EPICS Lecture @ KEK

Introduction Part II

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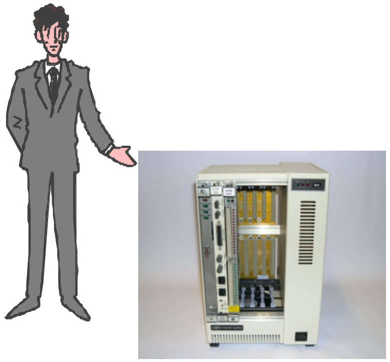
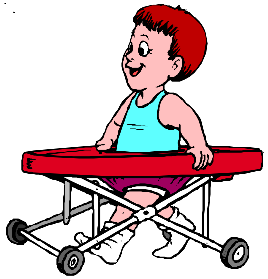
June 25th, 2013

Based on presentation by John Maclean, APS

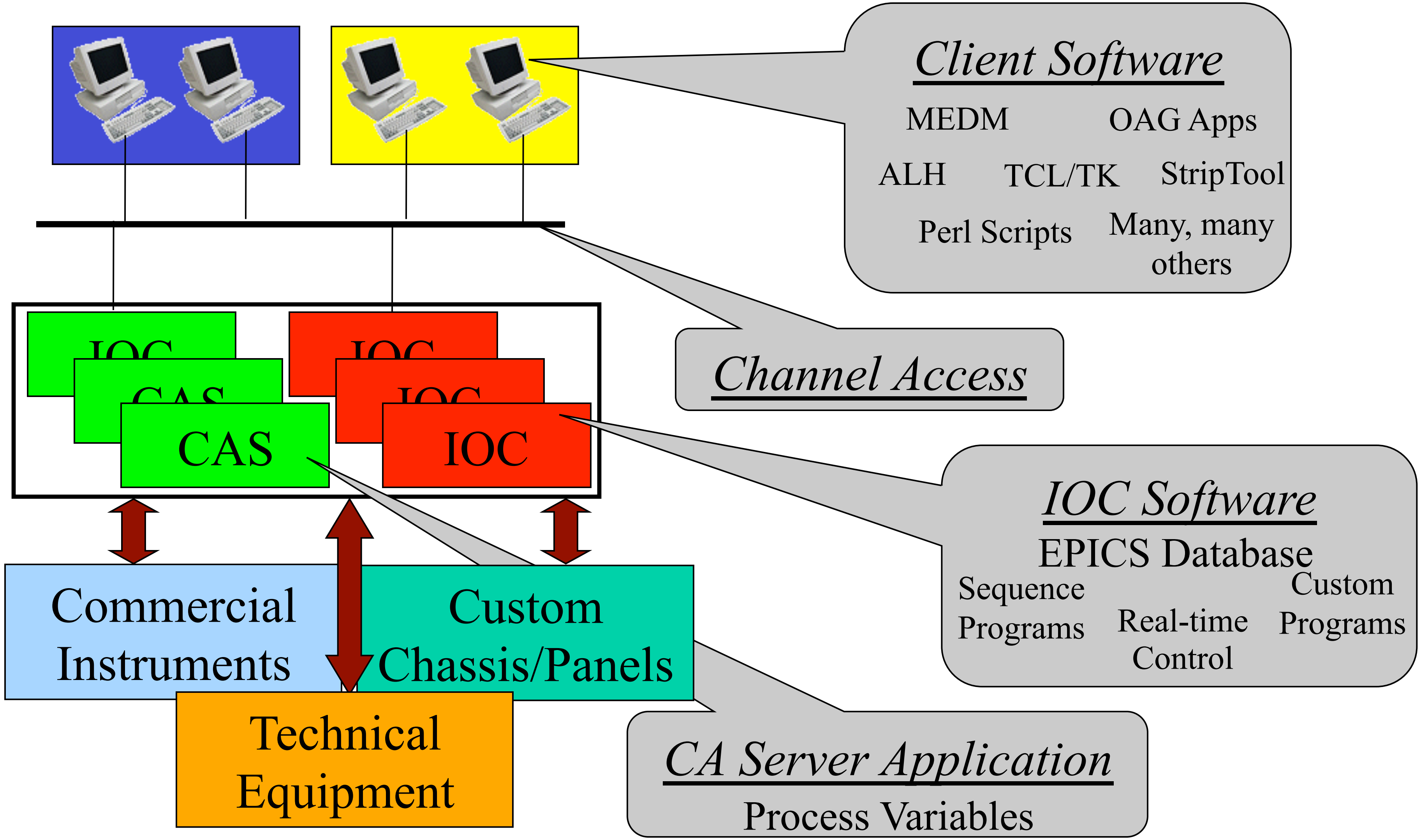
Overview

- **Lay the foundation for understanding an EPICS control system**
- **Introduce IOCs**
  - Channel Access (CA)
  - Database
  - Sequencer
  - Device Support
- **Choosing the correct tools for the job**
  - When to use a database
  - The sequencer, what is it good for?
  - Why write your own CA client program?
- **How fast is EPICS?**
- **How to find more information**
  - Website walk through





Canonical Form of an EPICS Control System

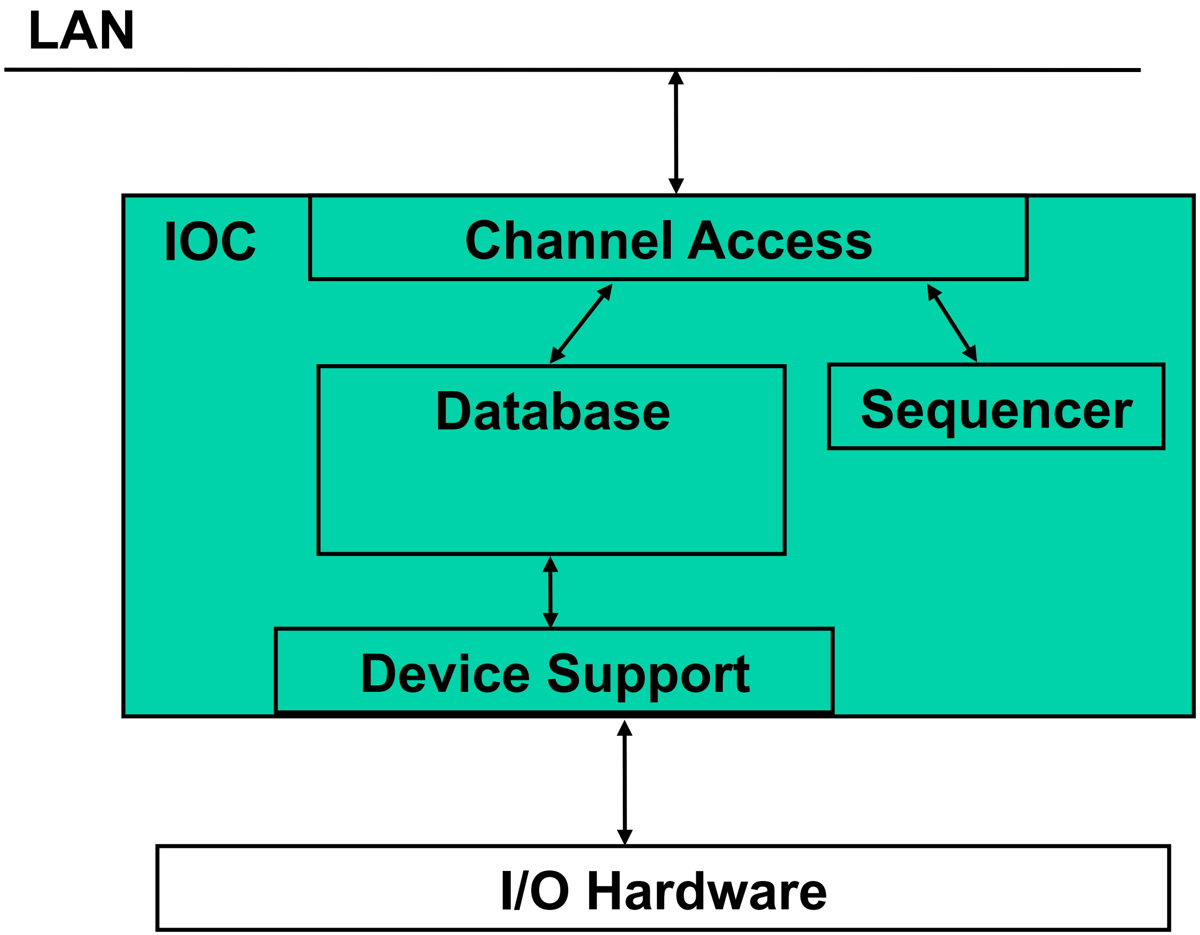


Introducing the IOC

- **Input Output Controller**
- **A computer running software called “*IOC Core*”**
- **The computer can be:**
  - VME based, running vxWorks (only choice until Release 3.14) or RTEMS
  - PC running Windows, Linux, RTEMS
  - Apple running OSX
  - UNIX Workstation running Solaris
- **Usually has Input and/or Output devices attached**
- **An EPICS control system must consist of at least one Channel Access Server (usually an IOC)**
- **An IOC has one or more *databases* loaded. The database tells it what to do**

Inside an IOC

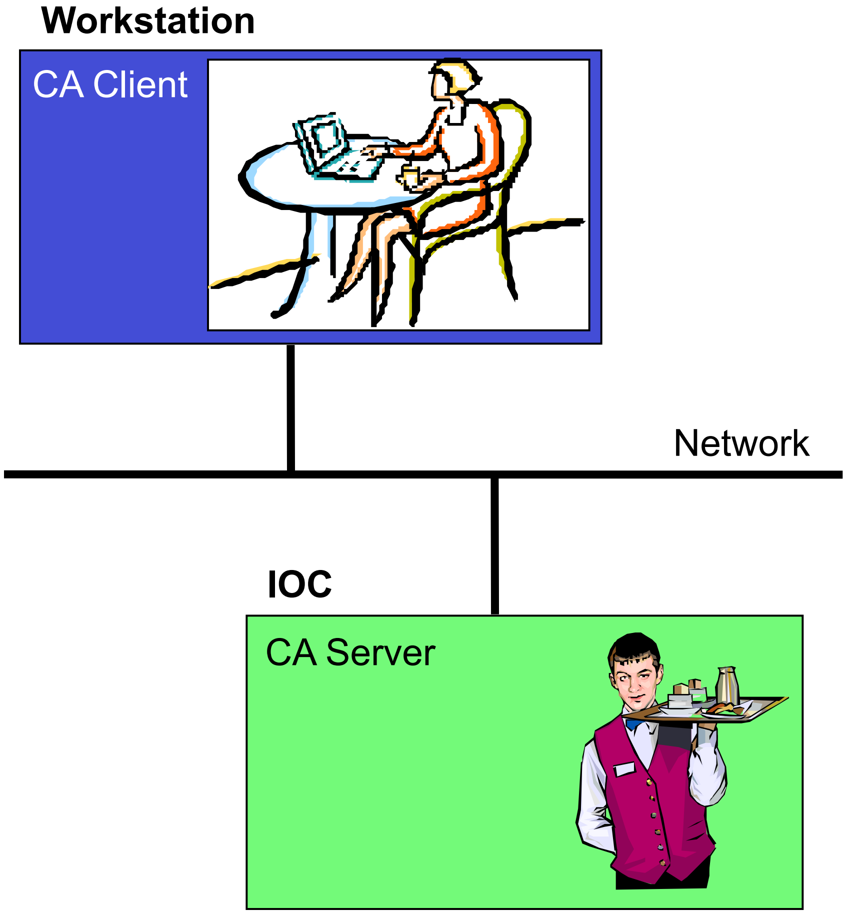
The major software components of an IOC (IOC Core)



Channel Access

- **Allows other programs (CA Clients) to see and change values of Process Variables in an IOC (CA Server)**
- **CA Clients may**
  - Put (write)
  - Get (read)
  - Monitor

  data of Process Variables
- **IOCs are both CA clients and CA servers. They can interact with data in other IOCs**
- **A CA Client can connect to many servers**
- **A CA Server may serve many clients**
- **A very efficient an reliable protocol**



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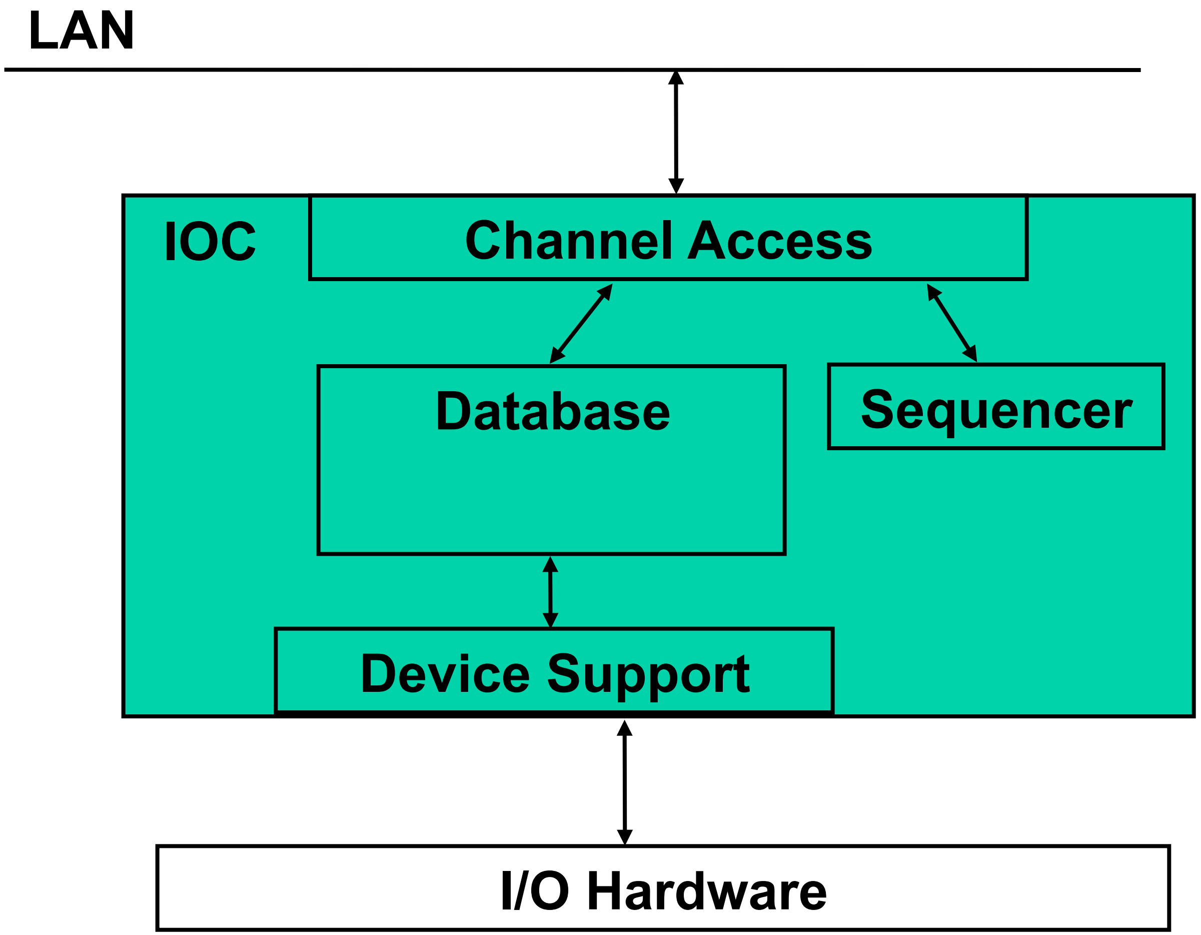
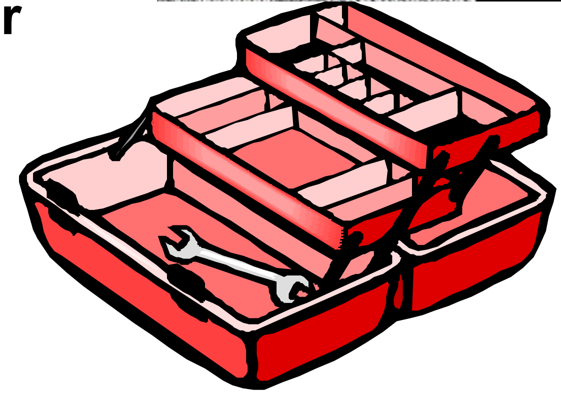
The major software components of an IOC (IOC Core)



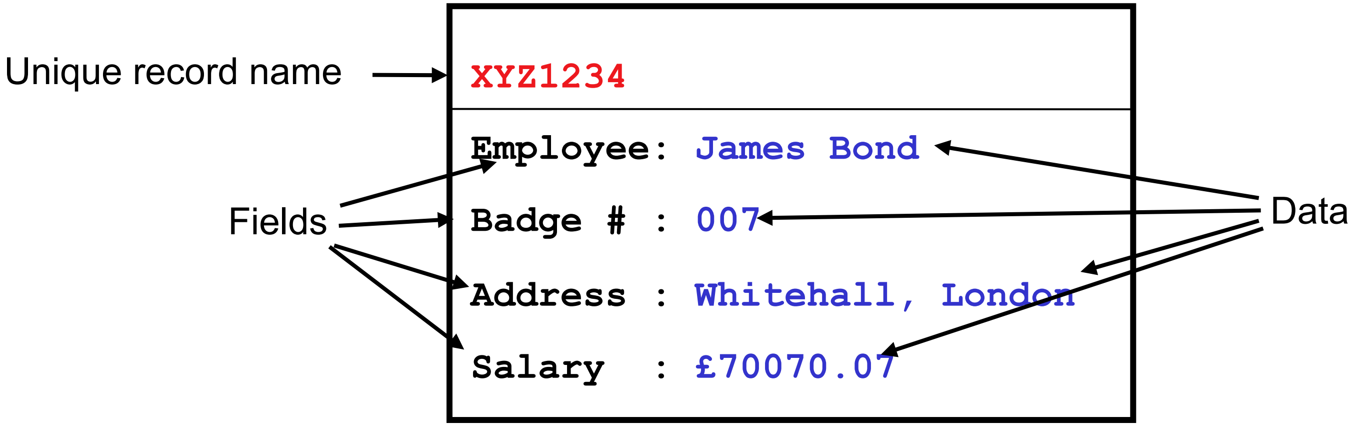
EPICS Databases – What are they for?

- Interface to process instrumentation
- Distribute processing
- Provide external access to all process information
- Use common, proven, objects (records) to collect, process and distribute data
- Provide a common toolkit for creating applications



What are records?

- **A record is an object with**
  - A unique name
  - Properties (fields) that contain information (data)
  - The ability to perform actions on that data
- **A personnel record in a relational database has a name, and fields containing data**



Unique record name

XYZ1234

Employee: James Bond

Badge # : 007

Address : Whitehall, London

Salary : £70070.07

Fields

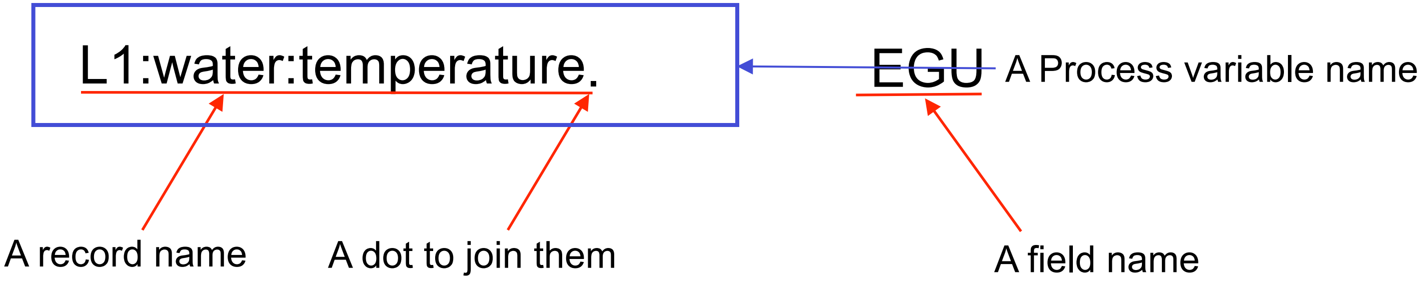
Data

What are EPICS records?

- **A record is an object with…**
  - A unique name e.g. ***S28:waterPressure***
  - Controllable properties (fields) e.g. ***EGU***
  - A behavior - defined by its record type
  - Optional associated hardware I/O (device support)
  - Links to other records
- **Each field can be accessed individually by name**
- **A record name and field name combined give a the name of a process variable (PV)**
- **A Process Variable name is what Channel Access needs to access data**

A Process Variable name

- **A PV name is comprised of two parts**
  - The record name, and
  - A the name of a field belonging to that record
- **For example…**



L1:water:temperature.

EGU

A Process variable name

A record name

A dot to join them

A field name

- **Note that if no field name is given, Channel Access will default to using the .VAL field**

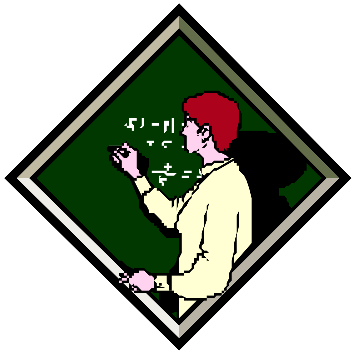
- **i.e. to CA, “`L1:water:temperature`” = “`L1:water:temperature.VAL`”**

What do records do?

- **Records are active, they do things**
    - Get data from other records or from hardware
    - Perform calculations
    - Check values are in range and 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 type and the values in its fields**
- **A wide range of records have already been created**
- **New record types can be added to a new application as needed**
- **A record does nothing until it is *processed***

Record types

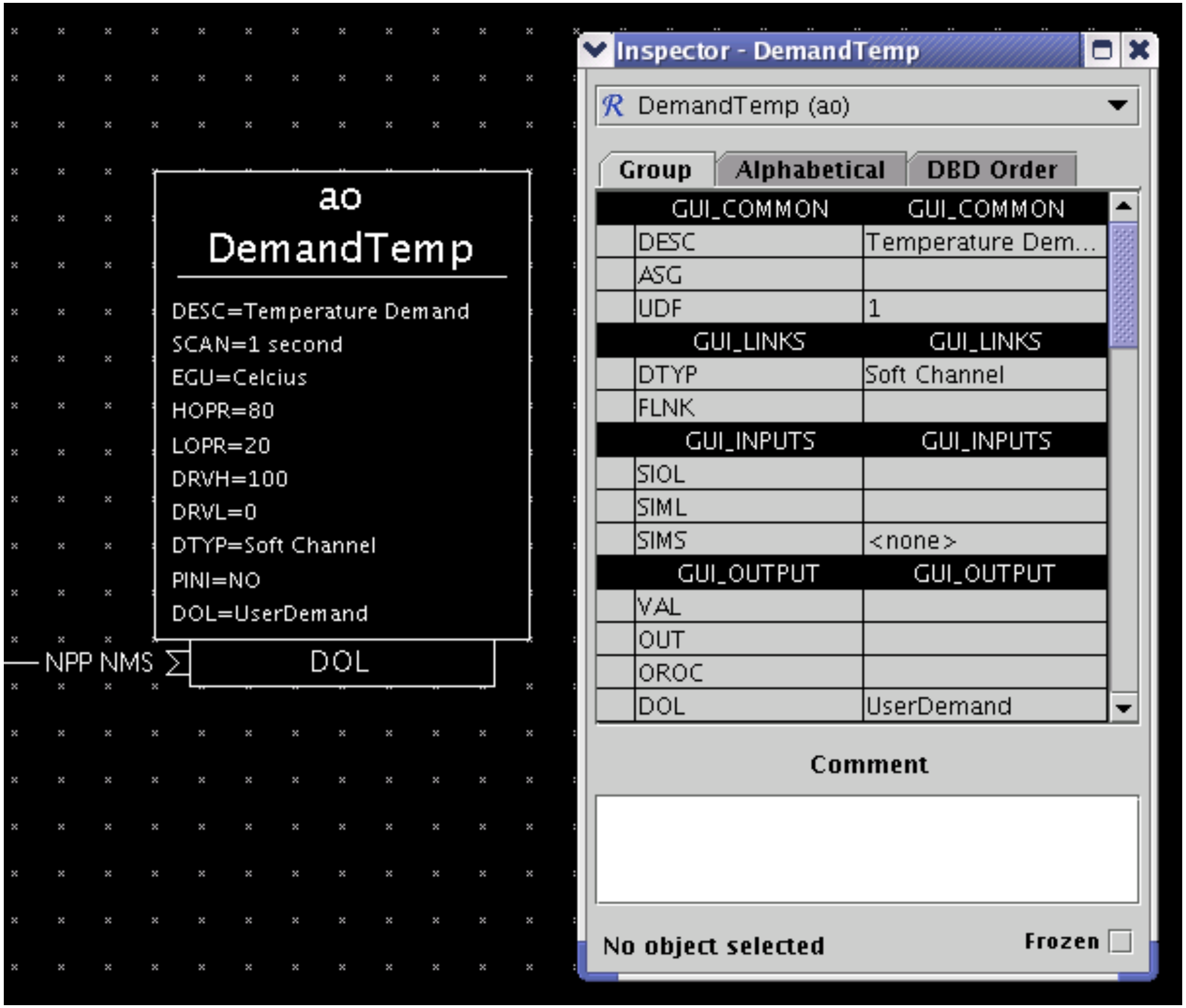
- **Classified into four general types**
- **Input: e.g.**
  - Analog In (AI)
  - Binary In (BI)
  - String In (SI)
- **Algorithm/control: e.g.**
  - Calculation (CALC)
  - Subroutine (SUB)
- **Output: e.g.**
  - Analog Out (AO)
  - Binary Out (BO)
- **Custom: e.g.**
  - Beam Position Monitor
  - Multi Channel Analyzer



Some record types

- Analog in
- Analog out
- Binary in
- Binary out
- Calculation
- Calculation out
- Compression
- Data fanout
- Event
- Fanout
- Histogram
- Motor
- Multi bit binary input
- Multi bit binary output
- PID control
- Pulse counter
- Pulse delay
- Scan
- Select
- Sequence
- String in
- String out
- Subarray
- Subroutine
- Waveform

Graphical view of a record



DESC=Temperature Demand
SCAN=1 second
EGU=Celcius
HOPR=80
LOPR=20
DRVH=100
DRVL=0
DTYP=Soft Channel
PINI=NO
DOL=UserDemand

GUI_COMMON	GUI_COMMON
DESC	Temperature Dem...
ASG	
UDF	1
GUI_LINKS	**GUI_LINKS**
DTYP	Soft Channel
FLNK	
GUI_INPUTS	**GUI_INPUTS**
SIOL	
SIML	
SIMS	<none>
GUI_OUTPUT	**GUI_OUTPUT**
VAL	
OUT	
OROC	
DOL	UserDemand

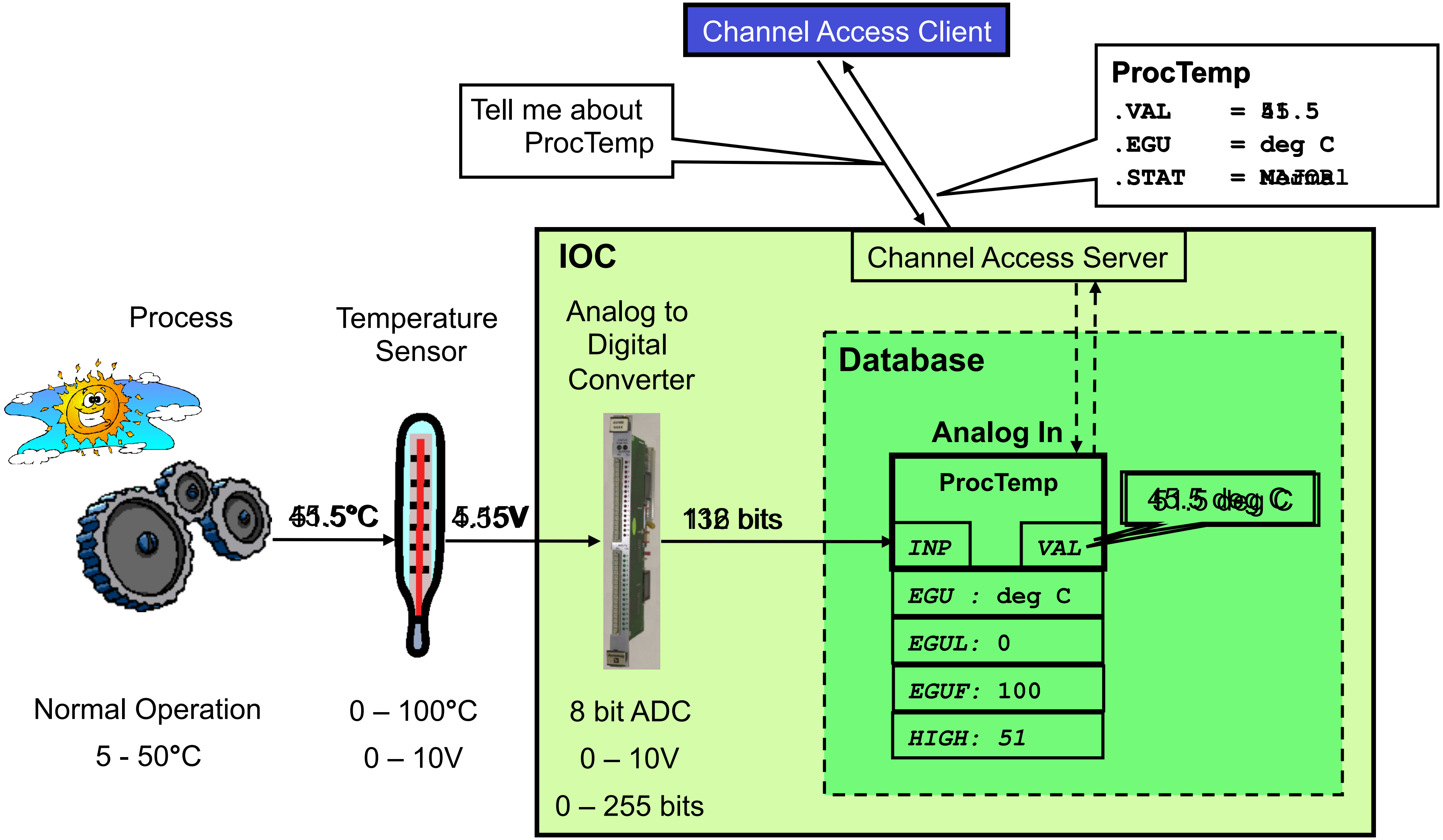
IOC view of a record

```
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")⌉
}
```

EPICS Databases – What are they?

- A collection of one or more EPICS *records* of various types
- Records can be interconnected and are used as building blocks to create applications
- A data file that’s loaded into IOC memory at boot time
- Channel access talks to the IOC memory copy of the database

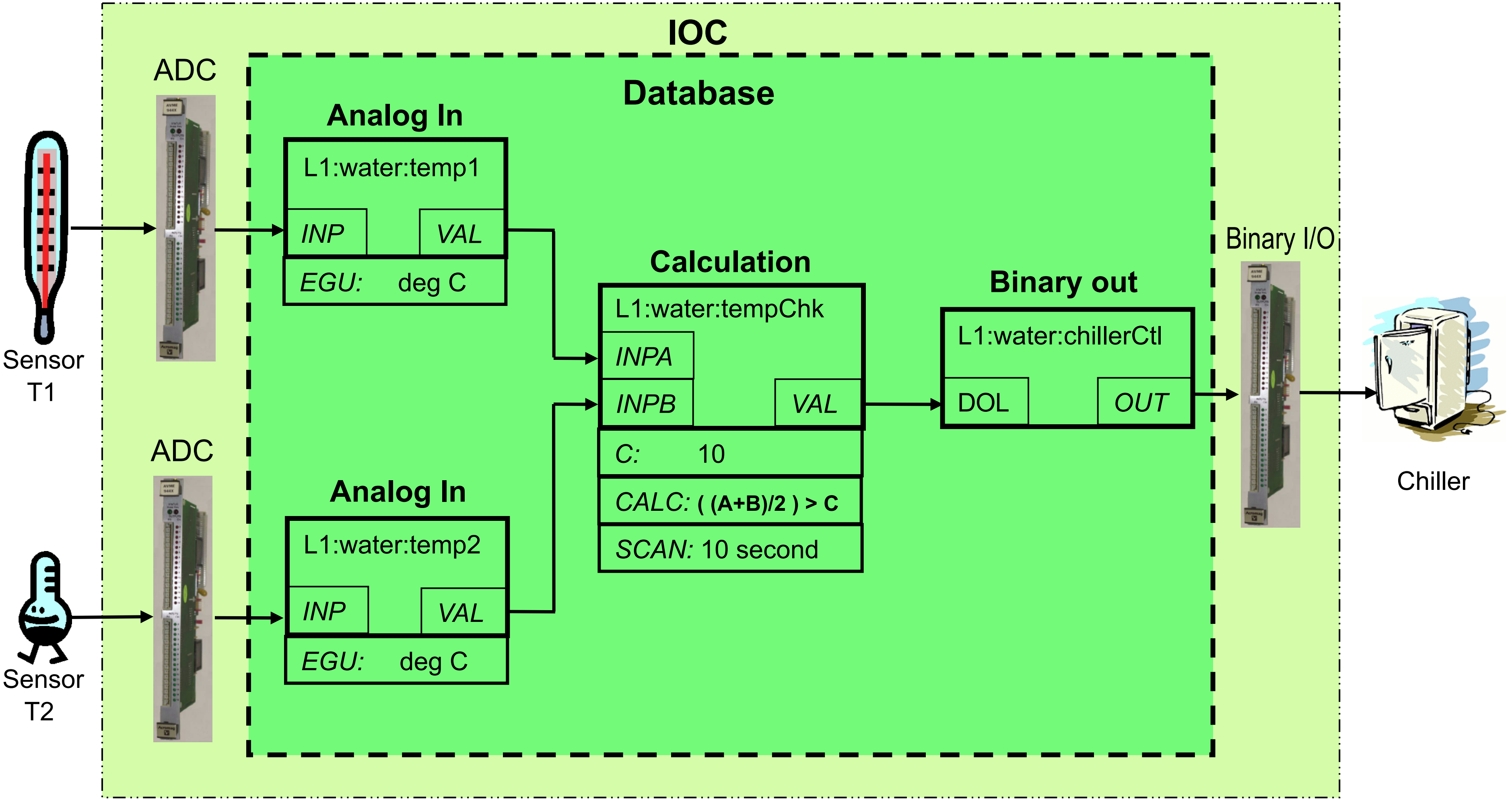
Our First Database



Record Processing

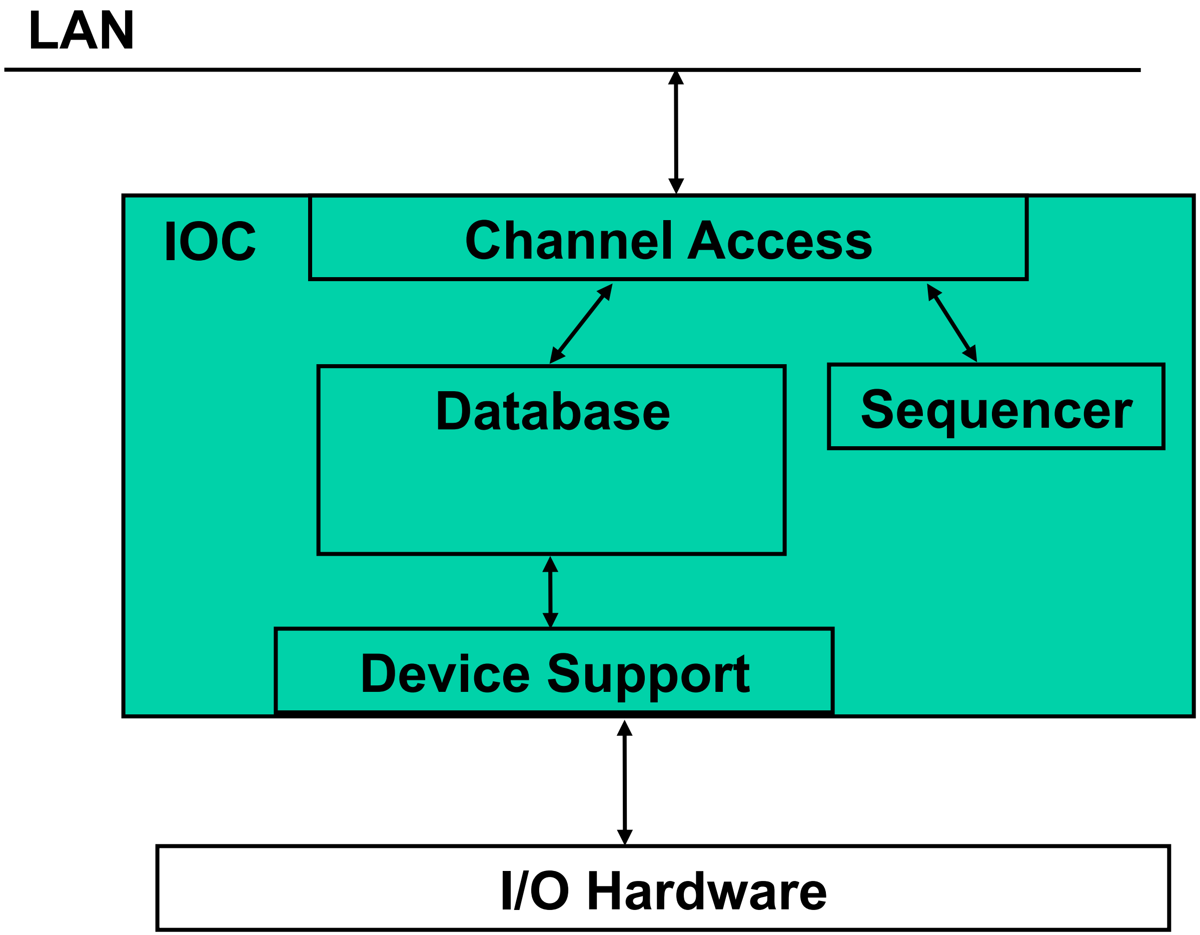
- **Record processing can be periodic or event driven**
- **Periodic: Standard scan rates are…**
  - 10, 5, 2, 1, 0.5, 0.2 and 0.1 seconds
  - Custom scan rates can be configured up to speeds allowed by operating system and hardware
- **Event driven: Events include**
  - Hardware interrupts
  - Request from another record via links
  - EPICS Events
  - Channel Access Puts

Database Processing



Inside an IOC

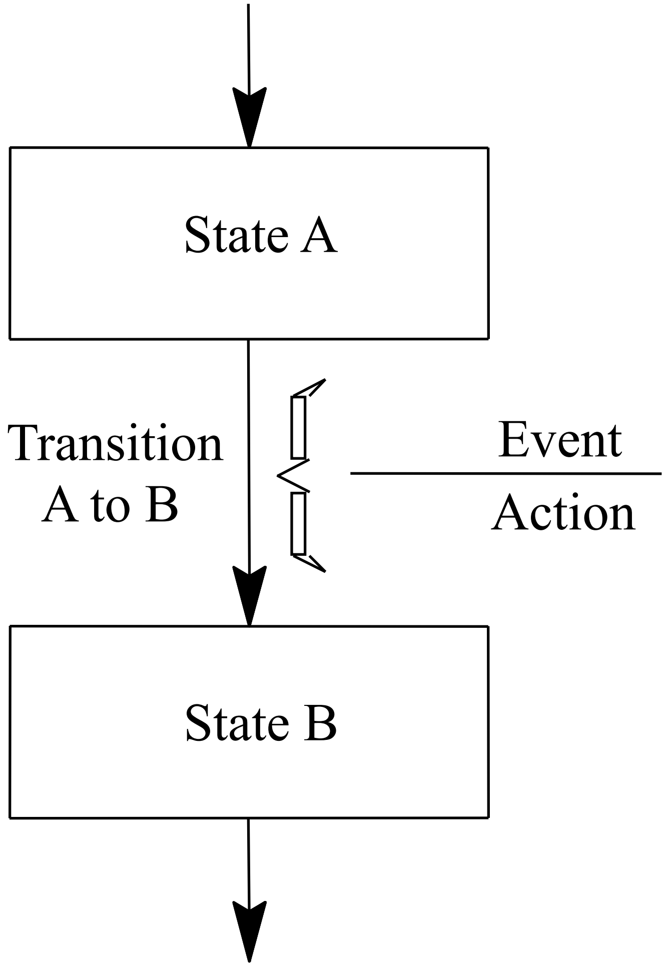
The major software components of an IOC (IOC Core)



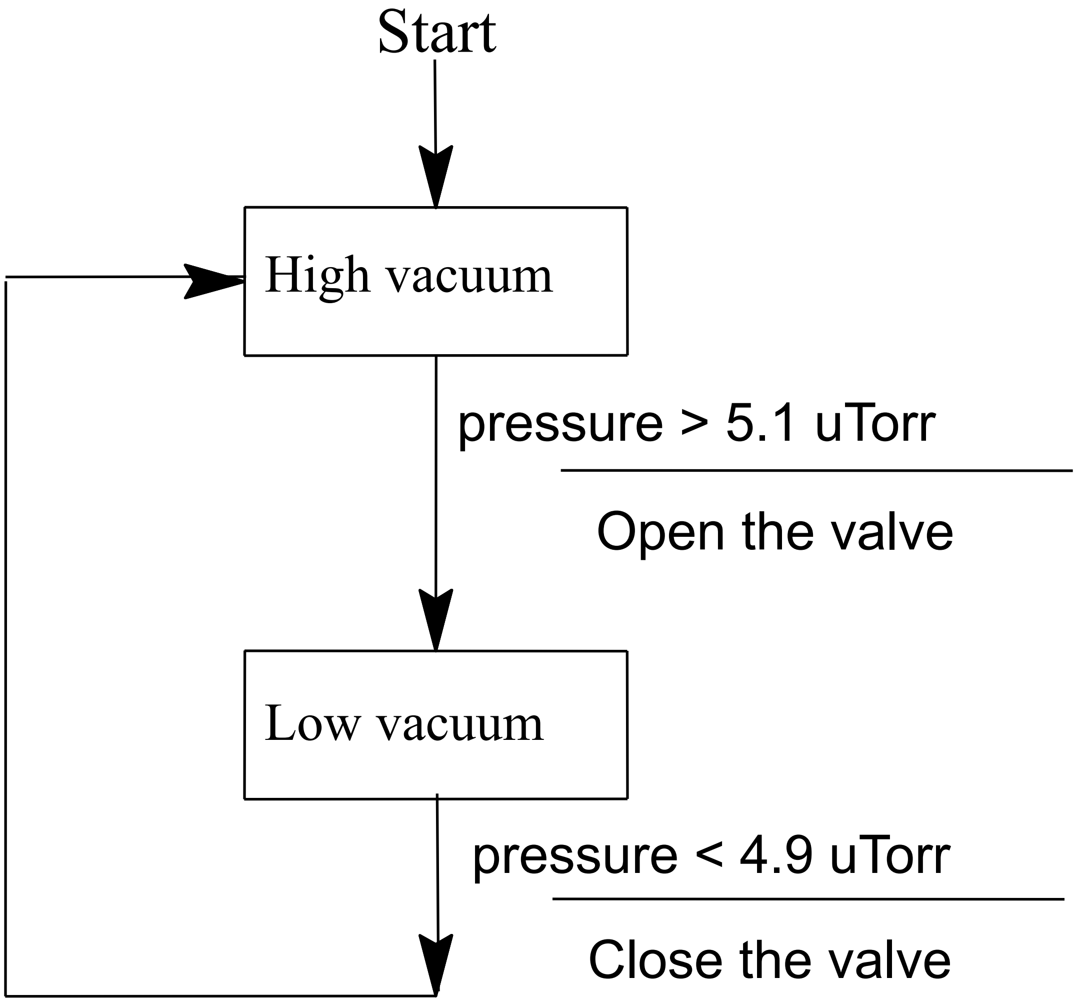
The Sequencer

- Runs programs written in State Notation Language (SNL)
- SNL is a ‘C’ like language to facilitate programming of sequential operations
- Fast execution - compiled code
- Programming interface to extend EPICS in the real-time environment
- Common uses
  - Provide automated start-up sequences like vacuum or RF where subsystems need coordination
  - Provide fault recovery or transition to a safe state
  - Provide automatic calibration of equipment

SNL implements State Transition Diagrams



STD Example



Start

High vacuum

pressure > 5.1 uTorr

Open the valve

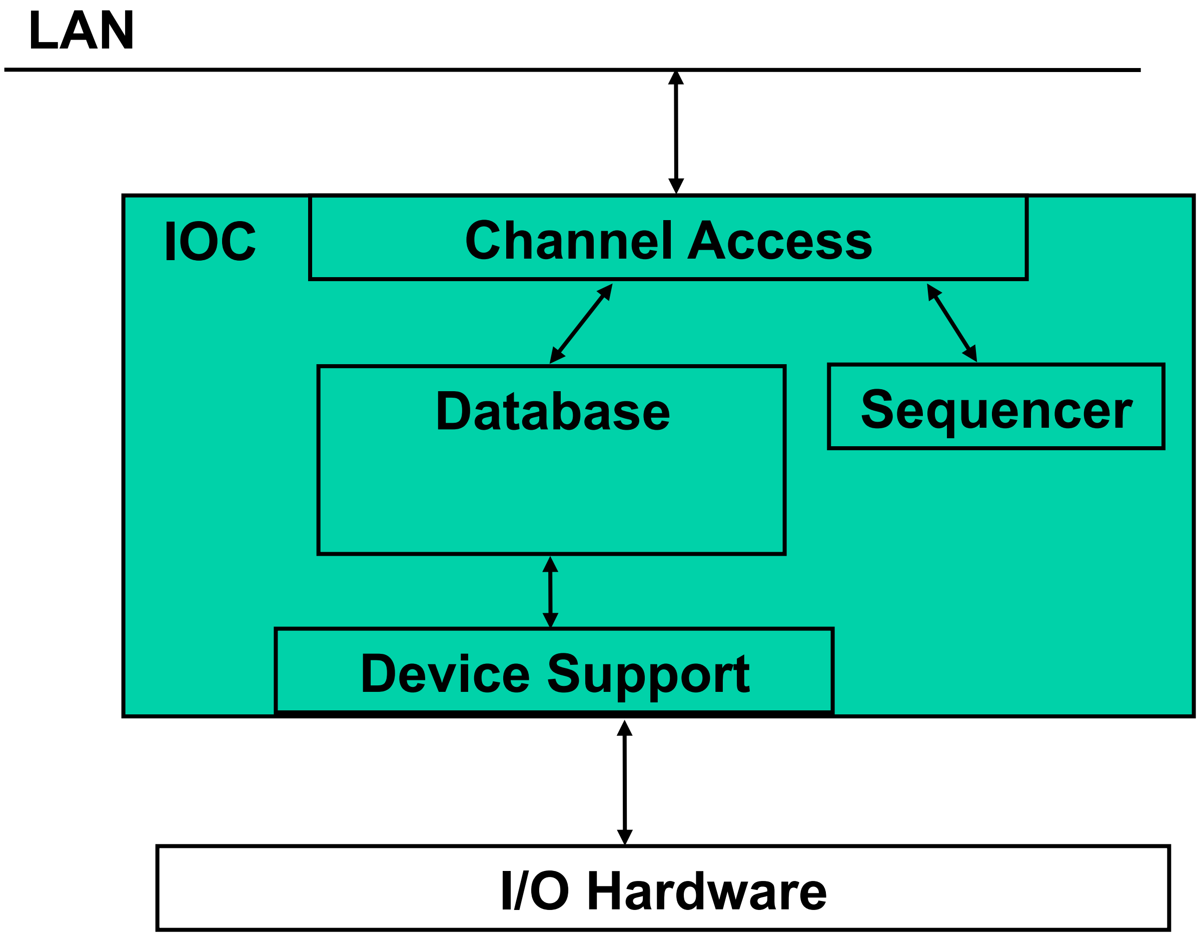
Low vacuum

pressure < 4.9 uTorr

Close the valve

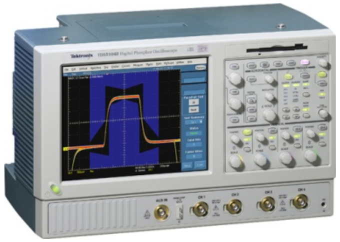
Inside an IOC

The major software components of an IOC (IOC Core)



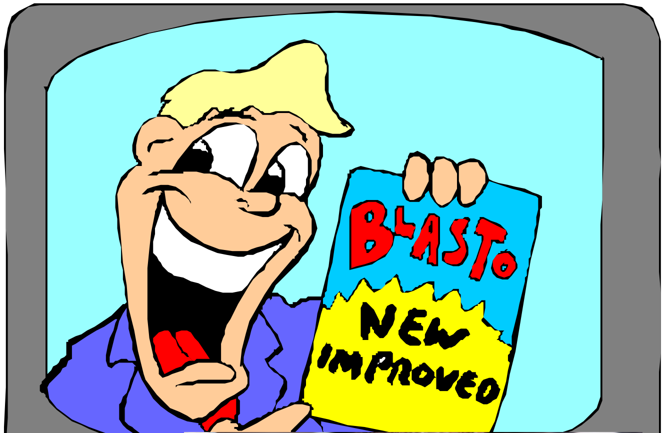
Device Support

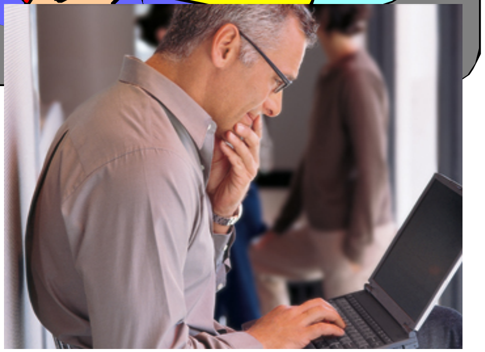
- Device and driver support interface hardware to the database
- Examples of devices….
- VME cards: ADC, DAC, Binary I/O e.t.c.
- Motor controllers
- Oscilloscopes
- PLCs



Device Support

- Usually has to be written for 'new' hardware
- Good news – someone, somewhere has usually written support for your device, or a very similar one before
- See the EPICS web site for available support
- Or ask the EPICS community





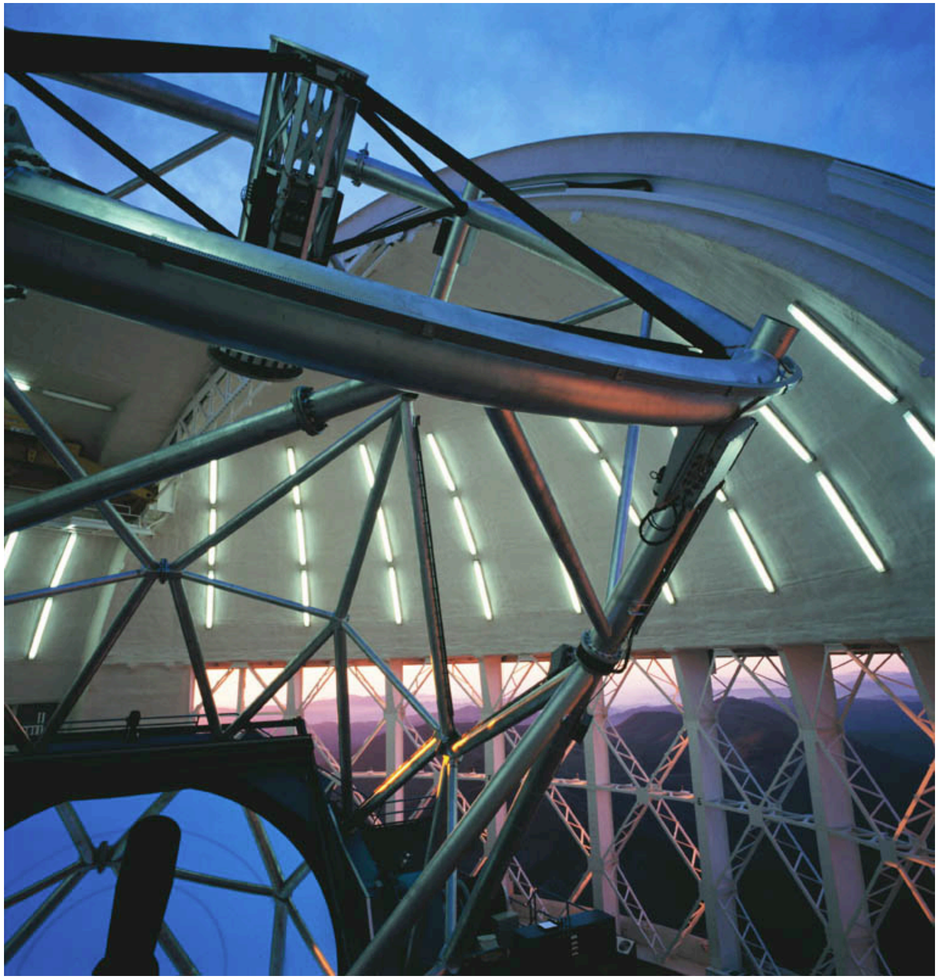
When to use databases

- Hardware connection
- Real time performance – no network latencies
- Whenever a database is good enough

Advantages	Disadvantages
Simplify hardware connection	If you have device support
Configuring not programming.	You need to understand database use
Database is easily understood by other EPICS developers	
Speed - All processing (often) in same machine	

When to use the sequencer

- For sequencing complex events
- E.g. Parking and unparking a telescope mirror



Photograph courtesy of the Gemini Telescopes project

When to use clients

- To interact with the control system
- Many already exist – MEDM, ALH, Strip Tool, archiver etc.
- For data analysis or visualization
- Supervisory control
- E.g. to manage an accelerator

How fast is EPICS?

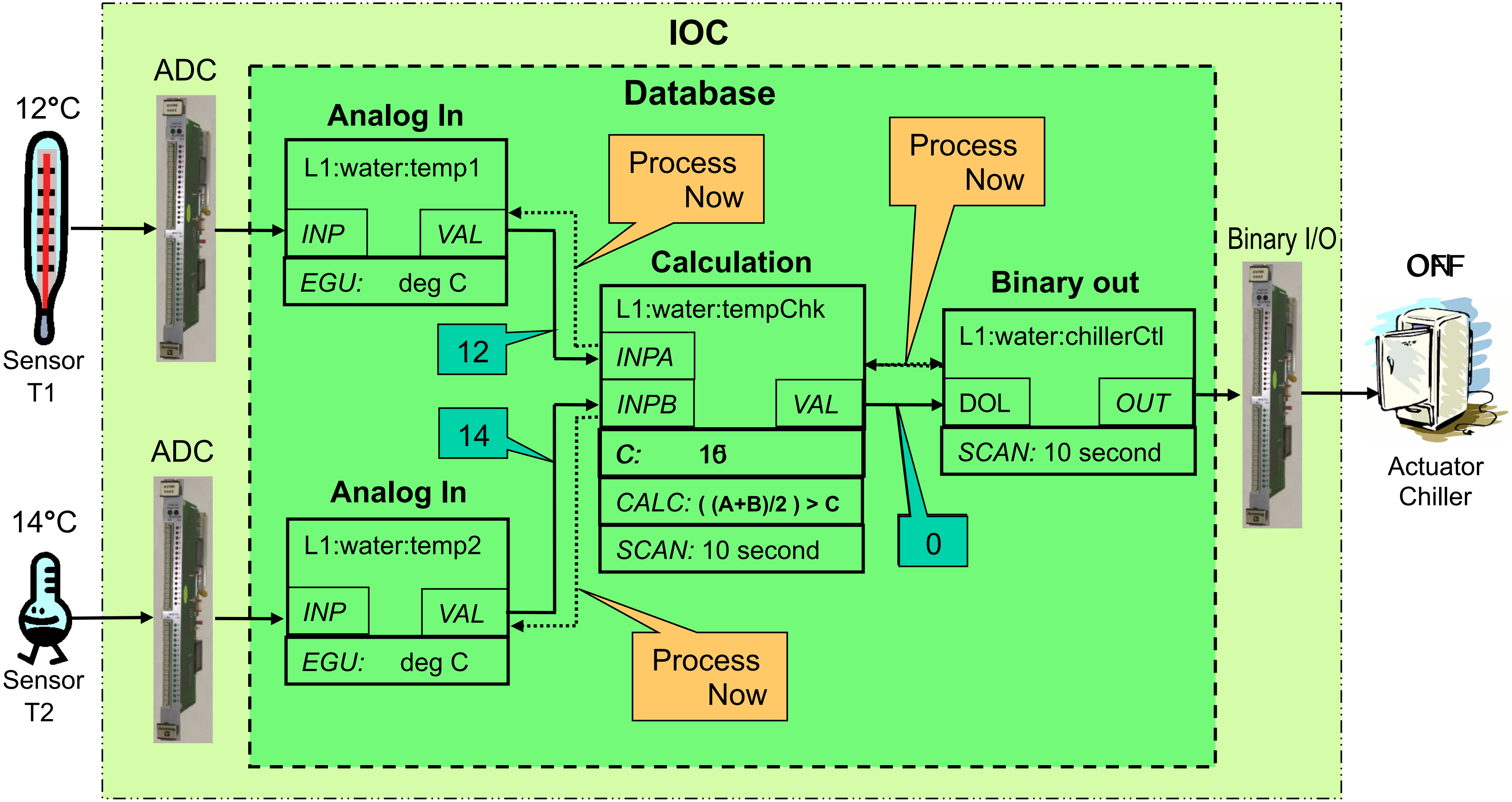
- Can be fast or slow, it depends how you use it!
- Use the correct tool for the job; Database, sequencer, custom code (ioc) or custom code (client)
- Ultimately speed depends upon hardware
- Some (a bit old) benchmarks*:

Machine	OS	CPU	Speed	Rec/sec	%CPU
MVME167	vxWorks	68040	33MHz	6000	50
MVME 2306	vxWorks	PPC604	300MHz	10000	10
MVME5100	vxWorks	PPC750	450MHz	40000**	10**
PC	Linux	PII	233MHz	10000	27
PC	Linux	P4	2.4GHz	50000	9

*Benchmark figures courtesy of Steve Hunt (PSI)
**Extrapolated from performance figures provided by L.Hoff, BNL

- Database design and periodic scanning effect *apparent* system speed

Apparent performance



IOC

Database

12°C

Sensor T1

14°C

Sensor T2

ADC

ADC

Analog In

L1:water:temp1

INP

VAL

EGU: deg C

Analog In

L1:water:temp2

INP

VAL

EGU: deg C

12

14

Process Now

Process Now

Process Now

Calculation

L1:water:tempChk

INPA

INPB

VAL

C: 16

CALC: ((A+B)/2) > C

SCAN: 10 second

0

Binary out

L1:water:chillerCtl

DOL

OUT

SCAN: 10 second

Binary I/O

ONF

Actuator Chiller

The EPICS web site

- **The central site for EPICS information**
- **Documentation**
  - Application Developers's Guide
  - Record Reference Manual
- **CA Clients**
- **Device support**
- **Tech-talk**
- **http://www.aps.anl.gov/epics**

Review

- Input Output Controllers are a fundamental part of an EPICS control system
- The database is the primary means of telling an IOC what to do
- An EPICS database is composed of records configured to perform an application
- Channel Access is a means for other computers to communicate with record fields
- Sequencer programs can be used to sequence complex operations
- Device support software allows records to interact with hardware inputs and outputs
- EPICS is fast and efficient but can appear slow if used without consideration

Acknowledgements

- Andrew Johnson (APS-Controls)
- John Maclean (APS-Controls)
- Bob Dalesio (LANL)
- Deb Kerstiens (LANL)
- Rozelle Wright (LANL)