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SWITCHING READOUT

CAEN
Tools for Discovery

This document describes the switching readout software written for Washington University, St. Louis.

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Document Change Log:

Date	Change:
July 11, 2015	Initial document.
July 16, 2015	Support MIXED acquisition mode for DPP config. Note this changes that modes event format as well.
July 22, 2015	• Changed the meaning of DC_OFFSET to match that of DPP-PSD control • Added DC_OFFSET to per channel params for waveform mode.
July 31, 2015	• Add EXTRA_SELECT parameter to choose what appears in the 'extras word' • Document new data format that has extras but not 'baseline' value.
August 1, 2015	• Document RECORD_LENGTH as a per channel parameter.
August 3, 2015	• Add extra select word to event format. • Tentatively take the FREQUENCY parameter back out.s

Introduction

FUNDAMENTAL CONCEPTS

The Switching Readout program reads data from an X730 digitizer with DPP-PSD firmware (e.g. DT5730 or V1730) alternating between DPP_PSD mode and waveform readout.

This document will describe:

- How to install this software
- How to describe the digitizer configuration in both DPP and waveform mode as well as how to describe to the digitizer when to switch modes.
- How to operate the program.
- The format of the data produced by the software.

It is assumed that:

- The target computer runs Linux
- The target computer has the g++ C++ compiler installed.
- The DPP-PSD control software has been has been installed and will be used to set up the initial configuration of the digitizer in DPP mode. Configuration files from this software can be used as a starting point for configuring the DPP mode of data taking. This software is available without charge at: http://www.caen.it/csite/CaenProd.jsp?idmod=802&parent=38

The switching readout distribution package contains the following items:

- CAEN Digitizer library and prerequisite software with the exception of the USB and Fiber optic device drivers. The USB driver can be downloaded here: http://www.caen.it/csite/CaenProd.jsp?parent=14&idmod=757
- The digiTES test software for the DPP digitizers. This is not public release software and is provided as is.
- The iniparser library (http://ndevilla.free.fr/iniparser/) with slight modifications. This library is used to process configuration files.
- The readout software itself.

Installation

The software is distributed as a tarball (.tar.gz) file. The tarball will be available via a dropbox public link that will be emailed to you. The downloaded tarball will be named WashUDAQ-1.0.tar.gz. To install it:

```
tar xzf WashUDAQ-1.0.tar.gz
cd WashUDAQ-1.0
./configure --prefix={installation-dir}
make all install
```

Where in the installation script above you should replace {installation-dir} with a directory in which you want to install the software. You must have write access to this directory. If you omit the –-prefix option and its value, the software will be installed in `/usr/local`.

The following sub-directories will be created underneath the prefix directory:

Directory	Contents
lib	The CAEN digitizer libraries and their pre-requisites as well as the iniparser library.
include	Header files for the CAEN digitizer libraries and their pre-requisites as well as those for the iniparser library.
bin	Excecutable programs. These are digitTES and readout.

It may be a good idea to add {installation-dir}/bin to your login's PATH so that the programs in this directory can be run without specifying their full paths.

Configuration

Three configuration files are used to describe the operation of the switching readout. These have a common format that is similar to that of windows INI files. The configuration file format exported by DPP-PSD control can be used as a starting point for the DPP configuration file. The other two configuration files tend to be much simpler.

CONFIGURATION FILE FORMAT

The configuration file format is similar to that of a Windows INI file. Each configuration file is divided into named sections. Then name of a section is in square brackets. Configuration parameters are then separated from their values with spaces or the **=** sign.

Comments begin with the **#** character and last until the end of the line on which they appear.

For example:

```
[GLOBAL]
RECORD_LENGTH 4000     # Number of samples acquired.
[0]
ENABLE_INPUT    YES
```

Is a configuration file that contains two sections **GLOBAL** and **0**. The **GLOBAL** section defines the parameter **RECORD_LENGTH** to have a value of **4000** while the **0** section defines the parameter **ENABLE_INPUT** to have the value **YES**.

The configuration files for individual modes have a **GLOBAL** section in which global parameters can be set as well as default values for per channel parameters. Each channel can have a section whose name is the channel number (e.g. **0**) above.

For the readout program defaults are handled as follows:

- Each parameter has a default value which is applied if the parameter is not supplied.
- Per channel values that appear in the **GLOBAL** section override this default.
- In the Waveform, default values are taken from the DPP configuration file if specified.

Note that parameter names and values are case sensitive.

The sections below describe the three configuration files, Master, DPP and Waveform the readout program needs to operate. Values that are hard coded are also described.

MASTER CONFIGURATION FILE

The Master configuration file has only one section **COMMON**. This section has the following parameters, all of which are mandatory (their default values don't make sense and cause the program to complain):

Parameter name	Description
dppconfig	Path to the DPP mode configuration file. Note that paths can be relative to the current working directory.
waveformconfig	Path to the waveform mode configuration file. Note that paths can be relative to the current working directory.
dpptriggers	(Integer) number of triggers that are accepted in DPP Mode before switching to waveform readout mode.
waveformtriggers	(Integer) Number of triggers that are accepted in waveform mode before switching to DPP Mode.

Here is a sample master configuration file:

```
[COMMON]

dppconfig          dppconfig.txt
waveformconfig     waveformconfig.txt
dpptriggers        10000
waveformtriggers   1
```

DPP CONFIGURATION FILE AND PARAMETERS

The DPP configuration file:

- Provides the digitizer connection parameters.
- Provides the parameters used to take data in DPP Mode.
- Provides default values for parameters in waveform mode.

There are both global and per-channel parameters. Global parameters are set in the **GLOBAL** section while per channel parameters can be set in the per channel sections **0, ...** If a per channel parameter appears in the **GLOBAL** section it sets a new default value for that parameter.

Note that the DPP-PSD Control program defines many more parameters than are used by the readout program. These extra parameters are ignored by readout.

Global Parameters:

These parameters are not associated with any channel of the digitizer but have global effect:

Parameter Name	Default	Description
OPEN	<none>	Defines the digitizer connection parameters. Thesea are three space separated values. The first describes the connection method (**USB** or **PCI** [for CONET Fiber optic connections]). The second specifies the interface number. The last parameter is used if the connection is via a VME Bus bridge, in which case it is the base address of the board in VME space. For example, direct USB connection: **USB 0 0** For USB via VME bus bridge to a board with VME base address set to 0x11110000 (my test setup): **USB 0 0x11110000**
ACQUISITION_MODE	LIST	Determines what is read from the device for each event. Valid values are technically: **LIST** only DPP parameters are read. **MIXED** DPP parameters and waveforms are read. **NOTE** Oscilloscope mode is not yet supported by the XX730 (in waveform mode I actually use mixed mode).
PSD_SEL_BASELINE	1	Enable/disable the automatic baseline compensation. Non zero values enable automatic baseline while zero values turn this off.
PSD_BL_THRESHOLD	255	Threshold for not computing baseline.
TRIGGER_MODE	NORMAL	This determines how the channel actual triggers are generated from discriminator 'firing's. Valid values are: **NORMAL** – each discriminator firing triggers channel readout/DPP processing. **COINCIDENCE** – Channel coincidence requirements must be satisfied to return a trigger back to the channel after discriminator firing. This is not fully supported yet so **NORMAL** must be used in this version of the software.

FPIO_LEVEL	NIM	Selects the LEMO front panel signaling levels. The alternatives are **NIM** and **TTL** with obvious meaning.
GATED_START	DISABLED	If **ENABLED**, once the digitizer is started, a front panel pulse on the TRGIN input is required to actually start data taking. This is normally used to synchronize the start of several digitizers. It should be left at **DISABLED** in this version of the software.
EXTERNAL_TRIGGER	ACQUISITION_ONLY	Specifies what should be done with an external trigger: **DISABLED -** The external trigger is ignored. This is probably correct for DPP Mode. **TRGOUT_ONLY** – The external triggers is echoed on the GPO output but otherwise ignored by the module. **ACQUISITION_ONLY –** the external trigger triggers readout of all module channels. **ACQUISITION_AND_TRGOUT –** The external trigger both triggers acquisition of all channels and is echoed on the GPO output.s
NEVT_AGGR	0	Number of events per aggregate. This determines the number of events that must have been acquired before the digitizer will claim it has data to read. **0** allows the firmware to attempt to optimize this.
MAX_NUM_EVENTS_BLT	0	Maximum number of events that will be transferred for each block transfer.
TRG_HOLDOFF	0	Trigger hold off in samples. The maximum of this and the long gate length determines how long after a trigger the next trigger is acceptable. Note that during this period, the baseline is also frozen if baseline compensation is enabled.
PUR_MODE	DETECT	Pile up rejection mode. Note that pile up rejection will be implemented in a firmware upgrade to the DPP-PSD firmware. Valid values are **DETECT** which flags the existence of a pile up only and **ENABLED** which rejects events with pile up (Note when this is enabled we need to add **RETRIGGER** to allow the retrigger mode to be supported).
PSD_PUR_GAP	0	The purge gap as described in the DPP-PSD manual appendix A. This is in units of ADC conversion values.

Per-channel Parameters:

Per channel parameters can be set in the [GLOBAL] section, in such a case, they define the default value for those parameters. This section describes the per channel parameters. To set one on a single channel place that in a section labeled by the channel number. For example section [0] will set parameters for channel 0 and so forth.

Parameter Name	Default Value	Description
RECORD_LENGTH	96	Number of samples acquired for each trigger. This value must be at least as long as the long gate value. This is settable on channel pairs. The value for the even channels is used for the subsequent odd channel. E.g.: [0] RECORD_LENGTH 256 Sets the record length for channels 0 and 1 to 256. If you provide a RECORD_LENGTH for an odd channel it will be ignored.
ENABLE_INPUT	NO	If **YES** the input is enabled to acquire data. If **NO** the input is disabled. Note that this differs from CHANNEL_TRIGGER which enables the channel to self-trigger. If the external trigger is turned on, all Enabled channels will acquire data on an external trigger.
DC_OFFSET	0	This is a double precision value between --50.0 and 50.0. The value represents the percentage of full scale range of DC offset to apply relative to the mid point value (e.g. 0.0 means no DC offset, 50.0 means maximum positive DC offset and -50.0 means maximum negative DC offset). **NOTE:** this has been changed to be compatible with the values in the settings files written by DPP-PSD-Control
PRE_TRIGGER	0	The number of samples kept prior to the trigger sample.
TRG_THRESHOLD	50	Channel self-trigger threshold. Note that this is relative to the baseline. This value only has meaning if the channel can self-trigger.
CHANNEL_TRIGGER	DISABLED	If **ENABLED** the channel can self-trigger, if **DISABLED** the channel will not self trigger.

PSD_LONG_GATE	60	Number of samples in the long gate.
PSD_SHORT_GATE	16	Number of samples in the short gate.
PSD_PRE_GATE	16	Number of samples prior to the trigger that the Long and short gates begin.
PSD_BL_SAMPLES	3	Sets the number of samples that are averaged to compute the baseline. This is an encoded value: **0** – fixed baseline (not fully supported yet by software). **1 –** 16 samples. **2** – 64 samples. **3 -** 256 samples. **4** - 512 samples.
PSD_SEL_CHARGE_SENSE	0	The meaning of the least significant bit of charge data: **0** – 5 fC **1 –** 20 fC **2** – 80 fC **3** – 320fC **4 –** 1280fC
TRIGGER_VALIDATION_WINDOW	50	Number of samples in the coincidence window when coincidence triggering is enabled. Note that coincidence triggering is not supported by this software.
CFD_DELAY	40	Signal delay in the CFD in ns (e.g. samples*2).
CFD_ATTENUATION	0	Attenuation factor for the CFD encoded: **0 -** 25% of input signal **1 –** 50% of input signal **2** – 75% of input signal **3 –** 100% of input signal (no attenuation).
CFD_INTERPOLATE	0	Defines which points on the waveform are used for interpolation. The values are 0-3. **0 -** use samples immediately before and after the zero crossing. **1 -** use the samples 2 cycles before and after the interpolation **2 -** use the samples 3 cycles before and after the zero crossing. **3 –** use the samples 4 cycles before and after the zero crossing. NOTE that interpolation is hard-coded as enabled.
DISC_MODE	LED	Discriminator mode **LED** or **CFD**

DYNAMIC_RANGE	.5	Sets the module dynamic range. **.5 –** .5Vpp **2 –** 2Vpp
RESOLUTION	14	Number of bits of resolution (waveform) This can have the values **10, 12, 13, 14**.
POLARITY	NEGATI VE	Channel input pulse polarity (can be **POSITIVE** or **NEGATIVE**).
PSD_CUT	DISABLED	Cut the data using the PSD cut. Can be **DISABLED, GAMMA,** or **NEUTRON**.
PSD_CUT_LEVEL	0.5	Fraction of the PSD full scale at which the PSD cut is.
EXTRA_SELECT	0	Select what appears in the 'extras' word: 0 – extended timestamp and baseline*4 1 extended timestamp and flags 2 Extended timestamp, flags and fine timestamp 3 Pulse peak value (bottom 15 bits – untested feature). 5 CFD samples on either side of zero crossing. 7 Fixed value of 0x12345678

WAVE FORM CONFIGURATION FILE AND PARAMETERS

The wave form configuration is assumed to be very close to the DPP configuration. Therefore all parameters have, as a default value, the parameters set for the DPP mode of operation. All of the parameters supported for the DPP mode are also supported for the waveform mode. In waveform mode, however, the digitizer is read in mixed mode such that the input waveform and trigger times are captured.

It may be advantageous to set the NEVT_AGGR value to 1 or else it is possible that you will need to see several external triggers before the device decides to return events.

Running the program

The program is named **readout** and lives in the **bin** subdirectory of the directory you specified as the **--prefix** value when configuring the build. It accepts, and requires two parameters:

- The first parameter is the path to the master configuration file.
- The second parameter is the path to the output file.

Once it starts, the program will continue to run, alternating between DPP and waveform mode until you type an 'x' on the program's terminal.

Format of output data files.

This section describes the format of the data files. The size of each element written to the output file is given in terms of definitions in the header <stdint.h>.

EVENT HEADER

Each event begins with a header:

Item Name	Data Type	Description
Size	uint32_t	Number of bytes in the event. This size is self-inclusive.
Event Type	uint32_t	Event type. The possible values of this field are **1** for DPP data and **2** for wave form data.
Channel	uint32_t	Channel number. The Digitizer considers each channel to be an independent generator of events. This field is the number of the channel from which the following data were taken. Channels are numbered beginning with 0.
Time Tag	uint32_t	The coarse time at which the trigger for this event occurred. This is in 2ns units. For DFP events this is also what is referred to as the *Coarse time stamp.*

The contents of the remainder of the event depends on the event type:

DPP EVENT BODY

DPP events have the following body.

Item Name	Data Type	Description
Extra select	uint16_t	The value of the EXTRA_SELECT parameter.
Extras	uint32_t	The 32 bit extras long sword as defined by the value of EXTRA_SELECT. The data are little endian (intel format) so the first uint16_t carries the bits 0-15.
Short Gate Charge	uint16_t	Charge integrated in the short gate.
Long Gate Charge	uint16_t	Charge integrated in the long gate.
Pile up rejection	uint16_t	Pile up detected flag. Note, at the time this is being written pile up detection is not yet implemented for the x730 modules. This is provided because this functionality will soon be added and I'm going to assume you'll want that when it is available.

Number of samples	uint32_t	Number of waveform samples that follow (note that in LIST mode, this will be 0.
Wave form data	uint16_t array	Array (possibly zero length) of waveform samples.

WAVEFORM EVENT BODY

Waveform events have the following body:

Item Name	**Data Type**	**Description**
Number of samples	uint32_t	Number of samples in the following waveform data.
Wave form data	uint16_t array	Array of samples. Note that since the digitzer is a 14 bit digitizer this value goes from 0-0xfffff. The value 0x80000 is zero, however the DC offset applied can move this around.