EPICS and CAEN x527 Series High Voltage Power Supplies at the CLS

Version 1.2

DRAFT

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Contents

1 General Description

1.1 Overview

1.1.1 CAEN x527 High Voltage Power Supply Hardware

The Canadian Light Source (CLS) uses high voltage power supplies manufactured by CAEN, particularly the model SY2527[3]. This model belongs to their line of "Universal Multichannel Power Supplies", in which there are models SY1527, SY2527, and SY3527, which will be referred to as the x527 series. These units are mainframes into which modules with the actual high voltage supplies plug in. Since there are a variety of modules, with multiple outputs, this system can accommodate a variety of applications from just one crate.

CAEN high voltage modules for this line typically have 6 to 12 channels of outputs. The CAEN 2527 crate has 6 slots for modules. Each channel typically has upwards of a dozen parameters that can be monitored, and each parameter has at least a couple of configuration settings that can be read. Thus, there is potentially a very large number of quantities that must somehow be organized and presented to the user.

There are multiple means of accessing the controls for individual channels of high voltage in the x527 line. Some models have a front panel with a screen, really a very small computer screen given that the crate controller is a computer. The primary means of access are remote. The crates accommodate RS232, CAENET, and Ethernet communications. All that is needed is the appropriate protocols and commands.

There is one mean of remote control that requires no special programs, TELNET access. TELNET is a communication protocol[5] for which most operating system distributions have a user interface, essentially, a simple "terminal program". Once the x527 crate is connected to Ethernet, a TELNET connection can be established and the user can log in. The user is then presented with a menu bar with which any number of tasks can be performed. The primary one is to display a list of channels and their parameters in text-navigator format. This is a fairly straight forward interface, with navigation accomplished merely by cursor movement, and changes made by either typing a new quantity or pressing the SPACE bar to toggle a state. However, this does lack the convenience of a point-and-click environment, within which the TELNET session will invariably be running in.

Thus, a point-and-click interface or graphical user interface (GUI) is required. The software side of the CLS control system for devices is predominantly EPICS [4, 7]. Building a GUI for this is fairly straight forward. However, the EPICS installation at the CLS did not support CAEN x527 crates. The possible solutions were: find existing EPICS drivers that could communicate with a crate by any of the protocols supported by the x527, find existing drivers and software that can communicate with the crate using OPC [OLE for ...?] [ref?], or write an EPICS driver from the ground up.

No existing EPICS drivers could be found. Some other standalone software was found, but these were not appropriate for the CLS because beamline users required customized GUIs.

CAEN does have some OPC software [2], but it requires an additional computer (in addition to the necessary EPICS IOC) running Microsoft Windows NT, acting as an OPC server which on one hand connects to HV crates and scans them, and on the other hand distributes data to OPC clients that request them. The crate itself is not an OPC server. That alone presented enough of a problem to discount it as a possible solution.

In searching for existing EPICS software, some potentially useful pieces of software were found that might facilitate writing EPICS software in-house. In particular, wrapper software was available from the crate manufacturere, CAEN, which already provided Ethernet, CAENET, and RS-232 communication, and the means to extract any data from one or more crates. With the difficulty encountered in finding adequate or approprite software, this made writing the EPICS software in-house very attractive.

1.1.2 CAEN HV Wrapper Software

CAEN has made a wrapper available for free downloading from its web site, provided you sign in. It is pre-compiled for LINUX, and for Microsoft Windows, and comes with all the necessary development files and an example text-only program. This wrapper provides subroutines for network communication with x527 crates, so that the programmer only need to be concerned about which parameters need to be read or set. The software was written with sufficient generality that practically all parameters in the crate, boards, and modules can be accessed through just a few functions.

1.2 CLS EPICS Implementation

For test purposes, a sub record was written to periodically scan all channels of a crate which then did a dbPutField() to respective records. The main routine called an initialization routine. This was abandoned to test having individual PVs independently and actively reading their value from the crate. Tests showed that the HVWrapper did not queue requests, and that responses were ending up in the wrong records. So the concept of a monolithic scan routine was re-implemented. This simplified code in the device support routines and made all scans synchronous, but at the price of lost individualized control of scans.

The current structure of the EPICS implementation is illustrated in Figure 1. Data flows both ways between the crate and the IOC via TCP/IP (typically on port 2527). The data flow within the IOC App differs for input and output. The red line in the IOC App indicates that output records simply send commands (via the HVWrapper), but input records actually get their values from a data structure filled by the scan function which does the actual extraction of data from the crate (blue line). The driver supports the scan function and the data structure, primarily providing initialization and service routines.

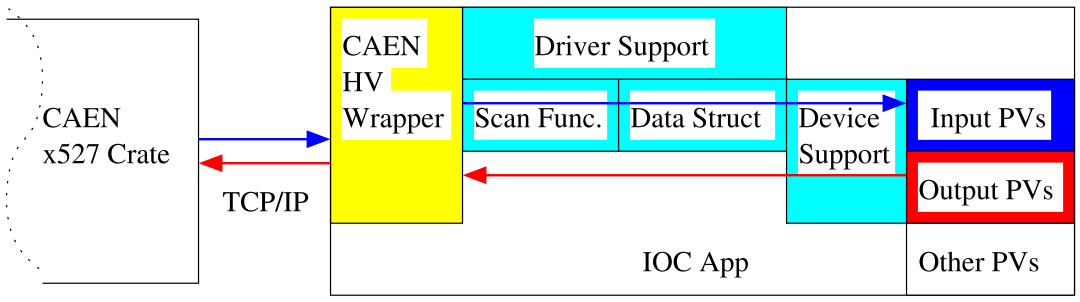


Figure 1: Schematic Structure of EPICS Control of CAEN x527 HV Power Supplies.

Note: At the time this was written, only basic channel-specific features are supported. Board- and Crate-specific features are expected to be added in future versions of the software. Further, the current EPICS records are basic, providing only input and output with the crate, some limit checking, and engineering units for display. Features such as Alarms have not yet been *implemented.*

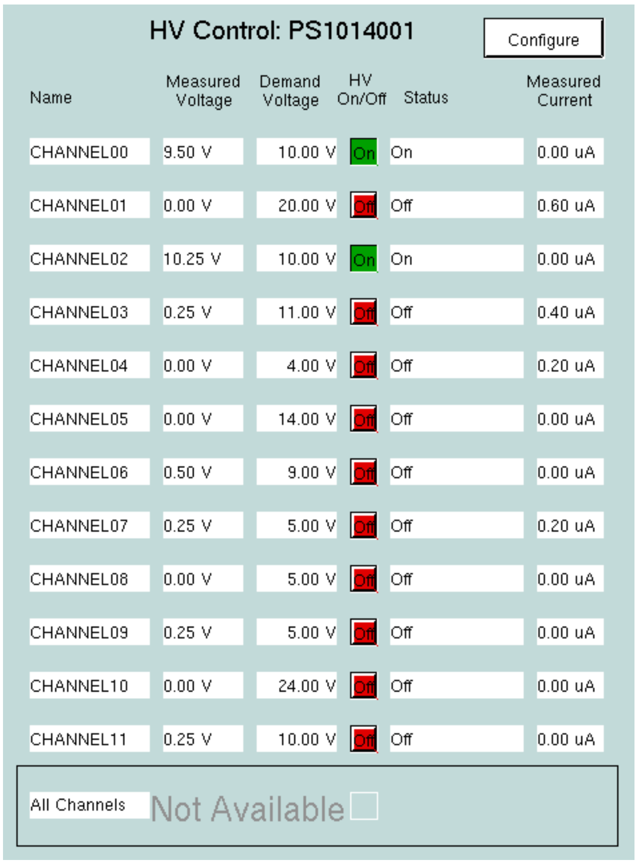
2 Use of Epics Software

The GUI API of choice for general purposes at the CLS is EDM [6]. The user control interface described here has been constructed with EDM, which serves both functions of application editor and user interface. It is designed specifically for communication with an EPICS-based control system.

2.1 Basic Graphical User Interface

There are three types of standard EDM GUIs to control or monitor a CAEN x527. In all cases, text fields used for changing values must be activated by pressing <return> or <enter>.

The simplest GUI, shown in Figure 2, controls only energizing or de-energizing the output of channels, and monitors the output voltage, output current, and status. The output is energized when the “HV on/off” button is depressed. Pressing the button again will de-energize the output. There is no bias control.



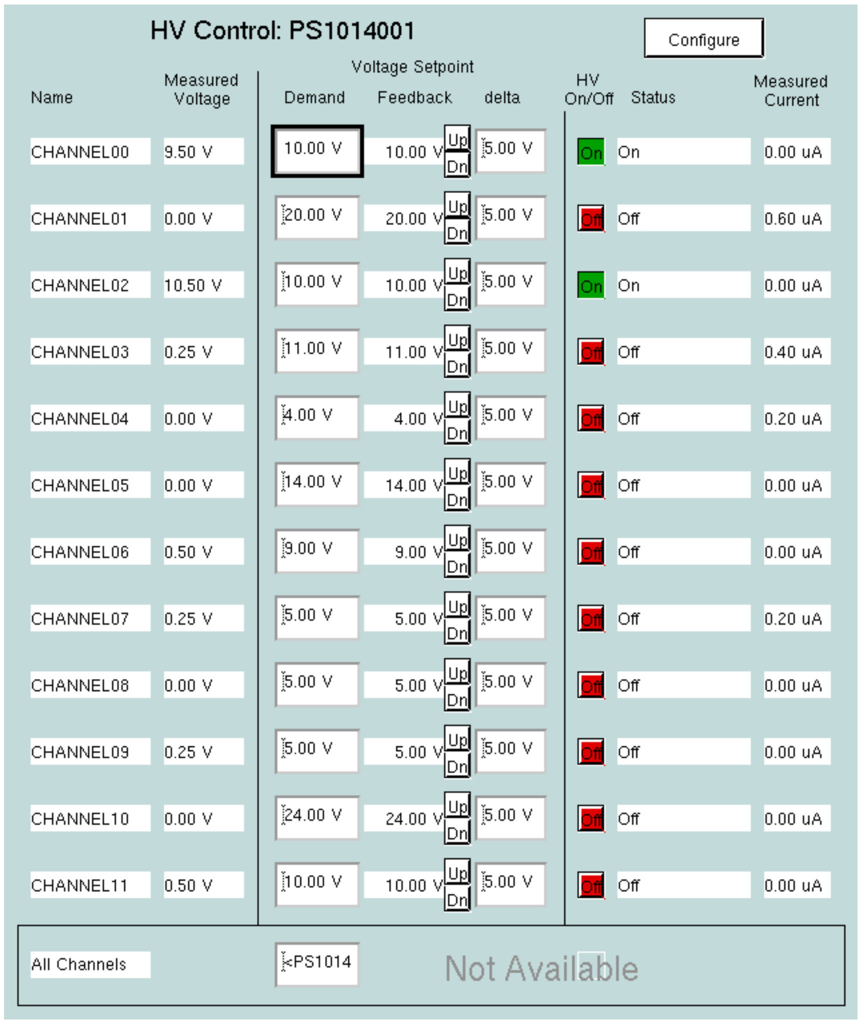
HV Control: PS1014001

Name	Measured Voltage	Demand Voltage	HV On/Off	Status	Measured Current
CHANNEL00	9.50 V	10.00 V	On	On	0.00 uA
CHANNEL01	0.00 V	20.00 V	Off	Off	0.60 uA
CHANNEL02	10.25 V	10.00 V	On	On	0.00 uA
CHANNEL03	0.25 V	11.00 V	Off	Off	0.40 uA
CHANNEL04	0.00 V	4.00 V	Off	Off	0.20 uA
CHANNEL05	0.00 V	14.00 V	Off	Off	0.00 uA
CHANNEL06	0.50 V	9.00 V	Off	Off	0.00 uA
CHANNEL07	0.25 V	5.00 V	Off	Off	0.20 uA
CHANNEL08	0.00 V	5.00 V	Off	Off	0.00 uA
CHANNEL09	0.25 V	5.00 V	Off	Off	0.00 uA
CHANNEL10	0.00 V	24.00 V	Off	Off	0.00 uA
CHANNEL11	0.25 V	10.00 V	Off	Off	0.00 uA

All Channels Not Available

Figure 2: Simplest User Interface

The standard interface, shown in Figure 3, has control for the voltage setting as well as turning output on or off, and also monitors output voltage, output current, and status. As with the simple GUI, the output is energized when the "HV on/off" button is depressed. Pressing the button again will de-energize the output. The voltage can be set to a particular value simply by entering a number in the "Setpoint" field of the requisite channel. Relative or incremental changes can be made simply by pressing the "up" or "dn" buttons. The increment is the (changeable) value entered in the "deltav" field of the respective channel.



HV Control: PS1014001

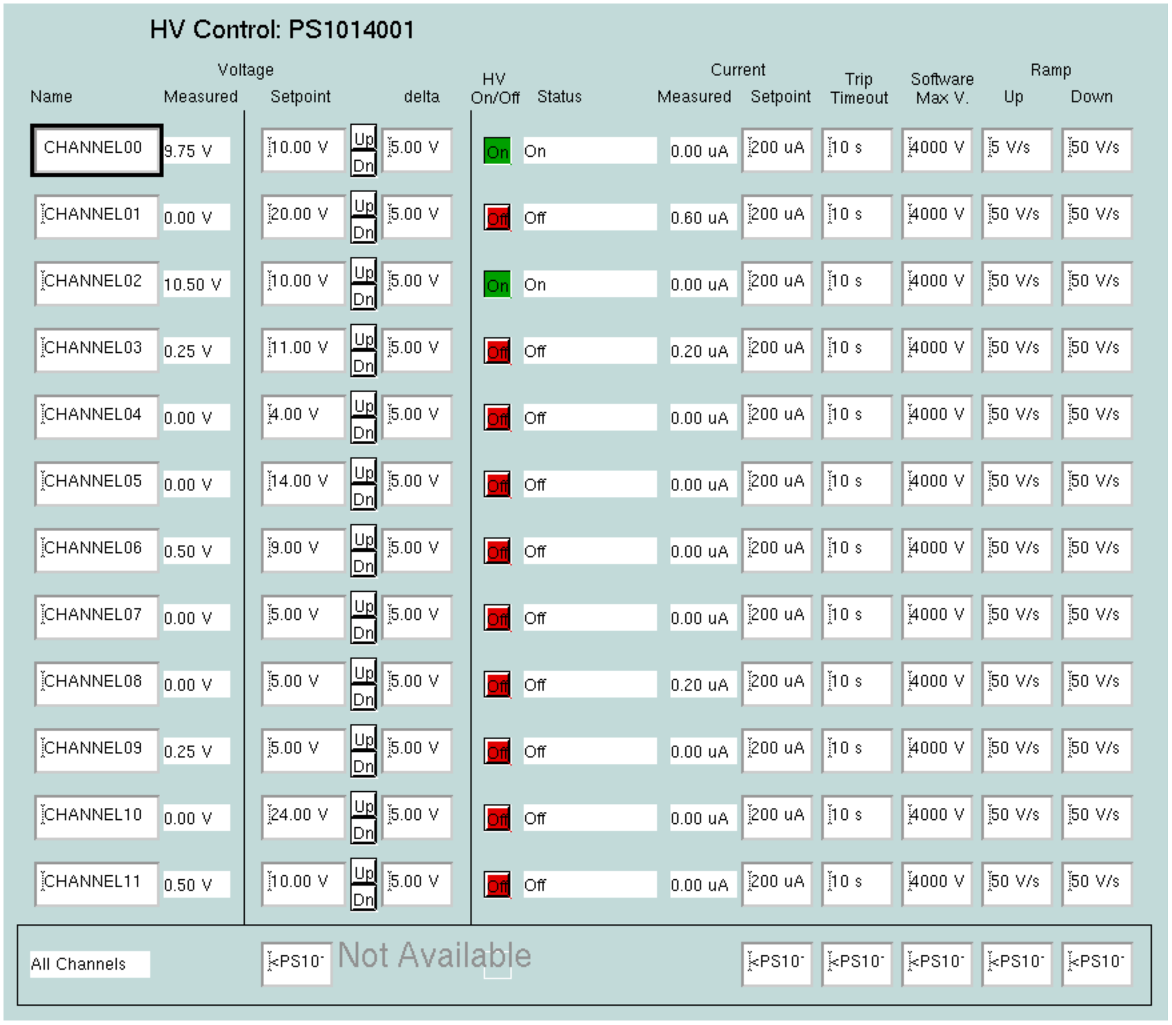
Configure

Name	Measured Voltage	Voltage Setpoint Demand	Feedback		delta	HV On/Off	Status	Measured Current
CHANNEL00	9.50 V	10.00 V	10.00 V	Up Dn	5.00 V	On	On	0.00 uA
CHANNEL01	0.00 V	20.00 V	20.00 V	Up Dn	5.00 V	Off	Off	0.60 uA
CHANNEL02	10.50 V	10.00 V	10.00 V	Up Dn	5.00 V	On	On	0.00 uA
CHANNEL03	0.25 V	11.00 V	11.00 V	Up Dn	5.00 V	Off	Off	0.40 uA
CHANNEL04	0.00 V	4.00 V	4.00 V	Up Dn	5.00 V	Off	Off	0.20 uA
CHANNEL05	0.00 V	14.00 V	14.00 V	Up Dn	5.00 V	Off	Off	0.00 uA
CHANNEL06	0.50 V	9.00 V	9.00 V	Up Dn	5.00 V	Off	Off	0.00 uA
CHANNEL07	0.25 V	5.00 V	5.00 V	Up Dn	5.00 V	Off	Off	0.20 uA
CHANNEL08	0.00 V	5.00 V	5.00 V	Up Dn	5.00 V	Off	Off	0.00 uA
CHANNEL09	0.25 V	5.00 V	5.00 V	Up Dn	5.00 V	Off	Off	0.00 uA
CHANNEL10	0.00 V	24.00 V	24.00 V	Up Dn	5.00 V	Off	Off	0.00 uA
CHANNEL11	0.50 V	10.00 V	10.00 V	Up Dn	5.00 V	Off	Off	0.00 uA
All Channels		<PS1014	Not Available					

Figure 3: Standard User Interface

The Expert or Configuration GUI, shown in Figure 4, has most of the controls available from EPICS, as well as monitors for output voltage, output current, and status. Most of the additional controls are implemented as text entry fields. As with the standard GUI, the output is energized when the "HV on/off" button is depressed. Pressing the button again will de-energize the output. The voltage can be set to a particular value simply by entering a number in the "Setpoint" field of the requisite channel. Relative or incremental changes can be made simply by pressing the "up" or "dn" buttons.

The increment is the (changeable) value entered in the “deltav” field of the respective channel.



HV Control: PS1014001

	Voltage				HV		Current		Trip	Software	Ramp	
Name	Measured	Setpoint		delta	On/Off	Status	Measured	Setpoint	Timeout	Max V.	Up	Down
CHANNEL00	9.75 V	10.00 V	Up Dn	5.00 V	On	On	0.00 uA	200 uA	10 s	4000 V	5 V/s	50 V/s
CHANNEL01	0.00 V	20.00 V	Up Dn	5.00 V	Off	Off	0.60 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL02	10.50 V	10.00 V	Up Dn	5.00 V	On	On	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL03	0.25 V	11.00 V	Up Dn	5.00 V	Off	Off	0.20 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL04	0.00 V	4.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL05	0.00 V	14.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL06	0.50 V	9.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL07	0.00 V	5.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL08	0.00 V	5.00 V	Up Dn	5.00 V	Off	Off	0.20 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL09	0.25 V	5.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL10	0.00 V	24.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
CHANNEL11	0.50 V	10.00 V	Up Dn	5.00 V	Off	Off	0.00 uA	200 uA	10 s	4000 V	50 V/s	50 V/s
All Channels		<PS10	Not Available					<PS10	<PS10	<PS10	<PS10	<PS10

Figure 4: Configuration Interface

2.2 EPICS Database Records

The EPICS controls may also be accessed by the standard EPICS tools such as the command line programs **caget** and **caput**. The database records are described below for the sake of both EPICS programmers and users who wish to communicate with the controls by other means.

2.2.1 Process Variables for Users

Table 1: Settable EPICS Database Records. $(PSNAME) typically is set to the crate name, $(CHANNUM) is typically set to the channel address.

Process Variable Name	Record Type	Description
$(PSNAME):$(CHANNUM):name	stringout	Set name of channel, set *in the crate.*
$(PSNAME):$(CHANNUM):name.DESC	char[29]	Set name of channel in EPICS only.
$(PSNAME):$(CHANNUM):v0set	ao	Set voltage setpoint.
$(PSNAME):$(CHANNUM):v0set:up	bo	Increase Voltage setpoint by “deltav”
$(PSNAME):$(CHANNUM):v0set:dn	bo	Decrease Voltage setpoint by “deltav”
$(PSNAME):$(CHANNUM):v0set:deltav	ao	Step size of incremental voltage changes.
$(PSNAME):$(CHANNUM):v1set	ao	Set voltage setpoint, secondary value.
$(PSNAME):$(CHANNUM):i0set	ao	Set software current limit.
$(PSNAME):$(CHANNUM):i1set	ao	Set software current limit, for secondary voltage.
$(PSNAME):$(CHANNUM):rampup	ao	Set voltage increase ramp rate.
$(PSNAME):$(CHANNUM):rampdn	ao	Set voltage decrease ramp rate.
$(PSNAME):$(CHANNUM):trip	ao	Set over-current condition trip period.
$(PSNAME):$(CHANNUM):svmax	ao	Set software maximum voltage.
$(PSNAME):$(CHANNUM):pwonoff	bo	Turn on/off channel output.
$(PSNAME):$(CHANNUM):pwupmode	bo	Set power-up mode (automatically energize output or leave un-energized).
$(PSNAME):$(CHANNUM):pwdnmode	bo	Set power-down mode (kill or ramp-down output).
$(PSNAME):$(CHANNUM):tripint	longout	Set internal trip connections.
$(PSNAME):$(CHANNUM):tripext	longout	Set external trip connections.
$(PSNAME):$(CHANNUM):ilock:in.INP	ai	Set name of PV to monitor for software trip condition.
$(PSNAME):$(CHANNUM):ilock:thresh	ao	Threshold at which software trip will be triggered.
$(PSNAME):$(CHANNUM):ilock:cond	mbbo	Set condition type which

Table 2: Read-Only EPICS Records. $(PSNAME) typically is set to the crate name, $(CHANNUM) is typically set to the channel address.

Process Variable Name	Record Type	Description
$(PSNAME):$(CHANNUM):name:fbk	stringin	Name of channel set *in the crate*.
$(PSNAME):$(CHANNUM):v0set:fbk	ai	Voltage setpoint.
$(PSNAME):$(CHANNUM):v1set:fbk	ai	Voltage setpoint, secondary value.
$(PSNAME):$(CHANNUM):i0set:fbk	ai	Software current limit.
$(PSNAME):$(CHANNUM):i1set:fbk	ai	Software current limit, secondary value.
$(PSNAME):$(CHANNUM):rampup:fbk	ai	Voltage increase ramp rate.
$(PSNAME):$(CHANNUM):rampdn:fbk	ai	Voltage decrease ramp rate.
$(PSNAME):$(CHANNUM):trip:fbk	ai	Over-current condition trip period.
$(PSNAME):$(CHANNUM):svmax:fbk	ai	Software maximum voltage.
$(PSNAME):$(CHANNUM):vmon	ai	Measured output voltage.
$(PSNAME):$(CHANNUM):imon	ai	Measured output current.
$(PSNAME):$(CHANNUM):status	mbbi	Channel status message.
$(PSNAME):$(CHANNUM):pwonoff:fbk	bi	Output on/off state.
$(PSNAME):$(CHANNUM):pwupmode:fbk	bi	Power-up mode (automatically energize output or leave un-energized).
$(PSNAME):$(CHANNUM):pwdnmode:fbk	bi	Power-down mode (kill or ramp-down output).
$(PSNAME):$(CHANNUM):tripint:fbk	longin	Internal trip connections.
$(PSNAME):$(CHANNUM):tripext:fbk	longin	External trip connections.

2.2.2 Description of Process Variables

$(PSNAME):$(CHANNUM):name The crate stores a label and this label can be changed with this PV. Hence, if the user wished to assign a label that will appear on any kind of interface (e.g. the CAEN TELNET screen), then this is the label to change.

$(PSNAME):$(CHANNUM):name.DESC This channel label is stored only in EPICS. Changes to this will not propagate to the crate, and the label will not persist between IOC restarts (unless a default is set in the record, or a script or routine sets it after initialization). This would be used if the user wants to assign a temporary or otherwise localized label (e.g. detector used only for one week).

$(PSNAME):$(CHANNUM):v0set This sets the voltage of the channel. This is the default PV for setting voltages. This does not necessarily energize the output of the channel (see $(PSNAME):$(CHANNUM):pwonoff). *Note: currently, it is always a positive value regardless of the polarity of the output, with the output polarity depending on the type of the HV board.*

$(PSNAME):$(CHANNUM):v0set:up This incrementally increases the voltage setting of the channel by $(PSNAME):$(CHANNUM):deltav. It is strictly binary, actuating when set on.

$(PSNAME):$(CHANNUM):v0set:dn This incrementally decreases the voltage setting of the channel by $(PSNAME):$(CHANNUM):deltav. It is strictly binary, actuating when set on.

$(PSNAME):$(CHANNUM):v0set:deltav This is the voltage increment used by $(PSNAME):$(CHANNUM):v0set:up and $(PSNAME):$(CHANNUM):v0set:dn.

$(PSNAME):$(CHANNUM):v1set This sets the secondary voltage of the channel. This value is selected by the voltage selection switch. *Note: currently, it is always a positive value regardless of the polarity of the output, with the output polarity depending on the type of the HV board. Note: Secondary voltage settings currently cannot be selected, so this setting is not yet relevant.*

$(PSNAME):$(CHANNUM):i0set This sets the upper limit of the output current. Exceeding this value is an over-current condition. *Note: currently, it is always a positive value regardless of the polarity of the output, with the output polarity depending on the type of the HV board.*

$(PSNAME):$(CHANNUM):i1set This sets the upper limit of the output current. Exceeding this value is an over-current condition. This value is selected by the current selection switch. *Note: currently, it is always a positive value regardless of the polarity of the output, with the output polarity depending on the type of the HV board. Note: Secondary current settings currently cannot be selected, so this setting is not yet relevant.*

$(PSNAME):$(CHANNUM):rampup This sets the output voltage ramp-up rate. When the magnitude of the voltage output is increased, this is the rate of the increase. Naturally, it has no effect on increasing only the setpoint.

$(PSNAME):$(CHANNUM):rampdn This sets the output voltage ramp-down rate. When the magnitude of the voltage output is decreased, this is the rate of the decrease. Naturally, it has no effect when decreasing only the setpoint.

$(PSNAME):$(CHANNUM):trip This sets the duration that an over-current condition must exist before an over-current trip occurs.

$(PSNAME):$(CHANNUM):svmax This sets the software maximum voltage. This is a separate limit from the hardware maximum voltage.

$(PSNAME):$(CHANNUM):pwonoff This energizes or de-energizes the output of the channel. The voltage will ramp up and down by the rates set in $(PSNAME):$(CHANNUM):rampup and $(PSNAME):$(CHANNUM):rampdn.

$(PSNAME):$(CHANNUM):pwupmode This sets the behaviour of the channel when the crate is powered up. It can be set to either remain off or to ramp up to the set voltage.

$(PSNAME):$(CHANNUM):pwdnmode This sets the behaviour of the channel when the crate is powered down. It can be set to either ramp down or to turn off immediately ("kill").

$(PSNAME):$(CHANNUM):tripint

$(PSNAME):$(CHANNUM):tripext

$(PSNAME):$(CHANNUM):ilock:in.INP The INP field of this record should be set to the name of the PV to be monitored that will cause the associated HV channel to trip via software. Don't forget to add the "CPP" qualifier to this field value.

$(PSNAME):$(CHANNUM):ilock:thresh This sets the threshold at which the monitored PV will cause the associated HV channel to shut down or turn on via software.

$(PSNAME):$(CHANNUM):ilock:cond This sets the type of condition that will cause the associated HV channel to shut down or turn on via software. Valid types are ">", "=", "<", and "!=", corresponding to whether the monitored value is greater than, equal to, less than, or not equal to the threshold value.

$(PSNAME):$(CHANNUM):ilock:act.DOL1 This is set to the value to set the associated HV channel when the software trip is triggered. It should normally be either "ON" or "OFF".

$(PSNAME):$(CHANNUM):name:fbk The label for this channel stored by the crate. This label will persist between power cycles.

$(PSNAME):$(CHANNUM):v0set:fbk The voltage setting stored in the crate.

$(PSNAME):$(CHANNUM):v1set:fbk The secondary voltage setting stored in the crate.

$(PSNAME):$(CHANNUM):i0set:fbk The current setting stored in the crate.

$(PSNAME):$(CHANNUM):i1set:fbk The secondary current setting stored in the crate.

$(PSNAME):$(CHANNUM):rampup:fbk The ramp-up setting stored in the crate.

$(PSNAME):$(CHANNUM):rampdn:fbk The ramp-down setting stored in the crate.

$(PSNAME):$(CHANNUM):trip:fbk The over-current condition duration setting stored in the crate.

$(PSNAME):$(CHANNUM):svmax:fbk The software voltage maximum stored in the crate.

$(PSNAME):$(CHANNUM):vmon The actual measured voltage output. *Note: currently, it is always a positive value regardless of the polarity of the output, with the output polarity depending on the type of the HV board.*

$(PSNAME):$(CHANNUM):imon The actual measured current output. *Note: currently, it is always a positive value regardless of the polarity of the output, with the output polarity depending on the type of the HV board.*

$(PSNAME):$(CHANNUM):status The status of the channel. For example, this will indicate if the voltage is ramping up or down, or if the channel is on or off.

$(PSNAME):$(CHANNUM):pwonoff:fbk This indicates whether the channel's output is energized.

$(PSNAME):$(CHANNUM):pwupmode:fbk This is the power-up mode setting stored in the crate.

$(PSNAME):$(CHANNUM):pwdnmode:fbk This is the power-down mode setting stored in the crate.

$(PSNAME):$(CHANNUM):tripint:fbk

$(PSNAME):$(CHANNUM):tripext:fbk

2.3 Starting the IOC Application

The normal syntax for starting the HVCAENx257 IOC application is,

```
<EPICS_INSTALL_PATH>/bin/<arch>/HVCAENx527 <st.cmd>
-d -D 0
-c <Crate0Name>@<Crate0 IP>
[-c <Crate1Name>@<Crate1 IP>]
```

where `<EPICS_INSTALL_PATH>` is where you installed the IOC application, `<arch>` is the system architecture you are running the application on, `<st.cmd>` is the usual EPICS "st.cmd" file, `<Crate0Name>` is a name that the crate will use to associate commands meant for it, `<Crate0IP>` is the IP address or name for the crate. There can be multiple instances of the "`-c`" option to account for multple crates. The "`-D`" option is to set debugging level, which is mostly for development purposes and normally should be set to 0 (no debugging).

3 Programming Notes

3.1 Files

license.txt

license_CAEN.txt License agreement text included for clarification. CAEN wrapper must be obtained separately

Makefile

HVCAENx527App/src

- **HVCAENx527Main.cpp** For linux-x86 IOCs, this is the main().
- **HVCAENx527.c**
- **HVCAENx527.h**
- **HVCAENx527Include.dbd**
- **HVCAENx527chAio.c**
- **HVCAENx527chBio.c**
- **HVCAENx527chLongio.c**
- **HVCAENx527chMBBio.c**
- **HVCAENx527chStringio.c**
- **Makefile**

HVCAENx527App/Db

- **HVCAENx527.tpl**

HVCAENx527ch.tpl

HVCAENx527chItLk.tpl

HVCAENx527ch.sub

HVCAENx527chItLk.sub

Makefile

iocBoot/iocHVCAENx527

st.cmd

clsHV Sample script for starting IOC application as a linux daemon.

opi

HVCAENx527config.edl

HVCAENx527.edl

HVCAENx527simple.edl

runCAENHV Sample script for starting EDM GUI.

3.2 CAEN HVWrapper

The functions for the CAEN HV Wrapper are quite well documented in the wrapper's manual[1]. The EPICS driver is based on calls to these functions.

The following HVWrapper functions were used for this EPICS implementation.

CAENHVInitSystem()
CAENHVDeinitSystem()
CAENHVGetChName()
CAENHVSetChName()
CAENHVGetChParamInfo()
CAENHVGetChParamProp()
CAENHVGetChParam()
CAENHVSetChParam()
CAENHVGetCrateMap()

Note: Board and crate support routines will be added to this list when board and crate parameters are added to the EPICS database.

3.3 Installation

3.3.1 Requirements

Installation of HVCAENx527 requires:

- the CAEN wrapper libraries which you must get from CAEN directly (registration is free and seems benign).
- a local installation of "msi", the epics "Macro Substitution and Include Tool"

3.3.2 Building

- Get a copy of the gzipped tar file, "`HVCAENx527_<version>.tgz`", where `<version>` is the version of the driver.
- Create and change to a working directory for building the driver.

  ```
  > tar -z -x -f HVCAENx527_<version>.tgz
  ```

  This should build a standard EPICS 3.14.6 build directory named "`HVCAENx527`".
- Change directory:

  ```
  > cd HVCAENx527
  ```

- You probably have to force a reconfiguration, so

  ```
  > make clean uninstall install
  ```

- The account name and password for crate access is hardcoded, so you will have to change all instances of them. Assuming you are still in directory "`HVCAENx527`", change to directory "`HVCAENx527App/src`".
  - Edit the file `HVCAENx527.c`

- Look for calls to function "`CAENHVInitSystem`" and change all instances of "`admin`" to the respective account name and passwords on the crate you want to connect to.

  Note: If you have multiple crates with different passwords you will have to either make them the same or run different instances of this IOC. That's an oversight to be dealt with in later versions.

- Next, the db records have to be configured.
  - Change to directory "`HVCAENx527/Db`" (e.g. in Linux if you are in src, '`cd ../Db`'). You should see files with names suffixed with "`.sub`". These are "**msi**" substitution files.
    - If you do not have "**msi**" or prefer to hand build your db files, you should at least use the template files (".tpl" suffix) as the basis.
  - Edit the substitution files and change entries corresponding to "`PSNAME`" to the basename you need.
    - In file "`HVCAENx527ch.sub`", add or delete entries for channels you want to provide support for. There are sample entries provided, so be sure to delete or change those.
    - File "`HVCAENx527chItLk.sub`" is for interlocking HV channels to external EPICS PVs. Add or delete entries as needed. There is one provided as an example, so be sure to change or delete it.
- Change directories back to "`HVCAENx527`".
- run '`make`'
- Change directory to "`iocBoot/iocHVCAENx527`", and edit st.cmd.
  - Change the entries for dbLoadRecords() to point to the "db" files that were built above.
  - You may also have to change the top line ("#!../../bin...") to match how your EPICS system is layed out.

3.3.3 Install

- Since installations tend to be quite different, an installation script has not been provided. It is assumed that the local facility has its own scripts for this purpose, or that the developer has the means to do so. The files to install are the standard EPICS ones: bin, db, dbd, and iocBoot.

3.4 EPICS Driver

The driver consists of functions and subroutines that communicate with the x527 crate via the HVWrapper, but have no contact with EPICS. These routines typically take care of initializing and shutting down crate communications, as well as initializing and destroying data structures used by EPICS support routines. But the primary function is to periodically scan the crate for relevant parameters.

3.4.1 Syntax of Routines

The following routines should NOT be used in any EPICS support routines.

3.4.2 Description of Routines

3.5 EPICS Driver Support Routines

These are routines that EPICS can use to interact with the driver. The routines simply initialize or shutdown the IOC. The routines discussed here are intended for use in driver support entry tables, but they also can appear in device support entry tables if conditions require it.

3.5.1 Syntax of Routines

```
void ParseCrateAddr( char (*straddr)[], short naddr);
void Shutdown();
```

3.5.2 Description of Routines

ParseCrateAddr() This subroutine performs two functions: determines the crate's IP address if given the crate's host name, connects to the crate, and initializes all crate, board, and channel data structures. In light of the latter, the subroutine is misnamed. The IP address is determined with the system host name resolution function `gethostbyname()`.

Shutdown() This subroutine deallocates data structures, and shuts down all connections to crate.

3.5.3 Driver Support Entry Table

```
struct
{
        long number;
        DRVSUPFUN       report;
        DRVSUPFUN       init;
} drvCAENx527 =
        {
                2,
                report,
                init
        };
```

3.5.4 Database Definition Syntax

Note: database definition syntax for the driver have yet to be implemented.

3.6 EPICS Device Support Routines

Device support routines provide the interaction of EPICS with either the driver or the crate through the driver. The routines discussed here are intended for use in device support entry tables.

3.6.1 Syntax of Routines

```
void *CAENx527ParseDevArgs( char *saddr);
void *CAENx527GetChParVal( PARPROP *pp);
int CAENx527SetChParVal( PARPROP *pp);
char *CAENx527GetChName( HVCHAN *hvch);
int CAENx527SetChName( HVCHAN *hvch, char *chname);
short CAENx527mbbi2state( PARPROP *pp);
void CAENx527mbbi2bits( PARPROP *pp, char *bits, short nbits);
char *CAENx527GetParUnit( PARPROP *pp, char *fieldval);
```

3.6.2 Description of Routines

CAENx527ParseDevArgs()

CAENx527GetChParVal()

CAENx527SetChParVal()

CAENx527GetChName()

CAENx527SetChName()

CAENx527mbbi2state()

CAENx527mbbi2bits()

CAENx527GetParUnit()

3.6.3 Device Support Entry Table

The format of Device Support Entry Tables (dset) are documented in EPICS documentation. The relevant parts are

```
struct
{
        long number;
        ...
        DEVSUPFUN        init_record;
        ...
        DEVSUPFUN        read/write_<recordtype>;
        ...
} devCAENx527ch<recordtype> =
        {
              6;
              ...
              init_record_<recordtype>,
              ...
              read/write_<recordtype>,
              ...
        };
```

3.6.4 Database Definition Syntax

The following `device()` definition entry syntax pertains to channel I/O.

```
device( <recordtype>, INST_IO, dev-
CAENx527ch<recordtype>, "CAEN x527 generic HV Channel")
```

The link type (second argument) must be INST_IO. The choice string (4th argument) must be ”CAEN x527 generic HV Channel”.

Note: database definition syntax for board and crate I/O have yet to be implemented.

3.6.5 Required Database Field Syntax

The two required fields in EPICS database input and output records are DTYP, OUT, and INP. For the HV channels, the db record syntax for these are

```
field( DTYP, "CAEN x527 generic HV Channel")
field( OUT, "@$(CHADDR) <channel output command>")
field( INP, "@$(CHADDR) <channel input command")
```

where $(CHADDR) is the channel address, formatted R.SS.CCC with R = 1-digit crate number, SS = 2-digit slot number, and CCC = 3-digit channel number, all left padded with “0”, e.g. a channel in crate 2, slot 4, channel 6 has an address 2.04.006. “@” prefix on the address is mandatory. This format was chosen because that is the format the x527 crate uses with the HVWrapper.

Note: field syntax for board and crate I/O have yet to be implemented. The proceeding discussion is only a proposal.

The required db record field syntax for board I/O records are

```
field( DTYP, "CAEN x527 generic HV Board")
field( OUT, "@$(BDADDR) <board output command>")
field( INP, "@$(BDADDR) <board input command>")
```

where $(BDADDR) is the board address, formatted R.SS with R = 1-digit crate number, SS = 2-digit slot number, all left padded with “0”, e.g. a board in crate 3, slot 1 would have an address of “3.01”. “@” prefix on the address is mandatory.

The required db record field syntax for board I/O records are

```
    field( DTYP, "CAEN x527 generic HV Crate")
    field( OUT, "@$(CRADDR) <board output command>")
    field( INP, "@$(CRADDR) <board input command>")
```

where $(CRADDR) is the board address, formatted R with R = 1-digit crate number, e.g. crate 3 would have an address of "3". "@" prefix on the address is mandatory.

References

[1] CAEN, 2002, *CAEN HV Wrapper, a C Library which permits the control of a generic CAEN Power Supply System* Programmer's Manual, Revision N.09.

[2] CAEN, 2004, *OPC Server for CAEN Power Supplies, Release 2.X*, Technical Information Manual, Revision n.5.

[3] CAEN, 2005, *SY2527, Universal Multichannel Power Supply System* User Manual, Revision 9.

[4] M. Kramer, J. Anderson, A. Johnson, E. Norum, J. Hill, R. Lange, 2004, *EPICS: Input/Ouput Controller Application Developer's Guide*, Release 3.14.6

[5] J. Postel and J. Reynolds, 1993, *TELNET PROTOCOL SPECIFICATION*, RFC 854.

[6] John Sinclair, 2002, *EDM: Extensible Display Manager* User Manual.

[7] P. Stanley, J. Anderson, and M. Kramer, 1995, *EPICS Record Reference Manual*, EPICS Release 3.13

4 To Do

4.1 Driver

4.1.1 Conversion to True EPICS Driver

Most PVs will need longer scan periods than the PVs of primary interest, so different timers are needed, too. These other timers should not run independent scan threads, triggering scans independently of the primary scan thread. Rather, they should only be used to notify the primary scan thread that a particular scan period has elapsed.

4.1.2 Scan Period Recoding

The concept of scan periods is currently implemented incorrectly. This was due to poor planning more than anything else. Most of the EPICS input records have periodic scanning activated, the scan thread has multiple timers corresponding to groups of PVs with different priorities, the scan thread has it's own base timer, and periods are assigned according to parameter type. The worst problem is that all of these are independent, which leads to confusion as to what actually determines the scan rate.

As long as the concept of a central scan thread remains, at the very least the EPICS input record SCAN fields should be set to passive, and the device support routines should return to performing dbPutField() to the input record. That leaves the matter of the other timers, which are needed to implement multiple scan periods, as discussed in Subsection 4.1.1. Finally, the scan lists should be first associated to a particular timer, then subdivided by parameter type. The reason for sub-lists by parameter type is that the CAEN HVWrapper functions can send values in bulk according to parameter type. So as soon as a timer has lapsed, the associated scan list loops through its parameter scan lists.

An alternative is to build a command queuing thread into the driver, then activate the SCAN periods in the input records. This may be required if a crate has multiple users (rather than multiple connections), or if “set” commands look like they are interfering with scans or vice versa. This thread should be started at IOC initialization. It would build a linked list (forward link should be sufficient) of command structs, adding a link to the end when a new request is queued and removing the link at the start when a request has been serviced. Two pointers should track the first and last link.

4.1.3 Scan period debugging

To aid with the assignment of timers, the EPICS routine scan_period() could be used, IF scan periods are to be based on record SCAN fields. It would have been incorporated for the current version but the routine caused crashes. So basically, work on this aspect of the driver is a debugging exercise, or should be abandoned if SCAN fields are not to be used.

4.1.4 Writes Triggering Reads

Many of the parameters are quite static, with interest in the feedback of their values only to confirm a change, or to occasionally check that there is nothing noteworthy of the parameter's value. For these, the corresponding network traffic and CPU usage can be reduced if the scan period is set quite long. However, after a parameter is set, it should be (and is) scanned immediately.

There occasionally is some lag between a setpoint being sent and the crate actually registering a change. The result is that the setpoint feedback PV does not get an updated value. One solution might be to temporarily make the scan period shorter after the user has set a new value.

For an extreme example, the ramp-up parameter's read scan period could be set to 5 minutes, but when the user sets the ramp-up to a new value, it would temporarily scan that parameter every second for ten seconds, and then go back to scanning every 5 minutes. Actually, the quick scan could be set up as a short-lived thread, shutting it down after the 10 seconds have passed.

The problem with the above is that it should be simple to implement if the scan routine controls the scan periods, but implementing it when the input record controls the scan period would be more complicated (i.e. there would not be a central scan routine). In that case a separate (temporary?) scan thread would be needed and have to perform a dbPutField() into the value field of the input record independently of the scanning activity of the record.

Of course, the idea of a temporary fast scan would be unnecesary if the crate response is adequate for simply setting then promptly reading back the set point.

4.1.5 Setting Scan Periods

If scan periods are centralized (e.g. by the continued use of the central scan routine), some PVs should be added to set and display the scan period.

4.1.6 Other Communication Methods

Do not bother implementing an RS-232 variant of the driver (actually, it only requires setting a software switch in the HVWrapper). The Ethernet version drives approximately 3 to 12 kB/s in each direction when servicing 24 channels. While this is certainly manageable for current serial cards, queuing problems will be much worse than with the network setup.

4.2 EPICS Record Alarms

Some channel parameters have limits, some of which may well be crucial to a user. There are currently no alarms set up in the EPICS records for the x527. Alarm support should be added, perhaps making use of the Minval and Maxval fields of the channel property structure, or at least initialized with them. This is probably the highest priority item.

4.3 Parsing the Device Address in Device Support

The device address parser, CAENx527ParseDevArgs(), currently only handles addresses for channel I/O. Three changes are required: the string from the DTYP field must be parsed with a different method, the data type must be determined according to the address type (crate, slot, or channel), and the return value reconciled with address type and existing use.

The core problem is that the DTYP string is currently parsed directly to crate number, slot number, channel number and command assuming the exact format for channels, i.e. with

```
narg = ss-
canf( saddr, "%hd.%hd.%hd %s", &cr, &sl, &ch, pnm);
```

This is inadequate for a variably structured address. Hence, first the address and command should be extract separately then the address type parsed.

4.4 Board and Crate Parameter Support

The type of parameters that should have the highest priority for parameters are crate status and crate-wide control EPICS records. In particular,

- Connection status. If the network connection is lost, the user interface will show no response. There is information available in the driver indicating the connection has been lost, so a PV indicating this should not be difficult to implement.

- Crate status. Many fault conditions are associated with individual channels, so there are not many similar parameters associated with the crate. But if there are any crate-specific parameters, some of them should have a PV.
- Board status. A multi-bit field could be used to indicate which slots have active boards, and perhaps alarms to indicate status.

Other lower priority parameters for consideration are:

- Crate-wide HV on/off. This might instead be an emergency off. The problem with making this truly crate-wide is that if there are multiple users using different channels, it would interfere with their apparatus. This might be better implemented either in the GUI or as a custom IOC record rather than incorporating it in the general code.

Most of the above do not have a corresponding parameter in the HVWrapper. They would have to be implemented in EPICS or at higher levels, in user interfaces.

There are a number of parameters to control and monitor the crate and boards in the crate. The wrapper has functions that access this information similarly to the way it accesses channel information. Thus, parameter structure lists should be added to the board and slot structures. Device support routines analogous to the ones for channel support should be added for board and crate parameters. The scan rate or priority for most of these should be the lowest since most are rather static. However, note that there are not many parameters that would be of interest to users, so this should be considered a low priority item.

4.5 Polarity

Some CAEN HV modules have a fixed polarity, that is, positive bias modules and negative bias modules. For those modules, the crate reports and expects only the magnitude of the bias. The polarity is not obvious at the user interface. There are two schools of thought on the issue. Users who know the device, particularly what bias it requires, will expect to input voltages with the appropriate sign and the lack of it in the display may confuse the user. On the other hand, forgetting to set the sign appropriately is a common mistake when manually entering a voltage. If the former is favoured, conversion will have to be added to device support. There are at least two ways of implementing this conversion.

At `init_record()`, the board type is known and can be used to set up record conversion (e.g. set ASLO or ESLO). Then, record conversion should be turned on (the default is to bypass conversion - this may require extra code in `read_ao()` and `write_ao()`).

Alternatively, all conversion could be done in `read_ao()` and `write_ao()`.

4.6 Host Name Lookup

For portability, EPICS routines for host name lookup should be used instead of `gethostbyname()`. That is, consider using `aToIPAddr()`.

4.7 Name and Password on Crates

Currently, the name and password on a given crate is hardcoded right in the call to initialize a crate. This must be made dynamic, to some extent, to accommodate systems where each crate has a different user name or password in each crate. For obvious security reasons, this should NOT be a command line option, nor should it be in user accessible configuration files.