The Actor Model applied to the Raspberry Pi and the Embedded Domain

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Agenda

- Current state of Embedded Systems
- Overview of the Actor Model
- Erlang Embedded Project
- Modelling and developing systems using Erlang
- Experiments with the Raspberry Pi
- Future Explorations
- Q & A

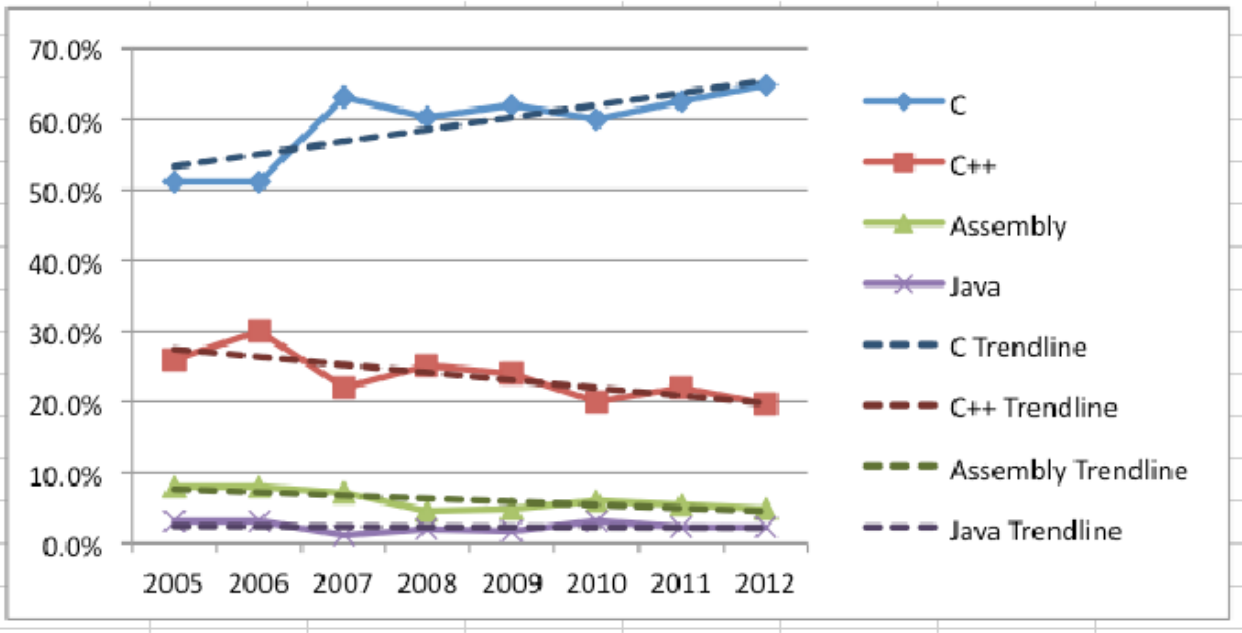
Embedded Systems

> *An embedded system is a computer system designed for specific control functions within a larger system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs.*

- Infinite Wisdom of Wikipedia

#include <stats.h>

The four languages most often reported as the primary language for embedded projects for the years 2005 to 2012, along with linear trendlines.



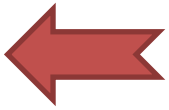
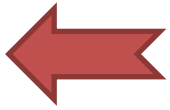
Source: http://embedded.com/electronics-blogs/programming-pointers/4372180/Unexpected-trends

Erlang SOLUTIONS

Current Challenges

- Complex SoC platforms
- “Internet of Things”
  - Connected and distributed systems
- Multicore and/or heterogeneous devices
- Time to market constraints

Embedded Systems

- Bare Metal
  - No underlying OS or high level abstractions
- RTOS 
  - Minimal interrupt and switching latency, scheduling guarantees, minimal jitter
- Embedded Linux 
  - Slimmed down Linux with hardware interfaces

RTOS Concepts

- Notion of “tasks”
- OS-supervised interprocess messaging
  - Shared memory
- Mutexes/Semaphores/Locks
- Scheduling
  - Pre-emptive: event driven
  - Round-robin: time multiplexed

Embedded Linux

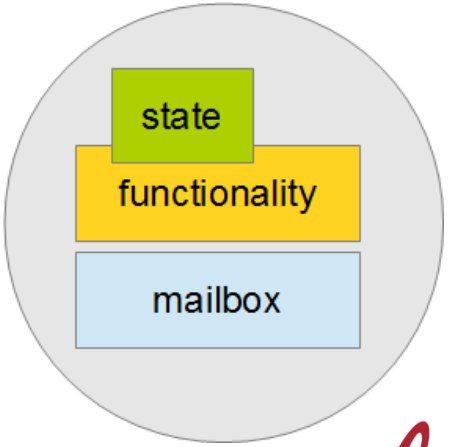
- Not a new concept, increased popularity due to abundant supply of cheap boards
  - Raspberry Pi, Beagleboard/Beaglebone, Gumstix et al.
- Familiar set of tools for software developers, new territory for embedded engineers
  - No direct mapping for RTOS concepts, especially tasks
- Complex device driver framework
  - Here be dragons

Actor Model

- Proposed in 1973 by Hewitt, Bishop and Steiger
  - "Universal primitives for concurrent computation"
- No shared-state, self-contained and atomic
- Building blocks for modular, distributed and concurrent systems
- Implemented in a variety of programming languages

Actor Model

- Asynchronous message passing
  - Messages kept in a mailbox and processed in the order they are received in
- Upon receiving messages, actors can:
  - Make local decisions and change internal state
  - Spawn new actors
  - Send messages to other actors



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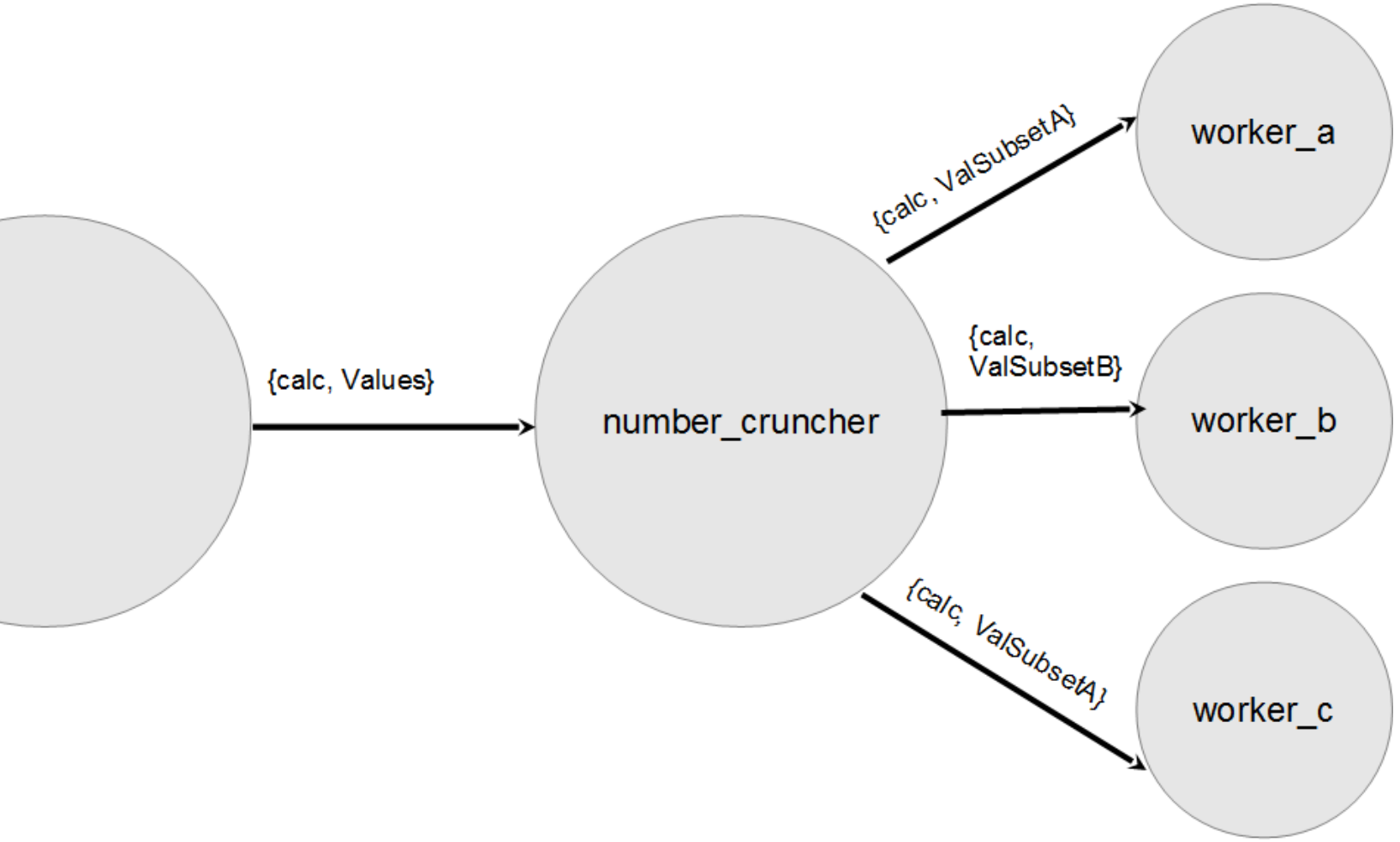
Actor Model



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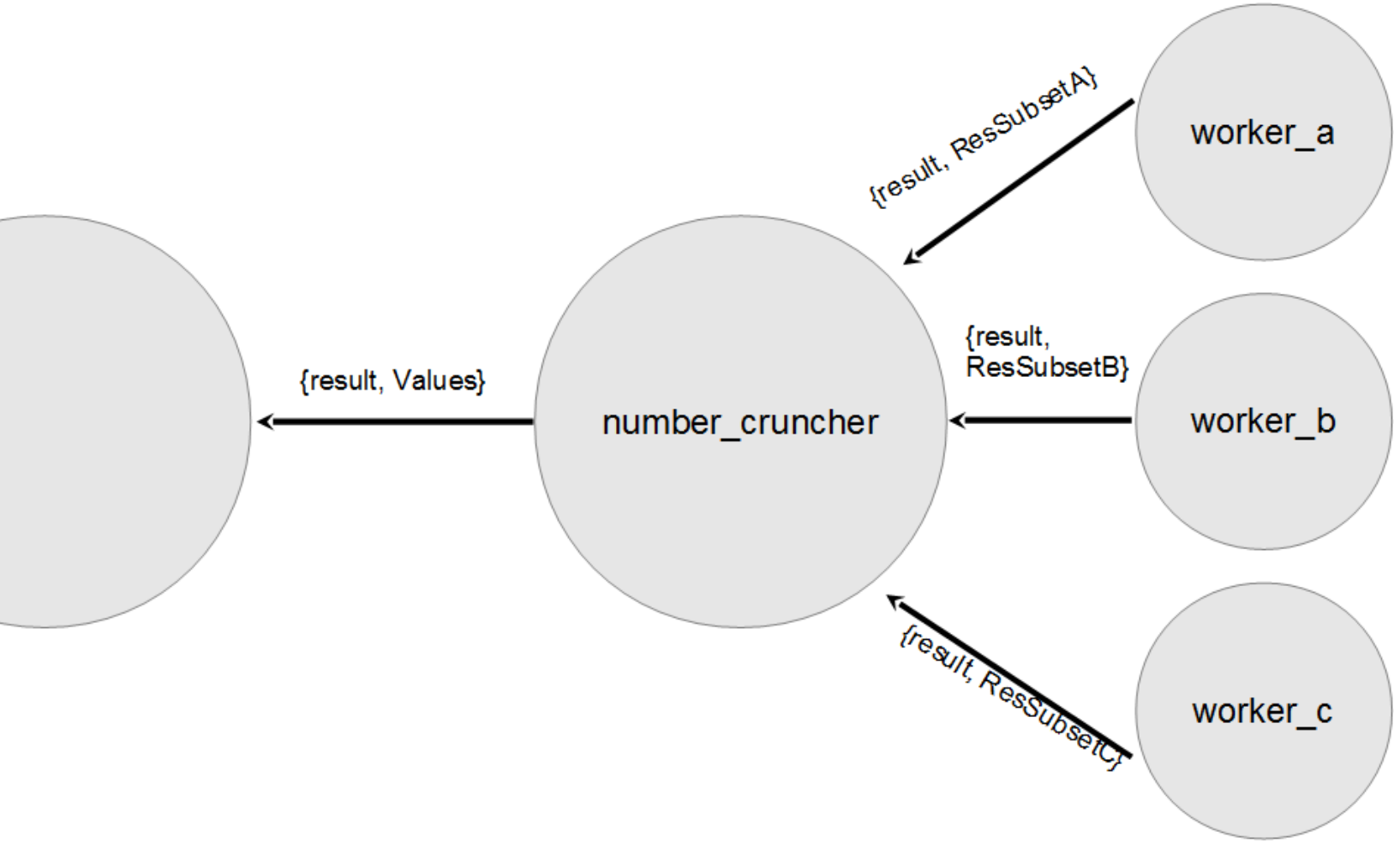
Actor Model



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Limitations of the Actor Model

- No notion of inheritance or general hierarchy
  - Specific to language and library implementation
- Asynchronous message passing can be problematic for certain applications
  - Ordering of messages received from multiple processes
  - Abstract definition may lead to inconsistency in larger systems
    - Fine/Coarse Grain argument

Erlang Embedded

- Knowledge Transfer Partnership between Erlang Solutions and University of Kent
  - Aim of the project: Bring the benefits of concurrent systems development using Erlang to the field of embedded systems; through investigation, analysis, software development and evaluation.

http://erlang-embedded.com

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Why Erlang?

- Implements the Actor model
- Battle-tested at Ericsson and many other companies
  - Originally designed for embedded applications
- Support for concurrency and distributed systems out of the box
- Easy to create robust systems
- (...and more!)

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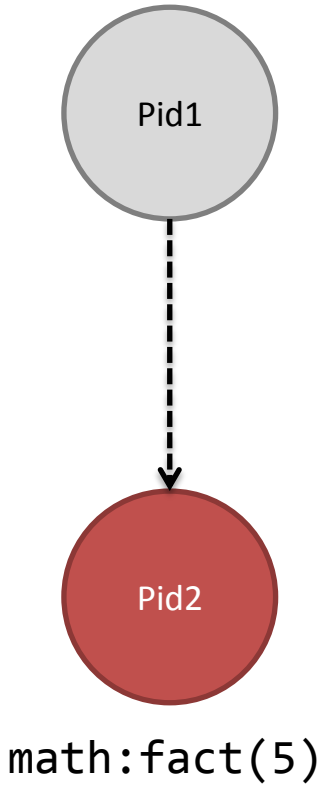
High Availability/Reliability

- Simple and consistent error recovery and supervision hierarchies
- Built in fault-tolerance
  - Isolation of Actors
- Support for dynamic reconfiguration
  - Hot code loading

Creating an Actor

```
spawn(math, fact, [5])
```



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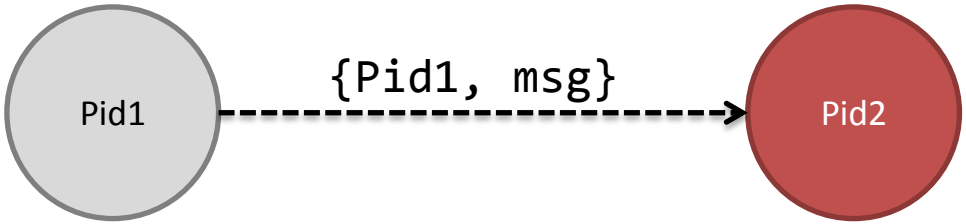
Communication




```
Pid2 ! {self(), msg}
```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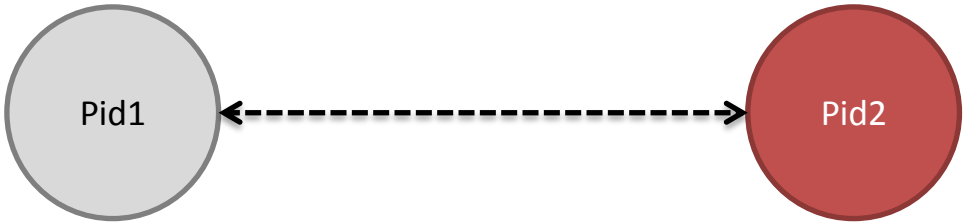
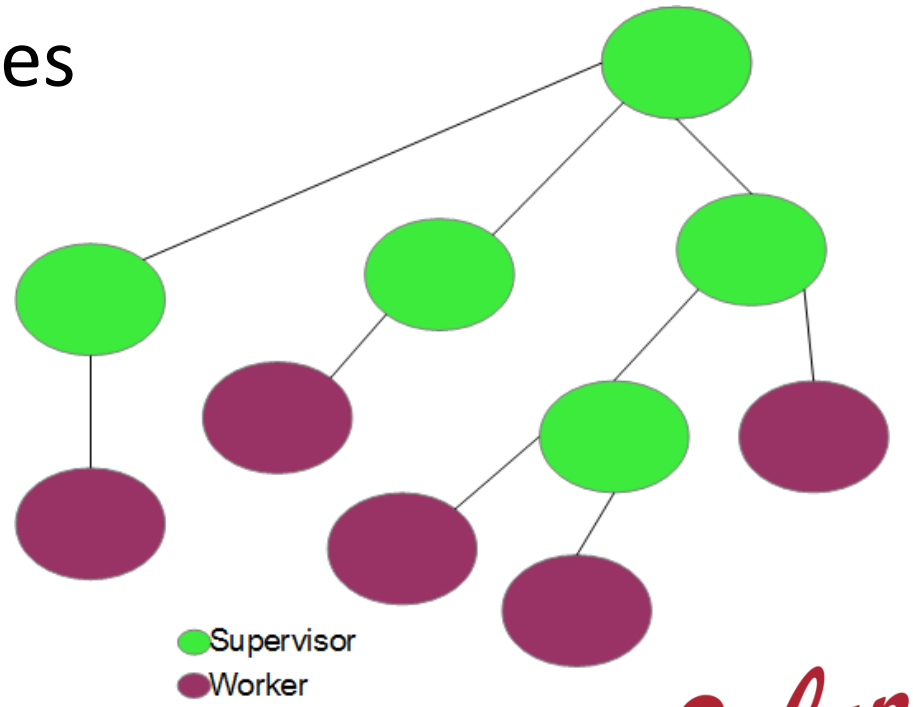
Bidirectional Links




```
link(Pid2)
```

Process Error Handling

- Let it Fail!
  - Abstract error handling away from the modules
  - Results in leaner modules
- Supervision hierarchies



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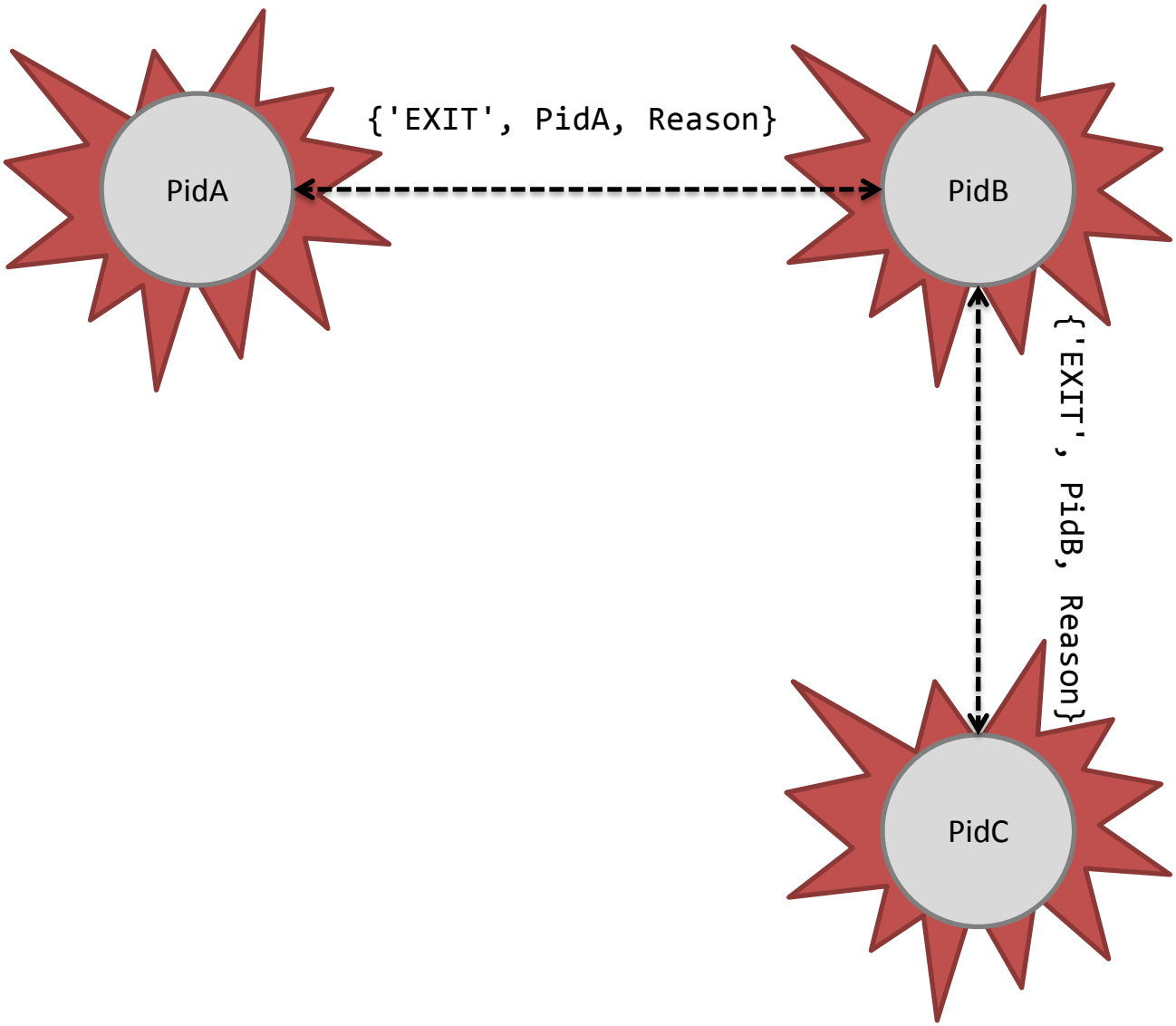
Propagating Exit Signals



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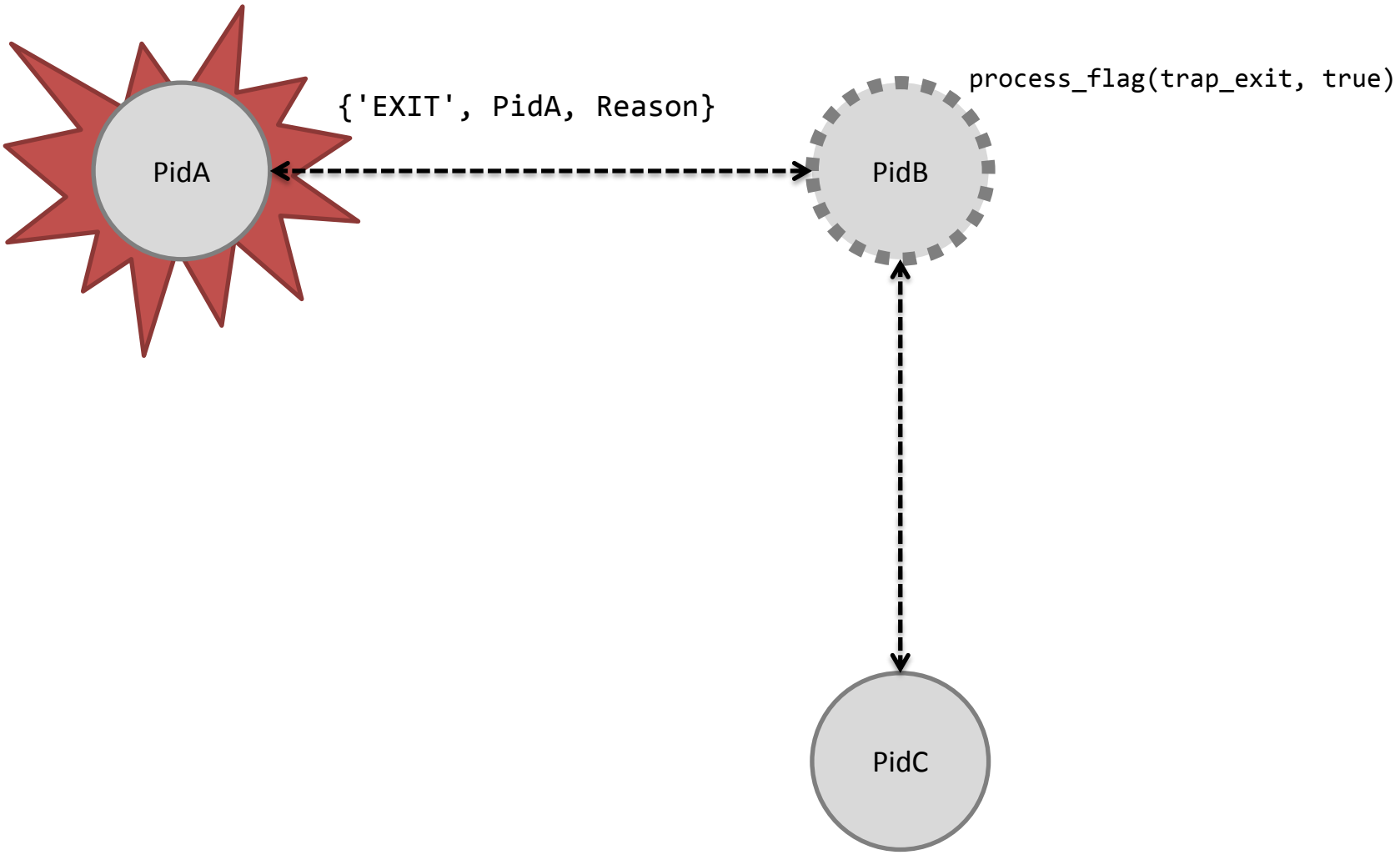
Trapping Exits



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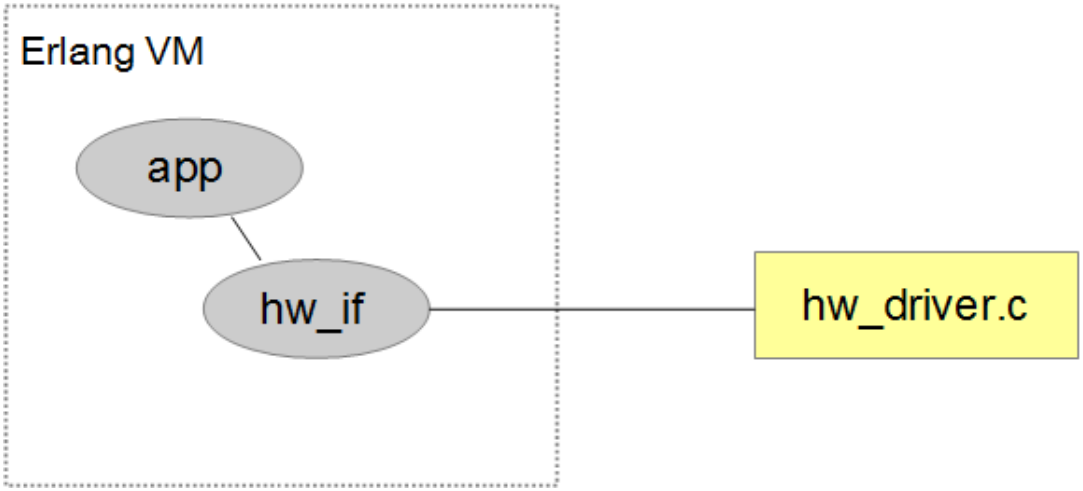
External Interfaces

- Native Implemented Functions (NIFs) and ports used to interface external world to the Erlang runtime.



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Erlang, the Maestro

(flickr/dereckesanches)

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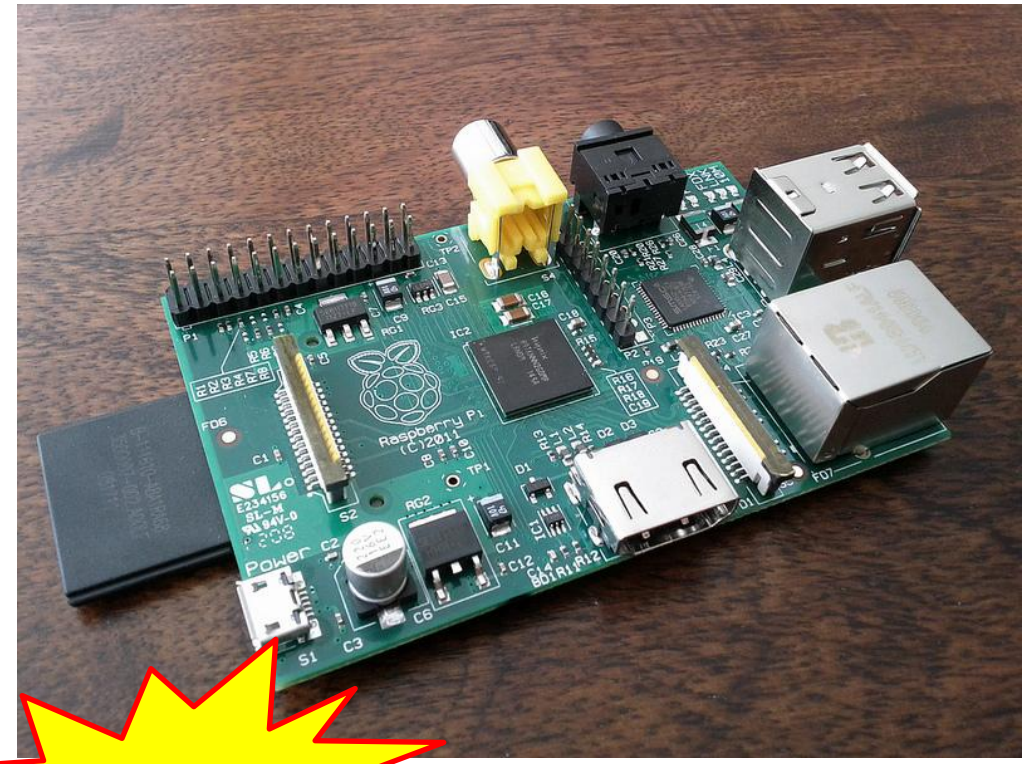
Raspberry Pi

- 700 MHz ARM11
- 256 MB DDR2 RAM
- 10/100Mb Ethernet
- 2x USB 2.0
- (HDMI, Composite Video, 3.5mm Stereo Jack, DSI, CSI-2)



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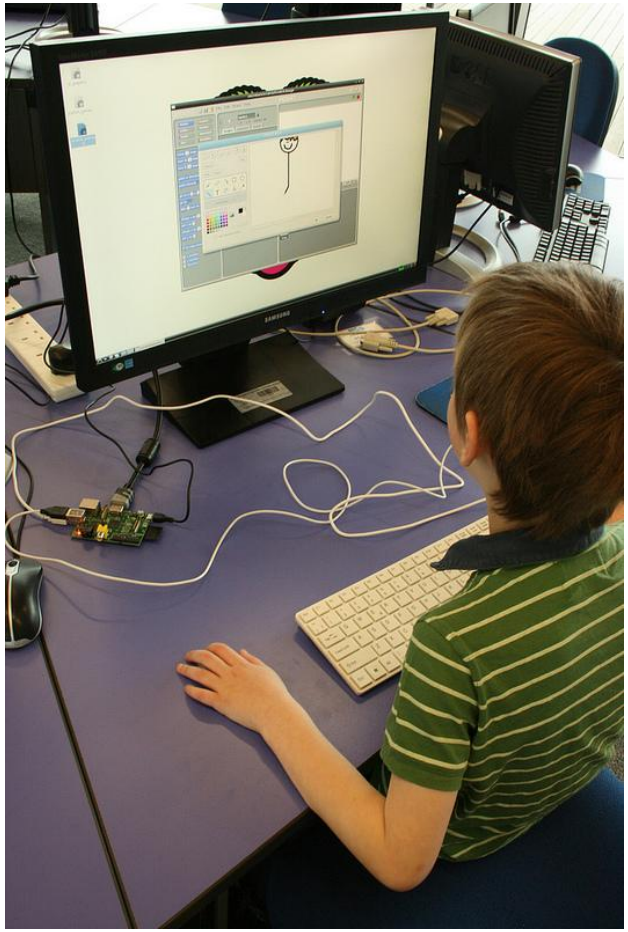
Raspberry Pi in Education



(flickr/lebeus)

- The Raspberry Pi Foundation is a UK registered charity.
- Mission statement: *"...to promote the study of computer science and related topics, especially at school level, and to put the fun back into learning computing.*"

Future Engineers/Programmers!

Raspberry Pi Peripherals

- GPIO
- UART
- I2C
- I2S
- SPI
- PWM
- DSI
- CSI-2

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Accessing peripherals

- Peripherals are memory mapped

- Access via /dev/mem
  - Faster, needs root, potentially dangerous!
- Use kernel modules/sysfs
  - Slower, doesn't need root, easier, relatively safer

GPIO Interface (I)

```
init(Pin, Direction) ->

  {ok, FdExport} = file:open("/sys/class/gpio/export", [write]),
  file:write(FdExport, integer_to_list(Pin)),
  file:close(FdExport),


  {ok, FdPinDir} = file:open("/sys/class/gpio/gpio" ++ integer_to_list(Pin)
++ "/direction", [write]),
  case Direction of
    in -> file:write(FdPinDir, "in");
    out -> file:write(FdPinDir, "out")
  end,
  file:close(FdPinDir),


  {ok, FdPinVal} = file:open("/sys/class/gpio/gpio" ++ integer_to_list(Pin)
++ "/value", [read, write]),

  FdPinVal.
```

GPIO Interface (II)

```
write(Fd, Val) ->
  file:position(Fd, 0),
  file:write(Fd, integer_to_list(Val)).


read(Fd) ->
  file:position(Fd, 0),
  {ok, Val} = file:read(Fd, 1),
  Val.


release(Pin) ->
  {ok, FdUnexport} = file:open("/sys/class/gpio/unexport",
[write]),
  file:write(FdUnexport, integer_to_list(Pin)),
  file:close(FdUnexport).
```

Concurrency Demo

http://vimeo.com/40769788

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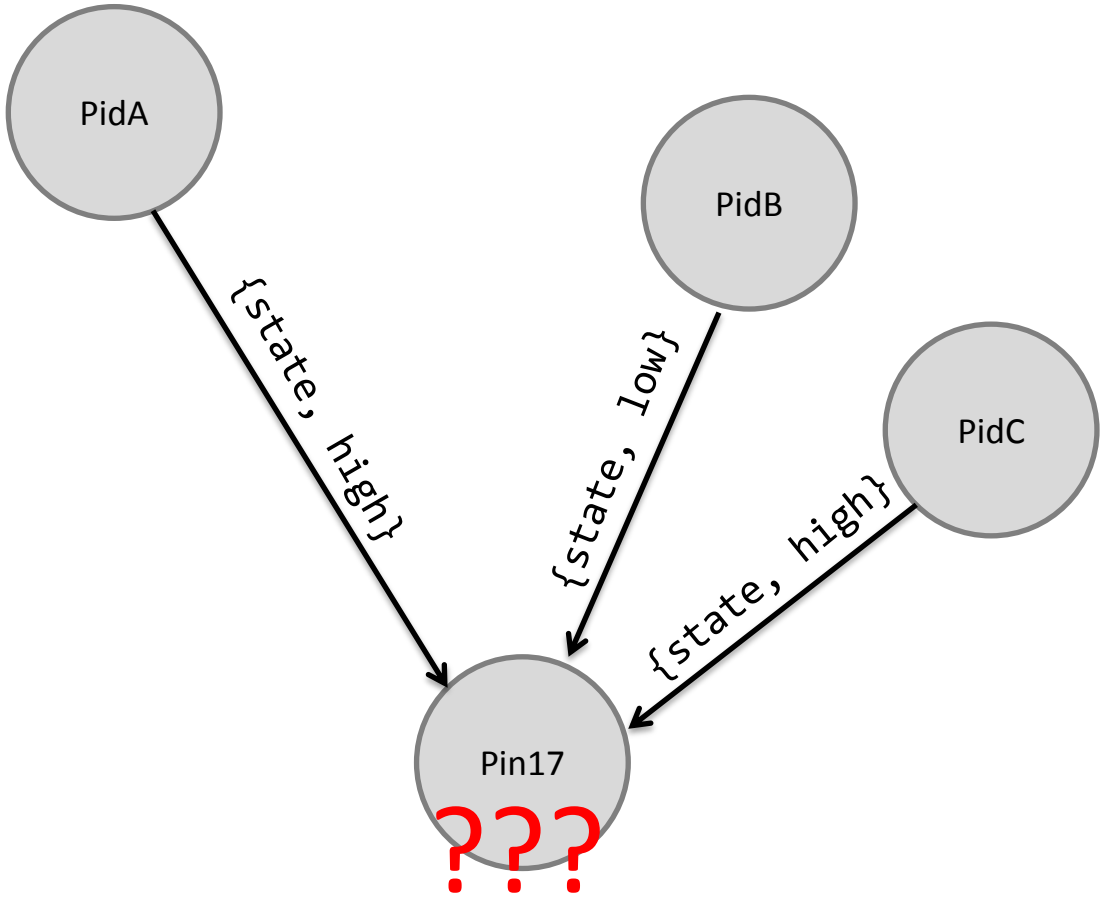
Example: GPIO



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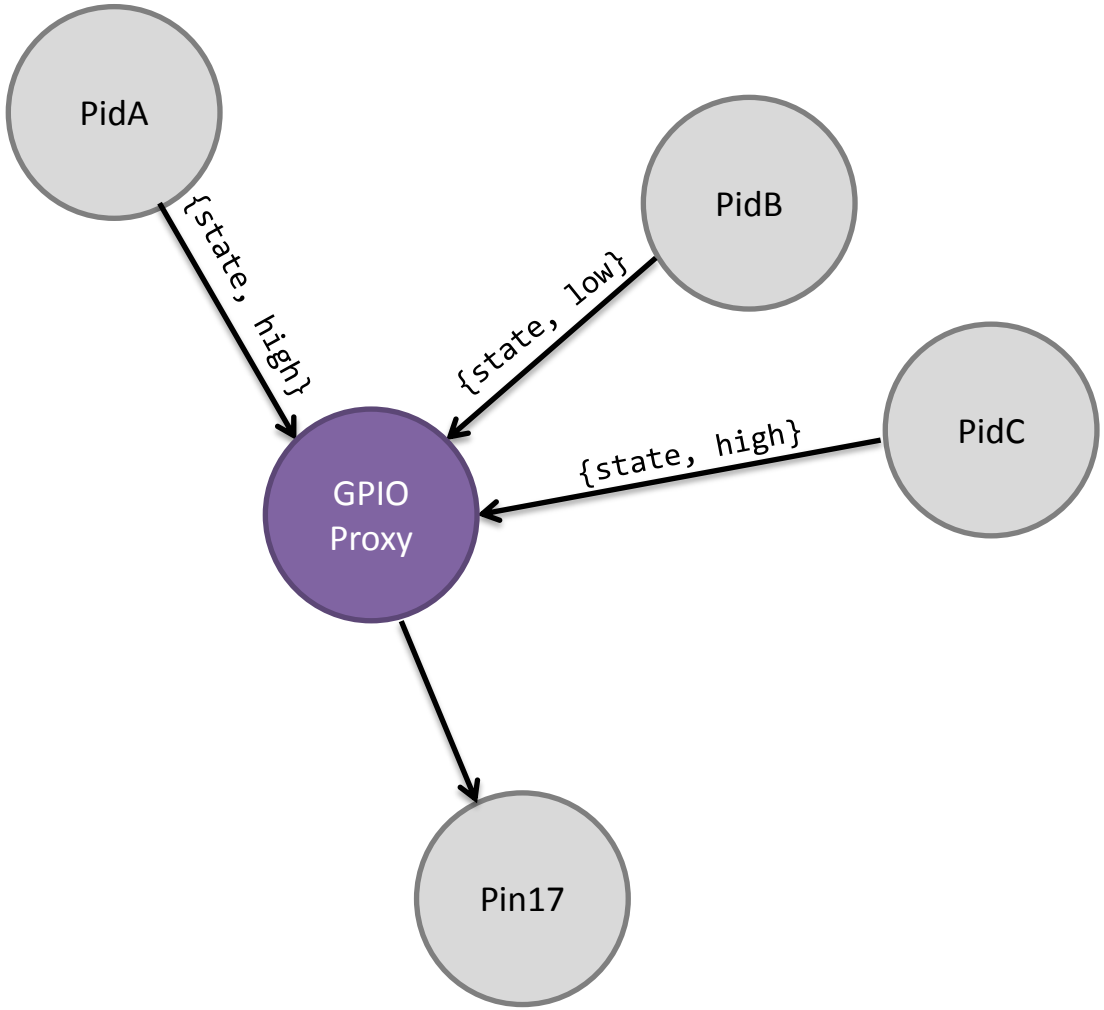
Example: GPIO



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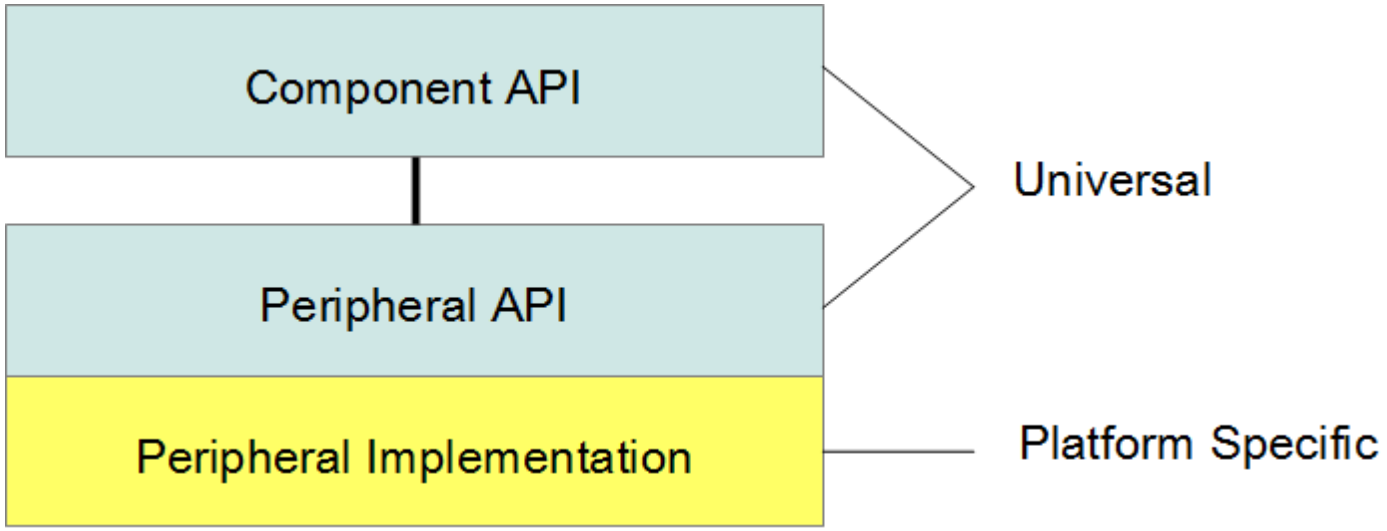
GPIO Proxy

- Replaces ‘locks’ in traditional sense of embedded design
  - Access control/mutual exclusion
- Can be used to implement safety constraints
  - Toggling rate, sequence detection, direction control, etc.

Fine Grain Abstraction

- Advantages
  - Application code becomes simpler
  - Concise and shorter modules
  - Testing becomes easier
  - Code re-use (potentially) increases
- Disadvantage
  - Architecting fine grain systems is difficult

Universal Peripheral/Component Modules



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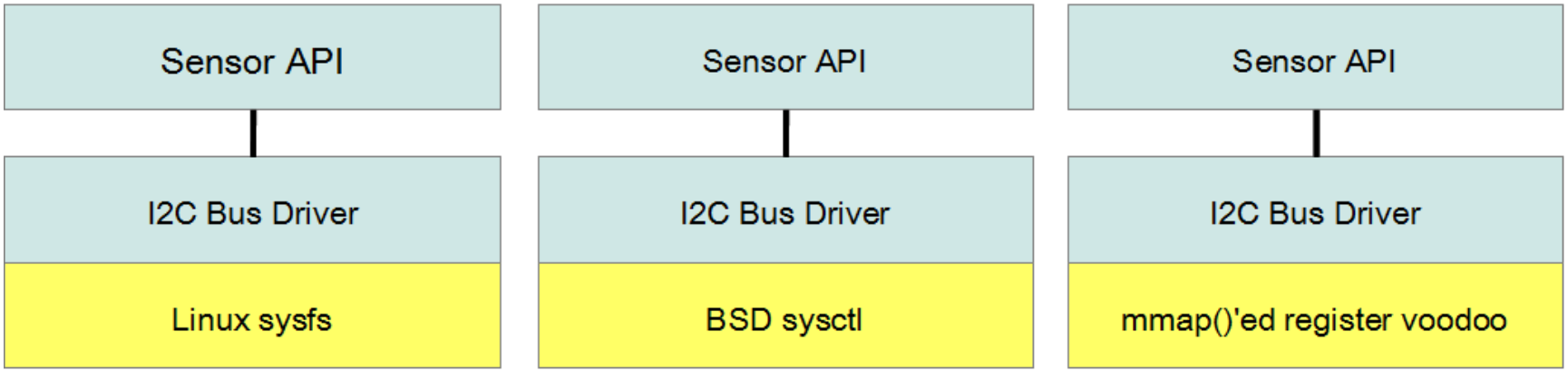
Universal Peripheral/Component Modules

An Example:

Temperature Sensor with I2C Interface



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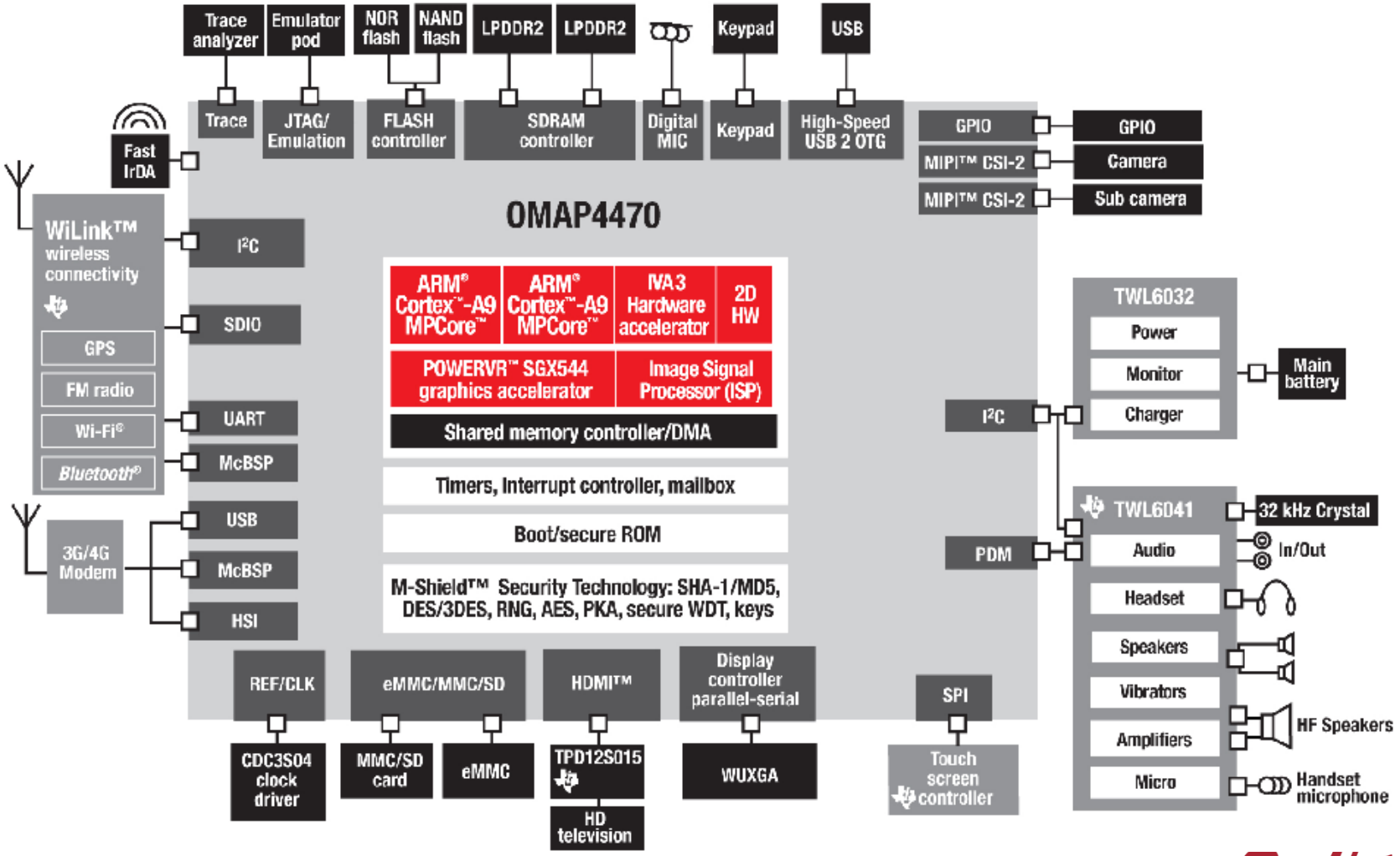
TI OMAP Reference System



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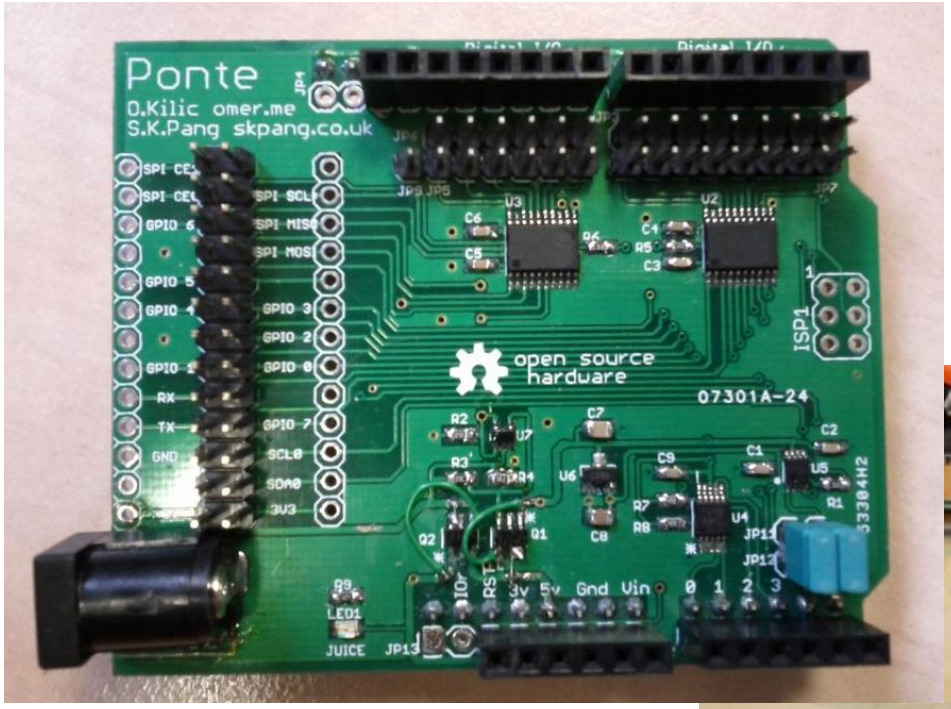
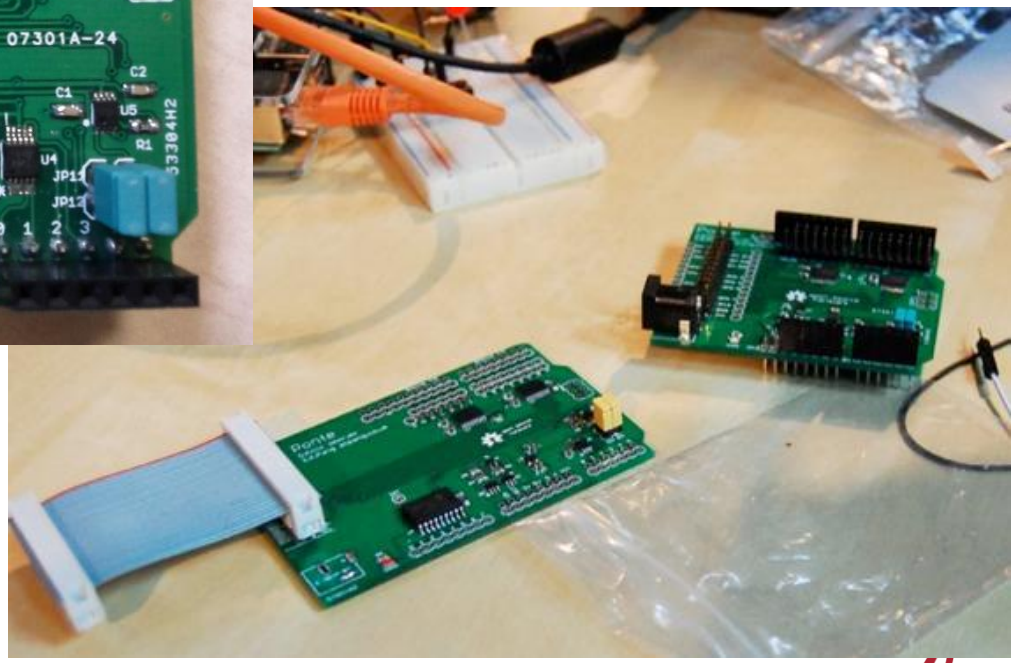
Hardware Projects – Ponte





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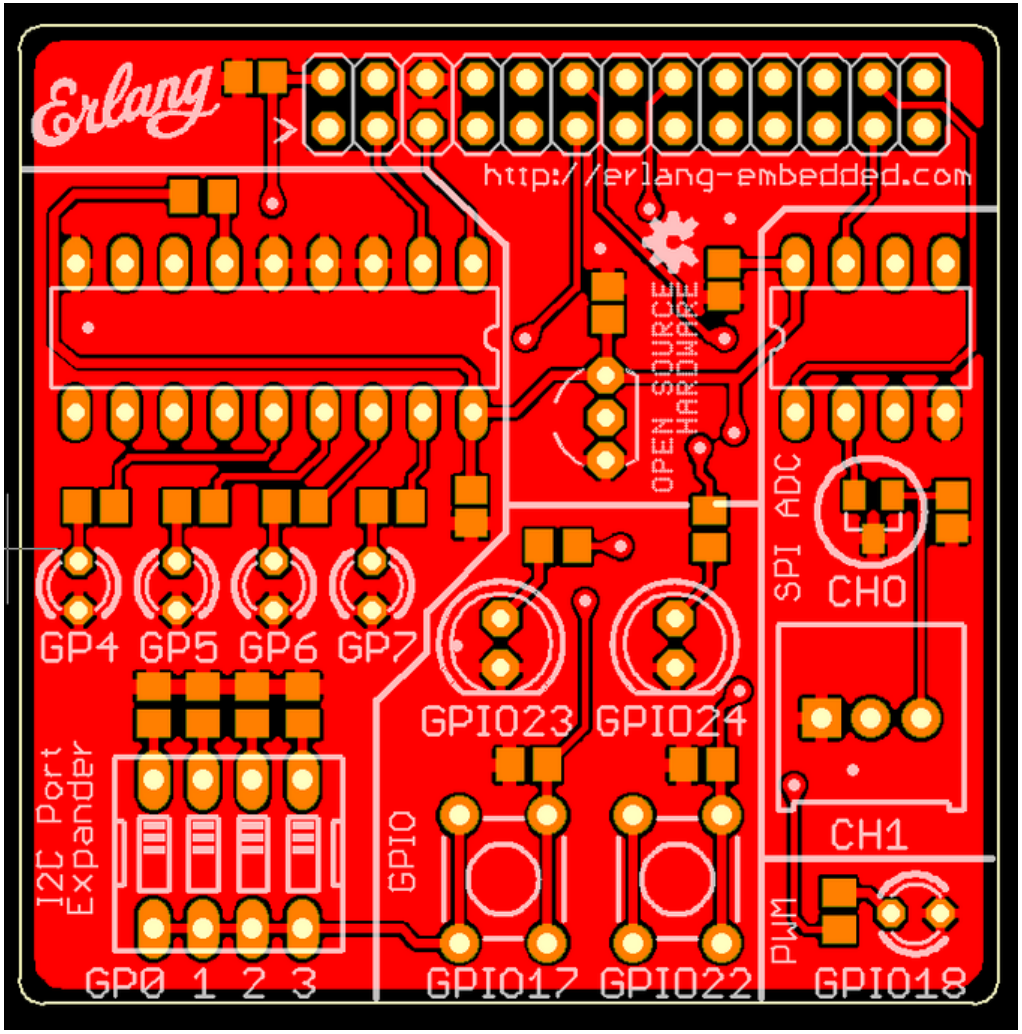
Hardware Projects – Demo Board



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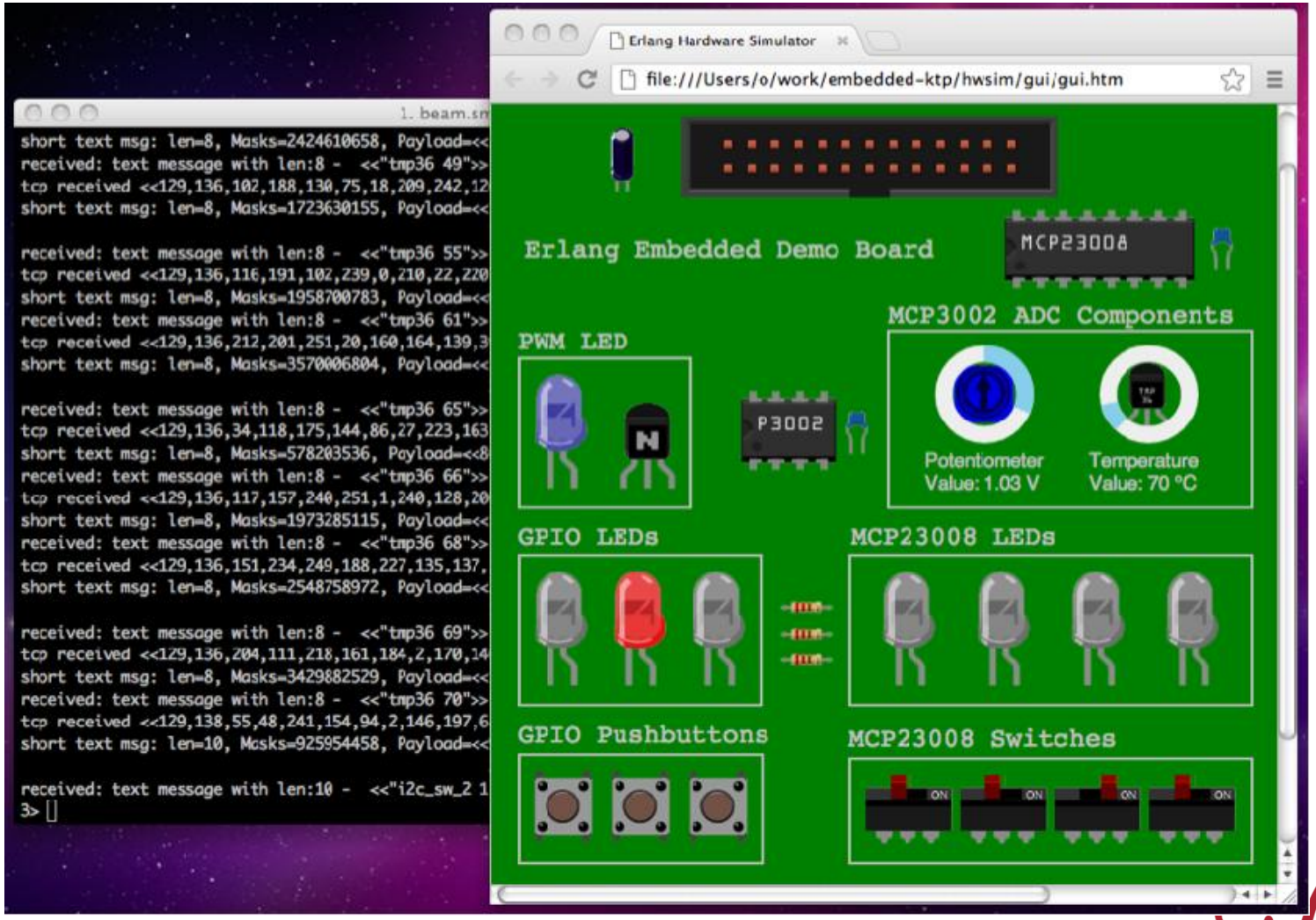
Hardware Simulator



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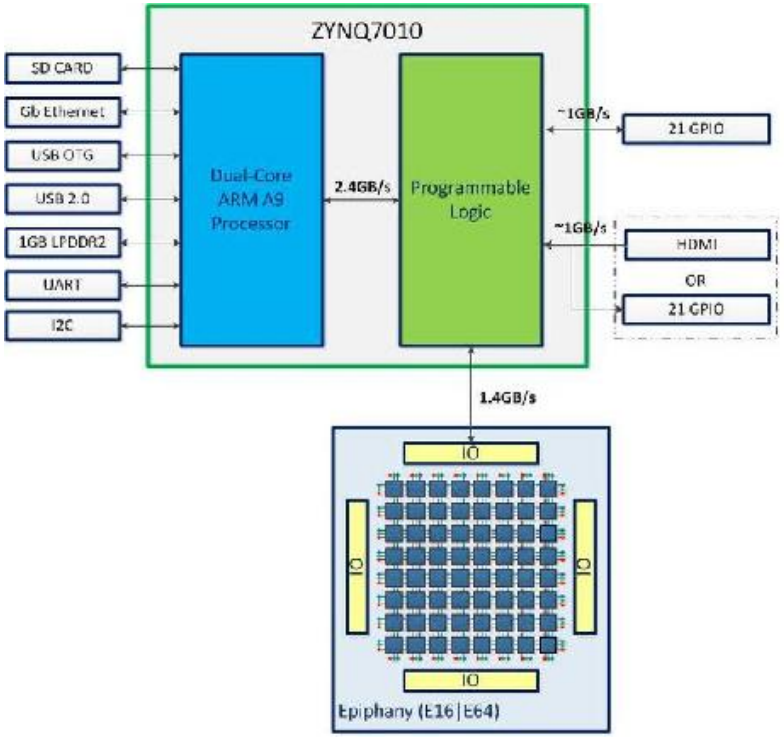
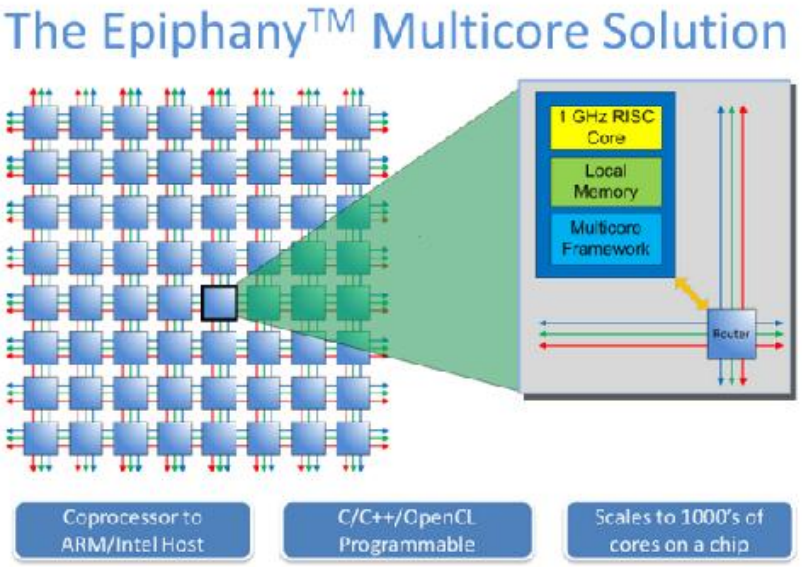
Future Explorations

Parallella:





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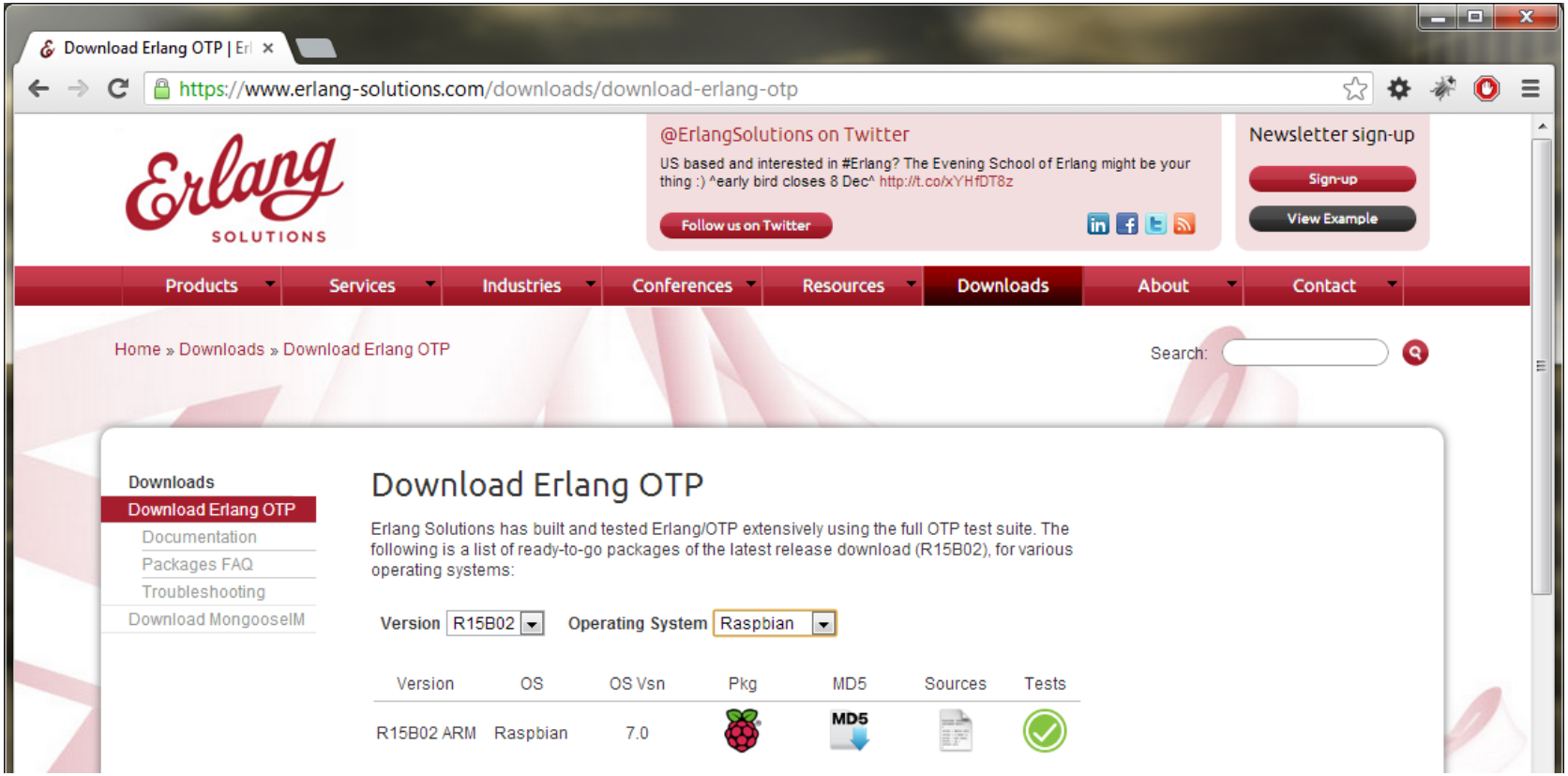
Packages for Embedded Architectures



https://www.erlang-solutions.com/downloads/download-erlang-otp

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Erlang Embedded Training Stack

- A complete package for people interested in developing the next generation of concurrent and distributed Embedded Systems
- Training Modules:
  - Embedded Linux Primer
  - Erlang/OTP 101
  - Erlang Embedded Framework

Get in touch if you're interested.

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Thank you

- http://erlang-embedded.com
- embedded@erlang-solutions.com
- @ErlangEmbedded

> “ The world is concurrent.
> Things in the world don't share data.
> Things communicate with messages.
> Things fail.

- Joe Armstrong

Co-inventor of Erlang

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