… for a brighter future

ASYN Device Support Framework

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2006-11-20

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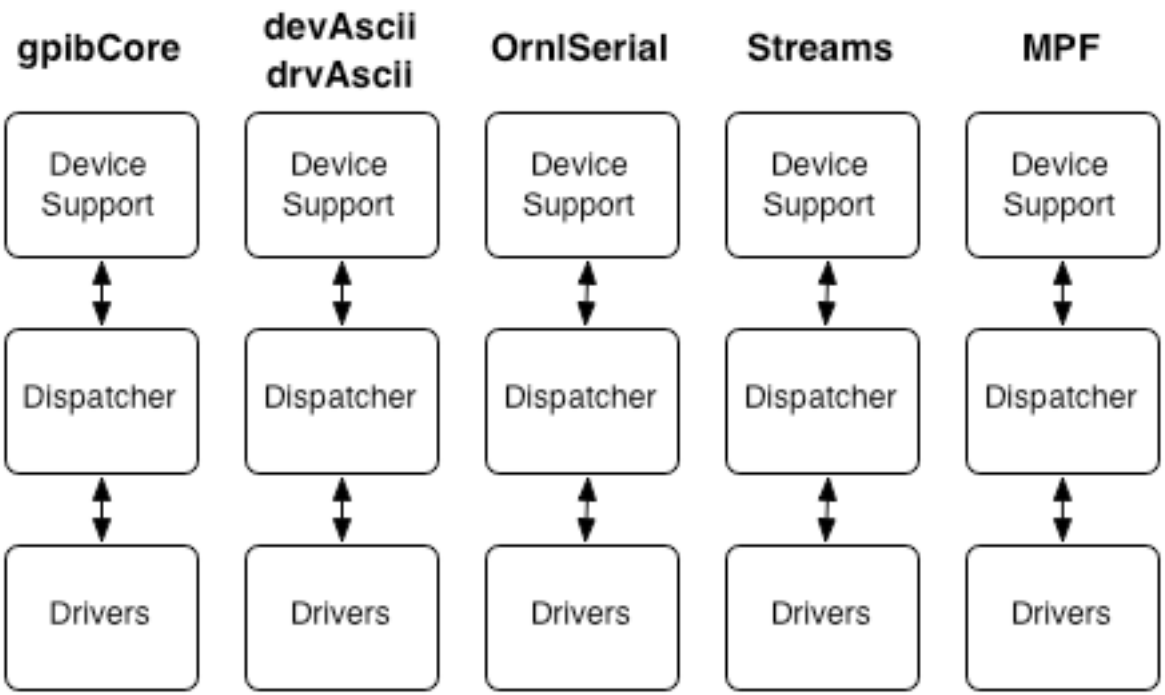
ASYN

- What is it?
- What does it do?
- How does it do it?
- How do I use it?

What is it?

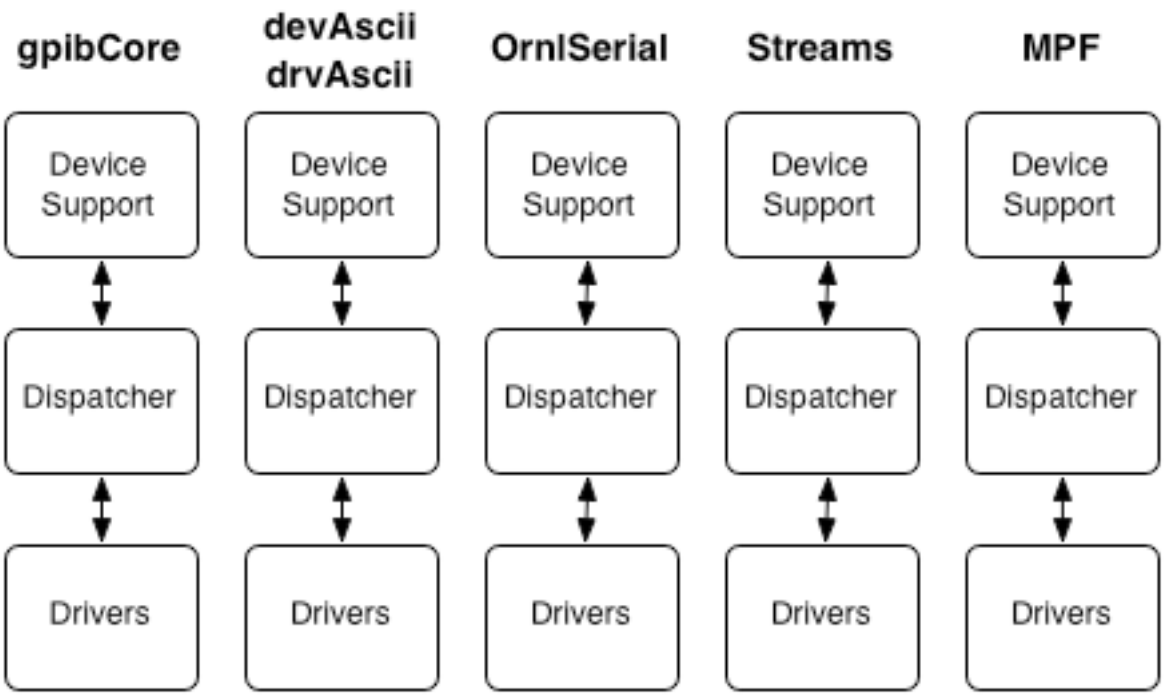
Asynchronous Driver Support is a general purpose facility for interfacing device specific code to low level communication drivers

The problem – Duplication of effort



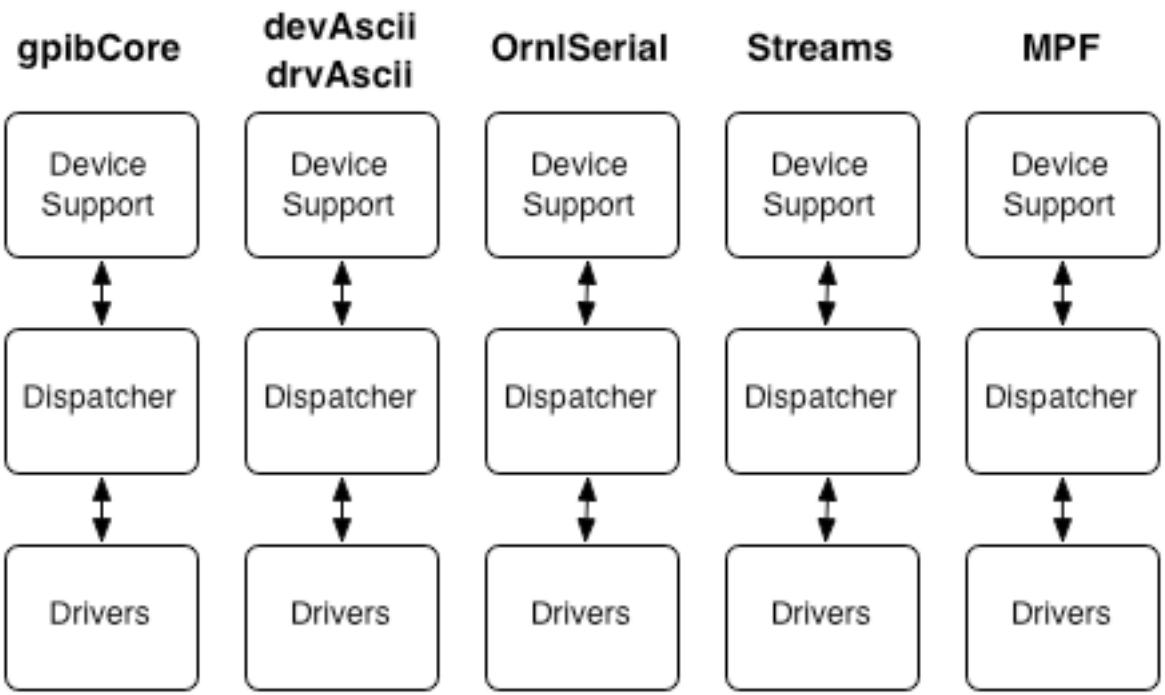
- Each device support has its own asynchronous I/O Dispatcher
  - All with different degrees of support for message concurrency and connection management

The problem – Duplication of effort



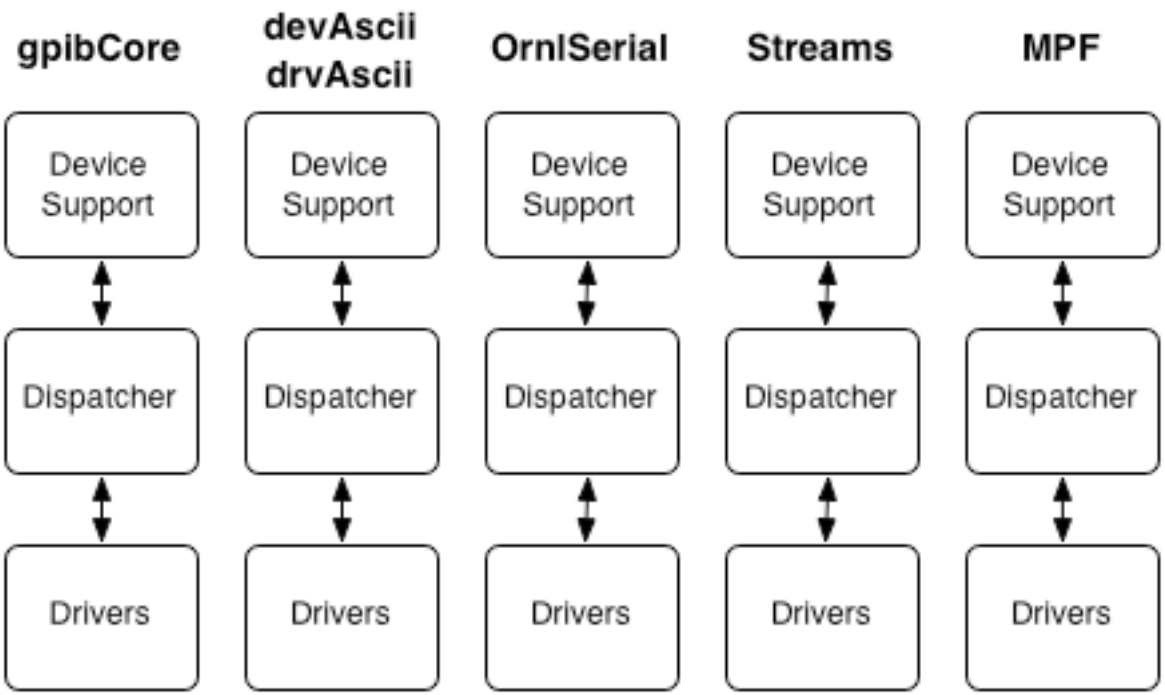
- Each device support has its own set of low-level drivers
  - All with different driver coverage

The problem – Duplication of effort



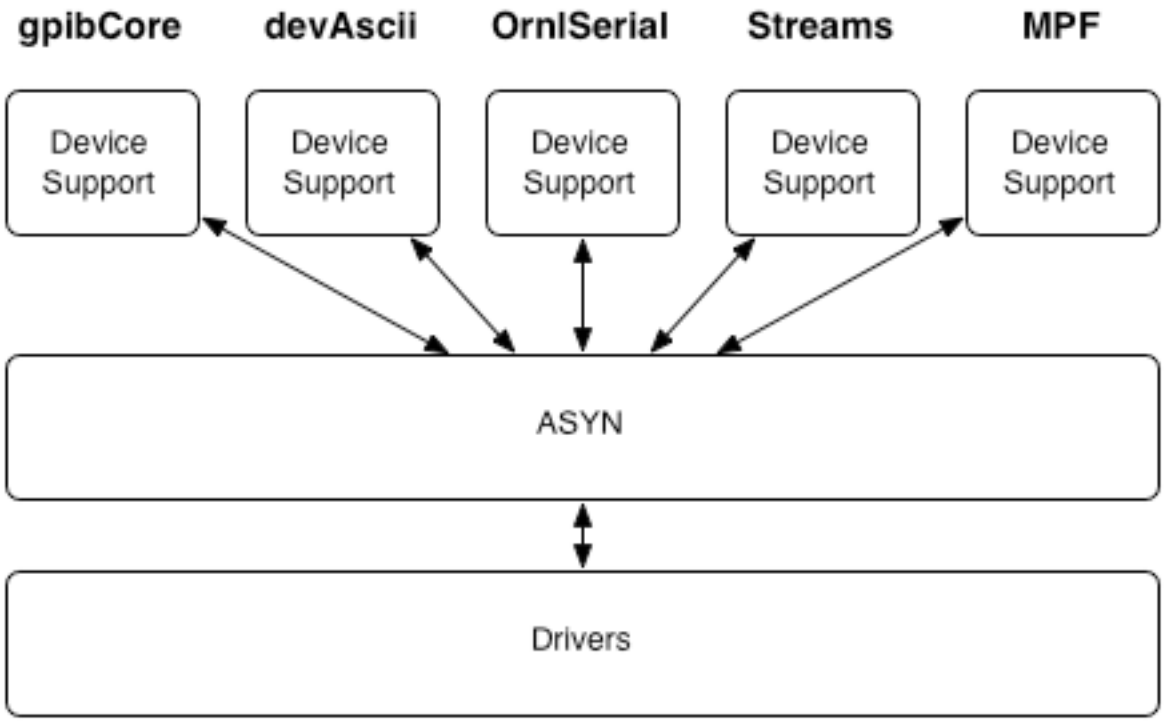
- Not possible to get all users to switch to one devXXX
  - Many 10s of thousands of record instances
  - 100s of device support modules

The problem – Duplication of effort

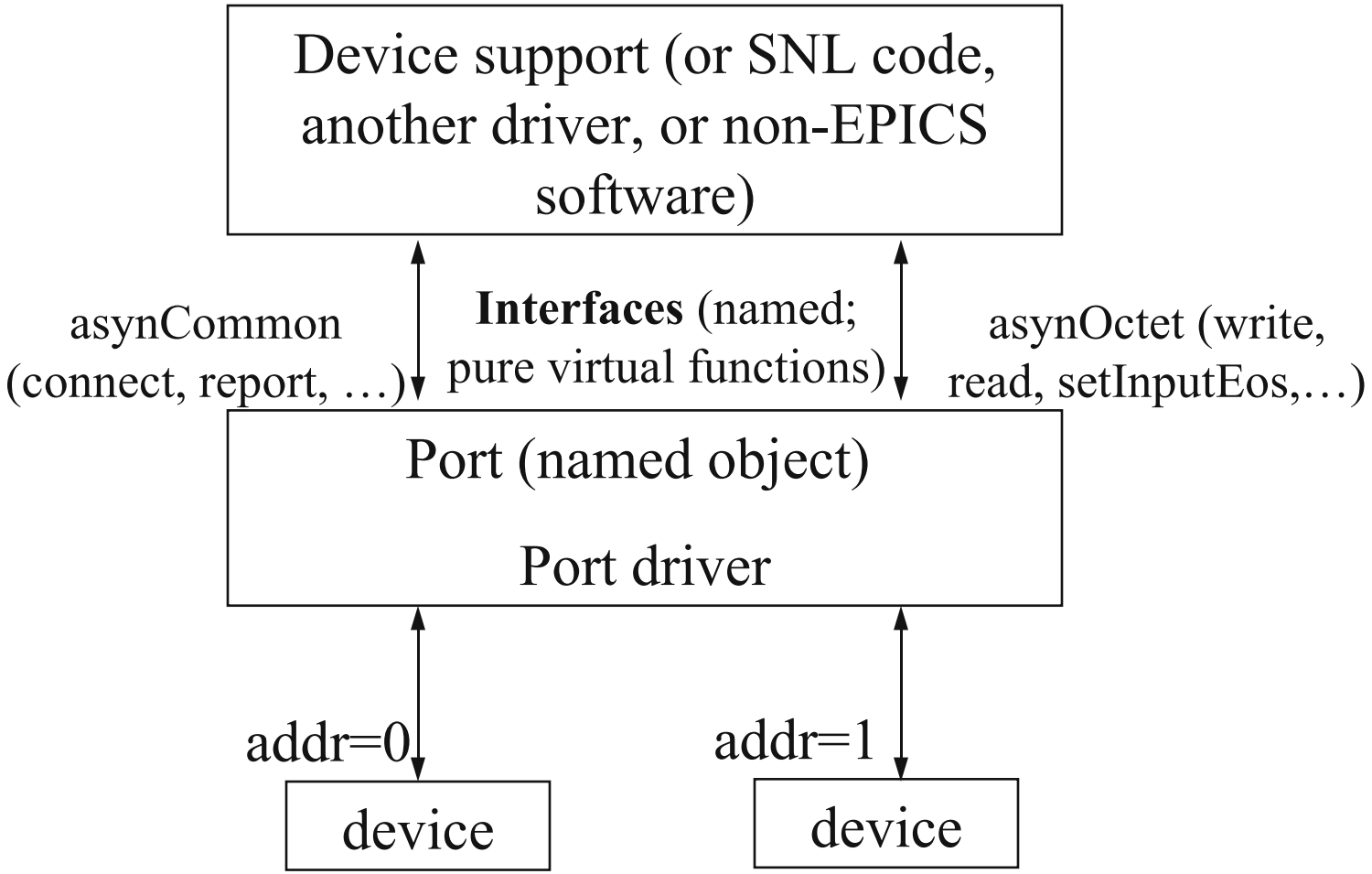


- R3.14 makes the situation a whole lot worse:
  - Adds another dimension to the table – multiple architectures
  - vxWorks, POSIX (Linux, Solaris, OS X), Windows, RTEMS

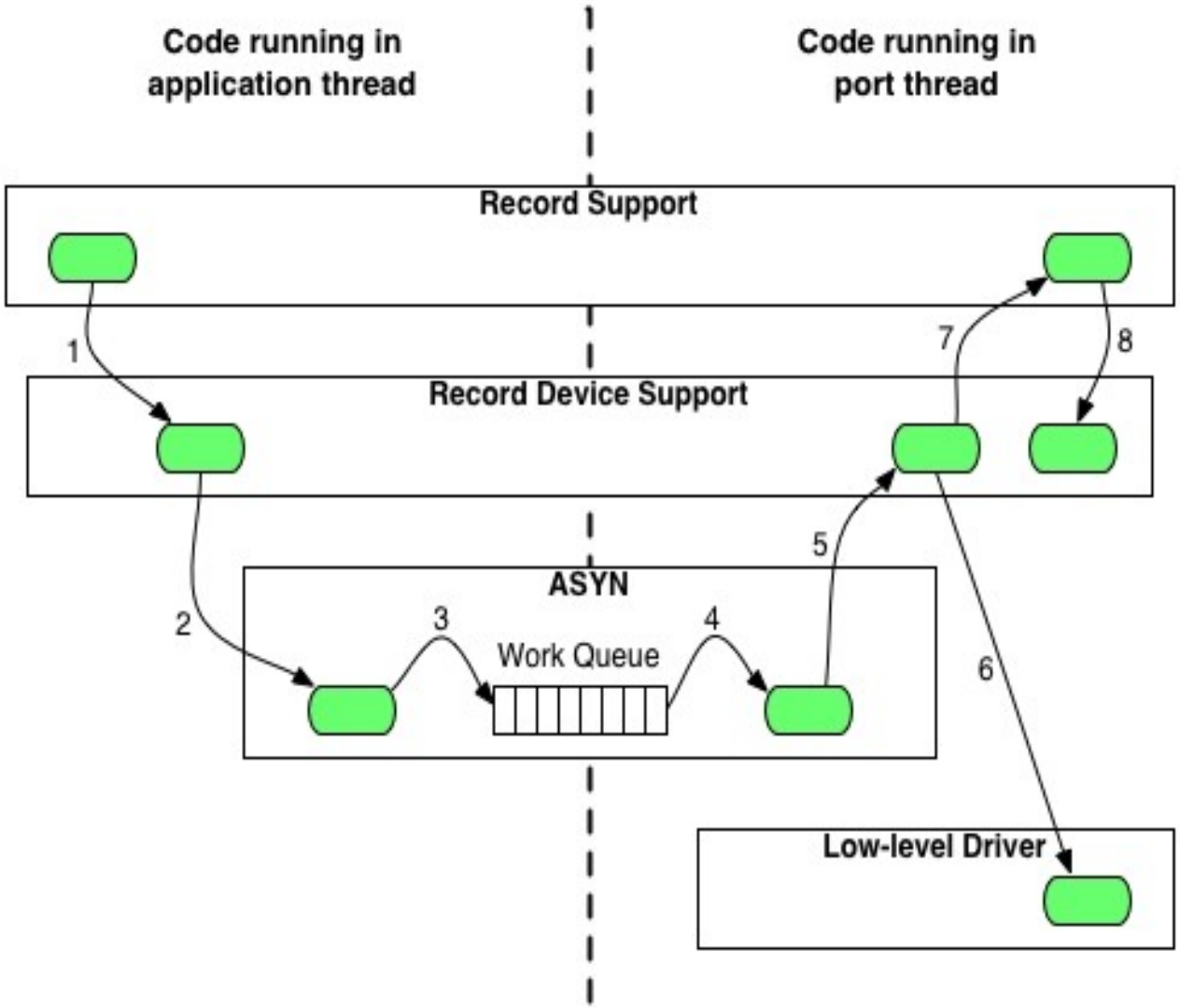
The solution – ASYN



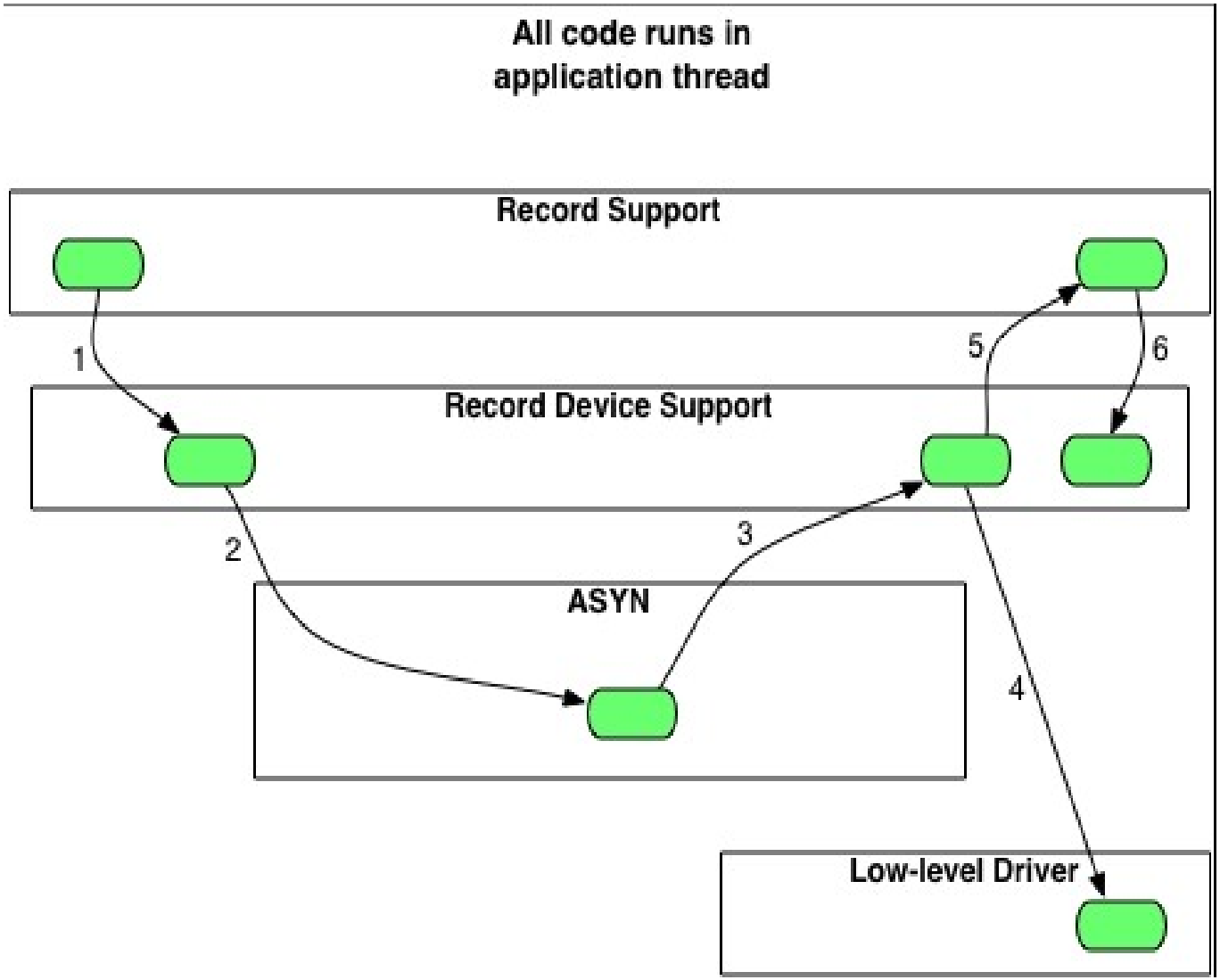
asyn Architecture



Control flow – asynchronous driver



Control flow – synchronous driver



ASYN Components – asynManager

- Provides thread for each communication interface
  - All driver code executes in the context of this thread
- Provides connection management
  - Driver code reports connect/disconnect events
- Queues requests for work
  - Nonblocking – can be called by scan tasks
  - User-supplied callback code run in worker-thread context makes calls to driver
  - Driver code executes in a single-threaded synchronous environment
- Handles registration
  - Low level drivers register themselves
  - Can ‘interpose’ processing layers

ASYN Components – asynCommon

- A group of methods provided by all drivers:
  - Report
  - Connect
  - Disconnect
  - Set option
  - Get option
    - *Options are defined by low-level drivers*
    - *e.g., serial port rate, parity, stop bits, handshaking*

ASYN Components – asynOctet

- Driver or interposed processing layer
- Methods provided in addition to those of asynCommon:
  - Read
  - Write
  - Set end-of-string character(s)
  - Get end-of-string character(s)
- All that's needed for serial ports, 'telnet-style' TCP/IP devices
- The single-threaded synchronous environment makes driver development much easier
  - No fussing with mutexes
  - No need to set up I/O worker threads

ASYN Components – asynGpib

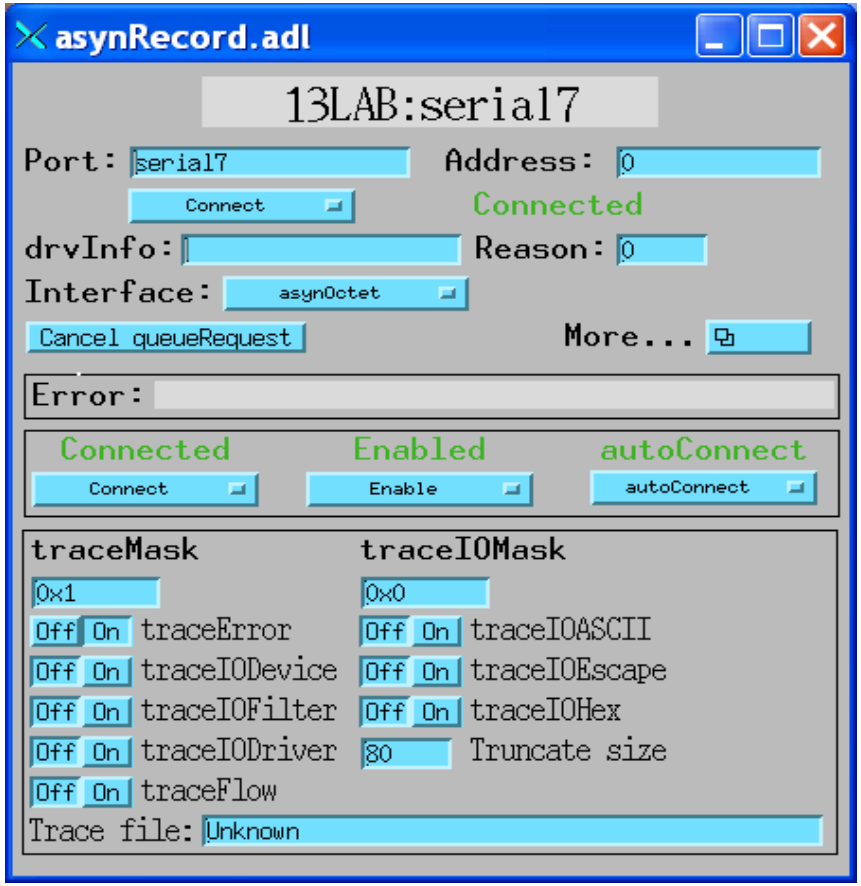
- Methods provided in addition to those of asynOctet:
  - Send addressed command string to device
  - Send universal command string
  - Pulse IFC line
  - Set state of REN line
  - Report state of SRQ line
  - Begin/end serial poll operation
- Interface includes asynCommon and asynOctet methods
  - Device support that uses read/write requests can use asynOctet drivers. Single device support source works with serial and GPIB!

ASYN Components – asynRecord

- Diagnostics
  - Set device support and driver diagnostic message masks
  - No more ad-hoc ‘debug’ variables!
- General-purpose I/O
  - Replaces synApps serial record and GPIB record
- Provides much of the old ‘GI’ functionality
  - Type in command, view reply
  - Works with **all** asyn drivers
- A single record instance provides access to all devices in IOC

asynRecord

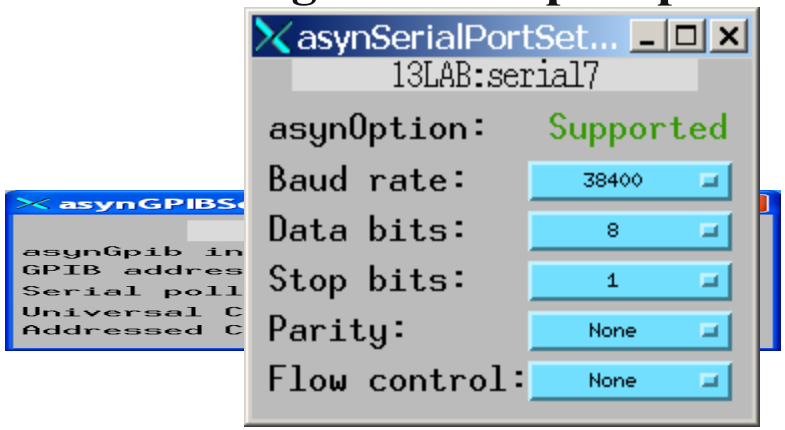
- EPICS record that provides access to most features of asyn, including standard I/O interfaces
- Applications:
  - Control tracing (debugging)
  - Connection management
  - Perform interactive I/O
- Very useful for testing, debugging, and actual I/O in many cases
- Replaces the old generic “serial” and “gpib” records, but much more powerful



asynRecord – asynOctet devices

Interactive I/O to serial device

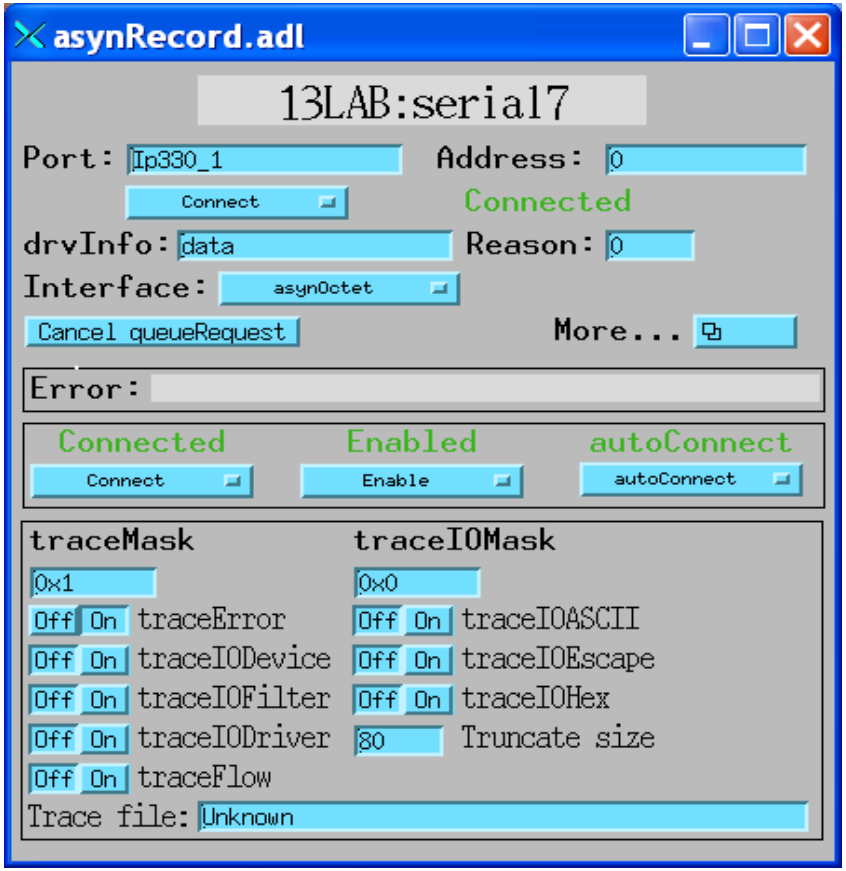
Configure serial port parameters



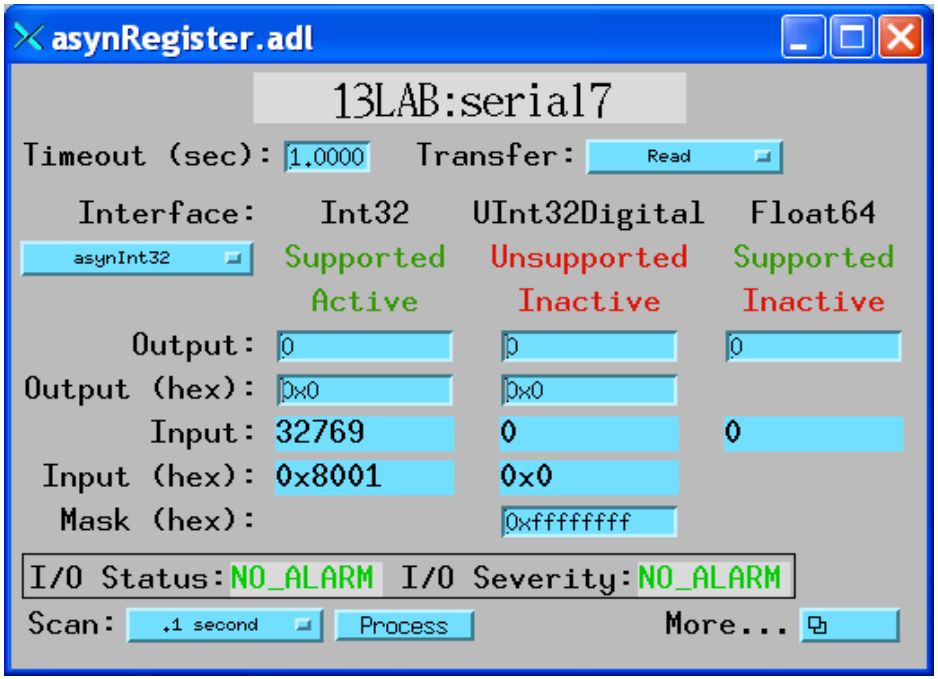
Perform GPIB specific operations

asynRecord – register devices

Same asynRecord, change to ADC port

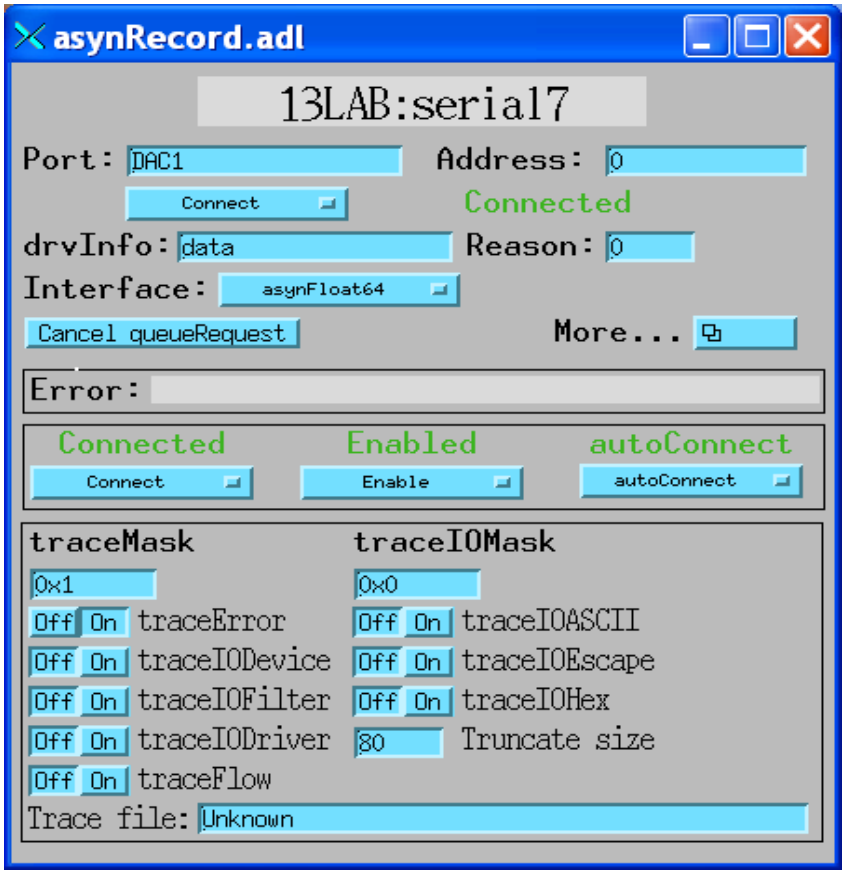


Read ADC at 10Hz with asynInt32 interface

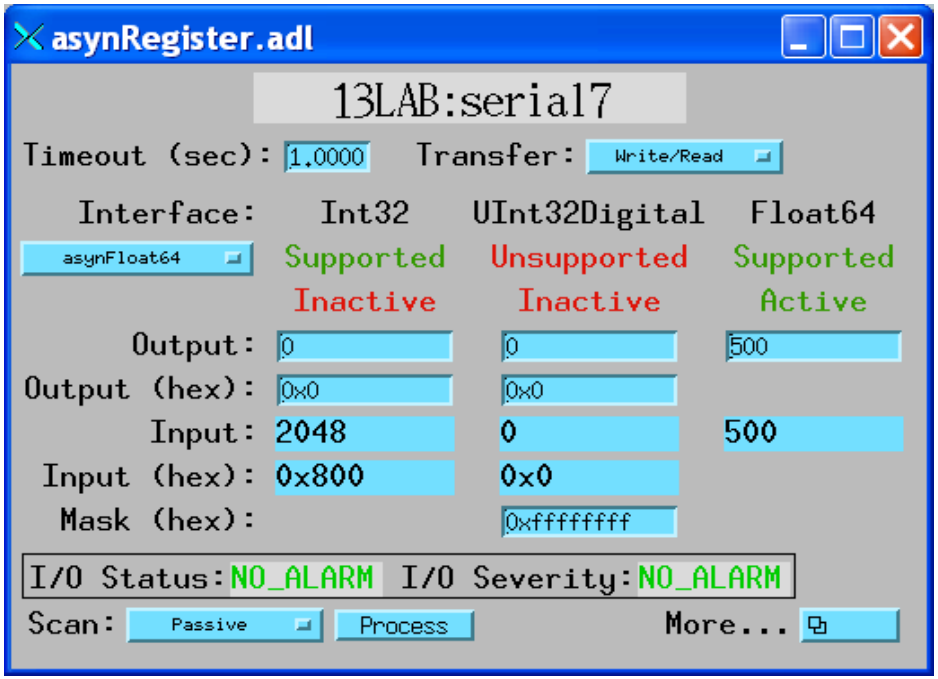


asynRecord – register devices

Same asynRecord, change to DAC port

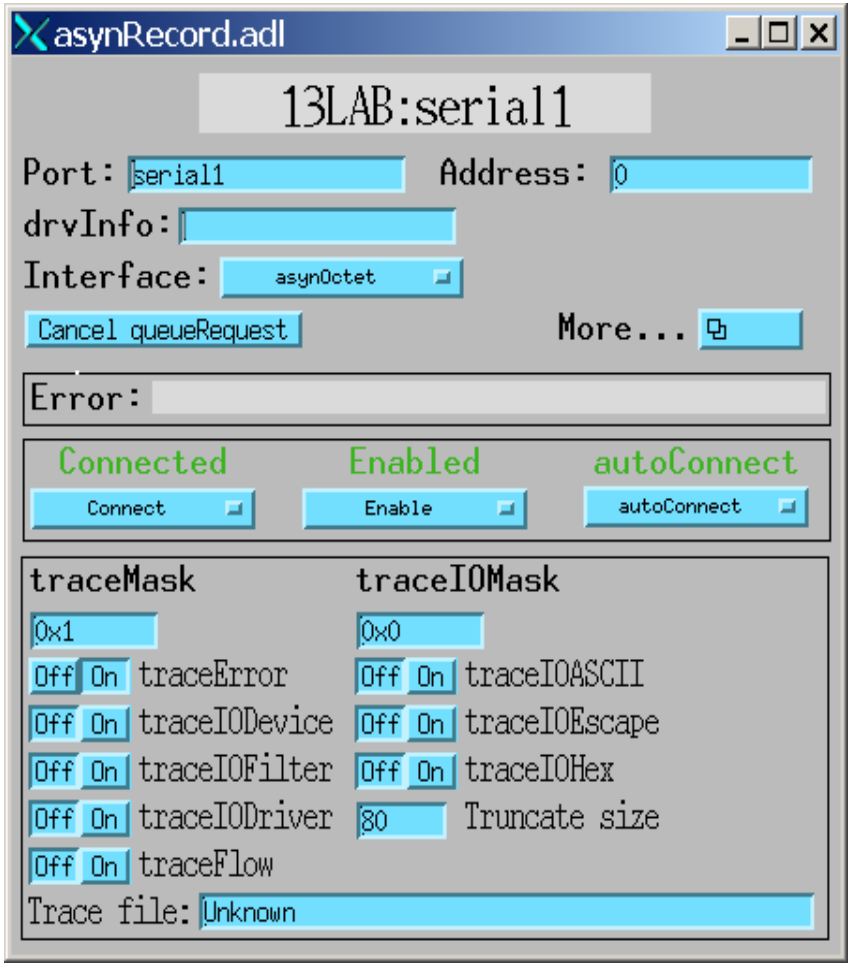


Write DAC with asynFloat64 interface



Tracing and Debugging

- Standard mechanism for printing diagnostic messages in device support and drivers
- Messages written using EPICS logging facility, can be sent to stdout, stderr, or to a file
- Device support and drivers call:
  - asynPrint(pasynUser, reason, format, ...)
  - asynPrintIO(pasynUser, reason, buffer, len, format, ...)
  - Reason:
    - *ASYN_TRACE_ERROR*
    - *ASYN_TRACEIO_DEVICE*
    - *ASYN_TRACEIO_FILTER*
    - *ASYN_TRACEIO_DRIVER*
    - *ASYN_TRACE_FLOW*
- Tracing is enabled/disabled for (port/addr)
- Trace messages can be turned on/off from iocsh, vxWorks shell, and from CA clients such as MEDM via asynRecord
- asynOctet I/O from shell



Great – So how do I use it?

1. Adding existing device support to an application
2. Writing support for a message-based (asynchronous) device
   - devGpib
   - StreamDevice
   - Custom
3. Writing support for a register-based (synchronous) device
4. Dealing with interrupts
   - ‘Completion’ interrupts
   - ‘Trigger’ (unsolicited) interrupts

Adding ASYN instrument support to an application

Adding ASYN instrument support to an application

- This is easy because the instrument support developers always follow all the guidelines – right?
- The following procedure is taken from:

  How to create EPICS device support for a simple serial or GPIB device

Make some changes to configure/RELEASE

- Edit the configure/RELEASE file created by makeBaseApp.pl
- Confirm that the EPICS_BASE path is correct
- Add entries for ASYN and desired instruments
- For example:
  - ***AB300 =/home/EPICS/modules/instrument/ab300/1-1***
  - ***ASYN =/home/EPICS/modules/soft/asyn/3-2***
  - ***EPICS_BASE=/home/EPICS/base***

Modify the application database definition file

- If you are building your application database definition from the application Makefile, you specify the additional database definitions there:

```
.
.
xxx_DBD += base.dbd
xxx_DBD += devAB300.dbd
xxx_DBD += drvAsynIPPort.dbd
xxx_DBD += drvAsynSerialPort.dbd
.
.
```

Add support libraries to the application

- You must link the instrument support library and the ASYN library with the application
- Add the lines

  *xxx*_LIBS += devAB300
  *xxx*_LIBS += asyn
  before the
  *xxx*_LIBS += $(EPICS_BASE_IOC_LIBS)
  line in the application Makefile

Modify the application startup script

dbLoadRecords(“db/devAB300.db”,”P=AB300:,R=,L=0,A=0”)

- P,R - PV name prefixes – PV names are (P)(R)name
- L - Link number from corresponding devxxxxConfigure command
  drvAsynIPPortConfigure("L0","192.168.3.137:4001",0,0,0)
- A - Device address

Writing ASYN instrument support

Converting or writing instrument support?

- Strive to make the instrument support useable by others
- Try to support all the capabilities of the instrument
- Keep names and functions as general as possible
- Stick to the prescribed source/library layout

Recommended source file arrangement

- Instrument support is not tied to EPICS base
- Support should not depend upon other instrument support
- Support should not influence other instrument support
- Which means that:
  - Instrument support is placed in CVS repository in
    - *<xxxxx>**/modules/instrument/**<instrumentname>**/***
  - Each *<instrumentname>* directory contains
    - ***Makefile***
    - ***configure/***
    - *<InstrumentName>**Sup/***
    - ***documentation/***
    - ***License***

There's a script to make this a little easier

- mkdir *xxxx*/modules/instrument/*myinst*
- cd *xxxx*/modules/instrument/*myinst*
- *xxxx*/modules/soft/asyn/bin/<*arch*>/makeSupport.pl -t devGPIB *MyInst*

```
Makefile
configure/
    CONFIG          Makefile        RULES           RULES_TOP
    CONFIG_APP      RELEASE         RULES_DIRS
MyInstSup/
    Makefile devMyInst.c devMyInst.db devMyInst.dbd
documentation/
   devMyInst.html
```

- A few changes to the latter 4 files and you're done!

Writing devGpib instrument support

Applies to serial and network devices too!

For instruments such as:

- Those connected to local GPIB ports (vxWorks-only)
  - IP-488
  - NI-1014
- Those connected to remote GPIB ports
  - Agilent E5810, E2050
  - Tektronix AD007
- Those connected to local serial ports (e.g. COM1:, /dev/ttyS0)
- Those connected to remote serial ports (e.g. MOXA box)
- Serial-over-Ethernet devices (‘telnet-style’)
- VXI-11 Ethernet devices (e.g., Tektronix TDS3000 oscilloscopes)

New support for a message-based instrument (devGPIB)

- /<*path*>/makeSupport.pl -t devGpib <*InstrumentName*>
- Confirm configure/RELEASE entries for ASYN and BASE
- Modify InstrumentNameSup/devInstrumentName.c
  - Specify appropriate TIMEOUT and TIMEWINDOW values
  - Specify tables of command/response strings and record initialization strings (if needed)
  - Write any custom conversion or I/O routines
  - Set respond2Writes as appropriate (in ***`init_ai`*** routine)
  - Fill in the command table

New support for a message-based instrument (devGPIB)

static char *setDisplay[] = {"DISP:TEXT 'WORKING'","DISPLAY:TEXT:CLEAR",NULL};

Table Entries

dset, type, priority, command, format, rsplen, msglen, convert, P1, P2, P3, pdevGpibNames, eos

- /* Param 0 - Identification string */
  {&DSET_SI,GPIBREAD,IB_Q_LOW,"*IDN?","%39[^\n]",0,80,0,0,NULL,NULL,NULL},
- /* Param 1 -- Set frequency */
  {&DSET_AO,GPIBWRITE,IB_Q_LOW,NULL,"FRQ %.4f HZ",0,80,NULL,0,0,NULL,NULL,NULL}
- /* Param 2 Display Message: BO */
  {&DSET_BO,GPIBEFASTO,IB_Q_HIGH,NULL,NULL,0,0,NULL,0,0,setDisplay,NULL,NULL},
- /* Param 3 Read Voltage: AI */
  {&DSET_AI,GPIBREAD,IB_Q_HIGH,"MEAS:VOLT:DC?","%lf",0,80,NULL,0,0,NULL,NULL,NULL},
  .
  .
- /* Param 20 -- read amplitude */
  {&DSET_AI,GPIBREAD,IB_Q_LOW,"IAMP",NULL,0,60,convertVoltage,0,0,NULL,NULL,NULL},

New support for a message-based instrument (devGPIB)

```
static int
convertVoltage(gpibDpvt *pgpibDpvt, int P1, int P2, char **P3)
{
    aiRecord *pai = (aiRecord *)pgpibDpvt->precord;
    asynUser *pasynUser = pgpibDpvt->pasynUser;
    double v;
    char units[4];

    if (sscanf(pgpibDpvt->msg, P1 == 0 ? "AMP %lf %3s" : "OFS %lf %3s", &v, units) != 2) {
        epicsSnprintf(pasynUser->errorMessage, pasynUser->errorMessageSize, "Scanf failed");
        return -1;
    }
    if (strcmp(units, "V") == 0) {
    } else if (strcmp(units, "MV") == 0) {
        v *= 1e-3;
    } else {
        epicsSnprintf(pasynUser->errorMessage, pasynUser->errorMessageSize, "Bad units");
        return -1;
    }
    pai->val = v;
    return 0;
}
```

New support for a message-based instrument (devGPIB)

```
record(stringin, "$(P)$(R)IDN")
{
    field(DESC, "SCPI identification string")
    field(DTYP, "myInst")
    field(INP,  "#L$(L) A$(A) @0")
    field(PINI, "YES")
}

record(ao, "$(P)$(R)SetFrequency")
{
    field(DESC, "Set instrument frequencyt")
    field(DTYP, "myInst")
    field(OUT,  "#L$(L) A$(A) @1")
}

.
.
.
```

New support for a message-based instrument (streamDevice)

- /<*path*>/makeSupport.pl -t streamSCPI <*InstrumentName*>
- Confirm configure/RELEASE entries for ASYN and BASE
- Add configure/RELEASE entry for STREAM
- Modify InstrumentNameSup/devInstrumentName.proto
  - Create/modifiy 'protocol descriptions'

New support for a message-based instrument (streamDevice)

```
getIDN {
    out "*IDN?";
    in "%\$1[^\r\n]";
    ExtraInput = Ignore;
}
cmd {
    out "\$1";
}
setD {
    out "\$1 %d";
}
getD {
    out "\$1?";
    in "%d";
    ExtraInput = Ignore;
}
```

New support for a message-based instrument (streamDevice)

```
record(bo, "$(P)$(R)CLS")
{
    field(DESC, "SCPI Clear status")
    field(DTYP, "stream")
    field(OUT,  "@devmyInst.proto cmd(*CLS) $(PORT) $
(A)")
}

record(longin, "$(P)$(R)GetSTB")
{
    field(DESC, "SCPI get status byte")
    field(DTYP, "stream")
    field(INP,  "@devmyInst.proto getD(*STB) $(PORT) $(A)")
}
```

New support for a message-based instrument (devGPIB)

```
record(stringin, "$(P)$(R)IDN")
{
    field(DESC, "SCPI identification string")
    field(DTYP, "stream")
    field(INP,  "@devmyInst.proto getIDN(39) $(PORT) $(A)")
    field(PINI, "YES")
}
record(waveform, "$(P)$(R)IDNwf")
{
    field(DESC, "SCPI identification string")
    field(DTYP, "stream")
    field(INP,  "@devmyInst.proto getIDN(199) $(PORT) $(A)")
    field(PINI, "YES")
    field(FTYP, "CHAR")
    field(NELM, "200")
}
```

asynManager – Methods for drivers

- registerPort
  - Flags for multidevice (addr), canBlock, isAutoConnect
  - Creates thread for each asynchronous port (canBlock=1)
- registerInterface
  - asynCommon, asynOctet, asynInt32, etc.
- registerInterruptSource, interruptStart, interruptEnd
- interposeInterface
- Example code:

```
pPvt->int32Array.interfaceType = asynInt32ArrayType;
pPvt->int32Array.pinterface  = (void *)&drvIp330Int32Array;
pPvt->int32Array.drvPvt = pPvt;
status = pasynManager->registerPort(portName,
                                    ASYN_MULTIDEVICE, /*is multiDevice*/
                                    1,  /*  autoconnect */
                                    0,  /* medium priority */
                                    0); /* default stack size */
status = pasynManager->registerInterface(portName,&pPvt->common);
status = pasynInt32Base->initialize(pPvt->portName,&pPvt->int32);
pasynManager->registerInterruptSource(portName, &pPvt->int32,
                                      &pPvt->int32InterruptPvt);
```

asynManager – asynUser

- asynUser data structure. This is the fundamental “handle” used by asyn.

```
asynUser = pasynManager->createAsynUser(userCallback process,userCallback timeout);
asynUser = pasynManager->duplicateAsynUser)(pasynUser, userCallback queue,userCallback
   timeout);
typedef struct asynUser {
    char *errorMessage;
    int errorMessageSize;
    /* The following must be set by the user */
    double       timeout;  /*Timeout for I/O operations*/
    void         *userPvt;
    void         *userData;
    /*The following is for user to/from driver communication*/
    void         *drvUser;
    /*The following is normally set by driver*/
    int          reason;
    /* The following are for additional information from method calls */
    int          auxStatus; /*For auxillary status*/
}asynUser;
```

Standard Interfaces

Common interface, all drivers must implement

- asynCommon: report(), connect(), disconnect()

I/O Interfaces, most drivers implement one or more

- All have write(), read(), registerInteruptUser() and cancelInterruptUser() methods
- asynOctet: writeRaw(), readRaw(), flush(), setInputEos(), setOutputEos(), getInputEos(), getOutputEos()
- asynInt32: getBounds()
- asynInt32Array:
- asynUInt32Digital:
- asynFloat64:
- asynFloat64Array:

Miscellaneous interfaces

- asynOption: setOption() getOption()
- asynGpib: addressCommand(), universalCommand(), ifc(), ren(), etc.
- asynDrvUser: create(), free()

ASYN API

- Hey, what with terms like ‘methods’ and ‘instances’ this looks very object-oriented – howcome the API is specified in C?
- "I made up the term 'object-oriented', and I can tell you I didn't have C++ in mind" – Alan Kay (The inventor of Smalltalk and of many other interesting things), OOPSLA '97

Generic Device Support

- asyn includes generic device support for many standard EPICS records and standard asyn interfaces
- Eliminates need to write device support in many cases. New hardware can be supported by writing just a driver.
- Record fields:
  - field(DTYP, “asynInt32”)
  - field(INP, “@asyn(portName, addr, timeout) drvParams)
- Examples:
  - asynInt32
    - *ao, ai, mbbo, mbbi, longout, longin*
  - asynInt32Average
    - *ai*
  - asynUInt32Digital, asynUInt32DigitalInterrupt
    - *bo, bi, mbbo, mbbi*
  - asynFloat64
    - *ai, ao*
  - asynOctet
    - *stringin, stringout, waveform*

Dealing with interrupts

'Solicited' interrupts

- e.g., command/response completion
- e.g., txEmpty/rxFull
- Easy to deal with – driver works in blocking, single-threaded environment
- Use devConnectInterruptVME to associate handler with hardware interrupt
- Call epicsEventSignal from low-level interrupt handler
- Driver write method might look like:

```
for(i = 0 ; i < numchars ; i++) {
   send next character to device
   epicsEventWaitWithTimeout(……);
}
```

'Unsolicited' interrupts

- Not quite as easy
- e.g., a trigger which will cause records with SCAN("I/O Intr") to process
- Driver initialization creates an task which waits for signal from low-level interrupt handler (ASYN routines must **not** be called from low-level handler)
- Configuration must invoke ASYN manager registerInterruptSource
  - Allows subsequent use of interruptStart/End
- The standard interfaces asynInt32, asynInt32Array, asynUInt32Digital, asynFloat64 and asynFloat64Array all support callback methods for interrupts
- Callbacks can be used by device support, other drivers, etc.

Support for Interrupts – Ip330 driver

```
static void intFunc(void *drvPvt)
{
...
for (i = pPvt->firstChan; i <= pPvt->lastChan; i++) {
        data[i] = (pPvt->regs->mailBox[i + pPvt->mailBoxOffset]);
    }
    /* Wake up task which calls callback routines */
    if (epicsMessageQueueTrySend(pPvt->intMsgQId, data, sizeof(data)) == 0)
...
}
static void intTask(drvIp330Pvt *pPvt)
{
while(1) {
        /* Wait for event from interrupt routine */
        epicsMessageQueueReceive(pPvt->intMsgQId, data, sizeof(data));
        /* Pass int32 interrupts */
        pasynManager->interruptStart(pPvt->int32InterruptPvt, &pclientList);
        pnode = (interruptNode *)ellFirst(pclientList);
        while (pnode) {
            asynInt32Interrupt *pint32Interrupt = pnode->drvPvt;
            addr = pint32Interrupt->addr;
            reason = pint32Interrupt->pasynUser->reason;
            if (reason == ip330Data) {
                pint32Interrupt->callback(pint32Interrupt->userPvt,
                                          pint32Interrupt->pasynUser,
                                          pPvt->correctedData[addr]);
            }
            pnode = (interruptNode *)ellNext(&pnode->node);
        }
        pasynManager->interruptEnd(pPvt->int32InterruptPvt);
...
}
```

Lab Session – Control a 'network-attached device'

- TCP socket at IP address 192.168.0.250, port 24742
- Supports 5 commands:
  - `*IDN?`
    - *Returns device identification string (up to 200 characters long)*
  - `LOADAV?`
    - *Returns three floating-point numbers (1, 5, 15 minute load average)*
  - `CLIENT?`
    - *Returns information about client*
  - `VOLTAGE?`
    - *Returns most recent voltage setting*
  - `VOLTAGE` *`n.nnnn`*
    - *Sets voltage*