Open Source Hardware and the Future of Embedded Systems

bunnie
In the Beginning....
Addendum to the

Apple II Reference Manual

The main logic board electromagnetic into the Apple boards with Manual. It will not unless you have chan

You will know you have the far left side of number 820-0044-xx,

MAIN LOGIC BOARD SCHEMATIC

U.S. Patent #4,136,359
Other U.S. and Foreign patents pending.
But Today...

6. Reinstall the processor tray, pushing it in until the latches are at a 90-degree angle.
7. Push the latches all the way in to close them and seat the processor tray.
8. Replace the side panel, following the instructions starting on page 52.

**NOTICE:** Always replace the side panel after installing components. Your Mac Pro doesn’t operate properly without the side panel in place.

Congratulations, you and your Mac Pro were made for each other.

- Shoulders relaxed
- Forearms and hands in a straight line
- Forearms level or tilted slightly
- Lower back supported
- Thighs tilted slightly
- 18-28 in. (45-70 cm)
- Top of the screen at or slightly below eye level
  (You may need to adjust the height of your display by raising or lowering your work surface)
- Screen positioned to avoid reflected glare
- Clearance under work surface
- Feet flat on the floor or on a footrest

More information about ergonomics is available on the web:

[www.apple.com/about/ergonomics](http://www.apple.com/about/ergonomics)
What Happened?
What Happened?

Did hardware become too hard and complex?
No!

Actually, hardware has been far too “easy” to improve
The Unrelenting Treadmill of Moore's Law
Hardware's Classic Problem: “Sit and Wait” >> Innovate
Product Cycle Times: HW vs SW

S: days to weeks
H: weeks to months

S: seconds to minutes
H: months

Total cycle time:
Software: weeks-months
Hardware: months-years

Innovate

Adopt

Distribute
In HW, Moore's Law Favors Big Business

- **Product Pipelines**
  - 2-3 generations in simultaneous development

- **Massive distribution**
  - Infrastructure to build, deploy millions per month

- **Secrecy**
  - Secrecy buys a few months delay from competition
This Too Shall Pass.
Clock Scaling 1970-2003
RIP
Famous Last Words...

Flickr/AndYaDontStop

Flickr/Jo Naylor
Is Moore's Law Dead?

- Density doubling rate is slower than 18 months
- Certain fundamental parameters have already hit the wall – Vdd, Vth, gate oxide thickness
- Where does it end?
What does this mean?

• Soon, these statements will be more true than false:
  – “Next year, you can't buy a faster computer”
  – “Next year, you can't buy a flash drive that stores more data”
  – “Next year, your phone won't be smaller or more powerful”

(* of course, all normalized to cost)
This is Good News.
(at least for “unemployed” engineers like me)
Moore's Law Revisited
Moore's Law Revisited (Log Scale)
Moore's Law Revisited (Log Scale)

+6 years for a product cycle
Implications
Architecture Becomes Relevant

• Status Quo: Nobody challenges x86
  – Alpha, SPARC, MIPS, PowerPC...all supplanted by x86
  – 4-6 years for development, compilers, code base porting
  – In same period of time, die-shrinking x86 gets 4x-8x performance boost

• Post-Moore
  – Taking a few years to roll out a new ISA...might just be worth it?
Example of the Past: Itanium

- Itanium
  - Merced, 180nm, 2Q01, 733MHz
  - Madison, 130nm, 4Q04, 1.6 GHz
  - Montvale, 90nm, 4Q07, 1.5GHz
  - Tukwila, 65nm, 1Q10, 1.5GHz
  - Poulson, 32nm, 4Q12, 2 GHz

- x86
  - Foster, 180nm, 2Q01, 1.4GHz
  - Prestonia, 130nm, 2Q02, 1.8GHz
  - Nocona, 90nm, 2Q04, 2.8GHz
  - Tulsa, 65nm, 3Q06, 3+ GHz
  - Clarkdale, 32nm, 4Q09, 3GHz x 4 cores
  - Ivy Bridge, 22nm, 4Q12, 3.5GHz x 4 cores
The Rise of ARM

- ARM used to be a controller for toasters and DVD players
- Now, it is a serious contender to x86
  - Cortex A15 implementations pushing 2+GHz, 4 cores
  - 64-bit versions targeting servers
Optimization Becomes Relevant

- Status Quo: don't optimize, cram in more features, wait 2 years and the software will start to run well
  - Remember how slow WinXP and Vista ran when they first came out?
  - Focus on features enabled due to new capability

- Post-Moore:
  - Spending 1.5 years to hand-optimize a library to get 2x performance makes sense
  - Got a big problem? Take a couple years to make a custom ASIC
    - e.g. Bitcoin
Style and Fashion Matters More

- Status Quo: Incentive to buy based solely upon hardware spec improvement
  - Performance
  - Size
  - Battery life
  - Cost
- Post-Moore: As specs flatten out, products must differentiate through other means
  - Style
  - Fashion
  - Usability
  - Apps

Irfan Nasir via Wikipedia
Moore Era

Post-Moore

Wikipedia /
Zach Vega (5S),
Justin14 (4 & 5C)
A Higher Value on Craftsmanship and Design

Flickr / midnightcomm

Public domain
A Rise in Repair Culture

- **Status Quo:** Replace, don't fix; the new model is better and cheaper than repair
- **Post-Moore:** Less incentive to replace, more incentive to fix
  - **Corollary #1:** Broken gadgets have recycling value
  - **Corollary #2:** Reverse engineering has more value
Repair Culture in China

• Emerging markets are a generation or two behind on tech
• Yesterday's phones are today's parts
Information Ecosystem
Result: New, Whacky Ideas (“Innovation”)
Opportunity for Small Innovators

• “Shanzhai” example demonstrates phones can be made by small teams with low capital investment
  – Stable platforms
  – “Open” documentation
  – Ecosystem of support tools
  – But this didn't happen overnight...
Open Products Take Time

2002

1991

LibreOffice
The Document Foundation

OpenOffice initial release 2002
The Open Hardware Situation

- Why has open hardware yet to take off?
  - Open source communities take years to grow
  - Until now, not a good match for hardware
    - Open source is developed on a shoestring budget
    - Arduino could flourish because its appeal is performance-independent
    - Beaglebone, Rpi have corporate sugar daddies
  - Hardware distribution takes time
    - Individuals have limited capital for investment into supply chain
    - Shelf-life of hardware was too short during Moore's Law
So, Moore's Law Now...?

(source: EETimes, “28nm – The Last Node of Moore's Law” by Zvi Or-Bach)
Adding it All Up

Technology stabilization + small disruptive teams + time for organic growth + repair/DIY culture = open hardware impact opportunity
Other Things to Look Forward To

• Arduino-like platforms as powerful as smartphones
• FPGAs that perform comparably to CPUs
• Competitive DIY chassis for notebooks and tablets
• A rise in repair/restoration culture
• The emergence of “heirloom” hardware
An Open Hardware Experiment

• Our Open Hardware computing platform, “Novena”

@novenakosagi
Open Hardware

Open Firmware

https://github.com/xobs/lab-repositories

- **novena-scope-gui**
  - GUI (based on Qt5) for Novena oscilloscope
  - Last updated 16 hours ago

- **novena-scope-drivers**
  - Forked from bunnies/novena-scope-drivers
  - Userspace drivers for oscilloscope module for Novena
  - Last updated 19 hours ago

- **novena-linux**
  - Linux kernel with Novena patches -- expect frequent rebases!
  - Last updated 2 days ago

- **barebox-novena**
  - Barebox with Novena support
  - Last updated 2 days ago

Sean Cross
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Design Timeline

- Project conceived June 2012
- PCBA EVT – Dec 2012
- “Router-style” prototype case Apr 2013
Inside the “Router” style case
DVT Evolution

- PCBA DVT – May 2013
- Home-made “laptop-style” case Dec 2013
Hand-made proto case
PVT Evolution

- PCBA PVT – January 2014
Gen-2 Design Start – Feb 2014
Proto Build – March 2014
Made for Mods & Hacks
Peek Array
Other Features

- Side panel covering ports is replaceable/upgradable
Other Features

• “Make it your own”
  – You pick the battery capacity, charger “learns” your battery
  – Easy to replace/fabricate LCD bezel
The “Heirloom” Model

• Invited designer and craftsman Kurt Mottweiler to create an “heirloom”-grade case
Why Heirloom?

- Make hardware with the intent that it will not be thrown away
  - Use of exquisite materials and craftsmanship
- An exercise in open hardware enablement
  - Case intended to be upgraded and used for years to come
  - Concurrent collaboration with 3rd party simplified, enabled; no NDA or onerous contract
Right Now

• PVT and heirloom designs funding at crowdsupply.com
  – https://www.crowdsupply.com/kosagi/novena-open-laptop
  – @novenakosagi
How is Novena Possible?

- i.MX6 fabbed in 40nm
- Conception
- Launch
- Delivery
Retrospective

i.MX6 fabbed in 40nm

Conception  Launch  Delivery
Where to Go from Here

• Open hardware is about building communities around platforms
  – Please, take our IP! (http://kosagi.com)
  – And if possible, contribute back to the community
  – And, if you don't want to build your own, you can buy it at crowdsupply.com
Recap: The Experiment

Technology stabilization + small disruptive teams + time for organic growth + repair/DIY culture = open hardware impact opportunity
Recap: The Experiment

Technology stabilization + small disruptive teams + time for organic growth + repair/DIY culture

= open hardware impact opportunity

+ crowd funding + backers = realized impact
Thanks!

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