

# What is an EPICS Database?

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Advanced Photon Source

## Outline

- ◆ Records
- ◆ Fields and field types
- ◆ Record Scanning
- ◆ Input and Output record types
- ◆ Links, link address types
- ◆ Connecting records together
- ◆ Protection mechanisms
- ◆ Alarms, deadbands, simulation and security

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*Database = Records + Fields +*

## Links

- ◆ A control system using EPICS will contain one or more IOCs
- ◆ Each IOC loads one or more Databases telling it what to do
- ◆ A Database is a collection of Records of various types
- ◆ A Record is an object with:
  - ❖ A unique name
  - ❖ A behaviour defined by its record type (class)
  - ❖ Controllable properties (fields)
  - ❖ Optional associated hardware I/O (device support)
  - ❖ Links to other records

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## Record Activity

- ◆ Records are active — they can do things:
  - ❖ Get data from other records or from hardware
  - ❖ Perform calculations
  - ❖ Check values are in range & raise alarms
  - ❖ Put data to other records or to hardware
  - ❖ Activate or disable other records
  - ❖ Wait for hardware signals (interrupts)
- ◆ What a record does depends upon its record type and the settings of its fields
- ◆ No action occurs unless a record is processed

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## How is a Record

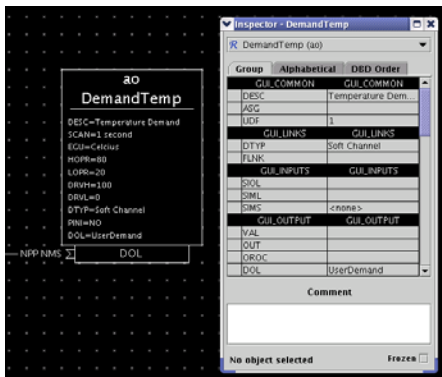
### implemented?

- ◆ A C structure with both data storage and pointers to record type information
- ◆ A record definition within a database provides
  - ❖ Record name
  - ❖ The record's type
  - ❖ Values for each design field
- ◆ A record type provides
  - ❖ Definitions of all the fields
  - ❖ Code which implements the record behaviour
- ◆ New record types can be added to an application as needed

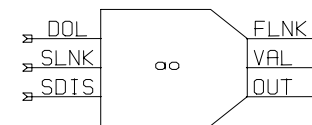
## One view of a Record



## A graphical view of a Record



## Another graphical view of a Record



The small CapFast symbol for an Analogue Output record

## The IOC's view



The full .db file entry for an Analogue Output Record

```
record(ao,"DemandTemp") {
  field(DESC,"Temperature")
  field(ASG,"")
  field(SCAN,"Passive")
  field(PINI,"NO")
  field(PHAS,"0")
  field(EVNT,"0")
  field(DTYP,"VMIC 4100")
  field(DISV,"1")
  field(SDIS,"")
  field(DISS,"NO_ALARM")
  field(PRIO,"LOW")
  field(FLNK,"")
  field(OUT,"#CO S0")
  field(OROC,"0.0e+00")
  field(DOL,"")
  field(OMSL,"supervisory")

  field(OIF,"Full")
  field(PREC,"1")
  field(LINR,"NO
  CONVERSION")
  field(BGUF,"100")
  field(BGUL,"0")
  field(BGU,"Celcius")
  field(DRVH,"100")
  field(DRVL,"0")
  field(HOPR,"80")
  field(LOPR,"10")
  field(HIHI,"0.0e+00")
  field(LOLO,"0.0e+00")
  field(HIGH,"0.0e+00")
  field(LOW,"0.0e+00")

  field(HHSV,"NO_ALARM")
  field(LLSV,"NO_ALARM")
  field(HLSV,"NO_ALARM")
  field(LSV,"NO_ALARM")
  field(HYST,"0.0e+00")
  field(ADEL,"0.0e+00")
  field(MDEL,"0.0e+00")
  field(SIOL,"")
  field(SIML,"")
  field(SIMS,"NO_ALARM")
  field(IVOA,"Continue
  normally")
  field(IVOV,"0.0e+00")
}
```

This shows only the design fields, there are other fields which are used only at run-time



## Fields are for...



### ◆ Defining

- ❖ What causes a record to process
- ❖ Where to get/put data from/to
- ❖ How to turn raw I/O data into a numeric engineering value
- ❖ Limits indicating when to report an alarm
- ❖ When to notify value changes to a client monitoring the record
- ❖ A Processing algorithm
- ❖ Anything else which needs to be set for each record of a given type

### ◆ Holding run-time data

- ❖ Input or output values
- ❖ Alarm status, severity and acknowledgements
- ❖ Processing timestamp
- ❖ Other data for internal use



## Field types



### ◆ Fields can contain

- ❖ **Integers**
  - ♦ char, short or long
  - ♦ signed or unsigned
- ❖ **Floating-point numbers**
  - ♦ float or double
- ❖ **Strings**
  - ♦ maximum useful length is 40 characters
- ❖ **Menu choices**
  - ♦ select one from up to 16 strings
  - ♦ stored as a short integer
- ❖ **Links**
  - ♦ to other records in this or other IOCs
  - ♦ to hardware signals (device support)
  - ♦ provide a means of getting or putting a value
- ❖ **Other private data**
  - ♦ not directly accessible



## All Records have these fields



### Design fields

**NAME** 60 Character unique name (using more than 28 char's can cause problems)  
**DESC** 28 Character description  
**ASG** Access security group  
**SCAN** Scan mechanism  
**PHAS** Scan order (phase)  
**PINI** Process at IOC initialization?  
**PRIO** Scheduling priority  
**SDIS** Scan disable input link  
**DISV** Scan disable value  
**DISS** Disabled severity  
**FLNK** Forward link

### Run-time fields

**PROC** Force processing  
**PACT** Process active  
**STAT** Alarm status  
**SEVR** Alarm severity  
**TPRO** Trace processing  
**UDF** Set if record value undefined  
**TIME** Time when last processed



## Record Scanning



- ◆ **SCAN field is a menu choice from**
  - ❖ Periodic — 0.1 seconds .. 10 seconds
  - ❖ I/O Interrupt (if device supports this)
  - ❖ Soft event — EVNT field
  - ❖ Passive (default)
- ◆ **The number in the PHAS field allows processing order to be set within a scan**
  - ❖ Records with PHAS=0 are processed first
  - ❖ Then those with PHAS=1 , PHAS=2 etc.
- ◆ **Records with PINI=YES are processed once at startup**
- ◆ **PRIO field selects Low/Medium/High priority for Soft event and I/O Interrupts**
- ◆ **A record is also processed whenever any value is written to its PROC field**



## Input records often have these fields

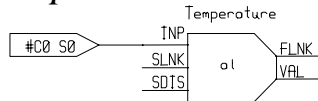


**INP**     **Input link**  
**DTYP**   **Device type**  
**RVAL**   **Raw data value**  
**VAL**     **Engineering value**  
**LOPR**   **Low operator range**  
**HOPR**   **High operator range**

- ◆ **Analogue I/O records have these fields:**
  - EGU**     **Engineering unit string**
  - LINR**   **Unit conversion control:** No conversion, Linear, Slope, breakpoint table name
  - EGUL**   **Low engineering value**
  - EGUF**   **High engineering value**
  - ESLO**   **Unit conversion slope**
  - EOFF**   **Unit conversion offset**



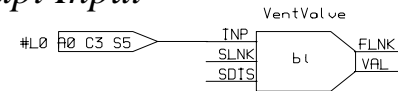
## Periodic Input



DTYP: XY566  
SCAN: .1 Second  
PHAS: 0  
LTNR: LLINEAR  
EGUL: 0  
EGUF: 120  
EGU: Celsius



## Interrupt Input



DTYP: AB-Binary Input  
SCAN: I/O Intr  
PHAS: 0  
ZNAM: Closed  
ONAM: Open  
ZSV: NO\_ALARM  
OSV: MAJOR\_ALARM



## Output records often have these fields

<i>OUT</i>	<b>Output link</b>
<i>DTYP</i>	<b>Device type</b>
<i>VAL</i>	<b>Engineering value</b>
<i>RVAL</i>	<b>Raw output value</b>
<i>DOL</i>	<b>Input link to fetch output value</b>
<i>OMSL</i>	<b>Output mode select:</b> Supervisory, Closed Loop
<i>LOPR</i>	<b>Low operator range</b>
<i>HOPR</i>	<b>High operator range</b>
◆	<b>Analogue outputs also have these fields:</b>
<i>OROC</i>	<b>Output rate of change</b>
<i>OIF</i>	<b>Incremental or Full output</b>
<i>OVAL</i>	<b>Output value</b>
<i>DRVH</i>	<b>Drive high limit</b>
<i>DRVL</i>	<b>Drive low limit</b>
<i>IVOA</i>	<b>Invalid output action</b>
<i>IVOV</i>	<b>Invalid output value</b>
<i>RBV</i>	<b>Read-back value</b>



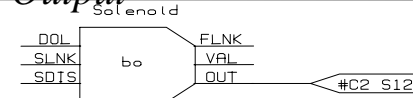
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## Passive Output



DTYP: XY220  
SCAN: Passive  
PHAS: 0  
ZNAM: Locked  
ONAM: Unlocked



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## Links

A link is a type of field, and is one of

- ◆ **Input link**
  - ❖ Fetches data
- ◆ **Output link**
  - ❖ Writes data
- ◆ **Forward link**
  - ❖ Points to the record to be processed once this record finishes processing



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## Input and Output links may be...

- ◆ **Constant numeric value, eg:**
  - 0
  - 3.1415926536
  - 1.6e-19
- ◆ **Hardware link**
  - A hardware I/O signal selector, the format of which depends on the device support layer
- ◆ **Process Variable link — the name of a record, which at run-time is resolved into**
  - ❖ Database link
    - Named record is in this IOC
  - ❖ Channel Access link
    - Named record not found in this IOC



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## Hardware links



VME\_IO #Cn Sn @parm  
Card, Signal

INST\_IO @parm

CAMAC\_IO #Bn Cn Nn An Fn @parm  
Branch, Crate, Node, Address, Function

AB\_IO #Ln An Cn Sn @parm  
or #Ln Pn Cn Sn Fn @parm  
Link, Adaptor, Card, Signal, Flag

GPIB\_IO #Ln An @parm  
Link, Address

BITBUS\_IO #Ln Nn Pn Sn @parm  
Link, Node, Port, Signal

BBGPIB\_IO #Ln Bn Gn @parm  
Link, Bitbus Address, GPIB Address

VXI\_IO #Vn Cn Sn @parm  
or #Vn Sn @parm  
Frame, Slot, Signal



## Database links



These comprise:

- ❖ **The name of a record in this IOC**  
myDb:myRecord
- ❖ **An optional field name**  
.VAL (default)
- ❖ **Process Passive flag**  
NPP (default)  
PP
- ❖ **Maximize Severity flag**  
NMS (default)  
MS

For example:

M1:current.RBV NPP MS

- ◆ **NB:** An input database link with PP set that is pointing to an asynchronous input record will not wait for the new value from that record



## Channel Access links



- ◆ Specified like a database link
- ◆ Name specifies a record not found in this IOC
- ◆ Use Channel Access protocol to communicate with remote IOC
- ◆ May include a field name (default .VAL)
- ◆ PP Link flags are ignored:
  - ❖ Input links are always NPP
  - ❖ Output links follow PP attribute of destination field
  - ❖ This behaviour is identical to all other CA clients
- ◆ MS Link flags apply to Input links:
  - ❖ Input links honour a given NMS (default) or MS flag
  - ❖ Output links are always NMS
- ◆ Additional flags for CA links
  - CA Forces a "local" link to use CA
  - CP On input link, process this record on CA monitor event
  - CPP Like CP but only process if SCAN is Process Passive



## Link flag summary



Type	Input Links	Output Links
DB	.PP or .NPP .MS or .NMS	.PP or .NPP .MS or .NMS
CA	Always .NPP .MS or .NMS .CA to force link type. .CP to process this record on change. .CPP is like .CP but only process if SCAN=Passive	.PP behavior of destination field. Always .NMS .CA to force link type.

Chapter 5 of the IOC Application Developer's Guide covers record links and scanning in detail, and is worth reading.



## Device Support



- ◆ Records do not access hardware directly
- ◆ The Device Support layer performs I/O operations on request
- ◆ A particular device support provides I/O for a single record type
- ◆ The DTYP field determines which device support to use
- ◆ The device support selected determines the format of the link (INP or OUT field) containing device address information
- ◆ Adding new device support does not require change to the record software
- ◆ Device support may call other software to do work for it (Driver Support)



## Synchronous vs Asynchronous I/O



- ◆ EPICS rules do not allow device support to busy-wait (delay record processing while waiting for the results of a slow I/O operation)
  - ❖ Fast I/O can be handled synchronously
  - ❖ Slow operations must operate asynchronously
- ◆ Register-based VME cards usually give an immediate response: synchronous
- ◆ When called, synchronous device support performs all I/O before returning
- ◆ Serial and most I/O field-bus devices take a long time (>10ms) to return data: asynchronous
- ◆ Asynchronous device support starts I/O when record calls it, flags it as incomplete by setting PACT true before returning
- ◆ Once results are available (CPU interrupt), device support calls the record's process routine which finishes the operation



## Soft Device Support



- ◆ "Hard" Input and Output records perform hardware I/O via device support
- ◆ "Soft" records access data from other records via DB or CA links
- ◆ 2 or 3 kinds of support are provided in recent R3.14 releases:
  - ❖ Soft Channel
    - Get/Put VAL through link, no units conversion performed
  - ❖ Async Soft Channel (new, for output records only)
    - Put VAL through CA link, no conversions, wait for completion
  - ❖ Raw Soft Channel
    - Inputs
      - Get RVAL via input link
      - Convert RVAL to VAL (record-type specific)
    - Outputs
      - Convert VAL to RVAL (record-type specific)
      - Put RVAL to output link



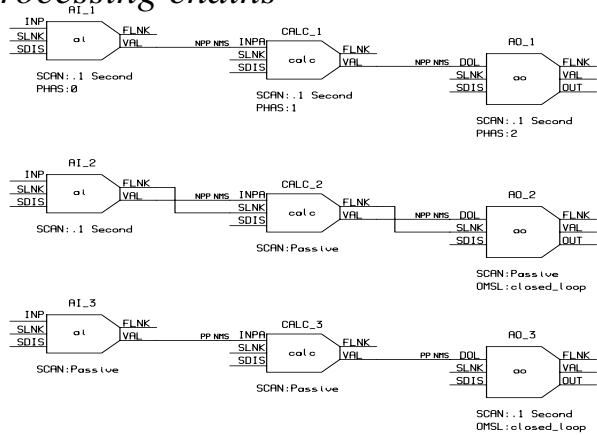
## Forward links



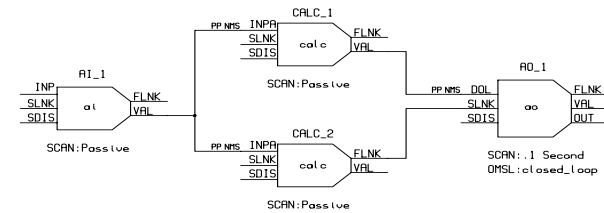
- ◆ Usually a Database link, referring to a record in same IOC
- ◆ Forward linking via Channel Access is possible, must explicitly name the PROC field of the remote record
- ◆ No flags (PP, NMS etc.)
- ◆ Destination record is only processed if it has  
SCAN = Passive
- ◆ Does not pass a value, just causes subsequent processing



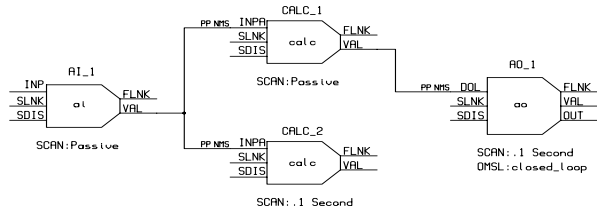
## Processing chains



## Which record is never processed?



## Which record is processed twice?

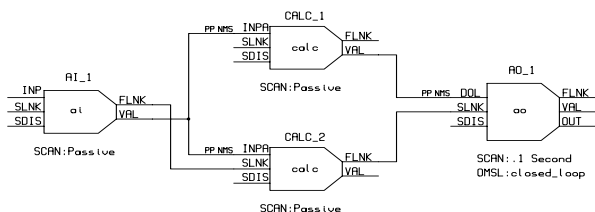


## The PACT field

- ◆ Every record has a boolean run-time field called **PACT (Process Active)**
- ◆ **PACT** breaks loops of linked records
- ◆ It is set to 'true' early in the act of processing the record
  - ❖ **PACT** is true whenever a link in that record is used to get/put a value
- ◆ **PACT** is set to false after record I/O and forward link processing are finished
- ◆ A **PP** link can never make a record process if it has **PACT** true
  - ❖ Input links take the current value
  - ❖ Output links just put their value



## What happens here?



## Preventing records from processing

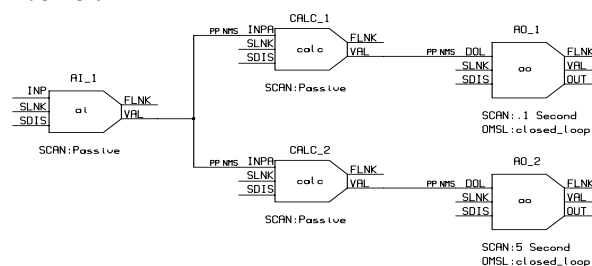
- ◆ It is useful to be able to stop an individual record from processing on some condition
- ◆ Before record-specific processing is called, a value is read through the SDIS input link into DISA
- ◆ If DISA=DISV, the record will not be processed
- ◆ A disabled record may be put into an alarm by giving the desired severity in the DISS field
- ◆ The FLNK of a disabled record is never triggered

## How are records given CPU time?

Several IOC tasks are used:

- ◆ callback (3 priorities) — I/O Interrupt
- ◆ scanEvent — Soft Event
- ◆ scanPeriod — Periodic
  - ❖ A separate task is used for each scan period
  - ❖ Faster scan rates are given a higher task priority (if supported by the IOC's Operating System)
- ◆ Channel Access tasks use lower priority than record processing
  - ❖ If a CPU spends all its time doing I/O and record processing, you may be unable to control or monitor the IOC via the network

## What could go wrong here?



## Lock-sets



- ◆ Prevent a record from being processed simultaneously from two scan tasks
  - ◆ A lock-set is a group of records interconnected by database links:
    - ❖ Output links
    - ❖ Forward links
    - ❖ Input links which are PP or MS
    - ❖ Any link transporting an Array
  - ◆ Lock-sets are determined automatically by the IOC at start-up, or whenever a database link is added, deleted or modified
- You can split a lock set with
- ◆ Channel Access links, using CA flag
  - ◆ Database links which are both NPP and NMS



## Alarms



- ◆ Every record has the fields
  - SEVR Alarm Severity  
*NONE, MINOR, MAJOR, INVALID*
  - STAT Alarm Status (reason)  
*READ, WRITE, UDF, HIGH, LOW, STATE, COS, CALC, DISABLE, etc.*
- ◆ Most numeric records check VAL against HIHI, HIGH, LOW and LOLO fields after the value has been determined
- ◆ The HYST field prevents alarm chattering
- ◆ A separate severity can be set for each numeric limit (HHSV, HSV, LSV, LLSV)
- ◆ Discrete (binary) records can raise alarms on entering a particular state, or on a change of state (COS)

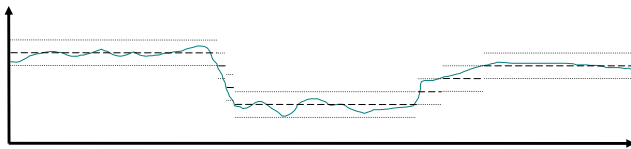


## Change notification: Monitor deadbands

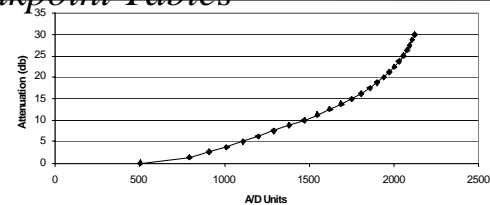


Channel Access notifies clients which are monitoring a numeric record when

- ❖ VAL changes by more than the value in field:
  - MDEL Value monitors
  - ADEL Archive monitors
- ❖ Record's Alarm Status changes
  - HYST Alarm hysteresis
- ❖ Analogue Input record provides smoothing filter to reduce input noise (SMOO)



## Breakpoint Tables



## Simulation



- ◆ **Input and output record types often allow simulation of hardware interfaces**
  - SIML Simulation mode link
  - SIMM Simulation mode value
  - SIOL Simulation input link
  - SIMS Simulation alarm severity
- ◆ **Before using its device support, a record reads SIMM through the SIML link**
- ◆ **If SIMM=YES, device support is ignored; record I/O uses the SIOL link instead**
- ◆ **An alarm severity can be set whenever simulating, given by SIMS field**



## Access Security



- ◆ **A networked control system must have the ability to enforce security rules**
  - ❖ Who can do what from where, and when?
- ◆ **In EPICS, security is enforced by the CA server (typically the IOC).**
- ◆ **A record is placed in the Access Security Group named in its ASG field**
  - ❖ DEFAULT is used if no group name is given
- ◆ **Rules for each group determine whether a CA client can read or write to records in the group, based on**
  - ❖ Client user ID
  - ❖ Client IP address
  - ❖ Access Security Level of the field addressed
  - ❖ Values read from the database



## Access Security Configuration



- ◆ **Security rules are loaded from an Access Security File Configuration File, for example:**

```
UAG(users) {user1, user2}
HAG(hosts) {host1, host2}
ASG(DEFAULT) {
  RULE(1, READ)
  RULE(1, WRITE) {
    UAG(users)
    HAG(hosts)
  }
}
```

- ◆ **If no security file is loaded, Security will be turned off and nothing refused**
- ◆ **For more details and the rule syntax, see Chapter 8 of the IOC Application Developers Guide**

