Introduction to EPICS

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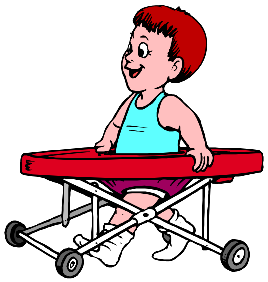
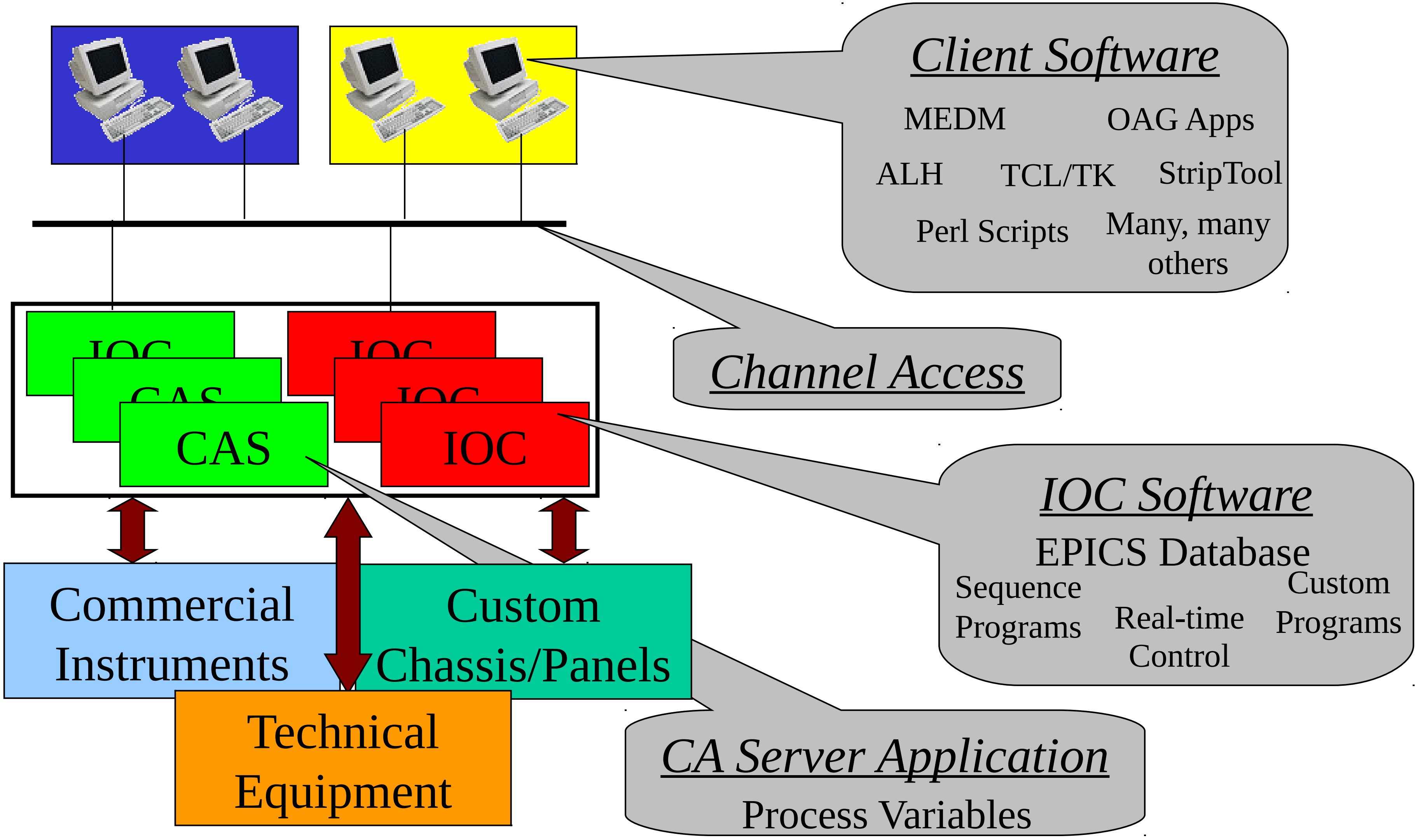
Overview

- 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?



Canonical Form of an EPICS Control System



Client Software

MEDM
OAG Apps
ALH
TCL/TK
StripTool
Perl Scripts
Many, many others

Channel Access

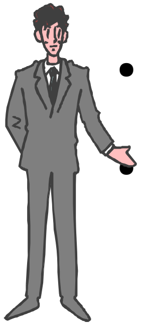
IOC Software

EPICS Database
Sequence Programs
Real-time Control
Custom Programs

CA Server Application

Process Variables

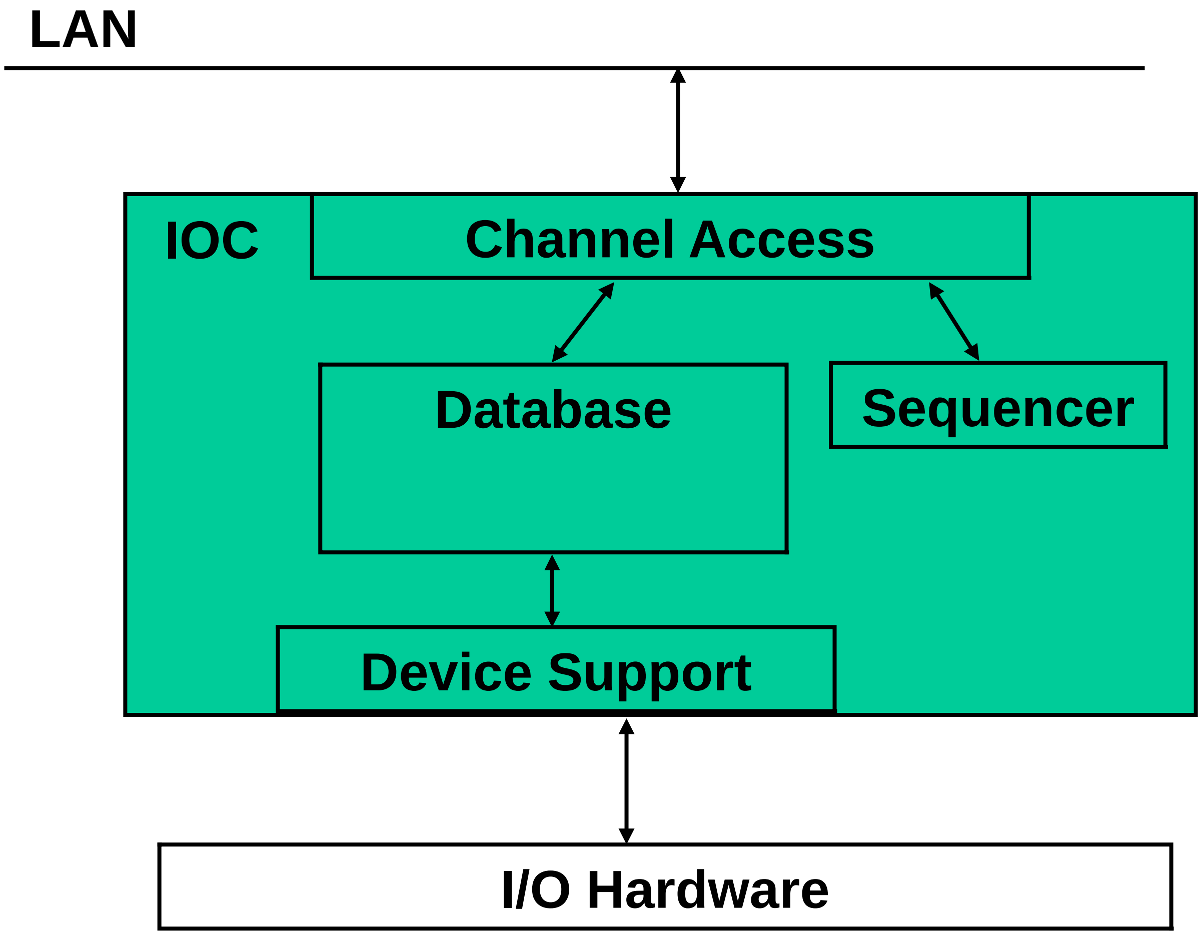
Introducing the IOC



- Input Output Controller
- A computer running software called “IOC Core”
- The computer can be:
  - VME based, running vxWorks, RTEMS, Linux
  - PC running Windows, Linux, RTEMS
  - Mac running OSX
  - Embedded processor running RTEMS, Linux
- 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

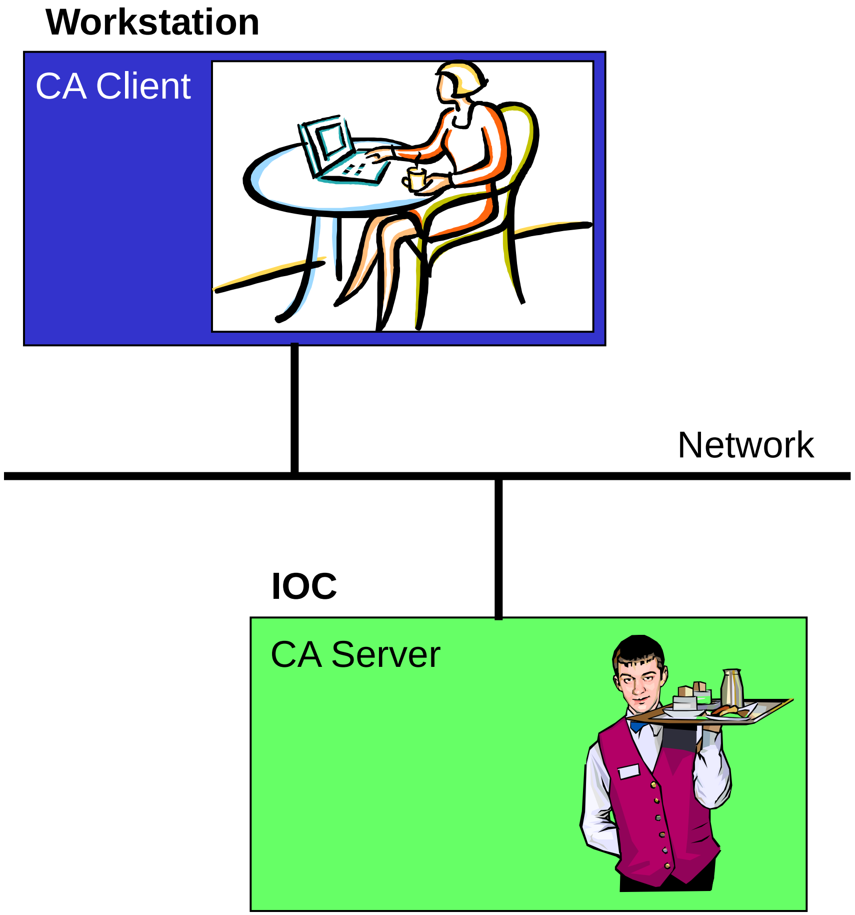
The major software components of an IOC (IOC Core)



Channel Access

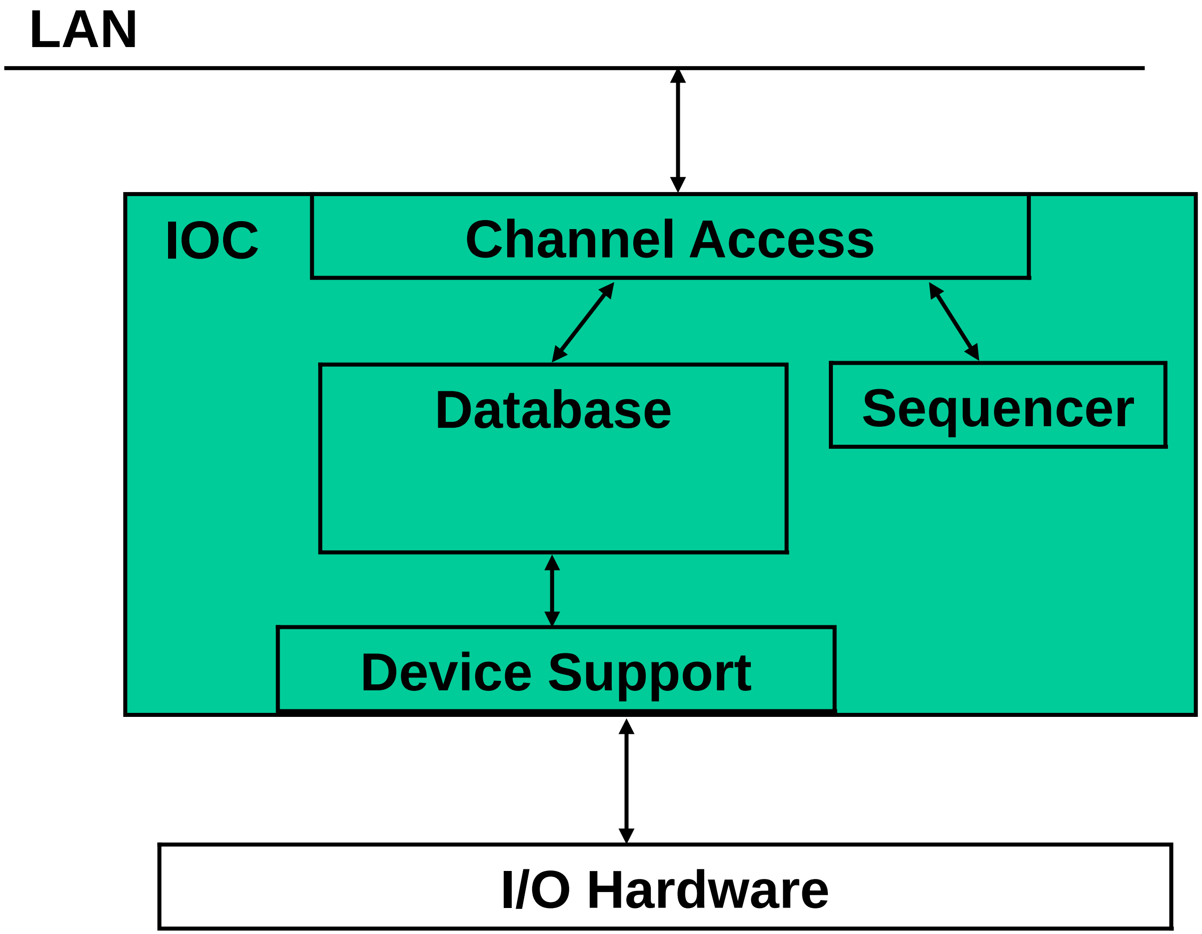
- Allows other programs (CA Clients) to see and change values of Process Variables in an IOC (CA Server)
- CA Clients may
  - Put (write)
  - Get (read)
  - Monitor

  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



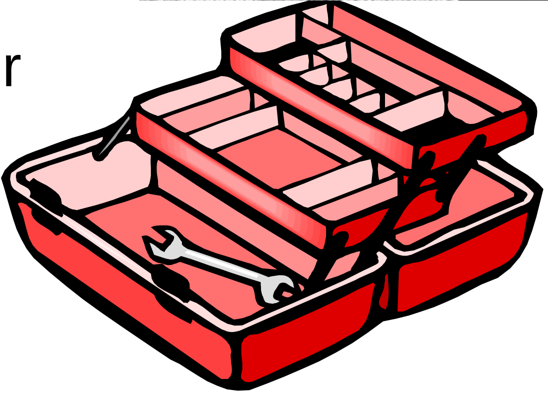
Inside an IOC

The major software components of an IOC (IOC Core)



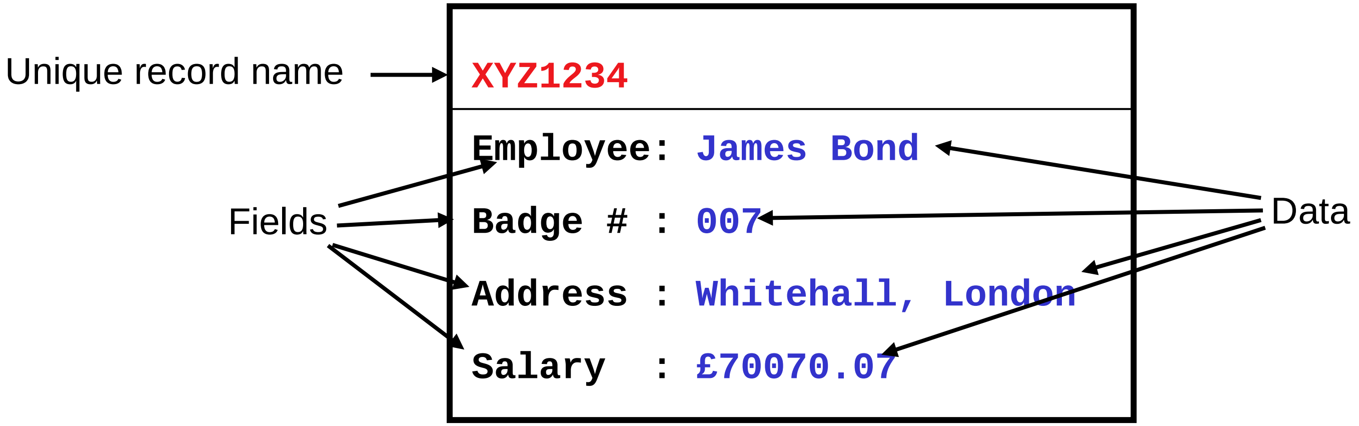
EPICS Databases – What are they for?

- 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

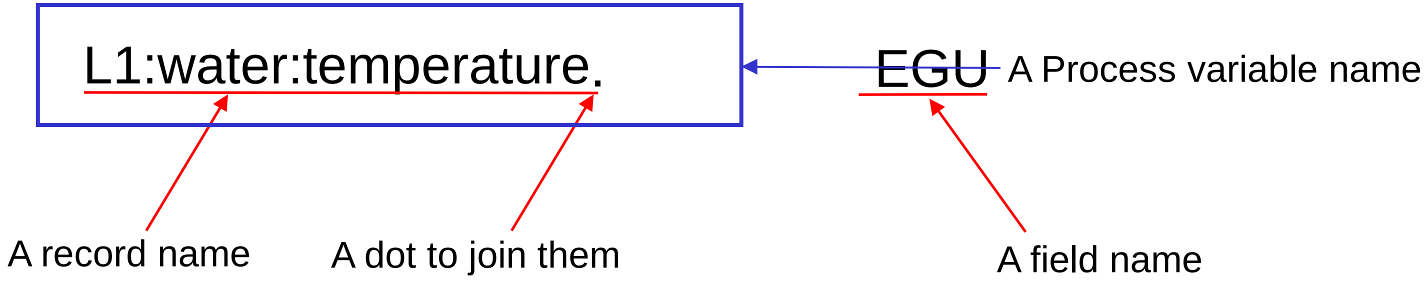
Data

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

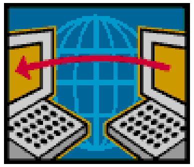
A record name

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?

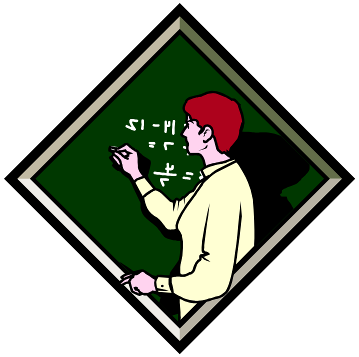


- Records are active, they do things
  - Get data from other records or from hardware
  - Perform calculations
  - Check values are in range and raise alarms
  - Put data to other records or to hardware
  - Activate or disable other records
  - Wait for hardware signals (interrupts)

- 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

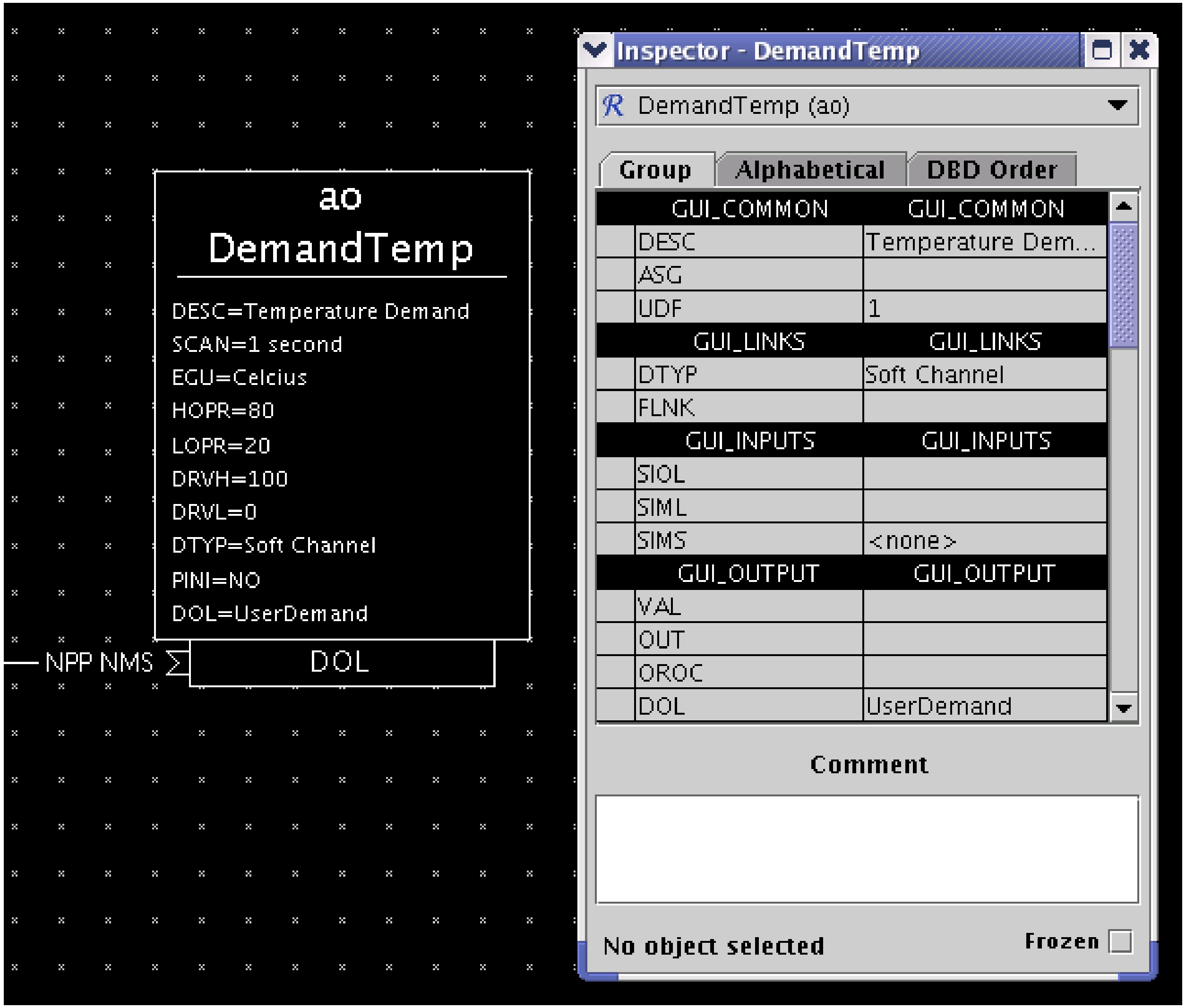
- Classified into four general types
- Input: e.g.
  - Analog In (AI)
  - Binary In (BI)
  - String In (SI)
- Algorithm/control: e.g.
  - Calculation (CALC)
  - Subroutine (SUB)
- Output: e.g.
  - Analog Out (AO)
  - Binary Out (BO)
- Custom: e.g.
  - Beam Position Monitor
  - Multi Channel Analyzer



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



ao
DemandTemp

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

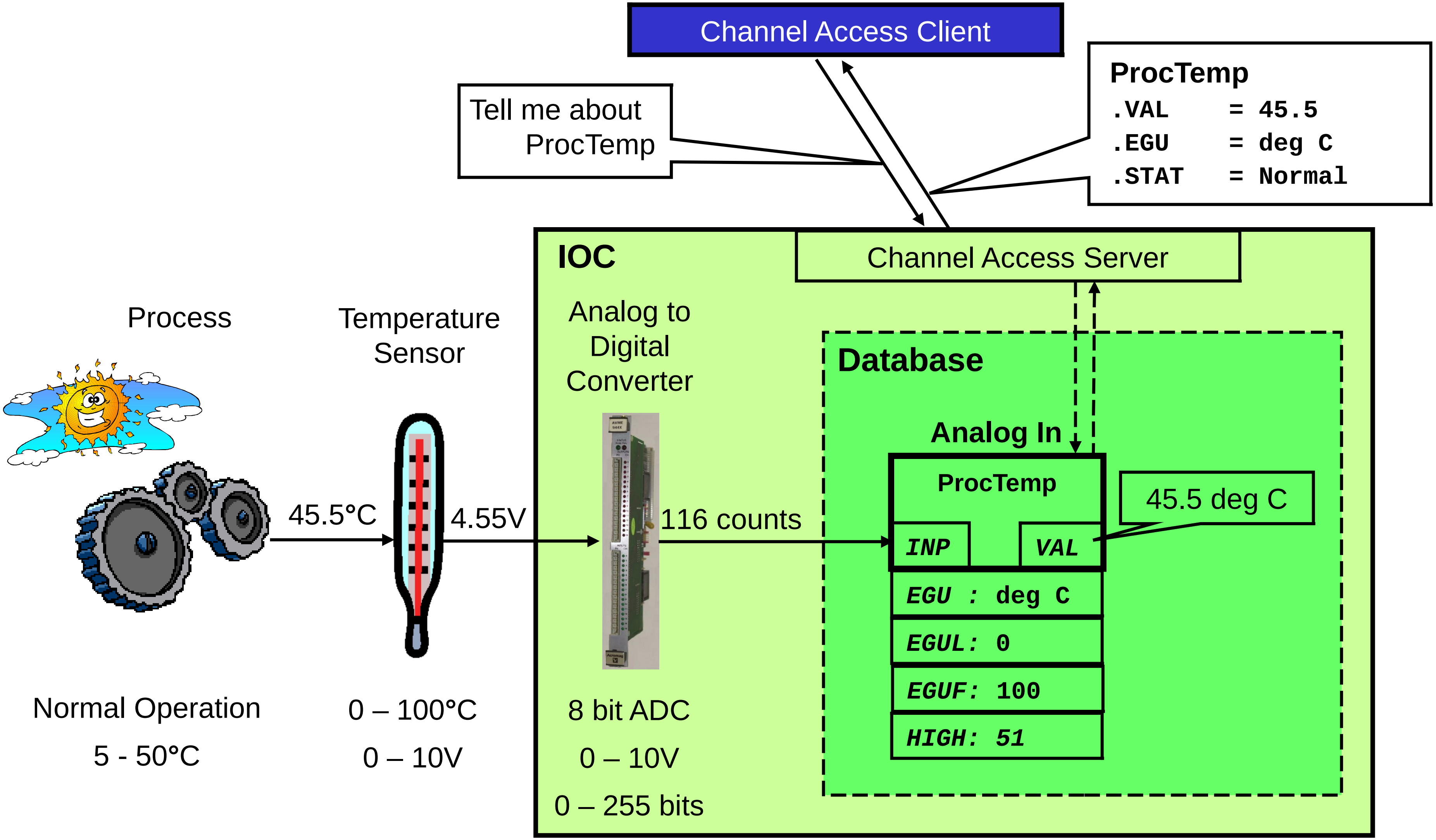
IOC view of a record

```
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?

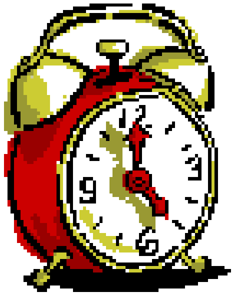
- A collection of one or more EPICS *records* of various types
- Records can be interconnected and are used as building blocks to create applications
- A data file that’s loaded into IOC memory at boot time
- Channel access talks to the IOC memory copy of the database

Our First Database

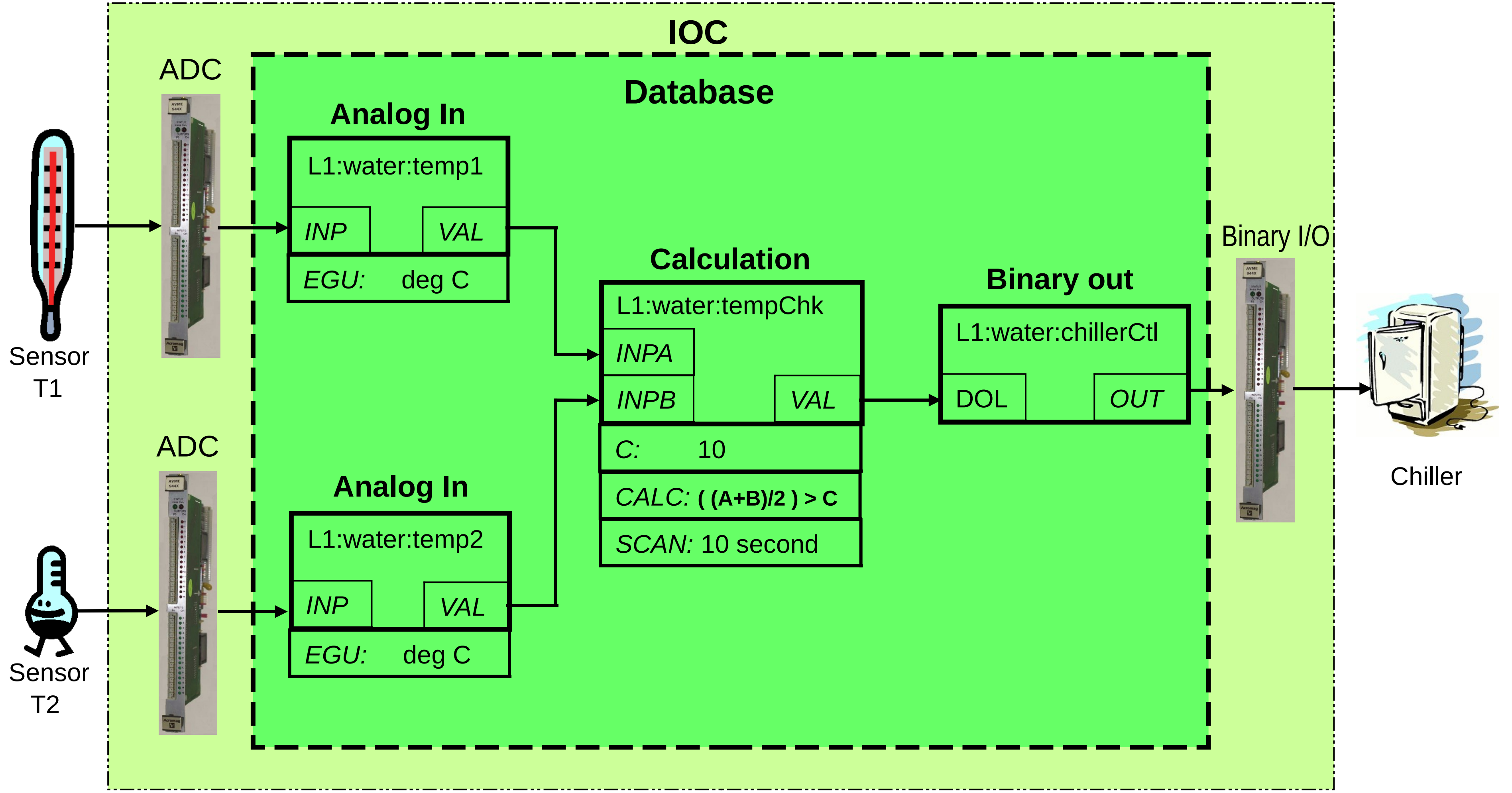


Record Processing

- 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

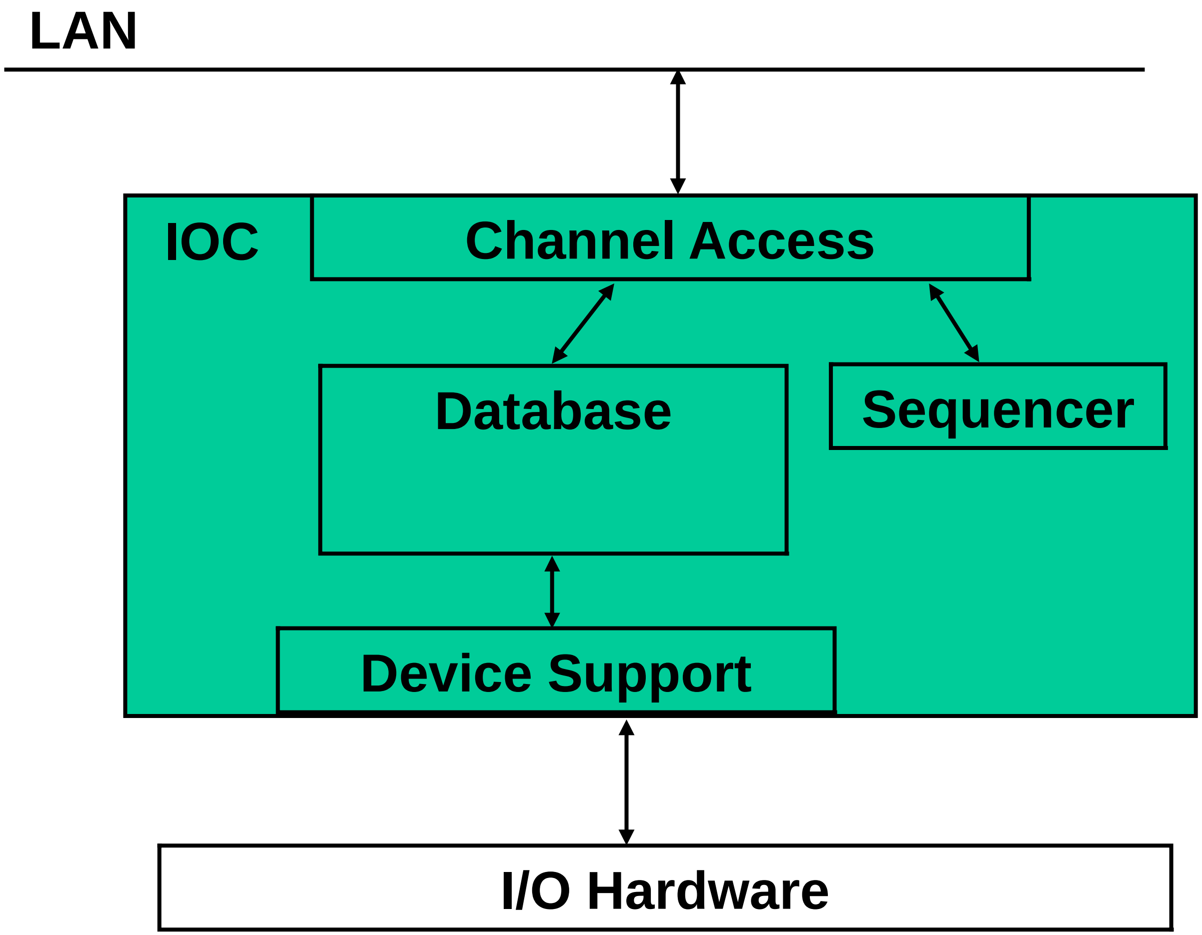


Database Processing



Inside an IOC

The major software components of an IOC (IOC Core)

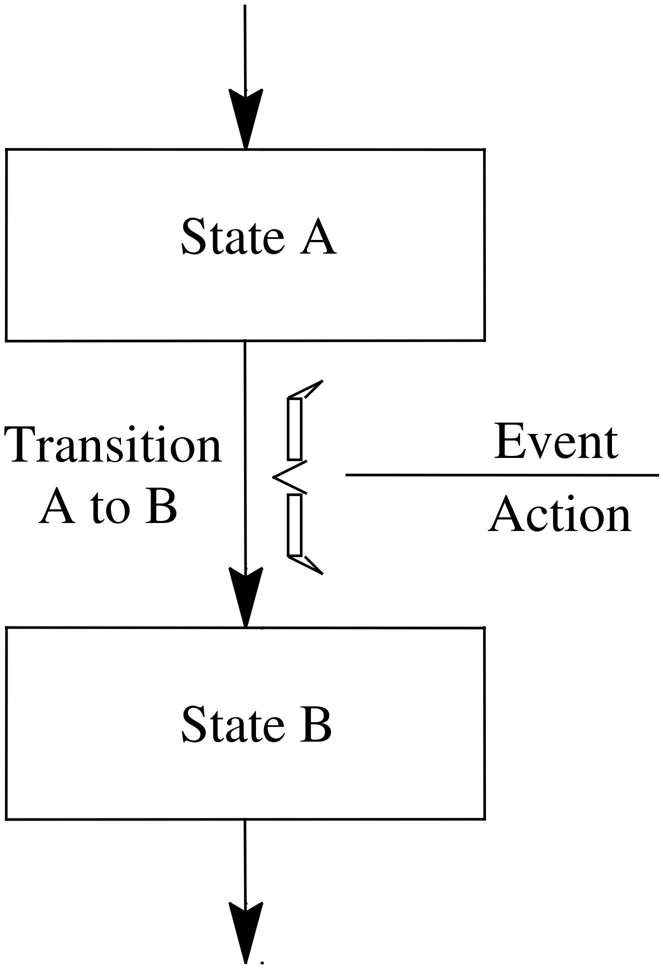


The Sequencer

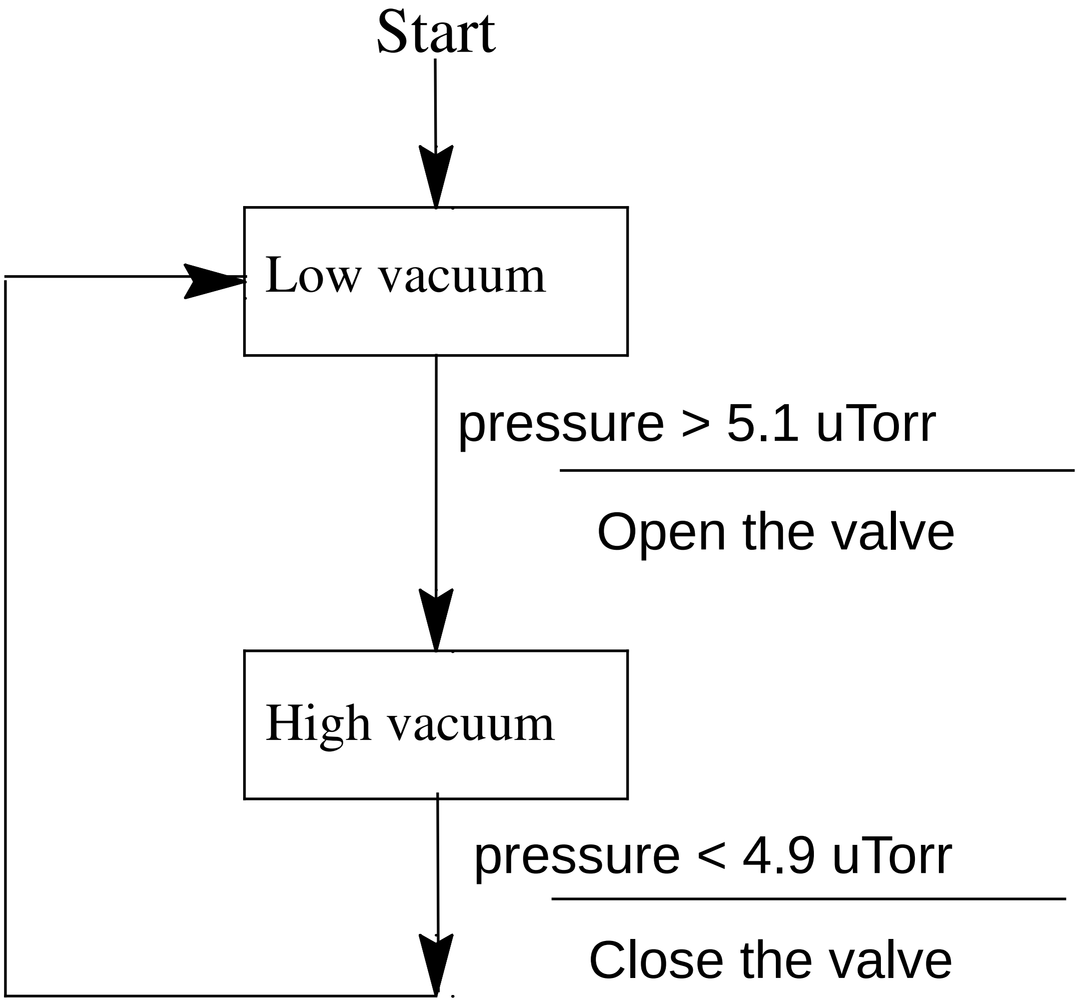
- Runs programs written in State Notation Language (SNL)
- SNL is a ‘C’ like language to facilitate programming of sequential operations

- 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



State Transition Example



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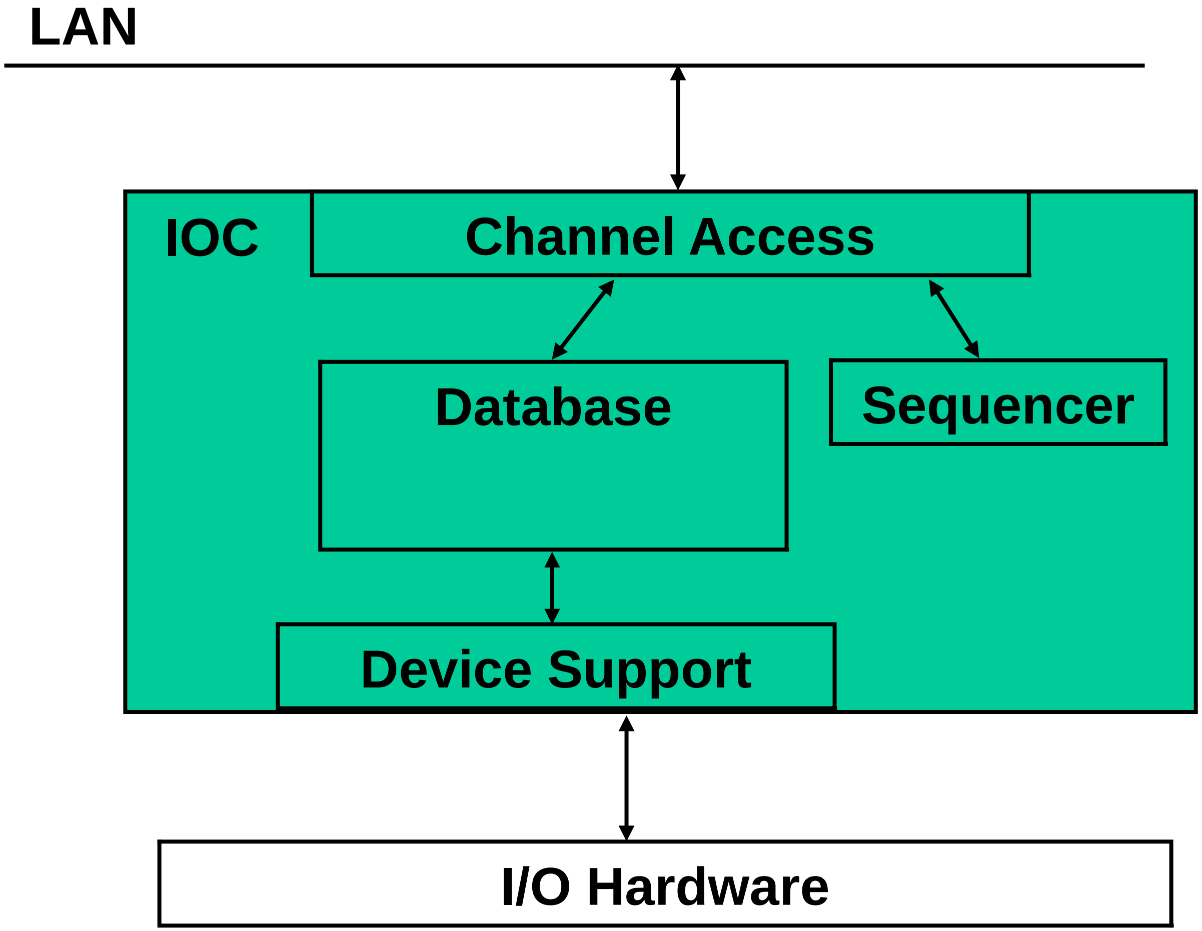
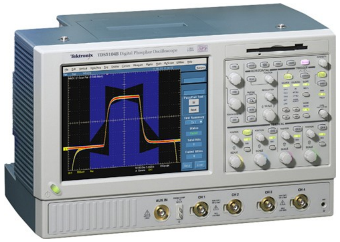


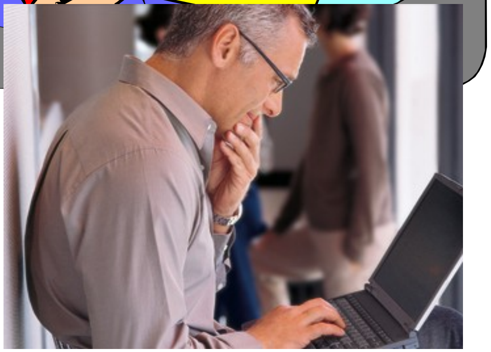
Device Support

- Device and driver support interface hardware to the database
- Examples of devices….
- VME cards
- ‘Network Attached Devices’
    - Motor controllers
    - Oscilloscopes
    - PLCs
- ‘Message-Based Devices’
    - USB or RS-232 serial devices
    - GPIB devices



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



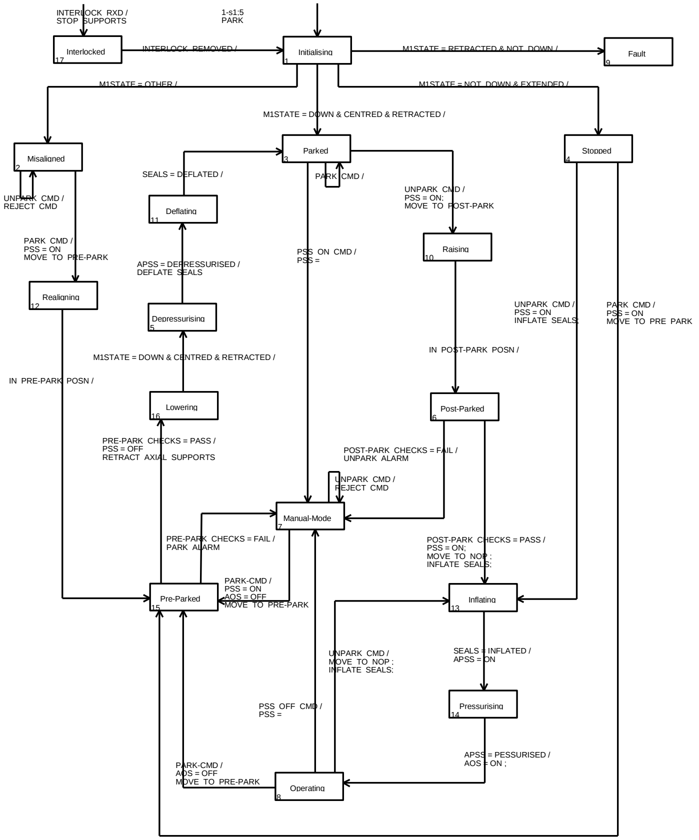
When to use databases

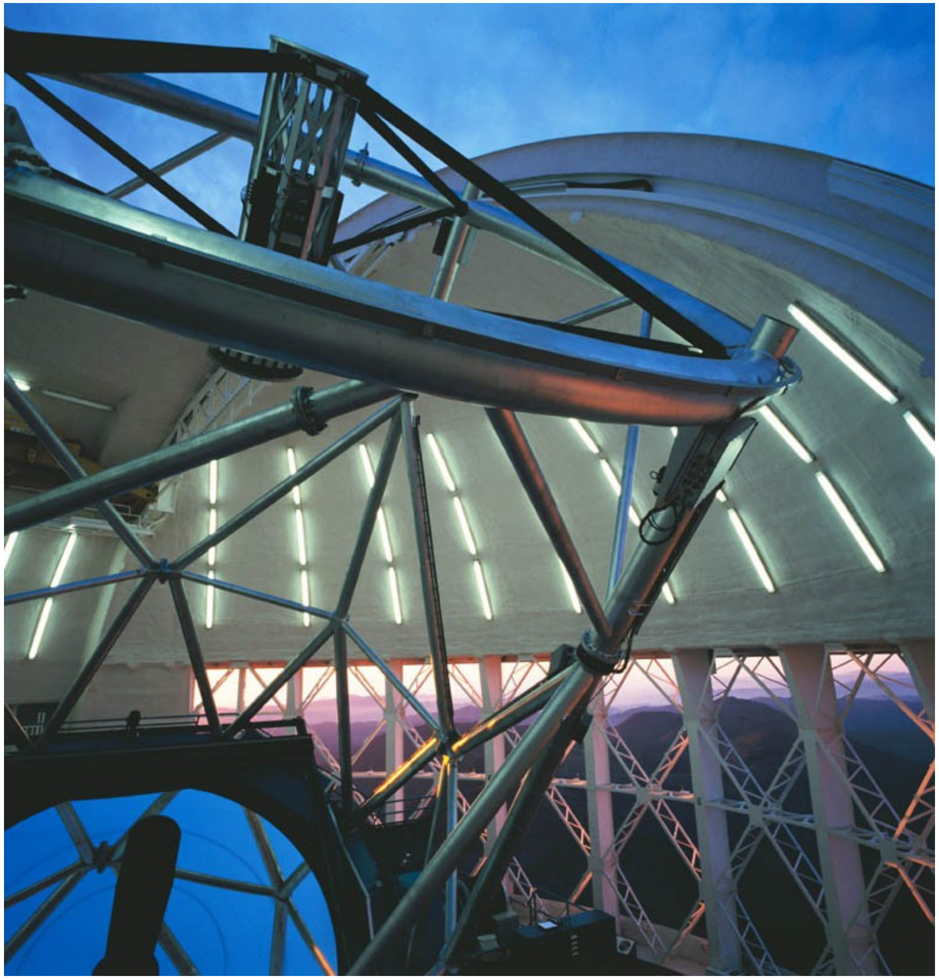
- Hardware connection
- Real time performance – no network latencies
- Whenever a database is good enough

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 – EDM/CSS, 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 benchmarks*:

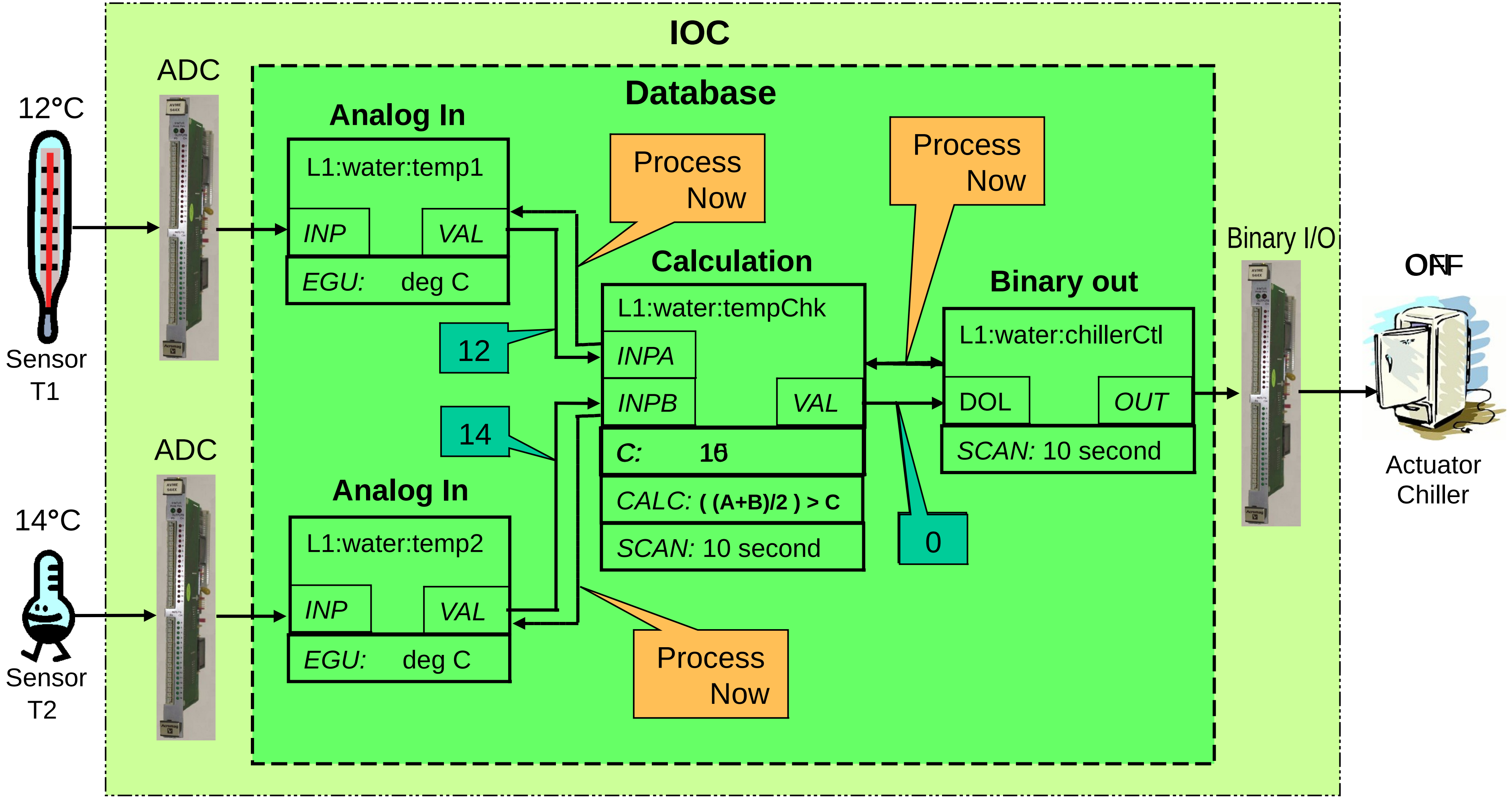
Machine	OS	CPU	Speed	Rec/sec	%CPU
MVME167	vxWorks	68040	33MHz	6000	50
MVME 2306	vxWorks	PPC604	300MHz	10000	10
MVME5100	vxWorks	PPC750	450MHz	40000**	10**
PC	Linux	PII	233MHz	10000	27
PC	Linux	P4	2.4GHz	50000	9

*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

ADC

12°C

Sensor T1

Analog In

L1:water:temp1

INP

VAL

EGU: deg C

12

ADC

14°C

Sensor T2

14

Analog In

L1:water:temp2

INP

VAL

EGU: deg C

Process Now

Calculation

L1:water:tempChk

INPA

INPB

VAL

C: 16

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

SCAN: 10 second

Process Now

Process Now

0

Binary out

L1:water:chillerCtl

DOL

OUT

SCAN: 10 second

Binary I/O

OFF

Actuator Chiller

The EPICS web site

- The central site for EPICS information
- Documentation
- CA Clients
- Device support
- Tech-talk
- http://www.aps.anl.gov/epics

Acknowledgements

- Andrew Johnson (APS-Controls)
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