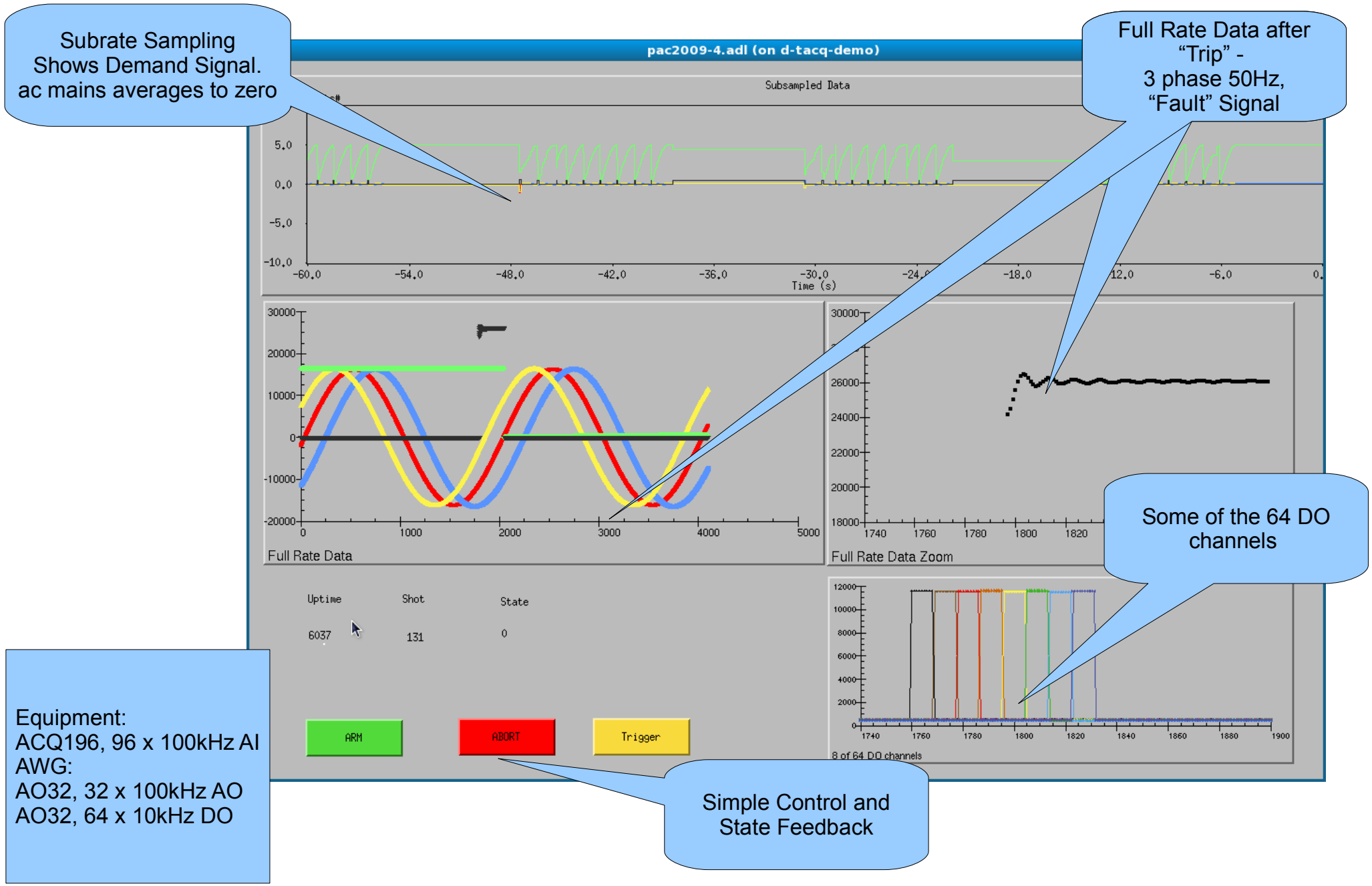
- 10Hz continuous output
- 100kHz continuous capture to local memory, gives full rate pre/post data on trip detect.

Slot	Make	Model	Function	IO
1	D-TACQ	ACQ196CPCI	System Controller	96AI
			Spare	
			Spare	
4	Third Party	cp7452	DIO	128DI, 128 DO

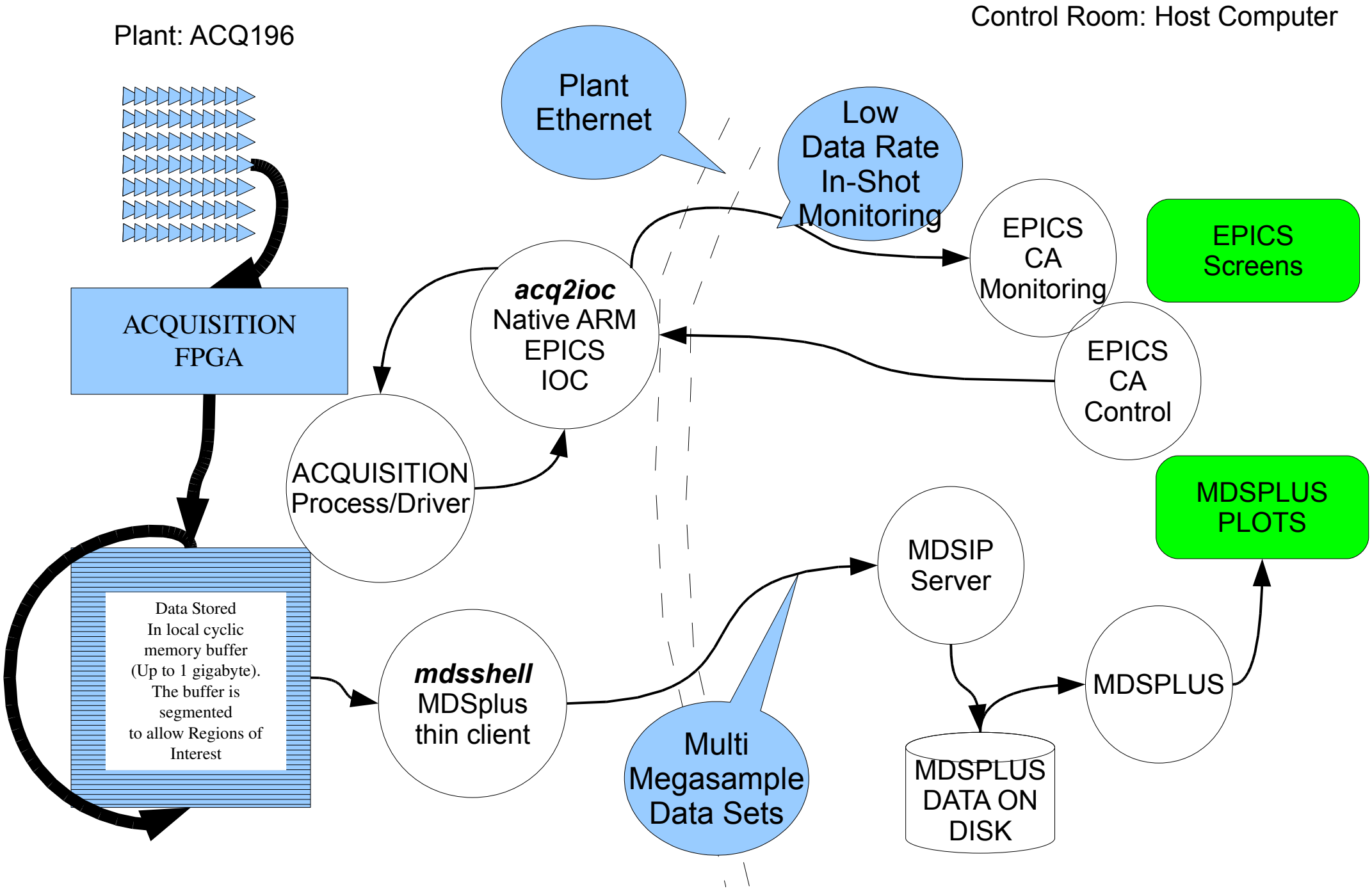
System is controlled by EPICS, this works well since the transient upload is fairly short (<64K points per channel).

MDSplus would be a better choice for the transient upload if the transient were longer.

EPICS IOC on-board: Simulated Power Supply Monitor



Embedded system supports MDSplus and EPICS



Precision Power Supply Controller

- ACQ164 24 bit card
- AO32-ER 18 bit output
- Relay switching card and Ethernet DVM for in-system calibration.

Slot	Make	Model	Function	IO
1	D-TACQ	ACQ164CPCI	System Controller	64AI, 24 bit
2	D-TACQ	AO32CPCI-ER	AWG	32 AO, 18 bit
3	Third Party	40-155	Relay Card	32 DPST relays
4	Third Party	cp7452	DIO	128DI, 128 DO
External Unit		Agilent 3441	Ethernet DVM	In System Test

- EPICS System. EPICS handles the in-system calibration, linearisation of the AO and data conversion.
- ACQ196 provides maximum simultaneous channels in one slot, AND possibility to add additional functionality with COTS cards.

Plasma Control System PCS

Slot	Make	Model	Function	IO
1	Third Party	Various	Host Bus Interface	Bus Extender
2	D-TACQ	ACQ196CPCI	AI,AO	96AI,16AO
3	D-TACQ	ACQ196CPCI	AI,AO	96AI,16AO
4	D-TACQ	AO32CPCI	AO	32AO
External Computer		x86	Control logic and math	Bus Extender

- ACQ196 runs a dedicated single thread control loop, dedicated to low latency
- HOST computer controls the sequence.
- Useful to 100kHz repetition rate.

- System optimised for minimum latency.

Continuous Data Capture System

Slot	Make	Model	Function	IO
1	Third Party	Various	Host Bus Interface	
2	D-TACQ	ACQ196CPCI	AI,AO	96AI,16AO
3	D-TACQ	ACQ196CPCI	AI,AO	96AI,16AO
4			Spare	
External Computer		x86	Data Archive	Bus Extender

- Suitable for Long-Pulse data acquisition
- Single crate captures 2 x 96 channels at 200 kHz continuously
- Host computer responsible for continuous data archive.

- System optimised for throughput.

Sonar System

- Runs a shot every 3 seconds
- ACQ196 implements a Digital Down Converter, extracts data to base band, reduces data volume by factor 8
- AWG function generates sonar chirp at the start of the shot.

Slot	Make	Model	Function	IO
1	D-TACQ	ACQ196CPCI	System Controller, AI, AWG	96AI, 2AO
2	D-TACQ	ACQ196CPCI	AI	96AI
3	D-TACQ	ACQ196CPCI	AI	96AI
4	Third Party	rfm2g	Reflective Memory – low latency data transfer	
External Unit		x86	Target detection and display	RFM

Demonstrates system-slot capability of the ACQ196. RFM module provides a low-latency, high bandwidth link to the remote host computer.
This system is controlled by a turnkey program running on the ACQ196.

Relevance to Fusion? - an experiment running shots at up to about 1Hz could use this technique. RFM is an alternate transport for PCS. For more rapid frame rates, a Repeating Gate Mode is available – single, segmented shot.

Conclusions

- D-TACQ digitizer provides multiple simultaneous inputs.
- Open standard interface on Ethernet, local Linux OS allows seamless connectivity with leading data management systems.
- Open standard interface on backplane, wide availability of Linux device drivers allows IO expansion and customisation using COTS cards.
- Digitizer becomes Programmable Automation Controller.