

EPICS Database Practice

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USPAS EPICS Course

EPICS record types

- Where do record types come from?
 - EPICS Base (<base>/src/rec)
 - General purpose record types
 - No record-type specific operator displays or databases
 - Documentation in the EPICS Record Reference Manual

 - EPICS collaboration
 - General purpose, and application-specific, record types
 - Some are supported for use by collaborators (some are NOT)
 - Some come with record-type specific displays and database templates

 - Custom record types can be written by any EPICS developer, and added to specific EPICS applications as needed.
 - Not in the scope of this lecture



The Record Reference Manual

- Where is it?
 - EPICS Home > Base > R3.14.11 > Reference Reference Manual (wiki)
- What is in it?
 - Database Concepts (good review)
 - Fields common to all records (covered earlier)
 - Fields common to many records (covered earlier)
 - Record Types – provides a description of the fields and record processing routines for the record types in base.
- When would I use it?
 - Skim through before writing any databases
 - Read through before writing any records
 - Otherwise, use as reference



Manual Outline

- Preface, Chapter 1: Essential background information
 - Note special meaning of the words scan, process, address, link, and monitor
- Chapter 2-39: Record reference
 - Some parts may still be slightly out of date
 - Descriptions of record fields, processing, and useful info for writing device support
 - Contains lots of tables like this:

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	FLOAT	Yes	0	Yes	Yes	No	No
LOPR	Low Operating Range	FLOAT	Yes	0	Yes	Yes	No	No
PREC	Display Precision	SHORT	Yes	0	Yes	Yes	No	No
NAME	Record Name	STRING [29]	Yes	Null	Yes	No	No	No
DESC	Description	STRING [29]	Yes	Null	Yes	Yes	No	No

Collaboration supported records

- Where are they found?
 - Soft-support list: <http://www.aps.anl.gov/epics/modules/soft.php>
 - The tech-talk email list
 - The soft-support list contains entries like this (among entries for other kinds of soft support):

Class	Name	Description	Contact	Link
record	epid	Enhanced PID record	Mark Rivers	CARS:epid Record
record	genSub	Multi-I/O subroutine, handles arrays	Andy Foster	OSL:epics
...
record	table	Control an optical table	Tim Mooney	APS:synApps /optics
record	timestamp	...exports its timestamp as a string	Stephanie Allison	SLAC:time stamp

Input Records

- ai - Analog input [BASE]
 - Read analog value, convert to engineering units, four alarm levels, simulation mode
- aai – Array analog input [BASE]
 - Read array of analog values, simulation mode
- bi - Binary input [BASE]
 - Single bit, two states, assign strings to each state, alarm on either state or change of state, simulation mode
- mbbi - Multi-bit binary input [BASE]
 - Multiple bit, sixteen states, assign input value for each state, assign strings to each state, assign alarm level to each state, simulation mode
- mbbiDirect – mbbi variant [BASE]
 - Read an unsigned short and map each bit to a field (16 BI records in one)



Input Records (cont..)

- stringin - String input [BASE]
 - 40 character (max) ascii string, simulation mode
- longin - Long integer input [BASE]
 - Long integer, four alarm levels, simulation mode
- waveform – array input [BASE]
 - Configurable data type and array length (16,000 bytes max for CA in EPICS 3.13)
- *mbbi32Direct* [ORNL] *longMbbiDirect* [KEK] – 32-bit *mbbiDirect*
 - Read an unsigned long and map each bit to a field (32 BI records in one)
- *mca* – *multichannel analyzer* [synApps]
 - Supports multichannel analyzers, multichannel scalers, and other array-input hardware



Input Records (cont..)

- *pulseCounter* [[ANL RecRefMan](#)]
 - Written to support a Mizar 8310 timing module
- *scaler* [[synApps](#)]
 - Controls a bank of counters
- *swf* [[BESSY](#)] , *wftime* [[SLAC](#)] – *waveform variants*
 - Includes scaling and time (wftime) information
- *timestamp* [[SLAC](#)]
 - Exports its timestamp as a string
 - No longer needed, use stringin record with timestamp device support



Algorithms/Control Records - Calc

- calc - run-time expression evaluation [BASE]
 - 12 input links, user specified expression (algebraic, trig, relational, boolean, bit-wise, “?:” and “:=” operators), four alarm levels
 - Sample expressions:
 - 0 read: “VAL = 0”
 - A returns value of record’s “A” field
 - A+B
 - $b * \sin(a * d2r)$; $a := a + 1$
 - $(A+B) < (C+D) ? E : F * G / 100$
- calcout – calc variant [BASE]
 - Conditional output link, second output CALC expression (.OCAL), output delay, and output event
 - Output-link options : “Every Time”, “On Change”, “When Zero”, “When Non-zero”, “Transition To Zero”, “Transition To Non-zero”

Algorithms/Control Records - Calc

- *sCalcout* – *calcout* variant [synApps]
 - Has both numeric fields (A,B,..L) and string fields (AA,BB,..LL)
 - Supports both numeric and string expressions. E.g.,
 - `A+DBL("value is 3.456")` -> **4.456**
 - `printf("SET:VOLT:%.21f", A+4)` -> **"SET:VOLT:5.00"**
 - Additional output-link option: "Never"
- *transform* – *calc/seq* variant [synApps]
 - Like 16 calcout records (but outlinks are not conditional)
 - Expressions read all variables, but write to just one.
 - Uses sCalcout record's calculation engine
 - Example expressions:
 - **A: 2 read: "<transform>.A = 2"**
 - **B: A+1+C uses new value of 'A', old value of 'C'**

Algorithms/Control Records - Array

- compress [BASE]
 - Input link can be scalar or array.
 - Algorithms include N to 1 compression (highest, lowest, or average), circular buffer of scalar input.
- histogram [BASE]
 - Accumulates histogram of the values of a scalar PV
- subArray [BASE]
 - Extracts a sub-array from a waveform.
- *aConcat* [KEK], *joinArray* [SLS]
 - Concatenate waveforms
- *aSub* – *sub variant* [BASE], *genSub* [OSL]
 - Multiple inputs and outputs
 - Handles arrays

Algorithms/Control Records - List

- dfanout – Data fanout [BASE]
 - Writes a single value to eight output links
- fanout [BASE]
 - Forward links to six other records.
 - Selection mask
- sel - Select [BASE]
 - 12 input links, four select options [specified, highest, lowest, median], four alarm levels
- seq - Sequence [BASE]
 - Ten “Input link/Value/Output link” sets: [inlink, delay, value, outlink]
 - Selection mask

Algorithms/Control Records - List

- *lseq* – seq variant [[JACH](#)]
 - 16 sets, instead of 10
- *sseq* – seq variant [[synApps](#)]
 - seq record for string or numeric data
 - optional wait for completion after each set executes
- *wfselector* – waveform/sel variant [[KEK](#)]
- *aSub* [[BASE](#)]
- *genSub* [[OSL](#)]
- *sCalcout* [[synApps](#)]
- *transform* [[synApps](#)]

Algorithms/Control Records - Loop

- scan [\[synApps\]](#)
 - Four “positioners”, two “detector triggers”, fifteen “detectors”.
 - Systematically sets conditions, triggers detectors, and acquires data into arrays.
 - Database detects completion and drives scan to next step.
- sscan – scan variant [\[synApps\]](#)
 - Uses `ca_put_callback()` to detect completion.
 - Four triggers, 70 detector signals (arrays, scalars, or mixed)
 - Array-prepare trigger at end of scan
 - Number of data points stored is limited only by memory
 - Supports scan pause; before/after-scan action; move-to-peak.
 - Handshake permits data-storage client to write old data while new data is being acquired.



Algorithms/Control Records - Subroutine

- sub – Subroutine [BASE]
 - 12 input links, user provided subroutine, four alarm levels
- aSub – Array Subroutine [BASE]
 - 21 input links, 21 output links, controllable data types and array sizes
 - user provided initialize and process subroutines
- genSub – original aSub variant [OSL]
 - Also handles structures

Algorithms/Control Records - Other

- event [[BASE](#)]
 - Posts a “soft” event which may trigger other records to process.
 - Simulation mode
- PID [[ANL](#)], CPID [[JLAB](#)], EPID [[synApps](#)]
 - Proportional/Integral/Derivative Control
- pal [[3.13 BASE](#)]
 - Emulates Programmable Array Logic
- cvt – ai/ao variant [[BESSY](#)]
 - 1 or 2 inputs, 1 output, conversion types: linear, subroutine, 1D or 2D table
- Permissive – handshake [[BASE](#)]
 - Implements a client-server handshake
- state – string state value [[BASE](#)]
 - Implements a string, for client-server communication



Output Records

- ao - Analog output [BASE]
 - Write analog value, convert from engineering units, four alarm levels, closed_loop mode, drive limits, output rate-of-change limit, INVALID alarm action, simulation mode
- aao – Array analog output [BASE]
 - ao for arrays
- bo - Binary output [BASE]
 - Single bit, two states, assign strings to each state, alarm on either state or change of state, closed_loop mode, momentary 'HIGH', INVALID alarm action, simulation mode
- longout [BASE]
 - Write long integer value, four alarm levels, closed_loop mode, INVALID alarm action, simulation mode

Output Records (cont..)

- mbbo - Multi-bit binary output [[BASE](#)]
 - Multiple bit, sixteen states, assign output value for each state, assign strings to each state, assign alarm level to each state, closed_loop mode, INVALID alarm action, simulation mode
- mbboDirect - mbbo variant [[BASE](#)]
 - 16 settable bit fields that get written as a short integer to the hardware, closed_loop mode, INVALID alarm action, sim. mode
- mbbo32Direct - mbbo variant [[ORNL](#)]
- longMbboDirect - mbbo variant [[KEK](#)]
 - 16 settable bit fields that get written as a long integer, closed_loop mode, INVALID alarm action, simulation mode
- motor [[synApps](#)]
 - Controls stepper and servo motors
 - Has its own lecture (*Motors*)

Output Records (cont..)

- steppermotor [3.13 BASE]
 - Position control, retry, speed, ramps, etc
- pulseDelay [3.13 BASE]
 - Written to support a Mizar 8310 timing module
- pulseTrain [3.13 BASE]
 - Written to support a Mizar 8310 timing module
- stringout [BASE]
 - Write a character string (40 max), closed_loop mode, INVALID alarm action, simulation mode

Examples of Custom Records

- rf - RF Amplitude Measurements [\[ANL\]](#)
 - Sample time, measurement in watts and db, waveform acquired through sweeping sample time
- bpm - Beam Position Monitor [\[ANL\]](#)
 - Four voltage inputs, numerous calibration constants, X-Y-I outputs, waveforms for each input
- *Many* others that are site-specific

Which record is right for ...

- Soft parameters entered by an operator
 - AO has DRVH, DRVL, OROC, closed loop
 - MBBO provides enumerated options which can be converted to constants (use DTYP = Raw Soft Channel)
 - Normally one does not use input records for this purpose
- Multiple output actions
 - Sequence record can have a different data source for each output link vs. the dfanout record which “fans out” a single source to multiple links
- Different output actions based on an operator selection
 - CALCOUT records that conditionally process sequence records
 - MBBO (Soft Raw Channel) forward linked to a single sequence record in “masked” mode. Mask is provided in MBBO for each state.

Defining the Database

- How does an IOC know what record *types* and device support options are available ?
 - Record types, device support options, choice menus, and other configuration options are defined in Database Definition files (.dbd)
 - The IOC build process creates a .dbd file containing everything the IOC needs
 - That .dbd file is loaded by the IOC when it starts up
- How does an IOC know about record *instances* (the user's database) ?
 - Record instances are describe in Database files (.db)
 - During the IOC booting process, one or more .db files are loaded
 - The .db files define the record instances for that IOC



Database Definition File

```
menu(menuPriority) {
  choice(menuPriorityLOW, "LOW")
  choice(menuPriorityMEDIUM, "MEDIUM")
  choice(menuPriorityHIGH, "HIGH")
}
menu(menuScan) {
  choice(menuScanPassive, "Passive")
  choice(menuScanEvent, "Event")
  choice(menuScanI_O_Intr, "I/O Intr")
  choice(menuScan10_second, "10 second")
  choice(menuScan5_second, "5 second")
  choice(menuScan2_second, "2 second")
  choice(menuScan1_second, "1 second")
  choice(menuScan_5_second, ".5 second")
  choice(menuScan_2_second, ".2 second")
  choice(menuScan_1_second, ".1 second")
}
```

```
device(ai, CONSTANT, devAiSoftRaw,
        "Raw Soft Channel")
device(ai, BITBUS_IO, devAiIObug,
        "Bitbus Device")
device(ao, CONSTANT, devAoSoftRaw,
        "Raw Soft Channel")
device(ao, VME_IO, devAoAt5Vxi,
        "VXI-AT5-AO")
device(bi, VME_IO, devBiAvme9440,
        "AVME9440 I")
device(bi, AB_IO, devBiAb,
        "AB-Binary Input")
driver(drvVxi)
driver(drvMxi)
driver(drvGpib)
driver(drvBitBus)
```

Extracts from a typical .dbd file

Database Definition File continued...

```
menu(aoOIF) {
  choice(aoOIF_Full,"Full")
  choice(aoOIF_Incremental,
         "Incremental")
}
recordtype(ao) {
  include "dbCommon.dbd"
  field(VAL,DBF_DOUBLE) {
    prompt("Desired Output")
    promptgroup(GUI_OUTPUT)
    asl(ASL0)
    pp(TRUE)
  }
  field(OUT,DBF_OUTLINK) {
    prompt("Output Specification")
    promptgroup(GUI_OUTPUT)
    interest(1)
  }
}
```

```
field(OIF,DBF_MENU) {
  prompt("Out Full/Incremental")
  promptgroup(GUI_OUTPUT)
  interest(1)
  menu(aoOIF)
}
field(OVAL,DBF_DOUBLE) {
  prompt("Output Value")
}
field(PREC,DBF_SHORT) {
  prompt("Display Precision")
  promptgroup(GUI_DISPLAY)
  interest(1)
}
...
}
```

Parts of the ao record type definition from a typical .dbd file

Database File

```
record(bo,"$(user):gunOnC") {
    field(DESC,"Controls e-gun")
}
record(bo,"$(user):gunOnC") {
    field(DESC,"Controls e-gun")
    field(DTYP,"Soft Channel")
    field(ZNAM,"Beam Off")
    field(ONAM,"Beam On")
}
record(ao,"$(user):cathodeCurrentC") {
    field(DESC,"set cathode current")
    field(DTYP,"Raw Soft Channel")
    field(SCAN,"1 second")
    field(OROC,".5")
    field(PREC,"2")
    field(EGU,"Amps")
    field(DRVH,"20")
    field(DRVL,"0")
    field(HOPR,"20")
    field(LOPR,"0")
}
```

```
record(calc,"$(user):rampM") {
    field(CALC,"A>6.27?0:A+.1")
    field(SCAN,"1 second")
    field(INPA,"$(user):rampM.VAL")
}
record(calc,"$(user):cathodeTempM") {
    field(DESC,"Measured Temp")
    field(SCAN,"1 second")
    field(CALC,"C+(A*7)+(SIN(B)*3.5)")
    field(INPA,"$(user):cathodeCurrentC.OVAL")
    field(INPB,"$(user):rampM.VAL")
    field(INPC,"70")
    field(EGU,"degF")
    field(PREC,"1")
    field(HOPR,"200")
    field(LOPR,"")
    field(HIHI,"180")
    field(LOLO,"130")
    field(HIGH,"160")
    field(LOW,"140")
    field(HHSV,"MAJOR")
    field(HSV,"MINOR")
    field(LLSV,"MAJOR")
    field(LSV,"MINOR")
}
```

Loading Database Files into the IOC

- A typical startup script (st.cmd) might contain

```
dbLoadDatabase (" ../ ../dbd/linacApp.dbd")
dbLoadRecords (" ../ ../db/xxLinacSim.db", "user=studnt1")
iocInit          /* starts database processing */
```

- One or more database definition files (.dbd) must be loaded first.
 - Any record type used in the database files must have been defined in the definition file
- Values for macros used within the database file (e.g. `$(user)`) can be specified when loading. This allows a database to be loaded more than once with different record names and I/O addresses each time

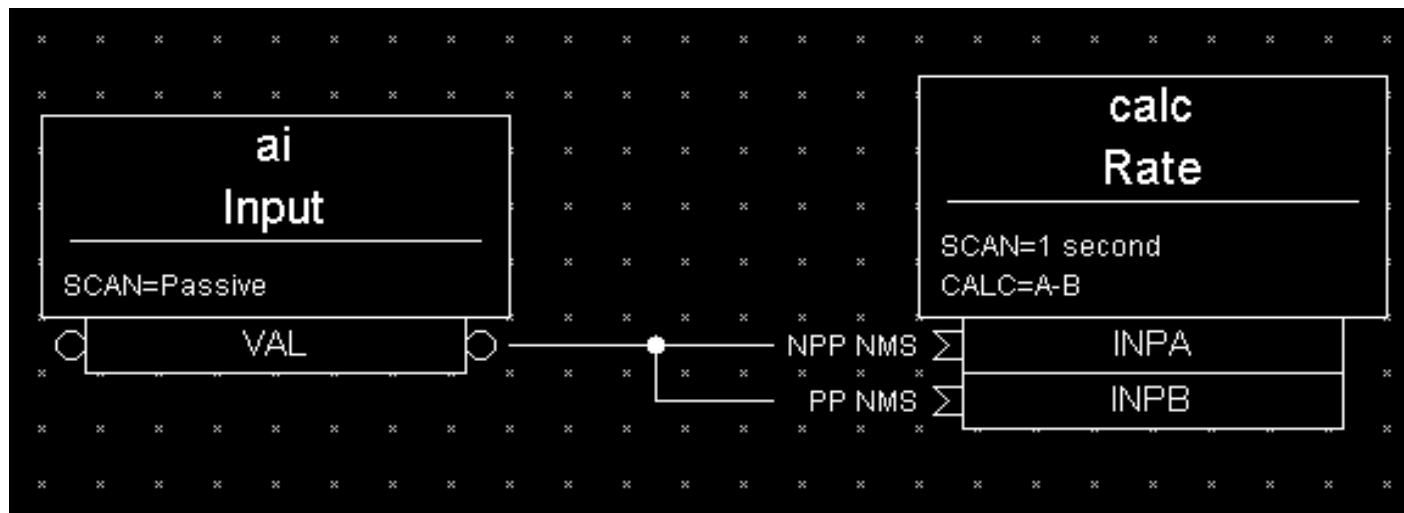
Creating Database Files

- Since the database file is a simple ascii file, it can be generated by numerous applications ... as long as the syntax is correct
 - Text editor
 - Script (Perl, Python, shell, awk, sed, ...)
 - Relational Database (Oracle, MySQL)
 - EPICS-aware Database Configuration Tools:
 - VDCT (recommended for new designs)
 - CAPFAST (a schematic entry application)
 - JDCT (not graphical)
- An EPICS-aware tool will read the IOC's .dbd file for menu selections of enumerated fields. It may also detect database errors prior to the boot process
- A hierarchical graphical tool is helpful for complex databases



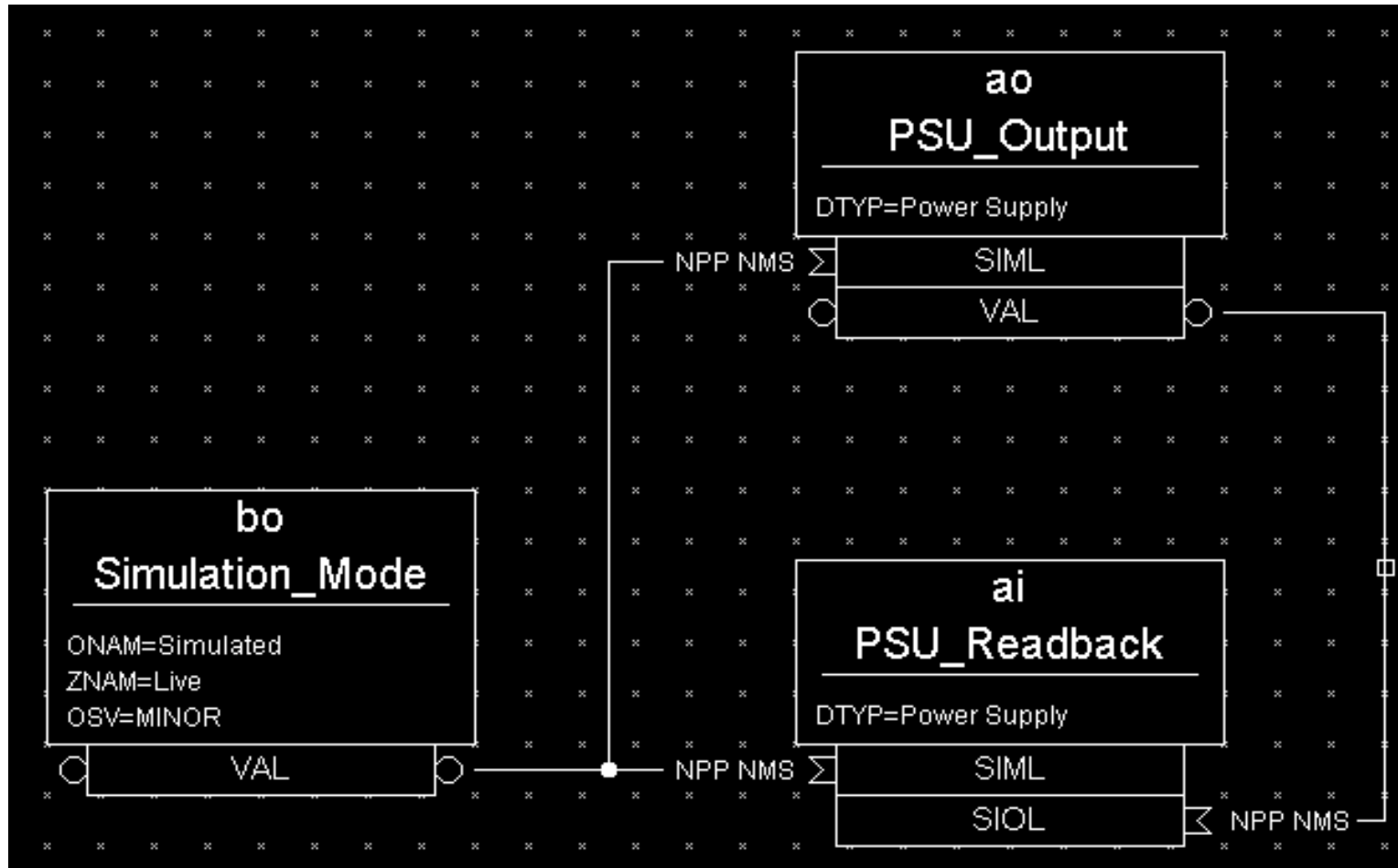
Database Examples

Calculating “Rate-of-Change” of an Input



INPA fetches data that is 1 second old because it does not request processing of the AI record. INPB fetches current data because it requests the AI record to process. The subtraction of these two values reflects the ‘rate of change’ (difference/sec) of the pressure reading.

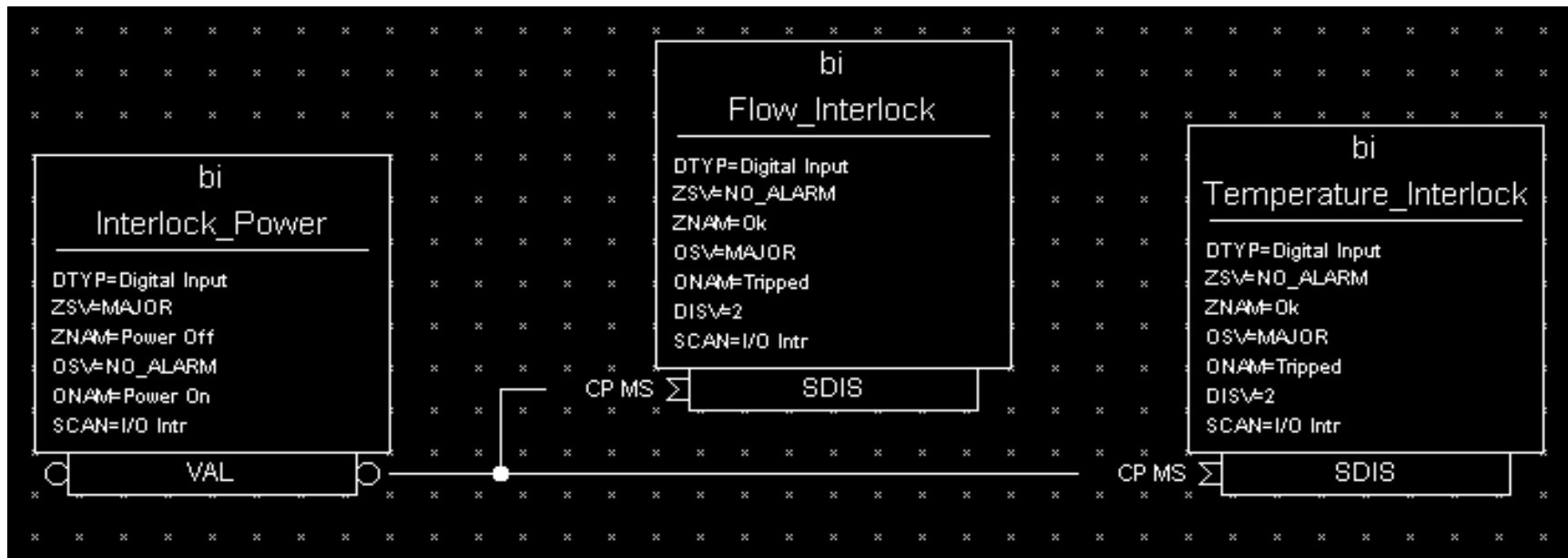
Database Examples



When in simulation mode, the AO record does not call device support and the AI record fetches its input from the AO record.

Database Examples

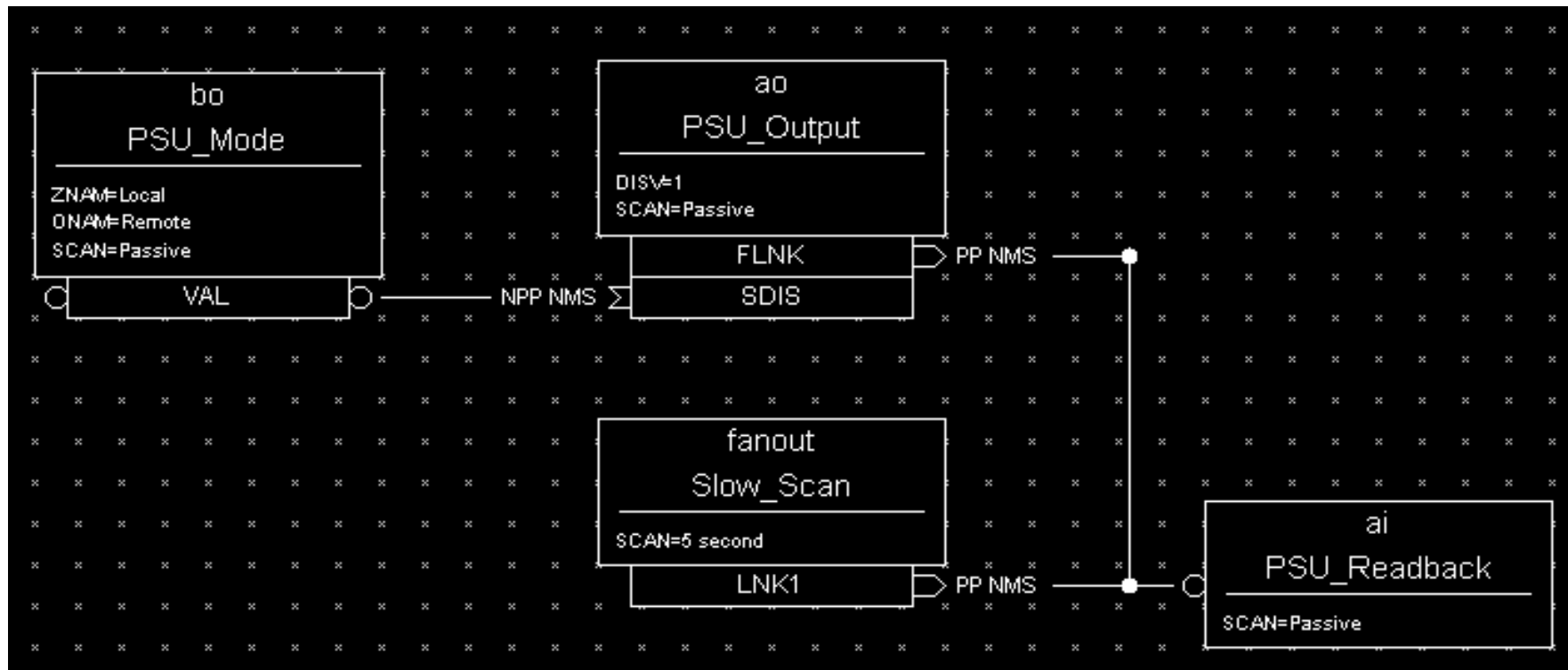
Maximize Severity



If chassis is powered off, Temp Trip and Flow Trip indicate Normal. Force these PVs into an alarm state by specifying .SDIS with .MS (maximize severity) to the Chassis On record. Set .DISV (disable value) to 2 so processing will never be disabled.

Database Examples

Slow Periodic Scan with Fast Change Response



The AI record gets processed every 5 seconds AND whenever the AO record is changed. This provides immediate response to an operator's changes even though the normal scan rate is very slow. Changes to the power supply settings are inhibited by the BO record, which represents a Local/Remote switch.

Database Examples

Different Actions Based on Operator Selection

```
record(mbbo,"$(user):PS:Control") {
  field(DTYP,"Raw Soft Channel")
  field(FLNK,"$(user):PS:ControlSQ.VAL PP NMS")
  field(ZRVL,"0x3") BIT MAP: 000000000000011 -> do LNK1, LNK2
  field(ZRST,"Off") menu item operator sees
  field(ONVL,"0x5") BIT MAP: 000000000000101 -> do LNK1, LNK3
  field(ONST,"On") menu item operator sees
  field(TWVL,"0xc") BIT MAP: 000000000001100 -> do LNK3, LNK4
  field(TWST,"Set @ Default") menu item operator sees
}
record(seq,"$(user):PS:ControlSQ") {
  field(SELM,"Mask")
  field(SELL,"$(user):PS:Control.RVAL NPP NMS")
  field(DLY1,"0")
  field(DOL1,"0")
  field(LNK1,"$(user):PS:setCurrent.VAL PP NMS")
  field(DLY2,"2")
  field(DOL2,"0")
  field(LNK2,"$(user):PS:pwrControl.VAL PP NMS")
  field(DLY3,"0")
  field(DOL3,"1")
  field(LNK3,"$(user):PS:pwrControl.VAL PP NMS")
  field(DLY4,"1")
  field(DOL4,"3.75")
  field(LNK4,"$(user):PS:setCurrent.VAL PP NMS")
}
```

Off

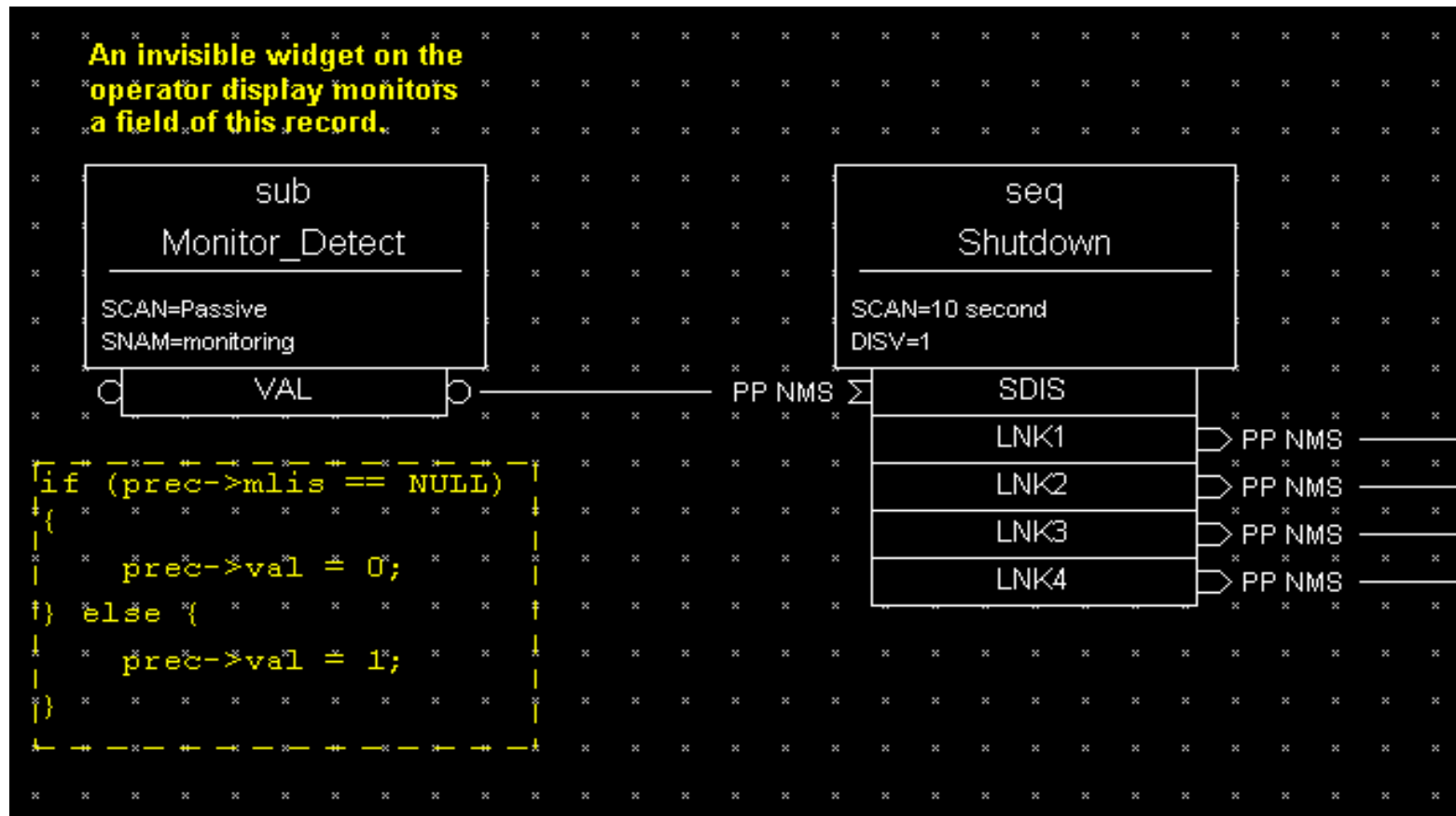
On

Set @ Default

Different links in the sequence record are executed for each selection of the mbbo. This allows much functionality to be specified in only two records.

Database Examples

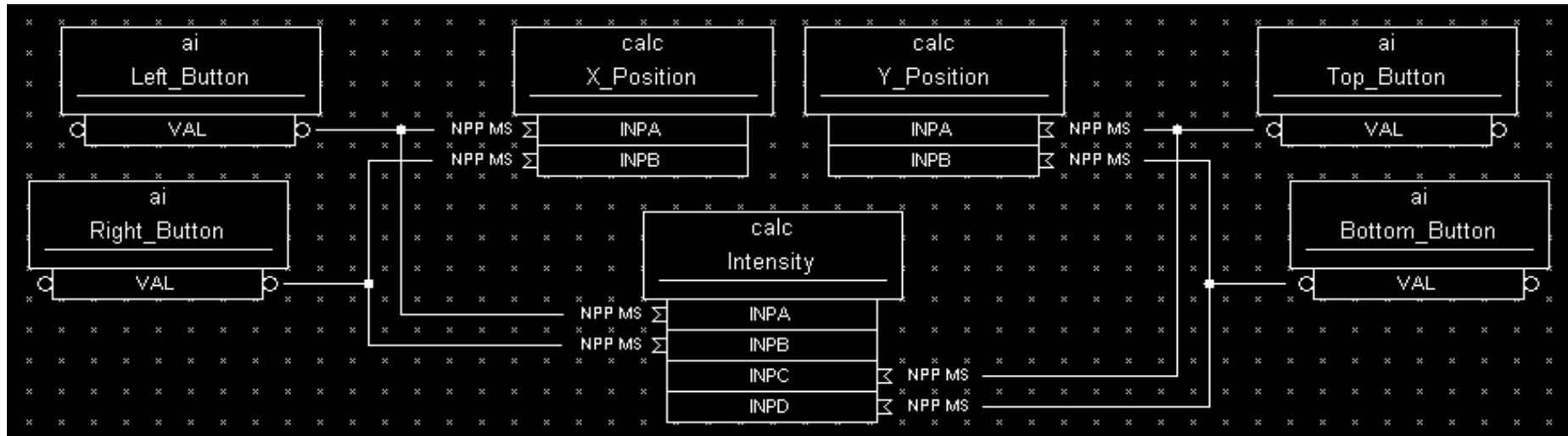
Automatic Shutdown on Logout



If no CA monitor exists on the SUB record (i.e. the operator logs out), MLIS will be NULL. The subroutine will then set the .VAL field to 0, causing the sequence record to process.

Database Examples

Quick Prototyping with Standard Records



Custom Record Definition

