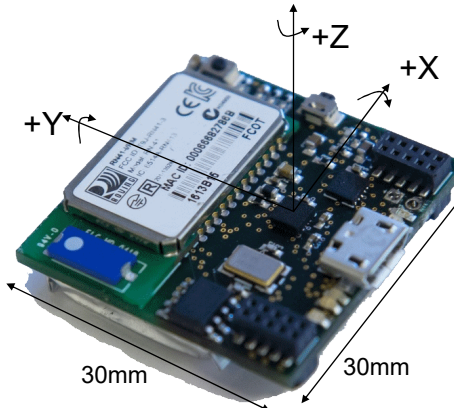
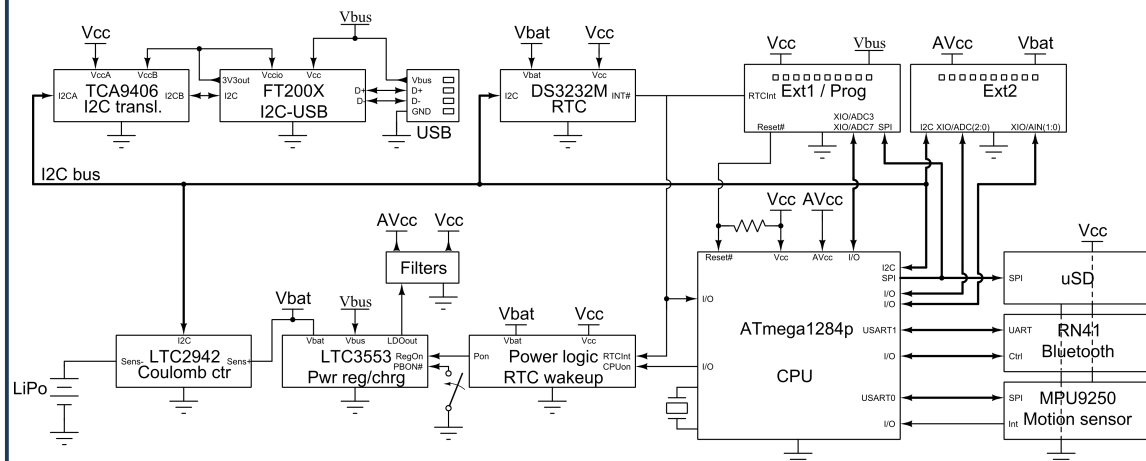


# BlueSense - Designing an Extensible Platform for Wearable Motion Sensing, Sensor Research and IoT Applications

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## The BlueSense platform

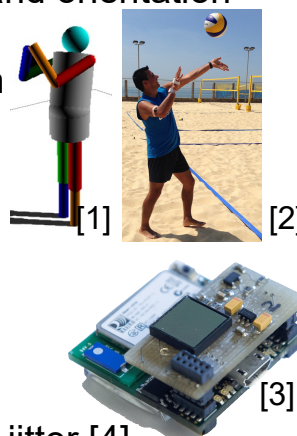


```
BlueSense2
Boot 20
DS3232 init... done
DS3232 registers:
00-0F: 46 52 16 01 06 02 18 46 52 16 06 02 18 00 18 00
10-1F: 00 19 C0 00 80 46 08 02 C5 A0 00 0B 01 44 00 C0
Setting time from RTC... done: 06.02.18 16:52:47 = 492767000 ms
Off power data:
Power off at: 492763287 Q: 21963 V: 3754
Power on at: 492767001 Q: 22068 V: 3756
Delta T: 3714 ms
pwr1: 382 mW pwr2: 473130 uW
RN41 setup
Basic parameters:
MAC: 0006669C3FCB
name: BlueSense-3FCB
baud: 115K
mode: 0
auth: 0
pin: 0000
Extended parameters:
srvcass: 0048
devclass: 0718
cfgtimer: 0
inquin: 0100
pagwin: 0100
Other parameters:
sniff: 0000
LowPower: 0000
RN41 configuration OK
Initialise MPU
MPU-9250 registers:
```

- 6 layer PCB, 30x30mm
- 82 components, 39 unique BoM lines, 0402 passive components
- LiPo battery (160mAh in the picture, other capacities possible)
- Approx. £80 per unit, excluding assembly
- SDHC data logging
- Bluetooth & USB data streaming
- 500Hz motion sensor (Invensense MPU9250)
- Terminal-based control interface

## Features and applications

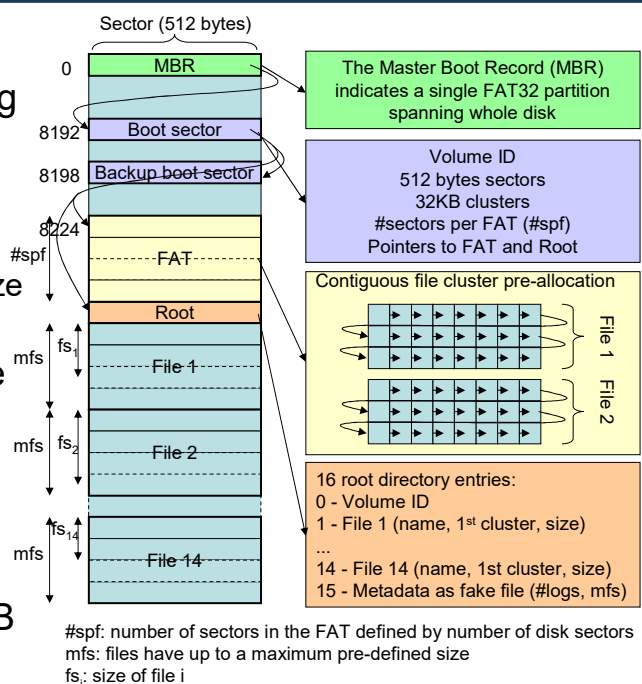
- Acceleration, rate of turn, magnetic field and orientation
  - Activity recognition, sports, motion tracking
- Extension connectors for sensor research
  - 4 ADC or I/O + 2 I/O + I2C + SPI
  - Power supply, power-up trigger
- Low-power IoT applications
  - True hardware-off
  - Power-up from real-time clock & extensions
- Coulomb counter to measure power use
- 5ppm real-time clock
- >1KHz ADC & streaming/logging w/ 30μs jitter [4]



[1] Ciliberto et al., Exploring human activity annotation using a privacy preserving 3D Model, *ISWC HASCA Workshop*, 2016  
[2] Cuspinera et al., Beach volleyball serve type recognition, *ISWC*, 2016  
[3] Pouryazdan et al., Wearable electric potential sensing: a new modality sensing hair touch and restless leg movement, *ISWC HASCA Workshop*, 2016  
[4] Roggen et al., Electric field phase sensing for wearable orientation and localisation applications, *ISWC*, 2016

## μFAT32 filesystem

- FAT32-compatible
- Optimised for streaming
  - Contiguous file layout
  - Fixed maximum file size
  - Multiblock SD write
  - On file close, only the size needs updating
- Minimized memory use
  - One 512 bytes buffer
- Caching writes if SD busy
  - Minimises latency
- SDHC, maximum 32GB
- Maximum 14 files

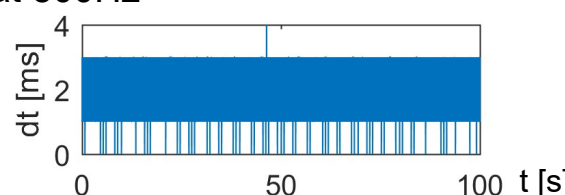


## Characterisation

Logging		Streaming		Idle		
500Hz	100Hz	500Hz	100Hz	No conn.	BT conn.	Off
98mW	94mW	200mW	184mW	18mW	92mW	70μW

### Sample write time interval at 500Hz

- 64-samples buffer
- Avoids losses when  $dt > 2ms$



### uFAT worst case write [KB/s]

Storage	Write Speed [KB/s]
Kingston 8GB class 10-U-I	129
Kingston 16GB class 4	7
Samsung Evo+ 32GB U-I	142
Sandisk 32GB U-III A1	160
Sandisk 16GB U-I	121

### CPU load while logging

	A+G+M	A+G+M+Orientation
500Hz:	15%	59%
200Hz:	6%	26%
100Hz:	3%	16%

All results are worst cases, when logging/streaming data which includes: packet counter, timestamp, annotation, battery level and motion data. Motion data includes acceleration, rate of turn, magnetic field and orientation.

## Conclusion

	BlueSense	XSens MTw	Shimmer3	x-io x-IMU	x-io NGIMU	[1]	[2]
mm	30x30	47x30	51x34	42x33	50x33	24x46	77x37
Hz	500	120*	512	512	400	128	200
Extensible	Y	N	Y	Y	Y	N	N
True off	Y	N	N	N	N	N	N
Interfaces	BUS	C	BU	BUS	BUWR	AS	BS

- High versatility for wearable sensing and IoT applications
- Square form factor for better wearability
- Open-firmware & open-hardware

<http://github.com/droggen/BlueSense2>

[1] Harms et al., ETHOS: Miniature Orientation Sensor for Wearable Human Motion Analysis, *IEEE Sensors Conference*, 2010

[2] Rodríguez-Martin et al., A Wearable Inertial Measurement Unit for Long-Term Monitoring in the Dependency Care Area, *Sensors*, 2013

\* Internal sample rate is 1200Hz, output is 120Hz

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