EPICS

Tools for Physicists

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10.07.2024

Structure

of this course

internal basics
hands on
profi talk

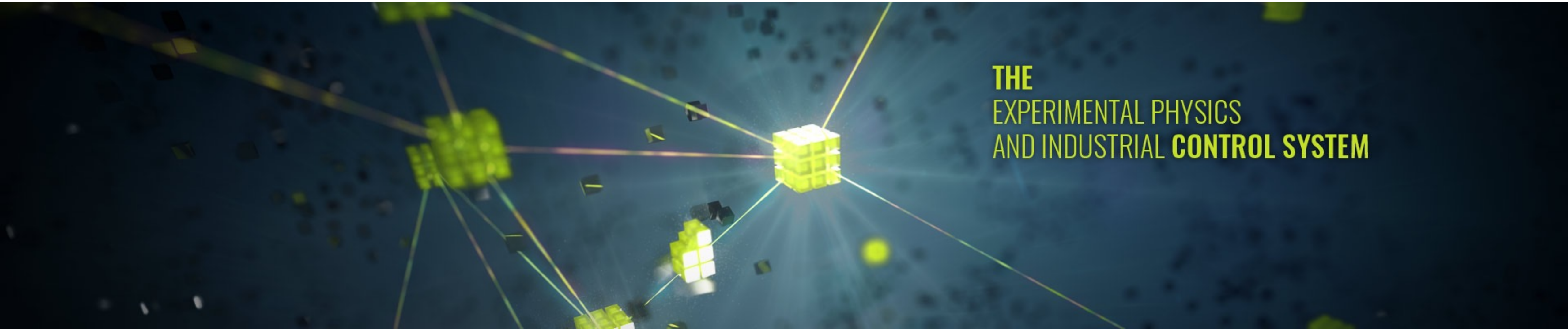
EPICS

EPICS is a set of Open Source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as a particle accelerators, telescopes and other large scientific experiments.

https://epics.anl.gov/index.php

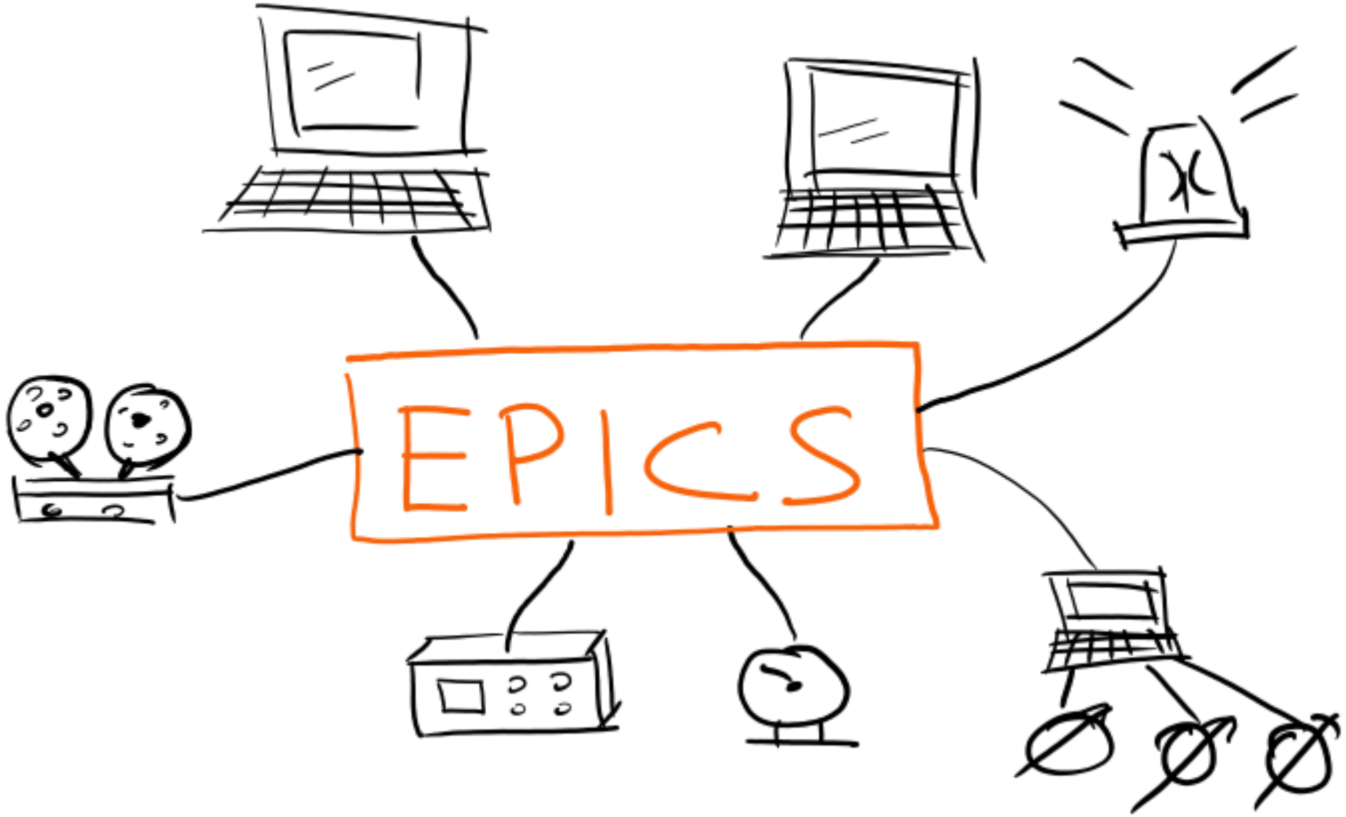
EPICS

https://epics-controls.org/

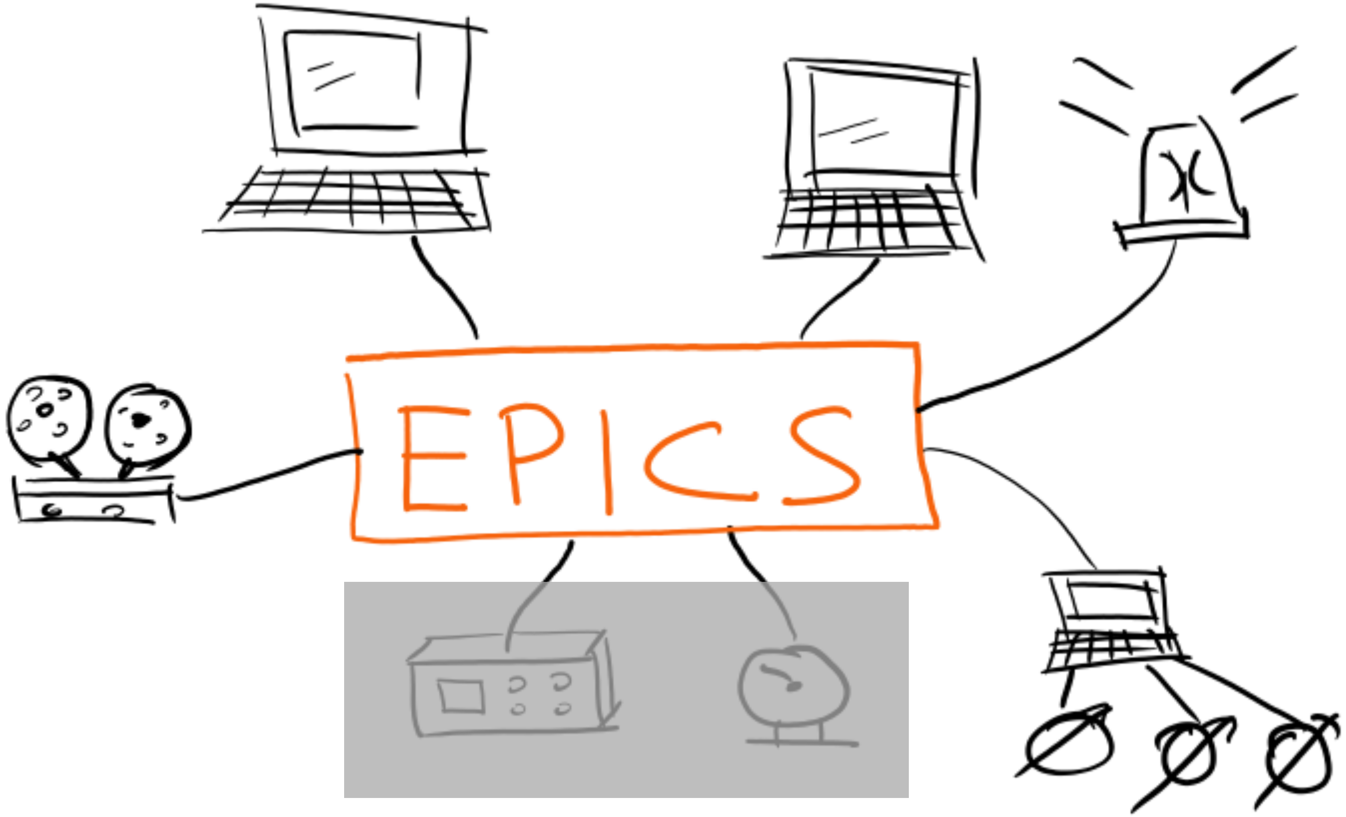


THE
EXPERIMENTAL PHYSICS
AND INDUSTRIAL **CONTROL SYSTEM**

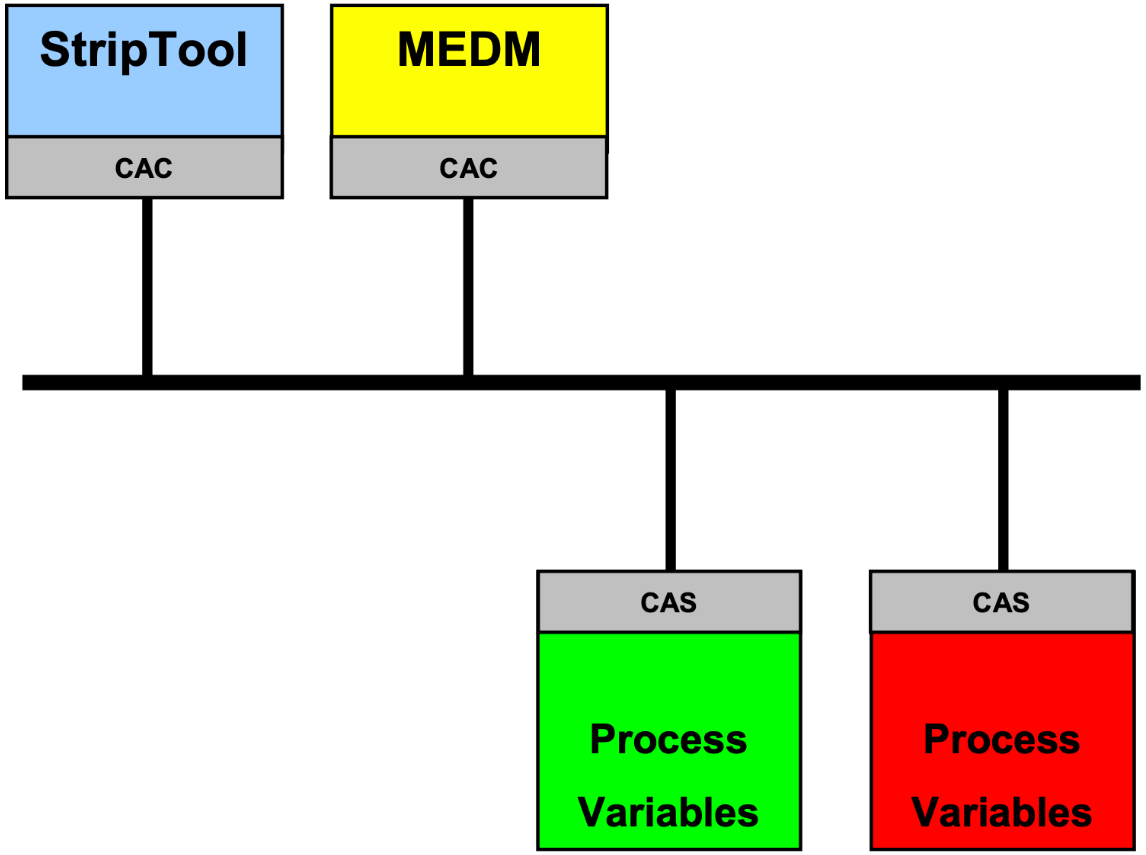
Natural Decentralized Structure



Scope Today

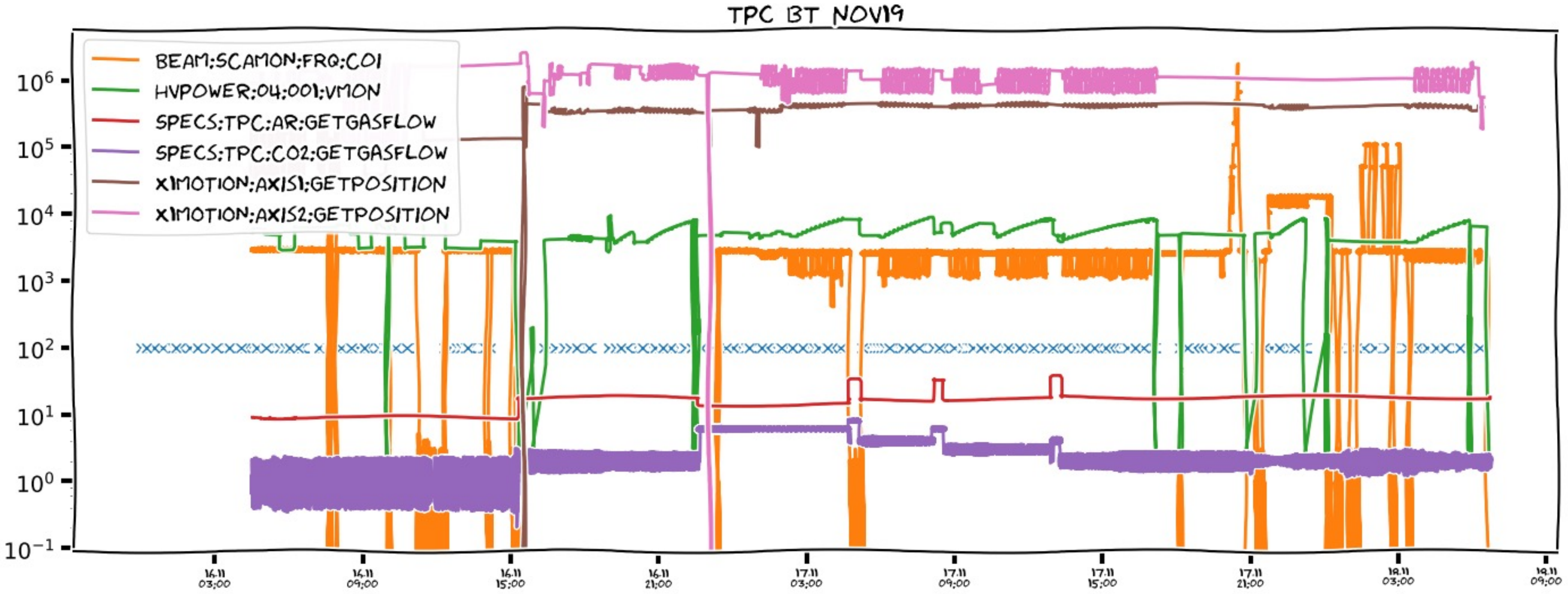


Channel Access Client – Server



PV – Process Variable

S1:VAC:reading	3.2e-08 torr
MX:Port:TPC:CathodeV	-17.2 kV
BOOSTER:gateValvePosition	‘OPEN’
S3:DIPOLE:PS:setPoint	123.4 Amps
MESA:Mode	‘ERL’
BL3:HISTOGRAM	{3, 8, 1, 2, 56}

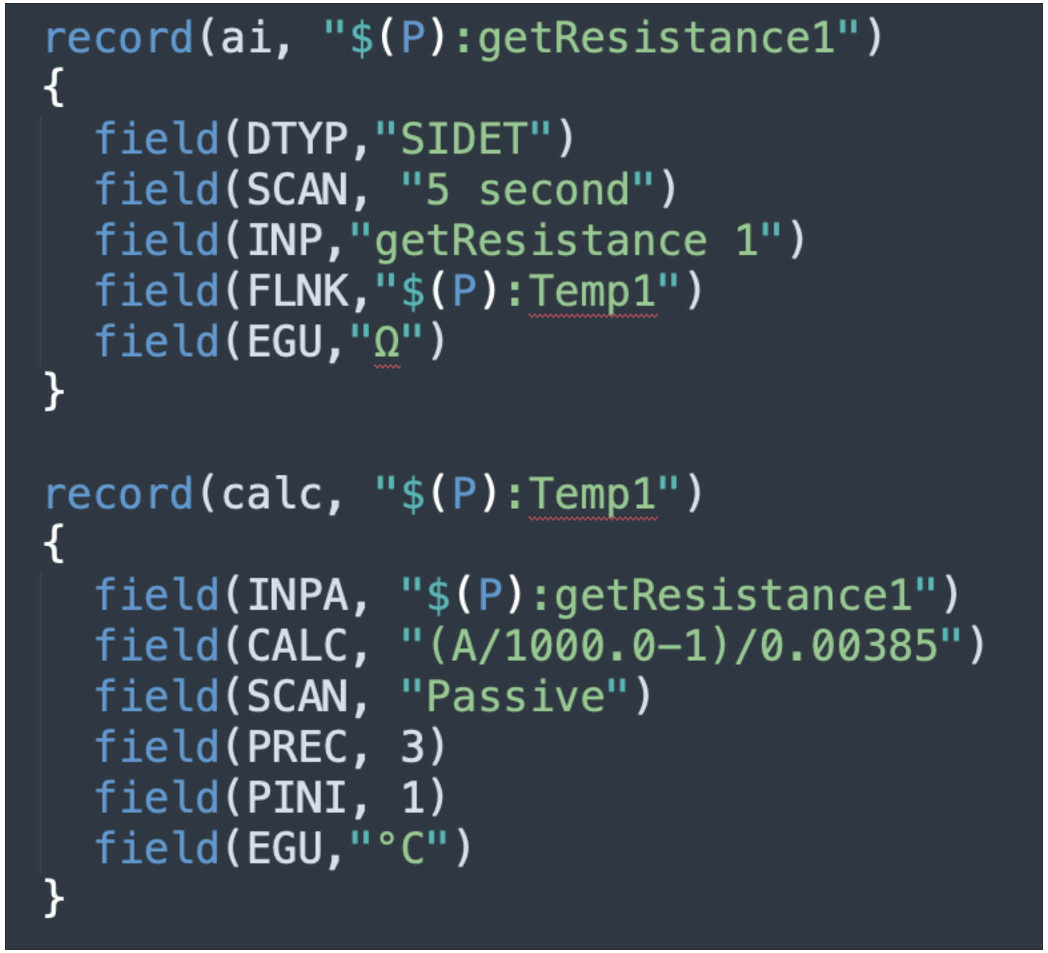


Record

```
record(ai,  "$(P):1:getVoltage") {
   field(DTYP, "stream")
   field(EGU,  "V")
   field(PREC, 3)
   field(INP,  "@devHMP4040.proto getVoltage($(P),1) $(PORT)")
   field(SCAN, "1 second")
   field(PINI, "YES")
}

record(ao, "$(P):1:setVoltage") {
   field(DTYP, "stream")
   field(EGU,  "V")
   field(PREC, 3)
   field(OUT,  "@devHMP4040.proto setVoltage($(P),1) $(PORT)")
}
```

```
magix@a1labor:~$ cat /opt/epics/MXSlowControl/db/devHMP4040.db
record(stringin, "$(P):ID")
{
   field(DESC, "Identification string")
   field(DTYP, "stream")
   field(INP,  "@devHMP4040.proto getID($(P)) $(PORT)")
   field(PINI, "YES")
}

record(ai,  "$(P):1:getVoltage") {
   field(DTYP, "stream")
   field(EGU,  "V")
   field(PREC, 3)
   field(INP,  "@devHMP4040.proto getVoltage($(P),1) $(PORT)")
   field(SCAN, "1 second")
   field(PINI, "YES")
}

record(ai,  "$(P):1:getCurrent") {
   field(DTYP, "stream")
   field(EGU,  "A")
   field(PREC, 3)
   field(INP,  "@devHMP4040.proto getCurrent($(P),1) $(PORT)")
   field(SCAN, "1 second")
   field(PINI, "YES")
}
```

Record

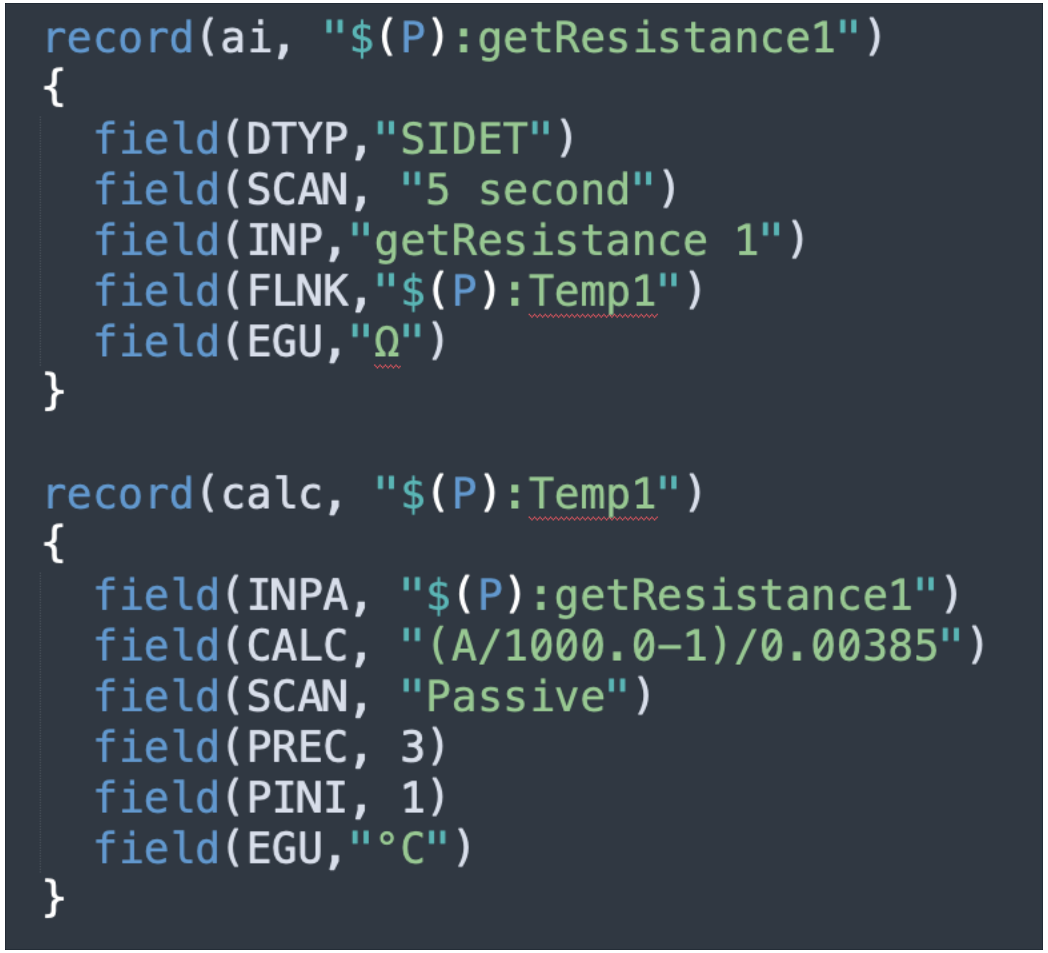


```
record(ai, "$(P):getResistance1")
{
  field(DTYP,"SIDET")
  field(SCAN, "5 second")
  field(INP,"getResistance 1")
  field(FLNK,"$(P):Temp1")
  field(EGU,"Ω")
}

record(calc, "$(P):Temp1")
{
  field(INPA, "$(P):getResistance1")
  field(CALC, "(A/1000.0-1)/0.00385")
  field(SCAN, "Passive")
  field(PREC, 3)
  field(PINI, 1)
  field(EGU,"°C")
}
```

Record - Types

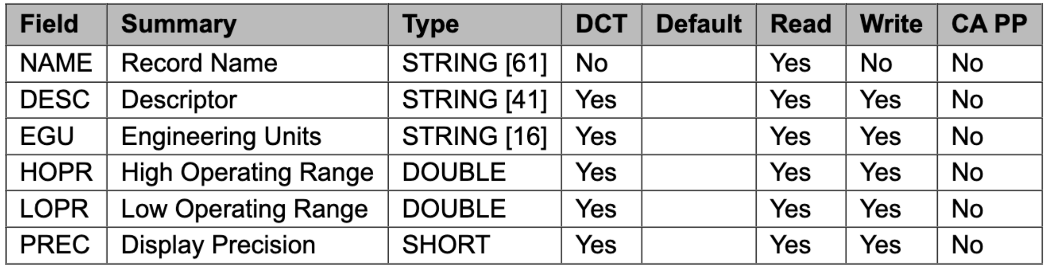
- ai Analog Input
- ao Analog Output
- calc Calculation Record
- …
- many more

https://epics.anl.gov/base/R7-0/6-docs/RecordReference.html



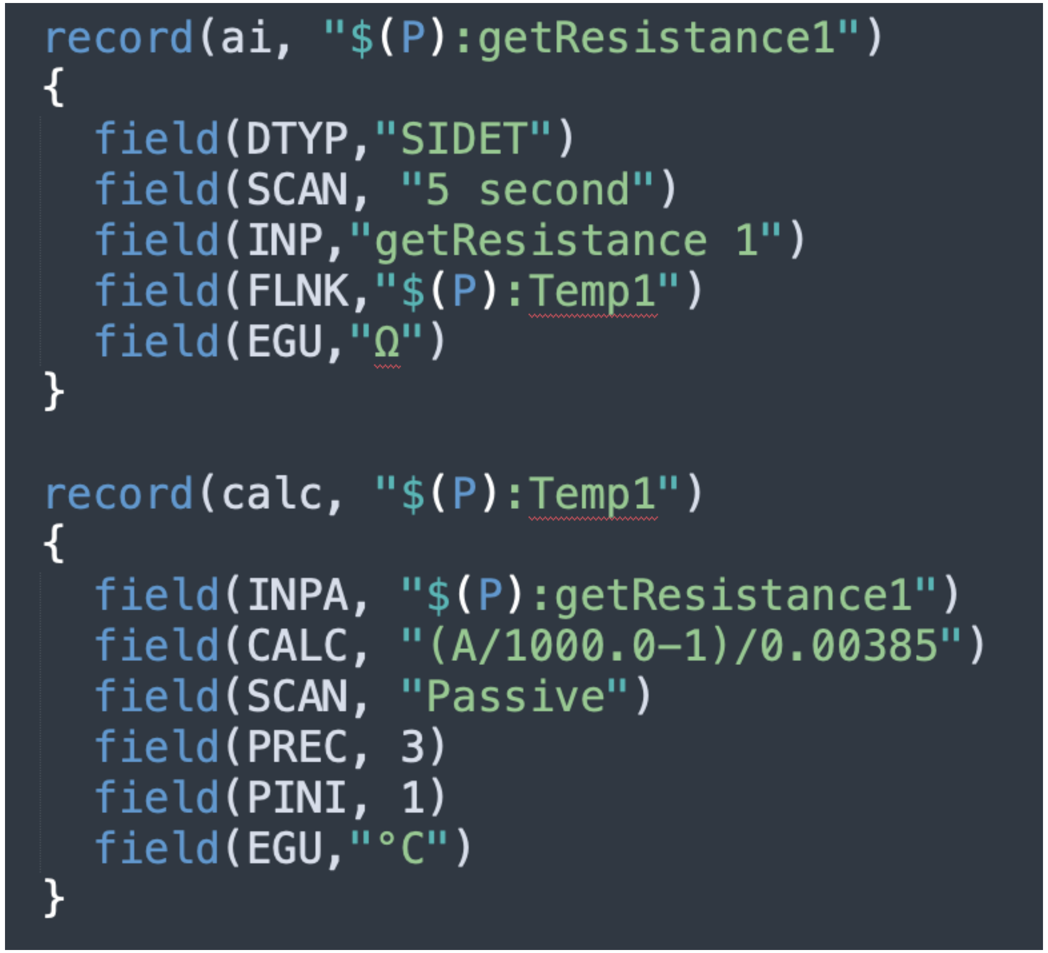
```
record(ai, "$(P):getResistance1")
{
  field(DTYP,"SIDET")
  field(SCAN, "5 second")
  field(INP,"getResistance 1")
  field(FLNK,"$(P):Temp1")
  field(EGU,"Ω")
}

record(calc, "$(P):Temp1")
{
  field(INPA, "$(P):getResistance1")
  field(CALC, "(A/1000.0-1)/0.00385")
  field(SCAN, "Passive")
  field(PREC, 3)
  field(PINI, 1)
  field(EGU,"°C")
}
```

Record - Fields



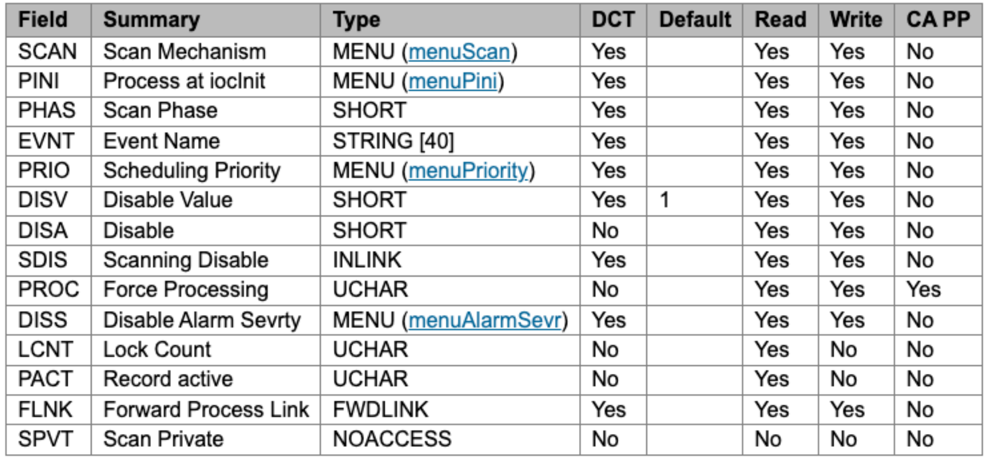
Field	Summary	Type	DCT	Default	Read	Write	CA PP
NAME	Record Name	STRING [61]	No		Yes	No	No
DESC	Descriptor	STRING [41]	Yes		Yes	Yes	No
EGU	Engineering Units	STRING [16]	Yes		Yes	Yes	No
HOPR	High Operating Range	DOUBLE	Yes		Yes	Yes	No
LOPR	Low Operating Range	DOUBLE	Yes		Yes	Yes	No
PREC	Display Precision	SHORT	Yes		Yes	Yes	No

https://epics.anl.gov/base/R7-0/6-docs/RecordReference.html



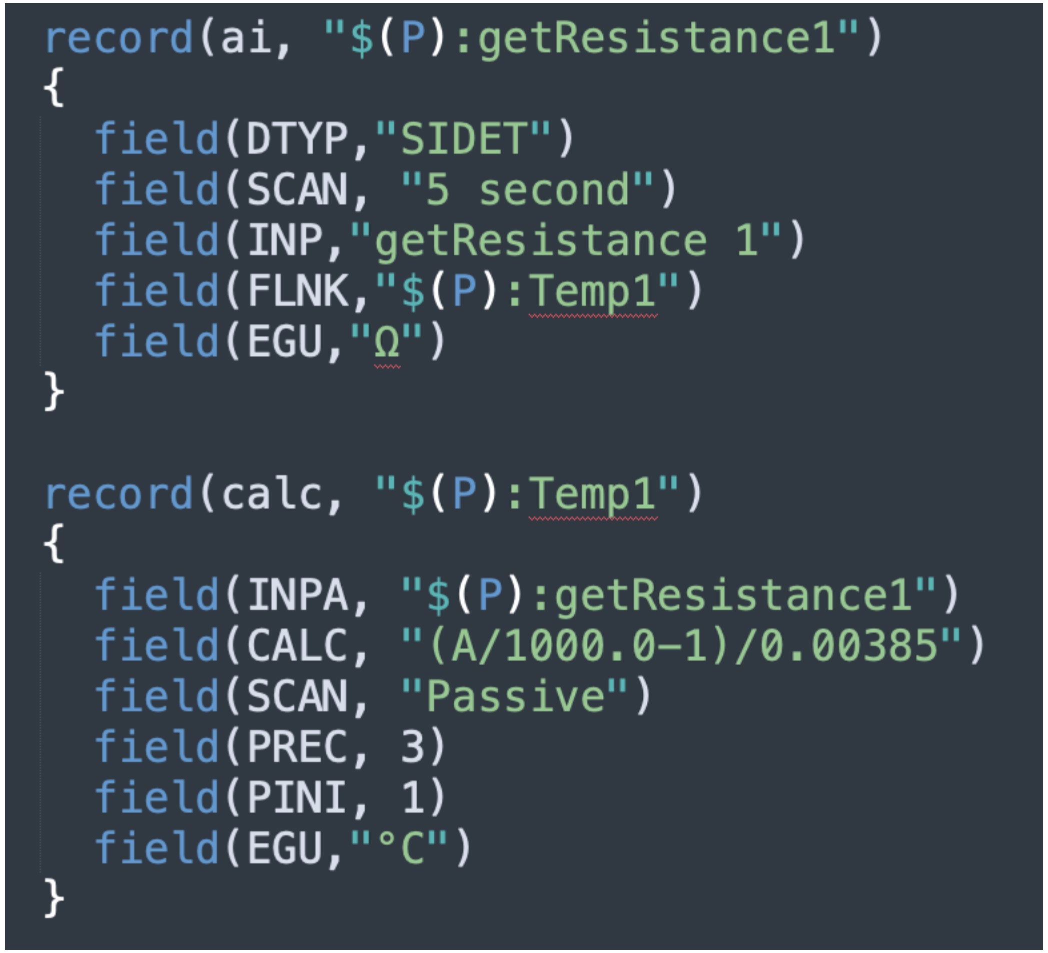
```
record(ai, "$(P):getResistance1")
{
  field(DTYP,"SIDET")
  field(SCAN, "5 second")
  field(INP,"getResistance 1")
  field(FLNK,"$(P):Temp1")
  field(EGU,"Ω")
}

record(calc, "$(P):Temp1")
{
  field(INPA, "$(P):getResistance1")
  field(CALC, "(A/1000.0-1)/0.00385")
  field(SCAN, "Passive")
  field(PREC, 3)
  field(PINI, 1)
  field(EGU,"°C")
}
```

Record – more Fields



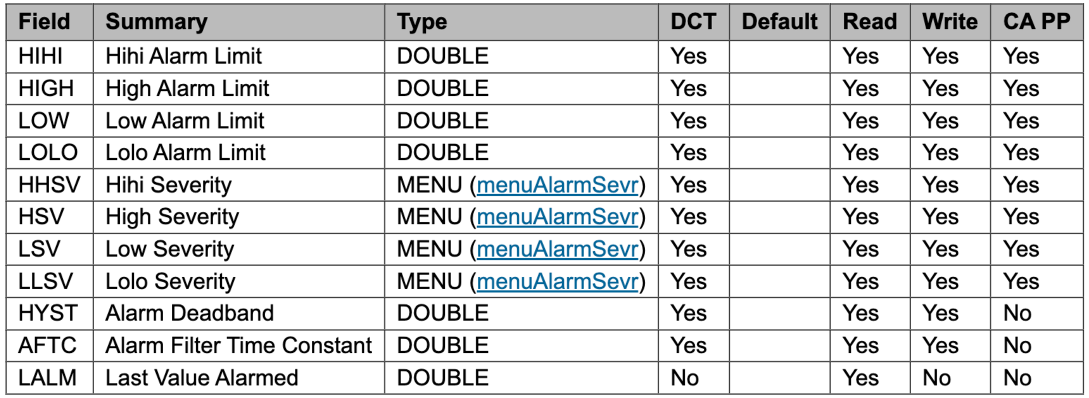
Field	Summary	Type	DCT	Default	Read	Write	CA PP
SCAN	Scan Mechanism	MENU (menuScan)	Yes		Yes	Yes	No
PINI	Process at iocInit	MENU (menuPini)	Yes		Yes	Yes	No
PHAS	Scan Phase	SHORT	Yes		Yes	Yes	No
EVNT	Event Name	STRING [40]	Yes		Yes	Yes	No
PRIO	Scheduling Priority	MENU (menuPriority)	Yes		Yes	Yes	No
DISV	Disable Value	SHORT	Yes	1	Yes	Yes	No
DISA	Disable	SHORT	No		Yes	Yes	No
SDIS	Scanning Disable	INLINK	Yes		Yes	Yes	No
PROC	Force Processing	UCHAR	No		Yes	Yes	Yes
DISS	Disable Alarm Sevrty	MENU (menuAlarmSevr)	Yes		Yes	Yes	No
LCNT	Lock Count	UCHAR	No		Yes	No	No
PACT	Record active	UCHAR	No		Yes	No	No
FLNK	Forward Process Link	FWDLINK	Yes		Yes	Yes	No
SPVT	Scan Private	NOACCESS	No		No	No	No

https://epics.anl.gov/base/R7-0/6-docs/RecordReference.html

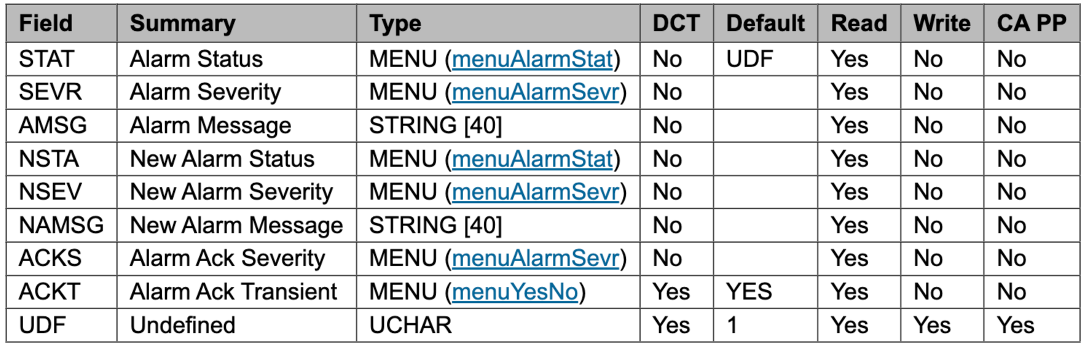


```
record(ai, "$(P):getResistance1")
{
  field(DTYP,"SIDET")
  field(SCAN, "5 second")
  field(INP,"getResistance 1")
  field(FLNK,"$(P):Temp1")
  field(EGU,"Ω")
}

record(calc, "$(P):Temp1")
{
  field(INPA, "$(P):getResistance1")
  field(CALC, "(A/1000.0-1)/0.00385")
  field(SCAN, "Passive")
  field(PREC, 3)
  field(PINI, 1)
  field(EGU,"°C")
}
```

Record - Alarm

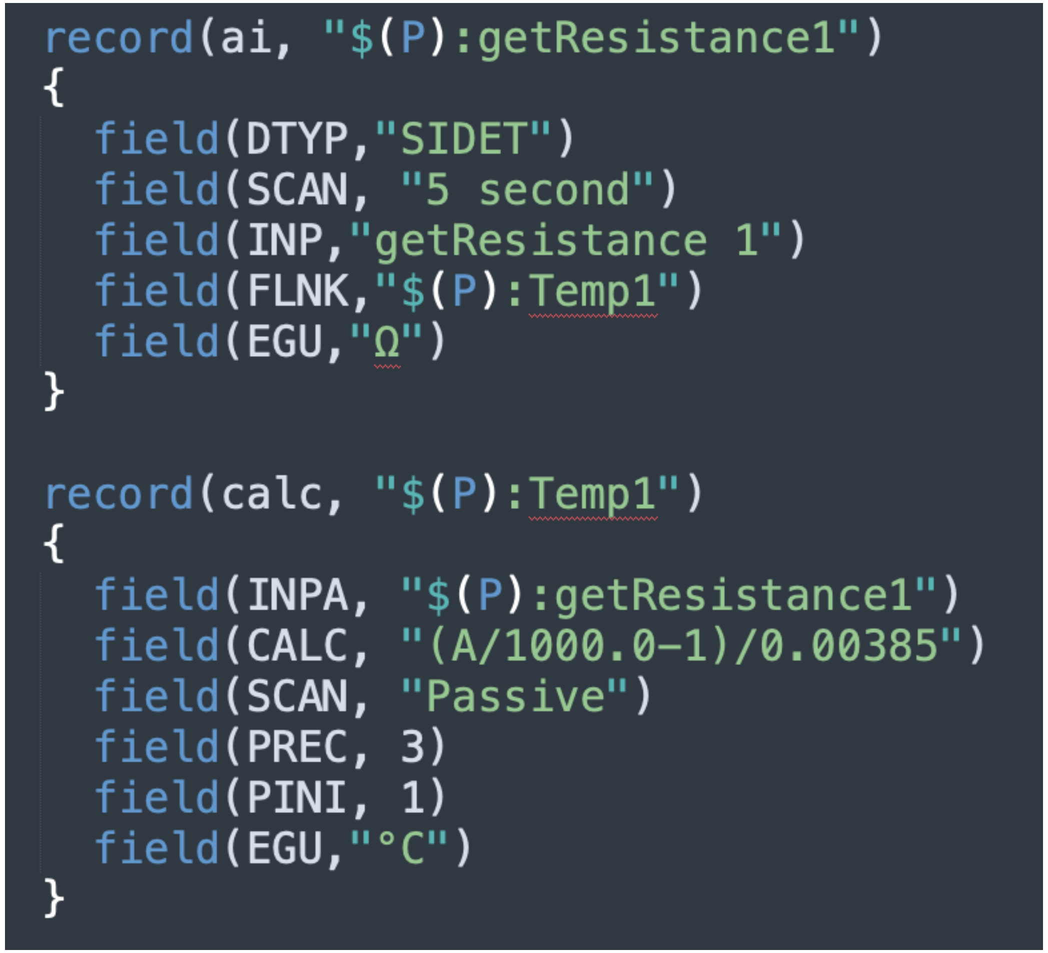


Field	Summary	Type	DCT	Default	Read	Write	CA PP
HIHI	Hihi Alarm Limit	DOUBLE	Yes		Yes	Yes	Yes
HIGH	High Alarm Limit	DOUBLE	Yes		Yes	Yes	Yes
LOW	Low Alarm Limit	DOUBLE	Yes		Yes	Yes	Yes
LOLO	Lolo Alarm Limit	DOUBLE	Yes		Yes	Yes	Yes
HHSV	Hihi Severity	MENU (menuAlarmSevr)	Yes		Yes	Yes	Yes
HSV	High Severity	MENU (menuAlarmSevr)	Yes		Yes	Yes	Yes
LSV	Low Severity	MENU (menuAlarmSevr)	Yes		Yes	Yes	Yes
LLSV	Lolo Severity	MENU (menuAlarmSevr)	Yes		Yes	Yes	Yes
HYST	Alarm Deadband	DOUBLE	Yes		Yes	Yes	No
AFTC	Alarm Filter Time Constant	DOUBLE	Yes		Yes	Yes	No
LALM	Last Value Alarmed	DOUBLE	No		Yes	No	No



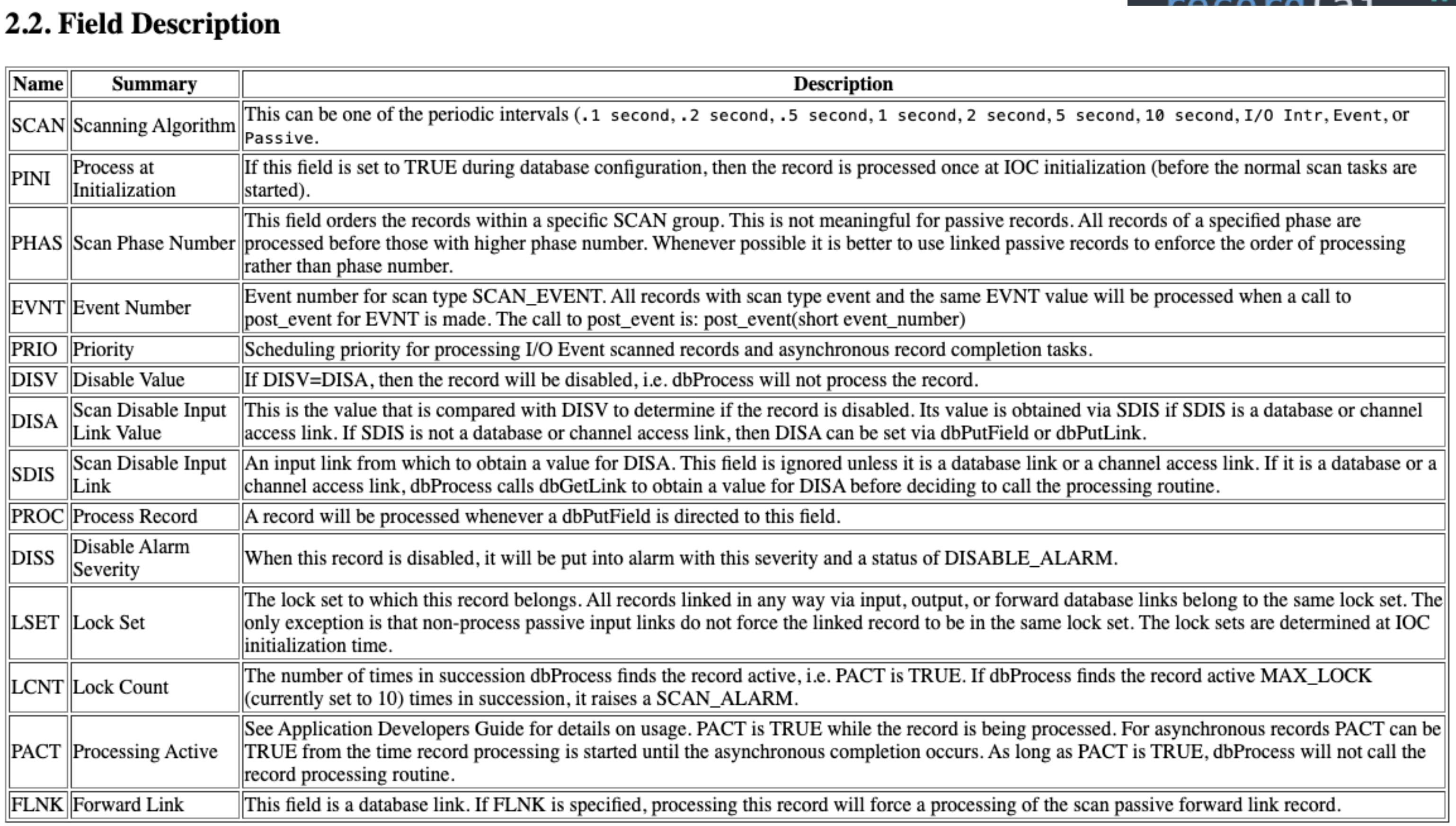
Field	Summary	Type	DCT	Default	Read	Write	CA PP
STAT	Alarm Status	MENU (menuAlarmStat)	No	UDF	Yes	No	No
SEVR	Alarm Severity	MENU (menuAlarmSevr)	No		Yes	No	No
AMSG	Alarm Message	STRING [40]	No		Yes	No	No
NSTA	New Alarm Status	MENU (menuAlarmStat)	No		Yes	No	No
NSEV	New Alarm Severity	MENU (menuAlarmSevr)	No		Yes	No	No
NAMSG	New Alarm Message	STRING [40]	No		Yes	No	No
ACKS	Alarm Ack Severity	MENU (menuAlarmSevr)	No		Yes	No	No
ACKT	Alarm Ack Transient	MENU (menuYesNo)	Yes	YES	Yes	No	No
UDF	Undefined	UCHAR	Yes	1	Yes	Yes	Yes

https://epics.anl.gov/base/R7-0/6-docs/RecordReference.html



```
record(ai, "$(P):getResistance1")
{
  field(DTYP,"SIDET")
  field(SCAN, "5 second")
  field(INP,"getResistance 1")
  field(FLNK,"$(P):Temp1")
  field(EGU,"Ω")
}

record(calc, "$(P):Temp1")
{
  field(INPA, "$(P):getResistance1")
  field(CALC, "(A/1000.0-1)/0.00385")
  field(SCAN, "Passive")
  field(PREC, 3)
  field(PINI, 1)
  field(EGU,"°C")
}
```

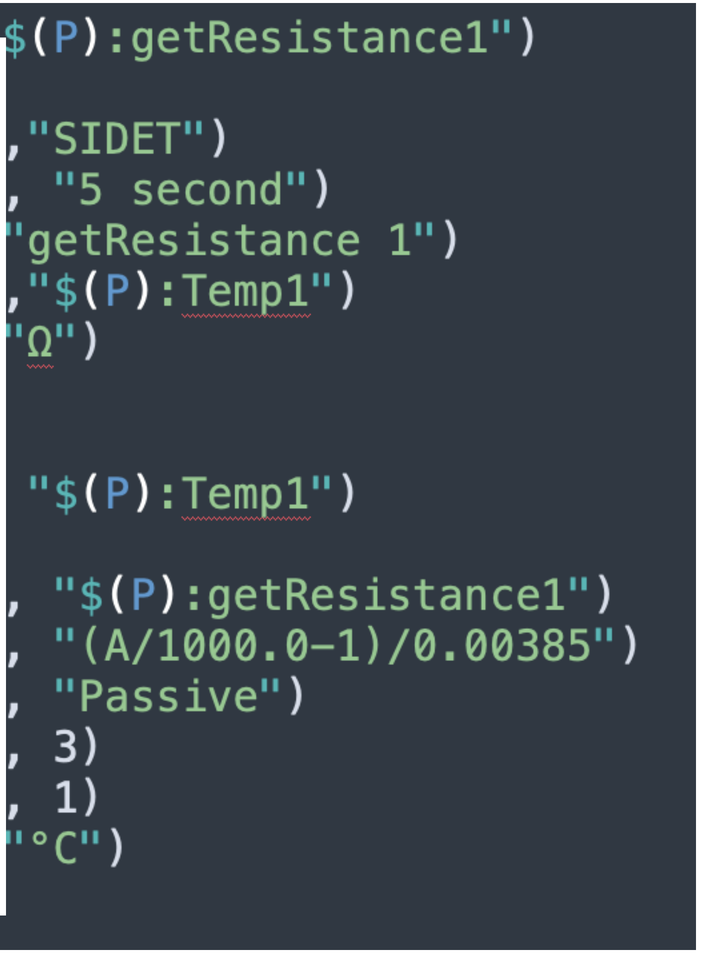
Record



2.2. Field Description

Name	Summary	Description
SCAN	Scanning Algorithm	This can be one of the periodic intervals (`.1 second`, `.2 second`, `.5 second`, `1 second`, `2 second`, `5 second`, `10 second`, `I/O Intr`, `Event`, or `Passive`.
PINI	Process at Initialization	If this field is set to TRUE during database configuration, then the record is processed once at IOC initialization (before the normal scan tasks are started).
PHAS	Scan Phase Number	This field orders the records within a specific SCAN group. This is not meaningful for passive records. All records of a specified phase are processed before those with higher phase number. Whenever possible it is better to use linked passive records to enforce the order of processing rather than phase number.
EVNT	Event Number	Event number for scan type SCAN_EVENT. All records with scan type event and the same EVNT value will be processed when a call to post_event for EVNT is made. The call to post_event is: post_event(short event_number)
PRIO	Priority	Scheduling priority for processing I/O Event scanned records and asynchronous record completion tasks.
DISV	Disable Value	If DISV=DISA, then the record will be disabled, i.e. dbProcess will not process the record.
DISA	Scan Disable Input Link Value	This is the value that is compared with DISV to determine if the record is disabled. Its value is obtained via SDIS if SDIS is a database or channel access link. If SDIS is not a database or channel access link, then DISA can be set via dbPutField or dbPutLink.
SDIS	Scan Disable Input Link	An input link from which to obtain a value for DISA. This field is ignored unless it is a database link or a channel access link. If it is a database or a channel access link, dbProcess calls dbGetLink to obtain a value for DISA before deciding to call the processing routine.
PROC	Process Record	A record will be processed whenever a dbPutField is directed to this field.
DISS	Disable Alarm Severity	When this record is disabled, it will be put into alarm with this severity and a status of DISABLE_ALARM.
LSET	Lock Set	The lock set to which this record belongs. All records linked in any way via input, output, or forward database links belong to the same lock set. The only exception is that non-process passive input links do not force the linked record to be in the same lock set. The lock sets are determined at IOC initialization time.
LCNT	Lock Count	The number of times in succession dbProcess finds the record active, i.e. PACT is TRUE. If dbProcess finds the record active MAX_LOCK (currently set to 10) times in succession, it raises a SCAN_ALARM.
PACT	Processing Active	See Application Developers Guide for details on usage. PACT is TRUE while the record is being processed. For asynchronous records PACT can be TRUE from the time record processing is started until the asynchronous completion occurs. As long as PACT is TRUE, dbProcess will not call the record processing routine.
FLNK	Forward Link	This field is a database link. If FLNK is specified, processing this record will force a processing of the scan passive forward link record.

https://epics.anl.gov/EpicsDocumentation/AppDevManuals/RecordRef/Recordref-6.html



```
record(ai, "$(P):getResistance1")

,"SIDET")
, "5 second")
"getResistance 1")
,"$(P):Temp1")
"Ω")


 "$(P):Temp1")

, "$(P):getResistance1")
, "(A/1000.0-1)/0.00385")
, "Passive")
, 3)
, 1)
"°C")
```

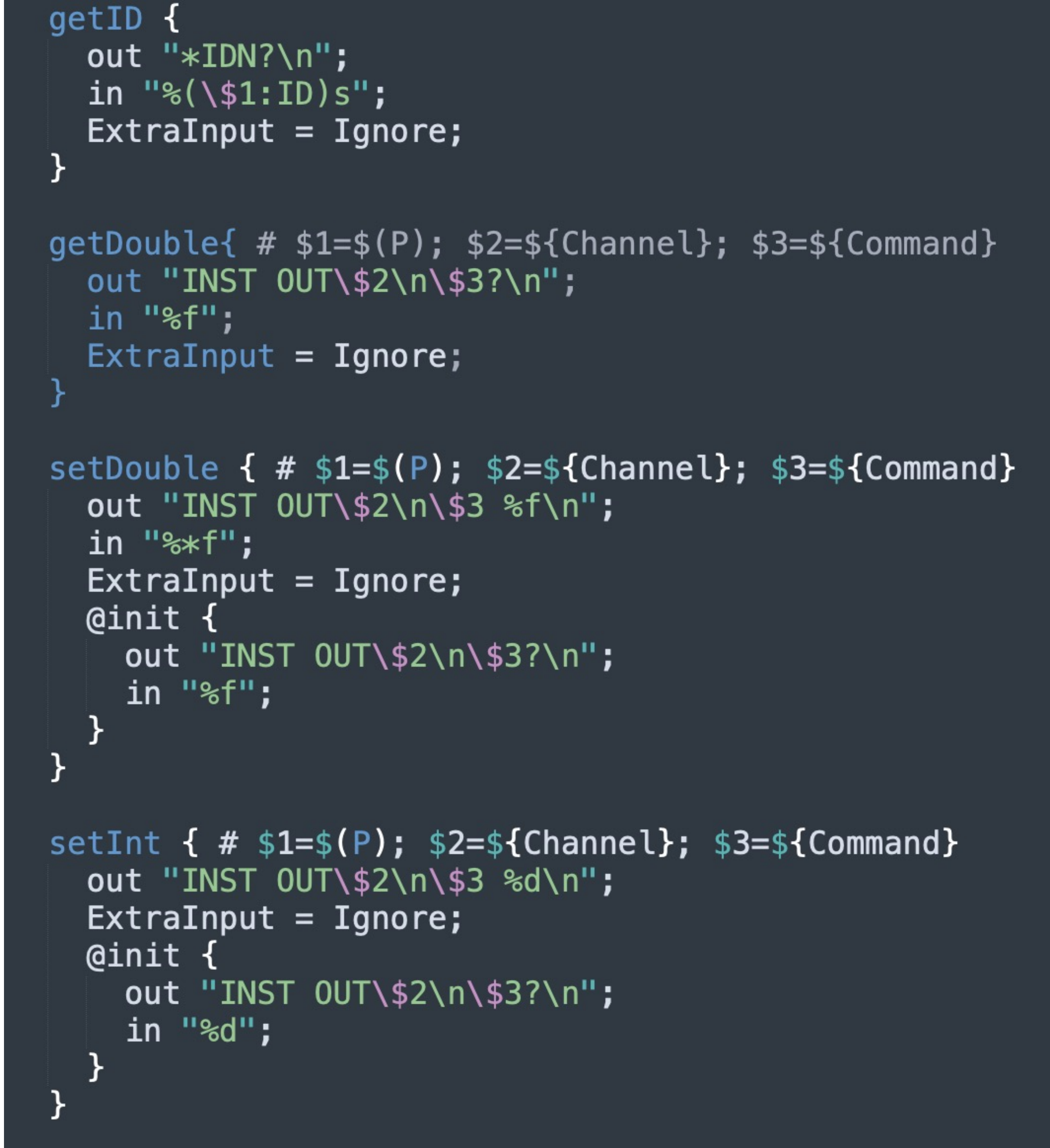
softIOC – Input Output Controller

- this is the core program
- loads the records
- inits the communication
- handles requests

```
drvAsynSerialPortConfigure("L1","/dev/SLA5850",0,0,0)
asynSetOption("L1", -1, "baud", "19200")
asynSetOption("L1", -1, "bits", "8")
asynSetOption("L1", -1, "parity", "odd")
asynSetOption("L1", -1, "stop", "1")
asynSetOption("L1", -1, "clocal", "Y")
asynSetOption("L1", -1, "crtscts", "N")
asynSetTraceIOMask("L1",-1,0x2)
asynSetTraceMask("L1",-1,0x1)


dbLoadRecords("db/devHMP4040.db","P=Specs:TPC:LV,
PORT=HMP4040")
iocInit
```

Where are all the devices?

- caput
- StreamDevice
- Asyn
- pyEPICS



```
getID {
  out "*IDN?\n";
  in "%(\$1:ID)s";
  ExtraInput = Ignore;
}

getDouble{ # $1=$(P); $2=${Channel}; $3=${Command}
  out "INST OUT\$2\n\$3?\n";
  in "%f";
  ExtraInput = Ignore;
}

setDouble { # $1=$(P); $2=${Channel}; $3=${Command}
  out "INST OUT\$2\n\$3 %f\n";
  in "%*f";
  ExtraInput = Ignore;
  @init {
    out "INST OUT\$2\n\$3?\n";
    in "%f";
  }
}

setInt { # $1=$(P); $2=${Channel}; $3=${Command}
  out "INST OUT\$2\n\$3 %d\n";
  ExtraInput = Ignore;
  @init {
    out "INST OUT\$2\n\$3?\n";
    in "%d";
  }
}
```

Why is this a good tool for physicists?

- PROs
- easy
- decentralized
- just need a PV name
- scaleable
- small setup may be directly integrated
- very stable
- “just throw a PI in the hall”

- CONs
- hard
- need central structures
- need the PV names
- maintainability

EPICS Jargon

- EPICS - Experimental Physics and Industrial Control System
- Channel Access - The communication protocol used by EPICS
- Process Variable - A piece of named data referred to by its PV name - The primary object of the Channel Access Protocol
- Channel - A synonym for Process Variable
- Channel Access Server - Software that provides access to a Process Variable using the Channel Access Protocol
- Channel Access Client - Software that requests access to a Process Variable using the Channel Access Protocol

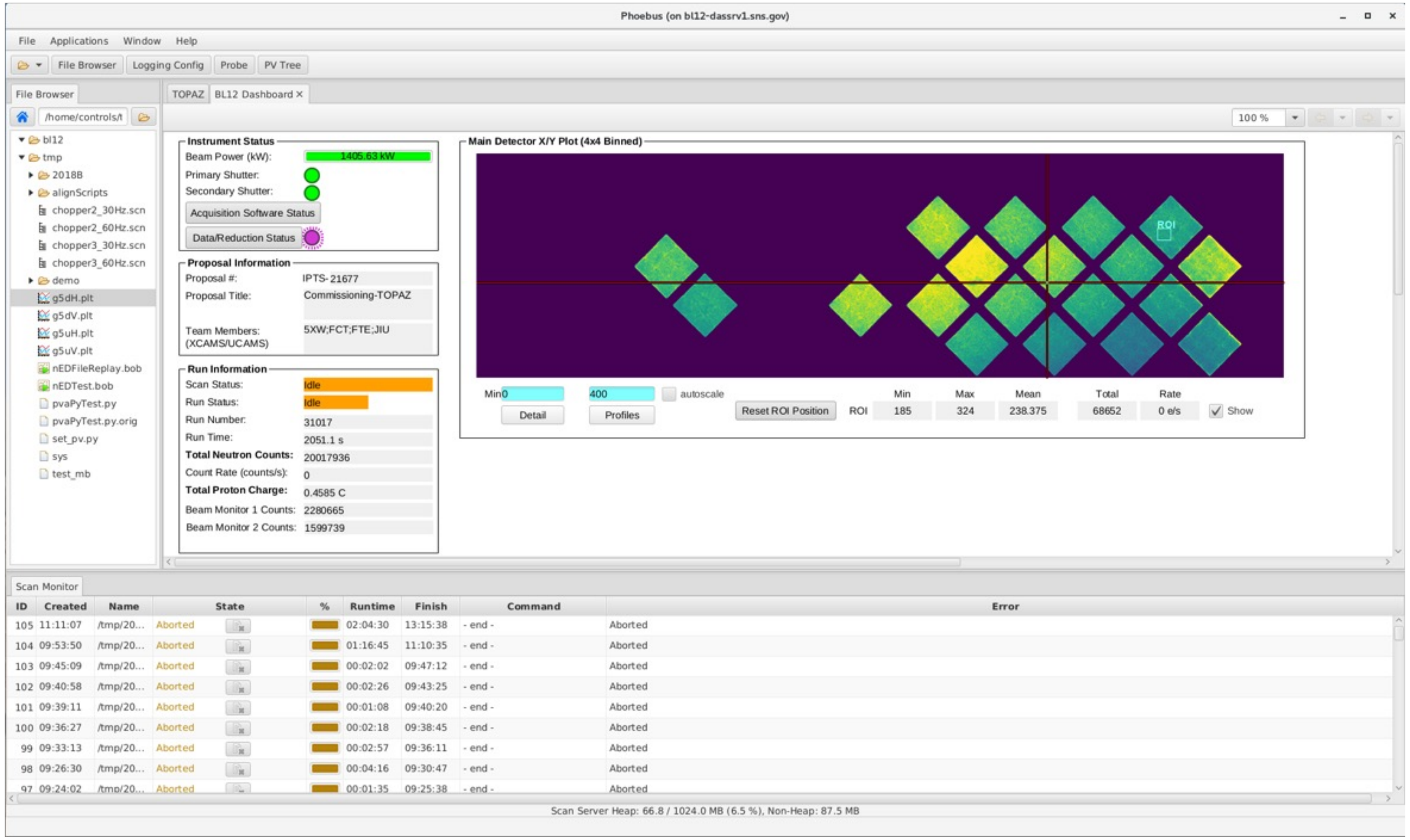
EPICS Jargon

- IOC – Input Output Controller - A computer running iocCore, a set of EPICS routines used to define process variables and implement real-time control algorithms - iocCore uses database records to define process variables and their behavior
- Soft IOC - An instance of iocCore running as a process on a “non-dedicated” computer (i.e. a computer that is performing other functions as well)
- Record - The mechanism by which a Process Variable is defined in an IOC (using iocCore) - Dozens of record types exist, each with it’s own attributes and processing routine that describe its functionality

EPICS User

- caget <pv_name>
- caput <pv_name> <value>
- camonitor <pv_name_list>

CSS phoebus



Instrument Status

Beam Power (kW): 1405.63 kW

Primary Shutter: ●

Secondary Shutter: ●

Proposal Information

Proposal #: IPTS- 21677

Proposal Title: Commissioning-TOPAZ

Team Members: (XCAMS/UCAMS) 5XW;FCT;FTE;JIU

Run Information

Scan Status: Idle

Run Status: Idle

Run Number: 31017

Run Time: 2051.1 s

Total Neutron Counts: 20017936

Count Rate (counts/s): 0

Total Proton Charge: 0.4585 C

Beam Monitor 1 Counts: 2280665

Beam Monitor 2 Counts: 1599739

Min 0 400 □ autoscale

	Min	Max	Mean	Total	Rate
ROI	185	324	238.375	68652	0 e/s

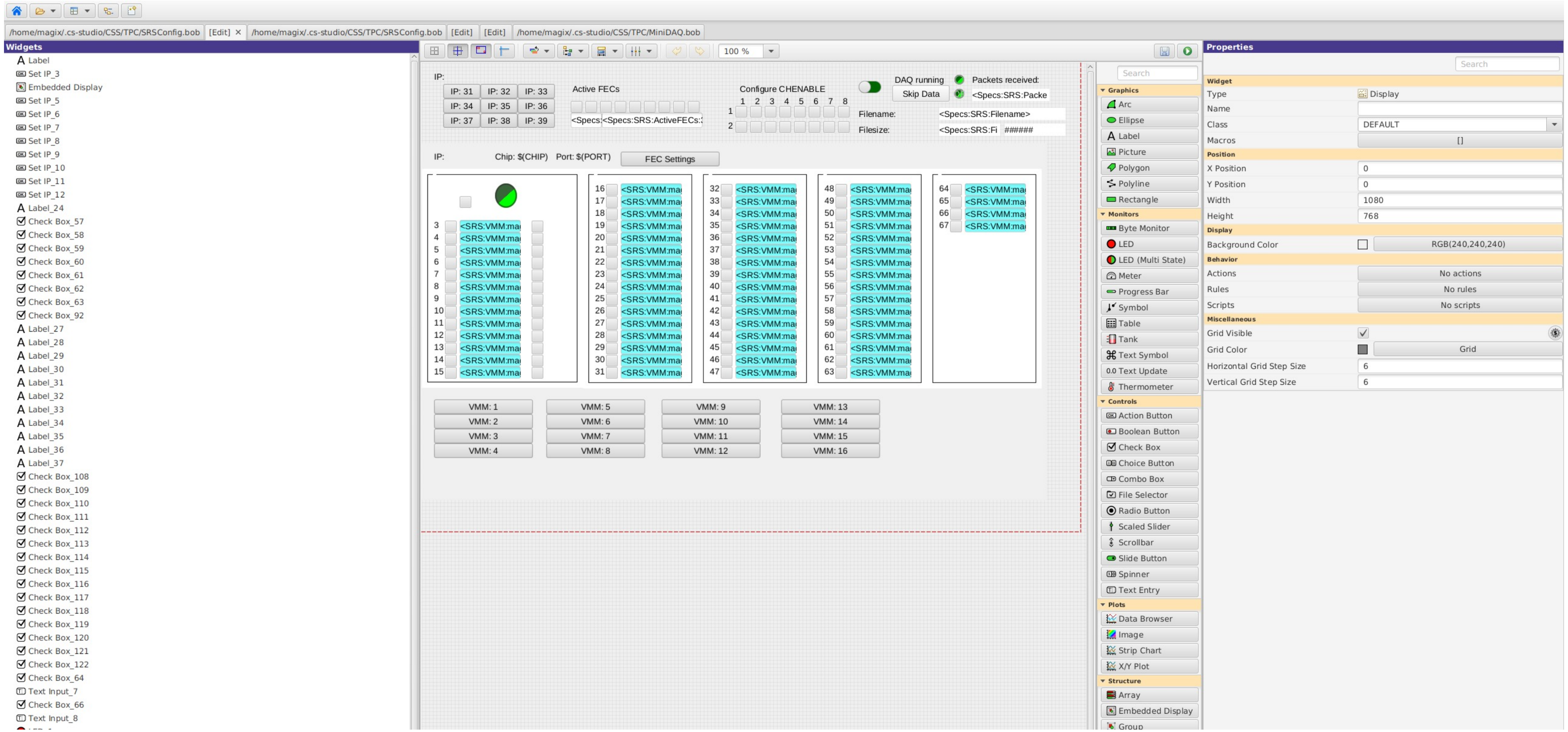
☑ Show

ID	Created	Name	State	%	Runtime	Finish	Command	Error
105	11:11:07	/tmp/20...	Aborted		02:04:30	13:15:38	- end -	Aborted
104	09:53:50	/tmp/20...	Aborted		01:16:45	11:10:35	- end -	Aborted
103	09:45:09	/tmp/20...	Aborted		00:02:02	09:47:12	- end -	Aborted
102	09:40:58	/tmp/20...	Aborted		00:02:26	09:43:25	- end -	Aborted
101	09:39:11	/tmp/20...	Aborted		00:01:08	09:40:20	- end -	Aborted
100	09:36:27	/tmp/20...	Aborted		00:02:18	09:38:45	- end -	Aborted
99	09:33:13	/tmp/20...	Aborted		00:02:57	09:36:11	- end -	Aborted
98	09:26:30	/tmp/20...	Aborted		00:04:16	09:30:47	- end -	Aborted
97	09:24:02	/tmp/20...	Aborted		00:01:35	09:25:38	- end -	Aborted

Scan Server Heap: 66.8 / 1024.0 MB (6.5 %), Non-Heap: 87.5 MB

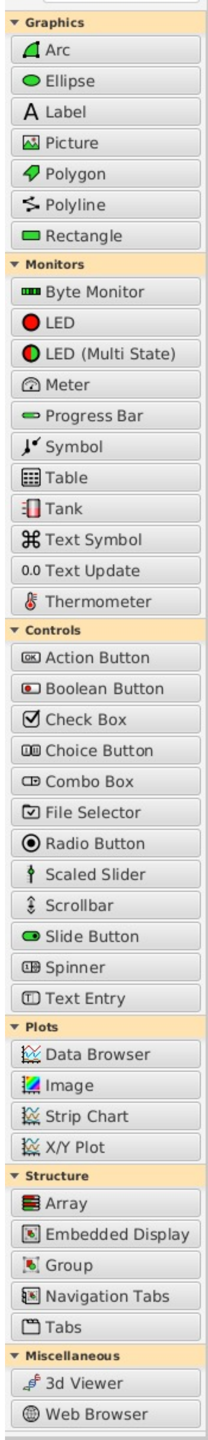
https://controlssoftware.sns.ornl.gov/css_phoebus/

CSS phoebus



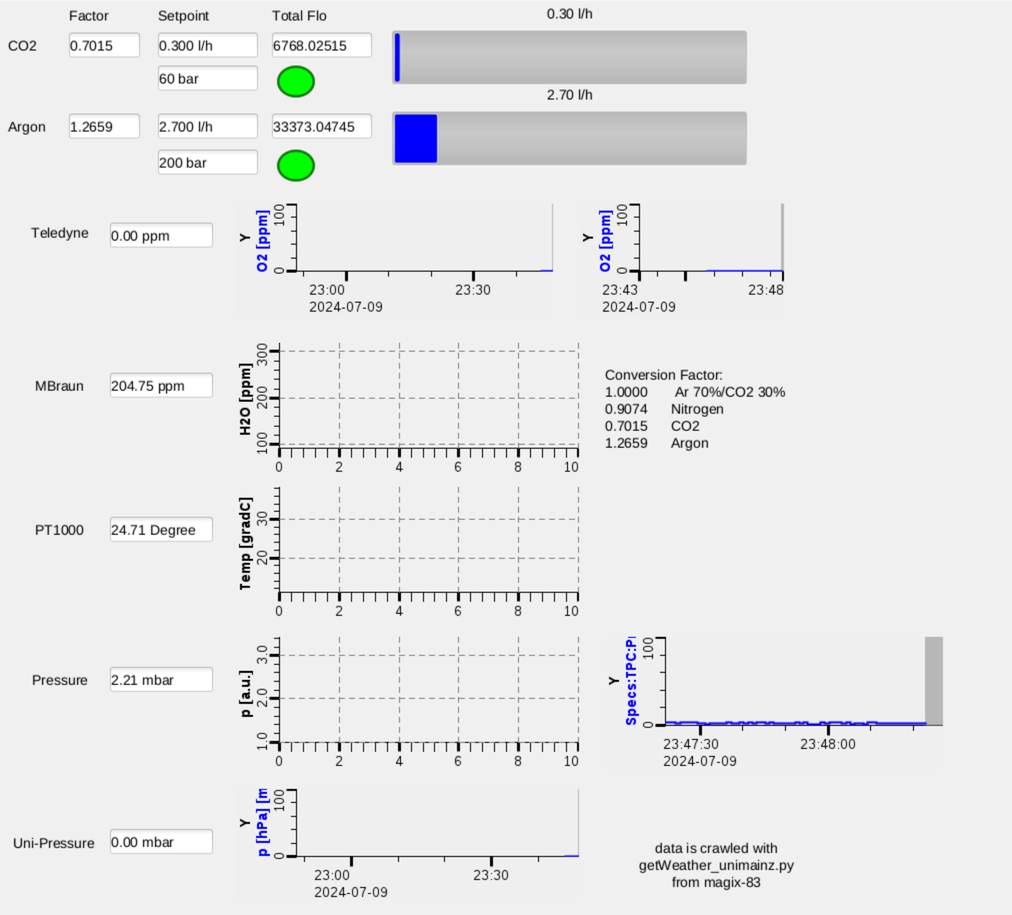
Properties

Widget	
Type	Display
Name	
Class	DEFAULT
Macros	[]
Position	
X Position	0
Y Position	0
Width	1080
Height	768
Display	
Background Color	RGB(240,240,240)
Behavior	
Actions	No actions
Rules	No rules
Scripts	No scripts
Miscellaneous	
Grid Visible	✓
Grid Color	Grid
Horizontal Grid Step Size	6
Vertical Grid Step Size	6



https://controlssoftware.sns.ornl.gov/css_phoebus/

CSS phoebus



	Factor	Setpoint	Total Flo
CO2	0.7015	0.300 l/h	6768.02515
		60 bar	🟢
Argon	1.2659	2.700 l/h	33373.04745
		200 bar	🟢

Teledyne 0.00 ppm

MBraun 204.75 ppm

PT1000 24.71 Degree

Pressure 2.21 mbar

Uni-Pressure 0.00 mbar

Conversion Factor:

1.0000	Ar 70%/CO2 30%
0.9074	Nitrogen
0.7015	CO2
1.2659	Argon

data is crawled with
getWeather_unimainz.py
from magix-83

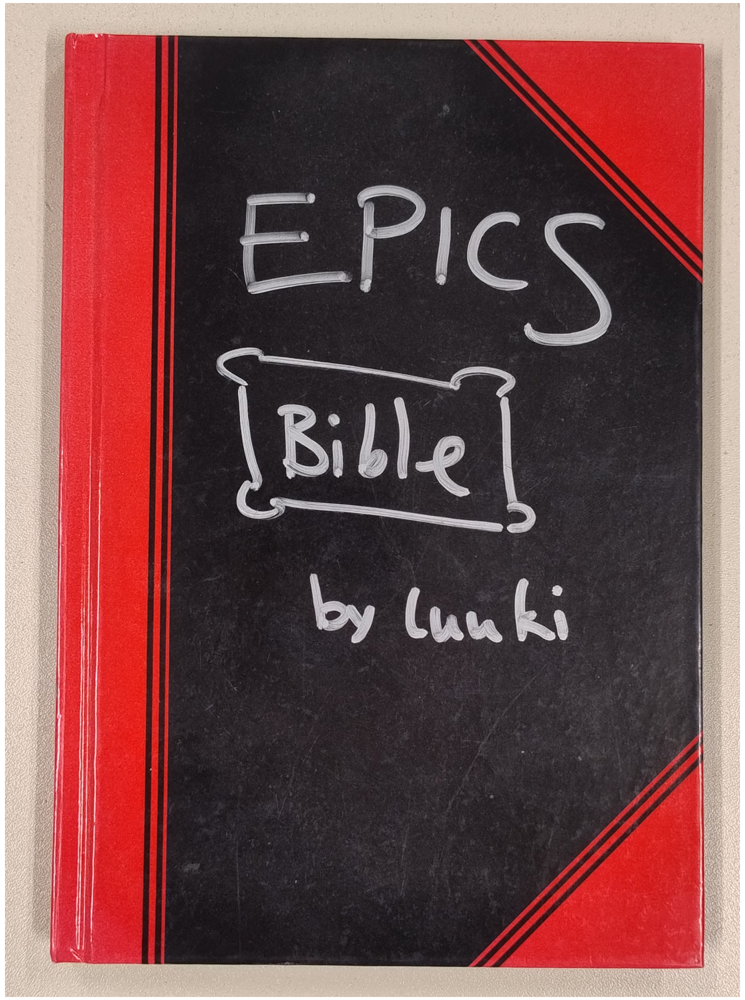
https://controlssoftware.sns.ornl.gov/css_phoebus/

Tutorial

- create db
- define records
- start IOC

MXEPICS

- Autocomplete
- tmux
- dbLoadMultiRecords
- Profibus
- /opt/epics/…/st_mx22.cmd



EPICS@MESA

- Forward PVs to experiments?
- Monthly meeting?
- Mattermost?
- Version? EPICS7!

Ressources

- https://epics.anl.gov/index.php
- https://epics-controls.org/
- https://docs.epics-controls.org/en/latest/index.html
- https://epics.anl.gov/docs/GSWE.php
- https://epics.anl.gov/EpicsDocumentation/AppDevManuals/RecordRef/Recordref-6.html
- https://controlssoftware.sns.ornl.gov/css_phoebus/
- https://magix-wiki.kph.uni-mainz.de/index.php/Manual:Tutorial:MXSlowControl#Device_Support
- https://gitlab.rlp.net/mxslowcontrol/MXEPICS

Ten Really Neat Things About EPICS

1. It is free. No license fees, no new payment for every upgrade. You can download EPICS free of charge from the web.
2. It is Open Source (i.e. the source code is accessible). Adaptions and changes due to a special environment are therefore possible.
3. There are lots of users. It is tested and most bugs are already found.
4. All a client needs to know to access data is a PV name. No single point of failure due to a nameserver and no messing around with fixed addresses.
5. You can pick the best tools out there …
6. … or build your own.
7. The boring stuff is already done. For example the communication with Channel Access is stable and well tested.
8. There is a lot of expertise available close by.
9. A good contribution becomes internationally known.
10. It doesn't matter whether you need 10 PVs or 10 Million PVs. You can scale EPICS almost freely.