PyEpics: Python Epics Channel Access

Release 3.3.2

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PyEpics is an interface for the Channel Access (CA) library of the Epics Control System to the Python Programming language. The pyepics package provides a base epics module to python, with methods for reading from and writing to Epics Process Variables (PVs) via the CA protocol. The package includes a thin and fairly complete layer over the low-level Channel Access library in the ca module, and higher level abstractions built on top of this basic functionality.

The package includes a very simple interface to CA similar to the Unix command-line tools and EZCA library with functions epics.caget(), epics.caput(), epics.cainfo(), and epics.camonitor(). These is also a pv.PV class which represents an Epics Process Variable as a full-featured and easy-to-use Python object. Additional modules provide higher-level programming support to CA, including grouping related PVs into a device.Device, creating alarms in alarm.Alarm, and saving PVs values in the autosave module. There is also support for conveniently using epics PVs to wxPython widgets in the wx module, and some support for using PyQt widgets in the qt module.

In addition to the Pyepics library described here, several applications built with pyepics are available at http://github.com/pyepics/epicsapps/. See http://pyepics.github.com/epicsapps/ for further details.
CHAPTER
ONE

DOWNLOADING AND INSTALLATION

1.1 Prerequisites

PyEpics works with Python version 2.7, 3.5, or 3.6. It is supported and regularly used and tested on 64-bit Linux, 64-bit Mac OSX, 64-bit Windows. It should still work on 32-bit Windows, 32-bit Linux, and on Linux with ARM processors, such as raspberry Pi, but these are tested regularly. It appears to work with Python 3.7, but this has tested much. It may also work with older versions of Python (such as 3.4), but these are not tested. For Windows, pyepics has been reported to work with IronPython (Python written with .NET), but this is not routinely tested.

The EPICS Channel Access library Version 3.14 or higher is required for pyepics to actually communicate with Epics variables. Specifically, the shared libraries libca and libCom (libca.so and libCom.so on Linux, libca.dylib and libCom.dylib on Mac OSX, or ca.dll and Com.dll on Windows) from Epics Base are required to use this module. Some features, including 'subarray records' will only work with version 3.14.12 and higher, and version 3.15 or higher is strongly recommended.

For all supported operating systems (linux-64, linux-32, linux-arm, windows-64, windows-32, and darwin-64), pre-built versions of libca (and libCom) built with 3.16.2 are provided, and will be installed within the python packages directory and used by default. That means that you do not need to install Epics base libraries or any other packages to use pyepics. For Epics experts who may want to use their own versions the libca from Epics base, instructions for how to do this are given below.

The Python numpy module is highly recommended, though it is not required. If available, it will be used to automatically convert between EPICS waveforms and numpy arrays.

The autosave module requires the pyparsing package, which is widely available and often installed by default with many Python distributions. The wx module requires the wxPython package, and the qt module requires PyQt or PySide.

1.2 Downloads and Installation

The latest stable version of the pyepics package is 3.3.2. Source code kits and Windows installers can be found at pyepics PyPI, and can be installed with:

```
pip install pyepics
```

If you’re using Anaconda Python, there are a few conda channels for pyepics, including:

```
conda install -c GSECARS pyepics
```

You can also download the source package, unpack it, and install with:

```
python setup.py install
```
1.3 Getting Started, Setting up the Epics Environment

As mentioned above, pyepics must be able to find and load the Channel Access dynamic library (libca.so, libca.dylib, or ca.dll depending on the system) at runtime in order to actually work. For the most commonly used operating systems and architectures, modern version of these libraries are provided, and will be installed and used with pyepics. We strongly recommend using these.

If these provided versions of libca do not work for you, please let us know. If you need to or wish to use a different version of libca, you can set the environmental variable PYEPICS_LIBCA to the full path of the dynamic library to use as libca, for example:

```bash
> export PYEPICS_LIBCA=/usr/local/epics/base-3.15.5/lib/linux-x86_64/libca.so
```

Note that libca will need to find another Epics CA library libCom. This is almost always in the same folder as libca, but you may need to make sure that the libca you are pointing to can find the required libCom. The methods for telling shared libraries (or executable files) how to find other shared libraries varies with system, but you may need to set other environmental variables such as LD_LIBRARY_PATH or DYLIB_LIBRARY_PATH or use ldconfig.

To find out which CA library will be used by pyepics, use:

```python
>>> import epics
>>> epics.ca.find_libca()
```

which will print out the full path of the CA dynamic library that will be used.

With the Epics library loaded, you will need to be able to connect to Epics Process Variables. Generally, these variables are provided by Epics I/O controllers (IOCs) that are processes running on some device on the network. If you are connecting to PVs provided by IOCs on your local subnet, you should have no trouble. If trying to reach further network, you may need to set the environmental variable EPICS_CA_ADDR_LIST to specify which networks to search for PVs.

1.4 Testing

Automated and continuous unit-testing is done with the TravisCI (https://travis-ci.org/pyepics/pyepics) for Python 2.7, 3.5, and 3.6 using an Epics IOC running in a Docker image. Many tests located in the tests folder can also be run using the script tests/simulator.py as long as the Epics database in tests/pydebug.db is loaded in a local IOC. In addition, tests are regularly run on Mac OSX, and 32-bit and 64-bit Windows.

1.5 Development Version

Development of pyepics is done through the pyepics github repository. To get a read-only copy of the latest version, use one of:

```bash
git clone http://github.com/pyepics/pyepics.git
```

1.6 Getting Help

For questions, bug reports, feature request, please consider using the following methods:
1. Send email to the Epics Tech Talk mailing list. You can send mail directly to Matt Newville <newville@cars.uchicago.edu>, but the mailing list has many Epics experts reading it, so someone else interested or knowledgeable about the topic might provide an answer. Since the mailing list is archived and the main mailing list for Epics work, a question to the mailing list has a better chance of helping someone else.

2. Create an Issue on http://github.com/pyepics/pyepics. Though the github Issues seem to be intended for bug tracking, they are a fine way to catalog various kinds of questions and feature requests.

3. If you are sure you have found a bug in existing code, or have some code you think would be useful to add to pyepics, consider making a Pull Request on http://github.com/pyepics/pyepics.

1.7 License

The pyepics source code, this documentation, and all material associated with it are distributed under the Epics Open License:

The epics python module was originally written by

Matthew Newville <newville@cars.uchicago.edu> CARS, University of Chicago

There have been several contributions from many others, notably Angus Gratton <angus.gratton@anu.edu.au>. See the Acknowledgements section of the documentation for a list of more contributors.

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1.8 Acknowledgments

pyepics was originally written and is maintained by Matt Newville <newville@cars.uchicago.edu>. Many important contributions to the library have come from Angus Gratton while at the Australian National University, and from Daron Chabot and Ken Lauer. Several other people have provided valuable additions, suggestions, pull requests or bug reports, which has greatly improved the quality of the library: Robbie Clarken, Daniel Allen, Michael Abbott, Thomas Caswell, Alain Peteut, Steven Hartmann, Rokvintar, Georg Brandl, Niklas Claesson, Jon Brinkmann, Marco Cammarata, Craig Haskins, David Vine, Pete Jemian, Andrew Johnson, Janko Kolar, Irina Kosheleva, Tim Mooney, Eric Norum, Mark Rivers, Friedrich Schotte, Mark Vigder, Steve Wasserman, and Glen Wright.
CHAPTER TWO

PYEPICS OVERVIEW

The Python epics package provides several functions, modules, and classes to interact with EPICS Channel Access. The simplest approach uses the functions `caget()`, `caput()`, and `cainfo()` within the top-level epics module to get and put values of Epics Process Variables. These functions are similar to the standard command line utilities and the EZCA library interface, and are described in more detail below.

To use the epics package, import it with:

```python
import epics
```

The main components of this module include

- functions `caget()`, `caput()`, `cainfo()` and others described in more detail below.
- a `ca` module, providing the low-level library as a set of functions, meant to be very close to the C library for Channel Access.
- a `PV` object, representing a Process Variable (PV) and giving a higher-level interface to Epics Channel Access.
- a `Device` object: a collection of related PVs, similar to an Epics Record.
- a `Motor` object: a Device that represents an Epics Motor.
- an `Alarm` object, which can be used to set up notifications when a PV’s values goes outside an acceptable bounds.
- an `epics.wx` module that provides wxPython classes designed for use with Epics PVs.

If you’re looking to write quick scripts or a simple introduction to using Channel Access, the `caget()` and `caput()` functions are probably where you want to start.

If you’re building larger scripts and programs, using PV objects provided by the `pv` module is recommended. The `PV` class provides a Process Variable (PV) object that has both methods (including `get()` and `put()`) to read and change the PV, and attributes that are kept automatically synchronized with the remote channel. For larger applications where you find yourself working with sets of related PVs, you may find the `Device` class helpful.

The lowest-level CA functionality is exposed in the `ca` module, and companion `dbr` module. While not necessary recommended for most use cases, this module does provide a fairly complete wrapping of the basic EPICS CA library. For people who have used CA from C or other languages, this module should be familiar and seem quite usable, if a little more verbose and C-like than using PV objects.

In addition, the epics package contains more specialized modules for alarms, Epics motors, and several other `devices` (collections of PVs), and a set of wxPython widget classes for using EPICS PVs with wxPython.

The epics package is supported and well-tested on Linux, Mac OS X, and Windows with Python versions 2.7, and 3.5 and above.
2.1 Quick Start

Whether you’re familiar with Epics Channel Access or not, start here. You’ll then be able to use Python’s introspection tools and built-in help system, and the rest of this document as a reference and for detailed discussions.

2.1.1 Procedural Approach: `caget()`, `caput()`

To get values from PVs, you can use the `caget()` function:

```python
>>> from epics import caget, caput, cainfo
>>> m1 = caget('XXX:m1.VAL')
>>> print(m1)
1.2001
```

To set PV values, you can use the `caput()` function:

```python
>>> caput('XXX:m1.VAL', 1.90)
>>> print(caget('XXX:m1.VAL'))
1.9000
```

To see more detailed information about a PV, use the `cainfo()` function:

```python
>>> cainfo('XXX:m1.VAL')
== XXX:m1.VAL (time_double) ==
  value = 1.9
  char_value = '1.9000'
  count = 1
  nelm = 1
  type = time_double
  units = mm
  precision = 4
  host = somehost.aps.anl.gov:5064
  access = read/write
  status = 0
  severity = 0
  timestamp = 1513352940.872 (2017-12-15 09:49:00.87179)
  posixseconds = 1513352940.0
  nanoseconds= 871788105
  upper_ctrl_limit = 50.0
  lower_ctrl_limit = -48.0
  upper_disp_limit = 50.0
  lower_disp_limit = -48.0
  upper_alarm_limit = 0.0
  lower_alarm_limit = 0.0
  upper_warning_limit = 0.0
  lower_warning_limit = 0.0
  PV is internally monitored, with 0 user-defined callbacks:
  ==============================```

The simplicity and clarity of these functions make them ideal for many cases.

2.1.2 Creating and Using PV Objects

If you are repeatedly referencing the same PV, you may find it more convenient to create a PV object and use it in a more object-oriented manner.
PV objects have several methods and attributes. The most important methods are `get()` and `put()` to receive and send the PV's value, and the `value` attribute which stores the current value. In analogy to the `caget()` and `caput()` examples above, the value of a PV can be fetched either with

```python
>>> print(pv1.get())
1.90
```

or

```python
>>> print(pv1.value)
1.90
```

To set a PV's value, you can either use

```python
>>> pv1.put(1.9)
```

or assign the `value` attribute

```python
>>> pv1.value = 1.9
```

You can see a few of the most important properties of a PV by simply printing it:

```python
>>> print(pv1)
<PV 'XXX:m1.VAL', count=1, type=time_double, access=read/write>
```

Even more complete information can be seen by printing the PVs `info` attribute:

```python
>>> print(pv1.info)
== XXX:m1.VAL (time_double) ==
  value = 1.9
  char_value = '1.9000'
  count = 1
  nelm = 1
  type = time_double
  units = mm
  precision = 4
  host = somehost.aps.anl.gov:5064
  access = read/write
  status = 0
  severity = 0
  timestamp = 1513352940.872 (2017-12-15 09:49:00.87179)
  posixseconds = 871788105
  nanoseconds= 871788105
  upper_ctrl_limit = 50.0
  lower_ctrl_limit = -48.0
  upper_disp_limit = 50.0
  lower_disp_limit = -48.0
  upper_alarm_limit = 0.0
  lower_alarm_limit = 0.0
  upper_warning_limit = 0.0
  lower_warning_limit = 0.0
PV is internally monitored, with 0 user-defined callbacks:
```

2.1. Quick Start
PV objects have several additional methods related to monitoring changes to the PV values or connection state including user-defined functions to be run when the value changes. There are also attributes associated with a PVs Control Attributes, like those shown above in the `info` attribute. Further details are at *PV: Epics Process Variables*.

### 2.2 Functions defined in `epics`: `caget()`, `caput()`, etc.

As shown above, the simplest interface to EPICS Channel Access is found with the functions `caget()`, `caput()`, and `cainfo()`. There are also functions `camonitor()` and `camonitor_clear()` to setup and clear a simple monitoring of changes to a PV. These functions all take the name of an Epics Process Variable (PV) as the first argument and are similar to the EPICS command line utilities of the same names.

Internally, these functions keeps a cache of connected PV (in this case, using `PV` objects) so that repeated use of a PV name will not actually result in a new connection to the PV – see *The get_pv() function and _PVcache_ cache of PVs* for more details. Thus, though the functionality is simple and straightforward, the performance of using these simple function can be quite good. In addition, there are also functions `caget_many()` and `caput_many()` for getting and putting values for multiple PVs at a time.

#### 2.2.1 `caget()`

```python
caget(pvname[, as_string=False[, count=None[, as_numpy=True[, timeout=None[, use_monitor=False]]]]])
```

retrieves and returns the value of the named PV.

**Parameters**

- `pvname` – name of Epics Process Variable.
- `as_string` (True/False) – whether to return string representation of the PV value.
- `count` (integer or None) – number of elements to return for array data.
- `as_numpy` (True/False) – whether to return the Numerical Python representation for array data.
- `timeout` (float or None) – maximum time to wait (in seconds) for value before returning None.
- `use_monitor` (True/False) – whether to rely on monitor callbacks or explicitly get value now.

The `count` and `as_numpy` options apply only to array or waveform data. The default behavior is to return the full data array and convert to a numpy array if available. The `count` option can be used to explicitly limit the number of array elements returned, and `as_numpy` can turn on or off conversion to a numpy array.

The `timeout` argument sets the maximum time to wait for a value to be fetched over the network. If the timeout is exceeded, `caget()` will return None. This might imply that the PV is not actually available, but it might also mean that the data is large or network slow enough that the data just hasn’t been received yet, but may show up later.

The `use_monitor` argument sets whether to rely on the monitors from the underlying PV. The default is False, so that each `caget()` will explicitly ask the value to be sent instead of relying on the automatic monitoring normally used for persistent PVs. This makes `caget()` act more like command-line tools, and slightly less efficient than creating a PV and getting values with it. If performance is a concern, using monitors is recommended. For more details on making `caget()` more efficient, see *Automatic Monitoring of a PV and The wait and timeout options for get*, `ca.get_complete()`.
The `as_string` argument tells the function to return the **string representation** of the value. The details of the string representation depends on the variable type of the PV. For integer (short or long) and string PVs, the string representation is pretty easy: 0 will become ‘0’, for example. For float and doubles, the internal precision of the PV is used to format the string value. For enum types, the name of the enum state is returned:

```python
>>> from epics import caget, caput, cainfo

>>> print(caget('XXX:m1.VAL'))  # A double PV
0.10000000000000001

>>> print(caget('XXX:m1.DESC'))  # A string PV
'Motor 1'

>>> print(caget('XXX:m1.FOFF'))  # An Enum PV
1
```

Adding the `as_string=True` argument always results in string being returned, with the conversion method depending on the data type, for example using the precision field of a double PV to determine how to format the string, or using the names of the enumeration states for an enum PV:

```python
>>> print(caget('XXX:m1.VAL', as_string=True))
'0.10000'

>>> print(caget('XXX:m1.FOFF', as_string=True))
'Frozen'
```

For integer or double array data from Epics waveform records, the regular value will be a numpy array (or a python list if numpy is not installed). The string representation will be something like ‘<array size=128, type=int>’ depending on the size and type of the waveform. An array of doubles might be:

```python
>>> print(caget('XXX:scan1.P1PA'))  # A Double Waveform
array([-0.08, -0.078, -0.076, ..., 1.99599814, 1.99799919, 2.])

>>> print(caget('XXX:scan1.P1PA', as_string=True))
'<array size=2000, type=time_double>'
```

As an important special case CHAR waveform records will be turned to Python strings when `as_string` is `True`. This is useful to work around the low limit of the maximum length (40 characters!) of EPICS strings which has inspired the fairly common usage of CHAR waveforms to represent longer strings:

```python
>>> epics.caget('MyAD:TIFF1:FilePath')

>>> epics.caget('MyAD:TIFF1:FilePath', as_string=True)
'/home/epics/scratch/
```

Of course, character waveforms are not always used for long strings, but can also hold byte array data, such as comes from some detectors and devices.

### 2.2.2 `caput()`

```python
epics.caput(pvname, value[, wait=False[, timeout=60]])
```

set the value of the named PV.

**Parameters**

- `pvname` – name of Epics Process Variable

---

2.2. Functions defined in `epics`: `caget()`, `caput()`, etc.
• **value** – value to send.
• **wait** (True/False) – whether to wait until the processing has completed.
• **timeout** (double) – how long to wait (in seconds) for put to complete before giving up.

**Return type** integer

The optional *wait* argument tells the function to wait until the processing completes. This can be useful for PVs which take significant time to complete, either because it causes a physical device (motor, valve, etc) to move or because it triggers a complex calculation or data processing sequence. The *timeout* argument gives the maximum time to wait, in seconds. The function will return after this (approximate) time even if the *caput()* has not completed.

This function returns 1 on success, and a negative number if the timeout has been exceeded.

```python
>>> from epics import caget, caput, cainfo

>>> caput('XXX:m1.VAL',2.30)
1

>>> caput('XXX:m1.VAL',-2.30, wait=True)
...
waits a few seconds ...
1
```

### 2.2.3 cainfo()

epics.*cainfo*(pvname[, print_out=True])

prints (or returns as a string) an informational paragraph about the PV, including Control Settings.

**Parameters**

- **pvname** – name of Epics Process Variable
- **print_out** – whether to write results to standard output (otherwise the string is returned).

### 2.2.4 camonitor()

epics.*camonitor*(pvname[, writer=None[, callback=None]])

This sets a monitor on the named PV, which will cause *something* to be done each time the value changes. By default the PV name, time, and value will be printed out (to standard output) when the value changes, but the action that actually happens can be customized.

**Parameters**

- **pvname** – name of Epics Process Variable
- **writer** (None or a callable function that takes a string argument.) – where to write results to standard output.
- **callback** (None or callable function) – user-supplied function to receive result

One can specify any function that can take a string as *writer*, such as the write() method of an open file that has been open for writing. If left as None, messages of changes will be sent to sys.stdout.write(). For more complete control, one can specify a *callback* function to be called on each change event. This callback should take keyword arguments for *pvname*, *value*, and *char_value*. See *User-supplied Callback functions* for information on writing callback functions for *camonitor()*.

```python
>>> from epics import camonitor

>>> camonitor('XXX.m1.VAL')
XXX.m1.VAL 2010-08-01 10:34:15.822452 1.3
```

(continues on next page)
2.2.5 `camonitor_clear()`

`epics.camonitor_clear(pvname)`

clears a monitor set on the named PV by `camonitor()`.

**Parameters**

- `pvname` – name of Epics Process Variable

This simple example monitors a PV with `camonitor()` for while, with changes being saved to a log file. After a while, the monitor is cleared and the log file is inspected:

```python
>>> import epics
>>> fh = open('PV1.log','w')
>>> epics.camonitor('XXX:DMM1Ch2_calc.VAL',writer=fh.write)
>>> .... wait for changes ...
>>> epics.camonitor_clear('XXX:DMM1Ch2_calc.VAL')  
>>> fh.close()
>>> fh = open('PV1.log','r')
>>> for i in fh.readlines(): print(i[:-1])
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:40.536946 -183.5035
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:41.536757 -183.6716
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:42.535568 -183.5112
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:43.535379 -183.5466
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:44.535191 -183.4890
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:45.535001 -183.5066
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:46.535813 -183.5085
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:47.536623 -183.5223
XXX:DMM1Ch2_calc.VAL 2010-03-24 11:56:48.536434 -183.6832
```

2.2.6 `caget_many()`

`epics.caget_many(pvlist[, as_string=False[, count=None[, as_numpy=True[, timeout=None ]]]]])`  

gets a list of PVs as quickly as possible. Returns a list of values for each PV in the list. Unlike `caget()`, this method does not use automatic monitoring (see `Automatic Monitoring of a PV`).

**Parameters**

- `pvlist` (list or tuple of str) – A list of process variable names.
- `as_string` (True/False) – whether to return string representation of the PV values.
- `count` (integer or None) – number of elements to return for array data.
- `as_numpy` (True/False) – whether to return the Numerical Python representation for array data.
- `timeout` (float or None) – maximum time to wait (in seconds) for value before returning None.

For detailed information about the arguments, see the documentation for `caget()`. Also see `Strategies for connecting to a large number of PVs` for more discussion.
2.2.7 caput_many()

```python
caput_many(pvlist, values[, wait=False[, connection_timeout=None[, put_timeout=60 ]]])
```

Put values to a list of PVs as quickly as possible. Returns a list of ints for each PV in the list: 1 if the put was successful, -1 if it timed out. Unlike `caput()`, this method does not use automatic monitoring (see Automatic Monitoring of a PV).

**Parameters**

- **pvlist** (list or tuple of str) – A list of process variable names.
- **values** (list or tuple) – values to put to each PV.
- **wait** – if 'each', `caput_many()` will wait for each PV to process before starting the next. If 'all', `caput_many()` will issue puts for all PVs immediately, then wait for all of them to complete. If any other value, `caput_many()` will not wait for put processing to complete.
- **connection_timeout** (float or None) – maximum time to wait (in seconds) for a connection to be established to each PV.
- **put_timeout** (float or None) – maximum time to wait (in seconds) for processing to complete for each PV (if wait is 'each'), or for processing to complete for all PVs (if wait is 'all').

Because connections to channels normally connect very quickly (less than a second), but processing a put may take a significant amount of time (due to a physical device moving, or due to complex calculations or data processing sequences), a separate timeout duration can be specified for connections and processing puts.

2.3 Motivation and design concepts

There are other Python wrappings for Epics Channel Access, so it is useful to outline the design goals for PyEpics. The motivations for PyEpics3 included:

1) providing both low-level (C-like) and higher-level access (Python objects) to the EPICS Channel Access protocol.

2) supporting as many features of Epics 3.14 as possible, including preemptive callbacks and thread support.

3) easy support and distribution for Windows and Unix-like systems.

4) support for both Python 2 and Python 3.

5) using Python’s ctypes library.

The idea is to provide both a low-level interface to Epics Channel Access (CA) that closely resembled the C interface to CA, and to build higher level functionality and complex objects on top of that foundation. The Python ctypes library conveniently allows such direct wrapping of a shared libraries, and requires no compiled code for the bridge between Python and the CA library. This makes it very easy to wrap essentially all of CA from Python code, and support multiple platforms. Since ctypes loads a shared object library at runtime, the underlying CA library can be upgraded without having to re-build the Python wrapper. The ctypes interface provides the most reliable thread-safety available, as each call to the underlying C library is automatically made thread-aware without explicit code. Finally, by avoiding the C API altogether, supporting both Python2 and Python3 is greatly simplified.
2.4 Status and to-do list

The PyEpics package is actively maintained, but the core library is reasonably stable and ready to use in production code. Features are being added slowly, and testing is integrated into development so that the chance of introducing bugs into existing codes is minimized. The package is targeted and tested to work with Python 2.7 and Python 3 simultaneously.

There are several desired features that are left unfinished or could use improvement:

- add more Epics Devices, including low-level epics records and more support for Area Detectors.
- build and improve applications using PyEpics, especially for common data acquisition needs.
- improve and extend the use of PyQt widgets with PyEpics.

If you are interested in working on any of these or other topics, please contact the authors.
The pv module provides a higher-level class pv.PV, which creates a PV object for an EPICS Process Variable. A PV object has both methods and attributes for accessing its properties.

### 3.1 The PV class

class pv.PV(pvname[, callback=None[, form='time'[[, verbose=False[, auto_monitor=None[, count=None[, connection_callback=None[, connection_timeout=None[, access_callback=None ]]]]]]]]])

create a PV object for a named Epics Process Variable.

**Parameters**

- **pvname** – name of Epics Process Variable
- **callback** (callable, tuple, list or None) – user-defined callback function on changes to PV value or state.
- **form** (string, one of ('native', 'ctrl', or 'time')) – which epics data type to use: the ‘native’, ‘time’, or the ‘ctrl’ (Control) variant.
- **verbose** (True/False) – whether to print out debugging messages
- **auto_monitor** (None, True, False, or bitmask (see Automatic Monitoring of a PV)) – whether to automatically monitor the PV for changes.
- **count** (int) – number of data elements to return by default (see here)
- **connection_callback** (callable or None) – user-defined function called on changes to PV connection status.
- **connection_timeout** (float or None) – time (in seconds) to wait for connection before giving up
- **access_callback** (callable or None) – user-defined function called on changes to PV access rights

Once created, a PV should (barring any network issues) automatically connect and be ready to use.

```python
>>> from epics import PV
>>> p = PV('XX:m1.VAL')
>>> print p.get()
>>> print p.count, p.type
```

The pvname is required, and is the name of an existing Process Variable.
The `callback` parameter specifies one or more python methods to be called on changes, as discussed in more detail at User-supplied Callback functions.

The `connection_callback` parameter specifies a python method to be called on changes to the connection status of the PV (that is, when it connects or disconnects). This is discussed in more detail at User-supplied Connection Callback functions.

The `form` parameter specifies which of the three variants ‘native’, ‘ctrl’ (Control) or ‘time’ (the default) to use for the PV. The ‘native’ form returns just the value, the ‘time’ form includes the timestamp from the server the PV lives on, as well as status information. The control form includes several additional fields such as limits to the PV, which can be useful in some cases. Also note that the additional ‘ctrl’ value fields (see the Table of Control Attributes) can be obtained with `get_ctrlvars()` even for PVs of ‘native’ or ‘time’ form.

The `auto_monitor` parameter specifies whether the PV should be automatically monitored. See Automatic Monitoring of a PV for a detailed description of this.

The `verbose` parameter specifies more verbose output on changes, and is intended for debugging purposes.

The `access_callback` parameter specifies a python method to be called on changes to the access rights of the PV (read/write access changes). This is discussed in more detail here.

### 3.1.1 methods

A PV has several methods for getting and setting its value and defining callbacks to be executed when the PV changes.

```python
pv.get([count=None, as_string=False, as_numpy=True, timeout=None, use_monitor=True, with_ctrlvars=False])
```

Get and return the current value of the PV.

**Parameters**

- `count` (integer or `None`) – maximum number of array elements to return.
- `as_string` (True/False) – whether to return the string representation of the value.
- `as_numpy` – whether to try to return a numpy array where appropriate.
- `timeout` (float or `None`) – maximum time to wait for data before returning `None`.
- `use_monitor` (True/False) – whether to rely on monitor callbacks or explicitly get value now.

see String representation for a PV for details on how the string representation is determined.

With the `as_numpy` option, an array PV (that is, a PV whose value has more than one element) will be returned as a numpy array, provided the numpy module is available. See Strategies for working with large arrays for a discussion of strategies for how to best deal with very large arrays.

The `use_monitor` option controls whether the most recent value from the automatic monitoring will be used or whether the value will be explicitly asked for right now. Usually, you can rely on a PV's value being kept up to date, and so the default here is True. But, since network traffic is not instantaneous and hard to predict, the value returned with `use_monitor=True` may be out-of-date.

The `timeout` sets how long (in seconds) to wait for the value to be sent. This only applies with `use_monitor=False`, or if the PV is not automatically monitored. Otherwise, the most recently received value will be sent immediately.

The `with_ctrlvars` option requests DBR_CTRL data, including control limits, precision, and so on, in addition to the value normally returned. This metadata will be available by accessing various attributes such as `lower_ctrl_limit`. 
See *Automatic Monitoring of a PV* for more on monitoring PVs and *The wait and timeout options for get(), ca.get_complete()* for more details on what happens when a `pv.get()` times out.

```python
pv.get_with_metadata([form=None, count=None, as_string=False, as_numpy=True, timeout=None, use_monitor=True, with_ctrlvars=False])
```

Returns a dictionary of the current value and associated metadata

**Parameters**

- `form` ({'native', 'time', 'ctrl', None}) – EPICS data type to request: the ‘native’, or the ‘ctrl’ (Control) or ‘time’ variant. Defaults to the PV instance attribute `form`.
- `count` (integer or None) – maximum number of array elements to return
- `as_string` (True/False) – whether to return the string representation of the value.
- `as_numpy` – whether to try to return a numpy array where appropriate.
- `timeout` (float or None) – maximum time to wait for data before returning `None`.
- `use_monitor` (True/False) – whether to rely on monitor callbacks or explicitly get value now.

See `PV.get`, above, for further notes on each of these parameters.

Each request to EPICS can optionally contain additional metadata associated with the value. While `PV.get` updates the PV instance with any metadata, `get_with_metadata` will return the requested metadata and value in a dictionary.

The exception is when the PV is set to auto-monitor and the `use_monitor` parameter here is set. This means that both the value and metadata will used the cached values instead of making a new request. Because of this, the metadata and value returned here will be a full dictionary of all known metadata for the PV instance.

```python
pv.put(value, wait=False, timeout=30.0, use_complete=False, callback=None, callback_data=None)
```

set the PV value, optionally waiting to return until processing has completed, or setting the `put_complete` to indicate complete-ness.

**Parameters**

- `value` – value to set PV
- `wait` (True/False) – whether to wait for processing to complete (or time-out) before returning.
- `timeout` (float) – maximum time to wait for processing to complete before returning anyway.
- `use_complete` (True/False) – whether to use a built-in callback to set `put_complete`.
- `callback` (None or a valid python function) – user-supplied function to run when processing has completed.
- `callback_data` – extra data to pass on to a user-supplied callback function.

The `wait` and `callback` arguments, as well as the ‘use_complete’ / `put_complete` attribute give a few options for knowing that a `put()` has completed. See *Put with wait, put callbacks, and put_complete* for more details.

```python
pv.get_ctrlvars()
```

returns a dictionary of the control values for the PV. This dictionary may have many members, depending on the data type of PV. See the *Table of Control Attributes* for details.


```
pyEpics: Python Epics Channel Access, Release 3.3.2

pv.get_timevars()
returns a dictionary of the time values for the PV, which include status, severity, and the timestamp from the CA server.

pv.poll([evt=1.e-4, iot=1.0])
poll for changes. This simply calls epics.ca.poll()
Parameters
- evt (float) – time to pass to epics.ca.pend_event()
- iot (float) – time to pass to epics.ca.pend_io()

pv.connect([timeout=None])
this explicitly connects a PV, and returns whether or not it has successfully connected. It is probably not that useful, as connection should happen automatically. See wait_for_connection().
Parameters timeout (float) – maximum connection time, passed to epics.ca.connect_channel()
Return type True/False
if timeout is None, the PVs connection_timeout parameter will be used. If that is also None, epics.ca.DEFAULT_CONNECTION_TIMEOUT will be used.

pv.wait_for_connection([timeout=None])
this waits until a PV is connected, or has timed-out waiting for a connection. Returns whether the connection has occurred.
Parameters timeout (float) – maximum connection time.
Return type True/False
if timeout is None, the PVs connection_timeout parameter will be used. If that is also None, epics.ca.DEFAULT_CONNECTION_TIMEOUT will be used.

pv.disconnect()
disconnect a PV, clearing all callbacks.

pv.reconnect()
reconnect (or try to) a disconnected PV.

pv.clear_auto_monitor()
turn off automatic monitoring of a PV. Note that this will suspend all event callbacks on a PV at the CA level by calling epics.ca.clear_subscription(), but will not clear the list of PVs callbacks. This means that doing reconnect() will resume event processing including any callbacks or the PV.

pv.add_callback(callback=None, index=None, with_ctrlvars=True, **kw)
adds a user-defined callback routine to be run on each change event for this PV. Returns the integer index for the callback.
Parameters
- callback (None or callable) – user-supplied function to run when PV changes.
- index (None (integer will be produced) or immutable) – identifying key for this callback
- with_ctrlvars – whether to (try to) make sure that accurate control values will be sent to the callback.
- kw – additional keyword/value arguments to pass to each execution of the callback.

Return type integer
```

Chapter 3. PV: Epics Process Variables
Note that multiple callbacks can be defined, each having its own index (a dictionary key, typically an integer). When a PV changes, all the defined callbacks will be executed. They will be called in order (by sorting the keys of the `callbacks` dictionary).

See also: `callbacks` attribute, User-supplied Callback functions

```python
PV.remove_callback(index=None)
```

remove a user-defined callback routine using supplied

**Parameters**
- `index` (None or integer) – index of user-supplied function, as returned by `add_callback()`, and also to key for this callback in the `callbacks` dictionary.

**Return type**
- integer

If only one callback is defined an index=''None'', this will clear the only defined callback.

See also: `callbacks` attribute, User-supplied Callback functions

```python
PV.clear_callbacks()
```

remove all user-defined callback routine.

```python
PV.run_callbacks()
```

execute all user-defined callbacks right now, even if the PV has not changed. Useful for debugging!

See also: `callbacks` attribute, User-supplied Callback functions

```python
PV.run_callback(index)
```

execute a particular user-defined callback right now, even if the PV has not changed. Useful for debugging!

See also: `callbacks` attribute, User-supplied Callback functions

```python
PV.force_read_access_rights()
```

force a read of the access rights for a PV. Normally, a PV will have access rights determined automatically and subscribe to changes in access rights. But sometimes (especially 64-bit Windows), the automatically reported values are wrong. This methods will explicitly read the access rights.

### 3.1.2 attributes

A PV object has many attributes, each associated with some property of the underlying PV: its `value`, `host`, `count`, and so on. For properties that can change, the PV attribute will hold the latest value for the corresponding property. Most attributes are read-only, and cannot be assigned to. The exception to this rule is the `value` attribute.

```python
PV.value
```

The current value of the PV.

**Note:** The `value` attribute can be assigned to. When read, the latest value will be returned, even if that means a `get()` needs to be called.

Assigning to `value` is equivalent to setting the value with the `put()` method.

```python
>>> from epics import PV
>>> p1 = PV('xxx.VAL')
>>> print p1.value
1.00
>>> p1.value = 2.00
```

```python
PV.char_value
```

The string representation of the string, as described in `get()`.

```python
PV.status
```

The PV status, which will be 1 for a Normal, connected PV.
`pv.type`  
string describing data type of PV, such as `double`, `float`, `enum`, `string`, `int`, `long`, `char`, or one of the `ctrl` or `time` variants of these, which will be named `ctrl_double`, `time_enum`, and so on. See the Table of DBR Types

`pv.ftype`  
The integer value (from the underlying C library) indicating the PV data type according to Table of DBR Types

`pv.host`  
string of host machine provide this PV.

`pv.count`  
number of data elements in a PV. 1 except for waveform PVs, where it gives the number of elements in the waveform. For recent versions of Epics Base (3.14.11 and later?), this gives the `.NORD` field, which gives the number of elements last put into the PV and which may be less than the maximum number allowed (see `nelm` below).

`pv.nelm`  
number of data elements in a PV. 1 except for waveform PVs where it gives the maximum number of elements in the waveform. For recent versions of Epics Base (3.14.11 and later?), this gives the `.NELM` parameter. See also the `count` attribute above.

`pv.read_access`  
Boolean (True/False) for whether PV is readable

`pv.write_access`  
Boolean (True/False) for whether PV is writable

`pv.access`  
string describing read/write access. One of ‘read/write’,’read-only’,’write-only’, ‘no access’.

`pv.severity`  
severity value of PV. Usually 0 for PVs that are not in an alarm condition.

`pv.timestamp`  
floating point timestamp (relative to the POSIX time origin, not the EPICS time origin) of the last event seen for this PV. Note that this is will contain the timestamp from the Epics server if the PV object was created with the `form='time'` option. Otherwise, the timestamp will be set to time according to the client, indicating when the data arrive from the server.

`pv.posixseconds`  
Integer number of seconds (relative to the POSIX time origin, not the EPICS time origin) of the last event seen for this PV. This will be set only if the PV object was created with the `form='time'` option, and will reflect the timestamp from the server. Otherwise, this value will be 0 which can be used to signal that the timestamp attribute is from the client.

`pv.nanoseconds`  
Integer number of nanoseconds for the last event seen for this PV. This will be set only if the PV object was created with the `form='time'` option, and will give higher time resolution than the timestamp attribute.

`pv.precision`  
number of decimal places of precision to use for float and double PVs

`pv.units`  
string of engineering units for PV

`pv.enum_strs`  
a list of strings for the enumeration states of this PV (for enum PVs)

`pv.info`  
a string paragraph (ie, including newlines) showing much of the information about the PV.
pv.\texttt{lower\_disp\_limit}
pv.\texttt{upper\_alarm\_limit}
pv.\texttt{lower\_alarm\_limit}
pv.\texttt{lower\_warning\_limit}
pv.\texttt{upper\_warning\_limit}
pv.\texttt{upper\_ctrl\_limit}
pv.\texttt{lower\_ctrl\_limit}

These are all the various kinds of limits for a PV.

pv.\texttt{put\_complete}

\texttt{a Boolean (True/False) value for whether the most recent put() has completed.}

pv.\texttt{callbacks}

\texttt{a dictionary of currently defined callbacks, to be run on changes to the PV. This dictionary has integer keys (generally in increasing order of when they were defined) which sets which order for executing the callbacks. The values of this dictionary are tuples of (callback, keyword_arguments).}

\textbf{Note: The \texttt{callbacks} attribute can be assigned to or manipulated directly. This is not recommended. Use the methods \texttt{add\_callback()}, \texttt{remove\_callback()}, and \texttt{clear\_callbacks()} instead of altering this dictionary directly.}

pv.\texttt{connection\_callbacks}

\texttt{a simple list of connection callbacks: functions to be run when the connection status of the PV changes. See User-supplied Connection Callback functions for more details.}

pv.\texttt{access\_callbacks}

\texttt{an list of access callbacks: functions to be run when the access rights of the PV changes. See User-supplied Access Rights Callback functions for more details.}

### 3.2 String representation for a PV

The string representation for a PV, as returned either with the \texttt{as\_string} argument to \texttt{epics.ca.get()} or from the \texttt{char\_value} attribute (they are equivalent) needs some further explanation.

The value of the string representation (hereafter, the \texttt{char\_value}), will depend on the native type and count of a PV. \textit{Table of String Representations}

Table of String Representations: How raw data \texttt{value} is mapped to \texttt{char\_value} for different native data types.

<table>
<thead>
<tr>
<th>data types</th>
<th>count</th>
<th>char_value</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>1</td>
<td>\texttt{=} value</td>
</tr>
<tr>
<td>char</td>
<td>1</td>
<td>\texttt{=} value</td>
</tr>
<tr>
<td>short</td>
<td>1</td>
<td>\texttt{=} \texttt{str(value)}</td>
</tr>
<tr>
<td>long</td>
<td>1</td>
<td>\texttt{=} \texttt{str(value)}</td>
</tr>
<tr>
<td>enum</td>
<td>1</td>
<td>\texttt{=} \texttt{enum_str[value]}</td>
</tr>
<tr>
<td>double</td>
<td>1</td>
<td>\texttt{=} (“%%.%if” % (precision)) % value</td>
</tr>
<tr>
<td>float</td>
<td>1</td>
<td>\texttt{=} (“%%.%if” % (precision)) % value</td>
</tr>
<tr>
<td>char</td>
<td>&gt; 1</td>
<td>\texttt{=} long string from bytes in array</td>
</tr>
<tr>
<td>all others</td>
<td>&gt; 1</td>
<td>\texttt{=} &lt;array size=*count*, type=*type*&gt;&gt;</td>
</tr>
</tbody>
</table>
For double/float values with large exponents, the formatting will be \( (\text{"%%.%ig"} \% \text{precision}) \% \text{value} \). For character waveforms \((\text{char data with count > 1})\), the \text{char_value} will be set according to:

\begin{verbatim}
>>> firstnull = val.index(0)
>>> if firstnull == -1: firstnull= len(val)
>>> char_value = ''.join([chr(i) for i in val[:firstnull]]).rstrip()
\end{verbatim}

### 3.3 Automatic Monitoring of a PV

When creating a PV, the \textit{auto_monitor} parameter specifies whether the PV should be automatically monitored or not. Automatic monitoring means that an internal callback will be registered for changes. Any callbacks defined by the user will be called by this internal callback when changes occur.

For most scalar-value PVs, this automatic monitoring is desirable, as the PV will see all changes (and run callbacks) without any additional interaction from the user. The PV’s value will always be up-to-date and no unnecessary network traffic is needed.

Possible values for \textit{auto_monitor} are:

- **False** For some PVs, especially those that change much more rapidly than you care about or those that contain large arrays as values, auto_monitoring can add network traffic that you don’t need. For these, you may wish to create your PVs with \textit{auto_monitor=False}. When you do this, you will need to make calls to \textit{get()} to explicitly get the latest value.

- **None** The default value for \textit{auto_monitor} is None, and is set to True if the element count for the PV is smaller than \texttt{epics.ca.AUTOMONITOR_MAXLENGTH} (default of 65536). To suppress monitoring of PVs with fewer array values, you will have to explicitly turn \textit{auto_monitor} to False. For waveform arrays with more elements, automatic monitoring will not be done unless you explicitly set \textit{auto_monitor=True}, or to an explicit mask. See \textit{Strategies for working with large arrays} for more details.

- **True** When \textit{auto_monitor} is set to True, the value will be monitored using the default subscription mask set at \texttt{epics.ca.DEFAULT_SUBSCRIPTION_MASK}.

This mask determines which kinds of changes cause the PV to update. By default, the subscription updates when the PV value changes by more than the monitor deadband, or when the PV alarm status changes. This behavior is the same as the default in EPICS’ \textit{camonitor} tool.

- **Mask** It is also possible to request an explicit type of CA subscription by setting \textit{auto_monitor} to a numeric subscription mask made up of \texttt{dbr.DBE_ALARM}, \texttt{dbr.DBE_LOG} and/or \texttt{dbr.DBE_VALUE}. This mask will be passed directly to \texttt{epics.ca.create_subscription()}. An example would be:

\begin{verbatim}
pv1 = PV('AAA', auto_monitor=\texttt{dbr.DBE\_VALUE})
pv2 = PV('BBB', auto_monitor=\texttt{dbr.DBE\_VALUE|dbr.DBE\_ALARM})
pv3 = PV('CCC', auto_monitor=\texttt{dbr.DBE\_VALUE|dbr.DBE\_ALARM|dbr.DBE\_LOG})
\end{verbatim}

which will generate callbacks for pv1 only when the value of ‘AAA’ changes, while pv2 will receive callbacks if the value or alarm state of ‘BBB’ changes, and pv3 will receive callbacks for all changes to ‘CCC’. Note that these \texttt{dbr.DBE\_****} constants are ORed together as a bitmask.

### 3.4 User-supplied Callback functions

This section describes user-defined functions that are called when the value of a PV changes. These callback functions are useful as they allow you to be notified of changes without having to continually ask for a PVs current value. Much of this information is similar to that in \textit{User-supplied Callback functions} for the \texttt{ca} module, though there are some important enhancements to callbacks on \texttt{PV} objects.
You can define more than one callback function per PV to be run on value changes. These functions can be specified when creating a PV, with the `callback` argument which can take either a single callback function or a list or tuple of callback functions. After a PV has been created, you can add callback functions with `add_callback()`, remove them with `remove_callback()`, and explicitly run them with `run_callback()`. Each callback has an internal unique `index` (a small integer number) that can be used for specifying which one to add, remove, and run.

When defining a callback function to be run on changes to a PV, it is important to know two things:

1. how your function will be called.
2. what is permissible to do inside your callback function.

Callback functions will be called with several keyword arguments. You should be prepared to have them passed to your function, and should always include `**kw` to catch all arguments. Your callback will be sent the following keyword parameters:

- `pvname`: the name of the pv
- `value`: the latest value
- `char_value`: string representation of value
- `count`: the number of data elements
- `ftype`: the numerical CA type indicating the data type
- `type`: the python type for the data
- `status`: the status of the PV (1 for OK)
- `precision`: number of decimal places of precision for floating point values
- `units`: string for PV units
- `severity`: PV severity
- `timestamp`: timestamp from CA server.
- `read_access`: read access (True/False)
- `write_access`: write access (True/False)
- `access`: string description of read- and write-access
- `host`: host machine and CA port serving PV
- `enum_strs`: the list of enumeration strings
- `upper_disp_limit`: upper display limit
- `lower_disp_limit`: lower display limit
- `upper_alarm_limit`: upper alarm limit
- `lower_alarm_limit`: lower alarm limit
- `upper_warning_limit`: upper warning limit
- `lower_warning_limit`: lower warning limit
- `upper_ctrl_limit`: upper control limit
- `lower_ctrl_limit`: lower control limit
- `chid`: integer channel ID
- `cb_info`: (index, self) tuple containing callback ID and the PV object

3.4. User-supplied Callback functions
Some of these may not be directly applicable to all PV data types, and some values may be None if the control parameters have not yet been fetched with get_ctrlvars().

It is important to keep in mind that the callback function will be run inside a CA function, and cannot reliably make any other CA calls. It is helpful to think “this all happens inside of a pend_event() call”, and in an epics thread that may or may not be the main thread of your program. It is advisable to keep the callback functions short and not resource-intensive. Consider strategies which use the callback only to record that a change has occurred and then act on that change later – perhaps in a separate thread, perhaps after pend_event() has completed.

The cb_info parameter supplied to the callback needs special attention, as it is the only non-Epics information passed. The cb_info parameter will be a tuple containing (index, self) where index is the key for the callbacks dictionary for the PV and self is PV object. A principle use of this tuple is to remove the current callback if an error happens, as for example in GUI code if the widget that the callback is meant to update disappears.

3.5 User-supplied Connection Callback functions

A connection callback is a user-defined function that is called when the connection status of a PV changes – that is, when a PV initially disconnects, reconnects due to the process serving the PV going away, or loss of network connection. A connection callback can be specified when a PV is created, or can be added by appending to the connection_callbacks list. If there is more than one connection callback defined, they will all be run when the connection state changes.

A connection callback should be prepared to receive the following keyword arguments:

- **pvname**: the name of the pv
- **conn**: the connection status

where conn will be either True or False, specifying whether the PV is now connected. A simple example is given below.

3.6 User-supplied Access Rights Callback functions

An access rights callback is a user-defined function that is called when the access rights - read/write permissions - of a PV undergo changes. The callback will be invoked upon successful initialization and at all events that change a PV’s access rights, including disconnection and reconnection events. An access rights callback can be specified when a PV is created, or can be added by appending to the accessCallbacks list of the PV object. If there are multiple access rights callbacks defined for a PV, they will all be run on access rights events.

3.7 Put with wait, put callbacks, and put_complete

Some EPICS records take a significant amount of time to fully process, and sometimes you want to wait until the processing completes before going on. There are a few ways to accomplish this. First, one can simply wait until the processing is done:

```python
import epics
p = epics.PV('XXX')
p.put(1.0, wait=True)
print 'Done'
```

This will hang until the processing of the PV completes (motor moving, etc) before printing ‘Done’. You can also specify a maximum time to wait – a timeout (in seconds):
which will wait up to 30 seconds. For the pedantic, this timeout should not be used as an accurate clock – the actual
wait time may be slightly longer.

A second method is to use the ‘use_complete’ option and watch for the put_complete attribute to become True
after a put(). This is somewhat more flexible than using wait=True as above, because you can more carefully control
how often you look for a put() to complete, and what to do in the interim. A simple example would be:

```python
p.put(1.0, use_complete=True)
waiting = True
while waiting:
    time.sleep(0.001)
    waiting = not p.put_complete
```

An additional advantage of this approach is that you can easily wait for multiple PVs to complete with python’s built-in all function, as with:

```python
pvgroup = (epics.PV('XXX'), epics.PV('YYY'), epics.PV('ZZZ'))
newvals = (1.0, 2.0, 3.0)
for pv, val in zip(pvgroup, newvals):
    pv.put(val, use_complete=True)
waiting = True
while waiting:
    time.sleep(0.001)
    waiting = not all([pv.put_complete for pv in pvgroup])
print 'All puts are done!'```

For maximum flexibility, one can all define a put callback, a function to be run when the put() has completed.
This function requires a pvname keyword argument, but will receive no others, unless you pass in data with the callback_data argument (which should be dict-like) to put(). A simple example would be:

```python
pv = epics.PV('XXX')
def onPutComplete(pvname=None, **kws):
    print 'Put done for %s' % pvname
pv.put(1.0, callback=onPutComplete)
```

### 3.8 The get_pv() function and _PVcache_ cache of PVs

As mentioned in the previous chapter, a cache of PVs is maintained for each process using pyepics. When using epics.caget(), epics.caput() and so forth, or when creating a PV directly, the corresponding PV is kept in a global cache, held in pv._PVcache_.

The function get_pv() will retrieve the named PV from this cache, or create a new PV if one is not found. In long-running or complex processes, it is not unusual to access a particular PV many times, perhaps calling a function that creates a PV but only keeping that PV object for the life of the function. Using get_pv() instead of creating a PV can improve performance (the PV is already connected) and is highly recommended.

```python
pv.get_pv(pvname[, form='time'[, connect=False[, timeout=5[, context=None[, **kws ]]]]]])
```

retrieves a PV from _PVcache or creates and returns a new PV.

**Parameters**

- **pvname** – name of Epics Process Variable
• **form** (string, one of ('native','ctrl', or 'time')) – which epics data type to use: the ‘native’, or the ‘ctrl’ (Control) or ‘time’ variant.

• **connect** (True/False) – whether to wait for the PV to connect.

• **timeout** (float or None) – maximum time to wait (in seconds) for value before returning None.

• **context** (integer or None (default)) – integer threading context.

Additional keywords are passed directly to `PV`.

```python
pv._PVcache_
A cache of PV objects for the process.
```

### 3.9 Examples

Some simple examples using PVS follow.

#### 3.9.1 Basic Use

The simplest approach is to simply create a PV and use its `value` attribute:

```python
>>> from epics import PV
>>> p1 = PV('xxx.VAL')
>>> print p1.value
1.00
>>> p1.value = 2.00
```

The `print p1.value` line automatically fetches the current PV value. The `p1.value = 2.00` line does a `put()` to set the value, causing any necessary processing over the network.

The above example is equivalent to

```python
>>> from epics import PV
>>> p1 = PV('xxx.VAL')
>>> print p1.get()
1.00
>>> p1.put(value = 2.00)
```

To get a string representation of the value, you can use either

```python
>>> print p1.get(as_string=True)
'1.000'
```

or, equivalently

```python
>>> print p1.char_value
'1.000'
```

#### 3.9.2 Requests including Metadata

It is also possible to get the metadata associated with a single Channel Access request using `get_with_metadata()`:

```python
```
3.9.3 Example of using info and more properties examples

A PV has many attributes. This can be seen from its *info* paragraph:

```python
>>> from epics import epics
>>> p = epics.PV('13IDA:m3')
>>> print(p.info)
== 13IDA:m3 (native_double) ==
  value = 0.2
  char_value = '0.200'
  count = 1
  type = double
  units = mm
  precision = 3
  host = ioc13ida.cars.aps.anl.gov:5064
  access = read/write
  status = 0
  severity = 0
  timestamp = 1274809682.967 (2010-05-25 12:48:02.967364)
  upper_ctrl_limit = 5.49393415451
  lower_ctrl_limit = -14.5060658455
  upper_disp_limit = 5.49393415451
  lower_disp_limit = -14.5060658455
  upper_alarm_limit = 0.0
  lower_alarm_limit = 0.0
  upper_warning_limit = 0.0
  lower_warning_limit = 0.0
```
PV is internally monitored, with 0 user-defined callbacks:
===============================================

The individual attributes can also be accessed as below. Many of these (the control attributes, see Table of Control Attributes) will not be filled in until either the info attribute is accessed or until get_ctrlvars() is called.

```python
>>> print p.type
double
>>> print p.units, p.precision, p.lower_disp_limit
mm 3 -14.5060658455
```

### 3.9.4 Getting a string value

It is not uncommon to want a string representation of a PVs value, for example to show in a display window or to write to some report. For string PVs and integer PVs, this is a simple task. For floating point values, there is ambiguity how many significant digits to show. EPICS PVs all have a precision field, which sets how many digits after the decimal point should be described. In addition, for ENUM PVs, it would be desire able to get at the name of the ENUM state, not just its integer value.

To get the string representation of a PVs value, use either the char_value attribute or the as_string=True argument to get()

### 3.9.5 Example of put()

To put a new value to a variable, either of these two approaches can be used:

```python
>>> import epics
>>> p = epics.PV('XXX')
>>> p.put(1.0)
```

Or (equivalently):

```python
>>> import epics
>>> p = epics.PV('XXX')
>>> p.value = 1.0
```

The value attribute is the only attribute that can be set.

### 3.9.6 Example of simple callback

It is often useful to get a notification of when a PV changes. In general, it would be inconvenient (and possibly inefficient) to have to continually ask if a PVs value has changed. Instead, it is better to set a callback function: a function to be run when the value has changed.

A simple example of this would be:

```python
import epics
import time

def onChanges(pvname=None, value=None, char_value=None, **kw):
    print 'PV Changed! ', pvname, char_value, time.ctime()
```

(continues on next page)
This first defines a *callback function* called `onChanges()` and then simply waits for changes to happen. Note that the callback function should take keyword arguments, and generally use `**kw` to catch all arguments. See *User-supplied Callback functions* for more details.

### 3.9.7 Example of connection callback

A connection callback:

```python
# example of using a connection callback that will be called
# for any change in connection status
import epics
import time
import sys
from pvnames import motor1

write = sys.stdout.write

def onConnectionChange(pvname=None, conn=None, **kws):
    write('PV connection status changed: %s %s
' % (pvname, repr(conn)))
    sys.stdout.flush()

def onValueChange(pvname=None, value=None, host=None, **kws):
    write('PV value changed: %s (%s) %s
' % (pvname, host, repr(value)))
    sys.stdout.flush()

mypv = epics.PV(motor1, connection_callback=onConnectionChange, callback=onValueChange)

mypv.get()

write('Now waiting, watching values and connection changes:
')
t0 = time.time()
while time.time() - t0 < 300:
    time.sleep(0.01)
```

### 3.9.8 Example of an access rights callback

Associating an access rights callback with a PV:

```python
import epics
import time
```

(continues on next page)
def access_rights_callback(read_access, write_access, pv=None):
    print "%s - read=%s, write=%s" % (pv.pvname, read_access, write_access)

# should immediately see the message upon connection
apv = epics.PV('pvname', access_callback=access_rights_callback)

try:
    start = time.time()
    while (time.time() - start) < 30:
        time.sleep(0.25)
except KeyboardInterrupt:
    pass
The ca module provides a low-level wrapping of the EPICS Channel Access (CA) library, using ctypes. Most users of the epics module will not need to be concerned with most of the details here, and will instead use the simple procedural interface (epics.caget(), epics.caput() and so on), or use the epics.PV class to create and use epics PV objects.

4.1 General description, difference with C library

The ca module provides a fairly complete mapping of the C interface to the CA library while also providing a pleasant Python experience. It is expected that anyone using this module is somewhat familiar with Channel Access and knows where to consult the Channel Access Reference Documentation. Here, we focus on the differences with the C interface, and assume a general understanding of what the functions are meant to do.

4.1.1 Name Mangling

As a general rule, a CA function named ca_XXX in the C library will have the equivalent function called XXX in the ca module. This is because the intention is that one will import the ca module with

```python
>>> from epics import ca
```

so that the Python function ca.XXX() will corresponds to the C function ca_XXX. That is, the CA library called its functions ca_XXX because C does not have namespaces. Python does have namespaces, and so they are used.

Similar name un-mangling also happens with the DBR prefixes for constants, held here in the dbr module. Thus, the C constant DBR_STRING becomes dbr.STRING in Python.

4.1.2 Other Changes and Omissions

Several function in the C version of the CA library are not implemented in the Python module. Most of these unimplemented functions are currently seen as unnecessary for Python, though some of these could be added without much trouble if needed. See Omissions for further details.

In addition, while the CA library supports several DBR types in C, not all of these are supported in Python. Only native types and their DBR_TIME and DBR_CTRL variants are supported here. The DBR_STS and DBR_GR variants are not, as they are subsets of the DBR_CTRL type, and space optimization is not something you’ll be striving for with Python. Several dbr_XXX functions are also not supported, as they appear to be needed only to be able to dynamically allocate memory, which is not necessary in Python.
4.2 Initialization, Finalization, and Life-cycle

The Channel Access library must be initialized before it can be used. There are 3 main reasons for this need:

1. CA requires a context model (preemptive callbacks or non-preemptive callbacks) to be specified before any actual calls can be made.
2. the ctypes interface requires that the shared library be loaded before it is used.
3. ctypes also requires that references to the library and callback functions be kept for the life-cycle of CA-using part of a program (or else they will be garbage collected).

As far as is possible, the ca module hides the details of the CA lifecycle from the user, so that it is not necessary to worry about explicitly initializing a Channel Access session. Instead, the library is initialized as soon as it is needed, and intervention is really only required to change default settings. The ca module also handles finalizing the CA session, so that core-dumps and warning messages do not happen due to CA still being ‘alive’ as a program ends.

Because some users may wish to customize the initialization and finalization process, the detailed steps will be described here. These initialization and finalization tasks are handled in the following way:

• The libca variable in the ca module holds a permanent, global reference to the CA shared object library (DLL).
• the function initialize_libca() is called to initialize libca. This function takes no arguments, but does use the global Boolean PREEMPTIVE_CALLBACK (default value of True) to control whether preemptive callbacks are used.
• the function finalize_libca() is used to finalize libca. Normally, this function is registered to be called when a program ends with atexit.register(). Note that this only gets called on a graceful shutdown. If the program crashes (for a non-CA related reason, for example), this finalization may not be done, and connections to Epics Variables may not be closed completely on the Channel Access server.

epics.ca.PREEMPTIVE_CALLBACK sets whether preemptive callbacks will be used. The default value is True. If you wish to run without preemptive callbacks this variable MUST be set before any other use of the CA library. With preemptive callbacks enabled, EPICS communication will not require client code to continually poll for changes. With preemptive callback disabled, you will need to frequently poll epics with pend_io() and func:pend_event.

epics.ca.DEFAULT_CONNECTION_TIMEOUT sets the default timeout value (in seconds) for connect_channel(). The default value is 2.0

epics.ca.AUTOMONITOR_MAXLENGTH sets the default array length (ie, how many elements an array has) above which automatic conversion to numpy arrays and automatic monitoring for PV variables is suppressed. The default value is 65536. To be clear: waveforms with fewer elements than this value will be automatically monitored changes, and will be converted to numpy arrays (if numpy is installed). Larger waveforms will not be automatically monitored.

*Working with waveform / array data* and *Strategies for working with large arrays* for more details.

4.3 Using the CA module

Many general-purpose CA functions that deal with general communication and threading contexts are very close to the C library:

epics.ca.initialize_libca() Initialize the Channel Access library.

This loads the shared object library (DLL) to establish Channel Access Connection. The value of PREEMPTIVE_CALLBACK sets the pre-emptive callback model.
This must be called prior to any actual use of the CA library, but will be called automatically by the the

\texttt{withCA()} decorator, so you should not need to call this directly from most real programs.

Returns

\texttt{libca} [object] ca library object, used for all subsequent ca calls

See also:

\texttt{withCA} decorator to ensure CA is initialized

Notes

This function must be called prior to any real CA calls.

\texttt{epics.ca.finalize\_libca()}
shutdowm channel access:
run \texttt{clear\_channel()} for all chids in \_cache, then calls \texttt{flush\_io()} and \texttt{poll()} a few times.

Parameters

\texttt{maxtime} [float] maximum time (in seconds) to wait for \texttt{flush\_io()} and \texttt{poll()} to com-

\texttt{epics.ca.pend\_io(timeout=1.0)}
polls CA for i/o.

\texttt{epics.ca.pend\_event(timeout=1.e-5)}
polls CA for events

\texttt{epics.ca.poll(evt=1.e-5[, iot=1.0])}
a convenience function which is equivalent to:: pend\_event(evt) pend\_io\_iot

\texttt{epics.ca.create\_context()} Create a new context, using the value of \texttt{PREEMPTIVE\_CALLBACK} to set the context type. Note that both\texttt{context\_create} and \texttt{create\_context} (which is more consistent with the Verb\_Object of the rest of the CA library) are supported.

Parameters

\texttt{ctx} [int] 0 – No preemptive callbacks, 1 – use use preemptive callbacks, None – use value of\texttt{PREEMPTIVE\_CALLBACK}

\texttt{epics.ca.destroy\_context()} destroy current context

\texttt{epics.ca.current\_context()} return the current context

\texttt{epics.ca.attach\_context(context)} attach to the supplied context

\texttt{epics.ca.detach\_context()} detach context

\texttt{epics.ca.use\_initial\_context()} Attaches to the context created when libca is initialized. Using this function is recommended when writing threaded programs that using CA.

See also:

4.3. Using the CA module
Using Python Threads

epics.ca.client_status(context, level)
print (to stderr) information about Channel Access status, including status for each channel, and search and connection statistics.

epics.ca.version()
Print Channel Access version string. Currently, this should report ‘4.13’

epics.ca.message(status)
Print a message corresponding to a Channel Access status return value.

epics.ca.flush_io()
flush i/o

epics.ca.replace_printf_handler(fcn=None)
replace the normal printf() output handler with the supplied function (defaults to sys.stderr.write())

Warning: replace_printf_handler() appears to not actually work.
We think this is due to a real limitation of Python’s ctypes module not supporting the mapping of C va_list function arguments to Python. If you are interested in this or have ideas of how to fix it, please let us know.

### 4.3.1 Creating and Connecting to Channels

The basic channel object is the Channel ID or chid. With the CA library (and ca module), one creates and acts on the chid values. These are simply ctypes.c_long (C long integers) that hold the memory address of the C representation of the channel, but it is probably a good idea to treat these as object instances.

epics.ca.create_channel(pvname, connect=False, callback=None, auto_cb=True)
create a Channel for a given pvname

creates a channel, returning the Channel ID chid used by other functions to identify this channel.

**Parameters**

- pvname [string] the name of the PV for which a channel should be created.
- connect [bool] whether to (try to) connect to PV as soon as possible.
- auto_cb [bool] whether to automatically use an internal connection callback.
- callback [callable or None] user-defined Python function to be called when the connection state changes.

**Returns**

- chid [ctypes.c_long] channel ID.

**Notes**

1. The user-defined connection callback function should be prepared to accept keyword arguments of

<table>
<thead>
<tr>
<th>keyword</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>pvname</td>
<td>name of PV</td>
</tr>
<tr>
<td>chid</td>
<td>Channel ID</td>
</tr>
<tr>
<td>conn</td>
<td>whether channel is connected</td>
</tr>
</tbody>
</table>
2. If auto_cb is True, an internal connection callback is used so that you should not need to explicitly connect to a channel, unless you are having difficulty with dropped connections.

3. If the channel is already connected for the PV name, the callback will be called immediately.

```python
epics.ca.connect_channel(chid, timeout=None, verbose=False)
```

connect to a channel, waiting up to timeout for a channel to connect. It returns the connection state, True or False.

This is usually not needed, as implicit connection will be done when needed in most cases.

**Parameters**

- `chid` [ctypes.c_long] Channel ID
- `timeout` [float] maximum time to wait for connection.
- `verbose` [bool] whether to print out debugging information

**Returns**

- `connection_state` [bool] that is, whether the Channel is connected

**Notes**

1. If `timeout` is None, the value of `DEFAULT_CONNECTION_TIMEOUT` is used (defaults to 2.0 seconds).

2. Normally, channels will connect in milliseconds, and the connection callback will succeed on the first attempt.

3. For un-connected Channels (that are nevertheless queried), the ‘ts’ (timestamp of last connection attempt) and ‘failures’ (number of failed connection attempts) from the `_cache` will be used to prevent spending too much time waiting for a connection that may never happen.

Many other functions require a valid Channel ID, but not necessarily a connected Channel. These functions are essentially identical to the CA library versions, and include:

```python
epics.ca.name(chid)
```

return PV name for channel name

```python
epics.ca.host_name(chid)
```

return host name and port serving Channel

```python
epics.ca.element_count(chid)
```

return number of elements in Channel’s data. 1 for most Channels, > 1 for waveform Channels

```python
epics.ca.replace_access_rights_event(chid, callback=None)
```

```python
epics.ca.read_access(chid)
```

return read access for a Channel: 1 for True, 0 for False.

```python
epics.ca.write_access(chid)
```

return write access for a channel: 1 for True, 0 for False.

```python
epics.ca.field_type(chid)
```

return the integer DBR field type.

See the `ftype` column from *Table of DBR Types*.

```python
epics.ca.clear_channel(chid)
```

clear the channel

```python
epics.ca.state(chid)
```

return state (that is, attachment state) for channel

### 4.3. Using the CA module
A few additional pythonic functions have been added:

```python
epics.ca.isConnected(chid)
    return whether channel is connected: dbr.CS_CONN==state(chid)
```

This is True for a connected channel, False for an unconnected channel.

```python
epics.ca.access(chid)
    returns a string describing read/write access: one of no access, read-only, write-only, or read/write
```

```python
epics.ca.promote_type(chid[ , use_time=False[ , use_ctrl=False ] ])
    promotes the native field type of a chid to its TIME or CTRL variant. Returns the integer corresponding to the
promoted field value.
```

See Table of DBR Types.

```python
epics.ca._cache
    The ca module keeps a global cache of Channels that holds connection status and a bit of internal information
for all known PVs. This cache is not intended for general use.
```

```python
epics.ca.show_cache(print_out=True)
    print out a listing of PVs in the current session to standard output. Use the print_out=False option to be returned
the listing instead of having it printed out.
```

```python
epics.ca.clear_cache()
    Clears global caches of Epics CA connections, and fully detaches from the CA context. This is important when
doing multiprocessing (and is done internally by CAProcess), but can be useful to fully reset a Channel Access
session.
```

### 4.3.2 Interacting with Connected Channels

Once a chid is created and connected there are several ways to communicating with it. These are primarily en-
capsulated in the functions `get()`, `put()`, and `create_subscription()`, with a few additional functions for
retrieving specific information.

These functions are where this python module differs the most from the underlying CA library, and this is mostly due
to the underlying CA function requiring the user to supply DBR TYPE and count as well as chid and allocated space
for the data. In python none of these is needed, and keyword arguments can be used to specify such options.

```python
epics.ca.get(chid, ftype=None, count=None, as_string=False, as_numpy=True, wait=True, timeout=None)
    return the current value for a Channel. Note that there is not a separate form for array data.
```

**Parameters**

- **chid** [ctypes.c_long] Channel ID
- **ftype** [int] field type to use (native type is default)
- **count** [int] maximum element count to return (full data returned by default)
- **as_string** [bool] whether to return the string representation of the value. See notes below.
- **as_numpy** [bool] whether to return the Numerical Python representation for array / waveform
data.
- **wait** [bool] whether to wait for the data to be received, or return immediately.
- **timeout** [float] maximum time to wait for data before returning None.

**Returns**
data  [object] Normally, the value of the data. Will return None if the channel is not connected, wait=False was used, or the data transfer timed out.

Notes

1. Returning None indicates an incomplete get

2. The as_string option is not as complete as the as_string argument for PV. get(). For Enum types, the name of the Enum state will be returned. For waveforms of type CHAR, the string representation will be returned. For other waveforms (with count > 1), a string like <array count=3, type=I> will be returned.

3. The as_numpy option will convert waveform data to be returned as a numpy array. This is only applied if numpy can be imported.

4. The wait option controls whether to wait for the data to be received over the network and actually return the value, or to return immediately after asking for it to be sent. If wait=False (that is, immediate return), the get operation is said to be incomplete. The data will be still be received (unless the channel is disconnected) eventually but stored internally, and can be read later with get_complete(). Using wait=False can be useful in some circumstances.

5. The timeout option sets the maximum time to wait for the data to be received over the network before returning None. Such a timeout could imply that the channel is disconnected or that the data size is larger or network slower than normal. In that case, the get operation is said to be incomplete, and the data may become available later with get_complete().

See Table of DBR Types for a listing of values of ftype,
See Strategies for working with large arrays for a discussion of strategies for how to best deal with very large arrays.
See Strategies for connecting to a large number of PVs for a discussion of when using wait=False can give a large performance boost.
See The wait and timeout options for get(), ca.get_complete() for further discussion of the wait and timeout options and the associated get_complete() function.

epics.ca.get_with_metadata (chid, ftype=None, count=None, as_string=False, as_numpy=True, wait=True, timeout=None)

Return the current value along with metadata for a Channel

Parameters

chid  [ctypes.c_long] Channel ID
ftype  [int] field type to use (native type is default)
count  [int] maximum element count to return (full data returned by default)
as_string  [bool] whether to return the string representation of the value. See notes.
as_numpy  [bool] whether to return the Numerical Python representation for array / waveform data.
wait  [bool] whether to wait for the data to be received, or return immediately.
timeout  [float] maximum time to wait for data before returning None.

Returns
data  [dict or None] The dictionary of data, guaranteed to at least have the ‘value’ key. Depending on ftype, other keys may also be present:
{'precision', 'units', 'status', 'severity', 'enum_strs', 'status', 'severity', 'timestamp', 'posixseconds', 'nanoseconds', 'upper_disp_limit', 'lower_disp_limit', 'upper_alarm_limit', 'upper_warning_limit', 'lower_warning_limit', 'lower_alarm_limit', 'upper_ctrl_limit', 'lower_ctrl_limit'}

Returns None if the channel is not connected, wait=False was used, or the data transfer timed out.

See also:
See func:get for additional usage notes.

epics.ca.get_complete(chid, ftype=None, count=None, as_string=False, as_numpy=True, timeout=None)
returns the current value for a Channel, completing an earlier incomplete get() that returned None, either because wait=False was used or because the data transfer did not complete before the timeout passed.

Parameters

chid [ctypes.c_long] Channel ID
ftype [int] field type to use (native type is default)
count [int] maximum element count to return (full data returned by default)
as_string [bool] whether to return the string representation of the value.
as_numpy [bool] whether to return the Numerical Python representation for array / waveform data.
timeout [float] maximum time to wait for data before returning None.

Returns
data [object] This function will return None if the previous get() actually completed, or if this data transfer also times out.

Notes

1. The default timeout is dependent on the element count:: default_timeout = 1.0 + log10(count) (in seconds)
2. Consult the doc for get() for more information.

See The wait and timeout options for get(), ca.get_complete() for further discussion.

epics.ca.get_complete_with_metadata(chid, ftype=None, count=None, as_string=False, as_numpy=True, timeout=None)
Returns the current value and associated metadata for a Channel

This completes an earlier incomplete get() that returned None, either because wait=False was used or because the data transfer did not complete before the timeout passed.

Parameters

chid [ctypes.c_long] Channel ID
ftype [int] field type to use (native type is default)
count [int] maximum element count to return (full data returned by default)
as_string [bool] whether to return the string representation of the value.
as_numpy [bool] whether to return the Numerical Python representation for array / waveform

data.

timeout [float] maximum time to wait for data before returning None.

Returns

data [dict or None] This function will return None if the previous get() actually completed,
or if this data transfer also times out.

See also:

See func:get_complete for additional usage notes.

epics.ca.put (chid, value, wait=False, timeout=30, callback=None, callback_data=None)

sets the Channel to a value, with options to either wait (block) for the processing to complete, or to execute a
supplied callback function when the process has completed.

Parameters

chid [ctypes.c_long] Channel ID

wait [bool] whether to wait for processing to complete (or time-out) before returning.

timeout [float] maximum time to wait for processing to complete before returning anyway.

callback [None or callable] user-supplied function to run when processing has completed.

callback_data [object] extra data to pass on to a user-supplied callback function.

Returns

status [int] 1 for success, -1 on time-out

Notes

1. Specifying a callback will override setting wait=True.

2. A put-callback function will be called with keyword arguments pvname=pvname,
data=callback_data

See User-supplied Callback functions for more on this put callback,

epics.ca.create_subscription (chid, use_time=False, use_ctrl=False, mask=None, callback=None)

create a subscription to changes. Sets up a user-supplied callback function to be called on any changes to the
channel.

Parameters

chid [ctypes.c_long] channel ID

use_time [bool] whether to use the TIME variant for the PV type

use_ctrl [bool] whether to use the CTRL variant for the PV type

ftype [integer or None] ftype to use, overriding native type, use_time or use_ctrl if None, the
native type is looked up, which requires a connected channel.

mask [integer or None] bitmask combination of dbr.DBE_ALARM, dbr.DBE_LOG, and
dbr.DBE_VALUE, to control which changes result in a callback. If None, defaults to
DEFAULT_SUBSCRIPTION_MASK.

callback [None or callable] user-supplied callback function to be called on changes

4.3. Using the CA module
timeout [None or int] connection timeout used for unconnected channels.

Returns

/callback_ref, user_arg_ref, event_id/ The returned tuple contains callback_ref an
/user_arg_ref/ which are references that should be kept for as long as the subscription
lives (otherwise they may be garbage collected, causing no end of trouble). event_id is the
id for the event (useful for clearing a subscription).

Notes

Keep the returned tuple in named variable!! if the return argument gets garbage collected, a coredump will
occur.

If the channel is not connected, the ftype must be specified for a successful subscription.

See User-supplied Callback functions for more on writing the user-supplied callback,

Warning: event_id is the id for the event (useful for clearing a subscription). You must keep the returned tuple
in active variables, either as a global variable or as data in an encompassing class. If you do not keep this data,
the return value will be garbage collected, the C-level reference to the callback will disappear, and you will see
coredumps.

On Linux, a message like:

```
Abort (core dumped)
```

is a hint that you have not kept this data.

epics.ca.DEFAULT_SUBSCRIPTION_MASK

This value is the default subscription type used when calling create_subscription() with mask=None.
It is also used by default when creating a PV object with auto_monitor is set to True.

The initial default value is dbr.DBE_ALARM|dbr.DBE_VALUE (i.e. update on alarm changes or value changes
which exceeds the monitor deadband.) The other possible flag in the bitmask is dbr.DBE_LOG for archive-
deadbond changes.

If this value is changed, it will change the default for all subsequent calls to create_subscription(), but
it will not change any existing subscriptions.

epics.ca.clear_subscription(event_id)

cancel subscription given its event_id

Several other functions are provided:

epics.ca.get_timestamp(chid)
return the timestamp of a Channel – the time of last update.

epics.ca.get_severity(chid)
return the severity of a Channel.

epics.ca.get_precision(chid)
return the precision of a Channel. For Channels with native type other than FLOAT or DOUBLE, this will be 0

epics.ca.get_enum_strings(chid)
return list of names for ENUM states of a Channel. Returns None for non-ENUM Channels
epics.ca.get_ctrlvars(chid)
return the CTRL fields for a Channel.

**Notes**

dependent on the native type, the keys may include status, severity, precision, units, enum_strs*, upper_disp_limit, lower_disp_limit, upper_alarm_limit*, lower_alarm_limit, upper_warning_limit*, lower_warning_limit, upper_ctrl_limit, lower_ctrl_limit

enum_strs will be a list of strings for the names of ENUM states.

See Table of Control Attributes

<table>
<thead>
<tr>
<th>attribute</th>
<th>data types</th>
</tr>
</thead>
<tbody>
<tr>
<td>status</td>
<td></td>
</tr>
<tr>
<td>severity</td>
<td></td>
</tr>
<tr>
<td>precision</td>
<td>0 for all but double, float</td>
</tr>
<tr>
<td>units</td>
<td></td>
</tr>
<tr>
<td>enum_strs</td>
<td>enum only</td>
</tr>
<tr>
<td>upper_disp_limit</td>
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</tr>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>upper_warning_limit</td>
<td></td>
</tr>
<tr>
<td>lower_warning_limit</td>
<td></td>
</tr>
<tr>
<td>upper_ctrl_limit</td>
<td></td>
</tr>
<tr>
<td>lower_ctrl_limit</td>
<td></td>
</tr>
</tbody>
</table>

Note that enum_strs will be a tuple of strings for the names of ENUM states.

epics.ca.get_timevars(chid)
returns a dictionary of TIME fields for a Channel. This will contain keys of status, severity, and timestamp.

### 4.3.3 Synchronous Groups

**Warning:** Synchronous groups are simulated in pyepics, but are not recommended, and probably don’t really make sense for usage within pyepics and using asynchronous i/o anyway.

Synchronous Groups are can be used to ensure that a set of Channel Access calls all happen together, as if in a transaction. Synchronous Groups should be avoided in pyepics, and are not well tested. They probably make little sens in the context of asynchronous I/O. The documentation here is given for historical purposes.

The idea is to first create a synchronous group, then add a series of sg_put() and sg_get() which do not happen immediately, and finally block while all the channel access communication is done for the group as a unit. It is important to not issue pend_io() during the building of a synchronous group, as this will cause pending sg_put() and sg_get() to execute.

epics.ca.sg_create()
create synchronous group. Returns a group id, gid, which is used to identify this group and to be passed to all other synchronous group commands.
epics.ca.sg_delete(gid)
   delete a synchronous group

epics.ca.sg_block(gid[, timeout=10.0])
   block for a synchronous group to complete processing

epics.ca.sg_get(gid, chid[, ftype=None[, as_string=False[, as_numpy=True]]]])
   synchronous-group get of the current value for a Channel. same options as get()

   This function will not immediately return the value, of course, but the address of the underlying data.

   After the sg_block() has completed, you must use _unpack() to convert this data address to the actual value(s).

Examples

>>> chid = epics.ca.create_channel(PV_Name)
>>> epics.ca.connect_channel(chid1)
>>> sg = epics.ca.sg_create()
>>> data = epics.ca.sg_get(sg, chid)
>>> epics.ca.sg_block(sg)
>>> print epics.ca._unpack(data, chid=chid)

epics.ca.sg_put(gid, chid, value)
   perform a put within a synchronous group.

   This put cannot wait for completion or for a a callback to complete.

epics.ca.sg_test(gid)
   test whether a synchronous group has completed.

epics.ca.sg_reset(gid)
   resets a synchronous group

4.4 Implementation details

The details given here should mostly be of interest to those looking at the implementation of the ca module, those interested in the internals, or those looking to translate lower-level C or Python code to this module.

4.4.1 DBR data types

   Table of DBR Types
<table>
<thead>
<tr>
<th>CA type</th>
<th>integer ftype</th>
<th>Python ctypes type</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
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<td>string</td>
</tr>
<tr>
<td>int</td>
<td>1</td>
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<td>float</td>
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</tr>
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</tr>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>ctrl_double</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

4.4.2 PySEVCHK and ChannelAccessException: checking CA return codes

**exception** epics.ca.ChannelAccessException

This exception is raised when the ca module experiences unexpected behavior and must raise an exception

epics.ca.**PySEVCHK** *(func_name, status[, expected=dbr.ECA_NORMAL]*)

This checks the return status returned from a libca.ca_*** and raises a ChannelAccessException if the value does not match the expected value (which is normally dbr.ECA_NORMAL.

The message from the exception will include the func_name (name of the Python function) and the CA message from message().

epics.ca.**withSEVCHK** *(fcn)*

decorator to raise a ChannelAccessException if the wrapped ca function does not return status = dbr.ECA_NORMAL. This handles the common case of running PySEVCHK() for a function whose return value is from a corresponding libca function and whose return value should be dbr.ECA_NORMAL.

4.4.3 Function Decorators

In addition to withSEVCHK(), several other decorator functions are used heavily inside of ca.py or are available for your convenience.

epics.ca.**withCA** *(fcn)*

decorator to ensure that libca and a context are created prior to function calls to the channel access library. This is intended for functions that need CA started to work, such as create_channel().

4.4. Implementation details
Note that CA functions that take a Channel ID (chid) as an argument are NOT wrapped by this: to get a chid, the library must have been initialized already.

```python
epics.ca.withCHID(fcn)
```

decorator to ensure that first argument to a function is a Channel ID, chid. The test performed is very weak, as any ctypes long or python int will pass, but it is useful enough to catch most accidental errors before they would cause a crash of the CA library.

```python
epics.ca.withConnectedCHID(fcn)
```

decorator to ensure that the first argument of a function is a fully connected Channel ID, chid. This test is (intended to be) robust, and will try to make sure a chid is actually connected before calling the decorated function.

```python
epics.ca.withInitialContext(fcn)
```

decorator to ensure that the wrapped function uses the initial threading context created at initialization of CA.

See [Using Python Threads](#) for further discussion.

### 4.4.4 Unpacking Data from Callbacks

Throughout the implementation, there are several places where data returned by the underlying CA library needs to be converted to Python data. This is encapsulated in the `_unpack()` function. In general, you will not have to run this code, but there is one exception: when using `sg_get()`, the values returned will have to be unpacked with this function.

```python
epics.ca._unpack(chid, data[, count=None[, ftype=None[, as_numpy=None ]]])
```

unpacks raw data for a Channel ID chid returned by libca functions including `ca_get_array_callback` or subscription callback, and returns the corresponding Python data.

Normally, users are not expected to need to access this function, but it will be necessary why using `sg_get()`.

**Parameters**
- **chid** [ctypes.c_long or None] channel ID (if not None, used for determining count and ftype)
- **data** [object] raw data as returned by internal libca functions.
- **count** [integer] number of elements to fetch (defaults to element count of chid or 1)
- **ftype** [integer] data type of channel (defaults to native type of chid)
- **as_numpy** [bool] whether to convert to numpy array.

### 4.5 User-supplied Callback functions

User-supplied callback functions can be provided for `put()`, `replace_access_rights_event()`, and `create_subscription()`. Note that callbacks for PV objects are slightly different: see [User-supplied Callback functions](#) in the `pv` module for details.

When defining a callback function to be run either when a `put()` completes or on changes to the Channel, as set from `create_subscription()`, or when read/write permissions change from `replace_access_rights_event()`, it is important to know two things:

1) how your function will be called.

2) what is permissible to do inside your callback function.
Callbacks will be called with keyword arguments for `put()` and for `create_subscription()`. You should be prepared to have them passed to your function. Use `**kw` unless you are very sure of what will be sent. For the case of `replace_access_rights_event()`, only positional arguments will be passed.

For callbacks sent when a `put()` completes, your function will be passed these:

- `pvname`: the name of the pv
- `data`: the user-supplied callback_data (defaulting to `None`).

For subscription callbacks, your function will be called with keyword/value pairs that will include:

- `pvname`: the name of the pv
- `value`: the latest value
- `count`: the number of data elements
- `ftype`: the numerical CA type indicating the data type
- `status`: the status of the PV (1 for OK)
- `chid`: the integer address for the channel ID.

For access rights event callbacks, your function will be passed:

- `read_access`: boolean indicating read access status
- `write_access`: boolean indicating write access status

Depending on the data type, and whether the CTRL or TIME variant was used, the callback function may also include some of these as keyword arguments:

- `enum_strs`: the list of enumeration strings
- `precision`: number of decimal places of precision.
- `units`: string for PV units
- `severity`: PV severity
- `timestamp`: timestamp from CA server.
- `posixseconds`: integer seconds since POSIX epoch of timestamp from CA server.
- `nanoseconds`: integer nanoseconds of timestamp from CA server.

Note that a the user-supplied callback will be run inside a CA function, and cannot reliably make any other CA calls. It is helpful to think “this all happens inside of a `pend_event()` call”, and in an epics thread that may or may not be the main thread of your program. It is advisable to keep the callback functions short and not resource-intensive. Consider strategies which use the callback only to record that a change has occurred and then act on that change later – perhaps in a separate thread, perhaps after `pend_event()` has completed.

### 4.6 Omissions

Several parts of the CA library are not implemented in the Python module. These are currently seen as unneeded (with notes where appropriate for alternatives), though they could be added on request.

```python
epics.ca.ca_add_exception_event()
Not implemented: Python exceptions are raised where appropriate and can be used in user code.
```

```python
epics.ca.ca_add_fd_registration()
Not implemented
```
epics.ca.ca_client_status()
   Not implemented

epics.ca.ca_set_puser()
   Not implemented: it is easy to pass user-defined data to callbacks as needed.

epics.ca.ca_puser()
   Not implemented: it is easy to pass user-defined data to callbacks as needed.

epics.ca.ca_SEVCHK()
   Not implemented: the Python function PySEVCHK() is approximately the same.

epics.ca.ca_signal()
   Not implemented: the Python function PySEVCHK() is approximately the same.

epics.ca.ca_test_event()
   Not implemented: this appears to be a function for debugging events. These are easy enough to simulate by directly calling Python callback functions.

epics.ca.ca_dump_dbr()
   Not implemented

In addition, not all DBR types in the CA C library are supported.

Only native types and their DBR_TIME and DBR_CTRL variants are supported: DBR_STS and DBR_GR variants are not. Several dbr_XXX functions are also not supported, as they are needed only to dynamically allocate memory.

4.7 CAThread class

class epics.ca.CAThread(group=None, target=None, name=None, args=(), kwargs={})
create a CA-aware subclass of a standard Python threading.Thread. See the standard library documentation for further information on how to use Thread objects.

A CAThread simply runs use_initial_context() prior to running each target function, so that use_initial_context() does not have to be explicitly put inside the target function.

The See Using Python Threads for further discussion.

4.8 Examples

Here are some example sessions using the ca module.

4.8.1 Create, Connect, Get Value of Channel

Note here that several things have been simplified compare to using CA in C: initialization and creating a main-thread context are handled, and connection of channels is handled in the background:

```python
from epics import ca
chid = ca.create_channel('XXX:m1.VAL')
count = ca.element_count(chid)
ftype = ca.field_type(chid)
print "Channel ", chid, count, ftype
value = ca.get()
print value
```
4.8.2 Put, waiting for completion

Here we set a PVs value, waiting for it to complete:

```python
from epics import ca
chid = ca.create_channel('XXX:m1.VAL')
ca.put(chid, 1.0, wait=True)
```

The `put()` method will wait to return until the processing is complete.

4.8.3 Define a callback to Subscribe to Changes

Here, we subscribe to changes for a PV, which is to say we define a callback function to be called whenever the PV value changes. In the case below, the function to be called will simply write the latest value out to standard output:

```python
from epics import ca
import time
import sys

# define a callback function. Note that this should
# expect certain keyword arguments, including 'pvname' and 'value'
def onChanges(pvname=None, value=None, **kw):
    fmt = 'New Value: %s value=%s, kw=%s
    sys.stdout.write(fmt % (pvname, str(value), repr(kw)))
    sys.stdout.flush()

# create the channel
mypv = 'XXX.VAL'
chid = ca.create_channel(mypv)

# subscribe to events giving a callback function
eventID = ca.create_subscription(chid, callback=onChanges)

# now we simply wait for changes
i0 = time.time()
while time.time() - i0 < 10.0:
    time.sleep(0.001)
```

It is vital that the return value from `create_subscription()` is kept in a variable so that it cannot be garbage collected. Failure to keep this value will cause trouble, including almost immediate segmentation faults (on Windows) or seemingly inexplicable crashes later (on linux).

4.8.4 Define a connection callback

Here, we define a connection callback – a function to be called when the connection status of the PV changes. Note that this will be called on initial connection:

```python
import epics
import time

def onConnectionChange(pvname=None, conn=None, chid=None):
    print 'ca connection status changed: ', pvname, conn, chid

# create channel, provide connection callback
motor1 = '13IDC:m1'
```

(continues on next page)
This will run the supplied callback soon after the channel has been created, when a successful connection has been made. Note that the callback should be prepared to accept keyword arguments of `pvname`, `chid`, and `conn` for the PV name, channel ID, and connection state (True or False).

### 4.8.5 Define an access rights change event callback

The following example demonstrates the addition of a function to be called when the access rights of a channel changes. Note this will be called immediately after successful installation:

```python
import epics
import time

def on_access_rights_change(read_access, write_access):
    print 'read access = %s, write access = %s' % (read_access, write_access)

# create a channel and attach the above function for access rights events
chid = epics.ca.create_channel('pv_name')
# a message should be printed immediately following this registration
epics.ca.replace_access_rights_event(chid, callback=on_access_rights_change)

# Affecting the channel's access rights, (for example, by enabling/disabling
# CA Security rules), should produce additional console messages
try:
    while True:
        time.sleep(0.25)
except KeyboardInterrupt:
    pass
```
WORKING WITH WAVEFORM / ARRAY DATA

Though most EPICS Process Variables hold single values, PVs can hold array data from EPICS waveform records. These are always data of a homogenous data type, and have a fixed maximum element count (defined when the waveform is created from the host EPICS process). Epics waveforms are most naturally mapped to Arrays from the numpy module, and this is strongly encouraged.

5.1 Arrays without Numpy

If you have numpy installed, and use the default `as_numpy=True` in `epics.ca.get()`, `pv.get()` or `epics.caget()`, you will get a numpy array for the value of a waveform PV. If you do not have numpy installed, or explicitly use `as_numpy=False` in a get request, you will get the raw C-like array reference from the Python ctypes module. These objects are not normally meant for casual use, but are not too difficult to work with either. They can be easily converted to a simple Python list with something like:

```python
>>> import epics
>>> epics.ca.HAS_NUMPY = False # turn numpy off for session
>>> p = epics.PV('XX:scan1.P1PA')
>>> p.get()
<epics.dbr.c_double_Array_500 object at 0x853980c>
>>> ldat = list(p.get())
```

Note that this conversion to a list can be very slow for large arrays.

5.2 Variable Length Arrays: NORD and NELM

While the maximum length of an array is fixed, the length of data you get back from a monitor, `epics.ca.get()`, `pv.get()`, or `epics.caget()`, may be shorter than the maximum length, reflecting the most recent data put to that PV. That is, if some process puts a smaller array to a PV than its maximum length, monitors on that PV may receive only the changed data. For example:

```python
>>> import epics
>>> p = epics.PV('Py:double2k')
>>> print p
<PV 'Py:double2k', count=2048/2048, type=double, access=read/write>
>>> import numpy
>>> p.put(numpy.arange(10)/5.0)
>>> print p.get()
array([ 0. , 0.2, 0.4, 0.6, 0.8, 1. , 1.2, 1.4, 1.6, 1.8])
```
To be clear, the `pv.put()` above could be done in a separate process – the `pv.get()` is not using a value cached from the `pv.put()`.

This feature was introduced in Epics CA 3.14.12.1, and may not work for data from IOCs running extremely old versions of Epics base.

### 5.3 Character Arrays

As noted in other sections, character waveforms can be used to hold strings longer than 40 characters, which is otherwise a fundamental limit for native Epics strings. Character waveforms shorter than `epics.ca.AUTOMONITOR_MAXLENGTH` can be turned into strings with an optional `as_string=True` to `epics.ca.get()`, `pv.get()`, or `epics.caget()`. If you’ve defined a Epics waveform record as:

```python
code
record(waveform,"$(P):filename") {
  field(DTYP,"Soft Channel")
  field(DESC,"file name")
  field(NELM,"128")
  field(FTVL,"CHAR")
}
```

Then you can use this record with:

```python
>>> import epics
>>> pvname = 'PREFIX:filename.VAL'
>>> pv = epics.PV(pvname)
>>> print pv.info
....
>>> plain_val = pv.get()
>>> print plain_val
array([ 84, 58, 92, 120, 97, 115, 95, 117, 115, 101, 114, 92, 77,
       97, 114, 99, 104, 50, 48, 49, 48, 92, 70, 97, 115, 116,
       77, 97, 112])
>>> char_val = pv.get(as_string=True)
>>> print char_val
'T:\xas_user\March2010\FastMap'
```

This example uses `pv.get()` but `epics.ca.get()` is essentially equivalent, as its `as_string` parameter works exactly the same way.

Note that Epics character waveforms as defined as above are really arrays of bytes. The conversion to a string assumes the ASCII character set. Unicode is not directly supported. If you are storing non-ASCII data, you would have to convert the raw array data yourself, perhaps like this (for Python3):

```python
>>> arr_data = pv.get()
>>> arr_bytes = bytes(list(array_data))
>>> arr_string = str(arr_bytes, 'LATIN-1')
```

### 5.3.1 Strategies for working with large arrays

EPICS Channels / Process Variables usually have values that can be stored with a small number of bytes. This means that their storage and transfer speeds over real networks is not a significant concern. However, some Process Variables can store much larger amounts of data (say, several megabytes) which means that some of the assumptions about dealing with Channels / PVs may need reconsideration.
When using PVs with large array sizes (here, I’ll assert that large means more than a few thousand elements), it is necessary to make sure that the environmental variable `EPICS_CA_MAX_ARRAY_BYTES` is suitably set. Unfortunately, this represents a pretty crude approach to memory management within Epics for handling array data as it is used not only sets how large an array the client can accept, but how much memory will be allocated on the server. In addition, this value must be set prior to using the CA library – it cannot be altered during the running of a CA program.

Normally, the default value for `EPICS_CA_MAX_ARRAY_BYTES` is 16384 (16k, and it turns out that you cannot set it smaller than this value!). As Python is used for clients, generally running on workstations or servers with sufficient memory, this default value is changed to `2**24`, or 16Mb) when `epics.ca` is initialized. If the environmental variable `EPICS_CA_MAX_ARRAY_BYTES` has not already been set.

The other main issue for PVs holding large arrays is whether they should be automatically monitored. For PVs holding scalar data or small arrays, any penalty for automatically monitoring these variables (that is, causing network traffic every time a PV changes) is a small price to pay for being assured that the latest value is always available. As arrays get larger (as for data streams from Area Detectors), it is less obvious that automatic monitoring is desirable.

The Python `epics.ca` module defines a variable `epics.ca.AUTOMONITOR_MAXLENGTH` which controls whether array PVs are automatically monitored. The default value for this variable is 65536, but can be changed at runtime. Arrays with fewer elements than `epics.ca.AUTOMONITOR_MAXLENGTH` will be automatically monitored, unless explicitly set, and arrays larger than `epics.ca.AUTOMONITOR_MAXLENGTH` will not be automatically monitored unless explicitly set. Auto-monitoring of PVs can be be explicitly set with

```python
>>> pv2 = epics.PV('ScalerPV', auto_monitor=True)
>>> pv1 = epics.PV('LargeArrayPV', auto_monitor=False)
```

## 5.4 Example handling Large Arrays

Here is an example reading data from an EPICS areaDetector, as if it were an image from a digital camera. This uses the common third-party library called Python Imaging Library or pillow for much of the image processing. This library can be installed with `pip install pillow` or `conda install pillow`:

```python
>>> import epics
>>> import Image
>>> pvname = '13IDCPS1:image1:ArrayData'
>>> img_pv = epics.PV(pvname)
>>> raw_image = img_pv.get()
>>> im_mode = 'RGB'
>>> im_size = (1360, 1024)
>>> img = Image.frombuffer(im_mode, im_size, raw_image, 'raw', im_mode, 0, 1)
>>> img.show()
```

The result looks like this (taken with a Prosilica GigE camera):
A more complete application for reading and displaying image from Epics Area Detectors is included at http://github.com/pyepics/epicsapps/.
6.1 Overview

The device module provides a simple interface to a collection of PVs. Here an epics device.Device is an object holding a set of PVs, all sharing a prefix, but having many attributes. Many PVs will have names made up of prefix+attribute, with a common prefix for several related PVs. This almost describes an Epics Record, but as it is concerned only with PV names, the mapping to an Epics Record is not exact. On the other hand, the concept of a device is more flexible than a predefined Epics Record as it can actually hold PVs from several different records:

```python
motor1 = epics.Device('XXX:motor1.', attrs=('VAL', 'RBV', 'DESC', 'RVAL', 'LVIO', 'HLS', 'LLS'))
motor1.put('VAL', 1)
print 'Motor %s = %.1f' % (motor1.get('DESC'), motor1.get('RBV'))
motor1.VAL = 0
print 'Motor %s = %.1f' % (motor1.DESC, motor1.RBV)
```

While useful on its own like this, the real point of a device is as a base class, to be inherited and extended. In fact, there is a more sophisticated Motor device described below at Epics Motor Device

```python
class device.Device(prefix=None[, delim='[, attrs=None ]])
```

The attribute PVs are built as needed and held in an internal buffer self._pvs. This class is kept intentionally simple so that it may be subclassed.

To pre-load attribute names on initialization, provide a list or tuple of attributes with the attr option.

Note that prefix is actually optional. When left off, this class can be used as an arbitrary container of PVs, or to turn any subclass into an epics Device.

In general, PV names will be mapped as prefix+delim+attr. See add_pv() for details of how to override this.

```python
device.PV(attr[, connect=True[, **kw]])
```
returns the PV object for a device attribute. The connect argument and any other keyword arguments are passed to epics.PV().

```python
device.put(attr, value[, wait=False[, timeout=10.0 ]])
```
put an attribute value, optionally wait for completion or up to a supplied timeout value

```python
device.get(attr[, as_string=False ])
```
get an attribute value, option as_string returns a string representation

```python
device.add_callback(attr, callback)
```
add a callback function to an attribute PV, so that the callback function will be run when the attribute’s value changes
device.add_pv(pvname, \[attr=None, **kw \])

adds an explicitly names epics.PV() to the device even though it may violate the normal naming rules (in which \[attr\] is mapped to epics.PV(prefix+delim+\[attr\]). That is, one can say:

```python
import epics
m1 = epics.Device('XXX:m1', delim='.
ml.add_pv('XXX:m2.VAL', attr='other')
print m1.VAL  # print value of XXX:m1.VAL
print m1.other  # prints value of XXX:m2.VAL
```

device.save_state()

return a dictionary of all current values – the ‘current state’.

device.restore_state(state)

restores a saved state, as saved with save_state().

device.write_state(fname, state=None)

write a saved state to a file. If no state is provide, the current state is written.

device.read_state(fname, restore=False)

reads a state from a file, as written with write_state(), and returns it. If ‘restore’ is True, the read state will be restored.

device._pvs

a dictionary of PVs making up the device.

6.2 Epics Motor Device

The Epics Motor record has over 100 fields associated with it. Of course, it is often preferable to think of 1 Motor with many attributes than 100 or so separate PVs. Many of the fields of the Motor record are interrelated and influence other settings, including limits on the range of motion which need to be respected, and which may send notifications when they are violated. Thus, there is a fair amount of functionality for a Motor. Typically, the user just wants to move the motor by setting its drive position, but a fully enabled Motor should allow the user to change and read many of the Motor parameters.

The Motor class helps the user create and use Epics motors. A simple example use would be:

```python
import epics
m1 = epics.Motor('XXX:m1')

print 'Motor: ', m1.DESC , ' Currently at ', m1.RBV

m1.tweak_val = 0.10
m1.move(0.0, dial=True, wait=True)

for i in range(10):
    m1.tweak(direction='forward', wait=True)
    time.sleep(1.0)
    print 'Motor: ', m1.DESC , ' Currently at ', m1.RBV
```

Which will step the motor through a set of positions. You’ll notice a few features for Motor:

1. Motors can use English-name aliases for attributes for fields of the motor record. Thus ‘VAL’ can be spelled ‘drive’ and ‘DESC’ can be ‘description’. The Table of Motor Attributes give the list of names that can be used.

2. The methods for setting positions can use the User, Dial, or Step coordinate system, and can wait for completion.
6.2.1 The epics.Motor class

class motor.Motor(pvname[, timeout=30.])
create a Motor object for a named Epics Process Variable.

Parameters

- **pvname** *(string)* – prefix name (no `.VAL` needed!) of Epics Process Variable for a Motor
- **timeout** *(float)* – time (in seconds) to wait before giving up trying to connect.

Once created, a Motor should be ready to use.

```python
>>> from epics import Motor
>>> m = Motor('XX:m1')
>>> print m.drive, m.description, m.slew_speed
1.030 Fine X 5.0
>>> print m.get('device_type', as_string=True)
'asynMotor'
```

A Motor has very many fields. Only a few of them are created on initialization – the rest are retrieved as needed. The motor fields can be retrieved either with an attribute or with the `get()` method. A full list of Motor attributes and their aliases for the motor record is given in Table of Motor Attributes.

Table of Aliases for attributes for the epics Motor class, and the corresponding attribute name of the Motor Record field.

<table>
<thead>
<tr>
<th>alias</th>
<th>Motor Record field</th>
<th>alias</th>
<th>Motor Record field</th>
</tr>
</thead>
<tbody>
<tr>
<td>disabled</td>
<td>_able.V AL</td>
<td>moving</td>
<td>MOVN</td>
</tr>
<tr>
<td>acceleration</td>
<td>ACCL</td>
<td>resolution</td>
<td>MRES</td>
</tr>
<tr>
<td>back_accel</td>
<td>BACC</td>
<td>motor_status</td>
<td>MSTA</td>
</tr>
<tr>
<td>backlash</td>
<td>BDST</td>
<td>offset</td>
<td>OFF</td>
</tr>
<tr>
<td>back_speed</td>
<td>BVEL</td>
<td>output_mode</td>
<td>OMSL</td>
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<tr>
<td>card</td>
<td>CARD</td>
<td>output</td>
<td>OUT</td>
</tr>
<tr>
<td>dial_high_limit</td>
<td>DHLM</td>
<td>prop_gain</td>
<td>PCOF</td>
</tr>
<tr>
<td>direction</td>
<td>DIR</td>
<td>precision</td>
<td>PREC</td>
</tr>
<tr>
<td>dial_low_limit</td>
<td>DLLM</td>
<td>readback</td>
<td>RBV</td>
</tr>
<tr>
<td>settle_time</td>
<td>DLY</td>
<td>retry_max</td>
<td>RTRY</td>
</tr>
<tr>
<td>done_moving</td>
<td>DMOV</td>
<td>retry_count</td>
<td>RCNT</td>
</tr>
<tr>
<td>dial_readback</td>
<td>DRBV</td>
<td>retry_deadband</td>
<td>RDBD</td>
</tr>
<tr>
<td>description</td>
<td>DESC</td>
<td>dial_difference</td>
<td>RDIF</td>
</tr>
<tr>
<td>dial_drive</td>
<td>DVAL</td>
<td>raw_encoder_pos</td>
<td>REP</td>
</tr>
<tr>
<td>units</td>
<td>EGU</td>
<td>raw_high_limit</td>
<td>RHLS</td>
</tr>
<tr>
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<td>ERES</td>
<td>raw_low_limit</td>
<td>RLLS</td>
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<td>freeze_offset</td>
<td>FOFF</td>
<td>relative_value</td>
<td>RLV</td>
</tr>
<tr>
<td>move_fraction</td>
<td>FRAC</td>
<td>raw_motor_pos</td>
<td>RMP</td>
</tr>
<tr>
<td>hi_severity</td>
<td>HHSV</td>
<td>raw_readback</td>
<td>RRBV</td>
</tr>
<tr>
<td>hi_alarm</td>
<td>HIGH</td>
<td>readback_res</td>
<td>RRES</td>
</tr>
<tr>
<td>hihi_alarm</td>
<td>HIHI</td>
<td>raw_drive</td>
<td>RVAL</td>
</tr>
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<td>high_limit</td>
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<td>dial_speed</td>
<td>RVEL</td>
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<td>HLS</td>
<td>s_speed</td>
<td>S</td>
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<tr>
<td>hw_limit</td>
<td>HLSV</td>
<td>s_back_speed</td>
<td>SBAK</td>
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<td>home_forward</td>
<td>HOMF</td>
<td>s_base_speed</td>
<td>SBAS</td>
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<tr>
<td>home_reverse</td>
<td>HOMR</td>
<td>s_max_speed</td>
<td>SMAX</td>
</tr>
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</table>

Continued on next page
Table 1 – continued from previous page

<table>
<thead>
<tr>
<th>alias</th>
<th>Motor Record field</th>
<th>alias</th>
<th>Motor Record field</th>
</tr>
</thead>
<tbody>
<tr>
<td>high_op_range</td>
<td>HOPR</td>
<td>set</td>
<td>SET</td>
</tr>
<tr>
<td>high_severity</td>
<td>HSV</td>
<td>stop_go</td>
<td>SPMG</td>
</tr>
<tr>
<td>integral_gain</td>
<td>ICOF</td>
<td>s_revolutions</td>
<td>SREV</td>
</tr>
<tr>
<td>jog_accel</td>
<td>JAR</td>
<td>stop</td>
<td>STOP</td>
</tr>
<tr>
<td>jog_forward</td>
<td>JOGF</td>
<td>t_direction</td>
<td>TDIR</td>
</tr>
<tr>
<td>jog_reverse</td>
<td>JOGR</td>
<td>tweak_forward</td>
<td>TWF</td>
</tr>
<tr>
<td>jog_speed</td>
<td>JVEL</td>
<td>tweak_reverse</td>
<td>TWR</td>
</tr>
<tr>
<td>last_dial_val</td>
<td>LDVL</td>
<td>tweak_val</td>
<td>TWV</td>
</tr>
<tr>
<td>low_limit</td>
<td>LLM</td>
<td>use_encoder</td>
<td>UEIP</td>
</tr>
<tr>
<td>low_limit_set</td>
<td>LLS</td>
<td>u_revolutions</td>
<td>UREV</td>
</tr>
<tr>
<td>lo_severity</td>
<td>LLSV</td>
<td>use_rdbl</td>
<td>URP</td>
</tr>
<tr>
<td>lolo_alarm</td>
<td>LOLO</td>
<td>drive</td>
<td>VAL</td>
</tr>
<tr>
<td>low_op_range</td>
<td>LOPR</td>
<td>base_speed</td>
<td>VBAS</td>
</tr>
<tr>
<td>low_alarm</td>
<td>LOW</td>
<td>slew_speed</td>
<td>VELO</td>
</tr>
<tr>
<td>last_rel_val</td>
<td>LRLV</td>
<td>version</td>
<td>VERS</td>
</tr>
<tr>
<td>last_dial_drive</td>
<td>LRVL</td>
<td>max_speed</td>
<td>VMAX</td>
</tr>
<tr>
<td>last_SPMG</td>
<td>LSPG</td>
<td>use_home</td>
<td>ATHM</td>
</tr>
<tr>
<td>low_severity</td>
<td>LSV</td>
<td>deriv_gain</td>
<td>DCOF</td>
</tr>
</tbody>
</table>

6.2.2 methods for epics.Motor

`motor.get(attr, as_string=False)`

sets a field attribute for the motor.

Parameters

- **attr**(string (from table above)) – attribute name
- **as_string**(True/False) – whether to return string value.

Note that `get()` can return the string value, while fetching the attribute cannot do so:

```python
>>> m = epics.Motor('XXX:m1')
>>> print m.device_type
0
>>> print m.get('device_type', as_string=True)
'asynMotor'
```

`motor.put(attr, value, wait=False, timeout=30)`

sets a field attribute for the motor.

Parameters

- **attr**(string (from table above)) – attribute name
- **value** – value for attribute
- **wait**(True/False) – whether to wait for completion.
- **timeout**(float) – time (in seconds) to wait before giving up trying to connect.

`motor.check_limits()`

checks whether the current motor position is causing a motor limit violation, and raises a MotorLimitException if it is.

returns `None` if there is no limit violation.
motor.within_limits(value [, limits=’user’])
checks whether a target value would be a limit violation.

Parameters

- **value** – target value
- **limits**(string) – one of ‘user’, ‘dial’, or ‘raw’ for which limits to consider

Return type  True/False

motor.move(val=None [, relative=None, wait=False, timeout=300.0, dial=False, raw=False, ignore_limits=False, confirm_move=False])
moves motor to specified drive position.

Parameters

- **val** – value to move to (float) [Must be provided]
- **relative** – move relative to current position (T/F) [F]
- **wait** – whether to wait for move to complete (T/F) [F]
- **timeout** – max time for move to complete (in seconds) [300]
- **dial** – use dial coordinates (T/F) [F]
- **raw** – use raw coordinates (T/F) [F]
- **ignore_limits** – try move without regard to limits (T/F) [F]
- **confirm_move** – try to confirm that move has begun (when wait=False) (T/F) [F]

Return type  integer

Returns an integer value, according the table below. Note that a return value of 0 with wait=False does not really guarantee a successful move, just that a move request was issued. If you’re interested in checking that a requested move really did start without waiting for the move to complete, you may want to use the confirm_move=True option.

Table of return values from move().

<table>
<thead>
<tr>
<th>return value</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>-13</td>
<td>invalid value (cannot convert to float). Move not attempted.</td>
</tr>
<tr>
<td>-12</td>
<td>target value outside soft limits. Move not attempted.</td>
</tr>
<tr>
<td>-11</td>
<td>drive PV is not connected: Move not attempted.</td>
</tr>
<tr>
<td>-8</td>
<td>move started, but timed-out.</td>
</tr>
<tr>
<td>-7</td>
<td>move started, timed-out, but appears done.</td>
</tr>
<tr>
<td>-5</td>
<td>move started, unexpected return value from put()</td>
</tr>
<tr>
<td>-4</td>
<td>move-with-wait finished, soft limit violation seen.</td>
</tr>
<tr>
<td>-3</td>
<td>move-with-wait finished, hard limit violation seen.</td>
</tr>
<tr>
<td>0</td>
<td>move-with-wait finish OK.</td>
</tr>
<tr>
<td>0</td>
<td>move-without-wait executed, not confirmed.</td>
</tr>
<tr>
<td>1</td>
<td>move-without-wait executed, move confirmed.</td>
</tr>
<tr>
<td>3</td>
<td>move-without-wait finished, hard limit violation seen.</td>
</tr>
<tr>
<td>4</td>
<td>move-without-wait finished, soft limit violation seen.</td>
</tr>
</tbody>
</table>

motor.tweak(direction=’forward’, wait=False, timeout=300.)
moves the motor by the current tweak value

Parameters
- **direction** (string: 'forward' (default) or 'reverse') – direction of motion
- **wait** (True/False) – whether to wait for completion
- **timeout** (float) – max time for move to complete (in seconds) [default=300]

```python
motor.get_position(readback=False, dial=False, raw=False)
```

Returns the motor position in user, dial or raw coordinates.

**Parameters**

- **readback** – whether to return the readback position in the desired coordinate system. The default is to return the drive position of the motor.
- **dial** – whether to return the position in dial coordinates. The default is user coordinates.
- **raw** – whether to return the raw position. The default is user coordinates.

The “raw” and “dial” keywords are mutually exclusive. The “readback” keyword can be used in user, dial or raw coordinates.

```python
motor.set_position(position, dial=False, raw=False)
```

set (that is, redefine) the current position to supplied value.

**Parameters**

- **position** – The new motor position
- **dial** – whether to set in dial coordinates. The default is user coordinates.
- **raw** – whether to set in raw coordinates. The default is user coordinates.

The ‘raw’ and ‘dial’ keywords are mutually exclusive.

```python
motor.get_pv(attr)
```

returns the PV for the corresponding attribute.

```python
motor.set_callback(attr='drive', callback=None, kw=None)
```

sets a callback on the PV for a particular attribute.

```python
motor.clear_callback(attr='drive')
```

clears a callback on the PV for a particular attribute.

```python
motor.show_info()
```

prints out a table of attributes and their current values.

## 6.3 Other Device Examples

An epics Device provides a general way to group together a set of PVs. The examples below show how to build on this generality, and may inspire you to build your own device classes.

### 6.3.1 A basic Device without a prefix

Here, we define a very simple device that does not even define a prefix. This is not much more than a collection of PVs. Since there is no prefix given, all PVs in the device must be fully qualified. Note that there is no requirement to share a common prefix in such a collection of PVs:
from epics import Device
dev = Device()

p1 = dev.PV('13IDC:m1.VAL')
p2 = dev.PV('13IDC:m2.VAL')
dev.put('13IDC:m1.VAL', 2.8)
dev.put('13IDC:m2.VAL', 3.0)
print dev.PV('13IDC:m3.DIR').get(as_string=True)

Note that this device cannot use the attributes based on field names.
This may not look very interesting – why not just use a bunch of PVs? If you consider Device to be a starting point for building more complicated objects by subclassing Device and adding specialized methods, then it can start to get interesting.

6.3.2 Epics ai record as Device

For a slightly more useful and typical example, the pyepics distribution includes a Device for an Epics ai (analog input record). The full implementation of this device is:

```python
#!/usr/bin/env python
"""Epics analog input record"
from .. import Device
class ai(Device):
    "Simple analog input device"

    attrs = ('VAL', 'EGU', 'HOPR', 'LOPR', 'PREC', 'NAME', 'DESC','DTYP', 'INP', 'LINR', 'RVAL', 'ROFF', 'EGUF', 'EGUL',
             'AOFF', 'ASLO', 'ESLO', 'EOFF', 'SMOQ', 'HIHI', 'LOLO',
             'HIGH', 'LOW', 'HHSV', 'LLSV', 'HSV', 'LSV', 'HYST')

def __init__(self, prefix, **kwargs):
    if prefix.endswith('.'):  
        prefix = prefix[:-1]  
    Device.__init__(self, prefix, delim='.', attrs=self.attrs, **kwargs)

The code simply pre-defines the fields that are the suffixes of an Epics ai input record, and subclasses Device with these fields to create the corresponding PVs. For most record suffixes, these will be available as attributes of the Device object. For example, the ai class above can be used simply and cleanly as:
```
from epics.devices import ai
This_ai = ai('XXX.PRES')
print 'Value: ', This_ai.VAL
print 'Units: ', This_ai.EGU
```

Of course, you can also use the get(), put() methods above for a basic Device:

```
This_ai.put('DESC', 'My Pump')
```

Several of the other standard Epics records can easily be exposed as Devices in this way, and the pyepics distribution includes such simple wrappings for the Epics ao, bi, and bo records, as well as several more complex records from synApps.

6.3. Other Device Examples
6.3.3 Epics Scaler Record as Device

For a slightly more complicated example: an incomplete, but very useful mapping of the Scaler Record from synApps, including methods for changing modes, and reading and writing data.

```python
#!/usr/bin/env python
"""Epics Scaler"
""
from .. import Device, poll

class Scaler(Device):
    """Simple implementation of SynApps Scaler Record."
    """
    attrs = ('CNT', 'CONT', 'TP', 'T', 'VAL')
    attr_kws = {'calc_enable': '%s_calcEnable.VAL'}
    chan_attrs = ('NM%i', 'S%i')
    calc_attrs = {'calc%i': '%s_calc%i.VAL', 'expr%i': '%s_calc%i.CALC'}
    _nonpvs = ('_prefix', '_pvs', '_delim', '_nchan', '_chans')

    def __init__(self, prefix, nchan=8):
        self._nchan = nchan
        self._chans = range(1, nchan+1)
        attrs = list(self.attrs)
        for i in self._chans:
            for att in self.chan_attrs:
                attrs.append(att % i)
        Device.__init__(self, prefix, delim='.', attrs=attrs)
        for key, val in self.attr_kws.items():
            self.add_pv(val % prefix, attr=key)
        for i in self._chans:
            for key, val in self.calc_attrs.items():
                self.add_pv(val % (prefix, i), attr=key % i)
        self._mutable = False

    def AutoCountMode(self):
        """set to autcount mode"
        self.put('CONT', 1)

    def OneShotMode(self):
        """set to one shot mode"
        self.put('CONT', 0)

    def CountTime(self, ctime):
        """set count time"
        self.put('TP', ctime)

    def Count(self, ctime=None, wait=False):
        """set count, with optional counttime"
        if ctime is not None:
            self.CountTime(ctime)
        self.put('CNT', 1, wait=wait)
poll()

    def EnableCalcs(self):
```

(continues on next page)
" enable calculations"
self.put('calc_enable', 1)

def setCalc(self, i, calc):
    " set the calculation for scaler i"
    attr = 'expr%i' % i
    self.put(attr, calc)

def getNames(self):
    " get all names"
    return [self.get('NM%i' % i) for i in self._chans]

def Read(self, use_calc=False):
    " read all values"
    attr = 'S%i'
    if use_calc:
        attr = 'calc%i'
    return [self.get(attr % i) for i in self._chans]

Note that we can then create a scaler object from its base PV prefix, and use methods like Count() and Read() without directly invoking epics calls:

```python
s1 = Scaler('XXX:scaler1')
s1.setCalc(2, '(B-2000*A/1000000.)')
s1.enableCalcs()
s1.OneShotMode()
s1.Count(t=5.0, wait=True)
print 'Names: ', s1.getNames()
print 'Raw values: ', s1.Read(use_calc=False)
print 'Calc values: ', s1.Read(use_calc=True)
```

### 6.3.4 Other Devices included in PyEpics

Several other Epics Records have been exposed as Devices, and included in PyEpics distribution. These vary some in how complete and feature-rich they are, and are definitely skewed toward data collection at synchrotron beamlines. A table of current Devices are listed in the Table of Included Epics Devices table below. For further details, consult the source code for these modules.

Table of Epics Devices Included in the PyEpics distribution. For those described as “pretty basic”, there are generally only PV suffixes to attributes mapped. Many of the others include one or more methods for specific use of that Device.
<table>
<thead>
<tr>
<th>module</th>
<th>class</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ad_base</td>
<td>AD_Camera</td>
<td>areaDetector Camera, pretty basic</td>
</tr>
<tr>
<td>ad_fileplugin</td>
<td>AD_FilePlugin</td>
<td>areaDetector File Plugin, many methods</td>
</tr>
<tr>
<td>ad_image</td>
<td>AD_ImagePlugin</td>
<td>areaDetector Image, with ArrayData attribute</td>
</tr>
<tr>
<td>ad_overlay</td>
<td>AD_OverlayPlugin</td>
<td>areaDetector Overlay, pretty basic</td>
</tr>
<tr>
<td>ad_perkinelmer</td>
<td>AD_PerkinElmer</td>
<td>PerkinElmer(xrd1600) detector, several methods</td>
</tr>
<tr>
<td>ai</td>
<td>ai</td>
<td>analog input, pretty basic (as above)</td>
</tr>
<tr>
<td>ao</td>
<td>ao</td>
<td>analog output, pretty basic</td>
</tr>
<tr>
<td>bi</td>
<td>bi</td>
<td>binary input, pretty basic</td>
</tr>
<tr>
<td>bo</td>
<td>bo</td>
<td>binary output, pretty basic</td>
</tr>
<tr>
<td>mca</td>
<td>MCA</td>
<td>epics DXP record, pretty basic</td>
</tr>
<tr>
<td>mca</td>
<td>DXP</td>
<td>epics MCA record, get_rois()/get_calib()</td>
</tr>
<tr>
<td>mca</td>
<td>MultiXMAP</td>
<td>Multiple XIA XMaps, several methods</td>
</tr>
<tr>
<td>scaler</td>
<td>Scaler</td>
<td>epics Scaler record, many methods</td>
</tr>
<tr>
<td>scan</td>
<td>Scan</td>
<td>epics SScan record, some methods</td>
</tr>
<tr>
<td>srs570</td>
<td>SRS570</td>
<td>SRS570 Amplifier</td>
</tr>
<tr>
<td>struck</td>
<td>Struck</td>
<td>SIS Multichannel Scaler, many methods</td>
</tr>
<tr>
<td>transform</td>
<td>Transform</td>
<td>epics userTransform record</td>
</tr>
<tr>
<td>xspress3</td>
<td>Xspress3</td>
<td>Quantum Electronics Xspress3 Multi-MCA</td>
</tr>
</tbody>
</table>
ALARMS: RESPOND WHEN A PV GOES OUT OF RANGE

7.1 Overview

The `alarm` module provides an Alarm object to specify an alarm condition and what to do when that condition is met.

```python
class alarm.Alarm(pvname, comparison=None, trip_point=None, callback=None, alert_delay=10)
```

creates an alarm object.

- **param pvname**: name of Epics PV (string)
- **param comparison**: operation used to compare PV value to trip_point.
  - type comparison: string or callable. Built in comparisons are listed in Table of Alarm Operators.
- **param trip_point**: value that will trigger the alarm
- **param callback**: user-defined callback function to be run when the PVs value meets the alarm condition
  - type callback: callable or None
- **param alert_delay**: time (in seconds) to wait before executing another alarm callback.

The alarm works by checking the value of the PV each time it changes. If the new value is outside the acceptable range (violates the trip_point), then the user-supplied callback function is run. This callback could be set do send a message or to take some other course of action.

The comparison supplied can either be a string as listed in Table of Alarm Operators or a custom callable function which takes the two values (PV.value, trip_point) and returns True or False based on those values.

Table of built-in Operators for Alarms:

<table>
<thead>
<tr>
<th>operator</th>
<th>Python operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>'eq', '=='</td>
<td><strong>eq</strong></td>
</tr>
<tr>
<td>'ne', '!='</td>
<td><strong>ne</strong></td>
</tr>
<tr>
<td>'le', '&lt;='</td>
<td><strong>le</strong></td>
</tr>
<tr>
<td>'lt', '&lt;'</td>
<td><strong>lt</strong></td>
</tr>
<tr>
<td>'ge', '&gt;='</td>
<td><strong>ge</strong></td>
</tr>
<tr>
<td>'gt', '&gt;'</td>
<td><strong>gt</strong></td>
</tr>
</tbody>
</table>

The `alert_delay` prevents the alarm callback from being called too many times. For PVs with floating point values, the value may fluctuate around the trip_point for a while. If the value violates the trip_point, then momentarily goes back to an acceptable value, and back again to a violating value, it may not be desirable to send repeated, identical
messages. To prevent this situation, the alarm callback will be called when the alarm condition is met and the callback was not called within the time specified by alert_delay.

### 7.2 Alarm Example

An epics Alarm is very easy to use. Here is an alarm set to print a message when a PV’s value reaches a certain value:

```python
from epics import Alarm, poll

def alertMe(pvname=None, char_value=None, **kw):
    print "Soup's on!  \$s = \$s" % (pvname, char_value)

my_alarm = Alarm(pvname = 'WaterTemperature.VAL',
                 comparison = '>',
                 callback = alertMe,
                 trip_point = 100.0,
                 alert_delay = 600)

while True:
    poll()
```

Chapter 7. Alarms: respond when a PV goes out of range
AUTO-SAVING: SIMPLE SAVE/RESTORE OF PVS

The autosave module provides simple save/restore functionality for PVS, with the functions save_pvs() and restore_pvs(), and an AutoSaver class. These are similar to the autosave module from synApps for IOCs in that they use a compatible request file which describes the PVs to save, and a compatible save file which holds the saved values. Of course, the reading and writing is done here via Channel Access, and need not be related to a single IOC.

Use of this module requires the pyparsing package to be installed. This is a fairly common third-party python package, included in many package managers, or installed with tools such as easy_install or pip, or downloaded from PyPI.

Request and Save file formats are designed to be compatible with synApps autosave. Notably, the file command with macro substitutions are supported, so that one can have a Request like:

```
# My.req
file "SimpleMotor.req", P=IOC:, Q=m1
```

with a SimpleMotor.req file of:

```
# SimpleMotor.req
$(P)$(Q).VAL
$(P)$(Q).DIR
$(P)$(Q).POFF
```

which can then be used for many instances of a SimpleMotor. There is, however, no automated mechanism for finding request files. You will need to include these in the working directory or specify absolute paths.

With such a file, simply using:

```
import epics.autosave
epics.autosave.save_pvs("My.req", "my_values.sav")
```

will save the current values for the PVs to the file my_values.sav. At a later time, these values can be restored with:

```
import epics.autosave
epics.autosave.restore_pvs("my_values.sav")
```

The saved file will be of nearly identical format as that of the autosave mechanism, and the restore_pvs() function can read and restore values using save files from autosave. Note, however, that the purpose here is quite different from that of the standard autosave module (which is designed to save values so that PVS can be initialized at IOC startup). Using the functions here will really do a caput() to the saved values.

autosave.save_pvs(request_file, save_file)

saves current value of PVS listed in request_file to the save_file

Parameters

- request_file – name of Request file to read PVS to save.
• **save_file** – name of file to save values to write values to

As discussed above, the **request_file** follows the conventions of the autosave module from synApps.

```python
autosave.restore_pvs(save_file)
```

reads values from **save_file** and restores them for the corresponding PVs

**Parameters**

- **save_file** – name of file to save values to read data from.

Note that **restore_pvs()** will restore all the values it can, skipping over any values that it cannot restore.

### 8.1 AutoSaver class

The **AutoSaver** class provides a convenient way to repeatedly save PVs listed in a request file without having to re-connect all of the PVs. The **AutoSaver** retains the PV connections, and provides a simple **save()** method to save the current PV values to a file. By default, that file will be named from the request file and the current time. This allows you to do something like this:

```python
#!/usr/bin/env python
# save PVs from a request file once per minute
import time
from epics.autosave import AutoSaver
my_saver = AutoSaver("My.req")

# save all PVs every minute for a day
# time.time() - t0 = 86400.0
while True:
    if time.localtime().tm_sec < 5:
        my_saver.save()
        time.sleep(30 - time.localtime().tm_sec)
    if time.time() - t0 > 86400.0:
        break
    time.sleep(0.5)
```

This will save PVs to files with names like **My_2017Oct02_141800.sav**.

```python
class autosave.AutoSaver(request_file)
```

create an Automatic Saver based on a request file.

**Parameters**

- **request_file** – name of request file

**AutoSaver** has two methods: **read_request_file()** to read a request file, and **save()** to save the results.

```python
autosave.read_request_file(request_file)
```

read and parse request file, begin making PV connections

**Parameters**

- **request_file** – name of request file

```python
autosave.save(save_file=None, verbose=False)
```

read current PV values, write save file.

**Parameters**

- **save_file** – name of save file or **None**. If **None**, the name of the request file and timestamp (to seconds) will be used to build a file name. Note that there is no check for overwriting files.

- **verbose** – whether to print results to the screen [default **False**]
8.2 Supported Data Types

All scalar PV values can be saved and restored with the *autosave* routines. There is some support for waveform (array) data. For example, character waveforms containing for long strings can be saved and restored. In addition, numerical arrays in waveform can be saved and restored. For array data, the results may not be fully compatible with the autosave module.

8.2.1 Examples

A simple example using the autosave module:

```python
import epics.autosave
# save values
epics.autosave.save_pvs("my_request_file.req",
                        "/tmp/my_recent_save.sav")

# wait 30 seconds
time.sleep(30)

# restore those values back
epics.autosave.restore_pvs("/tmp/my_recent_save.sav")
```
WX: WXPYTHON WIDGETS FOR EPICS

The \texttt{wx} module of \texttt{epics} (that is, \texttt{epics.wx}) provides a set of wxPython classes for epics PVs. Most of these are derived from wxPython widgets, with special support added for epics PVs, especially regarding when to automatically update the widget based on a changing value for a PV.

Some examples of code that uses pyepics and wxPython are included in the \texttt{scripts} folder of the pyepics source distribution kit. In addition, there are some full-fledged applications using Epics and wxPython at \texttt{pyepics applications}.

9.1 PV-aware Widgets

Several basic wxPython widgets have been extended so as to connect the widget with a corresponding PV. For example, setting the text value of a \texttt{PVTextCtrl} will forward that value to the epics PV, and if the PV is changed by externally, the value displayed in the widget will be automatically updated.

9.1.1 PVMixin

\begin{verbatim}
class \texttt{wx.PVMixin}([\texttt{pv=None}, \texttt{pvname=None}])
    This is a mixin class for wx Controls with epics PVs: This connects to PV, and manages connection and callback events for the PV. It provides the following basic methods used by most of the PV<->widget classes below.

\texttt{wx.SetPV} (\texttt{pv=None})
    set the PV corresponding to the widget.

\texttt{wx.Update} (\texttt{value=None})
    set the widgets value from the PV’s value. If value=’None’, the current value for the PV is used.

\texttt{wx.GetValue} (\texttt{as_string=True})
    return the PVs value.

\texttt{wx.OnEpicsConnect} ()
    PV connection event handler.

\texttt{wx.OnPVChange} (\texttt{value})
    PV monitor (subscription) event handler. Must be overwritten for each widget type.

\texttt{wx.GetEnumStrings} ()
    return enumeration strings for the PV
\end{verbatim}

9.1.2 PVCtrlMixin

\begin{verbatim}
class \texttt{wx.PVCtrlMixin} (\texttt{parent, pv=None, font=None, fg=None, bg=None, **kw})
\end{verbatim}
This is a mixin class for wx Controls with epics PVs: This subclasses PVCtrlMixin and adds colour translations PV, and manages callback events for the PV.

Parameters

- **parent** – wx parent widget
- **pv** – epics.PV
- **font** – wx.Font for display
- **fg** – foreground colour
- **bg** – background colour

A class that inherits from this class must provide a method called `_SetValue`, which will set the contents of the corresponding widget when the PV’s value changes.

In general, the widgets will automatically update when the PV changes. Where appropriate, setting the value with the widget will set the PV value.

### 9.1.3 PVText

class `wx.PVText`

```
wx.PVText (parent, pv=None, font=None, fg=None, bg=None, minor_alarm="DARKRED", major_alarm="RED", invalid_alarm="ORANGERED", auto_units=False, units="", **kw)
```

derived from wx.StaticText and PVCtrlMixin, this is a StaticText widget whose value is set to the string representation of the value for the corresponding PV.

By default, the text colour will be overridden when the PV enters an alarm state. These colours can be modified (or disabled by being set to `None`) as part of the constructor.

“units” specifies a unit suffix (like ‘ A’ or ‘ mm’) to put after the text value whenever it is displayed.

Alternatively, “auto_units” means the control will automatically display the “EGU” units value from the PV, whenever it updates. If this value is set, “units” is ignored. A space is inserted between the value and the unit.

### 9.1.4 PVTextCtrl

class `wx.PVTextCtrl`

```
wx.PVTextCtrl (parent, pv=None, font=None, fg=None, bg=None, dirty_timeout=2500, **kw)
```

derived from wx.TextCtrl and PVCtrlMixin, this is a TextCtrl widget whose value is set to the string representation of the value for the corresponding PV.

Setting the value (hitting Return or Enter) or changing focus away from the widget will set the PV value immediately. Otherwise, the widget will wait for ‘dirty_timeout’ milliseconds after the last keypress and then set the PV value to whatever is written in the field.

### 9.1.5 PVFloatCtrl

class `wx.PVFloatCtrl`

```
wx.PVFloatCtrl (parent, pv=None, font=None, fg=None, bg=None, **kw)
```

A special variation of a wx.TextCtrl that allows only floating point numbers, as associated with a double, float, or integer PV. Trying to type in a value that is not a floating point number will be ignored. Furthermore, if a PV’s limits can be determined, they will be used to limit the allowed range of input values. For a value that is within limits, the value will be put to the PV on return. Out-of-limit values will be highlighted in a different color.
9.1.6 PVBitmap

class `wx.PVBitmap` (parent, pv=None, bitmaps={}, defaultBitmap=None)

A Static Bitmap where the image is based on PV value.

If the bitmaps dictionary is set, it should be set as PV.Value(Bitmap) where particular bitmaps will be shown if the PV takes those certain values.

If you need to do any more complex or dynamic drawing, you may want to look at the OGL PV controls.

9.1.7 PVCheckBox

class `wx.PVCheckBox` (self, parent, pv=None, on_value=1, off_value=0, **kw)

Checkbox based on a binary PV value, both reads/writes the PV on changes. on_value and off_value are the specific values that are mapped to the checkbox.

There are multiple options for translating PV values to checkbox settings (from least to most complex):

- Use a PV with values 0 and 1
- Use a PV with values that convert via Python’s own bool(x)
- Set on_value and off_value in the constructor
- Use SetTranslations() to set a dictionary for converting various PV values to booleans.

9.1.8 PVFloatSpin

class `wx.PVFloatSpin` (parent, pv=None, deadTime=500, min_val=None, max_val=None, increment=1.0, digits=-1, **kw)

A FloatSpin is a floating point spin control with buttons to increase and decrease the value by a particular increment. Arrow keys and page up/down can also be used (the latter changes the value by 10x the increment.)

PVFloatSpin is a special derivation that assigns a PV to the FloatSpin control. deadTime is the delay (in milliseconds) between when the user finishes typing a value and when the PV is set to it (to prevent half-typed numeric values being set.)

9.1.9 PVButton

PVButton (parent, pv=None, pushValue=1, disablePV=None, disableValue=1, **kw)

A wx.Button linked to a PV. When the button is pressed, ‘pushValue’ is written to the PV (useful for momentary PVs with HIGH= set.) Setting disablePV and disableValue will automatically cause the button to disable when that PV has a certain value.

9.1.10 PVRadioButton

class `wx.PVRadioButton` (parent, pv=None, pvValue=None, **kw)

A PVRadioButton is a radio button associated with a particular PV and one particular value.

Suggested for use in a group where all radio buttons are PVRadioButtons, and they all have a discrete value set.
9.1.11 PVComboBox

```python
class wx.PVComboBox (parent, pv=None, **kw)
```
A ComboBox linked to a PV. Both reads/writes the combo value on changes.

9.1.12 PVEnumComboBox

```python
class wx.PVEnumComboBox (parent, pv=None, **kw)
```
A ComboBox linked to an “enum” type PV (such as bi, bo, mbii, mbbo.) The ComboBox is automatically populated with a non-editable list of the PV enum values, allowing the user to select them from the drop-down.

Both reads/writes the combo value on changes.

9.1.13 PVEnumButtons

```python
class wx.PVEnumButtons (parent, pv=None, font=None, fg=None, bg=None, **kw)
```
This will create a wx.Panel of buttons (a button bar), 1 for each enumeration state of an enum PV. The set of buttons will correspond to the current state of the PV.

9.1.14 PVEnumChoice

```python
class wx.PVEnumChoice (parent, pv=None, font=None, fg=None, bg=None, **kw)
```
This will create a dropdown list (a wx.Choice) with a list of enumeration states for an enum PV.

9.1.15 PVAlarm

```python
class wx.PVAlarm (parent, pv=None, font=None, fg=None, bg=None, trip_point=None, **kw)
```
This will create a pop-up message (wx.MessageDialog) that is shown when the corresponding PV trips the alarm level.

9.1.16 PVCollapsiblePane

```python
class wx.PVCollapsiblePane (parent, pv=None, minor_alarm="DARKRED", major_alarm="RED", invalid_alarm="ORANGERED", **kw)
```
This is equivalent to wx.CollapsiblePane, except the label shown on the pane’s “expansion button” comes from a PV.

The additional keyword arguments can be any of the other constructor arguments supported by wx.CollapsiblePane.

By default, the foreground colour of the pane button will be overridden when the PV enters an alarm state. On GTK, this means the colour of the triangular drop-down button but not the label text. These colours can be modified (or disabled by being set to None) as part of the constructor.

Supports the .SetTranslation() method, whose argument is a dictionary mapping PV values to display labels. If the PV value is not found in the dictionary, it will displayed verbatim as the label.
9.2 Decorators and other Utility Functions

wx.DelayedEpicsCallback()
decorator to wrap an Epics callback in a wx.CallAfter, so that the wx and epics ca threads do not clash. This also checks for dead wxPython objects (say, from a closed window), and remove callbacks to them.

wx.EpicsFunction()
decorator to wrap function in a wx.CallAfter() so that Epics calls can be made in a separate thread, and asynchronously. This decorator should be used for all code that mix calls to wx and epics.

wx.finalize_epics()
This function will finalize epics, and close all Channel Access communication, by calling epics.ca.finalize_libca(). This may be useful when closing an application, as in a method bound to wx.EVT_CLOSE event from a top-level application window. Be careful to not call this function when closing a Window if your application is not closing, and if you are still doing any Channel Access work in the other windows.

9.3 wxMotorPanel Widget

A dedicated wx Widget for Epics Motors is included in the wx module that provides an easy-to-use Motor panel that is similar to the normal MEDM window, but with a few niceties from the more sophisticated wx toolkit. This widget can be used simply as:

```
import wx
from epics.wx import MotorPanel
....
mymotor = MotorPanel(parent, 'XXX:m1')
```

A sample panel looks like this

![Epics Motor Panel](image)

Which shows from right to left: the motor description, an information message (blank most of the time), the readback value, the drive value, arrows to tweak the motor, and a drop-down combobox for tweak values, a “Stop” button and a “More” button. The panel has the following features:

- All controls are “live” and will respond to changes from other source.
- The values for the tweak values in the ComboBox are automatically generated from the precision and travel range of the motor.
- The entry box for the drive value will only accept numeric input, and will only set the drive value when hitting Enter or Return.
- The drive value will change to Red text on a Yellow background when the value in the box violates the motors (user) limits. If Enter or Return when the the displayed value violates the limit, the motor will not be moved, but the displayed value will be changed to the closest limit value.
- Pressing the “Stop” button will stop the motor (with the .SPMG field), and set the Info field to “Stopped”. The button label will change to “Go”, and the motor will not move until this button is pressed.
Finally, the “More” button will bring up a more complete form of Motor parameters that looks like:

![Motor Details](image)

<table>
<thead>
<tr>
<th>Drive</th>
<th>User</th>
<th>Dial</th>
<th>Raw</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>High Limit</td>
<td>1500.000</td>
<td>1500.000</td>
<td>50000</td>
<td>Stop</td>
</tr>
<tr>
<td>Readback</td>
<td>25.0000</td>
<td>25.0000</td>
<td></td>
<td>Pause</td>
</tr>
<tr>
<td>Move</td>
<td>25.0000</td>
<td>25.0000</td>
<td>50000</td>
<td>Move</td>
</tr>
<tr>
<td>Low Limit</td>
<td>-1500.000</td>
<td>-1500.000</td>
<td></td>
<td>Go</td>
</tr>
<tr>
<td>Tweak</td>
<td>&lt; 0.0100 &gt;</td>
<td></td>
<td></td>
<td></td>
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**Calibration**

<table>
<thead>
<tr>
<th>Mode:</th>
<th>Use</th>
<th>Set</th>
<th>Freeze Offset:</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction:</td>
<td>Pos</td>
<td>Neg</td>
<td>Offset Value:</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

**Dynamics**

| Max Speed   | 20.0000 |
| Speed       | 20.0000 | 1.0000 |
| Base Speed  | 1.0000  |
| Accel (s)   | 0.5000  | 0.2000 |
| Backslash Distance | 0.0000 |
| Move Fraction| 1.0000  |

**Resolution**

| Motor Res   | 0.0005 |
| Steps / Rev | 2000   |
| Precision   | 4      |
| Encoder Res | 0.0005 |
| Units / Rev | 1.0000 |
will look like this:

![Image of a GUI showing various PV values and controls]

### 9.4 OGL Classes

OGL is a graphics drawing library shipped with wxPython. It is built around the concept of “shapes” which are added to “canvases” and can be moved, scrolled, zoomed, animated, etc.

There is a PVShapeMixin class which allows PV callback functionality to be added to any OGL Shape class, and there are also PVRectangle and PVCircle subclasses already created.

A recommended way to use these OGL classes is to make a static bitmap background for your display, place it in an OGL Canvas and then add an overlay of shapes which appear/disappear/resize/change colour based on the PV values.

#### 9.4.1 PVShapeMixin

```python
class wx.PVShapeMixin(self, pv=None, pvname=None):
    Similar to PVMixin, this mixin should be added to any ogl.Shape subclass that needs PV callback support.
    The main method is PVChanged(self, raw_value), which should be overridden in the subclass to provide specific
    processing based on the changed value.
    There are also some built-in pieces of functionality. These are enough to do simple show/hide or change colour
    shape functionality, without needing to write specific code.
    SetBrushTranslations(translations) allows setting a dict of PV Value -> wx.Brush mappings, which can be used
    to automatically repaint the shape foreground (fill) when the PV changes.
    SetPenTranslations(translations) similar to brush translations, but the values are wx.Pen instances that are used
    to repaint the shape outline when the PV changes.
    SetShownTranslations(translations) sets a dictionary of PV Value ->bool values which are used to show/hide the
    shape depending on the PV value, as it changes.
```

#### 9.4.2 PVRectangle

```python
class wx.PVRectangle(self, w, h, pv=None, pvname=None):
    A PVCtrlMixin for the Rectangle shape class.
```
9.4.3 PVCircle

```python
class wx.PVCircle(self, diameter, pv=None, pvname=None)
    A PVCtrlMixin for the Circle shape class.
```

A PVCtrlMixin for the Circle shape class.
This chapter contains a variety of “usage notes” and implementation details that may help in getting the best performance from the pypics module.

10.1 The wait and timeout options for get(), ca.get_complete()

The get functions, \texttt{epics.caget()}, \texttt{pv.get()} and \texttt{epics.ca.get()} all ask for data to be transferred over the network. For large data arrays or slow networks, this can take a noticeable amount of time. For PVs that have been disconnected, the get call will fail to return a value at all. For this reason, these functions all take a timeout keyword option. The lowest level \texttt{epics.ca.get()} also has a wait option, and a companion function \texttt{epics.ca.get_complete()}. This section describes the details of these.

If you’re using \texttt{epics.caget()} or \texttt{pv.get()} you can supply a timeout value. If the value returned is None, then either the PV has truly disconnected or the timeout passed before receiving the value. If the get is incomplete, in that the PV is connected but the data has simply not been received yet, a subsequent \texttt{epics.caget()} or \texttt{pv.get()} will eventually complete and receive the value. That is, if a PV for a large waveform record reports that it is connected, but a \texttt{pv.get()} returns None, simply trying again later will probably work:

```
>>> p = epics.PV('LargeWaveform')
>>> val = p.get()
>>> val
>>> time.sleep(10)
>>> val = p.get()
```

At the lowest level (which \texttt{pv.get()} and \texttt{epics.caget()} use), \texttt{epics.ca.get()} issues a get-request with an internal callback function. That is, it calls the CA library function \texttt{libca.ca_array_get_callback()} with a pre-defined callback function. With \texttt{wait=True} (the default), \texttt{epics.ca.get()} then waits up to the timeout or until the CA library calls the specified callback function. If the callback has been called, the value can then be converted and returned.

If the callback is not called in time or if \texttt{wait=False} is used but the PV is connected, the callback will be called eventually, and simply waiting (or using \texttt{epics.ca.pend_event()} if \texttt{epics.ca.PREEMPTIVE_CALLBACK} is False) may be sufficient for the data to arrive. Under this condition, you can call \texttt{epics.ca.get_complete()}, which will NOT issue a new request for data to be sent, but wait (for up to a timeout time) for the previous get request to complete.

\texttt{epics.ca.get_complete()} will return None if the timeout is exceeded or if there is not an “incomplete get” that it can wait to complete. Thus, you should use the return value from \texttt{epics.ca.get_complete()} with care.

Note that \texttt{pv.get()} (and so \texttt{epics.caget()}) will normally rely on the PV value to be filled in automatically by monitor callbacks. If monitor callbacks are disabled (as is done for large arrays and can be turned off) or if the monitor hasn’t been called yet, \texttt{pv.get()} will check whether it should can \texttt{epics.ca.get()} or \texttt{epics.ca.get_complete()}. 
If not specified, the timeout for `epics.ca.get_complete()` (and all other get functions) will be set to:

```python
timeout = 0.5 + \log_{10}(\text{count})
```

Again, that’s the maximum time that will be waited, and if the data is received faster than that, the `get` will return as soon as it can.

### 10.2 Strategies for connecting to a large number of PVs

Occasionally, you may find that you need to quickly connect to a large number of PVs, say to write values to disk. The most straightforward way to do this, say:

```python
import epics

pvnamelist = read_list_pvs()
pv_vals = {}
for name in pvnamelist:
    pv = epics.PV(name)
    pv_vals[name] = pv.get()
```

or even just:

```python
values = [epics.caget(name) for name in pvnamelist]
```

...does incur some performance penalty. To minimize the penalty, we need to understand its cause.

Creating a PV object (using any of `pv.PV`, or `pv.get_pv()`, or `epics.caget()`) will automatically use connection and event callbacks in an attempt to keep the PV alive and up-to-date during the session. Normally, this is an advantage, as you don’t need to explicitly deal with many aspects of Channel Access. But creating a PV does request some network traffic, and the PV will not be “fully connected” and ready to do a `PV.get()` until all the connection and event callbacks are established. In fact, `PV.get()` will not run until those connections are all established. This takes very close to 30 milliseconds for each PV. That is, for 1000 PVs, the above approach will take about 30 seconds.

The simplest remedy is to allow all those connections to happen in parallel and in the background by first creating all the PVs and then getting their values. That would look like:

```python
# improve time to get multiple PVs: Method 1
import epics

pvnamelist = read_list_pvs()
pvs = [epics.PV(name) for name in pvnamelist]
values = [p.get() for p in pvs]
```

Though it doesn’t look that different, this improves performance by a factor of 100, so that getting 1000 PV values will take around 0.4 seconds.

Can it be improved further? The answer is Yes, but at a price. For the discussion here, we’ll can the original version “Method 0” and the method of creating all the PVs then getting their values “Method 1”. With both of these approaches, the script has fully connected PV objects for all PVs named, so that subsequent use of these PVs will be very efficient.

But this can be made even faster by turning off any connection or event callbacks, avoiding PV objects altogether, and using the `epics.ca` interface. This has been encapsulated into `epics.caget_many()` which can be used as:

```python
# get multiple PVs as fast as possible: Method 2
import epics

# (continues on next page)
In tests using 1000 PVs that were all really connected, Method 2 will take about 0.25 seconds, compared to 0.4 seconds for Method 1 and 30 seconds for Method 0. To understand what `epics.caget_many()` is doing, a more complete version of this looks like this:

```python
# epics.caget_many made explicit: Method 3
from epics import ca

pvnamelist = read_list_pvs()

data = {}
pvchids = []

# create, don't connect or create callbacks
for name in pvnamelist:
    chid = ca.create_channel(name, connect=False, auto_cb=False) # note 1
    pvchids.append(chid)

# connect
for chid in pvchids:
    ca.connect_channel(chid)

# request get, but do not wait for result
ca.poll()
for chid in pvchids:
    ca.get(chid, wait=False) # note 2

# now wait for get() to complete
ca.poll()
for chid in pvchids:
    val = ca.get_complete(data[0])
    data[ca.name(chid)] = val
```

The code here probably needs detailed explanation. As mentioned above, it uses the `ca` level, not `PV` objects. Second, the call to `epics.ca.create_channel()` (Note 1) uses `connect=False` and `auto_cb=False` which mean to not wait for a connection before returning, and to not automatically assign a connection callback. Normally, these are not what you want, as you want a connected channel and to be informed if the connection state changes, but we’re aiming for maximum speed here. We then use `epics.ca.connect_channel()` to connect all the channels. Next (Note 2), we tell the CA library to request the data for the channel without waiting around to receive it. The main point of not having `epics.ca.get()` wait for the data for each channel as we go is that each data transfer takes time. Instead we request data to be sent in a separate thread for all channels without waiting. Then we do wait by calling `epics.ca.poll()` once and only once, (not `len(pvnamelist)` times!). Finally, we use the `epics.ca.get_complete()` method to convert the data that has now been received by the companion thread to a python value.

Method 2 and 3 have essentially the same runtime, which is somewhat faster than Method 1, and much faster than Method 0. Which method you should use depends on use case. In fact, the test shown here only gets the PV values once. If you’re writing a script to get 1000 PVs, write them to disk, and exit, then Method 2 (`epics.caget_many()`) may be exactly what you want. But if your script will get 1000 PVs and stay alive doing other work, or even if it runs a loop to get 1000 PVs and write them to disk once a minute, then Method 1 will actually be faster. That is doing `epics.caget_many()` in a loop, as with:

```python
# caget_many() 10 times
import epics
import time
```

---

10.2. Strategies for connecting to a large number of PVs
pvnamelist = read_list_pvs()
for i in range(10):
    values = epics.caget_many(pvlist)
    time.sleep(0.01)

will take around considerably *longer* than creating the PVs once and getting their values in a loop with:

```python
import epics
import time
pvnamelist = read_list_pvs()
pvs = [epics.PV(name) for name in pvnamelist]
for i in range(10):
    values = [p.get() for p in pvs]
    time.sleep(0.01)
```

In tests with 1000 PVs, looping with `epics.caget_many()` took about 1.5 seconds, while the version looping over `PV.get()` took about 0.5 seconds.

To be clear, it is connecting to Epics PVs that is expensive, not the retrieving of data from connected PVs. You can lower the connection expense by not retaining the connection or creating monitors on the PVs, but if you are going to re-use the PVs, that savings will be lost quickly. In short, use Method 1 over `epics.caget_many()` unless you've benchmarked your use-case and have demonstrated that `epics.caget_many()` is better for your needs.

### 10.3 time.sleep() or epics.poll()?

In order for a program to communicate with Epics devices, it needs to allow some time for this communication to happen. With `epics.ca.PREEMPTIVE_CALLBACK` set to True, this communication will be handled in a thread separate from the main Python thread. This means that CA events can happen at any time, and `epics.ca.pend_event()` does not need to be called to explicitly allow for event processing.

Still, some time must be released from the main Python thread on occasion in order for events to be processed. The simplest way to do this is with `time.sleep()`, so that an event loop can simply be:

```python
>>> while True:
...     time.sleep(0.001)
```

Unfortunately, the `time.sleep()` method is not a very high-resolution clock, with typical resolutions of 1 to 10 ms, depending on the system. Thus, even though events will be asynchronously generated and epics with pre-emptive callbacks does not require `epics.ca.pend_event()` or `epics.ca.poll()` to be run, better performance may be achieved with an event loop of:

```python
>>> while True:
...     epics.poll(evt=1.e-5, iot=0.1)
```

as the loop will be run more often than using `time.sleep()`.

### 10.4 Using Python Threads

An important feature of the PyEpics package is that it can be used with Python threads, as Epics 3.14 supports threads for client code. Even in the best of cases, working with threads can be somewhat tricky and lead to unexpected behavior, and the Channel Access library adds a small level of complication for using CA with Python threads. The
result is that some precautions may be in order when using PyEpics and threads. This section discusses the strategies for using threads with PyEpics.

First, to use threads with Channel Access, you must have `epics.ca.PREEMPTIVE_CALLBACK = True`. This is the default value, but if `epics.ca.PREEMPTIVE_CALLBACK` has been set to `False`, threading will not work.

Second, if you are using PV objects and not making heavy use of the `epics.ca` module (that is, not making and passing around chids), then the complications below are mostly hidden from you. If you’re writing threaded code, it’s probably a good idea to read this just to understand what the issues are.

### 10.4.1 Channel Access Contexts

The Channel Access library uses a concept of *contexts* for its own thread model, with contexts holding sets of threads as well as Channels and Process Variables. For non-threaded work, a process will use a single context that is initialized prior to any real CA work (done in `epics.ca.initialize_libca()`). In a threaded application, each new thread begins with a new, uninitialized context that must be initialized or replaced. Thus each new python thread that will interact with CA must either explicitly create its own context with `epics.ca.create_context()` (and then, being a good citizen, destroy this context as the thread ends with `epics.ca.destroy_context()`) or attach to an existing context.

The generally recommended approach is to use a single CA context throughout an entire process and have each thread attach to the first context created (probably from the main thread). This avoids many potential pitfalls (and crashes), and can be done fairly simply. It is the default mode when using PV objects.

The most explicit use of contexts is to put `epics.ca.create_context()` at the start of each function call as a thread target, and `epics.ca.destroy_context()` at the end of each thread. This will cause all the activity in that thread to be done in its own context. This works, but means more care is needed, and so is not the recommended.

The best way to attach to the initially created context is to call `epics.ca.use_initial_context()` before any other CA calls in each function that will be called by `Thread.run()`. Equivalently, you can add a `withInitialContext()` decorator to the function. Creating a PV object will implicitly do this for you, as long as it is your first CA action in the function. Each time you do a `PV.get()` or `PV.put()` (or a few other methods), it will also check that the initial context is being used.

Of course, this approach requires CA to be initialized already. Doing that *in the main thread* is highly recommended. If it happens in a child thread, that thread must exist for all CA work, so either the life of the process or with great care for processes that do only some CA calls. If you are writing a threaded application in which the first real CA calls are inside a child thread, it is recommended that you initialize CA in the main thread.

As a convenience, the `CAThread` in the `epics.ca` module is is a very thin wrapper around the standard `threading.Thread` which adding a call of `epics.ca.use_initial_context()` just before your threaded function is run. This allows your target functions to not explicitly set the context, but still ensures that the initial context is used in all functions.

### 10.4.2 How to work with CA and Threads

Summarizing the discussion above, to use threads you must use run in PREEMPTIVE_CALLBACK mode. Furthermore, it is recommended that you use a single context, and that you initialize CA in the main program thread so that your single CA context belongs to the main thread. Using PV objects exclusively makes this easy, but it can also be accomplished relatively easily using the lower-level ca interface. The options for using threads (in approximate order of reliability) are then:

1. use PV objects for threading work. This ensures you’re working in a single CA context.
2. use `CAThread` instead of `Thread` for threads that will use CA calls.
3. put `epics.ca.use_initial_context()` at the top of all functions that might be a Thread target function, or decorate them with `withInitialContext()` decorator, `@withInitialContext`.

4. use `epics.ca.create_context()` at the top of all functions that are inside a new thread, and be sure to put `epics.ca.destroy_context()` at the end of the function.

5. ignore this advise and hope for the best. If you’re not creating new PVs and only reading values of PVs created in the main thread inside a child thread, you may not see a problems, at least not until you try to do something fancier.

### 10.4.3 Thread Examples

This is a simplified version of test code using Python threads. It is based on code originally from Friedrich Schotte, NIH, and included as `thread_test.py` in the `tests` directory of the source distribution.

In this example, we define a `run_test` procedure which will create PVs from a supplied list, and monitor these PVs, printing out the values when they change. Two threads are created and run concurrently, with overlapping PV lists, though one thread is run for a shorter time than the other.

```python
"""This script tests using EPICS CA and Python threads together
Based on code from Friedrich Schotte, NIH, modified by Matt Newville
19-Apr-2010
""
import time
from sys import stdout
from threading import Thread
import epics
from epics.ca import CAThread
from pvnames import updating_pvlist

pvlist_a = updating_pvlist[:-1]
pvlist_b = updating_pvlist[1:]

def run_test(runtime=1, pvnames=None, run_name='thread c'):
    msg = '-> thread "$s" will run for %.3f sec, monitoring $s\n'
    stdout.write(msg % (run_name, runtime, pvnames))

def onChanges(pvname=None, value=None, char_value=None, **kw):
    stdout.write(' %s = %s (%s)\n' % (pvname, char_value, run_name))
    stdout.flush()

# epics.ca.use_initial_context() # epics.ca.create_context()
start_time = time.time()
pvs = [epics.PV(pvn, callback=onChanges) for pvn in pvnames]

while time.time() - start_time < runtime:
    time.sleep(0.1)

    [p.clear_callbacks() for p in pvs]
    stdout.write( 'Completed Thread "$s" % (run_name))

stdout.write( "First, create a PV in the main thread:\n")
p = epics.PV(updating_pvlist[0])

stdout.write("Run 2 Background Threads simultaneously:\n")
th1 = CAThread(target=run_test, args=(3, pvlist_a, 'A'))
th1.start()

(continues on next page)
```
In light of the long discussion above, a few remarks are in order: This code uses the standard Thread library and explicitly calls `epics.ca.use_initial_context()` prior to any CA calls in the target function. Also note that the `run_test()` function is first called from the main thread, so that the initial CA context does belong to the main thread. Finally, the `epics.ca.use_initial_context()` call in `run_test()` above could be replaced with `epics.ca.create_context()`, and run OK.

The output from this will look like:

```
First, create a PV in the main thread:
Run 2 Background Threads simultaneously:
-> thread "A" will run for 3.000 sec, monitoring ['Py:ao1', 'Py:ai1', 'Py:long1']
-> thread "B" will run for 6.000 sec, monitoring ['Py:ai1', 'Py:long1', 'Py:ao2']
  Py:ao1 = 8.3948 (A)
  Py:ai1 = 3.14 (B)
  Py:ai1 = 3.14 (A)
  Py:ao1 = 0.7404 (A)
  Py:ai1 = 4.07 (B)
  Py:ai1 = 4.07 (A)
  Py:long1 = 3 (B)
  Py:long1 = 3 (A)
  Py:ao1 = 13.0861 (A)
  Py:ai1 = 8.49 (B)
  Py:ai1 = 8.49 (A)
  Py:ao2 = 30 (B)
Completed Thread A
  Py:ai1 = 9.42 (B)
  Py:ao2 = 30 (B)
  Py:long1 = 4 (B)
  Py:ai1 = 3.35 (B)
  Py:ao2 = 31 (B)
  Py:ai1 = 4.27 (B)
  Py:ao2 = 31 (B)
  Py:long1 = 5 (B)
  Py:ai1 = 8.20 (B)
  Py:ao2 = 31 (B)
Completed Thread B
Done
```

Note that while both threads A and B are running, a callback for the PV `Py:ai1` is generated in each thread.

Note also that the callbacks for the PVs created in each thread are explicitly cleared with:

```
[p.clear_callbacks() for p in pvs]
```

Without this, the callbacks for thread A will persist even after the thread has completed!
10.5 Using Multiprocessing with PyEpics

An alternative to Python threads that has some very interesting and important features is to use multiple processes, as with the standard Python multiprocessing module. While using multiple processes has some advantages over threads, it also has important implications for use with PyEpics. The basic issue is that multiple processes need to be fully separate, and do not share global state. For epics Channel Access, this means that all those things like established communication channels, callbacks, and Channel Access context cannot easily be share between processes.

The solution is to use a CAProcess, which acts just like multiprocessing.Process, but knows how to separate contexts between processes. This means that you will have to create PV objects for each process (even if they point to the same PV).

```python
class CAProcess(group=None, target=None, name=None, args=(), kwargs={}):
    a subclass of multiprocessing.Process that clears the global Channel Access context before running your target function in its own process.

class CAPool(processes=None, initializer=None, initargs=(), maxtasksperchild=None):
    a subclass of multiprocessing.pool.Pool, creating a Pool of CAProcess instances.
```

A simple example of using multiprocessing successfully is given:

```python
from __future__ import print_function
import epics
import time
import multiprocessing as mp
import threading
import pvnames

PVN1 = pvnames.double_pv # 'Py:ao2'
PVN2 = pvnames.double_pv2 # 'Py:ao3'

def subprocess(*args):
    print('==subprocess==', args)
    mypvs = [epics.PV(pvname) for pvname in args]

    for i in range(10):
        time.sleep(0.750)
        out = [(p.pvname, p.get(as_string=True)) for p in mypvs]
        out = ', '.join(['%s=%s' % o for o in out])
        print('==sub (%d): %s' % (i, out))

def main_process():
    def monitor(pvname=0, char_value=0, **kwargs):
        print('--main:monitor %s=%s' % (pvname, char_value))

    print('--main:')
    pvl = epics.PV(PVN1)
    print('--main:init $s=$s' % (PVN1, pvl.get()))
    pvl.add_callback(callback=monitor)

    try:
        proc1 = epics.CAProcess(target=subprocess, args=(PVN1, PVN2))
        proc1.start()
        proc1.join()
    except KeyboardInterrupt:
        print('--main: killing subprocess')
        proc1.terminate()
```

(continues on next page)
here, the main process and the subprocess can each interact with the same PV, though they need to create a separate connection (here, using `PV`) in each process.

Note that different `CAProcess` instances can communicate via standard `multiprocessing.Queue`. At this writing, no testing has been done on using multiprocessing Managers.
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