CLEMSON UNIVERSITY

A device to record natural daily wrist motion

MS Thesis Defense

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Outline

- Motivation and Background
- Methods
- Results
- Conclusion

Motivation

- Our vision: Wrist-worn eating activity monitor
- Previous work: **81%** accuracy detecting periods of eating (44 subjects, 1 day)
  86% accuracy counting bites during eating (49 subjects, 1 meal)
- Need: device to record large number of people for long period of time

The bite counter

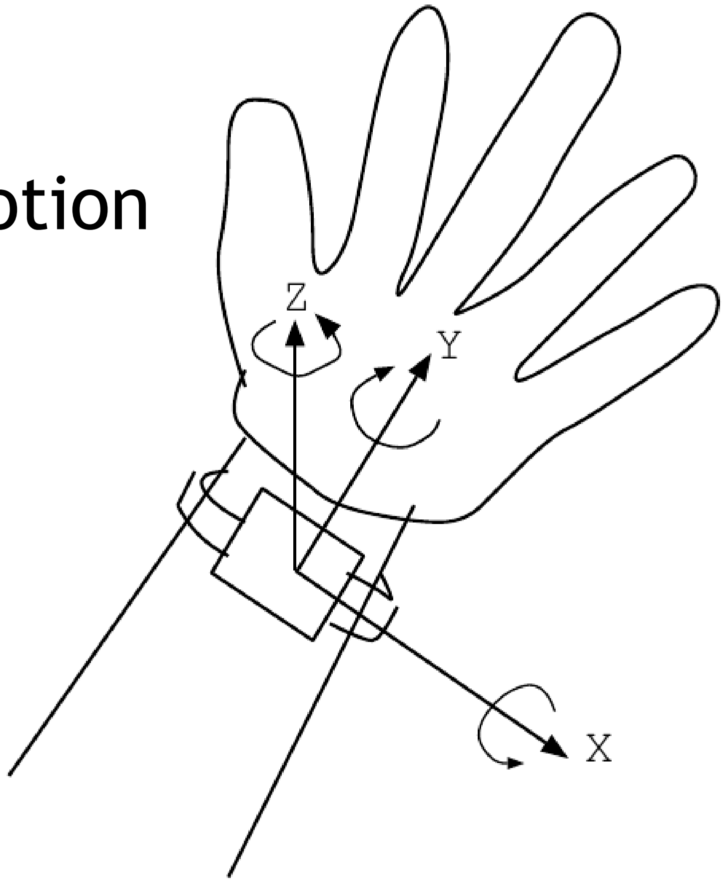
Background (cont)

Recording wrist movement data requires three basic components

Accelerometer – Translational motion

Gyroscope – Rotational Motion

Memory – Store Data



Background

- Multiple wrist worn devices available.
- None has addressed the need of recording translational and rotational wrist movement data.
- Many devices do not contain all the required sensors
- Others have unneeded features increasing cost, weight and discomfort, while reducing battery life.



Previous Work

- iPhone Based Data Logger
  - Long Battery Life
  - High resolution data
  - High customizability
  - Big Size
  - Low comfort

http://www.ces.clemson.edu/~ahoover/theses/dong-diss.pdf

Other Devices

- Activity Trackers
  - Long Battery Life
  - Small Size
  - High Comfort
  - Economical Cost

  - Low resolution data
  - No customizability
  - No gyroscope

The Fitbit Flex

https://www.flickr.com/photos/uscpsc/13104103473

Other Devices (cont)

- Research Devices
  - Average Battery Life
  - High resolution Data
  - High customizability
  - Medium Comfort

  - High cost
  - Development Kit: $2000
  - Unit : $249

Promotional photo of the SHIMMER

www.shimmersensing.com/shop/shimmer3

Other Devices (cont)

- Smartwatches
  - Average Battery Life
  - Average customizability
  - OK Comfort
  - Some have all sensors
  - High cost
  - Unit : $249
  - Low resolution data

Samsung Gear 2

https://www.flickr.com/photos/ridble/12794729274/in/photostream/

Summary

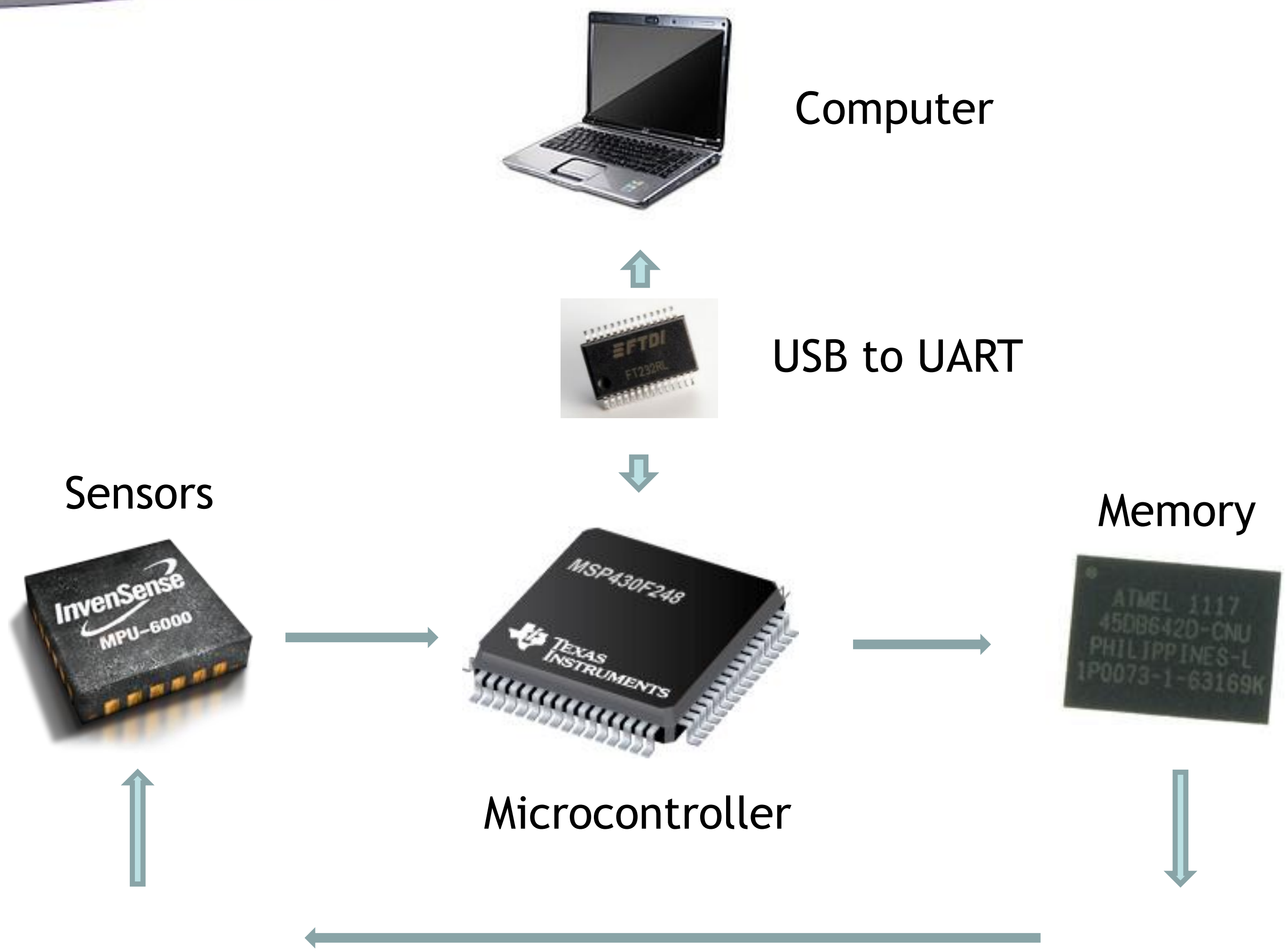
Name	Market Segments	Both Sensors	Size	Weight (g)	Active Battery Life (hours)	Extra components
iPhone	Mobile Phone	Y	Large	149	40	Display, GSM Module
MetaWatch	SmartWatch	N	Small	81	80	Display, Bluetooth Module
Samsung Gear 2	SmartWatch	Y	Small	68	48	Display, Bluetooth Module, Media Player
Fitbit Zip	Fitness Tracker	N	Small	8	6 mo	
Fitbit Flex	Fitness Tracker	N	Small	N/A	120	
Jawbone Up Move	Fitness Tracker	N	Small	6.8	168	
Jawbone Up 3	Fitness Tracker	N	Small	29	168	
Fitbit One	Fitness Tracker	N	Small	8	240	
Nike FuelBand	Fitness Tracker	N	Small	30	96	
SHIMMER	Research	Y	Medium	23.6	24	SD Card, Bluetooth Module
Thalmic Labs Myo	Research	Y	Medium	93	48	EMG Sensors

Note: Sizes are as follows:
Small : Wrist watch or similar
Medium: Larger than wrist watch, smaller than a smartphone.
Large: Smartphone

Novelty

- New Wrist mounted device to log motion data
  - Good Battery Life
  - High customizability
  - Economical Cost
  - High Comfort
- Smaller size leads to more comfort, and the user can wear it longer

Methods



http://www.ti.com/graphics/folders/partimages/MSP430F248.jpg https://www.flickr.com/photos/40875537@N04/5659910644
http://www.snowcap.fi/uploads//2011/12/mpu6000.png http://electronics-diy.com/img/FT232RL_chip.jpg
http://www.mouser.com/images/adestotechnologies/images/cason8.jpg

Components

- Sensor
- Memory chip
- Microcontroller
- USB to UART bridge
- Battery
- Battery charger
- LED
- Button
- Case

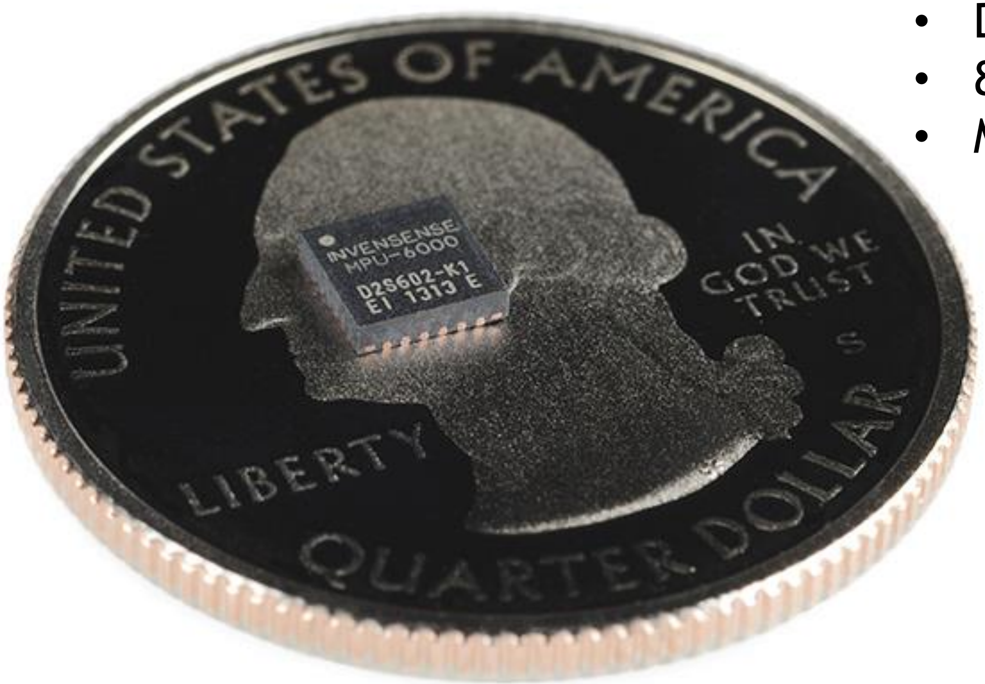
Procedure

- Part selection
- Circuit design / Prototype / Programming
- PCB design
- Soldering

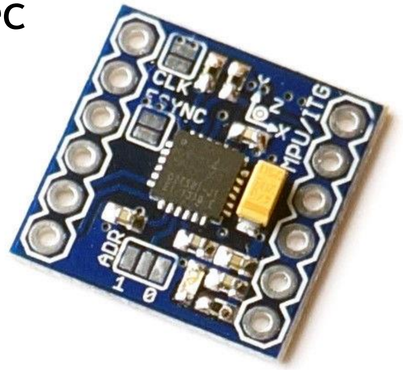
Sensor

MPU-6000: MEMS 6 axis sensor

- 2.375 – 3.46 V supply
- Current Consumption:
- Accelerometer : 200 uA
- Gyro + Acc: 3.8 mA
- Digital Communication over SPI / I^2C
- 8 KHz internal clock
- Measurement Range:
  - Accelerometer: ±2, ±4,±8,±16 g
  - Gyro: ±250/±500/±1000/±2000 °/sec



InvenSense MPU-6000

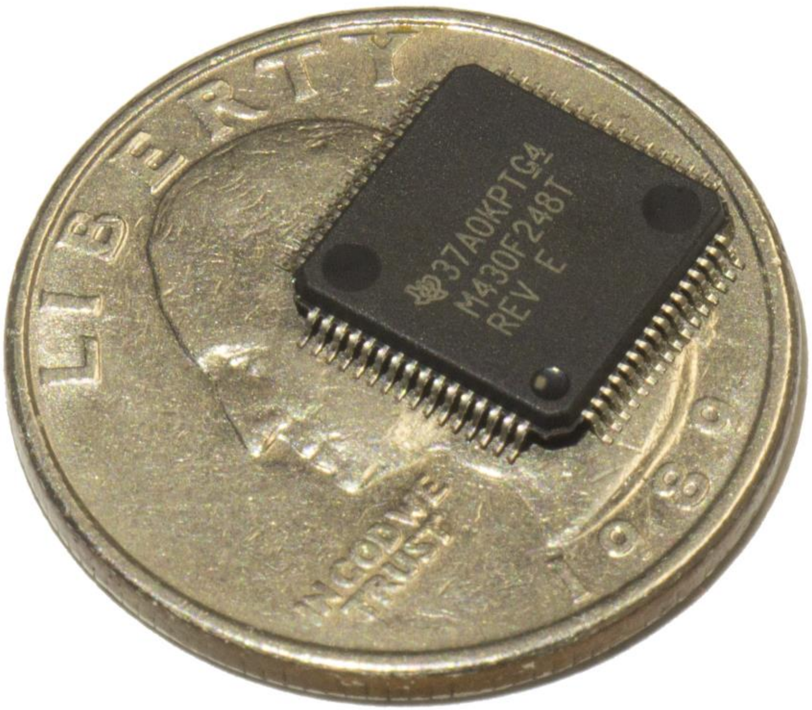


Breakout Board

https://www.sparkfun.com/products/11234
http://www.ebay.com/itm/261417344740

Current Consumption for STMicro LSM330: 6.1 mA

Microcontroller



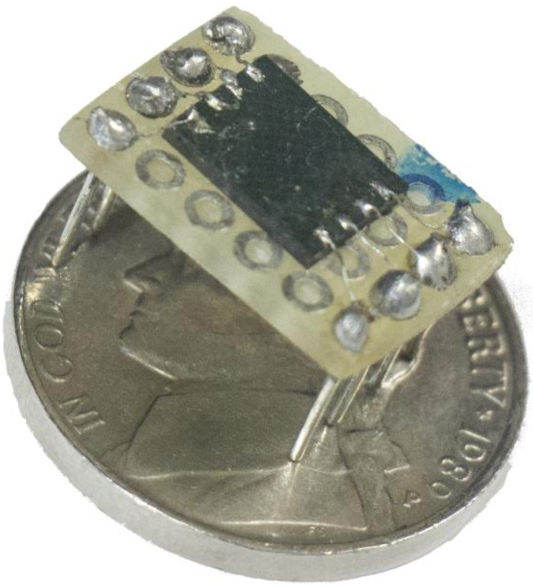
The MSP430F248 microcontroller

MSP430F248

- 1.8 – 3.46 V supply
- Current Consumption : 270 uA @ 1 MHz
- SPI and UART modules
- Two 16 bit timers
- **4 KB RAM**

Memory

$$\text{data} = 24 \text{ hours} \times \frac{60 \text{ minutes}}{\text{hour}} \times \frac{60 \text{ seconds}}{\text{minute}} \times \frac{15 \text{ polls}}{\text{second}} \times \frac{6 \text{ sensors}}{\text{poll}} \times \frac{1 \text{ byte}}{\text{sensor poll}}$$



Memory chip

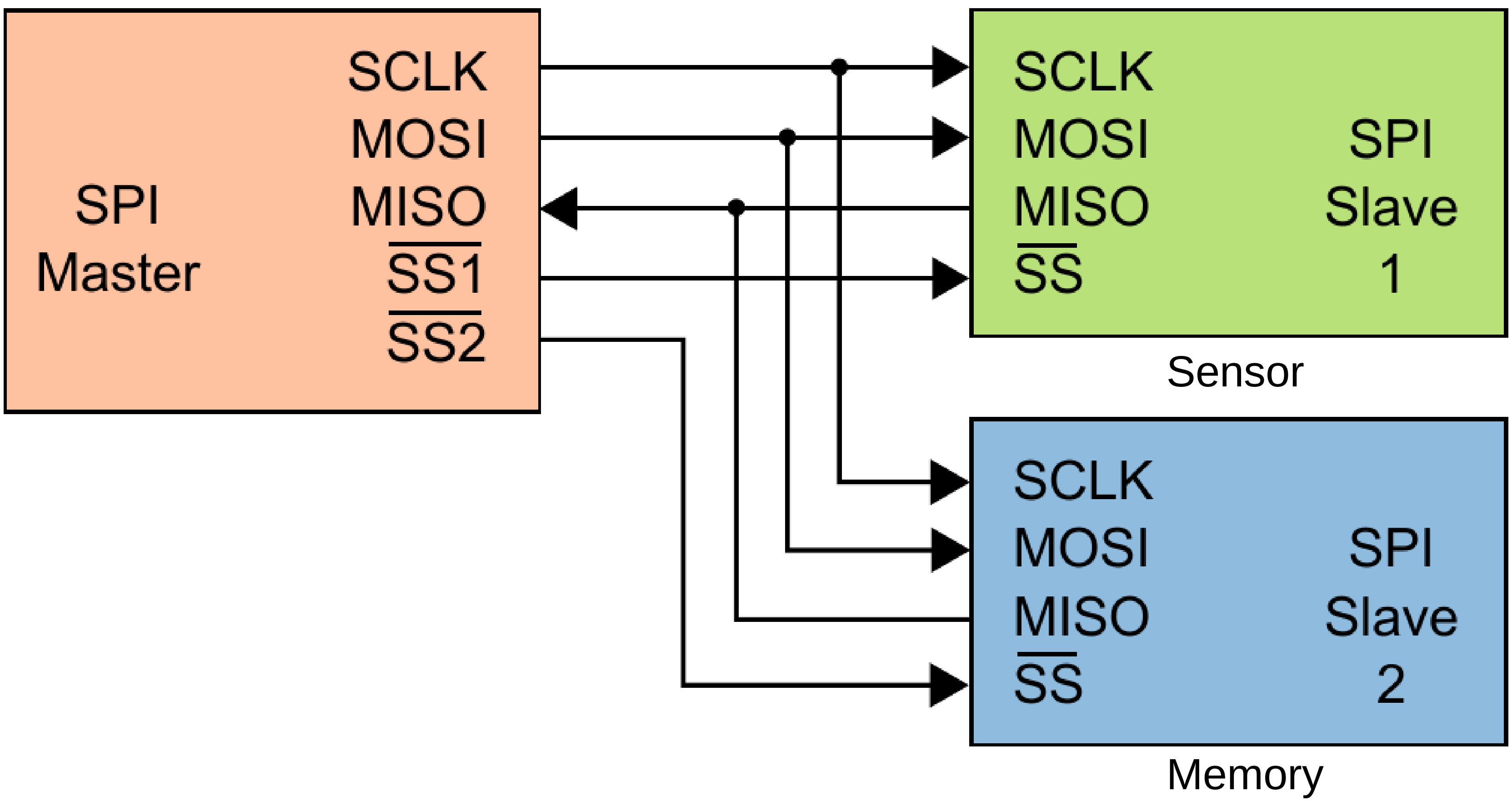
$$\text{data} = 7,776,000 \text{ bytes} \approx 7.5 \text{ MB}$$

AT45DB642D

- 2.7 – 3.6 V supply
- Current Consumption
  - Read : 15 mA
  - Write / Erase : 25 mA
  - Standby : 25 uA
- SPI communication
- Package : CASON

- Write duty cycle: 0.56%
- **Average current: 140 μA**

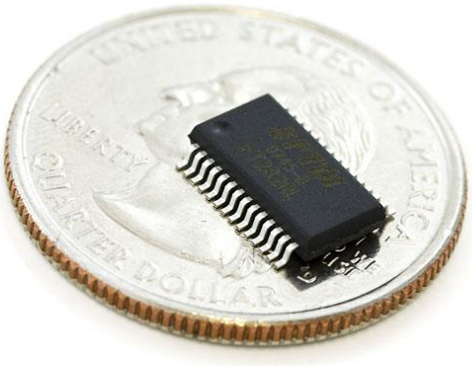
SPI



SPI master with two slaves on the same bus

http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus

Data Transfer



FT232RL

FT232RL USB to UART bridge

- 5 V supply
- Integrated 3.3 V level converter
- Data transfer technology would require 18 mA of current over 30 minutes
- Using a wired connection allows this power to be sourced from the host
- Battery can be charged with the same connector
- Allows us to get data off the device

https://www.sparkfun.com/products/650

LED

Photo of a LED

- Typical current draw of 20 mA
- Duty cycle: 0.56%
- **Average current: 110 μA**
- Off the shelf LED

Case

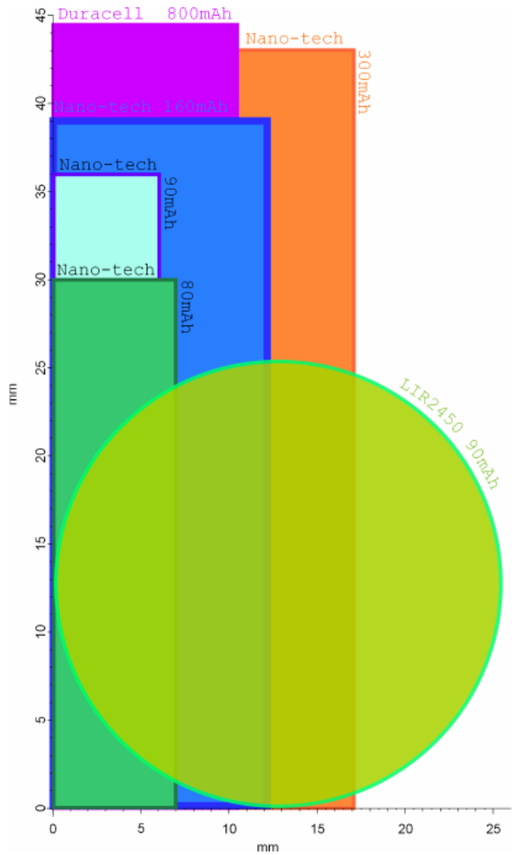
Ergo Minitec Series Cases

Ergo Minitec Series

- Largest case used for previous work
- Smallest case measures 52 mm x 32 mm x 15 mm
- Intermediate ring allows a strap to pass through
- Lightweight

http://www.okw.com/en/Plastic-enclosures/Minitec.htm

Battery

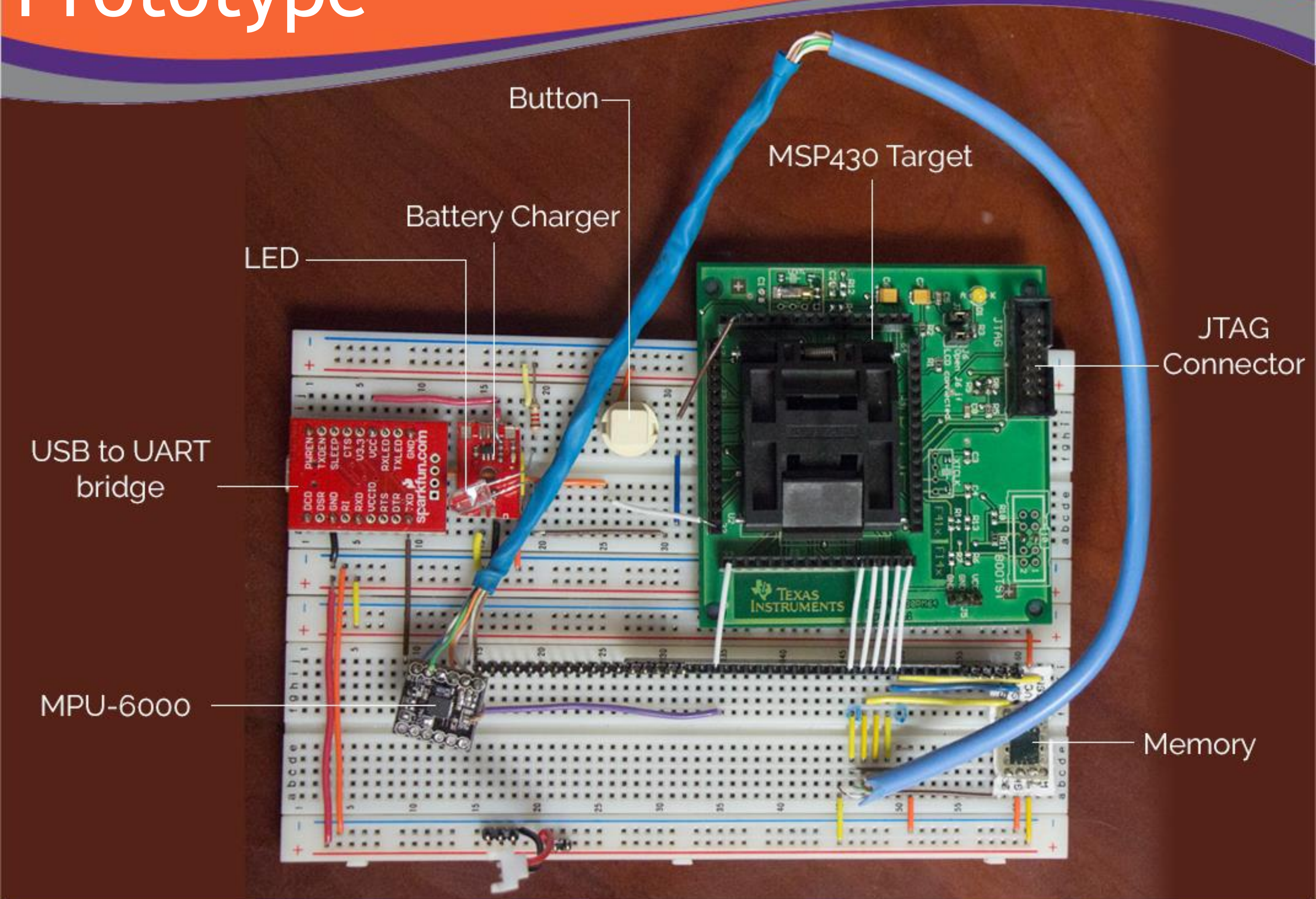


Top view profiles of different batteries considered

Turnigy Nano-tech 160 mAh

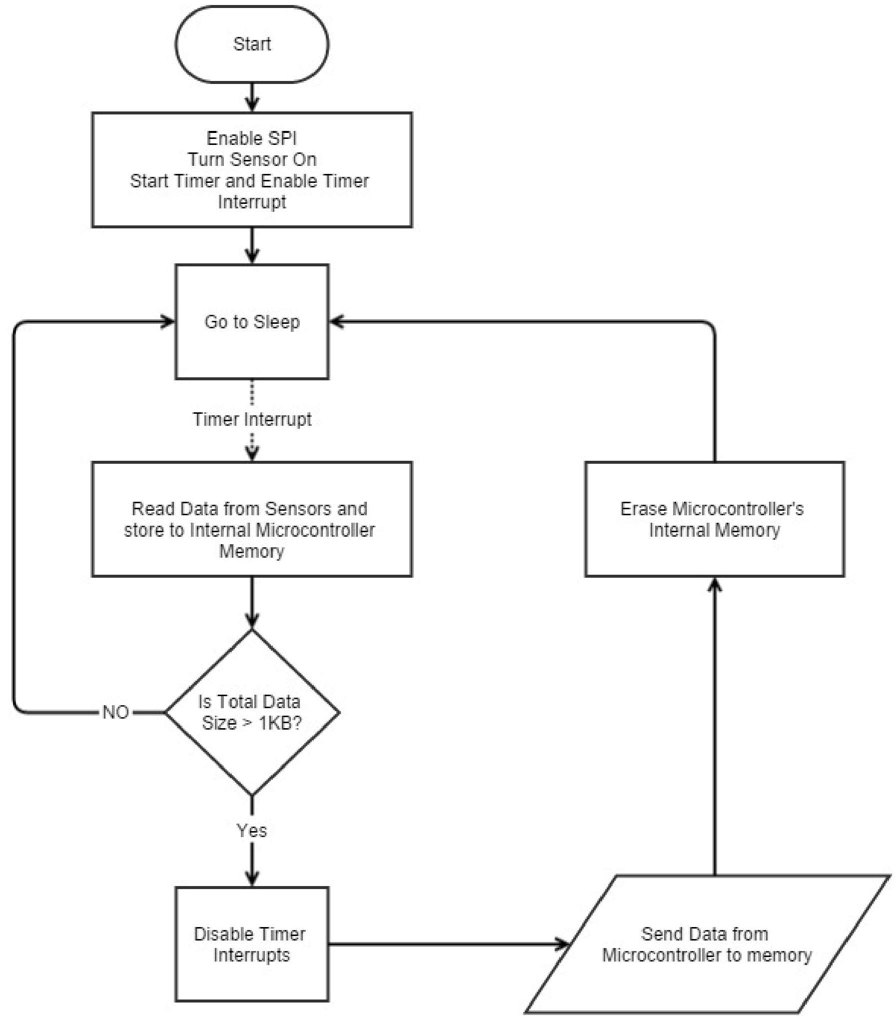
- Most batteries would fit in 52 mm x 32 mm
- Case is limiting factor
- Case is curved so the Duracell AAA 800 mAh, Nano-tech 300 mAh and LIR2450 90 mAh batteries wouldn't fit
- Nano-tech 160 mAh provides the highest battery capacity

Prototype

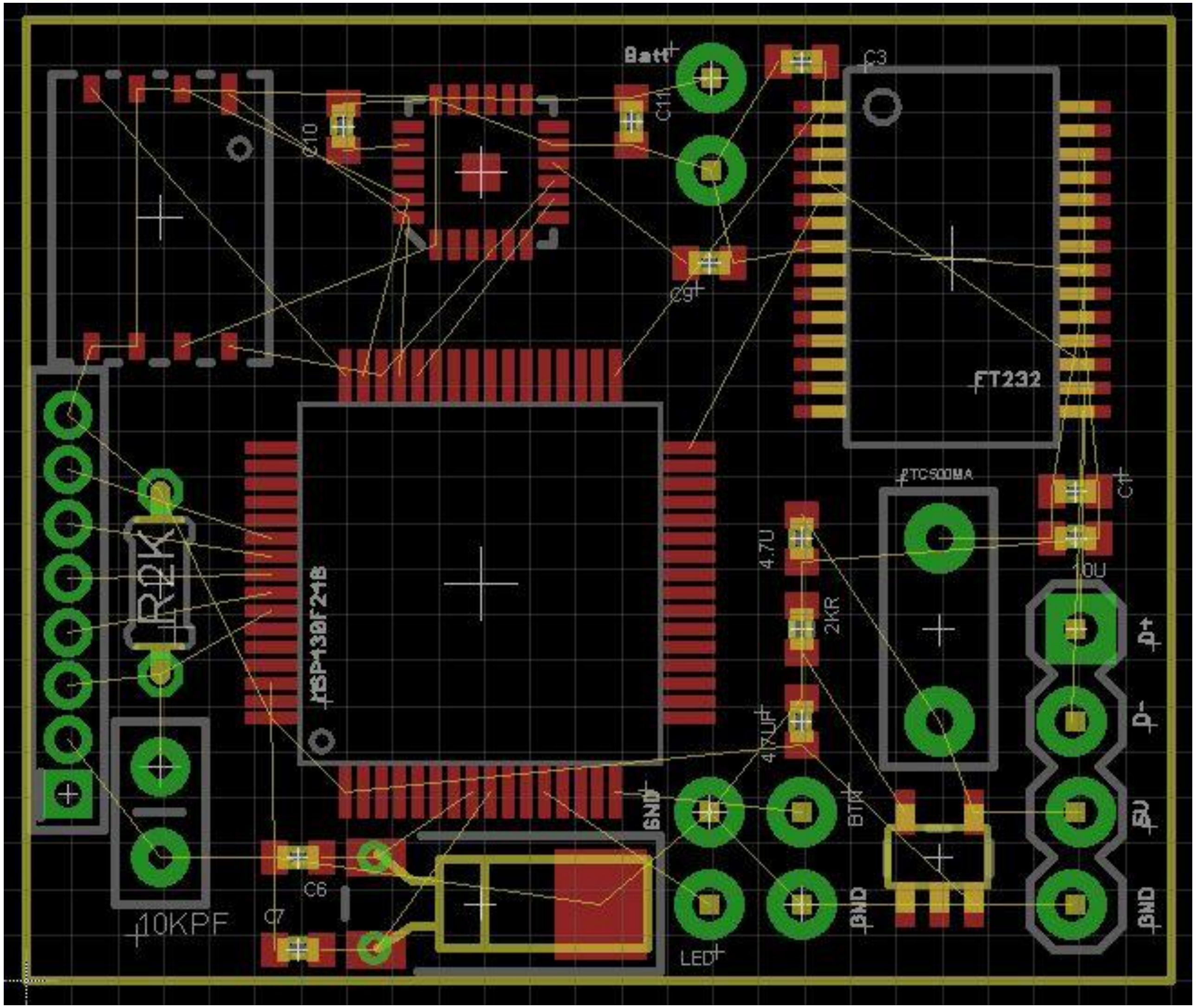

Button
MSP430 Target
Battery Charger
LED
JTAG Connector
USB to UART bridge
MPU-6000
Memory

Programming

Simplified algorithm for the device

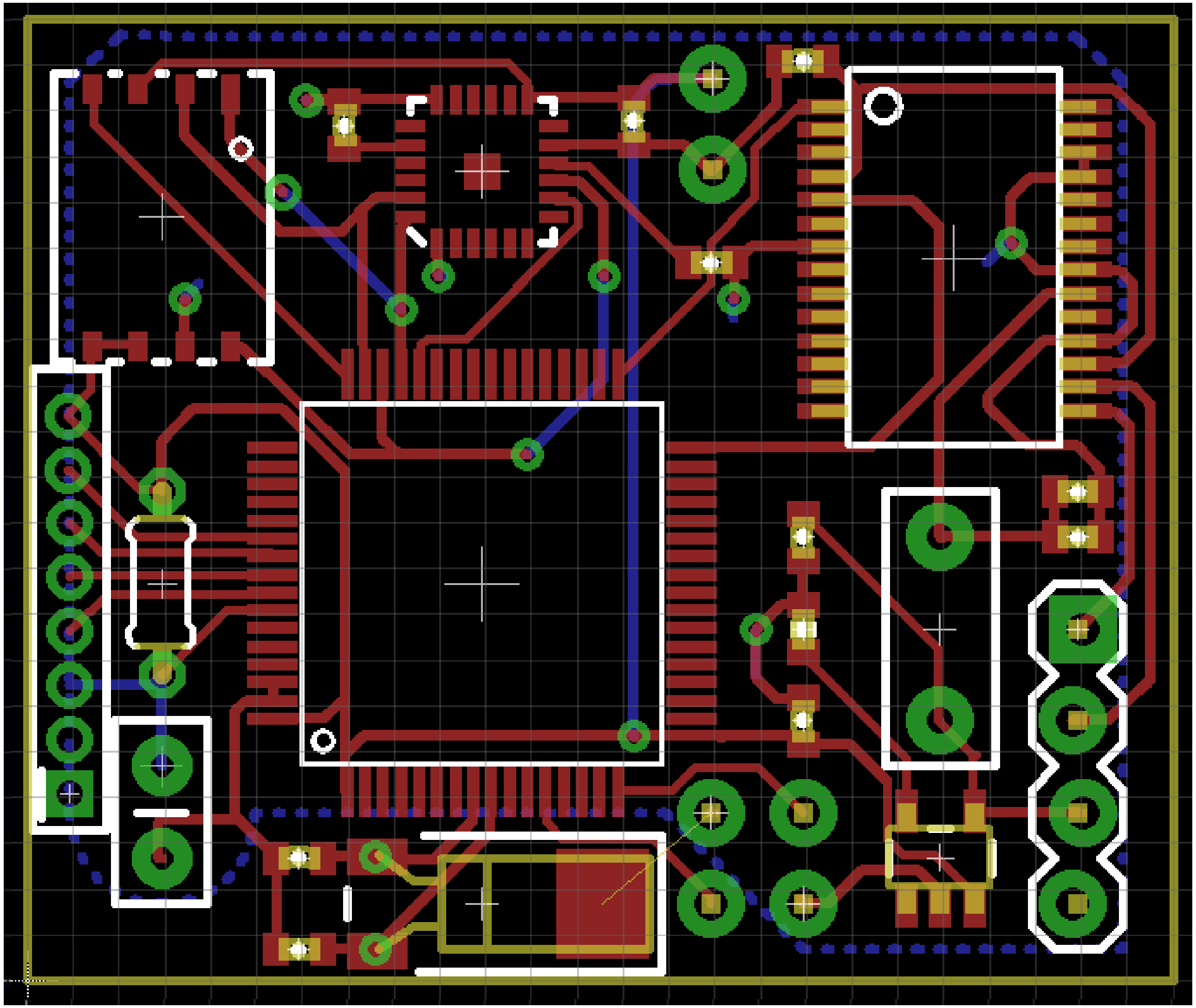


PCB Layout



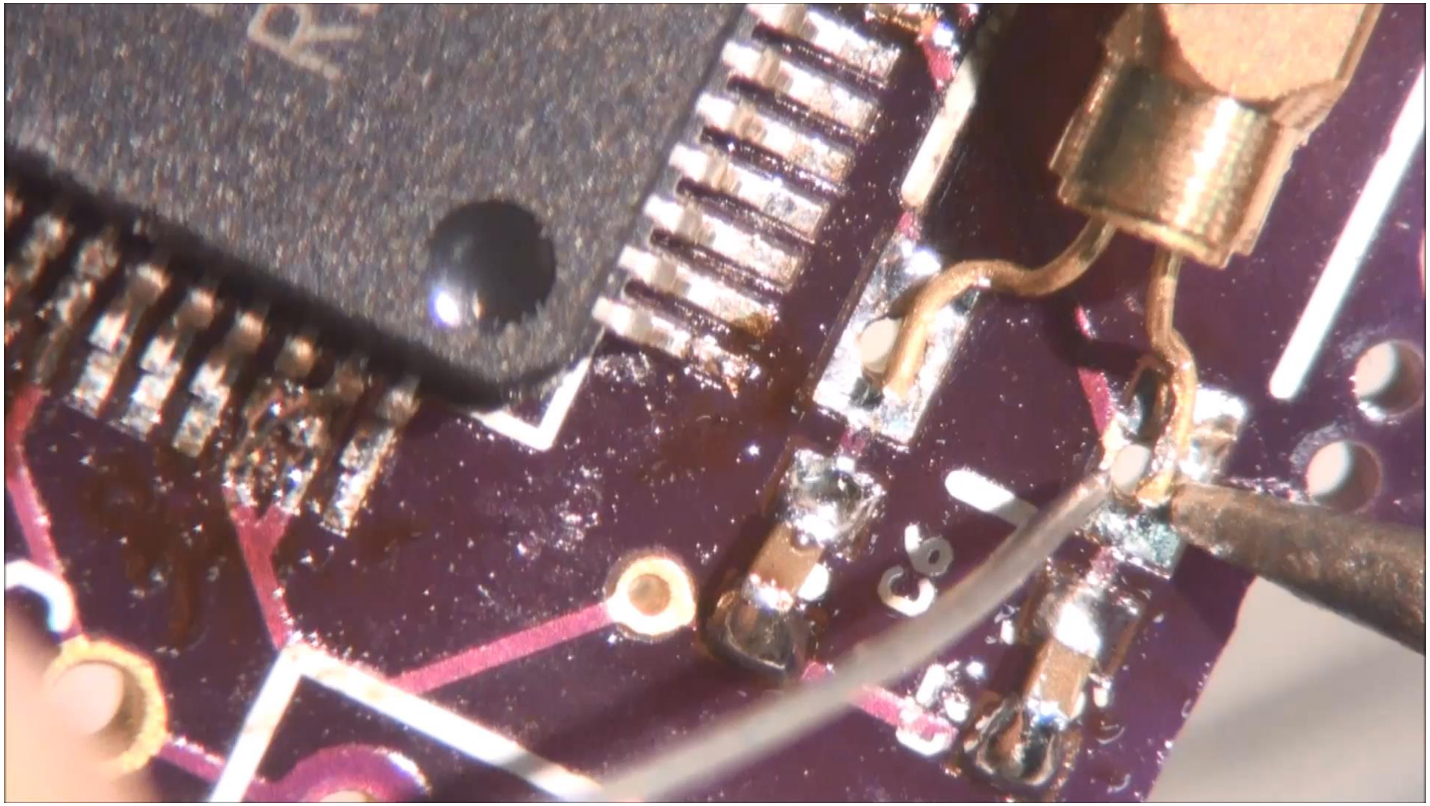
Parts placed before routing

PCB Layout (cont)



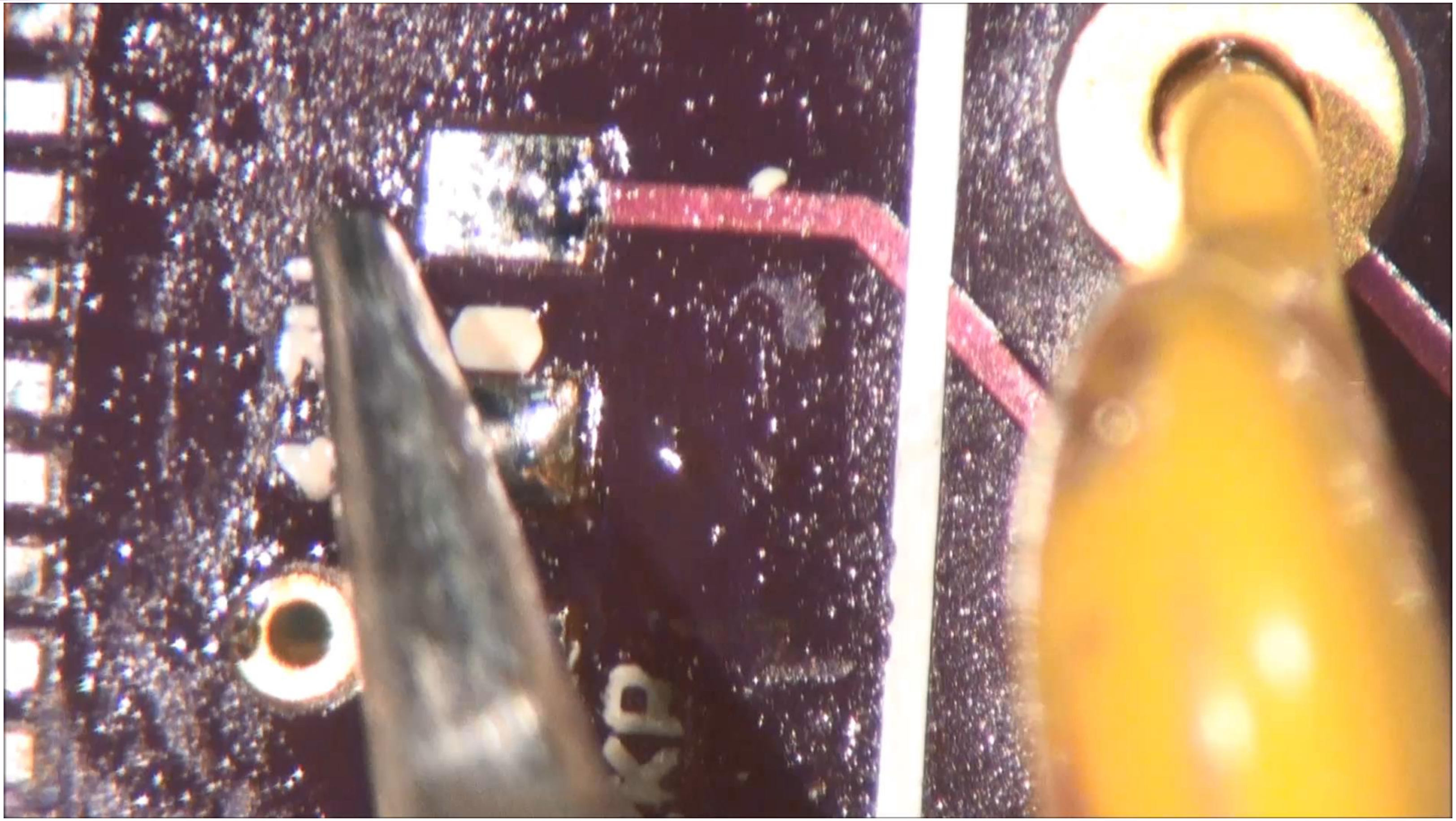
PCB layout after routing

Soldering (Mounting Parts)



Video : Soldering Crystal (41 seconds)
https://www.youtube.com/watch?v=VSIhrFNCuyM

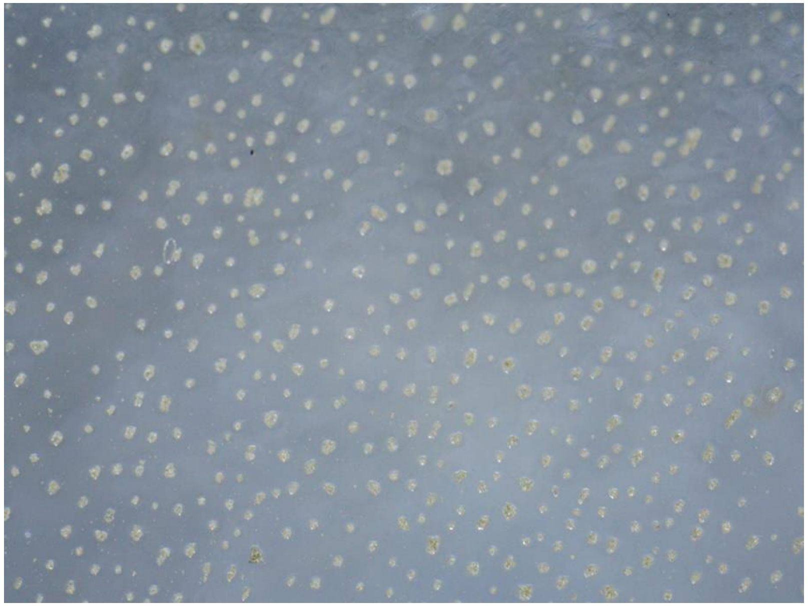
Soldering (cont)



Video : Soldering SMD Resistor (44 seconds)
https://www.youtube.com/watch?v=mzgT1sddoXY

Z – axis tape

Z – axis tape reel

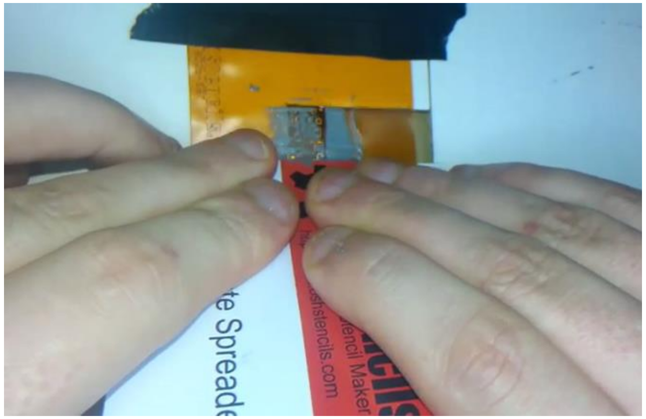


Z – axis tape under a microscope

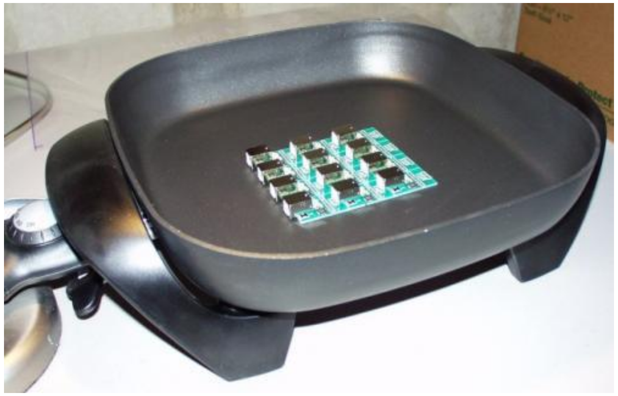
http://www.adafruit.com/product/1656
https://www.sparkfun.com/products/12042

Soldering (cont)

Stencil placement



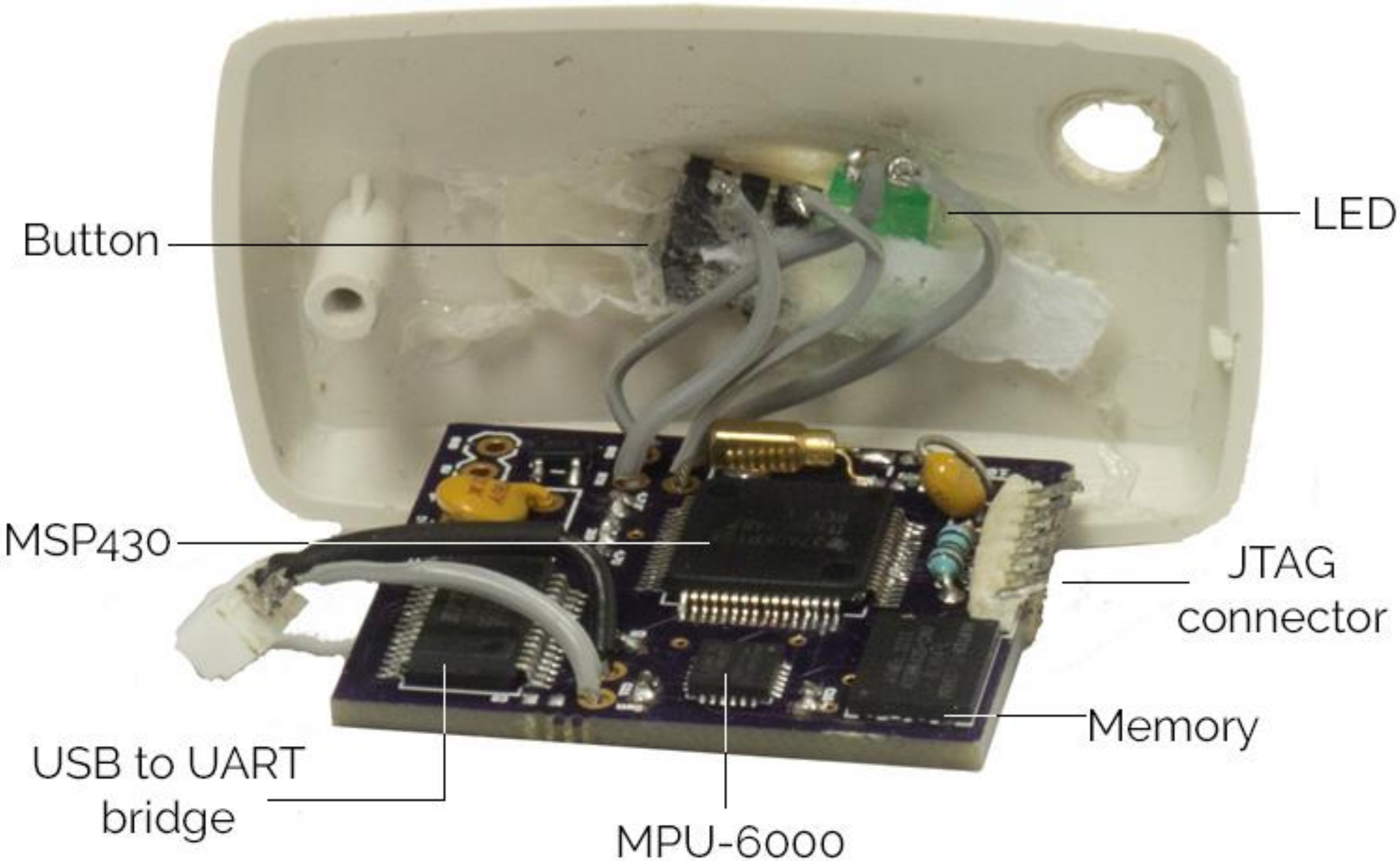
Solder paste application



Hot plate reflow soldering

https://www.sparkfun.com/tutorials/59
https://www.youtube.com/watch?v=P7Fa-WZHxbI
https://www.youtube.com/watch?v=1RMtOAHbfvU

Final Device

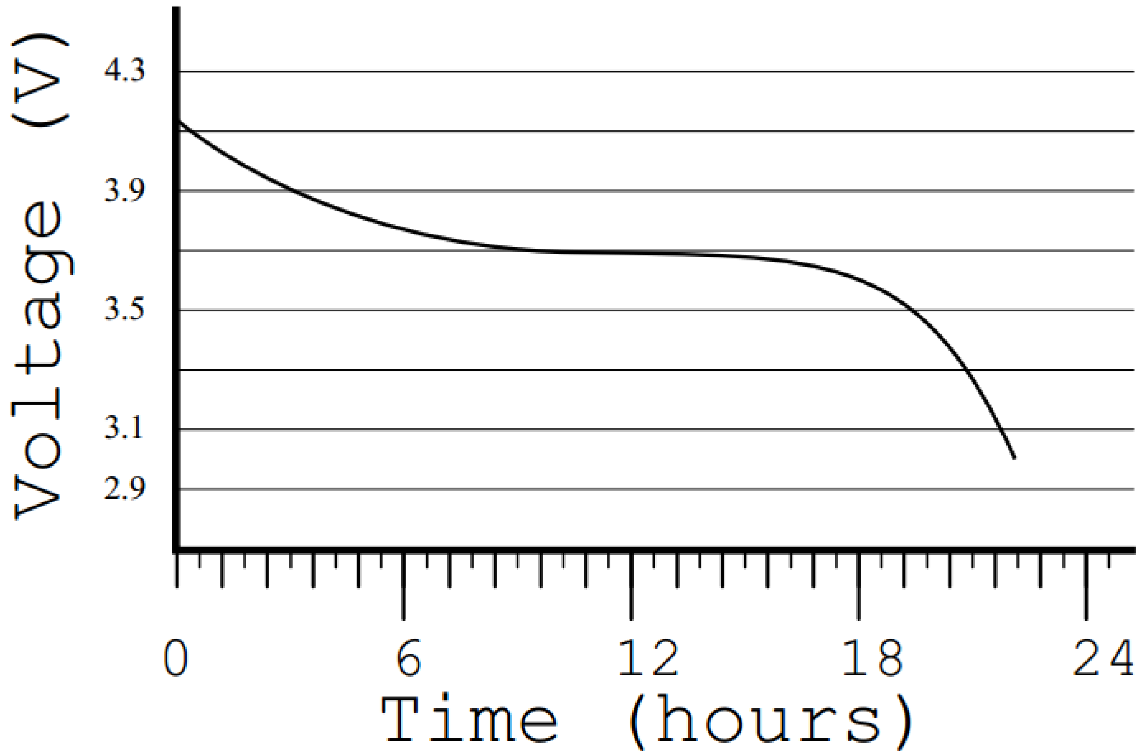


Final PCB with top case cover

Results

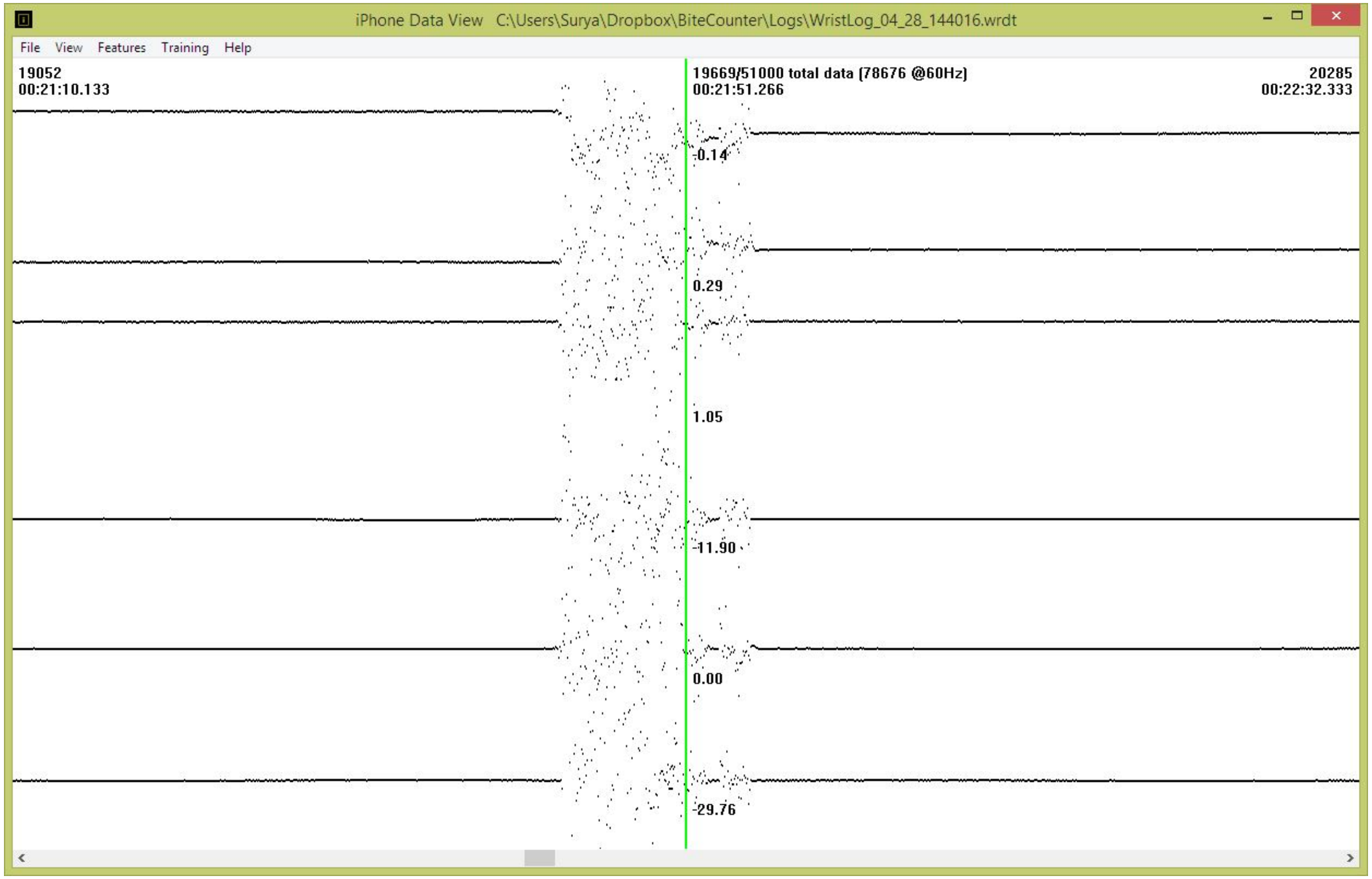
Final device mounted on wrist

Results (cont)



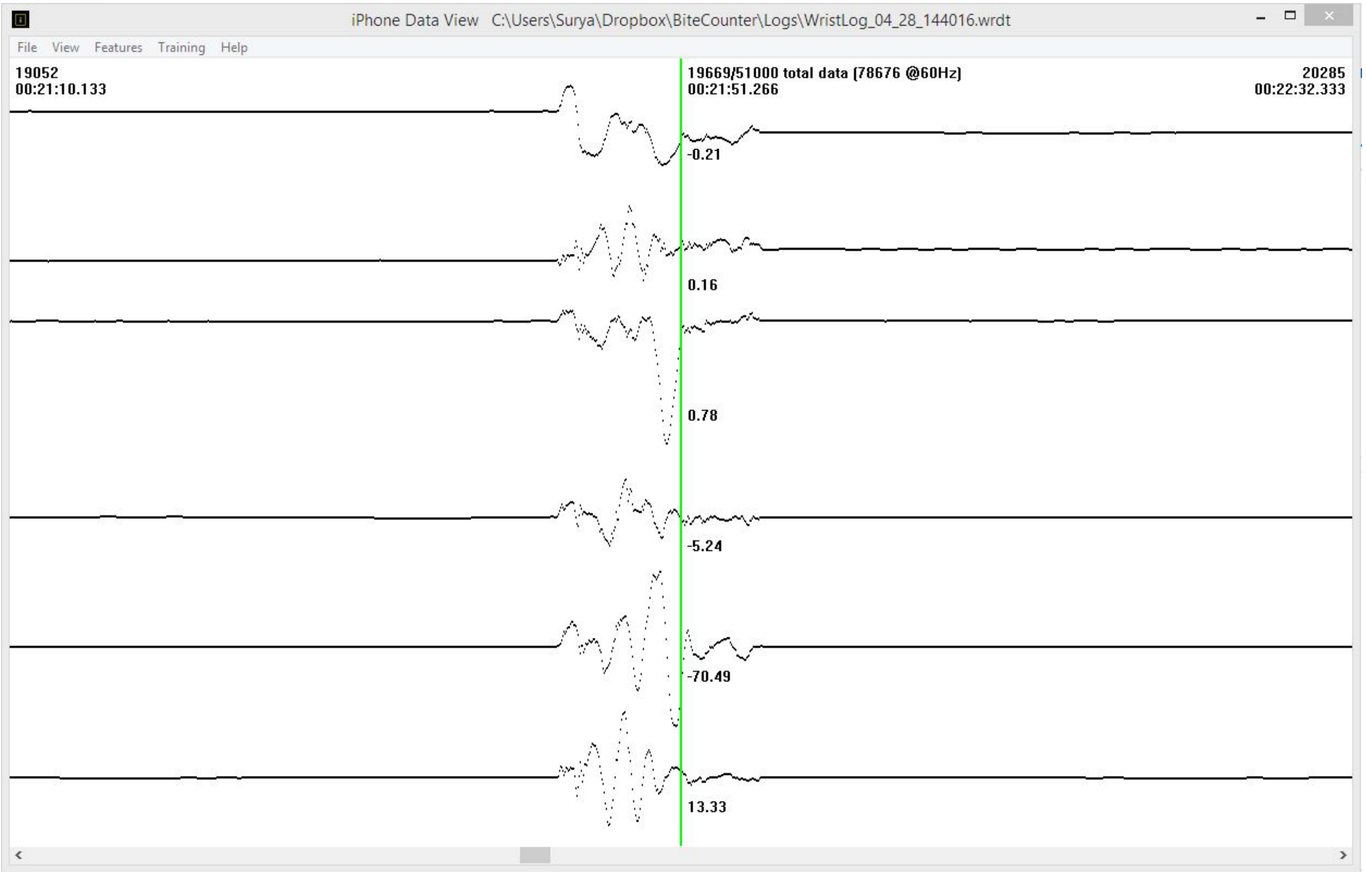
Battery life of active device

Results (cont)



WristView showing recorded data

Results (cont)



WristView showing smoothed data

Results (cont)

Description	Cost (US$)	Quantity
Capacitor, 0.1 uF	0.10	7
Capacitor, 4.7 uF	0.26	1
Capacitor, 10.0 uF	0.50	1
Capacitor, 10.0 nF	0.32	1
Resistor PTH, 2 kΩ	0.14	1
Resistor SMD, 2 kΩ	0.10	1
FT232RL	4.50	1
Fuse	0.35	1
MSP430F248	7.89	1
MPU-6000	14.9	1
MCP73831	0.67	1
Crystal, 32768 Hz	1.49	1
AT45DB642D	12.7	1
PCB Fabrication	2.99	1
Stencil	5.00	1
Total Cost	52.5	1

Device production cost

Results (cont)

Name of Device	Market Segments	Both Sensors	Size	Weight	Active Battery Life (hours)	Extra components
iPhone	Mobile Phone	Y	Large	149	40	Display, GSM Module
MetaWatch	SmartWatch	N	Small	81	80	Display, Bluetooth Module
Samsung Gear 2	SmartWatch	Y	Small	68	48	Display, Bluetooth Module, Media Player
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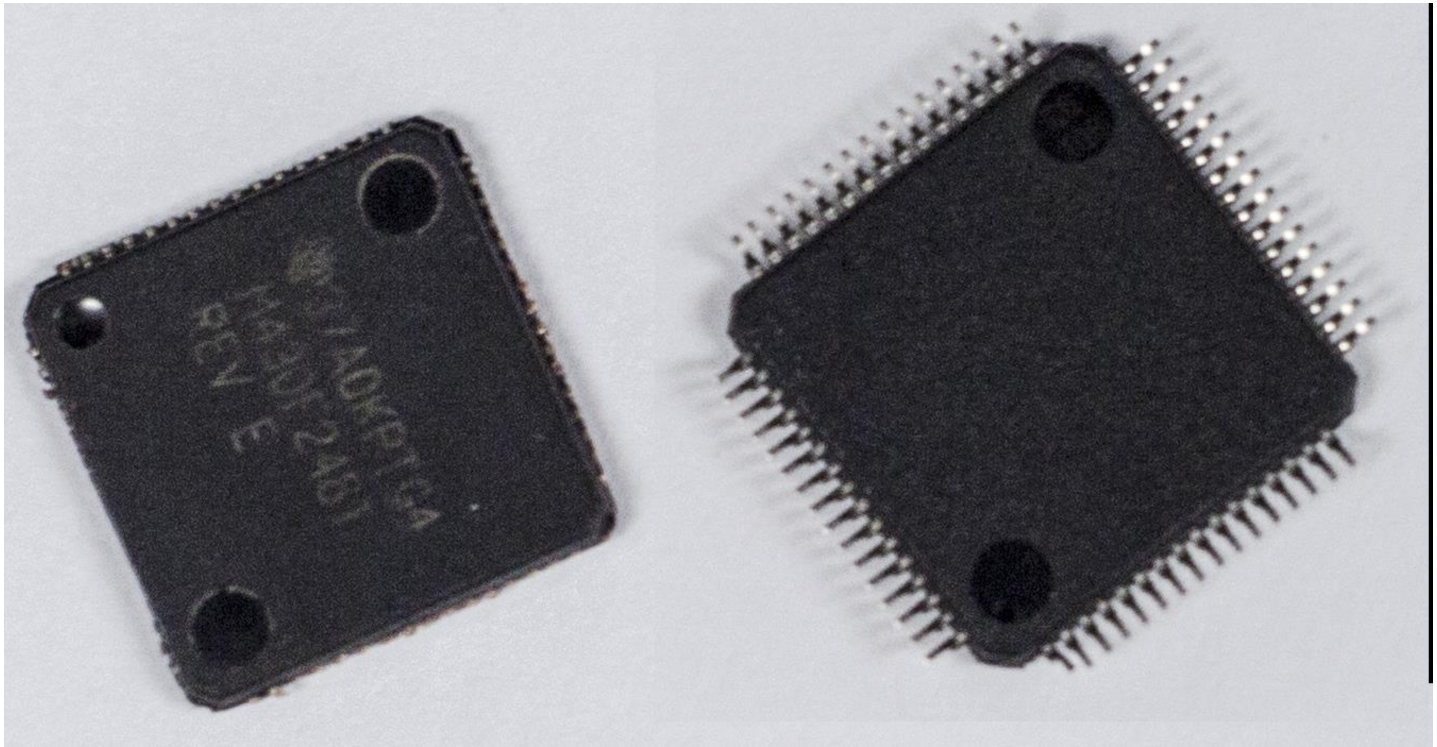
Fitbit One	Fitness Tracker	N	Small	8	240	
Nike FuelBand	Fitness Tracker	N	Small	30	96	
SHIMMER	Research	Y	Medium	23.6	24	SD Card, Bluetooth Module
Thalmic Labs Myo	Research	Y	Medium	93	48	EMG Sensors
This Work	**Research**	**Y**	**Small**	**26.6**	**24**	

Good Battery Life
High customizability
Economical Cost
High Comfort

Challenges



Microcontroller after cutting pins to desolder

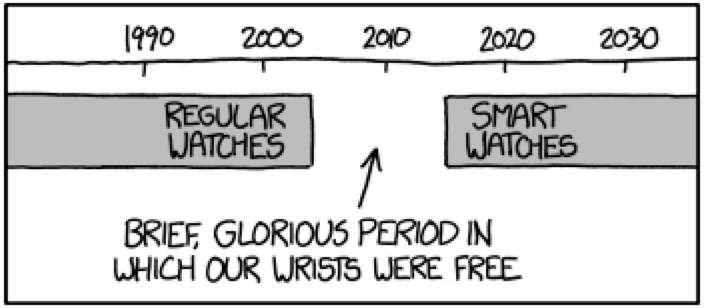
Future Work

- Dataset of wrist motion movement needs to be created
- 100 – 200 subjects wearing this device for up to 2 weeks each
- 20 – 25 devices needed

Future Work (cont)

- Add a local time feature to the watch
- Consider using EMG sensors to pursue new algorithms
- Try a different profile with custom molded case

Questions ?



Old people used to write obnoxious thinkpieces about how people these days always wear watches and are slaves to the clock, but now they've switched to writing thinkpieces about how kids these days don't appreciate the benefits of an old-fashioned watch. My position is: The word 'thinkpiece' sounds like a word made up by someone who didn't know about the word 'brain'.

http://xkcd.com/1420/