Writing Device Support

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Based on presentations by
Eric Norum, 2004
Ralph Lange, 2006

Writing Device Support – Scope

- An overview of the concepts associated with writing EPICS Device Support routines.
- Examples show the “stone knives and bearskins” approach.
- The ASYN package provides a framework which makes writing device support much easier.
  - The concepts presented here still apply.

Writing Device Support – Outline

- What is ‘Device Support’?
- The .dbd file entry
- The driver DSET
- Device addresses
- Support routines
- Using interrupts
- Asynchronous input/output
- Callbacks

What is ‘Device Support’?

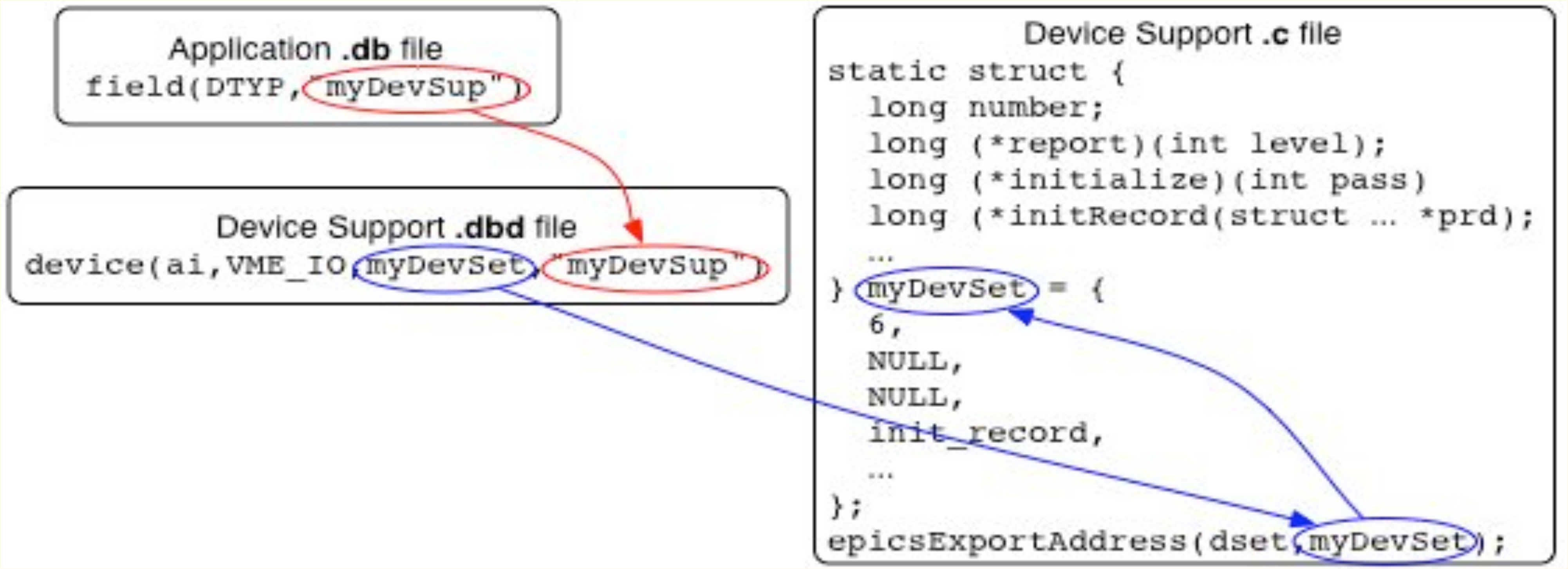
- Interface between record and hardware
- A set of routines for record support to call
  - The record type determines the required set of routines
  - These routines have full read/write access to any record field
- Determines synchronous/asynchronous nature of record
- Performs record I/O
  - Provides interrupt handling mechanism

Why use Device Support?

- Could instead make a different record type for each hardware interface, with fields to allow full control over the provided facilities.
- A separate device support level provides several advantages:
  - Users need not learn a new record type for each type of device
  - Increases modularity
    - I/O hardware changes are less disruptive
    - Device support is simpler than record support
    - Hardware interface code is isolated from record API
- Custom records are available if really needed.
  - By which I mean “really, really, really needed!”
  - Existing record types are sufficient for most applications.

How Does a Record Find Its Device Support?

Through .dbd ‘device’ statements:



Application **.db** file

```
field(DTYP,"myDevSup")
```

Device Support **.dbd** file

```
device(ai,VME_IO,myDevSet,"myDevSup")
```

Device Support **.c** file

```
static struct {
   long number;
   long (*report)(int level);
   long (*initialize)(int pass)
   long (*initRecord(struct … *prd);
   …
} myDevSet = {
   6,
   NULL,
   NULL,
   init_record,
   …
};
epicsExportAddress(dset,myDevSet);
```

The *.dbd* File Entry

- The IOC discovers device support from entries in .dbd files

device(*recType*,*addrType*,*dsetName*,”dtypeName”)

- *addrType* is one of

AB_IO BITBUS_IO CAMAC_IO GPIB_IO

INST_IO RF_IO VME_IO VXI_IO

- *dsetName* is the name of the C Device Support Entry Table (DSET)
    - By convention name indicates record and hardware type:

```
device(ai, GPIB_IO, devAidg535, "dg535")
device(bi, VME_IO, devBiXy240, "XYCOM-240")
```

The DSET

- A C structure containing pointers to functions
- Content dependent upon record type
- Each device support layer defines a DSET with pointers to its own functions
- A DSET structure declaration looks like:

```
struct dset {
             long number;
             long (*report)(int level);
             long (*initialize)(int pass);
             long (*initRecord)(struct … *precord);
             long (*getIoIntInfo)(…);
             … read/write and other routines as required
};
```

- `number` specifies number of pointers (often 5 or 6)
- A NULL is given when an optional routine is not implemented
- DSET structures and functions are usually declared `static`

The DSET – initialize

```
long initialize(int pass);
```

- Initializes the device support layer
- Optional routine, not always needed
- Used for one-time startup operations:
  - Start background tasks
  - Create shared tables
- Called twice by iocInit()
  - `pass=0` – Before any record initialization
    - Doesn't usually access hardware since device address information is not yet known
  - `pass=1` – After all record initialization
    - Can be used as a final startup step. All device address information is now known

The DSET – initRecord

```
long initRecord(struct … *precord);
```

- Called by iocInit() once for each record with matching DTYP
- Optional routine, but usually supplied
- Routines often
  - Validate the INP or OUTP field
  - Verify that addressed hardware is present
  - Allocate device-specific storage for the record
    - Each record contains a `void *dpvt` pointer for this purpose
  - Program device registers
  - Set record-specific fields needed for conversion to/from engineering units

The DSET – initRecord – Device Addresses

- **Device support .dbd entry was**

  `device(`*`recType`*`,`*`addrType`*`,`*`dset`*`,"`*`name`*`")`

- ***addrType*** **specifies the type to use for the address link, e.g.**

  ```
  device(bo,VME_IO,devBoXy240,"Xycom XY240")
  ```

  sets `pbo->out`**:**

  - `pbo->out.type = VME_IO`
  - **Device support uses** `pbo->out.value.vmeio` **which is a**

    ```
    struct vmeio {
        short card;
        short signal;
        char *parm;
    };
    ```

- **IOC Application Developer's Guide describes all types**

The DSET – report

```
long report(int level);
```

- Called by `dbior` shell command
- Prints information about current state, hardware status, I/O statistics, etc.
- Amount of output is controlled by the level argument
  - `level=0` – list hardware connected, one device per line
  - `level>0` – provide different type or more detailed information

The DSET – read/write

```
long read(struct … *precord);
long write(struct … *precord);
```

- Called when record is processed
- Perform (or initiate) the I/O operation:
  - Synchronous input
    - Copy value from hardware into *`precord->rval`*
    - Return 0 (to indicate success)
  - Synchronous output
    - Copy value from *`precord->rval`* to hardware
    - Return 0 (to indicate success)

A Simple Example (VME / vxWorks or RTEMS)

```
#include <recGbl.h>
#include <devSup.h>
#include <devLib.h>
#include <biRecord.h>
#include <epicsExport.h>
static long initRecord(struct biRecord *prec){
          char *pbyte, dummy;
          if ((prec->inp.type != VME_IO) ||
              (prec->inp.value.vmeio.signal < 0) || (prec->inp.value.vmeio.signal > 7)) {
                    recGblRecordError(S_dev_badInpType, (void *)prec, "devBiFirst: Bad INP");
                    return -1;
          }
          if (devRegisterAddress("devBiFirst", atVMEA16, prec->inp.value.vmeio.card, 0x1,
                                                                                &pbyte) != 0) {
                    recGblRecordError(S_dev_badCard, (void *)prec, "devBiFirst: Bad VME address");
                    return -1;
          }
          if (devReadProbe(1, pbyte, &dummy) < 0) {
                    recGblRecordError(S_dev_badCard, (void *)prec, "devBiFirst: Nothing there!");
                    return -1;
          }
          prec->dpvt = pbyte;
          prec->mask = 1 << prec->inp.value.vmeio.signal;
          return 0;
}
```

A Simple Example (VME / vxWorks or RTEMS)

```
static long read(struct biRecord *prec)
{
        volatile char *pbyte = (volatile char *)prec->dpvt;

        prec->rval = *pbyte;
        return 0;
}

static struct {
        long number;
        long (*report)(int);
        long (*initialize)(int);
        long (*initRecord)(struct biRecord *);
        long (*getIoIntInfo)();
        long (*read)(struct biRecord *);
} devBiFirst = {
        5, NULL, NULL, initRecord, NULL, read
};
epicsExportAddress(dset,devBiFirst);
```

A Simple Example – Device Support .dbd File

The .dbd file for the device support routines shown on the preceding pages might be

```
device(bi, VME_IO, devBiFirst, “simpleInput”)
```

A Simple Example – Application .db File

An application .db file using the device support routines shown on the preceding pages might contain

```
record(bi, "$(P):statusBit")
{
    field(DESC, "Simple example binary input")
    field(DTYP, "simpleInput")
    field(INP, "#C$(C) S$(S)")
}
```

A Simple Example – Application Startup Script

An application startup script (st.cmd) using the device support routines shown on the preceding pages might contain

```
dbLoadRecords("db/example.db","P=test,C=0x1E0,S=0")
```

which would expand the .db file into

```
record(bi, "test:statusBit")
{
    field(DESC, "Simple example binary input")
    field(DTYP, "simpleInput")
    field(INP, "#C0x1E0 S0")
}
```

Useful Facilities

- **ANSI C routines (EPICS headers fill in vendor holes)**
  - **epicsStdio.h – printf, sscanf, epicsSnprintf**
  - **epicsString.h – strcpy, memcpy, epicsStrDup**
  - **epicsStdlib.h – getenv, abs, epicsScanDouble**
- **OS-independent hardware access (devLib.h)**
  - **Bus address ⇔ Local address conversion**
  - **Interrupt control**
  - **Bus probing**
- **EPICS routines**
  - **epicsEvent.h – process synchronization semaphore**
  - **epicsMutex.h – mutual-exclusion semaphore**
  - **epicsThread.h – multithreading support**
  - **recGbl.h – record error and alarm reporting**

Device Interrupts

- vxWorks/RTEMS interrupt handlers can be written in C
- VME interrupts have two parameters
  - Interrupt level (1-7, but don't use level 7) – often set with on-board jumpers or DIP switches
  - Interrupt vector (0-255, <64 reserved on MC680x0) – often set by writing to an on-board register
- OS initialization takes two calls

1. Connect interrupt handler to vector

```
devConnectInterruptVME(unsigned vectorNumber,
          void (*pFunction)(void *),void *parameter);
```

2. Enable interrupt from VME to CPU

```
devEnableInterruptLevelVME (unsigned level);
```

I/O Interrupt Record Processing

- Record is processed when hardware interrupt occurs
- Granularity depends on device support and hardware
  - Interrupt per-channel vs. interrupt per-card
- #include <dbScan.h> to get additional declarations
- Call `scanIoInit` once for each interrupt source to initialize a local value:

```
scanIoInit(&ioscanpvt);
```

- DSET must provide a `getIoIntInfo` routine to specify the interrupt source associated with a record – a single interrupt source can be associated with more than one record
- Interrupt handler calls `scanIoRequest` with the ‘`ioscanpvt`’ value for that source – this is one of the very few routines which may be called from an interrupt handler

The DSET – getIoIntInfo

```
long getIoIntInfo(int cmd, struct … *precord,
                                    IOSCANPVT *ppvt);
```

- Set `*ppvt` to the value of the `IOSCANPVT` variable for the interrupt source to be associated with this record
- Must have already called `scanIoInit` to initialize the `IOSCANPVT` variable
- Return 0 to indicate success or non-zero to indicate failure – in which case the record `SCAN` field will be set to `Passive`
- Routine is called with
  - `(cmd=0)` when record is set to `SCAN=I/O Intr`
  - `(cmd=1)` when record `SCAN` field is set to any other value

The DSET – specialLinconv

```
long specialLinconv(struct … *precord, int after);
```

- Analog input (ai) and output (ao) record DSETs include this sixth routine
- Called just before (`after=0`) and just after (`after=1`) the value of the `LINR`, `EGUL` or `EGUF` fields changes
- “Before” usually does nothing
- “After” recalculates `ESLO` from `EGUL/EGUF` and the hardware range
- If record `LINR` field is `Linear` ai record processing will compute `val` as

```
  val = ((rval + roff) * aslo + aoff) * eslo + eoff
```

Ao record processing is similar, but in reverse

Asynchronous I/O

- Device support must not wait for slow I/O
- Hardware read/write operations which take “a long time” to complete must use asynchronous record processing
  - $T_{I/O} \geq 100\ \mu s$ – definitely “a long time”
  - $T_{I/O} \leq 10\ \mu s$ – definitely “not a long time”
  - $10\ \mu s < T_{I/O} < 100\ \mu s$ – ???
- If device does not provide a completion interrupt a “worker” thread can be created to perform the I/O
  - this technique is used for Ethernet-attached devices

Asynchronous I/O – Read/Write Operation

- **Check value of `precord->pact` and if zero:**
  - **Set precord->pact to 1**
  - **Start the I/O operation**
    - **write hardware or send message to worker thread**
  - **Return 0**
- **When operation completes run the following code from a thread (i.e. NOT from an interrupt handler)**

```
struct rset *prset = (struct rset *)precord->rset;
dbScanLock(precord);
(*prset->process)(precord);
dbScanUnlock(precord);
```

- **The record's process routine will call the device support read/write routine – with `precord->pact=1`**
  - **Complete the I/O, set `rval`, etc.**

Asynchronous I/O – Callbacks

- **An interrupt handler must not call a record's process routine directly**
- **Use the callback system (`callback.h`) to do this**
- **Declare a callback variable**

```
CALLBACK myCallback;
```

- **Issue the following from the interrupt handler**

```
callbackRequestProcessCallback(&myCallBack,
                              priorityLow, precord);
```

- **This queues a request to a callback handler thread which will perform the lock/process/unlock operations shown on the previous page**
- **There are three callback handler threads**
  - **With priorities Low, Medium and High**

Asynchronous I/O – ASYN

- This should be your first consideration for new device support
- It provides a powerful, flexible framework for writing device support for
  - Message-based asynchronous devices
  - Register-based synchronous devices
- Will be completely described in a subsequent lecture

ASYN will be covered in the next session.

You will find the package and documentation on the EPICS web site.

Caveat – there is a learning curve for ASYN … my rule of thumb:

ASYN makes it easy to do the hard stuff, but hard to do the easy stuff.

Hands on

```
# Commands to build a very simple device support
# k.furukawa, jan.2009.

# get rrcat.tar.gz from
#  http://www-linac.kek.jp/epics/second/rrcat.tar.gz

# open terminal
mkdir second
cd second
makeBaseApp.pl -t ioc Clock1
makeBaseApp.pl -t ioc -i -p Clock1 Clock1
tar xzf ~/Desktop/rrcat.tar.gz
perl  -i  -pe  s/CLOCK/{your-username}/   Clock1App/Db/aiSecond.db
# example: perl  -i  -pe  s/CLOCK/user7/  Clock1App/Db/aiSecond.db
make clean install 2>&1 | tee make.log
# (if your shell is csh : make clean install |& tee make.log)

cd iocBoot/iocClock1
chmod +x st.cmd
./st.cmd
```

```
# from another terminal
camonitor {your-username}:SEC1 {your-username}:SEC10
# example: camonitor user7:SEC1 user7:SEC10

# Please look in the files
Clock1App/src/devAiSecond.c
Clock1App/src/aiSecond.dbd
Clock1App/Db/aiSecond.db
```

Thank you