The ZIO Framework
A modular environment for laboratory I/O

http://www.ohwr.org/projects/zio

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Working for CERN "hardware and timing" group
The Requirements (hard)

Hardware timestamps (better than 1ns precision)

Big data blocks (stripes of many samples)

Off-line management of data blocks

High data rate

Easy monitoring of a diverse I/O environment
The Requirements (soft)

Sysfs-based configuration

No ioctl(2) thank you

Centralized locks (drivers must ignore the issue)

Modular design (each object should be replaceable)

A documented and stable framework
Device types

Both input and output from the start

All 3 of digital, analogue, and time

- Input: collect data at a specific time or event
- Output: drive waveforms at a specific time or event
- TDC: returns the timestamp of an input pulse
- DTC: outputs a pulse at a predefined time stamp
The basic concept of ZIO is the "cset". Channels in a cset share data size and trigger.
ZIO Layers

ZIO framework hierarchy

- **Device**
  - **Channel set**
  - **Channel set**
  - **Channel set**
    - **Channel**
    - **Channel**
    - **Channel**
    - **Channel**

The atomic data item in ZIO is a block
- It includes both data and meta-data ("control")
- Data within ZIO never travels without meta-data.
Control Structure

/* byte 0 */
uint8_t major_version;
uint8_t minor_version;
uint8_t more_ctrl; /* number of further ctrl, for interleaved */
uint8_t alarms; /* set by channel, persistent, write 1 to clr */

/* byte 4 */
uint32_t seq_num; /* block sequence number */
uint32_t flags; /* endianness etc, see below */
uint32_t nsamples; /* number of samples in this data block */

/* byte 16 */
uint16_t ssize; /* sample-size for each of them, in bytes */
uint16_t sbits; /* sample-bits: number of valid bits */
uint16_t cset_i; /* index of channel-set within device */
uint16_t chan_i; /* index of channel within cset */

/* byte 24 */
uint8_t hostid[8]; /* Macaddress or whatever unique */

/* byte 32 */
struct xio_timestamp tstamp;

/* byte 56 */
uint32_t mem_offset; /* position in mmap buffer of this block */
uint32_t reserved; /* possibly another offset, or space for 64b */

/* byte 64 */
/* The control block includes what device the data belongs to */
char devname[RIO_OBJ_NAME_LEN];

/* byte 76 */
/* Each data block is associated with a trigger and its features */
char triggername[RIO_OBJ_NAME_LEN];

/* byte 80 */
struct xio_ctrl_attr attr_channel;
struct xio_ctrl_attr attr_trigger;

/* byte 480 */
uint8_t __fill_end[RIO_CONTROL_SIZE - 480];
ZIO Device

Physically, the device is a PCB or a chip.

Logically, it is a probe unit and a kernel module.

For ZIO, it is simply a group of csets.
Triggers

A trigger is a software module that requests I/O.

- Time-driven (kernel timer or hardware-internal)
- Event-driven (external interrupt or hardware-internal)
- Data-driven (in-driver monitoring or hardware-internal)
- Transparent (requests I/O when user reads or writes)
Buffers

A buffer is a software module between trigger and user

- Kmalloc-based (only read/write)
- Vmalloc-based (mmap capable)
- DMA-oriented (maybe device-specific)
- On-board memory (device-specific)
- Software ring buffer (discarding metadata)
Input Data Flow

This is the input pipeline in ZIO (time flows down)

user space → file operations → buffer → trigger → driver → device

- read
- alloc_block
- store_block
- alloc_block
- input_cset
- data_done
- raw transfer
- free_block
- retr_block
Output Data Flow

The output pipeline is symmetrical

user space \(\rightarrow\) file operations \(\rightarrow\) buffer \(\rightarrow\) trigger \(\rightarrow\) driver \(\rightarrow\) device

- write
- alloc_block
- store_block
- retr_block
- output_cset
- data_done
- free_block

raw transfer
Char Devices

Data and metadata travel in two different devices

Control device: 512-byte fixed-size structures
Data device: blobs of samples

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Data flow (input or output)
Mmap Support

Using mmap (or DMA to user space) is trivial

The control structure includes the data_offset

The control channel times I/O and refers to mmap data
The Future: PF_ZIO

The next research idea is PF_ZIO, for I/O networks

SOCK_STREAM

SOCK_DGRAM

SOCK_RAW
PF_ZIO is not ZIO over Ethernet

Applications will perform I/O by exchanging frames

The PF_ZIO address space is I/O channels

A host may drive hundreds of channels over a field bus

Sockets may prove better than hundreds of char devices

Zero-copy networking will help with high data rates
Implementation Status (2012-02-05)

Software-only modules, for stress-test and benchmark
Simple hardware modules
(Hardware for the real use-case is almost ready)

device: zio-zero (input and output, raw or timely)
device: line discipline (input: uart or pty for stress-test)
device: GPIO (input and output)
device: AD7888/AD7887 (SPI input)
device: TDC/DTC

trigger: kernel timer
trigger: transparent trigger (user-driven)
trigger: external irq or external GPIO

buffer: kmalloc
buffer: vmalloc (mmap capable)
buffer: cbuf (SOCK_STREAM alike, coalescing blocks)
Thank you for your attention

http://www.ohwr.org/projects/zio

git://ohwr.org/misc/zio.git

http://www.ohwr.org/projects/zio/repository
http://www.ohwr.org/projects/zio/wiki
http://www.ohwr.org/projects/zio/documents

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