The Industrial IO Subsystem after 10 Years!

Jonathan Cameron / Huawei

jic23@kernel.org
1. History – where we came from
2. Interface principles
3. IIO architecture
4. Some of our mistakes!
5. Community
First some history
My personal itch…

• The SESAME project
  – Sensors on athletes
• Linux platform
  – Intel Research IMote2
• Sensor drivers
  – Accelerometers, ADCs
  – Upstream, but as what?
Requirements…

• Simple interface option (hwmon?)
• Efficient streaming option (Input?)
• So what to do?
  – Ask the Linux Kernel Mailing List!
    • Back then people actually read it.
  – Answer – You’ll need to do something new.
    
    https://lore.kernel.org/lkml/4832A211.4040206@gmail.com/
Requirements…

• Simple interface option (like hwmon)
• Efficient streaming option (like Input)

• Issue 1: My requirements are not always your requirements.

So what to do?
– Ask the Linux Kernel Mailing List!
  • Back then people actually read it.
– Answer – You’ll need to do something new.
So what is IIO?

Backwards definition: What is it not?

- Not a replacement for hwmon
- Not a replacement for Input
- These both do what they do well
I/O is broad

- Small focused subsystems?
- We tried that first!
  - /sys/class/als

“...I _do_ think that it's crazy to start doing new subsystems for every little thing. That way lies madness.”

- Linus
So what devices do we support?

- Anything that is at heart an:
  - Analog to Digital Convertors (IN)
  - Digital to Analog Convertors (OUT)
- ADCs, Accelerometers, Gyroscopes, Magnetometers, IMUs, Light, Chemical, Health, Rotation and many others.
- DACs, DPOTs
What is the interface?

• IIO’s most important characteristic is it’s user-space interface
• Allows generic user-space code
  – libiio, iio-sensor-proxy, android-iio-sensors-hal
• Must be consistent
  – Ideally should not ‘need’ to read the docs
Interface Principles

- All control and metadata via SYSFS
  - Human readable – no magic!
  - Consistent and predictable
- Single channel polled read via SYSFS
- Chrdev based FIFOs
- Chrdev based Events
The architecture

• Simple polled read, or…
• Trigger / Buffer (push) concept
  – ‘Concurrent’ samples from enabled channels
  – Buffers used to allow asynchronous reads
Synchronous Read / SYSFS

- Straight forward.
- Why is the core there?
  - Enforces ABI
  - Alternative interfaces!
Synchronous Read / Consumer Driver

• Service provider.
• Use cases:
  – hwmon
  – Thermal
  – Battery
  – Other IIO devices
• Issue 2: Coupling is too tight between user-space and backend
Why so complex?

• Flexibility
  – Not all devices have to do it all
  – Multiple devices can do different parts
  – One device can feed multiple data users
  – IIO user-space is just another in kernel user
Let's us do cool things!

- Generic ADC touch screen driver
- Chained IIO devices

---

Peter Rosin: 7fde1484af21
("iio: dpot-dac: DAC driver based on a digital potentiometer")

Peter Rosin: b475f80b354a1
("iio: envelope-detector: ADC driver based on a DAC and a comparator")
Issue 3: It is very difficult to predict the future
• Generalized simplicity over local simplicity.
  – `in_accel_x_raw` vs `in_accel_x0_raw`

• Compatibility with existing ABI nice, but don’t try too hard
  – Unit choices of hwmon weren’t good to copy
ABI ‘mistakes’

- Abstraction doesn’t always map well
- Counter drivers moving out of IIO to own subsystem.
  - Cleaner abstraction
  - Appropriate flexibility
  - Historic ABI has to be maintained.
Missing “indication of interest”

• Normal SYSFS flow provides no ‘I will read this shortly’.
• It is costly to stop triggered flow and read an ‘extra’ channel.
• No solution yet!
Issue 4: Where does high performance fit?
Issue 4: Mapping to High Speed

• High speed devices needs
  – DMA buffers (done for some time)
  – Handling of Complex multi sample triggering and state changes
  – Inline meta data, alignment tags etc
  – Often self describing flows

• These are not yet handled in mainline
Issue 5: Complex devices with proprietary user-space
When generalization breaks…

• Some sensors e.g. Pulse Oximeters need complex post processing to provide useful output.
• So far we have
  – Mapped to generic interfaces at boundary
• Is this always possible?
Building a Subsystem
Building a Community
Route to success!

- Posts to LKML
  - Some good feedback – slow progress

- Staging
  - Unusual route for a subsystem
  - It let us work out where we were going
  - Great feedback

- Making that jump
  - Need to reach ABI Stability
Growth of a subsystem

Number of Drivers

- drivers/iio
- drivers/staging

2009 2012 2015
So who wrote all these drivers?

- Certainly not me!
- Companies (20+)
- Hobbyists
- Students
- Outreachy / GSOC students
### Developers with the most changesets

<table>
<thead>
<tr>
<th>Developer</th>
<th>Changesets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan Cameron</td>
<td>845 (15.8%)</td>
</tr>
<tr>
<td>Lars-Peter Clausen</td>
<td>641 (12.0%)</td>
</tr>
<tr>
<td>Peter Meerwald-Stadler</td>
<td>235 (4.4%)</td>
</tr>
<tr>
<td>Michael Hennerich</td>
<td>166 (3.1%)</td>
</tr>
<tr>
<td>Brian Masney</td>
<td>164 (3.1%)</td>
</tr>
<tr>
<td>Sachin Kamat</td>
<td>162 (3.0%)</td>
</tr>
<tr>
<td>Srinivas Pandruvada</td>
<td>97 (1.8%)</td>
</tr>
<tr>
<td>Lorenzo Bianconi</td>
<td>86 (1.6%)</td>
</tr>
<tr>
<td>Matt Ranostay</td>
<td>81 (1.5%)</td>
</tr>
<tr>
<td>Linus Walleij</td>
<td>80 (1.5%)</td>
</tr>
<tr>
<td>Hartmut Knaack</td>
<td>77 (1.4%)</td>
</tr>
<tr>
<td>Daniel Baluta</td>
<td>75 (1.4%)</td>
</tr>
<tr>
<td>Alison Schofield</td>
<td>62 (1.2%)</td>
</tr>
<tr>
<td>Irina Tirdea</td>
<td>53 (1.0%)</td>
</tr>
<tr>
<td>Fabrice Gasnier</td>
<td>49 (0.9%)</td>
</tr>
<tr>
<td>Dan Carpenter</td>
<td>48 (0.9%)</td>
</tr>
<tr>
<td>Arnd Bergmann</td>
<td>45 (0.8%)</td>
</tr>
<tr>
<td>Cristina Opriceana</td>
<td>39 (0.7%)</td>
</tr>
<tr>
<td>Eva Rachel Retuya</td>
<td>36 (0.7%)</td>
</tr>
</tbody>
</table>

### Developers with the most changed lines

<table>
<thead>
<tr>
<th>Developer</th>
<th>Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan Cameron</td>
<td>61209 (16.8%)</td>
</tr>
<tr>
<td>Lars-Peter Clausen</td>
<td>38921 (10.7%)</td>
</tr>
<tr>
<td>Barry Song</td>
<td>23246 (6.4%)</td>
</tr>
<tr>
<td>Michael Hennerich</td>
<td>21217 (5.8%)</td>
</tr>
<tr>
<td>Peter Meerwald-Stadler</td>
<td>10953 (3.0%)</td>
</tr>
<tr>
<td>Srinivas Pandruvada</td>
<td>8949 (2.5%)</td>
</tr>
<tr>
<td>Linus Walleij</td>
<td>8405 (2.3%)</td>
</tr>
<tr>
<td>Sonic Zhang</td>
<td>7859 (2.2%)</td>
</tr>
<tr>
<td>Daniel Baluta</td>
<td>7660 (2.1%)</td>
</tr>
<tr>
<td>Matt Ranostay</td>
<td>7037 (1.9%)</td>
</tr>
<tr>
<td>Lorenzo Bianconi</td>
<td>5768 (1.6%)</td>
</tr>
<tr>
<td>Denis Ciocca</td>
<td>4505 (1.2%)</td>
</tr>
<tr>
<td>Fabrice Gasnier</td>
<td>4401 (1.2%)</td>
</tr>
<tr>
<td>Brian Masney</td>
<td>4173 (1.1%)</td>
</tr>
<tr>
<td>Irina Tirdea</td>
<td>3939 (1.1%)</td>
</tr>
<tr>
<td>Gregor Boirie</td>
<td>3405 (0.9%)</td>
</tr>
<tr>
<td>Jon Brenner</td>
<td>3269 (0.9%)</td>
</tr>
<tr>
<td>Akinobu Mita</td>
<td>3081 (0.8%)</td>
</tr>
<tr>
<td>Tiberiu Breana</td>
<td>2971 (0.8%)</td>
</tr>
</tbody>
</table>
It’s all about the long tails!

<table>
<thead>
<tr>
<th>Patches</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>P &gt; 200</td>
<td>3</td>
</tr>
<tr>
<td>P &gt; 100</td>
<td>6</td>
</tr>
<tr>
<td>P &gt; 50</td>
<td>14</td>
</tr>
<tr>
<td>P &gt; 25</td>
<td>27</td>
</tr>
<tr>
<td>P &gt; 10</td>
<td>78</td>
</tr>
<tr>
<td>P &gt; 5</td>
<td>143</td>
</tr>
<tr>
<td>P &gt; 2</td>
<td>229</td>
</tr>
<tr>
<td>P ≤ 2</td>
<td>512</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lines</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>L &gt; 10,000</td>
<td>5</td>
</tr>
<tr>
<td>L &gt; 5,000</td>
<td>11</td>
</tr>
<tr>
<td>L &gt; 2,500</td>
<td>23</td>
</tr>
<tr>
<td>L &gt; 1,000</td>
<td>65</td>
</tr>
<tr>
<td>L &gt; 500</td>
<td>112</td>
</tr>
<tr>
<td>L &gt; 250</td>
<td>158</td>
</tr>
<tr>
<td>L &gt; 100</td>
<td>205</td>
</tr>
</tbody>
</table>
Aspects of a good community

• Reviewers are the life blood of a kernel sub-system!
• Mentorship of new contributors
  – Including organised schemes and ad-hoc
• Willingness to engage and explain or be persuaded!
Why we get so many new contributors?

- Tangible things
- Cheap devices
- Can start simple
- History of new contributors
- (It’s certainly not our quality documentation!)
Outreach-Y / GSOC

• Great mentors
  – Daniel Băluță, Octavian Purdilă, Alison Schofield, Greg KH

• Great students!
  – (see reference list)
Getting involved

• Subscribe to linux-iio@vger.kernel.org
• Pick up one of the infrequent ‘todo’ items that get posted to the list.
• Pester me to send a todo if there isn’t one open.
• Grab a cheap bit of HW and see if it works.
• Develop a new driver. The various intern blogs are great to get you started.

• Whilst I naturally like keeping things on list, I don’t mind PMs to jic23@kernel.org
Reference list - talks

Industrial I/O and You: Nonsense Hacks
Matt Ranostay (ELC 2017)

LIBIIO – Access to sensor devices made easy
Lars-Peter Clausen (ELC 2016) https://www.youtube.com/watch?v=CS9NuRBzN5Y

IIO Industrial Input-Output
Linus Walleij (Lund Linux Conference 2016)

Android IIO sensors HAL
Daniel Baluta (Lund Linux Conference 2016)

Software Defined Radio using the Linux Industrial IO framework

Industrial I/O Subsystem: The Home of Linux Sensors
Daniel Baluta (LINUXCON Europe 2015)
https://events.static.linuxfound.org/sites/events/files/slides/lceu15_baluta.pdf

High-speed Data Acquisition using the Linux Industrial IO framework
Lars-Peter Clausen (ELCE 2014)
https://events.static.linuxfound.org/sites/events/files/slides/iio_high_speed.pdf

IIO, A New Subsystem For I/O Devices
Reference list – This Week!

Drone SITL Bringup with the IIO Framework
    Brandan Das (OSSE 2018!)

Introduction to IIO and Input Drivers
    Matt Porter (OSSE 2018 E-ALE)

Outreachy Linux Kernel Internship Report
    Various including Georgiana Chelu (OSSE 2018)
Reference list – Intern blogs

- Kristina Martšenko 2013 https://kristinamartsenko.wordpress.com
- Roberta Dobrescu 2014 https://iiobits.wordpress.com/
- Christina Moraru 2015 https://kernelsense.wordpress.com/
- Alison Schofield 2016 https://amsfield22.wordpress.com/
- Narcisa Vasile 2017 https://narcisaam.github.io/
- Georgiana Rodica Chelu 2018 https://giach.github.io/
- Himanshu Jha 2018 https://himanshujha199640.wordpress.com/
Getting involved

- Subscribe to linux-iio@vger.kernel.org
- Pick up one of the infrequent ‘todo’ items that get posted to the list.
- Pester me to send a todo if there isn’t one open.
- Grab a cheap bit of HW and see if it works.
- Develop a new driver. The various intern blogs are great to get you started.

- Whilst I naturally like keeping things on list, I don’t mind PMs to jic23@kernel.org