

# Getting Started with EPICS Lecture Series

## *Writing Device Support*

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*Based on presentation by Eric Norum*

# *Writing Device Support – Scope*

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- **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*

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- **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'?*

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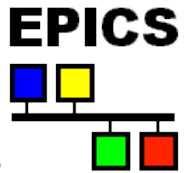
- **Interface between record and hardware**
- **A set of routines for record support to call**
  - The record type determines the required set of routines
  - These routines have full read/write access to any record field
- **Determines synchronous/asynchronous nature of record**
- **Performs record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

# Why use device support?

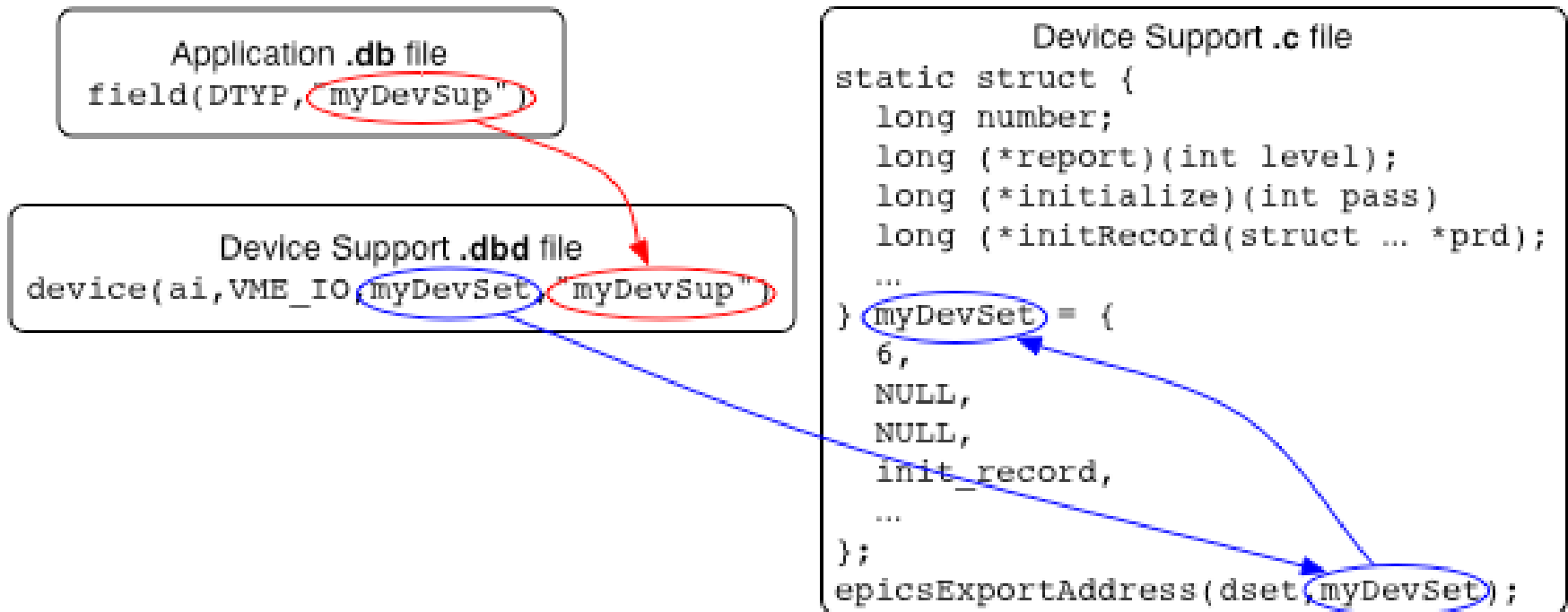
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- **Could instead make a different record type for each hardware interface, with fields to allow full control over the provided facilities.**
- **A separate device support level provides several advantages:**
  - Users need not learn a new record type 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:



# The .dbd file entry

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- **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

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- 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

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```
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*

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

- **Called by ioclnit() once for each record with matching DTYP**
- **Optional routine, but usually supplied**
- **Routines often**
  - Validate the INP or OUTF 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

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- 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*

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`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

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```
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 (*vxWorks* or *RTEMS*)

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```

#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", atVME16, 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 (*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*

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

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

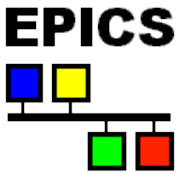
# *A simple example – application .db file*

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**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

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- **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  $\Leftrightarrow$  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

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- **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**
  - Connect interrupt handler to vector  

```
devConnectInterruptVME(unsigned vectorNumber,
                        void (*pFunction)(void *), void *parameter);
```
  - Enable interrupt from VME to CPU  

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

# I/O interrupt record processing

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- 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`

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```
long getIoIntInfo(int cmd, struct & *precd,
                  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

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```
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

$$\text{val} = ((\text{rval} + \text{roff}) * \text{aslo} + \text{aoff}) * \text{eslo} + \text{eoff}$$

**Ao record processing is similar, but in reverse**

# Asynchronous I/O

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- **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**
  - $T_{I/O} \geq 100 \mu\text{s}$  – definitely “a long time”
  - $T_{I/O} \leq 10 \mu\text{s}$  – definitely “not a long time”
  - $10 \mu\text{s} < T_{I/O} < 100 \mu\text{s}$  – ???
- **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

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- **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

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- **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*

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- **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**