Overview of Wearable Device Sensors

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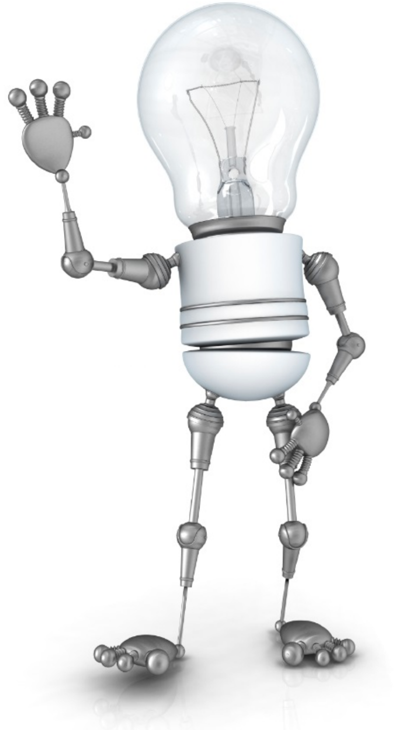
Product Development

Voler SYSTEMS

Agenda

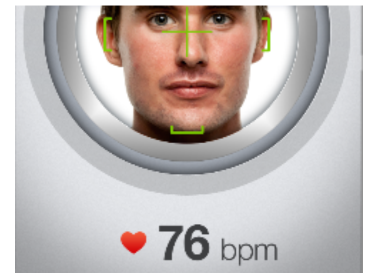
- Common physiological measurements
- Battery limitations
- Saving power



Innovation examples

FitBit
Activity Monitor

Elder monitor



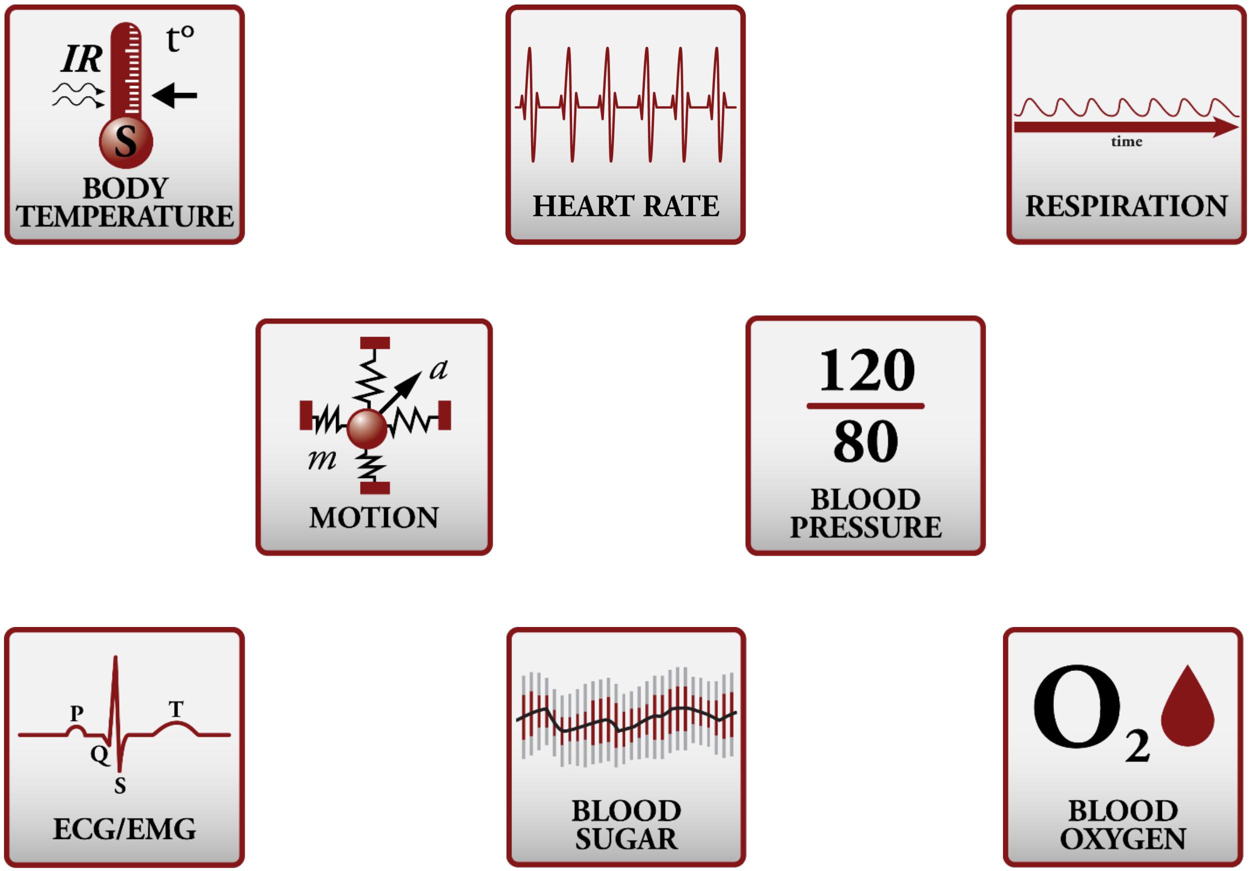
Azumio

Go Key

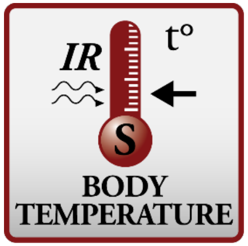
Bluetooth hearing aid

Game Golf

Common physiological measurements



Body temperature



- Few good locations to measure core temperature
  - Axilla (under arm) or forehead are best locations
  - Not convenient for a wearable device
- Extremeties (eg wrist) have variable temperature
- Algorithms can partially adjust over time
- Good contact is important – heat flow causes errors

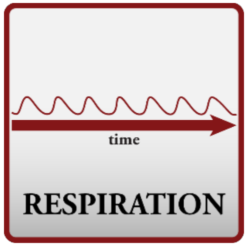
Heart rate

- Measured by
  - ECG electrodes – two are sufficient
  - Pulse oximeter sensing – reflected
    - Transmitted works on finger and ear
  - Pressure sensing of the pulse in the wrist
- Wrist measurement works well

Blood oxygen

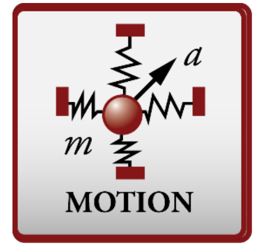
- Oxygen saturation in blood
- Measured by pulse oximeter (infra-red) technology
  - Measure loss through body of 2 IR wavelengths
  - Separates changes in blood from other changes
  - Measure pulse at the same time
- Transmissive or reflective measurement
- Reflective for wrist

Respiration rate



- Number of breaths per minute
- Few good locations to measure
- Movement of chest
  - Chest strap
  - Not convenient for a wearable device except shirt
- Thoracic Impedance eliminates chest strap
- Does not work on wrist

Motion

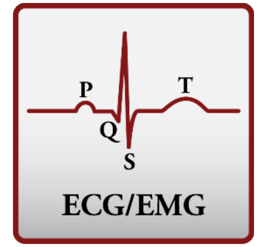


- The most studied and used parameter
- Step counts
- Gait analysis (illness)
- Types of motion (walking, standing, sitting)
- Dead reckoning (9-axis motion)
- Works on wrist, ankle, torso, etc.
  - Different algorithms at different locations

Blood pressure

- Measure of systolic and diastolic pressure
- Accurate measurement requires pressure cuff that is compressed and released
  - Does not work on wrist
- Pulse Transit Time – measure at wrist or elsewhere
  - Currently not accurate enough

EKG / EMG / EEG



- Measure of electrical and muscle activity
- EKG measurement points have to be rather far apart
  - At least one and a half inches – larger devices needed
  - More leads is better (up to 12 for standard ECG)
- EMG requires accurate placement (millimeters)
  - Measure the wrong muscle
- EEG must use electrodes on the head

Blood sugar (glucose)

- Measure of glucose level in blood sample
- Widely used
- Becoming a wearable
- Closed loop system replaces the pancreas
  - Measure and control glucose with a pump
- Attempts to not use finger tip – less accurate
- Not accurate on wrist

Agenda

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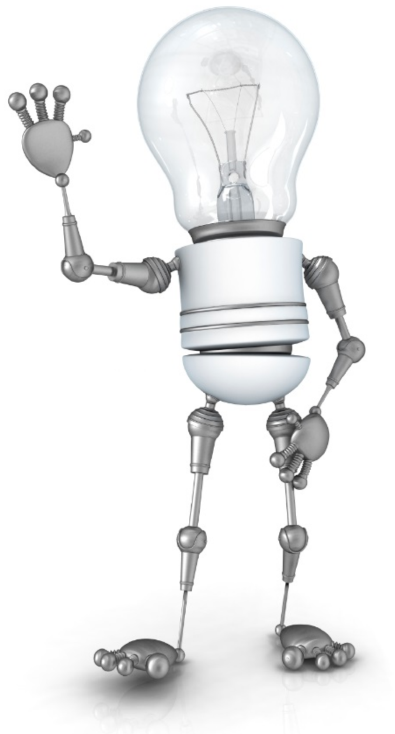
- **Battery limitations**
- Saving power

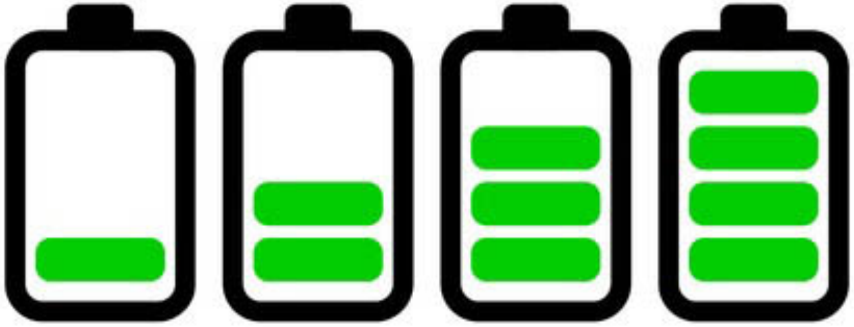


Battery Limitations

- Slow pace of improvement

  If improved like semiconductors:

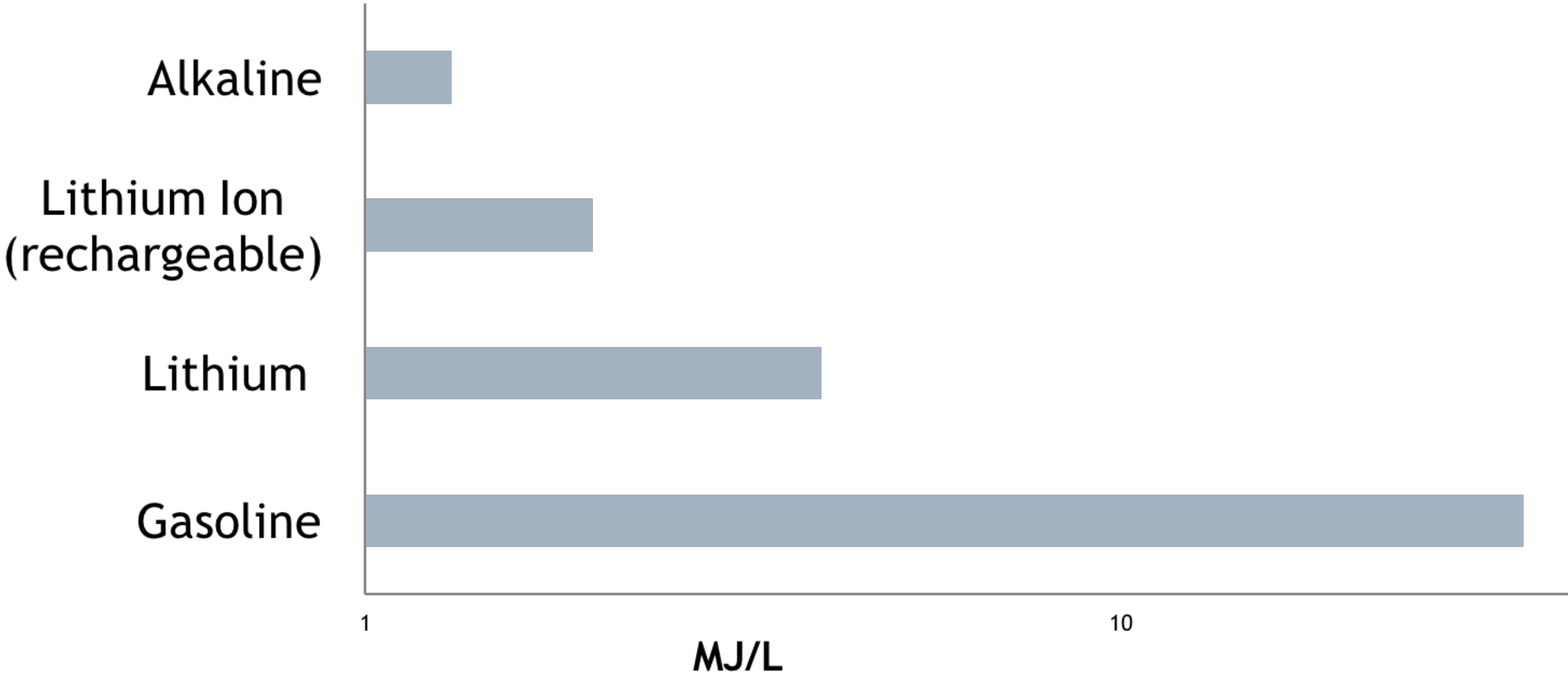
  Size of a pin head, could power your car, cost 1 cent
- Must always work around limitations
  - Long time between charging vs small size
- Battery life per charge



When will battery technology improve?

- Chemical energy storage is approaching the limit of its efficiency
- Nuclear energy is out of the question
- A lot of research being done on higher density and better safety
  - Perhaps 2 times higher density in a few years
  - Will safety suffer?

Energy Density



Energy Density and Safety

- As energy density has increased, safety has become more of a problem
- Safety circuits are required on Lithium batteries
- Poorly designed batteries can catch fire even with safety circuit
- Shipping of Lithium batteries is restricted and regulated
  - Cells without safety circuit cannot ship by air

Agenda

- Common physiological measurements
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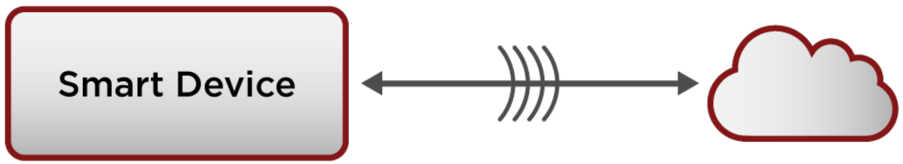
- **Saving power**

6 areas that impact power

- Wireless
- Displays
- Sensors
- Microprocessors
- Software

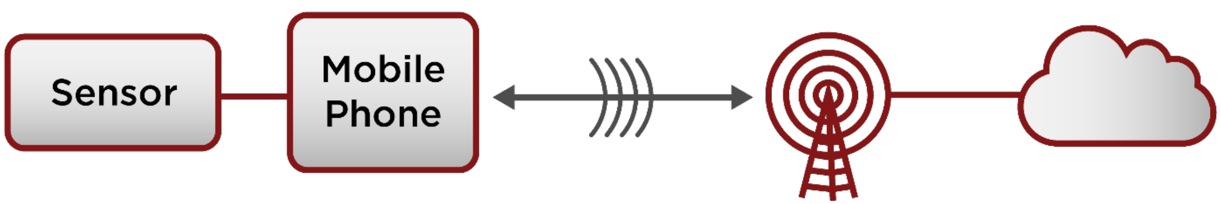
Three ways to get data into the cloud

1. Smart device directly to cloud



2. Sensor to gateway to cloud

3. Sensor to cell phone to cloud



Power- How much? How far?

	10 bytes/sec	1 Kbytes/sec	1 Mbytes/sec
1 m	lowest power	data rate	
100 m	distance		
1 km			highest power

All units in mW

Power- How much? How far?

	10 bytes/sec	1K bytes/sec	1 Mbytes/sec
1 m	BLE/Zigbee 0.15 LoRa 0.5 Bluetooth 25 WiFi 50	BLE/Zigbee 7.5 Bluetooth 50 WiFi 75	WiFi 300
100 m	LoRa 0.5 WiFi 100 3G Cellular 100 LTE Cellular 100	WiFi 100 3G Cellular 120 LTE Cellular 120	WiFi 400 LTE Cellular 500
1 km	LoRa 1 3G Cellular 120 LTE Cellular 120	3G Cellular 150 LTE Cellular 150	LTE Cellular 700

All units in mW

Voler SYSTEMS

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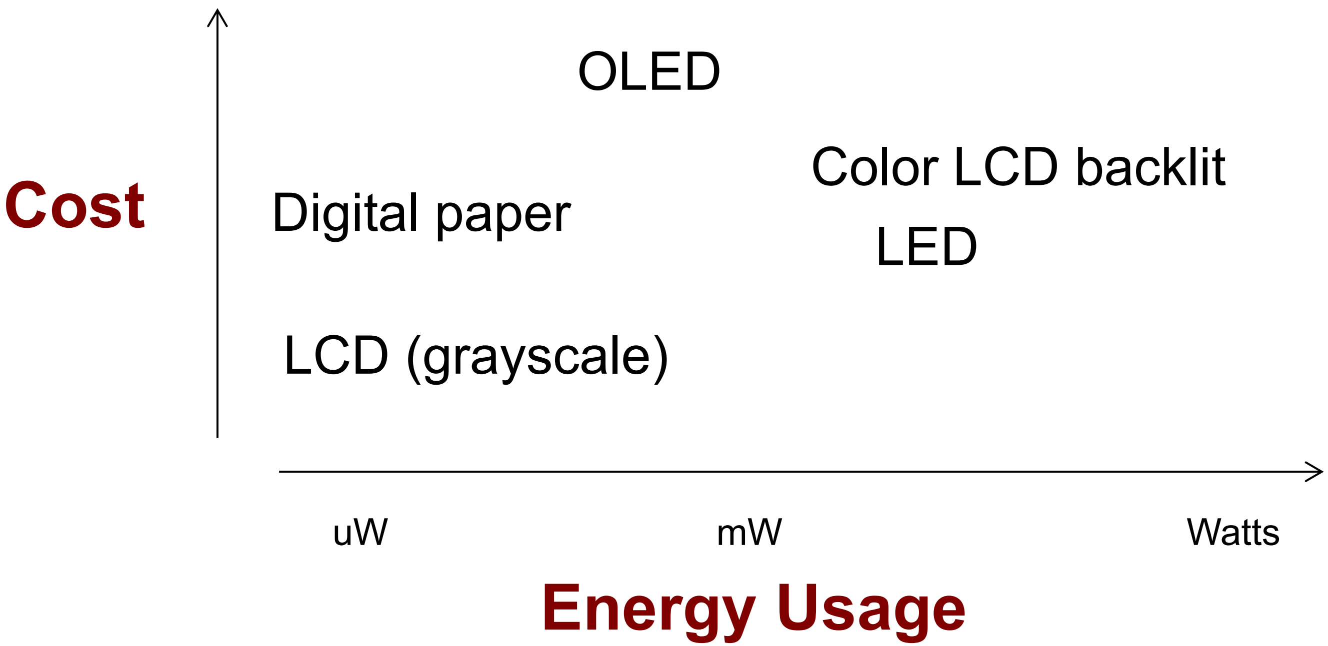
Display Technologies



Emerging Technology: Digital Paper (eInk)

- Nearly zero power when not changing

But:

- Not available in color (this is changing)
- Slow – can’t display video
- eInk kept prices high until they lost a patent fight in 2015
  - Market may expand now

Agenda

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- ✓ Displays
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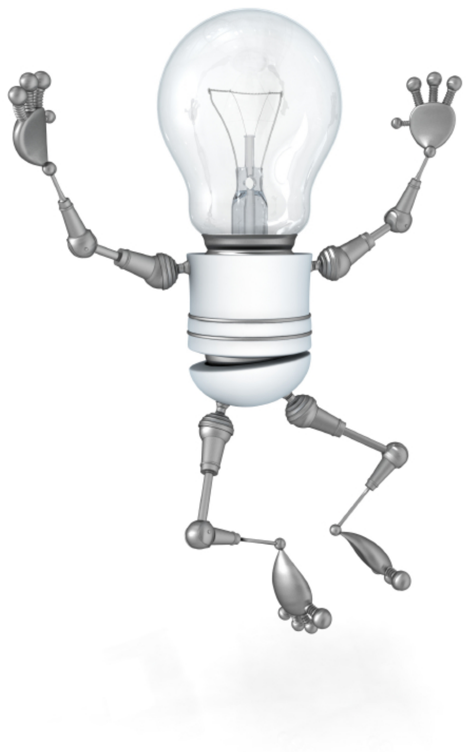
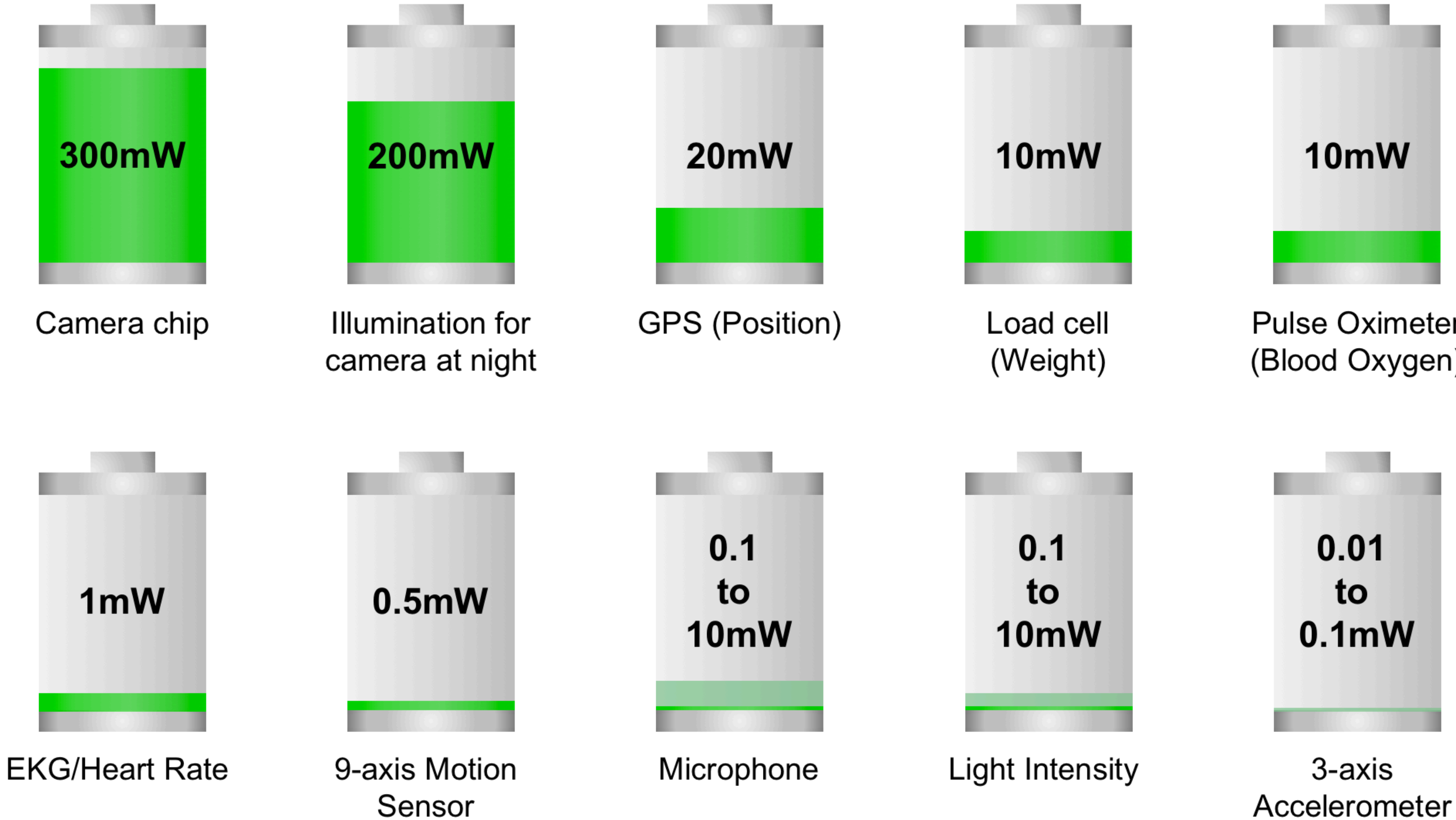
- Microprocessors
- Software



How much power do sensors use?



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- ✓ Displays
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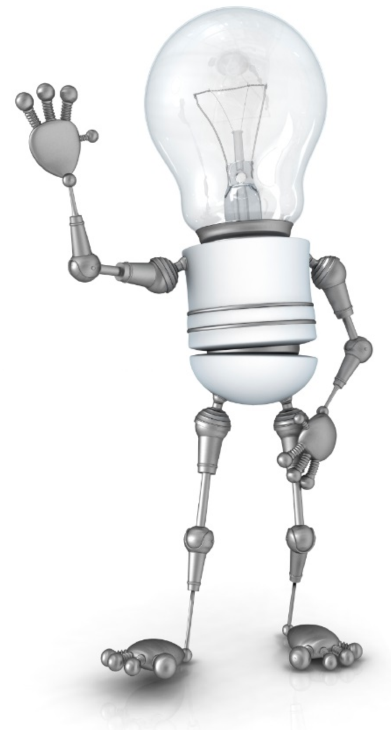

Microprocessor Power

- Low data rate sensor data collection: 1 to 10 mW
- Audio Compression: 10 to 100 mW
- Video Compression: 100 to 1000 mW
- Multi-processor running several Windows tasks: 5 to 50 Watts

Agenda

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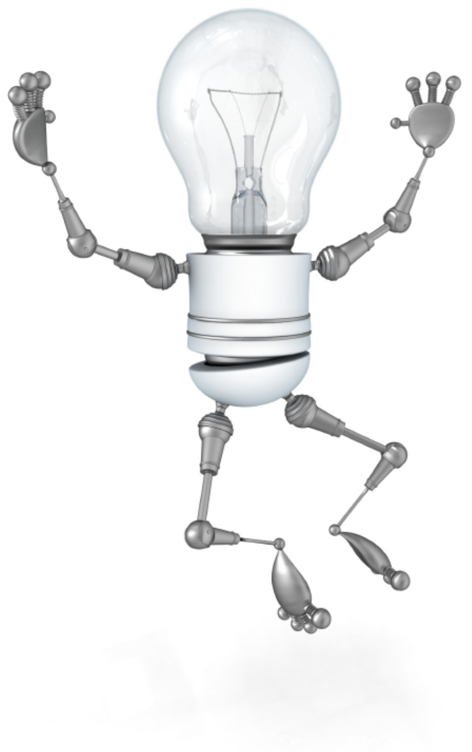

Common causes of power consumption issues

- Inefficient use of the cellular & WiFi network
  - Sending small data packets
- Not putting the processor to sleep
- Keeping the display backlight on too long
- Sampling data too often
- Using high power sensors when lower power sensors are available
- Inefficient (frequent) messages from an app

SUMMARY: Total Power of the System

- Sensor + Processor + Display + Wireless
- Low: 0.01 mW
  - 3 axis accelerometer, processor asleep, no display, Bluetooth LE sends one sample every hour
  - Runs years on a coin cell
- Medium: 1 mW
  - GPS every minute, processor making decisions, LCD display, no backlight, WiFi transmits once a minute
  - Runs 2 months on one AA Alkaline battery
- High: 1000 mW
  - Cell phone, many sensors, high power processor, color LCD display with backlight, always connected to WiFi and cellular
  - Runs a few hours

Latency for the Same Examples

- Low Power, 1 Hour latency
  - Bluetooth LE sends one sample every hour
- Medium Power, 1 Minute Latency
  - WiFi transmits once a minute
- High Power, Latency of milliseconds
  - Always connected to WiFi and cellular

SUMMARY

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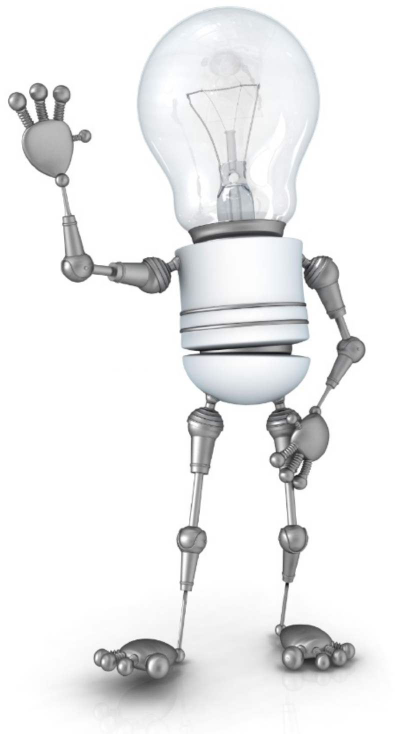

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Quality Electronic Design & Software

Sensor Interfaces

Wireless

Motion Control

Medical Devices