Research Consortium in Speckled Computing

The 5Cube and 5CubeOTS Projects

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Overview

- Background – What is a 5Cube
- Assembly Techniques
- Construction of the 5CubeOTS
- Plans for the 5Cube
- Questions

Background

- Overriding goal - small wireless sensors
- Minimum size is power limited - ~~1mm^3~~
- 5x5x5mm is a good challenge
- 2 projects to attack problems
  - 5Cube (Whole consortium)
  - 5CubeOTS (Smaller group)

Background – 5Cube

- Goal to produce ultra-low power device in 1/8ml
- Power budget 1mW peak total
- Must integrate:
  - Batteries (St.Andrews & Paisley)
  - Antenna & RF Frontend (Glasgow)
  - Laser Comms Frontend (St.Andrews)
  - DSP (Strathclyde)
  - MCU & OS & Apps (Edinburgh & Napier)

Background – 5CubeOTS

- How far can we get with off the shelf?
- Are packaging gaps filled?
- Lower success metrics
  - Allow poor runtime

    Requirements state a few minutes minimum
  - Allow poor communication distance/speed

    Requirements state > 10cm, no minimum speed

Assembly Techniques

- Small PCB design
- Packaged OTS chips too large
- Must bond die to PCB
- Must maintain mechanical integrity

Hopefully OptoCap, Scotland's packaging experts, will help solve our problems

Flip-Chip Bonding

Bonding a chip to a PCB

Chip has bonding pads

PCB made to have bonding pads in mirrored position

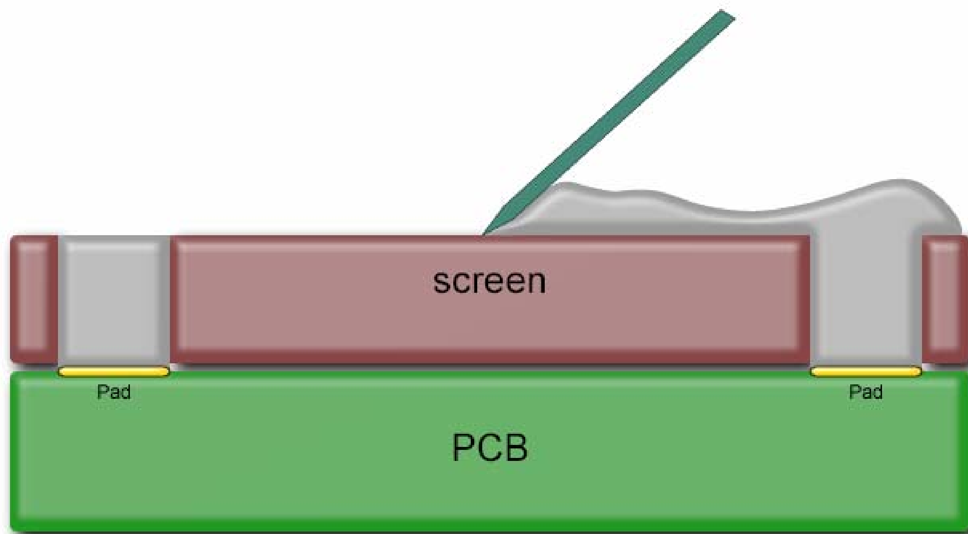
Flip chip bonding

- Least real estate
- Firm structure
- Chips prepared for bonding by manufacturer
- Not in our case

Flip-Chip Bonding

Solder paste is screen printed onto pads

Pads only about 80um wide

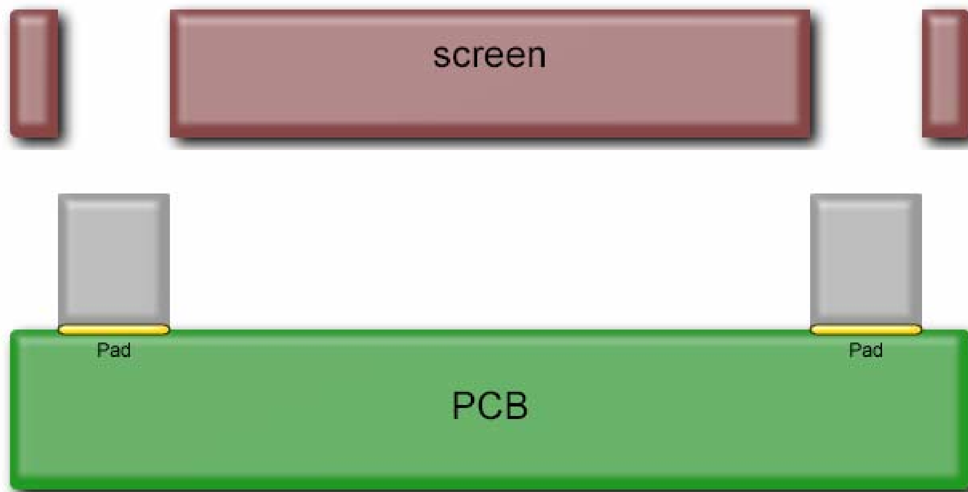


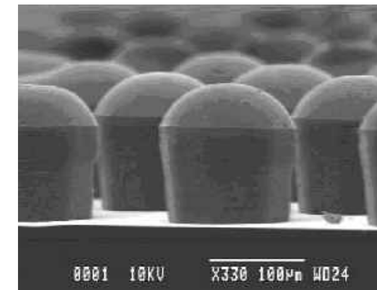
Squeegy forces paste over pads

Flip-Chip Bonding

Screen removed

Solder paste remains

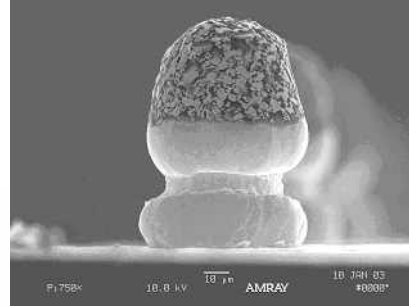




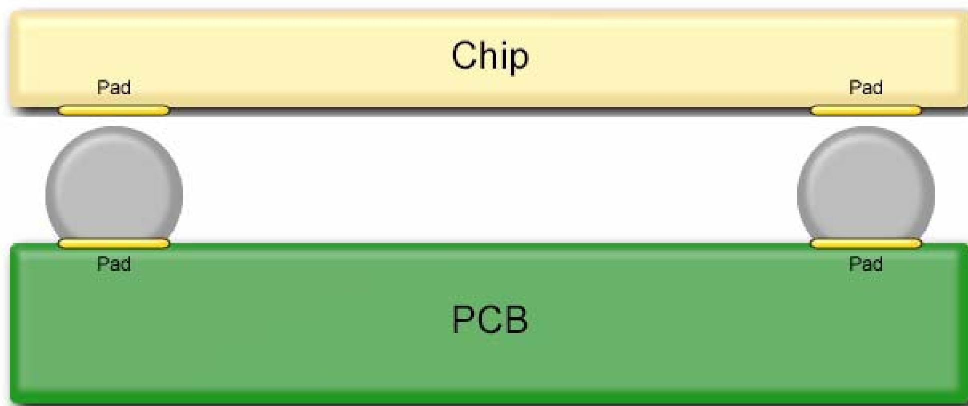
Flip-Chip Bonding

Reflow heats solder

Solder surface tension makes spheres ~50um

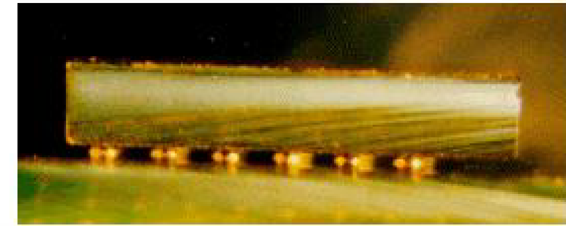


Chip carefully placed, flipped upside down



Flip-Chip Bonding

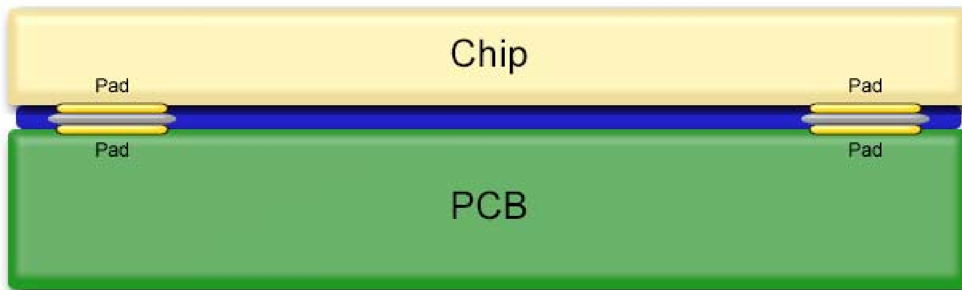
Heat melts solder



Flip chipping on both sides uncertain

Insulative epoxy run under chip
Provides mechanical support

Heat might melt already fused pads – positioning difficult



Possibly worth exploring

Ball-Wedge Bonding

Weld fine wires from chip pads to PCB pads

Chip placed pad side up

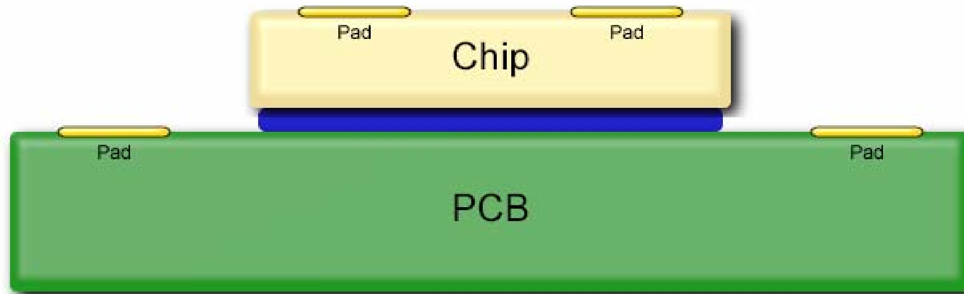
Much more PCB area

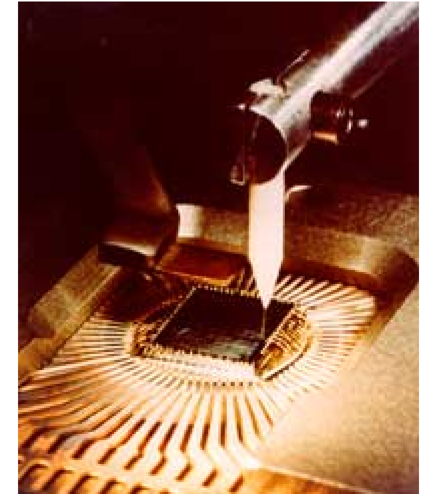
Delicate wires

PCB pads outside chip footprint

Ball-Wedge Bonding

Chip secured with insulative epoxy

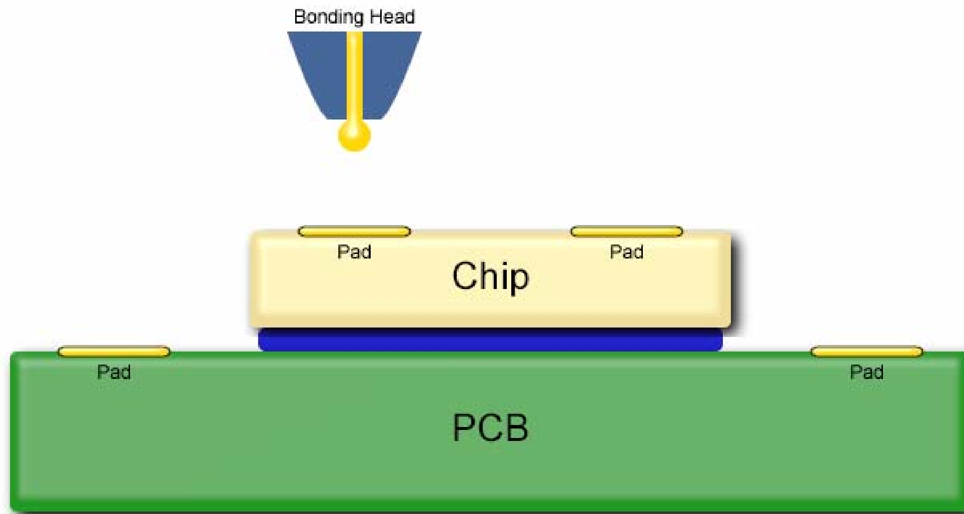




Ball-Wedge Bonding

Fine wire (25-50um) fed through bonding head

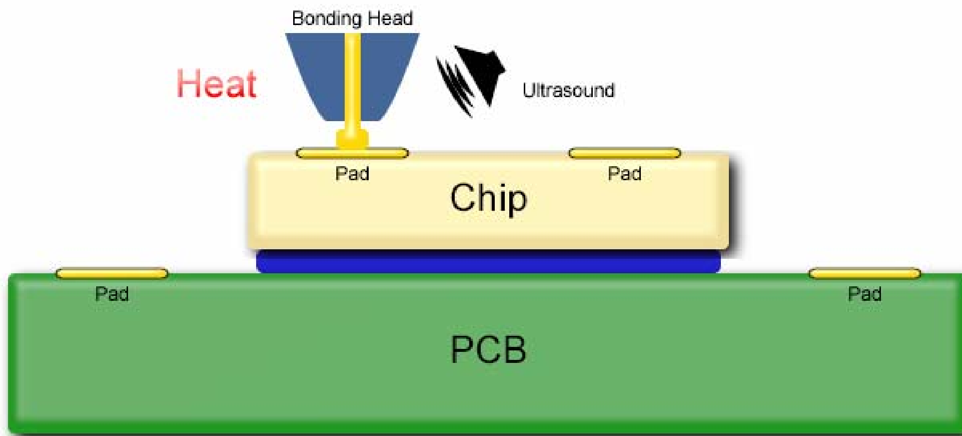
Small ball on end of wire



Head positioned over pad

Ball-Wedge Bonding

Head presses ball into pad

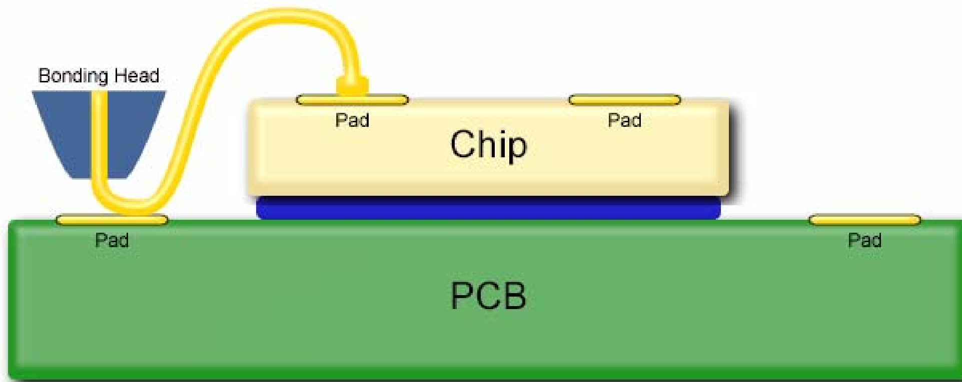


Ultrasound and heat fuse ball to pad

Ball-Wedge Bonding

Wire fed through bonding head

Head positioned over matching pad on substrate



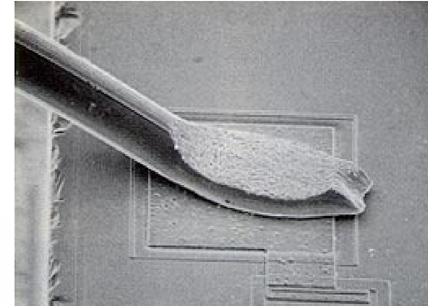
Minimum length of bond is 200-400um

Max length 2-3mm depending on wire

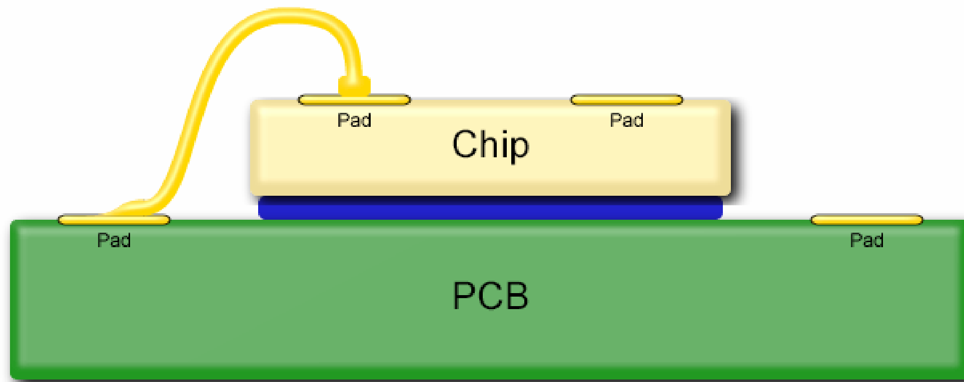
Gold round tight corners

Ball-Wedge Bonding

Second bond squeezed into wedge shape (heat & ultrasound)

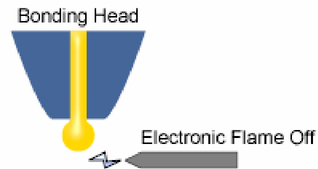


Length of remaining wire extends from head

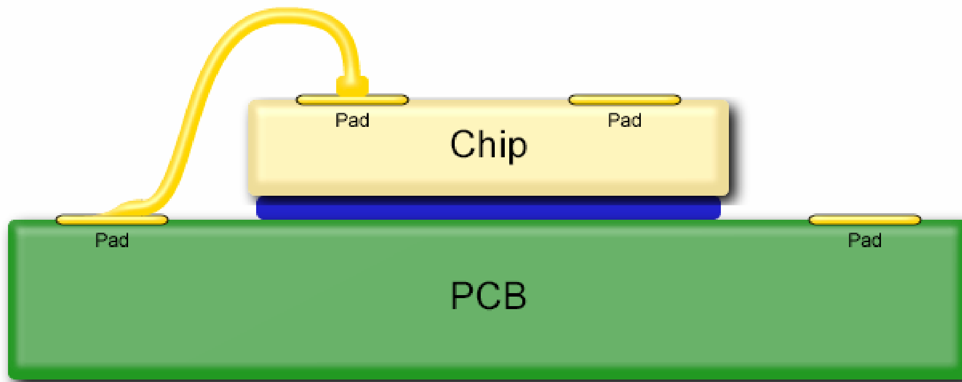


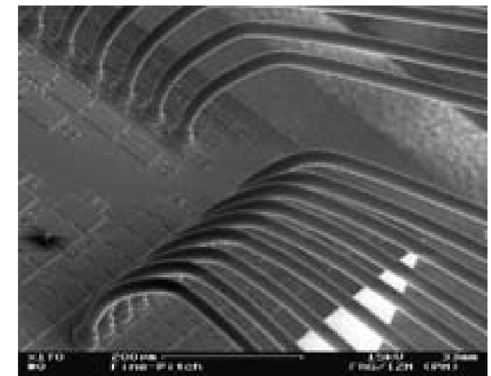
Ball-Wedge Bonding

Spark melts wire into new ball



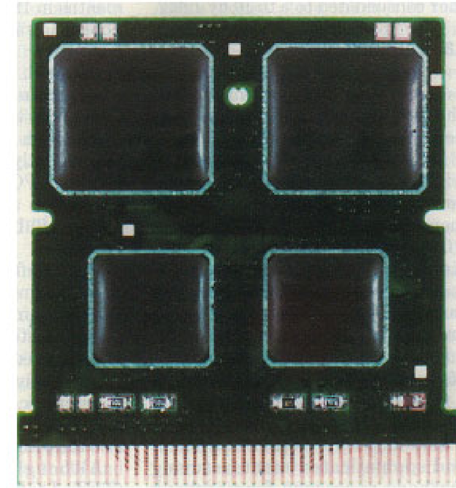
Length of wire determines ball size

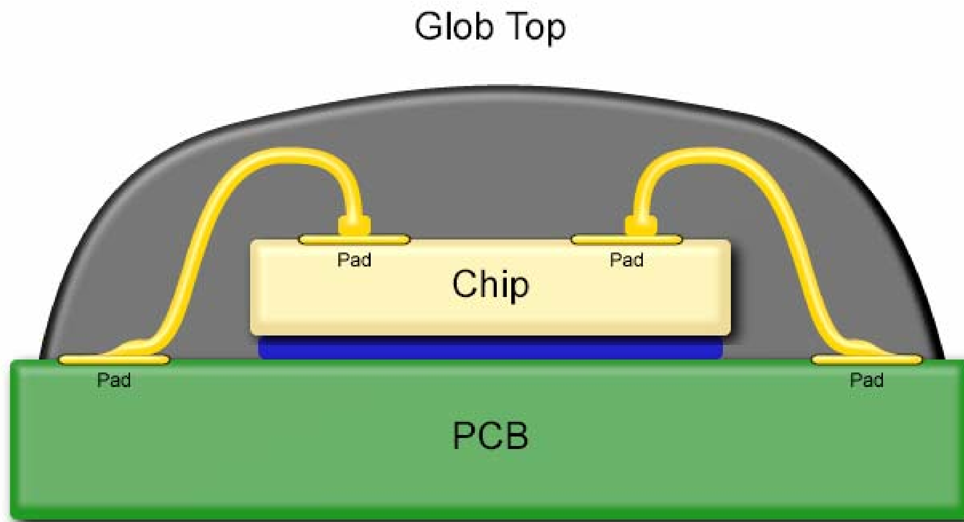




Ball-Wedge Bonding

Chip typically secured in hard black epoxy (glob top)





Alternatively die embedded in package cavity

5CubeOTS

- Create a 5x5x5mm sensor node from Off-The-Shelf components
- If possible baseline for future work
- Early insight to packaging issues
- Common components with 5Cube

- Not expected to be practical device without more batteries

5CubeOTS

- Components
  - MCU EM6812
  - RF Transceiver ZL70100
  - Batteries 2xML421
  - Crystal ABM11
  - LED Red 0402
  - Antenna 17cm whip

5CubeOTS – MUC EM6812

- EM MicroElectronic ultra low power MCU
- 8-bit CoolRISC core
- Active 120uA @ 1MHz, 25uA @ 70kHz
- Standby 0.8uA @ 1MHz
- GCC compiler
- RAM 512bytes FLASH ROM 8Kbytes

- Dies (4.2x2.5mm) and packaged acquired

5CubeOTS – RF ZL70100

- Zarlink ultra low power RF transceiver
- < 5mA continuous RX/TX 433MHz
- 200nA wakeup 2.45GHz
- 800kbps raw data rate

- Under NDA

- Packaged acquired, dies October

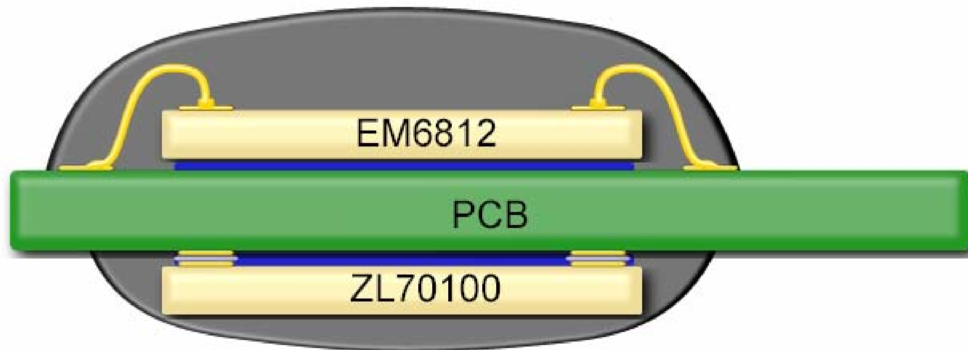
5CubeOTS – Batteries ML421

- Sanyo miniature, rechargeable Lithium button cells
- 3V 2.3mAh
- Diameter 4.8mm
- Height 2.1mm
- Only a few seconds at 5mA
  - If not enough to receive packet may add 1 more

5CubeOTS – Additional Components

- Antenna
  - 17cm whip – not included in volume
- Abracon ABM11 24MHz oscillator
  - Only 2x1.6x.45mm
- LED
- Antenna matching
- Power decoupling

5CubeOTS - Assembly

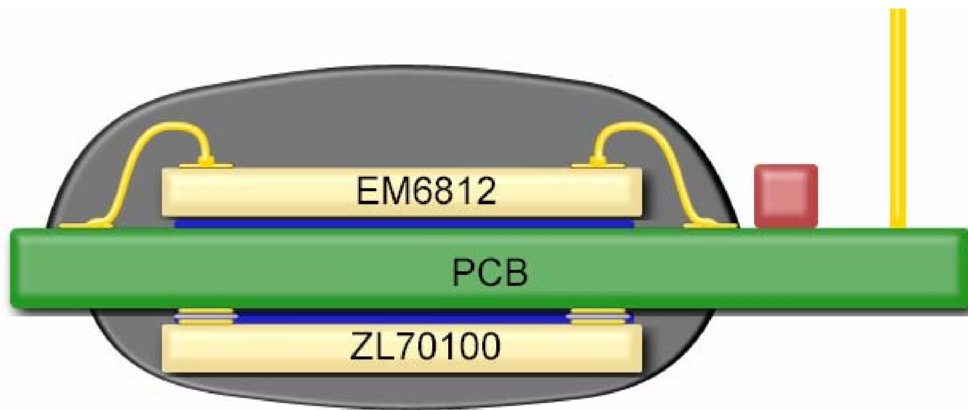


MCU and RF bonded to thin 200um PCB

If possible, both flip-chip

Worst case both ball-wedge bonded

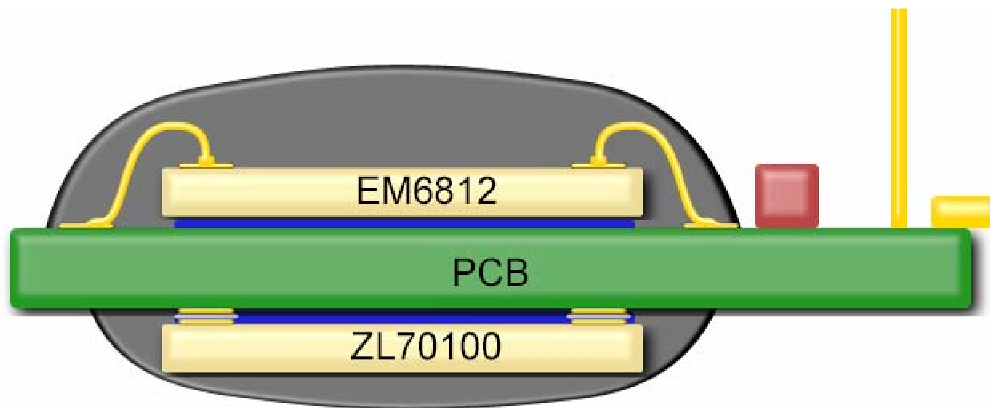
5CubeOTS - Assembly



Additional components soldered by normal techniques

This step may be before bonding

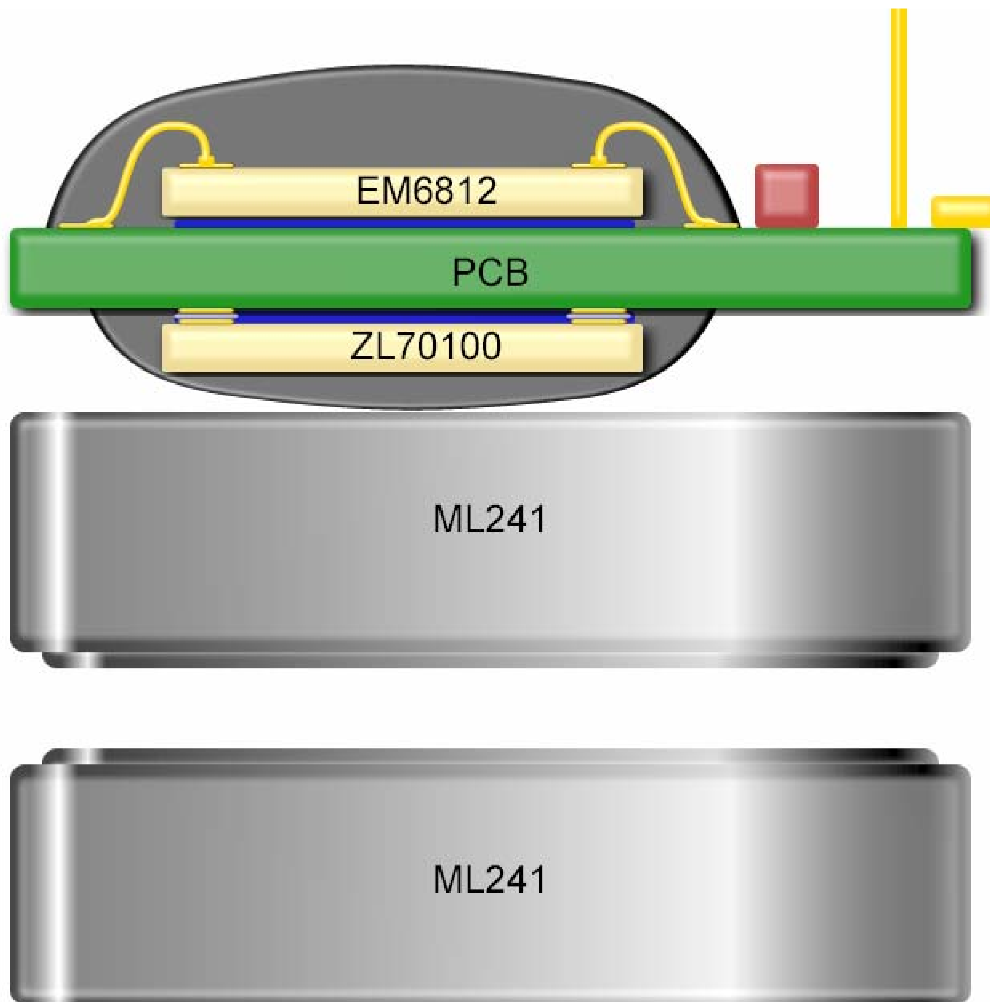
5CubeOTS - Assembly



Pins added, extending off board

- **Power/Recharge**
- **Programming**

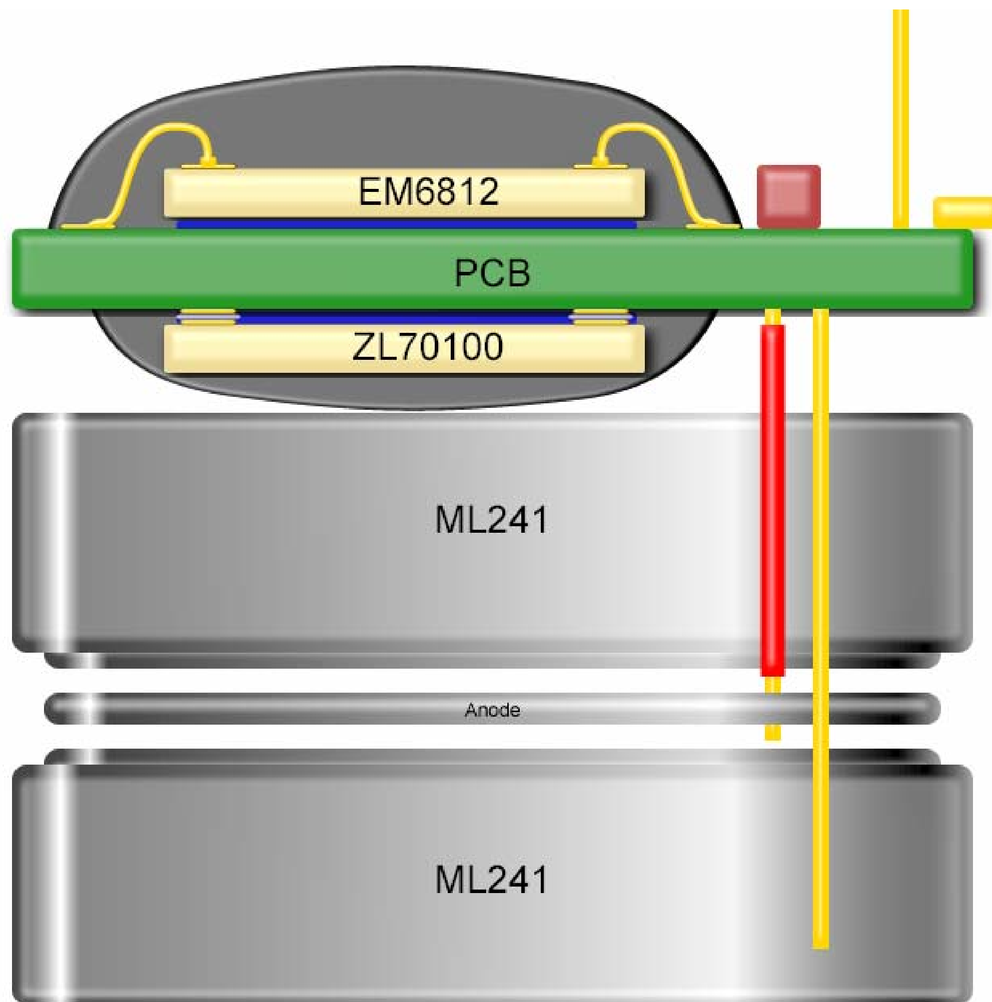
5CubeOTS - Assembly



Batteries added in parallel

Device current draw goes up as voltage goes up – so not serial

5CubeOTS - Assembly

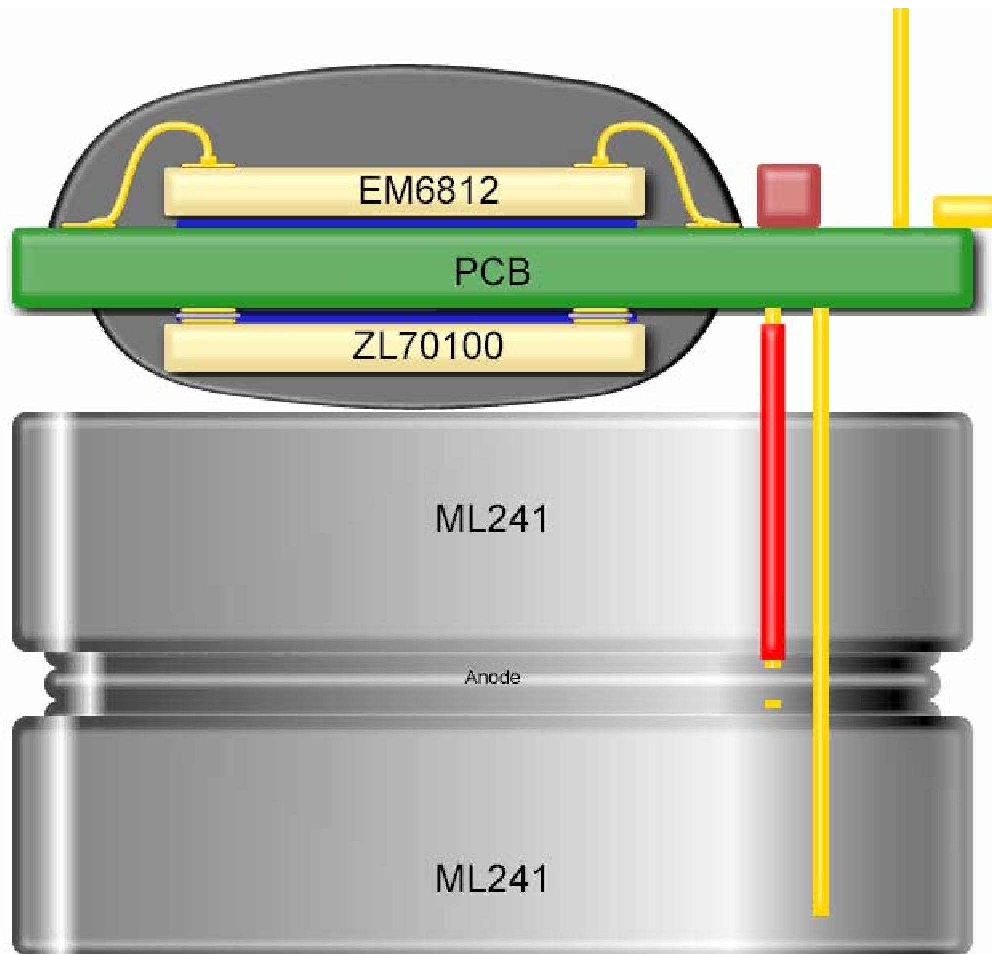


Power nets routed from batteries

Foil anode collects from between cells

Battery case for cathode

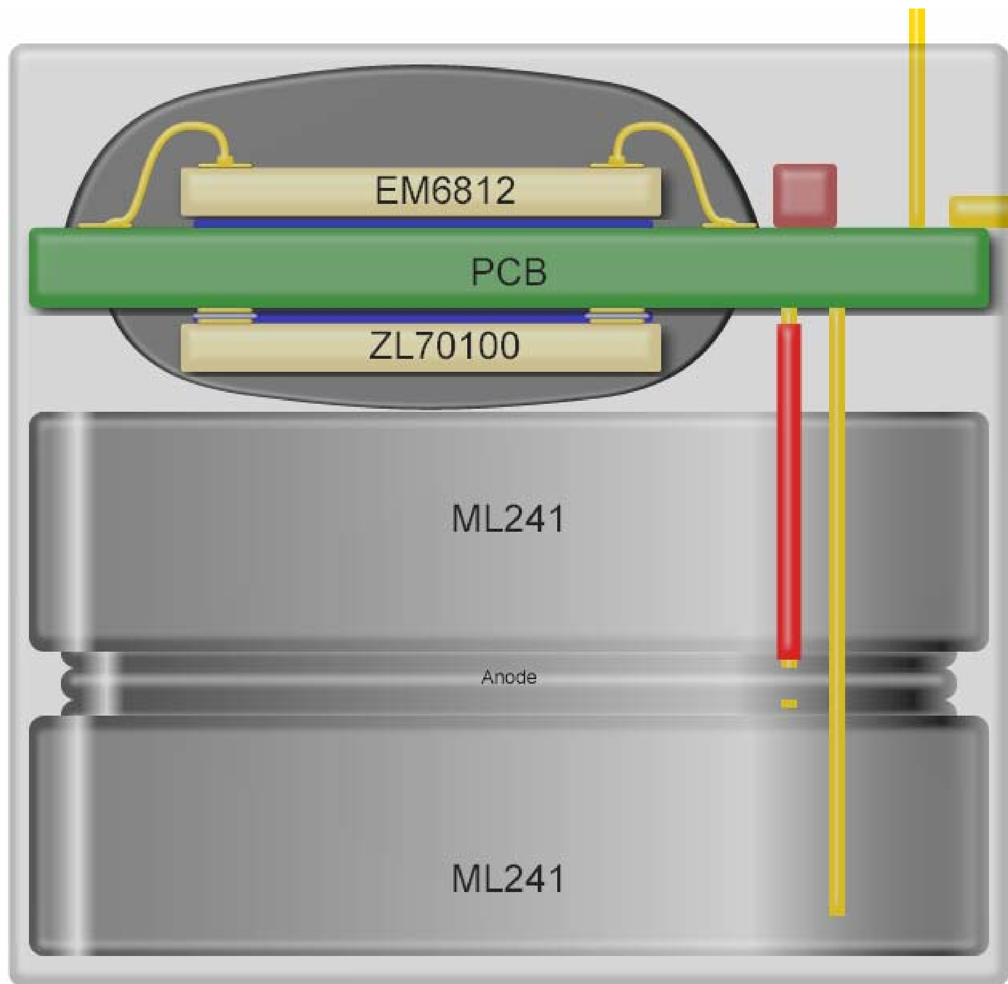
5CubeOTS - Assembly



Sandwiched anode is bonded by silver conducting epoxy

Batteries do not like being soldered

5CubeOTS - Assembly



A cuboidal mould is made

Clear epoxy secures device

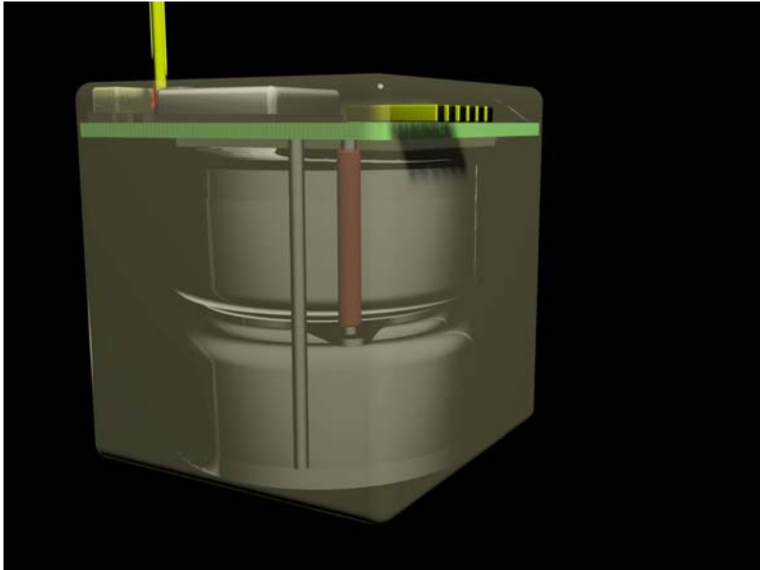
Total dimensions a little over 5x5x5

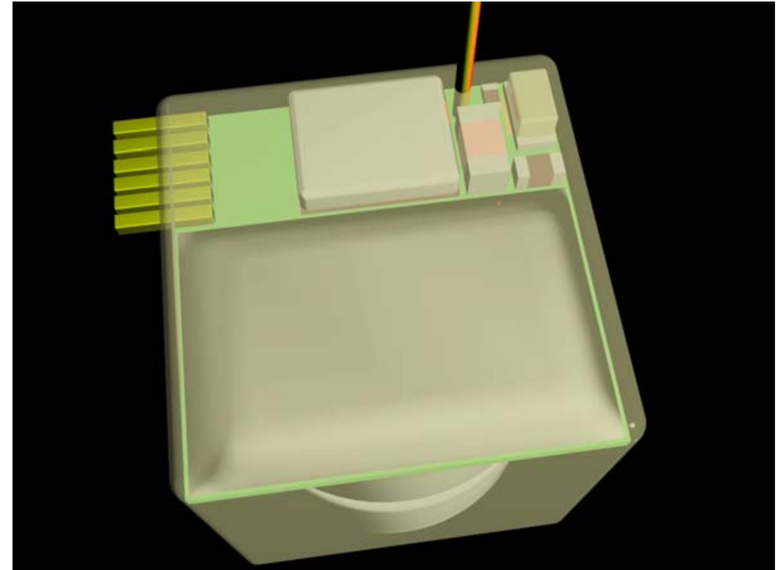
5CubeOTS - Schedule

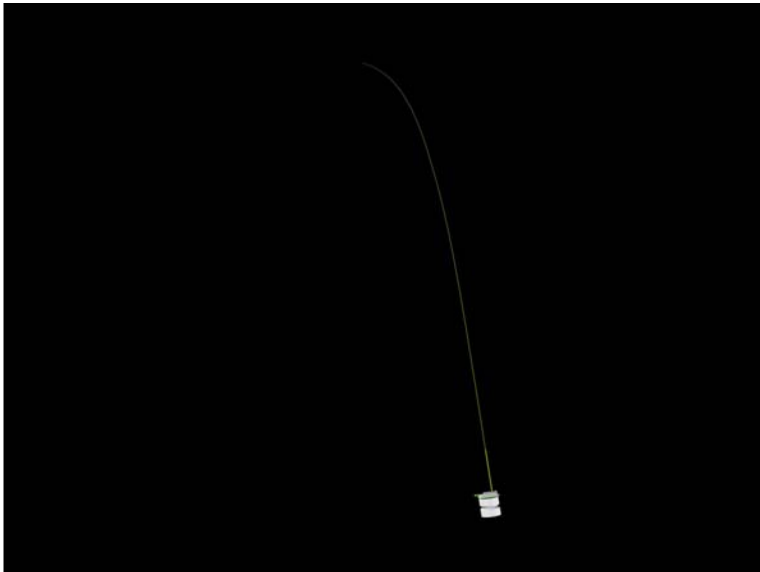
• Packaged Integration testing	late Sept/early Oct
• Power testing	Oct
• RF dies arrive	early Oct
• Die bonding PCB designed	late Oct/early Nov
• Packaging (Optocap)	early 2006

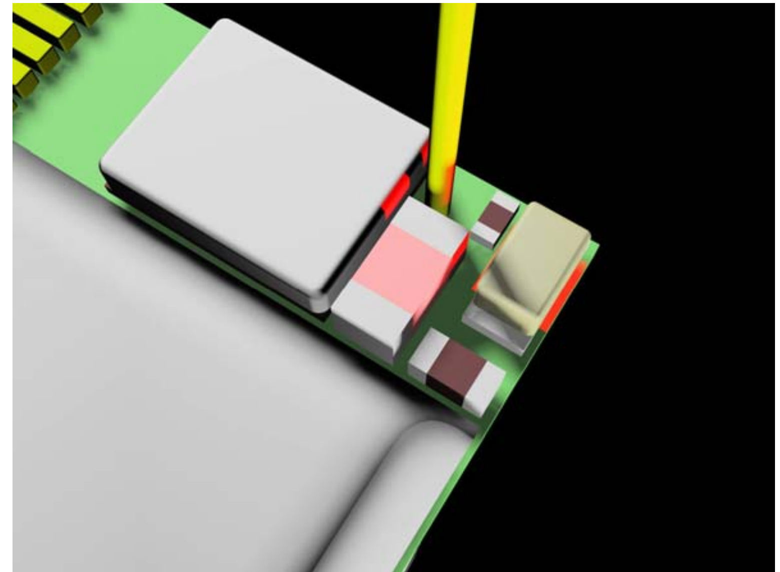
- Status of crucial ABM11 24MHz oscillator uncertain

5CubeOTS - Mockups









5Cube

- All custom in house version
- Much tighter power budget for continuous RX – 2.45+Ghz
- Expected to be useful
- Optical communications
- Antenna volume included
- No decision on sensors

- Other talks will provide deatils

5Cube – MCU

- Available MCUs (EM6812) well within power budget
- Consortium lacks CMOS expertise
- Will not develop in house MCU

5Cube - Schedule

• Tape out experience	complete
• DSP v0.1 (0.35um) tapeout	end Sept for early 2006
• DSP v0.3 + analogue (0.18um)	mid 2006
• Lumped RF frontend	complete
• GaAs RF frontend	mid 2006
• End to end testing with FPGA(DSP), Lumped RF, Whip	November
• End to end testing with v0.1 DSP, Lumped RF, Helix?	Early 2006
• VCSEL Comms	Late 2006?

Questions