EPICS

Tools for Physicists

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Structure

of this course

internal basics hands on profi talk



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-controls.org/

THE EXPERIMENTAL PHYSICS AND INDUSTRIAL **CONTROL SYSTEM**

Natural Decentralized Structure



Scope Today





Channel Access Client – Server



PV – Process Variable





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	Туре	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,"Q")
```

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

Record – more Fields

Field	Summary	Туре	DCT	Default	Read	Write	CA PP
SCAN	Scan Mechanism	MENU (menuScan)	Yes		Yes	Yes	No
PINI	Process at ioclnit	MENU (<u>menuPini</u>)	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,"Q")
```

}

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

Record - Alarm

Field	Summary	Туре	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	Туре	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 (<u>menuYesNo</u>)	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(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/0 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.

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

record(pi "\$(P):getResistance1")

"\$(P):Temp1")

"\$(P):getResistance1") "(A/1000.0-1)/0.00385") "Passive") 3)

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";
```

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";
```

in "%f";

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 "nondedicated" 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



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

CSS phoebus

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 Graphics 🗖 Arc Ellipse A Label Picture

🗸 Polygon S Polyline Rectangle Monitors Byte Monitor ● LED

LED (Multi State)

CSS phoebus



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

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

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.