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

Martin R. Kraimer
Argonne National Laboratory
Advanced Photon Source
October 2000
EPICS Release 3.14.0alpha1
# Table of Contents

Table of Contents .................................................. 1

Chapter 1: Introduction ........................................... 7  
  1.1. Overview .................................................... 7  
  1.2. Acknowledgments ........................................... 9

Chapter 2: New Features for 3.14 ................................. 11  
  2.1. Introduction ................................................ 11  
  2.2. Getting Started ............................................. 11  
  2.3. Shell for non vxWorks environment ....................... 12  
  2.4. Some Unresolved Items ................................. 13

Chapter 3: EPICS Overview ....................................... 15  
  3.1. What is EPICS? ............................................. 15  
  3.2. Basic Attributes .......................................... 15  
  3.3. Hardware - Software Platforms (Vendor Supplied) ....... 16  
  3.4. IOC Software Components ................................ 17  
  3.5. Channel Access ........................................... 19  
  3.6. OPI Tools .................................................. 20  
  3.7. EPICS Core Software .................................... 21

Chapter 4: EPICS Build Facility ............................... 23  
  4.1. Overview ................................................ 23  
  4.2. Makefiles ................................................ 25  
  4.3. Make ...................................................... 26  
  4.4. Makefile definitions .................................... 27  
  4.5. Table of Makefile definitions ......................... 32  
  4.6. 4.4 Configuration Files .............................. 37

Chapter 5: Database Locking, Scanning, And Processing .... 41  
  5.1. Overview ................................................ 41  
  5.2. Record Links ............................................ 42  
  5.3. Database Links ......................................... 42  
  5.4. Database Locking ....................................... 42  
  5.5. Database Scanning ..................................... 43  
  5.6. Record Processing ..................................... 44  
  5.7. Guidelines for Creating Database Links .............. 44  
  5.8. Guidelines for Synchronous Records .................... 46  
  5.9. Guidelines for Asynchronous Records .................. 47  
  5.10. Cached Puts ........................................... 49  
  5.11. Channel Access Links .................................. 49

Chapter 6: Database Definition ............................... 51
Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1. Overview</td>
<td>51</td>
</tr>
<tr>
<td>6.2. Brief Summary of Database Definition Syntax</td>
<td>51</td>
</tr>
<tr>
<td>6.3. General Rules for Database Definition</td>
<td>52</td>
</tr>
<tr>
<td>6.4. Menu</td>
<td>55</td>
</tr>
<tr>
<td>6.5. Record Type</td>
<td>55</td>
</tr>
<tr>
<td>6.6. Device</td>
<td>60</td>
</tr>
<tr>
<td>6.7. Driver</td>
<td>61</td>
</tr>
<tr>
<td>6.8. Breakpoint Table</td>
<td>61</td>
</tr>
<tr>
<td>6.9. Record Instance</td>
<td>62</td>
</tr>
<tr>
<td>6.10. Record Attribute</td>
<td>65</td>
</tr>
<tr>
<td>6.11. Breakpoint Tables - Discussion</td>
<td>65</td>
</tr>
<tr>
<td>6.12. Menu and Record Type Include File Generation</td>
<td>66</td>
</tr>
<tr>
<td>6.13. dbExpand</td>
<td>69</td>
</tr>
<tr>
<td>6.14. dbLoadDatabase</td>
<td>70</td>
</tr>
<tr>
<td>6.15. dbLoadRecords</td>
<td>71</td>
</tr>
<tr>
<td>6.16. dbLoadTemplate</td>
<td>71</td>
</tr>
<tr>
<td>6.17. dbReadTest</td>
<td>72</td>
</tr>
<tr>
<td><strong>Chapter 7: IOC Initialization</strong></td>
<td>75</td>
</tr>
<tr>
<td>7.1. Overview - Environments requiring a main program</td>
<td>75</td>
</tr>
<tr>
<td>7.2. Overview - vxWorks</td>
<td>75</td>
</tr>
<tr>
<td>7.3. Overview - RTEMS</td>
<td>76</td>
</tr>
<tr>
<td>7.4. iocInit</td>
<td>76</td>
</tr>
<tr>
<td>7.5. Changing iocCore fixed limits</td>
<td>78</td>
</tr>
<tr>
<td>7.6. TSconfigure</td>
<td>79</td>
</tr>
<tr>
<td>7.7. initHooks</td>
<td>79</td>
</tr>
<tr>
<td>7.8. Environment Variables</td>
<td>80</td>
</tr>
<tr>
<td>7.9. Initialize Logging</td>
<td>81</td>
</tr>
<tr>
<td><strong>Chapter 8: Access Security</strong></td>
<td>83</td>
</tr>
<tr>
<td>8.1. Overview</td>
<td>83</td>
</tr>
<tr>
<td>8.2. Quick Start</td>
<td>83</td>
</tr>
<tr>
<td>8.3. User’s Guide</td>
<td>84</td>
</tr>
<tr>
<td>8.4. Design Summary</td>
<td>89</td>
</tr>
<tr>
<td>8.5. Access Security Application Programmer’s Interface</td>
<td>91</td>
</tr>
<tr>
<td>8.6. Database Access Security</td>
<td>95</td>
</tr>
<tr>
<td>8.7. Channel Access Security</td>
<td>97</td>
</tr>
<tr>
<td>8.8. Access Control: Implementation Overview</td>
<td>98</td>
</tr>
<tr>
<td>8.9. Structures</td>
<td>100</td>
</tr>
<tr>
<td><strong>Chapter 9: IOC Test Facilities</strong></td>
<td>101</td>
</tr>
<tr>
<td>9.1. Overview</td>
<td>101</td>
</tr>
<tr>
<td>9.2. Database List, Get, Put</td>
<td>101</td>
</tr>
<tr>
<td>9.3. Breakpoints</td>
<td>103</td>
</tr>
<tr>
<td>9.4. Error Logging</td>
<td>105</td>
</tr>
<tr>
<td>9.5. Hardware Reports</td>
<td>105</td>
</tr>
<tr>
<td>9.6. Scan Reports</td>
<td>106</td>
</tr>
<tr>
<td>9.7. Time Server Report</td>
<td>106</td>
</tr>
<tr>
<td>9.9. Channel Access Reports</td>
<td>108</td>
</tr>
<tr>
<td>9.10. Interrupt Vectors</td>
<td>109</td>
</tr>
<tr>
<td>9.11. EPICS</td>
<td>109</td>
</tr>
<tr>
<td>9.12. Database System Test Routines</td>
<td>110</td>
</tr>
</tbody>
</table>
## Table of Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.8</td>
<td>Channel Access Database Links</td>
<td>179</td>
</tr>
<tr>
<td><strong>Chapter 16: Device Support Library</strong></td>
<td></td>
<td>183</td>
</tr>
<tr>
<td>16.1</td>
<td>Overview</td>
<td>183</td>
</tr>
<tr>
<td>16.2</td>
<td>Registering VME Addresses</td>
<td>183</td>
</tr>
<tr>
<td>16.3</td>
<td>Interrupt Connect Routines</td>
<td>184</td>
</tr>
<tr>
<td>16.4</td>
<td>Macros and Routines for Normalized Analog Values</td>
<td>185</td>
</tr>
<tr>
<td><strong>Chapter 17: EPICS General Purpose Tasks</strong></td>
<td></td>
<td>187</td>
</tr>
<tr>
<td>17.1</td>
<td>Overview</td>
<td>187</td>
</tr>
<tr>
<td>17.2</td>
<td>General Purpose Callback Tasks</td>
<td>187</td>
</tr>
<tr>
<td>17.3</td>
<td>Task Watchdog</td>
<td>190</td>
</tr>
<tr>
<td><strong>Chapter 18: Database Scanning</strong></td>
<td></td>
<td>193</td>
</tr>
<tr>
<td>18.1</td>
<td>Overview</td>
<td>193</td>
</tr>
<tr>
<td>18.2</td>
<td>Scan Related Database Fields</td>
<td>193</td>
</tr>
<tr>
<td>18.3</td>
<td>Scan Related Software Components</td>
<td>194</td>
</tr>
<tr>
<td>18.4</td>
<td>Implementation Overview</td>
<td>197</td>
</tr>
<tr>
<td><strong>Chapter 19: libCom</strong></td>
<td></td>
<td>203</td>
</tr>
<tr>
<td>19.1</td>
<td>bucketLib.h</td>
<td>203</td>
</tr>
<tr>
<td>19.2</td>
<td>calc</td>
<td>203</td>
</tr>
<tr>
<td>19.3</td>
<td>cvtFast.h</td>
<td>203</td>
</tr>
<tr>
<td>19.4</td>
<td>cxxTemplates.h</td>
<td>204</td>
</tr>
<tr>
<td>19.5</td>
<td>dbmf.h</td>
<td>204</td>
</tr>
<tr>
<td>19.6</td>
<td>ellLib.h</td>
<td>205</td>
</tr>
<tr>
<td>19.7</td>
<td>fdmgr.h</td>
<td>206</td>
</tr>
<tr>
<td>19.8</td>
<td>freeList.h</td>
<td>206</td>
</tr>
<tr>
<td>19.9</td>
<td>gpHash.h</td>
<td>206</td>
</tr>
<tr>
<td>19.10</td>
<td>logClient</td>
<td>207</td>
</tr>
<tr>
<td>19.11</td>
<td>macLib.h</td>
<td>207</td>
</tr>
<tr>
<td>19.12</td>
<td>misc</td>
<td>208</td>
</tr>
<tr>
<td>19.13</td>
<td>timer.h</td>
<td>210</td>
</tr>
<tr>
<td><strong>Chapter 20: libCom OSI libraries</strong></td>
<td></td>
<td>211</td>
</tr>
<tr>
<td>20.1</td>
<td>Overview</td>
<td>211</td>
</tr>
<tr>
<td>20.2</td>
<td>epicsAssert.h</td>
<td>212</td>
</tr>
<tr>
<td>20.3</td>
<td>osiEvent.h</td>
<td>212</td>
</tr>
<tr>
<td>20.4</td>
<td>osiFindGlobalSymbol.h</td>
<td>212</td>
</tr>
<tr>
<td>20.5</td>
<td>osiInterrupt.h</td>
<td>212</td>
</tr>
<tr>
<td>20.6</td>
<td>osiMutex.h</td>
<td>213</td>
</tr>
<tr>
<td>20.7</td>
<td>osiPoolStatus.h</td>
<td>214</td>
</tr>
<tr>
<td>20.8</td>
<td>osiProcess.h</td>
<td>214</td>
</tr>
<tr>
<td>20.9</td>
<td>osiRing.h</td>
<td>215</td>
</tr>
<tr>
<td>20.10</td>
<td>osiSem.h</td>
<td>215</td>
</tr>
<tr>
<td>20.11</td>
<td>osiSigPipeIgnore.h</td>
<td>218</td>
</tr>
<tr>
<td>20.12</td>
<td>osiSock.h</td>
<td>218</td>
</tr>
<tr>
<td>20.13</td>
<td>osiThread.h</td>
<td>218</td>
</tr>
<tr>
<td>20.14</td>
<td>osiTime.h</td>
<td>221</td>
</tr>
<tr>
<td>20.15</td>
<td>tsStamp.h</td>
<td>221</td>
</tr>
<tr>
<td><strong>Chapter 21: Registry</strong></td>
<td></td>
<td>223</td>
</tr>
<tr>
<td>21.1</td>
<td>Registry.h</td>
<td>223</td>
</tr>
<tr>
<td>21.2</td>
<td>registryRecordType.h</td>
<td>223</td>
</tr>
<tr>
<td>Chapter 21: Database Structures</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>21.3.registryDeviceSupport.h</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>21.4.registryDriverSupport.h</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>21.5.registryFunction.h</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>21.6.registerRecordDeviceDriver.c</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>21.7.registerRecordDeviceDriver.pl</td>
<td>224</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 22: Database Structures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.1.Overview</td>
<td>225</td>
</tr>
<tr>
<td>22.2.Include Files</td>
<td>225</td>
</tr>
<tr>
<td>22.3.Structures</td>
<td>227</td>
</tr>
</tbody>
</table>
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

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

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
Chapter 1: Introduction
Overview

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) interfaces 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" accessible 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:

  See LANL Web site for latest version.
- EPICS IOC Software Configuration Management, Marty Kraimer, Andrew Johnson, Janet Anderson, Ralph Lange
- 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.dctsd) 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 first 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 its own implementation.

It must be emphasized that this is alpha software. The first alpha version is not ready for existing vxWorks applications. Later versions will provide a relatively easy conversion path from 3.13 applications.

2.2 Getting Started

After epics base is built an example application can be built just like for release 3.13. i.e.

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

The example has been tested on vxWorks, RTEMS, solaris, linux, and win32.

Spend some time looking at the example files. You will notice the following differences from the 3.13 version.

- config is replaced by configure.
  
  NOTE: The old config is still supported for existing vxWorks applications.


- Each xxxSrc contains a single Makefile. Look at them. Chapter 4 describes the new build facility.
As mentioned the example can be run on vxWorks, RTEMS, or on a supported host.

- vxWorks - iocBoot/iocexample is very similar to the 3.13 version.
- 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/iocxxx`
  - `../../bin/solaris-sparc/example stcmd.host`

### 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:

```
iocrf("filename")
```

or

```
iocrf(0)
```

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

If iocrf can use the GNU readline utility, which provides bash style command history and command line editing. In order to implement these features it must be compiled with the options:

```
OP_SYS_LDLIBS = -lreadline
OP_SYS_CPPFLAGS = -DIOCSH_USE_READLINE
```

Iocrf supports the following built-in commands:

- `< "filename"`  Execute commands from filename
- `exit`  Exit iocrf
- `cd dir`  Change directory
- `show`  Show threads
- `threadInit`  Call threadInit

Iocrf calls registered commands. A call to iocrfRegister, which should be made in all main programs, registers the following:

```
   dbLoadDatabase
   dbLoadRecords
   dbLoadTemplate
```

Most commands described in chapter "IOC Test facilities"

NOTE: This started as just as a shell that could just call registered functions, which is why it is named iocrf. 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 running on the same workstation.
- Mutex Performance. Currently iocCore requires recursive mutexes, semMutexTakeTimeout, and semMutexTakeNoWait. Implementing these on many systems causes semMutexTake and semMutexGive to use excessive CPU cycles.
- CA client performance. Existing clients linked against 3.14 use considerably more CPU time than when linked against 3.13.
- libcom reviewed
  - C++ APIs in libCom. This is the first release of iocCore that is using C++. The current developer's are having major disputes about C++ conventions and design standards.
  - osi naming conventions. Current naming conventions are not uniform.
    - When should user code use "osi"
    - For C++ what are conventions
    - For c what are the conventions
  - osiRing
    - Move this from libCom/osi to libCom/ringBuffer. Change the name from osiRing. Perhaps ringBufferBytes?
    - Implement a ringPointer, which only gets and puts a single pointer. Use this in src/db instead of osiRing.
  - osiThread
    - Should threadDestroy be allowed?
  - osiMutex
    - Should we remove the requirement for recursive mutexes?
    - Should we remove semMutexTakeNoWait?
    - Should we remove semMutexTakeTimeout?
- shell for non vxWorks environments
  - Additional extensions to ioccrf? Also give it a better name such as iocsh.
    - Provide a help facility that shows callable functions and their arguments?
    - 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 2: New Features for 3.14
Some Unresolved Items
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.

```
         . . . OPI . . . OPI . . . OPI . . . . .
           |                   |                   |
          LAN              . . . IOC . . . IOC . .
```

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:
Chapter 3: EPICS Overview

3.3 Hardware - Software Platforms (Vendor Supplied)

- **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.

### 3.3.1 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
Chapter 3: EPICS Overview
IOC Software Components

- 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.
Chapter 3: EPICS Overview
IOC Software Components

• **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 163 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.
- **CAMA TH**: 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

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 <top> directory. They are created in the <top> directory by the build and contain the installed build components.

- **dbd** - Installed Database Definitions Directory.
- **include** - Include Directory. The directory into which C header files are installed. These header files may be generated from menu and record type definitions.
- **bin** - Bin Directory. 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** - Library Directory. This directory contains a subdirectory for each host architecture. These are the directories in which libraries are installed.
- **db** - Installed Databases Directory. This is the directory into which record instance, template, and substitution files are installed.
- **html** - Installed html Directory: This is the directory into which html documentation is installed.
- **Templates** - Installed Templates Directory: The directory into which template files are installed.
4.1.3 Elements of build system

The main ingredients of the build system are:

- An existing 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 directory structure to be built. The makeBaseApp.pl and makeBaseExtension.pl scripts create these files. Many of these configuration files will just include a file for 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 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.
- Existing configuration files need no changes at most sites
- Allows builds for all hosts and targets within a single <top> source directory tree.
- Allows sharing built 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. Examples are solaris-sparc, linux-x86, win32-x86. The EPICS base distribution tar file contains a startup script, EpicsHostArch, which can be used to define this variable.

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.
4.2 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>.

```
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 the 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_DIRS
<optional rules definitions>
```

4.2.4 Simple Makefile examples

< Insert examples here>
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 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 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 clean uninstall**

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

**gnumake tar**

This command makes a tar image of the entire <top> directory (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> ia 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

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 file, bpt<table name>.dbd, add the definition

\[
\text{BPTS} += \text{bpt<table name>.dbd}
\]

4.4.2 Record Type Definitions

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

\[
\text{RECTYPES} += \text{<rectype>Record.h}
\]

The associated record definition file <rectype>Record.dbd must exist.

4.4.3 Menus

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

\[
\text{MENUS} += \text{menu<name>.h}
\]

The header file will be created from the menu dbd file and installed into <top>/include directory.

4.4.4 Expanded Database Definition File

Files containing database definition files are expanded by utility dbExpand and installed into <top>/dbd. The following variables control the process:

\[
\begin{align*}
\text{DBDEXPAND} & += \text{xxxInclude.dbd} \\
\text{DBDNAME} & = \text{xxxApp.dbd} \\
\text{USER_DBDFLAGS} & += -I \text{ <include path>} \\
\text{USER_DBDFLAGS} & += -S \text{ <macro substitutions>}
\end{align*}
\]

where the entries are:

\[
\text{DBDEXPAND}
\]

A list of files containing database definitions to be expanded.
Chapter 4: EPICS Build Facility
Makefile definitions

DBDNAME
The name of the output file to contain the expanded definitions which will be installed into <top>/dbd.

USER_DBDFLAGS
Optional flags for dbExpand. Currently only an include path and macro substitution are supported.

4.4.5 Database Definition Files
The following line installs the named files into <top>/dbd without expansion.

    DBDINSTALL += <name>.dbd

4.4.6 Database Files
For all these types of databases, the names of the database has to be specified. Make will figure out how to generate the files:

    DB += xxx.db
Generates xxx.db depending on which source files exist. If xxx.db is template generated, the inflated database will be installed.

    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.

4.4.7 Object Module Libraries
An object library is created and installed into <top>/lib/<arch> by specifying it's name and the name of either the object or source file of each file containing code for the library. An object or source file name can appear with or without 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.

**Definition of <osclass>:** The architecture not including the processor. A few examples are:

    vxWorks-68040 : The <osclass> is vxWorks. The architecture is vxWorks-68040
    solaris-sparc : The <osclass> is solaris. The architecture is solaris-sparc.

**vxWorks Note:** For vxWorks, the library is installed into <top>/bin/<arch> NOT <top>/lib/<arch>

4.4.7.1 Specifying the library name.
Any of the following can be specified:
Chapter 4: EPICS Build Facility

4.4.7.2 Specifying Library object file names

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

- `<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 `<libraryname>_OBJS_<osclass>` definition specified.`

4.4.7.3 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.`
- `LIBSRCS += <name>
  Source files will be used for all libraries.`
- `<library name>_SRCS += <name>
  Source file will be used for the named library.`

4.4.7.4 Example:

```
LIBRARY_vxWorks += vxWorks
LIBRARY_IOC += iocOnly
LIBRARY_HOST += hostOnly
LIBRARY += all

vxWorks_OBJS += vxOnly1
vxWorks_SRCS += vxOnly2.c
iocOnly_OBJS += iocOnly1
iocOnly_SRCS += iocOnly2.cpp
hostOnly_OBJS += host1
all_OBJS += all1
all_SRCS += all2.cpp
```

If the architectures defined in `<top>/configure` are solaris-sparc and vxWorks-68040 then the following libraries will be created:

- `<top>/bin/vxWork-68040/vxWorks.* : vxOnly1.o vxOnly2.o`
- `<top>/bin/vxWork-68040/iocOnly.* : iocOnly1.o iocOnly2.o`
- `<top>/lib/solaris-sparc/libiocOnly.a : iocOnly1.o iocOnly2.o`
- `<top>/lib/solaris-sparc/libhostOnly.a : host1.o`
• <top>/bin/vxWork-68040/all.* : all1.o all2.o
• <top>/lib/solaris-sparc/liball.a : all1.o all2.o

4.4.8 Record support, device, driver, other object modules

For each such module, add a definition:

LIBOBJ += <name>

To combine these LIBOBJ files into a library, <libname>, add the lines:

LIBRARY+=<libname>
<libname>_OBJ += $(LIBOBJ)

It is also possible to generate object files not placed in LIBNAME by using definitions:

OBJS += name
OBJS_IOC += name
OBJS_HOST += name
OBJS_<osclass> += name

Both will cause the specified file to be generated, but PROD will also install the generated file into <top>/bin/<target_arch>.

4.4.9 State Notation Programs

For each state notation program, add the definition:

<library_name>_SRCS += <name>.c

The state notation programs must be called <name>.st or <name>.stt. The C preprocessor will be executed on <name>.st files before conversion.

4.4.10 Scripts, etc.

A definition of the form:

SCRIPTS += <name>

results in file <name> being installed from the src directory to the <top>/bin/<arch> directory.

Definitions of the form:

SCRIPTS_DEFAULT += <name>.h
SCRIPTS_<osclass> += <name>.h

results in file <name>.h being installed from the src directory to the appropriate <top>/bin/<osclass> directory.

4.4.11 Include files.

A definition of the form:

INC += <name>.h

results in file <name>.h being installed from the src directory to the <top>/include directory.

Definitions of the form:
Chapter 4: EPICS Build Facility
Makefile definitions

INCDefault += <name>.h
INCOsclass += <name>.h

results in file <name>.h being installed from the src directory into <top>/include/os/<osclass>.

A definition of the form:

INCDefault += <name>.h

Results in <name>.h being installed from the src directory into <top>/include/os/<osclass> for every defined <osclass>.

4.4.12 Object files.

A definition of the form:

OBJS += <name>

results in file <name>.<obj> being created from a src directory file and installed into all <top>/bin/<arch> directories.

Definitions of the form:

OBJS_DEFAULT += <name>
OBJS_Osclass += <name>

result in file <name>.<obj> being created from a src directory file and installed into the appropriate <top>/bin/os/<osclass> directory or directories.

Definitions of the form:

OBJS_HOST += <name>
OBJS_IOC += <name>

results in file <name>.<obj> being created from a src directory file during a host or ioc build and installed into the <top>/os/<osclass> host or ioc directory.

4.4.13 Html files

A definition of the form:

HTML += <name>

results in file <name> being installed from the src directory to the <top>/html 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 <top>/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

For each executable to be built add one of the following definition forms:

\verbatim
PROD += <name>
{name>_SRC += <srcname>.c
\endverbatim

results in file <name> being built from the <srcname>.c file in the src directory and then <name> is installed into the <install_dir>/bin/<arch> directory

### 4.5 Table of Makefile definitions

Makefile.Host has many facilities for building host components. Definitions given below containing <osclass> can be used to provide settings for use when building for a specific os class, and the <osclass> part of the name should be replaced by the os class concerned, e.g. solaris, vxWorks, etc. If a _DEFAULT setting is given but a particular <osclass> requires that the default not be used and the required setting is blank, the value “-nil-” should be assigned to the relevant <osclass> variable definition.

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Products to be built (host type archs only)</strong></td>
<td></td>
</tr>
<tr>
<td>PROD</td>
<td>Products to be built (host type archs only)</td>
</tr>
<tr>
<td>PROD_&lt;osclass&gt;</td>
<td>os specific products to build and install for host type archs only</td>
</tr>
<tr>
<td>PROD_DEFAULT</td>
<td>products to build and install for host type archs only systems with no PROD_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td><strong>Test products to be built (host type archs only)</strong></td>
<td></td>
</tr>
<tr>
<td>TESTPROD</td>
<td>Test product names (without execution suffix) to build but not install</td>
</tr>
<tr>
<td>TESTPROD_&lt;osclass&gt;</td>
<td>Os class specific test product names to build but not install</td>
</tr>
<tr>
<td>TESTPROD_DEFAULT</td>
<td>Test products to build but not install for systems with no TESTPROD_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td><strong>Libraries to be built</strong></td>
<td></td>
</tr>
<tr>
<td>LIBRARY</td>
<td>Name of library to build and install. The name should NOT include a</td>
</tr>
<tr>
<td></td>
<td>prefix or extension. e.g. specify Ca to build libCa.a on Unix,</td>
</tr>
<tr>
<td></td>
<td>Ca.lib,CaObj.li,b or Ca.dll on WIN32</td>
</tr>
<tr>
<td>LIBRARY_&lt;osclass&gt;</td>
<td>os specific libraries to build and install</td>
</tr>
</tbody>
</table>
## Build Option

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIBRARY_DEFAULT</td>
<td>libraries to build and install for systems with no LIBRARY_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>LIBRARY_IOC</td>
<td>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</td>
</tr>
<tr>
<td>LIBRARY_IOC_&lt;osclass&gt;</td>
<td>os specific libraries to build and install for ioc type archs</td>
</tr>
<tr>
<td>LIBRARY_IOC_DEFAULT</td>
<td>libraries to build and install for ioc type arch systems with no LIBRARY_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>LIBRARY_HOST</td>
<td>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</td>
</tr>
<tr>
<td>LIBRARY_HOST_&lt;osclass&gt;</td>
<td>os class specific libraries to build and install for host type archs</td>
</tr>
<tr>
<td>LIBRARY_HOST_DEFAULT</td>
<td>libraries to build and install for host type arch systems with no LIBRARY_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>SHARELIBRARIES</td>
<td>Build shared libraries? Must be YES or NO</td>
</tr>
<tr>
<td>SHRLIB_VERSION</td>
<td>Shared library version number</td>
</tr>
</tbody>
</table>

### Product and library source files

<table>
<thead>
<tr>
<th>Source Files</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRCs</td>
<td>source files to build all PRODs and LIBRARYs</td>
</tr>
<tr>
<td>SRCs_&lt;osclass&gt;</td>
<td>osclass specific source files to build all PRODs and LIBRARYs</td>
</tr>
<tr>
<td>SRCs_DEFAULT</td>
<td>source file to build all PRODs and LIBRARYs for systems with no SRCs_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>PROD_SRCS</td>
<td>source files to build all PRODs</td>
</tr>
<tr>
<td>PROD_SRCS_&lt;osclass&gt;</td>
<td>osclass specific source files to build all PRODs</td>
</tr>
<tr>
<td>PROD_SRCS_DEFAULT</td>
<td>source files needed to build PRODs for systems with no PROD_SRCS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>LIBSRCS</td>
<td>Source files for building LIBRARY (e.g. LIBSRCS=la.c lb.c lc.c)</td>
</tr>
<tr>
<td>LIBSRCS_&lt;osclass&gt;</td>
<td>os-specific library source files</td>
</tr>
<tr>
<td>LIBSRCS_DEFAULT</td>
<td>Library source files for systems with no LIBSRCS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_SRCS</td>
<td>source files to build a specific PROD or LIBRARY</td>
</tr>
<tr>
<td>&lt;name&gt;<em>SRCS</em>&lt;osclass&gt;</td>
<td>os specific source files to build a specific PROD or LIBRARY</td>
</tr>
<tr>
<td>&lt;name&gt;_SRCS_DEFAULT</td>
<td>source files needed to build a specific PROD or LIBRARY for systems with no &lt;prod&gt;<em>SRCS</em>&lt;osclass&gt; specified</td>
</tr>
</tbody>
</table>

### Compiler flags

<table>
<thead>
<tr>
<th>Compiler flags</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USR_CFLAGS</td>
<td>C compiler flags for all systems</td>
</tr>
<tr>
<td>USR_CFLAGS_&lt;osclass&gt;</td>
<td>os-specific C compiler flags</td>
</tr>
</tbody>
</table>
### Table of Makefile definitions

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USR_CFLAGS_DEFAULT</td>
<td>C compiler flags for systems with no &lt;prod&gt;<em>SRCS</em>&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_CFLAGS</td>
<td>&lt;name&gt;.c specific C compiler flags (e.g. xxxRecord_CFLAGS=-g)</td>
</tr>
<tr>
<td>USR_CXXFLAGS</td>
<td>C++ compiler flags for all systems</td>
</tr>
<tr>
<td>USR_CXXFLAGS_&lt;osclass&gt;</td>
<td>os-specific C++ compiler flags</td>
</tr>
<tr>
<td>USR_CXXFLAGS_DEFAULT</td>
<td>C++ compiler flags for systems with no USR_CXXFLAGS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_CXXFLAGS</td>
<td>prod specific C++ compiler flags</td>
</tr>
<tr>
<td>USR_CPPFLAGS</td>
<td>C pre-processor flags (for all makefile compiles)</td>
</tr>
<tr>
<td>USR_CPPFLAGS_&lt;osclass&gt;</td>
<td>os specific cpp flags</td>
</tr>
<tr>
<td>USR_CPPFLAGS_DEFAULT</td>
<td>cpp flags for systems with no USR_CPPFLAGS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_CPPFLAGS</td>
<td>prod specific C pre-processor flags (e.g. xxxRecord_CPPFLAGS=-DDEBUG)</td>
</tr>
<tr>
<td>USR_INCLUDES</td>
<td>Directories to search for include files with -I prefix (e.g. -I$(EPICS_EXTENSIONS_INCLUDE))</td>
</tr>
<tr>
<td>&lt;name&gt;_INCLUDES</td>
<td>Directories to search for include files when building a specific product (e.g. -I$(MOTIF_INC))</td>
</tr>
</tbody>
</table>

#### Linker options

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USR_LDFLAGS</td>
<td>linker options (for all makefile links)</td>
</tr>
<tr>
<td>USR_LDFLAGS_&lt;osclass&gt;</td>
<td>os specific linker options (for all makefile links)</td>
</tr>
<tr>
<td>USR_LDFLAGS_DEFAULT</td>
<td>linker options for systems with no USR_LDFLAGS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_LDFLAGS</td>
<td>Prod or library specific ld flags</td>
</tr>
<tr>
<td>USR_LIBS</td>
<td>load libraries (e.g. -lXt -lX11) (for all makefile links)</td>
</tr>
<tr>
<td>USR_LIBS_&lt;osclass&gt;</td>
<td>os specific load libraries (for all makefile links)</td>
</tr>
<tr>
<td>USR_LIBS_DEFAULT</td>
<td>load libraries for systems with no USR_LIBS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_OBJS</td>
<td>Object files (without file extension) needed for a specific prod or library</td>
</tr>
<tr>
<td>&lt;name&gt;<em>OBJS</em>&lt;osclass&gt;</td>
<td>os-specific object files needed for a specific prod or library</td>
</tr>
<tr>
<td>&lt;name&gt;_OBJS_DEFAULT</td>
<td>Object files needed to link a specific prod or library for systems with no &lt;name&gt;<em>OBJ</em>&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;name&gt;_LIBS</td>
<td>prod or library specific ld libraries (e.g. probe_LIBS=X11 Xt)</td>
</tr>
<tr>
<td>&lt;name&gt;<em>LIBS</em>&lt;osclass&gt;</td>
<td>os-specific libs needed to link a specific prod or library</td>
</tr>
<tr>
<td>&lt;name&gt;_LIBS_DEFAULT</td>
<td>libs needed to link a specific prod or library for systems with no &lt;name&gt;<em>LIBS</em>&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>PROD_LIBS</td>
<td>libs needed to link every PROD for all systems</td>
</tr>
</tbody>
</table>
### Build Option

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROD_LIBS_&lt;osclass&gt;</td>
<td>os-specific libs needed to link every PROD</td>
</tr>
<tr>
<td>PROD_LIBS_DEFAULT</td>
<td>libs needed to link every PROD for systems with no PROD_LIBS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;lib&gt;_DIR</td>
<td>Directory to search for the specified lib. (For libs listed in PROD_LIBS, &lt;lib&gt;_LIBS and USR_LIBS)</td>
</tr>
<tr>
<td>SYS_PROD_LIBS</td>
<td>system libs needed to link every PROD for all systems</td>
</tr>
<tr>
<td>SYS_PROD_LIBS_&lt;osclass&gt;</td>
<td>os-specific system libs needed to link every PROD</td>
</tr>
<tr>
<td>SYS_PROD_LIBS_DEFAULT</td>
<td>system libs needed to link every PROD for systems with no SYS_PROD_LIBS_&lt;osclass&gt; specified</td>
</tr>
<tr>
<td>&lt;prod&gt;_SYS_LIBS</td>
<td>prod specific system ld libraries (e.g. m)</td>
</tr>
<tr>
<td>&lt;prod&gt;<em>SYS_LIBS</em>&lt;osclass&gt;</td>
<td>os class specific system libs needed to link a specific prod</td>
</tr>
<tr>
<td>&lt;prod&gt;_SYS_LIBS_DEFAULT</td>
<td>system libs needed to link a specific prod for systems with no SYS_PROD_LIBS_&lt;osclass&gt; specified</td>
</tr>
</tbody>
</table>

### 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

### Documentation

- **DOCS**
  - List of 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**
  - List of 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**
  - List of template files to be installed into $(TEMPLATE_DIR)

### Options for other programs
### Chapter 4: EPICS Build Facility

#### Table of Makefile definitions

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>YACCOPT</td>
<td>yacc options</td>
</tr>
<tr>
<td>LEXOPT</td>
<td>lex options</td>
</tr>
<tr>
<td>SNCFLAGS</td>
<td>Snc options</td>
</tr>
<tr>
<td>E2DB_FLAGS</td>
<td>e2db options</td>
</tr>
<tr>
<td>SCH2EDIF_FLAGS</td>
<td>sch2edif options</td>
</tr>
<tr>
<td>RANLIBFLAGS</td>
<td>ranlib options</td>
</tr>
</tbody>
</table>

#### Miscellaneous settings

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMPLR</td>
<td>C compiler selection, TRAD, ANSI or STRICT (default is STRICT)</td>
</tr>
<tr>
<td>INSTALL_LOCATION</td>
<td>Location of install directory (default $(TOP))</td>
</tr>
<tr>
<td>USER_VPATH</td>
<td>List of directories</td>
</tr>
<tr>
<td>HOST_WARN</td>
<td>Are compiler warning messages desired (YES or NO) (default is NO)</td>
</tr>
<tr>
<td>HOST_OPT</td>
<td>Is compiler optimization desired (default is NO optimization)</td>
</tr>
<tr>
<td>STATIC_BUILD</td>
<td>Is static build desired (YES or NO) (default is NO)</td>
</tr>
</tbody>
</table>

#### Facilities for building Java programs

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASSES</td>
<td>Names of Java classes to be built and installed</td>
</tr>
<tr>
<td>TESTCLASSES</td>
<td>Names of Java classes to be built</td>
</tr>
<tr>
<td>PACKAGE</td>
<td>Names of Java package to be installed</td>
</tr>
<tr>
<td>JAR</td>
<td>Name of Jar file to be built</td>
</tr>
<tr>
<td>JAR_INPUT</td>
<td>Names of files to be included in JAR</td>
</tr>
<tr>
<td>MANIFEST</td>
<td>Name of manifest file for JAR</td>
</tr>
</tbody>
</table>

#### Facilities for Windows 95/NT resource (.rc) files

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCS</td>
<td>Resource files needed to build every PROD</td>
</tr>
<tr>
<td>&lt;prod&gt;_RCS</td>
<td>Resource files needed to build a specific PROD</td>
</tr>
<tr>
<td>&lt;prod&gt;<em>RCS</em>&lt;osclass&gt;</td>
<td>os specific resource files to build a specific PROD</td>
</tr>
</tbody>
</table>

#### Other definitions:

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USR_CFLAGS</td>
<td>C compiler flags</td>
</tr>
<tr>
<td>&lt;prod&gt;_CFLAGS</td>
<td>product specific C compiler flags</td>
</tr>
<tr>
<td>USR_CXXFLAGS</td>
<td>C++ compiler flags</td>
</tr>
<tr>
<td>&lt;prod&gt;_CXXFLAGS</td>
<td>product specific C++ compiler flags</td>
</tr>
<tr>
<td>CPPFLAGS</td>
<td>cpp flags</td>
</tr>
<tr>
<td>&lt;prod&gt;_CPPFLAGS</td>
<td>product specific cpp flags</td>
</tr>
</tbody>
</table>
### 4.4 Configuration Files

#### 4.6.1 Base Configure Directory

The base/configure directory has the following directory structure:

```plaintext
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.

<table>
<thead>
<tr>
<th>Build Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USR_INCLUDES</td>
<td>Include directory (e.g. -I$(EPICS_EXTENSIONS_BIN))</td>
</tr>
<tr>
<td>USR_LDFLAGS</td>
<td>linker options</td>
</tr>
<tr>
<td>&lt;prod&gt;_LDFLAGS</td>
<td>product specific ld flags</td>
</tr>
<tr>
<td>INC</td>
<td>header files to install</td>
</tr>
<tr>
<td>BIN_INSTALLS</td>
<td>Files in any directory to install to $(INSTALL_BIN)</td>
</tr>
<tr>
<td>YACCOPT</td>
<td>yacc options</td>
</tr>
<tr>
<td>LEXOPT</td>
<td>lex options</td>
</tr>
<tr>
<td>SNCFLAGS</td>
<td>snc options</td>
</tr>
<tr>
<td>&lt;prod&gt;_SNCFLAGS</td>
<td>product specific state notation language flags</td>
</tr>
<tr>
<td>VX_WARN</td>
<td>Compiler warning messages desired (YES or NO) (default NO)</td>
</tr>
<tr>
<td>VX_OPT</td>
<td>Is compiler optimization desired (YES or NO) (default is NO optimization)</td>
</tr>
<tr>
<td>INSTALL_LOCATION</td>
<td>Installation directory (defaults to $(TOP))</td>
</tr>
</tbody>
</table>

**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.
Chapter 4: EPICS Build Facility
4.4 Configuration Files

**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.

**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 if 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.
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 afterwards. 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 \texttt{dbProcess}. Each record support module must supply a routine \texttt{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:

\begin{center}
\begin{tikzpicture}
\node (A) at (0,0) {A};
\node (B) at (2,0) {B};
\node (C) at (4,0) {C};
\node (P) at (2,-1) {InLink PP};
\draw [->] (A) -- (B) node [midway, below] {FwdLink};
\draw [->] (B) -- (C) node [midway, below] {FwdLink};
\draw [->] (P) -- (A) node [midway, above] {InLink PP};
\end{tikzpicture}
\end{center}

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 \texttt{PP} after \texttt{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 \texttt{pact} (processing active), which is set \texttt{TRUE} when record processing begins and is not set \texttt{FALSE} until all processing completes. When C is processed A still has \texttt{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 \texttt{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 \texttt{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.

A linked record is not forced to be in the same lock set if all of the following conditions are true.

- The link is an INLINK (It is an input link)
- The link is NPP (It is no process passive)
- The link is NMS (It is no maximize severity)
- The number of elements is $<-1$ (The link references a scalar field)

\textbf{QUESTION: Now that CA links exist why not force all records linked via DB links into the same lock set.}

5.7.1.3 PACT - processing active

Each record contains a field \texttt{pact}. This field is set \texttt{TRUE} at the beginning of record processing and is not set \texttt{FALSE} until the record is completely processed. In particular no links are processed with \texttt{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 \texttt{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 \texttt{TRUE (PP)} or process passive \texttt{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 \texttt{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. Let's 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 \texttt{dbPutLink} and \texttt{dbPutField} provide for "cached" puts. This is necessary because of asynchronous records. Two cases arise.

The first results from a \texttt{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 \texttt{dbPutField} arranges to have the record reprocessed when the record finally completes processing.

The second case results from \texttt{dbPutLink} finding a record already active because of a \texttt{dbPutField} directed to the record. In this case \texttt{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 \texttt{ca_field_type} and \texttt{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.
Chapter 5: Database Locking, Scanning, And Processing

Channel Access Links

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 vice-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

```python
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(drivet_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 represent 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:

```c
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:

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

6.5 Record Type

6.5.1 Format:

```c
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 arise 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
  • GUIALARMS
  • 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.

```plaintext
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) {
```
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
}

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 Svrt")
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
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

```c
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:

```c
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.
  - **DBFDEVICE**
    - 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
Chapter 6: Database Definition
Record Instance

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 “pseudo” 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:

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

The arguments are:

- `recordTypename` - The name of recordtype.
- `name` - The attribute name, i.e. the pseudo 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.

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.
Chapter 6: Database Definition
Menu and Record Type Include File Generation.

If a breakpoint table is chosen, then the corresponding breakpoint file must be loaded into the IOC before \texttt{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 \texttt{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:

```plaintext
!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
```

The breakpoint table can be generated by executing

```bash
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:

```bash
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, \texttt{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, \texttt{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 record type 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 record type 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:

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

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

```c
#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:

```c
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:

```c
#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
#ifndef GEN_SIZE_OFFSET
int aoRecordSizeOffset(dbRecordType *pdbRecordType) {
    aoRecord *prec = 0;
```
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:

```c
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:

```c
#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/recBase.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`

```c
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:

```c
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:

```c
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:

```plaintext
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.

```plaintext
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:

```plaintext
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:

```plaintext
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 `-d`, 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 split between statements in the main program and statements residing in startup scripts passed to ioccrf. An example main program is:

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

`ioccrfRegisterCommon` registers the commands described in the chapter on IOC test facilities so that they can be called by ioccrf. `registerRecordDeviceDriverRegister` registers the record/device/driver support that is linked together with the main program. 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 built in commands like show.

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

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

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>")
```

---

EPICS Release: R3.14.0alpha1
EPICS IOC Application Developer's Guide
# 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 convenient 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 software, 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 <ttfbase>/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 message 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 purpose 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. It 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 is 1280 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.

\[
\text{TSConfigure}(\text{master}, \text{sync\_rate}, \text{clock\_rate}, \text{master\_port}, \text{slave\_port})
\]

- **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:

```c
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 initialization just realize that the following can be used if you want to use a private host log file.

\[
\text{putenv\{"EPICS_IOC_LOG_PORT=<port>"\}}  \\
\text{putenv\{"EPICS_IOC_LOG_INET=<inet addr>"\}}
\]

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.

\[
\text{iocLogDisable = 1}
\]

This must be given after iocCore is loaded and before any dbLoad commands.
Chapter 7: IOC Initialization

Initialize Logging
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.
5. Application Programmer’s Interface
8. Implementation Overview

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


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.
Chapter 8: Access Security
User's Guide

- 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) {
        [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).
    - **UAG** specifies a list of user access groups that can have the access privilege. If UAG is not defined then all users are allowed.
Chapter 8: Access Security
User’s Guide

- 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 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:

```bash
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 yourself 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:

```bash
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:

```bash
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:

```bash
asInit
```
Chapter 8: Access Security

User's Guide

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:

Let’s 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:levlpermit 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,grellick,berg,fuja,gsm}
UAG(linacSup) {gsm}
UAG(appDev) {nda,kko}
HAG(icr) {silver,phebos,gaea}
HAG(cr) {mars,hera,gold}
HAG(ioc) {iolicl1,iolicl2,ioclid1,ioclid2,ioclid3,ioclid4,ioclid5}
ASG(DEFAULT) {
    INPA(LI:OPSTATE)
    INPB(LI:levlpermit)
    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:levlpermit)
    RULE(1,WRITE) {
        UAG(opSup,linacSup,appdev)
    }
```
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.

Let's 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_put 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:

<table>
<thead>
<tr>
<th></th>
<th>R3.11.5</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before iocInit</td>
<td>4,244,520</td>
<td>4,860,840</td>
</tr>
<tr>
<td>After iocInit</td>
<td>4,995,416</td>
<td>5,964,904</td>
</tr>
<tr>
<td>After caput</td>
<td>5,449,780</td>
<td>6,658,868</td>
</tr>
<tr>
<td>After caget</td>
<td>8,372,444</td>
<td>9,751,796</td>
</tr>
</tbody>
</table>

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

```c
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

```c
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 initialization 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 \texttt{S\_asLib\_asNotActive} without doing anything if access control is not active.

### 8.5.4.2 change Client

\begin{verbatim}
long asChangeClient(ASCLIENTPVT ppvt, int asl, char *user, char*host);
\end{verbatim}

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

This routine returns \texttt{S\_asLib\_asNotActive} without doing anything if access control is not active.

### 8.5.4.3 remove Client

\begin{verbatim}
long asRemoveClient(ASCLIENTPVT *pvt);
\end{verbatim}

This call removes a client.

This routine returns \texttt{S\_asLib\_asNotActive} without doing anything if access control is not active.

### 8.5.4.4 get Client Pvt

\begin{verbatim}
void *asGetClientPvt(ASCLIENTPVT pvt);
\end{verbatim}

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 \texttt{NULL} if access security is not active.

### 8.5.4.5 put Client Pvt

\begin{verbatim}
void asPutClientPvt(ASCLIENTPVT pvt, void *userPvt);
\end{verbatim}

This routine is used to set the pointer returned by \texttt{asGetClientPvt}.

### 8.5.4.6 register Callback

\begin{verbatim}
long asRegisterClientCallback(ASCLIENTPVT pvt, ASCLIENTCALLBACK pcallback);
\end{verbatim}

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

This routine returns \texttt{S\_asLib\_asNotActive} without doing anything if access control is not active.

### 8.5.4.7 check Get

\begin{verbatim}
long asCheckGet(ASCLIENTPVT pvt);
\end{verbatim}

This routine, actually a macro, returns (\texttt{TRUE}, \texttt{FALSE}) if the client (has, doesn’t have) get access rights.

### 8.5.4.8 check Put

\begin{verbatim}
long asCheckPut(ASCLIENTPVT pvt);
\end{verbatim}

This routine, actually a macro, returns (\texttt{TRUE}, \texttt{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
crights

    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:

- ASL0: Assigned to fields used during normal operation
- ASL1: Assigned 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

```c
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.

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

This routine specifies macro substitutions.

```c
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

```c
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.

```c
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

```c
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 accidentally 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 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.

8.8.1 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.
- **asLib_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.

### 8.8.2 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.
8.9 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:

\[\text{dbl}("<record type>","<filename>","<field list>")\]

Examples

\[
\begin{align*}
\text{dbl} \\
\text{dbl("ai",0,0)}
\end{align*}
\]

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 \texttt{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:

\[\text{dbgrep}("<pattern>")\]

Examples

\[
\begin{align*}
\text{dbgrep("S0*")} \\
\text{dbgrep("*gpibAi+")}
\end{align*}
\]

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.
Chapter 9: IOC Test Facilities
Database List, Get, Put

9.2.3 dba

Database Address:

\[
\text{dba("<record\_name.field\_name>"})
\]

Example

\[
\text{dba("aitest")}
\]
\[
\text{dba("aitest.VAL")}
\]

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:

\[
\text{dbgf("<record\_name.field\_name>"})
\]

Example:

\[
\text{dbgf("aitest")}
\]
\[
\text{dbgf("aitest.VAL")}
\]

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:

\[
\text{dbpf("<record\_name.field\_name>","<value>"})
\]

Example:

\[
\text{dbpf("aitest","5.0")}
\]

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:

\[
\text{dbpr("<record\_name>"},<interest\_level>)
\]

Example

\[
\text{dbpr("aitest",2)}
\]

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:
Chapter 9: IOC Test Facilities

Breakpoints

```
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

```
dbc("<record_name>")
```

Continue:

Continues execution until another breakpoint is found. This command may also be called without an argument.

### 9.3.5 dbp

```
dbp("<record_name>,<interest_level>)
```

Print Fields Of Suspended Record:

Prints out the fields of the last record whose execution was suspended.

### 9.3.6 dbap

```
dbap("<record_name>")
```

Auto Print:

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

```
dbstat
```

Status:

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:

```
dbiort("<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 number. 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:

\[
\text{asSetSubstitutions("substitutions")}
\]

Specifies macro substitutions used when access security is initialized.

9.8.2 asSetFilename

Format:

\[
\text{asSetFilename("<filename>")}
\]

This command defines a new access security file.

9.8.3 asInit

Format:

\[
\text{asInit}
\]

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:

\[
\text{asdbdump}
\]

This provides a complete dump of the access security database.

9.8.5 aspuag

Format:

\[
\text{aspuag(<user access group>)}
\]

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:

\[
\text{asphag(<host access group>)}
\]
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:

\[<\text{name}>(\text{nrw})\]

where
- \(n\) is number of \text{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("<\text{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:

\[ \text{gft("<record\_name.field\_name>")} \]

Example:

\[
\begin{align*}
\text{gft("aitest")} \\
\text{gft("aitest.VAL")}
\end{align*}
\]

This performs a \text{db\_name\_to\_addr} and then calls \text{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:

\[ \text{pft("<record\_name.field\_name>"","<value>")} \]

Example:

\[
\begin{align*}
\text{pft("aitest","5.0")}
\end{align*}
\]

This command performs a \text{db\_name\_to\_addr}, \text{db\_put\_field}, \text{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:

\[ \text{tpn("<record\_name.field\_name>"","<value>")} \]

Example:

\[
\begin{align*}
\text{tpn("aitest","5.0")}
\end{align*}
\]

This routine tests \text{dbPutNotify} via the old database access interface.

9.15 Routines to dump database information

9.15.1 dbDumpPath

Dump Path:

\[ \text{dbDumpPath(pdbname)} \]

The current path for database includes is displayed.
9.15.2 dbDumpMenu

Dump Menu:

\[ \text{dbDumpMenu(pdbbase, "<menu>")} \]

\[ \text{dbDumpMenu(pdbbase, "menuScan")} \]

If the second argument is 0 then all menus are displayed.

9.15.3 dbDumpRecordType

Dump Record Description:

\[ \text{dbDumpRecordType(pdbbase, "<record type>")} \]

\[ \text{dbDumpRecordType(pdbbase, "ai")} \]

If the second argument is 0 then all descriptions of all records are displayed.

9.15.4 dbDumpFldDes

Dump Field Description:

\[ \text{dbDumpFldDes(pdbbase, "<record type>", "<field name>")} \]

\[ \text{dbDumpFldDes(pdbbase, "ai", "VAL")} \]

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:

\[ \text{dbDumpDevice(pdbbase, "<record type>")} \]

\[ \text{dbDumpDevice(pdbbase, "ai")} \]

If the second argument is 0 then the device support for all record types is displayed.

9.15.6 dbDumpDriver

Dump Driver Support:

\[ \text{dbDumpDriver(pdbbase)} \]

\[ \text{dbDumpDriver(pdbbase)} \]
9.15.7 `dbDumpRecord`

Dump Record Instances:

\[
\text{dbDumpRecord(pdbbase, }<\text{record type}>, \text{level)}
\]

\[
\text{dbDumpRecords(pdbbase, }\text{ai})
\]

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

\[
\text{dbDumpBreaktable(pdbbase, name)}
\]

\[
\text{dbDumpBreaktable(pdbbase, }\text{typeKdegF})
\]

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:

\[
\text{dbPvdDump(pdbbase, verbose)}
\]

\[
\text{dbPvdDump(pdbbase, 0)}
\]

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);
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

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:

```c
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

```c
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

```c
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

```c
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. An 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:

```c
#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:

```c
#define S_xxxxxxxx value /*string value*/
```

For example:

```c
#define S_dbAccessBadDBR (M_dbAccess|3) /*Invalid Database Request*/
```

For example, when `dbGetField` detects a bad database request type, it executes the statement:

```c
return(S_dbAccessBadDBR);
```

The calling routine checks the return status as follows:

```c
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 by default when iocInit runs. 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/". 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**
Chapter 10: IOC Error Logging

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 \textbf{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` \textbf{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` \textbf{FALSE} and return

The examples given below show how this can be done.

\section*{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 \texttt{epics/share/epicsH/recSup.h}. The concept of record support routines isolates the \texttt{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:

\begin{verbatim}
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_control_double;
    RECSUPFUN get_alarm_double;
};
\end{verbatim}

Each record support module must define its RSET. The external name must be of the form:

\begin{verbatim}
<record_type>RSET
\end{verbatim}

Any routines not needed for the particular record type should be initialized to the value \texttt{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
#define get_units();
#define 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,
gEnum_str,
gEnum_strs,
put_enum_str,
gGraphic_double,
gControl_double,
gAlarm_double);

/* declarations for associated DSET */
typedef struct xxxdset { /* analog input dset */
   long   number;
   DEV_SUPFUN   dev_report;
   DEV_SUPFUN   init;
   DEV_SUPFUN   init_record; /* returns: (1,0)=> (failure, success)*/
   DEV_SUPFUN   get_ioint_info;
   DEV_SUPFUN   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;
   xxdset   *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) ) {

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

```c
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 doesn't call again*/
        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 async 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);
}
```
Chapter 11: Record Support
Example Record Support Module

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

```c
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

```c
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

```c
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 occurred. 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

```c
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 be 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

```c
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

```c
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

```c
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

```c
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

```c
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

```c
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 than 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 occurred 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.

```c
recGblSetSevr(
    void   *precord,
    short   nsta,
    short   nsevr);
```

Returns: (TRUE, FALSE) if (did, did not) change nsta and nsev.

```c
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.

```c
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.

```c
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.

```c
recGblRecsupError(
    long   status,
    struct dbAddr   *paddr,
    char   *pcaller_name,   /* calling routine name */
    char   *psupport_name);   /* support routine name*/
```
Chapter 11: Record Support
Global Record Support Routines

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 than 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

```c
/* Create the dset for devAiSoft */
long init_record();
long read_ai();
struct {
    long number;
    DEVSUPFUN report;
    DEVSUPFUN init;
};
```
Chapter 12: Device Support
Example Synchronous Device Support Module

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;
  struct dbCommon *precord;
  WDOG_ID wd_id;
Chapter 12: Device Support
Example Asynchronous Device Support Module

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 {
            "devAiTestAsyn (read_ai) Illegal INP field";
            return(S_db_badField);
        }
    return(0);
    }
Chapter 12: Device Support

Device Support Routines

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

```c
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?

Let’s 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:

```c
LOCAL long report();
LOCAL long init();
struct {
    long    number;
```
Chapter 13: Driver Support

Device Drivers

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:

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level=0</td>
<td>Display a one line summary for each device</td>
</tr>
<tr>
<td>Level=1</td>
<td>Display more information</td>
</tr>
<tr>
<td>Level=2</td>
<td>Display a lot of information. It is even permissible to prompt for what is wanted.</td>
</tr>
</tbody>
</table>

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:

\begin{verbatim}
int
char *
double
\end{verbatim}

• 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:

```c
DBBASE *pdbbase;
```

14.2.2 DBENTRY

A typical declaration for a database entry structure is:

```c
DBENTRY *pdbentry;
pdbentry=dbAllocEntry(pdbbase);
```

Most static access to a database is via a DBENTRY structure. As many DBENTRYs as desired can be allocated.
Chapter 14: Static Database Access
Allocating and Freeing DBBASE

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

```c
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:
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

```c
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

```c
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

```c
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:

```c
int xxx(DBBASE *pdbbase)
{
    DBENTRY dbentry;
    DBENTRY *pdbentry = &dbentry;
    ...
    dbInitEntry(pdbbase,pdbentry);
    ...
    dbFinishEntry(pdbentry);
}
```

#### 14.4.3 dbCopyEntry
**dbCopyEntry**

**Contents**

```c
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**

```c
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 Definitions**

```c
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);
```
Chapter 14: Static Database Access
Manipulating Record Types

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

```c
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

```c
int dbGetNRecordTypes(DBENTRY *pdbentry);
```

This routine returns the number of record types in the database.

#### 14.6.2 Locate Record Type

```c
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:

```c
status = dbFirstRecordType(pdbentry);
while(!status) {
```
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 148, 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

```c
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

```c
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

```c
long dbPutRecordAttribute(DBENTRY *pdbentry, char *name, char*value)
```

This creates or modifies attribute name with value.

14.8.2 dbGetRecord Attribute

```c
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.
Chapter 14: Static Database Access
Manipulating Record Instances

14.9.1 Get Number of Records

```c
int  dbGetNRecords(DBENTRY *pdbentry);
```
Returns the number of record instances for the record type that DBENTRY currently references.

14.9.2 Locate Record

```c
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

```c
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

```c
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

```c
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

```c
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.

```c
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

```c
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

```c
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

```c
int dbGetNMenuChoices(DBENTRY *pdbentry);
```
This routine returns the number of menu choices for menu.

14.10.2 Get Menu Choice

```c
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

```c
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

```c
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

```c
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

```c
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

```c
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

```c
char **dbgGetFormPrompt(DBENTRY *pdbentry)
char **dbgGetFormValue(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 following 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

```c
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.

```c
/* 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...
");
        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("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:

- \texttt{dbDefs.h}: Miscellaneous database related definitions
- \texttt{dbFldTypes.h}: Field type definitions
- \texttt{dbAccess.h}: Runtime database access definitions.
- \texttt{link.h}: Definitions for link fields.

15.2.1 dbDefs.h

This file contains a number of database related definitions. The most important are:

- \texttt{PVNAME_SZ}: The number of characters allowed in the record name.
- \texttt{FLDNAME_SZ}: The number of characters formerly allowed in a field name. This restriction no longer applies in any base software except \texttt{dbCaLink.c}. THIS SHOULD BE FIXED. It is unknown what effect removing this restriction will have on Channel Access Clients.
- \texttt{MAX_STRING_SIZE}: The maximum string size for string fields or menu choices.
- \texttt{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.
Chapter 15: Runtime Database Access
Database Include Files

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`:

```c
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`.

```c
struct buffer {
    DBRstatus
    DBRtime
    float   value[10];
} buffer;
```
The associated `dbGetField` call is:

```c
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:

```c
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 than 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:

```c
long dbPutField(
    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 `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:
   a. If the record is already active ask for the record to be reprocessed when it completes.
   b. Call `dbScanPassive` after setting `puttf 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:

```c
long dbPutLink(
    struct db_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:

```c
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:

```c
long dbPutNotify(PUTNOTIFY *pputnotify);
```

where PUTNOTIFY is

```c
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:

```c
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:

```c
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 dbGetRest
Get address of a record support entry table.

Format:

```c
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:

```c
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:

```c
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:

```c
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.

```c
#include <caeventmask.h>

int db_post_events(void *precord, void *pfield,
                   unsigned int select);
```

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:

```c
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:

```c
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:

```c
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.

```c
void dbLockInitRecords(dbBase *pdbbase);
```

Called by iocInit.

15.7.0.5 dbLockSetMerge
Merge records into same lock set.

```c
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

```c
void dbLockSetSplit(struct dbCommon *psource);
```

This is called when dbPutField modifies links.

15.7.0.7 dbLockSetGblLock
Global lock for modifying links.

```c
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.

```c
void dbLockSetGblUnlock(void);
```

15.7.0.9 dbLockSetRecordLock
If record is not already scan locked lock it.

```c
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

```c
long dbCaGetAttributes(struct link *plink,
    void (*callback)(void *usrPvt), void *usrPvt);
```

15.8.1.7 dbCaGetControlLimits
Get Control Limits

```c
long dbCaGetControlLimits(struct link *plink, double *low, double *high);
```

15.8.1.8 dbCaGetGraphicLimits
Get graphic Limits

```c
long dbCaGetGraphicLimits(struct link *plink, double *low, double *high);
```

15.8.1.9 dbCaGetAlarmLimits
Get Alarm Limits

```c
long dbCaGetAlarmLimits(struct link *plink,
    double *lolo, double *low, double *high, double *hihi);
```

15.8.1.10 dbCaGetPrecision
Get Precision

```c
long dbCaGetPrecision(struct link *plink, short *precision);
```

15.8.1.11 dbCaGetUnits
Get Units

```c
long dbCaGetUnits(struct link *plink, char *units, int unitsSize);
```

15.8.1.12 dbCaGetNelements
Get Number of Elements

```c
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

```c
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

```c
long dbCaGetTimeStamp(struct link *plink, TS_STAMP *pstamp));
```
15.8.1.15 dbCaIsLinkConnected

Is Channel Connected

```c
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

```c
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

```c
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

```c
typedef enum {intCPU, intVME, intVXI} epicsInterruptType;
```

#### 16.3.2 Connect

```c
long devConnectInterrupt(
    epicsInterruptType intType,
    unsigned vectorNumber,
    void (*pFunction)(),
    void *parameter);
```

#### 16.3.3 Disconnect

```c
long devDisconnectInterrupt(
    epicsInterruptType intType,
    unsigned vectorNumber);
```

#### 16.3.4 Enable Level

```c
long devEnableInterruptLevel(
    epicsInterruptType intType,
    unsigned level);
```

#### 16.3.5 Disable Level

```c
long devDisableInterruptLevel(
    epicsInterruptType intType,
```
16.4 Macros and Routines for Normalized Analog Values

16.4.1 Normalized GetField

```c
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

```c
#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

```c
#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 errMsg, 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.

```c
struct {
  ...
  CALLBACK mycallback;
  ...
}
```

3. Call routines (actually macros) to initialize fields in `CALLBACK`

```c
callbackSetCallback(VOIDFUNCPT, 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.

```c
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.

```c
callbackSetUser(VOID *, CALLBACK *);
```

This call is used to save a value that can be retrieved via a call to:

```c
callbackGetUser(VOID *, CALLBACK *);
```

4. Whenever a callback request is desired just call one of the following:

```c
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:

```c
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
", &pmyStruct->begid[0],
                     &pmyStruct->endid[0]);
    }

    example(char *pbegid, char *pendid)
    {
        strcpy(&myStruct.begid[0],pbegid);
        strcpy(&myStruct.endid[0],pendid);
        callbackSetCallback(myCallback,&myStruct.callback);
Chapter 17: EPICS General Purpose Tasks

Task Watchdog

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:

element("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 be changed by calling callbackSetQueueSize before incInit in the startup file. The syntax is:

ing 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
Chapter 18: Database Scanning
Scan Related Software Components

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:

```plaintext
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:

```c
/* 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

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 scanpl(void);  /*print periodic lists*/
int scanpe1(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

```c
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.

```c
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:
196 EPICS IOC Application Developer's Guide

Chapter 18: Database Scanning
Scan Related Software Components

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 ioscanscan
   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 PRI0 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,
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:

```c
struct scan_list {  
    FAST_LOCK  lock;  
    ELLLIST  list;  
    short   modified;  
    long   ticks;  /*used only for periodic scan sets*/  
};
```

```c
struct scan_element{  
    ELLNODE  node;  
    struct scan_list  *pscan_list;  
    struct dbCommon   *precord;  
}
```
Chapter 18: Database Scanning
Implementation Overview

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:
  
  ```c
  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:

```c
#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:

```c
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)
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:

```c
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

```c
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

```c
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

```c
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`. 

---

Figure 18-1: Structure after iocInit
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.

```c
int scanOnceSetQueueSize(int size);
```
Chapter 19: 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.

19.1 bucketLib.h

This is a hash facility for integers, pointers, and strings. It is used by the Channel Access Server. It is currently undocumented.

19.2 calc

postfix.h defines routines used by 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.

```c
long postfix (char *pinfix, char *ppostfix, short *perror);
long calcPerform(double *parg, double *presult, char *ppostfix);
```

The caller calls postfix to convert the CALC expression from infix to postfix notation. It is the caller'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 on a array of doubles containing that arguments A,...L that can appear in the CALC expression.
- **presult** - The address of the 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

19.3 cvtFast.h

This provides routines for converting various numeric types to ascii string. They offer a combination of speed and convenience not available with sprintf.

```c
/*
 * each of these functions return the number of characters "transmitted"
 *      (as in ANSI-C/POSIX.1/XPG3 sprintf() functions)
 */
int cvtFloatToString(
    float value, char *pstring, unsigned short precision);
int cvtDoubleToString(
    double value, char *pstring, unsigned short precision);
int cvtFloatToExpString(
    float value, char *pstring, unsigned short precision);
```
19.4 cxxTemplates.h

This contains the following C++ templates:

- resourceLib - A C++ hash facility that implements the same functionality as bucketLib
- tsBTree - Binary tree.
- tsDLLList - Double Linked List
- tsFreeList - Free List for efficient new/delete
- tsMinMax - min and max.
- tsSLList - 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.

19.5 dbmf.h

Routines like dbLoadDatabase have the following attribute:

- They issue many calls to malloc followed a short time later by a call to free the memory.
- Between a call to malloc and the associated free, an additional call to malloc is issued that does NOT have an associated free.

In some environments, e.g. vxWorks, such behavior causes severe memory fragmentation.
Dmbf( Database Macro/Free) prevents 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. If dbmfMalloc is called with a request greater than size, the regular malloc is called.

```c
int dbmfInit(size_t size, int chunkItems);
void *dbmfMalloc(size_t bytes);
void dbmfFree(void* bytes);
void dbmfFreeChunks(void);
int dbmfShow(int level);
/* Rules:
 * 1) Size is always made a multiple of 8.
 * 2) if dbmfInit is not called before one of the other routines then it
 *    is automatically called with size=64 and chuckItems=10
 * 3) These routines should only be used to allocate storage that will
 *    shortly thereafter be freed.
 * 4) dbmfFreeChunks can only free chunks that contain only free items
 */
```

### 19.6 ellLib.h

This is a double linked list library. It provides functionality similar to the vxWorks lstLib library. See the vxWorks documentation for details. In most cases there is an ellXXX routine to replace each vxWorks lstXXX routine.

```c
typedef struct ELLNODE {
    struct ELLNODE *next;
    struct ELLNODE *previous;
} ELLNODE;

typedef struct ELLLIST {
    ELLNODE node;
    int count;
} ELLLIST;

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 *ellNch (ELLLIST *pList, int nodeNum);
ELLNODE *ellNStep (ELLNODE *pNode, int nStep);
int ellFind (ELLLIST *pList, ELLNODE *pNode);
void ellFree (ELLLIST *pList);
void ellVerify (ELLLIST *pList);
```
**Chapter 19: libCom**

*fdmgr.h*

### 19.7 fdmgr.h

File Descriptor Manager. A C and a C++ implementation is provided. Not currently documented.

### 19.8 freeList.h

This library can be used 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.

```c
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);
sizet freeListItemsAvail(void *pvt);
```

where

- `pvt` - For private use by library. Caller must provide 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.

### 19.9 gpHash.h

This library provides 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 `pvtid` for each directory.

```c
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 private use by library. Caller must provide 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.
19.10 logClient

The iocLog client. Thus does not really belong in libCom.

19.11 macLib.h

This is a general purpose macro substitution library. It is used for all macro substitution in base.

```c
long macCreateHandle(
    MAC_HANDLE **handle,       /* address of variable to receive pointer */
    MAC_HANDLE **handle,       /* 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 */
    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 */
       char        *defns,         /* macro definitions in "a=xxx,b=yyy" */
       char        **pairs[]       /* address of variable to receive pointer */
       /* format */
       /* 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.

19.12 misc

19.12.1 aToIPAddr

The function prototype appears in osiSock.h
aToIPAddr fills in the structure pointed to by the pIp argument with the Internet address and portnumber 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.
19.12.2 adjustment.h

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.

19.12.3 cantProceed.h

void cantProceed(const char *errorMessage);
void *callocMustSucceed(size_t count, size_t size, const char *errorMessage);
void *mallocMustSucceed(size_t size, const char *errorMessage);

These routines are provided for code that can’t proceed when an error occurs. 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.

19.12.4 dbDefs.h

This 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.

19.12.5 epicsString.h

int dbTranslateEscape(char *s, const char *ct);

dbTranslateEscape copies ct to s while substituting escape sequences. It returns the length of the resultant string (may contain nulls).

19.12.6 epicsTypes.h

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 epicsUInt32 epicsIndex;
typedef epicsInt32 epicsStatus;

epicsTypes.h contains a number of definitions that provide architecture independent data types. 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.

19.12.7 gsd_sync_defs.h

Not documented.
19.12.8 locationException.h

A C++ template. Not documented. This should be in cxxTemplates.

19.12.9 shareLib.

This is the header file for the "decorated names" that appear in header files, e.g.

```c
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.

19.12.10 truncateFile.h

```c
enum TF_RETURN {TF_OK=0, TF_ERROR=1};
TF_RETURN truncateFile
    const char *pFileName, /*name (and optionally path) of file*/
    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.

19.12.11 unixFileName.h

Specifies OSI_PATH_LIST_SEPARATOR and OSI_PATH_SEPARATOR

19.13 timer.h

This defines and implements osiTimer, which implements the timers used by base. For example the database callback facility uses osiTimer. Not documented except in the header file.
Chapter 20:  libCom OSI libraries

20.1 Overview

Directory <base>/src/libCom/osi contains code for implementing operating system independent code. The structure of this directory is:

osi/
osi*.h
*.cpp  - A few generic c++ implementations

os/
  Linux/
  RTEMS/
  WIN32/
  cygwin32/
  default/
  posix/
  solaris/
  vxWorks/

NOTE: Other systems also have a directory but only these are currently supported.

The osi directory contains header files that start with "osi". These contain the definitions used by user code. Each of the directories under osi/os contain architecture dependent code. Such code has names like osd*.h and osd*.c. These files contain operating system dependent headers and sources.

The rules for installing header files residing under libCom/osi are:

• Files in osi are installed into <top>/include
• Files in osi/os/* are installed into <top>/include/os/<arch>. The search order for locating a file is:
  • libCom/osi/os/<arch>
  • libCom/osi/os/posix
  • libCom/osi/os/default

When compiling the search order for locating header files is:

• .  - the current directory
• <top>/os/<arch>
• <top>/include
• libCom/*

The search order for locating source files is:

• libCom/osi/os/<arch>
• libCom/osi/os/posix
• libCom/osi/os/default
• libCom/*

NOTE: libCom/osi/os/* contains files osiFileName.h and osiSock.h I dont think these belong!!
20.2 epicsAssert.h

This is a replacement for ANSI C's assert. If 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 concerning 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.

20.3 osiEvent.h

class osiEvent {
public:
  osiEvent ();
~osiEvent ();
  void signal ();
  void wait (); /* blocks until full */
  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:
  ...

This is a C++ wrapper for semBinary, which is defined in osiSem.h

20.4 osiFindGlobalSymbol.h

void * osiFindGlobalSymbol(const char *name);

<table>
<thead>
<tr>
<th>Method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>osiFindGlobalSymbol</td>
<td>Return the address of the global variable name</td>
</tr>
</tbody>
</table>

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 osiFindGlobalSymbol. If osiFindGlobalSymbol can locate the global symbol it returns the address, otherwise it returns null.

On vxWorks osiFindGlobalSymbol calls symFindByName.
A default version just returns null, i.e. it always fails.

20.5 osiInterrupt.h

int interruptLock();
void interruptUnlock(int key);
int interruptIsInterruptContext();
void interruptContextMessage(const char *message);

<table>
<thead>
<tr>
<th>Method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>interruptLock</td>
<td>Lock interrupts and return a key to be passed to interruptUnlock</td>
</tr>
<tr>
<td></td>
<td>To lock the following is done.</td>
</tr>
<tr>
<td></td>
<td>int key;</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>key = interruptLock();</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>interruptUnlock(key);</td>
</tr>
<tr>
<td>interruptUnlock</td>
<td>Unlock interrupts.</td>
</tr>
<tr>
<td>interruptIsInterruptContext</td>
<td>Return (true, false) if current context is interrupt context.</td>
</tr>
<tr>
<td>interruptContextMessage</td>
<td>Generate a message while interrupt context is true.</td>
</tr>
</tbody>
</table>

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 multithreaded process. The global semaphore is thus only global within the process.

NOTES:

The generic version is intended for use on all except real time operating systems.

- The vxWorks type implementation will not produce the desired result on symetric multiprocessing systems.
- The reason this is needed is:
  - callbackRequest and scanOnce can be issued from interrupt level.
  - The errlog routines can be called while at interrupt level.

### 20.6 osiMutex.h

class epicsShareClass osiMutex {
public:
  osiMutex () ;
~osiMutex () ;
  void lock () const; /* blocks until success */
  bool lock (double timeOut) const; /* true if successful */
  bool tryLock () const; /* true if successful */
  void unlock () const;
  void show (unsigned level) const;

  class invalidSemaphore {}; /* exception */
  class noMemory {}; /* exception */
private:
  mutable semMutexId id;
};
Chapter 20: libCom OSI libraries

20.7 osiPoolStatus.h

This is a wrapper c++ class for semMutex described in osiSem.

```c
int osiSufficientSpaceInPool(void);
```

<table>
<thead>
<tr>
<th>Method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>osiSufficientSpaceInPool</td>
<td>Return (true,false) if there is sufficient free memory.</td>
</tr>
</tbody>
</table>

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.

20.8 osiProcess.h

```c
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.
20.9 **osiRing.h**

```c
ringId ringCreate(int nbytes);
void ringDelete(ringId id);
int ringGet(ringId id, char *value, int nbytes);
int ringPut(ringId id, char *value, int nbytes);
void ringFlush(ringId id);
int ringFreeBytes(ringId id);
int ringUsedBytes(ringId id);
int ringSize(ringId id);
int ringIsEmpty(ringId id);
int ringIsFull(ringId id);
```

**osiRing** has the following properties.
- For a single writer it is not necessary to lock puts.
- For a single reader it is not necessary to lock gets.
- `ringFlush` should only be used if both gets and puts are locked.

A vxWorks specific version is provided that maps directly to rngLib calls. The vxWorks implementation guarantees the above properties.

A default version is provided that works on all platforms and also guarantees the above properties.

20.10 **osiSem.h**

```c
typedef void *semBinaryId;
typedef enum {semTakeOK, semTakeTimeout, semTakeError} semTakeStatus;
typedef enum {semEmpty, semFull} semInitialState;
semBinaryId semBinaryCreate(semInitialState initialState);
```
semBinaryId semBinaryMustCreate (semInitialState initialstate);
void semBinaryDestroy (semBinaryId id);
void semBinaryGive (semBinaryId id);
semTakeStatus semBinaryTake (semBinaryId id);
void semBinaryMustTake (ID);
semTakeStatus semBinaryTakeTimeout (semBinaryId id, double timeout);
semTakeStatus semBinaryTakeNoWait (semBinaryId id);
void semBinaryShow (semBinaryId id, unsigned int level);

typedef void *semMutexId;
semMutexId semMutexCreate (void);
semMutexId semMutexMustCreate (void);
void semMutexDestroy (semMutexId id);
void semMutexGive (semMutexId id);
semTakeStatus semMutexTake (semMutexId id);
void semMutexMustTake (semMutexId id);
semTakeStatus semMutexTakeTimeout (semMutexId id, double timeOut);
semTakeStatus semMutexTakeNoWait (semMutexId id);
void epicsShareAPI semMutexShow (semMutexId id, unsigned int level);

<table>
<thead>
<tr>
<th>Method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>semBinaryCreate</td>
<td>Creates a binary semaphore. It can be created empty or full. If it is created empty then a semTake</td>
</tr>
<tr>
<td>semBinaryMustCreate</td>
<td>issued before a semGive will block. If created full then the first semTake will always succeed.</td>
</tr>
<tr>
<td></td>
<td>Multiple semGives may be issued between semTakes but have the same effect as a single semGive.</td>
</tr>
<tr>
<td></td>
<td>If semBinaryCreate is called the return value must be checked. A return value of 0 indicates</td>
</tr>
<tr>
<td></td>
<td>failure. semBinaryMustCreate does not return if it fails.</td>
</tr>
<tr>
<td>semBinaryDestroy</td>
<td>Remove the semaphore and any resources it uses. Any further use of the semaphore result in</td>
</tr>
<tr>
<td></td>
<td>unknown (most certainly bad) behavior. No outstanding take can be active when this call is made.</td>
</tr>
<tr>
<td>semBinaryGive</td>
<td>Set the semaphore full, i.e. ensures that the next or current call to semBinaryTake completes.</td>
</tr>
<tr>
<td>semBinaryTake</td>
<td>Wait until the semaphore is full. If semBinaryTake is issued then the return value must be checked.</td>
</tr>
<tr>
<td>semBinaryMustTake</td>
<td>It will be either semTakeOK or semTakeError. semBinaryMustTake will not return if an error is detected.</td>
</tr>
<tr>
<td>semBinaryTakeTimeout</td>
<td>Similar to semBinaryTake except that if the semaphore is empty the call completes after the</td>
</tr>
<tr>
<td>semBinaryTakeNoWait</td>
<td>specified timeout (semBinaryTakeTimeout) or immediately (semBinaryTakeNoWait). If the return</td>
</tr>
<tr>
<td></td>
<td>value is semTakeOK the semaphore was full. If the semaphore was never full during the timeout</td>
</tr>
<tr>
<td></td>
<td>period, the return value is semTakeTimeout.</td>
</tr>
<tr>
<td>semBinaryShow</td>
<td>Display information about the semaphore. The information displayed is architecture dependent.</td>
</tr>
<tr>
<td>semMutexCreate</td>
<td>Creates a mutual exclusion semaphore. If semMutexCreate is called the return value must be checked.</td>
</tr>
<tr>
<td>semMutexMustCreate</td>
<td>A return value of 0 indicates failure. semMutexMustCreate does not return if it fails.</td>
</tr>
<tr>
<td>semMutexDestroy</td>
<td>Remove the semaphore and any resources it uses. Any further use of the semaphore result in</td>
</tr>
<tr>
<td></td>
<td>unknown (most certainly bad) results. No outstanding takes can be active when this call is made.</td>
</tr>
<tr>
<td>semMutexGive</td>
<td>Called when the owner thread is done with a resource. If a thread issues recursive takes, there</td>
</tr>
<tr>
<td></td>
<td>must be a semMutexGive for each take.</td>
</tr>
</tbody>
</table>
Two types of semaphores are provided: Binary and Mutex.

The primary use of binary semaphores is for synchronization. They could also be used for mutual exclusion but this usage is discouraged. A example of using a binary semaphore is a consumer thread that processes requests from one or more producer threads. For example:

- Create the consumer thread:
  ```c
  semBinaryId id;
  ...
  id = semBinaryMustCreate(semEmpty);
  threadCreate("consumer"...)
  ```
- The consumer thread has code containing:
  ```c
  while(1) {
      semBinaryMustTake(id);
      while(/*more work*/) {
          /*process work*/
      }
  }
  ```
- Producers create requests and issue the statement:
  ```c
  semGive(id);
  ```

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:

```c
semMutexId id;
...
 id = semMutexMustCreate();
...
semMutexMustTake(id);
/* process resource */
semMutexGive(id);
```

NOTES: Mutual exclusion semaphores

- MUST implement recursive locking
- SHOULD implement priority inheritance and be deletion safe

A posix version is implemented via pthreads.
20.11 osiSigPipeIgnore.h

void installSigPipeIgnore (void);
Not documented.

20.12 osiSock.h

See the header file in <base>/src/libCom/osi.

20.13 osiThread.h

typedef void (*THREADFUNC)(void *parm);

static const unsigned threadPriorityMax = 99;
static const unsigned threadPriorityMin = 0;

/* some generic values */
static const unsigned threadPriorityLow = 10;
static const unsigned threadPriorityMedium = 50;
static const unsigned threadPriorityHigh = 90;

/* some iocCore specific values */
static const unsigned threadPriorityChannelAccessServer = 30;
static const unsigned threadPriorityScanLow = 60;
static const unsigned threadPriorityScanHigh = 70;

/* stack sizes for each stackSizeClass are implementation and CPU dependent */
typedef enum {
    threadStackSmall, threadStackMedium, threadStackBig
} threadStackSizeClass;

typedef enum {tbsFail, tbsSuccess} threadBoolStatus;

unsigned int threadGetStackSize(threadStackSizeClass size);

typedef int threadOnceId;
#define OSITHREAD_ONCE_INIT 0
void threadOnce(threadOnceId *id, THREADFUNC func, void *arg);

void threadInit(void);
void threadExitMain(void);

/* (threadId)0 is guaranteed to be an invalid thread id */
typedef void *threadId;
threadId threadCreate(const char *name,
    unsigned int priority, unsigned int stackSize,
    THREADFUNC funptr, void *parm);
### void threadSuspendSelf(void);
### void threadResume(threadId id);
### unsigned int threadGetPriority(threadId id);
### unsigned int threadGetPrioritySelf();
### void threadSetPriority(threadId id,unsigned int priority);
### threadBoolStatus threadHighestPriorityLevelBelow(
    unsigned int priority, unsigned *pPriorityJustBelow);
### threadBoolStatus threadLowestPriorityLevelAbove(
    unsigned int priority, unsigned *pPriorityJustAbove);
### int threadIsEqual(threadId id1, threadId id2);
### int threadIsSuspended(threadId id);
### void threadSleep(double seconds);
### threadId threadGetIdSelf(void);
### threadId threadGetId(const char *name);
### const char *threadGetNameSelf(void);

/* For threadGetName name is guaranteed to be null terminated */
/* size is size of buffer to hold name (including terminator */
/* Failure results in a null string stored in name */
void threadGetName(threadId id, char *name,size_t size);

### void threadShowAll(unsigned int level);
### void threadShow(threadId id,unsigned int level);

### typedef void * threadVarId;
### threadVarId threadPrivateCreate (void);
### void threadPrivateDelete (threadVarId id);
### void threadPrivateSet (threadVarId, void *);
### void * threadPrivateGet (threadVarId);

<table>
<thead>
<tr>
<th>Method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>threadGetStackSize</td>
<td>Get a stack size value that can be given to threadCreate. Three sizes can be requested: small, medium, and large.</td>
</tr>
</tbody>
</table>
| threadOnce           | This is used as follows:
  void myInitFunc(void * arg)
  {
    ...
  }
  ...
  threadOnceId onceFlag = OSITHREAD_ONCE_INIT;
  ...
  threadOnce(&onceFlag,myInitFunc,(void *)myParm)
  For each unique threadOnceId, threadOnce guarantees
  1) myInitFunc is called only once.
  2) myInitFunc completes before any threadOnce call completes. |
| threadInit           | This is called automatically by the thread implementation. NOTE: This should not appear in osiThread.h |
| threadExitMain       | 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 threadExitMain never returns. This must only be called by the main thread. |
### Thread Library Functions

<table>
<thead>
<tr>
<th>Method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>threadCreate</td>
<td>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.</td>
</tr>
<tr>
<td>threadSuspendSelf</td>
<td>This causes the calling thread to suspend. The only way it can resume is for another thread to call threadResume.</td>
</tr>
<tr>
<td>threadResume</td>
<td>Resume a suspended thread. Only do this if you know that it is safe to resume a suspended thread.</td>
</tr>
<tr>
<td>threadGetPriority</td>
<td>Get the priority of the specified thread.</td>
</tr>
<tr>
<td>threadGetPrioritySelf</td>
<td>Get the priority of this thread.</td>
</tr>
<tr>
<td>threadSetPriority</td>
<td>Set a new priority for the specified thread. Note that the result is implementation dependent. See comments about priorities above.</td>
</tr>
<tr>
<td>threadHighestPriority</td>
<td>Get a priority that just lower than the specified priority.</td>
</tr>
<tr>
<td>threadLowestPriority</td>
<td>Get a priority that is just above the specified priority.</td>
</tr>
<tr>
<td>threadIsEqual</td>
<td>Compares two threadIds and returns (0,1) if they (are not, are) the same.</td>
</tr>
<tr>
<td>threadIsSuspended</td>
<td>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.</td>
</tr>
<tr>
<td>threadSleep</td>
<td>Sleep for the specified period of time, i.e. sleep without using the cpu.</td>
</tr>
<tr>
<td>threadGetIdSelf</td>
<td>Get the threadId of the calling thread.</td>
</tr>
<tr>
<td>threadGetId</td>
<td>Get the threadId if the specified thread. A return of 0 means that no thread was found with the specified name.</td>
</tr>
<tr>
<td>threadGetNameSelf</td>
<td>Get the name of the calling thread.</td>
</tr>
<tr>
<td>threadGetName</td>
<td>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.</td>
</tr>
<tr>
<td>threadShowAll</td>
<td>Display info about all threads.</td>
</tr>
<tr>
<td>threadShow</td>
<td>Display info about the specified thread.</td>
</tr>
<tr>
<td>threadPrivateCreate</td>
<td>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 threadPrivateCreate. Each thread should call threadPrivateSet when the thread is created. Each library routine can call threadPrivateGet each time it is called.</td>
</tr>
<tr>
<td>threadPrivateDelete</td>
<td>Delete a thread private variable.</td>
</tr>
<tr>
<td>threadPrivateSet</td>
<td>Set the value for a thread private variable.</td>
</tr>
<tr>
<td>threadPrivateGet</td>
<td>Get the value of a thread private variable, the value is the value set by the call to threadPrivateSet that was made by the same thread. If called before threadPrivateSet it returns 0.</td>
</tr>
</tbody>
</table>
osiThread is meant as a somewhat minimal interface for multithread 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 threadCreate. 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.
- **threadOnce** - This provides the ability to have an initialization function that is guaranteed to be called exactly once.
- **main** - On systems requiring a main routine, threadInit MUST be called before any thread or semaphore routines. Since the errlog facility, which is used by many components of libCom, calls threadCreate, threadInit should be called before any other routines supplied with epics base. If a main routine finishes its work but wants to leave other threads running it can call threadExitMain, which should be the last statement in main.
- **Priorities** - Priorities range 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** - threadCreate 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.
- **threadId** - This is given a value as a result of a call to threadInit or threadCreate. 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.

### 20.14 osiTime.h

This is a replacement for tsLib.h. Currently only documented in the header file.

### 20.15 tsStamp.h

This is a set of C functions to access osiTime. Currently only documented via the header file.
Chapter 21: 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" accessible 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.

21.1 Registry.h

```c
int registryAdd(void *registryID, const char *name, void *data);
void *registryFind(void *registryID, const char *name);
int registrySetTableSize(int size);
void registryFree();
int registryDump();
```

This is the code which does the work. Each different set of things to register must have its 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.

21.2 registryRecordType.h

```c
typedef int (*computeSizeOffset)(dbRecordType *pdbRecordType);

typedef struct recordTypeLocation {
    struct rset *prset;
    computeSizeOffset sizeOffset;
}recordTypeLocation;

int registryRecordTypeAdd(const char *name, recordTypeLocation *ptrl);
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.
21.3 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.

21.4 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.

21.5 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.

21.6 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

21.7 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 22: Database Structures

22.1 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.

22.2 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.
- **caef.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 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.
- **initHooks.h** - Definitions used by initHooks.c routines.
Chapter 22: Database Structures
Include Files

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
22.3 Structures

- **dbBase**
  - menuList
  - recordTypeList
  - drvList
  - bptList
  - pathPvt
  - ppvd
  - pgpHash
  - ignoreMissingMenus

- **dbMenu**
  - node
  - name
  - nChoice
  - papChoiceName
  - papChoiceValue

- **dbRecordType**
  - node
  - attributeList
  - recList
  - devList
  - name
  - no_fields
  - no_prompt
  - link_ind
  - papsortFldName
  - sortFldInd
  - pvalFldDes
  - indvalFlddes
  - papFldDes
  - ...

- **drvSup**
  - node
  - name
  - pdrvset

- **brkTable**
  - node
  - name
  - number
  - papBrkInt

- **dbRecordNode**
  - node
  - precord
  - recordname
  - visible

- **dbFldDes**
  - prompt
  - name
  - extra
  - pdbRecordType
  - indRecordType
  - special
  - field_type
  - process_passive
  - base
  - promptgroup
  - interest
  - as_level
  - initial
  - ...

- **brkInt**
  - raw
  - slope
  - eng
INDEX

A

AB_IO .................................................. 63
Access Security ................................. 83
adpath ............................................ 52, 54
adjustToWorstCaseAlignment ........ 209
Alloc/Free DBENTRY ..................... 149
asAddClient ......................................... 92
asAddMember ......................................... 92
asChangeClient ................................. 93
asChangeGroup .................................... 92
ascheck ........................................... 86
asCheckGet( ................................. 93
asCheckPut ......................................... 93
asCompute ......................................... 94
asComputeAllAsg ............................... 94
asComputeAsg ................................. 94
asDbDump ...................................... 97, 107
asDbGetAsl .......................................... 96
asDbGetMemberPvt ...
<table>
<thead>
<tr>
<th>Function</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPICS_IOC_LOG_INET</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_IOC_LOG_FILE_NAME</td>
<td>119</td>
</tr>
<tr>
<td>EPICS_CA_CONN_TMO</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_BEACON_PERIOD</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_ADDR_LIST</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_AUTO_ADDR_LIST</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_ADDR_LIST</td>
<td>80</td>
</tr>
<tr>
<td>ellAdd</td>
<td>205</td>
</tr>
<tr>
<td>ellConcat</td>
<td>205</td>
</tr>
<tr>
<td>ellCount</td>
<td>205</td>
</tr>
<tr>
<td>ellDelete</td>
<td>205</td>
</tr>
<tr>
<td>ellExtract</td>
<td>205</td>
</tr>
<tr>
<td>ellFind</td>
<td>205</td>
</tr>
<tr>
<td>ellFirst</td>
<td>205</td>
</tr>
<tr>
<td>ellFree</td>
<td>205</td>
</tr>
<tr>
<td>ellGet</td>
<td>205</td>
</tr>
<tr>
<td>ellInit</td>
<td>205</td>
</tr>
<tr>
<td>ellInsert</td>
<td>205</td>
</tr>
<tr>
<td>ellLast</td>
<td>205</td>
</tr>
<tr>
<td>FDLNAME_SZ</td>
<td>163</td>
</tr>
<tr>
<td>Environment Variables</td>
<td>80</td>
</tr>
<tr>
<td>EPICS</td>
<td>7</td>
</tr>
<tr>
<td>Basic Attributes</td>
<td>7</td>
</tr>
<tr>
<td>Hardware/Software Platforms</td>
<td>16</td>
</tr>
<tr>
<td>Overview</td>
<td>7</td>
</tr>
<tr>
<td>EPICS_CA_ADDR_LIST</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_AUTO_ADDR_LIST</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_BEACON_PERIOD</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_CONN_TMO</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_REPEATER_PORT</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_CA_SERVER_PORT</td>
<td>80</td>
</tr>
<tr>
<td>EPICS_IOC_LOG_FILE_COMMAND</td>
<td>119</td>
</tr>
<tr>
<td>EPICS_IOC_LOG_FILE_LIMIT</td>
<td>119</td>
</tr>
<tr>
<td>EPICS_IOC_LOG_FILE_NAME</td>
<td>119</td>
</tr>
<tr>
<td>EPICS_IOC_LOG_INET</td>
<td>80</td>
</tr>
</tbody>
</table>
U

UAG ........................................ 84–85
Unquoted String ..................... 53

V

value - record instance definition .......... 62
veclist ................................. 109
VME_AM_EXT_SUP_DATA .......... 183
VME_AM_STD_SUP_DATA .......... 183
VME_AM_SUP_SHORT_IO .......... 183
VME_IO .......................... 63
VXI_IO .......................... 64
vxWorks startup command file ........ 75