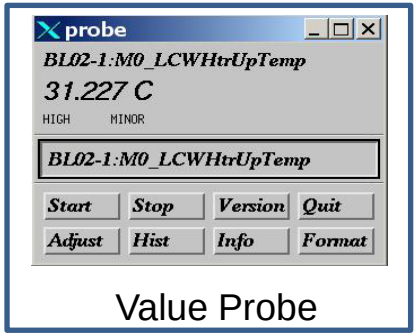
EPICS Class – Process Database

- Most slides here are taken from:
  - "EPICS Database Principles" by Andrew Johnson
- Some slides modified by me
- After lecture, study:
  - "EPICS Database Practice" by Andrew Johnson

EPICS Class – Process Database Outline

- What is a process database and why use it?
- Records
- Fields in Records (PVs)
- Record Processing
- Input and Output Records
- Record Linking
- Device Support and Soft Records
- Synchronous and Asynchronous I/O
- Common Fields/Functions in Most Records

Control System w/o EPICS Database*

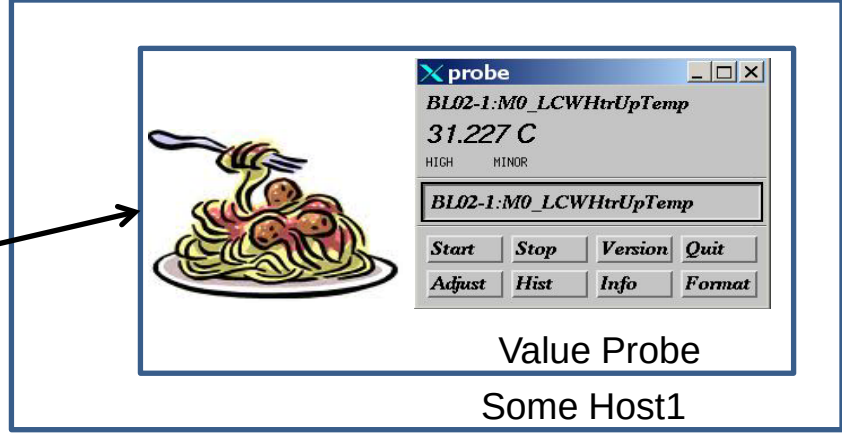


* An evolutionary tale.

Control System w/o EPICS Database

Network

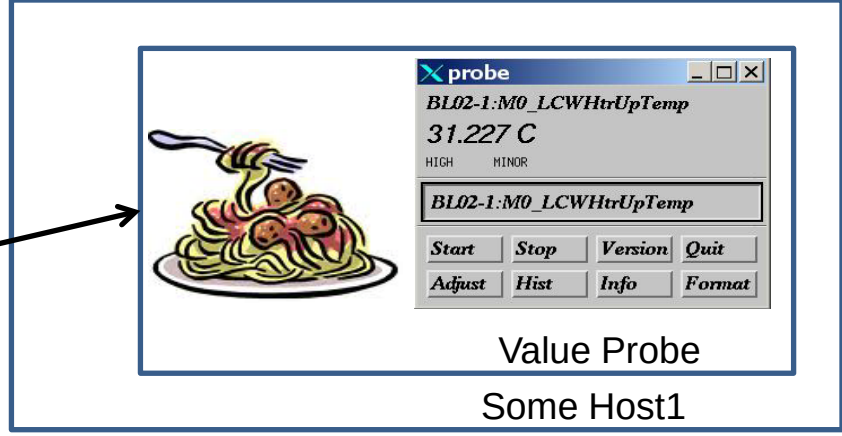
TCP

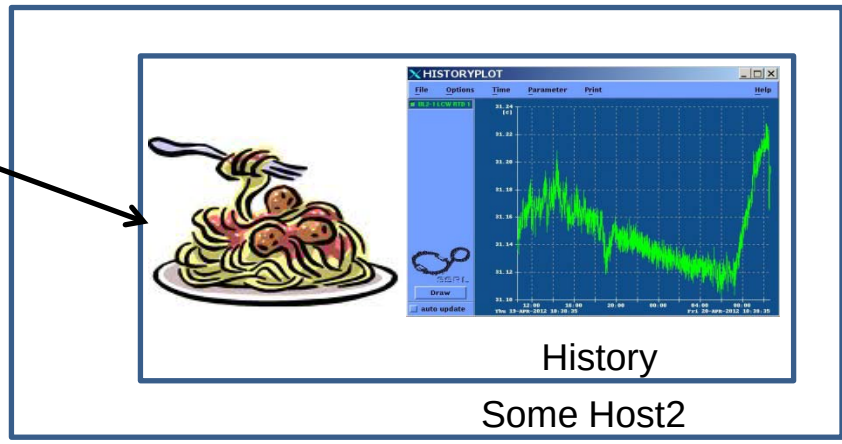


Control System w/o EPICS Database

Network

TCP





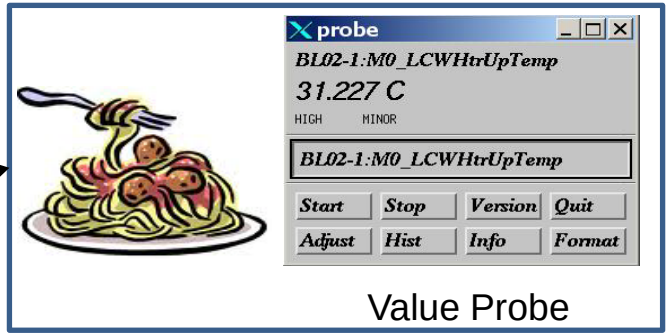
Control System w/o EPICS Database

Network

TCP

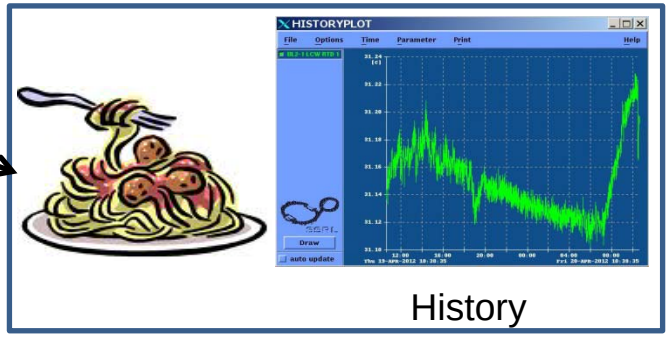
Only 2 Clients Allowed!

??



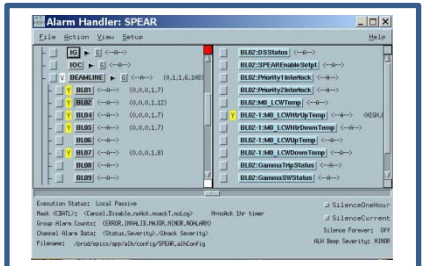
Value Probe

Some Host1



History

Some Host2



Alarm Handler

Some Host3

Control System w/o EPICS DB

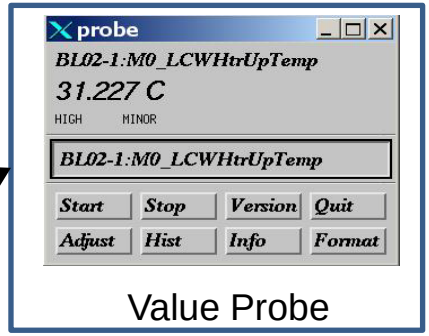
TCP

Some Driver1

Some Server1

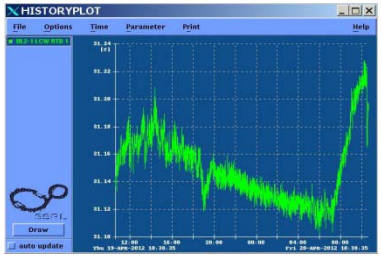
Network

TCP



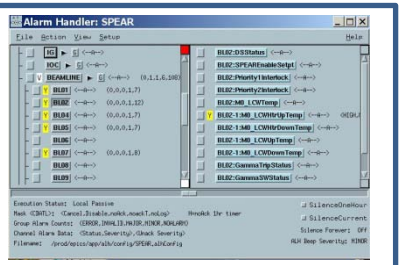
Value Probe

Some Host1



History

Some Host2



Alarm Handler

Some Host3

Control System w/o EPICS DB

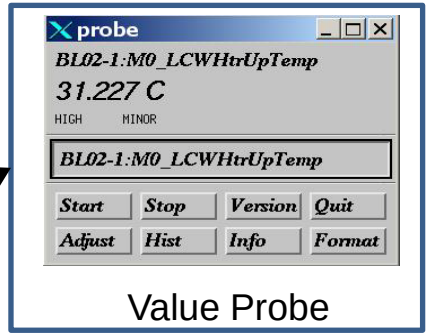
TCP

Some Driver1

Some Server1

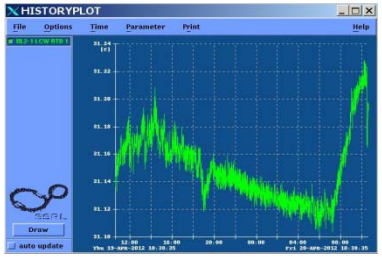
Network

TCP



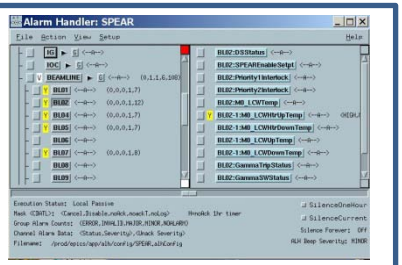
Value Probe

Some Host1



History

Some Host2



Alarm Handler

Some Host3

Control System w/o EPICS DB

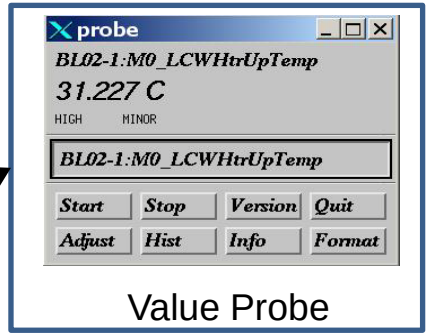
TCP

Some Driver1
with CA Server*

Some Server1

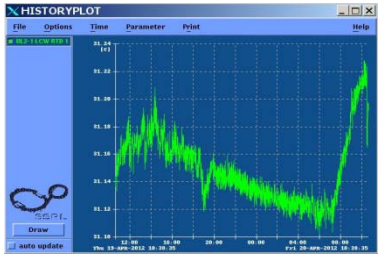
Network

Channel
Access



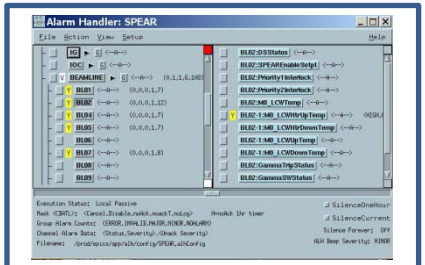
Value Probe

Some Host1



History

Some Host2



Alarm Handler

Some Host3

* Very few people actually do this – what they do instead will be discussed later .

Control System w/o EPICS DB

TCP

Some Driver1
with CA Server

Some Server1

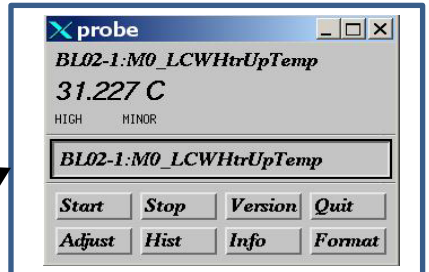
Network

Channel
Access

UDP

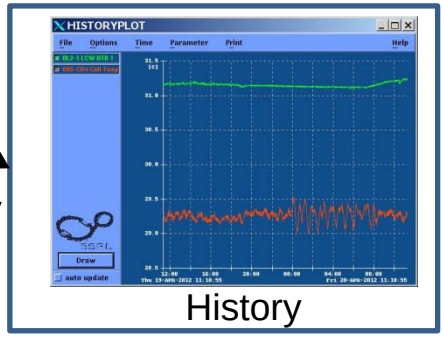
Some Driver2
with CA Server

Some Server2



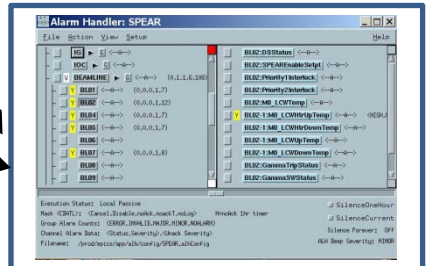
Value Probe

Some Host1



History

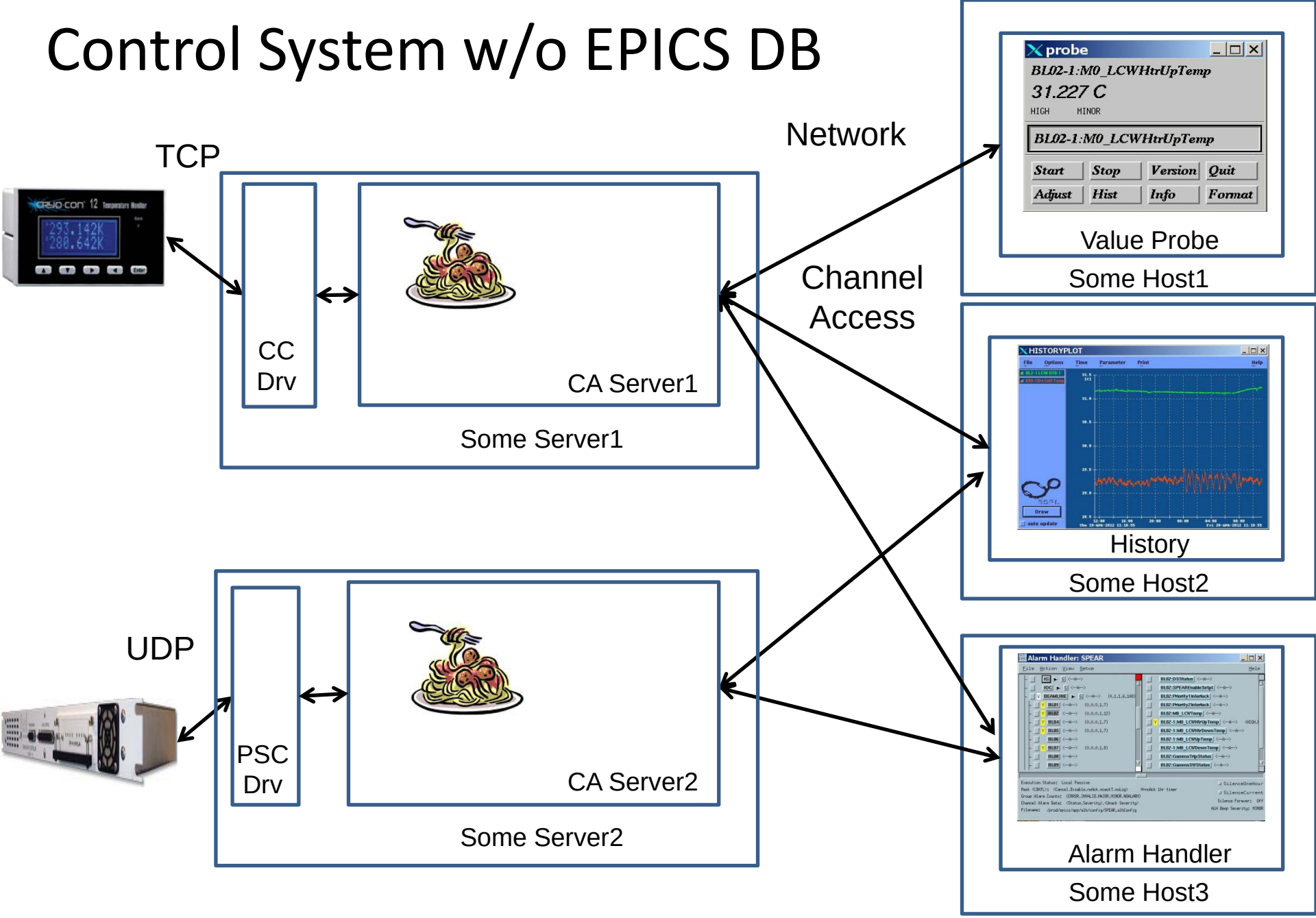
Some Host2



Alarm Handler

Some Host3

Control System w/o EPICS DB



Control System w/o EPICS DB

TCP

CC Drv

CC Analog Input Processing

CAS1

Some Server1

Network

Channel Access

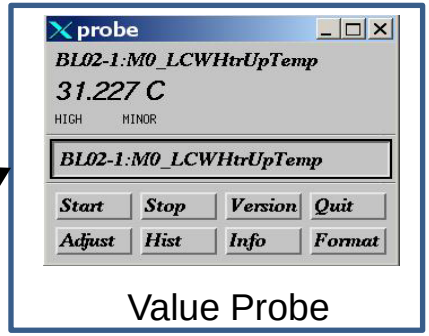
UDP

PSC Drv

PSC Analog Input Processing

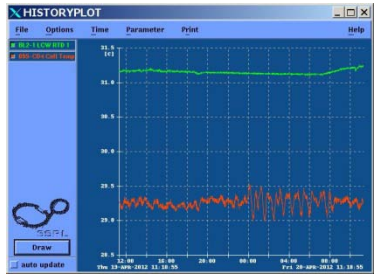
CAS2

Some Server2



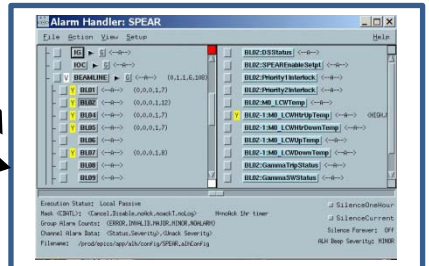
Value Probe

Some Host1



History

Some Host2



Alarm Handler

Some Host3

Control Sys with EPICS DB

TCP

CC Drv

CC Dev

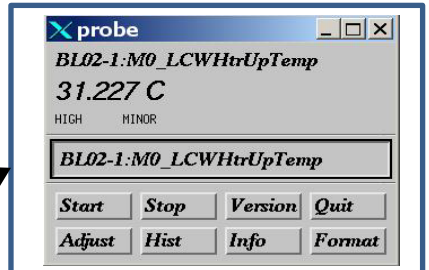
AI

CAS1

IOC1 on Server1

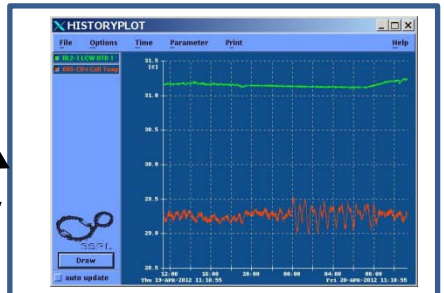
Network

Channel Access



Value Probe

Some Host1



History

Some Host2

Config files on NFS

UDP

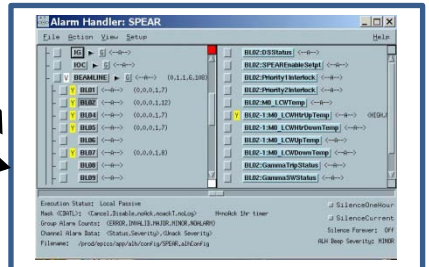
PSC Drv

PSC Dev

AI

CAS2

IOC2 on Server2



Alarm Handler

Some Host3

Database = Records + Fields + Links

- A control system using EPICS will contain one or more IOCs
- Each IOC loads one or more Database files telling it what to do
- A Database is a collection of Records of various types:
  - ai, ao, bi, bo, mbbi, mbbo, stringin, stringout, calc, etc
- A Record is an object with:
  - A unique name
  - A behavior 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 type implemented?

- A ‘C’ structure with a data member for each record field
  - All records start with a standard set of fields (dbCommon) that the system needs, including pointers to record type information (base/include/dbCommon.h)
  - Additional fields are added depending on record type
  - The configuration of the ‘C’ structure is provided by a database definition ASCII file (<name>Record.dbd) which is unique to the record type <name>
  - Standard records in base/src/rec/<name>Record.dbd
- Code (ie, ‘C’) which implements the record behavior
  - Standard records in base/src/rec/<name>Record.c
- New record types can be added to an application as needed – recommend only if absolutely necessary

How are individual Records defined?

- A database configuration ASCII file (.db or .template) providing record field values:
  - Record name
  - The record's type
  - Values for each design field
  - Can use macros for fields so that same configuration file is used for many records
- IOC application build (make) can create and/or install .db files
- Record instantiation (ie, memory allocation on IOC) done before iocInit by dbLoadRecords in the IOC startup file.

Record Reference Manual WIKI Example

EPICSWIKI

MAIN PAGE | ABOUT | HELP | FAQ | SPECIAL PAGES | LOG IN

EPICS Community Documentation

Printable version | Disclaimers | Privacy policy

Find

Go | Search

RRM 3-14 Analog Input

From EPICSWIKI

EPICS Record Reference Manual

▪ ▪ ▪

Operator Display Parameters

These parameters are used to present meaningful data to the operator. They display the value and other parameters of the analog input either textually or graphically. EGU is a string of up to 16 characters describing the units that the analog input measures. It is retrieved by the get_units record support routine.

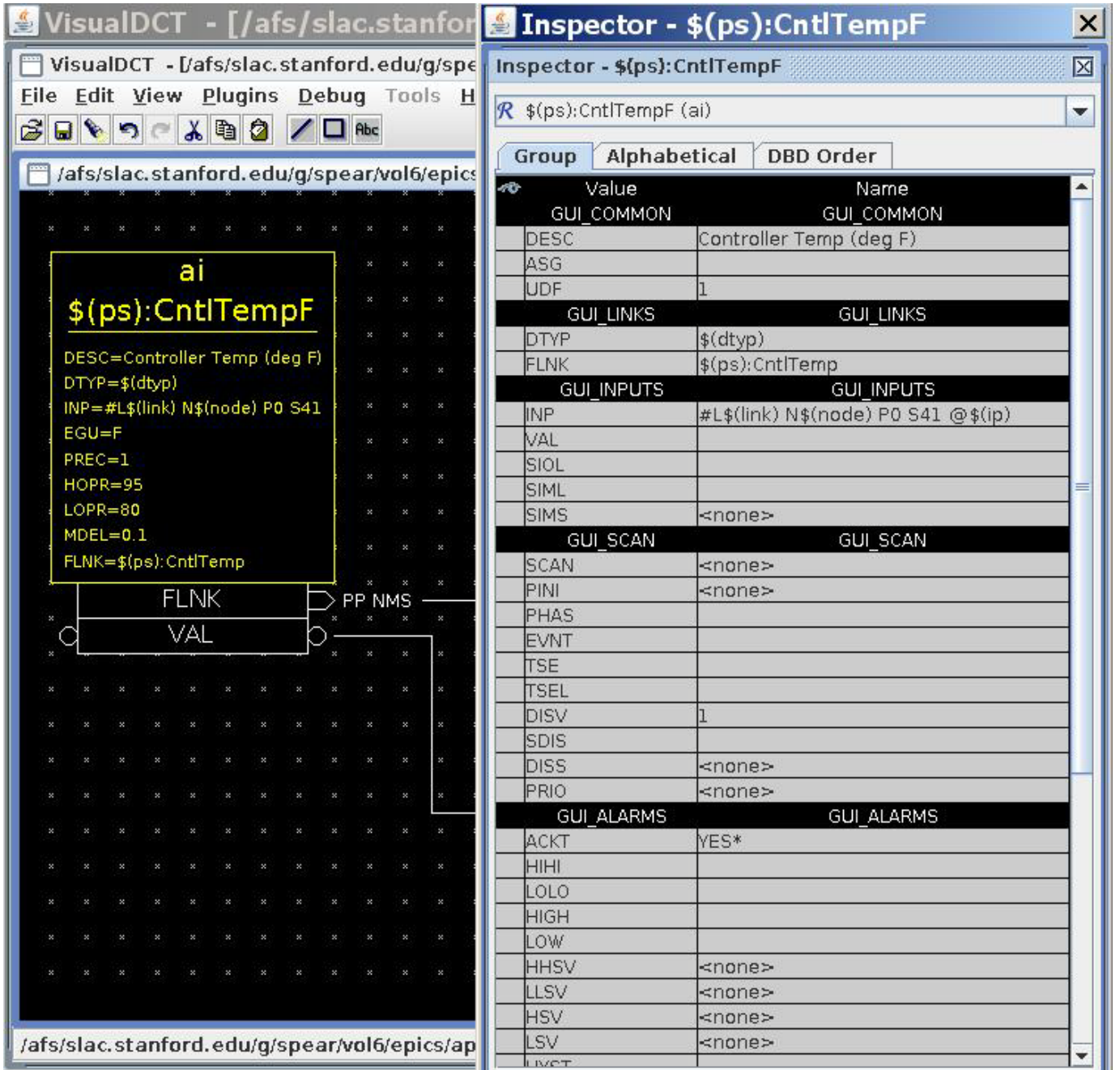
The HOPR and LOPR fields set the upper and lower display limits for the VAL, HIHI, HIGH, LOW, and LOLO fields. Both the get_graphic_double and get_control_double record support routines retrieve these fields.

The PREC field determines the floating point precision with which to display VAL. It is used whenever the get_precision record support routine is called.

See Fields Common to All Record Types for more on the record name (NAME) and description (DESC) fields.

Field	Summary	Type	DCT	Initial	Access	Modify	Rec Proc Monitor	PP
EGU	Engineering Units	STRING [16]	Yes	null	Yes	Yes	No	No
HOPR	High Operating Range	DOUBLE	Yes	0	Yes	Yes	No	No
LOPR	Low Operating Range	DOUBLE	Yes	0	Yes	Yes	No	No
PREC	Display Precision	SHORT	Yes	0	Yes	Yes	No	No
NAME	Record Name	STRING [29]	Yes	0	Yes	No	No	
DESC	Description	STRING [29]	Yes	Null	Yes	Yes	No	No

Graphical View of a Record (VDCT)



ASCII File View of a Record

```
record(ai, "MS1-BD:CntlTempF")
{
        field(DESC, "Controller Temp (deg F)")
        field(DTYP, "EtherPSC")
        field(INP,  "#L0 N0 P0 S41 @172.22.247.141")
        field(EGU, "F")
        field(PREC, "1")
        field(HOPR, "95")
        field(LOPR, "80")
        field(MDEL, "0.1")
        field(FLNK, "MS1-BD:CntlTemp")
}
```

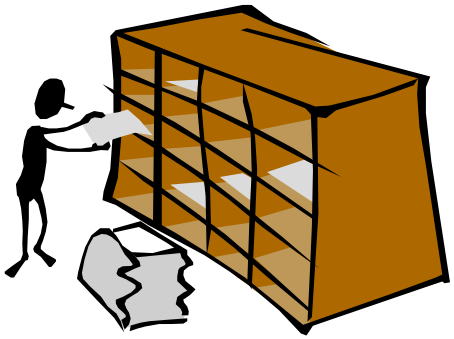
IOC View of a Record

```
soft-iocpsspr>dbpr("MS1-BD:CntlTempF",5)
ACKS: NO_ALARM      ACKT: YES           ADEL: 0
ALST: 95.4601745605469                  AOFF: 0             ASG:
ASLO: 1             ASP: (nil)          BKPT: 00
DESC: Controller Temp (deg F)           DISA: 0             DISP: 0
DISS: NO_ALARM      DISV: 1             DPVT: 0x1123b90     DSET: 0x768de0
DTYP: EtherPSC      EGU: F              EGUF: 0             EGUL: 0
EOFF: 0             ESLO: 1             EVNT: 0
FLNK:DB_LINK MS1-BD:CntlTemp            HHSV: NO_ALARM      HIGH: 0
HIHI: 0             HOPR: 95            HSV: NO_ALARM       HYST: 0
INIT: 0             INP:BITBUS_IO #L0 N0 P0 S41 @172.22.247.141
LALM: 95.4601745605469                  LBRK: 0             LCNT: 0
LINR: NO CONVERSION LLSV: NO_ALARM      LOLO: 0             LOPR: 80
LOW: 0              LSET: 0x1132ed0     LSV: NO_ALARM       MDEL: 0.1
MLIS: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
MLOK: 40 bd 0b 01 00 00 00 00           MLST: 95.4074172973633
NAME: MS1-BD:CntlTempF                  NSEV: NO_ALARM      NSTA: NO_ALARM
ORAW: 0             PACT: 0             PBRK: (nil)         PHAS: 0
PINI: NO            PPN: (nil)          PPNR: (nil)         PREC: 1
PRIO: LOW           PROC: 0             PUTF: 0             RDES: 0xd5e770
ROFF: 0             RPRO: 0             RSET: 0x76c3e0      RVAL: 0
SCAN: Passive       SDIS:CONSTANT       SEVR: NO_ALARM      SIML:CONSTANT
SIMM: NO            SIMS: NO_ALARM      SIOL:CONSTANT       SMOO: 0
SPVT: (nil)         STAT: NO_ALARM      SVAL: 0
TIME: 2012-04-20 15:15:16.521440756     TPRO: 0             TSE: 0
TSEL:CONSTANT       UDF: 0              VAL: 95.4601745605469
```

Fields – Process Variable (PV)

- PV = <record_name>.<field>
- Example: MS1-BD:CntrlTempF.DESC
- If .<field> is not provided, .VAL is assumed.

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 acknowledgments
  - 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
- Fixed length strings
  - normally 40 characters
- Enumerated/menu choices
  - select one of up to 16 strings
  - stored as a short integer
- Arrays of any of the above types
- 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 accessible remotely

All Records have these design fields:

NAME	***60 Character unique name (using more than 28 can cause problems)***
DESC	***28 Character description***
ASG	***Access security group***
SCAN	***Scan mechanism***
EVNT	***Event number***
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***

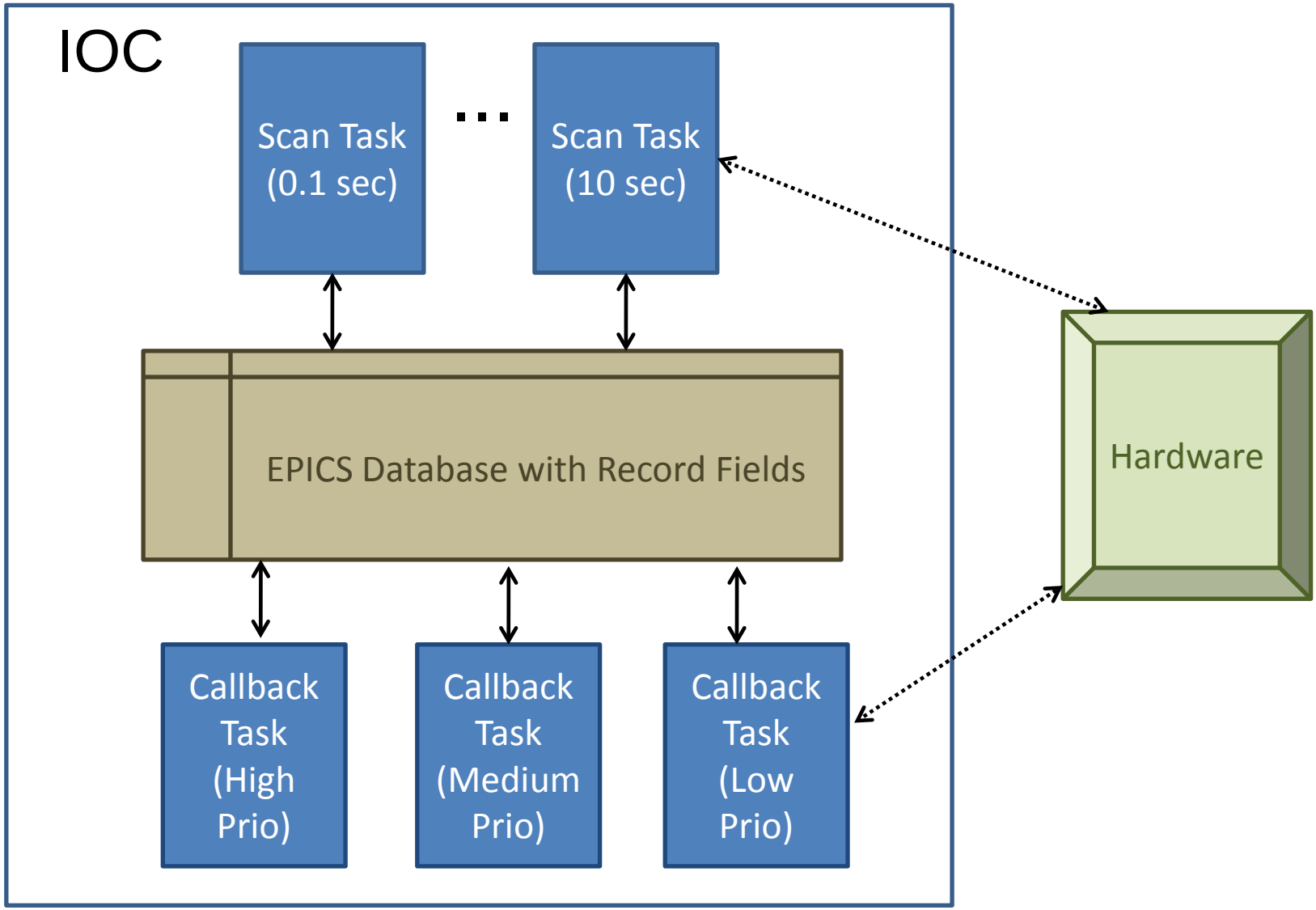
Plus more...

All Records have these Run-time fields:

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

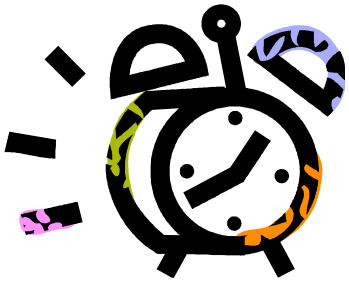
Plus more...

Record Processing



How are records given CPU time?

Several IOC tasks are used:



- callback (3 priorities) — I/O Interrupt and Event
- scanPeriod (periods are configurable) — 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)
- scanOnce – special purpose
- sequence and other run-time database tasks
- 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

Record Scanning

- **SCAN** field is a menu choice from
  - Periodic — 0.1 seconds .. 10 seconds
  - I/O Interrupt (if device supports this)
  - Soft and Hard 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 event and I/O Interrupts (selects which callback task will process the record)
- A record is also processed whenever any value is written to its **PROC** field

Listing Records for each SCAN Type

```
iocpsgendev>scanppl
Scan Period = 1 seconds
    IOCPSGENDEV:HEARTBEAT
    118-PSD4:BitbusCountCmd
    118-PSD4:BitbusCountRsp
    LTB-CORB2:BitbusCountCmd
    LTB-CORB2:BitbusCountRsp
    IOCPSGENDEV:TOD
    IOCPSGENDEV:UPTIME
iocpsgendev>scanpel
iocpsgendev>scanpiol
IO Event: Priority Low
    IOCPSGENDEV:CA_CLNT_CNT
    IOCPSGENDEV:CA_CONN_CNT
IO Event: Priority Low
    IOCPSGENDEV:FD_CNT
IO Event: Priority Low
    IOCPSGENDEV:IOC_CPU_LOAD
    IOCPSGENDEV:SUSP_TASK_CNT
    IOCPSGENDEV:SYS_CPU_LOAD
IO Event: Priority Low
    IOCPSGENDEV:MEM_FREE
    IOCPSGENDEV:MEM_MAX
    IOCPSGENDEV:MEM_USED
iocpsgendev>
```

Input and Output Records

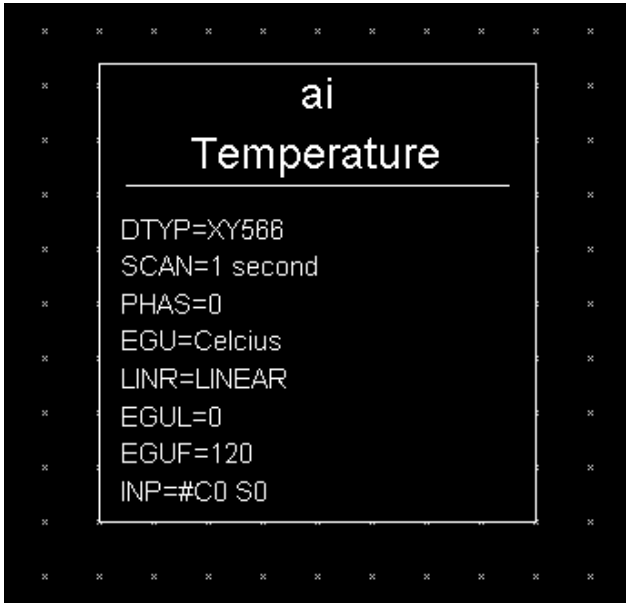
Input records often have these fields:

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

Analog I/O (ai, ao) records have these fields:

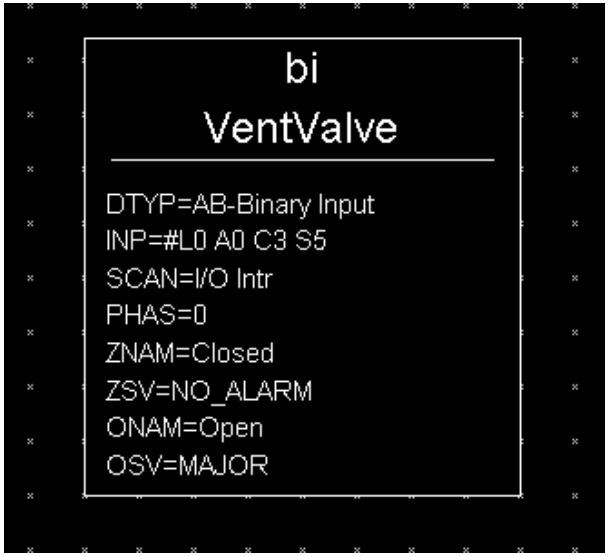
EGU	***Engineering unit string***
LINR	***Unit conversion control:*** No conversion, Linear, Slope, *breakpoint table name*
EGUL	***Low engineering value***
EGUF	***High engineering value***
ESLO	***Unit conversion slope***
EOFF	***Unit conversion offset***

Periodically Scanned Analog Input



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

Interrupt Scanned Binary Input



- 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

EPICS

Most output records have these fields

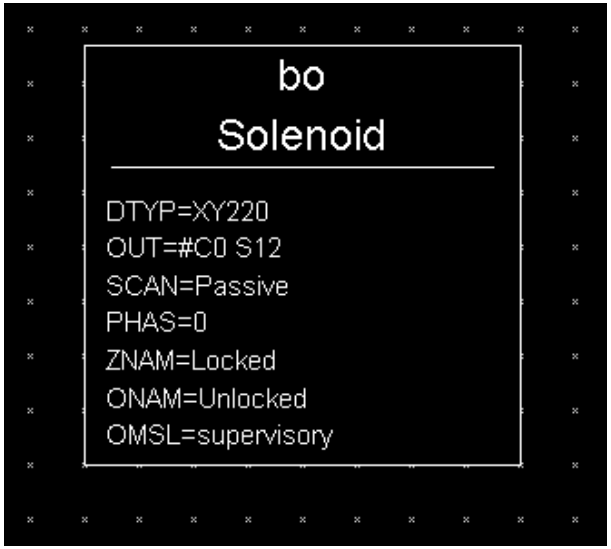
OUT	***Output link***
DTYP	***Device type***
VAL	***Engineering value***
RVAL	***Raw output value***
DOL	***Input link to fetch output value***
OMSL	***Output mode select:*** Supervisory, Closed Loop
LOPR	***Low operator range***
HOPR	***High operator range***

Analog outputs (ao) records 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***

Note: Restoration of field values (ie, analog output VAL, aka setpoint) on IOC restart is not provided by epics base. Software (or module, ie autosave module) external to epics base must be added to the IOC application and additional configuration done to add this very important functionality.

Passive Binary 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
  - 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 (ie, input record INP field, output record DOL field)
  - ❖ Fetches data
- Output link (ie, output record OUT field)
  - ❖ Writes data
- Forward link (ie, any record FLNK field)
  - ❖ Points to the record to be processed once this record finishes processing

Input and Output links may be...

- Constant numeric value, e.g.:

  0

  3.1415926536

  -1.6e-19

- “Hardware” link

  A hardware (or external) 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	***#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***	
		Link, Adapter, Card, Signal
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:
  - PV – process variable name
  - Process Passive flag
    - **NPP** (default), or **PP**
  - Maximize Severity flag
    - **NMS** No maximize severity (default)
    - **MS** Maximize severity
    - **MSS** Maximize Status and Severity
    - **MSI** Maximize Severity when Invalid
- Example

  ```
  M1:current.RBV NPP MS
  ```

- Beware: Database links with the **PP** flag set never wait for asynchronous record processing to finish, so an input link that triggers a read from slow hardware will return the previous data in that record

Channel Access links

- Similar to a database link
- Names a record that does not have to be in this IOC
- Use Channel Access protocol to communicate with the record
  - Just like any other CA client, even for local records
  - Input sets up a CA monitor on the channel
- 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
  - These are how all CA clients behave
- ***MS*** Link flags apply to Input links
  - Input links honor a given **NMS** (default) or **MS/MSS/MSI** 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 me if **SCAN** is Process Passive

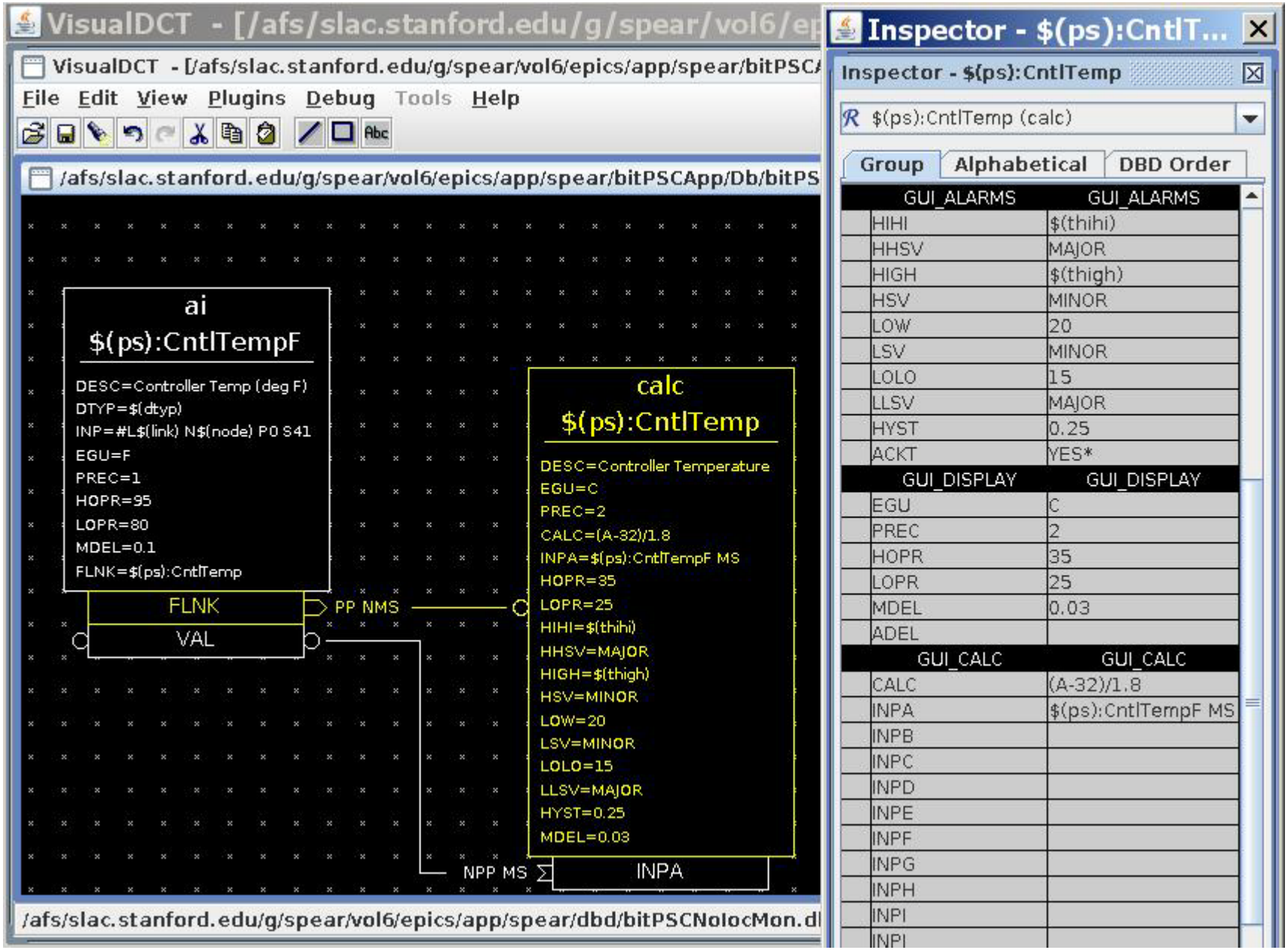
Forward links

- Usually a Database link, referring to a record in same IOC
- No flags (PP, MS etc.), although VDCT includes them erroneously
- Destination record is only processed if its **SCAN** field is `Passive`
- Does not pass a value, just causes subsequent processing
- Forward linking to another IOC via Channel Access is possible, but the link must explicitly name the **PROC** field of the remote record
  - In this case, the remote record does not need to have **SCAN** set to Passive

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

Good idea to just read the whole manual…

Simple FLNK and INP Link Example (VDCT)

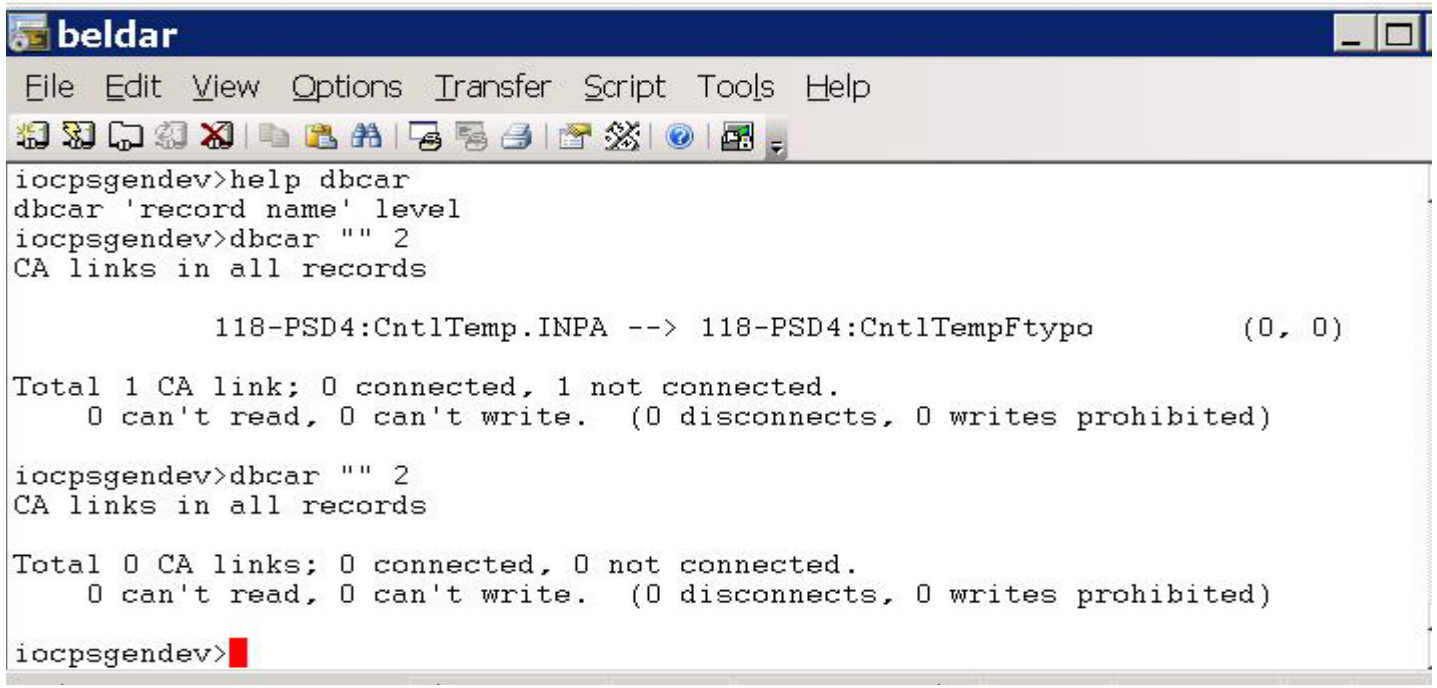


Trace Processing

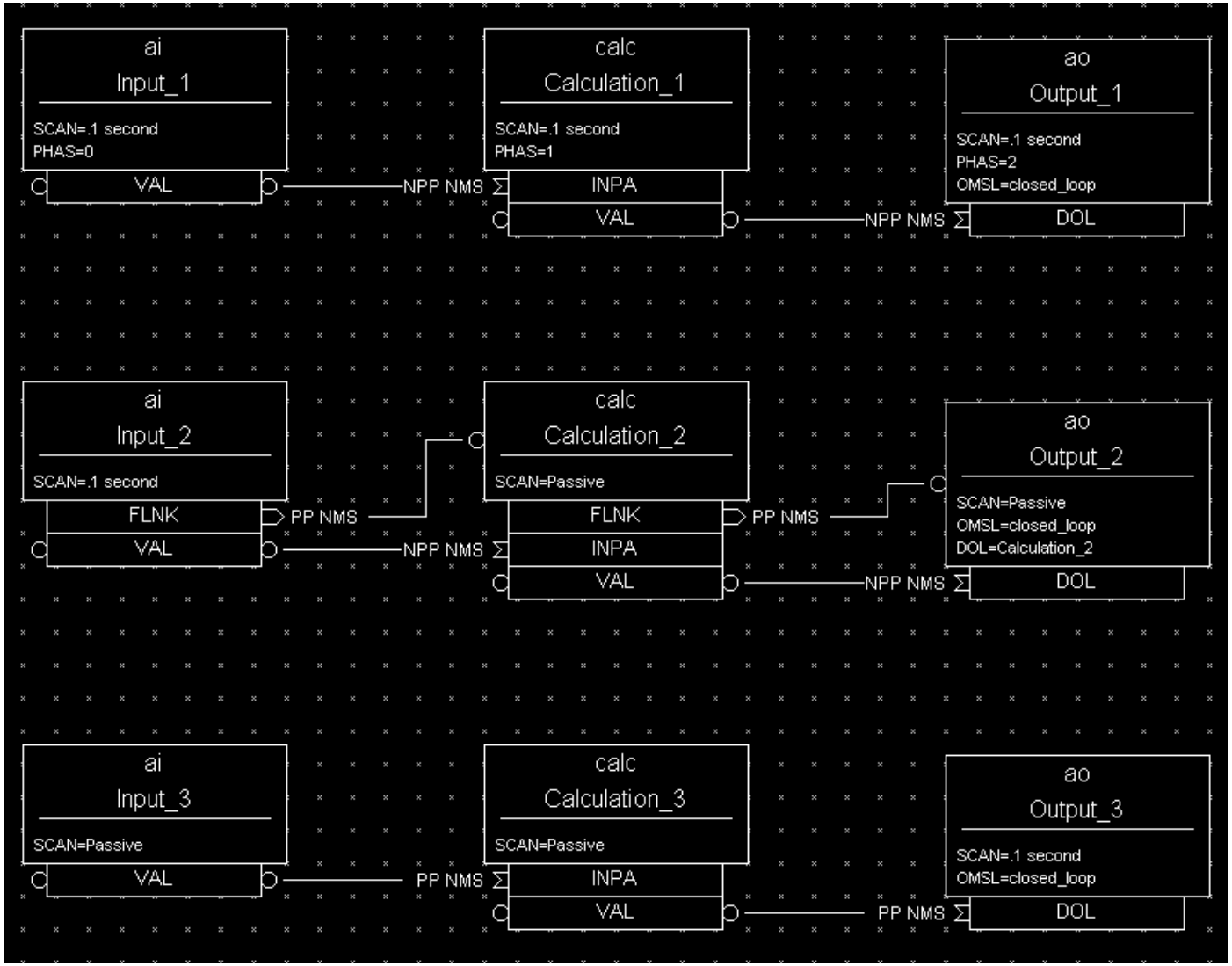
```
iocpsgendev>dbpf("118-PSD4:CntlTempF.TPRO","0")
DBR_UCHAR:          0         0x0
iocpsgendev>dbpf("118-PSD4:CntlTempF.TPRO","1")
DBR_UCHAR:          1         0x1
iocpsgendev>scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
scan1: Process 118-PSD4:CntlTempF
scan1: Process 118-PSD4:CntlTemp
```

Finding Typos in Links

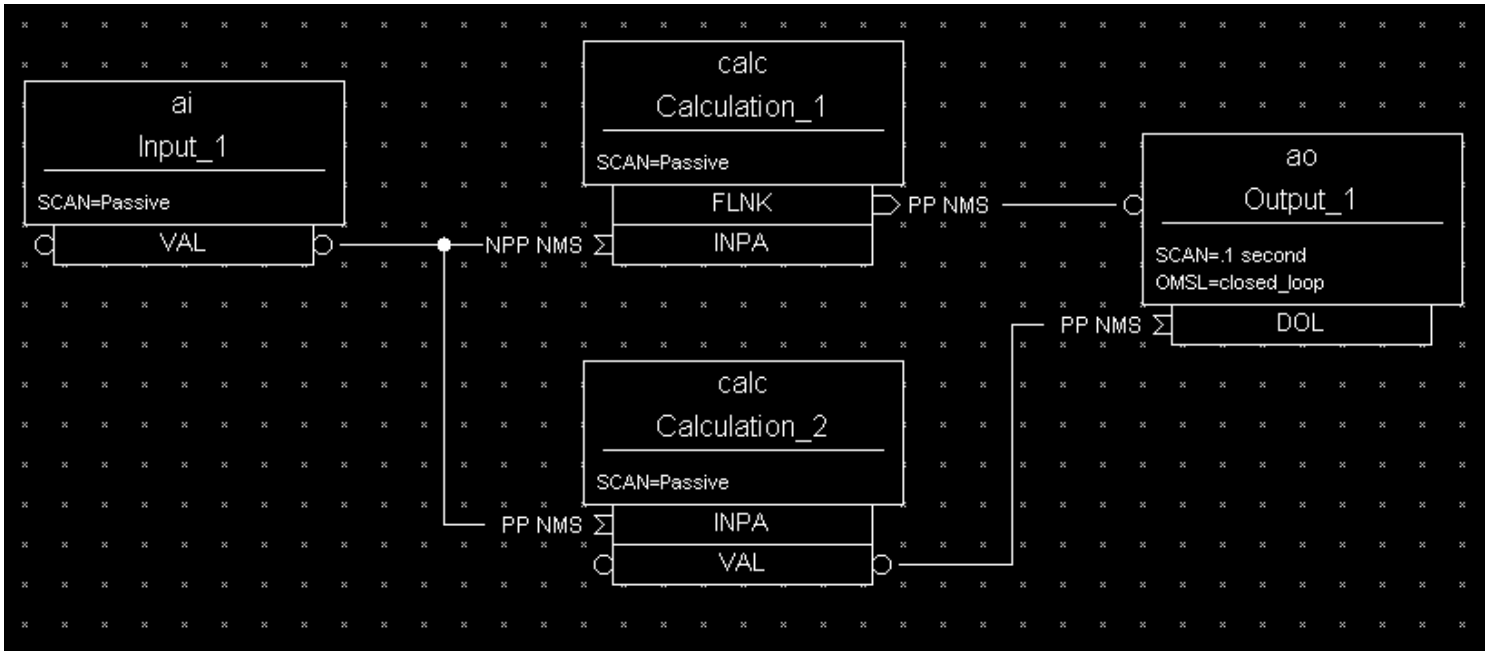
```
beldar:~$caput 118-PSD4:CntlTemp.INPA "118-PSD4:CntlTempFtypo NPP MS"
Old : 118-PSD4:CntlTemp.INPA          118-PSD4:CntlTempF NPP MS
New : 118-PSD4:CntlTemp.INPA          118-PSD4:CntlTempFtypo NPP MS
beldar:~$camonitor 118-PSD4:CntlTempF 118-PSD4:CntlTemp
118-PSD4:CntlTempF              2012-04-22 13:09:57.242178 85.6773
118-PSD4:CntlTemp               2012-04-22 13:09:57.242179 29.8154 LINK INVALID
118-PSD4:CntlTempF              2012-04-22 13:09:58.142895 85.6869
118-PSD4:CntlTempF              2012-04-22 13:09:59.043299 85.6885
^C
beldar:~$caput 118-PSD4:CntlTemp.INPA "118-PSD4:CntlTempF NPP MS"
Old : 118-PSD4:CntlTemp.INPA          118-PSD4:CntlTempFtypo NPP MS
New : 118-PSD4:CntlTemp.INPA          118-PSD4:CntlTempF NPP MS
beldar:~$camonitor 118-PSD4:CntlTempF 118-PSD4:CntlTemp
118-PSD4:CntlTempF              2012-04-22 13:10:03.545845 85.6877
118-PSD4:CntlTemp               2012-04-22 13:10:03.545845 29.8265
118-PSD4:CntlTempF              2012-04-22 13:10:04.446311 85.6875
118-PSD4:CntlTemp               2012-04-22 13:10:04.446317 29.8264
118-PSD4:CntlTempF              2012-04-22 13:10:05.346903 85.6856
118-PSD4:CntlTemp               2012-04-22 13:10:05.346911 29.8254
```



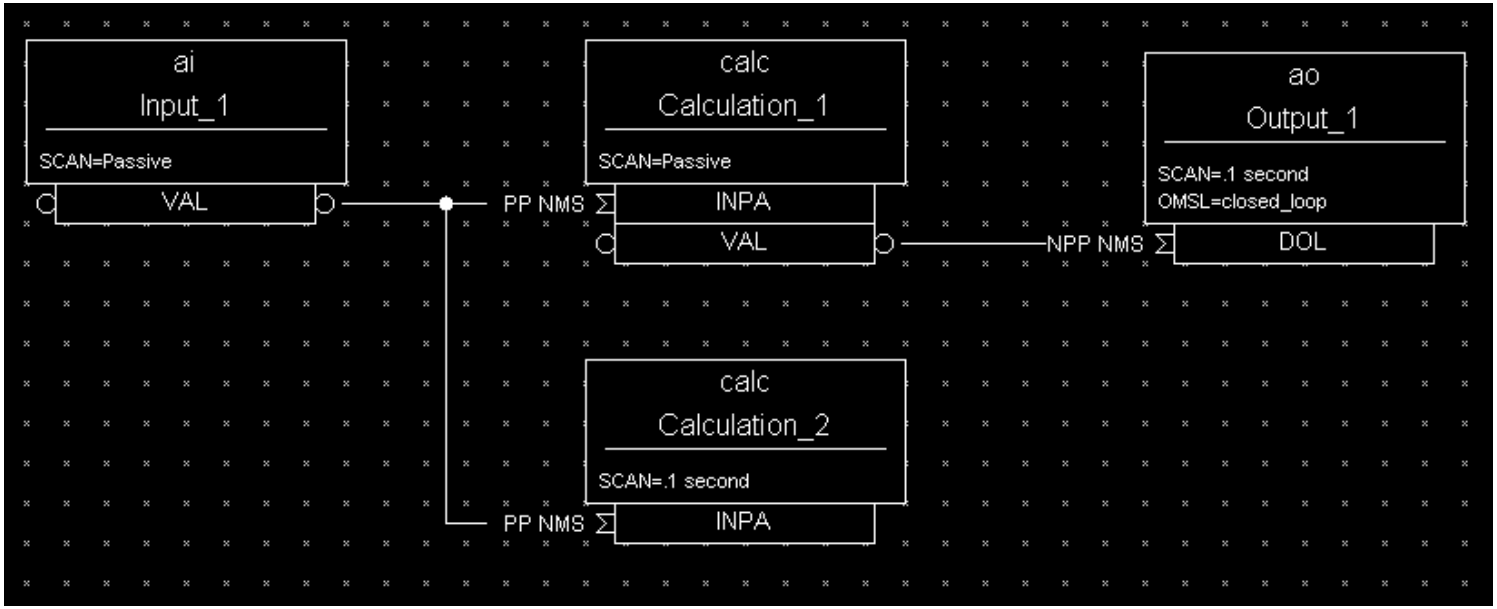
Processing chains



Which record is never processed?



How often is Input_1 processed?



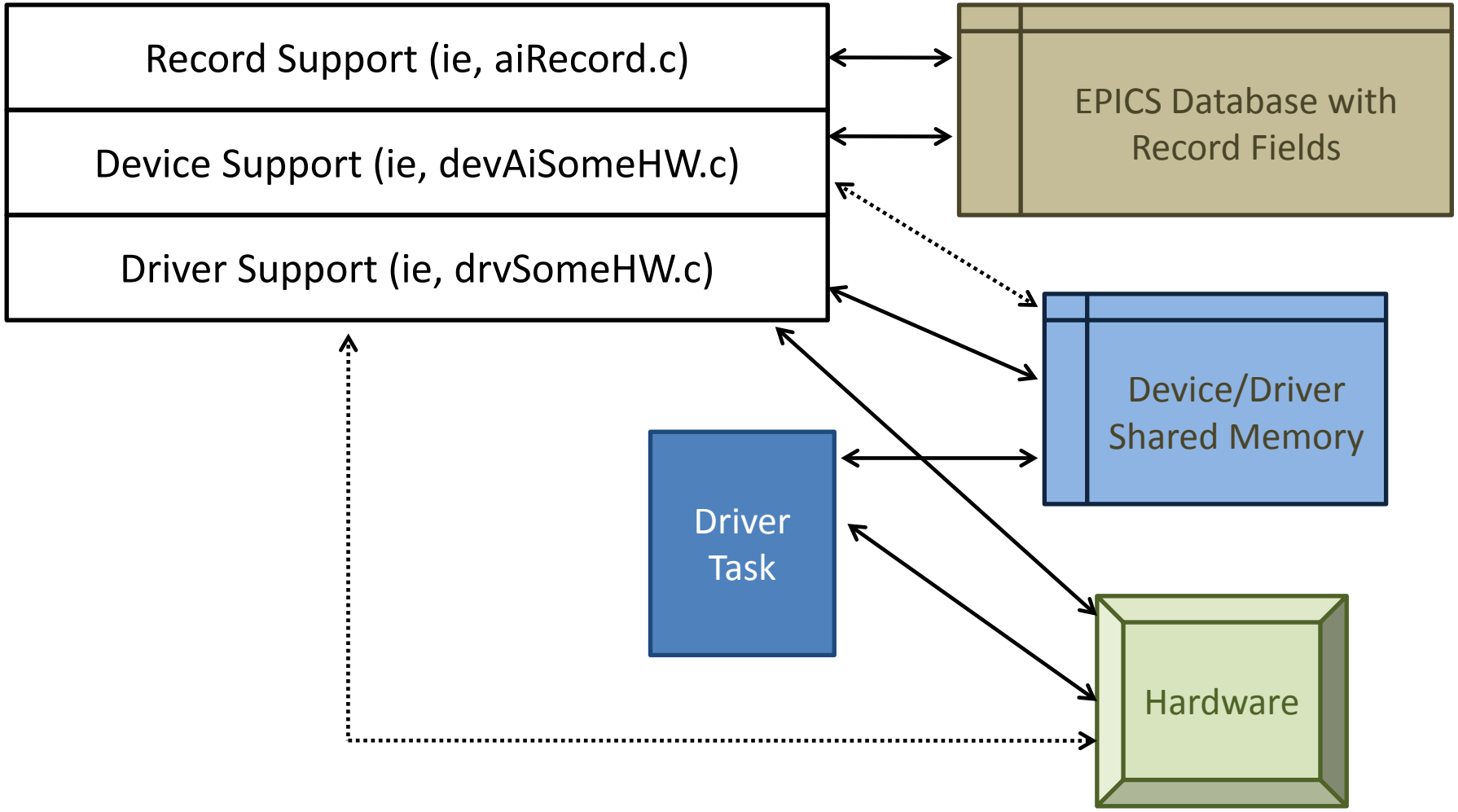
Device Support

- 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, default is normally “Soft Channel” support when not set
- The device support selected determines the format of the link (**INP** or **OUT** field) containing device address information
- Device support uses **DPVT** pointer to store device information for the record instance.
- Device support may also reset the **UDF** flag when the record is properly initialized.
- Additional fields added per record type for purpose of device support (examples, **MASK** and **SHFT** for mbbi, **ROFF** and **RVAL** for ai)

Device Support, cont

- Adding new device support does not require any changes or recompilation of the record type code
- Device support often calls other software to do work for it (Driver Support or other libraries)
- Device support most often thin layer – record and driver support do most of the legwork

Record/Device/Driver Example Software Hierarchy



Soft Device Support

- "Hard" input and output records do external 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 preformed
  - Async Soft Channel (currently 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
    - Note – remember **RVAL** is integer!!

Control System w/o traditional EPICS

TCP

Driver1 w CA Client

Some Server1

Network

Channel Access

Soft Records

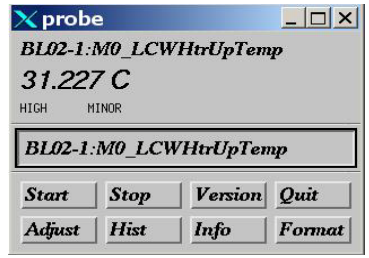
CAS

IOC on some Server3

UDP

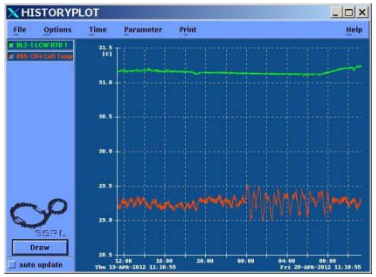
Driver2 w CA Client

Some Server2



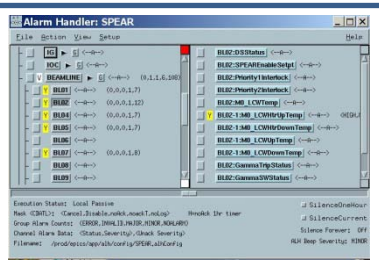
Value Probe

Some Host1



History

Some Host2



Alarm Handler

Some Host3

Control System with just Soft Records

- Do not have to read the App Dev Guide, take EPICS classes, or be an active EPICS collaborator.
- EPICS is a convenient scapegoat – system too slow? Blame it on EPICS. Changes take time to implement? Blame it on EPICS. Call mythbusters.
- However:
  - Changes DO take more time to implement on systems like this.
  - Harder to timestamp and correlate data.
  - Slower due to extra network traffic.
  - Harder to upgrade to different versions and platforms.
  - Cannot use other people's code (ie, areaDetector, motor).
  - Etc

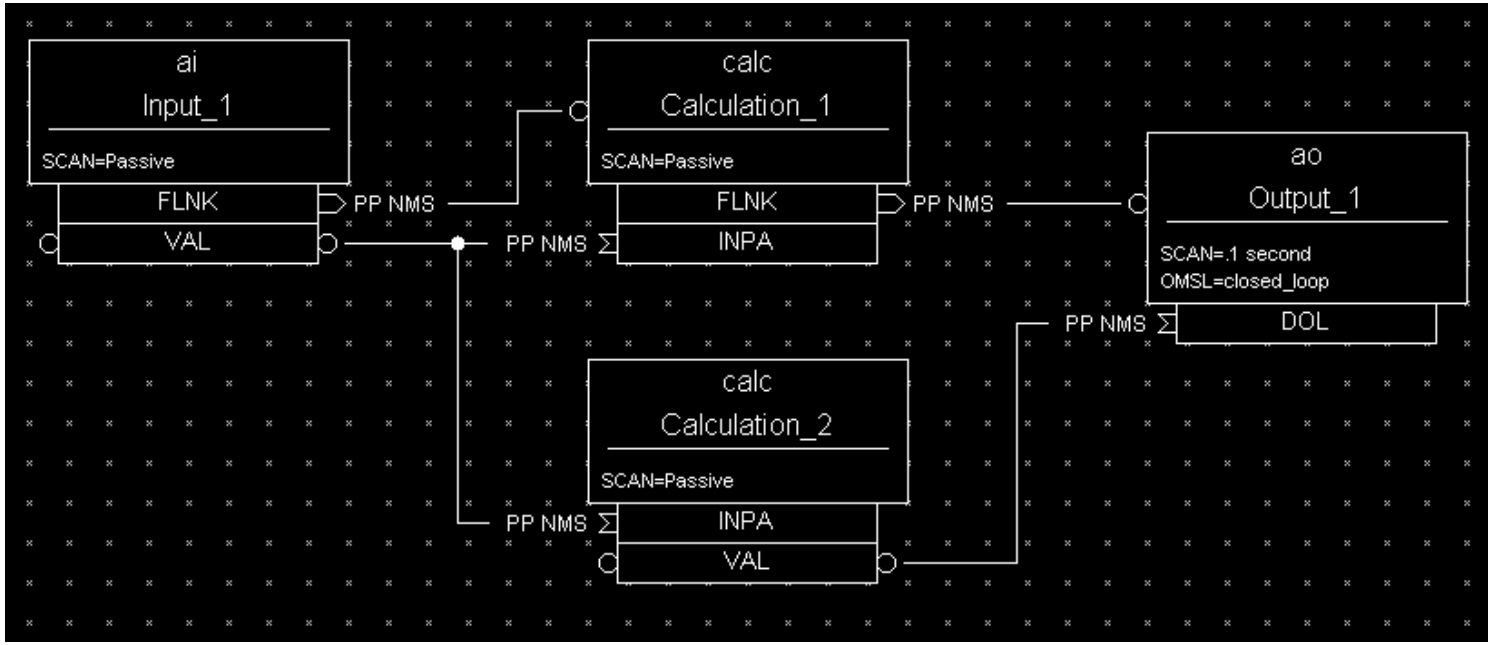
Synchronous vs Asynchronous I/O

- EPICS rules do not allow device support to busy-wait (i.e. 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/PCI cards usually give an immediate response: synchronous
  - When called, a synchronous read or write call to device support performs all I/O needed before returning
- Serial, network or field-bus I/O usually takes some time (>10ms) to return data: asynchronous
  - Asynchronous device support starts an I/O operation when the record calls it, flagging it as incomplete by setting **PACT** to true before returning
  - When the results are available (discovered by a CPU interrupt or polling background thread), the device support must call the record's process() routine to finish the record processing operations and set **PACT** to false

More about 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 (but it's not the first thing that the process routine does)
  - **PACT** should always be true whenever a link in that record is used to get/put a value
- **PACT** gets reset to false after all 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 will take the current field value
  - Output links just put their value to the field
  - Investigate cached puts

What happens here?



Other Common Fields and Functions

Record Status and Severity (**STAT/SEVR**)

- When record processing is started, the record **STAT** and **SEVR** enum fields are initialized to OK (NO_ALARM and NO_ALARM) by the IOC. Any record links or other processing may "maximize" STAT and SEVR (make them worse).
- Device support read/write routines must update record **STAT/SEVR** on a warning or error condition (such as a device or communication problem) so that clients can use the data intelligently.
- **SEVR** values are:
  - NO_ALARM, MINOR_ALARM, MAJOR_ALARM, INVALID_ALARM
  - INVALID_ALARM is most often used for failures.
- **STAT** values are listed in base/include/alarm.h and include:
  - READ, WRITE, UDF, HIGH, LOW, STATE, COS, CALC, DISABLE, etc
- Some processing also set **VAL** to NaN for failures.

Record Alarms

- Record **STAT** and **SEVR** can be set based on alarm limit or state checks done in record processing after the value is determined.
- Most numeric records check **VAL** against limits:
  - **HIHI**, **HIGH**, **LOW**, **LOLO**
- The **HYST** field prevents alarm chattering
- A separate alarm severity can be set for each numeric limit exceeded:
  - **HHSV**, **HSV**, **LSV**, **LLSV**
- Discrete (binary) records can raise alarms on entering a particular state, or on a change of state (COS)
- There is nothing to prevent alarm chattering for binary records so filtering in the alarm log CA client is normally used when needed.

Record Timestamp (**TIME**)

- The record timestamp (**TIME**) is set at the end of processing and is set based on the value of **TSE**:
  - 0 (default) - set to the system time (registered with generalTime)
  - -2 - set by device support
  - -1 - set by the default event time provider (registered with generalTime)
  - >0 - set by the event time provider with the **TSE** value as input
- If a **TSEL** PV link is provided, the timestamp is copied from that PV instead.
- Timestamps are useful to correlate data across IOCs when IOCs share a timing system.
- Might want a timestamp to reflect the time of a trigger vs the time that it takes to read and process the data.

Record Alarm and Timestamp Example

```
beldar:~$caput 118-PSD4:CntlTempF.MDEL 0
Old : 118-PSD4:CntlTempF.MDEL        0.03
New : 118-PSD4:CntlTempF.MDEL        0
beldar:~$caput 118-PSD4:CntlTemp.MDEL 0
Old : 118-PSD4:CntlTemp.MDEL         0.1
New : 118-PSD4:CntlTemp.MDEL         0
beldar:~$camonitor 118-PSD4:CntlTempF 118-PSD4:CntlTemp
118-PSD4:CntlTempF             2012-04-22 12:46:32.607235 85.6614
118-PSD4:CntlTemp              2012-04-22 12:46:32.607236 29.8119
118-PSD4:CntlTempF             2012-04-22 12:46:33.507582 85.6656
118-PSD4:CntlTemp              2012-04-22 12:46:33.507586 29.8142
^C
beldar:~$caput 118-PSD4:CntlTemp.HIHI 29
Old : 118-PSD4:CntlTemp.HIHI         41
New : 118-PSD4:CntlTemp.HIHI         29
beldar:~$camonitor 118-PSD4:CntlTempF 118-PSD4:CntlTemp
118-PSD4:CntlTempF             2012-04-22 12:47:09.526784 85.6887
118-PSD4:CntlTemp              2012-04-22 12:47:09.526785 29.827 HIHI MAJOR
118-PSD4:CntlTempF             2012-04-22 12:47:10.427425 85.7041
118-PSD4:CntlTemp              2012-04-22 12:47:10.427429 29.8356 HIHI MAJOR
^C
beldar:~$caput 118-PSD4:CntlTemp.TSEL "118-PSD4:CntlTempF.TIME"
Old : 118-PSD4:CntlTemp.TSEL         0
New : 118-PSD4:CntlTemp.TSEL         118-PSD4:CntlTempF.VAL NPP NMS
beldar:~$camonitor 118-PSD4:CntlTempF 118-PSD4:CntlTemp
118-PSD4:CntlTempF             2012-04-22 12:47:39.242830 85.6405
118-PSD4:CntlTemp              2012-04-22 12:47:39.242830 29.8003 HIHI MAJOR
118-PSD4:CntlTempF             2012-04-22 12:47:40.143155 85.6432
118-PSD4:CntlTemp              2012-04-22 12:47:40.143155 29.8018 HIHI MAJOR
118-PSD4:CntlTempF             2012-04-22 12:47:41.043640 85.6447
118-PSD4:CntlTemp              2012-04-22 12:47:41.043640 29.8026 HIHI MAJOR
^C
beldar:~$
```

Record Disabling (DISV/DISS)

- 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** (which defaults to 0 if the link is not set)
- If **DISA=DISV**, the record will ***not*** be processed
- The default value of the **DISV** field is 1
- A disabled record may be put into an alarm state by giving the desired severity in the **DISS** field (default of NO_ALARM)
- The **FLNK** of a disabled record is never triggered
- Trick – some applications use **SDIS** to propagate alarms instead of disable the record.

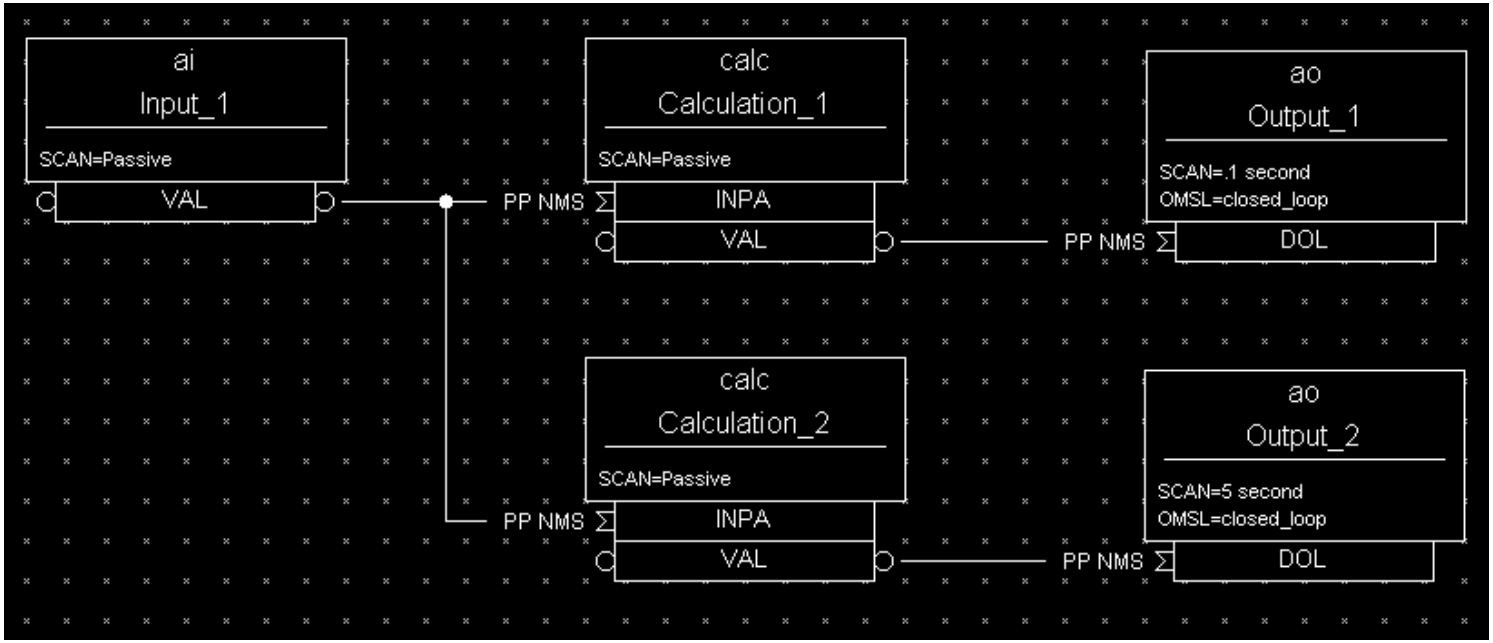
Record Lock-Sets (LSET)

- Prevent a record from being processed simultaneously from two different (ie, scan) tasks
  - PACT can't do that, it isn't set early enough and is not a Mutex
- A lock-set is a group of records interconnected by database links
- Lock-sets are determined automatically by the IOC at start-up, or whenever a database link is added, deleted or modified
- When lock-sets are too big and records process at a high rate, channel access (and other low priority tasks) performance may be affected.
- A lock-set can be split into different lock sets by making the link(s) joining them into Channel Access ones, using the CA flag
  - Remember that CA links behave slightly differently than DB links, make sure your design still works!
- A lock-set can also be split using event processing .

Lock Set Example

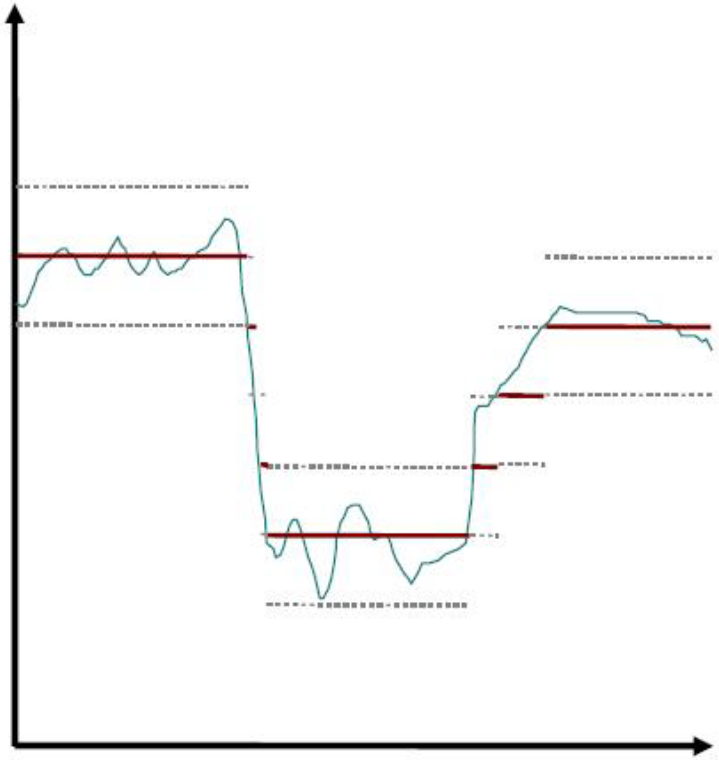
```
iocpsgendev>dblsr "118-PSD4:CntlTemp" 2
globalLock 0x10043b0
lockSetModifyLock 0x1004420
Lock Set 201 2 members epicsMutexId 0x1006190 Not Locked
118-PSD4:CntlTempF
        FLNK    FWDLINK NPP NMS 118-PSD4:CntlTemp
118-PSD4:CntlTemp
        INPA     INLINK NPP MS 118-PSD4:CntlTempF
iocpsgendev>dbpf("118-PSD4:CntlTemp.INPA","118-PSD4:CntlTempF CPP MS")
DBR_STRING:          "118-PSD4:CntlTempF CPP MS"
iocpsgendev>dbpf("118-PSD4:CntlTempF.FLNK","")
DBR_STRING:          "0"
iocpsgendev>dblsr "118-PSD4:CntlTemp" 2
globalLock 0x10043b0
lockSetModifyLock 0x1004420
Lock Set 204 1 members epicsMutexId 0x10060b0 Not Locked
118-PSD4:CntlTemp
iocpsgendev>dblsr "118-PSD4:CntlTempF" 2
globalLock 0x10043b0
lockSetModifyLock 0x1004420
Lock Set 203 1 members epicsMutexId 0x1006190 Not Locked
118-PSD4:CntlTempF
```

What could go wrong here?



Change Notification: Monitor Dead-bands

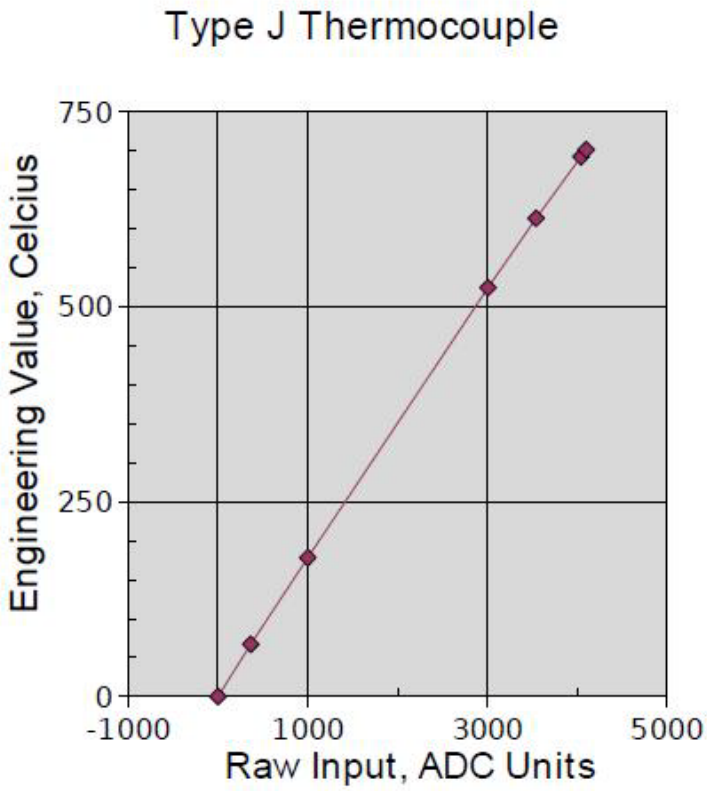
- Channel Access notifies clients that are monitoring a numeric record when
  - VAL changes by more than the value in field:
    - MDEL *Value monitors*
    - ADEL *Archive monitors*
  - Record's Alarm Status changes
    - HYST *Alarm hysteresis*
- The Analogue Input record has a smoothing filter to reduce noise on the input signal (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 some loaded .dbd file)

```
breaktable(typeKdegC) {
        0.000000   0.000000
      299.268700  74.000000
      660.752744 163.000000
     1104.793671 274.000000
     1702.338802 418.000000
     2902.787322 703.000000
     3427.599045 831.000000
     ...
}
```



Simulation

- Input and output record types often allow simulation of hardware interfaces
  - `SIML` Simulation mode link
  - `SIMM` Simulation mode value
  - `SIOL` Simulation input link
  - `SVAL` Simulated value
  - `SIMS` Simulation alarm severity
- Before calling device support, records read `SIMM` through the `SIML` link
- If `SIMM=YES` (1) or `RAW` (2) the device support is not used; record I/O is done through the `SIOL` link and `SVAL` field 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 (the IOC or gateway)
- A record is placed in the Access Security Group named in its `ASG` field
  - DEFAULT is used if no group name is given
- Rules are specified for each group to determine whether a CA client can read or write to records in that group, based on
  - Client user ID
  - Client host-name or IP address
  - Access Security Level of the field addressed
  - Values read from the database

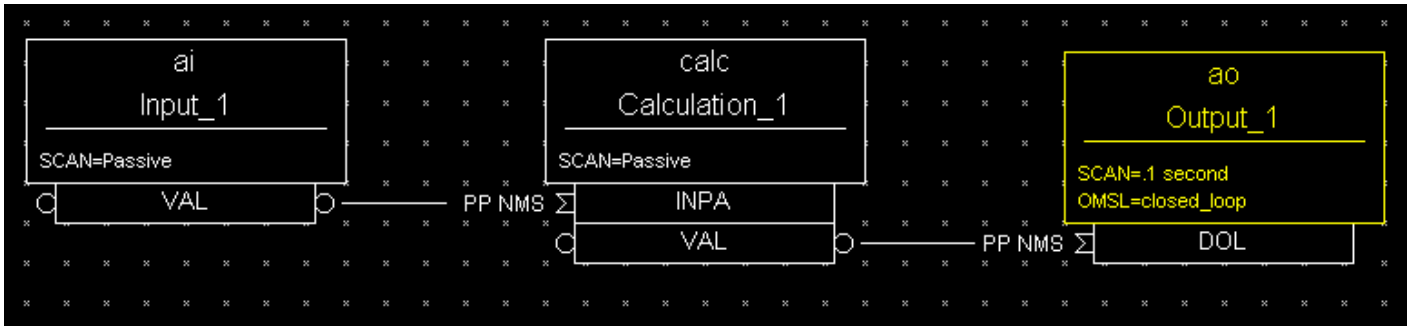
Access Security Configuration File

- 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)
    }
}
```

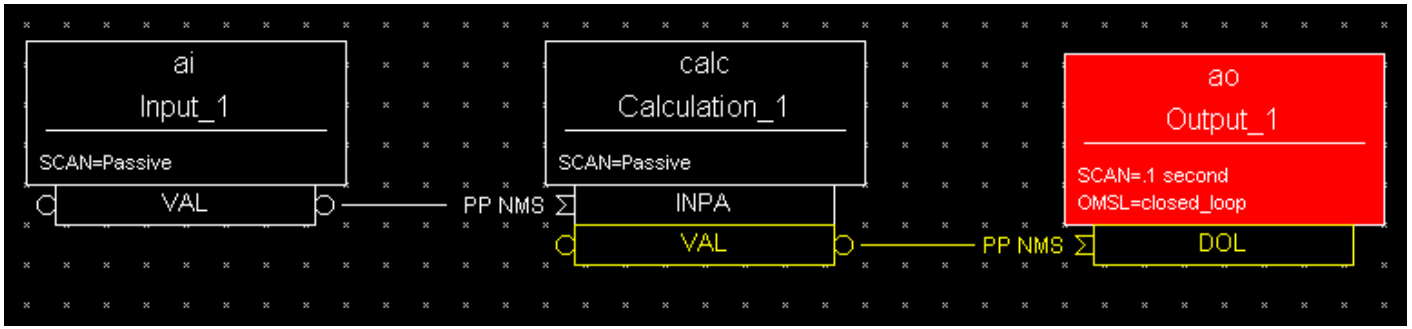
- If no security file is loaded, Security will be turned off and nothing refused
- For more details and the rule syntax, see Chapter 8 of the IOC Application Developers Guide

Order of Operations (Synchronous I/O)



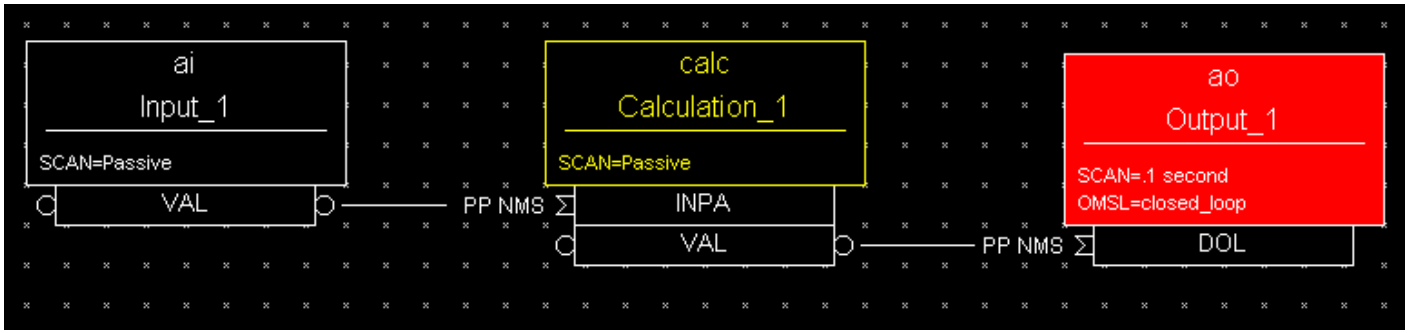
1. Every 0.1 seconds, iocCore will attempt to process the Output_1 record
2. The `Output_1.PACT` field is currently False, so the record is quiescent and can be processed
3. If set, the `Output_1.SDIS` link would be read into `Output_1.DISA`
4. Since **`DISA≠DISV`**, the ao record type's process() routine is called

Order of Operations (Synchronous I/O)



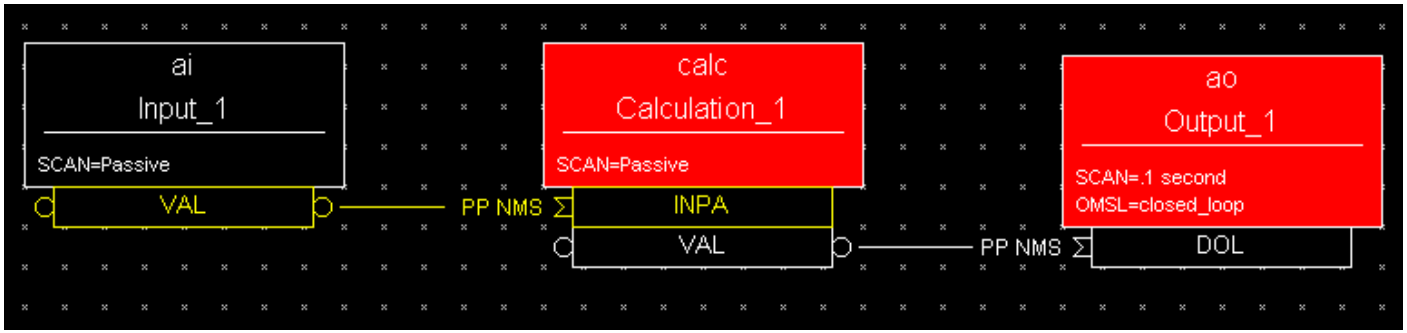
5. The ao's process() routine checks the `Output_1.OMSL` field; it is closed_loop, so
6. It sets `Output_1.PACT` to True, then
7. Reads a value through the `Output_1.DOL` link
8. The *`Output_1.DOL`* link contains *`Calculation_1.VAL PP`* so this first attempts to process the Calculation_1 record

Order of Operations (Synchronous I/O)



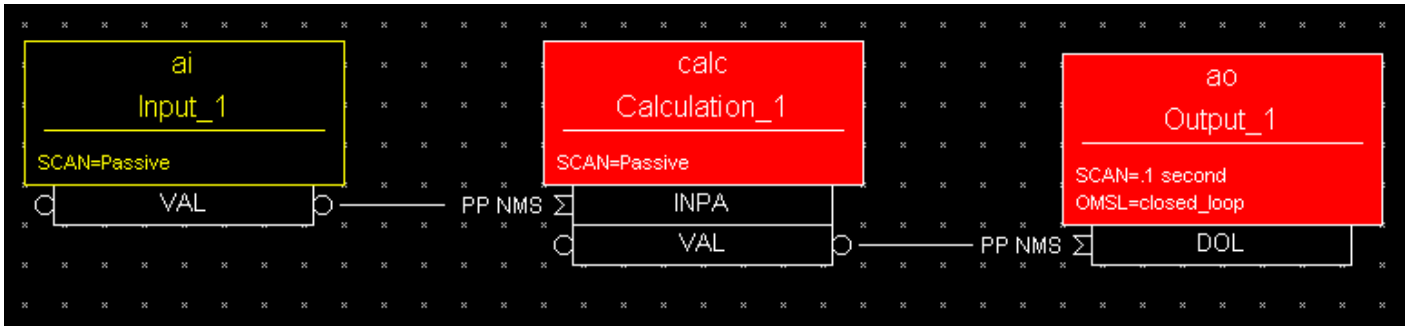
9. The `Calculation_1.SCAN` field is Passive and *`Calculation_1.PACT`* is False, so processing is possible
10. If set, the `Calculation_1.SDIS` link would be read into `DISA`
11. Since **`DISA≠DISV`**, the calc record type's process() routine is called

Order of Operations (Synchronous I/O)



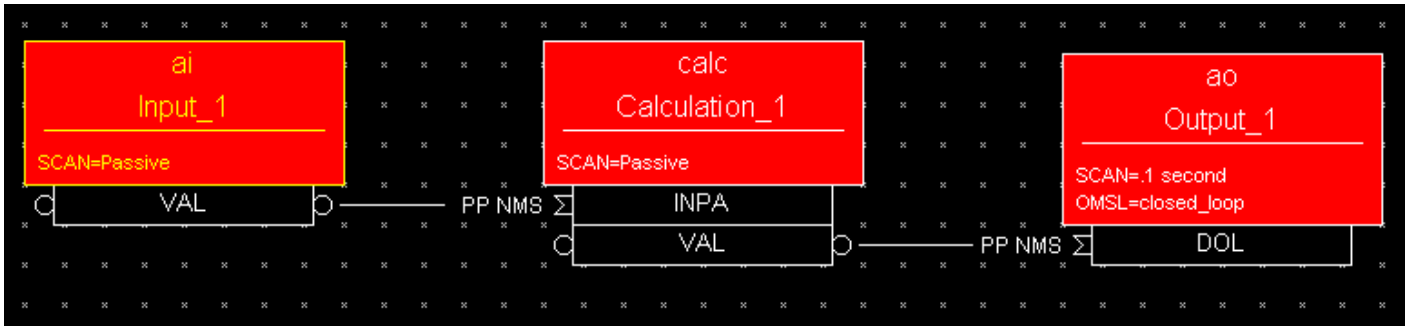
12. The calc's process() routine sets *`Calculation_1.PACT`* to True, then
13. Starts a loop to read values from the links `INPA` through `INPL`
14. The *`Calculation_1.INPA`* link is set to `Input_1.VAL` PP so this first attempts to process the Input_1 record

Order of Operations (Synchronous I/O)



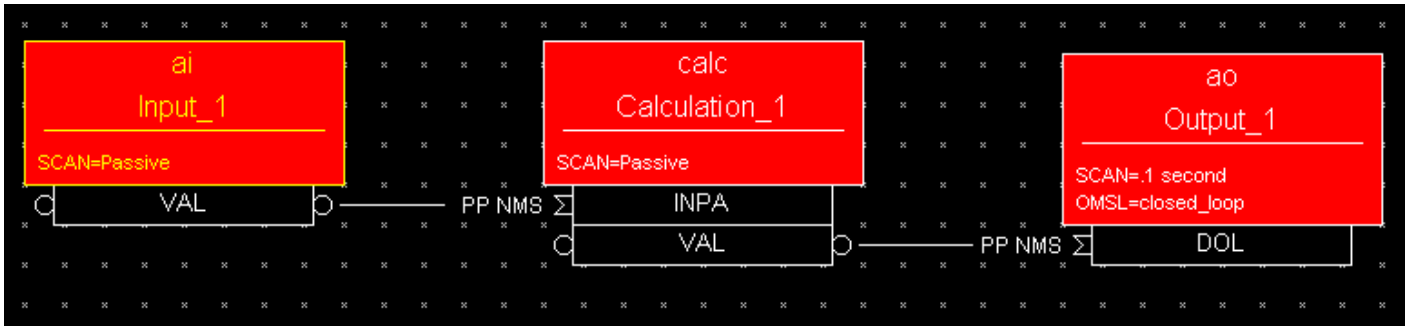
15. The `Input_1.SCAN` field is Passive and `Input_1.PACT` is False, so processing is possible
16. If set, the `Input_1.SDIS` link is read into the `Input_1.DISA` field
17. Since **`DISA≠DISV`**, the ai record type's process() routine is called
18. The ai process() calls the associated device support to read a value from the hardware it's attached to

Order of Operations (Synchronous I/O)



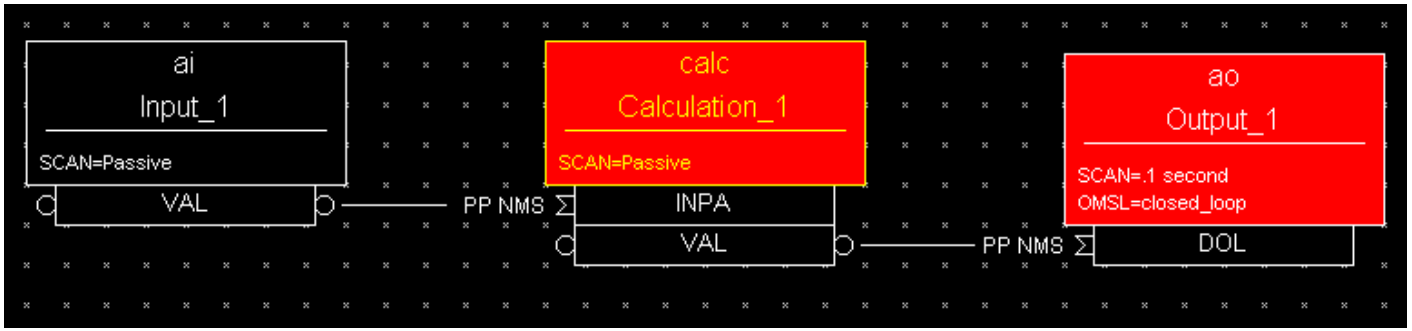
19. The device support is synchronous, so it puts the hardware input value into the `Input_1.RVAL` field and returns to the ai record's process() code
20. The `Input_1.PACT` field is set to True
21. The record's timestamp field `Input_1.TIME` is set to the current time
22. The raw value in `Input_1.RVAL` is converted to engineering units, smoothed, and the result put into the `Input_1.VAL` field

Order of Operations (Synchronous I/O)



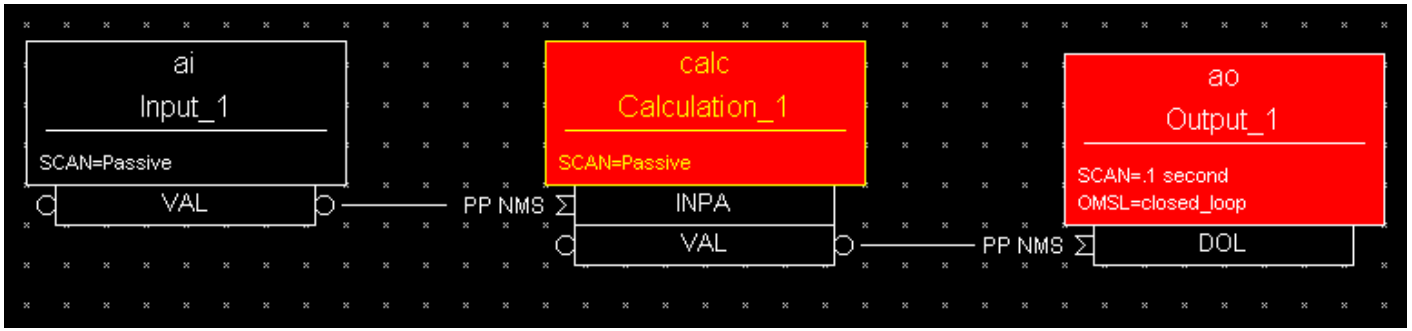
23. The `Input_1.VAL` is checked against alarm limits and monitor dead-bands, and appropriate actions is taken if these are exceeded
24. If the Forward Link field `Input_1.FLNK` is set, an attempt is made to process the record it points to
25. The `Input_1.PACT` field is set to False, and the process() routine returns control to the Calculation_1 record

Order of Operations (Synchronous I/O)



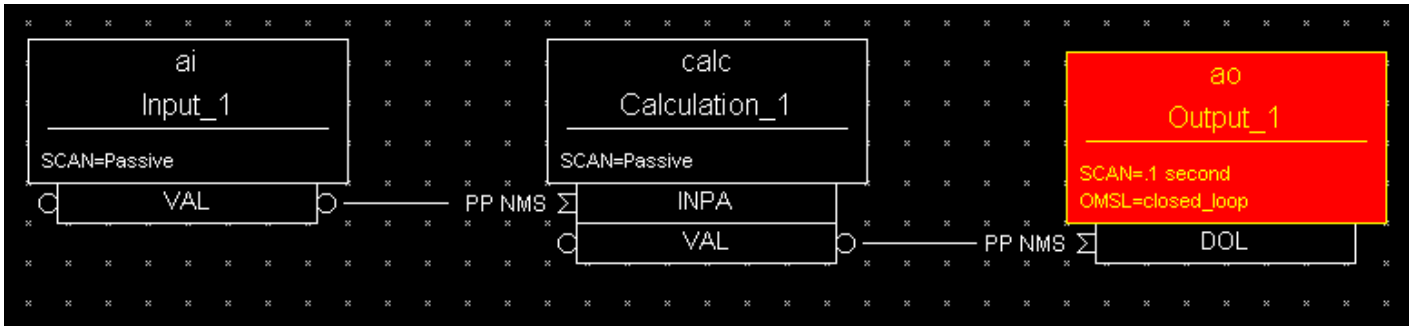
26. The value read through the *`Calculation_1.INPA`* link is copied into the *`Calculation_1.A`* field
27. The Calculation record type's process() routine continues to loop, reading its input links
28. In this example only the `INPA` link is set, so the routine finishes the loop and evaluates the *`Calculation_1.CALC`* expression (not shown)
29. The result of the expression is put in the `Calculation_1.VAL` field

Order of Operations (Synchronous I/O)



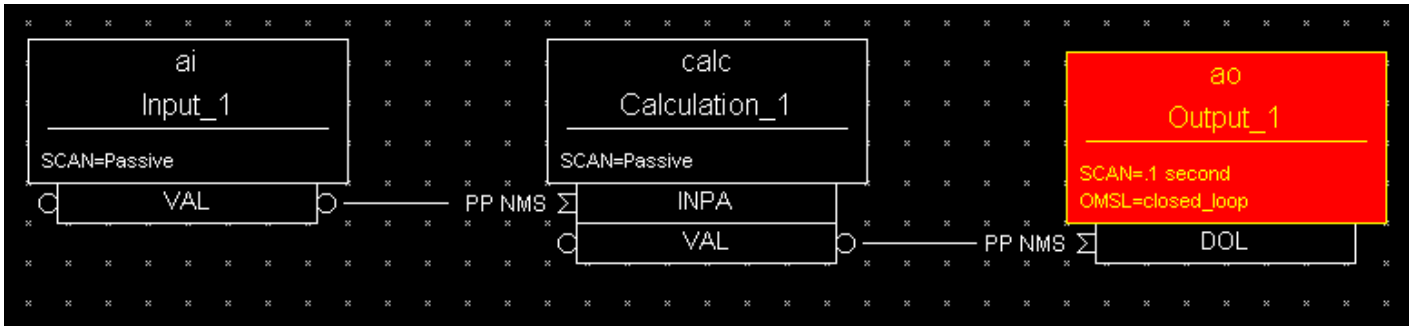
30. The record's timestamp field `Calculation_1.TIME` is set to the current time
31. `Calculation_1.VAL` is checked against alarm limits and monitor dead-bands, and appropriate action is taken if these are exceeded
32. If the Forward Link field `Calculation_1.FLNK` is set, an attempt is made to process the record it points to
33. The `Calculation_1.PACT` field is set to False, and the process() routine returns control to the Output_1 record

Order of Operations (Synchronous I/O)



34. The value read through the *`Output_1.DOL`* link would now be forced into the range `DRVL..DRVH` if those fields were set, but they aren't so it's copied to the `Output_1.VAL` field unchanged
35. The `Output_1.VAL` value is converted from engineering to raw units and placed in `Output_1.RVAL`
36. `Output_1.VAL` is checked against alarm limits and monitor dead-bands, and appropriate action is taken if these are exceeded
37. The associated device support is called to write the value to the hardware

Order of Operations (Synchronous I/O)



38. The device support is synchronous, so it outputs the value to the attached hardware and returns
39. The record's timestamp field `Output_1.TIME` is set to the current time
40. If the Forward Link field `Output_1.FLNK` is set, an attempt is made to process the record it points to
41. The `Output_1.PACT` field is set to False, and the process() routine returns