Automatic Concussion Evaluation (A.C.E.)

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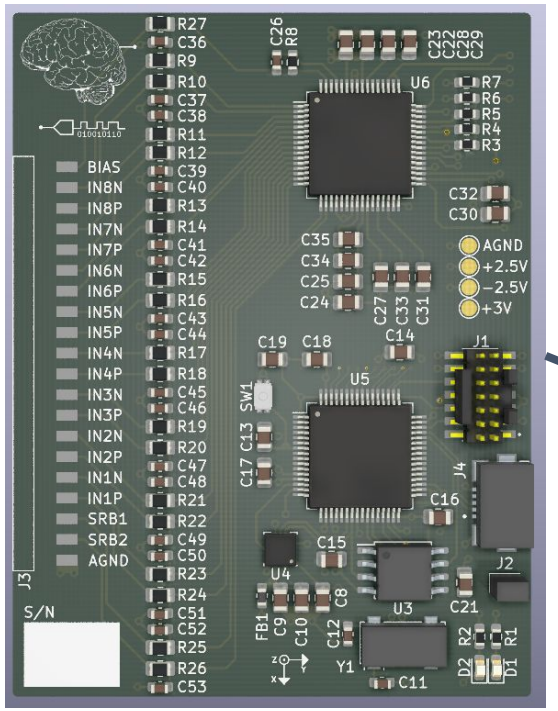
Thank you to our sponsors:

Texas Instruments

National Security Innovation Network

Our Solution

Example of a clinical EEG



Rendering of the ACE mini EEG

10 devices currently being manufactured!

Mockup of the ACE mini EEG inside of a Military Helmet

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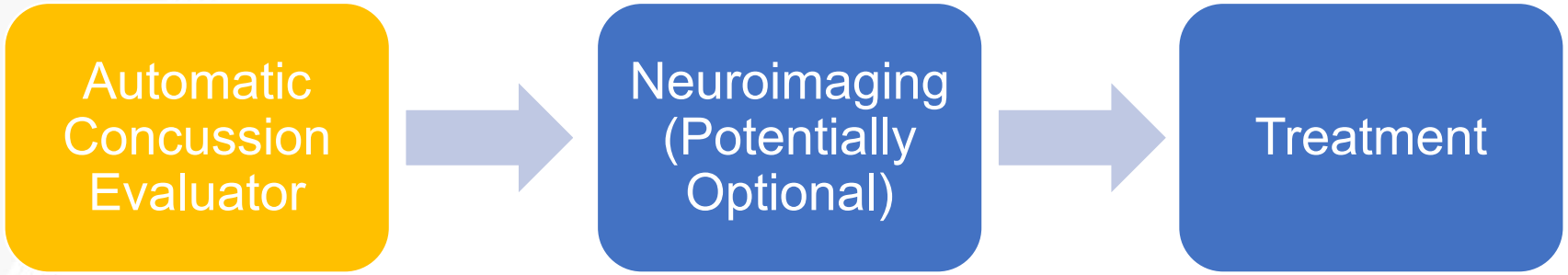
Implications – The New Standard of Care

- **Reduces screening uncertainty from 30-60% down to 10%**
- Currently working with Ft. Benning through NSIN to test prototypes
- Proper care of mTBI can **reduce** long term symptoms and the prevalence of comorbidities such as PTSD or CTE

New Care Sequence



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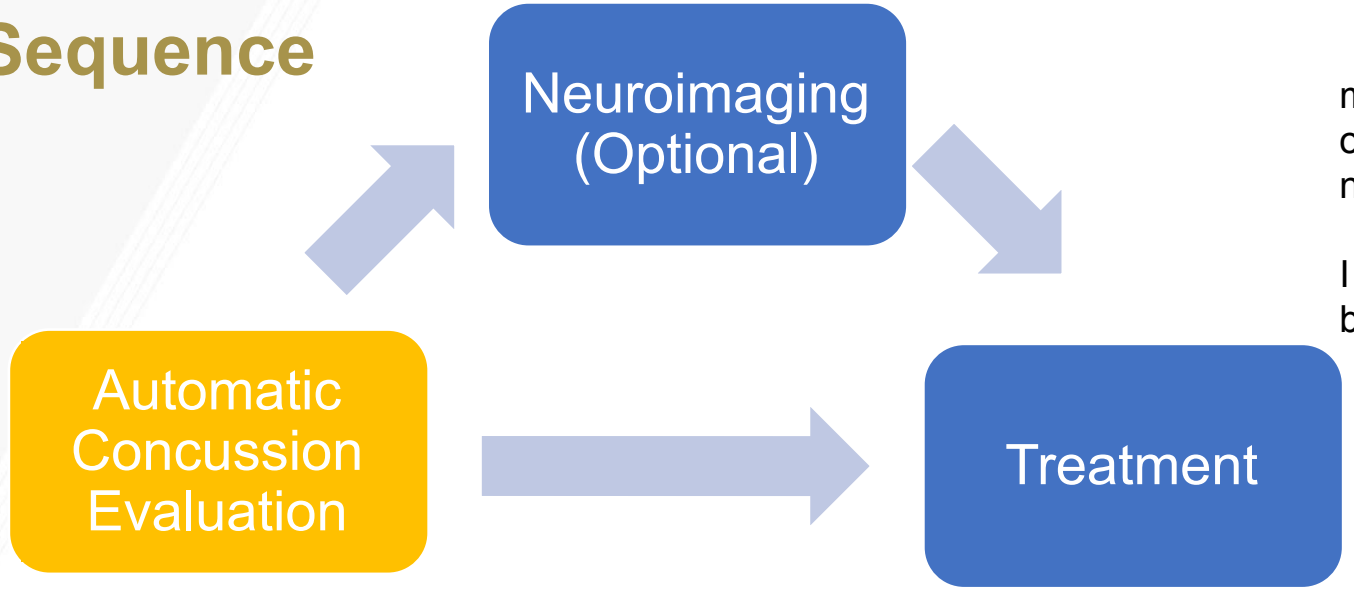
Current Care Sequence

Our Solution

New Care Sequence



maybe dashed arrow? or more opaque arrows (from ace to neuroimaging)

I want to keep font still somewhat big so it doesn't look squished

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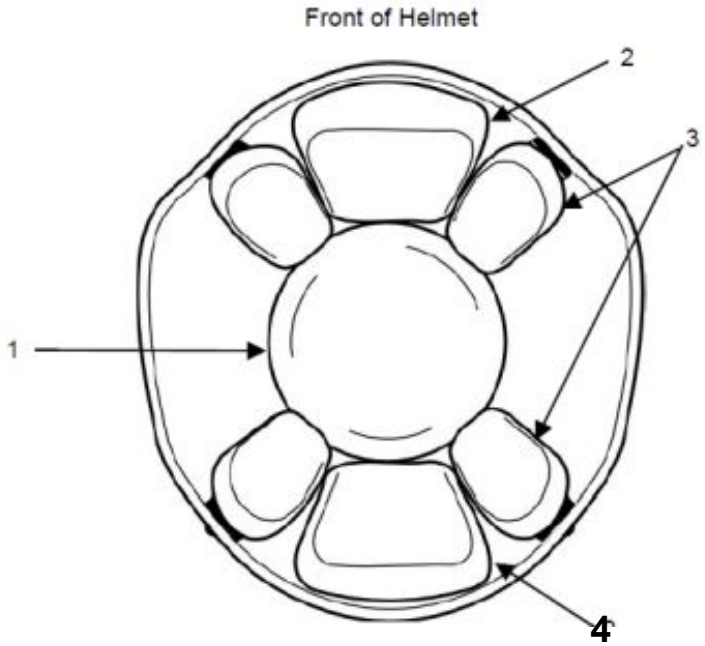
Real World Implementation??
Don’t like saying business

Technical Slides

Helmets

- **Limited space** on helmet due to volumetric constraints
- EEG electrodes placed mainly near occipital lobe
- Unit should fit within 70mm x 70mm x 5mm (W x L x H)
  - 2cm thick pads
  - Rigid PCB placed in rear (position 4)
  - Margin of 1cm
  - Max height of component housing ~5mm



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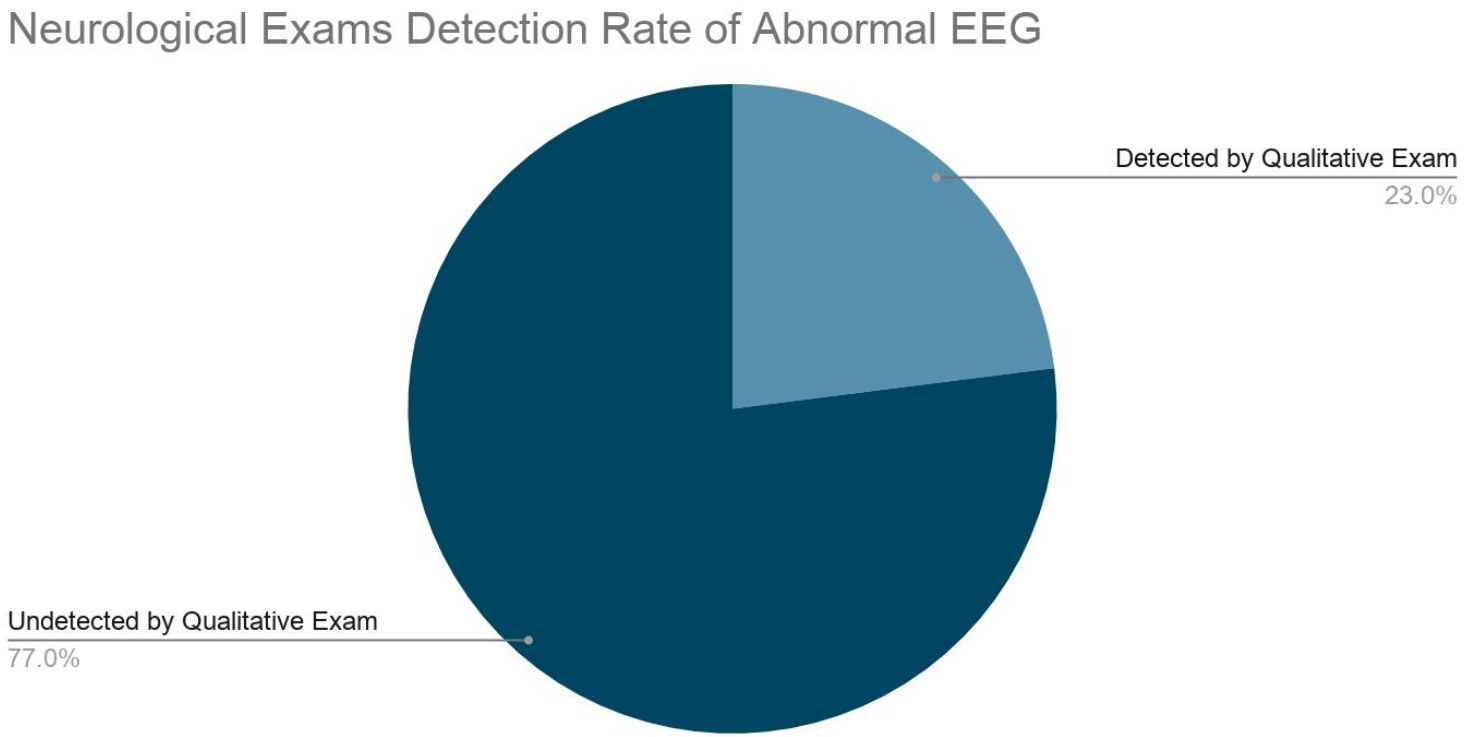
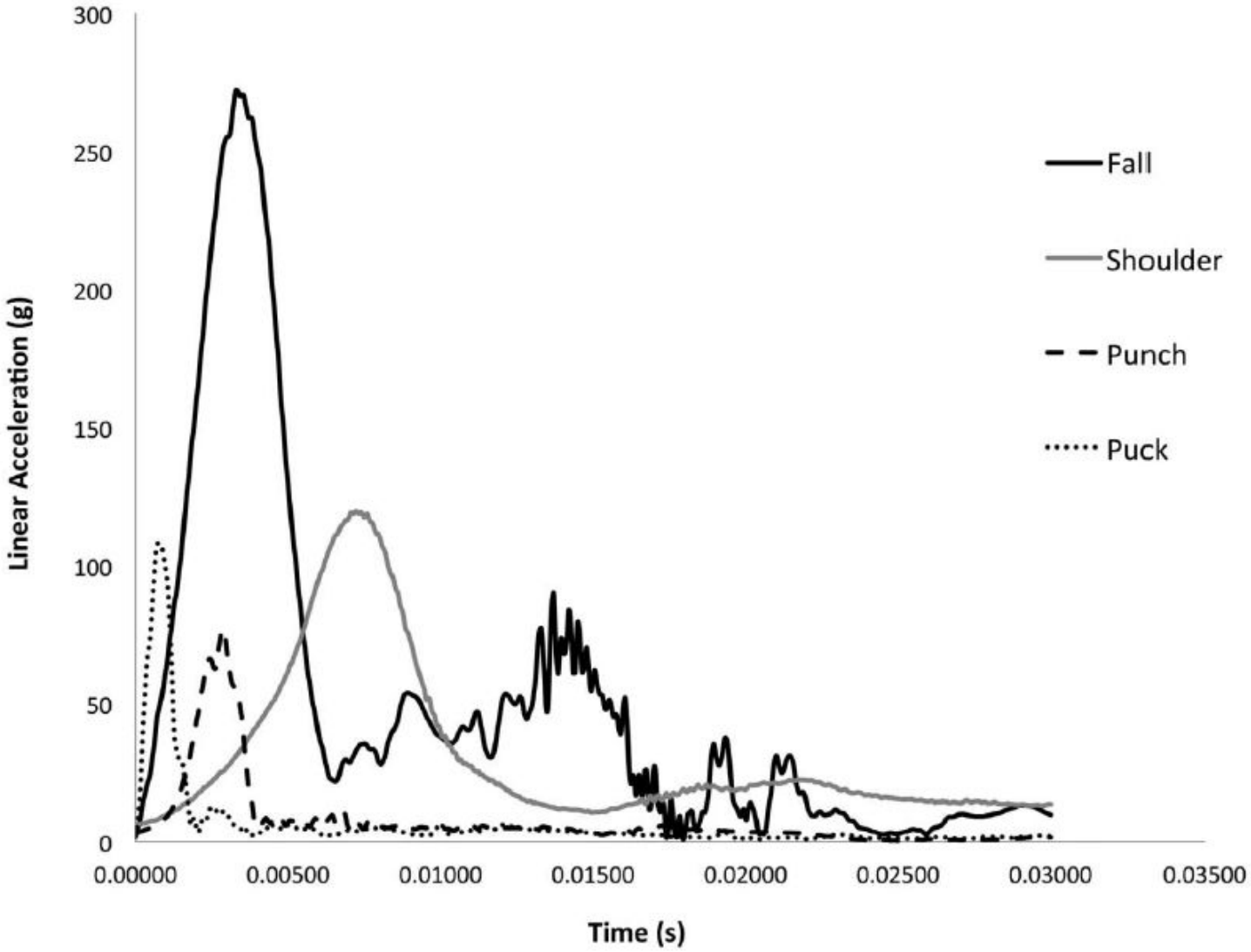
A Sensitive Tool for the Quantitative Screening of Head Injuries

- Electroencephalogram (EEG) analysis compared to neurological exams[5]
  - EEG analysis is shown to be **more sensitive** than qualitative neurological exams



[5] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5619208/

Linear acceleration-time curves



Impact Event	Peak Resultant Acceleration	
	Linear (*g*)	Rotational (rad/s^2)
Fall/Ice	264.4 (33.8)	11.204 (1867)
Collision/shoulder	112.5 (8.6)	9659 (728.5)
Punch	87.9 (9.8)	14.001 (1003)
Projectile (puck)	105.6 (14.6)	12.187 (2104)

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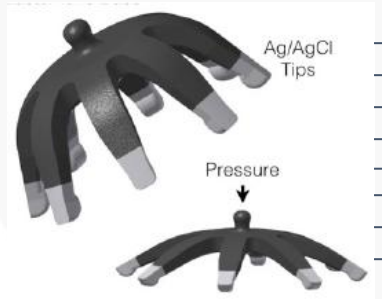
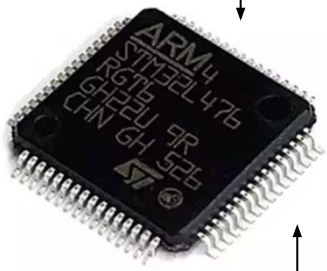
8-Channel System Overview



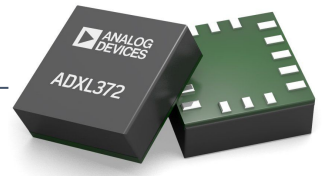
Analog Voltage ~5V

ADS1299 Biopotential Amplifier and ADC

Digital Voltage ~3V



STM32L4 Series Ultra-Low-Power ARM Cortex-M4 Microcontroller



ADXL372 High-Impact Ultra-Low-Power MEMs Accelerometer

Mass Flash Memory for Big Data Analysis and External Export

Emphasis on **high integration** and **low power**

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Electrodes

- Hot-pluggable systems allows for flexibility in electrode selection
- Most promising so far pictured below
- What mechanical connector should we use?
  - Direct through-hole solder joint seems most reliable for shock & vibration

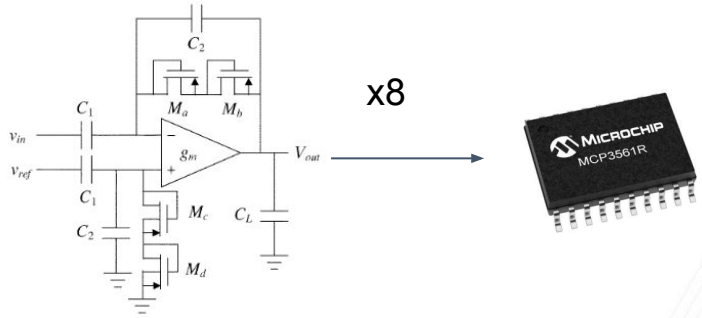
https://www.fri-fl-shop.com/product/reusable-5mm-ag-agcl-spike-snap-electrode-tde-212/

ADS1299 - Deciding Factors

Pros:

- High Integration/Small Footprint
- Simple Power Control
- Flexible Body Potential Bias Schemes
- High Resolution

versus



Cons:

- Cost

Bottom Line: While discretes were explored the ADS1299 offers the complete package, making up for its cost in reduced development time

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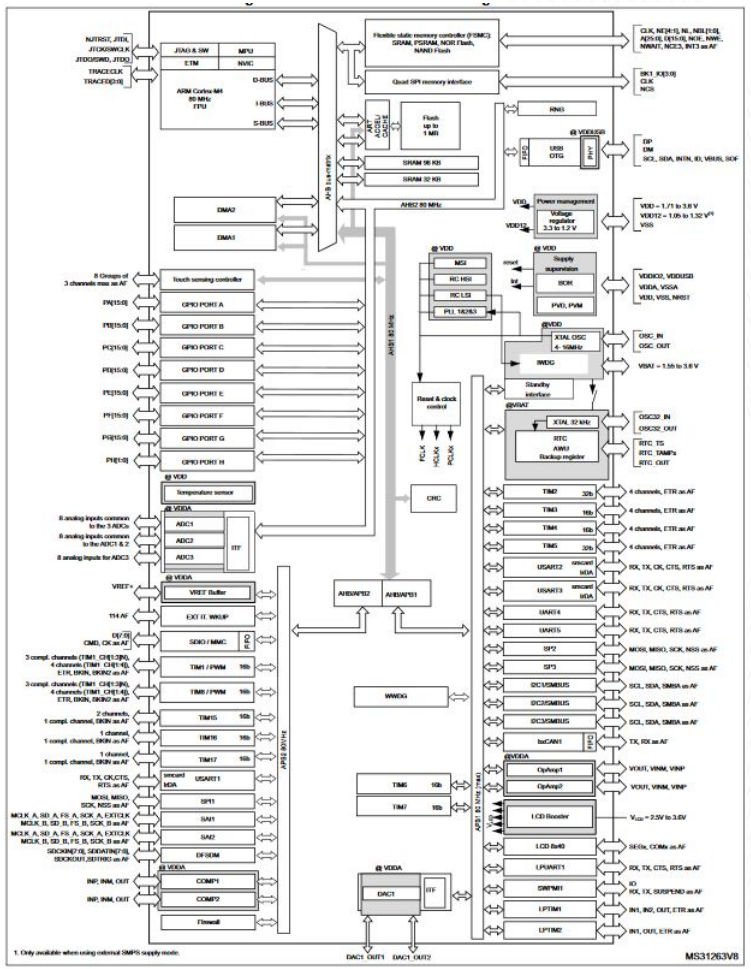
STM32L4 - Deciding Factors

Pros

- Low Cost
- Best-in-Class Ultra Low Power
- Best-in-Class Development Environment
  - ST HAL, STM32CubeIDE, CMSIS
  - MBED Enabled



Cons

- SDMMC 4 bit bus has silicon errata

Bottom Line: The STM32 microcontroller family is an industry staple. Tried and true, it just makes sense.

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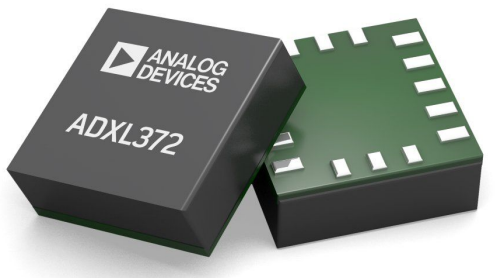
ADXL372 - Deciding Factors

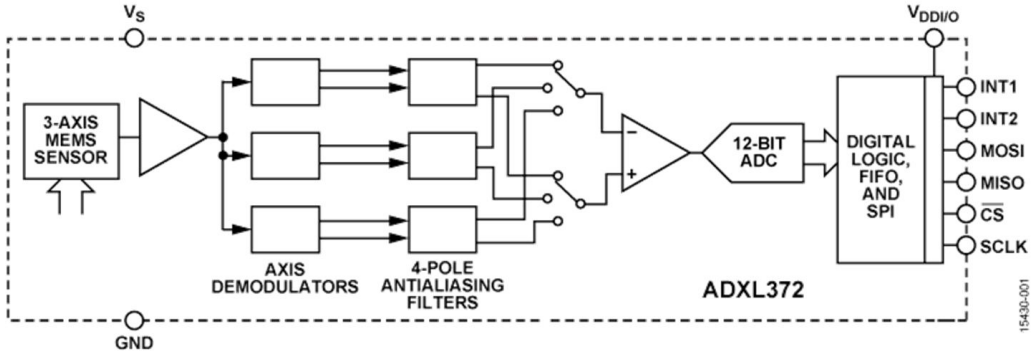
Pros

- Best-in-Class Ultra Low Power
- High Impact Capable
- Programmable Automated Interrupt Generation



Cons

- Cost



Bottom Line: While the ADXL372 is expensive, it is unparalleled in capability for our application - where power, measurement range, and interrupt handling are key factors.

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Mass Flash Storage - SDMMC

Pros:

- Cheap
- Easily interfaceable with ST HAL SDMMC
- Allows for simple export to an external PC
  - Good for exploratory algorithm development

Cons:

- Large footprint
- Weak link in environmental resilience
- Requires FatFs, a large middleware library

Power Consumption

- Alternate between analysis and low-power sleep modes
- Current Consumption

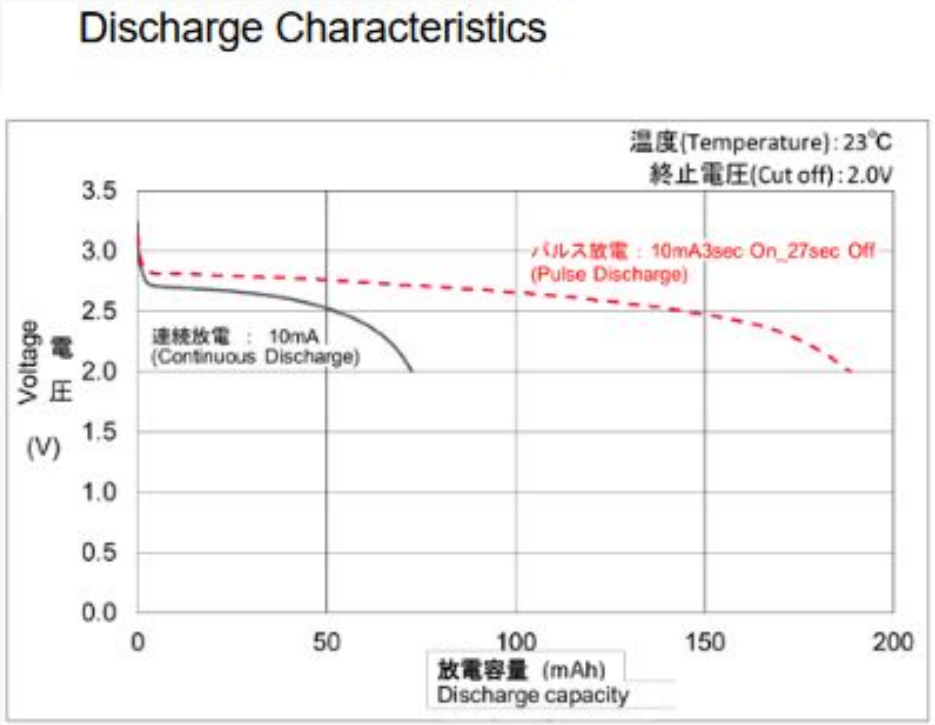
Op Mode	ADS1299	STM32L4	ADXL372	Total
Analysis	8.14mA	2.6mA	22uA	~11mA
Sleep	1.2uA	22nA	1.4uA	2.622uA

- Power supplied by coin cells
- Estimated battery life: 6-9 months

Power Delivery - Digital

Single Cell, Unregulated

IC	Operating Voltage	
	Min	Max
ADS1299	1.8	3.6
ADXL372	1.6	3.5
STM32L4	1.71	3.6



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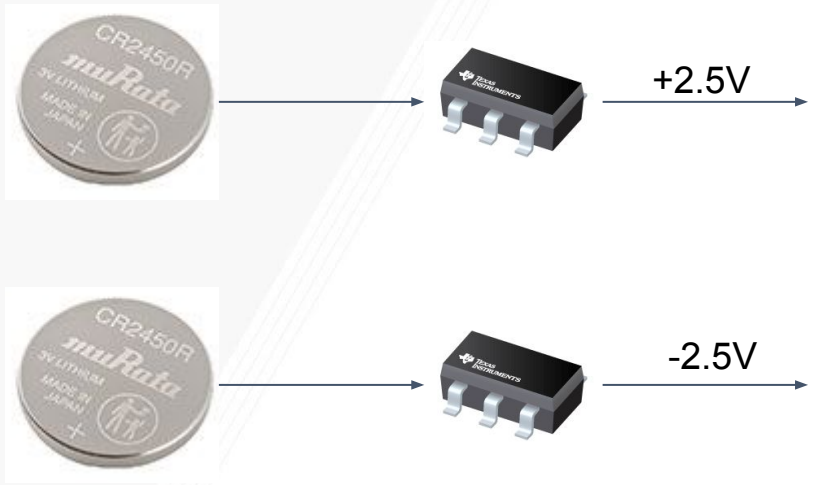
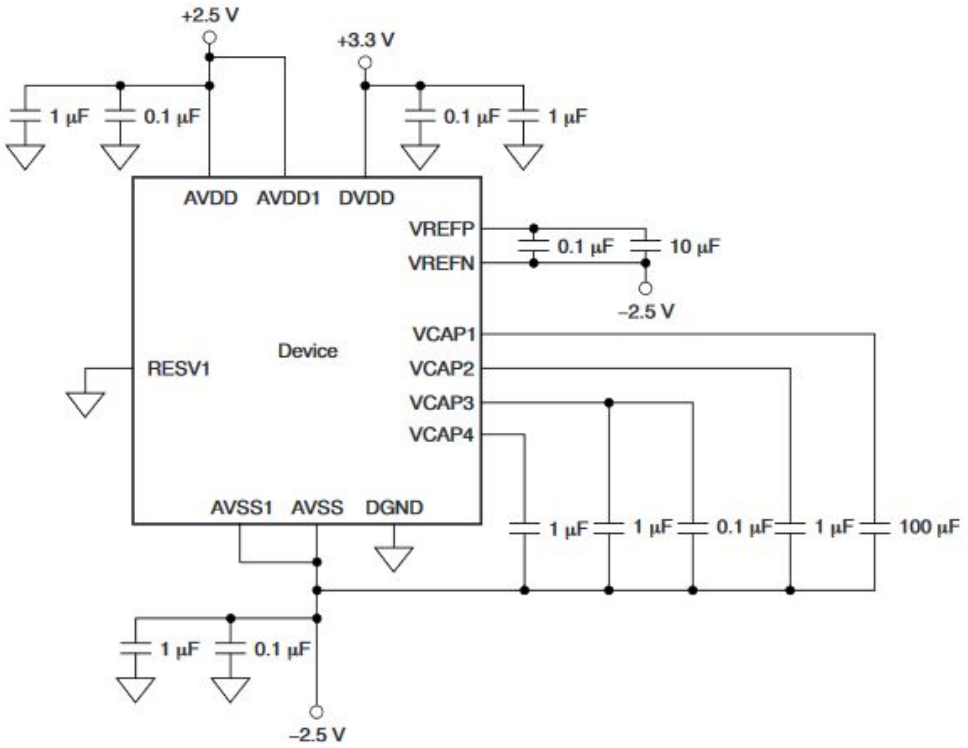
Power Deliver - Analog

- Low-Noise LDO Regulated
- Center-tapped AGND
- Ganged EN Pins to uController GPIO for absolute no-current state in idle mode
  - ADS1299 SHTDWN pin and LDO EN pins will be brought up in a single GPIO port mask





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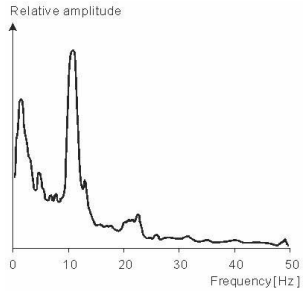
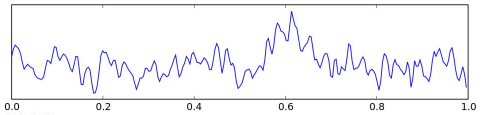
The Screening Signal Path





Electrodes

High Impact Sensor

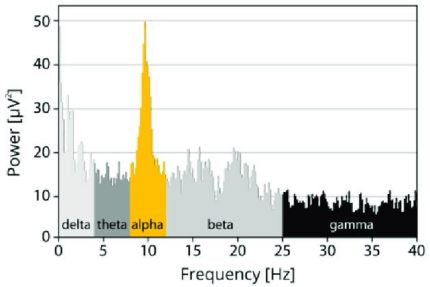
Analog Front-end and Digitization

Digital Signal Processing

Frequency Analysis

Power Analysis

Baseline Comparison and Notification of Abnormality



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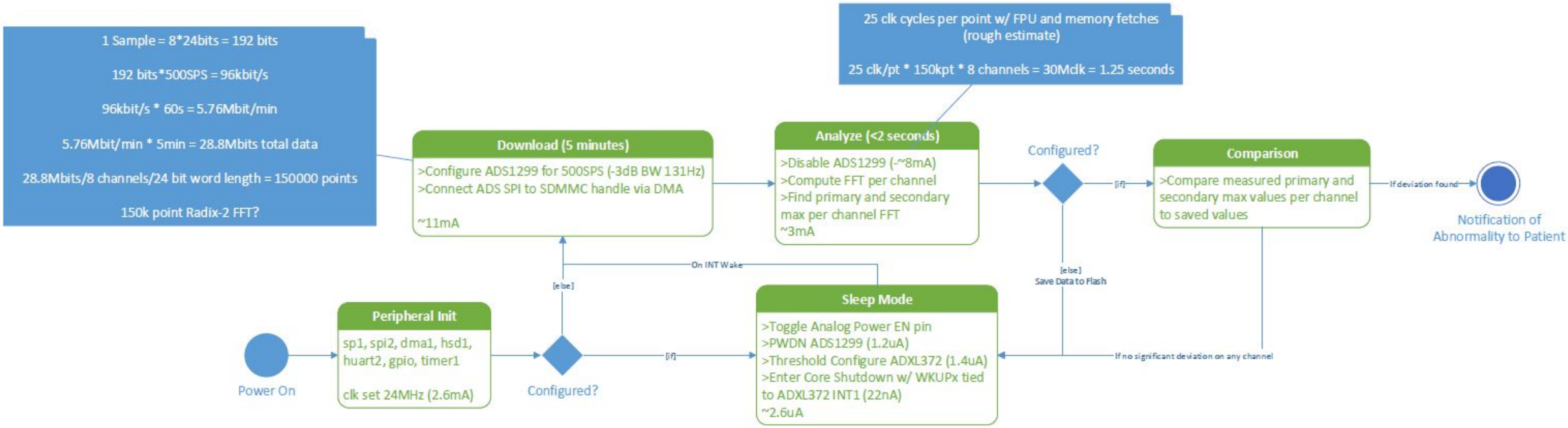
Firmware State Flow



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