D-TACQ 2G User Guide

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Date: 01 June 2010.

Date first issue: 7 September 2009

Primary Instruction and Command Reference for D-TACQ Intelligent Data Acquisition Cards:

- *ACQ132CPCI*
- *ACQ196CPCI*
- *ACQ216CPCI*
- *WAV232CPCI*
- *ACQ164CPCI*

Comments, corrections and constructive criticism welcome! :

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```
How to read this document:

We do not recommend reading the whole text in detail, it is more of
a reference. However for users unfamiliar with the ACQxxx
architecture, at least a skim-read of Sections 1-13 is recommended.


It is 140+ pages long : best not to print it.

Recommended way to view: Load in Acroread, use the Bookmarks window
for navigation - each section is book marked.
```

Rev	Date	Description
1	18 May 04	First issue
2	20 May 04	Work in progress
3	02 Jun 04	Add routing examples
4	23 Jul 04	Add RTMAO-16 description
5	23 Jul 04	dio32
6	09 Aug 04	FAWG description
7	20 Aug 04	Data interface description23 January 2008
8	07 Sep 04	Customization via /ffs/rc.local
9	20 Oct 04	Add clock routing scenarios
10	19 Nov 04	Add ssh login descr.
11	24 Feb 05	Routing concept diagram
12	1 March 05	Add to Low Latency section
13	15 March 05	Cal and Vin
14	1 April 05	Ll control updated, RTMDDS
15	10 April 05	Host Pull, Target Push distinction
16	16 May 05	Clarify remote if def.
17	29 July 05	LLCONTROL V2
18	01 Aug 05	Tidy up on LLCONTROL V2
19	02 Aug 05	Improve raw/cooked description.
20	10 Aug 05	Add counter and sundry service changes
21	01 Nov 05	Mean device and friends
22	10 Nov 05	MdsPutCh
23	02 Jan 06	Add rescue section, correct remote.update
24	05 Jan 06	Improve voltage range FAQ
25	09 Feb 06	AO, acq2sh comments.
26	06 May 06	Dt100d operational issues and options
27	13 June 06	Improved Trigger, Event defs
28	18 Sep 06	Calibration file, Channel Block commands
29	20 Sep 06	Improve MDSplus Thin Client coverage
30b	26 Sep 06	Full MDSplus/AO example.
31	01 Nov 06	/etc/postshot.d, calibrate changes
32	03 Jan 07	improve FAWG doc.
33	07 Jan 07	FTP server
34	11 Apr 07	corrected calibration formula
35	03 Aug 07	command sequence FAQ.
36	23 Jan 08	update

Rev	Date	Description
37	23 May 08	new /ffs structure
38	12 June 08	restored pre_post_mode (thanks Atma!)
40	07 August 08	Repeating Gate Mode, PREPs.
43	08/15/09	ACQ132 document update
44	09/07/09	ACQ132 setExternalClock
45	10/30/09	setExternalClock div detail
46	26/01/10	ACQ132 FIR
47	15/02/10	INTCLK_NOICS, LO_ICS opts for ACQ132CPCI
48	01/06/10	DualRate
49	17/09/10	Document set.acq1xx.role.
50	25/11/10	ACQ164 NACC accumulator.
52	19 June 2012	ACQ196 NACC accumulator.

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1 Introduction

1.1 Welcome

The D-TACQ second generation (2G) series is a revolutionary concept in Data Acquisition. We take the D-TACQ simultaneous *ADC* array, combined with a high bandwidth *FPGA* data path to fast *DDR* memory. This is managed by an on-board microprocessor – a 400MIPS *ARM* device; an embedded system running an advanced operating system. Not some specialist system, but Linux. Using Linux means that there is a familiar environment with excellent connectivity and data management facilities built in, and the system may be customized and extended using simple shell scripts and or by writing higher level applications in the familiar memory protected *POSIX* environment.

D-TACQ believes this is an ideal platform for ***High Performance Simultaneous Data Acquisition.***

1.1.1 Hard real time under Linux.

How do we expect true real time performance from Linux? The answer is, we don't. D-TACQ 2G has one critical interrupt, related to the acquisition *FIFO*. This is handled by the *ARM FIQ* interrupt; the *FIQ* operates outside the control of Linux and is never masked. The job of the *FIQ* is to arm the on-board *DMAC* and to detect external events; driver code under Linux has the responsibility of maintaining queues of empty *DMA* descriptors going to the *FIQ* and dequeuing full *DMA* descriptors coming back from the *DMAC*. Provided the queues are long compared with the maximum Linux task latency (and they are), Linux has sufficient real time capability for this task.

Please note that 2G is an exceedingly high bandwidth system (500 MBytes/sec sustained transfer to memory on ACQ216CPCI). When operating at full speed, the *FIQ*/*DMA* operation will occupy most of the available CPU resources and so the system will become unresponsive to application input. Applications requiring significant real time data processing are best handled in the *FPGA* .

In addition, it is possible to extend the capability of 2G using kernel modules; typically the kernel modules will disable interrupts altogether during capture and take complete control of microprocessor execution. An example of this is the Low Latency Control module.

1.2 Intended Audience

Users of D-TACQ 2G products, software developers integrating the products with existing data management systems, and software developers developing applications to enhance the product.

1.3 Scope

This guide is generic to all 2G products. Where products vary in detail, examples are provided for each.

Current applicable products are:

- ACQ196CPCI
- ACQ216CPCI
- ACQ132CPCI
- ACQ164CPCI
- WAV232CPCI

Functionality specific to each of these products is handled in a separate appendix.

1.4 Glossary

ACQxxx : generic reference to D-TACQ 2G card eg ACQ196CPCI, ACQ216CPCI

ADC: Analog to Digital Converter.

ARM: Advanced RISC Machine – a microprocessor architecture.

CompactPCI : industrial formfacto with Eurocard mechanics, PCI signaling

XSCALE: Intel implementation of the ARM architecture, used on D-TACQ 2G.

D-TACQ: D-TACQ Solutions Ltd.

DDR: Double Data Rate (double edged clocking memory standard).

DMA: Direct Memory Access, *DMAC*: *DMA* Controller.

ES: Event Signature - a marker inserted in the data stream at the point of an external event occurrence.

FIQ: ARM architecture Fast Interrupt.

FPGA: Field Programmable Gate Array.

PCI: Commonly used computer bus.

PLL: Phase Locked Loop

POSIX: Portable Operating System based on Unix (Unix API).

PS_CLK: Plant System CLK (typically at front panel)

SCLK: Sample Clock (to *ADC*)

ROI: Region Of Interest

RTM: Rear Transition Module.

RTOS : Real Time Operating System.

TARGET: in this context, an ACQxxx acquisition card, either connected via PCI backplane or Ethernet.

HOST: A computer that provides support for TARGET. Usually an x86 Linux computer, may connect either via PCI backplane or by Ethernet.

diskless : computer running with no local hard disk.

1.4.1 Signal Processing Terminology:

SNR: Signal to Noise Ratio

1.4.2 Filter Terminology:

AAF: Anti-Alias Filter (analog).

FIR: Finite Impulse Response (digital) filter

ISR: Input Sample Rate

OSR: Output Sample Rate

PASSBAND: Passband of the filter (3dB), frequency where roll-off starts.

STOPBAND: Stopband of the filter - frequency where maximum attenuation is obtained.

1.4.3 Software References

`dt100rc` : D-TACQ supplied HOST client reference program and GUI

`acq_demux` : D-TACQ API example program.

`streamer`: D-TACQ API example program.

`kst`: Open Source plot program suitable for large binary data sets

DirFile : simple binary file format

ftp : (Internet) File Transfer Protocol

1.4.4 References

1. Interface Control Document ICD : this is the primary command reference, and is unchanged from the 1G product range, except where overridden by new commands (see 20.1)
2. ACQxxx Hardware Installation Guide
3. D-TACQ Network Attached Satellite Data Acquisition (dtNasDaq.pdf)
4. SoftwareInstallationGuideR3
5. Intel 80321 IO Processor Developer's Manual (273517-002)

1.5 Notation

- **`command`** : indicates name of a program (command)
- `preformatted text` : literal input or output from terminal session.
- *Defined Term* : some term or acronym specific to this domain (perhaps referenced in the glossary)

2 Recommended Deployments

2.1 Standalone Networked

ACQxxx devices are capable, where fitted with Ethernet, of operating as *diskless* satellite units. This is outlined in [3].

The satellite may be controlled:

- Directly via applications using the **dt100** Remote Network Protocol as described in (ICD). D-TACQ supplies **dt100rc** as an example of such and application.
- indirectly via a **dt100-hub** middle layer server, allowing existing support software to run with the minimum change. Dt100 Networked Attached Satellite DAQ mode.
- Directly from the Linux shell on the box – the familiar acqcmd protocol is available on the box; it is feasible directly automate a local **telnet** shell session from a remote machine (e.g. using **expect**). Or it is possible to write a local server application (e.g. **mdsip**); this exercise would involve porting to the embedded ARM-LINUX environment.
- It is possible to write a local control process. Examples of this is the **autozero** and **calibrate** processes.

2.1.1 Network Topology

When operating on the Ethernet, best performance will be achieved if a dedicated "field bus" Ethernet can be deployed between the middle layer machine and the *ACQxxx*. This is not only for reasons of performance, but security as well:

- controlled link means maximum network bandwidth available for data upload.
- Controlled link mean that the embedded network interface is not exposed to uncontrolled incoming packet activity during the critical real time capture phase. The capture process has to handle real time data flows of up to 320MB/sec, and it has to check for remote abort packets on the network interface, so it is not possible to simply ignore network packets. If the acquisition card is connected direct to the global Ethernet, it is highly likely that it will be exposed to random, unrepeatable bursts of network activity – maybe not even addressed to it, that could cause hard to trace failures.

2.2 Backplane Peripheral Mode

ACQxxx cards by default act as *CompactPCI PCI* peripheral devices. The full speed 64 bit, 66MHz interface is supported, and so the *ACQxxx* will work with what ever speed and bus width is selected by the system slot card.

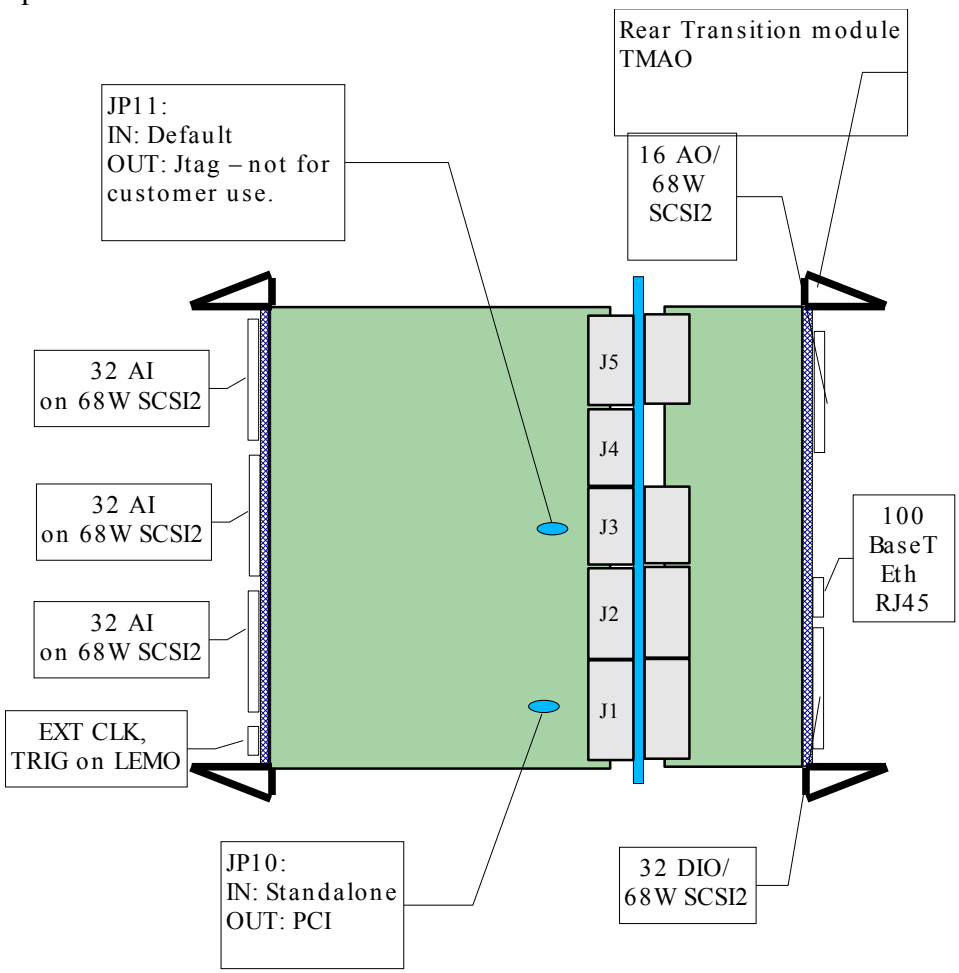
ACQxxx has a full master/slave interface, and, for maximum performance will

master data on the bus.

For installation instructions for *Host* side driver for this mode, please refer to [4]

2.3 System Slot Controller

By factory configuration option, *ACQxxx* cards are able to perform the system slot function for other cards in the *CompactPCI* chassis. In addition, *ACQ196* has a jumper option for "Standalone Mode" where the card isolates itself from the



backplane PCI logic.

3 Getting Started

1. Mechanical installation: refer to “Installation Guide”. Currently it is mandatory that each front side board have an accompanying *RTM* at the rear side.

   WARNING: Please ensure compatible RTM:

   ACQxxx must only be used with an *ACQxxx RTM*

   ACQxxx must only be used with an *ACQxxx RTM*

   Quick Check: *ACQxxx RTM* has twin RJ45 for dual Ethernet, *ACQ196 RTM* has single RJ-45

2. Jumpers: There is one user jumper on A*CQ196CPCI*: JP10. For standalone applications, JP10 should be fitted, for system slot and peripheral mode operation it should be removed. There are no user jumpers on *ACQ216CPCI*.

3. Console. Connect to console port to check configuration of firmware. Requires 9Way D null-modem cable and a terminal emulator. D-TACQ uses and recommends ***kermit*** (http://www.columbia.edu/kermit/). Terminal emulator should be set to 38400 baud, 8bit, [one stop] no parity.

4. Power up and confirm boot up through to Linux prompt. There is no longer any need to modify boot parameters in normal operation. If it doesn't appear to boot, please refer to “Trouble Shooting” in next section.

5. For standalone operation, make an Ethernet. connection to the RJ45 socket on the *RTM*. It is recommended that this connection be part of a data-acquisition-private network. A full duplex switched connection will work best, for *ACQ196* a dedicated cross-over cable to a dedicated client *NIC* is also a valid option. Default IP address settings are obtained by DHCP. Alternatively a static IP address may be configured by editing a boot script. (#6.2)

6. Check the system boots normally. If the console is connected, you will see boot prompts, if the front panel *LEDs* are visible, you will see the lamp sequence, as described in 4.1.

7. D-TACQ recommends use of the point and click **`dt100rc`** remote control program for initial testing. For serious volume data management and storage, D-TACQ recommends MDSplus (www.mdsplus.org). MDSplus control is provided via either the **`dt100-hub`** network interface, or via backplane drivers. MDSplus support is also available on the card, allowing automated submit of post-shot capture data direct to an MDSIP server.

8. Refer to the embedded web pages for diagnostics and status. The web pages are presented at port 80. D-TACQ recommends **`firefox`** or **`mozilla`** rev 1.5 or better for best viewing effect.

4 Trouble Shooting

4.1 Front Panel LEDs

1. On reset, all LEDs are out.
2. On release of reset, the boot loader lights all 4 LEDs (lamp test)
3. The lamp test remains in effect during LINUX boot up (about 1 minute).
4. When Linux is running, LEDs 3 and 4 are extinguished. LED2 (RED) will flash at about a 1Hz rate. LED1 (GREEN) indicates CPU idle – in normal rest state, this is one, and then will flash according to CPU activity.

4.2 Console Interface.

The RS232 console interface is provides the next level of access for customization and debug. Configuration of the boot loader is as described in #6.1.

5 Architecture Overview

5.1 2G Overview

The D-TACQ 2G architecture comprises :

- Analog front end array, one converter device per channel for simultaneous capture.
- Fast data path to control FPGA.
- Internal logic for data marshaling, trigger detection and clocking in the FPGA.
- Internal FIFO buffers in the FPGA
- Fast local bus to microprocessor
- High performance, low power microprocessor (400MHz, XSCALE/ARM arch)
- Very high speed 200MHz DDR bus to local memory
- 64bit/66MHz PCI interface to backplane.
- Optional Ethernet interface (2 x 1000baseT on *ACQ216*, 1x 1000baseT on *ACQ132/ACQ164*, 1x100baseT on *ACQ196*).
- The system is fully firmware controlled – both operating microprocessor and FPGA firmware images are stored in flash memory and may be upgraded in system without difficulty.

5.2 Operating Software

The local microprocessor runs Linux. This is a full virtual memory implementation, 2.6.x series. All kernel source code is available under GPL. The Linux system is stored in flash memory as a compressed kernel image. Initial and additional compressed file system images are held in flash memory, and expanded into a local ram disk at run time. The ram disk is self sizing, but is typically 20MB. An additional flash sector is formatted as JFFS2 to allow non-volatile disk storage, e.g. for calibration data and local customization. Finally, the FPGA image is stored in a dedicated sector. It is possible that alternative FPGA images may be stored in the file system images.

5.3 Flash Memory Layout

```
f0000000-f001ffff : /dev/mtd0 Bootldr
f0020000-f003ffff : /dev/mtd1 Env
f0040000-f01bffff : /dev/mtd2 SafeKrn
f01c0000-f01fffff : /dev/mtd3 FPGA
f0200000-f03fffff : /dev/mtd4 SafeRd
f0400000-f05fffff : /dev/mtd5 FieldKrn
f0600000-f07fffff : /dev/mtd6 FieldRd
f0000000-f0bbffff : /dev/mtd7 extra
f0bc0000-f0f3ffff : /dev/mtd8 home
f0f40000-f0ffffff : /dev/mtd9 cal
```

- `mtd0, mtd1`: Boot loader partitions: writable by u-boot only
- `mtd2..mtd7`: compressed images held in flash, Linux updateable.
- `mtd8, mtd9`: jffs2 flash file systems, for non-volatile customizations.

5.4 Boot sequence.

Boot loader U-Boot

`bootm <vmlinux.img> <initrd.img>`

Linux kernel boot up.

Mounts initrd as a ram disk, runs:

`init`

runs:

/`etc/init.d/rc.sysinit`

configures local ram disk file system

starts networking

sets `hostname` and installs core devices

calls

`/acq200/start.local`

expands file system image in `mtd7` and mounts as ram disk at `/extra`

calls

/`usr/local/bin/start.local` *`MACHINE`*

more initialisation based on extra disk.

`calls start.`*`MACHINE`*

Mounts `mtd9` as `/ffs`

runs `/ffs/cal/autozero` if it exists

runs /`ffs/rc.local` if it exists.

gets options from `/ffs/rc.local.options`

runs `/ffs/user/rc.user` if it exists

6 Personality

Please Note: Boot loader setup is now for ***expert users only***.

Initial setup (notably static IP address) is now achieved via custom boot script

`/ffs/user/rc.user` (Section6.2)

6.1 Boot loader

The boot loader is U-Boot (www.u-boot.org), and the boot loader interface is via the console port.

By default, the boot loader will attempt to auto boot Linux.

To break into the boot loader, press space bar within 3 seconds.

U-Boot is configured by means of boot parameters.

A typical setup is as follows:

```
setenv bootdelay 3
setenv baudrate 38400
setenv ramdisk ramdisk_size=16384 root=/dev/ram0
setenv console console=ttyS0,38400
setenv hn hostname=acq196_001
setenv ba acq100=acq196
setenv bootcmd bootm a0400000 a0600000
setenv mac gEmac0=10:01
setenv sn serialnum=d30001
setenv ipa ip0=dhcp
setenv boota $console $ramdisk $hn $sn $mac
setenv bootargs $boota $ipa $ba
setenv bootcmd bootm a0400000 a0600000
saveenv
```

6.1.1 IP address

Default is to use dhcp. Alternately a static IP address may be set as follows:

```
setenv ipS ip0=192.168.0.1
setenv bootargs $boota $ipS $ba

saveenv
```

Please note: this is superseded by Linux boot script /ffs/rc.local (# 6.2)

6.1.2 Bootcmd

The actual kernel and ramdisk images to be booted are specified as:

```
setenv bootcmd bootm a0400000 a0600000
```

6.1.3 Rescue

In the event that the default “field” images do not work, there is the possibility to fall back on stored “safe” images in order to boot safely, and reprogram the “field” images:

```
setenv bootcmd bootm a0040000 a0200000
boot
```

It is not necessary to save this command to flash – it is preferred to boot right away, repair the images, and on the next boot, U-Boot will default back to the field images and run them.

6.2 Customization Scripts

The non-volatile flash file system allows storage of system personality and customisation.

Two flash file system partitions are implemented:

1. /dev/mtd9 mapped as /ffs : 768K : custom boot, personality, patches
2. /dev/mtd8 mapped as /bigffs: 3584K : additional software eg EPICS image

Board specific personality can be added in `/ffs/user/`**`rc.user`**

A number of boot time options may be selected in `/ffs/`**`rc.local.options`**

These files may be edited locally in place.

A common requirement is to select a static IP address, and a command is provided for this:

`/sbin/set.static_ip`

example: to set a static IP address 192.168.111.222:

`/sbin/set.static_ip` `IP0  192.168.111.222`

In general, /ffs/rc.local should NOT be edited, changes will not be preserved through firmware updates. User customization should be made in /ffs/user/rc.user. The following directories are preserved through firmware update:

`/ffs/cal /ffs/user /ffs/dropbear`

`/ffs/rc.local.options` is backed up to `/ffs/rc.local.options.orig`

/bigffs is not touched by normal firmware update.

6.2.1 Typical /ffs/rc.local.options:

```
#!/bin/sh
# local configuration options for rc.local
# set static IP address from local file ONLY IF the file exists
#IP0=192.168.0.123
#IP1=0.0.0.0
# remote logging
#RLOG=YES
#RLOGHOST=192.168.0.1
# telnet, http enabled by default, uncomment to disable
#DISABLE_TELNET=YES
#DISABLE_HTTPD=YES
# usually a good idea to run this
SSHD=YES
# Clock Trigger Role - preset Clock Trigger behaviour
# choose one or none
# uncomment one of the following lines to configure clock and
trigger routing
# NB: only ONE master device per chassis!!
#CT_ROLE=LEMO_MASTER  ;# lemo in drives fpga and PXI - flashes LED4
for LEMO ID
#CT_ROLE=PXI_SLAVE    ;# fpga driven from PXI
#CT_ROLE=FPGA_MASTER  ;# fpga drives PXI for looptest - LED4 solid

# MDSplus thin client - stub it out if not needed
#MDSSHELL=YES

# mean device - subrate data during pre/post
#MEAN_DEV=YES
# EPICS - enable if needed. NB needs special EPICS image in /bigffs
#EPICS=YES
# For ACQ216CPCI-M5-RTMDDS:
#M5=YES
#RTMDDS=YES
# Live scope demo
#SCOPE_DEMO=YES
# for low-latency control mode (LLC) uncomment next line
#LLC=YES
# use this to activate DIO32 support. ONLY IF RTM WITH DIO32 IS
FITTED
#DIO32=YES
# NTP client, and ntp host for client
#NTP=YES
#NTPCLIENT=192.168.0.1
# external state monitor service
#STATED=YES
# ftp daemon
#FTPD=YES
# watchdog timer
#WDT=YES
# remote access to AO fungen or voltage source
#FGD=YES
```

```
#VSD=YES
```

7 Command and Monitoring Interfaces

7.1 CPCI Backplane

Standard `acqcmd` device interface by memory resident device driver.

Also offers extend able remote-shell interface.

7.2 Dt100d remote service

Operates on Ethernet, listening at port 53504.

Implements dt100 remote protocol (see ICD).

Compatible with **`dt100rc`** and **`dt100-hub`**.

The latter is a host side Linux driver, combined with a proxy server, emulates the backplane device interface. Instructions for use of **`dt100-hub`** are to be found in the *README* file for the **`dt100-hub`** source code package.

7.3 Web Service Interface

ACQxxx offers an remote RPC service based on SOAP.

The cards feature an embedded service built around the excellent gSOAP product.

At the lowest level, the standard **`acq2sh/acqcmd`** interface is offered.

Example cross platform remote client applications are provided running on both Linux and Windows. Binary executables and source code are provided for C++ remote clients. A VB.NET example is also provided.

A high level API is also offered, currently this is only available to remote clients coded in C++ and linked to gSOAP.

A full overview of the SOAP interface is available at:

http://www.d-tacq.com/details_page.php?prod_id=applications&page_id=2

The interface is documented at:

http://www.d-tacq.com/resources/SOAPI/html/index.html

7.4 Web interface

Web server based on **`thttp`** operates at port 80.

A series of cgi screens for monitoring and test are available at: `/cgi-bin/home.cgi.`

Please note: The Web interface is not intended as a production tool, since the setups generated are neither automated not persistent. The value of the Web interface is quick access to control parameters, allowing easy manual setup of tests.

D-TACQ recommends that users use the Web interface for initial setup. Once a

working scenario is achieved, to record and possibly script the same command sequence, consult the web log (with target based event log, logread, or, if using remote syslog facility, review the host syslog – usually `/var/log/messages` on Linux hosts).

A number of the web pages make use of JavaScript. This is tested to work on FireFox and Konqueror . Some of the pages may fail to work correctly under IE.

7.5 Console Interface

Occasional access to the local serial port console via RS232 is required.

D-TACQ recommends **`kermit`** to connect to the console, but any terminal emulation program will work (examples include **`minicom`**, **`hyperterm`**). 38400, 8np.

The console port is the only place where root login is available.

7.6 Telnet interface.

Telnet service is available at port 23. Login as user *dt100*. root login is disabled.

While this service is still enabled by default, D-TACQ recommends use of **`ssh`**:

7.7 Ssh interface.

Regular **`ssh`** service available at port 22. D-TACQ encourages use of this interface for remote log in and remote command execution. Login via public key exchange works well and is highly recommended, it is particularly useful when used with remote update.

Public keys are stored on the target in:

`/ffs/dropbear/root/.ssh/authorized_keys`

`/ffs/dropbear/home/dt100/.ssh/authorized_keys`

New keys should be appended to the file, then reboot the target to activate. The system ships with default d-tacq public keys, please leave them in place if you want to allow us in-system maintenance access.

The **`ssh`** interface also provides a useful runtime path copy utility – any files in `/ffs/dropbear` are copied to their corresponding locations in the root fs at boot time.

7.8 FTP client

A full **`ftp`** client implementation is supported. This can be used for automated "Target Push" upload post capture.

It is recommended that **`ftp`** is used with a `.netrc` file. Store a non volatile copy of your `.netrc` file in `/ffs/dropbear/root` and it will be updated to the `rootfs` at boot time.

7.9 FTP server

A full **ftp** server implementation is available onboard. For security this is disabled by default. The ftp server may be started as required or from `/ffs/rc.local`.

- **`/sbin/start.ftp`** : starts ftp server, works with dt100 and ftp (anonymous) logins
- **`/usr/local/bin/start.acq196.ftp :`** starts ftp server, as above, plus:
    - user *ai* : password free login gives access to AI data
    - user *ao*: password free login gives access to AO data.

- For security, it's not possible to login as root.
- The ftp server will not work with data sets > 6MB.

7.10 SFTP server

An sftp server is also available. This is file transfer over ssh. It's secure, but quite slow. So it is good for transferring setup data, but is not recommended for capture data.

7.11 SAMBA server

A SAMBA server is available, allowing direct export of captured data as an MS-Windows compatible network file share. This interface has good performance.

7.12 Restrict access to services using TCPwrapper.

The standard inetd implementation can be replaced by TCPwrapper, so that access to services may be controlled by ACL's.

8 Updating Firmware

ACQxxx cards ship with the latest firmware. However to take advantage of bug fixes and enhancements after delivery, it may be necessary to perform a firmware update.

Please note, in a correctly configured system, firmware upgrade is a routine procedure. However, it is not foolproof, so please monitor the upgrade process looking for error messages. If you do see errors, it may save you time not to reboot until the errors are resolved. The ACQxxx card does have a failsafe boot image which can be used if the firmware upgrade fails. [6.1.3]

8.1 What Images are involved:

Item	File Name	Description	Fmt	Frequency of Update	Scope
1	vmlinux.img	Linux kernel	u-boot	1	common
2	initrd.boot	Initial ramdisk	u-boot	1	common
3	Extra.img	Application ramdisk	gz	3	common
4	AcqXXX.rbt	FPGA firmware	gz	2	model
5	xxx.gz	Custom application	gz	2	common

Frequency 1 = seldom, 2 = more frequent, 3 = most frequent.

Images 1,2,3 are common to all ACQxxx, ACQxxx.

Image 4 is specific to the board model, and indeed to the FPGA device fitted on the board. Please contact D-TACQ for update advice.

Several Custom application images are available -

eg MDSplus Thick Client, EPICS IOC.

8.2 From host computer via ssh

This works well if you have public key login set up.

On the host:

```
In release top level directory:
./images/remote.update <ip> <hostname> [opts]
opts :: [vmlinux] [initrd][extra] [cal] [fpga] [allbutcal] [all]
```

This procedure works natively on a Linux computer, but has also been tested from Windows using cygwin.

8.3 Via CPCI Backplane

On slot 1 host (assumed x86 Linux), using **`upgrade.all.acq200`**.

Please note that **upgrade.all.acq200** will upgrade all boards unless boards are specified by number on the command line. The actual make up of the configured images is determined by a data file (def.def). Currently **upgrade.all.acq200** is unable to discriminate between target types, and in a mixed target system, it is recommended to to set `def.def` to suit each board individually, and to upgrade one board at a time. `def.def` is generally a soft link to a device specific file eg `acq196.def.`

```
cd images; ./upgrade.all.acq200 [b1 ... bn]
```

8.4 Via Ethernet using nfs

While this uses the fast Ethernet path to transfer data, however, it is necessary to login as root to do this.

```
nfsmount host:/exports   ;# mounts remote disk to /mnt
eflash [all | vmlinux | initrd | extra | cal | fpga]
```

8.5 Via Ethernet using anonymous ftp

Prerequisite: embedded ftp server has been started. [7.9]

Log in as root (console or ssh).

Ftp to the card as user "ftp" (no password).

For each image, upload via ftp, then, from the login session, run:

fflash [image]

8.6 Via Kermit (serial or Ethernet)

Kermit is available in the on board disk and is useful for file transfer when the above methods are not available. This possibility exists not only for the serial console interface, but also for the network interface. The latter is particularly useful with **dt100-hub** and port forwarding. (See [3]).

8.6.1 Using kermit via serial port.

This is slow – only use this method if Ethernet and PCI methods are unavailable.

1. Connect console interface in the normal way from a remote **kermit** session
2. **kermit** -x starts acqXXX-local server
3. Type kermit esc (CTRL-\) to drop back to local client
4. Type `send` *local-file remote file*
5. Type `fin` to exit local server
6. Type `c` to connect to ACQxxx
7. **kflash** [all | vmlinux | initrd | extra | cal | fpga]

8.6.2 Using kermit via telnet

Same as before but much faster. All steps other than Connect are the same:

1. Connect using

```
KERMIT> set telnet wait-for-negotiations off
KERMIT> telnet ACQxxx
```

2. repeat as above.

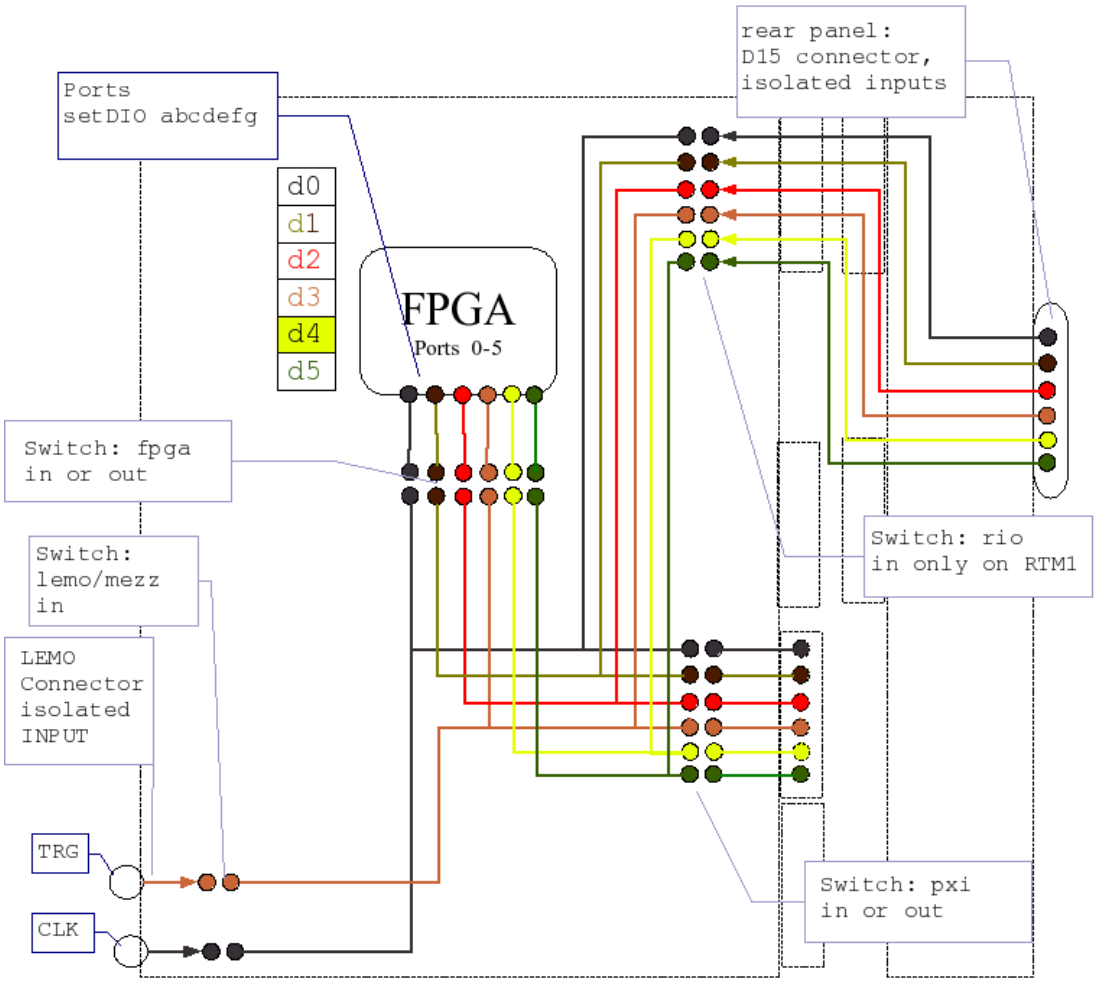
8.6.3 From a website using wget

A useful emergency procedure – place the firmware images on a local webserver.

Log in to the target (perhaps from the serial console), `cd /tmp`, use `wget` to fetch the images, program with **`kflash`**.

9 Concepts

9.1 Clock and Trigger Routing




```
Signal routing via switches:
Switches are directional, and only one source per line is allowed:
acq2sh set.route dX in {source} out [dest1] [dest2] [dest3]

The FPGA ports default to inputs:
FPGA port direction and value is controlled by
acqcmd setDIO abcdefg
where a is d0, b is d1 etc and
where x in [abcdefg]
d = - : input
d = 1 : output 1
d = 0 : output 0
```

set.route is described in more detail below, **acqcmd** setDIO is as described in the ICD.

9.2 Calibration

9.2.1 Offset Adjust

Where an effective hardware zero offset adjust mechanism is available, cards are supplied with a zero offset calibration that will be set up at boot. The cards may be recalibrated at any time using **autozero** Error: Reference source not foundError: Reference source not found.

Cards with this feature include ACQ196CPCI.

9.2.2 Gain Adjust

D-TACQ cards are NOT provided with a hardware gain adjustment, however an effective gain adjustment may be made by use of the calibration table:

9.2.3 Numeric Calibration Procedure

D-TACQ cards are provided with a calibration sequence. The calibration is used to adjust the values returned by the per-channel range report **get.vin.** 10.4.5.

The embedded system does not attempt to make any floating point data adjustment on the raw data, but stores the calibrated value in a table for use by external clients. The higher powered remote archival computers can make an accurate conversion from raw data to volts as required.

This sequence should be run if improved calibration is required, after any hardware offset adjust has been applied.

Computing the calibrated voltage is a matter of applying the straight line formula:

$$(y-Y1)/(x-X1)=(Y2-Y1)/(X2-X1)$$

recast as:

$$volts=V1+(raw+code_{min})*(V2-V1)/(code_{max}-code_{min})$$

where raw is the raw binary reading, and V1, V2 are the calibrated range limits.

$code_{min}$, $code_{max}$ are presented in the calibration file /etc/cal/caldef.xml

	code_min	***code_max***
ACQ164CPCI	-8388608	8388607
All other cards	-32768	323767

9.2.3.1 Equipment.

- DC Voltage source – should be stable, but accuracy is unimportant. RTM-AO16 makes a good voltage source.
- DC DVM – 4.5 digit – accuracy is important. We use Agilent Model 34410A, with Ethernet connectivity, and offer a fully automatic calibration when using this device.
- Cables to connect a group of channels to the source. On ACQ216, a group of 8 channels, entailing a 2 pass calibration to cover all the channels works well. While the procedure can handle fewer channels, clearly the overall process will take longer

9.2.3.2 Procedure

Log into the card as *root*.

Check that an appropriate file `/etc/caldef.xml` is present. Cards ship with the correct calibration file, but in the event of a configuration change (eg mezzanine change on *ACQ216CPCI*), a number of template files are present in the directory, and the closest fit should be selected.

For each input voltage range, choose two input voltages **V1**, **V2** – D-TACQ recommends **V1** = -75% full scale, **V2** = +75% full scale, but the actual values are unimportant.

ACQ196CPCI has only one input range. *ACQ216CPCI* has four input voltage ranges, and an automated procedure handles this.

The standard D-TACQ calibration procedure is a simple two point straight line process, operator choses two voltages **V1**, **V2.** A precision *DVM* should be used to measure the actual value, which is entered by hand* on the command line as follows:

```
calibrate -z -c ch1-chN
```

example:

```
calibrate -c 1-8
```

The program prompts for V1, V2, updates the calibration table for channels 1 to 8 and terminates.

```
calibrate -c 9-16
```

The program prompts for V1, V2, updates the calibration table for channels 9 to 16 and terminates.

*clearly, entry of the actual voltages can be automated, but this depends on your DVM.

-z : compensate such that code 0x0000 == 0.000V . This is a valid procedure for cards with effective auto zero mechanisms, eg ACQ196CPCI, ACQ216CPCI-

rev2.

Repeat for all channels, for all voltage ranges.

When the calibration is completed, make a non-volatile copy of the calibration table as follows:

```
  cp /etc/cal/caldef.xml /ffs/cal/{MTYPE}.{SERIAL}.xml
```

```
MTYPE: mezzanine M2, M5 for acq216 {M2 for M6}, acq196 for acq196.
```

```
SERIAL: serial number.
```

```
NB: there must be one, and only one file  of the form: /ffs/cal/
{MTYPE}*.xml
```

9.2.4 Calibration Table

The Calibration Table *CT* is stored in a text format (*XML*), so calibration data from any alternate user-supplied calibration process may be used.

The Calibration Table is also used to store the definitions of the available input ranges, and the default values for those ranges.

At boot time, the appropriate *CT* is available at

`/etc/cal/caldef.xml`
and if a custom (calibrated) *CT* is available, the master copy is held in *FFS* at

`/ffs/dropbear/etc/cal/Mx-caldef.xml`

9.2.5 Polarity

The *CT* is a handy place to implement a Polarity Inversion, if required, simply modify all the ranges such that the positive value comes first, and the negative second.

See “polarity” parameter in the DATA block.

9.2.6 Full automation example:

```
# valid for HiZ mezzanine:
rm /etc/cal/caldef.xml
ln -s /etc/cal/M2-hiZ.xml /etc/cal/caldef.xml

# identify our DVM by IP address: ignore this step for manual DVM
IP_34410=192.168.0.168
/usr/local/CARE/start.proxy.34410 $IP_34410
ln -s /usr/local/CARE/getvolts.34410 /usr/local/bin/read_dvm
# check it works:
read_dvm
+9.74757473E+00

# for manual input, omit this step, and calibrate will
# prompt for feedback:
export AUTO_DVM=1

# Our voltage source is a nearby ACQ196CPCI/RTMAO16
# with the "fungen service running.
# If you don't have a programmable voltage source, ignore this step,
# and the calibrate program will prompt for manual input.
# my voltage source has hostname acq196_010
export AUTO_VS=acq196_010



# now set up a suitable sampling configuration
. /usr/local/CARE/set.calibrate

# now run the calibration
/usr/local/CARE/calibrate_all_ranges [opts]

# typical opts are to limit the channels in the set - for
# example, you may only have cabling to run 4 channels at once:
root@acq216_023 ~ #time /usr/local/CARE/calibrate_all_ranges -c
6,7,8,9
1.6000,-1.6000
main $RCSfile: calibrate.cpp,v $ $Revision: 1.26 $ B1038

ACQ32:
ACQ32:
ch: 6 Raw: -32768, 32764 => Volts -1.7041,1.6839
ch: 7 Raw: -32768, 32764 => Volts -1.6267,1.6728
ch: 8 Raw: -32768, 32764 => Volts -1.6954,1.7083


  ...
```

9.2.7 Calibration Table Example:

```
<?xml version="1.0" standalone="no" ?>
<ACQ>
  <!-- m2-hiZ.xml $Revision: 1.1 $
    special M2 with HiZ has smaller ranges on lower settings -->
  <!-- calibration data -->
  <AcqCalibration>
    <Info>
      <CalDate>20070331:12:15</CalDate>
      <Version>$RCSfile: calibrate.cpp,v $ $Revision: 1.26 $
B1038</Version>
      <Model>ACQ216-M2</Model>
      <Serialnum>d41023</Serialnum>
    </Info>
    <Data AICHAN="16" polarity="REVERSED" code_min="-32768"
code_max="32764"
      <Range name="1.6" sw="0,0">
        <Nominal min="-1.6" max="1.6" />
        <Calibrated ch="2" min="-1.594217" max="1.598378" />
        <Calibrated ch="3" min="-1.580590" max="1.536258" />
 ...
        <Calibrated ch="16" min="-1.643807" max="1.625098" />
      </Range>
      <Range name="2.5" sw="1,0">
        <Nominal min="-2.5" max="2.5" />
        <Calibrated ch="2" min="-2.561408" max="2.565410" />
        <Calibrated ch="3" min="-2.524193" max="2.479898" />
 ...
        <Calibrated ch="16" min="-2.633520" max="2.614286" />
      </Range>
      <Range name="6" sw="0,1">
        <Nominal min="-6" max="6" />
        <Calibrated ch="2" min="-6.373147" max="6.423854" />
        <Calibrated ch="3" min="-6.293885" max="6.168747" />
 ...
         <Calibrated ch="16" min="-10.553202" max="10.469114" />
      </Range>
    </Data>
  </AcqCalibration>
  <ModelSpec>
    <ChannelBlockMask>
      <BlockWidth>4</BlockWidth>
      <BlockSet>&quot;1111&quot;,&quot;1110&quot;,&quot;1100&quot;,&
quot;1
    </ChannelBlockMask>
    <MaxAggregateRate>400 MB/sec</MaxAggregateRate>
    <MaxDeviceRate>50 MS/sec</MaxDeviceRate>
    <MinDeviceRate>1 MS/sec</MinDeviceRate>
    <CalClock>10000000</CalClock>
    <CalMeanN>1024000</CalMeanN>
  </ModelSpec>
</ACQ>
```

10 Command Reference.

For a complete comparison of **acqcmd**, **acqcmd** -b, **acqcmd** -s, **acq2sh** and just **shell**, please see #19.3

10.1 Operating Modes

The card will capture data in one of a number of modes.

- SOFT_TRANSIENT - a simple one shot capture
- SOFT_CONTINUOUS - continuous capture
- GATED_TRANSIENT - a one shot with a start trigger
- TRIGGEREDCONTINUOUS - "Pre/Post" capture, where the card captures data continuously to a circular buffer, until an external Event is received, when the card switches to a linear buffer, continues to capture data for a specified length and then stops.

There is complete flexibility over setting a start TRIGGER to enable any of the above captures, and the EVENT that controls transition from Pre- to Post- in TRIGGEREDCONTINUOUS mode is also use-specified.

A single command "set.pre_post_mode" is recommended to simplify client setup.

10.1.1 Linear Timebase

The default operating mode is to capture data continuously with a fixed clock. So the timebase of the data maps exactly to the sample clock times. Usually the clock is continuous and fixed, so this is referred to as a Linear timebase.

10.1.2 Regions of Interest - PRE Programmed triggers.

The normal *pre/post* mode of operation is to capture data continuously to a cyclic buffer until an external *Event* is received. In this case, usually all historical data is discarded, unless it is streamed off-board, usually at a sub-rate. However, under some circumstances, it is desirable to declare "Regions of Interest" at known times. On *ACQxxx*, this is the Preprogrammed Trigger (*PREP*) mechanism, and any number of *PREP's* can be defined. For detail see 14

10.1.3 Discontiguous Timebase: Repeating Gate Mode

Continuous timebase is effective on ACQxxx cards because of the large on-board memory, and the capability to stream data continuously. However, certain applications (laser strobing, radar/sonar pulses, probe plunging), the data of interest is bounded by a gate, and in this case makes no sense to capture data while the GATE (and therefore the signal) is OFF. *Repeating Gate Mode* [10.4.4] allows the user to specify that capture to be controlled by the Gate pulse. This allows for easy synchronization to the GATE pulse, and, importantly has potential for massive data reduction. Data is store to memory as a series of bursts. The data in memory no longer maps to linear time; however the card provides a timestamp with each burst to enable a linear timebase to be reconstructed for the data.

10.1.4 Random Multiple Events: MULTIVENT

ACQ132CPCI can be configured to accept random multiple events. Capture proceeds continuously. User specifies a region of interest with PRE, POST samples, and, on each event the surrounding raw data is reserved, and post processed. The data is made available in channelized format in a unique, network accessible directory. After consuming the data, a remote application can delete the directory, recycling the data. In this way, MULTIVENT can run indefinately, provided the average event rate does not cause the local DRAM to overflow.

MULTIVENT is described in detail in a separate document.

10.2 acqcmd Interface: (see ICD)

In addition, the basic Operating Modes are enhanced, by provision of

- User specified Trigger -

A Trigger is a digital input transition that starts a capture. In contrast to 1G where the trigger was a implied by the various modes, and the LINE and EDGE was fixed, in 2G the user can specify both LINE and EDGE. In order to user a trigger, it MUST be explicitly specified, and more generally, if a trigger is specified, it will apply regardless of Mode.

i.e.: if a trigger is specified, it will start capture, otherwise the capture is soft triggered.

- User specified Event -

Event is a digital input causing a transition from one Phase to another, at the moment only two Phases are defined (pre-, post-), and this in the SOFT_CONTINUOUS, TRIGGEREDCONTINUOUS modes.

In the same way as with the Trigger, LINE and EDGE is user definable.

Example Use:

- Traditional one shot capture:

Set Trigger, set Mode GATED_TRANSIENT (SOFT_TRANSIENT is equivalent if a Trigger is defined).

- Traditional pre-, post capture.

Set Event, setModeTriggeredContinuous, it is assumed that the pre- buffer is filled before event.

- Synchronized Streaming:

On multiple boards, set Trigger to be the same, mode SOFT_CONTINUOUS, all boards start on Trigger.

Please note, that, at this time, the “Enhanced Software Operation” modes (GPEM) are not available on 2G. However, it's also clear that, with user choice of Trigger and Event (s), equivalent functionality is to a large extent available.

10.3 dt100 remote interface

(see ICD, superceded by Section 20.1.

10.4 Shell command interface

Preferred way to add new functionality is via the shell command interface.

When operating as a two tier system using the dt100d server, shell commands are accessed via a connection configured using *dt100 open shell* from the dt100 remote interface. (See #20.1).

When operating via the PCI or dt100-hub interfaces, shell commands are accessed via the rsh pseudo-device

eg

```
acqcmd -f /dev/acq200/acq200.5.rsh hostname
```

acqcmd supports a short cut notation -s

```
acqcmd -s 5 hostname
```

A number of rsh scripts are implemented:

10.4.1 High level command Clock Role setting

ACQ1xx includes a flexible clock and trigger system. This allows lots of options that may be set individually. However, at least to start, D-TACQ recommends using the following role-base commands to set the clock scenario.

`set.acq196.role ROLE [CLKKHZ]`	
`set.acq132.role ROLE [CLKKHZ]`	
`set.acq164.role ROLE [CLKKHZ]`	

- `set.acq196.role ROLE [CLKKHZ]`
- `set.acq132.role ROLE [CLKKHZ]`
- `set.acq132.role ROLE [CLKKHZ]`

Where role is one of `SOLO|MASTER|SLAVE` and `CLKKHZ` is a valid output clock rate for the device.

On *ACQ164*, this command takes care of the additional *SYNC* signal routing, and selects the best *ADC MODE* based on sample rate.
On *ACQ132*, an additonal oversampling command 23.2.1may be needed to set exact oversampling condition.

10.4.2 Signals

Signals is the generic terms for

- Clocks - determine the instant of sampling
- Triggers - cause the start of a shot
- Event - places a marker in the data stream. Typically an Event will cause transition from pre- phase to post- phase.

10.4.2.1 Clock and trigger Routing

ACQ196CPCI, ACQ216CPCI, WAV232CPCI all feature clock and trigger routing capability on 6 dedicated DIO lines. This arrangement differs from previous generation ACQ32CPCI in terms of technology – instead of solid state switches, a line driver is used for higher performance at higher clock speeds.

These commands supercede "acqcmd setSyncRoute" found on ACQ32CPCI.

- DI[0-2] – recommended for Clocks – DO NOT SUPPORT "Wire OR"
- DI[3-5] – recommended for Trigger – open collector drivers, support Wire OR for "any board can declare a trigger applications".

LINE	*Default function*
DI0	External Clock
DI1	
DI2	
DI3	External Trigger
DI4	
DI5	

Source	*Description*	*Notes*
Mezz	Front panel input LEMO	DI0 : CLK DI3 : TRG others: not connected
Fpga	Local DIO output	Useful for driving other cards
Rio	Local Rear IO inputs	Depends on RTM
Pxi	Backplane PXI signaling	

One source can be routed to multiple destinations:

Destination.	*Description*	*Notes*
Fpga	Local DIO input	Always needed to respond to incoming signals
Rio	Local Rear IO outputs	Depends on RTM
Pxi	Backplane PXI signaling	Slave from other cards

Diagnostic and control available at http:/cgi-bin/dio.cgi

Scripted control via set.route:

```
set.route dX in {input} out {outputs}
```

Examples:

- Single card slaved from front panel.

```
# take trg in lemo, use locally only:
set.route D3 in mezz out fpga
```

- Master card distributes front panel LEMO signal to self and rack

```
# source trigger from mezza out fpga INPUT,  pxi:
set.route D3 in mezz out fpga pxi
```

- Slave card from pxi

```
# source trigger from pxi to fpga INPUT
set.route D3 in pxi out fpga
```

- Master card in rack, self clocking

```
# source trigger from fpga OUTPUT, drive  pxi:
set.route D3 in fpga out pxi
```

- Internal Clock on Master card can clock other cards:

```
# source clock on master
set.route D0 in fpga out pxi
# enable clk mastering

set.InternalClock NNN DO0

# ensure D0 is an output.

setDIO 0-----
```

10.4.2.2 Clock Selection

Individual Clocks can be defined as follows:

#	Command	Function
1	**set.ext_clk** DIx edge	Define external (AI) clock
2	**set.int_clk_src** DIx edge	Define internal clock source (in clock divider mode)
3	**mas_clk** DOx	Output for InternalClock
4	**counter_src** DIx edge	Source for counter unit
5*	**set.ao_clk** DI[012]	Define AO clock
6	**sync_trig_src** DIx edge	Source for sync trig
7	**sync_trig_mas** DOx	Output for sync trig
*		*ACQ196 ONLY*
	DIx : DI[012345] DOx : DO[012345] edge : falling|rising	

10.4.2.3 Trigger Selection

A trigger is a one shot edge used to start a one shot capture eg GATED_TRANSIENT

Software is able to select one of DI3, DI4, DI5 and rising | falling edge.

```
set.trig DIx sense

DIx    {DI3, DI4, DI5 }
sense  {falling, rising}

eg:
set.trig DI3 falling;# emulate GATED_TRANSIENT behaviour.

set.trig none        # cancel the trigger selection
```

Be sure to use **set.trig** none for a subsequent capture when no trigger is required.

The AO function has its own trigger:

set.ao_trig DIx edge	Define AO trigger

10.4.2.4 Event selection

An event is a digital edge detected *after* capture starts. Typically this causes a phase transition (eg pre to post).

ACQ[12]xx features detection of two separately defined events.

Set.event allows local specification of event to be used:

```
set.event eventE DIx sense

eventE {event0 | event1}
DIx    {DI3, DI4, DI5 }
sense  {falling, rising}

eg:
set.event event0 DI3 falling ;# emulate TriggeredContinuous behaviour
```

Report existing setting with:

```
get.event eventE     {event0 | event1}

# Alternate notation

set.event0 Dix sense

# Cancellation

set.event0 none
set.event event0 none
```

It is recommended that the event definition be re-asserted before each capture.

10.4.3 Generic Pre/Post Mode

set.pre_post_mode pre post [dix [sense]]

get.pre_post_mode

These are high level commands to simplify mode selection and to replace both:

```
set.event0 dix sense
acqcmd setModeTriggeredContinuous pre post
```

and

```
set.trig dix sense
acqcmd setMode GATED_TRANSIENT post
```

set·pre_post_mode makes the decision on which technique to use based on the values of `pre, post`; this relieves application code of this complexity and is *STRONGLY RECOMMENDED* for new interface designs.

Example:
set.pre_post_mode 10240 4000000 DI3 falling

continuous capture to pre-buffer, change phase to post-buffer on `DI3 falling,` finish up with 10240 samples `pre` and 4000000 samples `post.`

10.4.4 Repeating Gate Mode

Allows operation with discontiguous timebase. The card is first configured with one of the major modes (typically SOFT_TRANSIENT). The command to enable Repeating Gate Mode is:

set.dtacq RepeatingGateMode *MODE TLEN*

The Gate *signal* is *Event0*, and any of lines d3,d4,d5,[d0,d1,d2] may be selected together with programmable sense. On ACQ132CPCI *ONLY*, a separate gate source control is provided:

set.gate_src DIx {high|low}

Three separate Modes are implemented:

Value	MODE	TLEN	Description
0	OFF	X	Disable (Contiguous Timebase)
1	TRAN	1..65535	Start on Event0 Active Edge End after TLEN samples.
2	GATE	X	Start on Event0 Active Edge, End on Event0 Inactive Edge.
3	TRAN+GATE	1..65535	Start on Event0 Active Edge End on first of TLEN samples or Event0 Inactive Edge.

Each block of data in memory is preceded by an Event Signature *ES* and a 32-bit timestamp. The timestamp is driven from the internal time counter, which is set up in the normal way.

There are two ways to view the data:

1. Upload Raw Data and postprocess on a Host Computer - D-TACQ supplies the *rgm* shared library and *rgm_dump* utility to do this.
2. Onboard post-processing. Each channel is presented as a linear data set, together with an additional timebase vector on a dummy "channel". Client software (such as MDSplus) can plot channel vs linear time by plotting the channel data vs timebase.

10.4.4.1 Clock Options

The sample clock can be a "InternalClockMaster" where one designated card drives a 500kHz clock on the PXI backplane so that all cards clock simultaneously.

Alternatively, and external 500kHz clock can feed in the front panel of one card "LemoClockMaster", and this card again will feed the clock to all slaves.

By default, the Timestamp is driven from the sample clock. However, in a third possibility "Sysclock", a 1MHz SYSCLK is feeds the front panel LEMO of the

"SysclkMaster" card. The 1MHz clock is distributed on PXI and drives all the timestamp counter. Separately, the Master card divides SYSCLK by two to generate the Sample clock, and this is distributed to all cards on a separate PXI line.

10.4.5 Input Voltage Range

Certain models have input voltage selection (most ACQ216CPCI mezzanines).

To set all the channels to the same range:

```
set.vin  range-key
```

```
eg
set.vin 3
-3.0000,3.0000
```

To set a selection of channels to a voltage range:

```
set.vin selection range-key
```

```
selection:
          channel
          channel1[,channel2]
          channel1-channel2
```

To find out the valid set of `range-key` values :

```
get.vin range-keys
```

```
get.vin range-keys
"30","50","625","1","1.9","3"
```

Example:

- Set all channels to Range 3 (V)

```
set.vin 1-16 3
-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000
```

- Set channel 3 to Range 625 (mV)

```
#set.vin 3 625
-3.0000,3.0000-3.0000,3.0000-0.6250,0.6250-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000
```

- Set channels 10-16 to Range 1 (V)

```
set.vin 10-16 1
```

```
-3.0000,3.0000-3.0000,3.0000-0.6250,0.6250-3.0000,3.0000-
3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-3.0000,3.0000-
3.0000,3.0000-1.0000,1.0000-1.0000,1.0000-1.0000,1.0000-
1.0000,1.0000-1.0000,1.0000-1.0000,1.0000-1.0000,1.0000
```

To Read the voltage range, acqcmd getVoltsRange is provided for back compatibility, it will return the values of the largest selected range:

eg

```
acqcmd getVoltsRange
ACQ32:getVoltsRange AI=-3.0V,3.0V AO=-10.0V,10.0V
```

To recover the actual range that each channel is set to, including any calibration:

```
get.vin
-3.0000,3.0000,-3.0000,3.0000,-0.6250,0.6250,-3.0000,3.0000,-
3.0000,3.0000,-3.0000,3.0000,-3.0000,3.0000,-3.0000,3.0000,-
3.0000,3.0000,-1.0000,1.0000,-1.0000,1.0000,-1.0000,1.0000,-
1.0000,1.0000,-1.0000,1.0000,-1.0000,1.0000,-1.0000,1.0000
```

(if a calibrated range is not available, this command returns the default:)

(see `http:/cgi-bin/vin.cgi` for diagnostic).

It is of course also possible for any remote client to pick up the underlying XML calibration file (`/etc/cal/caldef.xml`) and to use this directly.

10.4.6 Channel Mask and Channel Count

This replaces **`acqcmd`** `setChannelMask`, `acqcmd getChannelMask` with an implementation that works better for 96 channels on ACQ196:

```
acq2sh set.channelMask {1,3,7}{2,4,5,6 also valid but less likely}
acq2sh get.channelMask reports setting (in hex).
acq2sh get.numChannels reports number of channels enabled by the mask
```

10.4.7 Block Technique for Setting Channel Mask

Not all possible combinations of channel mask are supported by hardware.
For example, on ACQ196, channels are enabled in blocks of 32 channels.
Using the original command setChannelMask, the only way to deduce this is to set a channel mask and then to see what you got:

ACQ196 Example:

```
acqcmd setChannelMask 1
ACQ32:
acqcmd getChannelMask
ACQ32:getChannelMask=11111111111111111111111111111000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
```

A more deterministic way to do this is by use of Channel Block commands.

- **get.modelspec ChannelBlockMask.BlockWidth** :
  returns width of each maskable channel block in channels
- **get.modelspec ChannelBlockMask.BlockSet**:
  returns the selection of channel block masks that have meaning on this platform.

ACQ196 Example - blocks of 32 channels

```
get.modelspec ChannelBlockMask.BlockWidth
32
get.modelspec ChannelBlockMask.BlockSet
"111","110","101","011","100","010","001"
```

ACQ216 Example - blocks of 4 channels, grouped from lowest logical channel

```
get.modelspec ChannelBlockMask.BlockWidth
4
get.modelspec ChannelBlockMask.BlockSet
"1111","1110","1100","1000"
```

Use this information as follows:

- **set.channelBlockMask <mask>**
- **get.channelBlockMask**

ACQ216 Example - setting a channel mask using block commands

```
#set.channelBlockMask 1100
acqcmd -- setChannelMask 1111111100000000

ACQ32:

acqcmd getChannelMask
ACQ32:getChannelMask=1111111100000000
```

10.4.8 Access fields in calibration file.

Default calibration file `/etc/cal/caldef.xml` contains all calibration and other useful parameters for the card. Applications may load and parse this file directly

eg

- **acq2sh** `cat /etc/cal/caldef.xml`
- **wget** `http:/hostname/etc/cal/caldef.xml`

Or it is possible to extract selected fields using

- **get.caldef <field>**
- **get.modelspec <field>**

```
get.caldef Info.CalDate
20041225
get.caldef Info.Version
B1007
get.caldef Info.Model
ACQ196
get.caldef Info.Serialnum
d30000
get.modelspec ChannelBlockMask.BlockWidth
32
get.modelspec ChannelBlockMask.BlockSet
"111","110","101","011","100","010","001"
get.modelspec MaxAggregateRate
80 MB/sec
get.modelspec MaxDeviceRate
500 kS/sec
```

10.4.9 set.autozero : start an autozero process (Acq196 only)

Assumes all inputs are open circuit.

Ramps input offset adjustment until all channels are zero calibrated, storing values for use next boot.

10.4.10 Analog Output Control

ACQ196CPCI- RTM-AO16 only

16 analog outputs with software control of DC values and Arbitrary Waveform Generation (AWG) capability. Two types of arbitrary waveform are supported:

- Hardware Arbitrary Waveform (***HAWG***)
- Software (FIFO) Arbitrary Waveform (***FAWG***).

At this time the **HAWG** is restricted to channels 01, 02, and 512 points maximum, but will run under hardware control at full speed (1000kHz), while the **FAWG** allows 16384 points maximum on all 16 channels, but with update rate controlled by an auxilliary timer interrupt., with a maximum practical update rate of 500kHz.

In general, use FAWG unless very high update rates are required.

The HAWG is designed for exact sample by sample matching with custom FPGA DSP firmware.

In either case, the firmware interface is virtually the same.

It should also be noted that the AWG is competing for local bus bandwidth with the acquisition process, as well as any Ethernet traffic, and full speed operation on all functions may not be possible. This trade off is roughly:

- *AI > 100KSPS, AO < 25kSPS.*

Please contact D-TACQ for evaluation of specific requirements.

10.4.10.1 Clock and Trigger

The AO function may use internal or external clock.

The AO function may use external trigger or soft trigger.

AO clock and trigger function is selected independently to the AI functions.

ie: AO clock/trigger can be the same, or it can be different to AI.

The default and most common setting for the AO clock is to simply slave off the internal clock.

NB: if no external trigger is used, a soft trigger MUST be explicitly asserted in order to change AO waveforms. DC values are not affected by trigger.

```
set.ao_clk DIx sense
set.ao_trig DIx sense

DIx    {DI3, DI4, DI5 }
sense  {falling, rising}

eg:
set.ao_trig DI3 falling;# emulate GATED_TRANSIENT behaviour.
set.ao_trig none        # cancel the trigger selection
```

10.4.10.2 Logical Device Nodes:

Driver provides the following device nodes. Access through **set.AO** is preferred, although for speed a client application may use direct access.

```
root@acq196_001 ~ #ls -1 /dev/acq196/AO
01                              ;# load ascii hex voltage def here
02
03
...
15
16
XX                              ;# load value to all channels
commit                          ;# 1=> commit DC, 2 => commit AWG
f.01                            ;# load binary waveform here
f.02
f.03                            ;# FAWG only from here.
..
f.16
coding                          ;# signed | unsigned
```

10.4.10.3 DC Control

Write a numeric representation of the raw output value to any/all of `/dev/acq196/AO/cc`

Examples:

```
echo 32767 > /dev/acq196/AO/01
echo -32768 > /dev/acq196/AO/01

# change by delta:
echo p10 >/dev/acq196/AO/01      # increment 10 steps
echo m10 >/dev/acq196/AO/01      # decrement 10 steps
```

For prototype and test purposes, please refer to `cgi-bin/AO.cgi` –

this provides a simple control panel to exercise the AO channels.

Each AO channel is represented by a logical device node and a script

`/usr/local/bin/set.AO`

is provided to give access to the AO channels. The script allows simple access from remote clients and cgi-scripts.

More formally, first, set the values in buffer memory:

```
set.AO <channel> <value>  :
          <channel: 01..16, XX (all channels)>,
          <value: decimal-value> :
                    decimal-value: -32768 .. 32767
```

The voltage coding is as specified in /dev/acq196/AO/coding, and it is anticipated that a default value will be set at boot time (eg by /ffs/rc.local boot script).

Then commit the values to hardware as follows:

```
set.AO commit 1
```

10.4.10.4 Hardware AWG "HAWG"

A hardware AWG function is available for channels 1 and 2. The ***HAWG*** has a maximum length of 512 samples.

To configure ***HAWG***:

1. Copy the data to the appropriate device node:

```
cat my-binary-data >/dev/acq196/AO/f.01
```

```
NB: this data is raw binary (not ascii as per the DC nodes), and the
voltage coding should match the selection in /dev/acq196/AO/coding.
```

2. Start the waveform with a commit 2:

```
set.AO commit 2                    # hardware trigger
set.AO commit 18                   # soft trigger
```

Two canned waveforms are provided:

```
set.AO <channel> sin
set.AO <channel> saw
```

set.AO has provision for two User Waveforms, to be stored on the FFS partition:

```
set.AO <channel> arb
```

Two make this work, store user binary waveforms in

```
/ffs/AO.awg.01
/ffs/AO.awg.02
```

The files should contain binary data, max length 256 samples.

If one data set is longer than the other, the channel with the shorter data set will have the last value repeated up to the end of the longer data set.

Please note that the ***HAWG*** function is repeated until stopped (HOW?), and may either be software triggered or triggered by external hardware event, in the same way as the AI capture. The AO trigger is independent of the AI trigger, but may be set to the same value as required.

10.4.10.5 Fifo AWG "FAWG"

As before**,** write binary waveforms to each required channel `/dev/acq196/AO/f.XX`

- max points 16384 - 8s @ 2KHz:

  ```
  cat /sys/module/acq196/parameters/fawg_max_samples
  ```

- Start: **`set.arm.AO.FAWG`** `[opts]`
- Stop: **`set.AO`** `commit 0`

The *FAWG* will replay all channels, up to the length of the longest channel definition.

If a channel definition is shorter than the longest, the last value in the definition is repeated until end of buffer. If the channel definition has zero length, the DC value is used.

A sample *FAWG* test routine is supplied in `/usr/local/CARE/acq196.FAWG.test`

FAWG update rate - reading data out of the FIFO is the AI sample clock divided by **`FAWG_DIV`** {1..255}

`/dev/dtacq/FAWG_DIV` : controls the output data rate as a fraction of AI sample rate.

10.4.10.6 FAWG Options

FAWG operation is controlled by **`set.arm.AO.FAWG.`**

This arranges for the underlying *commit* value to be set at the appropriate time.

```
set.arm.AO.FAWG [opts] :
ONCE | CYCLIC [default]                  : repetition mode
SOFT_TRIG | HARD_TRIG [default]          : trigger
IMMEDIATE | [default: write on setArm]   : when to commit the value
```

The default option [no args] is to schedule a hard triggered cyclic waveform to be armed at *setArm*. `IMMEDIATE` means arm immediately, NB: this will not work for the case of a `ONCE` one shot operation.

- Range of values for **`set.AO`** `commit`

`commit` is set as a combination of binary bit flags.

```
#define COMMIT_DC   0x01    /** set DC output                          */
```

```
#define COMMIT_HAWG 0x02    /** initiate HAWG output on trigger   */
#define COMMIT_FAWG 0x04    /** initiate FAWG output on trigger   */
#define COMMIT_REF  0x08    /** enables REF output (MAC fw only)  */
#define COMMIT_TRIG 0x10    /** software trigger on commit        */
#define COMMIT_ONESHOT 0x20 /** oneshot FAWG action when enabled  */
#define COMMIT_CONTINUOUS 0x40 /** continuous data feed */
                               /** default is cyclic repeat */
```

10.4.10.7 FAWG Example:

```
# assume clock routing has already been made

set.ao_clk DI0 falling
set.ao_trig DI3 falling
set.dtacq FAWG_div 20          # output DI0 / 20

# for AI clock < 100kHz, can use FAWG_div==1


# now generate some data
fungen --cycle 1 4 0 2.5
fungen --cycle 2 5 0 2
fungen --cycle 3 6 0 1.5

# or fetch it with curl:
curl -s -o /dev/acq196/AO/f.#1 ftp://anonymous@host/pub/f.[01-16]

# or push it with curl (assumes embedded ftp server running)

cat mydata | curl -T - -u ao: ftp://target/AO/f.01

# or simply transfer by hand with good old ftp


# configure hooks to start process with main AI capture:

set.arm.AO.FAWG CYCLIC HARD_TRIG

# sometime later - configure AI and setArm
```

10.4.10.8 Function Generator

A simple function generator program for use with the FAWG is supplied:

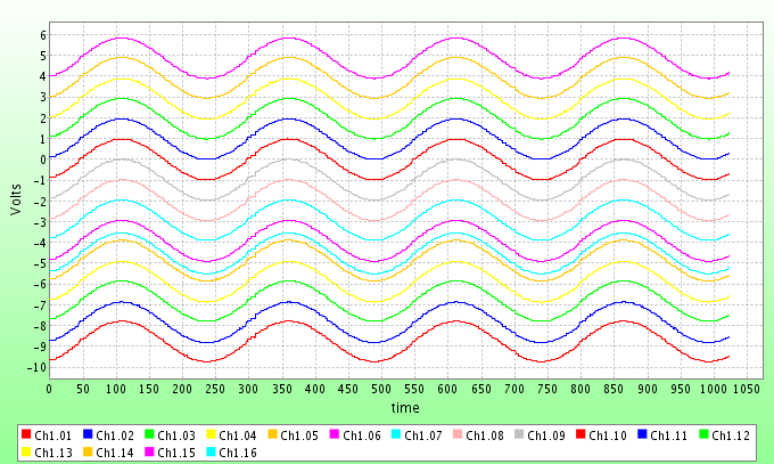
```
fungen channel [K] [A] [nsam]

function is channel = K + A sin (wt) (nsam samples).
K, A are floating point volts.
Takes about 30msec to generate 64 points. 64 points should be more
than enough for a typical coil drive.
```

Phase Control:

```
usage: fungen --sin -- ch K A [N] [P]
usage: fungen --cos -- ch K A [N] [P]

ch: channel 1..16
K,A  : offset, amplitude in volts (floating point)
N : number of samples per cycle (integer)
P : phase adjust (samples).
```

Example Script:

```
root@acq196_001 #for ch in 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
do
          let v="$ch-10"
          fungen $ch $v
done

ch:01 -9.00 + 1.00 * sin(wt) [64]
ch:02 -8.00 + 1.00 * sin(wt) [64]
ch:03 -7.00 + 1.00 * sin(wt) [64]
ch:04 -6.00 + 1.00 * sin(wt) [64]
ch:05 -5.00 + 1.00 * sin(wt) [64]
ch:06 -4.00 + 1.00 * sin(wt) [64]
ch:07 -3.00 + 1.00 * sin(wt) [64]
ch:08 -2.00 + 1.00 * sin(wt) [64]
ch:09 -1.00 + 1.00 * sin(wt) [64]
ch:10  0.00 + 1.00 * sin(wt) [64]
ch:11  1.00 + 1.00 * sin(wt) [64]
ch:12  2.00 + 1.00 * sin(wt) [64]
ch:13  3.00 + 1.00 * sin(wt) [64]
ch:14  4.00 + 1.00 * sin(wt) [64]
ch:15  5.00 + 1.00 * sin(wt) [64]
ch:16  6.00 + 1.00 * sin(wt) [64]
```



10.4.10.9 Function Generator Service

While **fungen** may be operated in batch mode from the command line (or using **acq2sh** commands), for interactive use this is a little sluggish, and so there is a high performance interactive mode, this runs as service on port 53506 under **inetd**. The service may be accessed via `telnet`, or more typically via a remote program; for example **dt100rc**.

Example:

Start the service on the target (this command may be placed in `/ffs/rc.local`)

```
start.fungen.service
```

From a remote machine:

```
[pgm@islay ~]$ telnet acq196_001 53505
Trying 192.168.0.156...
Connected to acq196_001.localnet (192.168.0.156).
Escape character is '^]'.
fungen>--autocommit 20 --sin 3 1 0.5 64
1 OK
fungen>--autocommit 20 --sin 3 1 2 64
2 OK
fungen>commit 20
3 OK
fungen>--sin -- 1 1 1 64
4 OK
fungen>--cos -- 2 2 2 64
5 OK
fungen>--sin -- 3 -1 2 64
6 OK
fungen>commit 20
7 OK
fungen>--autocommit 20 --sin -- 3 1 0.5 64
8 OK
```

```
fungen>--autocommit 20 --sin -- 3 1 1 64 10
9 OK
```

fungen caches the sine wave as a lookup table, assuming best performance when all the waveform have same number of samples (amplitude, offset and phase are all derived from the LUT data).

Waveforms are not written to the hardware until the commit action.

For the case of updating multiple channels it is best to commit at the end.

For the case of interactively updating a single channel, the `--autocommit` option will commit the channel data without the need for a separate command.

10.4.10.10 Test Sequence

The RTM-AO16 makes for an easy loopback test as follows:

- connect a S68 cable from AO connector to AI to run a loopback test.
- use Mozilla to connect to `<target-ip>/cgi-bin/AO.cgi`
- push "Ident" followed by "commit DC" to set up an identity set.
- capture some data and you should see the pretty ident picture.
- push "sin 1", "saw 2", commit DC+AWG, capture again to get second picture with waveforms.

10.4.11 RTM DIO32 Control

RTM features 32 bits programmable dio.

The RTM device driver is not loaded by default.

```
load.rtm  ;# should be loaded at boot time eg via /ffs/rc.local

set.DIO32 <diopattern>
get.DIO32
outputs: dioreadbackpattern

<diopattern> : [pat0[pat1[pat2 ... [pat32]]]

patX : X denotes bit number, values of X :
          '-' : input,
          '1' : output 1, '0': output 0,
          'x' : ignore

dioreadbackpattern : r0r1r2r3....r32

rX : 'L' : input LO, 'H': input HI, '1':output 1, '0': output 0.

eg:

set.DIO32 11110000----------------  # 4 HI, 4 LO, rest input
get.DIO32
11110000HHHHHHHHHHHHHHHHHHHH

set.DIO32 xxxx1xxxxx                 # set bit 4 only
set.DIO32 xxxx0xxxxx                # clear bit 4 only
set.DIO32 xxxxP                # Positive pulse, bit 4
set.DIO32 xxxxN                # Negative pulse, bit 4
```

It is also possible to access this control directly through the following device node:

```
/dev/dio32
```

10.4.12 Timer Counter

2G cards are equipped with a 32 bit clock counter module. The counter source may be selected from any one of DI0-5 or Internal clock. The counter starts counting when acquisition is triggered. An **`Immediate Count`** value may be queried at any time. A second value, **`Latched Count,`** may be configured to latch on the first occurrence of a selectable event – this can be **`Sample`**, **`Event0`** or **`Event1.`**

A typical use for the Counter is to count an extenal fixed clock (1Mhz, say), with the latch source set to Event0, providing a fixed measure of the time to the first event. This is then a direct and independent measure, that can either be used to verify the time of the event as measured by sample number, or, if the counter source clock is faster than the sample clock, to give a more precise measurement of the time

of the event.

The function is controlled and monitored via the following shell commands:

- **set.counter_src** DIx
- **get.counter_src**
- **set.counter_update** [0,1,2] [sample, event0, event1]
- **get.counter_update**
- **get.dtacq** clock_count_immediate
- **get.dtacq** clock_count_latched

10.4.13 Monitor state with acqstate / statemon.

It is possible to block on state changes by reading the node `/dev/tblocks/acqstate.`

This can be used as the basis for efficient event driven test sequences.

State change information is also available as an internet service:

To start the service, un-comment the “STATED” option in `/ffs/rc.local.options`

The state server may also be combined with a “remote client in the loop” hardware watchdog, to make use of this facility:

To allow use of the watchdog, un-comment the "WDT" option in `/ffs/rc.local.options`

The service is available from other networked computers on port 53535, for example:

```
[pgm@islay CARE]$ telnet acq196_010 53535
Trying 192.168.0.154...
Connected to acq196_010.localnet (192.168.0.154).
Escape character is '^]'.
78106.75 0 ST_STOP
78106.81 1 ST_ARM
78106.82 2 ST_RUN
78106.88 5 ST_CAPDONE
78106.94 4 ST_POSTPROCESS
78107.75 0 ST_STOP
```

The timestamp is in seconds from midnight.

This remote service may be easily incorporated into remote controller scripts eg using expect(1). This is superior to polling for state changes eg using `acqcmd --until,` since no event transitions are missed, while at the same time it has negligible loading on the embedded computer.

The acqstate service is actually implemented using the **`statemon`** program, and this has some additional options, commands available on the input:

- Set a heartbeat in seconds:

```
heartbeat=N
```

- Remote watchdog:

```
watchdog
```

The heartbeat prints a time-stamped report event N seconds.

The watchdog command enables the hardware watchdog, and, once enabled, the remote client must issue repeat "watchdog" commands with a maximum 12 s interval, or the hardware watchdog time will fire, rebooting the card. Once enabled, the hardware watchdog cannot be disabled.

It is anticipated that these commands will be used in electrically harsh environments, where electrical noise could be interfering with either the Ethernet or correct

operation of the card itself.

The networked watchdog enables "host-in-the-loop" watchdog control - the client application could implement as test-oriented policy, such as only refreshing the watchdog when data is received.

A verbose version of the same service is supported at port 53536:

This offers a sign on message containing the current state, and prints number of samples and state on every transition to stop. A remote status monitor program could connect to this service and show system status with no polling at all.

```
nc 192.168.1.237 53536
D-TACQ statemon:$Revision: 1.18 $ B1008
50542.34 0 ST_STOP SHOT=20 ACQ32:getNumSamples=40003584 pre=0
post=40003584 elapsed=40003584

OK
50546.29 1 ST_ARM
50546.41 2 ST_RUN
50547.21 5 ST_CAPDONE
50547.63 4 ST_POSTPROCESS
50570.25 0 ST_STOP SHOT=21 ACQ32:getNumSamples=40003584 pre=0
post=40003584 elapsed=40003584
```

An example remote client is `FUNCTIONAL_TESTS/time-states.py`

This progam lists the time spend in each state.

```
[pgm@hoy2 FUNCTIONAL_TESTS]$ ./time-states.py 192.168.1.237:10015
ST_ARM              : 0.09
ST_RUN              : 4.00
ST_CAPDONE          : 0.41
ST_POSTPROCESS      :22.74
ST_ARM              : 0.06
ST_RUN              : 0.80
ST_CAPDONE          : 0.41
ST_POSTPROCESS      :23.22
```

```
Sample Dialog:

D_TACQ statemon:$Revision:1$
heartbeat=1
heartbeat ENABLED
OK
33531.93 timestamp
33532.93 timestamp
33533.37 0 ST_STOP
33533.93 1 ST_ARM
33533.93 2 ST_RUN
33533.98 5 ST_CAPDONE
33534.41 4 ST_POSTPROCESS
33535.36 0 ST_STOP
33536.35 timestamp
watchdog
OK
33567.29 timestamp
33568.29 timestamp
33569.29 timestamp
33570.29 timestamp
watchdog
watchdog 1
OK
33571.29 timestamp
33572.29 timestamp
33574.29 timestamp
t33575.29 timestamp
watchdog
33576.29 timestamp
watchdog 2
OK
33577.40 timestamp
...
33585.40 timestamp
watchdog
33586.40 timestamp
watchdog 3
OK
33588.08 timestamp
33589.08 timestamp
...
33604.08 timestamp
33605.08 timestamp
33606.08 timestamp
33607.08 timestamp
33608.08 timestamp

WDT kicks in and the card reboots.
```

11 Data Interface: Transient Data.

11.1 Introduction

Default operation mode is to take a one-shot transient to local memory at a high sample rate, then stop and upload the data. Pre/Post capture has an element of continuous capture, however in terms of data upload, it's still a stop-and-upload mechanism. During a Pre/Post capture, the card is able to report subrate data results.

ACQxxx aims to present data to the user in a format that is both efficient and meaningful to the user.

For a transient capture, this usually means channelization – ie data is provided as a time series for each channel.

Channelized data may be considered to be an array ordered as:

```
data[channels][samples].
```

By contrast, the hardware produces data as a sample vector – for each sample, we have the data for each channel. During capture, the firmware is under a hard real time constraint, and copying the data to memory is handled in blocks using DMA. So the data is written to memory in the raw format produced by the hardware as the transposed matrix:

```
raw[samples][channels].
```

In addition, there may be a non-intuitive mapping between the logical channel order of the plant cable interface at the front panel and the in memory order of the converted data.

This implementation detail is hidden from external clients, by allowing data access through a series of channelized data device files. Typically, to make the client data access as efficient as possible, after a transient capture the firmware will also run a post processing job to sort the data into the logical channelized order (as described in #11.3)

The data is available on all interfaces, as described below.

We're aware that quantities of data are very large, so facilities are provided to reduce the amount of data that has to be uploaded. In particular we support the idea of an initial rough comb through the data, followed by upload of regions of interest – start offset and stride controls are provided for this purpose.

Finally, data may also be obtained in raw format. The software provides dynamic access to a lookup table describing the logical to memory order of the data.

11.2 Host Pull vs Target Push

Remote client applications can pull data from the ACQxxx on demand, either over the CPCI backplane or via Ethernet via the remote access port.

ACQxxx can also be configured to push data back to a remote host on completion of

a shot. Target Push examples using both FTP and MDSplus client software are available.

In continuous modes, low rate streaming data may be pushed continuously out the Ethernet interface, or high data rate backplane streaming is possible.

In general, Target Push will be more efficient and scaleable than Host Pull, because the data transfer can proceed as soon as the data is ready, with no polling required, and, with multiple ACQxxx cards , the operation is inherently parallel.

11.3 Post Processing

After a transient capture, a post processing task runs to transform data order in memory from ***raw*** `[samples][channels]` to ***cooked*** `[channels][samples]`. This allows for efficient application access afterwards. For a 1GB memory, the post processing will take about a minute. Since, during post processing all the captured data passes through the *cpu* data cache, and the loop operation is memory bound, there is scope for additional processing, and the user is free to provide a custom post-processing routine, following the example provided.

11.4 Custom Post-Shot Processing

Recall that the normal state sequence is:

ST_STOP => ST_ARM => ST_RUN => ST_POSTPROCESS => ST_STOP

After the shot has ended, embedded control software sets the STATE to ST_POSTPROCESS and runs a post shot script **`/usr/local/bin/acq200.pp.`**

It is possible to modify this script to perform custom post processing.

It is also possible for host (or client) software to leave post processing scripts - such as Target Push upload scripts that will be run automatically on completion of the shot.

Custom scripts may be left in either of two directories:

- `/etc/postshot.d` - scripts run at the end of **`acq200.pp`**, after data transform.
- `/etc/postshot0.d` - scripts run before the data transform

In this way, one or more uploads may be specified before the shot, without modifying the standard script.

Typical uses:

Write a strided data upload script to run in `/etc/postshot0.d` - eg an **`mdsPutCh`** command to upload and display a subset of data with minimum latency.

Write a full data upload script to run in `/etc/postshot.d` to upload the complete data set as soon as it is available.

For an example please see 11.14.1.1 .

11.5 Data Devices on target:

`/dev/acq200/data/CC` where `CC` is `01, 02 ..... nchannels`.

Applications can use regular read() calls to access this data. Users may also use standard UNIX tools like *hexdump, dd, cp, ftp* to access the data.

Post processing is controlled by the following script:

`/usr/local/bin/`**`acq200.pp`**

If access to the raw data is required, it is possible to stub out the post processing, and raw data is then available via the following logical device:

`/dev/acq200/data/XX`

It is also possible to modify **`acq200.pp`** to perform custom post processing or Target Push data upload after the shot.

11.6 Combing the data

Two global hooks are provided to control start point and stride value through the data,

these are:

`/dev/acq200/data/sample_read_start` –

offset in samples into data buffer (default:0)

/`dev/acq200/data/sample_read_stride` –

stride value through data (default:1).

/`dev/acq200/data/sample_read_length` -

maximum number of samples to read out

`/dev/acq200/data/sample_read_ssl` -

shortcut takes `start stride length` args, or `reset`

Convenience commands are provided to access these device files:

`set.sample_read_start`

`set.sample_read_stride`

`set.sample_read_length`

`set.sample_read_ssl`

A typical operation might be:

```
#!#bin/sh
# we use shell script for convenience – a compiled version may be
#        faster
```

```
# get all the data decimated by 100 in time to look
# for region of interest:

set.sample_read_stride 100
cp /dev/acq200/data/01 combfile

# get a region of interest

for channel in 01 02 03 04 05 06 07 08 09 10
do
          cp /dev/acq200/data/$ch roifile.$ch
done
```

These controls are most usefully combined with use of the ftp client facility.

11.7 Efficient Comb Read With readd

The **readd** utility is provided to give controlled access to the data nodes,

with either a START STRIDE STOP or a START STRIDE LENGTH idiom.

```
readd --help
Usage: readd [OPTION...] channel
  -s, --start=INT
  -e, --end=INT
  -l, --len=INT
  -K, --stride=INT
  -b, --buflen=INT
  -v, --version
  -d, --verbose=INT
```

In practise, use of normal read facilities **cat**, **dd**, **ftp** combined with **set.sample_read** xxx is more effective than **readd.**

11.8 MDSplus Thin Client

ACQxxx includes an MDSplus Thin Client, able to export data direct from channel to tree via an MDSIP server. The Thin Client is intended to provide an interface to MDSplus for regular shell interaction that is very similar to the interface that is presented in other environments like IDL.

11.8.1 Mdsshell detail:

The thin client implementation is an executable **mdsshell**.

One instance of **mdsshell** operates as a local proxy server, capable of holding up a TCP socket connection to a remote MDSIP server. Once the server is running, other instances of **mdsshell**, act as discrete, scriptable MDS commands. The commands are implemented for convenience as named links to the **mdsshell** executable, in the manner of **BusyBox**.

```
root@acq196_035 ~ #mdsshell --help
mdsshell $Revision: 1.4 $ B1010 mdsshell
mdsshell: multicall binary and server $Revision: 1.4 $ B1010
server:
mdsshell 2>&1 | logger -t mdsshell &
mdsConnect
mdsOpen
mdsPut
mdsValue
mdsClose
mdsSetDef
```

1. Run the server (perhaps from /ffs/rc.local).
   ```
   mdsshell 2>&1 | logger -t mdsshell &
   ```
2. Connect to a remote MDSIP host
   ```
   root@acq196_035 /bin #mdsConnect eltca1
   MDS_SOCK=7
   ```
3. Open a Tree
   ```
   mdsOpen MYTREE
   ```
4. Put Data
   ```
   mdsPut --format shorts --length 1000000 ch01 \
             'cat /dev/acq32/acq32.1.01'
   ```

11.8.2 mdsPut special features

```
mdsshell>mdsPut --help
mdsshell>Usage: mdsPut [OPTION...]
 -F, --format=STRING
 -l, --length=INT
 -d, --dim=STRING
 -s, --subarray=STRING                // STRING: major dimension:
offset,len
 -e, --expr=STRING
 -f, --file=STRING
 -t, --root=STRING
 -h, --help
 -u, --usage
```

Typical Use cases:

Assume shell variables:

```
$CHFILE    - /dev/acq200/data/CC
$XXP       - /dev/acq200/data/XXP
$SA        - available samples
$NC        - number of channels
$MDSFIELD - suitable MDS field name
```

- PUT Channelized data (extension of example above)

```
mdsPut --format short --dim $NSAM --file $CHFILE  $MDSFIELD
```

- PUT 2D array - if your application cannot wait for the channelization job

```
mdsPut --format short --dim $CH,$SA --file=$XXP $MDSFIELD
```

- PUT 2D subarray - reduce pressure on MDSplus by reducing data set size

```
mdsPut --format short --dim $CH,$SA --file=$XXP --subarray 1,32  \
                    $MDSFIELD:CH0132
```

A higher level, device specific interface is detailed in the next section.

11.8.3 mdsPutCh - device-aware upload

This is a device-aware high level version of MDSput. This command allows complex uploads to be easily scripted, preferably in a single line. Goals are:

- Single command handles a range of channels
- Simple support for timebase ranging - start/stop/stride
- Support for built in calibration using the MDSplus Expression associated with the mdsPut.
- High level support for timebase - autogenerates a timebase signal expression based on the actual sample rate and capture data set.

Synopsis:

- **mdsPutCh** `--expr EXPR --field FIELDFMT --timebase TIMEBASE CHANNELS`
- `CHANNELS`: list | timebase | sequence
  - list : 1,2,3,6,9,12
  - range: 1-16 (or 1:16)
  - sequence: list timebase ch ch ch
- `TIMEBASE`: start,samples,stride
  - start: default 0
  - samples: default * (all samples).
  - stride: default 1
  - alternative notation: :,:,1
- `FIELDFMT` : sprintf format string to build channel name. -For each channel, code calls sprintf(buf, FIELDFMT, channel) -default: 2d
- `EXPR`:
  - default : $ - mdsPlus data identity.
- KEYWORDS : format specifiers, analogous to printf format fields. KEYWORDS begin with %
  - KEYWORD SUBSTITUTIONS - most keywords are simple short hand
    - `%CAL` : this builds a raw to volts expression using the calibrated range, taking into account the current range setting for the channel, applying straight line formula:
      `%CAL : (%V1 + (%V2 - %V1)*($ -%R1)/(%R2 - %R1))`
      `%R1, %R2` : range range limits,
      default `%R1 = -32768, %R2 = +32767`
- KEYWORDS ...
  - KEYWORD EVALUATIONS - certain built-in keywords have custom, per-channel values inserted on processing a channel:
    - `%V1, %V2` : current calibrated voltage range limits from **`get.vin`**

- `%S0` : Start sample index from trigger
- `%S1` : Index at trigger (always zero)
- `%S2` : End sample index from trigger
- `%DT` : Time between samples, assuming a known clock. Includes stride

It is possible to create a custom user expression based on these values, for example:

- `--expr "(%V1 + $MYOFFSET + (%V2 - %V1)*($ -%R1)/(%R2 - %R1))"`
- DYNAMIC KEYWORDS : additional keywords may be defined at run time by adding lines to either of two setup files
  - `$HOME/.mdsPutCh.sh` - keywords generated by shell processing
    - default `.mdsPutCh.sh`:

```
# .mdsPutCh.sh - variables with shellinterpretation
# HostName is used for canonical card name convention
echo HN=`hostname`
```

  - $HOME/.mdsPutCh.nosh - literal keyword definitions
    - default .mdsPutCh.nosh

```
# .mdsPutCh.nosh - variables with NO SHELL interpretation.
# this is a comment. NB we need spaces around ':'
# because it is a valid tok char
# generic digitizer timebase support - T2 is end time
%T0=(%S0*%DT)
%T2=(%S2*%DT)
# timebase ... the Window takes the subrange into account
%win=Build_Window(0, %S2-%S0, Build_With_Units(0.0, 'seconds'))
%axis=Build_With_Units(Build_Range(%T0, %T2, %DT), 'seconds')
tbase=Build_Dim(%win, %axis)
# Build a raw to volts scaling expression
%SCAL=Build_With_Units((%V1 + (%V2 - %V1)*($VALUE - %R1)/
                                          (%R2 - %R1)),'volts')
# top level expression is quoted to beat shell quoting on command
# line
%calsig="Build_Signal(%SCAL,$,%tbase)"
```

- Saving data to MDSPLUS SIGNALS with correct timebase
  - use the `%calsig` expression
  - works with full, and sub timebases - the `--timebase` switch is automatically translated into the MDSplus expression.

Todo:

: future options to supporting REPEATED GATE:

- `--subshots <n,[step]>` : number of times to step and repeat timebase
- `--subfield SUBFMT` : MDSplus field definition d substitutes step# : subfield prepends field when set

Examples

```
# upload 96 channels, all the data, raw expression
mdsPutCh --field "HYPERACQ:CH%02d" 1:96

# upload 96 channels with unique calibration expression per channel
mdsPutCh --field "HYPERACQ:CH%02d" --expr %CAL 1:96

# upload 96 channels with signal timebase and calibration:
mdsPutCh --field "HYPERACQ:CH%02d" --expr %calsig 1:96

# upload 96 channels with a stride of 100 (for rapid upload) :
mdsPutCh --field "HYPERACQ:SUB_CH%02d" --expr %calsig \
          --timebase 1,:,100 1:96
# upload 10000 samples starting at sample #50000 :
mdsPutCh --field "HYPERACQ:ROI_CH%02d" --expr %calsig --timebase
50000,10000,1 1:96

# upload 10 subshots, length 10000
mdsPutCh -- subshots 10 --timebase 1,10000,1 --subfield \
          "SUBSHOT%04d" --field "CH%02d" 1:96
```

11.8.4 mdsValue - retrieve and store values

The **mdsValue** command is able to evaluate MDSplus expressions for a range of result types:

- short
- int
- float
- string

mdsValue will print the output for a scalar. Vector values may be saved to file using the `--output=file` option.

Example: Loading Waveforms to ACQ196 FAWG waveform generator

11.8.4.1 AO load script: /usr/local/mdsplus/bin/loadAO16mds

```
#!/bin/sh
# /usr/local/CARE/loadAO16mds : load FAWG waveform set.
# the waveforms are stored as vectors of shorts.

load16() {
          rhost=$1
          tree=$2
          node=$3
          AOf=/dev/acq196/AO/f

          mdsConnect $rhost
          mdsOpen $tree

          let ch=1
          while [ $ch -le 16 ]
          do
                    CH=`printf "%02d" $ch`
# uncomment for verbose:
#                   echo mdsValue --output $AOf.$CH ${node}$CH
                    mdsValue --output $AOf.$CH ${node}$CH
                    let ch="$ch+1"
          done

          mdsClose $tree
}
```

The same commands can of course be executed remotely, channel by channel.

And a full worked example using /usr/local/CARE/**load16AOmds**

```
# mdsip=kilda tree=iroko node=ACQ196_010AO
/usr/local/CARE/load16AOmds kilda iroko ACQ196_010AO:

root@acq196_010 ~ #/usr/local/CARE/load16AOmds kilda iroko
ACQ196_010AO
MDS_SOCK=6
OK
mdsValue --output /dev/acq196/AO/f.01 ACQ196_010AO:CH01
DTYPE_SHORT, dim:1 [512] length 2 /dev/acq196/AO/f.01
mdsValue --output /dev/acq196/AO/f.02 ACQ196_010AO:CH02
DTYPE_SHORT, dim:1 [512] length 2 /dev/acq196/AO/f.02
mdsValue --output /dev/acq196/AO/f.03 ACQ196_010AO:CH03
...
mdsValue --output /dev/acq196/AO/f.15 ACQ196_010AO:CH15
DTYPE_SHORT, dim:1 [512] length 2 /dev/acq196/AO/f.15
mdsValue --output /dev/acq196/AO/f.16 ACQ196_010AO:CH16
DTYPE_SHORT, dim:1 [512] length 2 /dev/acq196/AO/f.16
OK

# commit to FAWG for hardware trigger
set.AO commit 4


# to complete the example let's set a clocking scenario
# in real life, do this once _before_ loading the data
# AI clock is external, DIO [500kHz]
set.route d0 in lemo out fpga
set.ext_clk DI0 falling
acqcmd setExternalClock DI0

# AI clock is slaved off AI clock, but divided by 50 to give 10Hz
set.ao_clk DI0 falling
set.dtacq FAWG_div 50

# AI trig = AO trig = DI3
set.route d3 in lemo out fpga
set.trig DI3 falling
set.ao_trig DI3 falling
```

11.8.4.2 MDSplus Events

mdsValue also provides a convenient way to access MDSplus Events:

```
mdsValue "setevent('acq216_023d', 42ub)"
```

11.9 MDSplus Thick Client

ACQxxx also has MDSplus thick client functionality available as an additional flash disk image. The Thick Client is able to run TDI and supports an MDSIP server.

The combination of the Thick Client and Compact PCI system slot device is a particularly powerful one - this has been used to control a third party Compact PCI peripheral card using MDS TDI scripted device driver support.

11.10 Rolling mean Channel data available during shot

The "mean device" provides access to a boxcar running mean of data during capture. This allows applications to get trend data on all analog inputs while pre trigger capture proceeds at full sample rate to local memory.

- enable: **`load.mean`**
- view: `/dev/mean/CC` # data is presented as 4 byte ints for channels 01..NN

The mean device is intended for use with SCADA connectivity such as the EPICS IOC.

The mean device has the following controls:

- control #samples to average: `log2mean`
- control decimation : `skip`
- view actual rate: `update_interval_ms`

Examples accessing controls:

```
# set decimation 10
set.sys /sys/module/acq200_mean/parameters/skip 10
# set number of samples in mean to 16
set.sys /sys/module/acq200_mean/parameters/log2mean 4

# review actual sample rate:
get.sys /sys/module/acq200_mean/parameters/update_interval_ms
```

11.11 Rolling mean Cross-section data available during shot

The "mean device" also allows efficient access to a full sample slice of all channgel data.

- enable: **`load.mean`**
- view: `/dev/mean/XX` # data for all channels as 4 byte ints
- view: `/dev/mean/XXS` # data for all channels as 2byte shorts + frame word

The XXS device may be used directly for sub-rate streaming.

11.12 Logical to Memory Channel mapping table.

For applications accessing raw data, a table mapping logical channel numbers (front panel label {01..N}) to offset from start of sample ({0..N-1}) is provided by the device file:

```
/dev/dtacq/channel_mapping.
```

The contents of this file describe the mapping for the particular model of card, for the channel mask currently in effect.

11.13 Host Pull Examples

11.13.1 Access from host computer via PCI bus

The regular PCI device driver interface as described in the ICD is available for configurations where the ACQxxx is configured as a peripheral device on the local PCI bus.

11.13.2 Remote access via dt100d

Remote client applications may connect via the **dt100d** service and collect data via the remote interface (see ICD for details). A working example is provided in **dt100rc**.

11.13.3 Remote access via dt100-hub

Diskless NetworkedAttached Satellite Data Acquisition from multiple remote satellite ACQxxx units is easily set up using the **dt100-hub**.

The **dt100-hub** is a software subsystem running on a remote Linux box.

The hub acts as a local device proxy for one or more remote networked ACQxxx units. Applications communicate with the hub via the normal dt100 style device interface, and the hub translates this into network connections to the remote satellites.

The intention is that applications are unaware that the devices are not in fact located on the local pci bus, and that it is possible to run local pci and remote satellite devices concurrently.

11.13.4 Remote access via networked file system.

The data node virtual files may be exported as a SAMBA, NFS or SFTP file share.

This means that, for example an MS-Windows host computer can mount the data in memory as a network file share and client applications can view the channelized data as simple files. This is probably the simplest imaginable way to view data on a host computer.

11.13.5 http GET

The entire embedded file system is visible to an external web browser, connecting to port 80 in the normal way. It's possible to set the web browser to view the captured data files. Generally, a more useful approach is to use a command-line http tool such as `wget` to recursively fetch all the data.

```
time wget -qr –no-parent http://acq132_015/dev/acq200/data/
real      0m2.661s
du .
62600     ./acq132_015/dev/acq200/data

62MB in under 3s – that's fast!
```

11.14 Target Push Examples

11.14.1 MDSplus thin client

ACQxxx includes an MDSplus thin client, able to export data direct from channel to tree via an MDSIP server. The thin client may be invoked synchronously by a remote client, or asynchronously using a stored procedure. Remote client software can leave stored procedure scripts to be executed at automatically at the end of the shot.

11.14.1.1 MDS Thin Client Stored Procedure Example

Example:
From a remote client, create pre-transform and post-transform data upload scripts before the shot. The scripts can change from shot to shot. Multiple scripts (eg custom per channel) are possible.

```
# first, select HUB or SOAP transport. ssh will work as well...
# HUB:
export ACQ2SH="acqcmd -s 10"
# SOAP
export ACQ2SH="./acq2sh -u http://acq196_010:6666"

# first, write a one-line script to execute with minimum latency
$ACQ2SH echo 'TREE=mukwa\;\(TIMEBASE=:,:,100 NODE=\${HN}S:CH%02d
do_mdsPutCh \$TREE\)\;do_mdsSetEvent \${HN}_FAST'
 \>/etc/postshot0.d/stride


# second, write a one-line script to upload the full data set with
# maximum efficiency
$ACQ2SH echo 'TREE=mukwa\;\(do_mdsPutCh \$TREE\)\;do_mdsSetEvent \$
{HN}_FULL' \>/etc/postshot.d/full
```

The example looks more complicated than it is due to the need to protect shell variables from premature evaluation, first by the client side command $ACQ2SH, second by the target side command "echo".

The scripts that are created are as follows, (expanded to multiple lines for readability) :

```
/etc/postshot0.d/stride:
TREE=mukwa
(TIMEBASE=:,:,100 NODE=${HN}S:CH%02d do_mdsPutCh $TREE)
do_mdsSetEvent ${HN}_FAST


/etc/postshot.d/full
TREE=mukwa
(do_mdsPutCh $TREE)
do_mdsSetEvent ${HN}_FULL
```

- /etc/postshot0.d/stride : runs with minimum latency, opens the Tree "mukwa" and writes all channels ${HN}S:CH%02d with a stride of 100, then sets the event ${HN}_FAST.
- /etc/postshot.d/full : runs after the data transform, opens the Tree mukwa and writes all channels ${HN}:CH%02d (canonical name) with the full data set, then sets the event ${HN}_FULL.

Clearly, scripts to control other technologies eg FTP can be created on the fly by the host in the same way.

11.14.2 FTP client

ACQxxx includes a full ftp client implementation, and this may be scripted to automatically transfer data at the end of the shot.

1. Install suitable `.netrc` file in the `/root` directory. Must have `600` permission, to make a non-volatile copy, install in `/ffs/dropbear/root`
2. Develop an ftp script, perhaps by following the example given in

   /`usr/local/CARE/ftp.example`. Store this script in `/ffs/dropbear/bin`
3. Test the script interactively on existing data.
4. Modify `acq200.pp` to call the ftp script at the end of processing. Store a non-volatile copy of `acq200.pp` in `/ffs/dropbear/bin`

   `eg:`

   ```
   time /usr/local/CARE/ftp.example 2>&1 | logger -t ftp
   ```

11.14.3 Remotely specify an ftp batch job

`set.autoftp` creates an ftp batch job for data upload. **`acq200.pp`** can be configured to detect and call this file at the appropriate time

```
set.autoftp ftpHost ftpBaseDir ftpNewSubdir start stride length
chanlist
```

Alternatively, client software can create the ftp batch job directly in `/etc/postshot.d` or `/etc/postshot0.d`

11.14.3.1 Curl

A **curl** client is now available. **curl** is a universal tool for FTP/HTTP .. access, and can make scripting outgoing data transactions very simple.

For example: posting a heartbeat to a Web front end for Vista:

```
#!/bin/sh

# implement a hearbeat function using http post.
# use curl and an ssh tunnel to hit vista db

#HOST="localhost:10000"
URL=http://$HOST/channel/post_vchannel.php


postit() {
        /usr/lib/curl -d "value=$2&channel_name=$1" $URL
}


while [ 1 ]
do
        postit `hostname`_HEARBEAT `cat /proc/uptime`
        sleep 1
done
```

For documentation on **curl** see http://curl.haxx.se

12 Data Interface: Continuous Streaming

12.1 Introduction

ACQxxx products are capable of continuous data capture, however careful consideration must be taken to match the high possible capture data rate with possibly lower performance communication capability.

12.2 Ethernet: Host-Pull Streaming

In this mode, a host-side application pulls streaming data off the *ACQxxx* using the `dt100 stream` command 20.1.2.9. This is suitable for low rate data (<20MB/s), but it's simple to set up and is highly scaleable.

Example streaming client software includes the **`dt100rc`** GUI program, and **`streamer`**, an example application provided with the API. **`dt100rc`** is able to plot live data, and to store the data to disk a frame at a time. streamer is able to store data in *DirFile* format, ready for immediate plotting using **`kst`** or suitable for further processing.

12.3 Ethernet: Target-Push Streaming

In this mode, we assume that the *HOST* is set up as an *ftp* server.

The capture proceeds on the *ACQxxx*, filling the local 1GB *DDRAM* as a cyclic buffer. The buffer is divided into 6MB *TBLOCKS*, presented as virtual files.

A scripted process monitors the progress of the capture, controlling an *ftp* client session that will send each *TBLOCK* to the *HOST* as an *ftp* file transfer. The *HOST* side disk (we recommend a ramdisk) builds up a mirror of the local *DDRAM*, with a series of 6MB files 000..130. With a correctly configured network, this process can sustain a 40MB/s average data rate, with concurrent capture.

Cards suited to this technique include:

- ACQ164CPCI : continuous streaming at full rated sample rate
- ACQ132CPCI : continuous streaming at average 600kHz sample rate; this could be a continuous capture at 600kHz, where the 600kHz *OSR* could be downsampled from a higher *ISR*, or a *DualRateMode* capture, or a lower duty cycle capture in *RepeatingGateMode*.

The **`acq_demux`** application is provided with the API to extract the raw data into *DirFile* format, suitable for plotting using **`kst`** or making an easy start point for further format conversion.

In low data rate applications, the size of the *TBLOCK* may be reduced to increase the update rate on the host, to enable a faster live response.

This technique makes full use of the available 1GB buffer space as an elastic store to smooth out possible reductions in the output streaming rate (HOST congestion), and momentary increases in the input data rate eg high rate capture in *RepeatingGateMode* or *DualRateMode*.

12.4 CPCI Backplane: Target-Push Streaming

This is implemented for ACQ196; ACQ196 continuously sends across the *CPCI* backplane to a *HOST* PC. This makes for a very tightly coupled system, and is available for *HOST* PC's with a Linux 2.6.x backplane driver only. This system is rated to 350kHz (single ACQ196). With multiple cards, the shared backplane becomes a bottleneck.

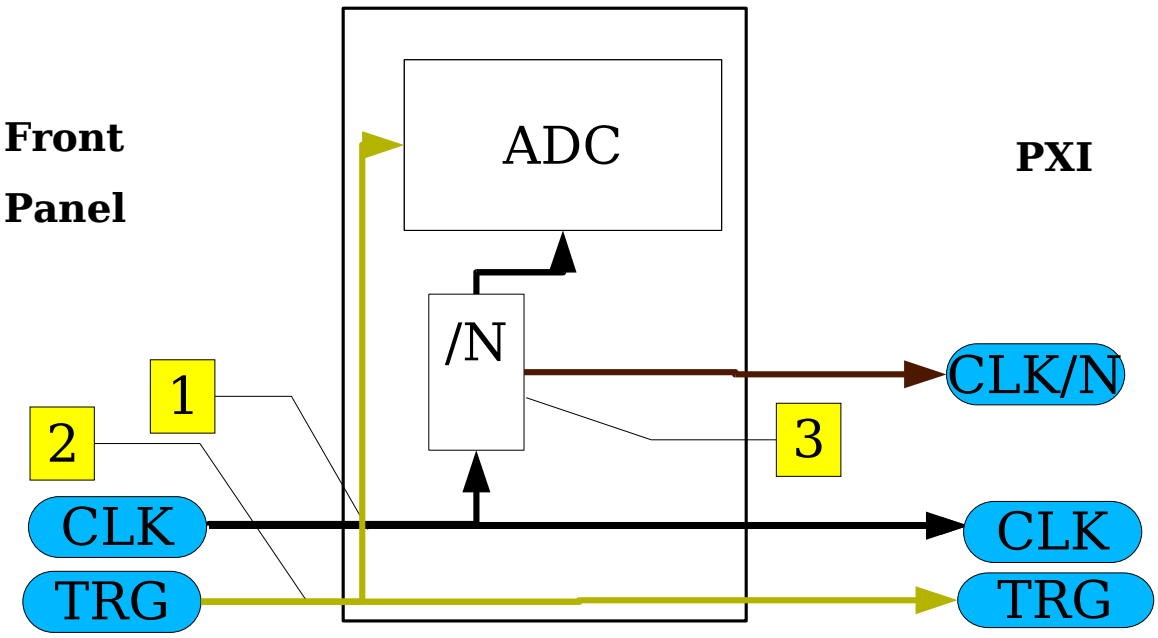
12.5 Cabled PCI-Express: Target-Push Streaming.

Q2 2010: D-TACQ propose to release RTM-T - a Rear Transition Module supporting a PCI-Express on cable link. This will be able to stream data at up to 200MB/s per card. RTM-T represents a comms link upgrade for ACQ196CPCI and ACQ132CPCI (and, to a lesser extent, ACQ164CPCI).

This is a still a tightly coupled system as per 12.4 , however, with one link per card, it does not suffer the shared bus data bottleneck problem. In addition, it gives a higher bandwidth data path direct from the ADC array, so we can expect to run devices like ACQ132CPCI at full speed and more.

13 Putting it all together – Use Cases

13.1 Chassis clock master uses local derived clock



Example: Master is ACQ196, CLK is 1MHz, local sample rate 250kHz: N= 4.

1 Route CLK from front Panel to rear PXI, connecting to local logic:

```
set.route d0 in mezz out fpga pxi
```

2 Route TRG from front Panel to rear PXI, connecting to local logic, active falling edge:

```
set.route d3 in mezz out fpga pxi
set.trig DI3 falling
```

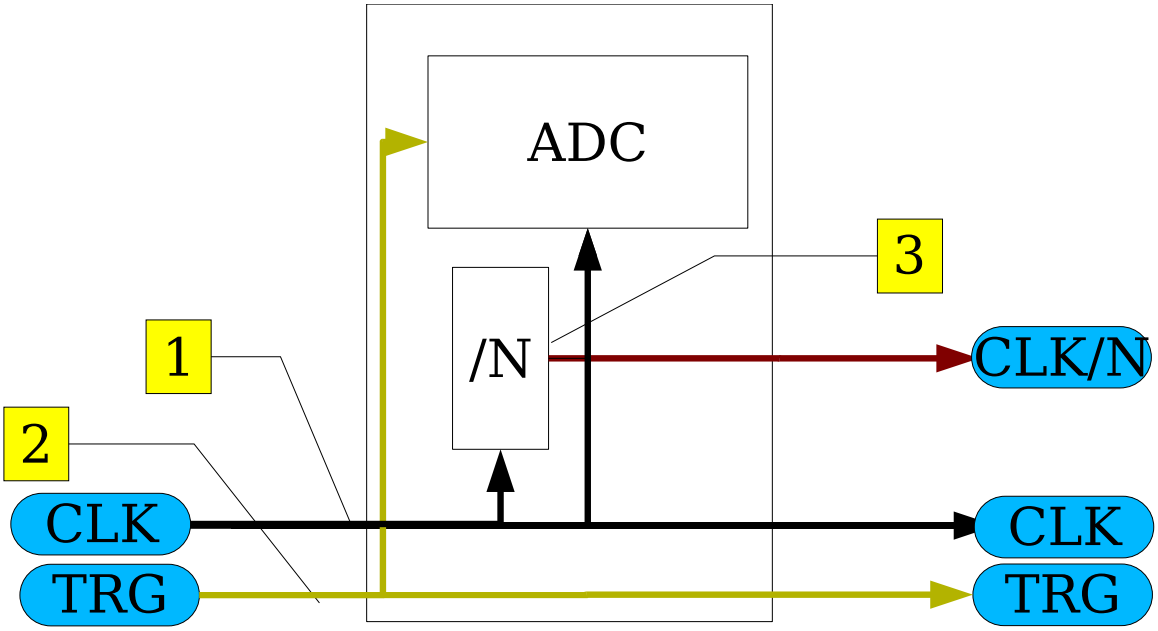
3 Generate local derived clock, output via PXI DO1

DO1 is an FPGA OUTPUT.

```
acqcmd setExternalClock DI0 4 DO1
set.route d1 in fpga out pxi
acqcmd -– setDIO -1------
```

NB: in order to configure a full master slave rack at constant phase, either start the external clock AFTER all ACQxxx setups are complete, or action 1: LAST.

13.2 Chassis Master uses plant clock, distributes derived clock



Example: Master is ACQ216, CLK is 10MHz, derived clock is 250kHz, N=40

1 Route CLK from front Panel to rear PXI, connecting to local logic:

```
set.route d0 in mezz out fpga pxi
```

2 Route TRG from front Panel to rear PXI, connecting to local logic, active falling edge:

```
set.route d3 in mezz out fpga pxi
set.trig DI3 falling
```

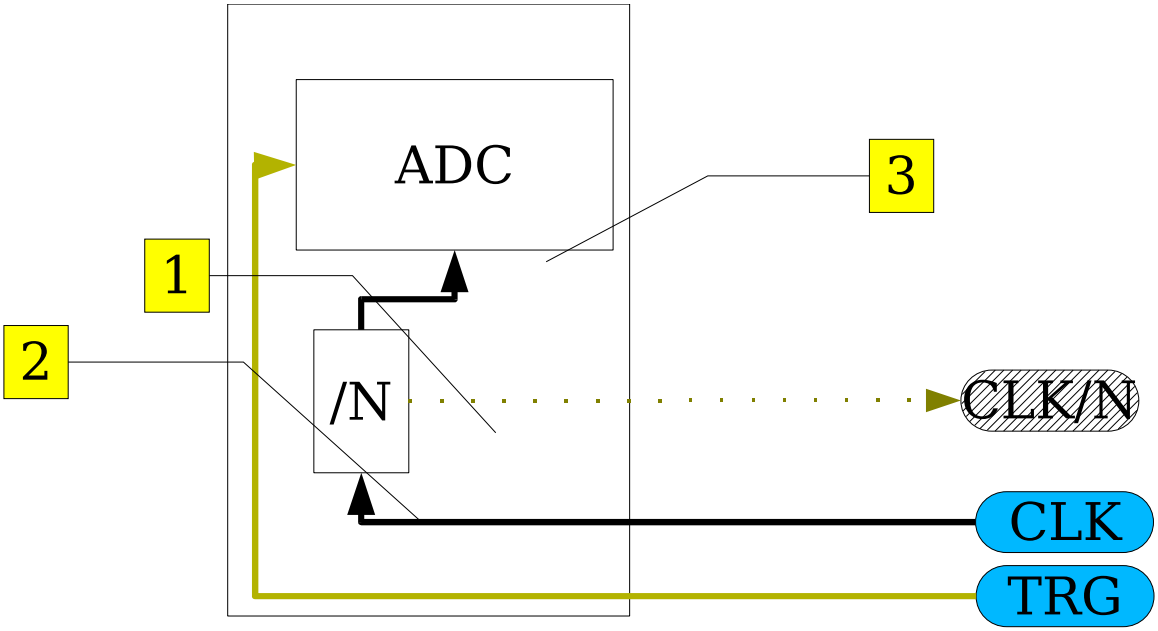
3 Generate local derived clock, output via PXI DO2

DO2 is an FPGA OUTPUT.

```
acqcmd setExternalClock DI0 40 DO2
set.route d2 in fpga out pxi
acqcmd -- setDIO --1-----
# resets ADC input, leaves divider setting
set.ext_clk DI0
```

NB: in order to configure a full master slave rack at constant phase, either start the external clock AFTER all ACQxxx setups are complete, or action 1: LAST.

13.3 Slave Derives Clock from Backplane



Example: Slave part of 13.1

Slave is ACQ196, CLK is 1MHz on backplane, local sample rate 250kHz: N= 4.

1 Route CLK from PXI, connecting to local logic:

```
set.route d0 in pxi out fpga
```

2 Route TRG from rear PXI, connecting to local logic, active falling edge:

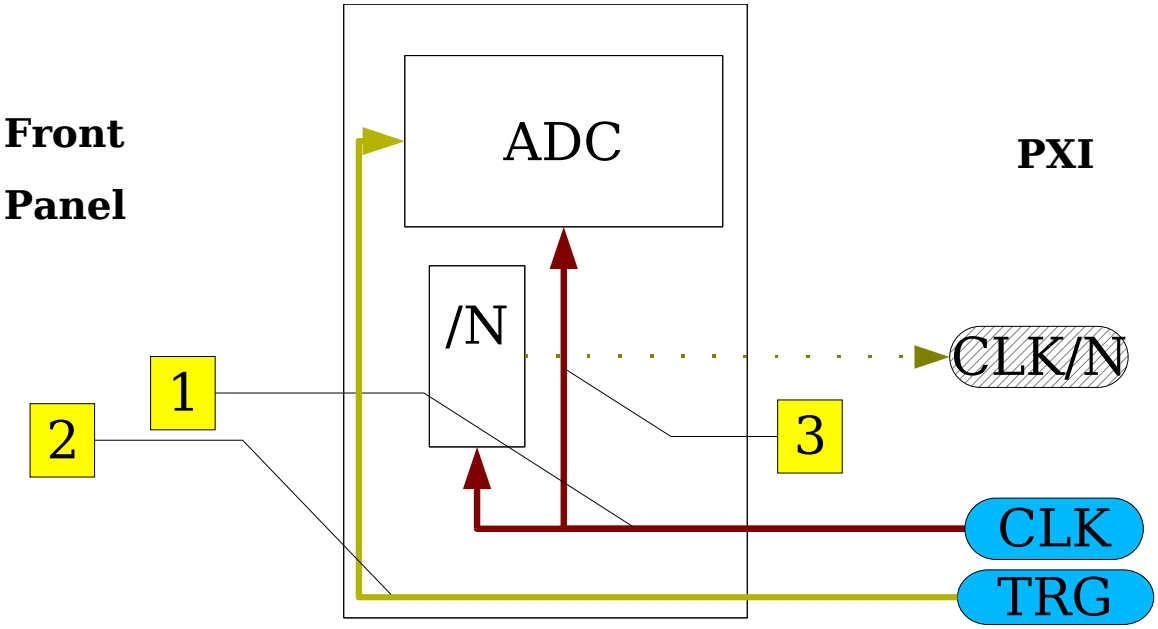
```
set.route d3 in pxi out fpga
set.trig DI3 falling
```

3 Generate local derived clock

```
acqcmd setExternalClock DI0 4
```

optionally output derived clock to DO1, DO1 is an FPGA OUTPUT.
Option is non preferred, since there should only be one card driving the line, and it may be simpler to configure all slaves the same.

13.4 Slave Uses Backplane Clock Directly



Example for use with 13.2

Example: Slave is ACQ196, CLK on backplane is 250kHz on d2

1 Route CLK from rear PXI, connecting to local logic:

```
set.route d2 in pxi out fpga
```

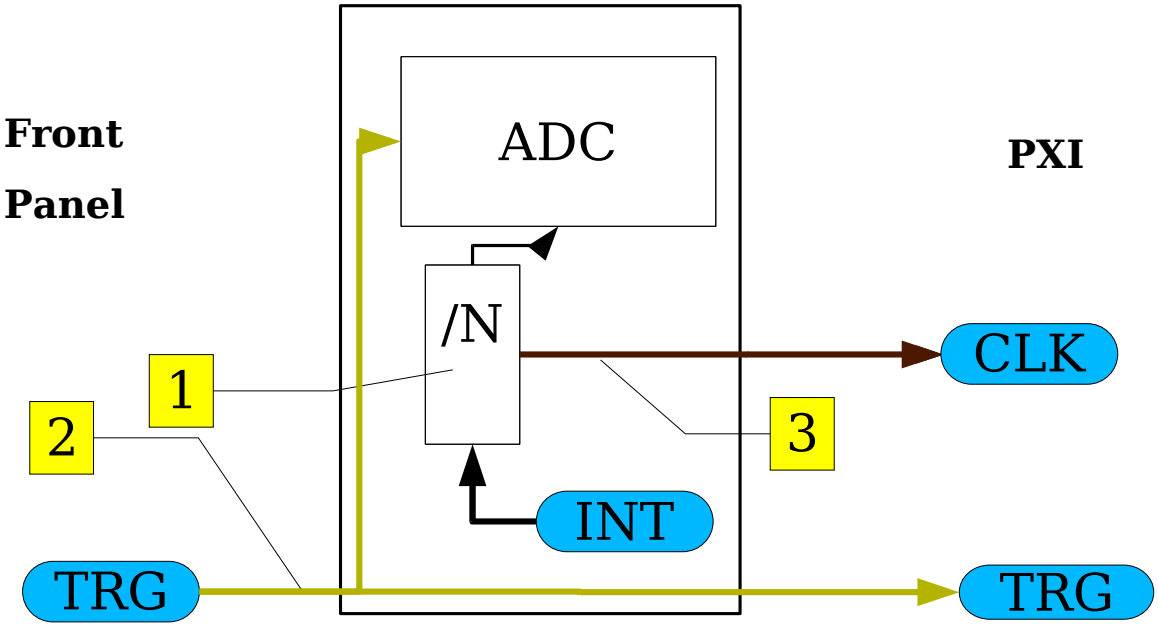
2 Route TRG from rear PXI, connecting to local logic, active falling edge:

```
set.route d3 in pxi out fpga
set.trig DI3 falling
```

3 Use Backplane clock directly

```
set.ext_clk DI2
```

13.5 Internal Clock, optional backplane Clock Master



Example: ACQ196, 250kHz, master to backplane on d1

1 Set Internal Clock

```
acqcmd setInternalClock 250000 DO1
```

2 Route Trigger

```
set.route d3 in pxi out fpga
set.trig DI3 falling
```

3 Output Clock

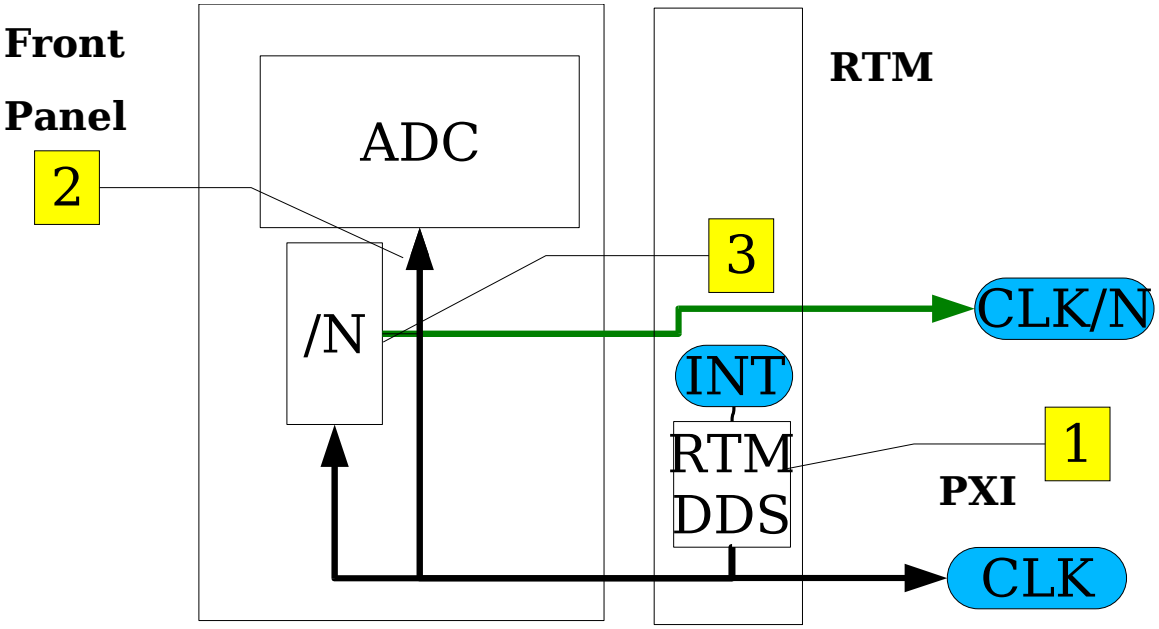
```
set.route d1 in fpga out pxi
acqcmd -– setDIO -1-----
```

This scenario also works well with ACQ216CPCI on-board clock, with 1kHz precision
eg:

```
acqcmd setInternalClock 10000000 DO0
set.route d0 in fpga out pxi
acqcmd -– setDIO 1------
```

Slave device could be another ACQ216 or an ACQ196 in configuration #13.3

13.6 ACQ216 Precision Internal Clock using RTM-DDS



Example: ACQ216, precision clock 1..100MHz
Optionally output a /100 derived clock on D1

1 Set DDS

```
Currently set by external host side client.
set.rtmdds clksrc REFCLK
set.rtmdds clkdst DO0
set.rtmdds rio_outputs 1
dds        FREQUENCY_Hz
```

2 Set Clock source

```
set.route d0 in rio out fpga
set.ext_clk DI0
```

3 Output Derived Clock (on DO2)

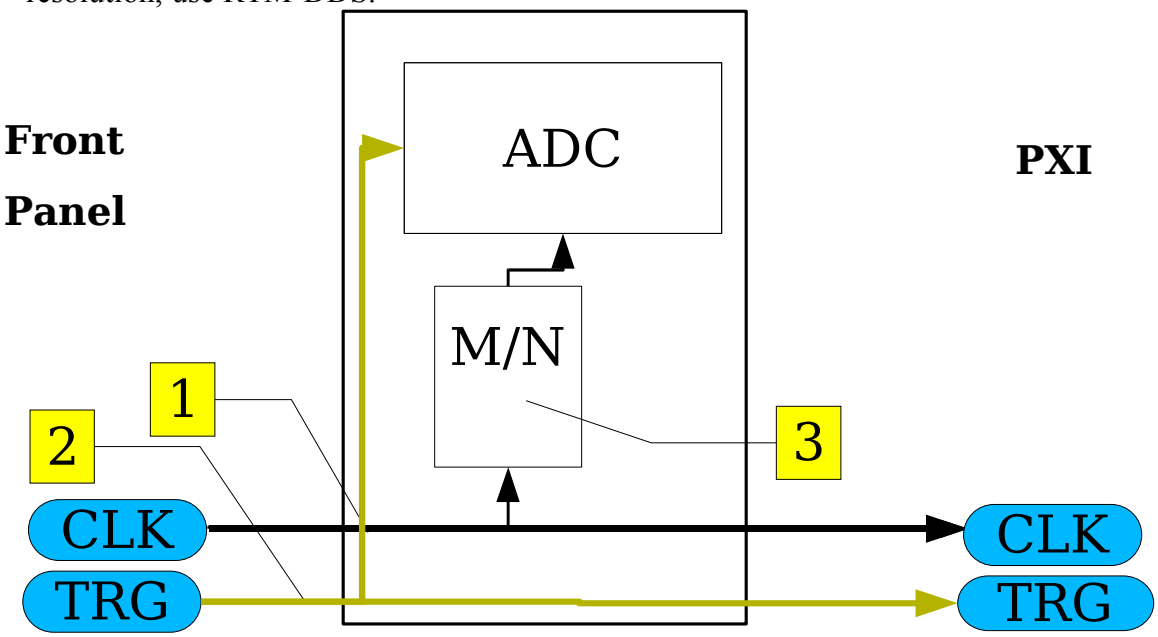
```
acqcmd setExternalClock DI0 100 DO2
set.route d2 in fpga out pxi
acqcmd -- setDIO --1---
# restore acquisition external clock setting.
set.ext_clk DI0
dds        FREQUENCY_Hz
```

13.7 ACQ216 Internal Clock Multiplier

Front panel clock limited to range 1..10MHz on ACQ216.

ACQ216 contains an internal clock multiplier resource to multiply the clock up, then divided again to allow clocks in the range 100, 50, 33, 25, 20, 12 Mhz.

NB: internal multiplier subject to significant jitter. For low jitter clock with fine resolution, use RTM-DDS.



1 Route CLK

```
set.route d0 in mezz out fpga pxi
```

2 Route TRG

```
set.route d3 in mezz out fpga pxi
set.trig DI3 falling
```

3 Output Derived Clock

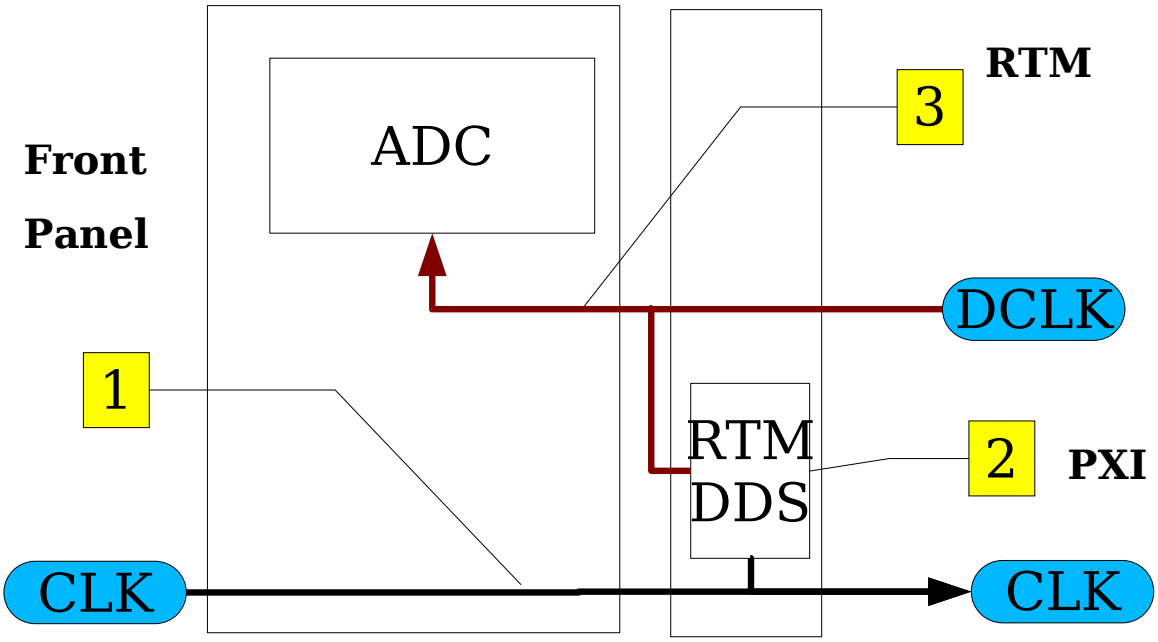
```
acqcmd setMultiplier DI0 M N
```

13.8 External Clock with precision RTM-DDS multiplier

Front panel clock limited to range 1..10MHz on ACQ216.

For highest resolution (1Hz) and lowest Jitter, D-TACQ recommends RTM DDS

DDS will allow 1..50MHz clock in steps of 1Hz.



1 Route CLK

```
set.route d0 in lemo out pxi rio
```

2 Set Up DDS

```
set.rtmdds clksrc DI0
set.rtmdds clkdst DO1
set.rtmdds rio_outputs 2      ;# DO1 is an output
set.rtmddc refclk_mult 20     ;# for input clock <= 15MHz
dds        FREQUENCY_Hz
```

3 Set Up Sample clock

```
set.route d1 in rio out fpga
set.ext_clk DI1

Alternative to running dds, run the clock control client:
java -jar ccc.jar host ext-clk refclk-mult
```

```
example: (external clock 4M, multiplier 20)

java -jar ccc.jar acq216_023 4000000 20
```

NB: there are now three techniques for setting the frequency
1. `ccc.jar` as described above
2. using local arm executable `/usr/local/bin/dds (--help)` for doc.
3. Direct from **`dt100rc`** (recommended).

14 Appendix: PREPs - Regions of Interest.

14.1 Preprogrammed Triggers

When running in a continuous mode, an application may be able to define, before the shot, regions of interest that will occur at well-known times. *ACQxxx* provides such a mechanism for any number of regions, to the limit of sample memory. Regions are defined in terms of start sample and length. Where the sample clock running at a constant rate (almost always the case), then there is a simple linear relationship between sample number and start time.

14.1.1 Example 1: "Dark Calibration"

An experiment requires data to be measured shortly before the shot when the "system is dark" for nulling purposes. The null-data capture must be tightly synchronized with the main experiment, so that data is taken at the right time, and main experiment data is not missed. Typically, a the system is configured to start on a *Trigger*, run in *pre/post* mode until an *Event* is received. The null data is captured in a *PREP* that starts at *Trigger*, and runs for a few thousand samples. The data capture system continuous to capture to its cyclic buffer until the *Event* or "Start of Experiment" signal activates the main capture. After the shot, experiment data is available in *pre/post* buffer in the normal way, while the dark data is available in the first *PREP*.

14.1.2 Example 2: Event as Trip.

A test stand captures data at high speed for a long time (1h typically). The users do not want to see all the data, but they do want a series of snapshots sampled at full rate, taken at intervals. Typically this could be a *PREP* or maybe 10 k-samples every minute, resulting in 60 *PREPs* during the course of the test. In this system, if there is an exception (eg a flashover, or power trip), then a large, full rate *pre/post* data set is required for post-mortem analysis. This is handled by the normal *pre/post* capture mechanism. At the end of the test, and trip data is uploaded in the normal way, while the *PREP* data is uploaded as described below.

14.2 Mechanism.

14.2.1 Overview

The Preprogrammed Trigger Mechanism (*PREP*) requires the internal data management to be segmented. During capture, firmware fills a large data buffer segment by segment. When a *PREP* is detected the segment is reserved, and protected from overwrite until it has been specifically freed by application code.

PREPs are defined in a batch before the shot.

A series of device nodes is used to allow a convenient application interface to the driver. As always, definition and status is *ASCII*, good for scripting, while the data is efficient binary.

A *PREP* may existing in the following states:

- *IDLE*: defined, before *ARM*
- *PENDING*: hasn't happened yet
- *BUSY*: in progress
- *COMPLETE*: *PREP* has completed, and data is reserved in memory
- *DELETED*: data has been returned to main capture buffer.

14.2.2 Enabling preps

To enable *PREP* :

- Do this once:

execute the shell command **`load.prep`**. Typically this will be scripted in the boot process script `/ffs/user/rc.user.`

To enable channelized data access:

`CDEV=1` **`load.prep`**

- Do this before every shot:

Load *PREP* definitions to `/dev/prep/spec`.

- Access data

Immediately - using **`acton_prep`**

or post-shot using normal data access methods.

14.2.3 Operational issues.

- The capture process will work to the limits of the capture memory buffer (384MB on ACQ196CPCI). If too many COMPLETE *PREPs* are allowed to pile up in memory, then eventually the capture process will no longer be able to run, and will terminate with error. It is the responsibility of the application to firstly ensure that the program of *PREP's* is not too demanding, and secondly to recycle COMPLETEd *PREPs* to ensure that buffer starvation does not occur.
- Segment size is 6MB, a COMPLETE *PREP* occupies at least one Segment. The Capture process requires at least 8 free segments in order to operate correctly.
- With 64 available segments in a typical capture buffer, a typical maximum number of about 50 COMPLETE *PREPs*, each of minimum length (6MB) is feasible.
- The *PREP SPEC* must be supplied pre-sorted.
- *PREPs* are restricted to being non-overlapping.

  START[n] >= START[n-1]+LENGTH[n-1]

14.2.4 Device Nodes:

Node	Description
/dev/prep/data/	Data appears under this directory
/dev/prep/spec	Define PREP's here
/dev/prep/status	Block on this node to get real time alert of new PREP completion
/dev/prep/summary	Summary of PREP status
/dev/prep/test	Test node
/dev/prep/data/iii.ssss/XXP	Example: PREP #iii starting sample ssss data in raw binary format.
/dev/prep/data/021.333333/XXP	Example: PREP #021 starting sample 333333, data in raw binary format.
dev/prep/data/021.333333/01	Example: with data channelization enabled, this is the data for channel 1.
dev/prep/data/021.333333/96	Example: with data channelization enabled, this is the data for channel 96.

14.2.5 Specification

All *PREPs* for the next shot are defined in a text file:

```
start-sample length [opts]
# comment
```

The text definition file should be copied to the spec device. The spec device is readable and prints error messages, a check for now errors is to compare input to output, if the same, there are no definition errors:

```
cp spec-file /dev/prep/spec
cmp spec-file /dev/prep/spec   ;# no diffs => no errors.
```

14.2.6 Run Time Status polling

A monitor task should block on the stat device, which will report when a *PREP* has been completed:

```
cat /dev/prep/stat
3333333 100000 COMPLETE
```

acton_prep [14.2.9] is an example of a monitor task.

14.2.7 Summary

```
cat /dev/prep/sum
123456 100000 DELETED
333333 100000 COMPLETE
666666 250000 PENDING
```

14.2.8 Data Handling

On Completion, a *PREP* will be represented by a subdirectory:

```
/dev/prep/data/PREP-ID      ;# PREP-ID : iii-ssssss iii: id sss:start
```

While capture is ongoing (the normal case), data will only be available in raw format.
Applications can access this data via the XXP device:

```
/dev/prep/data/PREP-ID/XXP
```

When the application is finished with the data, it should recycle it back to the driver, this is done using the standard file delete mechanism:

```
rm -Rf /dev/prep/data/PREP-ID
```

The standard channelization process is optionally supported, providing per-channel logical data nodes:

```
dev/prep/data/PREP-ID/nn    # 01 .. 96
```

14.2.9 Recommendation for immediately handling PREP data

Use **acton_prep** to fire an action on completion of a *PREP*:

```
acton_prep [opts] [command] [args]
opts: --norecycle – do not recycle data on completion.
```

Command: any ARM side command to run, with <args>

The command is run with the following environment variables set:

```
PREP_ID=id
PREP_PATH=path to prep data files
PREP_FILE=path to prep data file XXP
PREP_START=start
PREP_SAM=length in samples
PREP_SHORTS=length in shots
```

As a convenience, **mdsshell** supports passing environment vars as a quoted command line parameter:

Example Command:

```
acton_prep mdsPut --shorts \$PREP_SAM --file \$PREP_FILE \$PREP_ID
```

ie: on *PREP* completion, action **mdsPut** to transfer a data set length *$PREP_SAM* from binary file *$PREP_FILE* to field *$PREP_ID*.
For a more complex setup, command can of course be a shell script, at some cost startup speed. When using a shell script, script writing is simplified because there is no need to quote the shell variables.

14.2.10 How does acton_prep run.

acton_prep is run as a service, indirectly under *init*:

```
#1 init manages two "auxillary daemons" :
/etc/inittab:
tty6::respawn:/bin/start.daemon /usr/local/bin/start.auxd 1
tty7::respawn:/bin/start.daemon /usr/local/bin/start.auxd 2

#2 the auxillary daemons are customises at boot time by entries in
/ffs/dropbear/etc/auxd

auxd1 is conventionally mdsshell
auxd2 is, in this case, acton_prep:

#3 The acton_prep start up is defined as follows:

[pgm@islay ffs]$ cat dropbear/etc/auxd/auxd.2.conf
#!/bin/sh
# runs mdsshell

. /etc/profile

EUID=${EUID:-1000}
exec acton_prep /etc/auxd/acton_prep.job

#4 The default job:
[pgm@islay ffs]$ cat dropbear/etc/auxd/acton_prep.job
#!/bin/sh

echo place holder for acton_prep.job;env
```

- Customise auxd.2.conf (to make one-time setups)
- Customise acton_prep.job (to make per-prep action)
- Change files in /etc/auxd for one-time test
- Change files in /ffs/dropbear/etc/auxd for non-volatile change.

14.2.11 Channelized Data.

Channelized data is available in the normal binary format, file per channel for each *PREP*, so it's simple to upload eg using ftp.

For **mdsPutCh** [11.8.3], use the `--dataroot-format` option.

eg. to upload data from *PREP* 037.33003:

```
mdsPutCh --dataroot-format /dev/prep/data/037.33003/%02d [opts] FIELD
```

15 Appendix: D-TACQ Low Latency Mode

Low Latency mode transfers data to memory on a host computer across the backplane PCI bus. The acquisition system is configured for minimum latency, and data for a single sample is transferred immediately after conversion. In addition, ACQ196CPCI is able to transfer analog outputs from the host computer to the 16AO channels on RTM-AO16. The transfers are synchronized by the host, but controlled by the ACQ which uses efficient DMA transfers. As a result CPU loading on the host is very low, leaving the maximum possible number of processor cycles available for computation.

Low Latency mode is highly scaleable, with common configurations featuring multiple cards on one backplane. In a multiple card scenario, the bulk of the capture and data transfer processes occur in parallel across the cards, with only a brief and efficient hardware-mediated period of contention for the shared backplane bus.

- Input Latency: the time from ADC sample clock edge until data available in host memory.
- Output Latency: the time from the Host signaling availability of Output Data to change in output signal.
- Round trip Latency: Input Latency + Host copy Output to Input.

Using a fast host computer, D-TACQ has measured Round trip Latencies of 27 usecs and below for 96AI, 16AO; The underlying hardware process is using max 15 usecs, the remainder is occupied by software signaling and time stamp exchange, and further gains are possible by improving the software workflow.

Typical systems comprise a minimum 200 AI, and achieve a 20kHz rep rate or better.

The initial specification is referred to as LLCONTROL V1. The host side application is LLCONTROL and the target side firmware module is known as LLC.

To cater for higher reprates, a number of back compatible improvements known as LLCONTROL V2 are described. Using LLCONTROL V2, reprates of 100kHz should be achievable.

15.1 Notes on achieving Hard Real Time performance.

Hard Realtime performance can be achieved without the use of an RTOS by disabling interrupts on each computer (Host and Target). Then the computers are each running a single threaded loop of code, and Linux is effectively suspended for the duration of the shot. Such a system has proved to be well capable of hard real time performance with a loop running at up to 25kHz. Using an RTOS on the Host is not precluded, of course, and an Interrupt On Dma Done (IODD) facility is provided for this purpose. However, it should be noted that using an interrupt is not

necessarily “faster” than polling for DMA done, and may in fact be slower.

A critical factor as rep-rates shrink below 40 usecs is the bus performance itself, and the user will have to pay attention to operation of the PCI Master Latency Timer. This is usually controlled by a BIOS setting, and should be set to a value that allows repeatable low latency response. This is important, as, even with interrupts locked out, another bus master may take priority on the bus at a critical time.

A second factor that may become important as cycle times are reduced is Bridge Latency; a typical pci bus extender bridge may cause a single READ cycle to take 3usecs, no matter how fast the Host processor.

The LLCONTROL program supplied by D-TACQ includes an option for timing and polling a mailbox register on the ACQ196, to allow measurement both of delay due to the bridge (average latency), and the possibility of any bridge lockouts (maximum latency).

These factors are entirely application dependent and are beyond D-TACQ's control.

15.2 LLC Module

This is the target side module that customises the embedded firmware for the mode.

Now available both on ACQ196 and ACQ216. While the same application interface is used, operation is different:

- ACQ196CPCI – lowest latency capture of a single sample
- ACQ216CPCI – low latency capture of a block of samples.

Invoked at boot time:

```
load.llc   ;# add this to /ffs/rc.local
```

The mode is implemented as a module for faster debug, test and update, and for the relatively easy provision of custom variants.

The module exposes the following file nodes for user space diagnostics and control:

```
root@acq196_001 ~ #ls /dev/llc/
debug           imask           settings        version
detach_state    mode            stats
emergency_stop  run             status
```

- imask : set interrupt mask for llc when running
- status: view status of process.
- Emergency stop: set to “1” to stop runaway process
- run: start process (configured from acq200control via backplane controls).

An embedded web page with LLC diagnostics appears when the module is loaded, and together with the dio.cgi and signal.cgi pages, is useful for debug and diagnostics.

15.3 Signals

1. External Clock – nominal 1Mhz, input default on DI0
2. External Trigger – clears internal counters and starts acquisition, default on DI3
3. Derived Sample Clock output (master) – default DO1
4. Derived Sample Clock input (slave) -default DI1
5. Input signals (32/64/96 analog inputs).
6. Output signals (16 analog outputs on RTM-AO16)
7. Digital signals (6DI, 32 DO on RTM).

Using the normal clock/trigger signal and routing system, it is possible to use just about any combination of digital IO ports, front or rear.

The control signals may be routed via the PXI compatible backplane lines to connect to other ACQ cards in a single chassis.

An automated test routine is supplied, where a typical test with three cards in a rack supports the following roles:

- MB: Master Board, supplied sample clock to other
- SB: Slave Boards.
- CB: Optional Clock Board supplied 1MHz clock and trigger to the rest of the system.

15.4 Typical Plant Operating Scenario

The Plant supplies a 1MHz clock on DI0. The clock is divided down to an appropriate sample clock rate by on board firmware, and the derived clock is retransmitted to other boards in the system on DO1. All boards in the system sample from the derived clock on DI1. For multi chassis operation, D-TACQ supply a clock and trigger distributor module that ensures that one of the derived clocks is able to clock all the boards in the system.

The clock divide ratio is referred to as the “External Clock Multiple” ECM. So a system running at ECM40 has a 25kHz sample clock.

15.5 Bus Level Protocol

Regular ACQ32 bus level commands cause the board to enter low latency mode. In low latency mode, the four 32 bit PCI mailbox registers on the board are redefined for low latency specific functions. The operation of the mode is demonstrated via a “user mode driver” - an application that makes calls on the regular acq200-drv driver to map the mailbox registers into application space, and then controls the board via these registers. The application also has to map a fixed area of host memory to use as a target for the acquisition process. The AO functionality is implemented by i2o messaging, where a series of inbound, outbound buffer queues are maintained with assistance of common hardware registers.

The messaging unit register map is duplicated from [5], with additional functional definitions relevant to LLCONTROL added.

Messaging Unit Register MAP.

Offset	***Description***	***Ident***	***LLC Function***	***G***
0004H	reserved			
0008H	reserved			
000CH	reserved			
0010H	Inbound Message Register 0	IOP321_IMR0	BP_MB_LLC_CSR	4 R e
0014H	Inbound Message Register 1	IOP321_IMR1	BP_MB_LLC_DATA_ADDR	
0018H	Outbound Message Register 0	IOP321_OMR0	BP_MB_LLC_TADC	
001CH	Outbound Message Register 1	IOP321_OMR1	BP_MB_LLC_TINST	
0020H	Inbound Doorbell Register			2 a
0024H	Inbound Interrupt Status Register			
0028H	Inbound Interrupt Mask Register			4
002CH	Outbound Doorbell Register	IOP321_ODR		
0030H	Outbound Interrupt Status Register	IOP321_OISR		
0034H	Outbound Interrupt Mask Register	IOP321_OIMR		
0038H	reserved			
003CH	reserved			
0040H	Inbound Queue Port		AO data	2
0044H	Outbound Queue Port			P o
0048H	reserved			
004CH	reserved			
0050H 0FFCH	Local memory			1 0 R e

15.6 Description of Operation

1. The board is armed, setting parameters, including target address in host memory and external clock divide.
2. Acquisition is activated on the falling edge of the external clock. Firmware provides two 32 bit counts, LATCHED and IMMEDIATE.
3. The external clock is divided down, to give a sample clock pules on every zero count of the counter. At the sample clock, a conversion is triggered and the LATCHED count is updated.
4. When converted data is available, this is immediately transferred with minimum latency to the target memory on the host board.
5. Control software on the host board is able determine the state of the capture by polling the mailbox registers on the ACQ. The software is able to read the value of the two counters at any time. The LATCHED count is the clock count at the last sample, and the IMMEDIATE count is the external clock count at the time of the query. Control software is able to make use of the counter values to check for overrun, to determine when the next sample is expected, and to allow for tuning of the algorithm.

   An enhancement "hbpoll" sees the Host software polling an address in host local memory for status, this is both more efficient and avoids potential of blocking the PCI backplane. This concept is enhanced in LLCONTROL V2.
6. For best determinism, the control application is able to turn off all interrupts by making an ioctl() call to the host side driver. At this point the software becomes a single threaded system with 100% of cpu power available to it. Provided the control software is synchronised with the single input event ie the sample clock, this becomes a true hard real time system, regardless of host operating system.
7. AO uses i2o message buffers to pass a host buffer index to the ACQ; the ACQ receives the index and initiates a DMA transfer direct from Host memory to the AO DACs.

15.7 LLCONTROL Host side application

An example test application **`llcontrol`** is provided to exercise the LOW LATENCY facility. Detailed instructions may be found in the **`llcontrol`** source package available from D-TACQ.

15.8 Setup for Low Latency control.

Superceded for 2G: please follow instructions to run example script "setup.clocks2" provided with the software.

1. Connect 1MHz external clock and trigger signal.
2. Configure boot string for "bigbuf" operation (not essential, but recommended).

```
# Example /boot/grub/grub.conf entry
# 256MB system, but it don't start bigbuf at 128M as it
# would appear that Linux overlaps its limit a little
title Red Hat Linux (2.4.18-3.dt100.020916) bigbuf
        root (hd0,0)
        kernel /vmlinuz-2.4.18-3.dt100.020916 ro    root=/dev/hda3
          acq32_big_buf_base=0x0c000000
acq32_big_buf_len=0x04000000 mem=128M
          initrd /initrd-2.4.18-3.dt100.020916.img
```

Check that the **`llcontrol`** test application is correctly built.

```
[dt100@kst dt100]$ llcontrol --help
llcontrol $Revision: 1.28 $
llcontrol [opts] mode
```

3. Run **`llcontrol`**, in stats mode to check timing

```
[dt100@kst dt100]$ llcontrol --bigbuf  -t -n 1000 ECM 100 | more
mbox access mode NOT USE_IOCTL memory mapped - x86 only FAST
leave LLC
acq32_big_buf_base set c000000
acq32_big_buf_len set 4000000
       0      114      100        9
       1      214      200        9
       2      314      300        9
       3      414      400        9
...

     996    99467    99452       10
     997    99566    99552        8
     998    99667    99652        9
     999    99767    99752       10
```

4. Run again with interrupts enabled, confirm 100% correct timing

```
[dt100@kst dt100]$ llcontrol --bigbuf -M 0xffff  -t -n 1000 ECM 100
| more
mbox access mode NOT USE_IOCTL memory mapped - x86 only FAST
leave LLC
acq32_big_buf_base set c000000
acq32_big_buf_len set 4000000
    iter    tinst   tlatch tprocess
       0      114      100        9
       1      214      200        9
       2      314      300        9
...
   99995  9999614  9999600        8
   99996  9999714  9999700        8
   99997  9999814  9999800        9
   99998  9999915  9999900       10
   99999 10000014 10000000        9
```

5. Run in regular mode to view the data.

Run a regular SOFT_TRANSIENT capture first to fake a non zero number of samples in the driver. Then upload data from the LOWLATENCY capture and review:

(This is a 50Hz waveform sampled at ECM100 (1Mhz/100 = 10kHz)

15.9 Digital IO

LLCONTROL handles digital IO. The standard setup is to treat the 6 dedicated DIO lines as inputs, and the 32 bi directional lines on RTM-DIO32 as outputs.

The **`llcontrol`** module provides hooks for two constant HOST buffer addresses:

- /dev/llc/DO_src : Host buffer address for single 32 bit DO word
- /dev/llc/DI_target: Host buffer address for single 32 bit word with 6 lines of DI in {5:0}

```
Example Use:

echo 0x1a000000 >/dev/llc/DO_src
echo 0x1a000010 >/dev/llc/DI_target
```

`DI_target` is written immediately following write of the AI input vector.

`DO_src` is transferred immediately following write of an AO output vector.

Please note that `DO_src`, `DI_target` are single, constant addresses in the HOST memory space and are NOT updated during the shot. It it the responsibility of HOST software to ensure that the HOST side data is accessed at the correct times.

15.10 Host Side Driver Capability

D-TACQ supports a full featured Linux host side driver. The driver supports full access to all commands, provides a "remote shell over PCI" facility and provides mappings to card control registers and host memory. However this driver is large, and is currently restricted to:

- Linux 2.4.x or Linux 2.6.21 or better
- x86 architecture
- 32 bit pointers.

LLCONTROL applications using host systems outside this restriction is possible using the following minimum driver interface:

1. Driver provides a memory mapping of the ACQ196 messaging unit registers to the LLCONTROL application.
2. Driver provides a mapping of the 16MB slave memory area to the LLCONTROL application.

However, it should be noted that the target-side LLC module makes increasing use of *sysfs* files to allow user space control of acquisition parameters. Where parameters are not catered for by the basic message-register protocol, the *sysfs*-based parameters may be set by one or more of the following methods:

1. remote-shell (**`acq2sh`**) pci backplane messaging.
2. Embedded boot script on the target.
3. Over Ethernet, either by *cgi*-script or via *ssh*.
4. A future, block configuration setup via the *pci* backplane is proposed.

Method 1 is generally the most convenient, since the host side system is then able to control all the parameters without access to any external communication channel (ie Ethernet. However this will not be possible with the minimum driver interface. For test purposes, we strongly recommend interactive use of the Ethernet channel, and cgi scripts for setup and monitoring are provided. Mid term, appropriate settings can be made via a custom boot script stored in card-local flash file system, or set at run time via automated *cgi* or *ssh* scripts. Long term, it is planned to allow all parameters to be set on entry to LLCONTROL via a message block in host-side shared memory. This message block will NOT require setup of the full I2O messaging system.

15.11 LLCONTROL V2 Performance Enhancement:

15.11.1 Feature Set

15.11.1.1 Interrupt on DMA DONE (IODD)

This enhancement is implemented, and is intended to be of benefit to cases where the hosts side is controlled via an RTOS. IODD is a user selectable option.

15.11.1.2 Host side status delivery for zero mailbox polling.

ACQ196CPCI FPGA firmware includes two 12 bit counters for TLATCH and TINST. The Host Side status delivery mechanism, when enabled will result in delivery of the FPGA count values, together with a copy of the ACQ196 message register values to a user-specified address in host slave memory.

This obviates the need to poll the ACQ196 to determine TLATCH, as well as implementing a simple means to allow host side software to poll for incoming data in local memory, without having to go out on the PCI backplane.

However, in the original LLCONTROL firmware, it is the responsibility of the ARM firmware to track the two counters, and expand them to 32 bit for presentation to the host application via the message registers. Now part of this responsibility passes to the host side LLCONTROL application.

In systems with no other access to external timing, it may still be appropriate for host side software to poll the ACQ196 for current TINST to determine where in the cycle we are. Please note that this may become infeasible to do as the rep-rate approaches 100kHz.

15.11.1.3 Synchronous Output update for higher rep-rate operation.

LLCONTROL V1 features asynchronous update for Analog Outputs. The ACQ196CPCI maintains a hardware assisted queue of message frames. The frames are physically located in the host slave memory. In order to initiate an AO update, the host side LLCONTROL app will:

1. collect a message frame address MFA from the ACQ196 message Q.
2. copy the AO data to the frame memory.
3. Post the MFA to the ACQ196 message Q.

The LLC firmware will then:

1. receive the MFA.
2. Builds a DMA descriptor using the MFA.
3. Initiate a DMA direct from host slave memory to the DAC unit.

This AO scheme allows AO update that is asynchronous to the Analog Input (AI) sample clock. This is good when the AI clock period is relatively long, and the AO calculation is complete significantly before the next AI clock edge.

However, as the sample clock rate (controller rep-rate) increases, the overheads of this scheme become significant. The Synchronous Output scheme addresses this by performing the AO update as part of the input DMA chain, triggered by the ADC conversion initiated by the sample clock. The address of a fixed, shared AO buffer in host slave memory must be specified before the control process starts, and it is the responsibility of host side software to ensure that the AO buffer is updated in time for the next sample.

15.11.1.4 Hardware Gating pulse.

LLCONTROL V1 uses the external Trigger signal to start the control process, and to reset the external clock counters in hardware.

LLCONTROL V2 shall include the capability of using the Trigger signal as a gate. The Gate will not only start capture as before, but in addition, hardware will monitor the Gate signal, and inhibit capture while the Gate is inactive. There is no limit to the number of Gate transitions that may occur during the shot. Only the first active edge of the Trigger signal shall reset the counters.

15.11.2 Programming Interface.

All relevant control parameters are exposed via sysfs files. Control and monitoring of the parameters is then accomplished using simple application level ascii writes and reads.

15.11.2.1 Controls

The LLC module presents all controls as sysfs device files, accessible via short-cut from `/dev/llc`. A convenience function, **`list_knobs`** is useful for listing the files. The parameters may also be viewed and modified by web form `llc_setup.cgi`.

Controls Definition.

Parameters	Default	Func	Len	Description
AI_target	0X00000000 (LLC1)	HSBT	192	AI vector
AO_src	0X00000000 (DIS)	HSBS	32	SYNC AO vector
DI_target	0X00000000 (DIS)	HSBT	4	DI (6bits)
DO_src	0X00000000 (DIS)	HSBS	4	SYNC DO (32bits)
IODD	0 (DIS)			
PUAD	0X00000000			A32-A63 (if supported)
STATUS_target	0x00000000	HSBT	32	STATUS
adc_clkdly	100			Internal timing tweak
dac_lowlat	1	DAC output immediate. (alt: clocked)		
debug	0	Set debug level		
emergency_stop	0	Force quit		
imask	0x00000000	Selective interrupt disable for RT operation		
mode	no mode 0 0 0 0	LLC1 setting controls mode		

HSB: PCI address of host slave buffer.

HSBT: HSB, Target (input to host)

HSBS: HSB, Source(output from host)

LLC1: parameter set in the loop using LLCONTROL V1 protocol

DIS: default value means function is disabled

Status Definition

Offset	Name	Description
0x00	ACQ200_DIOCON	{5:0} : 6 bits DI (supercedes DI_target)
0x04	ACQ196_TCR_IMMEDIATE	{11:0} : Immediate count
0x08	ACQ196_TCR_LATCH	{11:0} : Tlatch
0x0c	ACQ196_BDR	Marker: set to 0xdeadbeef
0x10	IOP321_IMR0	BP_MB_LLC_CSR copy
0x14	IOP321_IMR1	BP_MB_LLC_DATA_ADDR
0x18	IOP321_OMR0	BP_MB_LLC_TADC
0x2c	IOP321_OMR1	BP_MB_LLC_TINST

The host side LLCONTROL application can use `BP_MB_LLC_TADC` to compute the 32 bit value of `ACQ196_TCR_IMMEDIATE.`

15.11.2.2 Host Side Memory Layout

Given the use of fixed target buffers, it is suggested that under LLCONTROL V2, the host slave buffer can be reduced to 4K, split into 4 partitions:

Offset	Name	Description
0x000	AI_HSBT	Analog Input host slave buffer
0x400	AO_HSBS	Analog Output host slave buffer
0x800	DO_HSBS	Digital Ouput host slave buffer
0xc00	STATUS_HSBT	Status host slave buffer

15.11.2.3 IODD Handling

The mode is enabled before commencement of LLCONTROL mode by setting `IODD` to '`1`'. Bit 2 (mask: `0x04`) of the Outbound Doorbell register will be set on DMA DONE. This will result in an interrupt request on the PCI host card, and a host side interrupt routine must service the interrupt by writing the mask value back to the register.

The reference Linux host side driver may be used to test this feature, although the LLCONTROL application does not make use of this feature.

15.11.2.4 Operation Sequence.

1. At boot time, ACQ196 is initialized using `load.llc.`
2. ACQ196 Controls are initialized.
3. LLCONTROL application starts, causes firmware transition to LLC mode.
4. Firmware polls for AI data or COMMAND.
5. On AI data, firmware triggers an SYNC DMA chain, this may include AO, DO if specified. At the end of DMA, the optional IODD interrupt is fired if enabled.

15.11.2.5 Simple host side controls setting.

Plan is to put all the application controls values into the AI area according to a predefined layout at initialization time, then the values will be accepted on entry to LLC.

Format of host side control block and parameters on entry to LLC are documented in `acq32busprot.h.`

15.11.3 SYNC_2V combined IO vectors minimize latency

By observation it was found that with typical PCI bus expanders such as Adlink 8570, the time to set up a bus transaction dominates the time on the wire. So SYNC_2V mode minimizes the number of transactions. There are two vectors:

- VI : ACQ->HOST contains all AI, DI, STATUS in one block transfer.
- VO: HOST->ACQ contains all AO, DO in one block transfer.

The relative positions of the data in the vector are described in the header `acq32busprot.h.`

SYNC_2V mode has been used up to 100kHz rep rate and is the recommended way to use LLCONTROL.

15.11.4 SYNC_2V_AO32

Extends the SYNC_2V concept to multiple AO32CPCI slave devices.

15.11.5 SYNC_2V_RFM

For use in systems with a host computer, and with data mirror to Reflective Memory RFM. In this mode, the VI vector is first copied to local memory on ACQ196, then copied to the standard destination in HOST memory, and then distributed again to a user-specifed address in the Reflective Memory module.

There is a small overhead in this mode

- due to the extra copy to local memory - max 2usec.
- due to the extra copy to RFM - could be as long as 5usec, however this should happen AFTER the critical VI->HOST copy, and so is of less concern.

16 Appendix: Low Latency mode on ACQ216

ACQ216 also supports a low latency mode. This is similar to the ACQ196 mode, and indeed the host side API is compatible, and the same host-side test harness is used to exercise it.

A fundamental difference is that the sample rate of the ACQ216 is high compared with the overhead of PCI bus messaging. Therefore the ACQ216 version of LLCONTROL DOES NOT deal in single samples, but in multi sample vectors.

A second difference is that the ACQ216 LLC uses the normal sample clock to

This is intended to find application in signal processing, where data sets are made available for host side processing with minimum delay, the data sets are binary powers of two samples long, suitable for FFT processing.

16.1 Initialisation:

Load.llc loads the connect kernel module.

The following parameters may be adjusted:

- **set.llc** `block_len {1024, 2048, 4096, 16384 }` - set block length
- **set.llc** `imask ffffffff` - mask all interrupts during run

16.2 Operation:

Example host-side operation shown below. *Tclock* is the time between bursts in microseconds.

```
[dt100@cp605 LOWLATENCY]$ acqcmd -s 3 set.llc block_len 4096
EOF 42
[dt100@cp605 LOWLATENCY]$ acqcmd -s 3 set.llc imask ffffffff
EOF 43
[dt100@cp605 LOWLATENCY]$ acqcmd -b 3 setInternalClock 10000000
ACQ32:
[dt100@cp605 LOWLATENCY]$ ./llcontrol -M ffff -b 3 -t --bigbuf -n 10
SCM
card 3
mbox access mode NOT USE_IOCTL memory mapped - x86 only FAST
mbox access mode NOT USE_IOCTL memory mapped - x86 only FAST
leave LLC
                                                      CARD: 3
    iter,      tinst,     tlatch, tprocess,   tclock,   hpol, tpol,
       0,        457,          0,      255,        0,      0,   34,
       1,       1007,        552,      255,      552,      0,   35,
       2,       1554,       1095,      255,      543,      0,   35,
       3,       2097,       1642,      255,      547,      0,   34,
       4,       2639,       2185,      255,      543,      0,   35,
       5,       3266,       2727,      255,      542,      0,   35,
       6,       3811,       3354,      255,      627,      0,   35,
       7,       4360,       3899,      255,      545,      0,   35,
       8,       4905,       4448,      255,      549,      0,   35,
       9,       5447,       4990,      255,      542,      0,   35,
```

17 Appendix: RTM-DDS

RTM-DDS is an RTM accessory compatible with ACQxxx – eg ACQ216.

It's recommended to control this clock using the high-level command **`set.acq164.role.`**

It provides a high resolution, low jitter, highly adjustable DDS clock source, realised using an AD 9854 device.

The DDS may be controlled in steps of 1Hz, and clock source may be selected from either internal 66.000 MHz source, or the usual DIO lines. The output may be selected among DIO lines in the usual way.

RTMDDS may be controlled via a setup dialog and control panel available from the Config tab in **`dt100rc`**. The same routings and setups are also presented by `rtmdds.cgi`, and a standalone frequency control program is provided as `ccc.jar`, please follow instructions on `rtmdds.cgi`.

The Frequency Tuning Word FTW may also be calculated locally using the **`dds`** command:

API:

```
load.rtmdds  ;# should be loaded at boot time eg via /ffs/rc.local
/dev/ftw1 : Frequency Tuning Word 1 – load with 6 byte hex number
dds frequency [ext-clk-frequency] [ext-clk-multiplier]
```

`set.acq164.role` *ROLE CLKHZ*

`ROLE :: {MASTER|EXTCLK_MASTER|SLAVE|SOLO}`

`CLKHZ :: 1000000 .. 100000000 Hz, 1Hz steps.`

`MASTER:`

source clock from Local Oscillator, share this clock on PXI D1.

Input trigger on TRG LEMO, share on PXI D3

`EXTCLK_MASTER :`

Take a 1MHz plant clock in CLK LEMO, multiply up to required sample rate. Share this clock on PXI D1

Input trigger on TRG LEMO, share on PXI D3

`SLAVE :`

accept clock on PXI D1, TRG on PXID3

`SOLO`:

source clock from Local Oscillator.

17.1 Clock Source

Clock source to the DDS is software selectable:

```
set.rtmdds clksrc {REFCLK | DI[0-5] }
```

REFCLK is a local 66.6666666MHz crystal.

17.2 Output Routing.

Output (DeSTination) of the DDS may be routed as follows:

```
set.rtmdds clkdst {DO[0-5]}
```

The signal must be routed out of the Rear IO and on to the local FPGA and optionally across PXI to other cards:

```
set.route in rio out fpga [pxi]
```

17.3 Control signal direction in relation to front-side board.

Fast signal lines may be configured as outputs from the RTM to act as front-side inputs,

or as inputs to the RTM to accept signals from the front side board.

Line D0-D5 are either connected to the DDS CLKDST, the DDS CLKSRC, or to input opto couplers from the rear panel HD15 connector.

The following command controls this direction with respect to the RTM:

```
set.rtmdds rio_outputs {output-mask}

where output mask is a mask of (1<<Dx) for all outputs, with the
result value expressed in hex or decimal.
```

NB: it is also necessary to set appropriate routing on the front side board.
For examples please see 13.6

17.4 Operational Considerations for DDS

For external clock applications, it is necessary to use the REFCLK MULTIPLIER to maximise internal clock frequency. At the same time, with the REFCLK MULTIPLIER enabled, the external clock should be > 5MHz. A clock multiplier accessory is avaialble to allo clock multiplication from a 1MHz source.

NB:

Fout = FTW / 2^48 * SYSCLK

And max frequency is SYSCLK/2 – FTW numbers > 0x800000000000 cause the frequency to fold back towards zero.

18 Appendix: Linux Tips

18.1 Dt100-hub configuration

When using the `dt100-hub` technique for disk-less satellite operation, D-TACQ recommends setting up a second Ethernet network from the hub machine. The satellite then sits on a private network protected from the main network by the hub.

The satellite system uses one network link per satellite board, in the case of a single satellite, this can be connected back to the hub via a single crossover cable. For the case of multiple satellites, a small Ethernet switch should be used.

Recommended convention for the satellite network is as follows:

- Hub second Ethernet address: 192.168.0.254
- First satellite address: 192.168.0.1
- Second satellite address: 192.168.0.2 ... etc

D-TACQ recommends NOT to set up transparent routing between the main network interface and the second interface, but rather to use ad-hoc port forwarding, so that hub-side access and addresses are always protected by password authentication at the hub.

18.2 Port forward remote satellite

Satellite is hidden from main network. But it is still accessible by port forwarding.

Example:

```
# Forward remote http, telnet, dt100d ports to local
# ports 8080, 2323, 53504 respectively:
$ ssh -f -N -C -L8080:192.168.0.1:80 dt100@crppdtacq8
$ ssh -f -N -C -L2323:192.168.0.1:23 dt100@crppdtacq8
$ ssh -f -N -C -L53504:192.168.0.1:53504 dt100@crppdtacq8
```

18.3 Hook to services via lsa

Local services such as **`acq200control`**, the EPICS IOC **`acq2ioc`** and others may run using the Local Socket Adapter **`lsa`**. The server is run using **`lsad`**, **`lsad`** spawns the server and blocks on a local (AF_UNIX) socket. Clients can connect via **`lsac`** to interrogate the server. This is used for example for IOC console access, where we do not want to dedicate the main console to IOC.

```
lsad --socket /tmp/epics -- acq2ioc $SCRIPT  &
echo To connect to epics, use lsac --socket /tmp/epics
```

18.4 Access MDSplus via shell scripts on x86 host

The MDSplus "Thin Client" **mdsshell** runs just as well on an x86 host computer as on the XSCALE ACQxxx cards. We have found this to be very useful, for example:

18.4.1 Submitting continuous framed data to MDSplus

Data is streamed continuously from ACQxxx cards at low rate. The **dt100rc** client manages the data stream, providing near real time plotting. An effective method of delivering this data to MDSplus as follows:

1. **dt100rc** controls the data stream, and saves raw framed data to a file tree.
2. every second, **dt100rc** spawns a scripted **mdsshell** job. MDSput is able to extract channel data from the raw framed data and to submit it to MDSplus.

This is implemented in a 300 channel, 1kSPS streaming system. The data is deframed efficiently in blocks of 32 channels. Full dechannelization is performed in the MDSplus tree at a later stage.

18.4.2 Extracting data from MDSplus to export to analysis.

D-TACQ makes extensive use of GNU-OCTAVE for data analysis. Octave is able to read binary data in either integer or float format, and we use **mdsshell** to extract the data

eg:

```
mdsValue -o /tmp/ch01.volts ACQ216_032:CH01
```

and the GNU-OCTAVE import script looks like this:

```
octave
octave>fp = fopen("/tmp/ch01.volts", "r");
octave>ch01 = fread(fp, "float");/* calibrated data from mdsPutCh */
octave>plot(ch01);
```

19 Appendix: FAQ

19.1 What is the Voltage Encoding?

As default, D-TACQ cards produce raw binary data in the form of 16bit signed numbers, with scalings shown in tables below.

Simple scaling function for symmetric ranges:

Volts = Raw * V2/ 32768.

"Perfect scaling function" used by **mdsPutCh**, effective where per-channel calibration is available (default ACQ216CPCI, use **get.vin** 10.4.5) :

Volts = V1 + (Raw – R1)* (V2 – V1)/(R2 – R1)

ACQ16	Hex	Decimal		Volts	
	0x8000	-32768	R1	-2.5V	V1
	0x0000	0		0.0V	
	0x7ffc	32764	R2	+2.5V	V2

ACQ32	Hex	Decimal		Volts	
	0x8000	-32768	R1	-10.0V	V1
	0x0000	0		0.0V	
	0x7fff	32767	R2	+10.0V	V2

ACQ196	Hex	Decimal		Volts	
	0x8000	-32768	R1	-10.0V	V1
	0x0000	0		0.0V	
	0x7fff	32767	R2	+10.0V	V2

ACQ196-uns!	Hex	Decimal		Volts	
	0x0000	0	R1	-10.0V	V1
	0xffff	65535	R2	+10.0V	V2

! selected through /dev/dtacq/coding

ACQ196-Neg*	Hex	Decimal		Volts	
	0x0000	0	R1	0.0V	V1
	0xffff	65535	R2	-10.0V	V2

* special order-time configuration. Other configurations on request.

ACQ216	Hex	Decimal		Volts	
	0x8000	-32768	R1	-XV	V1
	0x0000	0		0V	
	0x7ffc	32764	R2	+XV	V2

Where X depends on Range selected.

M2/M6: {2.5V, 4V, 6.25V or 10V }

M2 on early models { 2,5, 4, and 6.6V }

M5 : {30mV, 50mV, 625mV, 1V, 1.9V, 3V}

19.2 How to run custom inetd services.

In a trusted network environment, **inetd** is a convenient way to launch local utilities as remote services. Suitable candidates for this include **statemon** and **fungen**.

The default `inetd.conf` defines NO services. To define custom services, simply:

- Store custom `inetd.conf` as /`ffs/dropbear/etc/inetd.conf`; this will overwrite the default at boot time.
- Signal inetd to load the new configuration by adding this line to /`ffs/`**`rc.local`**:

  `kill` `-hup` `` `pidof inetd` ``

19.3 When do you use acqcmd -b, acqcmd -s, acq2sh?

acqcmd is a program that sends commands and queries to the main acquisition controller. **acqcmd** is resident both on the HOST and on the TARGET.

The "`acqcmd`" commands form a fairly tightly controlled set (defined in the ICD [1]).

The ACQxxx cards sport an ever increasing number of controls (tweaks, knobs). The preferred mechanism for accessing them is via shell commands that run on the TARGET. For historical reasons, these target side shell commands are referred to as "`acq2sh`" commands.

Generally, "`acqcmd`" operations are fast, frequent and/or critical, while "`acq2sh`" operations are one shot, slow things.

The issue then, is how to run the commands from various places.

Basically, wherever you are, for "`acqcmd`" commands, simply use **acqcmd.**
When running **acqcmd** on a HOST machine, the -b BOARD option should be applied, native **acqcmd** does not need this option.
To run shell commands from the TARGET, just run them in the normal way. To run shell commands remotely from a HOST, use "`acqcmd -s BOARD`".

Initially, D-TACQ provided a utility command "`acq2sh`" to perform remote shell commands via PCI, this is now deprecated in favour of "`acqcmd -s`". However the `acq2sh` name is too good to waste, so it is used as shorthand for "`acqcmd -s`".

Future versions of code will make "**`acq2sh -b`**" an exact synonym for "**`acqcmd -s`**".

Summarised in the following table:

19.3.1 Summary of acqcmd/shell usage

Location	*Mode*	*Command*
TARGET	**acqcmd**	**acqcmd**
	shell	**(sh)**
HOST (PCI)	**acqcmd**	**acqcmd -b**
	shell	**acqcmd -s**
HOST (HUB)	**acqcmd**	**acqcmd -b**
	shell	**acqcmd -s**

19.4 Why doesn't my command line argument work?

Many D-TACQ commands allow user customisation by making use of a combination of command line switches and arguments. Internally, the command line is usually handled by the popt(3) library.

Normally, switches are prefixed by '-' or '--' .

This can lead to a problem when arguments begin with '-' ; e.g. negative numbers.

The solution is to disable switch processing with a single '--'

eg:

```
acqcmd setDIO -1-----     # WRONG
acqcmd -- setDIO -1----   # CORRECT
```

```
prompt> mdsPut --expr $ --format float "\\MYTREE::TOP.MYSCALAR" "-
10.6092"
MDS ERROR "EOF ERR
"
ERROR must supply value

As it turns out, the minus sign on the value argument causes that
argument to be interpreted as an option.  The fix is to use the end-
of-options marker "--" :

prompt> mdsPut --expr $ --format float -- "\\MYTREE::TOP.MYSCALAR"
"-10.6092"
mdsPut( \MYTREE::TOP.MYSCALAR ) = -10.6092 OK
```

19.5 How do I set up public key login

We assume you have a valid user on a host Linux system (cygwin works also).

The host system is able to connect to the target (ACQxxx) using ssh, but you have to type the ACQxxx password each time. Public key exchange will eliminate the password step, enabling a secure by effort-free login, that is also useful for host-side automation (eg firmware update using remote.update).

19.5.1 First check if you already have a public key set up:

```
cd
ls -l .ssh
# if the file .ssh/id_rsa.pub exists, skip to step 3
```

19.5.2 Create host public keys

```
ssh-keygen -t rsa
# just answer yes to the prompts. No pass-phrase is needed
```

19.5.3 Copy the keys to the target

```
scp .ssh/id_rsa.pub root@TARGET:
ssh root@TARGET
# NB '>>' NOT '>' - append not override!
cp id_rsa.pub >>.ssh/authorized_keys
```

19.5.4 Check it Works

```
ssh root@TARGET
# auto logs in - no password required!
```

19.5.5 Save the keys to non-volatile disk system

```
cp .ssh/authorized_keys /ffs/dropbear/root/.ssh/authorized_keys
cp .ssh/authorized_keys \
          /ffs/dropbear/home/dt100/.ssh/authorized_keys
```

19.6 Trigger, Event – What, Why, When?

19.6.1 What:

- *Trigger*: starts acquisition. *Trigger* is actually wired to the hardware, and with trigger selected, no data is captured until the *Trigger* condition is met.
- *Event*: external digital edge is embedded in the Analog data stream, in order to mark the exact point of occurrence for downstream software. Events are also wired into the hardware, but have no effect until the capture has started.

19.6.2 Why

- Both *Trigger* and *Event* have the function of synchronizing analog data capture to an external signal.
- *Trigger* is simpler to implement - “Start Now”.
- Detecting external edges once the capture has started is less simple because the software data sink process is operating asynchronous to the sample clock – at the end of a (sometimes very deep) pipeline - it is not possible to indicate the exact point of occurrence to the software in real time. So instead we have the strategy of embedding the information in the data stream, so that the exact point of the transition can be identified relative to the analog date.

19.6.3 When

Common Uses

- Use *Trigger* to start a one-shot transient capture. (`SOFT_TRANSIENT len`).
- Use *Event* to cause transition between pre- and post- phases - (`setModeTriggeredContinuous pre- post`) . In most cases it is not necessary to use *Trigger* with pre- -post, since the starting pre- data is overwritten long before the Event.
- Use *Trigger* to start a SOFT_CONTINUOUS process, eg for streaming data in a synchronized way from multiple cards.

Less Common Uses:

- Use *Trigger* and *Event* together in a pre- post capture. This is used for combined streaming, fault detecting applications – eg stream synchronized data from multiple cards, starting on *Trigger*, but detect a “fault event” using Event that causes transition to post capture and system halt.
- Use *Event0*, *Event1* OR’d together – first event causes the pre to post transition.
- Use *Event0*, *Event1* in sequence, for example we have an application that offers a series of burst captures within a GPS second. The GPS ONEPPS pulse provides synchronization, that is detected via *Event1*, while software generates a series of burst captures, synchronized via *Event0*. Each burst is timed relative to the GPS edge.

19.7 What sequence must commands be issued in?

In general, in state ST_STOP, any command can be issued in any order, with the following exceptions:

```
acqcmd setChannelMask <mask>
```

SHALL be issued *BEFORE* setting the Mode

```
acqcmd setMode <mode> <pre> <post>
```

For this reason it is recommended that the Mode *SHOULD* be the last command before the card is Armed using

```
acqcmd setArm
```

When the card is not in state ST_STOP, then the only "setter" acqcmds that will be accepted are:

```
acqcmd setAbort
acqcmd setDIO
```

NB: all regular shell commands are still accepted, include **set.trig**, **set.event0**, but the effect of running such capture-specific commands after the card has been armed is *undefined*.

19.8 What is the sample phase when using derived clock?

For example, following:

```
acqcmd setExternalClock 10 DI0
```

The sample clock will occur on the 9th edge of DI0.

ie the sample clock is activated on the terminal count of the counter.

20 Appendix: ICD changes for 2G

Changes in this section supercedes items in the ICD.

NOT Supported on 2G:

- GPEM – regular TriggeredContinous has similar functionality owing to ability to specify event line and edge.
- **acqcmd** setSyncRoute – replaced by shell command **set.route.**
- **acqcmd** setChannel – no direct equivalent.
- Streaming: is not sub-rate, but full rate.

20.1 Remote Commands (replaces ICD 4.10.1)

20.1.1 Overview

A server daemon runs on the ACQxxx card, listening for socket connections on port 0xd100. The server daemon is multi threaded, and is able to accept multiple non conflicting sockets. The server makes a single line status report on opening the socket connection.

Each socket represents a conversation with a logical device, so all of the protocol defined in Device Level Interface still applies. In addition a number of remote level commands are added for session control and to enable device selection

It is highly recommended that separate sockets be opened concurrently for control (to master device) and for data (from data device).

The **dt100 read** command has binary output. When a client has read all the binary data, the server waits on this channel for another read command. To drop the channel, the socket should be discarded with a close() command at the client side.

For streaming data, the data socket should be discarded after use, and a new socket reopened when streaming is restarted. It is highly recommended to shut streaming down cleanly before closing the socket, or subsequent connection attempts may block on a long timeout.

It is also possible to operate streaming in a bursted mode. Bursting requires a repetitive trigger, and burst length and offset may be configured from **burst.cgi**. This is an advanced topic, please contact D-TACQ for details.

20.1.2 Command Summary

20.1.2.1 dt100 getBoards

Command	**dt100 getBoards**
Description	Get the current configuration
Master/Slave?	na
OK Response	DT100: <boards> <boards> : board configuration records, one line per board
ERROR Response	DT100: ERROR error string

20.1.2.2 dt100 open master

Command	**dt100 open master /dev/acq32/acq32.<board>.m<slaves>** <board> : { 1,2,3,4 } <slaves> : { bbb } eg 1234
Description	Open channel to selected device For direct connect to a single satellite device, <board> = 1. The channel supports "acqcmd" commands
Master/Slave?	M
OK Response	DT100:
ERROR Response	DT100: ERROR device in use

20.1.2.3 dt100 open shell

Command	**dt100 open shell**
Description	Open shell command channel to selected device.
Master/Slave?	M NB: this allows any shell command to be run, and so is a serious security hole. Terminate the shell using "exit". Then terminate the link using "bye".
OK Response	DT100:
ERROR Response	DT100: ERROR

Example:

```
[pgm@islay pgm]$ telnet acq196_010 53504
Trying 192.168.0.154...
Connected to acq196_010.
Escape character is '^]'.
MasterInterpreter
dt100 open shell
DT100:
get.route d0
d0 in mezz out fpga
EOF 1
exit
bye
Connection closed by foreign host.
```

20.1.2.4 dt100 open data

Command	**dt100 open data <device>** <device> : /dev/acq32/acq32.<board>.<channel> <board> : { 1,2,3,4 } <channel> : { nn, XX } eg 01.
Description	Open data channel to selected device, ignore sample_read_start, sample_read_stride rules
Master/Slave?	D
OK Response	DT100:
ERROR Response	DT100: ERROR device in use

20.1.2.5 dt100 open data1

Command	**dt100 open data1 <device>** <device> : /dev/acq32/acq32.<board>.<channel> <board> : { 1,2,3,4 } <channel> : { nn, XX } eg 01.
Description	Open data channel to selected device, obey sample_read_start, sample_read_stride rules
Master/Slave?	D
OK Response	DT100:
ERROR Response	DT100: ERROR device in use

20.1.2.6 dt100 open data2

Command	**dt100 open data2 <device>** <device> :/dev/acq32/acq32.<board>.<channel> <board> : { 1,2,3,4 } <channel> : { nn, XX } eg 01.
Description	Open data channel to selected device, obey sample_read_start, sample_read_stride rules, initial line of data in dt100 read is a 4 byte binary count - this makes for easier use with some programming products - eg LABVIEW.
Master/Slave?	D
OK Response	DT100:
ERROR Response	DT100: ERROR device in use

20.1.2.7 dt100 open sys

Command	**dt100 open sys file** <file> is typically a file in sysfs
Description	Open data channel to file, usually a device file. Any subsequent data is channeled efficiently to the file.
Master/Slave?	D
OK Response	DT100:
ERROR Response	DT100: ERROR device in use

20.1.2.8 dt100 read

Command	**dt100 read <start>,<stop>, <stride>**
Description	Open data channel to selected device
Master/Slave?	D
OK Response	DT100: <nn> bytes followed by Stream of data in RAW BINARY format. The data will be framed if setTagging has been set on Data size per read is limited to 256kB [default]. To read longer data sets, read the data in chunks, repeating the read command with updated <start> each time. This maximum size may be modified by setting the environment variable DT100D_DATABUFLEN
ERROR Response	DT100: ERROR device in use

20.1.2.9 dt100 stream

Command	**dt100 stream [<stride>] [<mean>] [np]** <stride> : { 1..1000, default 1 (full rate) } <mean> : { 0 = no-mean, 1= mean of stride samples } <np> : number of channel pairs (from 1st channel)
Description	Stream data taking every <stride> sample { default: <stride>=1 (full rate) } Terminate the stream cleanly using dt100 stream 0 0 0
Master/Slave?	D
OK Response	Stream of data in BINARY framed format.
ERROR Response	DT100: ERROR device in use
Notes	Max data rate is restricted. NB: only stride==1 is currently supported on ACQxxx. NB: only mean=0 is currently supported on ACQxxx. The Mean Device provides stride and averaging control. The channel pair argument can be an effective means of reducing data rate on the wire. Sample Tagging must be enabled

20.1.2.10 bye

Command	**bye**
Description	Close any open channels and drop the socket
Master/Slave?	M/S/D
OK Response	DT100:
ERROR Response	DT100: ERROR

20.1.2.11 acqcmd

Command	**acqcmd <device level interface command>**
Description	All device level commands on selected device Assumes previously opened Master or Slave channel.
Master/Slave?	M
OK Response	DT100:
ERROR Response	DT100: ERROR error string

20.1.3 Dt100d operational considerations.

The **`dt100d`** server will support multiple concurrent connections. However, only one Master Channel may be open at any one time.

The characteristic of **`dt100d`** may be modifying environment variables set in the file **`/etc/sysconfig/dt100d.conf`** [to make changes survive through reboot, save you customised copy of the file as **`/ffs/dropbear/etc/sysconfig/dt100d.conf`**

- `DT100D_TIMEOUT` – timeout in seconds, timeout occurs if the channel is waiting for remote command for longer than this time. The default is 24h, this will prevent an accumulation of stale channels. If the local network is challenging, or perhaps the clients are unreliable, then it may be helpful to `set this` timeout to a lower number.
- `DT100D_DATABUFLEN` – maximum single read size when reading data. This value may be increased to reduce or remove the nead for read buffer chunking. NB: in common with any IO operation, client code should not make any assumption about the number of bytes returned; client code must read the return value to determine the amount of data available per call.

`default` `/`etc/sysconfig/dt100d.conf

```
# options for dt100d
# option: timeout [secs] for unused sockets
DT100D_TIMEOUT=86400
# option: data buffer length: max segment for single read
DT100D_DATABUFLEN=0x400000
```

20.2 acqcmd command synopsis

acqcmd is a standalone executable, which can run on either host or target.

It accepts the following arguments:

```
[pgm@islay ~]$ acqcmd --help
acqcmd $Revision: 1.12.4.3 $
acqcmd [-f device][-b board {1..7}] [command]
acqcmd -s board [shell-command]
or export ACQCMD_DEV=device
if no command use stdin (tip:here docs are good)
special polling opts:
acqcmd --while state {ST_RUN|ST_STOP}
acqcmd --until state
acqcmd [-v verbose] (also slows while/until poll rate)
```

- To run an "acqmcd" - **acqcmd** -b board
- To run a "remote shell command " - **acqcmd** -s board

NB: if command includes parameters beginning with a hyphen '-', please use '--' to terminate switch processing

eg

```
acqcmd -b 1 setDIO 111---    # OK
acqcmd -b 1 setDIO ---111    # WRONG
acqcmd -b 1 -- setDIO ---111 # Always SAFE
```

21 Appendix: acq200.pp Postprocess Script

```
#!/bin/sh
# acq200.pp - post processing
# $Id: acq200.pp,v 1.13 2006/10/31 14:48:38 pgm Exp $

. /usr/local/ppfuns.sh

export HN=`hostname`

# comment this IN to use MDSplus Thin Client from here
. /usr/local/mdsplus/bin/mdsfuns.sh

# include next line if using postshot ftp
#. /usr/local/bin/ftpfuns.sh




# execution starts here:
# detect abort
ABORTS=`grep ABORT /proc/driver/acq200/stat_wo`
if [ "$?" = 0 ]
then
        log Abort $ABORTS detected
        exit
fi

do_event_cleanup

do_postshot_jobs /etc/postshot0.d
# comment out next line to eliminate transform.
do_transform

# example ftp Target Push
#time /usr/local/CARE/ftp.example 2>&1 | logger -t ftp

# example ftpUpload - channels, block, remotely defined batch
# ftpUpload 192.168.0.165
# blockFtpUpload 192.168.0.165 dt100:dt100
# batchFtpUpload

# comment in generic job handling. in general, remote app should
leave its
# job in /etc/postshot.d
do_postshot_jobs
```

22 Appendix: ACQ216CPCI Add-ons

22.1 RTMDDS

When fitted with RTMDDS, selecting the RTMDDS=YES option in /ffs/rc.local.options triggers the following initialization sequence:

```
start_rtmdds() {
        load.rtmdds
        set.rtmdds clkdst DO1
        set.rtmdds rio_outputs 2
        set.route d1 in rio out fpga
        set.ext_clk DI1 falling
        dds 10000000
        acqcmd setExternalClock DI1
}
```

A quick test to confirm that setup is to look at the DIO web page and note the '|' activity indicator for d1

A common scenario is to slave additional ACQ216CPCI cards from a single master RTMDDS. Easily done as follows:

```
master:
           set.route d1 in rio out fpga pxi

slave:
          set.route d1 in pxi
```

All cards are now controlled by the single master clock.

RTMDDS cards since 2008 have been fitted with an External Clock Multiplier ECM, this will sync to a 1MHz external clock on DI0, use as follows:

```
# take the LEMO clock through to the RTMDDS
set.route d0 in lemo out fpga rio
# set up the DDS for 10MSPS in, 10MSPS out:
# the External Clock Multiplier ECM multiplies a 1 MHz input by 10.
set.rtmdds.clksrc ECM falling
set.rtmdds.refclk_mult 20
set.rtmdds.clkdst DO1
set.rtmdds.rio_outputs 2
# the dds takes 10MHz, multiplies by 20 and sends 10MHz out..
dds -e 10000000 -m 20 10000000
# pick up the DDS output on DI1 :
set.route d1 in rio out fpga
set.ext_clk DI1 falling
acqcmd setExternalClock DI1
```

22.2 FPGA Personality.

ACQ216CPCI has two FPGA personalities, one optimised for 12/16 channel modes, and the other for 4/8 channel mode.

Personality is switched with a single command – do it once and reboot:

```
set.acq216.personality
```

23 Appendix: ACQ132CPCI Add-ons

ACQ132CPCI has much greater *FPGA* resource than other cards, and this is reflected in additional functionality. There are 8 *A_FPGA* devices, each one serving a 4 channel island or *QUAD*. The card supports a very high bus bandwidth between *ADC* and *A_FPGA*, and the A_*FPGA* devices may be used for simple buffering, or complex DSP data reduction. Downstream bus bandwidth from *A_FPGA* to a shared system *FPGA S_FPGA* is lower, then the *IOP* local bus bandwidth from *S_FPGA* to memory is a maximum of 128MB/s. The sample rates and duty cycles may be adjusted over a wide range of values, provided the local bus bandwidth is not exceeded on average.

An example of reduced duty cycle occurs in *Repeating Gate Mode RGM,* data capture only takes place while a pre-defined *GATE* signal is active. The functionality is the _same_ as 10.4.4, #2, *GATE* mode only. (However the programmable *Gate Pulse Generator* gives all the features of the standard *RGM* and more, see below).

A simple way of reducing the average rate is switched *DualRateMode*, intended for continuous capture.

While *ACQ196CPCI RGM* is primarily used to reduce data set size in memory; this is also a feature of *ACQ132CPCI RGM*, however the main reason to use *ACQ132CPCI RGM* is achieve very high sample rates, where the card can capture data at the maximum sample rate of the *ADC* device (10, 40, 65 MHz, depending on grade). The length of capture is determined by the length of the *GATE* pulse, but in any case should not exceed the available buffer memory in the *FPGA*. This is 4096 samples with all channels active, this maximum length may be increased to 8192 samples (2/4 channels active) and to 16384 (1/4 channels active).

An example *DSP* technique to reduce the output data rate :

ACQ132CPCI also features a generic oversampling filter, where the *ADC* may run at a higher sample rate, samples are accumulated in the *FPGA*, and output at a lower rate. It's possible to accumulate up to 16 samples per output word, and this results in improved *SNR*, up 2 bits effective improvement. An oversampling *FIR* filter *DSP* personality allows for higher processing gains.

Other *DSP* possibilities include a Digital Down-converter *DDC,* as well as analog threshold triggering.

23.1 Valid Channel Masks

The following masks are supported for regular operation:

#	Mask	Ch	Max Rate
1	11111111111111111111111111111111	32	2MSPS
2	11111111000000001111111100000000	16	4MSPS
3	11110000000000001111000000000000	8	8MSPS

Other masks are possible (see 23.5), but that should be considered as an "expert

option".

23.2 CLOCK

ACQ132CPCI is designed for higher sample rates than *ACQ196CPCI*, and so features a low-jitter clock multiplier device [ICS 527], known as the *OB_CLOCK*. The *FPGA* features the normal SYSTEM_CLK/N divider "internal_ clock", and with default settings this is set to 1MHz, and is set as the source for the *OB_CLOCK*. *OB_CLOCK* can generate sample clock signals in the range [4..100MHz] from an input clock in the range [1..10MHz]. For *SCLK* < 4MHz, the decimation factor is set on the *AI* channels, to achieve the required output sample rate, while keeping *SCLK* about 4MHz..

The input for the *OB_CLOCK* may be sourced from normal external clock sources such as *LEMO_CLK* or *PXI*. It's anticipated that a relatively low rate external clock (typically 1MHz) is use, and multiplied up locally to make the local high speed *SCLK*.

23.2.1 Oversampling: Decimate/Accumulate

ACQ132CPCI *ADC* devices are grouped into 4 channels per *FPGA*. This basic unit, known as *QUAD* has some per-quad functionality. Notably, control of oversampling rate, accumulate/decimate, and locate channel masking.

Control of individual *QUADS*, and channels within *QUADS* is complex to manage. In this section we describe a global control that sets all *QUADS* equally.

```
set.all.acq132.decimate NACC SHIFT
set.all.acq132.accumulate NACC SHIFT
sets all channels to decimate/accumulate by NACC samples, scaling
data by SHIFT

set.all.acq132.decimate 4 -2
Decimate by 4, left shift 2 presents 14 bit ADC word as a 16 bit
normalized short.
set.all.acq132.accumulate 4 0
Accumulate by 4, shift of zero. 4X accumulation, 14 bit word is
multiplied by 4 and scales to a 16 bit field.
set.all.acq132.accumulate 16 2
Accumulate over 16 samples. The 14 bit data values, multiplied by 16
has to be right shifted by 2 to fit a 16 bit field.
```

NB: `setInternalClock`, `setExternalClock` WILL SET decimation factor; users can override this if required by setting a specific accumulate/decimate value AFTER running the `setInternalClock`/`setExternalClock` command

23.2.2 Internal Clock

Examples SCLK: Sample Clock, DECIM: decimation.

Command	SCLK MHz	DECIM
acqcmd setInternalClock 4000000	4	1
acqcmd setInternalClock 2000000	4	2
acqcmd setInternalClock 250000	4	16

acqcmd setInternalClock 40000000	40	1

23.2.3 External Clock

ACQ132CPCI features a *PLL* based clock driver. The *PLL* provides fine clock adjustment, but more importantly jitter smoothing, giving improved performance. But of course, being a *PLL* there are some restrictions.

- We have to know the external clock frequency
- There is a minimum external clock frequency of 600kHz.
- There is a minimum *PLL* output frequency of 4MHz. Actual sample rates less than 4MHz are achieved by decimation.

Setting the *PLL* is handled by adding optional switches to the `setExternalClock` command. The idea behind this is to allow the same command to continue to be used for cards that do not need to know frequency (no *PLL*). However, if the switches are not applied, the command will error for *ACQ132CPCI*. The command will also adjust decimation to handle clock rates < 4MHz. Any custom decimation setting should be reapplied _after_ calling `setExternalClock.`

If the standard `setExternalClock` command is applied with no switches, then the PLL device is bypassed, and sampling will use the external clock directly. This form of the command resets decimation to 1. At high clock rates, jitter on the external clock and front panel optocoupler will give impaired SNR compared with using the PLL clock.

Usage:

```
acqcmd -- setExternalClock --fin FIN_KHZ --fout FOUT_KHZ DIx [DIV]

FIN_KHZ ::
          External Clock frequency (integer kHz)  [default: 1000]
FOUT_KHZ ::
          Required Sample Clock freq (integer kHz) [default:1000]
DIx ::
          DIx {0..5} line where clock appears eg DI0 (LEMO).
DIV ::
          optional pre-scale for external clock (less useful)
```

NB: **acqcmd** must be followed by a `"--"` character sequence to prevent the switches intended for `setExternalClock` being swallowed by **acqcmd**.

NB: always check the output from the command for errors.

Examples:

- External Clock 1MHz on DI0, 2MHz Sampling required:
  Real life example: External plant clock 1MHz on CLK LEMO

```
acqcmd -- setExternalClock --fin 1000 --fout 2000 DI0
```

- External Clock 20MHz on DI1, 2MHz Sampling required:
  Real life example: ACQ216/DDS on PXI D1

```
Method 1:
```

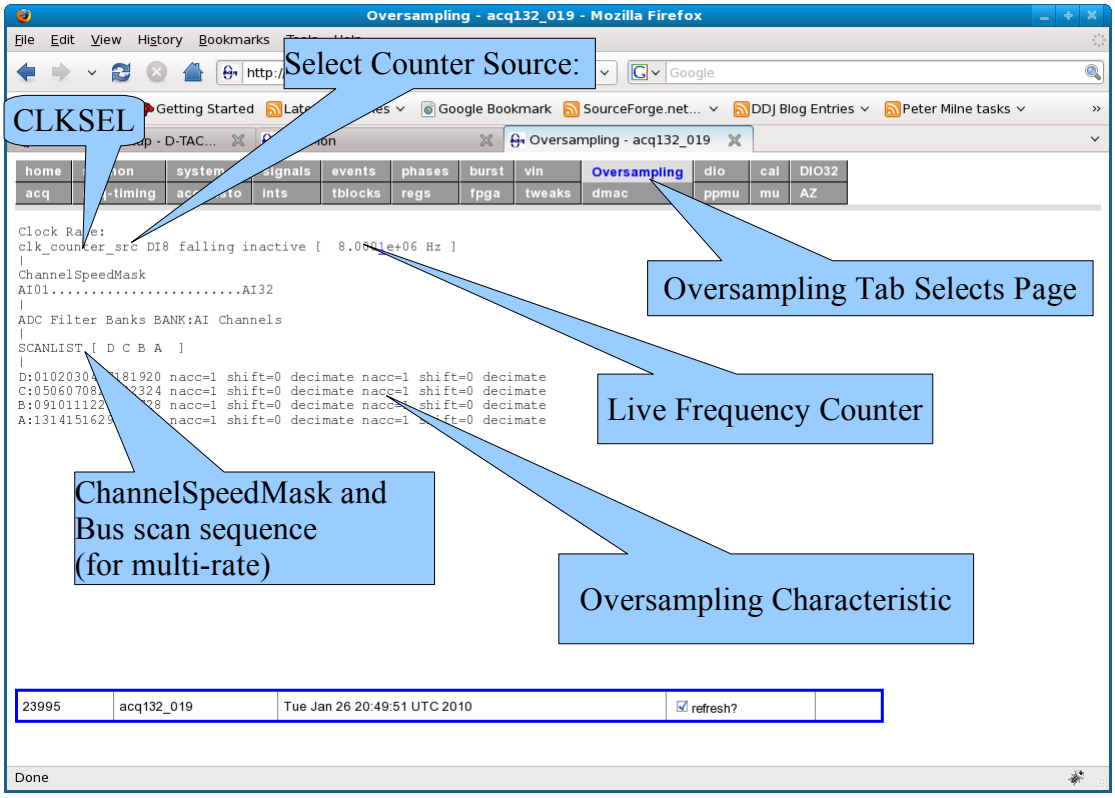
```
acqcmd -- setExternalClock --fin 2000 --fout 8000 DI1 10
set.all.acq132.decimate 4 -2

Method 2:
acqcmd -- setExternalClock --fin 20000 --fout 8000 DI1
```

- External Clock 20MHz on DI1, 6.666MHz sample rate:
  => *Sample rate does not have to be integer multiple.*

```
acqcmd -- setExternalClock --fin 20000 --fout 6666 DI1
```

23.2.4 Clock Diagnostic.

ACQ132 clock scenarios are complex. For better understanding and for diagnostic purposes, please refer to the Oversampling embedded web page. This gives a live reading of the currently selected clock, and shows the interaction between selected clock and decimation. It's possible to monitor the signal frequency of any of the *DIx* signal lines.



Select Counter Source:

- **set.dtacq** clk_counter_src clk_counter_src DIx,
- or select other source (eg DI0) on “Signals” page
- Default: “DI8” is the sample clock.

"CLKSEL" : shows internal clock selection mux setting:

- LO_ICS : 33MHz Local Oscillator feeds ICS (PLL) : Internal Clock
- INTCLK_ICS : FPGA feeds ICS(PLL) : External, derived clock
- INTCLK_NOICS : FPGA provides sample clock direct : External clock

23.3 ACQ132-32-65G: High Speed Transients RGM

Repeating Gate Mode RGM allows the ADC devices to be clocked at higher rates. The rate is then limited by the rating of the ADC (65MHz) and the average data rate that can be sustained on the local bus (128MB/s).

```
set.dtacq RepeatingGateMode 2
set.gate_src DIx {high|low}
# eg
set.gate_src DI4 high
# Now configure a capture in the normal way.
# A test script is provided:
/usr/local/CARE/configure_acq132_rgm_example [INTERVAL] [BLEN]
where INTERVAL, BLEN are parameters for gpdgen (see below).
```

23.3.1 Timebase

The timebase for the *RGM* data capture is made available after the shot at:

```
/dev/acq132/timebase
```

The format of the timebase is currently: 32 bit unsigned, nanoseconds.

This allows timing up to 4s. An option for a 64 bit timebase is planned.

View as follows:

```
hexdump -ve '1/4 "%d\n" /dev/acq132/timebase
```

It's anticipated that the timebase will be stored to *MDSplus*, one timebase per shot, and then all the channel data nodes configured to reference the timebase.

The Timebase put can use the standard command:

```
mdsPut --format unsigned --file /dev/acq132/timebase FIELD
```

The standard **mdsPutCh** command can be used to save the 32 channels data - essentially the action of the data nodes is unchanged.

23.4 GPG Gate Pulse Generator

The FPGA provides a 4 bit Gate Pulse Generator *GPG*. The *GPG* is programmed by a list of Gate Pulse Descriptors *GPD*, defining an output state to be achieved after a clock count. The output state is 4 bit, the count per element is 28 bit. The *GPG* is clocked by the *ICLK*.

- Output State : 4 bit (d4, d5, d6, d7)
- Resolution: 1usec (default)
- Maximum duration per element: 268s
- Number of elements: no limit.

23.4.1 Low Level Interface:

set.dtacq gpg_mas none

set.dtacq gpg_mas [dX1[,I1]] [dX2[,I2] [dX3[,I3]] [dX4[,I4]]

dXn : d4, d5, d6, d7

In : 0|1 initial state, default: I0: 0, IN: IN-1

eg

set.dtacq gpg_mas d7,1 d6,0 d5 d4

d7 is a master output, initial value 1

d6,5,4 are master outputs, initial value 0

Selects which bits are output from the *GPG*.

Program **gpdgen** (gpdgen --help) will generate simple gpd lists on the fly.

root@acq132_019 ~ #gpdgen --help

```
root@acq132_019 ~ #gpdgen --help
Usage: gpdgen [OPTION...]
  -n, --nbursts=INT            number of pulses
  -i, --interval=INT                    pulse spacing ICLKs
  -b, --blen=INT               pulse length ICLKs
  --pulse_on=INT               pulse ON pattern
  --pulse_off=INT              pulse OFF pattern
  --loop=INT                   1: loop forever

Show Defaults:
root@acq132_019 ~ #gpdgen --verbose 4
    device:/dev/acq132/GPD
   nbursts:1000
  interval:32768
      blen:128
      loop:0
  pulse_on:0
 pulse_off:0
```

23.4.2 High Level Interface

User generates an *ASCII csv* definition for each bit comprising start time, duration pairs.

A utility program merges up to 4 *csv* definitions, creates the low level *GPD* list and streams it to the *GPG* hardware in real-time.

```
Example:

cat - <<EOF >d0.csv
# d0 is FWD, FWD for 1 msec at 1s, 2s, 3s
1000000,1000
2000000,1000
3000000,1000
EOF

cat - <<EOF >d1.csv
# d1 REV, REV for 1msec at 1.01, 2.01, 3.01s
1010000,1000
2010000,1000
3010000,1000
EOF

cat - <<EOF >d3.csv
# d3 is the AI GATE pulse. GATE enable for 10 msec from 1.001s...
1001000,10000
2001000,10000
3001000,10000
EOF

The data is then translated by a utility

csv2gpd d0=d0.csv d1=d1.csv d4=d4.csv
```

23.5 Multi-Rate Capability.

ACQ132 can sustain data transfer on the local bus at 128MBytes/sec.

The headline capture rate is 32 ch * 2MSPS = 128MB/sec, but many other combinations are possible. A control **set.channelSpeedMask** is provided to allow a number of more common combinations.

set.channelSpeedMask *CHANNEL_SPEED_MASK*

get.channelSpeedMask

#	Sample Rate MSPS				NACC				SHIFT				MASK				SCAN
					parameters are computed automatically												
	16	8	4	2	A	B	C	D	A	B	C	D	A	B	C	D	
1				32	16	16	16	16	2	2	2	2	1111	1111	1111	1111	ABCD
2			16		8	8			1	1			0000	0000	1111	1111	CD
3	2		8		2	8			-1	1			0000	0000	1111	0001	CD
4	2	4			2	4			-1	0			0000	0000	1010	0001	CD
5		4	8		4	8			0	1			0000	0000	1111	1010	CD
6		4	4	8	4	8	16		0	1	2		0000	1111	1010	1010	DCDB
7		4		16	4	8	8		0	1	1		0000	1111	1111	1010	DCDB
	Channels																

The corresponding channelSpeedMasks are:

1	**set.channelSpeedMask** 11111111111111111111111111111111
2	**set.channelSpeedMask** 22222222000000002222222200000000
3	**set.channelSpeedMask** 80002222000000008000222200000000
4	**set.channelSpeedMask** 80004040000000008000404000000000
5	**set.channelSpeedMask** 40402222000000004040222200000000
6	**set.channelSpeedMask** 40402020111100004040202011110000
7	**set.channelSpeedMask** 40401111111100004040111111110000

It proved to be infeasible to reconstruct the channel data in *ACQ132* firmware, it is more efficient to upload the raw data as a block and then to de-channelize on a *HOST* computer. A host-side program is provided to do this.

```
acq132_decode -T clock -C csm RAWFILE

csm: the channelSpeedMask.
clock: clock rate in nsec
RAWFILE: a copy of /dev/acq200/data/XX on the host computer.
```

```
# Example upload script:
root@acq132_033 ~ #cat /etc/postshot0.d/curlup
#!/bin/sh
curl --netrc -T /dev/acq200/data/XX \
          ftp://rhum/ACQ132-MR/XX.$(get.channelSpeedMask)
```

23.5.1 Restrictions:

Use on *ACQ132-32-32F* only, base sample clock 32MHz.

23.6 Switched DualRateMode

This mode is intended for continuous operation.

We defined two sample rates:

- High Rate *HR*: set with normal `setInternalClock`, `setExternalClock` commands.
- Low Rate *LR* : set by decimation from *sample clock*.

The switch between *LR* and *HR* is controlled by an external *GATE* signal.

While the *GATE* signal is *ACTIVE*, capture occurs at *HR*, otherwise capture occurs at *LR*. The hardware inserts an *EVENT SIGNATURE ES* into the data stream at each speed transition. *HOST*- side software (**`acq_demux`**) is able to de-multiplex the data and match it to the correct timebase.

```
set.dtacq DualRate ENABLE [DECIM [SHIFT]]
# DECIM is decimation factor 12,4,8,..128
# SHIFT is the normal scaling factor (set -2 if no accumulation)
set.gate_src DIx {high|low}
# DIx is signal line DI0..DI5
```

23.6.1 Example:

ACQ132 is able to capture and stream raw data continuously over gigabit Ethernet to a remove (*ftp*) server at an average sample rate of 700kHz. A continuous capture application requires 2MHz capture during Region of Interest *ROI* (specified in advance by an external digital signal - some other system is required to identify this), with a background rate capture (125kHz) during the rest of the time.

```
# recommend data upload via FTP script in /etc/postshot.d

# External gate on pxi DI5
set.route d5 in pxi out fpga
set.gate_src DI5 high
set.trig DI5 rising
acqcmd setInternalClock 2000000
# HR: firmware choses CLOCK=8MHz, Decimation=4
set.dtacq DualRate 1 64 -2
# LR : will be 8MHz/64
set.channelBlockMask 11111111
set.pre_post_mode 0 1000000 DI5 rising
acqcmd setArm

# extract the data on the host: use API tool acq_demux:
# please refer to the ACQ2XX_API package
# clock period T: 125 nsec:
acq_demux -a acq132.def -T 125 --dual-rate 64,4 XX.SHOT.00001
```

```
# Plot using KST.
```

In normal operation (*GATE* LOW), the system streams data continuously at 125kHz (8MB/s). When the *ROI* is declared (*GATE* HIGH), the sampling rate increases to 2MHz (128MB/s) and the card offloads data as fast as it can - 40MB/s. Data backs up into on-board memory at 80MB/s, so there is capacity for about 10s data at high rate. When the *GATE* is de-asserted, data continues to stream at 40MB/s until the backlog has been eliminated (max 20s). This system works well for cases where the *GATE* signal may be fairly bursty, but it of short duration. eg maybe on average there is a 1s *GATE* signal every 30s, however, the buffer capacity is sufficient to allow up to 10 back-to-back 1s *GATE* signals if required.

23.7 Oversampling FIR Filter.

ACQ132-32-32F is available with an alternate *FPGA* personality, with *FIR* functionality.

- The *FIR* is a 501-tap, decimate by 16 filter.
- The coefficients are normalized to unity gain, 32 MHz input, 2MHz output. The *ACQ132* card MUST be operated at 32MHz to achieve the correct response.
- The frequency and attenuation characteristics of the filter are determined by the coefficients, and an number of filter personalities have been implemented. Other personalities are of course possible, contact *D-TACQ* for details.
- The regular oversampling and decimate/accumulate knobs are not connected.
- Coupled with the default 2.5MHz *AAF*, the *FIR* can eliminate unwanted signals and improve *SNR*. For results please see: oversampling_fir_filter

23.7.1 Available Personalities

The personalities are in the form of binary image files with a canonical name convention: {ID}_{*ISR*}_{*OSR*}_{*PASSBAND*}_{*STOPBAND*}.bin

Currently available characteristics are as shown below, corresponding to the personality names in section 23.7.2

#	ISR MHz	OSR (MHz)	PB (kHz)	SB (kHz)	Stop Band Attenuation (dB)
2	32	2	460	550	30
3	32	2	900	1000	35
4	32	2	900	1050	38
5	32	2	920	1000	30
6	32	2	940	1000	26
7	32	2	960	1000	19

23.7.2 Select.Personality

Change personality using this menu driven command:

```
root@acq132_019 /bigffs #select.personality
0:+ default
1:  acq132cpci_adc_fpga_top.bin
2:  acq132cpci_adc_fpga_top_fir_i32M_o2M_pb460k_sb550k.bin
3:  acq132cpci_adc_fpga_top_fir_i32M_o2M_pb900k_sb1000k.bin
4:  acq132cpci_adc_fpga_top_fir_i32M_o2M_pb900k_sb1050k.bin
5:  acq132cpci_adc_fpga_top_fir_i32M_o2M_pb920k_sb1000k.bin
6:  acq132cpci_adc_fpga_top_fir_i32M_o2M_pb940k_sb1000k.bin
7:  acq132cpci_adc_fpga_top_fir_i32M_o2M_pb960k_sb1000k.bin
Enter selection:
4

# example shows user loading personality #4.
# this can also be done on one line (useful for scripting)

select.personality  \
acq132cpci_adc_fpga_top_fir_i32M_o2M_pb900k_sb1050k
```

The new personality will be loaded at next boot. It can also be loaded on the fly using **acq132_reload_personality**

```
# example script to load a new personality on the fly:

select.personality   \
acq132cpci_adc_fpga_top_fir_i32M_o2M_pb900k_sb1050k
acq132_reload_personality.
```

24 ACQ164CPCI Special Characteristics

ACQ164CPCI is most similar to *ACQ196CPCI*, other than that it uses the same ICS_527 PLL clock cleaner as *ACQ132CPCI*. So the same clock commands apply as per *ACQ132CPCI*.

ICS_527 has min 4MHz rate.

ACQ164 has max 128kSPS rate. So the clock is in fact the INPUT clock and the output rate is much (256X/512X, depending on mode) slower.

Typical *ACQ164* ICLK is 32MHz. This is too fast to distribute on *PXI*.

So in a master/slave setup the firmware selects ICLK/8 to distribute, and this clock is multiplied by 8 on slave cards.

In addition, the AD1278 *ADC* device requires a SYNC pulse to start capture, and this sync pulse is shared between devices on a board, and between boards in a crate.

The *CPLD* generates *SYNC*, a single cycle of ICLK/8.

ACQ164CPCI operates a fixed clocking scheme:

D0	EXT_CLK	probably LEMO of MASTER, nominal 1MHz
D1	ICLK/8	MASTER -> SLAVES on PXI
D2	SYNC	MASTER -> SLAVES on PXI
D3	TRG	probably LEMO of MASTER -> SLAVES on PXI

D-TACQ recommends using **set.acq164.role** to hide this complexity 10.4.1

Default word size is 32 bit (right-most most 24 bits are valid). This is easy to process on a 32 bit processor, but is obviously wasteful of memory and wire bandwidth.

An OUTPUT WORD SIZE control is proposed to select the word-size, with a choice of sizes: 32/24/22/20/18/16 bits.

24.1 Accumulate/Decimate function.

ACQ164CPCI features an digital accumulator in the data path. This allows further *SNR* improvement by oversampling for a given slow output sample rate, a higher input sample rate can be used, keeping Nyquist high and reducing any alias effect.

- **set_nacc** NACC # NACC=1..256
- **get_nacc**

Recommended setting:

```
set.acq164.role ROLE 50;set_nacc 4;  # ISR = 50kHz, OSR 12.5kHz
```

With accumulation, the output signal is scaled up. Voltage scaling command **get.vin** is aware of this, and the *MINCODE*, *MAXCODE* values in */etc/cal/caldef.xml* are also scaled.

NB: earlier ACQ164CPCI firmware used left-justified data.

25 ACQ196CPCI Special Features

25.1 Pulse Generator

A simple hardware pulse generator is included. This is intended to generate a string of pulses from a trigger pulse. A typical trigger pulse runs at 1Hz – eg the ONE PPS signal from a GPS unit, with pulse output programmable from 1..8 Hz. Pulse position and length is programmable. A simple command selects from 1..8Hz with even spacing. Default trigger is on DI3, default output on DO1.

```
load.hw_pulse        # one time operation - /ffs/user/rc.user ?

set.pulse_def N      # N = 1..8
get.pulse_def

set.hw_pulse trig DI5 rising   # set alternate trigger
set.hw_pulse genDO DO3 rising  # set altenate output line and sense.
set.dtacq dio_bit 3 1          # the output bit MUST be an output
```

25.2 Final Stage Filter: Accumulate/Decimate function.

ACQ196CPCI features an digital accumulator in the data path. This allows further *SNR* improvement by oversampling for a given slow output sample rate, a higher input sample rate can be used, keeping Nyquist high and reducing any alias effect.

NACC: number of samples to accumulate before outputting a value.

SHR : number of bits to right shift to adjust gain and avoid overflow.

- **set_nacc** NACC [SHR] # NACC=0,2..32 SHR=2,3,4,5
- **get_nacc**

If SHR is omitted, the software will set SHR to give the largest scaling appropriate to the value of NACC without overflow. If your signals are know to be small, it's possible to override the SHR value to give a degree of digital gain

25.2.1 Examples:

NACC	SHR	ISR	OSR	ENOB	GAIN
32	5	500kHz	15kHz	+2.5 bits	1
32	4	500kHz	15kHz	+2.5 bits	2
25	4	500kHz	20kHz	+2.5 bits	25/16
16	4	500kHz	31.25kHz	+2.0 bits	2
04	2	500kHz	125kHz	+1.0 bits	1
01	0	500kHz	500kHz	default configuration	