Lessons We Learned and Lessons You Can Learn Building BeagleBoard

Gerald Coley

gerald@beagleboard.org

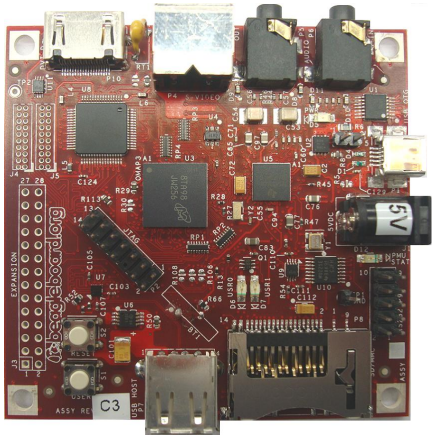
Agenda

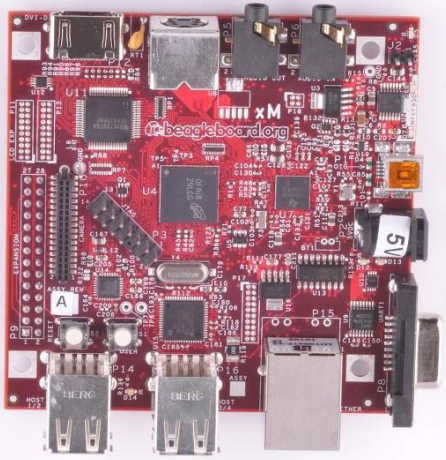
- The Tail of Two Beagles
- Lessons from the ABCs of Beagle
- Lessons applied to Beagle-xM
- Learn by building Beagle
- Adapting the Beagle to suit your needs

"If you stop learning you are done."

Dan Gable
Wrestling Coach
Iowa Hawkeyes

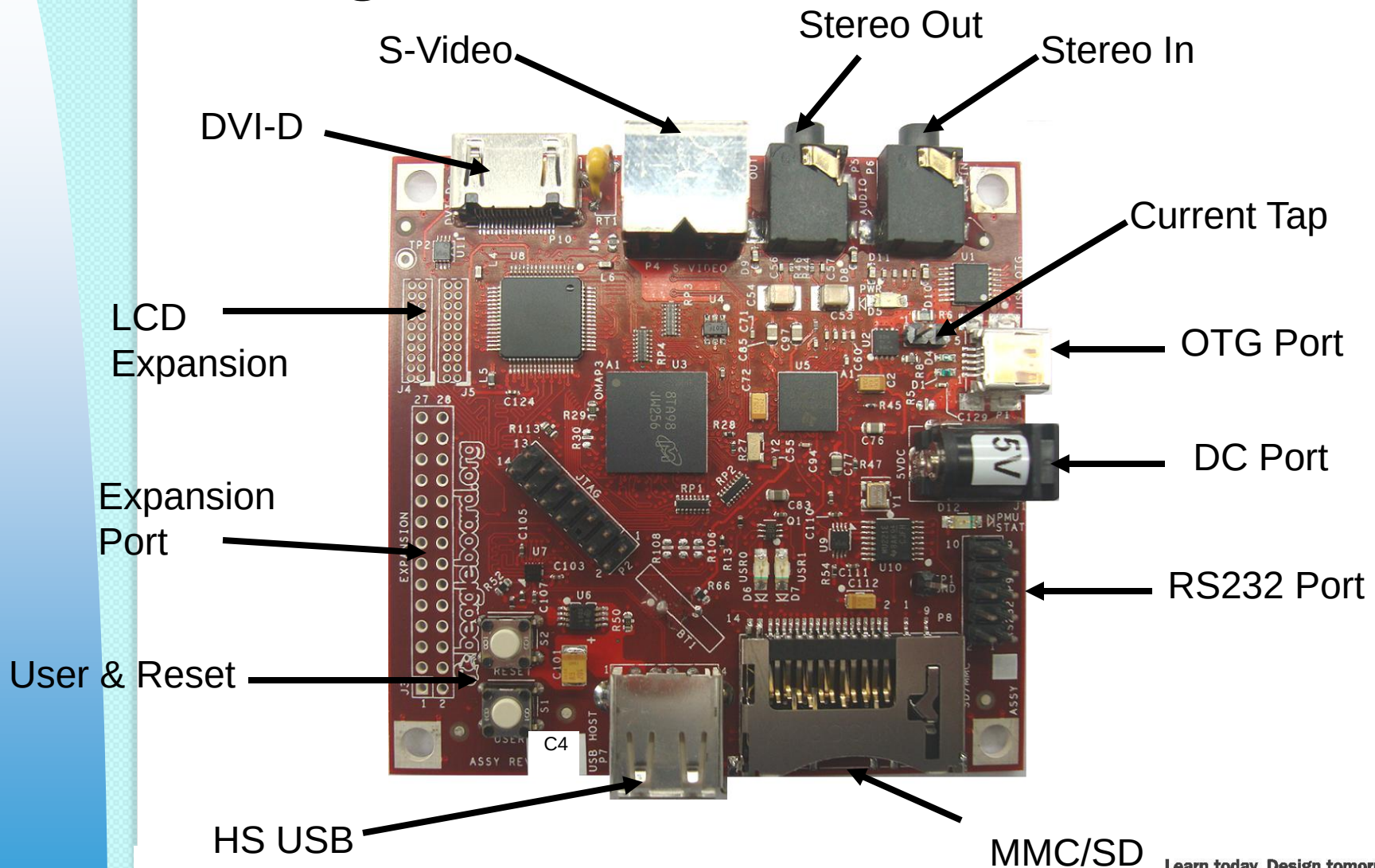
The Tail Of Two Beagles



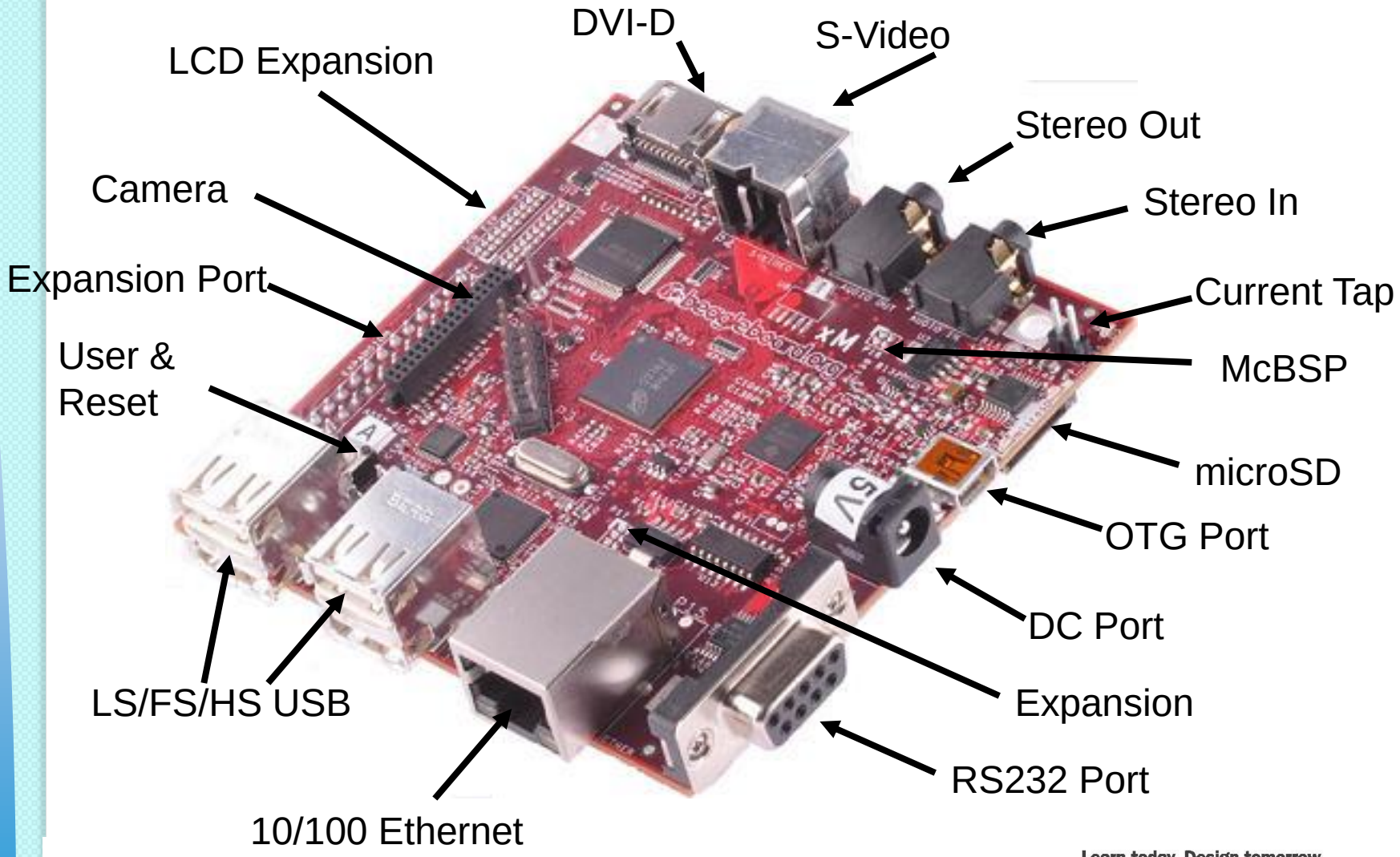


- You can buy two Beagles
  - Beagle Rev C4 ($149)
    - 20,000 units shipped in two years
  - Beagle-xM (End of June 2010,$179)
    - Newest member of family
- Same Mounting Holes
- Common Expansion Headers
  - -xM has additional connectors
- Common XLoader, UBoot
- Pick the one best suited for your application

Beagle Rev C4



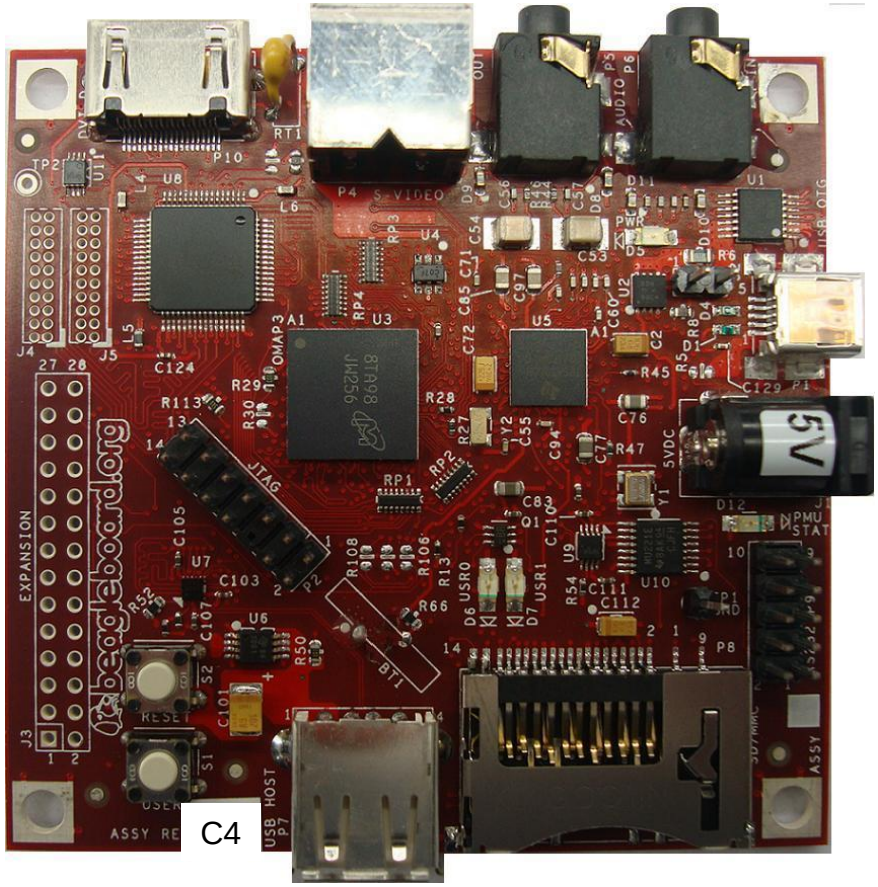
Beagle-xM


DVI-D
S-Video
LCD Expansion
Stereo Out
Camera
Stereo In
Expansion Port
Current Tap
User &
Reset
McBSP
microSD
OTG Port
DC Port
LS/FS/HS USB
Expansion
RS232 Port
10/100 Ethernet

Beagle C4 vs. Beagle-xM

AREA	-xM	C4	Comments
Processor	DM37xx	OMAP3530	Compatible with DM37xx,AM37xx,OMAP35xx
ARM Frequency	1GHZ	720MHz	
DSP Frequency	800Mhz	520MHz	
SGX Frequency	200Mhz	110MHz	
DDR	512MB	256MB	
DDR Speed	200MHz	166MHz	
NAND	0	256MB	
SD Connector	uSD	MMC/SD 6 in 1	
USB Host Ports (Speed)	4(FS/LS/HS)	1(HS)	
Serial Connector	DB9	Header	Direct connect to USB to Serial Adapter
Camera Header	Yes	No	
Ships with 4G SD card	Yes	No	Xloader & UBoot in NAND of C4
Overvoltage Protection	Yes	No	
Power LED turnoff	Yes	No	
Serial Port Power Turnoff	Yes	No	
MMC3 Expansion Header	Yes	No	
McBSP2 Expansion Header	Yes	No	

Lessons Learned From The ABCs of Beagle

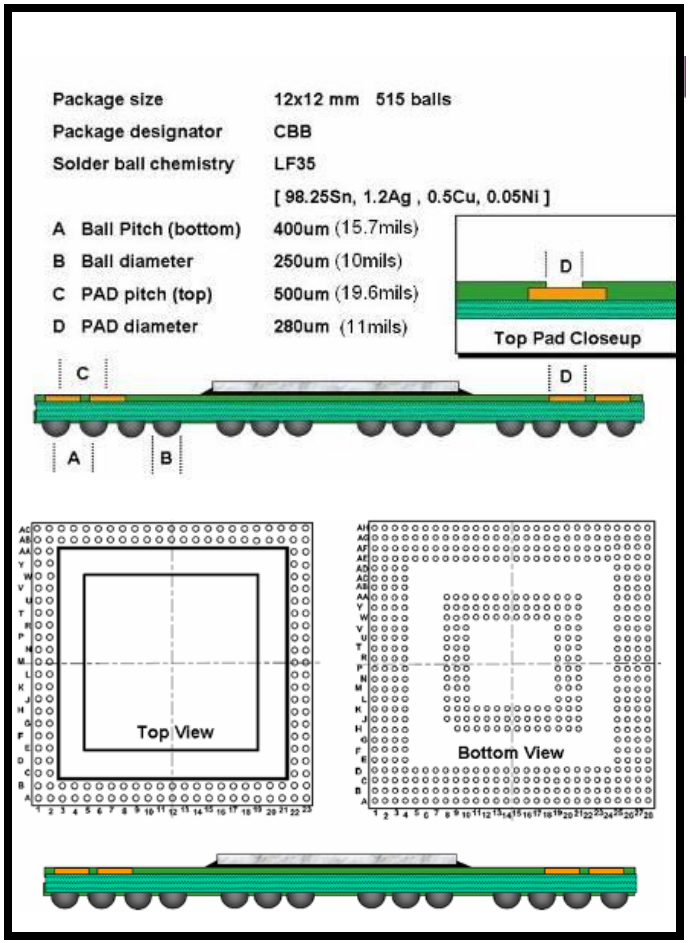


The PCB Design Challenges

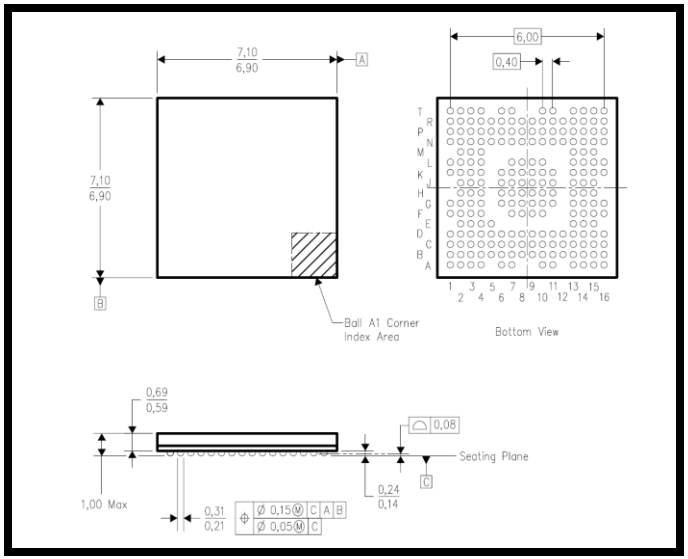
- OMAP35xx Package (Rev C4)
  - .4mm Pitch
  - Routing
- TPS65950
  - .4mm pitch PMIC
- POP Implications
- Limited area for connectors
  - Location driven and not layout driven
- Minimize layer count (cost)

Package Challenges

OMAP3530



TPS65950 PMIC

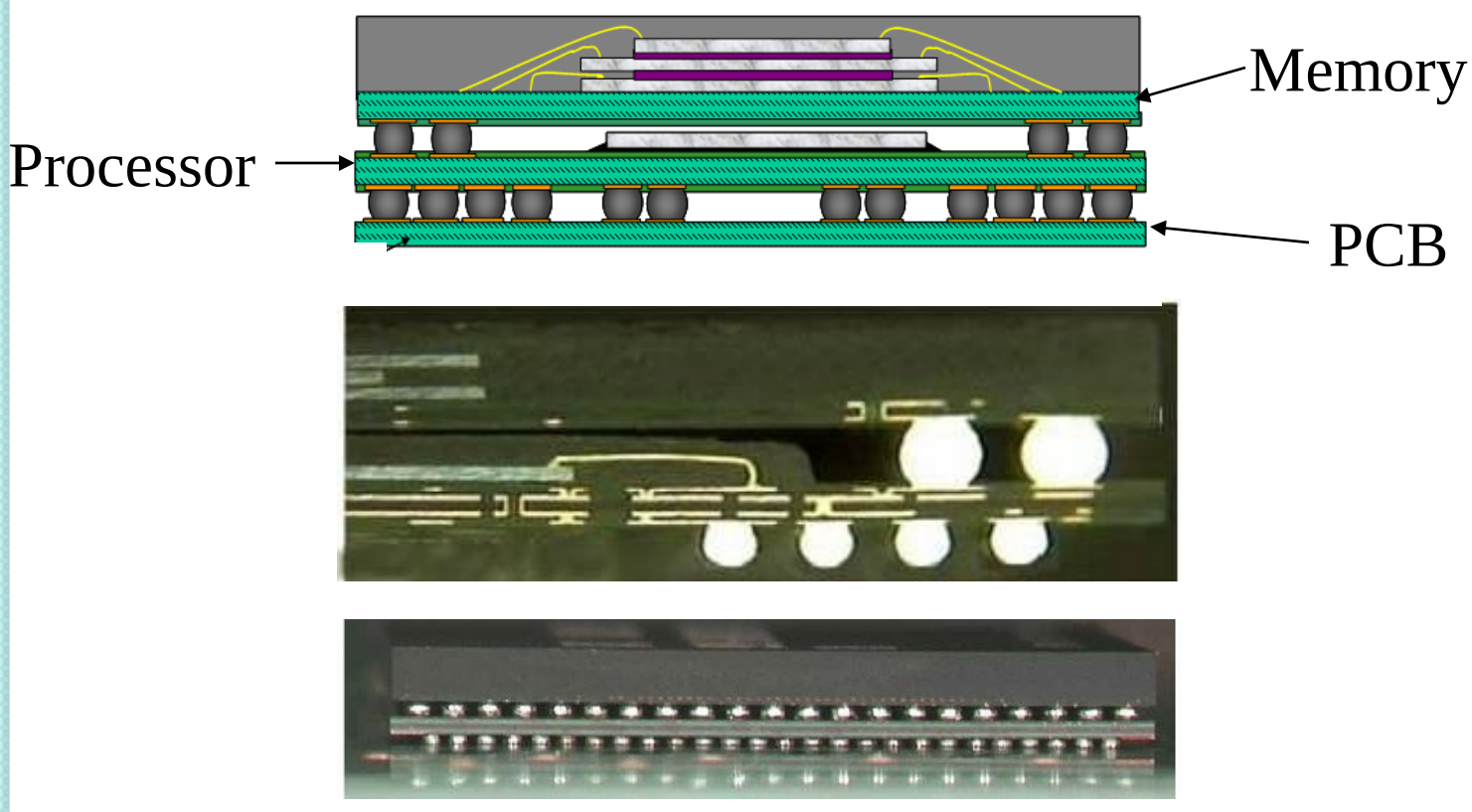


- No routing between pads
- Use top layer routing on outside pads
- Use vias-in-pad wherever needed

PCB Fabrication Concerns

- High Board cost
  - Because they can charge more
  - Unknown = $$$$$
    - Does not necessarily mean the production $$ will be high
- Unfamiliar with fine pitch
  - New technology for some PCB houses
- Soldermask registration could be an issue
- VIA technology could be a challenge
  - Lots of horror stories

POP Assembly Concerns



- POP was the number one concern
- Reflow issues?
- Mounting process?

Mounting .4mm Parts

- Equipment can handle it
  - Accuracy was not an issue
- There could be an issue with opens
  - Due to processor and memory contention
- Not sure about lead-free
  - High temperature requirements

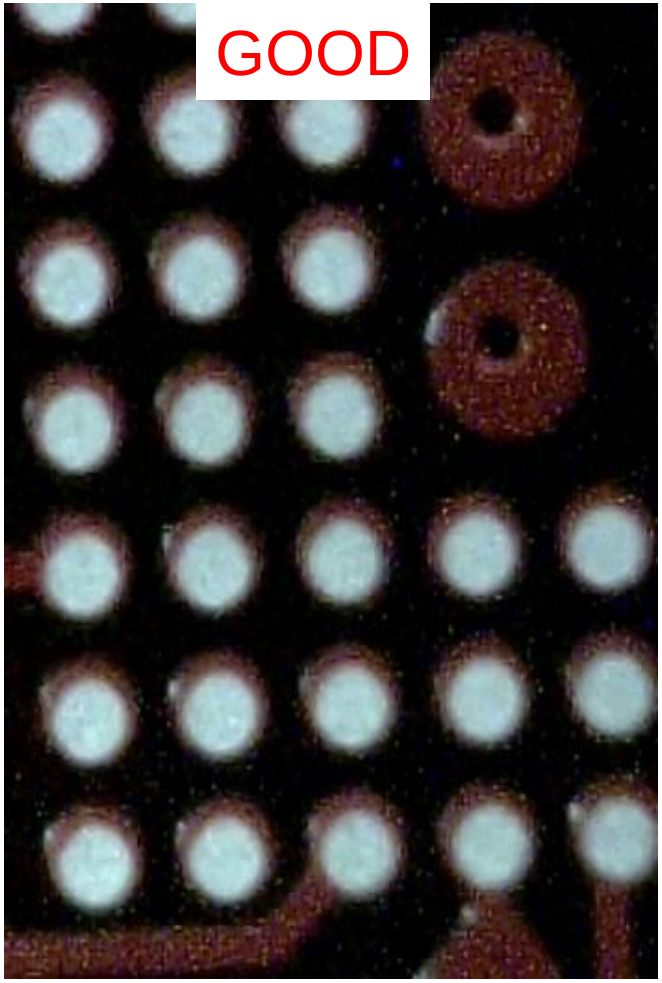
Finding a CM partner

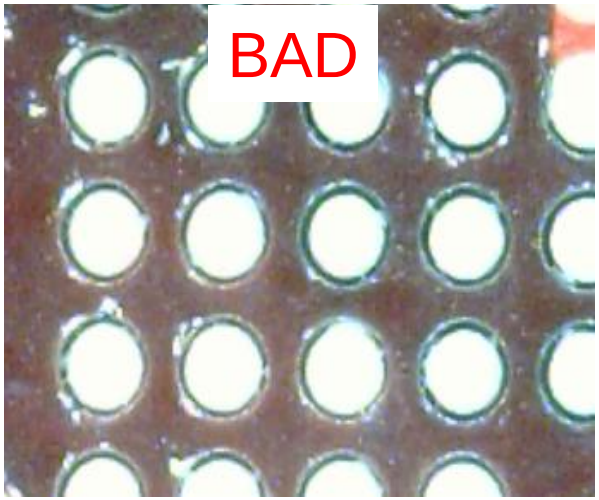
- Found one, showed them POP
  - They ran
- Found a second one
  - The were afraid, needed more equipment
- Found a third one
  - They would be happy to work us in
- Finally found one
  - No guts no glory
  - They build Beagles today

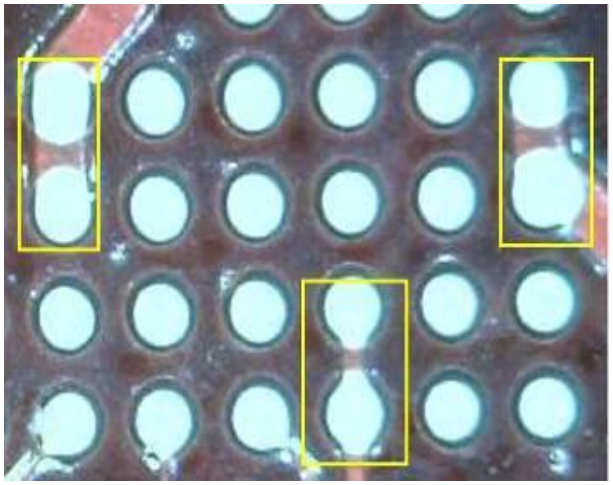
First Pass Assembly Results

- Uh, where did that truck come from?
- Initially had a LOT of assembly issues
  - Shorts
  - Tried finish, profile, solder, stencil
- Tried 1 PCB Supplier twice
  - Same bad results
- Switched PCB suppliers
  - Success!
- Went back to first supplier
  - Called in the marines and found the truck
  - Finally success!
- Found the PCB issue
  - PCB shops do not always do what you ask
  - Soldermask defined pads under .4mm parts
  - Good soldermask registration and tolerance critical
    - Some PCB houses open up the soldermask

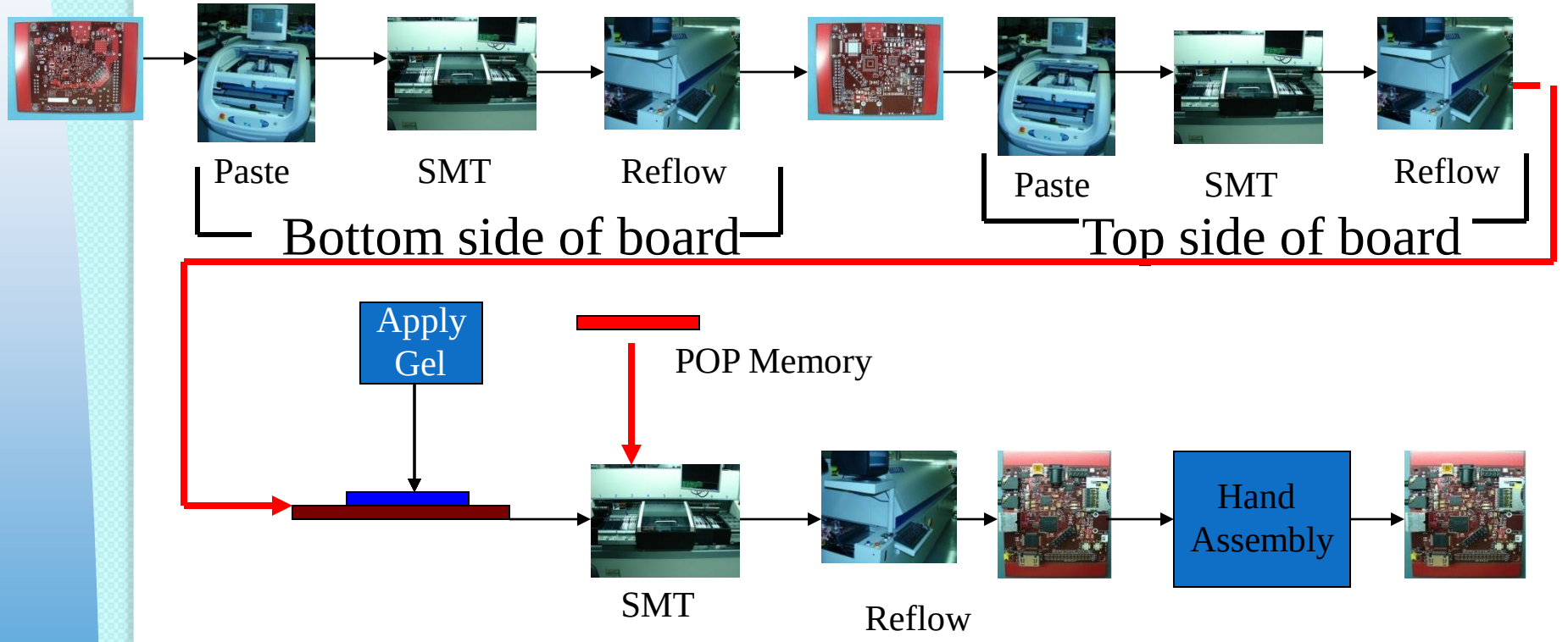
Soldermask Truck







Beagle Assembly Process



REV A

- Only 50 units built
- **Rev A**...Initial Version
- **Rev A1**…Normalized LED brightness levels
- **Rev A2**...Changed resistor loading options for S-Video
- **Rev A3**…Lowered pull-up values for the I2C busses
- **Rev A4**...Lowered value of USB cap due to turn on issues
- **Rev A5**...Incorrect inductor value on TPS65950 switchers
  - Issues to be fixed:
    - DC Voltage jack
    - 1K pull-up on wait line
    - Plated through hole issues
    - Remove 4 test points
    - User0 and User1 LEDS shorted

REV B

- **Rev B1**…Initial Release
  - Fixed outstanding Rev A issues
- **Rev B2**…USB Host not working reliably
  - Removed from BOM and assembly
  - Questions around the layout
- **Rev B3**…Added a few caps back in from B2
- **Rev B4**...Some USB HUBS not connecting on OTG Port
  - Noise level too high…Added a capacitor onto USB power rail
- **Rev B5**...Serial Port disconnects after a while
  - Removed a capacitor on the 32KHZ Clock
- **Rev B6**…PCB spin to change package of U9 and U11
  - U9 and U11 were dying in the field
  - BGA package could not handle the two passes
  - Initially Rev C board layout
- Issues still to be fixed:
  - USB Host

REV C

- **Rev C1**
  - Attempted to fix USB Host, significant improvement, still not 100%
  - This version became the board for Rev B6
  - Replaced U9 and U11 package
  - Changed Revision to B1
- **Rev C2**
  - Moved USB Host to port 2
  - Apparent success on Port 2
  - Added native LCD access (Community)
  - Added PWM Signals to Expansion (Community)
- **Rev C3**
  - The four mounting holes are now plated through and connected to ground. (Community)
  - Additional components were added to the S-Video interface to provide a slight improvement in the overall video quality.
  - A small Lithium battery was added to the PMIC to provide battery backup capabilities. (Community)
  - The TWL4030 PMIC was replaced with the TPS65950.
  - Started seeing Issues on EHCI
- **Rev C4**
  - Switched to the OMAP3530DCBB72 device which is the 720MHZ version of the OMAP3530
  - A more advanced fix for the EHCI noise issue on Rev C3 board. This involved a change in the power circuitry for the 1.8V rail supplied to the EHCI PHY
  - An updated version of the UBoot software, turning on VAUX2 for the EHCI fix

Learning From RMAs

- Current RMA Rate
  - 20,000 Boards Shipped
  - <2% Return rate
  - 30% Were NAND Corruption by User
  - 25% Were blown up boards (12V)
  - 40% No trouble Found
  - 2% Other User Abuse
  - 2% Other issues
  - Affective RMA rate of .04%
- Top Support Issue
  - Serial Port (Header)

User Experience Issues

- Very broad User base
  - Experienced
  - Newbies
  - Patient and impatient
- Slow to get board running
  - Serial port
  - Bootable SD card
  - Where's my GUI?
  - I gotta Beagle, now what?

Lessons From The ABCs Applied to -xM

Lessons Learned Applied to -xM

- New Features
  - Ethernet Port (Community)
  - More Memory (Community)
  - More Processing Power (Community)
  - Native Camera Interface (Community)
  - McBSP Audio Access (Community)
  - Real Serial Connector (Community)
- Improve User Experience
  - Remove NAND
    - No NAND corruption
    - More flexibility
    - Less RMAs
  - Ship SD Card
    - Better success out of box
  - Power Protection
    - Less smoke = Green
    - Less RMAs

Lessons Learned From -xM

- TBA

Building the Beagle to Learn

Things To Know

- BeagleBoard is open Source Hardware
  - You can use the documentation
  - We ask that you not use the beagleboard.org logo
  - You can adapt it for your own use
- We will not sell BeagleBoards for use in products

Key Things To Be Learned

Learn on Beagle and not your board!

- PCB Layout
  - Techniques that work
  - Ready made prototype
- PCB Fabrication
  - Soldermask
  - Via Technology
  - Which PCB house can do it?
- Assembly Experience
  - .4mm
  - POP
  - Is my CM up to it?

PCB Layout

- Current design can be evaluated
  - It is just one way to do it
- Decide what you can use and how to improve
- CAD and Gerber data available
  - Can be used as is
  - Can add new stuff

PCB Fabrication

- Allow the PCB house to build confidence
  - Build an existing board
  - Boards exist so it can be done
  - Help to get cost out before you build your design
- All information available
  - Gerber and CAD Data
  - Experienced PCB shops available

Circuit Board Assembly

- Reduce the risks
- PCB Sources
  - Those you have built
  - Existing boards
- Bill of Material provided
- Work with proven data and processes
  - Board profiles
  - Paste mask information
  - Use those that are working
  - Experiment with others
  - Just a place to start
- Third Party training available

Adapting the Beagle to Suit Your Needs

Beagle Interface Connectors

- Main Expansion
  - SPI, I2C, UART, McBSP
  - MMC, GPIO
  - Power, UART
- LCD Expansion
  - LCD signals, I2C,Power
- MMC Expansion(-xM Only)
  - MMC3,HSUSB1,ETK,GPIO
- McBSP2 (-xM Only)
  - McBSP2,GPIO
- Camera Connector (-xM Only)

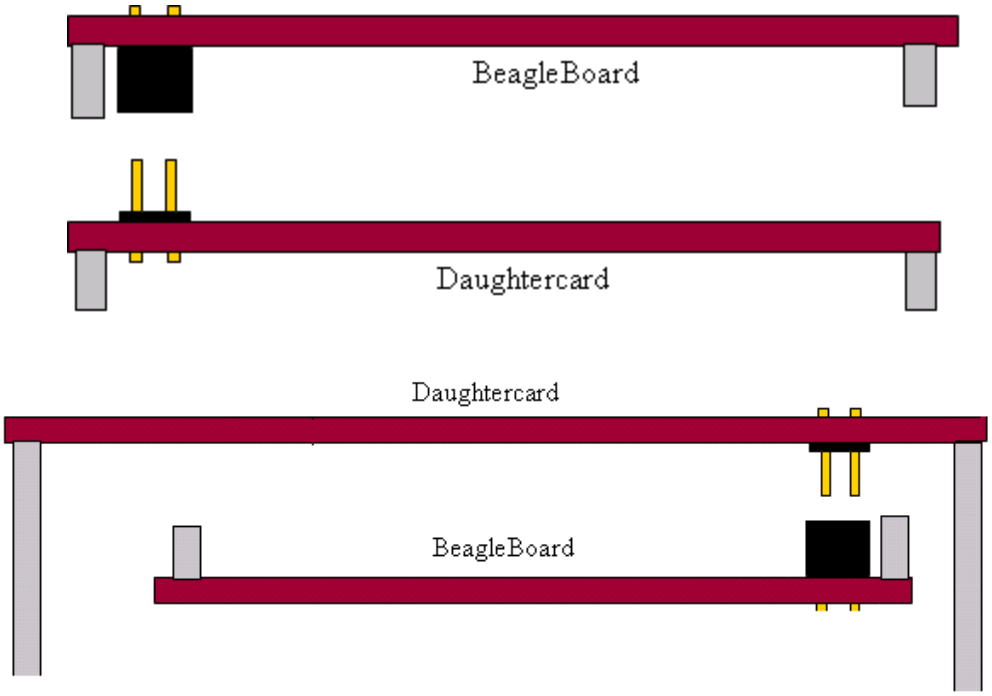
Adaptation Via Expansion

- Adding expansion Boards
  - Additional functions
  - Several different ones available
  - More coming
- Create your own Expansion
  - Add the needed circuitry

Expansion Ready

- Rev C4 does not come with expansion connectors
  - Can be added by user
- -xM does come with connectors
- Mounting holes are the same
- Common connectors in the same place

Expansion Card Mounting



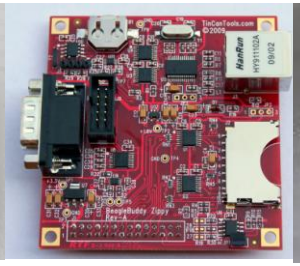
Gerber and CAD files available to assist in making your own PCB

NOTE: Some expansion boards do not meet this requirement and may require different header configurations.

Expansion Cards & Accessories

ZIPPY

TRAINER



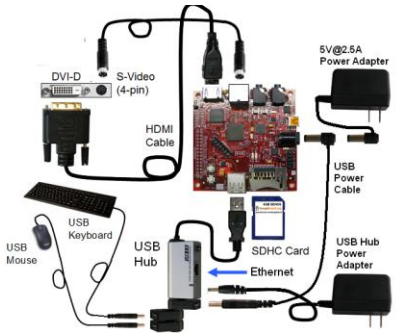
ZIPPY2

PLASTIC CASE

VGA ADAPTER

LCD DISPLAY

METAL CASE



Cables & Supplies

Custom Conversion

- Create a new schematic using the OrCAD files
- Take Beagle PCB files as the base
- Import new netlist into PCB files
- Place and route the new components
- Main delta is your new components and circuitry
- Quick prototype!

Available Resources

- Beagle Hardware Documentation
  - http://beagleboard.org/hardware/design
- Add-On Boards and Accessories
  - http://www.beagleboardtoys.com/
  - http://www.tincantools.com/home.php?cat=255
  - https://specialcomp.com/beagleboard/index.htm
  - http://www.esawdust.com/product/encl-dh-r1/

Questions?