asyn: An Interface Between EPICS Drivers and Device Support

Mark Rivers, Marty Kraimer, Eric Norum
University of Chicago
Advanced Photon Source
What is asyn and why do we need it?

**Motivation**

- Standard EPICS interface between device support and drivers is only loosely defined
- Needed custom device support for each driver
- asyn provides standard interface between device support and device drivers
- And a lot more too!
History – why the name asyn

• The initial releases of asyn were limited to “asynchronous” devices (e.g. slow devices)
  – Serial
  – GPIB
  – TCP/IP

• asyn provided the thread per port and queuing that this support needs.

• Current version of asyn is more general, synchronous (non-blocking) drivers are also supported.

• We are stuck with the name, or re-writing a LOT of code!
asyn Architecture

Device support (or SNL code, another driver, or non-EPICS software)

asynCommon (connect, report, …) \[\text{Interfaces} \text{(named; pure virtual functions)}\] asynOctet (write, read, setInputEos,…)

Port (named object)

Port driver

addr=0 \[\text{device}\] addr=1 \[\text{device}\]
Control flow – asynchronous driver
Control flow – synchronous driver
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 – Methods for Device Support

• Connect to device (port)
• Create asynUser
• Queue request for I/O to port
  – asynManager calls callback when port is free
    • Will be separate thread for asynchronous port
  – I/O calls done directly to interface methods in driver
    • e.g. pasynOctet->write()

• Example code:
  /* Create asynUser */
  pasynUser = pasynManager->createAsynUser(processCallback, 0);
  status = pasynEpicsUtils->parseLink(pasynUser, plink,
    &pPvt->portName, &pPvt->addr, &pPvt->userParam);
  status = pasynManager->connectDevice(pasynUser, pPvt->portName, pPvt->addr);
  status = pasynManager->canBlock(pPvt->pasynUser, &pPvt->canBlock);
  pasynInterface = pasynManager->findInterface(pasynUser, asynInt32Type, 1);
  ...
  status = pasynManager->queueRequest(pPvt->pasynUser, 0, 0);
  ...
  status = pPvt->pint32->read(pPvt->int32Pvt, pPvt->pasynUser, &pPvt->value);
asynManager – asynUser

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

```c
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 auxiliary 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(), registerInterruptUser() 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()
Standard Interfaces - drvUser

- `pdrvUser->create(void *drvPvt, asynUser *pasynUser, const char *drvInfo, const char **pptypeName, size_t *psize);`
- `drvInfo` string is parsed by driver.
- It typically sets `pasynUser->reason` to an enum value (e.g. `mcaElapsedLive`, `mcaErase`, etc.)
- More complex driver could set `pasynUser->drvUser` to a pointer to something.
- Example

```c
egrecord(mbbo, "$(P)$(HVPS)INH_LEVEL") {
    field(DESC,"Inhibit voltage level")
    field(PINI,"YES")
    field(ZRVL,"0")
    field(ZRST,"+5V")
    field(ONVL,"+12V")
    field(ONST,"+12V")
    field(DTYP, "asynInt32")
    field(OUT,"@asyn($(PORT))INHIBIT_LEVEL")
}
```

```c
cstatus = pasynEpicsUtils->parseLink(pasynUser, plink, &pPvt->portName, &pPvt->addr, &pPvt->userParam);
pasy8Interface = pasynManager->findInterface(pasynUser, asynDrvUserType,1);
cstatus = pasynDrvUser->create(drvPvt,pasynUser,pPvt->userParam,0,0);
```
Support for Interrupts

• The standard interfaces asynInt32, asynInt32Array, asynUInt32Digital, asynFloat64 and asynFloat64Array all support callback methods for interrupts
• registerInterruptUser(…,userFunction, userPrivate, …)
  – Driver will call userFunction(userPrivate, pasynUser, data) whenever an interrupt occurs
  – Callback will not be at interrupt level, so callback is not restricted in what it can do
• Callbacks can be used by device support, other drivers, etc.
• Current interrupt drivers
  – Ip330 ADC, IpUnidig binary I/O, quadEM APS quad electrometer
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);
...}
Support for Interrupts – Performance

- Ip330 ADC driver. Digitizing 16 channels at 1kHz.
- Generates interrupts at 1 kHz.
- Each interrupt results in:
  - 16 asynInt32 callbacks to devInt32Average generic device support
  - 1 asynInt32Array callback to fastSweep device support for MCA records
  - 1 asynFloat64 callback to devEpidFast for fast feedback
- 18,000 callbacks per second
- 21% CPU load on MVME2100 PPC-603 CPU with feedback on and MCA fast sweep acquiring.
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
Generic Device Support

- The following now use standard asyn device support, and no longer have specialized device support code:
  - Ip330 ADC
  - IpUnidig
  - quadEM
  - dac128V
  - Canberra ICB modules (Amp, ADC, HVPS, TCA)
- MCA and DXP records use special device support, because they are not base record types
- However, the MCA drivers now only use the standard asyn interfaces, so it would be possible to write a database using only standard records and control any MCA driver (Canberra, DXP, etc.).
corvette> view ../Db/ip330Scan.template
record(ai="$P$(R)"
{
    field(SCAN,"$SC$"
    field(DTYP,"asynInt32Average"
    field(INP,"@asyn($PORT) $S)"DATA"
    field(LINR,"LINEAR"
    field(EGUF,"$EGUF"
    field(EGUL,"$EGUL"
    field(HOPR,"$HOPR"
    field(LOPR,"$LOPR"
    field(PREC,"$PREC"

}

record(longout="$P$(R)Gain"
{
    field(PINI,"YES"
    field(VAL,"$GAIN"
    field(DTYP,"asynInt32"
    field(OUT,"@asyn($PORT) $S)GAIN"

}
Other Device Support

- synApps “ip” application is converted to asyn
  - devXxStrParm
  - devAiMks – MKS vacuum gauge controller
  - devMpc – MPC ion pump and TSP controller
- Love controller support being converted
- GPIB and serial support using configuration files (gpibCore)
- STREAMS and devAscii being converted
asynRecord

• New 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 – Differences from generic serial and generic gpib records

- ODEL field replaced by OEOS. Changed from a DBF_LONG to DBF_STRING to support multi-character terminators. The IDEL (serial) and EOS (gpib) fields replaced by IEOS. Changed from a DBF_LONG to DBF_STRING to support multi-character terminators.
- IEOS and OEOS fields only used if modified after connecting to port. Fields set to current eos strings for the port when connecting.
- INP field replaced by PORT and ADDR fields to support run-time connection to different devices.
- AOUT and OEOS fields are processed by dbTranslateEscape before being sent to the device. In rare cases this may require changing the output strings if these contained the "\" character.
- asyn record always posts monitors on the input field (AINP or BINP) when the record processes. Older records did not post monitors on the AINP field if the value was the same as the previous read. This caused problems for some SNL programs and data acquisition applications.
- ODEL and IDEL were used even when OFMT or IFMT were in "Binary" mode. OEOS and IEOS are now ignored when OFMT or IFMT respectively are in "Binary" mode, because readRaw and writeRaw are called.
- TMOT field has changed from DBF_LONG to DBF_DOUBLE, and the units have changed from milliseconds to seconds. TMOT=-1.0 now means wait forever.
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
Synchronous interfaces

• Standard interfaces also have a synchronous interface, even for slow devices, so that one can do I/O without having to implement callbacks
• Example: asynOctetSyncIO
  – write(), read(), writeRead()
• Very useful when communicating with a device that can block, when it is OK to block
• Example applications:
  – EPICS device support in init_record(), (but not after that!)
  – SNL programs, e.g. communicating with serial or TCP/IP ports
  – Motor drivers running in separate thread
  – iocsh commands
Synchronous interfaces – motor driver example

- **In initialization:**
  
  ```c
  /* Initialize communications channel */
  success_rtn = pasynOctetSyncIO->connect(cntrl->asyn_port,
                                       cntrl->asyn_address, &cntrl->pasynUser, NULL);
  ```

- **In IO:**

  ```c
  pasynOctetSyncIO->write(cntrl->pasynUser, com, strlen(com),
                          TIMEOUT, &nwrite);

  status = pasynOctetSyncIO->read(cntrl->pasynUser, com, BUFF_SIZE,
                                 timeout, &nread, &eomReason);
  ```
iocsh Commands

asynReport(filename,level,portName)
asynInterposeFlushConfig(portName,addr,timeout)
asynInterposeEosConfig(portName,addr)
asynSetTraceMask(portName,addr,mask)
asynSetTraceIOMask(portName,addr,mask)
asynSetTraceFile(portName,addr,filename)
asynSetTraceIOTruncateSize(portName,addr,size)
asynSetOption(portName,addr,key,val)
asynShowOption(portName,addr,key)
asynAutoConnect(portName,addr,yesNo)
asynEnable(portName,addr,yesNo)
asynOctetConnect(entry,portName,addr,oeos,ieos,timeout,buffer_len)
asynOctetRead(entry,nread,flush) asynOctetWrite(entry,output)
asynOctetWriteRead(entry,output,nread) asynOctetFlush(entry)
asynOctetSetInputEos(portName,addr,eos,drvInfo)
asynOctetGetInputEos(portName,addr,drvInfo)
asynOctetSetOutputEos(portName,addr,eos,drvInfo)
asynOctetGetOutputEos(portName,addr,drvInfo)
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`
Current asyn Drivers

- Unix/Linux/vxWorks/cygwin serial ports
- TCP/IP sockets
- GPIB via National Instruments VME, Ethernet/GPIB devices, Ip488 Industry Pack modules
- VXI-11
- dac128V digital-to-analog (Industry Pack)
- Canberra AIM multi-channel analyzer and ICB modules (Ethernet)
- XIA DXP DSP spectroscopy system (CAMAC, EPP, PXI soon)
- APS quad electrometer (VME). Supports interrupts.
- epid record fast feedback (float 64 with callbacks for input, float64 for output)
- Mca fast-sweep (Int32Array with callbacks)
Fast feedback device support (epid record)

- Supports fast PID control
- Input: any driver that supports asynFloat64 with callbacks (e.g. callback on interrupt)
- Output: any driver that supports asynFloat64.
- In real use at APS for monochromator feedback with IP ADC/DAC, and APS VME beam position monitor and DAC
- >1kHz feedback rate
Summary- Advantages of asyn

- Drivers implement standard interfaces that can be accessed from:
  - Multiple record types
  - SNL programs
  - Other drivers
- Generic device support eliminates the need for separate device support in 90% (?) of cases
  - synApps package 10-20% fewer lines of code, 50% fewer files with asyn
- Consistent trace/debugging at (port, addr) level
- asynRecord can be used for testing, debugging, and actual I/O applications
- Easy to add asyn interfaces to existing drivers:
  - Register port, implement interface write(), read() and change debugging output
  - Preserve 90% of driver code
- asyn drivers are actually EPICS-independent. Can be used in any other control system.