EPICS
Input / Output Controller (IOC)
Application Developer's Guide

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Chapter 1: Introduction

1.1 Overview

This document describes the core software that resides in an Input/Output Controller (IOC), one of the major components of EPICS. It is intended for anyone developing EPICS IOC databases and/or new record/device/driver support.

The plan of the book is:

New Features for release 3.14

> A brief description of new features. The most important new feature is that iocCore is now supported on systems in addition to vxWorks.

EPICS Overview

> An overview of EPICS is presented, showing how the IOC software fits into EPICS. This is the only chapter that discusses OPI software and Channel Access rather than just IOC related topics.

EPICS Build Facility

> This chapter, which was written by Janet Anderson, describes the EPICS build facility including directory structure, environment and system requirements, configuration files, Makefiles, and related build tools.

Database Locking, Scanning, and Processing

> Overview of three closely related IOC concepts. These concepts are at the heart of what constitutes an EPICS IOC.

Database Definition

> This chapter gives a complete description of the format of the files that describe IOC databases. This is the format used by Database Configuration Tools and is also the format used to load databases into an IOC.

IOC Initialization

> A great deal happens at IOC initialization. This chapter removes some of the mystery about initialization.

Access Security

> Channel Access Security is implemented in IOCs. This chapter explains how it is configured and also how it is implemented.

IOC Test Facilities

> Epics supplied test routines that can be executed via the epics or vxWorks shell.

IOC Error Logging

> IOC code can call routines that send messages to a system wide error logger.

Record Support

> The concept of record support is discussed. This information is necessary for anyone who wishes to provide customized record and device support.

Device Support

The concept of device support is discussed. Device support takes care of the hardware specific details of record support, i.e. it is the interface between hardware and a record support module. Device support can directly access hardware or may interface to driver support.

Driver Support

The concepts of driver support is discussed. Drivers, which are not always needed, have no knowledge of records but just take care of interacting with hardware. Guidelines are given about when driver support, instead of just device support, should be provided.

Static Database Access

This is a library that works on Unix and vxWorks and on initialized or uninitialized EPICS databases.

Runtime Database Access

The heart of the IOC software is the memory resident database. This chapter describes the interface to this database.

Device Support Library

A set of routines are provided for device support modules that use shared resources such as VME address space.

EPICS General Purpose Tasks

General purpose callback tasks and task watchdog.

Database Scanning

Database scan tasks, i.e. the tasks that request records to process.

libCom

EPICS base includes a subdirectory src/libCom, which contains a number of c and c++ libraries that are used by the other components of base. This chapter describes most of these libraries.

libCom OSI

This chapter describes the libraries in libCom that provide Operating System Independent (OSI) interrfaces used by the rest of EPICS base. LibCom also contains operating system dependent code that implements the OSI interfaces.

Registry

Under vxWorks osiFindGlobalSymbol can be used to dynamically bind to record, device, and driver support. Since on some systems this always returns failure, a registry facility is provided to implement the binding. The basic idea is that any storage meant to be "globally" accessable must be registered before it can be accessed

Database Structures

A description of the internal database structures.

Other than the first chapter this document describes only core IOC software. Thus it does not describe other EPICS tools which run in an IOC such as the sequencer. It also does not describe Channel Access.

The reader of this manual should also have the following documents:

- *EPICS Record Reference Manual*, Philip Stanley, Janet Anderson and Marty Kraimer
  See LANL Web site for latest version.
- EPICS IOC Software Configuration Management, Marty Kraimer, Andrew Johnson, Janet Anderson, Ralph Lange
  http://www.aps.anl.gov/asd/controls/epics/EpicsDocumentation/AppDevManuals/iocScm-3.13.2/index.html
- *vxWorks Programmer's Guide*, Wind River Systems
- *vxWorks Reference Manual*, Wind River Systems
- RTEMS C User's Guide, Online Applications Research

1.2 Acknowledgments

The basic model of what an IOC should do and how to do it was developed by Bob Dalesio at LANL/GTA. The principle ideas for Channel Access were developed by Jeff Hill of LANL/GTA. Bob and Jeff also were the principle implementers of the original IOC software. This software (called GTACS) was developed over a period of several years with feedback from LANL/GTA users. Without their ideas EPICS would not exist.

During 1990 and 1991, ANL/APS undertook a major revision of the IOC software with the major goal being to provide easily extendible record and device support. Marty Kraimer (ANL/APS) was primarily responsible for designing the data structures needed to support extendible record and device support and for making the changes needed to the IOC resident software. Bob Zieman (ANL/APS) designed and implemented the UNIX build tools and IOC modules necessary to support the new facilities. Frank Lenkszus (ANL/APS) made extensive changes to the Database Configuration Tool (DCT) necessary to support the new facilities. Janet Anderson developed methods to systematically test various features of the IOC software and is the principal implementer of changes to record support.

During 1993 and 1994, Matt Needes at LANL implemented and supplied the description of fast database links and the database debugging tools.

During 1993 and 1994 Jim Kowalkowski at ANL/APS developed GDCT and also developed the ASCII database instance format now used as the standard format. At that time he also created `dbLoadRecords` and `dbLoadTemplate`.

The `build` utility method resulted in the generation of binary files of UNIX that were loaded into IOCs. As new IOC architectures started being supported this caused problems. During 1995, after learning from an abandoned effort now referred to as `EpicsRX`, the build utilities and binary file (called `default.dctsdr`) were replaced by all ASCII files. The new method provides architecture independence and a more flexible environment for configuring the record/device/driver support. This principle implementer was Marty Kraimer with many ideas contributed by John Winans and Jeff Hill. Bob Dalesio made sure that we did not go to far, i.e. 1) make it difficult to upgrade existing applications and 2) lose performance.

In early 1996 Bob Dalesio tackled the problem of allowing runtime link modification. This turned into a cooperative development effort between Bob and Marty Kraimer. The effort included new code for database to Channel Access links, a new library for lock sets, and a cleaner interface for accessing database links.

In early 1999 the port of iocCore to non vxWorks operating systems was started. The principle developers were Marty Kraimer, Jeff Hill, and Janet Anderson. William Lupton converted the sequencer as well as helping with the posix threads implementation of osiSem and osiThread. Eric Norum provided the port to RTEMS and also contributed the shell that is used on non vxWorks environments.

Many other people have been involved with EPICS development, including new record, device, and driver support modules.

Chapter 2: New Features for 3.14

2.1 Introduction

This is the second release that supports iocCore on non vxWorks operating systems.

The following components of iocCore are included with base:

- Database locking, scanning, and processing
- Channel access client and server support
- Standard record types and soft device support
- Access security
- General purpose soft device support.
- The port to non vxWorks operating systems is based on the following assumptions:
    - All hardware support is unbundled from base.
    - A multithreaded environment is necessary.
- Operating system independent (OSI) components are defined such that:
    - vxWorks implementation has minimal overhead compared to vxWorks specific calls
    - The components can be implemented via a combination of POSIX, POSIX.4 (posix real time), and POSIX threads (pthreads).
    - Each OS can use the posix implementation or provide it's own implementation.

It must be emphasized that this is alpha software. In order to provide a relatively easy conversion path for existing 3.13 applications, the old config rules are still supported. Separate documentation explains how what must be done to convert 3.13 applications. We do NOT recommand converting existing applications at this time unless some of the new features are needed.

2.2 Example Application

This section explains how to create an example IOC application in a directory <top>, naming the application `exampleApp` and the ioc directory `iocexample`.

2.2.1 Check that `EPICS_HOST_ARCH` is defined

Execute the command:

```
echo $EPICS_HOST_ARCH         (Unix)
```

or

```
set EPICS_HOST_ARCH             (Windows)
```

This should display your workstation architecture, for example `solaris-sparc` or `win32-x86`. If you get an "Undefined variable" error, you should set EPICS_HOST_ARCH to your host operating system followed by a dash and then your host architecture, e.g. solaris-sparc. The perl script EpicsHostArch.pl in the base/startup directory has been provided to help set EPICS_HOST_ARCH.

2.2.2 Create the example application

The following commands create an example application.

```
mkdir <top>
cd <top>
<base>/bin/<arch>/makeBaseApp.pl -t example example
<base>/bin/<arch>/makeBaseApp.pl -i -t example example
```

The last command will ask you to enter an architecture. This is only used for a vxWorks target. Just enter one of the `CROSS_COMPILER_TARGET_ARCHS` specified in `<base>/configure/CONFIG_SITE`.

Windows Users Note: Perl scripts are invoked with the command perl <scriptname> on win95/NT. Perl script names are case sensitive. For example to create an application on WIN95/NT:

```
perl C:\epics\base\bin\win32\makeBaseApp.pl -t example example
```

2.2.3 Inspect files

Spend some time looking at the files that appear under <top>. Do this BEFORE building. This allows you to see typical files which are needed to build an application without seeing the files generated by make.

2.2.4 Sequencer Example

The sequencer is now supported as an unbundled product. The example includes an example state notation program; sncExample.stt. As created by makeBaseApp the example is not built or executed.

Before sncExample.st can be built, the sequencer must be built using the same version of base that the example uses.

To build sncExample edit the following files:

- configure/RELEASE - Set SNCSEQ to the location of the sequencer.
- exampleApp/src/Makefile - Remove comment character from the following lines:
  ```
  example_SRCS += sncExample.stt

  example_OBJS_vxWorks += $(SNCSEQ_BIN)/seqLibrary
  example_OBJS_vxWorks += $(SNCSEQ_BIN)/pvLibrary
  seq_DIR    = $(SNCSEQ_LIB
  example_LIBS += seq
  example_LIBS += pv
  ```
- iocBoot/iocexample - Both st.cmd and stcmd.host have a command to start the sequence program. Just remove the comment character.

The Makefile also comtains instructions for how to build sncExample as a standalone application, i.e. an application that does not use an epics database.

2.2.5 Build

In directory <top> execute the command

```
gnumake
```

Linux Note: On linux gnumake is the native make so just execute:

```
make
```

2.2.6 Inspect files

This time you will see the files generated by make as well as the original files.

2.2.7 Run the example

The example can be run on vxWorks, RTEMS, or on a supported host.

- vxWorks - Set your boot parameters as described below and then boot the ioc.
- RTEMS - RTEMS uses TFTP to read startup scripts and configuration files. On your TFTP server:
  - Copy all db/xxx files to <tftpbase>/epics/<target_hostname>/db/xxx.
  - Copy all dbd/xxx files to <tftpbase>/epics/<target_hostname>/dbd/xxx.
  - Copy iocBoot/iocexample/st.cmd to <tftpbase>/epics/<target_hostname>/st.cmd.
  - Transfer the application executable image to the target machine and start it. The method of doing this depends on your target hardware. Typical methods include BOOTP/TFTP, booting from a floppy disk, burning the application into flash memory or using gdb to download and execute the application.
- On a host, e.g. solaris
  - `cd <top>/iocBoot/iocexample`
  - `../../bin/solaris-sparc/example stcmd.host`

After the ioc is started try some of the shell commands (e.g. `dbl` or `dbpr <recordname>`) described in chapter "IOC Test Facilities". In particular run `dbl` to get a list of the records.

The channel access application caExample is run by executing the command

```
<mytop>/bin/<hostarch>/caExample <pvname>
```

where

`<mytop>` is the full path name to your application top directory.
`<hostarch>` is your host architecture.
`<pvname>` is one of the record names displayed by the `dbl` ioc shell command.

Except on vxWorks a help facility is available. Just type:

```
help
help <cmd>
```

Where `cmd` is one of the commands displayed by `help`.

On vxWorks the help facility is available by first typing:

```
iocsh
```

2.2.8 vxWorks boot parameters

The vxWorks boot parameters are set via the console serial port on your IOC. Life is much easier if you find out how to connect the serial port to a window on your workstation.

The vxWorks boot parameters look something like the following:

```
boot device            : xxx
processor number       : 0
host name              : xxx
file name              : <full path to board support>/vxWorks
inet on ethernet (e)   : xxx.xxx.xxx.xxx:<netmask>
host inet (h)          : xxx.xxx.xxx.xxx
user (u)               : xxx
ftp password (pw)      : xxx
flags (f)              : 0x0
target name (tn)       : <hostname for this inet address>
startup script (s)     : <top>/iocBoot/iocexample/st.cmd
```

The actual values for each field are site and IOC dependent. Two fields that you can change at will are the vxWorks boot image and the location of the startup script.

Note that the full path name for the correct board support boot image must be specified. If bootp is used the same information will need to be placed in the bootp host's configuration database instead.

When your boot parameters are set properly, just press the reset button on your IOC, or use the @ command to commence booting. You will find it VERY convenient to have the console port of the IOC attached to a scrolling window on your workstation.

2.3 Shell for non vxWorks environment

Because the vxWorks shell is not available, EPICS base provides a simple shell ioccrf(IOC Call Registered Function). In the main program it can be invoked as follows:

```
ioccrf("filename")
```

or

```
ioccrf(0)
```

If the argument is a filename, the commands in the file are executed and ioccrf returns. If the argument is 0 then ioccrf goes into interactive mode, i.e. it prompts for and executes commands until an exit command is issued.

This shell is described in more detail in Chapter 19, "IOC Shell" on page 213

NOTE: This started as a shell that could call registered functions, which is why it is named ioccrf. Since it is now more general it should have a different name. Perhaps iocsh?

2.4 Some Unresolved Items

- Currently beacons do not perform properly if two or more versions of iocCore and/or portable servers are runing on the same workstation.
- libcom reviewed

    - C++ APIs in libCom. This is the second release of iocCore that is using C++. The current developer's had some major disputes about C++ conventions and design standards. Many disputes have already been resolved but the C++ APIs may still change.
    - osi naming conventions. Current naming conventions are not uniform.
        - Most components that are new to 3.14 now start with the prefix epics. A few still start with osi.
        - For C++ namespaces and the standard C++ library are causing a problem because they are not implemented on all supported platforms.
    - epicsThread
        - Should epicsThreadDestroy be allowed?
- shell for non vxWorks environments
    - Additional extensions to ioccrf? Also give it a better name such as iocsh.
        - Other features?
    - Tcl/Tk wrapper ?
- facility initialization
    - Use c++ static classes to initialize where possible. This is already done in many places. Are we missing some?
    - What should applications use?
    - Lazy initialization? This is already done in many places. Are we missing some?
- Should logClient and logServer be moved to separate directory under src or even unbundled?
- devLib - Thus is actually support for VME. What should we do with devLib?
- Decorated Names. This is for creating win32 DLLs. We should consider a way of creating the DLLs which does not require the decorated names.
- Compiler optimization switches. What should we use? Turning on the -g flag for GNU causes a factor of 10 increase in size of libraries on Linux.

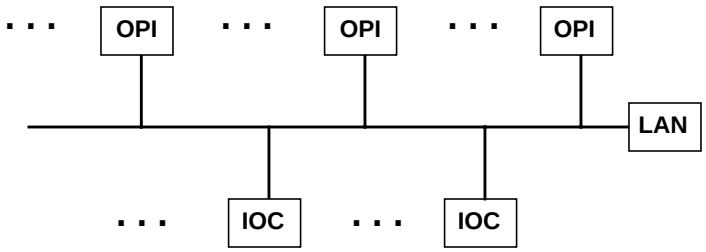
Chapter 3: EPICS Overview

3.1 What is EPICS?

EPICS consists of a set of software components and tools that Application Developers use to create a control system. The basic components are:

- **OPI**: Operator Interface. This is a workstation which can run various EPICS tools.
- **IOC**: Input/Output Controller. Any platform that can support EPICS run time databases together with the other software components described in the manual. One example is a workstation. Another example is a VME/VXI based system using vxWorks or RTEMS as the realtime operating system.
- **LAN**: Local Area Network. This is the communication network which allows the IOCs and OPIs to communicate. EPICS provides a software component, Channel Access, which provides network transparent communication between a Channel Access client and an arbitrary number of Channel Access servers.

A control system implemented via EPICS has the following physical structure.



The rest of this chapter gives a brief description of EPICS:

- **Basic Attributes**: A few basic attributes of EPICS.
- **Platforms**: The vendor supplied Hardware and Software platforms EPICS supports.
- **IOC Software**: EPICS supplied IOC software components.
- **Channel Access**: EPICS software that supports network independent access to IOC databases.
- **OPI Tools**: EPICS supplied OPI based tools.
- **EPICS Core**: A list of the EPICS core software, i.e. the software components without which EPICS will not work.

3.2 Basic Attributes

The basic attributes of EPICS are:

- **Tool Based**: EPICS provides a number of tools for creating a control system. This minimizes the need for custom coding and helps ensure uniform operator interfaces.
- **Distributed**: An arbitrary number of IOCs and OPIs can be supported. As long as the network is not saturated, no single bottle neck is present. A distributed system scales nicely. If a single IOC becomes saturated, its functions can be spread over several IOCs. Rather than running all applications on a single host, the applications can be spread over many OPIs.
- **Event Driven**: The EPICS software components are all designed to be event driven to the maximum extent possible. For example, rather than having to poll IOCs for changes, a Channel Access client can request that it be notified when a change occurs. This design leads to efficient use of resources, as well as, quick response times.
- **High Performance**: A SPARC based workstation can handle several thousand screen updates a second with each update resulting from a Channel Access event. A 68040 IOC can process more than 6,000 records per second, including generation of Channel Access events.

3.3 Hardware - Software Platforms (Vendor Supplied)

3.3.1 OPI

Hardware

- Unix based Workstations: Well supported platforms include SOLARIS, and HP-UX
- Linux
- Windows NT
- Limited support for VMS

Software

- UNIX or Linux or winNT
- X Windows
- Motif Toolkit

3.3.2 LAN

Hardware

- Ethernet (most flavors)

Software

- TCP/IP protocols via sockets

3.3.3 IOC

Hardware

- VME/VXI bus and crates
    - Various VME modules (ADCs, DAC, Binary I/O, etc.)
    - Allen Bradley Scanner (Most AB I/O modules)
    - GPIB devices
    - BITBUS devices

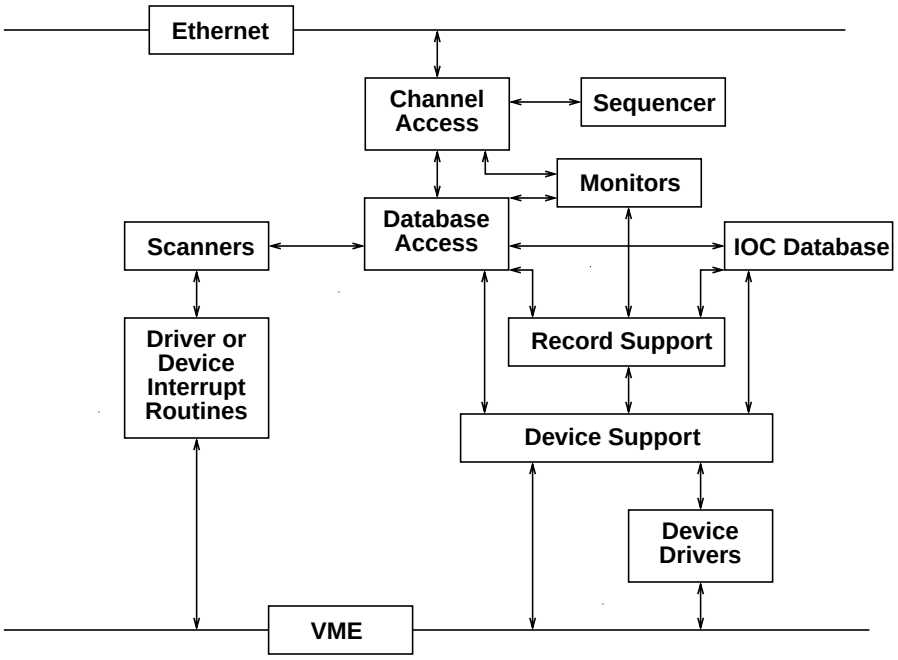
    - CAMAC
    - CANBUS
- Motorola 68xxx
- Intel
- PowerPC
- Sparc

Software

- vxWorks operating system
    - Real time kernel
    - Extensive “Unix like” libraries
- RTEMS
- Host, e.g. solaris

3.4 IOC Software Components

An IOC contains the following EPICS supplied software components.



- **IOC Database**: The memory resident database plus associated data structures.
- **Database Access**: Database access routines. With the exception of record and device support, all access to the database is via the database access routines.
- **Scanners**: The mechanism for deciding when records should be processed.
- **Record Support**: Each record type has an associated set of record support routines.
- **Device Support**: Each record type can have one or more sets of device support routines.
- **Device Drivers**: Device drivers access external devices. A driver may have an associated driver interrupt routine.

- **Channel Access**: The interface between the external world and the IOC. It provides a network independent interface to database access.
- **Monitors**: Database monitors are invoked when database field values change.
- **Sequencer**: A finite state machine.

Let's briefly describe the major components of the IOC and how they interact.

3.4.1 IOC Database

The heart of each IOC is a memory resident database together with various memory resident structures describing the contents of the database. EPICS supports a large and extensible set of record types, e.g. `ai` (Analog Input), `ao` (Analog Output), etc.

Each record type has a fixed set of fields. Some fields are common to all record types and others are specific to particular record types. Every record has a record name and every field has a field name. The first field of every database record holds the record name, which must be unique across all IOCs that are attached to the same TCP/IP subnet.

Data structures are provided so that the database can be accessed efficiently. Most software components, because they access the database via database access routines, do not need to be aware of these structures.

3.4.2 Database Access

With the exception of record and device support, all access to the database is via the channel or database access routines. See Chapter 15, "Runtime Database Access" on page 173 for details.

3.4.3 Database Scanning

Database scanning is the mechanism for deciding when to process a record. Five types of scanning are possible: Periodic, Event, I/O Event, Passive and Scan Once.

- **Periodic**: A request can be made to process a record periodically. A number of time intervals are supported.
- **Event**: Event scanning is based on the posting of an event by any IOC software component. The actual subroutine call is:
  `post_event(event_num)`
- **I/O Event**: The I/O event scanning system processes records based on external interrupts. An IOC device driver interrupt routine must be available to accept the external interrupts.
- **Passive**: Passive records are processed as a result of linked records being processed or as a result of external changes such as Channel Access puts.
- **Scan Once**: In order to provide for caching puts, The scanning system provides a routine `scanOnce` which arranges for a record to be processed one time.

3.4.4 Record Support, Device Support and Device Drivers

Database access needs no record-type specific knowledge, because each record-type has its associated record support module. Therefore, database access can support any number and type of records. Similarly, record support contains no device specific knowledge, giving each record type the ability to have any number of independent device support modules. If the method of accessing the piece of hardware is more complicated than what can be handled by device support, then a device driver can be developed.

Record types *not* associated with hardware do not have device support or device drivers.

The IOC software is designed so that the database access layer knows nothing about the record support layer other than how to call it. The record support layer in turn knows nothing about its device support layer other than how to call it. Similarly the only thing a device support layer knows about its associated driver is how to call it. This design allows a particular installation and even a particular IOC within an installation to choose a unique set of record types, device types, and drivers. The remainder of the IOC system software is unaffected.

Because an Application Developer can develop record support, device support, and device drivers, these topics are discussed in greater detail in later chapters.

Every record support module must provide a record processing routine to be called by the database scanners. Record processing consists of some combination of the following functions (particular records types may not need all functions):

- **Input**: Read inputs. Inputs can be obtained, via device support routines, from hardware, from other database records via database links, or from other IOCs via Channel Access links.
- **Conversion**: Conversion of raw input to engineering units or engineering units to raw output values.
- **Output**: Write outputs. Output can be directed, via device support routines, to hardware, to other database records via database links, or to other IOCs via Channel Access links.
- **Raise Alarms**: Check for and raise alarms.
- **Monitor**: Trigger monitors related to Channel Access callbacks.
- **Link**: Trigger processing of linked records.

3.4.5 Channel Access

Channel Access is discussed in the next section.

3.4.6 Database Monitors

Database monitors provide a callback mechanism for database value changes. This allows the caller to be notified when database values change without constantly polling the database. A mask can be set to specify value changes, alarm changes, and/or archival changes.

At the present time only Channel Access uses database monitors. No other software should use the database monitors. The monitor routines will not be described because they are of interest only to Channel Access.

3.5 Channel Access

Channel Access provides network transparent access to IOC databases. It is based on a client/ server model. Each IOC provides a Channel Access server which is willing to establish communication with an arbitrary number of clients. Channel Access client services are available on both OPIs and IOCs. A client can communicate with an arbitrary number of servers.

3.5.1 Client Services

The basic Channel Access client services are:

- **Search**: Locate the IOCs containing selected process variables and establish communication with each one.
- **Get**: Get value plus additional optional information for a selected set of process variables.
- **Put**: Change the values of selected process variables.

- **Add Event**: Add a change of state callback. This is a request to have the server send information only when the associated process variable changes state. Any combination of the following state changes can be requested: change of value, change of alarm status and/or severity, and change of archival value. Many record types provide hysteresis factors for value changes.

In addition to requesting process variable values, any combination of the following additional information may be requested:

- **Status**: Alarm status and severity.
- **Units**: Engineering units for this process variable.
- **Precision**: Precision with which to display floating point numbers.
- **Time**: Time when the record was last processed.
- **Enumerated**: A set of ASCII strings defining the meaning of enumerated values.
- **Graphics**: High and low limits for producing graphs.
- **Control**: High and low control limits.
- **Alarm**: The alarm `HIHI`, `HIGH`, `LOW`, and `LOLO` values for the process variable.

It should be noted that Channel Access does ***not*** provide access to database records as records. This is a deliberate design decision. This allows new record types to be added without impacting any software that accesses the database via Channel Access, and it allows a Channel Access client to communicate with multiple IOCs having differing sets of record types.

3.5.2 Search Server

Channel Access provides an IOC resident server which waits for Channel Access search messages. These are generated when a Channel Access client (for example when an Operator Interface task starts) searches for the IOCs containing process variables the client uses. This server accepts all search messages, checks to see if any of the process variables are located in this IOC, and, if any are found, replies to the sender with and “I have it” message.

3.5.3 Connection Request Server

Once the process variables have been located, the Channel Access client issues connection requests for each IOC containing process variables the client uses. The connection request server, in the IOC, accepts the request and establishes a connection to the client. Each connection is managed by two separate tasks: `ca_get` and `ca_put`. The `ca_get` and `ca_put` requests map to `dbGetField` and `dbPutField` database access requests. `ca_add_event` requests result in database monitors being established. Database access and/or record support routines trigger the monitors via a call to `db_post_event`.

3.5.4 Connection Management

Each IOC provides a connection management service. When a Channel Access server fails (e.g. its IOC crashes) the client is notified and when a client fails (e.g. its task crashes) the server is notified. When a client fails, the server breaks the connection. When a server crashes, the client automatically re-establishes communication when the server restarts.

3.6 OPI Tools

EPICS provides a number of OPI based tools. These can be divided into two groups based on whether or not they use Channel Access. Channel Access tools are real time tools, i.e. they are used to monitor and control IOCs.

3.6.1 Examples of channel Access Tools

A large number of Channel Access tools have been developed. The following are some representative examples.

- **MEDM**: Motif version of combined display manager and display editor.
- **DM**: Display Manager. Reads one or more display list files created by EDD, establishes communication with all necessary IOCs, establishes monitors on process variables, accepts operator control requests, and updates the display to reflect all changes.
- **ALH**: Alarm Handler. General purpose alarm handler driven by an alarm configuration file.
- **AR**: Archiver. General purpose tool to acquire and save data from IOCs.
- **Sequencer**: Runs in an IOC and emulates a finite state machine.
- **BURT**: Backup and Restore Tool. General purpose tool to save and restore Channel Access channels. The tool can be run via Unix commands or via a Graphical User Interface.
- **KM**: Knob Manager - Channel Access interface for the sun dials (a set of 8 knobs)
- **PROBE**: Allows the user to monitor and/or change a single process variable specified at run time.
- **CAMATH**: Channel Access interface for Mathematica.
- **CAWINGZ**: Channel Access interface for Wingz.
- **IDL/PVWAVE** Channel Access Interfaces exist for these products.
- **TCL/TK** Channel Access Interface for these products.
- **CDEV -** A library designed to provide a standard API to one or more underlying packages, typically control system interfaces. CDEV provides a Channel Access service.

3.6.2 Examples of other OPI Tools

- **JDCT:** Java Database Configuration Tool. A JAVA based toll for creating run time databases.
- **GDCT**: Graphical Database Configuration Tool. Used to create a run time database for an IOC. This is no longer being developed since it is based on an open source software system called unidraw, which is no longer being supported.
- **EDD**: Display Editor. This tool is used to create a display list file for the Display Manager. A display list file contains a list of static, monitor, and control elements. Each monitor and control element has an associated process variable.
- **SNC**: State Notation Compiler. It generates a C program that represents the states for the IOC Sequencer tool.
- **Database Tools -** Tools are provided which generate C include files from menu and record type database definition files.
- **Source/Release**: EPICS provides a Source/Release mechanism for managing EPICS.

3.7 EPICS Core Software

EPICS consists of a set of core software and a set of optional components. The core software, i.e. the components of EPICS without which EPICS would not function, are:

- Channel Access - Client and Server software
- IOC Database
- Scanners
- Monitors
- Database Definition Tools
- Source/Release

All other software components are optional. Of course, any application developer would be crazy to ignore tools such as MEDM (or EDD/DM). Likewise an application developer would not start from scratch developing record and device support. Most OPI tools do not, however, have to be used. Likewise any given record support module, device support module, or driver could be deleted from a particular IOC and EPICS will still function.

Chapter 4: EPICS Build Facility

Janet Anderson is the author of this chapter.

4.1 Overview

This chapter describes the EPICS build facility including directory structure, environment and system requirements, configuration files, Makefiles, and related build tools.

4.1.1 <top> Directory structure

EPICS software can be divided into multiple <top> areas. Examples of <top> areas are EPICS base itself, EPICS extensions, and simple or complicated IOC applications. Each <top> may be maintained separately. Different <top> areas can be on different releases of external software such as EPICS base releases.

A <top> directory has the following directory structure:

```
<top>/
    Makefile
    configure/
    dir1/
    dir2/
    ...
```

where configure is a directory containing build configuration files and a Makefile and where dir1, dir2, ... are user created subdirectory trees with Makefiles and source files to be built.

4.1.2 Install Directories

The following directories may also exist in the installation directory, $(INSTALL_LOCATION). which defaults to $(TOP), the <top> directory. They are created in the <top> directory by the build and contain the installed build components.

- **dbd** - Installed Database Definitions directory.
- **include** - The directory into which C header files are installed. These header files may be generated from menu and record type definitions.
- **bin** - This directory contains a subdirectory for the host architecture and for each target architecture. These are the directories in which executables, binaries, etc. are installed.
- **lib** - This directory contains a subdirectory for each host architecture. These are the directories in which libraries are installed.
- **db** - This is the directory into which database record instance, template, and substitution files are installed.
- **html** - This is the directory into which html documentation is installed.
- **templates** - This is the directory into which template files are installed.

4.1.3 Elements of build system

The main ingredients of the build system are:

- A set of configuration files and tools provided in the EPICS base/configure directory
- A corresponding set of configuration files in the <top>/configure directory of a non-base <top> directory structure to be built. The makeBaseApp.pl and makeBaseExtension.pl scripts create these configuration files. Many of these files just include a file of the same name from the base/configure directory.
- Makefiles in each directory of the <top> directory structure to be built

4.1.4 Features

The principal features of the build system are:

- Requires a single Makefile in each directory of a <top> directory structure
- Supports both host os vendor's native compiler and GNU compiler
- Supports building multiple types of software (libraries, executables, databases, java class files, etc.) stored in a single directory tree.
- Supports building EPICS base, extensions and IOC applications.
- Supports multiple host and target operating system - architecture combinations.
- Allows builds for all hosts and targets within a single <top> source directory tree.
- Allows sharing of components such as special record/device/drivers across <top> areas.
- gnumake is the only command used to build a <top> area.

4.1.5 Environment Prerequisites

Only one environment variable, `EPICS_HOST_ARCH`, is required to build EPICS <top> areas. This variable should be set to be your workstation's operating system - architecture combination to use the os vendor's c/c++ compiler for native builds or set to the operating system - architecture - alternate compiler combination to use an alternate compiler for native builds if an alternate compiler is supported on your system. The filenames of the `CONFIG.*.Common` files in base/configure/os show the currently supported values. Examples are `solaris-sparc`, `solaris-sparc-gnu`, `linux-x86`, `win32-x86`, and `win32-x86-borland`.

The startup directory in EPICS base contains a perl script, `EpicsHostArch.pl`, which can be used to define this variable. This script can be invoked with a command line parameter defining the alternate compiler (e.g. if invoking "`EpicsHostArch.pl`" yields solaris-sparc, then invoking "`EpicsHostArch.pl gnu`" will yield solaris-sparc-gnu).

4.1.6 System Prerequisites

Before you can build EPICS components your host system must have the following software installed:

- Perl version 5 or greater
- GNU make, version 3.7 or greater
- C++ compiler (host operating system vendor's compiler or GNU compiler)
- If you will be building EPICS components for vxWorks targets you will also need:
- Tornado II and one or more board support packages. Consult the vxWorks documentation for details.

4.1.7 Directory definitions

The configure files contain definitions for where to install various components. These are all relative to INSTALL_LOCATION. The default value for INSTALL_LOCATION is $(TOP,) and $(T_A) is the current build's target architecture.

```
INSTALL_LOCATION_LIB      = $(INSTALL_LOCATION)/lib
INSTALL_LOCATION_BIN      = $(INSTALL_LOCATION)/bin

INSTALL_HOST_BIN          = $(INSTALL_LOCATION_BIN)/$(EPICS_HOST_ARCH)
INSTALL_HOST_LIB          = $(INSTALL_LOCATION_LIB)/$(EPICS_HOST_ARCH)

INSTALL_INCLUDE           = $(INSTALL_LOCATION)/include
INSTALL_DOC               = $(INSTALL_LOCATION)/doc
INSTALL_HTML              = $(INSTALL_LOCATION)/html
INSTALL_TEMPLATES         = $(INSTALL_LOCATION)/templates
INSTALL_DBD               = $(INSTALL_LOCATION)/dbd
INSTALL_DB                = $(INSTALL_LOCATION)/db
INSTALL_CONFIG            = $(INSTALL_LOCATION)/configure
INSTALL_JAVA              = $(INSTALL_LOCATION)/javalib

#Directory for OS independant build created files
COMMON_DIR = ../O.Common

INSTALL_LIB               = $(INSTALL_LOCATION_LIB)/$(T_A)
INSTALL_SHRLIB            = $(INSTALL_LOCATION_LIB)/$(T_A)
INSTALL_TCLLIB            = $(INSTALL_LOCATION_LIB)/$(T_A)
INSTALL_BIN               = $(INSTALL_LOCATION_BIN)/$(T_A)
```

4.1.8 RELEASE file

Every <top>/configure directory contains a RELEASE file. RELEASE contains a user specified list of other <top> directory structures containing files needed by the current <top>. When make is executed in configure, a perl script, m**`akeConfigAppInclude.pl`**, generates CONFIG_APP_INCLUDE which contains include, bin, and library directory definitions for each external <top> definition in the RELEASE file. CONFIG_APP_INCLUDE is included into the CONFIG file so its definitions are available for use by Makefiles. Also when make is executed in configure, a perl script, m**`akeRulesInclude.pl`**, generates RULES_INCLUDE which contains an include statement for existing RULES_BUILD files from each external <top> definition in the RELEASE file. RULES_INCLUDE is included into the RULES_BUILD in EPICS base so all make rules in the external <top> RULES_BUILD files are available for use by Makefiles.

For example, if configure/RELEASE contains the following definition:

```
CAMAC = /home/epics/modules/bus/camac
```

then the created CONFIG_APP_INCLUDE will contain the following lines

```
CAMAC_BIN = /home/epics/modules/bus/camac/bin/solaris-sparc
CAMAC_LIB = /home/epics/modules/bus/camac/lib/solaris-sparc
INSTALL_INCLUDES += -I/home/epics/modules/bus/camac/include
INSTALL_DBDFLAGS += -I /home/epics/modules/bus/camac/dbd
```

and the created RULES_INCLUDE will contain the following line

```
-include /home/epics/modules/bus/camac/configure/RULES_BUILD
```

`INSTALL_DBDFLAGS` will appear on the command lines for the dbToRecordTypeH, makeDbDepends, and dbExpand tools, and INSTALL_INCLUDES will appear on compiler command lines. CAMAC_LIB and CAMAC_BIN can be used in a Makefile to define the location of needed headers, executables, object files, libraries or other files.

Definitions in configure/RELEASE can be overridden for a specific EPICS_HOST_ARCH architecture by providing a configure/RELEASE.<epics_host_arch> file containing overriding definitons.

4.1.9 Specifying osclass

Definitions in a Makefile will apply to the host system (the platform on which make is executed) and each system defined by CROSS_COMPILER_TARGET_ARCHS.

It is possible to limit the systems for which a particular definition applies. Most Makefile definitions can be specified with an appended underscore "_" followed by an osclass specification . If an _<osclass> is not specified, then the definition applies to the host and all CROSS_COMPILER_TARGET_ARCHS systems. If an _<osclass> is specified, then the definition applies only to systems with the specified os class. A Makefile definition can also have an appended _DEFAULT specification. If _DEFAULT is appended, then the Makefile definition will apply to all systems that do not have an _<osclass> specification for that definition. If a _DEFAULT is appended on a defination but definition should not apply to a particular system <osclass>, the value "-nil-" should be specified in the relevent Makefile definition.

Each system has an OS_CLASS definition in its configure/os/CONFIG.Common.<arch> file. A few examples are:

For vxWorks-68040 and vxWorks-pentium the <osclass> is vxWorks.
For solaris-sparc,solaris-x86 and solaris-sparc-gnu, the <osclass> is solaris.
For win32-x86 the <osclass> is WIN32.

For example the following Makefile lines specify that product aaa should be created for all systems. Product bbb should be created for systems that do not have OS_CLASS defined as solaris. No products should be built for systems that have OS_CLASS defined as solaris.

```
PROD = aaa
PROD_solaris = -nil-
PROD_DEFAULT = bbb
```

4.2 Makefiles

4.2.1 Name

The name of the makefile in each directory must be Makefile.

4.2.2 Included Files

Makefiles normally include files from <top>/configure. Thus the makefile "inherits" rules and definitions from configure. The files in <top>/configure may in turn include files from another <top>/configure. This technique makes it possible to share make variables and even rules across <top> directories.

4.2.3 Contents of Makefiles

Makefiles in directories containing subdirectories

A Makefile in this type of directory must define where <top> is relative to this directory, include <top>/configure files, and specify the subdirectories in the desired order of make execution. Running gnumake in a directory with the following Makefile lines will cause gnumake to be executed in <dir1> first and then <dir2>. The build rules do not allow a Makefile to specify both subdirectories and components to be built.

```
TOP=../..
include $(TOP)/configure/CONFIG
DIRS += <dir1> <dir2>
include $(TOP)/configure/RULES_DIRS
```

Makefiles in directories where components are to be built

A Makefile in this type of directory must define where <top> is relative to this directory, include <top> configure files, and specify the target component definitions. Optionally it may contain user defined rules. Running gnumake in a directory with this type of Makefile will cause gnumake to create an O.<arch> subdirectory and then execute gnumake to build the defined components in this subdirectory. It contains the following lines:

```
TOP=../../..
include $(TOP)/configure/CONFIG
   <component definition lines>
include $(TOP)/configure/RULES
   <optional rules definitions>
```

4.2.4 Simple Makefile examples

Create an IOC type library named asIoc from the source file asDbLib.c and install it into the $(INSTALL_LOCATION)/lib/<arch> directory .

```
TOP=../../..
include $(TOP)/configure/CONFIG
LIBRARY_IOC += asIoc
asIoc_SRCS += asDbLib.c
include $(TOP)/configure/RULES
```

For each Host type target architecture, create an executable named catest from the catest1.c and catest2.c source files linking with the existing EPICS base ca and Com libraries, and then install the catest executable into the $(INSTALL_LOCATION)/bin/<arch> directory.

```
TOP=../../..
include $(TOP)/configure/CONFIG
PROD = catest
catest_SRCS += catest1.c catest2.c
catest_LIBS = ca Com
include $(TOP)/configure/RULES
```

4.3 Make

4.3.1 Make vs. gnumake

EPICS provides an extensive set of make rules. These rules only work with the GNU version of make, gnumake, which is supplied by the Free Software Foundation. Thus, on most Unix systems, the native make will not work. On some systems, e.g. Linux, GNU make may be the default. This manual always uses gnumake in the examples.

4.3.2 Frequently used Make commands

NOTE: It is possible to invoke the following commands for a single target architecture by appending .<arch> to the target in the command.

The most frequently used make commands are:

`gnumake`
: This rebuilds and installs everything that is not up to date.
NOTE: Executing gnumake without arguments is the same as gnumake install

`gnumake <arch>`
: This rebuilds and installs everything that is not up to date for a single specified target arch.
NOTE: This is the same as gnumake install.<arch>

`gnumake clean`
: This can be used to save disk space by deleting the O.<arch> directories, but does not remove any installed files from the bin, db, dbd etc. directories. .<arch> can be appended to invoke clean for a single architecture.

`gnumake rebuild`
: This is the same as gnumake clean install. If you are unsure about the state of the generated files in an application, just execute gnumake rebuild.

`gnumake uninstall`
: This command can be executed from the <top> directory only. It will remove everything installed by gnumake in the include, lib, bin, db, dbd, etc. directories.

`gnumake tar`
: This command can be executed from the <top> directory only. It will make a tar image of the entire <top> directory structure (excluding any CVS directories). This target is available on Unix type hosts only.

`gnumake depends`
: This command creates a DEPENDS file in the O.<arc> subdirectory containing a list of header file dependencies for each c or c++ source file. This target is not available on Win32 hosts.

4.3.3 Make targets

The following is a summary of targets that can be specified for gnumake:

- <action>
- <arch>
- <action>.<arch>
- <dir>

- <dir>.<action>
- <dir>.<arch>
- <dir>.<action>.<arch>

where:

<arch> is EPICS_HOST_ARCH, solaris-sparc, vxWorks-68040, win32-x86, etc. - builds named architecture only.
<action> is clean, inc, install, build, rebuild, buildInstall, depends, or uninstall
NOTE: uninstall can only be specified at <top>
<dir> is subdirectory name

Note: You can build using your os vendors' native compiler and also build using a supported alternate compiler in the same directory structure because the executables and libraries will be created and installed into separate directories (e.g bin/solaris-sparc and bin/solaris-sparc-gnu). You can do this by changining your `EPICS_HOST_ARCH`, environment variable between builds or by setting `EPICS_HOST_ARCH` on the gnumake command line.

4.4 Makefile definitions

The following components can be defined in a Makefile to be built when gnumake is invoked:

4.4.1 Breakpoint Tables

For each breakpoint table dbd file, bpt<table name>.dbd, to be created from an existing bpt<table name>.data file, add the definition

```
DBD += bpt<table name>.dbd
```

to the Makefile. The following Makefile will create a bptTypeJdegC.dbd file from an existing bptTypeJdegC.data file and install the new dbd file into the $(INSTALL_LOCATION)/dbd directory.

```
TOP=../../..
include $(TOP)/configure/CONFIG
DBD += bptTypeJdegC.dbd
include $(TOP)/configure/RULES
```

4.4.2 Record Type Definitions

For each new record type, the following definition should be added to the makefile:

```
DBINC += <rectype>Record
```

A <rectype>Record.h header file will be created from an existing <rectype>Record.dbd file. This header will be installed into the $(INSTALL_LOCATION)/include directory and the dbd file will be installed into the $(INSTALL_LOCATION)/dbd directory.

The following Makefile will create xxxRecord.h from an existing xxxRecord.dbd file, install xxxRecord.h into $(INSTALL_LOCATION)/include, and install xxxRecord.dbd into $(INSTALL_LOCATION)/dbd.

```
TOP=../../..
include $(TOP)/configure/CONFIG
DBINC += xxxRecord
include $(TOP)/configure/RULES
```

4.4.3 Menus

If a menu menu<name>.dbd file is present, then add the following definition:

```
DBDINC += menu<name>.h
```

The header file, menu<name>.h will be created from the existing menu<name>.dbd file and installed into the $(INSTALL_LOCATION)//include directory and the menu dbd file will be installed into $(INSTALL_LOCATION)/dbd .

The following Makefile will create a menuConvert.h file from an existing menuConvert.dbd file and install menuConvert.h to $(INSTALL_LOCATION)/include and menuConvert.dbd to $(INSTALL_LOCATION)/dbd.

```
TOP=../../..
include $(TOP)/configure/CONFIG
DNDINC = menuConvert.h
include $(TOP)/configure/RULES
```

4.4.4 Expanded Database Definition File

Database definition files named <name>Include.dbd containing includes for other database definition files can be expanded by utility dbExpand into a created <name>.dbd file and the <name>.dbd file will be installed into $(INSTALL_LOCATION)/dbd. The following variables control the process:

```
DBD += <name>.dbd
USER_DBDFLAGS += -I <include path>
USER_DBDFLAGS += -S <macro substitutions>
```

where the entries are:

```
DBD += <name>.dbd
```

The name of the output dbd file to contain the expanded definitions. It will be created from an existing <name>Include.dbd file and installed into $(INSTALL_LOCATION)/dbd. An example of a file to be exanded is exampleInclude.dbd containing the following lines

```
        include "base.dbd"
        include "xxxRecord.dbd"
        device(xxx,CONSTANT,devXxxSoft,"SoftChannel")
```

`USER_DBDFLAGS` defines optional flags for dbExpand. Currently only an include path (-I <path>) and macro substitution (-S <substitution>) are supported. The include paths for EPICS base/dbd, and other <top>/dbd directories will automatically be added during the build if the <top> names are specified in the configure/RELEASE file.

The following Makefile will create an expanded dbd file named example.dbd from an existing exampleInclude.dbd file and install example.dbd into the $(INSTALL_LOCATION)/dbd directory.

```
TOP=../../..
include $(TOP)/configure/CONFIG
DBD += exampleApp.dbd
include $(TOP)/configure/RULES
```

4.4.5 Registering Support Routines for Expanded Database Definition Files

A source file which registers record/device/driver support routines can be created. The list of routines to register is obtained from an existing `dbd` file.

The following line in src/Makefile will result in `<name>_registerRecordDeviceDriver.cpp` being created, compiled, and linked into `<prodname>`. It requires that file `<name>.dbd` exist.

```
<prodname>_SRCS += <name>_registerRecordDeviceDriver.cpp
```

4.4.6 Database Definition Files

The following line installs the existing named dbd files into $(INSTALL_LOCATION)/dbd without expansion.

```
DBD += <name>.dbd
```

4.4.7 Database Files

For most databases just the name of the database has to be specified. Make will figure out how to generate the file:

```
DB += xxx.db
```

Generates xxx.db depending on which source files exist and installs it into $(INSTALL_LOCATION)/db.

```
DB += xxx.template xxx.substitutions
```

Generates and installs these files. If one or more xxx.substitutions files are to be created by script, the script name must be placed in the CREATESUBSTITUTIONS variable (e.g. CREATESUBSTITUTIONS=mySubst.pl). This script will be executed by gnumake with the prefix of the substitution file name to be generated as its argument. If (and only if) there are script generated substitutions files, the prefix of any inflated database's name may not equal the prefix of the name of any template used within the directory.

In order to record dependency information correctly all template files that are needed but not installed (i.e. those not listed in DB), must be added to the USES_TEMPLATE variable:

```
USES_TEMPLATE += yyy.template
USES_TEMPLATE += $(SHARE)/installDb/zzz.template
```

If specified with a path (full or relative), the templates will be soft linked (UNIX) or copied (WIN) into the O.<arch> directory. After the first make run, template dependencies will be generated automatically.

4.4.8 Libraries

A library is created and installed into $(INSTALL_LOCATION)/lib/<arch> by specifying it's name and the name of the object and/or source files containing code for the library. An object or source file name can appear with or without a directory prefix. If the file name has a directory prefix e.g. $(EPICS_BASE_BIN), it is taken from the specified location. If a directory prefix is not present, make will first look in the source directory for a file with the specified name and next try to create the file using existing configure rules. A library filename suffix appropriate for the library type and target arch (e.g. .a, .so, .lib, .dll) will be appended to the filename when the file is created.

vxWorks Note: For vxWorks, both an object module library, <name>.o, and a munched object module library, <name>.munch, are created and both libraries are installed into $(INSTALL_LOCATION)/bin/<arch> **NOT** $(INSTALL_LOCATION)/lib/<arch> See the vxWorks documentation for a description of munched files.

Shared libraries Note: Shared libraries can be built for any or all HOST type architectures. The definition of SHARED_LIBRARIES (YES/NO) in base/configure/CONFIG_SITE determines whether shared or archive libraries will be built. This definition can be overridden for a specific arch in an configure/os/CONFIG_SITE.<arch>.Common file.,The default definition in the EPICS base distribution file is YES for win32 and NO for all other hosts.

win32 Note: One object library file is created when SHARED_LIBRARIES=NO, <name>Obj.lib which is installed into $(INSTALL_LOCATION)/lib/<arch>. Three files are created when SHARED_LIBRARIES=YES, <name>.lib and <name>Obj.lib which are installed into $(INSTALL_LOCATION)/lib/<arch>, and <name>.dll which is installed into

$(INSTALL_LOCATION)/bin/<arch>. (Warning: The file <name>.lib will only be created by the build if there are exported symbols from the library.) If SHARED_LIBRARIES=YES, the directory $(INSTALL_LOCATION)/lib/<arch> must be in the user's path when invoking executables which were linked with shared libraries.

4.4.8.1 Specifying the library name.

Any of the following can be specified:

`LIBRARY += <name>`
: A library will be created for every target arch.

`LIBRARY_<osclass> += <name>`
: Library <name>.will be created for all archs of the specified osclass.

`LIBRARY_DEFAULT += <name>`
: Library <name> will be created for any arch that does not have a LIBRARY_<osclass> definition

`LIBRARY_IOC += <name>`
: Library <name> will be created for IOC type archs.

`LIBRARY_IOC_<osclass> += <name>`
: Library <name>.will be created for all IOC type archs of the specified osclass.

`LIBRARY_IOC_DEFAULT += <name>`
: Library <name> will be created for any IOC type arch that does not have a LIBRARY_IOC_<osclass> definition

`LIBRARY_HOST += <name>`
: Library <name> will be created for HOST type archs.

`LIBRARY_HOST_<osclass> += <name>`
: Library <name>.will be created for all HOST type archs of the specified osclass.

`LIBRARY_HOST_DEFAULT += <name>`
: Library <name> will be created for any HOST type arch that does not have a LIBRARY_HOST_<osclass> definition

4.4.8.2 Specifying library object file names

Object file names, which should have a directory prefix and which do **not** need a suffix such as .o, are defined as follows:

`LIB_OBJS += <name>`
: Object files will be used in builds of all libraries)

`LIB_OBJS_<osclass> += <name>`
: Object files will be used in builds of all libraries for archs of the specified osclass.

LIB_OBJS_DEFAULT += <name>
: Object files will be used in builds of all libraries for archs without a LIB_OBJS_<osclass> definition specified.

`<library name>_OBJS += <name>`
: Object files will be used for all builds of the named library)

`<library name>_OBJS_<osclass> += <name>`
: Object files will be used in builds of the library for archs with the specified osclass.

`<library name>_OBJS_DEFAULT += <name>`
: Object files will be used in builds of the library for archs without a <library name>_OBJS_<osclass> definition specified.

4.4.8.3 LIBOBJS definitions

Previous versions of epics (3.13 and before) accepted definitions like:

```
LIBOBJS += $(<support>_BIN)/xxx.o
```

These are gathered together in files such as baseLIBOBJS. To use such definitions include the lines:

```
-include ../baseLIBOBJS
<library name>_OBJS += $(LIBOBJS)
```

4.4.8.4 Specifying library DLL file names

The library builds on WIN32 require all external references to be resolved, so if a library contains references to items in other DLL libraries, these DLL library names must be specified (without directory prefix) as follows:

`DLL_LIBS += <name>`
: These DLLs will be used for all libraries.

`<library_name>_DLL_LIBS += <name>`
: These DLLs will be used for the named library.

Each DLL must have a corresponding <dll_name>_DIR definition specifying its directory location.

4.4.8.5 Specifying library source file names

Source file names, which must have a suffix, are defined as follows:

`SRCS += <name>`
: Source files will be used for all defined libraries and products.

`SRCS_<osclass> += <name>`
: Source files will be used for all defined libraries and products for all archs of the specified osclass.

`SRCS_DEFAULT += <name>`
: Source files will be used for all defined libraries and products for any arch that does not have a SRCS_<osclass> definition

LIBSRCS and LIB_SRCS have the same meaning. LIBSRCS is retained for R3.13 compatibility.

`LIBSRCS += <name>`
: Source files will be used for all defined libraries.

`LIBSRCS_<osclass> += <name>`
: Source files will be used for all defined libraries for all archs of the specified osclass.

`LIBSRCS_DEFAULT += <name>`
: Source files will be used for all defined libraries for any arch that does not have a LIBSRCS_<osclass> definition

`LIB_SRCS += <name>`
: Source files will be used for all libraries.

`LIB_SRCS_<osclass> += <name>`
: Source files will be used for all defined libraries for all archs of the specified osclass.

`LIB_SRCS_DEFAULT += <name>`
: Source files will be used for all defined libraries for any arch that does not have a LIB_SRCS_<osclass> definition

`<library name>_SRCS += <name>`
: Source files will be used for the named library.

`<library name>_SRCS_<osclass> += <name>`
: Source files will be used for named library for all archs of the specified osclass.

`<library name>_SRCS_DEFAULT += <name>`
: Source files will be used for named library for any arch that does not have a <library name>_SRCS_<osclass> definition

4.4.8.6 Library example:

```
LIBRARY_vxWorks += vxWorksOnly
LIBRARY_IOC += iocOnly
```

```
LIBRARY_HOST += hostOnly
LIBRARY += all

vxWorksOnly_OBJS += $(LINAC_BIN)/vxOnly1
vxWorksOnly_SRCS += vxOnly2.c
iocOnly_OBJS += $(LINAC_BIN)/iocOnly1
iocOnly_SRCS += iocOnly2.cpp
hostOnly_OBJS +=  $(LINAC_BIN)/host1
all_OBJS += $(LINAC_BIN)/all1
all_SRCS += all2.cpp
```

If the architectures defined in <top>/configure are solaris-sparc and vxWorks-68040 and LINAC is defined in the <top>/CONFIGURE/RELEASE file, then the following libraries will be created:

- $(INSTALL_LOCATION)/bin/vxWork-68040/vxWorksOnly.* : $(LINAC_BIN)/vxOnly1.o vxOnly2.o
- $(INSTALL_LOCATION)/bin/vxWork-68040/iocOnly.* : $(LINAC_BIN/iocOnly1.o iocOnly2.o
- $(INSTALL_LOCATION)/lib/solaris-sparc/libiocOnly.a : $(LINAC_BIN)/iocOnly1.o iocOnly2.o
- $(INSTALL_LOCATION)/lib/solaris-sparc/libhostOnly.a : $(LINAC_BIN)/host1.o
- $(INSTALL_LOCATION)/bin/vxWork-68040/all.* : $(LINAC_BIN)/all1.o all2.o
- $(INSTALL_LOCATION)/lib/solaris-sparc/liball.a : $(LINAC_BIN)/all1.o all2.o

4.4.9 Generate and install object Files

It is possible to generate and install object files by using definitions:

```
OBJS += <name>
OBJS_<osclass> += <name>
OBJS_DEFAULT += <name>
OBJS_IOC += <name>
OBJS_IOC_<osclass> += <name>
OBJS_IOC_DEFAULT += <name>
OBJS_HOST += <name>
OBJS_HOST_<osclass> += <name>
OBJS_HOST_DEFAULT += <name>
```

These will cause the specified file to be generated from an existing source file for the appropriate target arch and installed into $(INSTALL_LOCATION)/bin/<target_arch>.

The following Makefile will create the abc object file for all target architectures, the object file def for all target archs except vxWorks, and the xyz object file for only the vxWorks target architecture and install them into the appropriate $(INSTALL_LOCATION)/bin/<arch> directory.

```
TOP=../../..
include $(TOP)/configure/CONFIG
OBJS += abc
OBJS_vxWorks += xyz
OBJS_DEFAULT += def
include $(TOP)/configure/RULES
```

4.4.10 State Notation Programs

A state notation program file can be specified as a source file in any SRC definition. For example:

```
<libname>_SRCS += <name>.stt
```

The state notation compiler, `snc`, will create two files. `<name>.c`, which contains source code generated from `<name>.stt, and <name>_sncreg.cpp`, which contains C++ source code to register the snc programs so that they can be invoked from the shell. These two files are compiled and the resulting object files are linked into the `<libname>` library.

A state notation source file must have the extension `.st` or `.stt`. A `.stt` file is passed through the C preprocessor before it is given to the `snc`.

4.4.11 Scripts, etc.

A definition of the form:

```
SCRIPTS += <name>
```

results in file <name> being installed from the src directory to the $(INSTALL_LOCATION)/bin/<arch> directories.

Definitions of the form:

```
SCRIPTS_DEFAULT += <name1>
SCRIPTS_<osclass> += <name2>
```

results in the <name2> script being installed from the src directory to the $(INSTALL_LOCATION)/bin/<arch> directories for all target archs of the specified os class <osclass> and the <name1> script installed into the $(INSTALL_LOCATION)/bin/<arch> directories of all other target archs.

4.4.12 Include files

A definition of the form:

```
INC += <name>.h
```

results in file <name>.h being installed from the src directory to the $(INSTALL_LOCATION)/include directory.

Definitions of the form:

```
INC_DEFAULT += <name>.h
INC_<osclass> += <name>.h
```

results in file <name>.h being installed from the src directory into the appropriate $(INSTALL_LOCATION)/include/os/<osclass> directory..

4.4.13 Html and Doc files

A definition of the form:

```
HTMLS_DIR = <dirname>
HTMLS += <name>
```

results in file <name> being installed from the src directory to the $(INSTALL_LOCATION)/html/<dirname> directory.

A definition of the form:

```
DOCS += <name>
```

results in file <name> being installed from the src directory to the $(INSTALL_LOCATION)/doc directory.

4.4.14 Templates

Adding definitions of the form

```
TEMPLATES_DIR = <dirname>
TEMPLATES += <name>
```

results in the file <name> being installed from the src directory to the $(INSTALL_LOCATION)/templates/<dirname> directory. If a directory structure of template files is to be installed, the template file names may include a directory prefix.

4.4.15 Lex and yac

If a <name>.c source file specified in a Makefile definition is not found in the source directory, Make will try to build it from <name>.y and <name>_lex.l files in the source directory.

4.4.16 Products

A product executable is created for each HOST type <arch> and installed into $(INSTALL_LOCATION)/bin/<arch> by specifying it's name and the name of either the object or source files containing code for the product. An object or source file name can appear with or without a directory prefix. Object files should contain a directory prefix. If the file has a directory prefix e.g. $(EPICS_BASE_BIN), it is taken from the specified location. If a directory prefix is not present, make will look in the source directory for a file with the specified name or try build it using existing rules.

PROD specifications in the Makefile are ignored for IOC only type arches unless PROD_<osclass> is specified for an IOC only type arch. An executable filename suffix appropriate for the target arch (e.g. .exe) may be appended to the filename when the file is created.

```
<PROD += <name>
name>_SRC += <srcname>.c
```

results in the executable <name> being built for each HOST type <arch> from a <srcname>.c file. Then <name> is installed into the $(INSTALL_LOCATION)/bin/<arch> directory.

4.4.16.1 Specifying the product name.

Any of the following can be specified:

`PROD += <name>`
: Product <name> will be created for every HOST type target arch .

`PROD_<osclass> += <name>`
: Product <name> will be created for all archs of the specified osclass.

`PROD_DEFAULT += <name>`
: Product <name> will be created for any HOST type arch that does not have a PROD_<osclass> definition

4.4.16.2 Specifying product object file names

Object file names, which do **not** need a suffix such as .o, are defined as follows:

`PROD_OBJS += <name>`
: Object files will be used in builds of all products

`PROD_OBJS_<osclass> += <name>`
: Object files will be used in builds of all products for archs with the specified osclass.

PROD_OBJS_DEFAULT += <name>
: Object files will be used in builds of all products for archs without a PROD_OBJS_<osclass> definition specified.

`<prod name>_OBJS += <name>`

Object files will be used for all builds of the named product

`<prod name>_OBJS_<osclass> += <name>`
: Object files will be used in builds of the named product for archs with the specified osclass.

`<prod name>_OBJS_DEFAULT += <name>`
: Object files will be used in builds of the named product for archs without a <prodname>_OBJS_<osclass> definition specified.

4.4.16.3 Specifying product source file names

Source file names, which must have a suffix, are defined as follows:

`SRCS += <name>`
: Source files will be used for all defined libraries and products.

`SRCS_<osclass> += <name>`
: Source files will be used for all defined libraries and products for all archs of the specified osclass.

`SRCS_DEFAULT += <name>`
: Source files will be used for all defined libraries and products for any arch that does not have a SRCS_<osclass> definition

`PROD_SRCS += <name>`
: Source files will be used for all products.

`PROD_SRCS_<osclass> += <name>`
: Source files will be used for all defined products for all archs of the specified osclass.

`PROD_SRCS_DEFAULT += <name>`
: Source files will be used for all defined products for any arch that does not have a PROD_SRCS_<osclass> definition

`<prod name>_SRCS += <name>`
: Source file will be used for the named product.

`<prod name>_SRCS_<osclass> += <name>`
: Source files will be used for named product for all archs of the specified osclass.

<prod name>_SRCS_DEFAULT += <name>
: Source files will be used for named product for any arch that does not have a <prod name>_SRCS_<osclass> definition

4.4.16.4 Specifying libraries to be linked when creating the product

For each library name specified which is not a system library nor a library from EPICS_BASE, a <library_name>_DIR definition must be present in the Makefile to specify the location of the library.

Library names, which must not have a directory prefix nor a suffix, are defined as follows:

`PROD_LIBS += <name>`
: Libraries to be used when linking all defined products.

`PROD_LIBS_<osclass> += <name>`
: Libraries to be used or all archs of the specified osclass when linking all defined products.

`PROD_LIBS_DEFAULT += <name>`
: Libraries to be used for any arch that does not have a PROD_LIBS_<osclass> definition when linking all defined products.

`USR_LIBS += <name>`
: Libraries to be used when linking all defined products.

`USR_LIBS_<osclass> += <name>`
: Libraries to be used or all archs of the specified osclasswhen linking all defined products.

`USR_LIBS_DEFAULT += <name>`

Libraries to be used for any arch that does not have a USR_LIBS_<osclass> definition when linking all defined products.

`<prod name>_LIBS += <name>`
: Libraries to be used for linking the named product.

`<prod name>_LIBS_<osclass> += <name>`
: Libraries will be used for all archs of the specified osclass for linking named product.

`<prod name>`_LIBS_DEFAULT += <name>
: Libraries to be used for any arch that does not have a <prod name>_LIBS_<osclass> definition when linking named product.

`SYS_PROD_LIBS += <name>`
: System libraries to be used when linking all defined products.

`SYS_PROD_LIBS_<osclass> += <name>`
: System libraries to be used for all archs of the specified osclass when linking all defined products.

`SYS_PROD_LIBS_DEFAULT += <name>`
: System libraries to be used for any arch that does not have a PROD_LIBS_<osclass> definition when linking all defined products.

`<prod name>_SYS_LIBS += <name>`
: System libraries to be used for linking the named product.

`<prod name>_SYS_LIBS_<osclass> += <name>`
: System libraries will be used for all archs of the specified osclass for linking named product.

`<prod name>_SYS_LIBS_DEFAULT += <name>`
: System ibraries to be used for any arch that does not have a <prod name>_LIBS_<osclass> definition when linking named product.

4.4.17 Test Products

Test products and test product libraries, source, and object files are specified in exactly the same way as regular products. The difference is that test products will not be installed into $(INSTALL_LOCATION)/bin/<arch> directories.

Any of the following can be specified:

`TESTPROD += <name>`
: Test product <name> will be created for every HOST type target arch.

`TESTPROD_<osclass> += <name>`
: Test product <name> will be created for all archs of the specified osclass.

`TESTPROD_DEFAULT += <name>`
: Test product <name> will be created for any HOST type arch that does not have a PROD_<osclass> definition

4.4.18 Target files

A definition of the form:

```
TARGETS += <name>
```

results in the file <name> being built in the O.<arch> directory from existing rules and files in the source directory. These target files are not installed.

4.4.19 Bin install files

Definitions of the form:

```
BIN_INSTALLS += <name>
BIN_INSTALLS_DEFAULT += <name>
BIN_INSTALLS_<osclass> += <name>
```

result in files being installed to the appropriate $(INSTALL_LOCATION)/bin/<arch> directory. The file <name> can appear with or without a directory prefix. If the file has a directory prefix e.g. $(EPICS_BASE_BIN), it is copied from the specified location. If a directory prefix is not present, make will look in the source directory for the file.

4.4.20 TCL libraries

Definitions of the form:

```
TCLLIBNAME += <name>
TCLINDEX += <name>
```

result in the specified tcl files being installed to the $(INSTALL_LOCATION)/lib/<arch> directory.

4.5 Table of Makefile definitions

Definitions given below containing <osclass> are used when building for target archs of a specific osclass, and the <osclass> part of the name should be replaced by the desired osclass, e.g. solaris, vxWorks, etc. If a _DEFAULT setting is given but a particular <osclass> requires that the default not apply and there are no items in the definition that apply for that <osclass>, the value "-nil-" should be specified in the relevent Makefile definition.

Build Option	Description
Products to be built (host type archs only)	
PROD	products (names without execution suffix) to build and install for host type archs only. Specify xyz to build executable xyz on Unix and xyz.exe on WIN32
PROD_<osclass>	os class specific products to build and install for <osclass> archs only
PROD_DEFAULT	products to build and install for host type archs with no PROD_<osclass> specified
Test products to be built (host type archs only)	
TESTPROD	test products (names without execution suffix) to build but not install
TESTPROD_<osclass>	os class specific test product names to build but not install
TESTPROD_DEFAULT	test products to build but not install for archs with no TESTPROD_<osclass> specified
Libraries to be built	

Build Option	Description
LIBRARY	name of library to build and install. The name should NOT include a prefix or extension e.g. specify Ca to build libCa.a on Unix, Ca.lib, CaObj.lib, or Ca.dll on WIN32
LIBRARY_<osclass>	os specific libraries to build and install
LIBRARY_DEFAULT	libraries to build and install for archs with no LIBRARY_<osclass> specified
LIBRARY_IOC	name of library to build and install for ioc type archs. The name should NOT include a prefix or extension e.g. specify Ca to build libCa.a on Unix, Ca.lib,CaObj.lib, or Ca.dll on WIN32
LIBRARY_IOC_<osclass>	os specific libraries to build and install for ioc type archs
LIBRARY_IOC_DEFAULT	libraries to build and install for ioc type arch systems with no LIBRARY_<osclass> specified
LIBRARY_HOST	name of library to build and install for host type archs. The name should NOT include a prefix or extension, e.g. specify Ca to build libCa.a on Unix, Ca.lib, CaObj.lib, or Ca.dll on WIN32
LIBRARY_HOST_<osclass>	os class specific libraries to build and install for host type archs
LIBRARY_HOST_DEFAULT	libraries to build and install for host type arch systems with no LIBRARY_<osclass> specified
SHARED_LIBRARIES	build shared libraries? Must be YES or NO
SHRLIB_VERSION	shared library version number
Product and library source files	
SRCS	source files to build all PRODs and LIBRARYs
SRCS_<osclass>	osclass specific source files to build all PRODs and LIBRARYs
SRCS_DEFAULT	source file to build all PRODs and LIBRARYs for archs with no SRCS_<osclass> specified
PROD_SRCS	source files to build all PRODs
PROD_SRCS_<osclass>	osclass specific source files to build all PRODs
PROD_SRCS_DEFAULT	source files needed to build PRODs for archs with no SRCS_<osclass> specified
LIBSRCS	source files for building LIBRARY (e.g. LIBSRCS=la.c lb.c lc.c)
LIBSRCS_<osclass>	os-specific library source files
LIBSRCS_DEFAULT	library source files for archs with no LIBSRCS_<osclass> specified
<name>_SRCS	source files to build a specific PROD or LIBRARY
<name>_SRCS_<osclass>	os specific source files to build a specific PROD or LI|BRARY
<name>_SRCS_DEFAULT	source files needed to build a specific PROD or LIBRARY for archs with no <prod>_SRCS_<osclass> specified
Compiler flags	

Build Option	Description
USR_CFLAGS	C compiler flags for all systems
USR_CFLAGS_<osclass>	os-specific C compiler flags
USR_CFLAGS_DEFAULT	C compiler flages for archs with no USR_CFLAGS_<osclass> specified
<name>_CFLAGS	<name>.c file specific C compiler flags (e.g. xxxRecord_CFLAGS=-g)
USR_CXXFLAGS	C++ compiler flags for all systems
USR_CXXFLAGS_<osclass>	os-specific C++ compiler flags
USR_CXXFLAGS_DEFAULT	C++ compiler flags for systems with no USR_CXXFLAGS_<osclass> specified
<name>_CXXFLAGS	<name>.cpp file specific C++ compiler flags
USR_CPPFLAGS	C pre-processor flags (for all makefile compiles)
USR_CPPFLAGS_<osclass>	os specific cpp flags
USR_CPPFLAGS_DEFAULT	cpp flags for systems with no USR_CPPFLAGS_<osclass> specified
<name>_CPPFLAGS	file specific C pre-processor flags (e.g. xxxRecord_CPPFLAGS=-DDEBUG)
USR_INCLUDES	directories to search for include files with -I prefix (e.g. -I$(EPICS_EXTENSIONS_INCLUDE))
<name>_INCLUDES	directories to search for include files when building a specific object file (e.g. -I$(MOTIF_INC))
HOST_WARN	Are compiler warning messages desired for host type builds? (YES or NO) (default is NO)
HOST_OPT	Is host build compiler optimization desired (default is NO optimization)
CROSS_WARN	C cross-compiler warning messages desired (YES or NO) (default NO)
CROSS_OPT	Is cross-compiler optimization desired (YES or NO) (default is NO optimization)
CMPLR	C compiler selection, TRAD, ANSI or STRICT (default is STRICT)
Linker options	
USR_LDFLAGS	linker options (for all makefile links)
USR_LDFLAGS_<osclass>	os specific linker options (for all makefile links)
USR_LDFLAGS_DEFAULT	linker options for systems with no USR_LDFLAGS_<osclass> specified
<name>_LDFLAGS	prod or library specific linker options
<name>_OBJS	object files (without file extension) needed for a specific prod or library
<name>_OBJS_<osclass>	os-specific object files needed for a specific prod or library
<name>_OBJS_DEFAULT	object files needed to link a specific prod or library for systems with no <name>_OBJ_<osclass> specified

Build Option	Description
USR_LIBS	load libraries (e.g. -lXt -lX11) (for all makefile links)
USR_LIBS_<osclass>	os specific load libraries (for all makefile links)
USR_LIBS_DEFAULT	load libraries for systems with no USR_LIBS_<osclass> specified
<name>_LIBS	prod or library specific ld libraries (e.g. probe_LIBS=X11 Xt)
<name>_LIBS_<osclass>	os-specific libs needed to link a specific prod or library
<name>_LIBS_DEFAULT	libs needed to link a specific prod or library for systems with no <name>_LIBS_<osclass> specified
PROD_LIBS	libs needed to link every PROD for all systems
PROD_LIBS_<osclass>	os-specific libs needed to link every PROD
PROD_LIBS_DEFAULT	libs needed to link every PROD for systems with no PROD_LIBS_<osclass> specified
<lib>_DIR	directory to search for the specified lib. (For libs listed in PROD_LIBS, <prod>_LIBS and USR_LIBS)
SYS_PROD_LIBS	system libs needed to link every PROD for all systems
SYS_PROD_LIBS_<osclass>	os-specific system libs needed to link every PROD
SYS_PROD_LIBS_DEFAULT	system libs needed to link every PROD for systems with no SYS_PROD_LIBS_<osclass> specified
<prod>_SYS_LIBS	prod specific system ld libraries (e.g. m)
<prod>_SYS_LIBS_<osclass>	os class specific system libs needed to link a specific prod
<prod>_SYS_LIBS_DEFAULT	system libs needed to link a specific prod for systems with no SYS_PROD_LIBS_<osclass> specified
STATIC_BUILD	Is static build desired (YES or NO) (default is NO)
Header files to be installed	
INC	list of include files to install into $(INSTALL_DIR)/include
INC_<osclass>	os specific includes to installed under $(INSTALL_DIR)/include/os/<osclass>
INC_DEFAULT	include files to install where no INC_<osclass> is specified
Perl, csh, tcl etc. script installation	
SCRIPTS	scripts to install for all systems
SCRIPTS_<osclass>	os-specific scripts to install
SCRIPTS_DEFAULT	scripts to install for systems with no SCRIPTS_<osclass> specified
TCLLIBNAME	list of tcl scripts to install into $(INSTALL_DIR)/lib/<osclass> (Unix hosts only)
TCLINDEX	name of tcl index file to create from TCLLIBNAME scripts

Build Option	Description
Object files	The name in the following OBJS definitions should NOT include a suffix (.o or .obj).
OBJS	object files to build and install for all system.
OBJS_<osclass>	os-specific object files to build and install.
OBJS_DEFAULT	object files to build and install for systems with no OBJS_<osclass> specified..
OBJS_IOC	object files to build and install for ioc type archs.
OBJS_IOC_<osclass>	os specific object files to build and install for ioc type archs
OBJS_IOC_DEFAULT	object files to build and install for ioc type arch systems with no OBJS_<osclass> specified
OBJS_HOST	object files to build and install for host type archs. T
OBJS_HOST_<osclass>	os class specific object files to build and install for host type archs
OBJS_HOST_DEFAULT	object files to build and install for host type arch systems with no OBJS_<osclass> specified
Documentation	
DOCS	text files to be installed into the $(INSTALL_DIR)/doc directory
HTMLS_DIR	name install Hypertext directory name i.e. $(INSTALL_DIR)/html/ $(HTMLS_DIR)
HTMLS	hypertext files to be installed into the $(INSTALL_DIR)/html/ $(HTMLS_DIR) directory
TEMPLATES_DIR	template directory to be created as $(INSTALL_DIR)/templates/ $(TEMPLATE_DIR)
TEMPLATES	template files to be installed into $(TEMPLATE_DIR)
Database Definition files	
DBD	Name of database definition file to be installed or created from bpt data or dbd include and installed into $(INSTALL_DBD).
DBDINC	Name, without suffix, of a menu or record database definition and header to be installed or created and installed.
USR_DBDFLAGS	Optional flags for dbExpand. Currently only include path (-I <path>) and macro substitution (-S <substitution>) are supported.
Database Files	
DB	Name of a database file to be installed or created and installed into $(INSTALL_DB).
Options for other programs	
YACCOPT	yacc options
LEXOPT	lex options

Build Option	Description
SNCFLAGS	state notation language, snc, options
<prod>_SNCFLAGS	product specific state notation language options
E2DB_FLAGS	e2db options
SCH2EDIF_FLAGS	sch2edif options
RANLIBFLAGS	ranlib options
Facilities for building Java programs	
CLASSES	names of Java classes to be built and installed
TESTCLASSES	names of Java classes to be built
PACKAGE	names of Java package to be installed
JAR	name of Jar file to be built
JAR_INPUT	names of files to be included in JAR
MANIFEST	name of manifest file for JAR
Facilities for Windows 95/NT resource (.rc) files	
RCS	resource files (<name>.rc) needed to build every PROD
<prod>_RCS	resource files needed to build a specific PROD
<prod>_RCS_<osclass>	os specific resource files to build a specific PROD
Other definitions:	
USER_VPATH	list of directories
BIN_INSTALLS	files in any directory to install to $(INSTALL_BIN)
TARGETS	files to create but not install
INSTALL_LOCATION	installation directory (defaults to $(TOP))

4.6 Configuration Files

4.6.1 Base Configure Directory

The base/configure directory has the following directory structure:

```
base/
   configure/
      os/
      tools/
```

4.6.2 Base Configure File Descriptions

The configure files contain definitions and make rules to be included in the various makefiles.

`CONFIG.CrossCommon`
This file contains definitions for all hosts and all targets for a cross build (host different than target).

`CONFIG_ADDONS`
This file contains definitions which setup the variables that have <osclass> and DEFAULT options.

`CONFIG_BASE`
This file contains EPICS base specific definitions.

`CONFIG_BASE_VERSION`
This file contains definitions for the version number of EPICS base. This file is used for creating epicsVersion.h which is installed into base/include.

`CONFIG_COMMON`
This file contains definitions common to all builds.

`CONFIG_ENV`
This file contains default definitions of the EPICS environment variables. This file is used for creating envDefs.h which is installed into base/include.

`CONFIG_SITE`
This is the file in which you add to or modify make variables in EPICS base. A definition normally overridden is:

```
CROSS_COMPILER_TARGET_ARCHS =
```

`CONFIG_SITE_ENV`
This file contains defaults for site specific definitions of EPICS environment variables. This file is used for creating envDefs.h which is installed into base/include.

`CONFIG`
This is the file which contains include statements for all the other configure files. You can override any definitions by putting override definitions at the end of this file.

`RELEASE`
This file specifies the location of external products such as Tornado II and external <tops> such as EPICS base.

`RULES`
This file just includes the appropriate rules configuration file.

`RULES.Db`
This file contains rules for building and installing database and database definition files. Databases generated from templates and/or CapFast schematics are supported.

`RULES_ARCHS`
This file contains definitions and rules which allow building the make target for each target architecture.

`RULES_BUILD`
This is a file containing the build rules for the Makefiles

`RULES_DIRS`
This file contains definitions and rules which allow building the make targets in each subdirectory. This file is included by Makefiles in directories with subdirectories to be built.

`RULES_JAVA`
This file contains definitions and rules which allow building java class files and java jar files.

`RULES_TOP`
This file contains the rules specific to a <top> level directory e.g. uninstall and tar. It also includes the RULES_DIRS file.

4.6.3 Base configure/os File Descriptions

The configure/os directory contains os specific make definitions. The naming convention for the files in this directory is CONFIG.<host>.<target> where <host> is either the arch for the host system or Common which means all arch combinations and <target> is either the arch for the build target system or Common for all build target systems.

For example, the file CONFIG.Common.vxWorks-pentium will contain make definitions to be used for builds on all host systems when building for a vxWorks-pentium target system.

Also, if a group of host or target files have the same make definitions these common definitions can be moved to a new file which is then included in each host or target file. An example of this is all Unix hosts which have common definitions in a CONFIG.UnixCommon.Common file and all vxWorks targets with definitions in CONFIG.Common.vxWorksCommon.

4.6.4 Base configure/tool File Descriptions

The configure/tools directory contains Perl script tools used for the build. The tools currently in this directory are:

`cp.pl`
: This Perl script copies an existing file.

`installEpics.pl`
: This is a Perl script that installs build created files into the install directories.

`makeConfigAppInclude.pl`
: This Perl script generates include directory, bin directory, and library directory definitions from the external <top> and product definitions in the RELEASE file. These definitions are included into the CONFIG file.

`makeDbDepends.pl`
: This is a perl script that generates make dependencies from substitutions files.

`makeIocCdCommands.pl`
: This is a perl script that generates a cdCommands file for use by IOCs.

`makeMakefile.pl`
: This is a perl script that creates a Makefile in the created O.<arch> directories.

`makeMakefileInclude.pl`
: This perl script creates a file to be included by Makefiles. This file contains a build target's specific definitions and dependencies.

`mkdir.pl`
: This perl script creates a directory like the Unix mkdir command.

`munch.pl`
: This is a perl script that creates a ctdt.c file for vxWorks target arch builds which lists the c++ static constructors and destructors. See munching in the vxWorks documentation for more information.

`mv.pl`
: This perl script moves an existing file.

`replaceVAR.pl`
: This is a perl script that changes VAR(xxx) style macros in CapFast generated databases into the $(xxx) notation used in EPICS databases.

`rm.pl`
: This perl script quietly removes an existing file.

Chapter 5: Database Locking, Scanning, And Processing

5.1 Overview

Before describing particular components of the IOC software, it is helpful to give an overview of three closely related topics: Database locking, scanning, and processing. Locking is done to prevent two different tasks from simultaneously modifying related database records. Database scanning is the mechanism for deciding when records should be processed. The basics of record processing involves obtaining the current value of input fields and outputting the current value of output fields. As records become more complex so does the record processing.

One powerful feature of the DATABASE is that records can contain links to other records. This feature also causes considerable complication. Thus, before discussing locking, scanning, and processing, record links are described.

5.2 Record Links

A database record may contain links to other records. Each link is one of the following types:

- INLINK
  OUTLINK
  INLINKs and OUTLINKs can be one of the following:
  - constant link
    Not discussed in this chapter
  - database link
    A link to another record in the same IOC.
  - channel access link
    A link to a record in another IOC. It is accessed via a special IOC client task. It is also possible to force a link to be a channel access link even it references a record in the same IOC.
  - hardware link
    Not discussed in this chapter
- FWDLINK
  A forward link refers to a record that should be processed whenever the record containing the forward link is processed. The following types are supported:
  - constant link
    Ignored.
  - database link
    A link to another record in the same IOC.
  - channel access link
    A link to a record in another IOC or a link forced to be a channel access link. Unless the link references the PROC field it is ignored. If it does reference the PROC field a channel access put with a value of 1 is issued.

Links are defined in file `link.h`.

NOTE: This chapter discusses mainly database links.

5.3 Database Links

Database links are referenced by calling one of the following routines:

- **dbGetLink**: The value of the field referenced by the input link retrieved.
- **dbPutLink**: The value of the field referenced by the output link is changed.
- **dbScanPassive**: The record referred to by the forward link is processed if it is passive.

A forward link only makes sense when it refers to a passive record that the should be processed when the record containing the link is processed. For input and output links, however, two other attributes can be specified by the application developer, process passive and maximize severity.

5.3.1 Process Passive

Process passive (`PP` or `NPP`), is either `TRUE` or `FALSE`. It determines if the linked record should be processed before getting a value from an input link or after writing a value to an output link. The linked record will be processed, via a call to `dbProcess`, only if the record is a passive record and process passive is `TRUE`.

NOTE: Three other options may also be specified: CA, CP, and CPP. These options force the link to be handled like a Channel Access Link. See last section of this chapter for details.

5.3.2 Maximize Severity

Maximize severity (`MS` or `NMS`), is `TRUE` or `FALSE`. It determines if alarm severity is propagated across links. For input links the alarm severity of the record referred to by the link is propagated to the record containing the link. For output links the alarm severity of the record containing the link is propagated to the record referred to by the link. In either case, if the severity is changed, the alarm status is set to `LINK_ALARM`.

The method of determining if the alarm status and severity should be changed is called ”maximize severity”. In addition to its actual status and severity, each record also has a new status and severity. The new status and severity are initially 0, which means `NO_ALARM`. Every time a software component wants to modify the status and severity, it first checks the new severity and only makes a change if the severity it wants to set is greater than the current new severity. If it does make a change, it changes the new status and new severity, not the current status and severity. When database monitors are checked, which is normally done by a record processing routine, the current status and severity are set equal to the new values and the new values reset to zero. The end result is that the current alarm status and severity reflect the highest severity outstanding alarm. If multiple alarms of the same severity are present the status reflects the first one detected.

5.4 Database Locking

The purpose of database locking is to prevent a record from being processed simultaneously by two different tasks. In addition, it prevents ”outside” tasks from changing any field while the record is being processed.

The following routines are provided for database locking.

```
dbScanLock(precord);
```

```
dbScanUnlock(precord);
```

The basic idea is to call `dbScanLock` before accessing database records and calling `dbScanUnlock` afterwords. Because of database links (Input, Output, and Forward) a modification to one record can cause modification to other records. Records linked together are placed in the same lock set. `dbScanLock` locks the entire lock set not just the record requested. `dbScanUnlock` unlocks the entire set.

The following rules determine when the lock routines must be called:

1. The periodic, I/O event, and event tasks lock before and unlock after processing:
2. `dbPutField` locks before modifying a record and unlocks afterwards.
3. `dbGetField` locks before reading and unlocks afterwards.
4. Any asynchronous record support completion routine must lock before modifying a record and unlock afterwards.

All records linked via `OUTLINKs` and `FWDLINKs` are placed in the same lock set. Records linked via `INLINKs` with `process_passive` or `maximize_severity` `TRUE` are also forced to be in the same lock set.

5.5 Database Scanning

Database scanning refers to requests that database records be processed. Four types of scanning are possible:

1. **Periodic** - Records are scanned at regular intervals.
2. **I/O event** - A record is scanned as the result of an I/O interrupt.
3. **Event** - A record is scanned as the result of any task issuing a `post_event` request.
4. **Passive** - A record is scanned as a result of a call to `dbScanPassive`. `dbScanPassive` will issue a record processing request if and only if the record is passive and is not already being processed.

A `dbScanPassive` request results from a task calling one of the following routines:

- **dbScanPassive**: Only record processing routines, `dbGetLink`, `dbPutLink`, and `dbPutField` call `dbScanPassive`. Record processing routines call it for each forward link in the record.
- **dbPutField**: This routine changes the specified field and then, if the field has been declared `process_passive`, calls `dbScanPassive`. Each field of each record type has the attribute `process_passive` declared `TRUE` or `FALSE` in the definition file. This attribute is a global property, i.e. the application developer has no control of it. This use of `process_passive` is used only by `dbPutField`. If `dbPutField` finds the record already active (this can happen to asynchronous records) and it is supposed to cause it to process, it arranges for it to be processed again, when the current processing completes.
- **dbGetLink**: If the link specifies process passive, this routine calls `dbScanPassive`. Whether or not `dbScanPassive` is called, it then obtains the specified value.
- **dbPutLink**: This routine changes the specified field. Then, if the link specifies process passive, it calls `dbScanPassive`. `dbPutLink` is only called from record processing routines. Note that this usage of `process_passive` is under the control of the application developer. If `dbPutLink` finds the record already active because of a `dbPutField` directed to this record then it arranges for the record to be processed again, when the current processing completes.

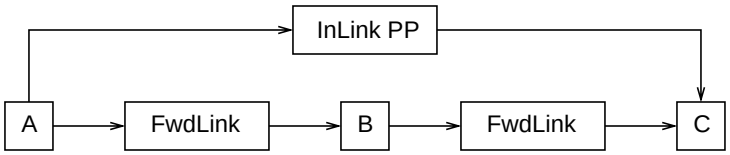
All non-record processing tasks (Channel Access, Sequence Programs, etc.) call `dbGetField` to obtain database values. `dbGetField` just reads values without asking that a record be processed.

5.6 Record Processing

A record is processed as a result of a call to `dbProcess`. Each record support module must supply a routine `process`. This routine does most of the work related to record processing. Since the details of record processing are record type specific this topic is discussed in greater detail in Chapter "Record Support" for details.

5.7 Guidelines for Creating Database Links

The ability to link records together is an extremely powerful feature of the IOC software. In order to use links properly it is important that the Application Developer understand how they are processed. As an introduction consider the following example :



Assume that A, B, and C are all passive records. The notation states that A has a forward link to B and B to C. C has an input link obtaining a value from A. Assume, for some reason, A gets processed. The following sequence of events occurs:

1. A begins processing. While processing a request is made to process B.
2. B starts processing. While processing a request is made to process C.
3. C starts processing. One of the first steps is to get a value from A via the input link.
4. At this point a question occurs. Note that the input link specifies process passive (signified by the `PP` after `InLink`). But process passive states that A should be processed before the value is retrieved. Are we in an infinite loop? The answer is no. Every record contains a field `pact` (processing active), which is set `TRUE` when record processing begins and is not set `FALSE` until all processing completes. When C is processed A still has `pact` `TRUE` and will not be processed again.
5. C obtains the value from A and completes its processing. Control returns to B.
6. B completes returning control to A
7. A completes processing.

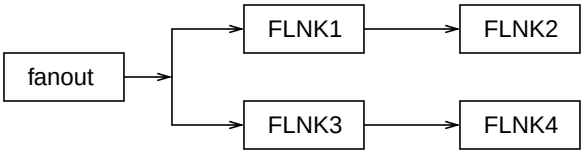
This brief example demonstrates that database links needs more discussion.

5.7.1 Rules Relating to Database Links

5.7.1.1 Processing Order

The processing order is guaranteed to follow the following rules:

1. Forward links are processed in order from left to right and top to bottom. For example the following records are processed in the order `FLNK1`, `FLNK2`, `FLNK3`, `FLNK4` .
2. If a record has multiple input links (calculation and select records) the input is obtained in the natural order. For example if the fields are named `INPA`, `INPB`, ..., `INPL`, then the links are read in the order A then B then C, etc. Thus if obtaining an input results in a record being processed, the processing order is guaranteed.



3. All input and output links are processed before the forward link.

5.7.1.2 Lock Sets

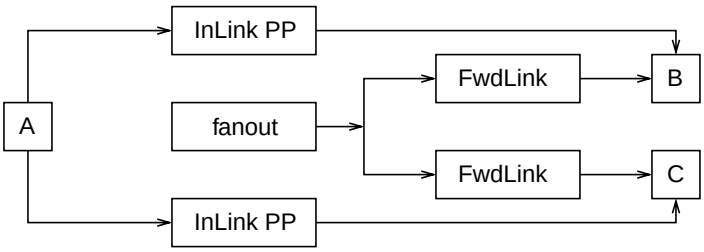
All records, except for the conditions listed in the next paragraph, linked together directly or indirectly are placed in the same lock set. When `dbScanLock` is called the entire set, not just the specified record, is locked. This prevents two different tasks from simultaneously modifying records in the same lock set.

5.7.1.3 PACT - processing active

Each record contains a field `pact`. This field is set `TRUE` at the beginning of record processing and is not set `FALSE` until the record is completely processed. In particular no links are processed with `pact FALSE`. This prevents infinite processing loops. The example given at the beginning of this section gives an example. It will be seen in the next two sections that `pact` has other uses.

5.7.1.4 Process Passive: Link option

Input and output links have an option called process passive. For each such link the application developer can specify process passive `TRUE` (`PP`) or process passive `FALSE` (`NPP`). Consider the following example

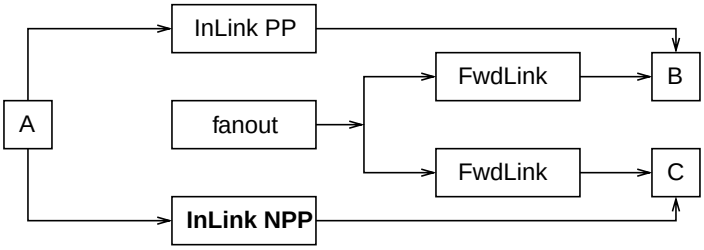


Assume that all records except fanout are passive. When the fanout record is processed the following sequence of events occur:

1. Fanout starts processing and asks that B be processed.
2. B begins processing. It calls `dbGetLink` to obtain data from A.
3. Because the input link has process passive true, a request is made to process A.
4. A is processed, the data value fetched, and control is returned to B
5. B completes processing and control is returned to fanout. Fanout asks that C be processed.
6. C begins processing. It calls `dbGetLink` to obtain data from A.
7. Because the input link has process passive `TRUE`, a request is made to process A.
8. A is processed, the data value fetched, and control is returned to C.
9. C completes processing and returns to fanout

10. The fanout completes

Note that A got processed twice. This is unnecessary. If the input link to C is declared no process passive then A will only be processed once. Thus we should have .



5.7.1.5 Process Passive: Field attribute

Each field of each database record type has an attribute called `process_passive`. This attribute is specified in the record definition file. It is not under the control of the application developer. This attribute is used only by `dbPutField`. It determines if a passive record will be processed after `dbPutField` changes a field in the record. Consult the record specific information in the record reference manual for the setting of individual fields.

5.7.1.6 Maximize Severity: Link option

Input and output links have an option called maximize severity. For each such link the application developer can specify maximize severity `TRUE` (`MS`) or maximize severity `FALSE` (`NMS`).

When database input or output links are defined, the application developer can specify if alarm severities should be propagated across links. For input links the severity is propagated from the record referred to by the link to the record containing the link. For output links the severity of the record containing the link is propagated to the record referenced by the link. The alarm severity is transferred only if the new severity will be greater than the current severity. If the severity is propagated the alarm status is set equal to `LINK_ALARM`.

5.8 Guidelines for Synchronous Records

A synchronous record is a record that can be completely processed without waiting. Thus the application developer never needs to consider the possibility of delays when he defines a set of related records. The only consideration is deciding when records should be processed and in what order a set of records should be processed.

The following reviews the methods available to the application programmer for deciding when to process a record and for enforcing the order of record processing.

1. A record can be scanned periodically (at one of several rates), via I/O event, or via Event.
2. For each periodic group and for each Event group the phase field can be used to specify processing order.
3. The application programmer has no control over the record processing order of records in different groups.
4. The disable fields (`SDIS`, `DISA`, and `DISV`) can be used to disable records from being processed. By letting the `SDIS` field of an entire set of records refer to the same input record, the entire set can be enabled or disabled simultaneously. See the Record Reference Manual for details.

5. A record (periodic or other) can be the root of a set of passive records that will all be processed whenever the root record is processed. The set is formed by input, output, and forward links.
6. The `process_passive` option specified for each field of each record determines if a passive record is processed when a `dbPutField` is directed to the field. The application developer must be aware of the possibility of record processing being triggered by external sources if `dbPutFields` are directed to fields that have `process_passive` `TRUE`.
7. The `process_passive` option for input and output links provides the application developer control over how a set of records are scanned.
8. General link structures can be defined. The application programmer should be wary, however, of defining arbitrary structures without carefully analyzing the processing order.

5.9 Guidelines for Asynchronous Records

The previous discussion does not allow for asynchronous records. An example is a GPIB input record. When the record is processed the GPIB request is started and the processing routine returns. Processing, however, is not really complete until the GPIB request completes. This is handled via an asynchronous completion routine. Lets state a few attributes of asynchronous record processing.

During the initial processing for all asynchronous records the following is done:

1. `pact` is set `TRUE`
2. Data is obtained for all input links
3. Record processing is started
4. The record processing routine returns

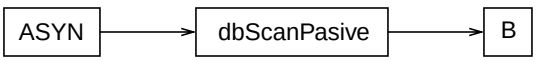
The asynchronous completion routine performs the following algorithm:

5. Record processing continues
6. Record specific alarm conditions are checked
7. Monitors are raised
8. Forward links are processed
9. `pact` is set `FALSE`.

A few attributes of the above rules are:

10. Asynchronous record processing does not delay the scanners.
11. Between the time record processing begins and the asynchronous completion routine completes, no attempt will be made to again process the record. This is because `pact` is `TRUE`. The routine `dbProcess` checks `pact` and does not call the record processing routine if it is `TRUE`. Note, however, that if `dbProcess` finds the record active 10 times in succession, it raises a `SCAN_ALARM`.
12. Forward and output links are triggered only when the asynchronous completion routine completes record processing.

With these rules the following works just fine:

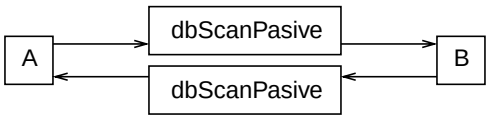


When `dbProcess` is called for record ASYN, processing will be started but `dbScanPassive` will not be called. Until the asynchronous completion routine executes any additional attempts to process ASYN are ignored. When the asynchronous callback is invoked the `dbScanPassive` is performed.

Problems still remain. A few examples are:

5.9.1 Infinite Loop

Infinite processing loops are possible.



Assume both A and B are asynchronous passive records and a request is made to process A. The following sequence of events occur.

1. A starts record processing and returns leaving `pact TRUE`.
2. Sometime later the record completion for A occurs. During record completion a request is made to process B. B starts processing and control returns to A which completes leaving its `pact` field `FALSE`.
3. Sometime later the record completion for B occurs. During record completion a request is made to process A. A starts processing and control returns to B which completes leaving its `pact` field `FALSE`.

Thus an infinite loop of record processing has been set up. It is up to the application developer to prevent such loops.

5.9.2 Obtain Old Data

A `dbGetLink` to a passive asynchronous record can get old data.

If A is a passive asynchronous record then the `dbGetLink` request forces `dbProcess` to be called for A. `dbProcess` starts the processing and returns. `dbGetLink` then reads the desired value which is still old because processing will only be completed at a later time.

5.9.3 Delays

Consider the following:

The second ASYN record will not begin processing until the first completes, etc. This is not really a problem except that the application developer must be aware of delays caused by asynchronous records. Again, note that scanners are not delayed, only records downstream of asynchronous records.

5.9.4 Task Abort

If the processing task aborts and the watch dog task cleans up before the asynchronous processing routine completes what happens? If the asynchronous routine completes before the watch dog task runs everything is okay. If it doesn't? This is a more general question of the consequences of having the watchdog timer restart a scan task. EPICS currently does not allow scanners to be automatically restarted.

5.10 Cached Puts

The rules followed by `dbPutLink` and `dbPutField` provide for "cached" puts. This is necessary because of asynchronous records. Two cases arise.

The first results from a `dbPutField`, which is a put coming from outside the database, i.e. Channel Access puts. If this is directed to a record that already has `pact TRUE` because the record started processing but asynchronous completion has not yet occurred, then a value is written to the record but nothing will be done with the value until the record is again processed. In order to make this happen `dbPutField` arranges to have the record reprocessed when the record finally completes processing.

The second case results from `dbPutLink` finding a record already active because of a `dbPutField` directed to the record. In this case `dbPutLink` arranges to have the record reprocessed when the record finally completes processing. Note that it could already be active because it appears twice in a chain of record processing. In this case it is not reprocessed because the chain of record processing would constitute an infinite loop.

Note that the term caching not queuing is used. If multiple requests are directed to a record while it is active, each new value is placed in the record but it will still only be processed once, i.e. last value wins.

5.11 Channel Access Links

A channel access link is:

1. A record link that references a record in a different IOC.
2. A link that the application developer forces to be a channel access link.

A channel access client task (dbCa) handles all I/O for channel access links. It does the following:

At IOC initialization dbCa issues channel access search requests for each channel access link.

For each input link it establishes a channel access monitor. It uses `ca_field_type` and `ca_element_count` when it establishes the monitor. It also monitors the alarm status. Whenever the monitor is invoked the new data is stored in a buffer belonging to dbCa. When iocCore or the record support module asks for data the data is taken from the buffer and converted to the requested type.

For each output link, a buffer is allocated the first time iocCore/record support issues a put and a channel access connection has been made. This buffer is allocated according to `ca_field_type` and `ca_element_count`. Each time iocCore/record support issues a put, the data is converted and placed in the buffer and a request is made to dbCa to issue a new ca_put.

Even if a link references a record in the same IOC it can be useful to force it to act like a channel access link. In particular the records will not be forced to be in the same lock set. As an example consider a scan record that links to a set of unrelated records, each of which can cause a lot of records to be processed. It is often NOT desirable to force all these records into the same lock set. Forcing the links to be handled as channel access links solves the problem.

Because channel access links imply network activity, they are fundamentally different than database links. For this reason and because channel access does not understand process passive or maximize severity, the semantics of channel access links are not the same as database links. Let's discuss the channel access semantics of INLINK, OUTLINK, and FWDLINK separately.

5.11.1 INLINK

The options for process passive are:

- **PP** or **NPP** - This link is made a channel access link because the referenced record is not found in the local IOC. It is not possible to honor PP, thus the link always acts like NPP.
- **CA** - Force the link to be a channel access link.
- **CP** - Force the link to be a channel access link and also request that the record containing the link be processed whenever a monitor occurs.
- **CPP** - Force the link to be a channel access link and also request that the record containing the link, if it is passive, be processed whenever a monitor occurs.

Maximize Severity is honored.

5.11.2 OUTLINK

The options for process passive are:

- **PP** or **NPP** - This link is made a channel access link because the referenced record is not found in the local IOC. It is not possible to honor PP thus the link always acts like NPP.
- **CA** - Force the link to be a channel access link.

Maximize Severity is not honored.

5.11.3 FWDLINK

A channel access forward link is honored only if it references the PROC field of a record. In that case a ca_put with a value of 1 is written each time a forward link request is issued.

The options for process passive are:

- **PP** or **NPP** - This link is made a channel access link because the referenced record is not found in the local IOC. It is not possible to honor PP thus it always acts like NPP.
- **CA** - Force the link to be a channel access link.

Maximize Severity is not honored.

Chapter 6: Database Definition

6.1 Overview

This chapter describes database definitions. The following definitions are described:

- Menu
- Record Type
- Device
- Driver
- Breakpoint Table
- Record Instance

Record Instances are fundamentally different from the other definitions. A file containing record instances should never contain any of the other definitions and vise-versa. Thus the following convention is followed:

- **Database Definition File** - A file that contains any type of definition except record instances.
- **Record Instance File** - A file that contains only record instance definitions.

This chapter also describes utility programs which operate on these definitions

Any combination of definitions can appear in a single file or in a set of files related to each other via include files.

6.2 Brief Summary of Database Definition Syntax

```
path "path"
addpath "path"
include "filename"
#comment
menu(name) {
   include "filename"
   choice(choice_name,"choice_value")
   ...
}

recordtype(record_type) {
   include "filename"
   field(field_name,field_type) {
      asl(asl_level)
      initial("init_value")
      promptgroup(gui_group)
      prompt("prompt_value")
      special(special_value)
      pp(pp_value)
```

```
         interest(interest_level)
         base(base_type)
         size(size_value)
         extra("extra_info")
         menu(name)
      }
      ...
   }

   device(record_type,link_type,dset_name,”choice_string”)
      ...


   driver(drvet_name)
     ...


   breaktable(name) {
      raw_value, eng_value,
      ...
   }

#The Following defines a Record Instance

   record(record_type,record_name) {
      include "filename"
      field(field_name,"value")
      ...
   }
#NOTE: GDCT uses grecord instead of record
```

6.3 General Rules for Database Definition

6.3.1 Keywords

The following are keywords, i.e. they may not be used as values unless they are enclosed in quotes:

```
path
addpath
include
menu
choice
recordtype
field
device
driver
breaktable
record
grecord
```

6.3.2 Unquoted Strings

In the summary section, some values are shown as quoted strings and some unquoted. The actual rule is that any string consisting of only the following characters does not have to be quoted:

```
a-z A-Z 0-9 _ - : . [ ] < > ;
```

These are also the legal characters for process variable names. Thus in many cases quotes are not needed.

6.3.3 Quoted Strings

A quoted string can contain any ascii character except the quote character ". The quote character itself can given by using \ as an escape. For example "\"" is a quoted string containing the single character ".

6.3.4 Macro Substitution

Macro substitutions are permitted inside quoted strings. The macro has the form:

```
$(name)
or
${name}
```

6.3.5 Escape Sequences

Except for \" the database routines never translate standard C escape sequences, however, `dbTranslateEscape` can be used to translate the standard C escape sequences:

\a \b \f \n \r \t \v \\ \? \' \" \000 \xhh

(\000 represenst an octal number of 1, 2, or 3 digits. \xhh represents a hexadecimal number of 1 or 2 digits) A typical use is device support which expects escape sequences in the parm field:

The routine is:

```
int dbTranslateEscape(char *s,const char *ct);
/*
 * copies ct to s while substituting escape sequences
 * returns the length of the resultant string
 * The result may contain 0 characters
*/
```

6.3.6 Define before referencing

No item can be referenced until it is defined. For example a `recordtype` menu field can not reference a menu unless that menu definition has already been defined. Another example is that a record instance can not appear until the associated record type has been defined.

6.3.7 Multiple Definitions

If a particular menu, recordtype, device, driver, or breakpoint table is defined more than once, then only the first instance is used. Record instance definitions are cumulative, i.e. each time a new field value is encountered it replaces the previous value.

6.3.8 filename extension

By convention:

- Record instances files have the extension ".db"
- Database definition files have the extension ".dbd".

6.3.9 path addpath

The path follows the standard Unix convention, i.e. it is a list of directory names separated by colons (Unix) or semicolons (winXX).

Format:

```
path "dir:dir...:dir"
addpath "dir:dir...:dir
```

NOTE: In winXX the separator is ; instead of :

The `path` command specifies the current path. The `addpath` appends directory names to the current path. The path is used to locate the initial database file and included files. An empty `dir` at the beginning, middle, or end of a non-empty path string means the current directory. For example:

```
nnn::mmm    # Current directory is between nnn and mmm
:nnn        # Current directory is first
nnn:        # Current directory is last
```

Utilities which load database files (`dbExpand`, `dbLoadDatabase`, etc.) allow the user to specify an initial path. The `path` and `addpath` commands can be used to change or extend the initial path.

The initial path is determined as follows:

> If an initial path is specified, it is used. Else:
> If the environment variable `EPICS_DB_INCLUDE_PATH` is defined, it is used. Else:
> the default path is ".", i.e. the current directory.

The path is used unless the filename contains a / or \. The first directory containing the specified file is used.

6.3.10 include

Format:

```
include "filename"
```

An include statement can appear at any place shown in the summary. It uses the path as specified above.

6.3.11 comment

The comment symbol is "#". Whenever the comment symbol appears, it and all characters through the end of the line are ignored.

6.3.12 dbTranslateEscape

6.3.13 dbTranslateEscape

6.4 Menu

Format:

```
menu(name) {
   choice(choice_name,"choice_value")
   ...
}
```

Where:

name - Name for menu. This is the unique name identifying the menu. If duplicate definitions are specified, only the first is used.
choice_name - The name placed in the `enum` generated by `dbToMenuH` or `dbToRecordtypeH`
choice_value - The value associated with the choice.

Example:

```
menu(menuYesNo) {
   choice(menuYesNoNO,"NO")
   choice(menuYesNoYES,"YES")
}
```

6.5 Record Type

6.5.1 Format:

```
recordtype(record_type) {
   field(field_name,field_type) {
      asl(asl_level)
      initial("init_value")
      promptgroup(gui_group)
      prompt("prompt_value")
      special(special_value)
      pp(pp_value)
      interest(interest_level)
      base(base_type)
      size(size_value)
      extra("extra_info")
      menu("name")
   }
```

```
    ...
}
```

6.5.2 rules

- **asl** - Access Security Level. The default is `ASL1`. Access Security is discussed in a later chapter. Only two values are permitted for this field (`ASL0` and `ASL1`). Fields which operators normally change are assigned `ASL0`. Other fields are assigned `ASL1`. For example, the `VAL` field of an analog output record is assigned `ASL0` and all other fields `ASL1`. This is because only the `VAL` field should be modified during normal operations.
- **initial** - Initial Value.
- **promptgroup** - Prompt group to which field belongs. This is for use by Database Configuration Tools. This is defined only for fields that can be given values by database configuration tools. File `guigroup.h` contains all possible definitions. The different groups allow database configuration tools to present the user with groups of fields rather than all prompt fields. I don't know of any tool that currently uses groups.
- **prompt** - A prompt string for database configuration tools. Optional if `promptgroup` is not defined.
- **special** - If specified, then special processing is required for this field at run time.
- **pp** - Should a passive record be processed when Channel Access writes to this field? The default is `NO`.
- **interest** - Only used by the `dbpr` shell command.
- **base** - For integer fields, a base of `DECIMAL` or `HEX` can be specified. The default is `DECIMAL`.
- **size** - Must be specified for `DBF_STRING` fields.
- **extra** - Must be specified for `DBF_NOACCESS` fields.
- **menu** - Must be specified for `DBF_MENU` fields. It is the name of the associated menu.

6.5.3 definitions

- **record_type** - The unique name of the record type. If duplicates are specified, only the first definition is used.
- **field_name** - The field name. Only alphanumeric characters are allowed. When include files are generated, the field name is converted to lower case. Previous versions of EPICS required that field name be a maximum of four characters. Although this restriction no longer exists, problems may arrise with some Channel Access clients if longer field names are chosen.
- **field_type** - This must be one of the following values:
    - `DBF_STRING`
    - `DBF_CHAR`
    - `DBF_UCHAR`
    - `DBF_SHORT`
    - `DBF_USHORT`
    - `DBF_LONG`
    - `DBF_ULONG`
    - `DBF_FLOAT`
    - `DBF_DOUBLE`
    - `DBF_ENUM`
    - `DBF_MENU`
    - `DBF_DEVICE`
    - `DBF_INLINK`
    - `DBF_OUTLINK`
    - `DBF_FWDLINK`
    - `DBF_NOACCESS`

- **asl_level** - This must be one of the following values:
  - `ASL0`
  - `ASL1` (default value)
- **init_value** - A legal value for data type.
- **prompt_value** - A prompt value for database configuration tools.
- **gui_group** - This must be one of the following:
  - `GUI_COMMON`
  - `GUI_ALARMS`
  - `GUI_BITS1`
  - `GUI_BITS2`
  - `GUI_CALC`
  - `GUI_CLOCK`
  - `GUI_COMPRESS`
  - `GUI_CONVERT`
  - `GUI_DISPLAY`
  - `GUI_HIST`
  - `GUI_INPUTS`
  - `GUI_LINKS`
  - `GUI_MBB`
  - `GUI_MOTOR`
  - `GUI_OUTPUT`
  - `GUI_PID`
  - `GUI_PULSE`
  - `GUI_SELECT`
  - `GUI_SEQ1`
  - `GUI_SEQ2`
  - `GUI_SEQ3`
  - `GUI_SUB`
  - `GUI_TIMER`
  - `GUI_WAVE`
  - `GUI_SCAN`

    NOTE: `GUI` types were invented with the intention of allowing database configuration tools to prompt for groups of fields and when a user selects a group the fields within the group. This feature has never been used and a result is that many record types have not assigned the correct GUI groups to each field.
- **special_value** must be one of the following:
  - An integer value greater than 103. In this case, the record support special routine is called whenever the field is modified by database access. This feature is present only for compatibility. New support modules should use `SPC_MOD`.

    The following value disallows access to field.
  - `SPC_NOMOD` - This means that field can not be modified at runtime except by the record/device support modules for the record type.

    The following values are used for database common. They must NOT be used for record specific fields.
  - `SPC_SCAN` - Scan related field.
  - `SPC_ALARMACK` - Alarm acknowledgment field.
  - `SPC_AS` - Access security field.

The following value is used if record support wants to trap `dbNameToAddr` calls.

- `SPC_DBADDR` - This is set if the record support `cvt_dbaddr` routine should be called whenever `dbNameToAddr` is called, i.e. when code outside record/device support want to access the field.

  The following values all result in the record support special routine being called whenever database access modifies the field. The only reason for multiple values is that originally it seemed like a good idea. New support modules should only use `SPC_MOD`.

- `SPC_MOD` - Notify when modified, i.e. call the record support special routine whenever the field is modified by database access.
- `SPC_RESET` - a reset field is being modified.
- `SPC_LINCONV` - A linear conversion field is being modified.
- `SPC_CALC` - A calc field is being modified.

- **pp_value** - Should a passive record be processed when Channel Access writes to this field? The allowed values are:
  - `NO` (default)
  - `YES`
- **interest_level -** An interest level for the `dbpr` command.
- **base** - For integer type fields, the default base. The legal values are:
  - `DECIMAL` (Default)
  - `HEX`
- **size_value** - The number of characters for a `DBF_STRING` field.
- **extra_info** - For `DBF_NOACCESS` fields, this is the C language definition for the field. The definition must end with the fieldname in lower case.

6.5.4 Example

The following is the definition of the binary input record.

```
recordtype(bi) {
   include "dbCommon.dbd"
   field(INP,DBF_INLINK) {
      prompt("Input Specification")
      promptgroup(GUI_INPUTS)
      special(SPC_NOMOD)
      interest(1)
   }
   field(VAL,DBF_ENUM) {
      prompt("Current Value")
      asl(ASL0)
      pp(TRUE)
   }
   field(ZSV,DBF_MENU) {
      prompt("Zero Error Severity")
      promptgroup(GUI_ALARMS)
      pp(TRUE)
      interest(1)
      menu(menuAlarmSevr)
   }
   field(OSV,DBF_MENU) {
```

```
      prompt("One Error Severity")
      promptgroup(GUI_BITS1)
      pp(TRUE)
      interest(1)
      menu(menuAlarmSevr)
   }
   field(COSV,DBF_MENU) {
      prompt("Change of State Svr")
      promptgroup(GUI_BITS2)
      pp(TRUE)
      interest(1)
      menu(menuAlarmSevr)
   }
   field(ZNAM,DBF_STRING) {
      prompt("Zero Name")
      promptgroup(GUI_CALC)
      pp(TRUE)
      interest(1)
      size(20)
   }
   field(ONAM,DBF_STRING) {
      prompt("One Name")
      promptgroup(GUI_CLOCK)
      pp(TRUE)
      interest(1)
      size(20)
   }
   field(RVAL,DBF_ULONG) {
      prompt("Raw Value")
      pp(TRUE)
   }
   field(ORAW,DBF_ULONG) {
      prompt("prev Raw Value")
      special(SPC_NOMOD)
      interest(3)
   }
   field(MASK,DBF_ULONG) {
      prompt("Hardware Mask")
      special(SPC_NOMOD)
      interest(1)
   }
   field(LALM,DBF_USHORT) {
      prompt("Last Value Alarmed")
      special(SPC_NOMOD)
      interest(3)
   }
   field(MLST,DBF_USHORT) {
      prompt("Last Value Monitored")
      special(SPC_NOMOD)
      interest(3)
   }
   field(SIOL,DBF_INLINK) {
      prompt("Sim Input Specifctn")
```

```
      promptgroup(GUI_INPUTS)
      special(SPC_NOMOD)
      interest(1)
   }
   field(SVAL,DBF_USHORT) {
      prompt("Simulation Value")
   }
   field(SIML,DBF_INLINK) {
      prompt("Sim Mode Location")
      promptgroup(GUI_INPUTS)
      special(SPC_NOMOD)
      interest(1)
   }
   field(SIMM,DBF_MENU) {
      prompt("Simulation Mode")
      interest(1)
      menu(menuYesNo)
   }
   field(SIMS,DBF_MENU) {
      prompt("Sim mode Alarm Svrty")
      promptgroup(GUI_INPUTS)
      interest(2)
      menu(menuAlarmSevr)
   }
}
```

6.6 Device

6.6.1 Format:

```
   device(record_type,link_type,dset_name,”choice_string”)
      ...
```

6.6.2 definitions

- **record_type** - Record type. The combination of `record_type` and `choice_string` must be unique. If the same combination appears multiple times, the first definition is used.
- **link_type -** Link type. This must be one of the following:
    - `CONSTANT`
    - `PV_LINK`
    - `VME_IO`
    - `CAMAC_IO`
    - `AB_IO`
    - `GPIB_IO`
    - `BITBUS_IO`
    - `INST_IO`
    - `BBGPIB_IO`

  - `RF_IO`
  - `VXI_IO`
- **dset_name -** The exact name of the device support entry table without the trailing "`DSET`". Duplicates are not allowed.
- **choice_string** Choice string for database configuration tools. Note that it must be enclosed in "". Note that for a given record type, each `choice_string` must be unique.

6.6.3 Examples

```
device(ai,CONSTANT,devAiSoft,"Soft Channel")
device(ai,VME_IO,devAiXy566Se,"XYCOM-566 SE Scanned")
```

6.7 Driver

6.7.1 Format:

```
   driver(drvet_name)
```

6.7.2 Definitions

- **drvet_name** - If duplicates are defined, only the first is used.

6.7.3 Examples

```
driver(drvVxi)
driver(drvXy210)
```

6.8 Breakpoint Table

6.8.1 Format:

```
breaktable(name) {
   raw_value, eng_value,
   ...
}
```

6.8.2 Definitions

- **name** - Name, which must be alpha-numeric, of the breakpoint table. If duplicates are specified the first is used.
- **raw_value** - The raw value, i.e. the actual ADC value associated with the beginning of the interval.
- **eng_value** - The engineering value associated with the beginning of the interval.

6.8.3 Example

```
breaktable(typeJdegC) {
    0.000000 0.000000
    365.023224 67.000000
    1000.046448 178.000000
    3007.255859 524.000000
    3543.383789 613.000000
    4042.988281 692.000000
    4101.488281 701.000000
}
```

6.9 Record Instance

6.9.1 Format:

```
record(record_type,record_name) {
   field(field_name,"value")
   ...
}
```

6.9.2 definitions

- **record_type** - The record type.
- **record_name** - The record name. This must be composed of the following characters:
  a-z A-Z 0-9 _ - : [ ] < > ;
  NOTE: If macro substitutions are used the name must be quoted.
  If duplicate definitions are given for the same record, then the last value given for each field is the value assigned to the field.
- **field_name** - The field name
- **value** - Depends on field type.
  - `DBF_STRING`
    Any ASCII string. If it exceeds the field length, it will be truncated.
  - `DBF_CHAR`, `DBF_UCHAR`, `DBF_SHORT`, `DBF_USHORT`, `DBF_LONG`, `DBF_ULONG`
    A string that represents a valid integer. The standard C conventions are applied, i.e. a leading 0 means the value is given in octal and a leading 0x means that value is given in hex.
  - `DBF_FLOAT`, `DBF_DOUBLE`
    The string must represent a valid floating point number.
  - `DBF_MENU`
    The string must be one of the valid choices for the associated menu.
  - `DBF_DEVICE`
    The string must be one of the valid device choice strings.
  - `DBF_INLINK`, `DBF_OUTLINK`
    `NOTES:`
    - In the field is INP or OUT then it is associated with field DTYP. Other DBF_INLINK and DBF_OUTLINK fields can be either CONSTANT or PV_LINKs
    - `DTYP` must be defined before the associated INP or OUT field.

- Choosing the DTYP implicitly chooses a bus type.
- A DTYP of CONSTANT can be either a constant or a PV_LINK.

The allowed value depends on the bus type as follows:

- `CONSTANT`
  A constant valid for the field associated
- `PV_LINK`
  A value of the form:

  record.field process maximize

  `field, process`, and `maximize` are optional.
  The default value for `field` is `VAL`.
  `process` can have one of the following values:
  - `NPP` - No Process Passive (Default)
  - `PP` - Process Passive
  - `CA` - Force link to be a channel access link
  - `CP` - CA and process on monitor
  - `CPP` - CA and process on monitor if record is passive
    NOTES:
    CP and CPP are valid only for INLINKs.
    FWD_LINKs can be PP or CA. If a FWD_LINK is a channel access link it must reference the PROC field.

  `maximize` can have one of the following values
  - `NMS` - No Maximize Severity (Default)
  - `MS` - Maximize severity
- `VME_IO`
  #Ccard Ssignal @parm
  where:
  `card` - the card number of associated hardware module.
  `signal` - signal on card
  `parm` - An arbitrary character string of up to 31 characters.
  This field is optional and is device specific.
- `CAMAC_IO`
  #Bbranch Ccrate Nstation Asubaddress Ffunction @parm
  `branch`, `crate`, `station`, `subaddress`, and `function` should be obvious to `camac` users. `Subaddress` and `function` are optional (0 if not given). `Parm` is also optional and is device dependent (25 characters max).
- `AB_IO`
  #Llink Aadapter Ccard Ssignal @parm
  `link` - Scanner., i.e. vme scanner number
  `adapter` - Adapter. Allen Bradley also calls this rack
  `card` - Card within Allen Bradley Chassis
  `signal` - signal on card
  `parm` - An optional character string that is device dependent(27 char max)
- `GPIB_IO`
  #Llink Aaddr @parm
  `link` - gpib link, i.e. interface
  `addr` - GPIB address
  `parm` - device dependent character string (31 char max)
- `BITBUS_IO`
  #Llink Nnode Pport Ssignal @parm

`link` - link, i.e. vme bitbus interface.
`node` - bitbus node
`port` - port on the node
`signal` - signal on port
`parm` - device specific character string(31 char max)

- `INST_IO`
  @parm
  `parm` - Device dependent character string(35 char max)
- `BBGPIB_IO`
  #Llink Bbbaddr Ggpibaddr @parm
  `link` - link, i.e. vme bitbus interface.
  `bbadddr` - bitbus address
  `gpibaddr` - gpib address
  `parm` - optional device dependent character string(31 char max)
- `RF_IO`
  `#Rcryo Mmicro Ddataset Eelement`
- `VXI_IO`
  #Vframe Cslot Ssignal @parm (Dynamic addressing)
  or
  `#Vla Signal @parm (Static Addressing)`
  `frame` - VXI frame number
  `slot` - Slot within VXI frame
  `la` - Logical Address
  `signal` - Signal Number
  `parm` - device specific character string(25 char max)

- `DBF_FWDLINK`
  This is either not defined or else is a `PV_LINK`. See above for definitions.

6.9.3 Examples

```
record(ai,STS_AbAiMaS0) {
   field(SCAN,".1 second")
   field(DTYP,"AB-1771IFE-4to20MA")
   field(INP,"#L0 A2 C0 S0 F0 @")
   field(PREC,"4")
   field(LINR,"LINEAR")
   field(EGUF,"20")
   field(EGUL,"4")
   field(EGU,"MilliAmps")
   field(HOPR,"20")
   field(LOPR,"4")
}
record(ao,STS_AbAoMaC1S0) {
   field(DTYP,"AB-1771OFE")
   field(OUT,"#L0 A2 C1 S0 F0 @")
   field(LINR,"LINEAR")
   field(EGUF,"20")
   field(EGUL,"4")
   field(EGU,"MilliAmp")
   field(DRVH,"20")
   field(DRVL,"4")
   field(HOPR,"20")
```

```
   field(LOPR,"4")
}
record(bi,STS_AbDiA0C0S0) {
   field(SCAN,"I/O Intr")
   field(DTYP,"AB-Binary Input")
   field(INP,"#L0 A0 C0 S0 F0 @")
   field(ZNAM,"Off")
   field(ONAM,"On")
}
```

6.10 Record Attribute

Each record type can have a set of record attributes. Each attribute is a “psuedo” field that can be accessed via database and channel access. An attribute is given a name the acts like a field name which has the same value for every instance of the record type. Two attributes are generated automatically for each record type: RTYP and VERS. The value for RTYP is the record type name. The default value for VERS is "none specified", which can be changed by record support. Record support can call the following routine to create new attributes or change existing attributes:

```
long dbPutAttribute(char *recordTypename,
    char *name,char*value)
```

The arguments are:

`recordTypename` - The name of recordtype.
`name` - The attribute name, i.e. the psuedo field name.
`value` - The value assigned to the attribute.

6.11 Breakpoint Tables - Discussion

The menu `menuConvert` is used for field `LINR` of the `ai` and `ao` records. These records allow raw data to be converted to/from engineering units via one of the following:

1. No Conversion.
2. Linear Conversion.
3. Breakpoint table.

Other record types can also use this feature. The first two choices specify no conversion and linear conversion. The remaining choices are assumed to be the names of breakpoint tables. If a breakpoint table is chosen, the record support modules calls `cvtRawToEngBpt` or `cvtEngToRawBpt`. You can look at the `ai` and `ao` record support modules for details.

If a user wants to add additional breakpoint tables, then the following should be done:

- Copy the `menuConvert.dbd` file from EPICS `base/src/bpt`
- Add definitions for new breakpoint tables to the end
- Make sure modified `menuConvert.dbd` is loaded into the IOC instead of EPICS version.

It is only necessary to load a breakpoint file if a record instance actually chooses it. It should also be mentioned that the Allen Bradley IXE device support misuses the `LINR` field. If you use this module, it is very important that you do not change any of the EPICS supplied definitions in `menuConvert.dbd`. Just add your definitions at the end.

If a breakpoint table is chosen, then the corresponding breakpoint file must be loaded into the IOC before `iocInit` is called.

Normally, it is desirable to directly create the breakpoint tables. However, sometimes it is desirable to create a breakpoint table from a table of raw values representing equally spaced engineering units. A good example is the Thermocouple tables in the OMEGA Engineering, INC Temperature Measurement Handbook. A tool `makeBpt` is provided to convert such data to a breakpoint table.

The format for generating a breakpoint table from a data table of raw values corresponding to equally spaced engineering values is:

```
!comment line
<header line>
<data table>
```

The header line contains the following information:

- **Name**: An alphanumeric ascii string specifying the breakpoint table name
- **Low Value Eng**: Engineering Units Value for first breakpoint table entry
- **Low Value Raw**: Raw value for first breakpoint table entry
- **High Value Eng**: Engineering Units: Highest Value desired
- **High Value Raw**: Raw Value for High Value Eng
- **Error**: Allowed error (Engineering Units)
- **First Table**: Engineering units corresponding to first data table entry
- **Last Table**: Engineering units corresponding to last data table entry
- **Delta Table**: Change in engineering units per data table entry

An example definition is:

```
”TypeKdegF” 32 0 1832 4095 1.0 -454 2500 1
<data table>
```

The breakpoint table can be generated by executing

```
makeBpt bptXXX.data
```

The input file must have the extension of data. The output filename is the same as the input filename with the extension of dbd.

Another way to create the breakpoint table is to include the following definition in a Makefile.Vx:

```
BPTS += bptXXX.dbd
```

NOTE: This requires the naming convention that all data tables are of the form bpt<name>.data and a breakpoint table bpt<name>.dbd.

6.12 Menu and Record Type Include File Generation.

6.12.1 Introduction

Given a file containing menus, `dbToMenuH` generates an include file that can be used by any code which uses the associated menus. Given a file containing any combination of menu definitions and record type definitions, `dbToRecordtypeH` generates an include file that can be used by any code which uses the menus and record type.

EPICS base uses the following conventions for managing menu and recordtype definitions. Users generating local record types are encouraged to do likewise.

- Each menu that is either for fields in database common (for example `menuScan`) or is of global use (for example `menuYesNo`) is defined in a separate file. The name of the file is the same as the menu name with an extension of `dbd`. The name of the generated include file is the menu name with an extension of `h`. Thus `menuScan` is defined in a file `menuScan.dbd` and the generated include file is named `menuScan.h`
- Each record type definition is defined in a separate file. In addition, this file contains any menu definitions that are used only by that record type. The name of the file is the same as the recordtype name followed by `Record.dbd`. The name of the generated include file is the same name with an extension of `h`. Thus `aoRecord` is defined in a file `aoRecord.dbd` and the generated include file is named `aoRecord.h`. Since `aoRecord` has a private menu called `aoOIF`, the `dbd` file and the generated include file have definitions for this menu. Thus for each record type, there are two source files (`xxxRecord.dbd` and `xxxRecord.c`) and one generated file (`xxxRecord.h`).

Before continuing, it should be mentioned that Application Developers don't have to execute `dbToMenuH` or `dbToRecordtypeH`. If a developer uses the proper naming conventions, it is only necessary to add definitions to their `Makefile`. Consult the chapter on the EPICS Build Facility for details..

6.12.2 dbToMenuH

This tool is executed as follows:

```
dbToMenuH -Idir -Smacsub menuXXX.dbd
```

It generates a file which has the same name as the input file but with an extension of `h`. Multiple `-I` options can be specified for an include path and multiple `-S` options for macro substitution.

For example `menuPriority.dbd`, which contains the definitions for processing priority contains:

```
menu(menuPriority) {
   choice(menuPriorityLOW,"LOW")
   choice(menuPriorityMEDIUM,"MEDIUM")
   choice(menuPriorityHIGH,"HIGH")
}
```

The include file, `menuPriority.h`, generated by `dbToMenuH` contains:

```
#ifndef INCmenuPriorityH
#define INCmenuPriorityH
typedef enum {
   menuPriorityLOW,
   menuPriorityMEDIUM,
   menuPriorityHIGH,
}menuPriority;
#endif /*INCmenuPriorityH*/
```

Any code that needs to use the priority menu values should use these definitions.

6.12.3 dbToRecordtypeH

This tool is executed as follows:

```
dbTorecordtypeH -Idir -Smacsub xxxRecord.dbd
```

It generates a file which has the same name as the input file but with an extension of `h`. Multiple `-I` options can be specified for an include path and multiple `-S` options for macro substitution.

For example `aoRecord.dbd`, which contains the definitions for the analog output record contains:

```
menu(aoOIF) {
   choice(aoOIF_Full,"Full")
   choice(aoOIF_Incremental,"Incremental")
}
recordtype(ao) {
   include "dbCommon.dbd"
   field(VAL,DBF_DOUBLE) {
      prompt("Desired Output")
      asl(ASL0)
      pp(TRUE)
   }
   field(OVAL,DBF_DOUBLE) {
      prompt("Output Value")
   }
   ... (Many more field definitions
   }
}
```

The include file, `aoRecord.h`, generated by `dbToRecordtypeH` contains:

```
#include <vxWorks.h>
#include <semLib.h>
#include "ellLib.h"
#include "fast_lock.h"
#include "link.h"
#include "tsDefs.h"

#ifndef INCaoOIFH
#define INCaoOIFH
typedef enum {
        aoOIF_Full,
        aoOIF_Incremental,
}aoOIF;
#endif /*INCaoOIFH*/
#ifndef INCaoH
#define INCaoH
typedef struct aoRecord {
        char            name[29]; /*Record Name*/
        ... Remaining fields in database common
        double          val;    /*Desired Output*/
        double          oval;   /*Output Value*/
        ... remaining record specific fields
} aoRecord;
#define aoRecordNAME    0
... defines for remaining fields in database common
#define aoRecordVAL     42
#define aoRecordOVAL    43
... defines for remaining record specific fields
#ifdef GEN_SIZE_OFFSET
int aoRecordSizeOffset(dbRecordType *pdbRecordType)
{
    aoRecord *prec = 0;
```

```
  pdbRecordType->papFldDes[0]->size=sizeof(prec->name);
  pdbRecordType->papFldDes[0]->offset=
      (short)((char *)&prec->name - (char *)prec);
  ... code to compute size&offset for other fields in dbCommon
  pdbRecordType->papFldDes[42]->size=sizeof(prec->val);
  pdbRecordType->papFldDes[42]->offset=
      (short)((char *)&prec->val - (char *)prec);
  pdbRecordType->papFldDes[43]->size=sizeof(prec->oval);
  pdbRecordType->papFldDes[43]->offset=
      (short)((char *)&prec->oval - (char *)prec);
  ... code to compute size&offset for remaining fields
  pdbRecordType->rec_size = sizeof(*prec);
  return(0);
}
#endif /*GEN_SIZE_OFFSET*/
```

The analog output record support module and all associated device support modules should use this include file. No other code should use it. Let's discuss the various parts of the file.:

- The `enum` generated from the menu definition should be used to reference the value of the field associated with the menu.
- The `typedef` and `structure` defining the record are used by record support and device support to access fields in an analog output record.
- A `#define` is present for each field within the record. This is useful for the record support routines that are passed a pointer to a `DBADDR` structure. They can have code like the following:

```
switch (dbGetFieldIndex(pdbAddr)) {
   case aoRecordVAL :
      ...
       break;
   case aoRecordXXX:
      ...
      break;
   default:
      ...
}
```

The C source routine `aoRecordSizeOffset` is automatically called when a record type file is loaded into an IOC. Thus user code does not have to be aware of this routine except for the following convention: The associate record support module MUST include the statements:

```
#define GEN_SIZE_OFFSET
#include "xxxRecord.h"
#undef GEN_SIZE_OFFSET
```

This convention ensures that the routine is defined exactly once.

6.13 dbExpand

```
dbExpand -Idir -Smacsub file1 file2 ...
```

Multiple `-I` options can be specified for an include path and multiple `-S` options for macro substitution. Note that the environment variable `EPICS_DB_INCLUDE_PATH` can also be used in place of the `-I` options.

NOTE: This is supported only on the host.

This command reads the input files and then writes, to `stdout`, a file containing ASCII definitions for all information described by the input files. The difference is that comment lines do not appear and all include files are expanded.

This routine is extremely useful if an IOC is not using NFS for the `dbLoadDatabase` commands. It takes more than 2 minutes to load the `base/rec/base.dbd` file into an IOC if NFS is not used. If `dbExpand` creates a local `base.dbd` file, it takes about 7 seconds to load (25 MHZ 68040 IOC).

6.14 dbLoadDatabase

`dbLoadDatabase(char *db_file, char *path, char *substitutions)`

NOTES:

- IOC Only
- Using a path on a vxWorks ioc does not work very well.
- Both path and substitutions can be null.

This command loads a database file containing any of the definitions given in the summary at the beginning of this chapter.

`dbfile` must be a file containing only *record instances* in standard ASCII format. Such files should have an extension of "`.db`".

`As each line of dbfile` is read, the substitutions specified in `substitutions` is performed. The substitutions are specified as follows:

```
"var1=sub1,var2=sub3,..."
```

Variables are specified in the dbfile as $(variable_name). If the substitution string

```
"a=1,b=2,c=\"this is a test\""
```

were used, any variables `$(a)`, `$(b)`, `$(c)` would be substituted with the appropriate data.

6.14.1 EXAMPLE

For example, let `test.db` be:

```
record(ai,"$(pre)testrec1")
record(ai,"$(pre)testrec2")
record(stringout,"$(pre)testrec3") {
   field(VAL,"$(STR)")
   field(SCAN,"$(SCAN)")
}
```

Then issuing the command:

`dbLoadDatabase("test.db",0,"pre=TEST,STR=test,SCAN=Passive")`

gives the same results as loading:

```
record(ai,"TESTtestrec1")
record(ai,"TESTtestrec2")
```

```
record(stringout,"TESTtestrec3") {
   field(VAL,"test")
   field(SCAN,"Passive")
}
```

6.15 dbLoadRecords

`dbLoadRecords(char* dbfile, char* substitutions)`

NOTES:

- IOC Only.
- dbfile must contain only record instances.
- `dbLoadRecords` is no longer needed.It will probably go away in the future. At the present time dbLoadRecords loads faster than dbLoadDatabase.

6.16 dbLoadTemplate

`dbLoadTemplate(char* template_def)`

NOTES:

- IOC Only.
- MSI can be used to expand templates on the host.

`dbLoadTemplate` reads a template definition file. This file contains rules about loading database instance files, which contain $(`xxx`) macros, and performing substitutions.

`template_def` contains the rules for performing substitutions on the instance files. For convenience two formats are provided. The format is:

```
file name.db {
   put Version-1 or Version-2 here
}
```

Version-1

```
{ set1var1=sub1, set1var2=sub2,...... }
{ set2var1=sub1, set2var2=sub2,...... }
{ set3var1=sub1, set3var2=sub2,...... }
```

- or -

Version-2

```
pattern{ var1,var2,var3,....... }
{ sub1_for_set1, sub2_for_set1, sub3_for_set1, ... }
{ sub1_for_set2, sub2_for_set2, sub3_for_set2, ... }
{ sub1_for_set3, sub2_for_set3, sub3_for_set3, ... }
```

The first line (file `name.db`) specifies the record instance input file.

Each set of definitions enclosed in {} is variable substitution for the input file. The input file has each set applied to it to produce one composite file with all the completed substitutions in it. Version 1 should be obvious. In version 2, the variables are listed in the "`pattern{}`" line, which must precede the braced substitution lines. The braced substitution lines contains sets which match up with the `pattern{}` line.

6.16.1 EXAMPLE

Two simple template file examples are shown below. The examples specify the same substitutions to perform: `this=sub1` and `that=sub2` for a first set, and `this=sub3` and `that=sub4` for a second set.

```
file test.db {
   { this=sub1,that=sub2 }
   { this=sub3,that=sub4 }
}

file test.db {
   pattern{this,that}
   {sub1,sub2}
   {sub3,sub4 }
```

Assume that `test.db` is:

```
record(ai,"$(this)record") {
   field(DESC,"this = $(this)")
}
record(ai,"$(that)record") {
   field(DESC,"this = $(that)")
}
```

Using `dbLoadTemplate` with either input is the same as defining the records:

```
record(ai,"sub1record") {
   field(DESC,"this = sub1")
}
record(ai,"sub2record") {
   field(DESC,"this = sub2")
}

record(ai,"sub3record") {
   field(DESC,"this = sub3")
}
record(ai,"sub4record") {
   field(DESC,"this = sub4")
}
```

6.17 dbReadTest

`dbReadTest -Idir -Smacsub file.dbd ... file.db ...`

This utility can be used to check for correct syntax in database definition and database instance files. It just reads all the specified files

Multiple `-I,` and `-S` options can be specified. An arbitrary number of database definition and database instance files can be specified.

Chapter 7: IOC Initialization

7.1 Overview - Environments requiring a main program

If a main program is required (most likely on all environments except vxWorks and RTEMS), then initialization is performed by statements residing in startup scripts passed to ioccrf. An example main program is:

```
int main(int argc,char *argv[])
{
    if(argc>=2) {
        ioccrf(argv[1]);
    }
    ioccrf(NULL);
    return(0);
}
```

The first call to `ioccrf` executes the commands from the filename passed as an argument to the program containing main. The second call to `ioccrf` puts `ioccrf` into interactive mode. This allows the user to issue the commands described in chapter "IOC Test Facilities" as well as some commands like show and help.

The file passed as the argument to the command contains statements like:

```
dbLoadDatabase("../../dbd/<appname>App.dbd",0,0)
registerRecordDeviceDriver(pdbbase)
dbLoadRecords("../../db/<file>.db")
iocInit()
```

7.2 Overview - vxWorks

After vxWorks is loaded at IOC boot time, commands like the following, normally in the vxWorks startup command file, are issued to load and initialize the control system software:

```
# For many board support packages the following must be added
#cd <full path to target bin directory>
< cdCommands
#The following sets timezone properly on vxWorks
#YOU MUST enter correct values for
#  name,minutesWest,start daylight,end daylight
#putenv("TIMEZONE=<name>::<minutesWest>:<start daylight>:<end daylight>")
#For example
#putenv("TIMEZONE=US/Central::360:040102:100102")

cd topbin
ld  <  <appname>Library.munch
threadInit()
```

```
cd top
dbLoadDatabase(”dbd/<appname>App.dbd”)
registerRecordDeviceDriver(pdbbase)
dbLoadRecords("db/<file>.db")
   . . .
iocInit()
```

`cdCommands` defines vxWorks global variables that allow vxWorks cd commands for convient locations. For example in one of my test areas the following `cdCommands` file appears:

```
startup = "/home/phoebus6/MRK/epics/example/R3-14/iocBoot/iocexample"
appbin = "/home/phoebus6/MRK/epics/example/R3-14//bin/vxWorks-68040"
top = "/home/phoebus6/MRK/epics/example/R3-14"
topbin = "/home/phoebus6/MRK/epics/example/R3-14/bin/vxWorks-68040"
```

NOTE: This file is automatically generated via make rules.

The `ld` command loads the core EPICS softwar, record/device,/driver support, and any other application specific modules.

The `dbLoadDatabase` command loads database definition files describing the record/device/driver support used by the application..

The `dbLoadRecords` commands load record instance definitions.

iocInit initializes the various epics components.

7.3 Overview - RTEMS

RTEMS applications read commands from a startup script in <tftpbase>/epics/<target_hostname>/st.cmd. In many cases this script can be the same as the one used with vxWorks. The RTEMS shell does not provide commands such as cd, ld, or assignment to variables (e.g. startup, appbin, etc.) but this does not present a major problem since the db and dbd files have been copied to standard locations and the entire application has been statically linked before execution begins.

7.4 iocInit

`iocInit` performs the following functions:

7.4.1 coreRelease

Prints a messages showing which version of iocCore is being loaded.

7.4.2 taskwdInit

start the task watchdog task. This task accepts requests to watch other tasks. It runs periodically and checks to see if any of the tasks is suspended. If so it issues an error message. It can also optionally invoke a callback routine

7.4.3 callbackInit

Start the general purpose callback tasks. Three tasks are started with the only difference being scheduling priority.

7.4.4 dbCaLinkInit

Calls `dbCaLinkInit`. The initializes the task that handles database channel access links.

7.4.5 initDrvSup

`InitDrvSup` locates each device driver entry table and calls the init routine of each driver.

7.4.6 initRecSup

`InitRecSup` locates each record support entry table and calls the init routine.

7.4.7 initDevSup

`InitDevSup` locates each device support entry table and calls the init routine with an argument specifying that this is the initial call.

7.4.8 initDatabase

`InitDatabase` makes three passes over the database performing the following functions:

- Pass 1: Initializes following fields: `rset`, `dset`, `mlis`. Calls record support `init_record` (First pass)
- Pass 2: Convert each `PV_LINK` to `DB_LINK or CA_LINK`
- Pass 3: Calls record support `init_record` (second pass)

After the database is initialized `dbLockInitRecords` is called. It creates the lock sets.

7.4.9 finishDevSup

`InitDevSup` locates each device support entry table and calls the init routine with an argument specifying that this is the finish call.

7.4.10 scanInit

The periodic, event, and io event scanners are initialized and started.

7.4.11 interruptAccept

A global variable "`interruptAccept`" is set `TRUE`. Until this time no request should be made to process records and all interrupts should be ignored.

7.4.12 initialProcess

`dbProcess` is called for all records that have `PINI TRUE`.

7.4.13 rsrv_init

The Channel Access servers are started

7.5 Changing iocCore fixed limits

The following commands can be issued after iocCore is loaded to change iocCore fixed limits. The commands should be given before any dbLoad commands.

```
callbackSetQueueSize(size)
dbPvdTableSize(size)
scanOnceSetQueueSize(size)
errlogInit(buffersize)
```

NOTE: If a main program is required, these routines should be called immediately after threadInit.

7.5.1 callbackSetQueueSize

Requests for the general putpose callback tasks are placed in a ring buffer. This command can be used to set the size for the ring buffers. The default is 2000. A message is issued when a ring buffer overflows. It should rarely be necessary to override this default. Normally the ring buffer overflow messages appear when a callback task fails.

7.5.2 dbPvdTableSize

Record instance names are stored in a process variable directory, which is a hash table. The default number of hash entries is 512. `dbPvdTableSize` can be called to change the size. It must be called before any `dbLoad` commands and must be a power of 2 between 256 and 65536. If an IOC contains very large databases (several thousand) then a larger hash table size speeds up searches for records.

7.5.3 scanOnceSetQueueSize

scanOnce requests are placed in a ring buffer. This command can be used to set the size for the ring buffer. The default is 1000. t should rarely be necessary to override this default. Normally the ring buffer overflow messages appear when the scanOnce task fails.

7.5.4 errlogInit

Thus overrides the default buffer size for the errlog message queue. The default is1280 bytes.

7.6 TSconfigure

NOTE: This is only supported on vxWorks.

EPICS supports several methods for an IOC to obtain time so that accurate time stamps can be generated. The default is to obtain NTP time stamps from another computer. The following can be used to change the defaults. If ant argument is given the value 0 then the default is applied.

`TSConfigure(master,sync_rate,clock_rate,master_port,slave_port)`

- **master**: 1=master timing IOC, 0=slave timing, default is slave.
- **sync_rate**: The clock sync rate in seconds. This rate tells how often the synchronous time stamp support software will confirm that an IOC clock is synchronized. The default is 10 seconds.
- **clock_rate**: The frequency in hertz of the clock, the default is 1000Hz for the event system. The value will be set to the IOC's internal clock rate when soft timing is used.
- **master_port**: UDP port for master. The default is 18233
- **slave_port**: UDP port for slave.
- **time_out:** UDP information request time out in milliseconds, if zero is entered here, the default will be used which is 250ms.
- **type**: 0=normal operation, 1=force soft timing type

See "Synchronous Time Stamp Support", by Jim Kowalkowski for details. Note that the default is to be a slave. If no master is found the slave will obtain a starting time from Unix.

7.7 initHooks

NOTE: starting with release 3.13.0beta12 initHooks was changed drastically (thanks to Benjamin Franksen at BESY). Old initHooks.c functions will still work but users are encouraged to switch to the new method.

The inithooks facility allows application specific functions to be called at various states during ioc initialization. The states are defined in initHooks.h, which contains the following definitions:

```
typedef enum {
    initHookAtBeginning,
    initHookAfterCallbackInit,
    initHookAfterCaLinkInit,
    initHookAfterInitDrvSup,
    initHookAfterInitRecSup,
    initHookAfterInitDevSup,
    initHookAfterInitDatabase,
    initHookAfterFinishDevSup,
    initHookAfterScanInit,
    initHookAfterInterruptAccept,
    initHookAfterInitialProcess,
    initHookAtEnd
}initHookState;

typedef void (*initHookFunction)(initHookState state);
int initHookRegister(initHookFunction func);
```

Any new functions that are registered before iocInit reaches the desired state will be called when iocInit reaches that state. The following is skeleton code to use the facility:

```
static initHookFunction myHookFunction;

int myHookInit(void)
{
  return(initHookRegister(myHookFunction));
}

static void myHookFunction(initHookState state)
{
  switch(state) {
    case initHookAfterInitRecSup:
      ...
      break;
    case initHookAfterInterruptAccept:
      ...
      break;
    default:
      break;
  }
}
```

An arbitrary number of functions can be registered.

7.8 Environment Variables

The following environment variables are used by iocCore:

```
EPICS_CA_ADDR_LIST
EPICS_CA_CONN_TMO
EPICS_CA_BEACON_PERIOD
EPICS_CA_AUTO_ADDR_LIST
EPICS_CA_REPEATER_PORT
EPICS_CA_SERVER_PORT
EPICS_TS_NTP_INET
EPICS_IOC_LOG_PORT
EPICS_IOC_LOG_INET
```

On vxWorks these variables can be overridden via the putenv function. For example:

```
    putenv("EPICS_CA_CONN_TMO=10")
```

Any putenv commands should be issued after iocCore is loaded and before any dbLoad commands.

7.9 Initialize Logging

Initialize the logging system. See chapter "IOC Error Logging" for details. For initiliization just realise that the following can be used if you want to use a private host log file.

```
putenv("EPICS_IOC_LOG_PORT=<port>")
putenv("EPICS_IOC_LOG_INET=<inet addr>")
```

These command must be given immediately after iocCore is loaded.

If you want to disable logging to the system wide log file just give the command.

```
iocLogDisable = 1
```

This must be given after iocCore is loaded and before any dbLoad commands.

Chapter 8: Access Security

8.1 Overview

This chapter describes access security. i.e. the system that limits access to IOC databases. It consists of the following sections:

1. Overview - This section
2. Quick start - A summary of the steps necessary to start access security.
3. User's Guide - This explains what access security is and how to use it.
4. Design Summary - Functional Requirements and Design Overview.
5. Application Programmer's Interface
6. Database Access Security - Access Security features for EPICS IOC databases.
7. Channel Access Security - Access Security features in Channel Access
8. Implementation Overview

The requirements for access security were generated at ANL/APS in 1992. The requirements document is:

EPICS: Channel Access Security - Functional Requirements, Ned D. Arnold, 03/-9/92.

This document is available via the EPICS WWW documentation

8.2 Quick Start

In order to "turn on" access security for a particular IOC the following must be done:

- Create the access security file.
- IOC databases may have to be modified
  - Record instances may have to have values assigned to field ASG. If ASG is null the record is in group DEFAULT.
  - Access security files can be reloaded after iocInit via a subroutine record with `asSubInit` and `asSubProcess` as the associated subroutines. Writing the value 1 to this record will cause a reload.
- The vxWorks startup file must contain the following command before iocInit.
  `asSetFilename("accessSecurityFile")`
  The following is an optional command.
  `asSetSubstitutions("var1=sub1,var2=sub2,...”))`

The following rules decide if access security is turned on for an IOC:

- If asSetFilename is not executed before iocInit, access security will NEVER be started..
- If asSetFile is given and any error occurs while first initializing access security, then ALL access to that ioc is denied.

- If after successfully starting access security, an attempt is made to restart and an error occurs then the previous access security configuration is maintained.

8.3 User's Guide

8.3.1 Features

Access security protects IOC databases from unauthorized Channel Access Clients. Access security is based on the following:

- **Who**: Userid of the channel access client.
- **Where**: Hostid where the user is logged on. This is the host on which the channel access client exists. Thus no attempt is made to see if a user is local or is remotely logged on to the host.
- **What**: Individual fields of records are protected. Each record has a field containing the Access Security Group (ASG) to which the record belongs. Each field has an access security level, which must be 0 or 1.The security level is defined in the ascii record definition file. Thus the access security level for a field is the same for all record instances of a record type.
- **When**: Access rules can contain input links and calculations similar to the calculation record.

8.3.2 Limitations

An IOC database can be accessed only via Channel Access or via the vxWorks shell. It is assumed that access to the local IOC console is protected via physical security and `telnet`/`rlogin` access protected via normal Unix and physical security.

No attempt has been made to protect against the sophisticated saboteur. Unix security must be used to limit access to the subnet on which the iocs reside.

8.3.3 Definitions

This document uses the following terms:

- **ASL**: Access Security Level (Called access level in Req Doc)
- **ASG**: Access Security Group (Called PV Group in Req Doc)
- **UAG**: User Access Group
- **HAG**: Host Access Group

8.3.4 Access Security Configuration File

This section describes the format of a file containing definitions of the user access groups, host access groups, and access security groups. An IOC creates an access configuration database by reading an access configuration file (the extension `.acf` is recommended). Lets first give a simple example and then a complete description of the syntax.

8.3.4.1 Simple Example

```
UAG(uag) {user1,user2}
HAG(hag) {host1,host2}
```

```
ASG(DEFAULT) {
   RULE(1,READ)
   RULE(1,WRITE) {
      UAG(uag)
      HAG(hag)
   }
}
```

These rules provide read access to anyone located anywhere and write access to `user1` and `user2` if they are located at `host1` or `host2`.

8.3.4.2 Syntax Definition

In the following description:

[ ]Lists optional elements
|Separator for alternatives
...Means that an arbitrary number of definitions may be given.
Any line beginning with # is a comment

```
UAG(<name>) [{ <user> [, <user> ...] }]
...
HAG(<name>) [{ <host> [, <host> ...] }]
...
ASG(<name>) [{
   [INP<index>(<pvname>)
   ...]
   RULE(<level>,NONE | READ | WRITE [, NOTRAPWRITE | TRAPWRITE]) {
      [UAG(<name> [,<name> ...])]
      [HAG(<name> [,<name> ...])]
      CALC("<calculation>")
   }
   ...
}]
...
```

8.3.4.3 Discussion

- **UAG**: User Access Group. This is a list of userids. The list may be empty. The same userid can appear in multiple UAGs. For iocs the userid is taken from the user field of the boot parameters.
- **HAG**: Host Access Group. This is a list of host names. It may be empty. The same host name can appear in multiple HAGs. For iocs the host name is taken from the target name of the boot parameters.
- **ASG**: An access security group. The group "`DEFAULT`" is a special case. If a member specifies a null group or a group which has no ASG definition then the member is assigned to the group "`DEFAULT`".
  - **INP<index>** Index must have one of the values "`A`" to "`L`". These are just like the `INP` fields of a calculation record. It is necessary to define `INP` fields if a `CALC` field is defined in any `RULE` for the ASG.
  - **RULE** This defines access permissions. <`level`> must be 0 or 1. Permission for a level 1 field implies permission for level 0 fields. The permissions are `NONE`, `READ`, and `WRITE`. `WRITE` permission implies `READ` permission. The standard EPICS record types have all fields set to level 1 except for `VAL`, `CMD` (command), and `RES` (reset). An optional argument specifies if writes should be trapped. See the section below on trapping Channel Access writes for how this is used. If not given the default is NOTRAPWRITE.

- **UAG** specifies a list of user access groups that can have the access privilege. If UAG is not defined then all users are allowed.
- **HAG** specifies a list of host access groups that have the access privilege. If HAG is not defined then all hosts are allowed.
- **CALC** is just like the `CALC` field of a calculation record except that the result must evaluate to TRUE or `FALSE`. If the calculation results in (0,1) meaning (`FALSE`,`TRUE`) then the rule (doesn't apply, does apply) . The actual test is .99 < `result` < 1.01.

Each IOC record contains a field `ASG`, which specifies the name of the ASG to which the record belongs. If this field is null or specifies a group which is not defined in the access security file then the record is placed in group "`DEFAULT`".

The access privilege for a channel access client is determined as follows:

1. The ASG associated with the record is searched.
2. Each RULE is checked for the following:
   a. The field's level must be less than or equal to the level for this RULE.
   b. If UAG is defined, the user must belong to one of the specified UAGs. If UAG is not defined all users are accepted.
   c. If HAG is defined, the user's host must belong to one one of the HAGs. If HAG is not defined all hosts are accepted.
   d. If CALC is specified, the calculation must yield the value 1, i.e. TRUE. If any of the INP fields associated with this calculation are in INVALID alarm severity the calculation is considered false. The actual test for TRUE is .99 < result < 1.01.
3. The maximum access allowed by step 2 is the access chosen.

Multiple RULEs can be defined for a given ASG, even RULEs with identical levels and access permission.

8.3.5 ascheck - Check Syntax of Access Configuration File

After creating or modifying an access configuration file it can be checked for syntax errors by issuing the command:

```
ascheck -S "xxx=yyy,..." < "filename"
```

This is a Unix command. It displays errors on `stdout`. If no errors are detected it prints nothing. Only syntax errors not logic errors are detected. Thus it is still possible to get your self in trouble. The flag `-S` means a set of macro substitutions may appear. This is just like the macro substitutions for dbLoadDatabase.

8.3.6 IOC Access Security Initialization

In order to have access security turned on during IOC initialization the following command must appear in the startup file before `iocInit` is called:

```
asSetFilename("<access security file>")
```

If this command does not appear then access security will not be started by `iocInit`. If an error occurs when iocInit calls `asInit` than all access to the ioc is disabled, i.e. no channel access client will be able to access the ioc.

Access security also supports macro substitution just like `dbLoadDatabase`. The following command specifies the desired substitutions:

```
asSetSubstitutions("var1=sub1,var2=sub2,...")
```

This command must be issued before `iocInit`.

After an IOC is initialized the access security database can be changed. The preferred way is via the subroutine record described in the next section. It can also be changed by issuing the following command to the vxWorks shell:

```
asInit
```

It is also possible to reissue `asSetFilename` and/or `asSetSubstitutions` before `asInit`. If any error occurs during `asInit` the old access security configuration is maintained. It is **NOT** permissable to call `asInit` before `iocInit` is called.

Restarting access security after ioc initialization is an expensive operation and should not be used as a regular procedure.

8.3.7 Database Configuration

8.3.7.1 Access Security Group

Each database record has a field `ASG` which holds a character string. Any database configuration tool can be used to give a value to this field. If the ASG of a record is not defined or is not equal to a ASG in the configuration file then the record is placed in `DEFAULT`.

8.3.7.2 Subroutine Record Support

Two subroutines, which can be attached to a subroutine record, are available (provided with `iocCore`):

```
asSubInit
asSubProcess
```

If a record is created that attaches to these routines, it can be used to force the IOC to load a new access configuration database. To change the access configuration:

1. Modify the file specified by the last call to `asSetFilename` so that it contains the new configuration desired.
2. Write a 1 to the subroutine record `VAL` field. Note that this can be done via channel access.

The following action is taken:

3. When the value is found to be 1, `asInit` is called and the value set back to 0.
4. The record is treated as an asynchronous record. Completion occurs when the new access configuration has been initialized or a time-out occurs. If initialization fails the record is placed into alarm with a severity determined by `BRSV`.

8.3.7.3 Record Type Description

Each field of each record type has an associated access security level of `ASL0` or `ASL1`. See the chapter "Database Definition" for details.

8.3.8 Example:

Lets design a set of rules for a Linac. Assume the following:

1. Anyone can have read access to all fields at anytime.
2. Linac engineers, located in the injection control or control room, can have write access to most level 0 fields only if the Linac is not in operational mode.
3. Operators, located in the injection control or control room, can have write access to most level 0 fields anytime.
4. The operations supervisor, linac supervisor, and the application developers can have write access to all fields but must have some way of not changing something inadvertently.
5. Most records use the above rules but a few (high voltage power supplies, etc.) are placed under tighter control. These will follow rules 1 and 4 but not 2 or 3.

6. IOC channel access clients always have level 1 write privilege.

Most Linac IOC records will not have the ASG field defined and will thus be placed in ASG "DEFAULT". The following records will have an ASG defined:

- LI:OPSTATE and any other records that need tighter control have ASG="critical". One such record could be a subroutine record used to cause a new access configuration file to be loaded. LI_OPSTATE has the value (0,1) if the Linac is (not operational, operational).
- LI:lev1permit has ASG="permit". In order for the opSup, linacSup, or an appDev to have write privilege to everything this record must be set to the value 1.

The following access configuration satisfies the above rules.

```
UAG(op) {op1,op2,superguy}
UAG(opSup) {superguy}
UAG(linac) {waw,nassiri,grelick,berg,fuja,gsm}
UAG(linacSup) {gsm}
UAG(appDev) {nda,kko}
HAG(icr) {silver,phebos,gaea}
HAG(cr) {mars,hera,gold}
HAG(ioc) {ioclic1,ioclic2,ioclid1,ioclid2,ioclid3,ioclid4,ioclid5}
ASG(DEFAULT) {
   INPA(LI:OPSTATE)
   INPB(LI:lev1permit)
   RULE(0,WRITE) {
      UAG(op)
      HAG(icr,cr)
      CALC(”A=1”)
   }
   RULE(0,WRITE) {
      UAG(op,linac,appdev)
      HAG(icr,cr)
      CALC(”A=0”)
   }
   RULE(1,WRITE) {
      UAG(opSup,linacSup,appdev)
      CALC("B=1")
   }
   RULE(1,READ)
   RULE(1,WRITE) {
      HAG(ioc)
   }
}
ASG(permit) {
   RULE(0,WRITE) {
       UAG(opSup,linacSup,appDev)
   }
   RULE(1,READ)
   RULE(1,WRITE) {
      HAG(ioc)
   }
}
ASG(critical) {
   INPB(LI:lev1permit)
   RULE(1,WRITE) {
```

```
      UAG(opSup,linacSup,appdev)
      CALC("B=1")
   }
   RULE(1,READ)
   RULE(1,WRITE) {
      HAG(ioc)
   }
}
```

8.4 Design Summary

8.4.1 Summary of Functional Requirements

A brief summary of the Functional Requirements is:

1. Each field of each record type is assigned an access security level.
2. Each record instance is assigned to a unique access security group.
3. Each user is assigned to one or more user access groups.
4. Each node is assigned to a host access group.
5. For each access security group a set of access rules can be defined. Each rule specifies:
   a. Access security level
   b. READ or READ/WRITE access.
   c. An optional list of User Access Groups or * meaning anyone.
   d. An optional list of Host Access Groups or * meaning anywhere.
   e. Conditions based on values of process variables

8.4.2 Additional Requirements

8.4.2.1 Performance

Although the functional requirements doesn't mention it, a fundamental goal is performance. The design provides almost no overhead during normal database access and moderate overhead for the following: channel access client/server connection, ioc initialization, a change in value of a process variable referenced by an access calculation, and dynamically changing a records access control group. Dynamically changing the user access groups, host access groups, or the rules, however, can be a time consuming operation. This is done, however, by a low priority IOC task and thus does not impact normal ioc operation.

8.4.2.2 Generic Implementation

Access security should be implemented as a stand alone system, i.e. it should not be imbedded tightly in database or channel access.

8.4.2.3 No Access Security within an IOC

Within an IOC no access security is invoked. This means that database links and local channel access clients calls are not subject to access control. Also test routines such as dbgf should not be subject to access control.

8.4.2.4 Defaults

It must be possible to easily define default access rules.

8.4.2.5 Access Security is Optional

When an IOC is initialized, access security is optional.

8.4.3 Design Overview

The implementation provides a library of routines for accessing the security system. This library has no knowledge of channel access or IOC databases, i.e. it is generic. Database access, which is responsible for protecting an IOC database, calls library routines to add each IOC record to one of the access control groups.

Lets briefly discuss the access security system and how database access and channel access interact with it.

8.4.3.1 Configuration File

User access groups, host access groups, and access security groups are configured via an ASCII file.

8.4.3.2 Access Security Library

The access security library consists of the following groups of routines: initialization, group manipulation, client manipulation, access computation, and diagnostic. The initialization routine reads a configuration file and creates a memory resident access control database. The group manipulation routines allow members to be added and removed from access groups. The client routines provide services for clients attached to members.

8.4.3.3 IOC Database Access Security

The interface between an IOC database and the access security system.

8.4.3.4 Channel Access Security

Whenever the Channel Access broadcast server receives a `ca_search` request and finds the process variable, it calls `asAddClient`. Whenever it disconnects it calls `asRemoveClient`. Whenever it issues a get or put to the database it must call `asCheckGet` or `asCheckPut`.

Channel access is responsible for implementing the requirement of allowing the user to be changed dynamically.

8.4.4 Comments

It is likely that the access rules will be defined such that many IOCs will attach to a common process variable. As a result the IOC containing the PV will have many CA clients.

What about password protection and encryption? I maintain that this is a problem to be solved in a level above the access security described in this document. This is the issue of protecting against the sophisticated saboteur.

8.4.5 Performance and Memory Requirements

Performance has not yet been measured but during the tests to measure memory usage no noticeable change in performance during ioc initialization or during Channel Access clients connection was noticed. Unless access privilege is violated the overhead during channel access gets and puts is only an extra comparison.

In order to measure memory usage, the following test was performed:

1. A database consisting of 5000 soft analog records was created.
2. A channel access client (`caput`) was created that performs `ca_puts` on each of the 5000 channels. Each time it begins a new set of puts the value increments by 1.
3. A channel access client (`caget`) was created that has monitors on each of the 5000 channels.

The memory consumption was measured before `iocInit`, after `iocInit`, after `caput` connected to all channels, and after `caget` connected to all 5000 channels. This was done for APS release 3.11.5 (before access security) and the first version which included access security. The results were:

	R3.11.5	After
Before iocInit	4,244,520	4,860,840
After iocInit	4,995,416	5,964,904
After caput	5,449,780	6,658,868
After caget	8,372,444	9,751,796

Before the database was loaded the memory used was 1,249,692 bytes. Thus most of the memory usage before iocInit resulted from storage for records. The increase since R3.11.5 results from added fields to `dbCommon`. Fields were added for access security, synchronous time support and for the new caching put support. The other increases in memory usage result from the control blocks needed to support access control. The entire design was based on maximum performance. This resulted in increased memory usage.

8.5 Access Security Application Programmer's Interface

8.5.1 Definitions

```
typedef struct asgMember *ASMEMBERPVT;
typedef struct asgClient *ASCLIENTPVT;
typedef int (*ASINPUTFUNCPTR)(char *buf,int max_size);
typedef enum{
    asClientCOAR/*Change of access rights*/
    /*For now this is all*/
} asClientStatus;
typedef void (*ASCLIENTCALLBACK)(ASCLIENTPVT,asClientStatus);
```

8.5.2 Initialization

```
long asInitialize(ASINPUTFUNPTR inputFunction)
long asInitFile(const char *filename,const char *substitutions)
long asInitFP(FILE *fp,const char *substitutions)
```

These routines read an access definition file and perform all initialization necessary. The caller must provide a routine to provide input lines for `asInitialize. asInitFile` and `asInitFP` do their own input and also perform macro substitutions.

The initilization routines can be called multiple times. If an access system already exists the old definitions are removed and the new one initialized. Existing members are placed in the new ASGs.

8.5.3 Group manipulation

8.5.3.1 add Member

```
long asAddMember(ASMEMBERPVT *ppvt, char *asgName);
```

This routine adds a new member to ASG `asgName`. The calling routine must provide storage for `ASMEMBERPVT`. Upon successful return `*ppvt` will be equal to the address of storage used by the access control system. The access system keeps an orphan list for all `asgNames` not defined in the access configuration.

The caller must provide permanent storage for `asgName`.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.3.2 remove Member

```
long asRemoveMember(ASMEMBERPVT *ppvt);
```

This routine removes a member from an access control group. If any clients are still present it returns an error status of S_asLib_clientExists without removing the member.

This routine returns S_asLib_asNotActive without doing anything if access control is not active.

8.5.3.3 get Member Pvt

```
void *asGetMemberPvt(ASMEMBERPVT pvt);
```

For each member, the access system keeps a pointer that can be used by the caller. This routine returns the value of the pointer.

This routine returns NULL if access security is not active

8.5.3.4 put Member Pvt

```
long asPutMemberPvt(ASMEMBERPVT pvt,void *userPvt);
```

This routine is used to set the pointer returned by asGetMemberPvt.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.3.5 change Group

```
long asChangeGroup(ASMEMBERPVT *ppvt, char *newAsgName);
```

This routine changes the group for an existing member. The access rights of all clients of the member are recomputed.

The caller must provide permanent storage for `newAsgName`.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.4 Client Manipulation

8.5.4.1 add Client

```
long asAddClient(ASCLIENTPVT *ppvt,ASMEMBERPVT pvt,int asl,
                     char *user,char*host);
```

This routine adds a client to an ASG member. The calling routine must provide storage for `ASCLIENTPVT`. `ASMEMBERPVT` is the value that was set by calling `asAddMember`. `asl` is the access security level.

The caller must provide permanent storage for `user` and `host`.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.4.2 change Client

```
long asChangeClient(ASCLIENTPVT ppvt,int asl,
   char *user,char*host);
```

This routine changes one or more of the values `asl`, `user`, and `host` for an existing client. Again the caller must provide permanent storage for `user` and `host`. It is permissible to use the same `user` and `host` used in the call to `asAddClient` with different values.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.4.3 remove Client

```
long asRemoveClient(ASCLIENTPVT *pvt);
```

This call removes a client.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.4.4 get Client Pvt

```
void *asGetClientPvt(ASCLIENTPVT pvt);
```

For each client, the access system keeps a pointer that can be used by the caller. This routine returns the value of the pointer.

This routine returns `NULL` if access security is not active.

8.5.4.5 put Client Pvt

```
void asPutClientPvt(ASCLIENTPVT pvt, void *userPvt);
```

This routine is used to set the pointer returned by `asGetClientPvt`.

8.5.4.6 register Callback

```
long asRegisterClientCallback(ASCLIENTPVT pvt,
   ASCLIENTCALLBACK pcallback);
```

This routine registers a callback that will be called whenever the access privilege of the client changes.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.4.7 check Get

```
long asCheckGet(ASCLIENTPVT pvt);
```

This routine, actually a macro, returns (`TRUE`,`FALSE`) if the client (has, doesn't have) get access rights.

8.5.4.8 check Put

```
long asCheckPut(ASCLIENTPVT pvt);
```

This routine, actually a macro, returns (`TRUE`,`FALSE`) if the client (has, doesn't have) put access rights

8.5.5 Access Computation

8.5.5.1 compute all Asg

```
long asComputeAllAsg(void);
```

This routine calls `asComputeAsg` for each access security group.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.5.2 compute Asg

```
long asComputeAsg(ASG *pasg);
```

This routine calculates all `CALC` entries for the `ASG` and calls `asCompute` for each client of each member of the specified access security group.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.5.3 compute access rights

```
long asCompute(ASCLIENTPVT pvt);
```

This routine computes the access rights of a client. This routine is normally called by the access library itself rather than use code.

This routine returns `S_asLib_asNotActive` without doing anything if access control is not active.

8.5.6 Diagnostic

8.5.6.1 dump

```
int asDump(void (*member)(ASMEMBERPVT),
   void (*client)(ASCLIENTPVT),int verbose);
```

This routine prints the current access security database. If verbose is 0 (`FALSE`), then only the information obtained from the access security file is printed.

If verbose is `TRUE` then additional information is printed. The value of each `INP` is displayed. The list of members belonging to each ASG and the clients belonging to each member are displayed. If member callback is specified as an argument, then it is called for each member. If client callback is specified, it is called for each access security client.

8.5.6.2 dump UAG

```
int asDumpUag(char *uagname)
```

This routine displays the specified `UAG` or if `uagname` is `NULL` each `UAG` defined in the access security database.

8.5.6.3 dump HAG

```
int asDumpHag(char *hagname)
```

This routine displays the specified `UAG` or if `uagname` is `NULL` each `UAG` defined in the access security database.

8.5.6.4 dump Rules

```
int asDumpRules(char *asgname)
```

This routine displays the rules for the specified ASG or if asgname is NULL the rules for each ASG defined in the access security database.

8.5.6.5 dump member

```
int asDumpMem(char *asgname,
   void (*memcallback)(ASMEMBERPVT),int clients)
```

This routine displays the member and, if clients is TRUE, client information for the specified ASG or if asgname is NULL the member and client information for each ASG defined in the access security database. It also calls memcallback for each member if this argument is not NULL.

8.5.6.6 dump hash table

```
int asDumpHash(void)
```

This shows the contents of the hash table used to locate UAGs and HAGs,

8.6 Database Access Security

8.6.1 Access Level definition

The definition of access level means that a level is defined for each field of each record type.

1. Structure fldDes (dbBase.h), which describes the attributes of each field, contains a field access_security _level. In addition definitions exist for the symbols: ASL0 and ASL1.
2. Each field description in a record description contains a field with the value ASLx.

The meanings of the Access Security Level definitions are as follows:

- ASL0Assigned to fields used during normal operation
- ASL1Assigned to fields that may be sensitive to change. Permission to access this level implies permission for ASL0.

Most record types assign ASL as follows: The fields VAL, RES (Reset), and CMD use the value ASL0. All other fields use ASL1.

8.6.2 Access Security Group definition

dbCommon contains the fields ASG and ASP. ASG (Access Security Group) is a character string. The value can be assigned via a database configuration tool or else a utility could be provided to assign values during ioc initialization. ASP is an access security private field. It contains the address of an ASGMEMBER.

8.6.3 Access Client Definition

Struct dbAddr contains a field asPvt, which contains the address of an ASGCLIENT. This definition is also added to struct db_addr so that old database access also supports access security.

8.6.4 Database Access Library

Two files `asDbLib.c` and `asCa.c` implement the interface between IOC databases and access control. It contains the following routines:

8.6.4.1 Initialization

```
int asSetFilename(char *acf)
```

Calling this routine sets the filename of an access configuration file. The next call to `asInit` uses this file. This routine must be called before `iocInit`otherwise access configuration is disabled. Is access security is disabled during iocInit it will never be turned on.

```
int asSetSubstitutions(char *substitutions)
```

This routine specifies macro substitutions.

```
int asInit()
int asInitAsyn(ASDBCALLBACK *pcallback)
```

This routines call `asInitialize`. If the current access configuration file, as specified by `asSetFilename`, is `NULL` then the routine just returns, otherwise the configuration file is used to create the access configuration database.

This routine is called by `iocInit`. `asInit` can also be called at any time to change the access configuration information.

`asInitAsyn` spawns a task `asInitTask` to perform the initialization. This allows `asInitAsyn` to be called from a subroutine called by the process entry of a subroutine record. `asInitTask` calls `taskwdInsert` so that if it suspends for some reason `taskwd` can detect the failure. After initialization all records in the database are made members of the appropriate access control group.

If the caller provides an `ASDBCALLBACK` then when either initialization completes or `taskwd` detects a failure the users callback routine is called via one of the standard callback tasks.

`asInitAsyn` will return a value of `-1` if access initialization is already active. It returns 0 if `asInitTask` is successfully spawned.

8.6.4.2 Routines used by Channel Access Server

```
int asDbGetAsl(void *paddr)
```

Get Access Security level for the field referenced by a database access structure. The argument is defined as a `void*` so that both old and new database access can be used.

```
void * asDbGetMemberPvt(void *paddr)
```

Get `ASMEMBERPVT` for the field referenced by a database access structure. The argument is defined as a `void*` so that both old and new database access can be used.

8.6.4.3 Routine to test asAddClient

```
int astac(char *pname,char *user,char *host)
```

This is a routine to test `asAddClient`. It simulates the calls that are made by Channel Access.

8.6.4.4 Subroutines attached to a subroutine record

These routines are provided so that a channel access client can force an ioc to load a new access configuration database.

```
long asSubInit(struct subRecord *prec,int pass)
long asSubProcess(struct subRecord *prec)
```

These are routines that can be attached to a subroutine record. Whenever a 1 is written to the record, `asSubProcess` calls `asInit`. If `asInit` returns success, it returns with asynchronously. When `asInitTask` calls the completion routine supplied by `asSubProcess`, the return status is used to place the record in alarm.

8.6.4.5 Diagnostic Routines

These routines provide interfaces to the `asDump` routines described in the previous chapter. They do NOT lock before calling the associated routine. Thus they may fail if the access security configuration is changing while they are running. However the danger of the user accidently aborting a command and leaving the access security system locked is considered a risk that should be avoided.

`asdbdump(void)`

This routine calls `asDump` with a member callback and with verbose `TRUE`.

```
aspuag(char *uagname)
```

This routine calls `asDumpUag`.

```
asphag(char *hagname)
```

This routine calls `asDumpHag`.

```
asprules(char *asgname)
```

This routine calls `asDumpRules`.

```
aspmem(char *asgname,int clients)
```

This routine calls `asDumpMem`.

8.7 Channel Access Security

EPICS Access Security is designed to protect Input Output Controllers (IOCs) from unauthorized access via the Channel Access (CA) network transparent communication software system. This chapter describes the interaction between the CA server and the Access Security system. It also briefly describes how the current access rights state is communicated to clients of the EPICS control system via the CA communication system and the CA client interface.

8.7.1 CA Server Interfaces to the Access Security System

The CA server calls `asAddClient()` and `asRegisterClientCallback()` for each of the channels that a client connects to the server. The routine `asRemoveClient()` is called whenever the client clears (removes) a channel or when the client disconnects.

The server maintains storage for the clients host and user names. The initial value of these strings are supplied to the server when the client connects and can be updated at any time by the client. When these strings change then `asChangeClient()` is called for each of the channels maintained by the server for the client.

The server checks for read access when processing gets and for write access when processing puts. If access is denied then an exception message is sent to the client.

The server checks for read access when processing requests to register an event callback (monitor) for the client. If there is read access the server always sends an initial update indicating the current value. If there isn't read access the server sends one update indicating no read access and disables subsequent updates.

The server receives asynchronous notification of access rights change via the callback registered with `asRegisterClientCallback()`. When a channel's access rights change the server communicates the current state to the client library. If read access to a channel is lost and there are events (monitors) registered on the channel then the server sends an update to the client for each of them indicating no access and disables future updates for each event. If read access is reestablished to a channel and there are events (monitors) registered on the channel then the server re-enables updates and sends an initial update message to the client for each of them.

8.7.2 Client Interfaces

Additional details on the channel access client side callable interfaces to access security can be obtained from the "Channel Access Reference Manual".

The client library stores and maintains the current state of the access rights for each channel that it has established. The client library receives asynchronous updates of the current access rights state from the server. It uses this state to check for read access when processing gets and for write access when processing puts. If a program issues a channel access request that is inconsistent with the client library's current knowledge of the access rights state then access is denied and an error code is returned to the application. The current access rights state as known by the client library can be tested by an applications program with the C macros `ca_read_access()` and `ca_write_access()`.

An application program can also receive asynchronous notification of changes to the access rights state by registering a function to be called back when the client library updates its storage of the access rights state. The application's call back function is installed for this purpose by calling `ca_replace_access_rights_event()`.

If the access rights state changes in the server after a request is queued in the client library but before the request is processed by the server then it is possible that the request will fail in the server. Under these circumstances then an exception will be raised in the client.

The server always sends one update to the client when the event (monitor) is initially registered. If there isn't read access then the status in the arguments to the application program's event call back function indicates no read access and the value in the arguments to the clients event call back is set to zero. If the read access right changes after the event is initially registered then another update is supplied to the application programs call back function.

8.8 Trapping Channel Access Writes

Access security provides a facility asTrapWrite that can trap write requests and pass them to any facility that registers a listener. In order to use this facility three things are necessary:

1. The facility, e.g. the channel access server, using access security must make two calls: `asTrapWriteBefore` and `asTrapWriteAfter`. These are described in asLib.h. The Channel access server on the ioc makes these calls.
2. asTrapWrite gets called by `asTrapWriteBefore` and `asTrapWriteAfter`. asTrapWrite uses the `TRAPWRITE` option specified with the RULEs given in the access configuration file to decide if listeners should be called. asTrapWrite also includes a routine `asTrapWriteRegisterListener`.
3. Some facility not included with access security must call asTrapWriteRegisterListener. If nothing calls `asTrapWriteRegisterListener`, asTrapWrite does nothing.

The purpose of this section is to describe how a facility can use `asTrapWrite.h`, which has the description:

```
typedef struct asTrapWriteMessage {
    char *userid;
    char *hostid;
    void *serverSpecific;
    void *userPvt;
} asTrapWriteMessage;


typedef void *asTrapWriteId;
typedef void(*asTrapWriteListener)(asTrapWriteMessage *pmessage,int after);

asTrapWriteId asTrapWriteRegisterListener(asTrapWriteListener func);
void asTrapWriteUnregisterListener(asTrapWriteId id);
```

After a facility calls `asTrapWriteRegisterListener` it's `asTrapWriteListener` will get called before and after each write with an associated RULE that has the option LOGWRITE set.

`asTrapWriteRegisterListener` is passed the address of a `asTrapWriteMessage`. This message contains thye following fields:

- `userid` - Userid of whoever originated the request.
- `hostid` - Hostid of whoever originated the request.
- `serverSpecific` - The meaning of this field is server specific. The listener MUST know what type of server is supplying the messages.
- `userPvt` - This field is for use by the `asTrapWriteListener`. When the listener is called before the write, `userPvt` has the value 0. The listener can give it any value it desires and `userPvt` will have have the same value when the listener gets called after the write.

asTrapWriteListener delays the associated server thread so it must not do anything that causes to to block.

The IOC Channel Acess Server makes the calls to `asTrapWriteBefore` and `asTrapWriteAfter`. `ServerSpecific` is the dbAddr describing the database location.

8.9 Access Control: Implementation Overview

This chapter provides a few aids for reading the access security code. Include file `asLib.h` describes the control blocks used by the access security library.

8.9.1 Implementation Overview

The following files form the access security system:

- **asLib.h** Definitions for the portion of access security that is independent of IOC databases.
- **asDbLib.h** Definitions for access routines that interface to an IOC database.
- a**sLib_lex.l** `Lex` and `Yacc` (actually EPICS `flex` and `antelope`) are used to parse the access configuration file. This is the `lex` input file.
- **asLib.y** This is the `yacc` input file. Note that it includes `asLibRoutines.c`, which do most of the work.
- **asLibRoutines.c** These are the routines that implement access security. This code has no knowledge of the database or channel access. It is a general purpose access security implementation.
- **asDbLib.c** This contains the code for interfacing access security to the IOC database.

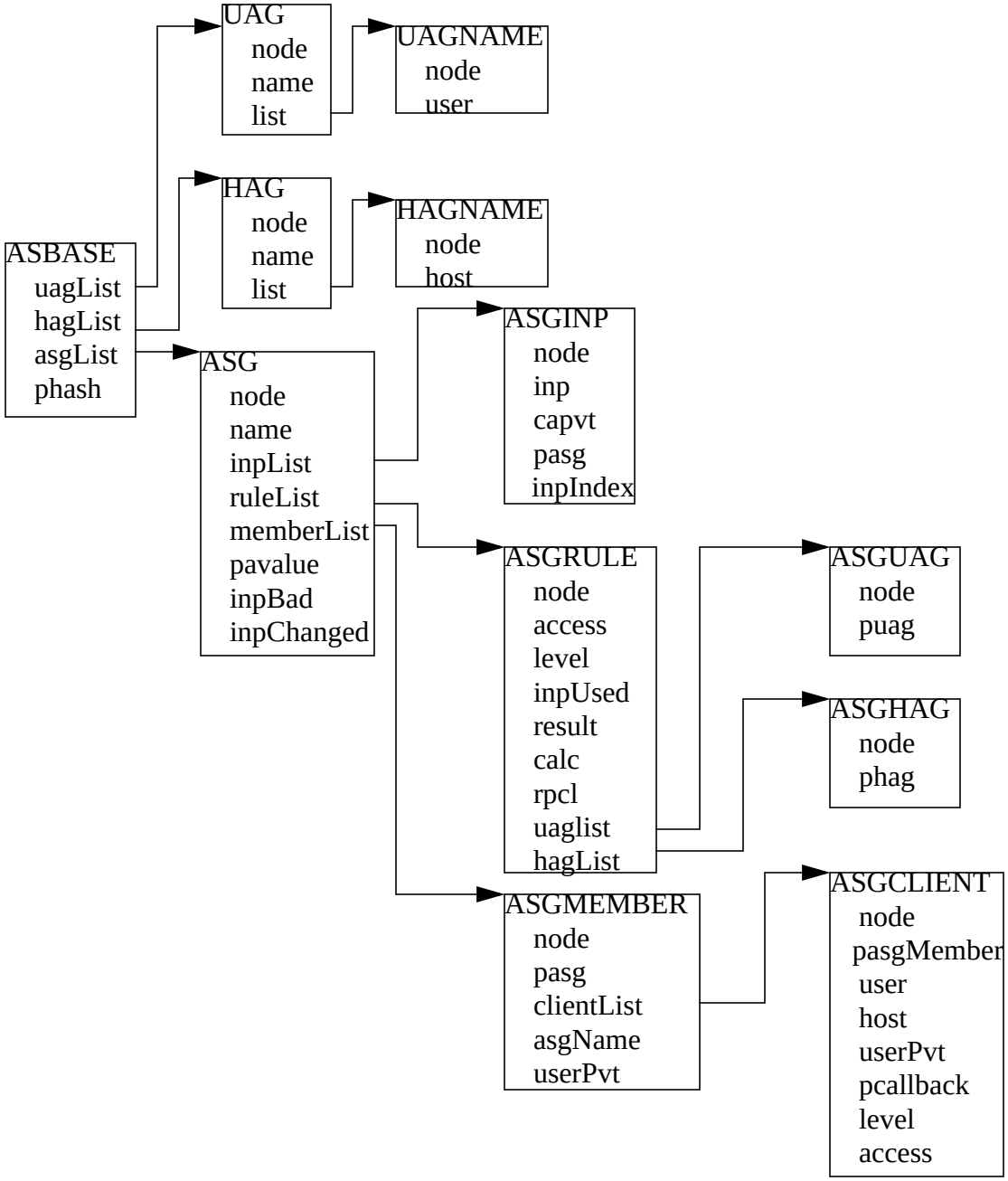
- **asCa.c** This code contains the channel access client code that implements the `INP` and `CALC` definitions in an access security database.
- **ascheck.c** The Unix program which performs a syntax check on a configuration file.

8.9.2 Locking

Because it is possible for multiple tasks to simultaneously modify the access security database it is necessary to provide locking. Rather than try to provide low level locking, the entire access security database is locked during critical operations. The only things this should hold up are access initialization, CA searches, CA clears, and diagnostic routines. It should NEVER cause record processing to wait. In addition CA gets and puts should never be delayed. One exception exists. If the ASG field of a record is changed then `asChangeGroup` is called which locks.

All operations invoked from outside the access security library that cause changes to the internal structures of the access security database.routines lock.

8.10 Structures



Chapter 9: IOC Test Facilities

9.1 Overview

This chapter describes a number of IOC test routines that are of interest to both application developers and system developers. All routines can be executed from the vxWorks shell. The parentheses are optional, but the arguments must be separated by commas. All character string arguments must be enclosed in “”.

The user should also be aware of the field `TPRO`, which is present in every database record. If it is set `TRUE` then a message is printed each time its record is processed and a message is printed for each record processed as a result of it being processed.

9.2 Database List, Get, Put

9.2.1 dbl

Database List:

```
dbl(“<record type>”,”<filename>”,"<field list>")
```

Examples

```
dbl
dbl(“ai”,0,0)
```

This command prints the names of records in the run time database. If `<record type>` is not specified, all records are listed. If `<record type>` is specified, then only the names of the records of that type are listed.

If `<filename>` is specified the output is written to the specified file (if the file already exists it is overwritten). If this argument is 0 then the output is sent to `stdout`.

If `<field list>` is given then the values of the fields specified are also printed.

9.2.2 dbgrep

List Record Names That Match a Pattern:

```
dbgrep(“<pattern>”)
```

Examples

```
dbgrep(“S0*”)
dbgrep(“*gpibAi*”)
```

Lists all record names that match a pattern. The pattern can contain any characters that are legal in record names as well as “*”, which matches 0 or more characters.

9.2.3 dba

Database Address:

```
dba("<record_name.field_name>")
```

Example

```
dba("aitest")
dba("aitest.VAL")
```

This command calls `dbNameToAddr` and then prints the value of each field in the `dbAddr` structure describing the field. If the field name is not specified then `VAL` is assumed (the two examples above are equivalent).

9.2.4 dbgf

Get Field:

```
dbgf("<record_name.field_name>")
```

Example:

```
dbgf("aitest")
dbgf)"aitest.VAL")
```

This performs a `dbNameToAddr` and then a `dbGetField`. It prints the field type and value. If the field name is not specified then `VAL` is assumed (the two examples above are equivalent).

9.2.5 dbpf

Put Field:

```
dbpf("<record_name.field_name>","<value>")
```

Example:

```
dbpf("aitest","5.0")
```

This command performs a `dbNameToAddr` followed by a `dbPutField` and `dbgf`. If `<field_name>` is not specified `VAL` is assumed.

9.2.6 dbpr

Print Record:

```
dbpr("<record_name>",<interest level>)
```

Example

```
dbpr("aitest",2)
```

This command prints all fields of the specified record up to and including those with the indicated interest level. Interest level has one of the following values:

- **0**: Fields of interest to an Application developer and that can be changed as a result of record processing.
- **1**: Fields of interest to an Application developer and that do not change during record processing.
- **2**: Fields of major interest to a System developer.
- **3**: Fields of minor interest to a System developer.

- **4**: Fields of no interest.

9.2.7 dbtr

Test Record:

```
dbtr("<record_name>")
```

This calls `dbNameToAddr`, then `dbProcess` and finally `dbpr` (interest level 3). Its purpose is to test record processing.

9.2.8 dbnr

Print number of records:

```
dbnr(<all_recordtypes>)
```

This command displays the number of records of each type and the total number of records. If `all_record_types` is 0 then only record types with record instances are displayed otherwise all record types are displayed.

9.3 Breakpoints

A breakpoint facility that allows the user to step through database processing on a per lockset basis. This facility has been constructed in such a way that the execution of all locksets other than ones with breakpoints will not be interrupted. This was done by executing the records in the context of a separate task.

The breakpoint facility records all attempts to process records in a lockset containing breakpoints. A record that is processed through external means, e.g.: a scan task, is called an entrypoint into that lockset. The `dbstat` command described below will list all detected entrypoints to a lockset, and at what rate they have been detected.

9.3.1 dbb

Set Breakpoint:

```
dbb("<record_name>")
```

Sets a breakpoint in a record. Automatically spawns the `bkptCont`, or breakpoint continuation task (one per lockset). Further record execution in this lockset is run within this task's context. This task will automatically quit if two conditions are met, all breakpoints have been removed from records within the lockset, and all breakpoints within the lockset have been continued.

9.3.2 dbd

Remove Breakpoint:

```
dbd("<record_name>")
```

Removes a breakpoint from a record.

9.3.3 dbs

Single Step:

```
dbs("<record_name>")
```

Steps through execution of records within a lockset. If this command is called without an argument, it will automatically step starting with the last detected breakpoint.

9.3.4 dbc

Continue:

```
dbc("<record_name>")
```

Continues execution until another breakpoint is found. This command may also be called without an argument.

9.3.5 dbp

Print Fields Of Suspended Record:

```
dbp("<record_name>,<interest_level>)
```

Prints out the fields of the last record whose execution was suspended.

9.3.6 dbap

Auto Print:

```
dbap("<record_name>")
```

Toggles the automatic record printing feature. If this feature is enabled for a given record, it will automatically be printed after the record is processed.

9.3.7 dbstat

Status:

```
dbstat
```

Prints out the status of all locksets that are suspended or contain breakpoints. This lists all the records with breakpoints set, what records have the autoprint feature set (by `dbap`), and what entrypoints have been detected. It also displays the vxWorks task ID of the breakpoint continuation task for the lockset. Here is an example output from this call:

```
LSet: 00009  Stopped at: so#B: 00001   T: 0x23cafac
             Entrypoint: so#C: 00001   C/S:     0.1
             Breakpoint: so(ap)
LSet: 00008#B: 00001   T: 0x22fee4c
             Breakpoint: output
```

The above indicates that two locksets contain breakpoints. One lockset is stopped at record "`so`." The other is not currently stopped, but contains a breakpoint at record "`output`." "`LSet:`" is the lockset number that is being considered. "`#B:`" is the number of breakpoints set in records within that lockset. "`T:`" is the vxWorks task ID of the continuation task. "`C:`" is the total number of calls to the entrypoint that have been detected. "`C/S:`" is the number of those calls that have been detected per second. `(ap)` indicates that the autoprint feature has been turned on for record "`so`."

9.4 Error Logging

9.4.1 eltc

Display error log messages on console:

```
eltc(int noYes)
```

This determines if error messages are displayed on vxWorks console. A value of 0 means no and any other value means yes.

9.5 Hardware Reports

9.5.1 dbior

I/O Report:

```
dbior (“<driver_name>”,<interest level>)
```

This command calls the report entry of the indicated driver. If `<driver_name>` is not specified then the report for all drivers is generated. It also calls the report entry of all device support modules. Interest level is one of the following:

- **0**: Print a short report for each module.
- **1**: Print additional information.
- **2**: Print even more info. The user may be prompted for options.

9.5.2 dbhcr

Hardware Configuration Report:

```
dbhcr("filename")
```

This command produces a report of all hardware links. To use it on the IOC, issue the command:

```
dbhcr > report
 or
dbhcr("report")
```

The report will probably not be in the sort order desired. The Unix command:

```
sort report > report.sort
```

should produce the sort order you desire.

9.6 Scan Reports

9.6.1 scanppl

Print Periodic Lists:

```
scanppl(double rate)
```

This routine prints a list of all records in the periodic scan list of the specified rate. If rate is 0.0 all period lists are shown.

9.6.2 scanpel

Print Event Lists:

```
scanpel(int event_number)
```

This routine prints a list of all records in the event scan list for the specified event nunber. If event_number is 0 all event scan lists are shown.

9.6.3 scanpiol

Print I/O Event Lists:

```
scanpiol
```

This routine prints a list of all records in the I/O event scan lists.

9.7 Time Server Report

NOTE: TSreport is implemented bt drvTS.c. It is only available on vxWorks

9.7.1 TSreport

Format:

```
TSreport
```

This routine prints out information about the Time server. This includes:

- Slave or Master
- Soft or Hardware synchronized
- Clock and Sync rates
- etc.

9.8 Access Security Commands

9.8.1 asSetSubstitutions

Format:

```
asSetSubstitutions("substitutions")
```

Specifies macro substitutions used when access security is initialized.

9.8.2 asSetFilename

Format:

```
asSetFilename(“<filename>”)
```

This command defines a new access security file.

9.8.3 asInit

Format:

```
asInit
```

This command reinitializes the access security system. It rereads the access security file in order to create the new access security database. This command is useful either because the `asSetFilename` command was used to change the file or because the file itself was modified. Note that it is also possible to reinitialize the access security via a subroutine record. See the access security document for details.

9.8.4 asdbdump

Format:

```
asdbdump
```

This provides a complete dump of the access security database.

9.8.5 aspuag

Format:

```
aspuag(“<user access group>”)
```

Print the members of the user access group. If no user access group is specified then the members of all user access groups are displayed.

9.8.6 asphag

Format:

```
asphag(“<host access group>”)
```

Print the members of the host access group. If no host access group is specified then the members of all host access groups are displayed.

9.8.7 asprules

Format:

```
asprules("<access security group>")
```

Print the rules for the specified access security group or if no group is specified for all groups.

9.8.8 aspmem

Format:

```
aspmem("<access security group>", <print clients>)
```

Print the members (records) that belong to the specified access security group, for all groups if no group is specified. If `<print clients>` is (0, 1) then Channel Access clients attached to each member (are not, are) shown.

9.9 Channel Access Reports

9.9.1 ca_channel_status

Format:

```
ca_channel_status(taskid)
```

Prints status for each channel in use by specialized vxWorks task.

9.9.2 casr

Channel Access Server Report

```
casr(<level>)
```

Level can have one of the following values:

0
: Prints server's protocol version level and a one line summary for each client attached. The summary lines contain the client's login name, client's host name, client's protocol version number, and the number of channel created within the server by the client.

1
: Level one provides all information in level 0 and adds the task id used by the server for each client, the client's IP protocol type, the file number used by the server for the client, the number of seconds elapsed since the last request was received from the client, the number of seconds elapsed since the last response was sent to the client, the number of unprocessed request bytes from the client, the number of response bytes which have not been flushed to the client, the client's IP address, the client's port number, and the client's state.

2

Level two provides all information in levels 0 and 1 and adds the number of bytes allocated by each client and a list of channel names used by each client. Level 2 also provides information about the number of bytes in the server's free memory pool, the distribution of entries in the server's resource hash table, and the list of IP addresses to which the server is sending beacons. The channel names are shown in the form:

<name>(nrw)

where
n is number of ca_add_events the client has on this channel
r is (-,R) if client (does not, does) have read access to the channel.
w is(-, W) if client (does not, does) have write access to the channel.

9.9.3 dbel

Format:

```
dbel("<record_name>")
```

This routine prints the Channel Access event list for the specified record.

9.9.4 dbcar

Database to Channel Access Report - See "Record Link Reports"

9.10 Interrupt Vectors

9.10.1 veclist

Format:

```
veclist
```

NOTE: Only available on vxWorks

Print Interrupt Vector List

9.11 EPICS

9.11.1 epicsPrtEnvParams

Format:

```
epicsPrtEnvParams
```

Print Environment Variables

9.11.2 epicsRelease

Format:

```
coreRelease
```

Print release of iocCore.

9.12 Database System Test Routines

These routines are normally only of interest to EPICS system developers NOT to Application Developers.

9.12.1 dbt

Measure Time To Process A Record:

```
dbt("<record_name")
```

Times the execution of 100 successive processings of record `record_name`. Note that process passive and forward links within this record may incur the processing of other records in its lockset. This function is a wrapper around the VxWorks `timexN()` function, and directly displays its output. Therefore one must divide the result by 100 to get the execution time for one processing of `record_name`.

9.12.2 dbtgf

Test Get Field:

```
dbtgf("<record_name.field_name>")
```

Example:

```
dbtgf("aitest")
dbtgf)"aitest.VAL")
```

This performs a `dbNameToAddr` and then calls `dbGetField` with all possible request types and options. It prints the results of each call. This routine is of most interest to system developers for testing database access.

9.12.3 dbtpf

Test Put Field:

```
dbtpf("<record_name.field_name>","<value>")
```

Example:

```
dbtpf("aitest","5.0")
```

This command performs a `dbNameToAddr`, then calls `dbPutField,` followed by `dbgf` for each possible request type. This routine is of interest to system developers for testing database access.

9.12.4 dbtpn

Test Put Notify:

```
dbtpn("<record_name.field_name>","<value>")
```

Example:

```
dbtpn("aitest","5.0")
```

This command performs a `dbNameToAddr`, then calls `dbPutNotify` and has a callback routine that prints a message when it is called. This routine is of interest to system developers for testing database access.

9.13 Record Link Reports

9.13.1 dblsr

Lock Set Report:

```
dblsr(<recordname>,<level>)
```

This command generates a report showing the lock set to which each record belongs. If `recordname` is 0 all records are shown, otherwise only records in the same lock set as `recordname` are shown.

`level` can have the following values:

0 - Show lock set information only.
1 - Show each record in the lock set.
2 - Show each record and all database links in the lock set.

9.13.2 dbcar

Database to channel access report

```
dbcar(<recordname>,<level>)
```

This command generates a report showing database channel access links. If `recordname` is 0 then information about all records is shown otherwise only information about the specified record.

`level` can have the following values:

0 - Show summary information only.
1 - Show summary and each CA link that is not connected.
2 - Show summary and status of each CA link.

9.13.3 dbhcr

Report hardware links. See "Hardware Reports".

9.14 Old Database Access Testing

These routines are of interest to EPICS system developers. They are used to test the old database access interface, which is still used by Channel Access.

9.14.1 gft

Get Field Test:

```
gft("<record_name.field_name>")
```

Example:

```
gft("aitest")
gft("aitest.VAL")
```

This performs a `db_name_to_addr` and then calls `db_get_field` with all possible request types. It prints the results of each call. This routine is of interest to system developers for testing database access.

9.14.2 pft

Put Field Test:

```
pft("<record_name.field_name>","<value>")
```

Example:

```
pft("aitest","5.0")
```

This command performs a `db_name_to_addr`, `db_put_field`, `db_get_field` and prints the result for each possible request type. This routine is of interest to system developers for testing database access.

9.14.3 tpn

Test Put Notify:

```
tpn("<record_name.field_name>","<value>")
```

Example:

```
tpn("aitest","5.0")
```

This routine tests `dbPutNotify` via the old database access interface.

9.15 Routines to dump database information

9.15.1 dbDumpPath

Dump Path:

`dbDumpPath(pdbbase)`

```
dbDumpPath(pdbbase)
```

The current path for database includes is displayed.

9.15.2 dbDumpMenu

Dump Menu:

```
dbDumpMenu(pdbbase,"<menu>")
```

```
dbDumpMenu(pdbbase,"menuScan")
```

If the second argument is 0 then all menus are displayed.

9.15.3 dbDumpRecordType

Dump Record Description:

```
dbDumpRecordType(pdbbase,"<record type>")
```

```
dbDumpRecordType(pdbbase,"ai")
```

If the second argument is 0 then all descriptions of all records are displayed.

9.15.4 dbDumpFldDes

Dump Field Description:

```
dbDumpFldDes(pdbbase,"<record type>","<field name>")
```

```
dbDumpFldDes(pdbbase,"ai","VAL")
```

If the second argument is 0 then the field descriptions of all records are displayed. If the third argument is 0 then the description of all fields are displayed.

9.15.5 dbDumpDevice

Dump Device Support:

```
dbDumpDevice(pdbbase,"<record type>")
```

```
dbDumpDevice(pdbbase,"ai")
```

If the second argument is 0 then the device support for all record types is displayed.

9.15.6 dbDumpDriver

Dump Driver Support:

```
dbDumpDriver(pdbbase)
```

```
dbDumpDriver(pdbbase)
```

9.15.7 dbDumpRecord

Dump Record Instances:

```
dbDumpRecord(pdbbase,"<record type>",level)
```

```
dbDumpRecords(pdbbase,"ai")
```

If the second argument is 0 then the record instances for all record types is displayed. The third argument determines which fields are displayed just like for the command `dbpr`.

9.15.8 dbDumpBreaktable

Dump breakpoint table

```
dbDumpBreaktable(pdbbase,name)
```

```
dbDumpBreaktable(pdbbase,"typeKdegF")
```

This command dumps a breakpoint table. If the second argument is 0 all breakpoint tables are dumped.

9.15.9 dbPvdDump

Dump the Process variable Directory:

```
dbPvdDump(pdbbase,verbose)
```

```
dbPvdDump(pdbbase,0)
```

This command shows how many records are mapped to each hash table entry of the process variable directory. If verbose is not 0 then the command also displays the names which hash to each hash table entry.

Chapter 10: IOC Error Logging

10.1 Overview

Errors detected by an IOC can be divided into classes: Errors related to a particular client and errors not attributable to a particular client. An example of the first type of error is an illegal Channel Access request. For this type of error, a status value should be passed back to the client. An example of the second type of error is a device driver detecting a hardware error. This type of error should be reported to a system wide error handler.

Dividing errors into these two classes is complicated by a number of factors.

- In many cases it is not possible for the routine detecting an error to decide which type of error occurred.
- Normally, only the routine detecting the error knows how to generate a fully descriptive error message. Thus, if a routine decides that the error belongs to a particular client and merely returns an error status value, the ability to generate a fully descriptive error message is lost.
- If a routine always generates fully descriptive error messages then a particular client could cause error message storms.
- While developing a new application the programmer normally prefers fully descriptive error messages. For a production system, however, the system wide error handler should not normally receive error messages cause by a particular client.

If used properly, the error handling facilities described in this chapter can process both types of errors.

This chapter describes the following:

- Error Message Generation Routines - Routines which pass messages to the errlog Task.
- errlog Task - A task that displays error messages on the target console and also passes the messages to all registered system wide error logger.
- status codes - EPICS status codes.
- iocLog- A system wide error logger supplied with base. It writes all messages to a system wide file.

NOTE: `recGbl` error routines are also provided. They in turn call one of the error message routines.

10.2 Error Message Routines

10.2.1 Basic Routines

```
int errlogPrintf(const char *pformat, ...);
int errlogVprintf(const char *pformat,va_list pvar);
int errlogMessage(const char *message);
void errlogFlush(void);
```

`errlogPrintf` and `errlogVprintf` are like `printf` and `vprintf` provided by the standard C library, except that the output is sent to the errlog task. Consult any book that describes the standard C library such as "The C Programming Language ANSI C Edition" by Kernighan and Ritchie.

`errlogMessage` sends message to the errlog task.

`errlogFlush` wakes up the errlog task and then waits until all messages are flushed from the queue.

10.2.2 Log with Severity

```
typedef enum {
     errlogInfo,errlogMinor,errlogMajor,errlogFatal
}errlogSevEnum;

int errlogSevPrintf(const errlogSevEnum severity,
     const char *pformat, ...);
int errlogSevVprintf(const errlogSevEnum severity,
     const char *pformat,va_list pvar);

char *errlogGetSevEnumString(const errlogSevEnum severity);

void  errlogSetSevToLog(const errlogSevEnum severity );
errlogSevEnum errlogGetSevToLog(void);
```

`errlogSevPrintf` and `errlogSevVprintf` are like `errlogPrintf` and `errlogVprintf` except that they add the severity to the beginning of the message in the form "sevr=<value>" where value is on of "info, minor, major, fatal". Also the message is suppressed if severity is less than the current severity to suppress.

`errlogGetSevEnumString` gets the string value of severity.

`errlogSetSevToLog` sets the severity to log. `errlogGetSevToLog` gets the current severity to log.

10.2.3 Status Routines

```
void errMessage(long status, char *message);

void errPrintf(long status, const char *pFileName,
     int lineno, const char *pformat, ...);
```

Routine `errMessage` (actually a macro that calls `errPrintf`) has the following format:

```
void errMessage(long  status, char  *message);
```

Where status is defined as:

- **0**: Find latest vxWorks or Unix error.
- **-1**: Don't report status.
- Other: See "Return Status Values" above.

`errMessage`, via a call to `errPrintf`, prints the message, the status symbol and string values, and the name of the task which invoked `errMessage`. It also prints the name of the source file and the line number from which the call was issued.

The calling routine is expected to pass a descriptive message to this routine. Many subsystems provide routines built on top of `errMessage` which generate descriptive messages.

An IOC global variable `errVerbose`, defined as an `external` in `errMdef.h`, specifies verbose messages. If `errVerbose` is `TRUE` then `errMessage` should be called whenever an error is detected even if it is known that the error belongs to a specific client. If `errVerbose` is `FALSE` then `errMessage` should be called only for errors that are not caused by a specific client.

Routine `errPrintf` has the following format:

```
void errPrintf(long  status, __FILE__, __LINE__,
      char  *fmtstring <arg1>, ...);
```

Where status is defined as:

- **0**: Find latest vxWorks or Unix error.
- **-1**: Don't report status.
- Other: See "Return Status Values", above.

FILE and LINE are defined as:

- __FILE__ As shown or `NULL` if the file name and line number should not be printed.
- __LINE__ As shown

The remaining arguments are just like the arguments to the C `printf` routine. `errVerbose` determines if the filename and line number are shown.

10.2.4 Obsolete Routines

```
int epicsPrintf(const char *pformat, ...);
int epicsVprintf(const char *pformat,va_list pvar);
```

These are macros that call errlogPrintf and errlogVprintf. They are provided for compatibility.

10.3 errlog Task

The error message routines can be called by any non-interrupt level code. These routines merely pass the message to the errlog Task.

Task errlog manages the messages. Messages are placed in a message queue, which is read by the errlog task. The message queue uses a fixed block of memory to hold all messages. When the message queue is full additional messages are rejected but a count of missed messages is kept. The next time the message queue empties an extra message about the missed messages is generated.

The maximum message size is 256 characters. If a message is longer, the message is truncated and a message explaining that it was truncated is appended. There is a chance that long messages corrupt memory. This only happens if client code is defective. Long messages most likely result from "%s" formats with a bad string argument.

The error message routines are partially implemented on the host. The host version just calls fprintf or vfprintf instead of using a separate task and a message queue. Thus host messages are NOT sent to a system wide error logger.

10.3.1 Add and Remove Log Listener

```
typedef void(*errlogListener) (const char *message);
void errlogAddListener(errlogListener listener,void *pPrivate);
void errlogRemoveListener(errlogListener listener);
```

These routines add/remove a callback that receives each error message. These routines are the interface to the actual system wide error handlers.

10.3.2 target console routines

```
int eltc(int yesno); /* error log to console (0 or 1) */
int errlogInit(int bufsize);
```

eltc determines if errlog task writes message to the console. During error messages storms this command can be used to suppress console messages. A argument of 0 suppresses the messages and any other value lets the message go to the console.

errlogInit can be used to initialize the error logging system with a larger buffer. The default is 1280 bytes. An extra MAX_MESSAGE_SIZE (currently 256) bytes are allocated but never used. This is a small extra protection against long error messages.

10.4 Status Codes

EPICS defined status values provide the following features:

- Whenever possible, IOC routines return a status value: (0, non-0) means (`OK`, `ERROR`).
- The include files for each IOC subsystem contain macros defining error status symbols and strings.
- Routines are provided for run time access of the error status symbols and strings.
- A global variable `errVerbose` helps code decide if error messages should be generated.

WARNING: During the fall of 1995 a series of tech-talk messages were generated concerning EPICS status values. No consensus was reached.

Whenever it makes sense, IOC routines return a long word status value encoded similar to the vxWorks error status encoding. The most significant short word indicates the subsystem module within which the error occurred. The low order short word is a subsystem status value. In order that status values do not conflict with the vxWorks error status values all subsystem numbers are greater than 500.

A file `epics/share/epicsH/errMdef.h` defines each subsystem number. For example the `define` for the database access routines is:

```
#define M_dbAccess  (501 << 16)   \
      /*Database Access Routines*/
```

Directory ”`epics/share/epicsH`” contains an `include` library for every IOC subsystem that returns standard status values. The status values are encoded with lines of the following format:

```
#define S_xxxxxxx value /*string value*/
```

For example:

```
#define S_dbAccessBadDBR (M_dbAccess|3) \
      /*Invalid Database Request*/
```

For example, when `dbGetField` detects a bad database request type, it executes the statement:

```
return(S_dbAccessBadDBR);
```

The calling routine checks the return status as follows:

```
status = dbGetField( ...);
if(status) {/* Call was not successful */ }
```

10.5 iocLog

This consists of two modules: iocLogServer and iocLogClient. The client code runs on each ioc and listens for the messages generated by the errlog system. It also reports the messages from vxWorks logMsg.

10.5.1 iocLogServer

This runs on a host. It receives messages for all enabled iocLogClients in the local area network. The messages are written to a file. Epics base provides a startup file "base/src/util/rc2.logServer", which is a shell script to start the server. Consult this script for details.

10.5.2 iocLogClient

This runs on each ioc. It is started calling:

```
iocLogInit();
```

The global variable iocLogDisable can be used to enable/disable the messages from being sent to the server. Setting this variable to (0,1) (enables,disables) the messages generation. If iocLogDisable is set to 1 immediately after iocCore is loaded then iocLogClient will not even initialize itself.

10.5.3 Initialize Logging

Initialize the logging system. This system traps all `logMsg` calls and sends a copy to a Unix file. Note that this can be disabled by issuing the command `iocLogDisable=1` before issuing `iocInit`.

The following description was supplied by Jeff Hill:

It is possible to configure EPICS so that a log of IOC error messages is stored in a circular ASCII file on a PC or UNIX workstation. Each entry in the log contains the IOC's DNS name, the date and time when the message was received by the log server, and the text of the message generated on the IOC.

All messages generated by the EPICS functions epicsPrintf() and errMessage() are placed in the log. Messages generated by the vxWorks function logMsg() are also placed in the log (logMsg() can be safely called from interrupt level). Messages generated by printf() do not end up in the log and are instead used primarily by diagnostic functions called from the vxWorks shell.

To start a log server on a UNIX or PC workstation you must first set the following environment variables and then run the executable "iocLogServer" on your PC or UNIX workstation.

EPICS_IOC_LOG_FILE_NAME
: The name and path to the log file.

EPICS_IOC_LOG_FILE_LIMIT
: The maximum size in characters for the log file (after which it becomes a circular file and writes new messages over old messages at the beginning of the file). If the value is zero then there is no limit on the size of the log file.

EPICS_IOC_LOG_FILE_COMMAND
: A shell command string used to obtain the log file path name during initialization and in response to SIGHUP. The new path name will replace any path name supplied in EPICS_IOC_LOG_FILE_NAME.
Thus, if EPICS_IOC_LOG_FILE_NAME is
"a/b/c.log" and EPICS_IOC_LOG_FILE_COMMAND returns "A/B" or "A/B/" the log server will be stored at "A/B/c.log"

If EPICS_IOC_LOG_FILE_COMMAND is empty then this behavior is disabled. This feature was donated to the collaboration by KECK, and it is used by them for switching to a new directory at a fixed time each day. This variable is currently used only by the UNIX version of the log server.

EPICS_IOC_LOG_PORT
: THE TCP/IP port used by the log server.

To configure an IOC so that its messages are placed in the log you must set the environment variable EPICS_IOC_LOG_INET to the IP address of the host that is running the log server and EPICS_IOC_LOG_PORT to the TCP/IP port used by the log server.

Defaults for all of the above parameters are specified in the files $(EPICS_BASE)/config/CONFIG_SITE_ENV and $(EPICS_BASE)/config/CONFIG_ENV.

In base/src/util there is a solaris script for starting the log server. This can be adapted for use on other host architectures.

10.5.4 Configuring a Private Log Server

In a testing environment it is desirable to use a private log server. This can be done as follows:

- Add a putenv command to your IOC startup file. For example
  ```
  ld < iocCore
  putenv("EPICS_IOC_LOG_INET=xxx.xxx.xxx.xxx")
  ```
  The inet address is for your host workstation.
- On you host start a version of the log server.

Chapter 11: Record Support

11.1 Overview

The purpose of this chapter is to describe record support in sufficient detail such that a C programmer can write new record support modules. Before attempting to write new support modules, you should carefully study a few of the existing support modules. If an existing support module is similar to the desired module most of the work will already be done.

From previous chapters, it should be clear that many things happen as a result of record processing. The details of what happens are dependent on the record type. In order to allow new record types and new device types without impacting the core IOC system, the concept of record support and device support has been created. For each record type, a record support module exists. It is responsible for all record specific details. In order to allow a record support module to be independent of device specific details, the concept of device support has been created.

A record support module consists of a standard set of routines that can be called by database access routines. This set of routines implements record specific code. Each record type can define a standard set of device support routines specific to that record type.

By far the most important record support routine is `process`, which `dbProcess` calls when it wants to process a record. This routine is responsible for the details of record processing. In many cases it calls a device support I/O routine. The next section gives an overview of what must be done in order to process a record. Next is a description of the entry tables that must be provided by record and device support modules. The remaining sections give example record and device support modules and describe some global routines useful to record support modules.

The record and device support modules are the only modules that are allowed to include the record specific include files as defined in `base/rec`. Thus they are the only routines that access record specific fields without going through database access.

11.2 Overview of Record Processing

The most important record support routine is `process`. This routine determines what record processing means. Before the record specific "`process`" routine is called, the following has already been done:

- Decision to process a record.
- Check that record is not active, i.e. `pact` must be FALSE.
- Check that the record is not disabled.

The `process` routine, together with its associated device support, is responsible for the following tasks:

- Set record active while it is being processed
- Perform I/O (with aid of device support)
- Check for record specific alarm conditions
- Raise database monitors
- Request processing of forward links

A complication of record processing is that some devices are intrinsically asynchronous. It is **NEVER** permissible to wait for a slow device to complete. Asynchronous records perform the following steps:

1. Initiate the I/O operation and set `pact TRUE`
2. Determine a method for again calling process when the operation completes
3. Return immediately without completing record processing
4. When process is called after the I/O operation complete record processing
5. Set `pact FALSE` and return

The examples given below show how this can be done.

11.3 Record Support and Device Support Entry Tables

Each record type has an associated set of record support routines. These routines are located via the data structures defined in `epics/share/epicsH/recSup.h`. The concept of record support routines isolates the `iocCore` software from the details of each record type. Thus new records can be defined and supported without affecting the IOC core software.

Each record type also has zero or more sets of device support routines. Record types without associated hardware, e.g. calculation records, normally do not have any associated device support. Record types with associated hardware normally have a device support module for each device type. The concept of device support isolates IOC core software and even record support from device specific details.

Corresponding to each record type is a set of record support routines. The set of routines is the same for every record type. These routines are located via a Record Support Entry Table (RSET), which has the following structure

```
struct rset {   /* record support entry table */
   long     number;       /* number of support routine */
   RECSUPFUN   report;       /* print report */
   RECSUPFUN   init;         /* init support */
   RECSUPFUN   init_record;  /* init record */
   RECSUPFUN   process;      /* process record */
   RECSUPFUN   special;     /* special processing */
   RECSUPFUN   get_value;   /* OBSOLETE: Just leave NULL */
   RECSUPFUN   cvt_dbaddr;   /* cvt  dbAddr */
   RECSUPFUN   get_array_info;
   RECSUPFUN   put_array_info;
   RECSUPFUN   get_units;
   RECSUPFUN   get_precision;
   RECSUPFUN   get_enum_str;   /* get string from enum */
   RECSUPFUN   get_enum_strs;   /* get all enum strings */
   RECSUPFUN   put_enum_str;   /* put enum from string */
   RECSUPFUN   get_graphic_double;
   RECSUPFUN   get_control_double;
   RECSUPFUN   get_alarm_double;
};
```

Each record support module must define its RSET. The external name must be of the form:

```
<record_type>RSET
```

Any routines not needed for the particular record type should be initialized to the value `NULL`. Look at the example below for details.

Device support routines are located via a Device Support Entry Table (DSET), which has the following structure:

```
struct dset {   /* device support entry table */
   long         number;   /* number of support routines */
   DEVSUPFUN   report;   /* print report */
   DEVSUPFUN   init;   /* init support */
   DEVSUPFUN   init_record;/* init record instance*/
   DEVSUPFUN    get_ioint_info;   /* get io interrupt info*/
   /* other functions are record dependent*/
};
```

Each device support module must define its associated DSET. The external name must be the same as the name which appears in `devSup.ascii`.

Any record support module which has associated device support must also include definitions for accessing its associated device support modules. The field"`dset`", which is located in `dbCommon`, contains the address of the DSET. It is given a value by `iocInit`.

11.4 Example Record Support Module

This section contains the skeleton of a record support package. The record type is `xxx` and the record has the following fields in addition to the `dbCommon` fields: `VAL`, `PREC`, `EGU`, `HOPR`, `LOPR`, `HIHI`, `LOLO`, `HIGH`, `LOW`, `HHSV`, `LLSV`, `HSV`, `LSV`, `HYST`, `ADEL`, `MDEL`, `LALM`, `ALST`, `MLST`. These fields will have the same meaning as they have for the `ai` record. Consult the Record Reference manual for a description.

11.4.1 Declarations

```
/* Create RSET - Record Support Entry Table*/
#define report NULL
#define initialize NULL
static long init_record();
static long process();
#define special NULL
#define get_value NULL
#define cvt_dbaddr NULL
#define get_array_info NULL
#define put_array_info NULL
static long get_units();
static long get_precision();
#define get_enum_str NULL
#define get_enum_strs NULL
#define put_enum_str NULL
static long get_graphic_double();
static long get_control_double();
static long get_alarm_double();

struct rset xxxRSET={
   RSETNUMBER,
   report,
   initialize,
   init_record,
```

```
   process,
   special,
   get_value,
   cvt_dbaddr,
   get_array_info,
   put_array_info,
   get_units,
   get_precision,
   get_enum_str,
   get_enum_strs,
   put_enum_str,
   get_graphic_double,
   get_control_double,
   get_alarm_double};

/* declarations for associated DSET */
typedef struct xxxdset { /* analog input dset */
   long   number;
   DEVSUPFUN   dev_report;
   DEVSUPFUN   init;
   DEVSUPFUN   init_record; /* returns: (1,0)=> (failure, success)*/
   DEVSUPFUN   get_ioint_info;
   DEVSUPFUN   read_xxx;
}xxxdset;

/* forward declaration for internal routines*/
static void checkAlarams(xxxRecord *pxxx);
static void monitor(xxxRecord *pxxx);
```

The above declarations define the Record Support Entry Table (RSET), a template for the associated Device Support Entry Table (DSET), and forward declarations to private routines.

The RSET must be declared with an external name of `xxxRSET`. It defines the record support routines supplied for this record type. Note that forward declarations are given for all routines supported and a `NULL` declaration for any routine not supported.

The template for the DSET is declared for use by this module.

11.4.2 init_record

```
static long init_record(void *precord, int  pass)
{
   xxxRecord*pxxx = (xxxRecord *)precord;
   xxxdset  *pdset;
   long     status;

   if(pass==0) return(0);

   if((pdset = (xxxdset *)(pxxx->dset)) == NULL) {
      recGblRecordError(S_dev_noDSET,pxxx,"xxx: init_record");
      return(S_dev_noDSET);
   }
   /* must have read_xxx function defined */
   if( (pdset->number < 5) || (pdset->read_xxx == NULL) ) {
```

```
      recGblRecordError(S_dev_missingSup,pxxx,
         ”xxx: init_record”);
      return(S_dev_missingSup);
   }
   if( pdset->init_record ) {
      if((status=(*pdset->init_record)(pxxx))) return(status);
   }
   return(0);
}
```

This routine, which is called by `iocInit` twice for each record of type `xxx`, checks to see if it has a proper set of device support routines and, if present, calls the `init_record` entry of the DSET.

During the first call to `init_record` (pass=0) only initializations relating to this record can be performed. During the second call (pass=1) initializations that may refer to other records can be performed. Note also that during the second pass, other records may refer to fields within this record. A good example of where these rules are important is a waveform record. The `VAL` field of a waveform record actually refers to an array. The waveform record support module must allocate storage for the array. If another record has a database link referring to the waveform `VAL` field then the storage must be allocated before the link is resolved. This is accomplished by having the waveform record support allocate the array during the first pass (pass=0) and having the link reference resolved during the second pass (pass=1).

11.4.3 process

```
static long process(void *precord)
{
   xxxRecord*pxxx = (xxxRecord *)precord;
   xxxdset  *pdset = (xxxdset *)pxxx->dset;
   long     status;
   unsigned char pact=pxxx->pact;

   if( (pdset==NULL) || (pdset->read_xxx==NULL) ) {
      /* leave pact true so that dbProcess doesnt call again*/
      pxxx->pact=TRUE;
      recGblRecordError(S_dev_missingSup,pxxx,”read_xxx”);
      return(S_dev_missingSup);
   }

   /* pact must not be set true until read_xxx completes*/
   status=(*pdset->read_xxx)(pxxx); /* read the new value */
    /* return if beginning of asynch processing*/
   if(!pact && pxxx->pact) return(0);
   pxxx->pact = TRUE;
   recGblGetTimeStamp(pxxx);

   /* check for alarms */
   alarm(pxxx);
   /* check event list */
   monitor(pxxx);
   /* process the forward scan link record */
   recGblFwdLink(pxxx);

   pxxx->pact=FALSE;
   return(status);
```

```
}
```

The record processing routines are the heart of the IOC software. The record specific process routine is called by `dbProcess` whenever it decides that a record should be processed. Process decides what record processing really means. The above is a good example of what should be done. In addition to being called by `dbProcess` the process routine may also be called by asynchronous record completion routines.

The above model supports both synchronous and asynchronous device support routines. For example, if `read_xxx` is an asynchronous routine, the following sequence of events will occur:

- `process` is called with `pact FALSE`
- `read_xxx` is called. Since `pact` is `FALSE` it starts I/O, arranges callback, and sets `pact TRUE`
- `read_xxx` returns
- because `pact` went from `FALSE` to `TRUE` process just returns
- Any new call to `dbProcess` is ignored because it finds `pact TRUE`
- Sometime later the callback occurs and `process` is called again.
- `read_xxx` is called. Since `pact` is `TRUE` it knows that it is a completion request.
- `read_xxx` returns
- `process` completes record processing
- `pact` is set `FALSE`
- `process` returns

At this point the record has been completely processed. The next time `process` is called everything starts all over from the beginning.

11.4.4 Miscellaneous Utility Routines

```
static long get_units(DBADDR *paddr, char *units)
{
   xxxRecord  *pxxx=(xxxRecord *)paddr->precord;

   strncpy(units,pxxx->egu,sizeof(pxxx->egu));
   return(0);
}

static long get_graphic_double(DBADDR *paddr,
      struct dbr_grDouble *pgd)
{
   xxxRecord  *pxxx=(xxxRecord *)paddr->precord;
   int      fieldIndex = dbGetFieldIndex(paddr);

   if(fieldIndex == xxxRecordVAL) {
      pgd->upper_disp_limit = pxxx->hopr;
      pgd->lower_disp_limit = pxxx->lopr;
   } else recGblGetGraphicDouble(paddr,pgd);
   return(0);
}
/* similar routines would be provided for */
/* get_control_double and get_alarm_double*/
```

These are a few examples of various routines supplied by a typical record support package. The functions that must be performed by the remaining routines are described in the next section.

11.4.5 Alarm Processing

```
static void checkAlarms(xxxRecord *pxxx)
{
   double        val;
   float         hyst,lalm,hihi,high,low,lolo;
   unsigned short hhsv,llsv,hsv,lsv;

   if(pxxx->udf == TRUE ){
      recGblSetSevr(pxxx,UDF_ALARM,VALID_ALARM);
      return;
   }

   hihi=pxxx->hihi; lolo=pxxx->lolo;
   high=pxxx->high; low=pxxx->low;
   hhsv=pxxx->hhsv; llsv=pxxx->llsv;
   hsv=pxxx->hsv; lsv=pxxx->lsv;
   val=pxxx->val; hyst=pxxx->hyst; lalm=pxxx->lalm;

   /* alarm condition hihi */
   if (hhsv && (val >= hihi
   || ((lalm==hihi) && (val >= hihi-hyst)))) {
      if(recGblSetSevr(pxxx,HIHI_ALARM,pxxx->hhsv)
          pxxx->lalm = hihi;
      return;
   }
   /* alarm condition lolo */
   if (llsv && (val <= lolo
   || ((lalm==lolo) && (val <= lolo+hyst)))) {
      if(recGblSetSevr(pxxx,LOLO_ALARM,pxxx->llsv))
         pxxx->lalm = lolo;
      return;
   }
   /* alarm condition high */
   if (hsv && (val >= high
   || ((lalm==high) && (val >= high-hyst)))) {
      if(recGblSetSevr(pxxx,HIGH_ALARM,pxxx->hsv))
         pxxx->lalm = high;
      return;
   }
   /* alarm condition low */
   if (lsv && (val <= low
   || (lalm==low) && (val <= low+hyst)))) {
      if(recGblSetSevr(pxxx,LOW_ALARM,pxxx->lsv))
         pxxx->lalm = low;
      return;
   }
   /*we get here only if val is out of alarm by at least hyst*/
   pxxx->lalm=val;
   return;
}
```

This is a typical set of code for checking alarms conditions for an analog type record. The actual set of code can be very record specific. Note also that other parts of the system can raise alarms. The algorithm is to always maximize alarm severity, i.e. the highest severity outstanding alarm will be reported.

The above algorithm also honors a hysteresis factor for the alarm. This is to prevent alarm storms from occurring in the event that the current value is very near an alarm limit and noise makes it continually cross the limit. It honors the hysteresis only when the value is going to a lower alarm severity.

11.4.6 Raising Monitors

```
static void monitor(xxxRecord *pxxx)
{
   unsigned short   monitor_mask;
   float            delta;

   monitor_mask = recGblResetAlarms(pxxx);
   /* check for value change */
   delta = pxxx->mlst - pxxx->val;
   if(delta<0.0) delta = -delta;
   if (delta > pxxx->mdel) {
      /* post events for value change */
      monitor_mask |= DBE_VALUE;
      /* update last value monitored */
      pxxx->mlst = pxxx->val;
   }
   /* check for archive change */
   delta = pxxx->alst - pxxx->val;
   if(delta<0.0) delta = 0.0;
   if (delta > pxxx->adel) {
      /* post events on value field for archive change */
      monitor_mask |= DBE_LOG;
      /* update last archive value monitored */
      pxxx->alst = pxxx->val;
   }
   /* send out monitors connected to the value field */
   if (monitor_mask){
      db_post_events(pxxx,&pxxx->val,monitor_mask);
   }
   return;
}
```

All record types should call `recGblResetAlarms` as shown. Note that `nsta` and `nsev` will have the value 0 after this routine completes. This is necessary to ensure that alarm checking starts fresh after processing completes. The code also takes care of raising alarm monitors when a record changes from an alarm state to the no alarm state. It is essential that record support routines follow the above model or else alarm processing will not follow the rules.

Analog type records should also provide monitor and archive hysteresis fields as shown by this example.

`db_post_events` results in channel access issuing monitors for clients attached to the record and field. The call is

```
int db_post_events(void *precord, void *pfield,
      unsigned int monitor_mask)
```

where:

`precord` - The address of the record
`pfield` - The address of the field
`monitor_mask` - A bit mask that can be any combinations of the following:
DBE_ALARM - A change of alarm state has occured. This is set by `recGblResetAlarms`.
DBE_LOG - Archive change of state.
DBE_VAL - Value change of state

IMPORTANT: The record support module is responsible for calling `db_post_event` for any fields that change as a result of record processing. Also it should **NOT** call `db_post_event` for fields that do not change.

11.5 Record Support Routines

This section describes the routines defined in the RSET. Any routine that does not apply to a specific record type must be declared `NULL`.

11.5.1 Generate Report of Each Field in Record

```
report(void *precord);   /* addr of record*/
```

This routine is not used by most record types. Any action is record type specific.

11.5.2 Initialize Record Processing

```
initialize(void);
```

This routine is called once at IOC initialization time. Any action is record type specific. Most record types do not need this routine.

11.5.3 Initialize Specific Record

```
init_record(
   void *precord,   /* addr of record*/
   int     pass);
```

`iocInit` calls this routine twice (pass=0 and pass=1) for each database record of the type handled by this routine. It must perform the following functions:

- Check and/or issue initialization calls for the associated device support routines.
- Perform any record type specific initialization.
- During the first pass it can only perform initializations that affect the record referenced by precord.
- During the second pass it can perform initializations that affect other records.

11.5.4 Process Record

```
process(void *precord);   /* addr of record*/
```

This routine must follow the guidelines specified previously.

11.5.5 Special Processing

```
special(
   struct dbAddr   *paddr,
   int   after);/*(FALSE,TRUE)=>(Before,After)Processing*/
```

This routine implements the record type specific special processing for the field referred to by `dbAddr`. Note that it is called twice. Once before any changes are made to the associated field and once after. File `special.h` defines special types. This routine is only called for user special fields, i.e. fields with `SPC_xxx` >= 100. A field is declared special in the ASCII record definition file. New values should not by added to `special.h`, instead use `SPC_MOD`.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.6 Get Value

This routine is no longer used. It should be left as a NULL procedure in the record support entry table.

11.5.7 Convert dbAddr Definitions

```
cvt_dbaddr(struct dbAddr *paddr);
```

This routine is called by `dbNameToAddr` if the field has special set equal to `SPC_DBADDR`. A typical use is when a field refers to an array. This routine can change any combination of the `dbAddr` fields: `no_elements`, `field_type`, `field_size`, `special`, and `dbr_type`. For example if the `VAL` field of a waveform record is passed to `dbNameToAddr`, `cvt_dbaddr` would change `dbAddr` so that it refers to the actual array rather then `VAL`.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

NOTES:

- Channel access calls db_name_to_addr, which is part of old database access. Db_name_to_addr calls dbNameToAddr. This is done when a client connects to the record.
- no_elements must be set to the maximum number of elements that will ever be stored in the array.

11.5.8 Get Array Information

```
get_array_info(
   struct dbAddr  *paddr,
   long   *no_elements,
   long   *offset);
```

This routine returns the current number of elements and the offset of the first value of the specified array. The offset field is meaningful if the array is actually a circular buffer.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.9 Put Array Information

```
put_array_info(
   struct dbAddr   *paddr,
   long   nNew);
```

This routine is called after new values have been placed in the specified array.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.10 Get Units

```
get_units(
   struct dbAddr  *paddr,
   char  *punits);
```

This routine sets units equal to the engineering units for the field.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.11 Get Precision

```
get_precision(
   struct dbAddr  *paddr,
   long   *precision);
```

This routine gets the precision, i.e. number of decimal places, which should be used to convert the field value to an ASCII string. `recGblGetPrec` should be called for fields not directly related to the value field.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.12 Get Enumerated String

```
get_enum_str(
   struct dbAddr  *paddr,
   char  *p);
```

This routine sets `*p` equal to the ASCII string for the field value. The field must have type `DBF_ENUM`.

Look at the code for the `bi` or `mbbi` records for examples.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.13 Get Strings for Enumerated Field

```
get_enum_strs(
   struct dbAddr   *paddr,
   struct dbr_enumStrs  *p);
```

This routine gives values to all fields of structure `dbr_enumStrs`.

Look at the code for the `bi` or `mbbi` records for examples.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.14 Put Enumerated String

```
put_enum_str(
   struct dbAddr  *paddr,
   char  *p);
```

Given an ASCII string, this routine updates the database field. It compares the string with the string values associated with each enumerated value and if it finds a match sets the database field equal to the index of the string which matched.

Look at the code for the `bi` or `mbbi` records for examples.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.15 Get Graphic Double Information

```
get_graphic_double(
   struct dbAddr  *paddr,
   struct dbr_grDouble  *p);   /* addr of return info*/
```

This routine fills in the graphics related fields of structure `dbr_grDouble`. `recGblGetGraphicDouble` should be called for fields not directly related to the value field.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.16 Get Control Double Information

```
get_control_double(
   struct dbAddr  *paddr,
   struct dbr_ctrlDouble  *p);  /* addr of return info*/
```

This routine gives values to all fields of structure `dbr_ctrlDouble`. `recGblGetControlDouble` should be called for fields not directly related to the value field.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.5.17 Get Alarm Double Information

```
get_alarm_double(
   struct dbAddr  *paddr,
   struct dbr_alDouble  *p);  /* addr of return info*/
```

This routine gives values to all fields of structure `dbr_alDouble`.

The database access routine, `dbGetFieldIndex` can be used to determine which field is being modified.

11.6 Global Record Support Routines

A number of global record support routines are available. These routines are intended for use by the record specific processing routines but can be called by any routine that wishes to use their services.

The name of each of these routines begins with ”`recGbl`”.

11.6.1 Alarm Status and Severity

Alarms may be raised in many different places during the course of record processing. The algorithm is to maximize the alarm severity, i.e. the highest severity outstanding alarm is raised. If more than one alarm of the same severity is found then the first one is reported. This means that whenever a code fragment wants to raise an alarm, it does so only if the alarm severity it will declare is greater then that already existing. Four fields (in database common) are used to implement alarms: `sevr`, `stat`, `nsev`, and `nsta`. The first two are the status and severity after the record is completely processed. The last two fields (`nsta` and `nsev`) are the status and severity values to set during record processing. Two routines are used for handling alarms. Whenever a routine wants to raise an alarm it calls `recGblSetSevr`. This routine will only change `nsta` and `nsev` if it will result in the alarm severity being increased. At the end of processing, the record support module must call `recGblResetAlarms`. This routine sets `stat`=`nsta`, `sevr`=`nsev`, `nsta`=0, and `nsev`=0. If `stat` or `sevr` has changed value since the last call it calls `db_post_event` for `stat` and `sevr` and returns a value of

DBE_ALARM. If no change occured it returns 0. Thus after calling recGblResetAlarms everything is ready for raising alarms the next time the record is processed. The example record support module presented above shows how these macros are used.

```
recGblSetSevr(
   void   *precord,
   short   nsta,
   short   nsevr);
```

Returns: (TRUE, FALSE) if (did, did not) change nsta and nsev.

```
unsigned short recGblResetAlarms(void  *precord);
```

Returns: Initial value for monitor_mask

11.6.2 Alarm Acknowledgment

Database common contains two additional alarm related fields: acks (Highest severity unacknowledged alarm) and ackt (does transient alarm need to be acknowledged). These field are handled by iocCore and recGblResetAlarms and are not the responsibility of record support. These fields are intended for use by the alarm handler.

11.6.3 Generate Error: Process Variable Name, Caller, Message

SUGGESTION: use epicsPrintf instead of this for new code.

```
recGblDbaddrError(
   long   status,
   struct dbAddr  *paddr,
   char   *pcaller_name); /* calling routine name */
```

This routine interfaces with the system wide error handling system to display the following information: Status information, process variable name, calling routine.

11.6.4 Generate Error: Status String, Record Name, Caller

SUGGESTION: use epicsPrintf instead of this for new code.

```
recGblRecordError(
   long   status,
   void   *precord,   /* addr of record  */
   char   *pcaller_name);   /* calling routine name */
```

This routine interfaces with the system wide error handling system to display the following information: Status information, record name, calling routine.

11.6.5 Generate Error: Record Name, Caller, Record Support Message

SUGGESTION: use epicsPrintf instead of this for new code.

```
recGblRecsupError(
   long   status,
   struct   dbAddr   *paddr,
   char   *pcaller_name,   /* calling routine name */
   char   *psupport_name);   /* support routine name*/
```

This routine interfaces with the system wide error handling system to display the following information: Status information, record name, calling routine, record support entry name.

11.6.6 Get Graphics Double

```
recGblGetGraphicDouble(
   struct dbAddr  *paddr,
   struct dbr_grDouble  *pgd);
```

This routine can be used by the `get_graphic_double` record support routine to obtain graphics values for fields that it doesn't know how to set.

11.6.7 Get Control Double

```
recGblGetControlDouble(
   struct dbAddr  *paddr,
   struct dbr_ctrlDouble   *pcd);
```

This routine can be used by the `get_control_double` record support routine to obtain control values for fields that it doesn't know how to set.

11.6.8 Get Alarm Double

```
recGblGetAlarmDouble(
   struct dbAddr  *paddr,
   struct dbr_alDouble  *pcd);
```

This routine can be used by the `get_alarm_double` record support routine to obtain control values for fields that it doesn't know how to set.

11.6.9 Get Precision

```
recGblGetPrec(
   struct dbAddr  *paddr,
   long  *pprecision);
```

This routine can be used by the `get_precision` record support routine to obtain the precision for fields that it doesn't know how to set the precision.

11.6.10 Get Time Stamp

```
recGblGetTimeStamp(void *precord)
```

This routine gets the current time stamp and puts it in the record

11.6.11 Forward link

```
recGblFwdLink(
   void *precord);
```

This routine can be used by process to request processing of forward links.

11.6.12 Initialize Constant Link

```
int recGblInitConstantLink(
  struct link  *plink,
  short  dbfType,
  void   *pdest);
```

Initialize a constant link. This routine is usually called by `init_record` (or by associated device support) to initialize the field associated with a constant link. It returns(FALSE, TRUE) if it (did not, did) modify the destination.

Chapter 12: Device Support

12.1 Overview

In addition to a record support module, each record type can have an arbitrary number of device support modules. The purpose of device support is to hide hardware specific details from record processing routines. Thus support can be developed for a new device without changing the record support routines.

A device support routine has knowledge of the record definition. It also knows how to talk to the hardware directly or how to call a device driver which interfaces to the hardware. Thus device support routines are the interface between hardware specific fields in a database record and device drivers or the hardware itself.

Database common contains two device related fields:

- **dtyp**: Device Type.
- **dset**: Address of Device Support Entry Table.

The field `dtyp` contains the index of the menu choice as defined by the device ASCII definitions. `iocInit` uses this field and the device support structures defined in `devSup.h` to initialize the field `dset`. Thus record support can locate its associated device support via the `dset` field.

Device support modules can be divided into two basic classes: synchronous and asynchronous. Synchronous device support is used for hardware that can be accessed without delays for I/O. Many register based devices are synchronous devices. Other devices, for example all GPIB devices, can only be accessed via I/O requests that may take large amounts of time to complete. Such devices must have associated asynchronous device support. Asynchronous device support makes it more difficult to create databases that have linked records.

If a device can be accessed with a delay of less then a few microseconds then synchronous device support is appropriate. If a device causes delays of greater than 100 microseconds then asynchronous device support is appropriate. If the delay is between these values your guess about what to do is as good as mine. Perhaps you should ask the hardware designer why such a device was created.

If a device takes a long time to accept requests there is another option than asynchronous device support. A driver can be created that periodically polls all its attached input devices. The device support just returns the latest polled value. For outputs, device support just notifies the driver that a new value must be written. the driver, during one of its polling phases, writes the new value. The EPICS Allen Bradley device/driver support is a good example.

12.2 Example Synchronous Device Support Module

```
/* Create the dset for devAiSoft */
long init_record();
long read_ai();
struct {
   long   number;
   DEVSUPFUN   report;
   DEVSUPFUN   init;
```

```
   DEVSUPFUN   init_record;
   DEVSUPFUN   get_ioint_info;
   DEVSUPFUN   read_ai;
   DEVSUPFUN   special_linconv;
}devAiSoft={
   6,
   NULL,
   NULL,
   init_record,
   NULL,
   read_ai,
   NULL};

static long init_record(void *precord)
{
   aiRecord  *pai = (aiRecord *)precord;
   long status;

   /* ai.inp must be a CONSTANT, PV_LINK, DB_LINK or CA_LINK*/
   switch (pai->inp.type) {
      case (CONSTANT) :
         recGblInitConstantLink(&pai->inp,
            DBF_DOUBLE,&pai->val);
         break;
      case (PV_LINK) :
      case (DB_LINK) :
      case (CA_LINK) :
         break;
      default :
         recGblRecordError(S_db_badField, (void *)pai,
            ”devAiSoft (init_record) Illegal INP field”);
      return(S_db_badField);
   }
   /* Make sure record processing routine does not perform any conversion*/
   pai->linr=0;
   return(0);
}

static long read_ai(void *precord)
{
   aiRecord*pai =(aiRecord *)precord;
   long  status;

   status=dbGetGetLink(&(pai->inp.value.db_link),
      (void *)pai,DBR_DOUBLE,&(pai->val),0,1);
   if(status) return(status);
   return(2); /*don’t convert*/
}
```

The example is `devAiSoft`, which supports soft analog inputs. The `INP` field can be a constant or a database link or a channel access link. Only two routines are provided (the rest are declared `NULL`). The `init_record` routine first checks that the link type is valid. If the link is a constant it initializes `VAL` If the link is a Process Variable link it calls `dbCaGetLink` to turn it into a Channel Access link. The `read_ai` routine obtains an input value if the link is a database or Channel Access link, otherwise it doesn't have to do anything.

12.3 Example Asynchronous Device Support Module

This example shows how to write an asynchronous device support routine. It does the following sequence of operations:

1. When first called `pact` is `FALSE`. It arranges for a callback (`myCallback`) routine to be called after a number of seconds specified by the `VAL` field. `callbackRequest` is an EPICS supplied routine. The watchdog timer routines are supplied by vxWorks.
2. It prints a message stating that processing has started, sets `pact` `TRUE`, and returns. The record processing routine returns without completing processing.
3. When the specified time elapses `myCallback` is called. It locks the record, calls `process`, and unlocks the record. It calls the process entry of the record support module, which it locates via the `rset` field in `dbCommon`, directly rather than `dbProcess`. `dbProcess` would not call `process` because `pact` is `TRUE`.
4. When `process` executes, it again calls `read_ai`. This time `pact` is `TRUE`.
5. `read_ai` prints a message stating that record processing is complete and returns a status of 2. Normally a value of 0 would be returned. The value 2 tells the record support routine not to attempt any conversions. This is a convention (a bad convention!) used by the analog input record.
6. When `read_ai` returns the record processing routine completes record processing.

At this point the record has been completely processed. The next time process is called everything starts all over.

```
/* Create the dset for devAiTestAsyn */
long init_record();
long read_ai();
struct {
   long  number;
   DEVSUPFUN   report;
   DEVSUPFUN   init;
   DEVSUPFUN   init_record;
   DEVSUPFUN   get_ioint_info;
   DEVSUPFUN   read_ai;
   DEVSUPFUN   special_linconv;
} devAiTestAsyn={
   6,
   NULL,
   NULL,
   init_record,
   NULL,
   read_ai,
   NULL};

/* control block for callback*/
typedef struct myCallback {
   CALLBACK   callback;
   sruct dbCommon   *precord;
   WDOG_ID   wd_id;
```

```
}myCallback;

static void myCallback(CALLBACK *pcallback)
{
    dbCommon *precord;
    struct rset*prset;

   callbackGetUser(precord,pcallback);
   prset = (struct rset *)precord->rset;
   dbScanLock(precord);
   *(prset->process)(precord);
   dbScanUnlock(precord);
}


static long init_record(void *precord)
{
    aiRecord      *pai = (aiRecord *)precord;
    myCallback    *pcallback;

    /* ai.inp must be a CONSTANT*/
   switch (pai->inp.type) {
   case (CONSTANT) :
      pcallback = (myCallback *)(calloc(1,sizeof(myCallback)));
      pai->dpvt = (void *)pcallback;
      callbackSetCallback(myCallback, &pcallback->callback);
      callbackSetUser(precord, &pcallback->callback);
      pcallback->precord = (struct dbCommon *)pai;
      pcallback->wd_id = wdCreate();
      pai->val = pai->inp.value.value;
      pai->udf = FALSE;
      break;
   default :
      recGblRecordError(S_db_badField, (void *)pai,
         ”devAiTestAsyn (init_record) Illegal INP field”);
      return(S_db_badField);
   }
   return(0);
}

static long read_ai(void *precord)
{
   aiRecord   *pai = (aiRecord *)precord;;
   struct callback *pcallback=(struct callback *)(pai->dpvt);
   int   wait_time;

   /* ai.inp must be a CONSTANT*/
   switch (pai->inp.type) {
   case (CONSTANT) :
      if(pai->pact) {
         printf(”%s Completed\n”,pai->name);
         return(2); /* don‘t convert*/
      } else {
```

```
         wait_time = (int)(pai->val * vxTicksPerSecond);
         if(wait_time<=0) return(0);
         callbackSetPriority(pai->prio,&pcallback->callback);
         printf("%s Starting asynchronous processing\n",
            pai->name);
         wdStart(pcallback->wd_id,wait_time,
            (FUNCPTR)callbackRequest,
            (int)&pcallback->callback);
         pai->pact = TRUE;
         return(0);
      }
   default :
      if(recGblSetSevr(pai,SOFT_ALARM,VALID_ALARM)) {
         if(pai->stat!=SOFT_ALARM) {
            recGblRecordError(S_db_badField, (void *)pai,
               "devAiTestAsyn (read_ai) Illegal INP field");
         }
      }
   }
   return(0);
}
```

12.4 Device Support Routines

This section describes the routines defined in the DSET. Any routine that does not apply to a specific record type must be declared `NULL`.

12.4.1 Generate Device Report

```
report(
   int   interest);
```

This routine is responsible for reporting all I/O cards it has found. If `interest` is (0,1) then generate a (short, long) report. If a device support module is using a driver, it normally does not have to implement this routine because the driver generates the report.

12.4.2 Initialize Record Processing

```
init(
   int   after);
```

This routine is called twice at IOC initialization time. Any action is device specific. This routine is called twice: once before any database records are initialized and once after all records are initialized but before the scan tasks are started. `after` has the value (0,1) (before, after) record initialization.

12.4.3 Initialize Specific Record

```
init_record(
   void *precord);   /* addr of record*/
```

The record support `init_record` routine calls this routine.

12.4.4 Get I/O Interrupt Information

```
get_ioint_info(
   int   cmd,
   struct dbCommon   *precord,
   IOSCANPVT   *ppvt);
```

This is called by the I/O interrupt scan task. If `cmd` is (0,1) then this routine is being called when the associated record is being (placed in, taken out of) an I/O scan list. See the chapter on scanning for details.

It should be noted that a previous type of I/O event scanning is still supported. It is not described in this document because, hopefully, it will go away in the near future. When it calls this routine the arguments have completely different meanings.

12.4.5 Other Device Support Routines

All other device support routines are record type specific.

Chapter 13: Driver Support

13.1 Overview

It is not necessary to create a driver support module in order to interface EPICS to hardware. For simple hardware device support is sufficient. At the present time most hardware support has both. The reason for this is historical. Before EPICS there was GTACS. During the change from GTACS to EPICS, record support was changed drastically. In order to preserve all existing hardware support the GTACS drivers were used without change. The device support layer was created just to shield the existing drivers form the record support changes.

Since EPICS now has both device and driver support the question arises: When do I need driver support and when don't I? Lets give a few reasons why drivers should be created.

- The hardware is actually a subnet, e.g. GPIB. In this case a driver should be provided for accessing the subnet. There is no reason to make the driver aware of EPICS except possibly for issuing error messages.
- The hardware is complicated. In this case supplying driver support helps modularized the software. The Allen Bradley driver, which is also an example of supporting a subnet, is a good example.
- An existing driver, maintained by others, is available. I don't know of any examples.
- The driver should be general purpose, i.e. not tied to EPICS. The CAMAC driver is a good example. It is used by other systems, such as CODA.

The only thing needed to interface a driver to EPICS is to provide a driver support module, which can be layered on top of an existing driver, and provide a database definition for the driver. The driver support module is described in the next section. The database definition is described in chapter "Database Definition".

13.2 Device Drivers

Device drivers are modules that interface directly with the hardware. They are provided to isolate device support routines from details of how to interface to the hardware. Device drivers have no knowledge of the internals of database records. Thus there is no necessary correspondence between record types and device drivers. For example the Allen Bradley driver provides support for many different types of signals including analog inputs, analog outputs, binary inputs, and binary outputs.

In general only device support routines know how to call device drivers. Since device support varies widely from device to device, the set of routines provided by a device driver is almost completely driver dependent. The only requirement is that routines `report` and `init` must be provided. Device support routines must, of course, know what routines are provided by a driver.

File `drvSup.h` describes the format of a driver support entry table. The driver support module must supply a driver entry table. An example definition is:

```
LOCAL long report();
LOCAL long init();
struct {
     long    number;
```

```
        DRVSUPFUN       report;
        DRVSUPFUN       init;
   } drvAb={
        2,
        report,
        init
   };
```

The above example is for the Allen Bradley driver. It has an associated ascii definition of:

```
driver(drvAb)
```

Thus it is seen that the driver support module should supply two EPICS callable routines: `int` and `report`.

13.2.0.1 init

This routine, which has no arguments, is called by `iocInit`. The driver is expected to look for and initialize the hardware it supports. As an example the init routine for Allen Bradley is:

```
LOCAL long init()
{
 return(ab_driver_init());
}
```

13.2.0.2 report

The report routine is called by the `dbior`, an IOC test routine. It is responsible for producing a report describing the hardware it found at init time. It is passed one argument, level, which is a hint about how much information to display. An example, taken from Allen Bradley, is:

```
LOCAL long report(int level)
{
return(ab_io_report(level));
}
```

Guidelines for level are as follows:

Level=0	Display a one line summary for each device
Level=1	Display more information
Level=2	Display a lot of information. It is even permissible to prompt for what is wanted.

13.2.0.3 Hardware Configuration

Hardware configuration includes the following:

- VME/VXI address space
- VME Interrupt Vectors and levels
- Device Specific Information

The information contained in hardware links supplies some but not all configuration information. In particular it does not define the VME/VXI addresses and interrupt vectors. This additional information is what is meant by hardware configuration in this chapter.

The problem of defining hardware configuration information is an unsolved problem for EPICS. At one time configuration information was defined in `module_types.h` Many existing device/driver support modules still uses this method. It should **NOT** be used for any new support for the following reasons:

- There is no way to manage this file for the entire EPICS community.

- It does not allow arbitrary configuration information.
- It is hard for users to determine what the configuration information is.

The fact that it is now easy to include ASCII definitions for only the device/driver support used in each IOC makes the configuration problem much more manageable than previously. Previously if you wanted to support a new VME modules it was necessary to pick addresses that nothing in `module_types.h` was using. Now you only have to check modules you are actually using.

Since there are no EPICS defined rules for hardware configuration, the following minimal guidelines should be used:

- Never use `#define` to specify things like VME addresses. Instead use variables and assign default values. Allow the default values to be changed before iocInit is executed. The best way is to supply a global routine that can be invoked from the IOC startup file. Note that all arguments to such routines should be one of the following:
  ```
  int
  char *
  double
  ```
- Call the routines described in chapter “Device Support Library” whenever possible.

Chapter 14: Static Database Access

14.1 Overview

An IOC database is created on a Unix system via a Database Configuration Tool and stored in a Unix file. EPICS provides two sets of database access routines: Static Database Access and Runtime Database Access. Static database access can be used on Unix or IOC database files. Runtime database requires an initialized IOC databases. Static database access is described in this chapter and runtime database access in the next chapter.

Static database access provides a simplified interface to a database, i.e. much of the complexity is hidden. `DBF_MENU` and `DBF_DEVICE` fields are accessed via a common type called `DCT_MENU`. A set of routines are provided to simplify access to link fields. All fields can be accessed as character strings. This interface is called static database access because it can be used to access an uninitialized, as well as an initialized database.

Before accessing database records, the files describing menus, record types, and devices must be read via `dbReadDatabase` or `dbReadDatabaseFP`. These routines, which are also used to load record instances, can be called multiple times.

Database Configuration Tools (DCTs) should manipulate an EPICS database only via the static database access interface. An IOC database is created on a Unix system via a database configuration tool and stored in a Unix file with a file extension of ".db". Three routines (`dbReadDatabase, dbReadDatabaseFP` and `dbWriteRecord`) access a Unix database file. These routines read/write a database file to/from a memory resident EPICS database. All other access routines manipulate the memory resident database.

An include file `dbStaticLib.h` contains all the definitions needed to use the static database access library. Two structures (`DBBASE` and `DBENTRY`) are used to access a database. The fields in these structures should not be accessed directly. They are used by the static database access library to keep state information for the caller.

14.2 Definitions

14.2.1 DBBASE

Multiple memory resident databases can be accessed simultaneously. The user must provide definitions in the form:

```
DBBASE *pdbbase;
```

14.2.2 DBENTRY

A typical declaration for a database entry structure is:

```
DBENTRY *pdbentry;
pdbentry=dbAllocEntry(pdbbase);
```

Most static access to a database is via a `DBENTRY` structure. As many `DBENTRYs` as desired can be allocated.

The user should NEVER access the fields of DBENTRY directly. They are meant to be used by the static database access library.

Most static access routines accept an argument which contains the address of a DBENTRY. Each routine uses this structure to locate the information it needs and gives values to as many fields in this structure as possible. All other fields are set to NULL.

14.2.3 Field Types

Each database field has a type as defined in the next chapter. For static database access a new and simpler set of field types are defined. In addition, at runtime, a database field can be an array. With static database access, however, all fields are scalars. Static database access field types are called DCT field types.

The DCT field types are:

- **DCT_STRING**: Character string.
- **DCT_INTEGER**: Integer value
- **DCT_REAL**: Floating point number
- **DCT_MENU**: A set of choice strings
- **DCT_MENUFORM**: A set of choice strings with associated form.
- **DCT_INLINK**: Input Link
- **DCT_OUTLINK**: Output Link
- **DCT_FWDLINK**: Forward Link
- **DCT_NOACCESS**: A private field for use by record access routines

A DCT_STRING field contains the address of a NULL terminated string. The field types DCT_INTEGER and DCT_REAL are used for numeric fields. A field that has any of these types can be accessed via the dbGetString, dbPutString, dbVerify, and dbGetRange routines.

The field type DCT_MENU has an associated set of strings defining the choices. Routines are available for accessing menu fields. A menu field can also be accessed via the dbGetString, dbPutString, dbVerify, and dbGetRange routines.

The field type DCT_MENUFORM is like DCT_MENU but in addition the field has an associated link field. The information for the link field can be entered via a set of form manipulation fields.

DCT_INLINK (input), DCT_OUTLINK (output), and DCT_FWDLINK (forward) specify that the field is a link, which has an associated set of static access routines described in the next subsection. A field that has any of these types can also be accessed via the dbGetString, dbPutString, dbVerify, and dbGetRange routines.

14.3 Allocating and Freeing DBBASE

14.3.1 dbAllocBase

```
DBBASE *dbAllocBase(void);
```

This routine allocates and initializes a DBBASE structure. It does not return if it is unable to allocate storage.

dbAllocBase allocates and initializes a DBBASE structure. Normally an application does not need to call dbAllocBase because a call to dbReadDatabase or dbReadDatabaseFP automatically calls this routine if pdbbase is null. Thus the user only has to supply code like the following:

```
DBBASE  *pdbbase=0;
...
status = dbReadDatabase(&pdbbase,"sample.db",
      "<path>","<macro substitutions>");
```

The static database access library allows applications to work with multiple databases, each referenced via a different (DBBASE *) pointer. Such applications may find it necessary to call `dbAllocBase` directly.

`dbAllocBase` does not return if it is unable to allocate storage.

14.3.2 dbFreeBase

```
void dbFreeBase(DBBASE *pdbbase);
```

`dbFreeBase` frees the entire database reference by `pdbbase` including the DBBASE structure itself.

14.4 DBENTRY Routines

14.4.1 Alloc/Free DBENTRY

```
DBENTRY *dbAllocEntry(DBBASE *pdbbase);
void dbFreeEntry(DBENTRY *pdbentry);
```

These routines allocate, initialize, and free `DBENTRY` structures. The user can allocate and free `DBENTRY` structures as necessary. Each `DBENTRY` is, however, tied to a particular database.

`dbAllocEntry` and `dbFreeEntry` act as a pair, i.e. the user calls `dbAllocEntry` to create a new DBENTRY and calls `dbFreeEntry` when done.

14.4.2 dbInitEntry dbFinishEntry

```
void dbInitEntry(DBBASE *pdbbase,DBENTRY *pdbentry);
void dbFinishEntry(DBENTRY *pdbentry);
```

The routines `dbInitEntry` and `dbFinishEntry` are provided in case the user wants to allocate a `DBENTRY` structure on the stack. Note that the caller MUST call `dbFinishEntry` before returning from the routine that calls `dbInitEntry`. An example of how to use these routines is:

```
int xxx(DBBASE *pdbbase)
{
   DBENTRY dbentry;
   DBENTRY *pdbentry = &dbentry;
   ...
   dbInitEntry(pdbbase,pdbentry);
   ...
   dbFinishEntry(pdbentry);
}
```

14.4.3 dbCopyEntry

dbCopyEntry
Contents

```
DBENTRY *dbCopyEntry(DBENTRY *pdbentry);
void dbCopyEntryContents(DBENTRY *pfrom,DBENTRY *pto);
```

The routine `dbCopyEntry` allocates a new entry, via a call to `dbAllocEntry`, copies the information from the original entry, and returns the result. The caller must free the entry, via `dbFreeEntry` when finished with the DBENTRY.

The routine `dbCopyEntryContents` copies the contents of pfrom to pto. Code should never perform structure copies.

14.5 Read and Write Database

14.5.1 Read Database File

```
long dbReadDatabase(DBBASE **ppdbbase,const char *filename,
      char *path, char *substitutions);
long dbReadDatabaseFP(DBBASE **ppdbbase,FILE *fp,
      char *path, char *substitutions);
long dbPath(DBBASE *pdbbase,const char *path);
long dbAddPath(DBBASE *pdbbase,const char *path);
```

`dbReadDatabase` and `dbReadDatabaseFP` both read a file containing database definitions as described in chapter “Database Definitions”. If `*ppdbbase` is NULL, `dbAllocBase` is automatically invoked and the return address assigned to `*pdbbase`. The only difference between the two routines is that one accepts a file name and the other a "FILE *". Any combination of these routines can be called multiple times. Each adds definitions with the rules described in chapter “Database Definitions”.

The routines `dbPath` and `dbAddPath` specify paths for use by include statements in database definition files. These are not normally called by user code.

14.5.2 Write Database Definitons

```
long dbWriteMenu(DBBASE *pdbbase,char *filename,
   char *menuName);
long dbWriteMenuFP(DBBASE *pdbbase,FILE *fp,char *menuName);
long dbWriteRecordType(DBBASE *pdbbase,char *filename,
   char *recordTypeName);
long dbWriteRecordTypeFP(DBBASE *pdbbase,FILE *fp,
   char *recordTypeName);
long dbWriteDevice(DBBASE *pdbbase,char *filename);
long dbWriteDeviceFP(DBBASE *pdbbase,FILE *fp)
long dbWriteDriver(DBBASE *pdbbase,char *filename);
long dbWriteDriverFP(DBBASE *pdbbase,FILE *fp);
long dbWriteBreaktable(DBBASE *pdbbase,
   const char *filename);
long dbWriteBreaktableFP(DBBASE *pdbbase,FILE *fp);
```

Each of these routines writes files in the same format accepted by `dbReadDatabase` and `dbReadDatabaseFP`. Two versions of each type are provided. The only difference is that one accepts a filename and the other a "`FILE *`". Thus only one of each type has to be described.

`dbWriteMenu` writes the description of the specified menu or, if `menuName` is NULL, the descriptions of all menus.

`dbWriteRecordType` writes the description of the specified record type or, if `recordTypeName` is NULL, the descriptions of all record types.

`dbWriteDevice` writes the description of all devices to stdout.

`dbWriteDriver` writes the description of all drivers to stdout.

14.5.3 Write Record Instances

```
long dbWriteRecord(DBBASE *pdbbase,char * file,
   char *precordTypeName,int level);
long dbWriteRecordFP(DBBASE *pdbbase,FILE *fp,
   char *precordTypeName,int level);
```

Each of these routines writes files in the same format accepted by `dbReadDatabase` and `dbReadDatabaseFP`. Two versions of each type are provided. The only difference is that one accepts a filename and the other a "`FILE *`". Thus only one of each type has to be described.

`dbWriteRecord` writes record instances. If `precordTypeName` is NULL, then the record instances for all record types are written, otherwise only the records for the specified type are written. `level` has the following meaning:

- 0 - Write only prompt fields that are different than the default value.
- 1 - Write only the fields which are prompt fields.
- 2 - Write the values of all fields.

14.6 Manipulating Record Types

14.6.1 Get Number of Record Types

```
int  dbGetNRecordTypes(DBENTRY *pdbentry);
```

This routine returns the number of record types in the database.

14.6.2 Locate Record Type

```
long dbFindRecordType(DBENTRY *pdbentry,
   char *recordTypeName);
long dbFirstRecordType(DBENTRY *pdbentry);
long dbNextRecordType(DBENTRY *pdbentry);
```

`dbFindRecordType` locates a particular record type. `dbFirstRecordType` locates the first, in alphabetical order, record type. Given that DBENTRY points to a particular record type, `dbNextRecordType` locates the next record type. Each routine returns 0 for success and a non zero status value for failure. A typical code segment using these routines is:

```
status = dbFirstRecordType(pdbentry);
while(!status) {
```

```
   /*Do something*/
status = dbNextRecordType(pdbentry)
}
```

14.6.3 Get Record Type Name

```
char *dbGetRecordTypeName(DBENTRY *pdbentry);
```

This routine returns the name of the record type that DBENTRY currently references. This routine should only be called after a successful call to `dbFindRecordType`, `dbFirstRecordType`, or `dbNextRecordType`. It returns NULL if DBENTRY does not point to a record description.

14.7 Manipulating Field Descriptions

The routines described in this section all assume that DBENTRY references a record type, i.e. that `dbFindRecordType`, `dbFirstRecordType`, or `dbNextRecordType` has returned success or that a record instance has been successfully located.

14.7.1 Get Number of Fields

```
int  dbGetNFields(DBENTRY *pdbentry,int dctonly);
```

Returns the number of fields for the record instance that DBENTRY currently references.

14.7.2 Locate Field

```
long dbFirstField(DBENTRY *pdbentry,int dctonly);
long dbNextField(DBENTRY *pdbentry,int dctonly);
```

These routines are used to locate fields. If any of these routines returns success, then DBENTRY references that field description.

14.7.3 Get Field Type

```
int  dbGetFieldType(DBENTRY *pdbentry);
```

This routine returns the integer value for a DCT field type, see Section 14.2.3 on page 158, for a description of the field types.

14.7.4 Get Field Name

```
char *dbGetFieldName(DBENTRY *pdbentry);
```

This routine returns the name of the field that DBENTRY currently references. It returns NULL if DBENTRY does not point to a field.

14.7.5 Get Default Value

```
char *dbGetDefault(DBENTRY *pdbentry);
```

This routine returns the default value for the field that DBENTRY currently references. It returns NULL if DBENTRY does not point to a field or if the default value is NULL.

14.7.6 Get Field Prompt

```
char *dbGetPrompt(DBENTRY *pdbentry);
int   dbGetPromptGroup(DBENTRY *pdbentry);
```

The `dbGetPrompt` routine returns the character string prompt value, which describes the field. `dbGetPromptGroup` returns the field group as described in guigroup.h.

14.8 Manipulating Record Attributes

A record attribute is a "psuedo" field definition attached to a record type. If a attribute value is assigned to a psuedo field name then all record instances of that record type appear to have that field with the defined value. All attribute fields are DCT_STRING fields.

Two field attributes are automatically created: RTYP and VERS. RTYP is set equal to ,the record type name. VERS is initialized to the value "none specified" but can be changed by record support.

14.8.1 dbPutRecord Attribute

```
long dbPutRecordAttribute(DBENTRY *pdbentry,
    char *name,char*value)
```

This creates or modifies attribute `name` with `value`.

14.8.2 dbGetRecord Attribute

```
long dbGetRecordAttribute(DBENTRY *pdbentry,char *name);
```

14.9 Manipulating Record Instances

With the exception of dbFindRecord, each of the routines described in this section require that DBENTRY references a valid record type, i.e. that `dbFindRecordType`, `dbFirstRecordType`, or `dbNextRecordType` has been called and returned success.

14.9.1 Get Number of Records

```
int  dbGetNRecords(DBENTRY *pdbentry);
```

Returns the number of record instances for the record type that DBENTRY currently references.

14.9.2 Locate Record

```
long dbFindRecord(DBENTRY *pdbentry,char *precordName);
long dbFirstRecord(DBENTRY *pdbentry);
long dbNextRecord(DBENTRY *pdbentry);
```

These routines are used to locate record instances. If any of these routines returns success, then DBENTRY references the record. `dbFindRecord` can be called without DBENTRY referencing a valid record type. `dbFirstRecord` only works if DBENTRY references a record type. The `dbDumpRecords` example given at the beginning of this chapter shows how these routines can be used.

`dbFindRecord` also calls `dbFindField` if the record name includes a field name, i.e. it ends in ".XXX". The routine `dbFoundField` returns (`TRUE`, `FALSE`) if the field (was, was not) found. If it was not found, then `dbFindField` must be called before individual fields can be used.

14.9.3 Get Record Name

```
char *dbGetRecordName(DBENTRY *pdbentry);
```

This routine only works properly if called after `dbFindRecord`, `dbFirstRecord`, or `dbNextRecord` has returned success.

14.9.4 Create/Delete/Free Record

```
long dbCreateRecord(DBENTRY *pdbentry,char *precordName);
long dbDeleteRecord(DBENTRY *pdbentry);
long dbFreeRecords(DBBASE *pdbbase);
```

`dbCreateRecord`, which assumes that `DBENTRY` references a valid record type, creates a new record instance and initializes it as specified by the record description. If it returns success, then `DBENTRY` references the record just created. `dbDeleteRecord` deletes a single record instance/. `dbFreeRecords` deletes all record instances.

14.9.5 Copy Record

```
long dbCopyRecord(DBENTRY *pdbentry, char *newRecordName
   int overWriteOK)
```

This routine copies the record instance currently referenced by `DBENTRY`. Thus it creates and new record with the name `newRecordName` that is of the same type as the original record and copies the original records field values to the new record. If `newRecordName` already exists and `overWriteOK` is true, then the original `newRecordName` is deleted and recreated. If `dbCopyRecord` completes successfully, DBENTRY references the new record.

14.9.6 Rename Record

```
long dbRenameRecord(DBENTRY *pdbentry, char *newname)
```

This routine renames the record instance currently referenced by DBENTRY. If dbRenameRecord completes successfully, DBENTRY references the renamed record.

14.9.7 Record Visibility

These routines are for use by graphical configuration tools.

```
long dbVisibleRecord(DBENTRY *pdbentry);
long dbInvisibleRecord(DBENTRY *pdbentry);
int dbIsVisibleRecord(DBENTRY *pdbentry);
```

dbVisibleRecord sets a record to be visible. dbInvisibleRecord sets a record invisible. dbIsVisibleRecord returns TRUE if a record is visible and FALSE otherwise.

14.9.8 Find Field

```
long dbFindField(DBENTRY *pdbentry,char *pfieldName);
int dbFoundField(DBENTRY *pdbentry);
```

Given that a record instance has been located, dbFindField finds the specified field. If it returns success, then DBENTRY references that field. dbFoundField returns (FALSE, TRUE) if (no field instance is currently available, a field instance is available).

14.9.9 Get/Put Field Values

```
char *dbGetString(DBENTRY *pdbentry);
long dbPutString(DBENTRY *pdbentry,char *pstring);
char *dbVerify(DBENTRY *pdbentry,char *pstring);
char *dbGetRange(DBENTRY *pdbentry);
int   dbIsDefaultValue(DBENTRY *pdbentry);
```

These routines are used to get or change field values. They work on all the database field types except DCT_NOACCESS but should **NOT** be used to prompt the user for information for DCT_MENU, DCT_MENUFORM, or DCT_LINK_xxx fields. dbVerify returns (NULL, a message) if the string is (valid, invalid). Please note that the strings returned are volatile, i.e. the next call to a routines that returns a string will overwrite the value returned by a previous call. Thus it is the caller's responsibility to copy the strings if the value must be kept.

DCT_MENU, DCT_MENUFORM and DCT_LINK_xxx fields can be manipulated via routines described in the following sections. If, however dbGetString and dbPutString are used, they do work correctly. For these field types dbGetString and dbPutString are intended to be used only for creating and restoring versions of a database.

14.10 Manipulating Menu Fields

These routines should only be used for DCT_MENU and DCT_MENUFORM fields. Thus they should only be called if dbFindField, dbFirstField, or dbNextField has returned success and the field type is DCT_MENU or DCT_MENUFORM.

14.10.1 Get Number of Menu Choices

```
int  dbGetNMenuChoices(DBENTRY *pdbentry);
```

This routine returns the number of menu choices for menu.

14.10.2 Get Menu Choice

```
char **dbGetMenuChoices(DBENTRY *pdbentry);
```

This routine returns the address of an array of pointers to strings which contain the menu choices.

14.10.3 Get/Put Menu

```
int  dbGetMenuIndex(DBENTRY *pdbentry);
long dbPutMenuIndex(DBENTRY *pdbentry,int index);
char *dbGetMenuStringFromIndex(DBENTRY *pdbentry,int index);
int dbGetMenuIndexFromString(DBENTRY *pdbentry,
      char *choice);
```

NOTE: These routines do not work if the current field value contains a macro definition.

`dbGetMenuIndex` returns the index of the menu choice for the current field, i.e. it specifies which choice to which the field is currently set. `dbPutMenuIndex` sets the field to the choice specified by the index.

`dbGetMenuStringFromIndex` returns the string value for a menu index. If the index value is invalid NULL is returned. `dbGetMenuIndexFromString` returns the index for the given string. If the string is not a valid choice a -1 is returned.

14.10.4 Locate Menu

```
dbMenu *dbFindMenu(DBBASE *pdbbase,char *name);
```

`dbFindMenu` is most useful for runtime use but is a static database access routine. This routine just finds a menu with the given name.

14.11 Manipulating Link Fields

14.11.1 Link Types

Links are the most complicated types of fields. A link can be a constant, reference a field in another record, or can refer to a hardware device. Two additional complications arise for hardware links. The first is that field `DTYP`, which is a menu field, determines if the `INP` or `OUT` field is a device link. The second is that the information that must be specified for a device link is bus dependent. In order to shelter database configuration tools from these complications the following is done for static database access.

- Static database access will treat `DTYP` as a `DCT_MENUFORM` field.
- The information for the link field related to the `DCT_MENUFORM` can be entered via a set of form manipulation routines associated with the `DCT_MENUFORM` field. Thus the link information can be entered via the `DTYP` field rather than the link field.

- The Form routines described in the next section can also be used with any link field.

Each link is one of the following types:

- **DCT_LINK_CONSTANT**: Constant value.
- **DCT_LINK_PV**: A process variable link.
- **DCT_LINK_FORM**: A link that can only be processed via the form routines described in the next chapter.

Database configuration tools can change any link between being a constant and a process variable link. Routines are provided to accomplish these tasks.

The routines `dbGetString`, `dbPutString`, and `dbVerify` can be used for link fields but the form routines can be used to provide a friendlier user interface.

14.11.2 All Link Fields

```
int  dbGetNLinks(DBENTRY *pdbentry);
long dbGetLinkField(DBENTRY *pdbentry,int index)
int  dbGetLinkType(DBENTRY *pdbentry);
```

These are routines for manipulating `DCT_xxxLINK` fields. `dbGetNLinks` and `dbGetLinkField` are used to walk through all the link fields of a record. `dbGetLinkType` returns one of the values: `DCT_LINK_CONSTANT`, `DCT_LINK_PV`, `DCT_LINK_FORM`, or the value -1 if it is called for an illegal field.

14.11.3 Constant and Process Variable Links

```
long dbCvtLinkToConstant(DBENTRY *pdbentry);
long dbCvtLinkToPvlink(DBENTRY *pdbentry);
```

These routines should be used for modifying `DCT_LINK_CONSTANT` or `DCT_LINK_PV` links. They should not be used for `DCT_LINK_FORM` links, which should be processed via the associated `DCT_MENUFORM` field described above.

14.12 Manipulating MenuForm Fields

These routines are used with a `DCT_MENUFORM` field (a `DTYP` field) to manipulate the associated `DCT_INLINK` or `DCT_OUTLINK` field. They can also be used on any `DCT_INLINK`, `DCT_OUTLINK`, or `DCT_FWDLINK` field.

14.12.1 Alloc/Free Form

```
int dbAllocForm(DBENTRY *pdbentry)
long dbFreeForm(DBENTRY *pdbentry)
```

`dbAllocForm` allocates storage needed to manipulate forms. The return value is the number of elements in the form. If the current field value contains a macro definition, the number of lines returned is 0.

14.12.2 Get/Put Form

```
char **dbGetFormPrompt(DBENTRY *pdbentry)
char **dbGetFormValue(DBENTRY *pdbentry)
long dbPutForm(DBENTRY *pdbentry, char **value)
```

`dbGetFormPrompt` returns a pointer to an array of pointers to character strings specifying the prompt string. `dbGetFormValue` returns the current values. `dbPutForm`, which can use the same array of values returned by `dbGetForm`, sets new values.

14.12.3 Verify Form

```
char **dbVerifyForm(DBENTRY *pdbentry,char **value)
```

`dbVerifyForm` can be called to verify user input. It returns `NULL` if no errors are present. If errors are present, it returns a pointer to an array of character strings containing error messages. Lines in error have a message and correct lines have a `NULL` string.

14.12.4 Get Related Field

```
char *dbGetRelatedField(DBENTRY *pdbentry)
```

This routine returns the field name of the related field for a DCT_MENUFORM field. If it is called for any other type of field it returns NULL.

14.12.5 Example

The following is code showing use of these routines:

```
char  **value;
char  **prompt;
char  **error;
int  n;

...
n = dbAllocForm(pdbentry);
if(n<=0) {<Error>}
prompt = dbGetFormPrompt(pdbentry);
value = dbGetFormValue(pdbentry);
for(i=0; i<n; i++) {
   printf("%s (%s) : \n",prompt[i],value[i]);
   /*The follwing accepts input from stdin*/
   scanf("%s",value[i]);
}
error = dbVerifyForm(pdbentry,value);
if(error) {
   for(i=0; i<n; i++) {
      if(error[i]) printf("Error: %s (%s) %s\n", prompt[i],
         value[i],error[i]);
   }
}else {
   dbPutForm(pdbentry,value)
}
dbFreeForm(pdbentry);
```

All value strings are `MAX_STRING_SIZE` in length.

A set of form calls for a particular DBENTRY, **MUST** begin with a call to dbAllocForm and end with a call to dbFreeForm. The values returned by dbGetFormPrompt, dbGetFormValue, and dbVerifyForm are valid only between the calls to dbAllocForm and dbFreeForm.

14.13 Find Breakpoint Table

```
brkTable *dbFindBrkTable(DBBASE *pdbbase,char *name)
```

This routine returns the address of the specified breakpoint table. It is normally used by the runtime breakpoint conversion routines so will not be discussed further.

14.14 Dump Routines

```
void dbDumpPath(DBBASE *pdbbase)
void dbDumpRecord(DBBASE *pdbbase,char *precordTypeName,
   int level);
void dbDumpMenu(DBBASE *pdbbase,char *menuName);
void dbDumpRecordType(DBBASE *pdbbase,char *recordTypeName);
void dbDumpFldDes(DBBASE *pdbbase,char *recordTypeName,
   char *fname);
void dbDumpDevice(DBBASE *pdbbase,char *recordTypeName);
void dbDumpDriver(DBBASE *pdbbase);
void dbDumpBreaktable(DBBASE *pdbbase,char *name);
void dbPvdDump(DBBASE *pdbbase,int verbose);
void dbReportDeviceConfig(DBBASE *pdbbase,FILE *report);
```

These routines are used to dump information about the database. dbDumpRecord, dbDumpMenu, and dbDumpDriver just call the corresponding dbWritexxxFP routine specifying stdout for the file. dbDumpRecDes, dbDumpFldDes, and dbDumpDevice give internal information useful on an ioc. Note that all of these commands can be executed on an ioc. Just specify pdbbase as the first argument.

14.15 Examples

14.15.1 Expand Include

This example is like the dbExpand utility, except that it doesn't allow path or macro substitution options, It reads a set of database definition files and writes all definitions to stdout. All include statements appearing in the input files are expanded.

```
/* dbExpand.c */
#include <stdlib.h>
#include <stddef.h>
#include <stdio.h>
#include <epicsPrint.h>
```

```
#include <dbStaticLib.h>

DBBASE *pdbbase = NULL;


int main(int argc,char **argv)
{
   long     status;
   int      i;
   int      arg;

   if(argc<2) {
      printf("usage: expandInclude file1.db file2.db...\n");
      exit(0);
    }
   for(i=1; i<argc; i++) {
      status = dbReadDatabase(&pdbbase,argv[i],NULL,NULL);
      if(!status) continue;
      fprintf(stderr,"For input file %s",argv[i]);
      errMessage(status,"from dbReadDatabase");
   }
   dbWriteMenuFP(pdbbase,stdout,0);
   dbWriteRecordTypeFP(pdbbase,stdout,0);
   dbWriteDeviceFP(pdbbase.stdout);
   dbWriteDriverFP(pdbbase.stdout);
   dbWriteRecordFP(pdbbase,stdout,0,0);
   return(0);
}
```

14.15.2 dbDumpRecords

NOTE: This example is similar but not identical to the actual `dbDumpRecords` routine.

The following example demonstrates how to use the database access routines. The example shows how to locate each record and display each field.

```
void dbDumpRecords(DBBASE *pdbbase)
{
   DBENTRY  *pdbentry;
   long  status;

   pdbentry = dbAllocEntry(pdbbase);
   status = dbFirstRecordType(pdbentry);
   if(status) {printf(”No record descriptions\n”);return;}
   while(!status) {
      printf(”record type: %s”,dbGetRecordTypeName(pdbentry));
      status = dbFirstRecord(pdbentry);
      if(status) printf(”  No Records\n”);
      else printf(”\n  Record:%s\n”,dbGetRecordName(pdbentry));
      while(!status) {
         status = dbFirstField(pdbentry,TRUE);
         if(status) printf(”    No Fields\n”);
```

```
        while(!status) {
           printf("    %s:%s",dbGetFieldName(pdbentry),
              dbGetString(pdbentry));
           status=dbNextField(pdbentry,TRUE);
        }
        status = dbNextRecord(pdbentry);
     }
     status = dbNextRecordType(pdbentry);
  }
  printf("End of all Records\n");
  dbFreeEntry(pdbentry);
}
```

Chapter 15: Runtime Database Access

15.1 Overview

This chapter describes routines for manipulating and accessing an initialized IOC database.

This chapter is divided into the following sections:

- Database related include files. All of interest are listed and those of general interest are discussed briefly.
- Runtime database access overview.
- Description of each runtime database access routine.
- Runtime modification of link fields.
- Lock Set Routines
- Database to Channel Access Routines
- Old Database Access. This is the interface still used by Channel Access and thus by Channel Access clients.

15.2 Database Include Files

Directory `base/include` contains a number of database related include files. Of interest to this chapter are:

- **dbDefs.h**: Miscellaneous database related definitions
- **dbFldTypes.h**: Field type definitions
- **dbAccess.h**: Runtime database access definitions.
- **link.h**: Definitions for link fields.

15.2.1 dbDefs.h

This file contains a number of database related definitions. The most important are:

- **PVNAME_SZ**: The number of characters allowed in the record name.
- **FLDNAME_SZ**: The number of characters formerly allowed in a field name. This restriction no longer applies in any base software except `dbCaLink.c`. THIS SHOULD BE FIXED. It is unknown what effect removing this restriction will have on Channel Access Clients.
- **MAX_STRING_SIZE**: The maximum string size for string fields or menu choices.
- **DB_MAX_CHOICES**: The maximum number of choices for a choice field.

15.2.2 dbFldTypes.h

This file defines the possible field types. A field's type is perhaps its most important attribute. Changing the possible field types is a fundamental change to the IOC software, because many IOC software components are aware of the field types.

The field types are:

- **DBF_STRING**: ASCII character string
- **DBF_CHAR**: Signed character
- **DBF_UCHAR**: Unsigned character
- **DBF_SHORT**: Short integer
- **DBF_USHORT**: Unsigned short integer
- **DBF_LONG**: Long integer
- **DBF_ULONG**: Unsigned long integer
- **DBF_FLOAT**: Floating point number
- **DBF_DOUBLE**: Double precision float
- **DBF_ENUM**: An enumerated field
- **DBF_MENU**: A menu choice field
- **DBF_DEVICE**: A device choice field
- **DBF_INLINK**: Input Link
- **DBF_OUTLINK**: Output Link
- **DBF_FWDLINK**: Forward Link
- **DBF_NOACCESS**: A private field for use by record access routines

A field of type `DBF_STRING`, ..., `DBF_DOUBLE` can be a scalar or an array. A `DBF_STRING` field contains a `NULL` terminated ascii string. The field types `DBF_CHAR`, ..., `DBF_DOUBLE` correspond to the standard C data types.

`DBF_ENUM` is used for enumerated items, which is analogous to the C language enumeration. An example of an enum field is field `VAL` of a multi bit binary record.

The field types `DBF_ENUM`, `DBF_MENU`, and `DBF_DEVICE` all have an associated set of ASCII strings defining the choices. For a `DBF_ENUM`, the record support module supplies values and thus are not available for static database access. The database access routines locate the choice strings for the other types.

`DBF_INLINK` and `DBF_OUTLINK` specify link fields. A link field can refer to a signal located in a hardware module, to a field located in a database record in the same IOC, or to a field located in a record in another IOC. A `DBF_FWDLINK` can only refer to a record in the same IOC. Link fields are described in a later chapter.

`DBF_INLINK` (input), `DBF_OUTLINK` (output), and `DBF_FWDLINK` (forward) specify that the field is a link structure as defined in `link.h`. There are three classes of links:

1. Constant - The value associated with the field is a floating point value initialized with a constant value. This is somewhat of a misnomer because constant link fields can be modified via `dbPutField` or `dbPutLink`.
2. Hardware links - The link contains a data structure which describes a signal connected to a particular hardware bus. See `link.h` for a description of the bus types currently supported.
3. Process Variable Links - This is one of three types:
   a. PV_LINK: The process variable name.
   b. DB_LINK: A reference to a process variable in the same IOC.
   c. CA_LINK: A reference to a variable located in another IOC.

DCT always creates a `PV_LINK`. When the IOC is initialized each `PV_LINK` is converted either to a `DB_LINK` or a `CA_LINK`.

`DBF_NOACCESS` fields are for private use by record processing routines.

15.2.3 dbAccess.h

This file is the interface definition for the run time database access library, i.e. for the routines described in this chapter.

An important structure defined in this header file is `DBADDR`

```
typedef struct dbAddr{
   struct dbCommon *precord;/* address of record*/
   void     *pfield;    /* address of field*/
   void     *pfldDes;   /* address of struct fldDes*/
   void     *asPvt;     /* Access Security Private*/
   long     no_elements; /* number of elements (arrays)*/
   short    field_type; /* type of database field*/
   short    field_size; /* size (bytes) of the field*/
   short    special;    /* special processing*/
   short    dbr_field_type; /*optimal database request type*/
}DBADDR;
```

- **precord**: Address of record. Note that its type is a pointer to a structure defining the fields common to all record types. The common fields appear at the beginning of each record. A record support module can cast `precord` to point to the specific record type.
- **pfield**: Address of the field within the record. Note that `pfield` provides direct access to the data value.
- **pfldDes**: This points to a structure containing all details concerning the field. See Chapter "Database Structures" for details.
- **asPvt**: A field used by access security.
- **no_elements**: A string or numeric field can be either a scalar or an array. For scalar fields `no_elements` has the value 1. For array fields it is the maximum number of elements that can be stored in the array.
- **field_type**: Field type.
- **field_size**: Size of one element of the field.
- **special**: Some fields require special processing. This specifies the type. Special processing is described later in this manual.
- **dbr_field_type**: This specifies the optimal database request type for this field, i.e. the request type that will require the least CPU overhead.

NOTE: `pfield`, `no_elements`, `field_type`, `field_size`, `special`, and `dbr_field_type` can all be set by record support (`cvt_dbaddr`). Thus `field_type`, `field_size`, and `special` can differ from that specified by `pfldDes`.

15.2.4 link.h

This header file describes the various types of link fields supported by EPICS.

15.3 Runtime Database Access Overview

With the exception of record and device support, all access to the database is via the channel or database access routines. Even record support routines access other records only via database or channel access. Channel Access, in turn, accesses the database via database access.

Perhaps the easiest way to describe the database access layer is to list and briefly describe the set of routines that constitute database access. This provides a good look at the facilities provided by the database.

Before describing database access, one caution must be mentioned. The only way to communicate with an IOC database from outside the IOC is via Channel Access. In addition, any special purpose software, i.e. any software not described in this document, should communicate with the database via Channel Access, not database access, even if it resides in the

same IOC as the database. Since Channel Access provides network independent access to a database, it must ultimately call database access routines. The database access interface was changed in 1991, but Channel Access was never changed. Instead a module was written which translates old style database access calls to new. This interface between the old and new style database access calls is discussed in the last section of this chapter.

The database access routines are:

- **dbNameToAddr**: Locate a database variable.

- **dbGetField**: Get values associated with a database variable.
- **dbGetLink**: Get value of field referenced by database link (Macro)
- **dbGetLinkValue**: Get value of field referenced by database link (Subroutine)
- **dbGet**: Routine called by `dbGetLinkValue` and `dbGetField`

- **dbPutField**: Change the value of a database variable.
- **dbPutLink**: Change value referenced by database link (Macro)
- **dbPutLinkValue**: Change value referenced by database link (Subroutine)
- **dbPut**: Routine called by `dbPutxxx` functions.
- **dbPutNotify**: A database put with notification on completion
- **dbNotifyCancel**: Cancel `dbPutNotify`
- **dbNotifyAdd**: Add a new record for to notify set.
- **dbNotifyCompletion**: Announce that put notify is complete.

- **dbBufferSize**: Determine number of bytes in request buffer.
- **dbValueSize**: Number of bytes for a value field.
- **dbGetRset**: Get pointer to Record Support Entry Table
- **dbIsValueField**: Is this field the VAL field.
- **dbGetFieldIndex**: Get field index. The first field in a record has index 0.
- **dbGetNelement:** Get number of elements in the field
- **dbIsLinkConnected**: Is the link field connected.
- **dbGetPdbAddrFromLink**: Get address of DBADDR.
- **dbGetLinkDBFtype**: Get field type of link.
- **dbGetControlLimits**: Get Control Limits.
- **dbGetGraphicLimits**: Get Graphic Limits.
- **dbGetAlarmLimits**: Get Alarm Limits
- **dbGetPrecision**: Get Precision
- **dbGetUnits**: Get Units
- **dbGetNelements**: Get Number of Elements
- **dbGetSevr**: Get Severity
- **dbGetTimeStamp**: Get Time Stamp

- **dbPutAttribute** Give a value to a record attribute.

- **dbScanPassive**: Process record if it is passive.
- **dbScanLink**: Process record referenced by link if it is passive.
- **dbProcess**: Process Record
- **dbScanFwdLink**: Scan a forward link.

15.3.1 Database Request Types and Options

Before describing database access structures, it is necessary to describe database request types and request options. When `dbPutField` or `dbGetField` are called one of the arguments is a database request type. This argument has one of the following values:

- **DBR_STRING**: Value is a `NULL` terminated string
- **DBR_CHAR**: Value is a signed char
- **DBR_UCHAR**: Value is an unsigned char
- **DBR_SHORT**: Value is a short integer
- **DBR_USHORT**: Value is an unsigned short integer
- **DBR_LONG**: Value is a long integer
- **DBR_ULONG**: Value is an unsigned long integer
- **DBR_FLOAT**: Value is an IEEE floating point value
- **DBR_DOUBLE**: Value is an IEEE double precision floating point value
- **DBR_ENUM**: Value is a short which is the enum item
- **DBR_PUT_ACKT**: Value is an unsigned short for setting the `ACKT`.
- **DBR_PUT_ACKS**: Value is an unsigned short for global alarm acknowledgment.

The request types `DBR_STRING`,..., `DBR_DOUBLE` correspond exactly to valid data types for database fields. `DBR_ENUM` corresponds to database fields that represent a set of choices or options. In particular it corresponds to the fields types `DBF_ENUM`, `DBF_DEVICE`, and `DBF_MENU`. The complete set of database field types are defined in `dbFldTypes.h`. `DBR_PUT_ACKT` and `DBR_PUT_ACKS` are used to perform global alarm acknowledgment.

`dbGetField` also accepts argument options which is a mask containing a bit for each additional type of information the caller desires. The complete set of options is:

- **DBR_STATUS**: returns the alarm status and severity
- **DBR_UNITS**: returns a string specifying the engineering units
- **DBR_PRECISION**: returns a long integer specifying floating point precision.
- **DBR_TIME**: returns the time
- **DBR_ENUM_STRS**: returns an array of strings
- **DBR_GR_LONG**: returns graphics info as long values
- **DBR_GR_DOUBLE**: returns graphics info as double values
- **DBR_CTRL_LONG**: returns control info as long values
- **DBR_CTRL_DOUBLE**: returns control info as double values
- **DBR_AL_LONG**: returns alarm info as long values
- **DBR_AL_DOUBLE**: returns alarm info as double values

15.3.2 Options
Example

The file `dbAccess.h` contains macros for using options. A brief example should show how they are used. The following example defines a buffer to accept an array of up to ten float values. In addition it contains fields for options `DBR_STATUS` and `DBR_TIME`.

```
struct buffer {
   DBRstatus
   DBRtime
   float  value[10];
} buffer;
```

The associated dbGetField call is:

```
long options,number_elements,status;
    ...
options = DBR_STATUS | DBR_TIME;
number_elements = 10;
status = dbGetField(paddr,DBR_FLOAT,&buffer,&options,&number_elements);
```

Consult dbAccess.h for a complete list of macros.

Structure dbAddr contains a field dbr_field_type. This field is the database request type that most closely matches the database field type. Using this request type will put the smallest load on the IOC.

Channel Access provides routines similar to dbGetField, and dbPutField. It provides remote access to dbGetField, dbPutField, and to the database monitors described below.

15.3.3 ACKT and ACKS

The request types DBR_PUT_ACKT and DBR_PUT_ACKS are used for global alarm acknowledgment. The alarm handler uses these requests. For each of these types the user (normally channel access) passes an unsigned short value. This value represents:

DBR_PUT_ACKT - Do transient alarms have to be acknowledged? (0,1) means (no, yes).

DBR_PUT_ACKS - The highest alarm severity to acknowledge. If the current alarm severity is less then or equal to this value the alarm is acknowledged.

15.4 Database Access Routines

15.4.1 dbNameToAddr

Locate a process variable, format:

```
long dbNameToAddr(
   char  *pname, /*ptr to process variable name */
   struct dbAddr  *paddr);
```

The most important goal of database access can be stated simply: Provide quick access to database records and fields within records. The basic rules are:

- Call dbNameToAddr once and only once for each field to be accessed.
- Read field values via dbGetField and write values via dbPutField.

The routines described in this subsection are used by channel access, sequence programs, etc. Record processing routines, however, use the routines described in the next section rather then dbGetField and dbPutField.

Given a process variable name, this routine locates the process variable and fills in the fields of structure dbAddr. The format for a process variable name is:

“<record_name>.<field_name>”

For example the value field of a record with record name sample_name is:

“sample_name.VAL”.

The record name is case sensitive. Field names always consist of all upper case letters.

`dbNameToAddr` locates a record via a process variable directory (PVD). It fills in a structure (`dbAddr`) describing the field. `dbAddr` contains the address of the record and also the field. Thus other routines can locate the record and field without a search. Although the PVD allows the record to be located via a hash algorithm and the field within a record via a binary search, it still takes about 80 microseconds (25MHz 68040) to located a process variable. Once located the `dbAddr` structure allows the process variable to be accessed directly.

15.4.2 Get Routines

15.4.2.1 dbGetField

Get values associated with a process variable, format:

```
long dbGetField(
   struct dbAddr  *paddr,
   short  dbrType,  /* DBR_xxx */
   void   *pbuffer,  /*addr of returned data */
   long   *options,  /*addr of options */
   long   *nRequest,  /*addr of number of elements */
   void   *pfl);  /*used by monitor routines */
```

Thus routine locks, calls `dbGet`, and unlocks.

15.4.2.2 dbGetLink and dbGetLinkValue

Get value from the field referenced by a database link, format:

```
long dbGetLink(
   struct db_link  *pdbLink,/*addr of database link*/
   short  dbrType,/* DBR_xxx*/
   void  *pbuffer,/*addr of returned data*/
   long  *options,/*addr of options*/
   long  *nRequest);/*addr of number of elements desired*/

NOTES:
   1) options can be NULL if no options are desired.
   2) nRequest can be NULL for a scalar.
```

`dbGetLink` is actually a macro that calls `dbGetLinkValue`. The macro skips the call for constant links. User code should never call `dbGetLinkValue`.

This routine is called by database access itself and by record support and/or device support routines in order to get values for input links. The value can be obtained directly from other records or via a channel access client. This routine honors the link options (process and maximize severity). In addition it has code that optimizes the case of no options and scalar.

15.4.2.3 dbGet

Get values associated with a process variable, format:

```
long dbGet(
   struct dbAddr*paddr,
   short dbrType, /* DBR_xxx*/
   void  *pbuffer,/*addr of returned data
   long  *options,/*addr of options*/
   long  *nRequest,/*addr of number of elements*/
   void  *pfl);   /*used by monitor routines*/
```

Thus routine retrieves the data referenced by `paddr` and converts it to the format specified by `dbrType`.

"`options`" is a read/write field. Upon entry to `dbGet`, `options` specifies the desired options. When `dbGetField` returns, `options` specifies the options actually honored. If an option is not honored, the corresponding fields in buffer are filled with zeros.

"`nRequest`" is also a read/write field. Upon entry to `dbGet` it specifies the maximum number of data elements the caller is willing to receive. When `dbGet` returns it equals the actual number of elements returned. It is permissible to request zero elements. This is useful when only option data is desired.

"`pfl`" is a field used by the Channel Access monitor routines. All other users must set `pfl=NULL`.

`dbGet` calls one of a number of conversion routines in order to convert data from the `DBF` types to the `DBR` types. It calls record support routines for special cases such as arrays. For example, if the number of field elements is greater then 1 and record support routine `get_array_info` exists, then it is called. It returns two values: the current number of valid field elements and an offset. The number of valid elements may not match `dbAddr.no_elements`, which is really the maximum number of elements allowed. The offset is for use by records which implement circular buffers.

15.4.3 Put Routines

15.4.3.1 dbPutField

Change the value of a process variable, format:

```
long dbPutField(
   structdbAddr *paddr,
   short dbrType, /* DBR_xxx*/
   void  *pbuffer,/*addr of data*/
   long  nRequest);/*number of elements to write*/
```

This routine is responsible for accepting data in one of the `DBR_xxx` formats, converting it as necessary, and modifying the database. Similar to `dbGetField`, this routine calls one of a number of conversion routines to do the actual conversion and relies on record support routines to handle arrays and other special cases.

It should be noted that routine `dbPut` does most of the work. The actual algorithm for `dbPutField` is:

1. If the `DISP` field is `TRUE` then, unless it is the `DISP` field itself which is being modified, the field is not written.
2. The record is locked.
3. `dbPut` is called.
4. If the `dbPut` is successful then:
   If this is the `PROC` field or if both of the following are `TRUE`: 1) the field is a process passive field, 2) the record is passive.
   a. If the record is already active ask for the record to be reprocessed when it completes.
   b. Call `dbScanPassive` after setting `putf` `TRUE` to show the process request came from `dbPutField`.
5. The record is unlocked.

15.4.3.2 dbPutLink and dbPutLinkValue

Change the value referenced by a database link, format:

```
long dbPutLink(
   structdb_link  *pdbLink,/*addr of database link*/
   short dbrType, /* DBR_xxx*/
   void  *pbuffer,/*addr of data to write*/
   long  nRequest);/*number of elements to write*/
```

`dbPutLink` is actually a macro that calls `dbPutLinkValue`. The macro skips the call for constant links. User code should never call `dbPutLinkValue`.

This routine is called by database access itself and by record support and/or device support routines in order to put values into other database records via output links.

For Channel Access links it calls `dbCaPutLink`.

For database links it performs the following functions:

1. Calls `dbPut`.
2. Implements maximize severity.
3. If the field being referenced is `PROC` or if both of the following are true: 1) `process_passive` is `TRUE` and 2) the record is passive then:
   a. If the record is already active because of a `dbPutField` request then ask for the record to be reprocessed when it completes.
   b. otherwise call `dbScanPassive`.

15.4.3.3 dbPut

Put a value to a database field, format:

```
long dbPut(
   struct dbAddr  *paddr,
   short dbrType, /* DBR_xxx*/
   void  *pbuffer,/*addr of data*/
   long  nRequest);/*number of elements to write*/
```

This routine is responsible for accepting data in one of the `DBR_xxx` formats, converting it as necessary, and modifying the database. Similar to `dbGet`, this routine calls one of a number of conversion routines to do the actual conversion and relies on record support routines to handle arrays and other special cases.

15.4.4 Put Notify Routines

`dbPutNotify` is a request to notify the caller when all records that are processed as a result of a put complete processing. The complication occurs because of record linking and asynchronous records. A put can cause an entire chain of records to process. If any record is an asynchronous record then record completion means asynchronous completion.

The following rules are implemented:

1. If a putNotify is already active on the record to which the put is directed, `dbPutNotify` just returns `S_db_Blocked` without calling the callback routine.

   In all other cases, i.e. the cases for the following rules, the callback routine will be always be called unless `dbNotifyCancel` is called.
2. The user supplied callback is called when all processing is complete or when an error is detected. If everything completes synchronously the callback routine will be called BEFORE `dbPutNotify` returns.
3. The user supplied callback routine must not issue any calls that block such as Unix I/O requests.
4. In general a set of records may need to be processed as a result of a single `dbPutNotify`. If database access detects that another `dbPutNotify` request is active on any record in the set, other then the record referenced by the `dbPutNotify`, then the `dbPutNotify` request will restarted
5. If a record in the set is found to be active because of a `dbPutField` request then when that record completes the `dbPutNotify` will be restarted.

6. If a record is found to already be active because of the original `dbPutNotify` request then nothing is done. This is what is done now and any attempt to do otherwise could easily cause existing databases to go into an infinite processing loop.

It is expected that the caller will arrange a timeout in case the `dbPutNotify` takes too long. In this case the caller can call `dbNotifyCancel`

15.4.4.1 dbPutNotify

Perform a database put and notify when record processing is complete.

Format:

```
   long dbPutNotify(PUTNOTIFY *pputnotify);

   where PUTNOTIFY is

   typedef struct putNotify{
      void     (*userCallback)(struct putNotify *);
      DBADDR   *paddr;     /*dbAddr set by dbNameToAddr*/
      void     *pbuffer;   /*address of data*/
      long     nRequest;   /*number of elements to be written*/
      short    dbrType;    /*database request type*/
      void     *usrPvt;    /*for private use of user*/
      /*The following is status of request.Set by dbPutNotify*/
      long     status;
      /*fields private to database access*/
      ...
}PUTNOTIFY;
```

The caller must allocate a `PUTNOTIFY` structure and set the fields:

```
   userCallback - Routine that is called upon completion
   paddr - address of a DBADDR
   pbuffer - address of data
   nRequest - number of data elements
   dbrType - database request type
   usrPvt - a void * field that caller can use as needed.
```

The status value returned by `dbPutNotify` is either:

- **S_db_Pending**: Success: Callback may already have been called or will be called later.
- **S_db_Blocked**: The request failed because a `dbPutNotify` is already active in the record to which the put is directed.

When the user supplied callback is called, the status value stored in `PUTNOTIFY` is one of the following:

- **0**: Success
- **S_xxxx**: The request failed due to some other error.

The user callback is always called unless `dbPutNotify` returns S_db_Blocked or `dbNotifyCancel` is called before the put notify competes.

15.4.4.2 dbNotifyCancel

Cancel an outstanding `dbPutNotify`.

Format:

```
void dbNotifyCancel(PUTNOTIFY *pputnotify);
```

This cancels an active `dbPutNotify`.

15.4.4.3 dbNotifyAdd

This routine is called by database access itself. It should never be called by user code.

15.4.4.4 dbNotifyCompletion

This routine is called by database access itself. It should never be called by user code.

15.4.5 Utility Routines

15.4.5.1 dbBufferSize

Determine the buffer size for a `dbGetField` request, format:

```
long dbBufferSize(
   short dbrType, /* DBR_xxx*/
   long  options, /* options mask*/
   long  nRequest);/* number of elements*/
```

This routine returns the number of bytes that will be returned to `dbGetField` if the request type, options, and number of elements are specified as given to `dbBufferSize`. Thus it can be used to allocate storage for buffers.

NOTE: This should become a Channel Access routine

15.4.5.2 dbValueSize

Determine the size a value field, format:

```
dbValueSize(short  dbrType);/* DBR_xxx*/
```

This routine returns the number of bytes for each element of type `dbrType`.

NOTE: This should become a Channel Access routine

15.4.5.3 dbGetRset

Get address of a record support entry table.

Format:

```
struct rset *dbGetRset(DBADDR *paddr);
```

This routine returns the address of the record support entry table for the record referenced by the `DBADDR`.

15.4.5.4 dbIsValueField

Is this field the VAL field of the record?

Format:

```
int dbIsValueField(struct dbFldDes *pdbFldDes);
```

This is the routine that makes the `get_value` record support routine obsolete.

15.4.5.5 dbGetFieldIndex

Get field index.

Format:

```
int dbGetFieldIndex(DBADDR *paddr);
```

Record support routines such as `special` and `cvt_dbaddr` need to know which field the `DBADDR` references. The include file describing the record contains define statements for each field. `dbGetFieldIndex` returns the index that can be matched against the define statements (normally via a switch statement).

15.4.5.6 dbGetNelements

Get number of elements in a field.

Format:

```
long dbGetNelements(struct link *plink,long *nelements);
```

This sets `*nelements` to the number of elements in the field referenced by plink.

15.4.5.7 dbIsLinkConnected

Is the link connected.

Format:

```
int dbIsLinkConnected(struct link *plink);
```

This routine returns (TRUE, FALSE) if the link (is, is not) connected.

15.4.5.8 dbGetPdbAddrFromLink

Get address of DBADDR from link.

Format:

```
DBADDR *dbGetPdbAddrFromLink(struct link *plink);
```

This macro returns the address of the DBADDR for a database link and NULL for all other link types.

15.4.5.9 dbGetLinkDBFtype

Get field type of a link.

Format:

```
int dbGetLinkDBFtype(struct link *plink);
```

15.4.5.10 dbGetControlLimits

Get Control Limits for link.

Format:

```
long dbGetControlLimits(struct link *plink,double *low, double *high);
```

15.4.5.11 dbGetGraphicLimits

Get Graphic Limits for link.

Format:

```
long dbGetGraphicLimits(struct link *plink,double *low, double *high);
```

15.4.5.12 dbGetAlarmLimits

Get Alarm Limits for link.

Format:

```
long dbGetAlarmLimits(struct link *plink,
   double lolo,double *low, double *high,double hihi);
```

15.4.5.13 dbGetPrecision

Get Precision for link.

Format:

```
long dbGetPrecision(struct link *plink,short *precision);
```

15.4.5.14 dbGetUnits

Get Units for link.

Format:

```
long dbGetUnits(struct link *plink,char *units,int unitsSize);
```

15.4.5.15 dbGetSevr

Get Severity for link.

Format:

```
long dbGetSevr(struct link *plink,short *sevr);
```

15.4.5.16 dbGetTimeStamp

Get Time Stamp for record containing link.

Format:

```
long dbGetTimeStamp(struct link *plink,TS_STAMP *pstamp);
```

15.4.6 Attribute Routine

15.4.6.1 dbPutAttribute

Give a value to a record attribute.

```
long dbPutAttribute(char *recordTypename,
    char *name,char*value);
```

This sets the record attribute `name` for record type `recordTypename` to `value`. For example the following would set the version for the ai record.

```
dbPutAttribute("ai","VERS","V800.6.95")
```

15.4.7 Process Routines

15.4.7.1 dbScanPassive
dbScanLink
dbScanFwdLink

Process record if it is passive, format:

```
long dbScanPassive(
   struct dbCommon  *pfrom,
   struct dbCommon  *pto);   /* addr of record*/
long dbScanLink(
   struct dbCommon *pfrom,
   struct dbCommon *pto);
void dbScanFwdLink(struct link *plink);
```

`dbScanPassive` and `dbScanLink` are given the record requesting the scan, which may be `NULL`, and the record to be processed. If the record is passive and `pact=FALSE` then `dbProcess` is called. Note that these routine are called by `dbGetLink`, `dbPutField`, and by `recGblFwdLink.`

`dbScanFwdLink` is given a link that must be a forward link field. It follows the rules for scanning a forward link. That is for DB_LINKs it calls dbScanPassive and for CA_LINKS it does a dbCaPutLink if the PROC field of record is being addressed.

15.4.7.2 dbProcess

Request that a database record be processed, format:

```
long dbProcess(struct dbCommom  *precord);
```

Request that record be processed. Record processing is described in detail below.

15.5 Runtime Link Modification

Database links can be changed at run time but only via a channel access client, i.e. via calls to `dbPutField` but not to `dbPutLink`. The following restrictions apply:

- Only `DBR_STRING` is allowed.
- If a link is being changed to a different hardware link type then the `DTYP` field must be modified before the link field.
- The syntax for the string field is exactly the same as described for link fields in chapter “Database Definition”

NOTE: For this release modification to/from hardware links has not been tested. In addition modification to record/device support will be needed in order to properly support dynamic modification of hardware links.

15.6 Channel Access Monitors

There are facilities within the Channel Access communication infrastructure which allow the value of a process variable to be monitored by a channel access client. It is a responsibility of record support (and db common) to notify the channel access server when the internal state of a process variable has been modified. State changes can include changes in the value of a process variable and also changes in the alarm state of a process variable. The routine "db_post_events()" is called to inform the channel access server that a process variable state change event has occurred.

```
   #include <caeventmask.h>

int db_post_events(void *precord, void *pfield,
   unsigned intselect);
```

The first argument, "precord", should be passed a pointer to the record which is posting the event(s). The second argument, "pfield", should be passed a pointer to the field in the record that contains the process variable that has been modified. The third argument, "select", should be passed an event select mask. This mask can be any logical or combination of {DBE_VALUE, DBE_LOG, DBE_ALARM}. A description of the purpose of each flag in the event select mask follows.

- DBE_VALUE This indicates that a significant change in the process variable's value has occurred. A significant change is often determined by the magnitude of the monitor "dead band" field in the record.
- DBE_LOG This indicates that a change in the process variable's value significant to archival clients has occurred. A significant change to archival clients is often determined by the magnitude of the archive "dead band" field in the record.
- DBE_ALARM This indicates that a change in the process variable's alarm state has occurred.

The function "db_post_events()" returns 0 if it is successful and -1 if it fails. It appears to be common practice within EPICS record support to ignore the status from "db_post_events()". At this time "db_post_events()" always returns 0 (success). because so many records at this time depend on this behavior it is unlikely that it will be changed in the future.

The function "db_post_events()" is written so that record support will never be blocked attempting to post an event because a slow client is not able to process events fast enough. Each call to "db_post_events()" causes the current value, alarm status, and time stamp for the field to be copied into a ring buffer. The thread calling "db_post_events()" will not be delayed by any network or memory allocation overhead. A lower priority thread in the server is responsible for transferring the events in the event queue to the channel access clients that may be monitoring the process variable.

Currently, when an event is posted for a DBF_STRING field or a field containing array data the value is NOT saved in the ring buffer and the client will receive whatever value happens to be in the field when the lower priority thread transfers the event to the client. This behavior may be improved in the future.

15.7 Lock Set Routines

User code only calls `dbScanLock` and `dbScanUnlock`. All other routines are called by `iocCore`.

15.7.0.1 dbScanLock

Lock a lock set:

```
   long void dbScanLock(struct dbCommon *precord);
```

Lock the lock set to which the specified record belongs.

15.7.0.2 dbScanUnlock

Unlock a lock set:

```
long void dbScanUnlock(struct dbCommon *precord);
```

Lock the lock set to which the specified record belongs

15.7.0.3 dbLockGetLockId

Get lock set id:

```
long dbLockGetLockId(struct dbCommon *precord);
```

Each lock set is assigned a unique ID. This routine retrieves it. This is most useful to determine if two records are in the same lock set.

15.7.0.4 dbLockInitRecords

Determine lock sets for each record in database.

```
void dbLockInitRecords(dbBase *pdbbase);
```

Called by `iocInit`.

15.7.0.5 dbLockSetMerge

Merge records into same lock set.

```
void dbLockSetMerge(struct dbCommon *pfirst,
   struct dbCommon *psecond);
```

If specified records are not in same lock set the lock sets are merged. Called by dbLockInitRecords and also when links are modified by `dbPutField`.

15.7.0.6 dbLockSetSplitSl

Recompute lock sets for given lock set

```
void dbLockSetSplit(struct dbCommon *psource);
```

This is called when `dbPutField` modifys links.

15.7.0.7 dbLockSetGblLock

Global lock for modifying links.

```
void dbLockSetGblLock(void);
```

Only one task at a time can modify link fields. This routine provides a global lock to prevent conflicts.

15.7.0.8 dbLockSetGblUnlock

Unlock the global lock.

```
void dbLockSetGblUnlock(void);
```

15.7.0.9 dbLockSetRecordLock

If record is not already scan locked lock it.

```
void dbLockSetRecordLock(struct dbCommon *precord);
```

15.8 Channel Access Database Links

The routines described here are used to create and manipulate Channel Access connections from database input or output links. At IOC initialization an attempt is made to convert all process variable links to database links. For any link that fails, it is assumed that the link is a Channel Access link, i.e. a link to a process variable defined in another IOC. The routines described here are used to manage these links. User code never needs to call these routines. They are automatically called by iocInit and database access.

At `iocInit` time a task `dbCaLink` is spawned. This task is a channel access client that issues channel access requests for all channel access links in the database. For each link a channel access search request is issued. When the search succeeds a channel access monitor is established. The monitor is issued specifying `ca_field_type` and `ca_element_count`. A buffer is also allocated to hold monitor return data as well as severity. When `dbCaGetLink` is called data is taken from the buffer, converted if necessary, and placed in the location specified by the `pbuffer` argument.

When the first `dbCaPutLink` is called for a link an output buffer is allocated, again using `ca_field_type` and `ca_element_count`. The data specified by the pbuffer argument is converted and stored in the buffer. A request is then made to `dbCaLink` task to issue a `ca_put`. Subsequent calls to `dbCaPutLink` reuse the same buffer.

15.8.1 Basic Routines

These routines are normally only called by database access, i.e. they are not called by record support modules.

15.8.1.1 dbCaLinkInit

Called by `iocInit` to initialize the `dbCa` library

```
void dbCaLinkInit(void);
```

15.8.1.2 dbCaAddLink

Add a new channel access link

```
void dbCaAddLink(struct link *plink);
```

15.8.1.3 dbCaRemoveLink

Remove channel access link.

```
void dbCaRemoveLink(struct link *plink);
```

15.8.1.4 dbCaGetLink

Get link value

```
long dbCaGetLink(struct link *plink,short dbrType,
   void *pbuffer,unsigned short *psevr,long *nRequest);
```

15.8.1.5 dbCaPutLink

Put link value

```
long dbCaPutLink(struct link *plink,short dbrType,
   void *buffering nRequest);
```

15.8.1.6 dbCaGetAttributes

Get Attributes

```
long dbCaGetAttributes(struct link *plink,
   void (*callback)(void *usrPvt),void *usrPvt);
```

15.8.1.7 dbCaGetControlLimits

Get Control Limits

```
long dbCaGetControlLimits(struct link *plink,double *low, double *high);
```

15.8.1.8 dbCaGetGraphicLimits

Get graphic Limits

```
long dbCaGetGraphicLimits(struct link *plink,double *low, double *high);
```

15.8.1.9 dbCaGetAlarmLimits

Get Alarm Limits

```
long dbCaGetAlarmLimits(struct link *plink,
   double *lolo, double *low, double *high, double *hihi);
```

15.8.1.10 dbCaGetPrecision

Get Precision

```
long dbCaGetPrecision(struct link *plink,short *precision);
```

15.8.1.11 dbCaGetUnits

Get Units

```
long dbCaGetUnits(struct link *plink,char *units,int unitsSize);
```

15.8.1.12 dbCaGetNelements

Get Number of Elements

```
long dbCaGetNelements(struct link *plink,long *nelements);
```

This call, which returns an error if link is not connected, sets the native number of elements.

15.8.1.13 dbCaGetSevr

Get Alarm Severity

```
long dbCaGetSevr(struct link *plink,short *severity);
```

This call, which returns an error if link is not connected, sets the alarm severity.

15.8.1.14 dbCaGetTimeStamp

Get Time Stamp

```
long dbCaGetTimeStamp(struct link *plink,TS_STAMP *pstamp));
```

15.8.1.15 dbCaIsLinkConnected

Is Channel Connected

```
int dbCaIsLinkConnected(struct link *plink)
```

This routine returns (TRUE, FALSE) if the link (is, is not) connected.

15.8.1.16 dbCaGetLinkDBFtype

Get link type

```
int dbCaGetLinkDBFtype(struct link *plink);
```

Chapter 16: Device Support Library

NOTE: For 3.14 this is only available on vxWorks

16.1 Overview

Include file `devLib.h` provides definitions for a library of routines useful for device and driver modules. These are a new addition to EPICS and are not yet used by all device/driver support modules. Until they are, the registration routines will not prevent addressing conflicts caused by multiple device/drivers trying to use the same VME addresses.

16.2 Registering VME Addresses

16.2.1 Definitions of Address Types

```
typedef enum {
   atVMEA16,
   atVMEA24,
   atVMEA32,
   atLast /* atLast must be the last enum in this list */
   } epicsAddressType;

char  *epicsAddressTypeName[]
   = {
   ”VME A16”,
   ”VME A24”,
   ”VME A32”
   };
int EPICStovxWorksAddrType[]
   = {
   VME_AM_SUP_SHORT_IO,
   VME_AM_STD_SUP_DATA,
   VME_AM_EXT_SUP_DATA
};
```

16.2.2 Register Address

```
long  devRegisterAddress(
const char *pOwnerName,
   epicsAddressType  addrType,
   void  *baseAddress,
```

```
      unsigned  size,
      void  **pLocalAddress);
```

This routine is called to register a VME address. This routine keeps a list of all VME addresses requested and returns an error message if an attempt is made to register any addresses that are already being used. `*pLocalAddress` is set equal to the address as seen by the caller.

16.2.3 Unregister Address

```
   long  devUnregisterAddress(
      epicsAddressType  addrType,
      void  *baseAddress,
      const char *pOwnerName);
```

This routine releases addresses previously registered by a call to `devRegisterAddress`.

16.3 Interrupt Connect Routines

16.3.1 Definitions of Interrupt Types

```
   typedef enum {intCPU, intVME, intVXI} epicsInterruptType;
```

16.3.2 Connect

```
   long  devConnectInterrupt(
      epicsInterruptType      intType,
      unsigned  vectorNumber,
      void  (*pFunction)(),
      void  *parameter);
```

16.3.3 Disconnect

```
   long  devDisconnectInterrupt(
      epicsInterruptType  intType,
      unsigned  vectorNumber);
```

16.3.4 Enable Level

```
   long  devEnableInterruptLevel(
      epicsInterruptType  intType,
      unsigned  level);
```

16.3.5 Disable Level

```
   long  devDisableInterruptLevel(
      epicsInterruptType  intType,
```

```
    unsigned  level);
```

16.4 Macros and Routines for Normalized Analog Values

16.4.1 Normalized GetField

```
long  devNormalizedGblGetField(
   long  rawValue,
   unsigned  nbits,
   DBREQUEST  *pdbrequest,
   int  pass,
   CALLBACK  *pcallback);
```

This routine is just like `recGblGetField`, except that if the request type is `DBR_FLOAT` or `DBR_DOUBLE`, the normalized value of `rawValue` is obtained, i.e. `rawValue` is converted to a value in the range 0.0<=value<.1.0

16.4.2 Convert Digital Value to a Normalized Double Value

```
#define devCreateMask(NBITS)((1<<(NBITS))-1)
#define devDigToNml(DIGITAL,NBITS) \
   (((double)(DIGITAL))/devCreateMask(NBITS))
```

16.4.3 Convert Normalized Double Value to a Digital Value

```
#define devNmlToDig(NORMAL,NBITS) \
   (((long)(NORMAL)) * devCreateMask(NBITS))
```

Chapter 17: EPICS General Purpose Tasks

17.1 Overview

This chapter describes two sets of EPICS supplied general purpose tasks: 1) Callback, and 2) Task Watchdog.

Often when writing code for an IOC there is no obvious task under which to execute. A good example is completion code for an asynchronous device support module. EPICS supplies the callback tasks for such code.

If an IOC tasks "crashes" there is normally no one monitoring the vxWorks shell to detect the problem. EPICS provides a task watchdog task which periodically checks the state of other tasks. If it finds that a monitored task has terminated or suspended it issues an error message and can also call other routines which can take additional actions. For example a subroutine record can arrange to be put into alarm if a monitored task crashes.

Since IOCs normally run autonomously, i.e. no one is monitoring the vxWorks shell, IOC code that issues `printf` calls generates errors messages that are never seen. In addition the vxWorks implementation of fprintf requires much more stack space then `printf` calls. Another problem with vxWorks is the `logMsg` facility. `logMsg` generates messages at higher priority then all other tasks except the shell. EPICS solves all of these problems via an error message handling facility. Code can call any of the routines `errMessage`, `errPrintf`, or `epicsPrintf`. Any of these result in the error message being generated by a separate low priority task. The calling task has to wait until the message is handled but other tasks are not delayed. In addition the message can be sent to a system wide error message file.

17.2 General Purpose Callback Tasks

17.2.1 Overview

EPICS provides three general purpose IOC callback tasks. The only difference between the tasks is scheduling priority: Low, Medium, and High. The low priority task runs at a priority just higher than Channel Access, the medium at a priority about equal to the median of the periodic scan tasks, and the high at a priority higher than the event scan task.The callback tasks provide a service for any software component that needs a task under which to run. The callback tasks use the task watchdog (described below). They use a rather generous stack and can thus be used for invoking record processing. For example the I/O event scanner uses the general purpose callback tasks.

The following steps must be taken in order to use the general purpose callback tasks:

1. Include callback definitions:

```
#include <callback.h>
```

2. Provide storage for a structure that is a private structure for the callback tasks:

```
CALLBACK mycallback;
```

It is permissible for this to be part of a larger structure, e.g.

```
struct {
   ...
   CALLBACK mycallback;
   ...
} ...
```

3. Call routines (actually macros) to initialize fields in `CALLBACK`:

```
callbackSetCallback(VOIDFUNCPTR, CALLBACK *);
```

This defines the callers callback routine. The first argument is the address of a function returning `VOID`. The second argument is the address of the `CALLBACK` structure.

```
callbackSetPriority(int, CALLBACK *);
```

The first argument is the priority, which can have one of the values: `priorityLow`, `priorityMedium`, or `priorityHigh`. These values are defined in `callback.h`. The second argument is again the address of the `CALLBACK` structure.

```
callbackSetUser(VOID *, CALLBACK *);
```

This call is used to save a value that can be retrieved via a call to:

```
callbackGetUser(VOID *,CALLBACK *);
```

4. Whenever a callback request is desired just call one of the following:

```
callbackRequest(CALLBACK *);
callbackRequestProcessCallback(CALLBACK *);
```

Either can be called from interrupt level code. The callback routine is passed a single argument, which is the same argument that was passed to `callbackRequest`, i.e., the address of the `CALLBACK` structure.

17.2.2 Syntax

The following calls are provided:

```
void callbackInit(void);

void callbackSetCallback(void *pcallbackFunction,
   CALLBACK *pcallback);
void callbackSetPriority(int priority, CALLBACK *pcallback);
void callbackSetUser(void *user, CALLBACK *pcallback);

void callbackRequest(CALLBACK *);
void callbackRequestProcessCallback(CALLBACK *pCallback,
   int Priority, void *pRec);

void callbackGetUser(void *user, CALLBACK *pcallback);
```

Notes:

- `callbackInit` is performed automatically when EPICS initializes and IOC. Thus user code never calls this function.
- `callbackSetCallback`, `callbackSetPriority`, `callbackSetUser`, and `callbackGetUser` are actually macros.
- `callbackRequest` and `callbackRequestProcessCallback` can both be called at interrupt level.
- `callbackRequestProcessCallback` is designed for the completion phase of asynchronous record processing. It issues the calls:

```
callbackSetCallback(ProcessCallback, pCallback);
callbackSetPriority(Priority, pCallback);
callbackSetUser(pRec, pCallback);
callbackRequest(pCallback);
```

  `ProcessCallback`, which is designed for asynchronous device completion applications, consists of the following code:

```
static void ProcessCallback(CALLBACK *pCallback)
{
   dbCommon    *pRec;
   struct rset *prset;

   callbackGetUser(pRec, pCallback);
   prset = (struct rset *)pRec->rset;
   dbScanLock(pRec);
   (*prset->process)(pRec);
   dbScanUnlock(pRec);
}
```

17.2.3 Example

An example use of the callback tasks.

```
#include <callback.h>

static structure {
   char      begid[80];
   CALLBACK callback;
   char     endid[80];
}myStruct;

void myCallback(CALLBACK *pcallback)
{
   struct myStruct *pmyStruct;
   callbackGetUser(pmyStruct,pcallback)
   printf(”begid=%s endid=%s\n”,&pmyStruct->begid[0],
      &pmStruct->endid[0]);
}
example(char *pbegid, char*pendid)
{
   strcpy(&myStruct.begid[0],pbegid);
   strcpy(&myStruct.endid[0],pendid);
   callbackSetCallback(myCallback,&myStruct.callback);
```

```
        callbackSetPriority(priorityLow,&myStruct.callback);
        callbackSetUser(&myStruct,&myStruct.callback);
        callbackRequest(&myStruct.callback);
    }
```

The example can be tested by issuing the following command to the vxWorks shell:

```
example("begin","end")
```

This simple example shows how to use the callback tasks with your own structure that contains the `CALLBACK` structure at an arbitrary location.

17.2.4 Callback Queue

The callback requests put the requests on a vxWorks ring buffer. Thus buffer is set by default to hold 2000 requests. This value can bechanged by calling `callbackSetQueueSize` before `incInit` in the startup file. The syntax is:

```
int callbackSetQueueSize(int size)
```

17.3 Task Watchdog

EPICS provides an IOC task that is a watchdog for other tasks. Any task can make a request to be watched. The task watchdog runs periodically and checks each task in its task list. If any task is suspended, an error message is issued and, optionally, a callback task is invoked. The task watchdog provides the following features:

1. Include module:

   ```
   #include <taskwd.h>
   ```

2. Insert request:

   ```
   taskwdInsert (int tid, TASKWDFUNCPRR callback,
      VOID *userarg);
   ```

   This is the request to include the task with the specified `tid` in the list of tasks to be watched. If callback is not `NULL` then if the task becomes suspended, the callback routine will be called with a single argument `userarg`.

3. Remove request:

   ```
   taskwdRemove(int tid);
   ```

   This routine would typically be called from the callback routine invoked when the original task goes into the suspended state.

4. Insert request to be notified if any task suspends:

   ```
   taskwdAnyInsert(void *userpvt,TASKWDFUNCPRR callback,
      VOID *userarg);
   ```

   The callback routine will be called whenever any of the tasks being monitored by the task watchdog task suspends. `userpvt` must have a non `NULL` unique value `taskwdAnyInsert`, because the task watchdog system uses this value to determine who to remove if `taskwdAnyRemove` is called.

5. Remove request for `taskwdAnyInsert:`

```
taskwdAnyRemove(void *userpvt);
```

`userpvt` is the value that was passed to `taskwdAnyInsert`.

Chapter 18: Database Scanning

18.1 Overview

Database scanning is the mechanism for deciding when to process a record. Five types of scanning are possible:

- **Periodic**: A record can be processed periodically. A number of time intervals are supported.
- **Event**: Event scanning is based on the posting of an event by another component of the software via a call to the routine `post_event`.
- **I/O Event**: The original meaning of this scan type is a request for record processing as a result of a hardware interrupt. The mechanism supports hardware interrupts as well as software generated events.
- **Passive**: Passive records are processed only via requests to `dbScanPassive`. This happens when database links (Forward, Input, or Output), which have been declared "Process Passive" are accessed during record processing. It can also happen as a result of `dbPutField` being called (This normally results from a Channel Access put request).
- **Scan Once**: In order to provide for caching puts, The scanning system provides a routine `scanOnce` which arranges for a record to be processed one time.

This chapter explains database scanning in increasing order of detail. It first explains database fields involved with scanning. It next discusses the interface to the scanning system. The last section gives a brief overview of how the scanners are implemented.

18.2 Scan Related Database Fields

The following fields are normally defined via DCT. It should be noted, however, that it is quite permissible to change any of the scan related fields of a record dynamically. For example, a display manager screen could tie a menu control to the `SCAN` field of a record and allow the operator to dynamically change the scan mechanism.

18.2.1 SCAN

This field, which specifies the scan mechanism, has an associated menu of the following form:

Passive: Passively scanned.
Event: Event Scanned. The field `EVNT` specifies event number
I/O Event scanned.
10 Second: Periodically scanned - Every 10 seconds
...
.1 Second: Periodically scanned - Every .1 seconds

18.2.2 PHAS

This field determines processing order for records that are in the same scan set. For example all records periodically scanned at a 2 second rate are in the same scan set. All Event scanned records with the same EVNT are in the same scan set, etc. For records in the same scan set, all records with PHAS=0 are processed before records with PHAS=1, which are processed before all records with PHAS=2, etc.

In general it is not a good idea to rely on PHAS to enforce processing order. It is better to use database links.

18.2.3 EVNT - Event Number

This field only has meaning when SCAN is set to Event scanning, in which case it specifies the event number. In order for a record to be event scanned, EVNT must be in the range 0,...255. It should also be noted that some EPICS software components will not request event scanning for event 0. One example is the eventRecord record support module. Thus the application developer will normally want to define events in the range 1,...,255.

18.2.4 PRIO - Scheduling Priority

This field can be used by any software component that needs to specify scheduling priority, e.g. the event and I/O event scan facility uses this field.

18.3 Scan Related Software Components

18.3.1 menuScan.dbd

This file contains definitions for a menu related to field SCAN. The definitions are of the form:

```
menu(menuScan) {
   choice(menuScanPassive,"Passive")
   choice(menuScanEvent,"Event")
   choice(menuScanI_O_Intr,"I/O Intr")
   choice(menuScan10_second,"10 second")
   choice(menuScan5_second,"5 second")
   choice(menuScan2_second,"2 second")
   choice(menuScan1_second,"1 second")
   choice(menuScan_5_second,".5 second")
   choice(menuScan_2_second,".2 second")
   choice(menuScan_1_second,".1 second")
}
```

The first three choices must appear first and in the order shown. The remaining definitions are for the periodic scan rates, which must appear in order of decreasing rate. At IOC initialization, the menu values are read by scan initialization. The number of periodic scan rates and the value of each rate is determined from the menu values. Thus periodic scan rates can be changed by changing menuScan.dbd and loading this version via dbLoadDatabase. The only requirement is that each periodic definition must begin with the value and the value must be in units of seconds.

18.3.2 dbScan.h

All software components that interact with the scanning system must include this file.

The most important definitions in this file are:

```
/* Note that these must match the first four definitions*/
/* in choiceGbl.dbd*/
#define SCAN_PASSIVE   0
#define SCAN_EVENT   1
#define SCAN_IO_EVENT   2
#define SCAN_1ST_PERIODIC   3

/*definitions for SCAN_IO_EVENT */
typedef void * IOSCANPVT;
extern int interruptAccept;

long scanInit(void);
void post_event(int event);
void scanAdd(struct dbCommon *);
void scanDelete(struct dbCommon *);
void scanOnce(void *precord);
int scanOnceSetQueueSize(int size);
int scanppl(void);   /*print periodic lists*/
int scanpel(void);   /*print event lists*/
int scanpiol(void);   /*print io_event list*/
void scanIoInit(IOSCANPVT *);
void scanIoRequest(IOSCANPVT);
```

The first set of definitions defines the various scan types. The next two definitions (`IOSCANPVT` and `interruptAccept`) are for interfacing with the I/O event scanner. The remaining definitions define the public scan access routines. These are described in the following subsections.

18.3.3 Initializing Database Scanners

```
scanInit(void);
```

The routine `scanInit` is called by `iocInit`. It initializes the scanning system.

18.3.4 Adding And Deleting Records From Scan List

The following routines are called each time a record is added or deleted from a scan list.

```
scanAdd(struct dbCommon *);
scanDelete(struct dbCommon *);
```

These routines are called by `scanInit` at IOC initialization time in order to enter all records created via DCT into the correct scan list. The routine `dbPut` calls `scanDelete` and `scanAdd` each time a scan related field is changed (each scan related field is declared to be `SPC_SCAN` in `dbCommon.dbd`). `scanDelete` is called before the field is modified and `scanAdd` after the field is modified.

18.3.5 Declaring Database Event

Whenever any software component wants to declare a database event, it just calls:

```
post_event(event)
```

This can be called by virtually any IOC software component. For example sequence programs can call it. The record support module for `eventRecord` calls it.

18.3.6 Interfacing to I/O Event Scanning

Interfacing to the I/O event scanner is done via some combination of device and driver support.

1. Include `<dbScan.h>`
2. For each separate event source the following must be done:
   a. Declare an `IOSCANPVT` variable, e.g.
      ```
      static IOSCANPVT ioscanpvt;
      ```
   b. Call `scanIoInit`, e.g.
      ```
      scanIoInit(&ioscanpvt);
      ```
3. Provide the device support `get_ioint_info` routine. This routine has the format:
   ```
   long get_ioint_info(
      int  cmd,
      struct dbCommon  *precord,
         IOSCANPVT  *ppvt);
   ```
   This routine is called each time the record pointed to by `precord` is added or deleted from an I/O event scan list. `cmd` has the value (0,1) if the record is being (added to, deleted from) an I/O event list. This routine must give a value to `*ppvt`.
4. Whenever an I/O event is detected call `scanIoRequest`, e.g.
   ```
   scanIoRequest(ioscanpvt)
   ```
   This routine can be called from interrupt level. The request is actually directed to one of the standard callback tasks. The actual one is determined by the `PRIO` field of `dbCommon`.

The following code fragment shows an event record device support module that supports I/O event scanning:

```
#include  <vxWorks.h>
#include  <types.h>
#include  <stdioLib.h>
#include  <intLib.h>
#include  <dbDefs.h>
#include  <dbAccess.h>
#include  <dbScan.h>
#include  <recSup.h>
#include  <devSup.h>
#include  <eventRecord.h>
/* Create the dset for devEventXXX */
long init();
long get_ioint_info();
struct {
   long  number;
   DEVSUPFUN  report;
   DEVSUPFUN  init;
   DEVSUPFUN  init_record;
   DEVSUPFUN  get_ioint_info;
   DEVSUPFUN  read_event;
}devEventTestIoEvent={
   5,
```

```
   NULL,
   init,
   NULL,
   get_ioint_info,
   NULL};
static IOSCANPVT ioscanpvt;
static void int_service(IOSCANPVT ioscanpvt)
{
    scanIoRequest(ioscanpvt);
}

static long init()
{
    scanIoInit(&ioscanpvt);
    intConnect(<vector>,(FUNCPTR)int_service,ioscanpvt);
    return(0);
}
static long get_ioint_info(
   int   cmd,
   struct eventRecord   *pr,
   IOSCANPVT   *ppvt)
{
    *ppvt = ioscanpvt;
    return(0);
}
```

18.4 Implementation Overview

The code for the entire scanning system resides in `dbScan.c`, i.e. periodic, event, and I/O event. This section gives an overview of how the code in `dbScan.c` is organized. The listing of `dbScan.c` must be studied for a complete understanding of how the scanning system works.

18.4.1 Definitions And Routines Common To All Scan Types

Everything is built around two basic structures:

```
   struct scan_list {
      FAST_LOCK  lock;
      ELLLIST  list;
      short   modified;
      long   ticks;   /*used only for periodic scan sets*/
   };

   struct scan_element{
      ELLNODE  node;
      struct scan_list  *pscan_list;
      struct dbCommon   *precord;
   }
```

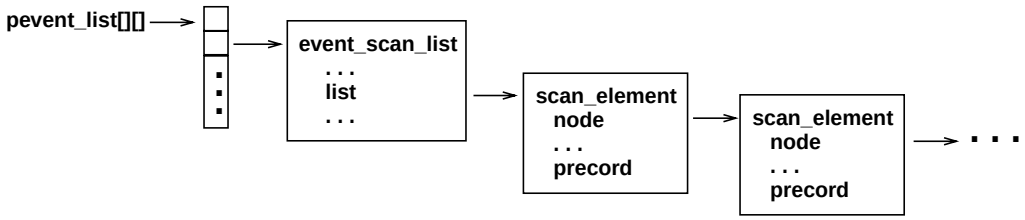


Figure 18-1: Scan List Memory Layout

Later we will see how `scan_lists` are determined. For now just realize that `scan_list.list` is the head of a list of records that belong to the same scan set (for example, all records that are periodically scanned at a 1 second rate are in the same scan set). The node field in `scan_element` contain the list links. The normal vxWorks `lstLib` routines are used to access the list. Each record that appears in some scan list has an associated `scan_element`. The `SPVT` field which appears in `dbCommon` holds the address of the associated `scan_element`.

The `lock`, `modified`, and `pscan_list` fields allow `scan_elements`, i.e. records, to be dynamically removed and added to scan lists. If `scanList`, the routine which actually processes a scan list, is studied it can be seen that these fields allow the list to be scanned very efficiently if no modifications are made to the list while it is being scanned. This is, of course, the normal case.

The `dbScan.c` module contains several private routines. The following access a single scan set:

- **printList**: Prints the names of all records in a scan set.
- **scanList**: This routine is the heart of the scanning system. For each record in a scan set it does the following:
  ```
  dbScanLock(precord);
  dbProcess(precord);
  dbScanUnlock(precord);
  ```
  It also has code to recognize when a scan list is modified while the scan set is being processed.
- **addToList**: This routine adds a new element to a scan list.
- **deleteFromList**: This routine deletes an element from a scan list.

18.4.2 Event Scanning

Event scanning is built around the following definitions:

```
#define MAX_EVENTS 256
typedef struct event_scan_list {
     CALLBACK        callback;
     scan_list       scan_list;
}event_scan_list;
static event_scan_list
      *pevent_list[NUM_CALLBACK_PRIORITIES][MAX_EVENTS];
```

`pevent_list` is a 2d array of pointers to `scan_lists`. Note that the array allows for 256 events, i.e. one for each possible event number. In other words, each event number and priority has its own scan list. No `scan_list` is actually created until the first request to add an element for that event number. The event scan lists have the memory layout illustrated in Figure 18-1.

18.4.2.1 post_event

```
post_event(int event)
```

This routine is called to request event scanning. It can be called from interrupt level. It looks at each `event_scan_list` referenced by `pevent_list[*][event]` (one for each callback priority) and if any elements are present in the `scan_list` a `callbackRequest` is issued. The appropriate callback task calls routine `eventCallback`, which just calls `scanList`.

18.4.3 I/O Event Scanning

I/O event scanning is built around the following definitions:

```
struct io_scan_list {
   CALLBACK   callback;
   struct scan_list   scan_list;
   struct io_scan_list   *next;
}
static struct io_scan_list
    *iosl_head[NUM_CALLBACK_PRIORITIES]
      = {NULL,NULL,NULL};
```

The array `iosl_head` and the field `next` are only kept so that `scanpiol` can be implemented and will not be discussed further. I/O event scanning uses the general purpose callback tasks to perform record processing, i.e. no task is spawned for I/O event. The callback field of `io_scan_list` is used to communicate with the callback tasks.

The following routines implement I/O event scanning:

18.4.3.1 scanIoInit

```
scanIoInit (IOSCANPVT  *ppioscanpvt)
```

This routine is called by device or driver support. It is called once for each interrupt source. `scanIoInit` allocates and initializes an array of `io_scan_list` structures; one for each callback priority and puts the address in `pioscanpvt`. Remember that three callback priorities are supported (low, medium, and high). Thus for each interrupt source the structures are illustrated in Figure 18-1:

When `scanAdd` or `scanDelete` are called, they call the device support routine `get_ioint_info` which returns `pioscanpvt`. The `scan_element` is added or deleted from the correct scan list.

18.4.3.2 scanIoRequest

```
scanIoRequest (IOSCANPVT pioscanpvt)
```

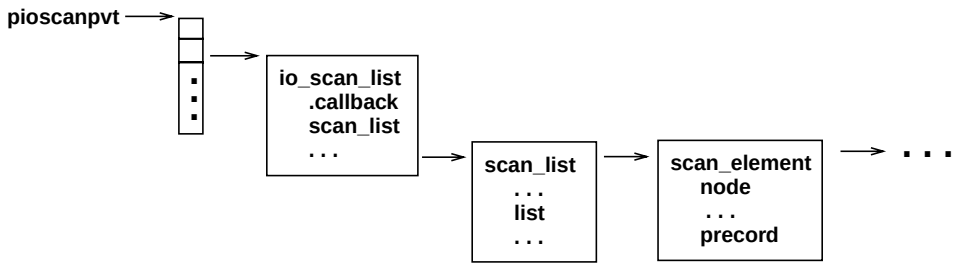


Figure 18-1: Interrupt Source Structure

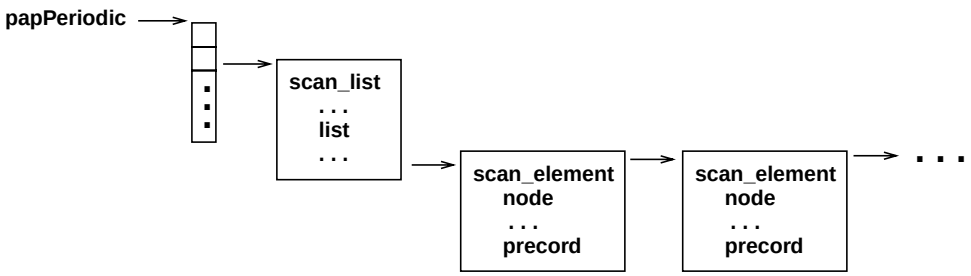


Figure 18-1: Structure after iocInit

This routine is called to request I/O event scanning. It can be called from interrupt level. It looks at each `io_scan_list` referenced by `pioscanpvt` (one for each callback priority) and if any elements are present in the `scan_list` a `callbackRequest` is issued. The appropriate callback task calls routine `ioeventCallback`, which just calls `scanList`.

18.4.4 Periodic Scanning

Periodic scanning is built around the following definitions:

```
static int nPeriodic;
static struct scan_list **papPeriodic;
static int *periodicTaskId;
```

`nPeriodic`, which is determined at `iocInit` time, is the number of periodic rates. `papPeriodic` is a pointer to an array of pointers to `scan_lists`. There is an array element for each scan rate. Thus the structure illustrated in Figure 18-1 exists after `iocInit`.

A periodic scan task is created for each scan rate. The following routines implement periodic scanning:

18.4.4.1 initPeriodic

```
initPeriodic()
```

This routine first determines the scan rates. It does this by accessing the `SCAN` field of the first record it finds. It issues a call to `dbGetField` with a `DBR_ENUM` request. This returns the menu choices for `SCAN`. From this the periodic rates are determined. The array of pointers referenced by `papPeriodic` is allocated. For each scan rate a `scan_list` is allocated and a `periodicTask` is spawned.

18.4.4.2 periodicTask

```
periodicTask (struct scan_list *psl)
```

This task just performs an infinite loop of calling `scanList` and then calling `taskDelay` to wait until the beginning of the next time interval.

18.4.5 Scan Once

18.4.5.1 scanOnce

```
void scanOnce (void *precord)
```

A task `onceTask` waits for requests to issue a `dbProcess` request. The routine `scanOnce` puts the address of the record to be processed in a ring buffer and wakes up `onceTask`.

This routine can be called from interrupt level.

18.4.5.2 SetQueueSize

scanOnce places its request on a vxWorks ring buffer.This is set by default to 1000 entries. It can be changed by executing the following command in the vxWorks startup file.

```
int scanOnceSetQueueSize(int size);
```

Chapter 19: IOC Shell

Eric Norum is the author of this chapter.

19.1 Introduction

The EPICS IOC shell is a simple command interpreter which provides a subset of the capabilities of the vxWorks shell. It is used to interpret startup scripts (st.cmd) and to execute commands entered at the console terminal. In most cases vxWorks startup scripts can be interpreted by the IOC shell without modification. The following sections of this chapter describe the operation of the IOC shell from the user's and programmer's points of view.

19.2 IOC Shell Operation

The IOC shell reads lines of input, breaks them into commands and arguments and calls functions corresponding to the decoded command. Commands and arguments are separated by one or more `space' characters. Characters interpreted as spaces include the actual space character and the tab character as well as commas and open and close parentheses. Thus, the command line

```
dbLoadRecords("db/dbExample1.db","user=mrk")
```

would be interpreted by the IOC shell as the `dbLoadRecords` command with arguments `db/dbExample1.db` and `user=mrk`.

Unrecognized commands result in a diagnostic message but are otherwise ignored. Missing arguments are given a default value (0 for numeric arguments, NULL for string arguments). Extra arguments are ignored.

Unlike the vxWorks shell, string arguments do not have to be enclosed in quotes unless they contain one or more of the `space' characters in which case one of the quoting mechanisms described in the following section must be used.

19.2.1 Quoting

Quoting is used to remove the special meaning normally assigned to certain characters and can be used to include `space' or quote characters in arguments. Quoting can not be used to extend a command over more than one input line.

There are three quoting mechanisms: the backslash character, single quotes, and double quotes. A backslash (\) preserves the literal value of the following character. Enclosing characters in single or double quotes preserves the literal value of each character (except a backslash) within the quotes. A single quote may occur between double quotes and a double quote may occur between single quotes.

19.2.2 Command-line editing and history

The IOC shell can use the readline library to obtain input from the console terminal. This provides full command-line editing as well as easy access to previous commands through the command-line history capabilties provided by the readline routines. See the readline library documentation for full details. Command and argument completion is not supported.

If the readline library is not used, the only command-line editing and history capabilities will be those supplied by the underlying operating system. The console keyboard driver in Windows, for example, provides its own command-line editing and history commands.

19.2.3 Utility Commands

The IOC shell recognizes the following commands as well as the commands described in chapter 6 (Database Design) and chapter 9 (IOC Test Facilities) among others. In addition, the commands described in the sequencer documentation are recognized.

Command	Description
< *filename*	Read commands from *filename* until an exit command or EOF is encountered. The IOC shell then resumes reading commands from the current source. Commands read from *filename* are not added to the readline command history. The level of nesting is limited only by the maximum number of files can be open simultaneously.
help [command ...]	Print synopsis of specified commands. With no arguments print a list of all commands.
#	A `#' in the first column of a line indicates the beginning of a comment which continues to the end of the line
exit	Stop reading commands. If the top-level command interpreter encounters an exit command or end-of-file (EOF) it will return to its caller.
cd *directory*	Change working directory to *directory.*
pwd	Print the name of the working directory.
show [-*level*] [*task* ...]	Show information about specified tasks. If no *task* arguments are present, show information on all tasks. The *level* argument controls the amount of information printed. The default *level* is 0. The *task* arguments can be task names or task i.d. numbers.
putenv *var=value*	Set environment variable *var* to have the specified *value*.
iocLogInit	Initialize IOC logging.
epicsThreadSleep *sec*	Pause execution of IOC shell for *sec* seconds.

19.2.4 ENVIRONMENT VARIABLES

The IOC shell uses the following environment variables to control its operation.

Variable	Description

IOCSH_PS1	Prompt string. Default is "epics> ".
IOCSH_HISTSIZE	Number of previous command lines to remember. If the IOCSH_HISTSIZE environment variable is not present the value of the HISTSIZE environment variable is used. In the absence of both environment variables, 10 command lines will be remembered.
TERM, INPUTRC	These and other environment variables are used by the readline and termcap libraries and are described in the documentation for those libraries.

19.3 IOC Shell Programming

The declarations described in this section are included in the <ioccrf.h> header file. The header file name, and the names of the data structures and functions within it reflect the heritage of the IOC shell code which was originally written to allow IOC applications to `call registered functions'.

19.3.1 Invoking the IOC shell

The prototype for the IOC shell command interpreter is:

```
int ioccrf (const char *pathname);
```

The argument is the name of the file from which commands are to be read. If the *pathname* argument is NULL, commands are read from the standard input and prompts are issued to the standard output. Commands are read until an exit command is encountered or until end-of-file is reached at which point ioccrf returns a value of 0. If the specified file can not be opened ioccrf returns -1.

19.3.2 Registering Commands

Commands must be registered before they can be recognized by the IOC shell. Registration is achieved by calling the registration function:

```
void ioccrfRegister(const ioccrfFuncDef *pioccrfFuncDef, ioccrfCallFunc func);
```

The first argument is a pointer to a data structure which describes the command and any arguments it may take. The second argument is a pointer to a function which will be called by ioccrf when the corresponding command is encountered.

The command is described by the `ioccrfFuncDef` structure:

```
struct ioccrfFuncDef {
    const char *name;
    int nargs;
    const ioccrfArg * const *arg;
};
```

The name element is the name of the command. The arg element is a pointer to an array of pointers to structures each of which defines a single argument. The nargs element declares the number of entries in the array of pointers to the argument descriptions. The structures which define each of the arguments is:

```
struct ioccrfArg {
    const char *name;
    ioccrfArgType type;
}ioccrfArg;
```

The name element is used by the help command to print a synopsis for the command. The type element describes the type of the argument and should take on one of the following values:

ioccrfArgInt	The argument will be converted to an integer value.
ioccrfArgDouble	The argument will be converted to a double-precision floating point value.
ioccrfArgString	The argument will be left as a string.
ioccrfArgPdbbase	The argument must be pdbbase.
ioccrfArgArgv	An arbitrary number of arguments is expected. Subsequent ioccrfArg structures will be ignored.

The `handler' function which is called when its corresponding command is recognized should be of the form:

```
void showCallFunc(const ioccrfArgBuf *args);
```

The argument to the handler function is a pointer to an array of unions. The number of elements in this array is equal to the number of arguments specified in the structure describing the command. The type and name of the union element which contains the argument value depends on the `type' element of the corresponding argument descriptor:

ioccrfArgInt	int	args[i].ival
ioccrfArgDouble	double	args[i].dval
ioccrfArgString	char *	args[i].sval
ioccrfArgPdbbase	void *	args[i].vval
ioccrfArgArgv	int char **	args[i].aval.ac args[i].aval.av

If an `ioccrfArgArgv` argument type is present it is usually the first and only argument specified for the command. In this case, `args[0].aval.av[0]` will be the name of the command, `args[0].aval.av[1]` will be the first argument, and so on.

19.3.3 Automatic Command Registration

A C++ static constructor can be used to register IOC shell commands before the EPICS application begins. The following example shows how the `<' command could be described and registered.

```
#include "ioccrf.h"

static const ioccrfArg runScriptArg0 = { "command file name",ioccrfArgString};
static const ioccrfArg * const runScriptArgs[1] = {&runScriptArg0};
static const ioccrfFuncDef runScriptFuncDef = {"<",1,runScriptArgs};
static void runScriptCallFunc(const ioccrfArgBuf *args)
{
    ioccrf (args[0].sval);
}

class IoccrfRegister {
  public:
    IoccrfRegister() { ioccrfRegister(runScriptFuncDef,runScriptCallFunc); }
```

```
};
static IoccrfRegister ioccrfRegisterObj;
```

Chapter 20: libCom

This chapter and the next describe the facilities provided in `<base>/src/libCom`. This chapter describes facilities which are platform independent. The next chapter describes facilities which have different implementations on different platforms.

20.1 bucketLib

`bucketLib.h` describes a hash facility for integers, pointers, and strings. It is used by the Channel Access Server. It is currently undocumented.

20.2 calc

`postfix.h` defines routines used by the calculation record type calcRecord, access security, and other code. Read the description of the calcRecord in the Record Reference Manual to see a description of what is supported.

```
long postfix(char *pinfix, char *ppostfix, short *perror);
long calcPerform(double *parg, double *presult, char  *ppostfix);
```

The caller calls postfix() to convert the expression from infix to postfix notation. It is the callers's responsibility to make sure that *ppostfix* points to sufficient storage to hold the postfix expression. The calcRecord uses an array of size 200.

The arguments to calcPerform() are:

> *parg* - The address of a array of doubles containing the arguments A-L that can appear in the expression.
> *presult* - The address of the calculation result of calling calcPerform().
> *ppostfix* - The postfix expression created by postfix().

`sCalcPostfix.h` contains definitions for code that adds string manipulation facilities in addition to the facilities supported by `postfix.h`

20.3 cppStd

This subdirectory of libCom is intended for facilities such as class and function templates that implement parts of the ISO standard C++ library where such facilities are not available or not efficient on all the target platforms on which EPICS is supported. Eventually it is hoped that these files will not be required, although the speed of some standard library implementations may prevent their removal in all cases.

20.3.1 epicsList

`epicsList.h` provides a C++ doubly-linked list template class that has been optimized for speed while remaining compatible with the the std::list template from the standard C++ header `list`. The epicsList template provides most of the functionality of std::list but omits some of the more esoteric member functions, can only be instantiated for pointer types (integers may also work but have not been tested), and cannot be assigned or copied. This requires the application to manage the creation and destruction of objects that are inserted or removed from the list, but because only pointers are stored such objects do not have to be assignable or default-constructable. Detailed information on the list and iterator member functions can be found in any recent C++ textbook that covers the final ISO standard C++ library.

```
template <class T>
class epicsList {
public:
    typedef size_t size_type;
    class iterator;
    class const_iterator;

    epicsList();
    ~epicsList();

    iterator begin();
    const_iterator begin() const;
    iterator end();
    const_iterator end() const;

    bool empty() const;
    size_type size() const;

    T front();
    const T front() const;
    T back();
    const T back() const;

    void push_front(const T x);
    void pop_front();
    void push_back(const T x);
    void pop_back();

    iterator insert(iterator position, const T x);
    iterator erase(iterator position);
    iterator erase(iterator position, iterator leave);
    void swap(epicsList<T>& x);
    void clear();
private:
    ...
};
```

Method	Meaning
epicsList()	Create a new, empty list.
~epicsList()	Destructor, releases list nodes back to central pool.

Method	Meaning
begin()	Returns an iterator or const_iterator for the first item on the list.
end()	Returns an iterator or const_iterator that is one beyond the last item on the list.
empty()	Returns true if list contains no items.
size()	Number of elements the list contains.
front()	Returns the first item on the list.
back()	Returns the last item on the list.
push_front(const T *x*)	Pushes *x* onto the front of the list (*x* becomes the new first element).
pop_front()	Removes the first item from the list (returns nothing).
push_back(const T *x*)	Pushes *x* onto the back of the list (*x* becomes the new last element).
pop_back()	Removes the last item from the list (returns nothing).
insert(iterator *pos*, const T *x*)	Insert new element *x* immediately before *pos*, returns an iterator referring to *x*.
erase(iterator *pos*)	Remove list element at *pos*, returns iterator for the following element or end().
erase(iterator *pos*, iterator *leave*)	Remove list elements from *pos* up to but excluding *leave*.
swap(epicsList<T>& x)	Swap contents of this list with list *x*.
clear()	Remove all items from list.

```
template <class T>
    inline void swap(epicsList<T>& x, epicsList<T>& y);
template <class T>
    inline void epicsSwap(epicsList<T>& x, epicsList<T>& y);
```

The two convenience template functions given above define the common algorithms swap(a, b) and epicsSwap(a, b) for epicsList template classes.

The list template provides two iterator classes which are used to step through the list and have the functionality shown in the table below. Note that a const_iterator cannot be used to modify an object it refers to, being analagous to a const pointer, but is otherwise interchangable with a normal iterator in the expressions below unless stated otherwise.

Expression	Meaning
epicsList<T>::iterator *it_a*;	Constructs *it_a* , which initially points nowhere.
epicsList<T>::iterator *it_b* = *it_a*;	Copy constructor, *it_a* and *it_b* now refer to the same element (maybe nowhere!).
epicsList<T>::const_iterator *cit_a* = *it_a*	A const_iterator can be copy-constructed from a mutable iterator, but not vice-versa.
it_a = *it_b*	Iterator assignment is allowed, the operator=() being compiler generated.
cit_a = *it_b*	A mutable iterator can be assigned to a const_iterator, but not the reverse.
**it_a*	Dereference, returns the list object at the iterator's current position. Note that this returns a copy of the list object, not a reference to it so (unlike a std::list<T>::iterator where T is a pointer) you can't use an iterator to modify the pointer that the list holds.
it_b->member	Dereference as for **it_a*, gives access to member data and functions of class *T

Expression	Meaning
it_a++	Steps *iterator* to next list item but returns a temporary iterator that refers to the original list item. Because of this temporary, where possible use the pre-increment form below.
++it_b	Steps *iterator* to the next list item and returns a reference to itself.
it_a--	Steps iterator to the previous list item but returns a temporary iterator that refers to the original list item. As before, where possible use the pre-decrement form below.
--it_b	Steps iterator to the previous list item and returns a reference to itself.
(*it_a* == *it_b*), (*it_a* != *it_b*)	Iterators are (in)equality-comparable, but not less-than or grater-than comparable.

20.3.2 epicsAlgorithm

`epicsAlgorithm.h` contains a few templates that are also available in the C++ standard header `algorithm`, but are provided here in a much smaller file – `algorithm` contains many templates for sorting and searching. If all you need from there is std::min(), std::max() and/or std::swap() your code will compile faster if you include `epicsAlgorithm.h` and use epicsMin(), epicsMax() and epicsSwap() instead.

template <class T>	Meaning
const T& epicsMin(const T& *a*, const T& *b*)	Returns the smaller of *a* or *b* compared using *a*<*b*.
const T& epicsMax(const T& *a*, const T& *b*)	Returns the larger of *a* or *b* compared using *a*<*b*.
void epicsSwap(T& *a*, T& *b*)	Swaps the values of *a* and *b*; T must have a copy-constructor and operator=.

20.3.3 epicsExcept

`epicsExcept.h` contains definitions and macros that can be used to throw an exception along with source file and line number information indicating where the exception arose. Although similar to the functionality provided in the header file `locationException.h` this version allows all such exceptions to be caught and reported by single a handler that does not have to use C++ Run-Time Type Identification. Any C++ exception class may be used in conjuntion with this facility, including those defined in `stdexcept`.

FIXME: This should be merged into `locationException.h`, it doesn't belong here anyway - ANJ

20.4 cvtFast

`cvtFast.h` provides routines for converting various numeric types into an ascii string. They offer a combination of speed and convenience not available with sprintf().

```
/* These functions return the number of ASCII characters generated */
int cvtFloatToString(float value, char *pstr, unsigned short precision);
int cvtDoubleToString(double value, char *pstr, unsigned short prec);
int cvtFloatToExpString(float value, char *pstr, unsigned short prec);
int cvtDoubleToExpString(double value, char *pstr, unsigned short prec);
int cvtFloatToCompactString(float value, char *pstr, unsigned short prec);
```

```
int cvtDoubleToCompactString(double value, char *pstr, unsigned short prec);
int cvtCharToString(char value, char *pstring);
int cvtUcharToString(unsigned char value, char *pstr);
int cvtShortToString(short value, char *pstr);
int cvtUshortToString(unsigned short value, char *pstr);
int cvtLongToString(long value, char *pstr);
int cvtUlongToString(unsigned long value, char *pstr);
int cvtLongToHexString(long value, char *pstr);
int cvtLongToOctalString(long value, char *pstr);
unsigned long cvtBitsToUlong(
        unsigned long src,
        unsigned bitFieldOffset,
        unsigned bitFieldLength);
unsigned long cvtUlongToBits(
        unsigned long src,
        unsigned long dest,
        unsigned bitFieldOffset,
        unsigned bitFieldLength);
```

20.5 cxxTemplates

This directory contains the following C++ template headers:

- `resourceLib.h` - A C++ hash facility that implements the same functionality as bucketLib
- `tsBTree.h` - Binary tree.
- `tsDLList.h` - Double Linked List
- `tsFreeList.h` - Free List for efficient new/delete
- `tsMinMax.h` - min and max.
- `tsSLList.h` - Single Linked List

Currently these are only being used by Channel Access Clients and the portable Channel Access Server. It has not been decided if any of these will remain in libCom.

20.6 dbmf

`dbmf.h` (Database Macro/Free) describes a facility that prevents memory fragmentation when memory is allocated and then freed a short time later.

Routines within iocCore like dbLoadDatabase() have the following attributes:

- They issue many calls to malloc() followed a short time later by a call to free().
- Between a call to malloc() and the associated free(), an additional call to malloc() is made that does NOT have an associated free().

In some environments, e.g. vxWorks, this behavior causes severe memory fragmentation.

The dbmf facility stops the memory fragmentation. It should NOT be used by code that allocates storage and then keeps it for a considerable period of time before releasing. Such code can use the freeList library described below.

```
int dbmfInit(size_t size, int chunkItems);
```

```
void *dbmfMalloc(size_t bytes);
void dbmfFree(void* bytes);
void dbmfFreeChunks(void);
int dbmfShow(int level);
```

Routine	Meaning
dbmfInit()	Initialize the facility. Each time malloc() must be called `size*chunkItems` bytes are allocated. `size` is the maximum size request from dbmfMalloc() that will be allocated from the dbmf pool. If dbmfInit() was not called before one of the other routines then it is automatically called with `size=64` and `chuckItems=10`.
dbmfMalloc()	Allocate memory. If `bytes` is > `size` then malloc() is used to allocate the memory.
dbmfFree()	Free the memory allocated by dbmfMalloc().
dbmfFreeChunks()	Free all chunks that have contain only free items.
dbmfShow()	Show the status of the dbmf memory pool.

20.7 ellLib

`ellLib.h` describes a double linked list library. It provides functionality similar to the vxWorks lstLib library. See the vxWorks documentation for details. There is an ellXXX() routine to replace most vxWorks lstXXX() routines.

New code that is written in C++ should seriously consider using the `epicsList` template class instead of ellLib.

```
typedef struct ELLNODE {
  struct ELLNODE  *next;
  struct ELLNODE  *previous;
}ELLNODE;

typedef struct ELLLIST {
  ELLNODE  node;
  int   count;
void ellInit (ELLLIST *pList);
int ellCount (ELLLIST *pList);
ELLNODE *ellFirst (ELLLIST *pList);
ELLNODE *ellLast (ELLLIST *pList);
ELLNODE *ellNext (ELLNODE *pNode);
ELLNODE *ellPrevious (ELLNODE *pNode);
void ellAdd (ELLLIST *pList, ELLNODE *pNode);
void ellConcat (ELLLIST *pDstList, ELLLIST *pAddList);
void ellDelete (ELLLIST *pList, ELLNODE *pNode);
void ellExtract (ELLLIST *pSrcList, ELLNODE *pStartNode,
    ELLNODE *pEndNode, ELLLIST *pDstList);
ELLNODE *ellGet (ELLLIST *pList);
void ellInsert (ELLLIST *plist, ELLNODE *pPrev, ELLNODE *pNode);
ELLNODE *ellNth (ELLLIST *pList, int nodeNum);
ELLNODE *ellNStep (ELLNODE *pNode, int nStep);
int ellFind (ELLLIST *pList, ELLNODE *pNode);
```

```
void ellFree (ELLLIST *pList);
void ellVerify (ELLLIST *pList);
```

20.8 epicsRingBytes

`epicsRingBytes.h` contains

```
epicsRingBytesId epicsRingBytesCreate(int nbytes);
void epicsRingBytesDelete(epicsRingBytesId id);
int epicsRingBytesGet(epicsRingBytesId id, char *value,int nbytes);
int epicsRingBytesPut(epicsRingBytesId id, char *value,int nbytes);
void epicsRingBytesFlush(epicsRingBytesId id);
int epicsRingBytesFreeBytes(epicsRingBytesId id);
int epicsRingBytesUsedBytes(epicsRingBytesId id);
int epicsRingBytesSize(epicsRingBytesId id);
int epicsRingBytesIsEmpty(epicsRingBytesId id);
int epicsRingBytesIsFull(epicsRingBytesId id);
```

Method	Meaning
epicsRingBytesCreate()	Create a new ring buffer of size *nbytes*. The returned epicsRingBytesId is passed to the other ring methods.
epicsRingBytesDelete()	Delete the ring buffer and free any associated memory.
epicsRingBytesGet()	Move up to *nbytes* from the ring buffer to *value*. The number of bytes actually moved is returned.
epicsRingBytesPut()	Move up to *nbytes* from *value* to the ring buffer. The number of bytes actually moved is returned.
epicsRingBytesFlush()	Make the ring buffer empty.
epicsRingBytesFreeBytes()	Return the number of free bytes in the ring buffer.
epicsRingBytesUsedBytes()	Return the number of bytes currently stored in the ring buffer.
epicsRingBytesSize()	Return the size of the ring buffer, i.e., *nbytes* specified in the call to epicsRingBytesCreate().
epicsRingBytesIsEmpty()	Return (true, false) if the ring buffer is currently empty.
epicsRingBytesIsFull()	Return (true, false) if the ring buffer is currently empty.

epicsRingBytes has the following properties:

- For a ring buffer with a single writer it is not necessary to lock epicsRingBytesPut() calls.
- For a ring buffer with a single reader it is not necessary to lock epicsRingBytesGet() calls.
- epicsRingBytesFlush() should only be used when both gets and puts are locked out.

20.9 epicsRingPointer

`epicsRingPointer.h` describes a C++ and a C facility for a commonly used type of ring buffer.

20.9.1 C++ Interface

EpicsRingPointer provides methods for creating and using ring buffers (first in first out circular buffers) that store pointers. It is designed so that a writer thread and reader thread can access the ring simultaneously without requiring mutual exclusion.

```
template <class T>
class epicsRingPointer {
public:
    epicsRingPointer(int size);
    ~epicsRingPointer();
    bool push(T *p);
    T* pop();
    void flush();
    int getFree() const;
    int getUsed() const;
    int getSize() const;
    bool isEmpty() const;
    bool isFull() const;

private: // Prevent compiler-generated member functions
    // default constructor, copy constructor, assignment operator
    epicsRingPointer();
    epicsRingPointer(const epicsRingPointer &);
    epicsRingPointer& operator=(const epicsRingPointer &);

private: // Data
    ...
};
```

An epicsRingPointer cannot be assigned to, copy-constructed, or constructed without giving the *size* argument. The C++ compiler will object to some of the statements below:

```
epicsRingPointer rp0();   // Error: default constructor is private
epicsRingPointer rp1(10); // OK
epicsRingPointer rp2(t1); // Error: copy constructor is private
epicsRingPointer *prp;    // OK, pointer
*prp = rp1;               // Error: assignment operator is private
prp = &rp1;               // OK, pointer assignment and address-of
```

Method	Meaning
epicsRingPointer()	Constructor. The size is the maximum number of elements (pointers) that can be stored in the ring.
~epicsRingPointer()	Destructor.
push()	Push a new entry on the ring. It returns (false,true) is (successful, failed). Failure means the ring was full. If a single writer is present it does not have to use a lock while performing the push. If multiple writers are present they must use a common lock while issuing the push.
pop()	Take a element off the ring. It returns 0 (null) if the ring was empty. If a single reader is present it does not have to lock while issuing the pop. If multiple readers are present they must use a common lock while issuing the pop.

Method	Meaning
flush()	Remove all elements from the ring. If this operation is performed then all access to the ring should be locked.
getFree()	Return the amount of empty space in the ring, i.e. how many additional elements it can hold.
getUsed()	Return the number of elements stored on the ring
getSize()	Return the size of the ring, i.e. the value of *size* specified when the ring was created.
isEmpty()	Returns true if the ring is empty, else false.
isFull()	Returns true if the ring is full, else false.

20.9.2 C interface

```
typedef void *epicsRingPointerId;
    epicsRingPointerId epicsRingPointerCreate(int size);
    void epicsRingPointerDelete(epicsRingPointerId id);
    /*epicsRingPointerPop returns 0 if the ring was empty */
    void * epicsRingPointerPop(epicsRingPointerId id) ;
    /*epicsRingPointerPush returns (0,1) if p (was not, was) put on ring*/
    int epicsRingPointerPush(epicsRingPointerId id,void *p);
    void epicsRingPointerFlush(epicsRingPointerId id);
    int epicsRingPointerGetFree(epicsRingPointerId id);
    int epicsRingPointerGetUsed(epicsRingPointerId id);
    int epicsRingPointerGetSize(epicsRingPointerId id);
    int epicsRingPointerIsEmpty(epicsRingPointerId id);
    int epicsRingPointerIsFull(epicsRingPointerId id);
```

Each C function corresponds to one of the C++ methods.

20.10 epicsTimer

`epicsTimer.h` describes a C++ and a C timer facility.

20.10.1 C++ Interface

20.10.1.1 epicsTimerNotify and epicsTimer

```
class epicsTimerNotify {
public:
    enum restart_t { noRestart, restart };
    class expireStatus;
    virtual expireStatus expire () = 0;
    virtual void show ( unsigned int level ) const;
};
```

```
class epicsTimerNotify::expireStatus {
public:
    expireStatus ( restart_t );
    expireStatus ( restart_t, const double &expireDelaySec );
    bool restart () const;
    double expirationDelay () const;
private:
    ...
};

class epicsTimer {
public:
    virtual ~epicsTimer () = 0;
    virtual void start ( const epicsTime & ) = 0;
    virtual void start ( double delaySeconds ) = 0;
    virtual void cancel () = 0;
    virtual double getExpireDelay () const = 0;
    virtual void show ( unsigned int level ) const = 0;
};
```

Method	Meaning
epicsTimerNotify expire()	Code using an epicsTimer must include a class that inherits from epicsTimerNotify. The derived class must implement the method expire(), which is called by the epicsTimer when the associated timer expires. epicsTimerNotify defines a class expireStatus which makes it easy to implement both one shot and periodic timers. A one-shot expire() returns with the statement: `return(noRestart);` A periodic timer returns with a statement like: `return(restart,10.0);` where is second argument is the delay until the next callback.
epicsTimer	epicsTimer is an abstract base class. The intended way to create a timer is by calling the createTimer() method of either epicsTimerQueueThreaded or epicsTimerQueueNonThreaded.
~epicsTimer()	Destructor. This will automatically call cancel before freeing all resources used by the timer.
start()	Starts the timer to expire either at the specified time or the specified number of seconds in the future. If the timer is already active when start is called, it is first canceled.
cancel()	If the timer is scheduled, cancel it. If it is not scheduled do nothing. Note that if the expire() method is already running, this call delays until the expire() completes.
getExpireDelay()	Return the number of seconds until the timer will expire.
show()	Display info about object.

20.10.1.2 epicsTimerQueue

```
class epicsTimerQueue {
public:
    static epicsTimerQueue & allocate ( bool okToShare,
        int threadPriority = epicsThreadPriorityMin + 10 );
    virtual void release () = 0;
    virtual epicsTimer & createTimer ( epicsTimerNotify & ) = 0;
    virtual void show ( unsigned int level ) const = 0;
```

```
protected:
    virtual ~epicsTimerQueue () = 0;
};
```

Method	Meaning
allocate()	A "factory" method to allocate a threaded timer queue. This is the only way to create a threaded timer queue because the constructor is protected. The first argument specifies if other facilities can share this queue. The second argument specifies the thread priority.
createTimer()	This is a "factory" method to create timers which use this queue.
show()	Display info about object
release()	Release the queue, i.e. the calling facility will no longer use the queue. The caller MUST ensure that it does not own any active timers, i.e. it must cancel all active timers it owns before calling release(). When the last facility sharing a queue calls release(), all resources used by the queue are freed.

20.10.1.3 epicsTimerQueueNotify and epicsTimerQueuePassive

Two classes `epicsTimerQueueNotify` and `epicsTimerQueuePassive` are provided to manage a timer queue in single thread applications. Since it is single threaded, the application is responsible for requesting that the queue be processed.

```
class epicsTimerQueueNotify {
public:
    // called when a new timer is inserted into the queue and the
    // delay to the next expire has changed
    virtual void reschedule () = 0;
};

class epicsTimerQueuePassive {
public:
    static epicsTimerQueuePassive & create ( epicsTimerQueueNotify & );
    virtual ~epicsTimerQueuePassive () = 0;
    virtual epicsTimer & createTimer ( epicsTimerNotify & ) = 0;
    virtual void process () = 0;
    virtual double getNextExpireDelay () const = 0;
    virtual void show ( unsigned int level ) const = 0;
};
```

Method	Meaning
epicsTimerQueueNotify reschedule()	This class has a single method reschedule(). It is called whenever a new timer is inserted into the queue or the delay to the next expire is changed.
epicsTimerQueuePassive	epicsTimerQueuePassive is an abstract base class so cannot be instantiated directly, but contains a static member function to create a concrete passive timer queue object of a (hidden) derived class.
create()	A "factory" method to create a non-threaded timer queue. The calling software also passes an object derived from epicsTimerQueueNotify to receive reschedule() callbacks.

Method	Meaning
~epicsTimerQueuePassive()	Destructor. The caller MUST ensure that it does not own any active timers, i.e. it must cancel any active timers before deleting the epicsTimerQueuePassive object.
createTimer()	This is a "factory" method for creating timers which uses this queue.
process()	This calls expire() for all timers that have expired. The facility that creates the queue MUST call this, using getExpireDelay() and its epicsTimerQueueNotify::reschedule() method to work out when it will next be needed.
getExpireDelay()	Return the number of seconds until the first timer in the queue will expire. The result will be 0.0 if no timers are scheduled.
show()	Display info about object

20.10.2 C Interface

```
typedef struct epicsTimerForC * epicsTimerId;
typedef void ( *epicsTimerCallback ) ( void *pPrivate );

/* thread managed timer queue */
typedef struct epicsTimerQueueForC * epicsTimerQueueId;
epicsTimerQueueId epicsTimerQueueAllocate(
    int okToShare, unsigned int threadPriority );
void epicsTimerQueueRelease ( epicsTimerQueueId );
epicsTimerId epicsTimerQueueCreateTimer(
    epicsTimerQueueId queueid, epicsTimerCallback callback, void *arg );
void  epicsTimerQueueShow ( epicsTimerQueueId id, unsigned int level );

/* passive timer queue */
typedef struct epicsTimerQueuePassiveForC * epicsTimerQueuePassiveId;
typedef void ( *epicsTimerQueueRescheduleCallback ) ( void *pPrivate );
epicsTimerQueuePassiveId epicsTimerQueuePassiveCreate (
    epicsTimerQueueRescheduleCallback, void *pPrivate );
void epicsTimerQueuePassiveDestroy ( epicsTimerQueuePassiveId );
epicsTimerId epicsTimerQueuePassiveCreateTimer (
    epicsTimerQueuePassiveId queueid,epicsTimerCallback pCallback,void *pArg);
void epicsTimerQueuePassiveProcess ( epicsTimerQueuePassiveId );
double epicsTimerQueuePassiveGetDelayToNextExpire ( epicsTimerQueuePassiveId );
void  epicsTimerQueuePassiveShow (
    epicsTimerQueuePassiveId id, unsigned int level );

/* timer */
void epicsTimerDestroy ( epicsTimerId id );
void epicsTimerStartTime ( epicsTimerId id, const epicsTimeStamp *pTime );
void epicsTimerStartDelay ( epicsTimerId id, double delaySeconds );
void epicsTimerCancel ( epicsTimerId id );
double epicsTimerGetExpireDelay ( epicsTimerId id );
void  epicsTimerShow ( epicsTimerId id, unsigned int level );
```

The C interface provides most of the facilities as the C++ interface. It does not support the periodic timer features.

20.10.3 Example

This example creates a timer queue and two objects which have a timer that uses the queue. Each object is requested to schedule itself. The expire() callback just prints the name of the object. After scheduling each object the main thread just sleeps long enough for each expire to occur and then just returns.

```
#include <stdio.h>

#include "epicsTimer.h"

class something;
class myCallback: public epicsTimerNotify {
public:
    myCallback(something &ref): owner(ref) {}
    virtual expireStatus expire();
private:
    something& owner;
};

class something {
public:
    something(const char* nm,epicsTimerQueueThreaded &queue)
    : name(nm), callback(*this), timer(queue.createTimer(callback)) {}
    ~something() {delete &timer;}
    void printName() {printf("%s\n",name);}
    void schedule(double delay) {timer.start(delay);}
    void start(double delay) {timer.start(delay);}
private:
    const char* name;
    myCallback callback;
    epicsTimer &timer;
};

epicsTimerNotify::expireStatus myCallback::expire()
{owner.printName(); return(noRestart);}

int main()
{
    epicsTimerQueueThreaded &queue = epicsTimerQueueThreaded::allocate(true);
    something first("first",queue);
    something second("second",queue);

    first.start(1.0);
    second.start(1.5);
    epicsThreadSleep(2.0);
    queue.release();
    return(0);
}
```

20.11 fdmgr

File Descriptor Manager. `fdManager.h` describes a C++ implementation. `fdmgr.h` describes a C implementation. Neither is currently documented.

20.12 freeList

`freeList.h` describes routines to allocate and free fixed size memory elements. Free elements are maintained on a free list rather then being returned to the heap via calls to free. When it is necessary to call malloc(), memory is allocated in multiples of the element size.

```
void freeListInitPvt(void **ppvt, int size, int nmalloc);
void *freeListCalloc(void *pvt);
void *freeListMalloc(void *pvt);
void freeListFree(void *pvt, void*pmem);
void freeListCleanup(void *pvt);
size_t freeListItemsAvail(void *pvt);
```

where

pvt - For internal use by the freelist library. Caller must provide storage for a "void *pvt"
size - Size in bytes of each element. Note that all elements must be same size
nmalloc - Number of elements to allocate when regular malloc() must be called.

20.13 gpHash

`gpHash.h` describes a general purpose hash table for character strings. The hash table contains *tableSize* entries. Each entry is a list of members that hash to the same value. The user can maintain separate directories which share the same table by having a different *pvt* value for each directory.

```
typedef struct{
    ELLNODE     node;
    const char  *name;          /*address of name placed in directory*/
    void        *pvtid;         /*private name for subsystem user*/
    void        *userPvt;       /*private for user*/
} GPHENTRY;

/*tableSize must be power of 2 in range 256 to 65536*/
void gphInitPvt(void **ppvt,int tableSize);
GPHENTRY *gphFind(void *pvt,const char *name,void *pvtid);
GPHENTRY *gphAdd(void *pvt,const char *name,void *pvtid);
void gphDelete(void *pvt,const char *name,void *pvtid);
void gphFreeMem(void *pvt);
void gphDump(void *pvt);
```

where

pvt - For internal use by the gpHash library. Caller must provide storage for a "void *pvt"
name - The character string that will be hashed and added to table.
pvtid - The name plus value of this pointer constitute a unique entry.

20.14 logClient

The iocLog client. This does not really belong in libCom.

20.15 macLib

`macLib.h` describes a general purpose macro substitution library. It is used for all macro substitution in base.

```
long macCreateHandle(
    MAC_HANDLE  **handle,       /* address of variable to receive pointer */
                                /* to new macro substitution context */
    char        *pairs[]        /* pointer to NULL-terminated array of */
                                /* {name,value} pair strings; a NULL */
                                /* value implies undefined; a NULL */
                                /* argument implies no macros */
);

void macSuppressWarning(
    MAC_HANDLE  *handle,        /* opaque handle */
    int         falseTrue       /*0 means ussue, 1 means suppress*/
);

/*following returns #chars copied, <0 if any macros are undefined*/
long macExpandString(
    MAC_HANDLE  *handle,        /* opaque handle */
    char        *src,           /* source string */
    char        *dest,          /* destination string */
    long        maxlen          /* maximum number of characters to copy */
                                /* to destination string */
);


/*following returns length of value */
long macPutValue(
    MAC_HANDLE  *handle,        /* opaque handle */
    char        *name,          /* macro name */
    char        *value          /* macro value */
);

/*following returns #chars copied (<0 if undefined) */
long macGetValue(
    MAC_HANDLE  *handle,        /* opaque handle */
    char        *name,          /* macro name or reference */
    char        *value,         /* string to receive macro value or name */
                                /* argument if macro is undefined */
    long        maxlen          /* maximum number of characters to copy */
                                /* to value */
);

long macDeleteHandle(MAC_HANDLE *handle);
long macPushScope(MAC_HANDLE *handle);
```

```
long macPopScope(MAC_HANDLE *handle);
long macReportMacros(MAC_HANDLE *handle);

/* Function prototypes (utility library) */

/*following returns #defns encountered; <0 = ERROR */
long macParseDefns(
     MAC_HANDLE *handle,        /* opaque handle; can be NULL if default */
                                /* special characters are to be used */
    char        *defns,         /* macro definitions in "a=xxx,b=yyy" */
                                /* format */
    char        **pairs[]       /* address of variable to receive pointer */
                                /* to NULL-terminated array of {name, */
                                /* value} pair strings; all storage is */
                                /* allocated contiguously */
);

/*following returns #macros defined; <0 = ERROR */
long macInstallMacros(MAC_HANDLE *handle,
    char        *pairs[]        /* pointer to NULL-terminated array of */
                                /* {name,value} pair strings; a NULL */
                                /* value implies undefined; a NULL */
                                /* argument implies no macros */
);
```

NOTE: The directory <base>/src/libCom/macLib contains two files `macLibNOTES` and `macLibREADME` that explain this library.

20.16 misc

20.16.1 aToIPAddr

The function prototype for this routine appears in `osiSock.h`

```
int aToIPAddr(const char *pAddrString, unsigned short defaultPort,
              struct sockaddr_in *pIP);
```

aToIPAddr() fills in the structure pointed to by the *pIP* argument with the Internet address and port number specified by the *pAddrString* argument.

Three forms of *pAddrString* are accepted:

1. n.n.n.n:p
   The Internet address of the host, specified as four numbers separated by periods.
2. xxxxxxxx:p
   The Internet address number of the host, specified as a single number.
3. hostname:p
   The Internet host name of the host.

In all cases the ':p' may be omitted in which case the port number is set to the value of the *defaultPort* argument. All numbers are read in base 16 if they begin with '0x' or '0X', in base 8 if they begin with '0', and in base 10 otherwise.

20.16.2 adjustment

`adjustment.h` describes a single function:

```
size_t adjustToWorstCaseAlignment(size_t size);
```

adjustToWorstCaseAlignment() returns a value >= *size* that an exact multiple of the worst case alignment for the architecture on which the routine is executed.

20.16.3 cantProceed

`cantProceed.h` describes routines that are provided for code that can't proceed when an error occurs.

```
void cantProceed(const char *errorMessage);
void *callocMustSucceed(size_t count, size_t size,const char *errorMessage);
void *mallocMustSucceed(size_t size, const char *errorMessage);
```

cantProceed() issues the error message and does not return. callocMustSucceed() and mallocMustSucceed() can be used in place of calloc() and malloc(). If they fail they just call cantProceed().

20.16.4 dbDefs

`dbDefs.h` contains definitions that are still used in base but should not be. Hopefully these all go away some day. This has been the hope for about ten years.

20.16.5 epicsString

`epicsString.h` currently describes a single function.

```
int dbTranslateEscape(char *dst, const char *src);
```

dbTranslateEscape() copies the string *src* to *dst* while substituting escape sequences. It returns the length of the resultant string (which may contain null bytes). The caller must ensure that the buffer *dst* is large enough.

20.16.6 epicsTypes

`epicsTypes.h` provides typedefs for architecture independent data types.

```
typedef char            epicsInt8;
typedef unsigned char   epicsUInt8;
typedef short           epicsInt16;
typedef unsigned short  epicsUInt16;
typedef epicsUInt16     epicsEnum16;
typedef int             epicsInt32;
typedef unsigned        epicsUInt32;
typedef float           epicsFloat32;
typedef double          epicsFloat64;
typedef unsigned long   epicsIndex;
typedef epicsInt32      epicsStatus;
```

So far the definitions provided in this header file have worked on all architectures. In addition to the above definitions `epicsTypes.h` has a number of definitions for displaying the types and other useful definitions. See the header file for details.

20.16.7 gsd_sync_defs.h

Not documented.

20.16.8 locationException

A C++ template. Not documented, nor particularly useful with the C++ standard exception hierarchy. This should be in cxxTemplates or replaced with `epicsExcept.h`.

20.16.9 shareLib.h

This is the header file for the "decorated names" that appear in header files, e.g.

```
epicsShareFunc int epicsShareAPI a_func (int arg)
```

This is used for creating DLLs for windows. Hopefully a way can be found to generated win32 DLLs which does not require decorated names.

20.16.10 truncateFile.h

```
enum TF_RETURN {TF_OK=0, TF_ERROR=1};
TF_RETURN truncateFile (const char *pFileName, unsigned size);
```

where

pFileName - name (and optionally path) of file

truncateFile() truncates the file to the specified size. truncate() is not used because it is not portable. It returns TF_OK if the file is less than size bytes or if it was successfully truncated. It returns TF_ERROR if the file could not be truncated.

20.16.11 unixFileName.h

Defines macros OSI_PATH_LIST_SEPARATOR and OSI_PATH_SEPARATOR

Chapter 21: libCom OSI libraries

21.1 Overview

Most code in base is operating system independent, i.e. the code is exactly the same for all supported operating systems. This is accomplished by providing epics defined libraries for facilities that are different on the various systems. The code is called Operating System Independent or OSI. OSI libraries have multiple implementations.

21.1.1 OSI source directory

Directory `<base>/src/libCom/osi` contains the code for the operating system independent libraries. The structure of this directory is:

```
osi/
   epics*.h
   *.cpp  - A few generic c++ implementations
   os/
       Linux/
       RTEMS/
       WIN32/
       cygwin32/
       default/
       posix/
       solaris/
       vxWorks/
NOTE: Other systems are also present but are not currently supported.
```

21.1.2 Rules for building OSI.

The osi directory contains header files that start with `epics`. These contain the definitions used by user code. Each of the directories `under osi/<arch>` contain architecture dependent code. The file names begin with `osd`. In most cases both a header and source file are present.

Installing header files residing under `src/libCom/osi` into `<base>/include`

- Files in `osi` are installed into `<base>/include`
- Files in `osi/os/<*>` are installed into `<base>/include/os/<arch>`. The search order for locating a file is:
  - `libCom/osi/os/<arch>`
  - `libCom/osi/os/posix`
  - `libCom/osi/os/default`

The search order for locating `osd` source files is:

- libCom/osi/os/<arch>

- libCom/osi/os/posix
- libCom/osi/os/default

21.1.3 Locating OSI header files.

When code is compiled the search order for locating header files in `base/include` is:

- <base>/include/os/<arch>
- <base>/include

21.2 epicsAssert

This is a replacement for ANSI C's `assert`. To use this version just include:

```
include "epicsAssert.h"
```

instead of

```
include <assert.h>
```

If an `assert` fails, it calls `errlog` indicating the program's author, file name, and line number. Under each OS there are specialized instructions assisting the user to diagnose the problem and generate a good bug report. For instance, under vxWorks, there are instructions on how to generate a stack trace, and on posix there are instructions about saving the core file. After printing the message the calling thread is suspended.

21.3 epicsEvent

`epicsEvent.h` contains a C++ and a C description for an event semaphore.

21.3.1 C++ Interface

```
typedef enum {
    epicsEventWaitOK,epicsEventWaitTimeout,epicsEventWaitError
}epicsEventWaitStatus;

typedef enum {epicsEventEmpty,epicsEventFull} epicsEventInitialState;

class epicsEvent{
public:
    epicsEvent(epicsEventInitialState initial=epicsEventEmpty);
    ~epicsEvent();
    void signal();
    void wait();
    bool wait( double timeOut ); /* false if empty at time out */
    bool tryWait(); /* false if empty */
    void show( unsigned level ) const;

    class invalidSemaphore {}; /* exception */
```

```
    class noMemory {}; /* exception */
private:
    epicsEventId id;
};
```

Method	Meaning
epicsEvent	An epicsEvent can be created empty or full. If it is created empty then a wait issued before a signal will block. If created full then the first wait will always succeed. Multiple signals may be issued between waits but have the same effect as a single signal.
~epicsEvent	Remove the event and any resources it uses. Any further use of the semaphore result in unknown (most certainly bad) behavior. No outstanding take can be active when this call is made.
signal	Signal the event i.e. ensures that the next or current call to wait completes.
wait()	Wait for the event.
wait(double timeOut)	Similar to wait except that if event does not happen the call completes after the specified time out. The return value is (false,true) if the event (did not, did) happen.
tryWait()	Similar to wait except that if event does not happen the call completes immediately. The return value is (false,true) if the event (did not, did) happen.
show	Display information about the semaphore. The information displayed is architecture dependent.

The primary use of an event semaphore is for synchronization. An example of using an event semaphore is a consumer thread that processes requests from one or more producer threads. For example:

- When creating the consumer thread also create an epicsEvent.
  ```
  epicsEvent *pevent = new epicsEvent;
  ```
- The consumer thread has code containing:
  ```
  while(1) {
      pevent->wait();
      while(/*more work*/) {
          /*process work*/
      }
  }
  ```
- Producers create requests and issue the statement:
  ```
  pevent->signal();
  ```

21.3.2 C Interface

```
typedef void *epicsEventId;

epicsEventId epicsEventCreate(epicsEventInitialState initialState);
epicsEventId epicsEventMustCreate (epicsEventInitialState initialState);
void epicsEventDestroy(epicsEventId id);
void epicsEventSignal(epicsEventId id);
```

```
epicsEventWaitStatus epicsEventWait(epicsEventId id);
void epicsEventMustWait(epicsEventId id);
epicsEventWaitStatus epicsEventWaitWithTimeout(epicsEventId id, double timeOut);
epicsEventWaitStatus epicsEventTryWait(epicsEventId id);
void epicsEventShow(epicsEventId id, unsigned int level);
```

Each C routine corresponds to one of the C++ methods. `epicsEventMustCreate` and `epicsEventMustWait` do not return if they fail.

21.4 epicsFindSymbol

`epicsFindSymbol.h` contains the following definition:

```
void * epicsFindSymbol(const char *name);
```

Method	Meaning
epicsFindSymbol	Return the address of the variable name

vxWorks provides a function symFindByName, which finds and returns the address of global variables. The registry, described in the next chapter, provides an alternative but also requires extra work by iocCore and/or user code. If the registry is asked for a name that has not been registered, it calls epicsFindSymbol. If epicsFindSymbol can locate the global symbol it returns the address, otherwise it returns null.

On vxWorks epicsFindSymbol calls symFindByName.

A default version just returns null, i.e. it always fails.

21.5 epicsInterrupt

`epicsInterrupt.h` contains the following:

21.5.1 C Interface

```
int epicsInterruptLock();
void epicsInterruptUnlock(int key);
int epicsInterruptIsInterruptContext();
```

```
void epicsInterruptContextMessage(const char *message);
```

Method	Meaning

epicsInterruptLock	Lock interrupts and return a key to be passed to epicsInterruptUnlock
	To lock the following is done.
	int key;
	...
	key = epicsInterruptLock();
	...
	epicsInterruptUnlock(key);

epicsInterruptUnlock	Unlock interrupts.
epicsInterruptIsInterruptContext	Return (true, false) if current context is interrupt context.
epicsInterruptContextMessage	Generate a message while interrupt context is true.

21.5.2 Implementation notes

A vxWorks specific version is provided. It maps directly to intLib calls.

An RTEMS version is provided that maps to rtems_ calls.

A default version is provided that uses a global semaphore to lock. This version is intended for operating systems in which iocCore will run as a multi threaded process. The global semaphore is thus only global within the process. This version is intended for use on all except real time operating systems.

The vxWorks implementation will most likely not work on symmetric multiprocessing systems.

The reason epicsInterrupt is needed is:

- callbackRequest and scanOnce can be issued from interrupt level.
- The errlog routines can be called while at interrupt level.

21.6 epicsMutex

`epicsMutex.h` contains both C++ and C descriptions for a mutual exclusion semaphore.

21.6.1 C++ Interface

```
typedef enum {
    epicsMutexLockOK,epicsMutexLockTimeout,epicsMutexLockError
} epicsMutexLockStatus;
class epicsMutex {
public:
    epicsMutex ();
    ~epicsMutex ();
```

```
    void lock (); /* blocks until success */
    bool lock ( double timeOut ); /* true if successful */
    bool tryLock (); /* true if successful */
    void unlock ();
    void show ( unsigned level ) const;

    class invalidSemaphore {}; /* exception */
    class noMemory {}; /* exception */
private:
};
// Automatically applies and releases the mutex.
// This is for use in situations where C++ exceptions are possible.
class epicsAutoMutex {
public:
    epicsAutoMutex ( epicsMutex & );
    ~epicsAutoMutex ();
private:
};
// Automatically releases and reapplies the mutex.
// This is for use in situations where C++ exceptions are possible.
class epicsAutoMutexRelease {
public:
    epicsAutoMutexRelease ( epicsMutex & );
    ~epicsAutoMutexRelease ();
private:
    epicsAutoMutexRelease ( const epicsAutoMutex & );
    epicsAutoMutexRelease & operator = ( const epicsAutoMutex & );
    epicsMutex & rMutex;
};
```

Method	Meaning
epicsMutex	Create a mutual exclusion semaphore.
~epicsMutex	Remove the semaphore and any resources it uses. Any further use of the semaphore result in unknown (most certainly bad) results.
lock()	Wait until the resource is free. After a successful lock additional, i.e. recursive, locks of any type can be issued but each must have an associated unlock.
lock(double timeOut)	Similar to lock except that, if the resource is owned by another thread, the call completes after the specified time out. The return value is (false,true) if the resource (is not, is) owned by the caller.
tryLock()	Similar to lock except that, if the resource is owned by another thread, the call completes immediately. The return value is (false,true) if the resource (is not, is) owned by the caller.
unlock	Release the resource. If a thread issues recursive locks, there must be an unlock for each lock
semMutexShow	Display information about the semaphore. The results are architecture dependent.

Method	Meaning

epicsAutoMutex	Automatically applies and releases the mutex. This is useful for situations where exceptions are possible: For example
	`epicsMutex lock;`
	`...`
	`{`
	`  epicsAutoMutex safeLock(lock);`
	`...`
	`}`
	When safeLock is constructed it locks `lock`. When either an exception occurs or when the block exits the destructor for safeLock automatically unlocks `lock`.

epicsAutoMutexRelease	Automatically releases and then reapplys the mutex. This is useful for situations where exceptions are possible: For example
	`epicsMutex lock;`
	`...`
	`{`
	`  epicsAutoMutexRelease safeUnlock(lock);`
	`...`
	`}`
	When safeUnlock is constructed it releases `lock`. When either an exception occurs or when the block exits the destructor for safeUnlock automatically locks `lock`.

Mutual exclusion semaphores are for situations requiring mutually exclusive access to resources. A mutual exclusion semaphore may be taken recursively, i.e. can be taken more than once by the owner thread before releasing it. Recursive takes are useful for a set of routines that call each other while working on a mutually exclusive resource.

The typical use of a mutual exclusion semaphore is:

```
epicsMutex *plock = new epicsMutex;
...
...
plock->lock();
/* process resource */
plock->unlock();
```

21.6.2 C Interface

```
typedef void *epicsMutexId;

epicsMutexId epicsMutexCreate(void);
epicsMutexId epicsMutexMustCreate (void);
void epicsMutexDestroy(epicsMutexId id);
void epicsMutexUnlock(epicsMutexId id);
epicsMutexLockStatus epicsMutexLock(epicsMutexId id);
epicsMutexLockStatus epicsMutexMustLock(epicsMutexId id);
epicsMutexLockStatus epicsMutexLockWithTimeout(epicsMutexId id, double timeOut);
epicsMutexLockStatus epicsMutexTryLock(epicsMutexId id);
void epicsMutexShow(epicsMutexId id,unsigned  int level);
```

Each C routine corresponds to one of the C++ methods. `epicsMutexMustCreate` and `epicsMutexMustLock` do not return if they fail.

21.6.3 Implementation Notes

The implementation:

- Must implement recursive locking
- May implement priority inheritance and be deletion safe

A posix version is implemented via pthreads.

21.7 epicsThread

`epicsThread.h` comtains C++ and C descriptions for a thread.

21.7.1 C Interface

```
typedef void (*EPICSTHREADFUNC)(void *parm);

static const unsigned epicsThreadPriorityMax = 99;
static const unsigned epicsThreadPriorityMin = 0;
/* some generic values */
static const unsigned epicsThreadPriorityLow = 10;
static const unsigned epicsThreadPriorityMedium = 50;
static const unsigned epicsThreadPriorityHigh = 90;
/* some iocCore specific values */
static const unsigned epicsThreadPriorityChannelAccessServer = 30;
static const unsigned epicsThreadPriorityScanLow = 60;
static const unsigned epicsThreadPriorityScanHigh = 70;

/* stack sizes for each stackSizeClass are implementation and CPU dependent */
typedef enum {
    epicsThreadStackSmall, epicsThreadStackMedium, epicsThreadStackBig
} epicsThreadStackSizeClass;

typedef enum {
    epicsThreadBooleanStatusFail, epicsThreadBooleanStatusSuccess
} epicsThreadBooleanStatus;

unsigned int epicsThreadGetStackSize(epicsThreadStackSizeClass size);

typedef int epicsThreadOnceId;
#define EPICS_THREAD_ONCE_INIT 0

void epicsThreadOnce(epicsThreadOnceId *id, EPICSTHREADFUNC, void *arg);

void epicsThreadExitMain(void);

/* (epicsThreadId)0 is guaranteed to be an invalid thread id */
```

```
typedef void *epicsThreadId;

epicsThreadId epicsThreadCreate(const char *name,
    unsigned int priority, unsigned int stackSize,
    EPICSTHREADFUNC funptr,void *parm);
void epicsThreadSuspendSelf(void);
void epicsThreadResume(epicsThreadId id);
unsigned int epicsThreadGetPriority(epicsThreadId id);
unsigned int epicsThreadGetPrioritySelf();
void epicsThreadSetPriority(epicsThreadId id,unsigned int priority);
epicsThreadBooleanStatus epicsThreadHighestPriorityLevelBelow (
        unsigned int priority, unsigned *pPriorityJustBelow);
epicsThreadBooleanStatus epicsThreadLowestPriorityLevelAbove (
        unsigned int priority, unsigned *pPriorityJustAbove);
int epicsThreadIsEqual(epicsThreadId id1, epicsThreadId id2);
int epicsThreadIsSuspended(epicsThreadId id);
void epicsThreadSleep(double seconds);
epicsThreadId epicsThreadGetIdSelf(void);
epicsThreadId epicsThreadGetId(const char *name);

const char * epicsThreadGetNameSelf(void);
void epicsThreadGetName(epicsThreadId id, char *name, size_t size);

void epicsThreadShowAll(unsigned int level);
void epicsThreadShow(epicsThreadId id,unsigned int level);

typedef void * epicsThreadPrivateId;
epicsThreadPrivateId epicsThreadPrivateCreate(void);
void epicsThreadPrivateDelete(epicsThreadPrivateId id);
void epicsThreadPrivateSet(epicsThreadPrivateId,void *);
void * epicsThreadPrivateGet(epicsThreadPrivateId);
```

Method	Meaning
epicsThreadGetStackSize	Get a stack size value that can be given to epicsThreadCreate. Three sizes can be requested: small, medium, and large.

epicsThreadOnce	This is used as follows:
	void myInitFunc(void * arg)
	{
	...
	}
	...
	epicsThreadOnceId onceFlag = OSITHREAD_ONCE_INIT;
	...
	epicsThreadOnce(&onceFlag,myInitFunc,(void *)myParm)
	For each unique epicsThreadOnceId, epicsThreadOnce guarantees
	1) myInitFunc is called only once.
	2) myInitFunc completes before any epicsThreadOnce call completes.

Method	Meaning
epicsThreadExitMain	If the main routine is done but wants to let other threads run it can call this routine. This should be the last call in main, except the final return. On most systems epicsThreadExitMain never returns. This must only be called by the main thread.
epicsThreadCreate	Create a new thread. The use made of the name, priority, and stacksize arguments is implementation dependent. Some implementation may ignore one or more of these. The funptr argument specifies a function that implements the thread and parm is the single argument passed to funptr. A thread terminates when funptr returns.
epicsThreadSuspendSelf	This causes the calling thread to suspend. The only way it can resume is for another thread to call epicsThreadResume.
epicsThreadResume	Resume a suspended thread. Only do this if you know that it is safe to resume a suspended thread.
epicsThreadGetPriority	Get the priority of the specified thread.
epicsThreadGetPrioritySelf	Get the priority of this thread.
epicsThreadSetPriority	Set a new priority for the specified thread. The result is implementation dependent.
epicsThreadHighestPriorityLevelBelow	Get a priority that is just lower than the specified priority.
epicsThreadLowestPriorityLevelAbove	Get a priority that is just above the specified priority.
epicsThreadIsEqual	Compares two threadIds and returns (0,1) if they (are not, are) the same.
epicsThreadIsSuspended	BAD NAME. taskwd needs this call. It really means: Is there something wrong with this thread? This could mean suspended or no longer exists or etc. It is a problem because it is implementation dependent.
epicsThreadSleep	Sleep for the specified period of time, i.e. sleep without using the cpu.
epicsThreadGetIdSelf	Get the threadId of the calling thread.
epicsThreadGetId	Get the threadId if the specified thread. A return of 0 means that no thread was found with the specified name.
epicsThreadGetNameSelf	Get the name of the calling thread.
epicsThreadGetName	Get the name of the specified thread. The value is copied to a caller specified buffer so that if the thread terminates the caller is not left with a pointer to something that may no longer exist.
epicsThreadShowAll	Display info about all threads.
epicsThreadShow	Display info about the specified thread.
epicsThreadPrivateCreate	Thread private variables are intended for use by legacy libraries written for a single threaded environment and which uses a global variable to store private data. The only code in base that currently needs this facility is channel access. A library that needs a private variable should make exactly one call to epicsThreadPrivateCreate. Each thread should call epicsThreadPrivateSet when the thread is created. Each library routine can call epicsThreadPrivateGet each time it is called.

Method	Meaning
epicsThreadPrivateDelete	Delete a thread private variable.
epicsThreadPrivateSet	Set the value for a thread private variable.
epicsThreadPrivateGet	Get the value of a thread private variable, the value is the value set by the call to epicsThreadPrivateSet that was made by the same thread. If called before epicsThreadPrivateSet it returns 0.

epicsThread is meant as a somewhat minimal interface for multithreaded applications. It can be implemented on a wide variety of systems with the restriction that the system MUST support a multithreaded environment. A POSIX pthreads version is provided.

The interface provides the following thread facilities, with restrictions as noted:

- Life cycle - A thread starts life as a result of a call to epicsThreadCreate. It terminates when the thread function returns. It should not return until it has released all resources it uses. If a thread is expected to terminate as a natural part of it's life cycle then the thread function must return.
- epicsThreadOnce - This provides the ability to have an initialization function that is guaranteed to be called exactly once.
- main - If a main routine finishes it's work but wants to leave other threads running it can call epicsThreadExitMain, which should be the last statement in main.
- Priorities - Ranges between 0 and 99 with a higher number meaning higher priority. A number of constants are defined for iocCore specific threads. The underlying implementation may collapse the range 0 to 99 into a smaller range; even a single priority. User code should never use priorities to guarantee correct behavior.
- Stack Size - epicsThreadCreate accepts a stack size parameter. Three generic sizes are available: small, medium, and large. Portable code should always use one of the generic sizes. Some implementation may ignore the stack size request and use a system default instead. Virtual memory systems providing generous stack sizes can be expected to use the system default.
- epicsThreadId - This is given a value as a result of a call to epicsThreadCreate. A value of 0 always means no thread. If a threadId is used for a thread that has terminated the result is not defined (but will normally lead to bad things happening). Thus code that looks after other threads MUST be aware of threads terminating.

21.7.2 C++ Interface

```
class epicsShareClass epicsThreadRunable {
public:
    virtual void run() = 0;
    virtual void stop();
    virtual void show(unsigned int level) const;
};

class epicsShareClass epicsThread {
public:
    epicsThread (epicsThreadRunable &,const char *name, unsigned int stackSize,
        unsigned int priority=epicsThreadPriorityLow);
    virtual ~epicsThread ();
    void start();
    void resume ();
    void getName (char *name, size_t size) const;
    unsigned int getPriority () const;
```

```
    void setPriority (unsigned int);
    bool priorityIsEqual (const epicsThread &otherThread) const;
    bool isSuspended () const;
    bool isCurrentThread () const;
    bool operator == (const epicsThread &rhs) const;
    /* these operate on the current thread */
    static void suspendSelf ();
    static void sleep (double seconds);
    static epicsThread & getSelf ();
    static const char * getNameSelf ();
private:
    epicsThreadRunable &runable;
    epicsThreadId id;
    epicsEvent exit;
    epicsEvent begin;
    bool cancel;

    epicsThread ( const epicsThread & );
    epicsThread & operator = ( const epicsThread & );

    friend void epicsThreadCallEntryPoint (void *pPvt);
};

template <class T>
class epicsThreadPrivate {
public:
    epicsThreadPrivate ();
    ~epicsThreadPrivate ();
    T *get () const;
    void set (T *);
    class unableToCreateThreadPrivate {}; // exception
private:
    epicsThreadPrivateId id;
};
```

The C++ interface is just a wrapper around the C interface. Two differences are the method `start` and the class `epicsThreadRunable`.

The method `start` must be called only after the `epicsThead` object is constructed. It in turn calls the `run` method of the `epicsThreadRunable` object.

Code using the C++ interface code must provide a class that derives from `epicsThreadRunable`. One way to accomplish this is as follows:

```
class myThread: public epicsThreadRunable {
public:
    myThread(int arg,const char *name);
    virtual ~myThread();
    virtual void run();
    epicsThread thread;
    ...
}

myThread::myThread(int arg,const char *name) :
    thread(*this,name,epicsThreadGetStackSize(epicsThreadStackSmall),50)
```

```
{
    thread.start();
}

myThread::~myThread() {}

void myThread::run()
{
    ...
}
```

21.8 epicsTime

`epicsTime.h` contains C++ and C descriptions for time.

21.8.1 Time Related Structures

```
/* epics time stamp for C interface*/
typedef struct epicsTimeStamp {
    epicsUInt32    secPastEpoch;   /* seconds since 0000 Jan 1, 1990 */
    epicsUInt32    nsec;           /* nanoseconds within second */
} epicsTimeStamp;

/*TS_STAMP is deprecated */
#define TS_STAMP epicsTimeStamp

struct timespec; /* POSIX real time */
struct timeval; /* BSD */

/* Network Time Protocal Timestamp */
struct ntpTimeStamp {
    epicsUInt32 l_ui; /* sec past NTP epoch */
    epicsUInt32 l_uf; /* fractional seconds */
};
// The next two structures are used only by C++ interface
// extended ANSI C RTL "struct tm" which includes  nano seconds within a second.
struct tm_nano_sec {
    struct tm ansi_tm; /* ANSI C time details */
    unsigned long nSec; /* nano seconds extension */
};
struct time_t_wrapper {
    time_t ts;
};
```

The above structures are for the various time formats.

- `epicsTimeStamp` - This is the structure used by the C interface for epics time stamps. The C++ interface stores this information in private members. The two elements of the class are:
    - `secPastEpoch` - The number of seconds since January 1, 1990 (the epics epoch).
    - nsec - nanoseconds within a second

NOTE: `TS_STAMP` is defined for compatibility with existing code.

- `timespec` - This is defined by POSIX Real Time. It requires two mandatory fields:
  - `time_t tv_sec` - Number of seconds since 1970 (The POSIX epoch)
  - `long tv_nsec` - nanoseconds within a second
- `timeval` - BSD and SRV5 Unix timestamp. It has two fields:
  - `time_t tv_sec` - Number of seconds since 1970 (The POSIX epoch)
  - `time_t tv_nsec` - nanoseconds within a second
- `ntpTimeStamp` - Network Time Protocol timestamp. The fields are:
  - l_ui - Number of seconds since 1900 (The NTP epoch)
  - l_uf - Fraction of a second. For example 0x800000000 represents 1/2 second.
- `tm` - Defined by standard C library
- `tm_nano_sec` - Defined by epics. It just adds a nanosecond field to `struct tm`.
- `time_t_wrapper` - This is for converting to/from the ANSI C `time_t`. Since `time_t` is usually an elementary type providing a conversion operator from `time_t` to/from `epicsTime` could cause undesirable implicit conversions. Providing a conversion operator to/from a `time_t_wrapper` prevents implicit conversions.

NOTE on conversion. The epics implementation will properly convert between the various formats from the beginning of the EPICS epoch until at least 2038. Unless the underlying architecture support has defective POSIX, BSD/SRV5, or standard C time support the epics implementation should be valid until 2106.

21.8.2 C++ Interface

```
class epicsTime;

class epicsTimeEvent
{
    friend class epicsTime;
public:
    epicsTimeEvent (const int &eventName);
private:
    unsigned eventNumber;
};

class epicsTime
{
public:
    // exceptions
    class unableToFetchCurrentTime {};
    class formatProblemWithStructTM {};

    epicsTime ();
    epicsTime (const epicsTime &t);

    static epicsTime getEvent (const epicsTimeEvent &event);
    static epicsTime getCurrent ();

    // convert to and from EPICS epicsTimeStamp format
    operator epicsTimeStamp () const;
    epicsTime (const epicsTimeStamp &ts);
    epicsTime operator = (const epicsTimeStamp &rhs);
```

```
// convert to and from ANSI time_t
operator time_t_wrapper () const;
epicsTime (const time_t_wrapper &tv);
epicsTime operator = (const time_t_wrapper &rhs);

// convert to and from ANSI C’s "struct tm" (with nano seconds)
operator tm_nano_sec () const;
epicsTime (const tm_nano_sec &ts);
epicsTime operator = (const tm_nano_sec &rhs);

// convert to and from POSIX RT’s "struct timespec"
operator struct timespec () const;
epicsTime (const struct timespec &ts);
epicsTime operator = (const struct timespec &rhs);

// convert to and from BSD’s "struct timeval"
operator struct timeval () const;
epicsTime (const struct timeval &ts);
epicsTime operator = (const struct timeval &rhs);

// convert to and from NTP timestamp format
operator ntpTimeStamp () const;
epicsTime (const ntpTimeStamp &ts);
epicsTime operator = (const ntpTimeStamp &rhs);

// convert to and from GDD’s aitTimeStamp format
operator aitTimeStamp () const;
epicsTime (const aitTimeStamp &ts);
epicsTime operator = (const aitTimeStamp &rhs);

// arithmetic operators
double operator- (const epicsTime &rhs) const; // returns seconds
epicsTime operator+ (const double &rhs) const; // add rhs seconds
epicsTime operator- (const double &rhs) const; // subtract rhs seconds
epicsTime operator+= (const double &rhs); // add rhs seconds
epicsTime operator-= (const double &rhs); // subtract rhs seconds

// comparison operators
bool operator == (const epicsTime &rhs) const;
bool operator != (const epicsTime &rhs) const;
bool operator <= (const epicsTime &rhs) const;
bool operator < (const epicsTime &rhs) const;
bool operator >= (const epicsTime &rhs) const;
bool operator > (const epicsTime &rhs) const;

// convert current state to user-specified string
size_t strftime (char *pBuff, size_t bufLength, const char *pFormat) const;

// dump current state to standard out
void show (unsigned interestLevel) const;

// useful public constants
```

```
    static const unsigned secPerMin;
    static const unsigned mSecPerSec;
    static const unsigned uSecPerSec;
    static const unsigned nSecPerSec;
    static const unsigned nSecPerUSec;

    // depricated
    static void synchronize ();
private:
    unsigned long secPastEpoch;// seconds since 1990
    unsigned long nSec;// nanoseconds within second
};
```

21.8.3 class epicsTimeEvent

Method	Meaning
epicsTimeEvent	This is the only method provided for this class. IT IS NOT DEFINED. Why is it needed?

21.8.4 class epicsTime

Method	Meaning
epicsTime() epicsTime(const epicsTime& t);	The default constructor sets the time to the beginning of the epics epoch.
getEvent	Returns the time for the associated event. See the description of the C routine epicsTimeGetEvent described below for details.
getCurrent	Gets the current time. An example is: `epicsTime time = epicsTime::getCurrent();`

Method	Meaning

convert to/from epicsTimeStamp	Three methods are provided for epicsTimeStamp. A copy constructor, an assignment operator, and a conversion to epicsTimeStamp. Assume the following definitions:
	`epicsTime time;`
	`epicsTimeStamp ts;`
	An example of the copy constructor is:
	`epicsTime time1(ts);`
	An example of the assignment operator is:
	`time = ts;`
	An example of the epicsTimeStamp operator is:
	`ts = time;`

Convert to/from ANSI time_t	Three methods are provided for ANSI time_t. A copy constructor, an assignment operator, and a conversion to time_t_wrapper. The structure time_t_wrapper must be used instead of time_t because undesired conversions could occur: Assume the following definitions:
	`time_t tt;`
	`time_t_wrapper ttw;`
	`epicsTime time;`
	An example of the copy constructor is:
	`ttw.tt = tt;`
	`epicsTime time1(ttw);`
	An example of the assignment operator is:
	`time = ttw;`
	An example of the time_t_wrapper operator is:
	`ttw = time;`
	`tt = ttw.tt;`

convert to and from tm_nano_sec	Three methods are provided for tm_nano_sec A copy constructor, an assignment operator, and a conversion to tm_nano_sec. Assume the following definitions:
	`tm_nano_sec ttn;`
	`epicsTime time;`
	An example of the copy constructor is:
	`epicsTime time1(ttn);`
	An example of the assignment operator is:
	`time = ttn;`
	An example of the tm_nano_sec operator is:
	`ttn = time;`

Method	Meaning

convert to and from POSIX RT's "struct timespec"	Three methods are provided for struct timespec. A copy constructor, an assignment operator, and a conversion to struct timespec. Assume the following definitions:
	`struct timespec tts;`
	`epicsTime time;`
	An example of the copy constructor is:
	`epicsTime time1(tts);`
	An example of the assignment operator is:
	`time = tts;`
	An example of the struct timespec operator is:
	`ttn = time;`

convert to and from BSD's "struct timeval"	Three methods are provided for struct timeval. A copy constructor, an assignment operator, and a conversion to struct timeval. Assume the following definitions:
	`struct timeval ttv;`
	`epicsTime time;`
	An example of the copy constructor is:
	`epicsTime time1(ttv);`
	An example of the assignment operator is:
	`time = ttv;`
	An example of the struct timeval operator is:
	`ttn = time;`

convert to and from NTP timestamp format	Three methods are provided for ntpTimeStamp. A copy constructor, an assignment operator, and a conversion to ntpTimeStamp. Assume the following definitions:
	`ntpTimeStamp ntp;`
	`epicsTime time;`
	An example of the copy constructor is:
	`epicsTime time1(ntp);`
	An example of the assignment operator is:
	`time = ntp;`
	An example of the ntpTimeStamp operator is:
	`ntp = time;`

Method	Meaning

arithmetic operators
-
+
+=
-=
	The arithmetic operators allow the difference of two epicsTimes, with the result in seconds. It also allows -, +, +=, and -= where the left hand argument is an epicsTime and the right hand argument is a double. Examples are:
	`epicsTime time, time1, time2;`
	`double t1,t2,t3;`
	`...`
	`t1 = time2 - time1;`
	`time = time1 + 4.5;`
	`time = time2 - t3;`
	`time2 += 6.0;`

Comparison operators
==, |=, <=, <, >=, >
	Two epics times can be compared:
	`epicsTime time1, time2;`
	`...`
	`if(time1<=time2) { ...`

strftime	This is a facility similar to the ANSI C library routine strftime. See K&R for details about strftime. The epicsTime method also provides support for the printing the nanoseconds portion of the time. It looks at the end of the format string for something on the form "%0<n>f". It uses this format to display the nanoseconds converted to the correct precision. For example:
	`epicsTime time = epicsTime::getCurrent();`
	`char buf[20];`
	`time.strftime(buf,20,"%Y/%m/%d %H:%M:%S.%06f");`
	`printf("%s\n",buf);`
	Will print the time in the format:
	`2001/01/26 20:50:29.813505`

show	Shows the date/time.

21.8.5 C Interface

```
/* All epicsTime routines return (-1,0) for (failure,success) */
#define epicsTimeOK 0
#define epicsTimeERROR (-1)

#define epicsTimeEventCurrentTime 0

/* convert to and from ANSI C's "time_t" */
int epicsTimeGetCurrent (epicsTimeStamp *pDest);
int epicsTimeGetEvent (epicsTimeStamp *pDest, unsigned eventNumber);

/* convert to and from ANSI C's "struct tm" with nano second */
int epicsTimeToTime_t (time_t *pDest, const epicsTimeStamp *pSrc);
int epicsTimeFromTime_t (epicsTimeStamp *pDest, time_t src);

/*convert to and from ANSI C's "struct tm" with nano seconds */
int epicsTimeToTM (
    struct tm *pDest, unsigned long *pNSecDest, const epicsTimeStamp *pSrc);
```

```
int epicsTimeFromTM (
    epicsTimeStamp *pDest, const struct tm *pSrc, unsigned long nSecSrc);

/* convert to and from POSIX RT's "struct timespec" */
int epicsTimeToTimespec (struct timespec *pDest, const epicsTimeStamp *pSrc);
int epicsTimeFromTimespec (epicsTimeStamp *pDest, const struct timespec *pSrc);

/* convert to and from BSD's "struct timeval" */
int epicsTimeToTimeval (struct timeval *pDest, const epicsTimeStamp *pSrc);
int epicsTimeFromTimeval (epicsTimeStamp *pDest, const struct timeval *pSrc);
/*arithmetic operations */
double epicsTimeDiffInSeconds (
    const epicsTimeStamp *pLeft, const epicsTimeStamp *pRight);
void epicsTimeAddSeconds (
    epicsTimeStamp *pDest, double secondsToAdd); /* adds seconds to *pDest */

/*comparison operations: returns (0,1) if (false,true) */
int epicsTimeEqual(const epicsTimeStamp *pLeft, const epicsTimeStamp *pRight);
int epicsTimeNotEqual(const epicsTimeStamp *pLeft,const epicsTimeStamp *pRight);
int epicsTimeLessThan(const epicsTimeStamp *pLeft,const epicsTimeStamp *pRight);
int epicsTimeLessThanEqual(
    const epicsTimeStamp *pLeft, const epicsTimeStamp *pRight);
int epicsTimeGreaterThan (
    const epicsTimeStamp *pLeft, const epicsTimeStamp *pRight);
int epicsTimeGreaterThanEqual (
    const epicsTimeStamp *pLeft, const epicsTimeStamp *pRight);
/*convert to ASCII string */
size_t epicsTimeToStrftime (
    char *pBuff, size_t bufLength, const char *pFormat, const epicsTimeStamp
*pTS);

/* dump current state to standard out */
void epicsTimeShow (const epicsTimeStamp *, unsigned interestLevel);
```

The C interface provides most of the features as the C++ interface. The features of the C++ operators are provided as functions.

21.9 osiPoolStatus

`osiPoolStatus.h` contains the following description:

```
int osiSufficentSpaceInPool(void);
```

Method	Meaning
osiSufficentSpaceInPool	Return (true,false) if there is sufficient free memory.

This determines if enough free memory exists to continue.

A vxWorks version returns (true,false) if memFindMax returns (>100000, <=100000) bytes.

The default version always returns true.

21.10 osiProcess

`osiProcess.h` contains the following:

```
typedef enum osiGetUserNameReturn {
    osiGetUserNameFail,
    osiGetUserNameSuccess
}osiGetUserNameReturn;

osiGetUserNameReturn osiGetUserName (char *pBuf, unsigned bufSize);

/*
 * Spawn detached process with named executable, but return
 * osiSpawnDetachedProcessNoSupport if the local OS does not
 * support heavy weight processes.
 */
typedef enum osiSpawnDetachedProcessReturn {
    osiSpawnDetachedProcessFail,
    osiSpawnDetachedProcessSuccess,
    osiSpawnDetachedProcessNoSupport
}osiSpawnDetachedProcessReturn;

osiSpawnDetachedProcessReturn osiSpawnDetachedProcess(
    const char *pProcessName, const char *pBaseExecutableName);
```

Not documented.

21.11 osiSigPipeIgnore

`osiSigPipeIgnore.h` contains the following:

```
void installSigPipeIgnore (void);
```

Not documented.

21.12 osiSock.h

See the header file in <base>/src/libCom/osi.

Chapter 22: Registry

Under vxWorks osiFindGlobalSymbol can be used to dynamically bind to record, device, and driver support. Since on some systems this always returns failure, a registry facility is provided to implement the binding. The basic idea is that any storage meant to be "globally" accessable must be registered before it can be accessed by other code.

A perl script is provided that reads the xxxApp.dbd file and produces a c file containing a routine registerRecordDeviceDriver, which registers all record/device/driver support defined in the xxxApp.dbd file.

22.1 Registry.h

```
int registryAdd(void *registryID,const char *name,void *data);
void *registryFind(void *registryID,const char *name);
int registrySetTableSize(int size);
void registryFree();
int registryDump(void);
```

This is the code which does the work. Each different set of things to register must have it's own unique ID. Everything to be registered is stored in the same gpHash table.

Routine registrySetTableSize is provided in case the default hash table size (1024 entries) is not sufficient.

22.2 registryRecordType.h

```
typedef int (*computeSizeOffset)(dbRecordType *pdbRecordType);

typedef struct recordTypeLocation {
struct rset *prset;
computeSizeOffset sizeOffset;
}recordTypeLocation;


int registryRecordTypeAdd(const char *name,recordTypeLocation *prtl);
recordTypeLocation *registryRecordTypeFind(const char *name);
```

Some features:

- Access to both the record support entry table and to the routine which computes the size and offset of each field are provided
- Type safe access is provided.

22.3 registryDeviceSupport.h

```
int registryDeviceSupportAdd(const char *name,struct dset *pdset)
struct dset *registryDeviceSupportFind(const char *name);
```

This provides access to the device support entry table.

22.4 registryDriverSupport.h

```
int registryDriverSupportAdd(const char *name,struct drvet *pdrvet);
struct drvet *registryDriverSupportFind(const char *name);

/* The following function is generated by registerRecordDeviceDriver/pl */
int registerRecordDeviceDriver(DBBASE *pdbbase);
```

This provides access to the driver support table.

22.5 registryFunction.h

```
typedef void (*REGISTRYFUNCTION)(void);
/* c interface definitions */
int registryFunctionAdd(const char *name,REGISTRYFUNCTION func);
REGISTRYFUNCTION registryFunctionFind(const char *name);
```

This registers a function. This is used for subroutine like records.

22.6 registerRecordDeviceDriver.c

A version of this is provided for vxWorks. This version makes it unnecessary to use registerRecordDeviceDriver.pl or register other external names. Thus for vxWorks everything can work almost exactly like it did in release 3.13.x

22.7 registerRecordDeviceDriver.pl

This is the perl script which creates a c source file that registers record/device/driver support. Make rules:

- execute this script using the dbd file created by dbExpand
- compile the resulting C file
- Make the object file part of the xxxLib file

Chapter 23: Database Structures

23.1 Overview

This chapter describes the internal structures describing an IOC database. It is of interest to EPICS system developers but serious application developers may also find it useful. This chapter is intended to make it easier to understand the IOC source listings. It also gives a list of the header files used by IOC Code.

23.2 Include Files

This section lists the files in base/include that are of most interest to IOC Application Developers:

alarm.h alarmString.h - These files contain definitions for all alarm status and severity values.

cadef.h caerr.h caeventmask.h - These files are of interest to anyone writing channel access clients.

callback.h - The definitions for the General Purpose callback system.

dbAccess.h - Definitions for the runtime database access routines.

dbBase.h - Definitions for the structures used to store an EPICS database.

dbDefs.h - A catchall file for definitions that have no other reasonable place to appear.

dbFldTypes.h - Definitions for `DBF_xxx` and `DBR_xxx` types.

dbScan.h - Definitions for the scanning system.

dbStaticLib.h - The static databases access system.

db_access.h db_addr.h - Old database access.

devLib.h - The device support library

devSup.h - Device Support Modules

drvSup.h - Driver Support Modules

ellLib.h - A library that is provides the same functions as the vxWorks `lstLib`. All routines start with `ell` instead of `lst`. The `ellLib` routines work on both IOCs and on UNIX.

epicsPrint.h errMdef.h - EPICS error handling system

fast_lock.h - The FASTLOCK routines.

freeList.h - A general purpose free list facility

gpHash.h - A general purpose hash library.

guigroup.h - The guigroup definitions.

i**nitHooks.h** - Definitions used by `initHooks.c` routines.

link.h - Link definitions

module_types.h - VME hardware configuration. **SHOULD NOT BE USED BY NEW SUPPORT.**

recSup.h - The record global routines.

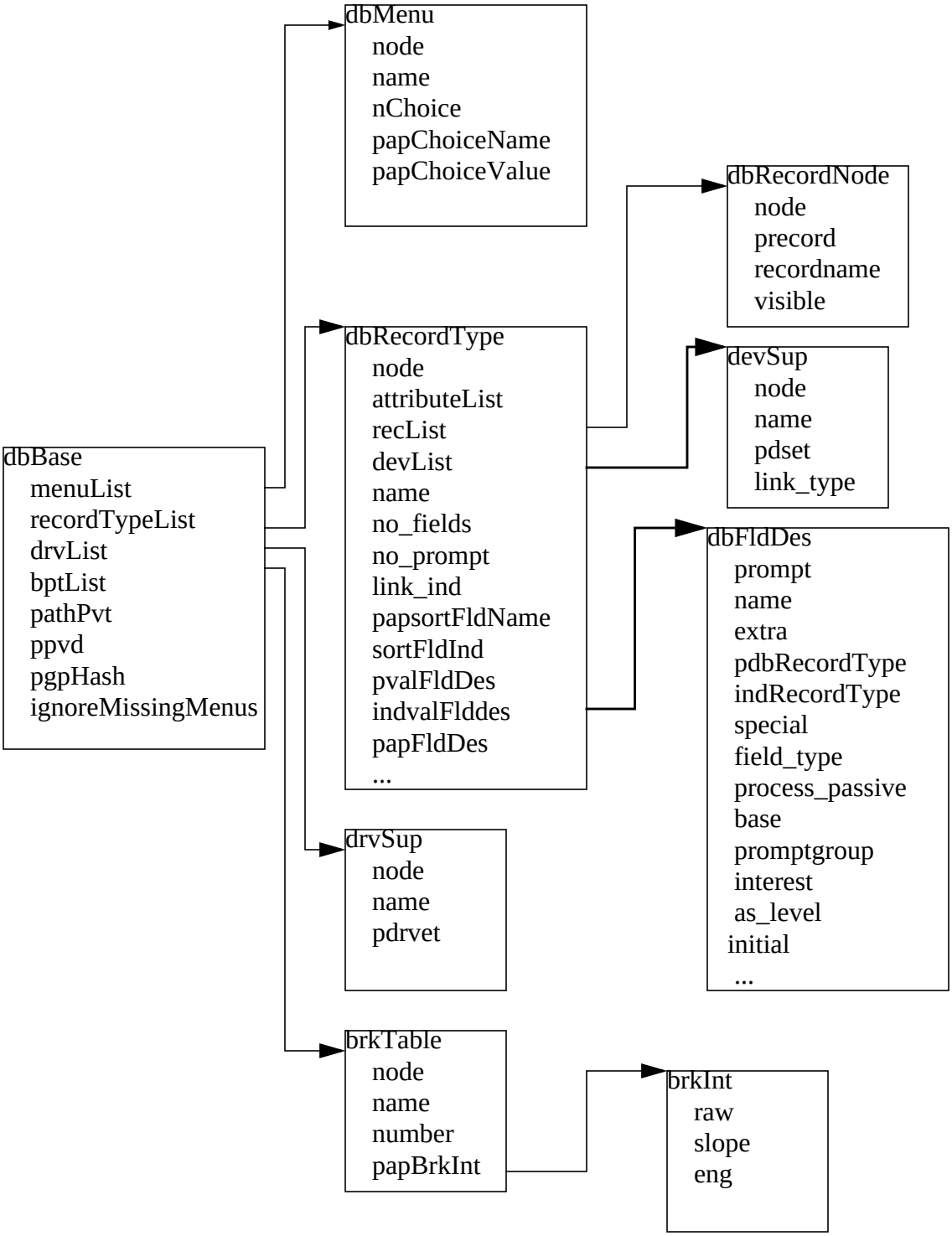
special.h - Definitions for special fields, i.e. `SPC_xxx`.

task_params.h - Definitions for task priorities, stack space, etc.

taskwd.h - Task Watchdog System

tsDefs.h - Time stamp routines. Will also have to look at `base/src/libCom/tsSubr.c`

23.3 Structures



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