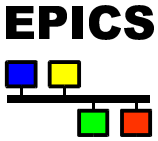
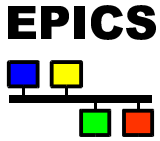


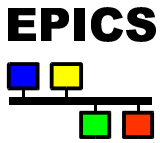
What is an EPICS Database?

Andrew Johnson
APS



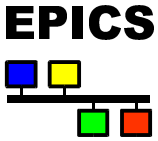
Outline

- Records
- Fields and field types
- Record Scanning
- Input and Output record types
- Hardware support
- Links
- Chaining Records together
- Protection mechanisms
- Alarms, deadbands, simulation and security



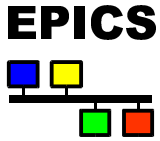
Database = Records + Fields + Links

- 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



Record Activity

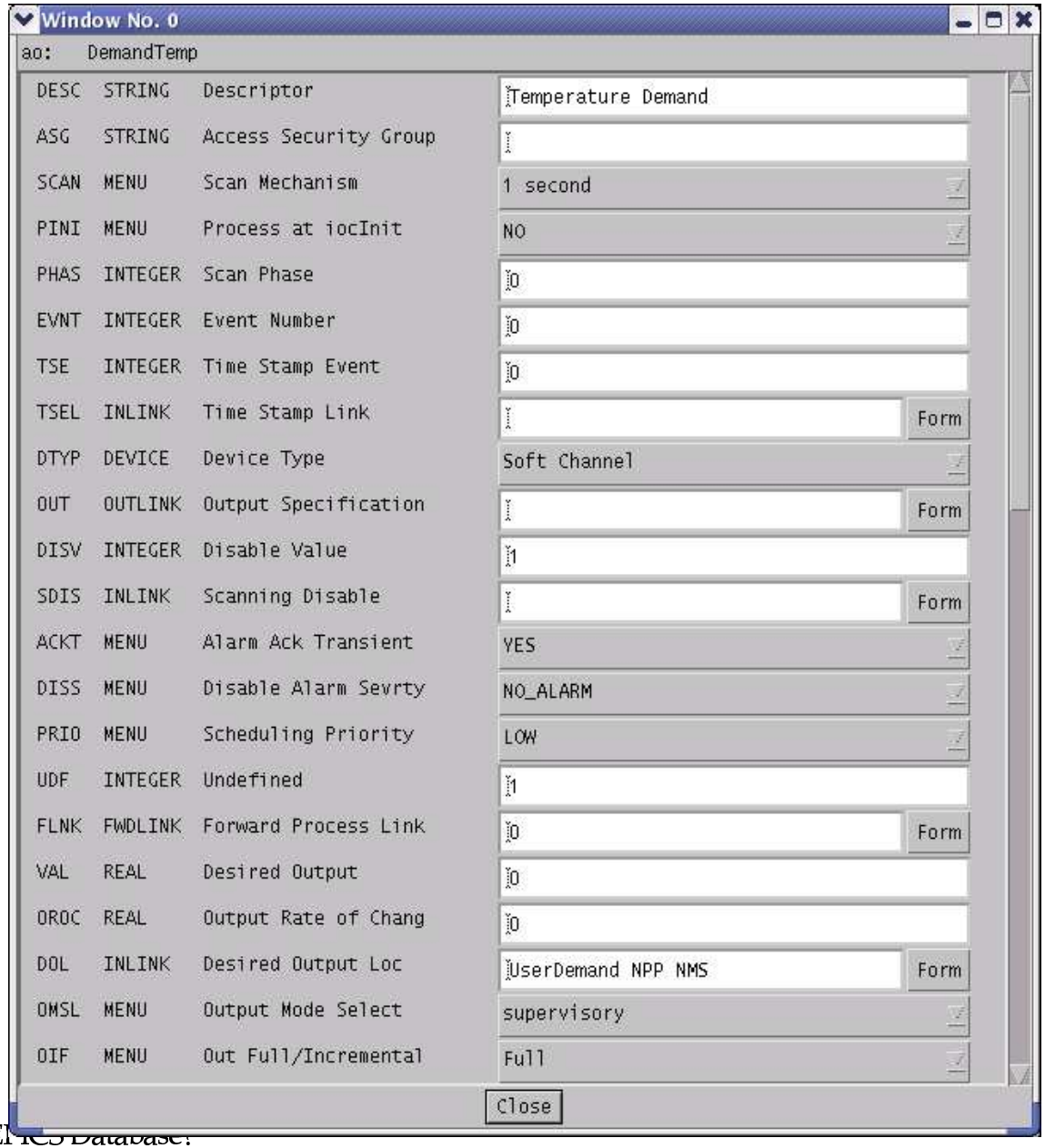
- Records are active — they can do things:
  - Get data from other records or from hardware
  - Perform calculations
  - Check values are in range & raise alarms
  - Put data to other records or to hardware
  - Activate or disable other records
  - Wait for hardware signals (interrupts)
- What a record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



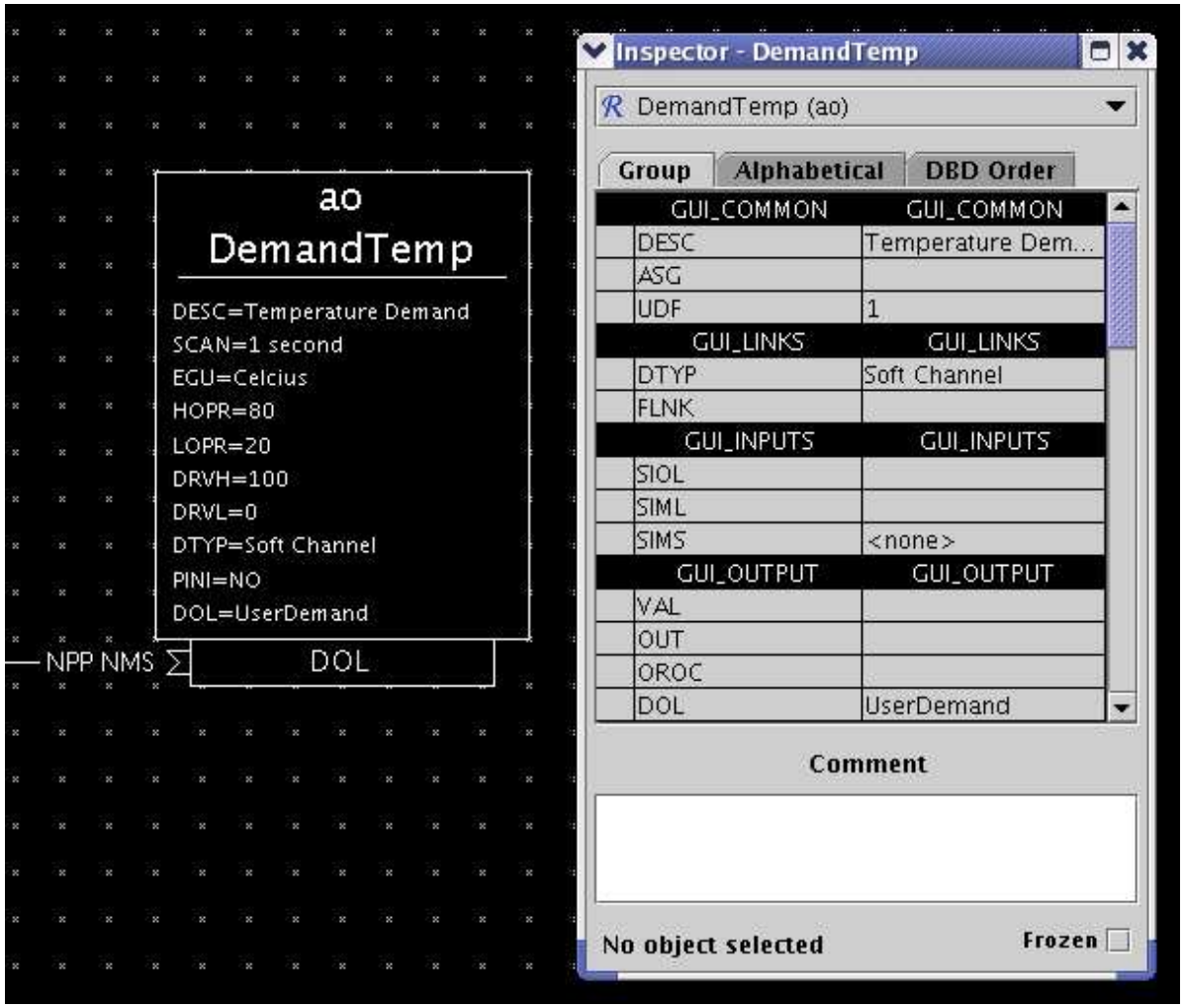
How is a Record implemented?

- 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

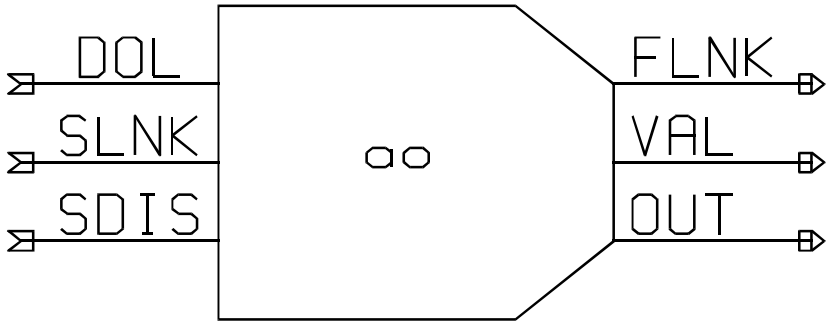
One view of a Record



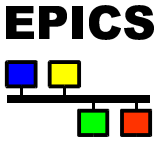
A graphical view of a Record



Another graphical view of a Record



The small CapFast symbol for an Analogue Output record

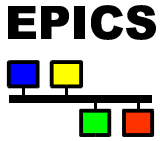


The IOC's view

The full **.db** file entry for an Analogue Output Record

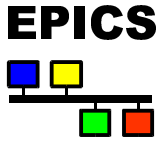
```
record(ao,"DemandTemp") {
    field(DESC,"Temperature")
    field(ASG,"")
    field(SCAN,"Passive")
    field(PINI,"NO")
    field(PHAS,"0")
    field(EVNT,"0")
    field(DTYP,"VMIC 4100")
    field(DISV,"1")
    field(SDIS,"")
    field(DISS,"NO_ALARM")
    field(PRIO,"LOW")
    field(FLNK,"")
    field(OUT,"#C0 S0")
    field(OROC,"0.0e+00")
    field(DOL,"")
    field(OMSL,"supervisory")
    field(OIF,"Full")
    field(PREC,"1")
    field(LINR,"NO CONVERSION")
    field(EGUF,"100")
    field(EGUL,"0")
    field(EGU,"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(HSV,"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



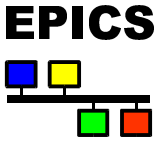
Fields are for...

- 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
    - max length 40 characters or less
  - Menu choices
    - select one from several 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



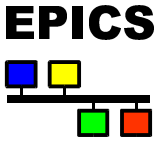
All Records have these fields

Design fields

NAME	28 Character unique name
DESC	28 Character description
ASG	Access security group
SCAN	Scan mechanism
PHAS	Scan order (phase)
PINI	Process at startup?
PRIO	Scheduling priority
SDIS	Scan disable input link
DISV	Scan disable value
DISS	Disabled severity
FLNK	Forward link

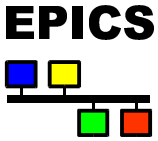
Run-time fields

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



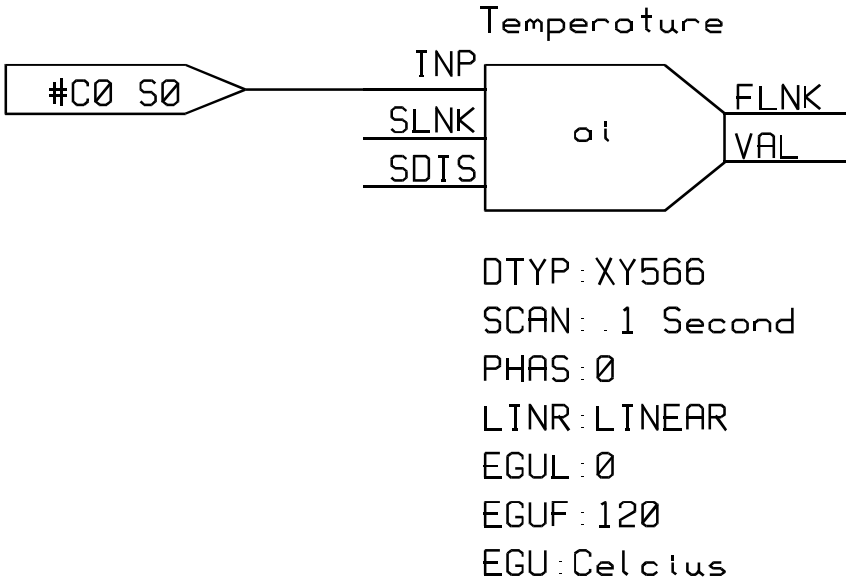
Input records often have these fields

`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:

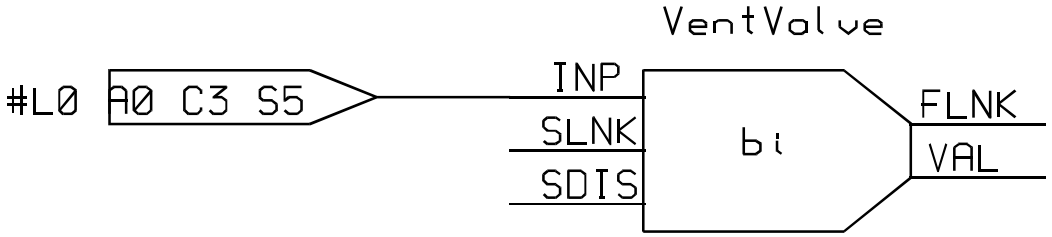
`LINR`	Unit conversion control
	No conversion, Linear, breakpoint tables…
`EGUL`	Low engineering value
`EGUF`	High engineering value
`EGU`	Engineering unit string

Periodic Input



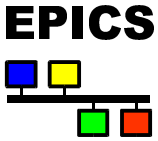
- Analogue Input “Temperature”
- Reads from the Xycom XY566 ADC Card 0 Signal 0
- Gets a new value every 0.1 seconds
- Data is converted from ADC range to 0..120 Celsius

Interrupt Input




```
DTYP:AB-Binary Input
SCAN:I/O Intr
PHAS:0
ZNAM:Closed
ONAM:Open
ZSV:NO_ALARM
OSV:MAJOR_ALARM
```

- Binary Input “VentValve”
- Reads from Allen-Bradley TTL I/O Link 0, Adaptor 0, Card 3, Signal 5
- Processed whenever value changes
- 0 = “Closed”, 1 = “Open”
- Major alarm when valve open



Output records often have these fields

`OUT`	Output link
`DTYP`	Device type
`VAL`	Engineering value
`RVAL`	Raw output value
`DOL`	Input link to fetch output value
`OMSL`	Output mode select

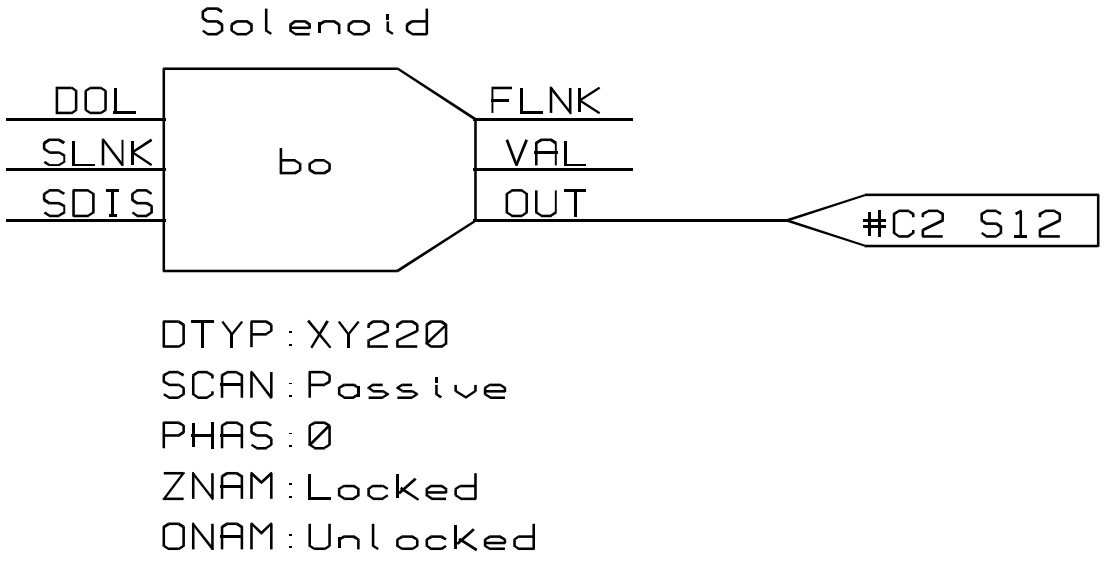
- Supervisory, Closed Loop

`LOPR`	Low operator range
`HOPR`	High operator range

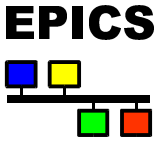
- Analogue outputs also have these fields:

`OROC`	Output rate of change
`OIF`	Incremental or Full output
`OVAL`	Output value
`DRVH`	Drive high limit
`DRVL`	Drive low limit
`IVOA`	Invalid output action
`IVOV`	Invalid output value
`RBV`	Read-back value

Passive Output



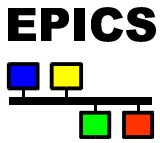
- Binary Output "Solenoid"
- Controls Xycom XY220 Digital output Card 2 Signal 12
- Record is only processed by
  - Channel Access 'put' to a `PP` field (e.g. `.VAL`)
  - Another record writes to a `PP` field (e.g. `.VAL`)
  - Forward Link from another record
  - Another record reads this with `PP`



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



Input and Output links may be...

- Constant numeric value, eg:

  0

  3.1415926536

  1.6e-19

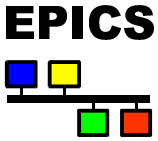
- Hardware link

  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



Hardware links

`VME_IO` `#C`*n* `S`*n* `@`*parm*

Card, Signal

`INST_IO` `@`*parm*

`CAMAC_IO` `#B`*n* `C`*n* `N`*n* `A`*n* `F`*n* `@`*parm*

Branch, Crate, Node, Address, Function

`AB_IO` `#L`*n* `A`*n* `C`*n* `S`*n* `@`*parm*

or `#L`*n* `P`*n* `C`*n* `S`*n* `F`*n* `@`*parm*

Link, Adaptor, Card, Signal, Flag

`GPIB_IO` `#L`*n* `A`*n* `@`*parm*

Link, Address

`BITBUS_IO` `#L`*n* `N`*n* `P`*n* `S`*n* `@`*parm*

Link, Node, Port, Signal

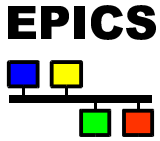
`BBGPIB_IO` `#L`*n* `B`*n* `G`*n* `@`*parm*

Link, Bitbus Address, GPIB Address

`VXI_IO` `#V`*n* `C`*n* `S`*n* `@`*parm*

or `#V`*n* `S`*n* `@`*parm*

Frame, Slot, Signal



Database links

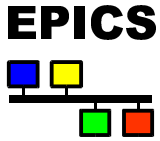
These comprise:

- 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
```

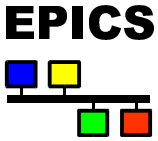
- NB: Get with `PP` from record with asynchronous device support will not return the new value



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 behavior 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

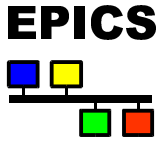
`CA`	Forces a "local" link to use CA
`CP`	For input link, process this record on CA monitor event
`CPP`	Like `CP` but only process if Scan is Process Passive



Link flag summary

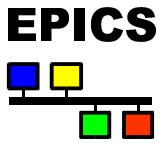
	Input Links	Output Links
DB Links	.PP or **.NPP** .MS or **.NMS**	.PP or **.NPP** .MS or **.NMS**
CA Links	Always **.NPP** .MS or **.NMS** .CA to force. .CP to process this record on change. .CPP only process if SCAN=Passive	.PP behavior of destination field. Always **.NMS** .CA to force.

Pages 16 thru 23 of the IOC Application Developer's Guide cover this topic.



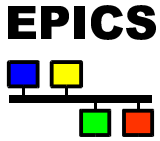
Device Support

- 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)



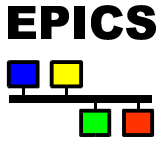
Synchronous vs Asynchronous I/O

- EPICS rules do not allow device support to busy-wait (poll for results of slow I/O)
- Register-based VME cards usually give an immediate response: synchronous
- When called, synchronous device support performs all I/O before returning
- Serial & I/O-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

- Input and Output records are designed to perform hardware I/O via device support
- They can also access other records via DB or CA links, using soft device support
- 2 kinds of support are provided:
  - Soft Channel
    - Get/Put `VAL` through link, no conversion
  - 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



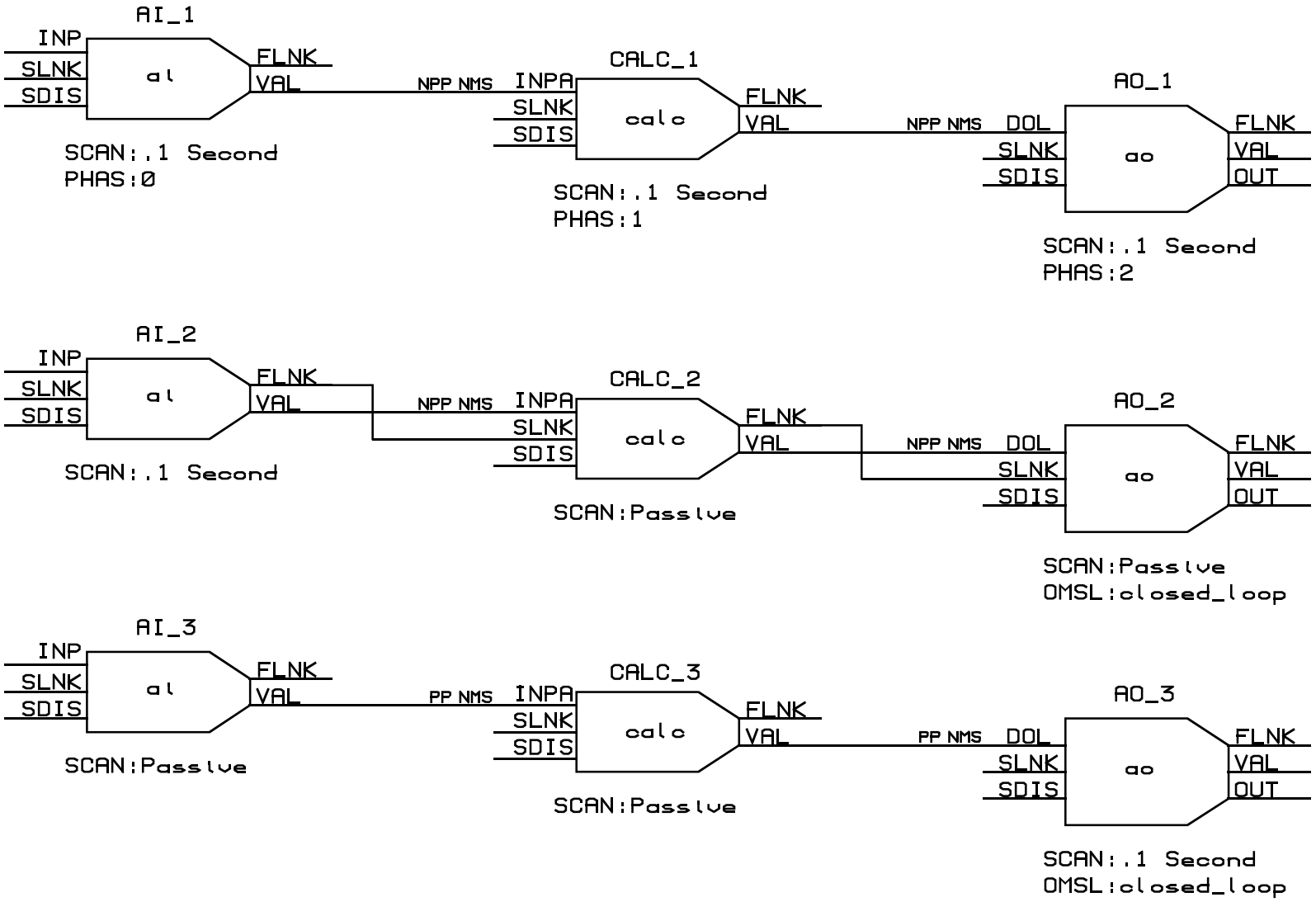
Forward links

- Usually a database link refering to a record in same IOC
- Channel Access links possible, must name the `PROC` field of the remote record
- No flags (`PP`, `NMS` etc)
- Destination record must have

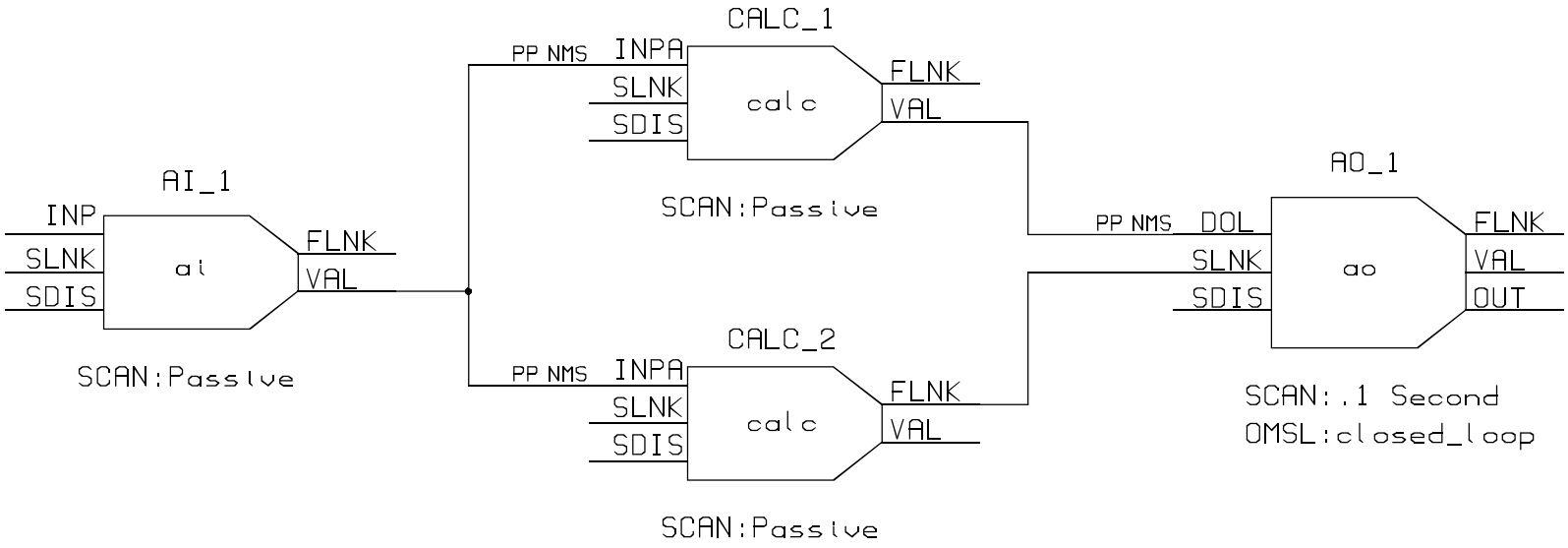
  ```
  SCAN = Passive
  ```

  for it to be processed
- Does not pass a value, just causes subsequent processing

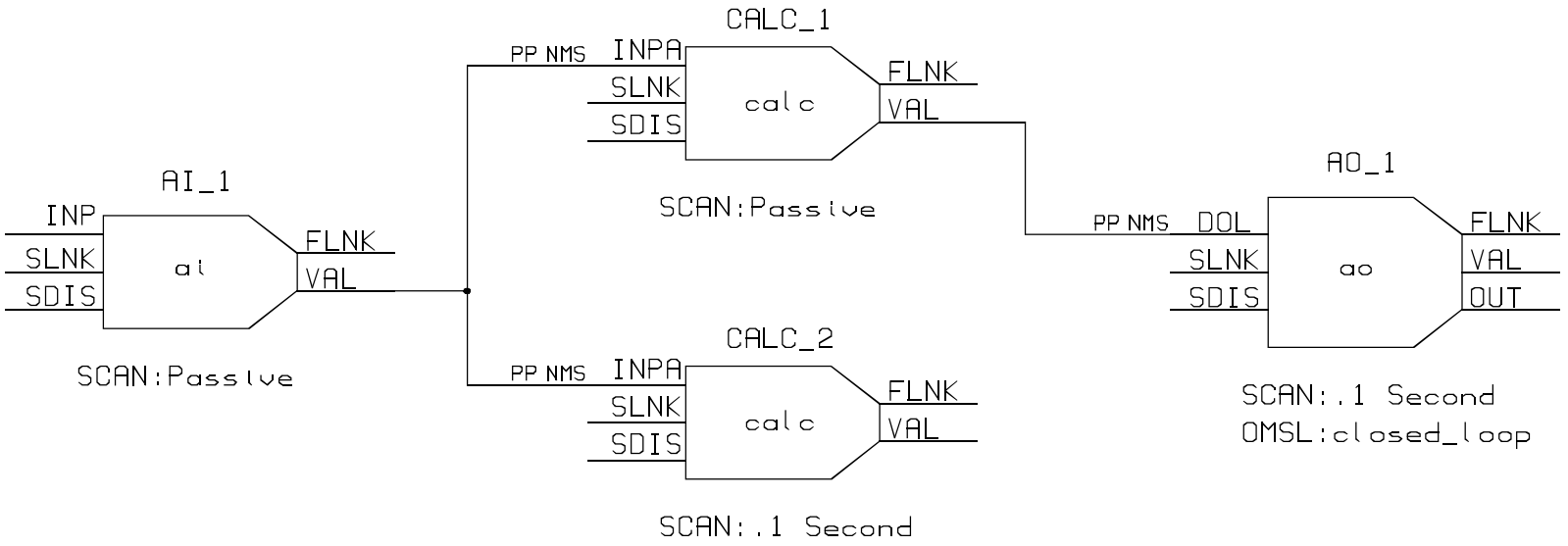
Processing chains

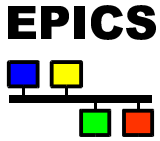


Which record is never processed?



Which record is processed twice?

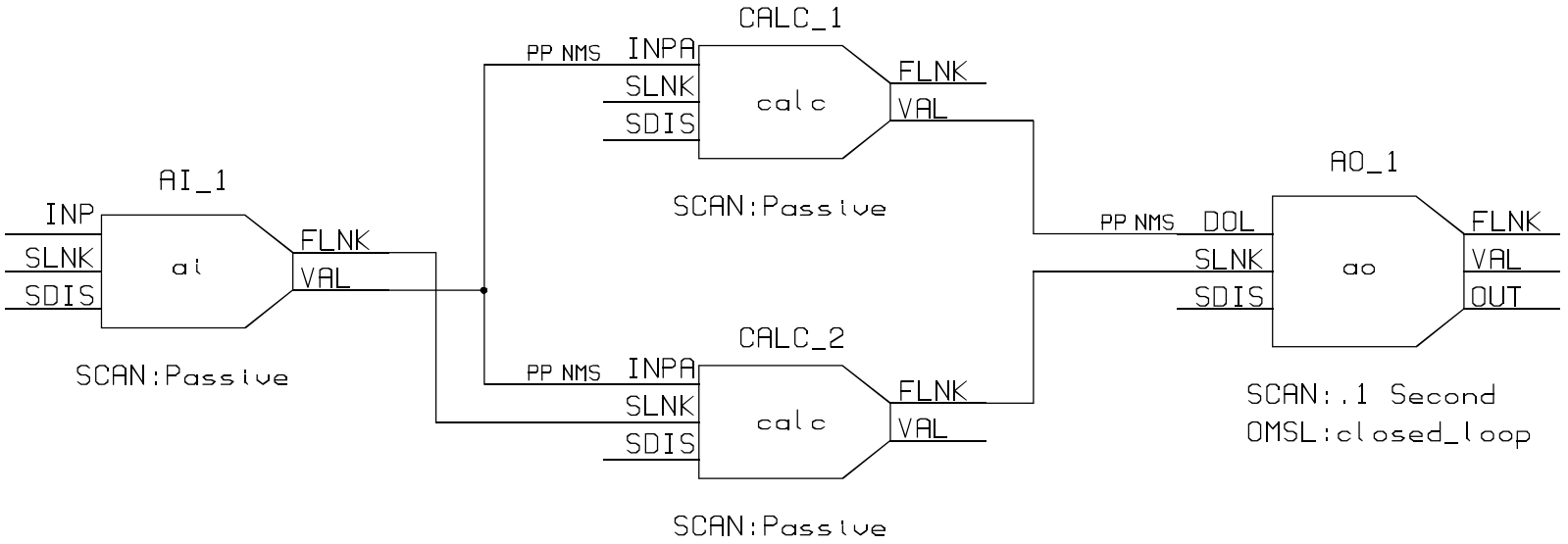


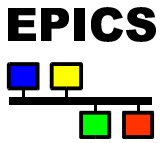


The PACT field

- 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

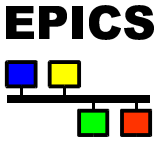
What happens here?





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 is alarmed by giving the desired severity in the `DISS` field
- The `FLNK` of a disabled record is not triggered

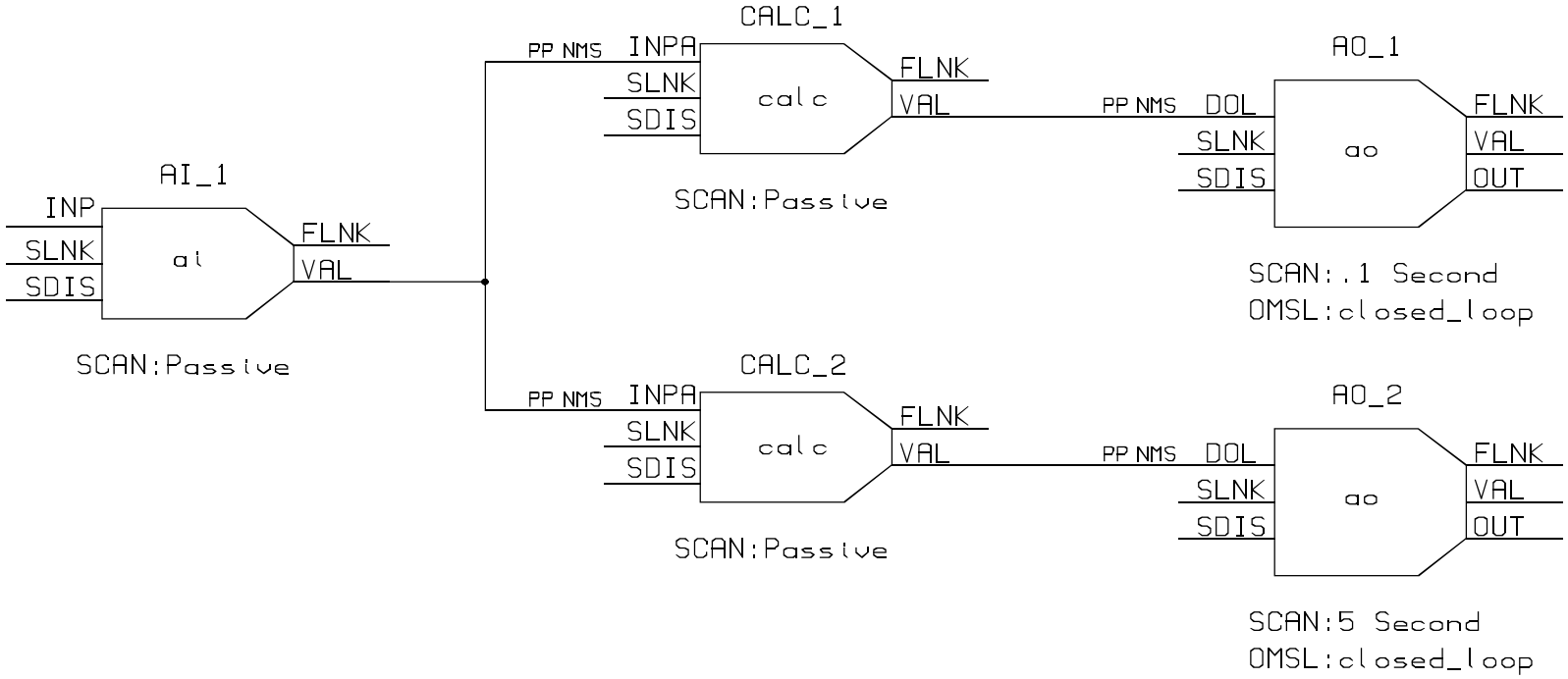


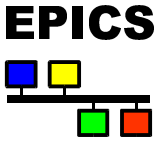
How are records given CPU time?

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 OS)
- Channel Access tasks use lower priority than record processing
  - If a CPU spends all the time doing I/O and processing, you will be unable to control or monitor the IOC via the network

What could go wrong here?



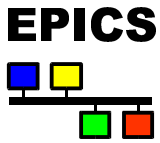


Lock-sets

- Prevent a record from being processed simultaneously from two scan tasks
- A lock-set is a group of records interconnected by:
  - Output Database links
  - Forward links
  - Input links which are `PP` or `MS`
  - Arrays
- Lock-sets are determined automatically by the IOC at start-up

You can split a lock set with

- Channel Access links, using `CA` flag
- Database links which are `NPP NMS`



Alarms

- Every record has the fields

  `SEVR` Alarm Severity

  NONE, MINOR, MAJOR, INVALID

  `STAT` Alarm Status (reason)

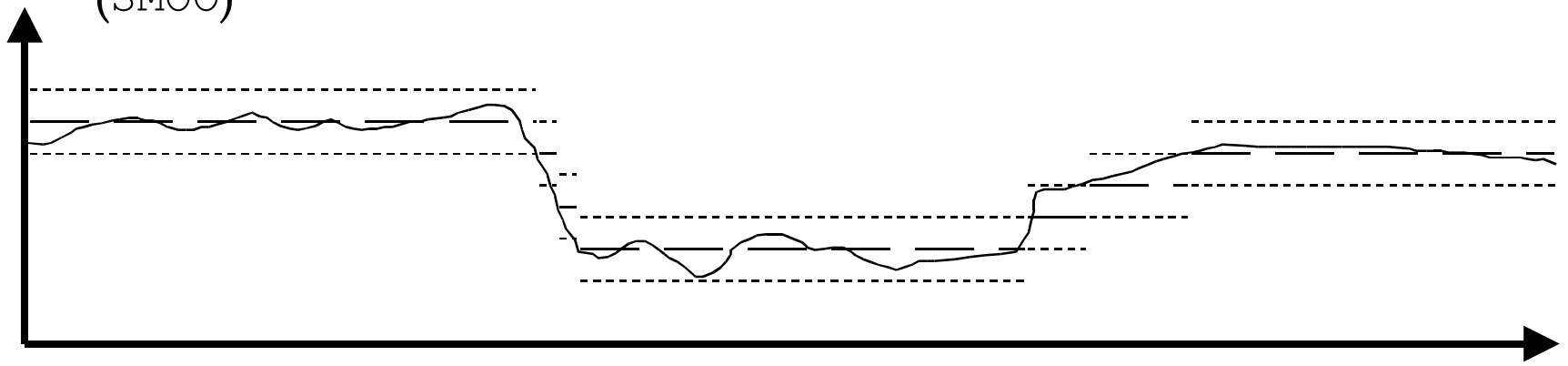
  READ, WRITE, UDF, HIGH, LOW, STATE, COS, CALC, DISABLE, etc.

- 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)

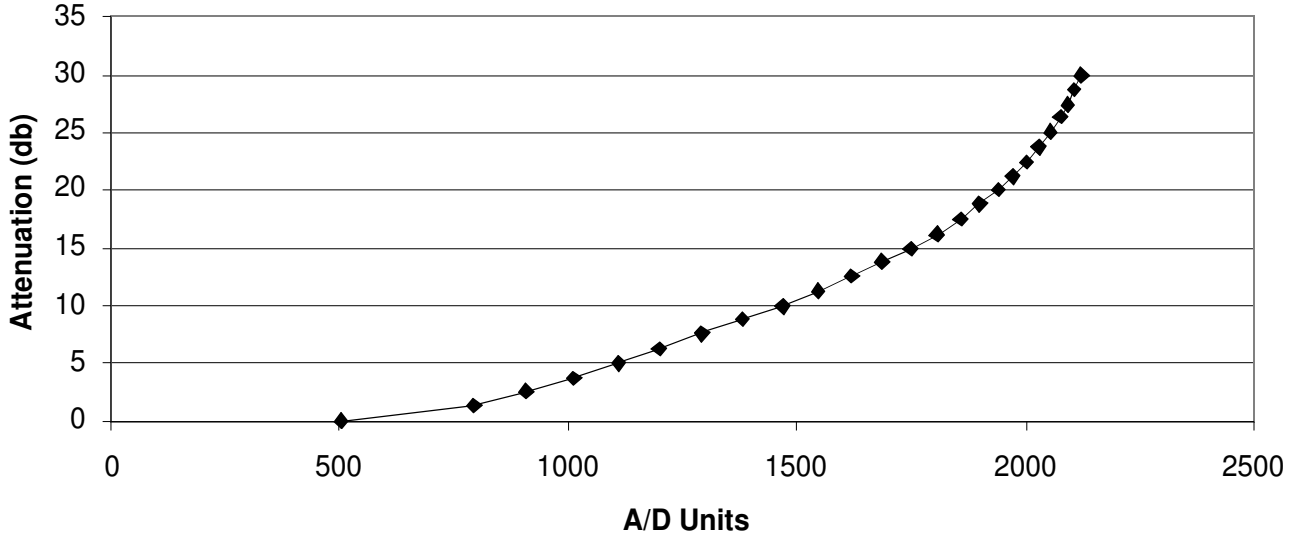
Change notification: Monitor deadbands

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)

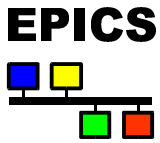


Breakpoint Tables



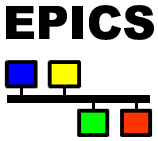
- Analogue Input and Output records can do non-linear conversions from/to the raw hardware value
- Breakpoint tables interpolate values from a given table
- To use, set the record's LINR field to the name of the breakpoint table you want to use
- Example breakpoint table (in your .dbd file)

```
breaktable(attenuator1_1) {
     504,    0
     795,    1.25
     909,    2.5
    1012,    3.75
    ...
}
```



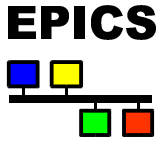
Simulation

- 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 File

- Security rules are loaded from an Access Security 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 details and syntax, see Chapter 5 of the IOC Application Developers Guide