Agenda

- What is the problem?
- What is agile?
- What is agile hardware?
- Agile hardware methods
  - PCBs
  - FPGAs
  - ASICs
- Conclusion

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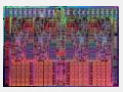
What is hardware?

- PCB: Printed circuit board
  - Mechanically holds components and electrically connects components together

- FPGA: Field programmable gate array
  - Reconfigurable logic that is primarily digital

- ASIC: Application-specific integrated circuit



SoC (System on a Chip) which includes hardware + processor(s) + software can be ASIC or FPGA

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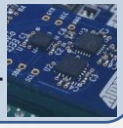

- FPGA: Field programmable gate array
  - Reconfigurable logic that is primarily digital

- ASIC: Application-specific integrated circuit

Although this presentation focuses on PCBs, we will touch on FPGAs and ASICs. Agile methods can be successfully applied to all three!

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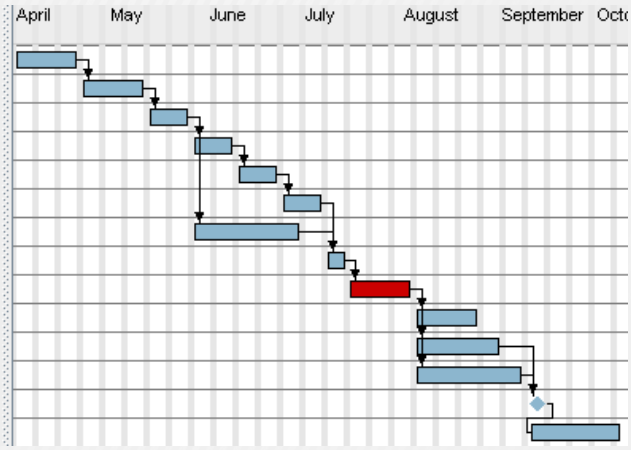
Typical waterfall PCB schedule

Name
Architecture & Features
Specification & Design
Schematic capture
Layout
Fabrication
Assembly
Board test development
Board bring-up & test
HW / SW integration
QA Testing
Manufacturing pilots
Compliance testing
Release to production
Manufacturing ramp



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Concerns

- When do we discover feature problems?
  - Miscommunications? Customers often only fully know what they want when the see it!
  - Customer, marketing & sales feedback?
  - What happens when features change?
- When do we discover design problems?
- What happens to the schedule when a problem is discovered?
- How much time before estimated product launch do we discover problems?

To manage risk, we want to take our lumps early and often.
Delaying discovery of the unknown exacerbates problems.

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Manifesto for Agile Software Development

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

That is, while there is value in the items on the right, we value the items on the left more.

http://agilemanifesto.org/

Agile in practice

Dawn Manser, flickr

- Agile teams usually
- Always have a working code base
- Incrementally add functionality over time
- Deliver & demonstrate frequently – every 2 weeks is not atypical
- Minimize risk of change through comprehensive unit tests
- Manage features through stories with WHO, WHAT, WHY and conversations

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Agile in practice

- Instead of building everything sequentially, section off and complete independent areas
  - One build cycle versus numerous smaller build cycles
  - Difference between building one skyscraper and building a campus!
- Build vertical feature sets that iterate to full solution, not just one build of all features

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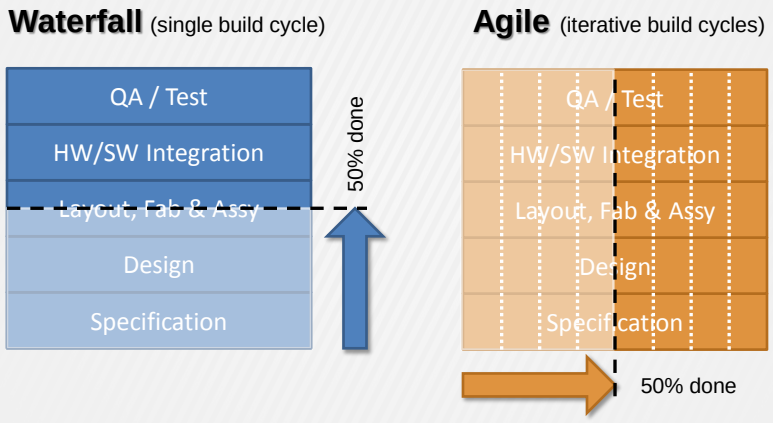
Agile in practice



Graphic concept courtesy of Neil Johnson, XtremeEDA Corporation

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What does Agile mean for HW?

- The Agile Manifesto Principles are software focused
  - But hardware has customers, requirements and deliverables, too!
  - Changing requirements are now the norm
- Can we better collaborate with Agile software teams?
- Can we reduce overall project risk, not just hardware risk?
- Can we deliver working hardware sooner and cost-effectively evolve functionality over time?
  - Make progress on all levels simultaneously!
  - Iteratively converge to the final solution
  - Working hardware can be defined by the design validation test!

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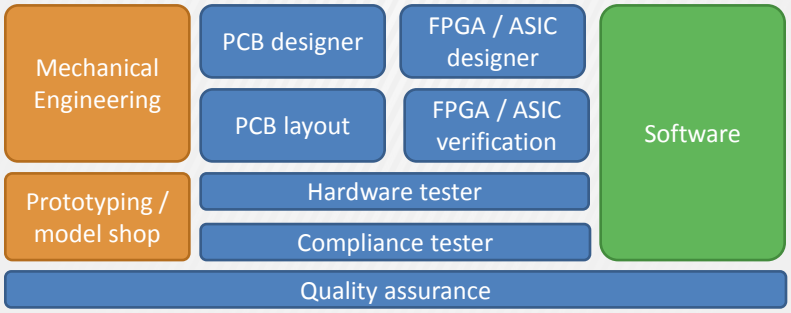
HW & SW: What is different?

- Cost of “building”
- Tedium (manual steps) of “building”
- Silos of expertise & specialized experts



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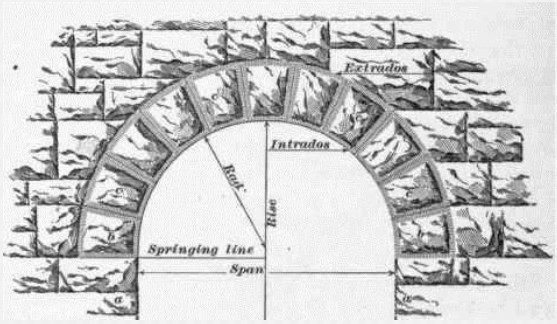
Agile limitation?

- Can you build an arch from left to right?



A Treatise On Architecture And Building Construction Vol2: Masonry. Carpentry. Joinery

- Is hardware inevitably like a single arch?

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Agile PCBs

Techniques include:

- Reference boards
- Quick-turn interconnect boards
- Rapid prototypes
- Design and run verification testing sooner, starting with reference boards!

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Reference boards

An off-the-shelf reference design by the chip vendor or a third party

- Often quick to procure
- Can emulate complete product
- But may not be fully representative of the “final” hardware
  - May have different configuration options
  - May lack key peripherals

Reference boards for microprocessors are the most common, but many other reference boards are available.

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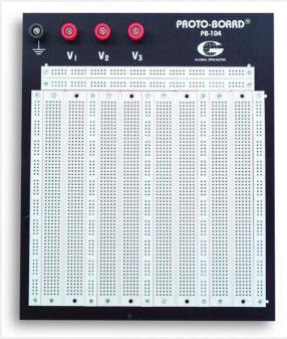
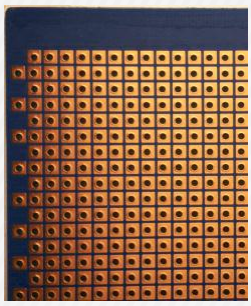
Connecting boards & parts



Breadboard



Perfboard

http://commons.wikimedia.org/wiki/File:CopperCladPerfboard_1.png

Printed Circuit Board

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One possible agile approach

- Cobble together reference boards
- Design quick-turn interconnect boards to reliably tie together the reference boards
  - Optionally use breadboards first
  - Design PCBs for reliability & repeatability!
- Fabricate your own reference boards for other components
- Share hardware early & often
- Build “final” production hardware

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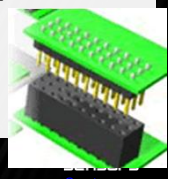
Quick-turn interconnects

- Can inexpensively design, manufacture and receive small 2-layer PCBs in under 3 days
  - Overnight possible at slightly more expense!
- PCB Tools do not have to be expensive
  - EaglePCB ($820 for 6 layer, 16 x 10 cm)
  - Altium Designer ($4995)
- Hardware designers can (and should?) do layout for small boards



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PCB resources

- Quick turn PCB fabrication
  - Advanced Circuits
  - Sunstone Circuits / PCBexpress
- Quick turn PCB assembly
  - Advanced Assembly
  - Screaming Circuits
  - … but most interconnect boards can be hand-assembled by the engineer

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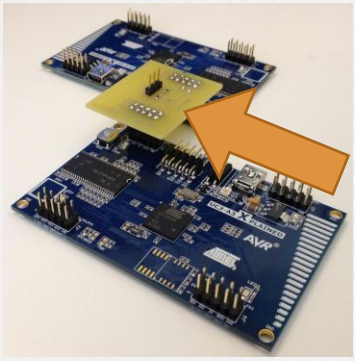
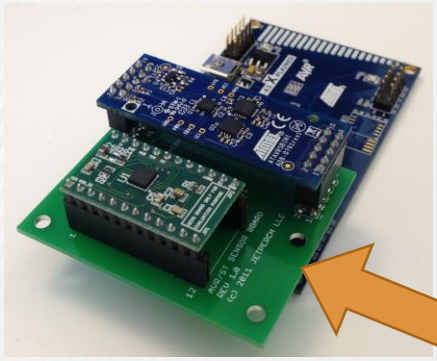
Examples





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Rapid prototyping

- When off-the-shelf hardware is not available, build a reference module yourself!
  - Limit functionality to fit in iteration cycle time
  - Do not overdesign!
- Reuse the schematic (and hopefully the layout) in the next module iteration
- Iterations should be feature cumulative
  - But sometimes designing a parallel vertical feature slice fits better into an iteration cycle

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Cost argument for agile HW

Item	Quantity	Units	Cost	Units
Annual engineer cost (fully loaded)			$ 175,000	USD/year
Cost per day per engineer	200	days/year	$ 875	USD/day
Team cost	6	engineers	$ 5,250	USD/day
HW/SW Integration (50% confidence)	10	days	$ 52,500	USD
HW/SW Integration (95% confidence)	30	days	$ 157,500	USD
Cost for 50% to 95% confidence	20	days	$ 105,000	USD
Last minute respin duration	15	days	$ 78,750	USD
Estimated risk cost			$ 183,750	

- What if we could reduce risk 70% for only 30% of the estimated risk cost?

Modify the argument to match your team's circumstances!

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Agile FPGAs

- The FPGA development process is very similar to a software development process except:
  - Builds takes longer
  - The toolchain often has less flexibility
  - “Working” has more aspects
  - Full simulation / emulation is SLOW
- FPGA test benches are often designed at a low-level

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Agile FPGAs

- Key is to identify the smallest integral component that you can demonstrate
  - Not the full system!
  - One vertical feature
- Architect the system
  - But go light on the full architecture document
  - Fill out architecture & document as design progresses
  - Only build what is needed at the time
- Create modular, reusable blocks
  - Testbench / unit test each block
  - Use a higher-level language to create tests & stimulus

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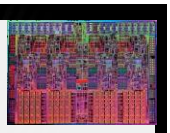
Agile ASICs



- A single ASIC build is very expensive and takes a long time – not very agile
- BUT we can use the FPGA design cycle
  - Buy the a suitable COTS FPGA board and partition the design across FPGAs
  - Do design and demonstration using FPGAs
- Demonstrations will likely be SLOW compared to the final product
- Real-time products may need to be demonstrated off-line

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Releasing agile hardware

- At some point, hardware will transition from development to production
- Transition often incurs costs and handoff between teams
  - Compliance testing & regulatory approval
  - Tooling & manufacturing test
  - FPGAs can be the exception!
- Most companies have a release gate that is intentionally not agile

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Complications

- Long-lead parts
- Limited part quantities / on allocation
- High-speed interconnects between reference modules
- Very high pin count or pin geometries near current assembly process limits
- Large number of layers (> 6)
- High component cost relative to NRE

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Agile culture for HW

- Teams
  - Build collaborative, interdisciplinary teams of software, hardware, mechanical
  - Break down us/them mentality
  - Work together to reduce project risk
- Results & collaboration
  - Always be ready with a demonstration
  - Show demonstrations to all stakeholders
- Adapt
  - Incorporate feedback from demonstrations
  - Fail early rather than late!

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What's next?

- Learn more about agile methods
- Convince yourself that agile can help
  - Do you like HW/SW integration, delivering late, stress and the blame game?
  - Would you like to improve your ability to predict delivery times?
- Identify a project
  - Small, new project
  - Horrifically late mess of a project

For small projects where you are the only HW engineer, you may be able to introduce agile methods today!

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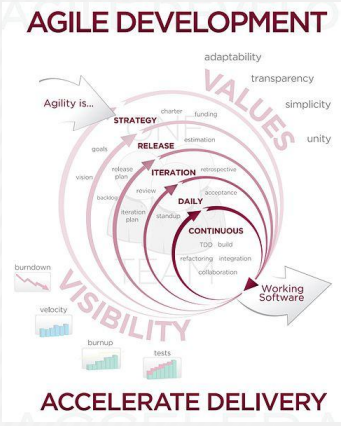
Your first agile HW

- Identify the smallest integral chunk
  - Single vertical feature slice
  - One “path” through the hardware
- Deliver that one chunk
  - Commit to delivering in 2 weeks!
  - Design, fabricate & demonstrate
  - Create tests along the way!
- Identify the next smallest integral chuck
- … and repeat!



Agile Software Development Methodology - Wikipedia

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References & resources

- Top 10 questions when using agile on hardware projects – Larry Maccerone http://maccherone.com/larry/2010/02/23/top-10-questions-when-using-agile-on-hardware-projects/
- Agile in a Nutshell, Jonathan Rassmusson http://agilewarrior.files.wordpress.com/2009/05/agile-in-a-nutshell.pdf
- www.AgileSoC.com by Neil Johnson
- Pick up any highly rated agile book

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Conclusion

- Agile methods can help hardware
  - Technology evolves & schedules shorten
  - Successful teams must meet the challenge
- Quick turn PCB cost reductions can tip the balance between thinking and acting
- No one right methodology and we should strive to continuously improve!

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