Medialogy – Aalborg University Copenhagen

Minivosc - a minimal virtual oscillator driver for ALSA (Advanced Linux Sound Architecture)

http://imi.aau.dk/~sd/phd/index.php?title=Minivosc
http://www.alsa-project.org/main/index.php/Minivosc

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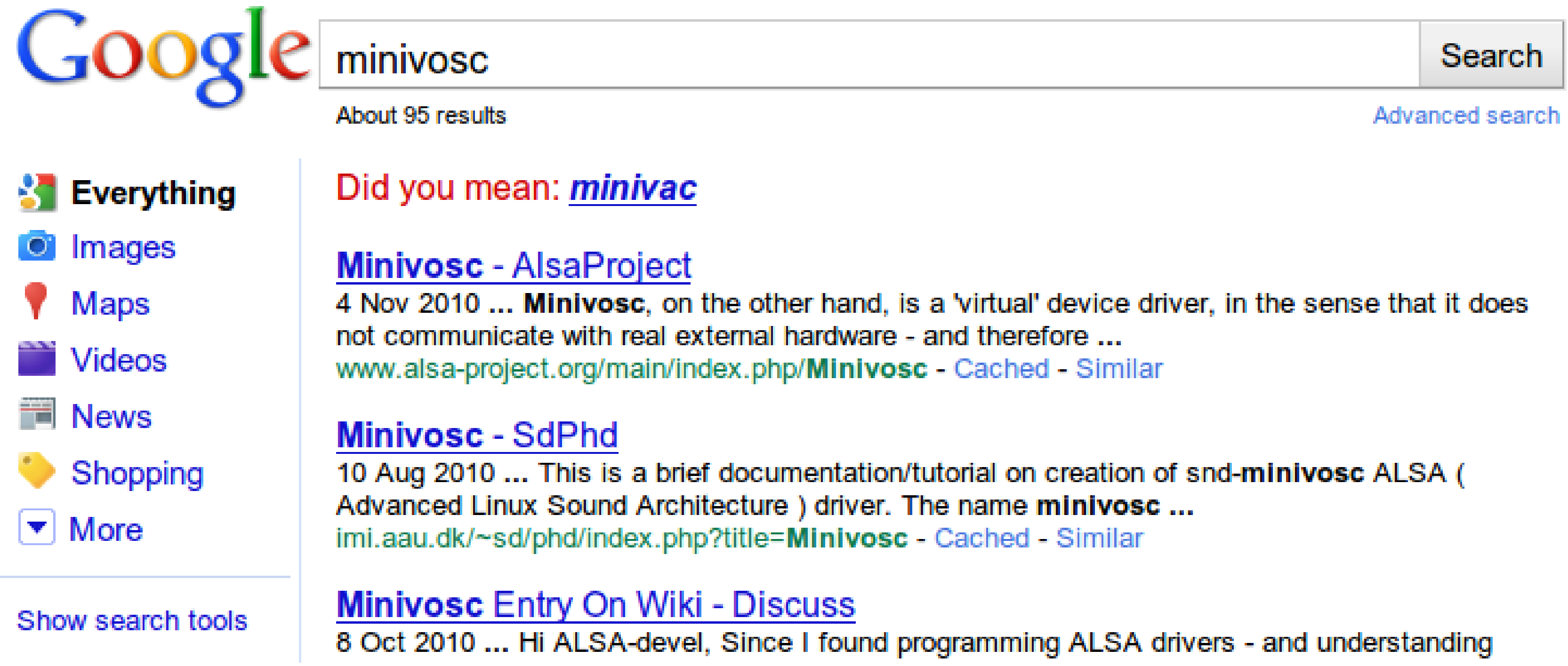
Introduction - links

- Minivosc is a driver, and a corresponding tutorial (and paper):
  - http://www.alsa-project.org/main/index.php/Minivosc (on ALSA project Wiki)
  - http://imi.aau.dk/~sd/phd/index.php?title=Minivosc (local author copy)
    - (*need syncing* + *paper link*)



About 95 results

Did you mean: ***minivac***

Minivosc - AlsaProject
4 Nov 2010 ... **Minivosc**, on the other hand, is a 'virtual' device driver, in the sense that it does not communicate with real external hardware - and therefore ...
www.alsa-project.org/main/index.php/**Minivosc** - Cached - Similar

Minivosc - SdPhd
10 Aug 2010 ... This is a brief documentation/tutorial on creation of snd-**minivosc** ALSA (Advanced Linux Sound Architecture) driver. The name **minivosc** ...
imi.aau.dk/~sd/phd/index.php?title=**Minivosc** - Cached - Similar

Minivosc Entry On Wiki - Discuss
8 Oct 2010 ... Hi ALSA-devel, Since I found programming ALSA drivers - and understanding

Introduction – name and properties

- What's in a name?
  - Minivosc stands for **mini**mal **v**irtual **osc**illator
- What is it?
  - An example of a ***capture-only***, **8-bit**, **8 kHz** driver
  - Written with the intent of being the simplest ALSA driver for study
  - Does not require any actual soundcard hardware

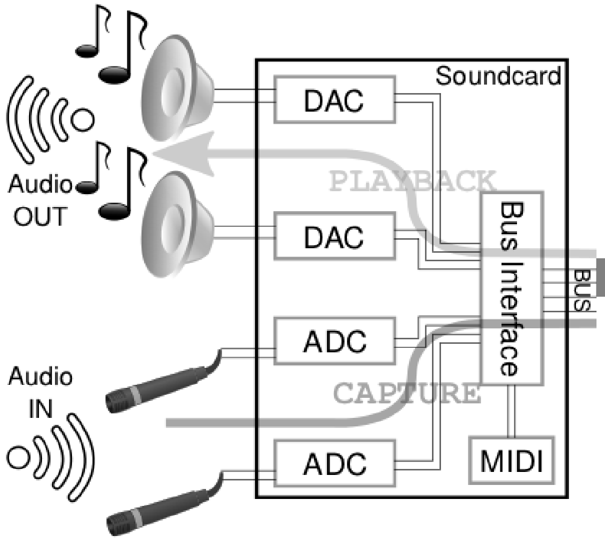
Focus in driver development

- Role of a driver – provide users with a simple (*high-level*) interface to peripheral hardware, in a PC OS
  - What are these high-level actions afforded to a user?
- Two aspects are most important in *low-level* understanding of drivers from the PC OS side:
  - How do things happen **memory**-wise (where?)
  - How do things happen **time**-wise (when?)

Motivation

- Build a card for the (obsolete) ISA slot
  - Write simple “for” loop in userland C (*without* any rate/period information)...
  - ... obtain 17 kHz sampling rate ??!
  - Problem – non real-time OS
- Build an FPGA card...
  - Implement a “blinking LED” example without a problem...
  - ... but how to make it play sound ??!
- Need to look at software – *drivers* !!

“Chicken-and-egg” problem



driver (software)
required to understand
(soundcard) hardware ...

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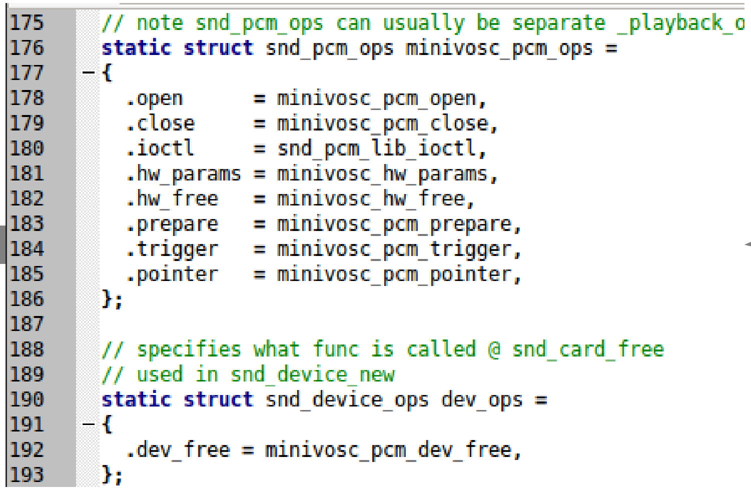


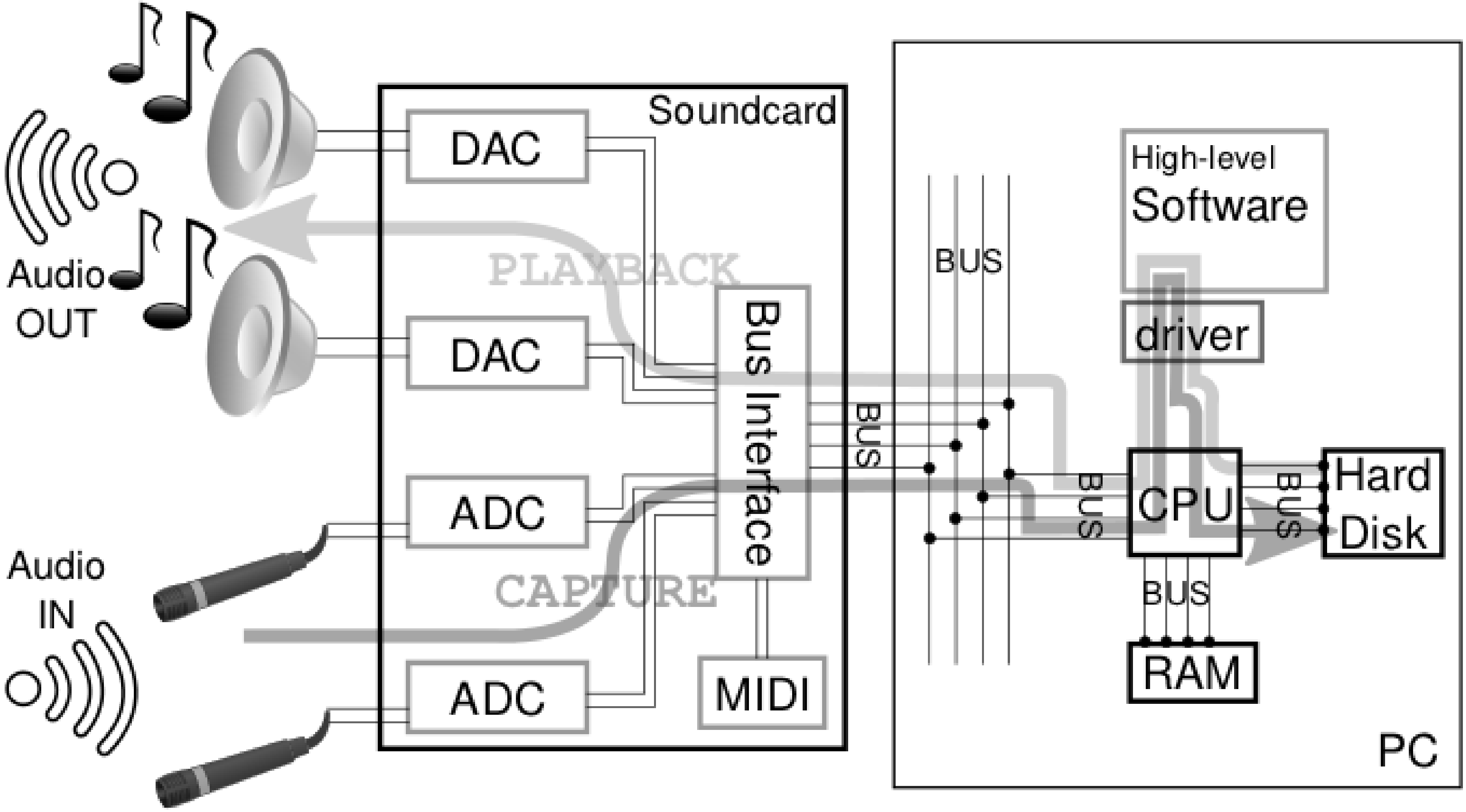
```
// note snd_pcm_ops can usually be separate _playback_o
static struct snd_pcm_ops minivosc_pcm_ops =
{
    .open      = minivosc_pcm_open,
    .close     = minivosc_pcm_close,
    .ioctl     = snd_pcm_lib_ioctl,
    .hw_params = minivosc_hw_params,
    .hw_free   = minivosc_hw_free,
    .prepare   = minivosc_pcm_prepare,
    .trigger   = minivosc_pcm_trigger,
    .pointer   = minivosc_pcm_pointer,
};

// specifies what func is called @ snd_card_free
// used in snd_device_new
static struct snd_device_ops dev_ops =
{
    .dev_free = minivosc_pcm_dev_free,
};
```

Prior related work

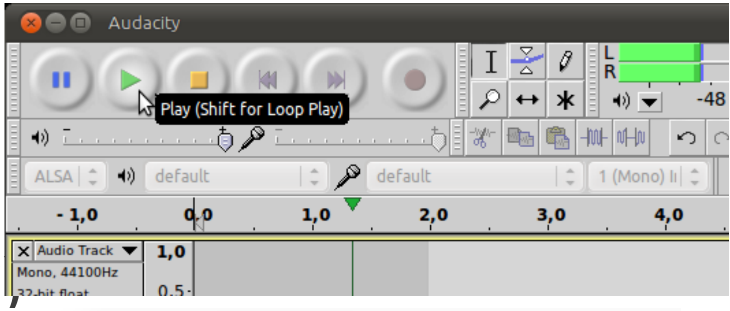
- Sources for research and development of minivosc:
  - Takashi Iwai's The ALSA Driver API
    - *Documentation*
  - Stéphan K.'s HowTo Asynchronous Playback - ALSA wiki
    - *Documentation (now offline?)*
  - Takashi Iwai's Writing an ALSA Driver
    - *Not beginner; undisclosed PCI hardware*
  - Ben Collins: Writing an ALSA driver
    - *Undisclosed hardware; no memory ops*
  - `dummy.c` driver
    - *Virtual driver; no memory ops*
  - `aloop-kernel.c` driver
    - *Virtual driver; multichannel*

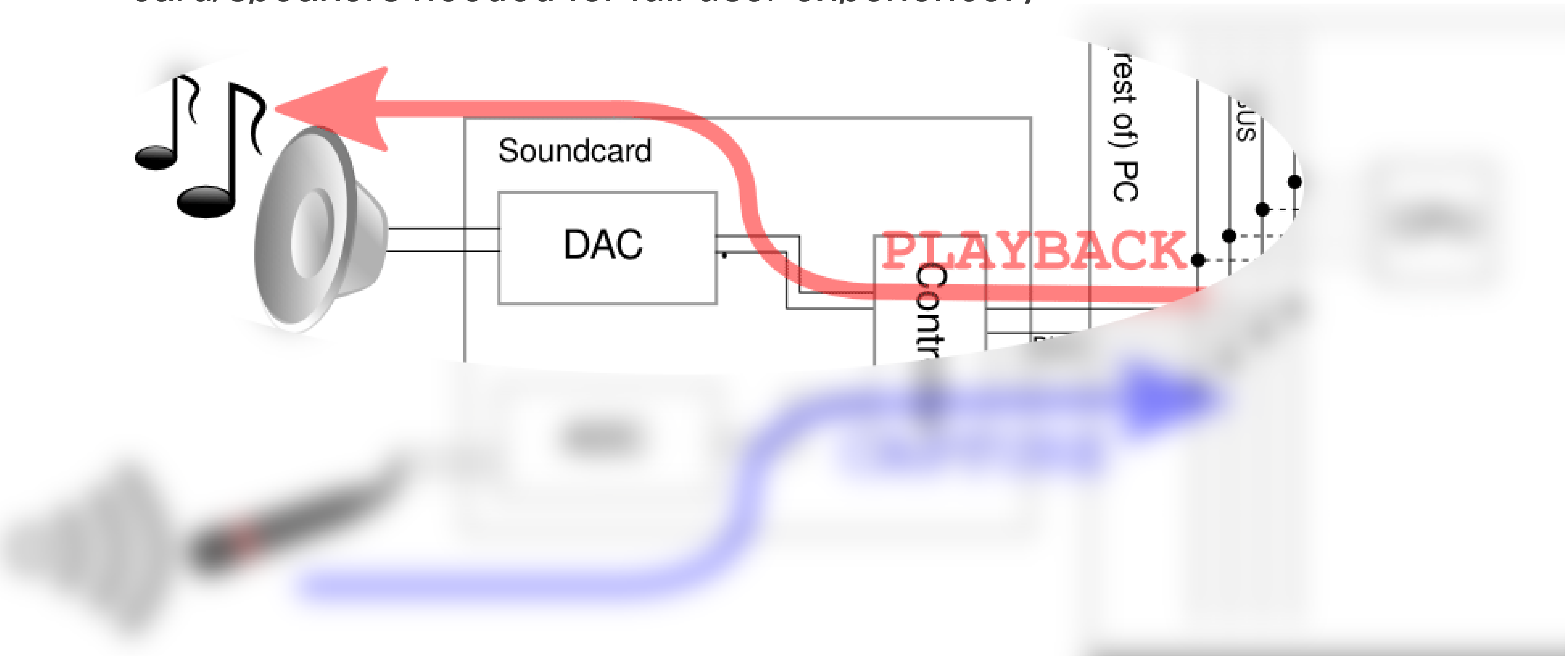
Overview diagram – PC soundcard context



High-level user actions (playback direction)

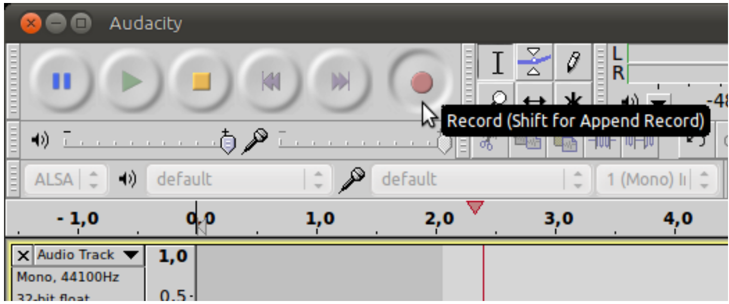
- Playback direction – from PC to soundcard (speakers)
- User can:
  - Press PLAY (start playback)
  - Press STOP (stop playback)
  - (*user expects to **hear** sound - card/speakers needed for full user experience!*)

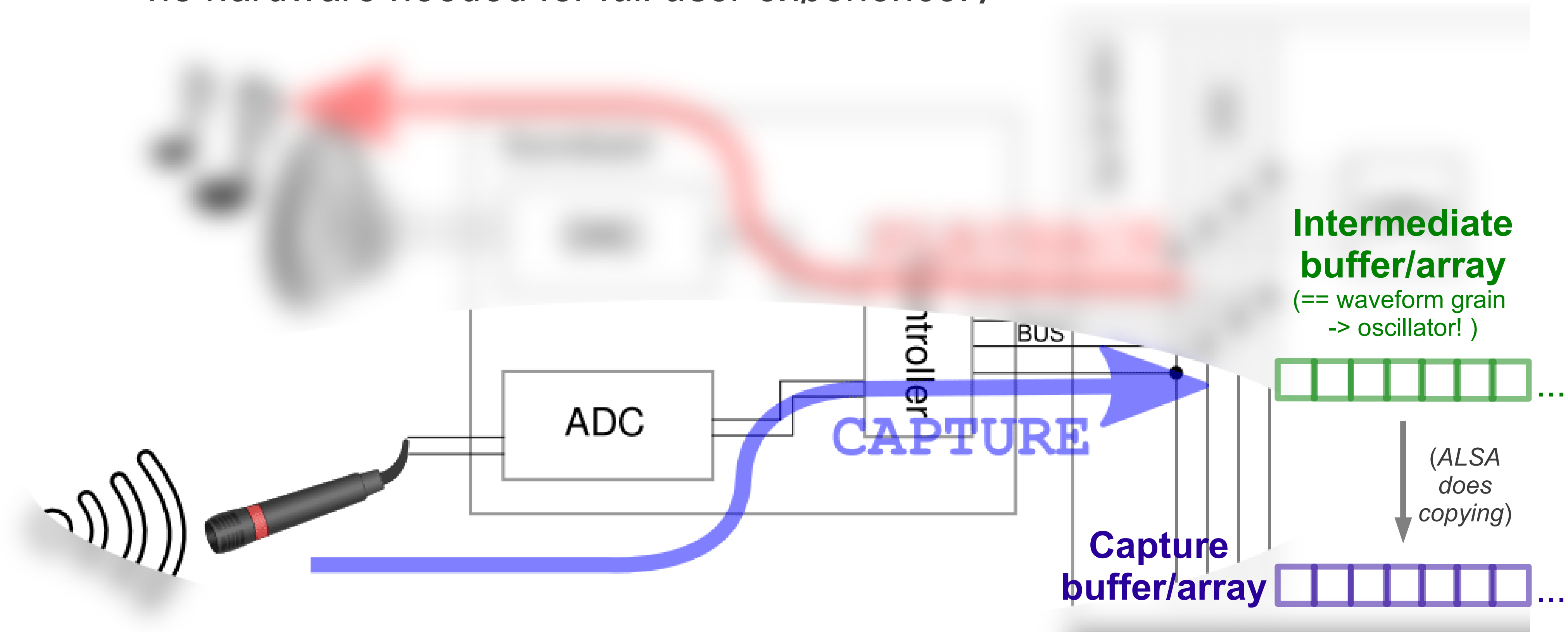




High-level user actions (capture direction)

- Capture direction – from soundcard (microphone) to PC
- User can:
  - Press RECORD (start capture)
  - Press STOP (stop capture)
  - (*user expects to* ***see*** *recording action - no hardware needed for full user experience!*)





Intermediate buffer/array

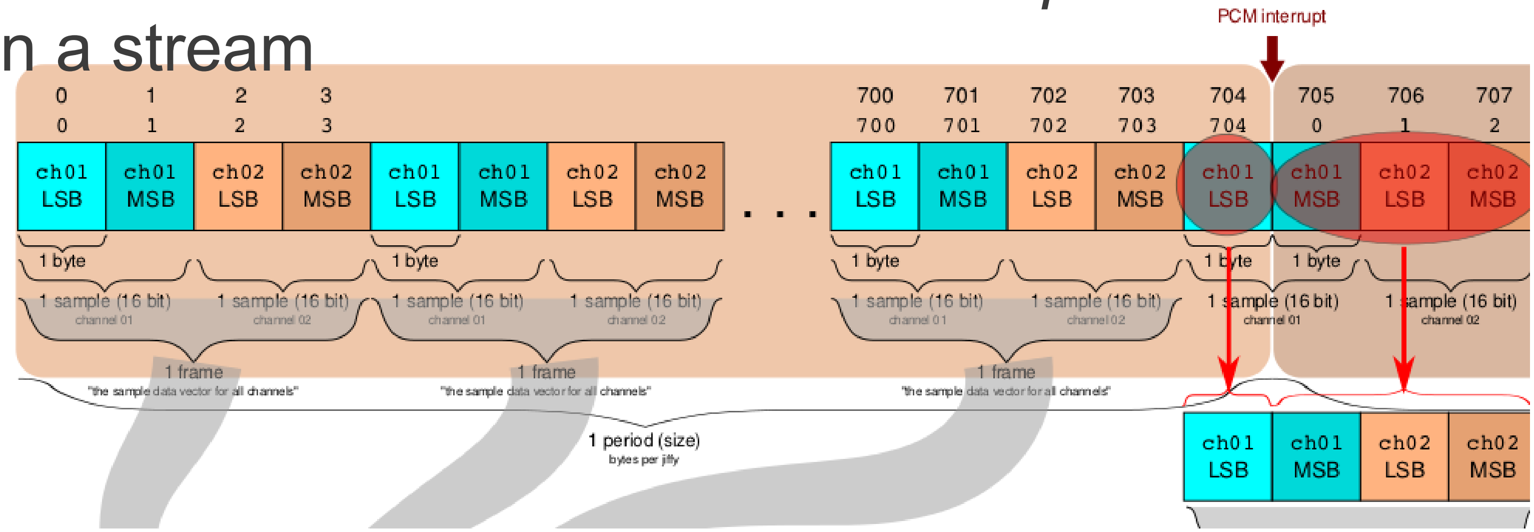
(== waveform grain -> oscillator!)

(ALSA does copying)

Capture buffer/array

Initial summary

- Easier to demonstrate **capture** direction in a virtual (no hardware) driver – *while* preserving high-level user expectations (*i.e. what happens in audio software*)
- **8 kHz** sampling rate – next lowest possible in ALSA; avoid potential bottleneck problems with fast sampling rates
- **Mono, 8-bit** signal – avoid conceptual complication with ALSA frames:
  - ALSA frame – collection of one *sample* from all channels in a stream



  - With mono, 8-bit: 1 byte ~ 1 sample ~ 1 frame

Linux driver models

- Declaration of driver devices:
- For devices interfacing through the PCI bus:

```
struct pci_driver my_driver ....
pci_register_driver(&my_driver) ... //[init]
```

- For devices interfacing through the USB bus:

```
struct usb_driver my_driver ...
usb_register(&my_driver) ... //[init]
```

- For virtual devices (no hardware) – `platform` model:

```
struct platform_driver my_driver ...
platform_driver_register(&my_driver) ... //[init]
```

Driver device structure

- Device structure contains references to needed data

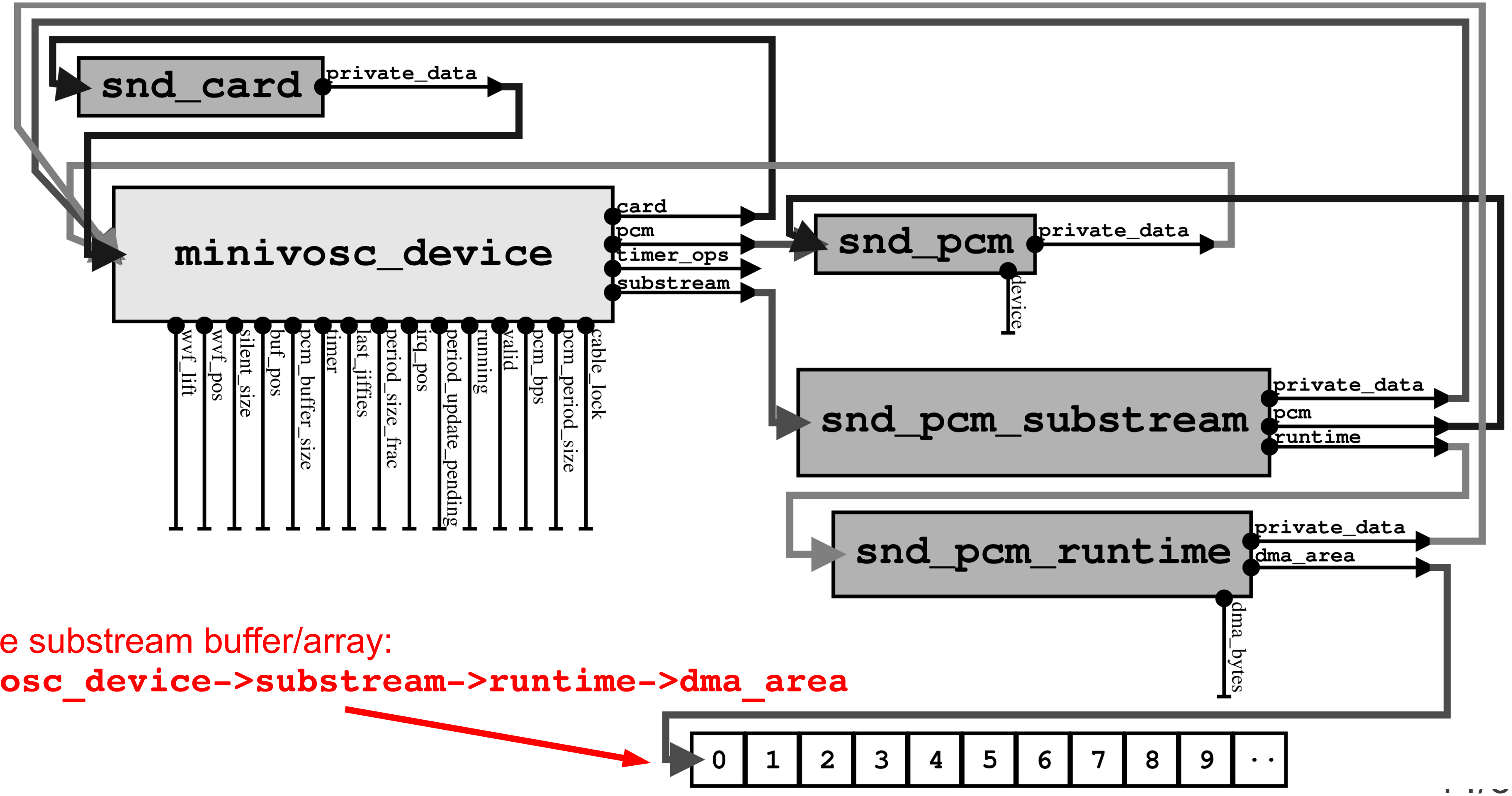
```
struct minivosc_device
{
  struct snd_card *card;
  struct snd_pcm *pcm;
  const struct minivosc_pcm_ops *timer_ops;
  /* we have only one substream, so all data in this struct */
  struct mutex cable_lock;
  /* PCM parameters */
  unsigned int pcm_period_size;
  unsigned int pcm_bps;    /* bytes per second */
  /* flags */
  unsigned int valid;
  unsigned int running;
  unsigned int period_update_pending :1;
  /* timer stuff */
  unsigned int irq_pos;    /* fractional IRQ position */
  unsigned int period_size_frac;
  unsigned long last_jiffies;
  struct timer_list timer;
  /* copied from struct loopback_pcm: */
  struct snd_pcm_substream *substream;
  unsigned int pcm_buffer_size;
  unsigned int buf_pos; /* position in buffer */
  unsigned int silent_size;
  /* added for waveform: */
  unsigned int wvf_pos; /* position in waveform array */
  unsigned int wvf_lift;  /* lift of waveform array */
};
```

References can be established at different stages of driver lifetime!

Should *eventually* contain a reference to ALSA capture substream buffer/array!

Driver device structure

- Device structure can be difficult to navigate, especially for finding capture buffer/array
  - For easier navigation: *partial structure map* diagram



Capture substream buffer/array:
`minivosc_device->substream->runtime->dma_area`

Hardware parameters – sample rate & format

- Definition of *possible allowed* values – struct `minivosc_pcm_hw`:

```
#define MAX_BUFFER (32 * 48)
static struct snd_pcm_hardware minivosc_pcm_hw =
{
  .info = (SNDRV_PCM_INFO_MMAP |
  SNDRV_PCM_INFO_INTERLEAVED |
  SNDRV_PCM_INFO_BLOCK_TRANSFER |
  SNDRV_PCM_INFO_MMAP_VALID),
  .formats          = SNDRV_PCM_FMTBIT_U8,
  .rates            = SNDRV_PCM_RATE_8000,
  .rate_min         = 8000,
  .rate_max         = 8000,
  .channels_min     = 1,
  .channels_max     = 1,
  .buffer_bytes_max = MAX_BUFFER, //(32 * 48) = 1536,
  .period_bytes_min = 48,
  .period_bytes_max = 48,
  .periods_min      = 1,
  .periods_max      = 32,
};
```

Sample format (unsigned byte)

Sampling rate (frequency, Hz)

Number of audio channels

Buffering

- (Audio software could choose arbitrarily from the allowed values)

Driver/device initialization functions

- Callbacks that run when device is attached/removed – or when driver is loaded/unloaded
  - Minivosc virtual driver: driver loading ~ device attachment

```
// * functions for driver/kernel module initialization
static void minivosc_unregister_all(void);
static int __init alsa_card_minivosc_init(void);
static void __exit alsa_card_minivosc_exit(void);

// * declare functions for this struct describing the driver (to be defined later):
static int __devinit minivosc_probe(struct platform_device *devptr);
static int __devexit minivosc_remove(struct platform_device *devptr);
```

_probe and _remove are declared in the platform_driver struct

```
// specifies what func is called @ snd_card_free
// used in snd_device_new
static struct snd_device_ops dev_ops =
{
  .dev_free = minivosc_pcm_dev_free,
};
// ....
// * we need a struct describing the driver:
static struct platform_driver minivosc_driver =
{
  .probe     = minivosc_probe,
  .remove    = __devexit_p(minivosc_remove),
  .driver    = {
    .name = SND_MINIVOSC_DRIVER,
    .owner = THIS_MODULE
  },
};
```

Driver/device initialization functions – exec order

- Execution sequence upon *driver loading*:

```
# at insmod:
[48803.808593] ./minivosc.c: alsa_card_minivosc_init
[48803.808821] ./minivosc.c: minivosc_probe : probe
```

- Execution sequence upon *driver unloading*:

```
# at rmmod:
[49005.736089] ./minivosc.c: alsa_card_minivosc_exit
[49005.736097] ./minivosc.c: minivosc_unregister_all
[49005.736146] ./minivosc.c: minivosc_remove
[49005.755433] ./minivosc.c: minivosc_pcm_dev_free
[49005.755445] ./minivosc.c: minivosc_pcm_free
```

Digital audio (PCM) Interface functions

- Functions that handle digital audio based on commands from high-level audio software:

```
// note snd_pcm_ops can usually be separate
_playback_ops and _capture_ops
static struct snd_pcm_ops minivosc_pcm_ops =
{
  .open      = minivosc_pcm_open,
  .close     = minivosc_pcm_close,
  .ioctl     = snd_pcm_lib_ioctl,
  .hw_params = minivosc_hw_params,
  .hw_free   = minivosc_hw_free,
  .prepare   = minivosc_pcm_prepare,
  .trigger   = minivosc_pcm_trigger,
  .pointer   = minivosc_pcm_pointer,
};
```

Digital audio (PCM) Interface functions – exec order

- Execution sequence upon *(a)record start*:

```
[48810.487603] ./minivosc.c: minivosc_pcm_open
[48810.488110] ./minivosc.c: minivosc_hw_params
[48810.488162] ./minivosc.c: minivosc_pcm_prepare
[48810.488170] :        bps: 8000; runtime->buffer_size: 1536;
mydev->pcm_buffer_size: 1536
[48810.488478] ./minivosc.c: minivosc_pcm_trigger - trig 1
```

- Execution sequence upon *(a)record stop*:

```
[48811.489504] ./minivosc.c: minivosc_pcm_trigger - trig 0
[48811.489527] ./minivosc.c: minivosc_hw_free
[48811.489588] ./minivosc.c: minivosc_hw_free
[48811.489596] ./minivosc.c: minivosc_pcm_close
```

Populating the device structure

- We need to save references for device structure *ourselves*!

OS kernel/ALSA provides this

```
static int __devinit minivosc_probe(struct platform_device *devptr)
{

  struct snd_card *card;
  struct minivosc_device *mydev;
  // ....
  int dev = devptr->id; // from aloop-kernel.c
  // ....
  ret = snd_card_create(index[dev], id[dev],
                        THIS_MODULE, sizeof(struct minivosc_device), &card);
  // ....
  mydev = card->private_data;
  mydev->card = card;

  // ....
```

We instantiate using the input argument...

We save the result in the device structure *ourselves*!

Populating the device structure

- We need to save references for device structure *ourselves*!

OS kernel/ALSA provides this – _open is the first time the substream is defined!

```
static int minivosc_pcm_open(struct snd_pcm_substream *ss)
{
  struct minivosc_device *mydev = ss->private_data;

  //....

  ss->runtime->hw = minivosc_pcm_hw;

  mydev->substream = ss;
  ss->runtime->private_data = mydev;

  // ....
```

We assign ourselves...

We save the references in the device structure *ourselves*!

- If we don't save the references to substream here – we will not be able to retrieve them, when the time comes to handle the capture buffer!

The capture process – timing and memory

- Polling or interrupt?
  - There is no actual hardware that can generate interrupts for the PC...
  - ... so we can simulate a polling process by using a *timer function*
- Different Linux kernel timers
  - default, “timer wheel” (jiffies);
  - high-resolution timers.

The capture process – timing and memory

- Process:
  - `_pcm_open`: we specify `_timer_function` is our timer function
  - `_pcm_prepare`: buffer positions/sizes are initialized
  - `_pcm_trigger`: here `_timer_start` (or stop) is called
  - `_timer_start`: here timer expiry time is set, and timer is “started” via `` `add_timer` `` function

  - At this point, the OS kernel/ALSA can arbitrarily call our `_pcm_pointer` function (which then calls `_pos_update`), to find out what are our *current* buffer positions!

  - After the timer has expired, `_timer_function` runs;
    - and it also calls `_pos_update`!
    - (additionally, it calls `snd_pcm_period_elapsed` to inform ALSA)

The capture process – timing and memory

- Process (cont.):
  - from _pos_update perspective:
    - If delta jiffies from last _pos_update is zero; then we've been called by _pcm_pointer; ignore
    - If delta jiffies from last _pos_update is >0; then we've been called by _timer_function - execute buffer copying through _xfer_buf!
      - _xfer_buf merely outsources copying algorithm to _fill_capture_buf
  - _fill_capture_buf finally does the copying algorithm:

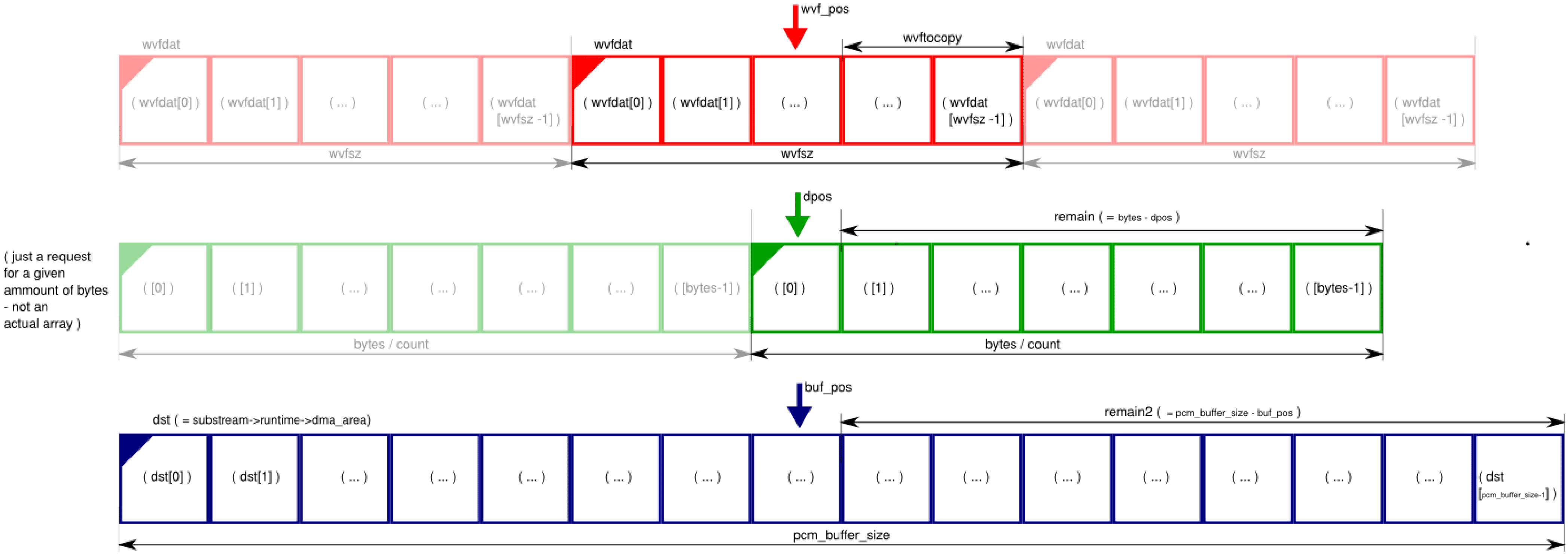
```
char *dst = mydev->substream->runtime->dma_area;
...
  for (j=0; j<bytes; j++) {
    //* ...
    dst[mydev->buf_pos] = wvfdat[mydev->wvf_pos];
    dpos++; mydev->buf_pos++;
    mydev->wvf_pos++;
    //* or by using memcpy...
    //* ...
```

The capture process – timing and memory

- Special problem – wrapping of buffers; in minivosc we can distinguish:
  - intermediate (waveform) buffer/array - `wvfdat` - size 21 bytes
    - size preset by driver programmer
  - 'individual' transfer chunk size - given by bytes / count - size 32 (or 64) bytes
    - size dependent on timing between consecutive executions of `_timer_function` & stream(s) format
  - PCM substream buffer/array - dev->substream->runtime->dma_area - size 816 (or 1536) bytes
    - size chosen by software (?): audacity usually claims 816 bytes, arecord 1536 bytes
  - **pcm_period_size** - size 48 bytes,
    - for calling snd_pcm_period_elapsed, size set by stream(s) format & kernel timer frequency

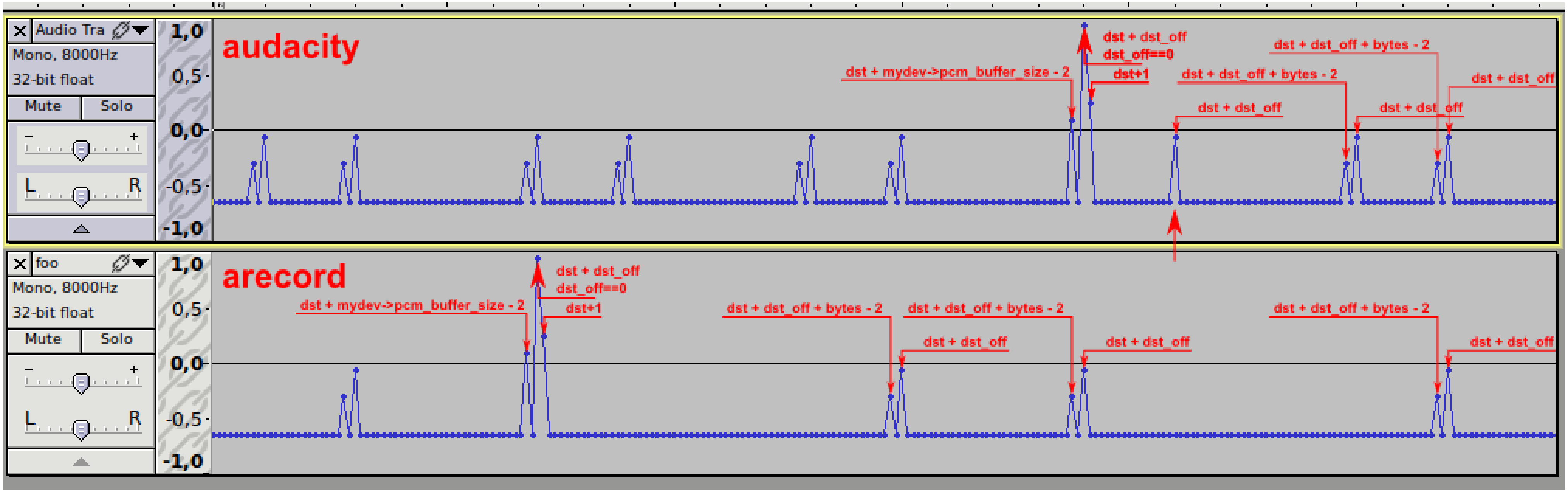
The capture process – buffer wrapping

- Special problem – wrapping of buffers; visualisation:



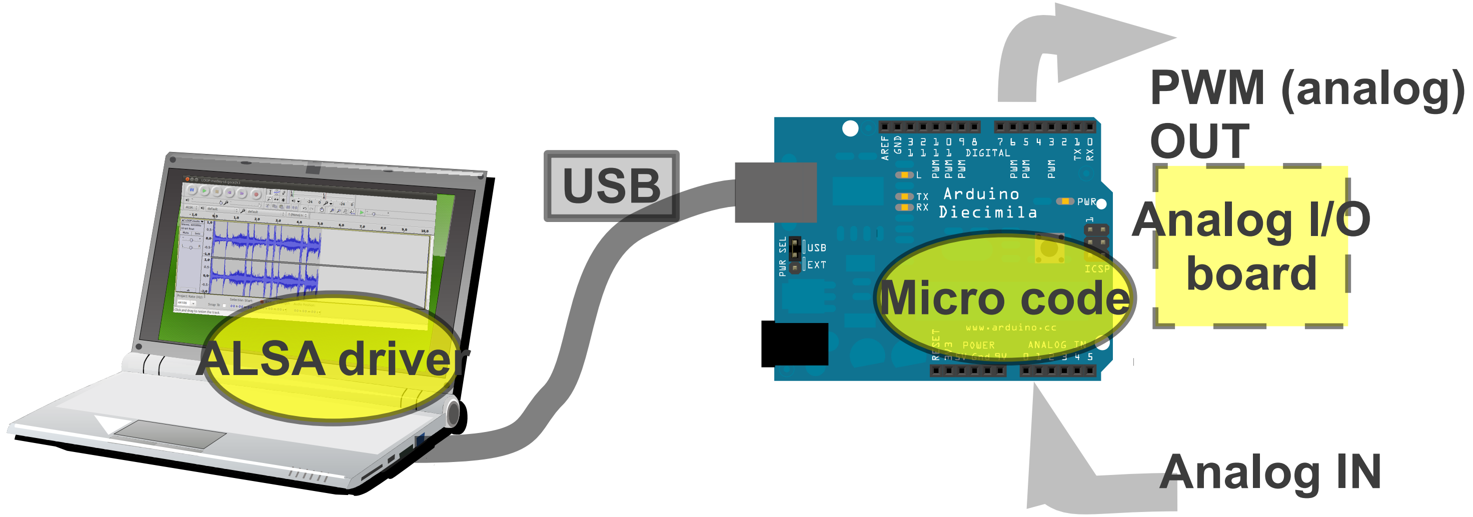
Buffer wrapping - “buffermarks”

- We can write special values in the beginning and end of all respective chunks; then in an audio editor we would obtain samples that will indicate the buffer sizes, or “buffermarks”

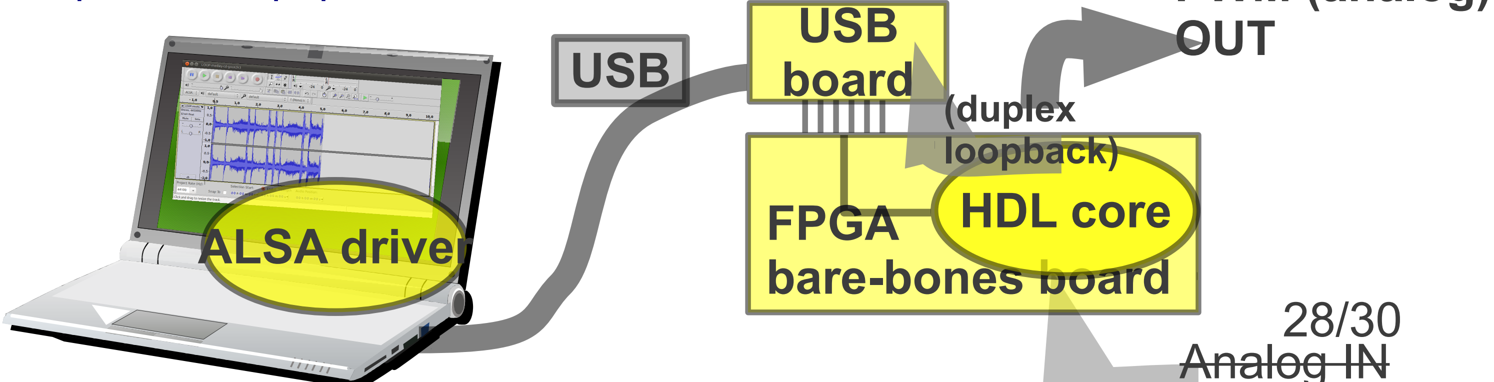


Conclusion

- Minivosc led to development of two open soundcard platforms (based on the same ALSA driver)
  - AudioArduino http://imi.aau.dk/~sd/phd/index.php?title=AudioArduino



  - Audio Bare-bones FPGA http://imi.aau.dk/~sd/phd/index.php?title=AudioBareBonesFPGA



Trivia

- First released in 2010 ...

Demonstration

- Here a demonstration of building the driver