Design considerations for low power sensor systems

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About me

- Embedded FW / Applications Engineer
- Electrical Engineering (Masters)
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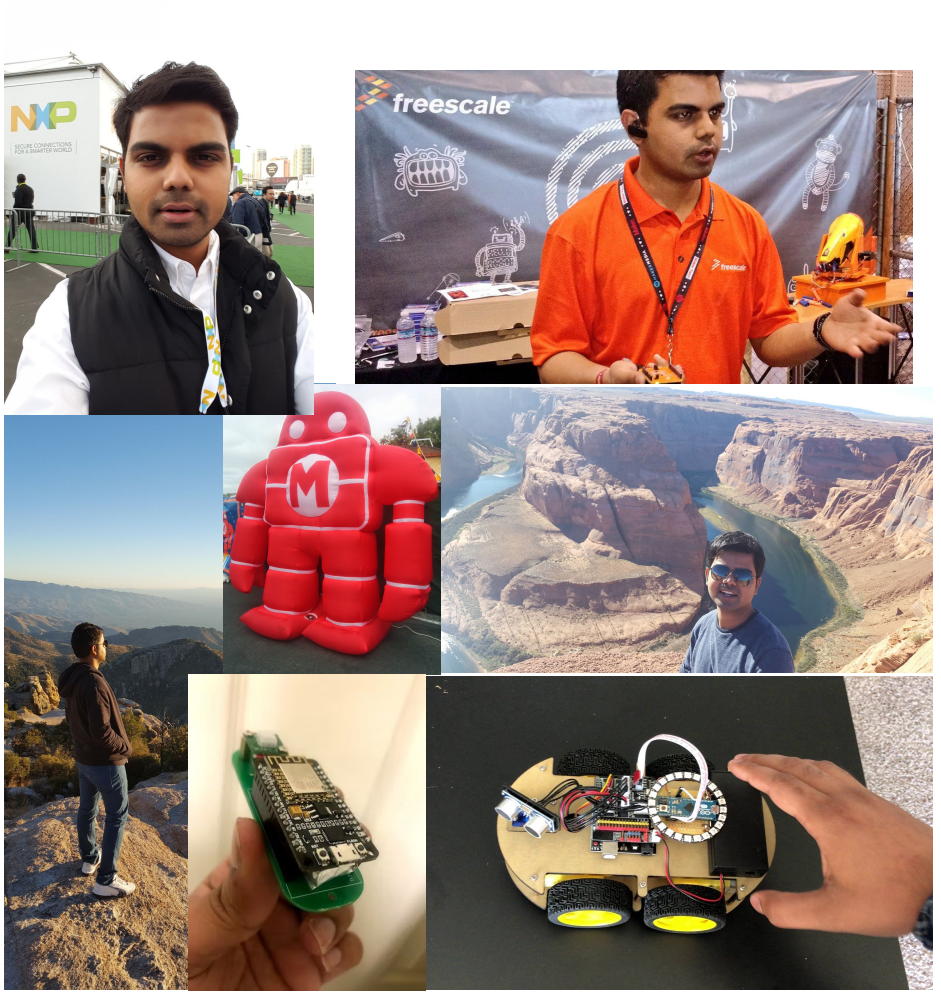
- Maker, Garage Tinkerer, Curious coder



About me

NXP

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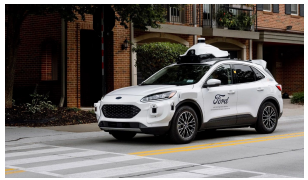

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

LiDAR

Capgemini engineering
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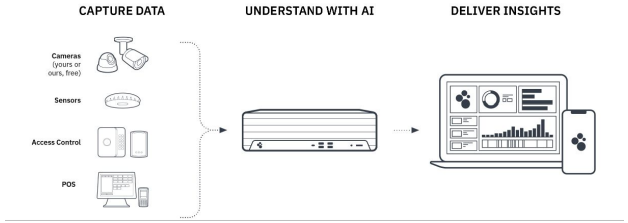


Reference images from Internet

Need for low power sensing

- Greener systems with extended battery life
- Portable - place the sensors anywhere not just where power is available
- Deployment to inaccessible locations where battery replacement is difficult/expensive

  ex: oil/gas
- Reduced BOM costs, small form factor designs.
- Saving every mA or even uA counts!

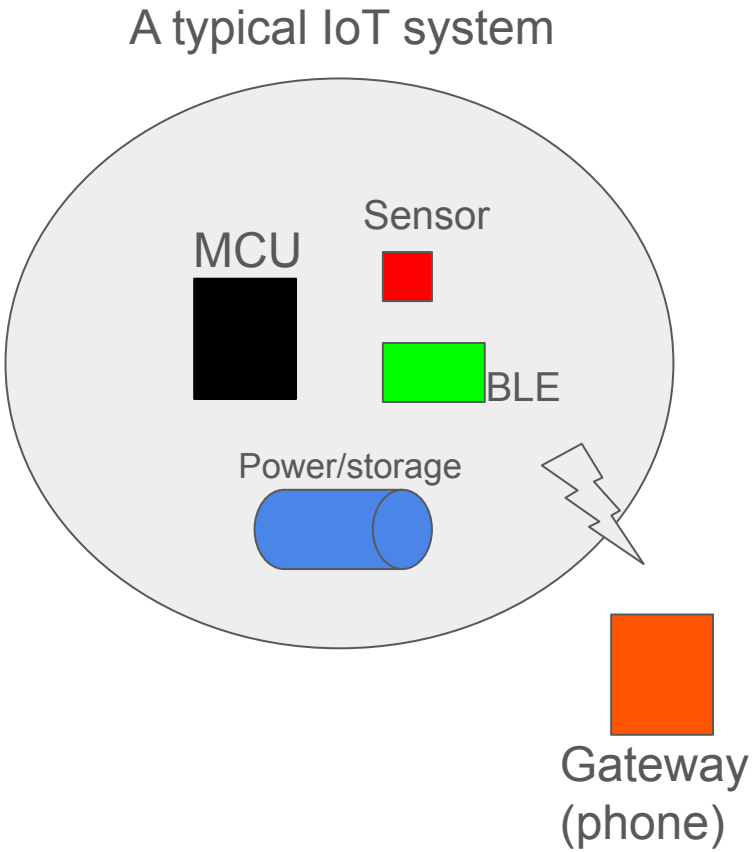
  Typical smartphone consumption:

Reference images from Internet

Battery Life ~ 15 hrs, Battery capacity ~3000 mAh ⟶ Avg current 200 mA

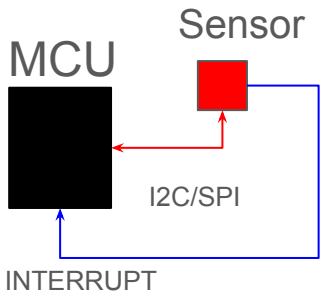
Key system design factors

- MCU power modes and external interrupts
- Sensor power modes and concept of power gating
- MCU free systems
- FIFO buffer, DMA and more
- BLE
- Energy Harvesting



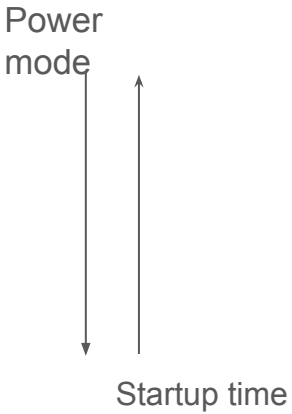
MCU low power modes & External interrupts

- Polling vs Interrupt modes
- MCU can be in sleep mode until data is available from sensor (external wake-up event)
- Added intelligence in sensor to filter out for events - tap, freefall, temperature, pressure alert etc. (avoids data analysis overhead in MCU)
    - Sensor with mux'd interrupt sources



MCU low power modes & External interrupts

- 3 basic power modes of MCU (ex: ARM)
  - **Run** - processor fully on
  - **Sleep** - CPU clock off, system/peripherals/flash clocks on. NVIC (Nested Vectored Interrupt Controller) enabled (synchronous wakeup)
  - **Deep sleep** - all the above off, asynchronous wakeup interrupt sources configured
- MCU Wake/Startup time and low power modes are inversely proportional
- RAM retention - tradeoff write to & read from flash instead?

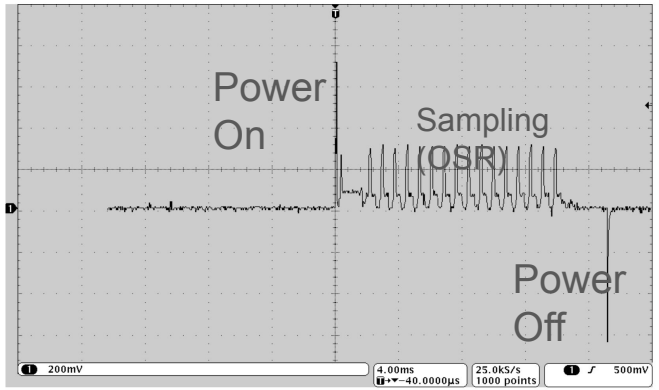


Typical MCU current consumption

Mode	**Current**
Run	8 mA
Sleep mode	~500 uA - 3 mA
Deep sleep mode	~ 100 nA

Sensor power modes & Power gating

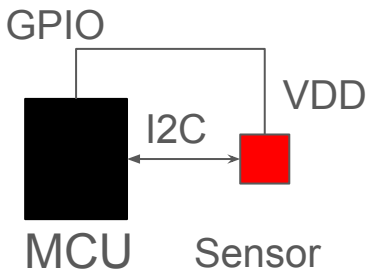
- Active mode (highest ODR)
- Lower power states & configuration settings retention
  - Standby - retained
  - Shutdown (OFF) - lost
- Oversampling ratio (OSR) - how many averages per sample?
- Power gating the sensors for low duty cycle applications using GPIO
  - Downsides with data output time as opposed to standby mode
  - Sensor noise



Reference: NXP

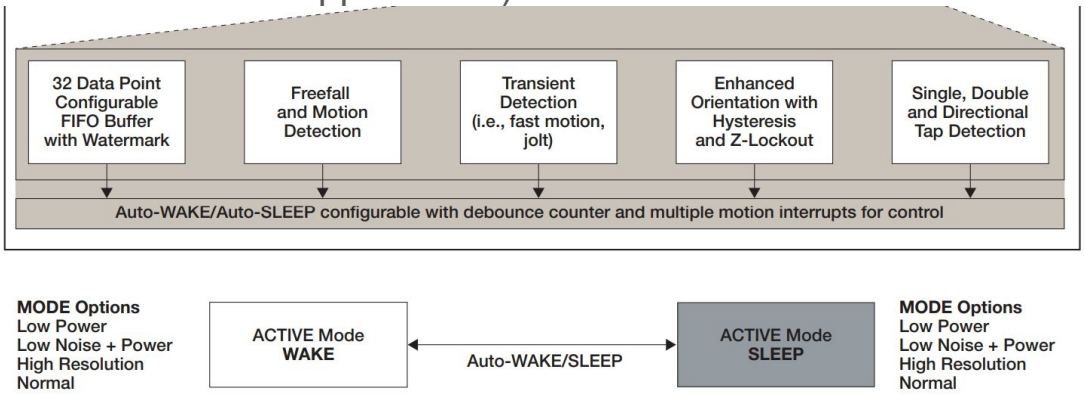
Typical sensor current consumption

Modes	**Current in uA**
Active (high ODR, high resolution)	~20
Standby	2
Shutdown	-



Sensor intelligence

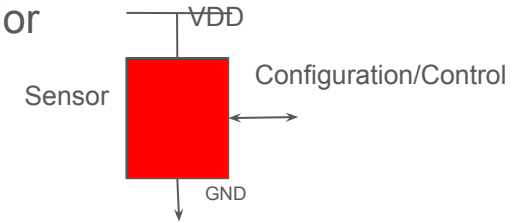
- Integrated ASIC features for event detection - orientation, freefall
- Dynamic data rates and power management (automatically increase or decrease data sampling rates as needed)
- Dedicated interrupts/flags for various event detection with mux capability (much needed for pin resource constrained applications)

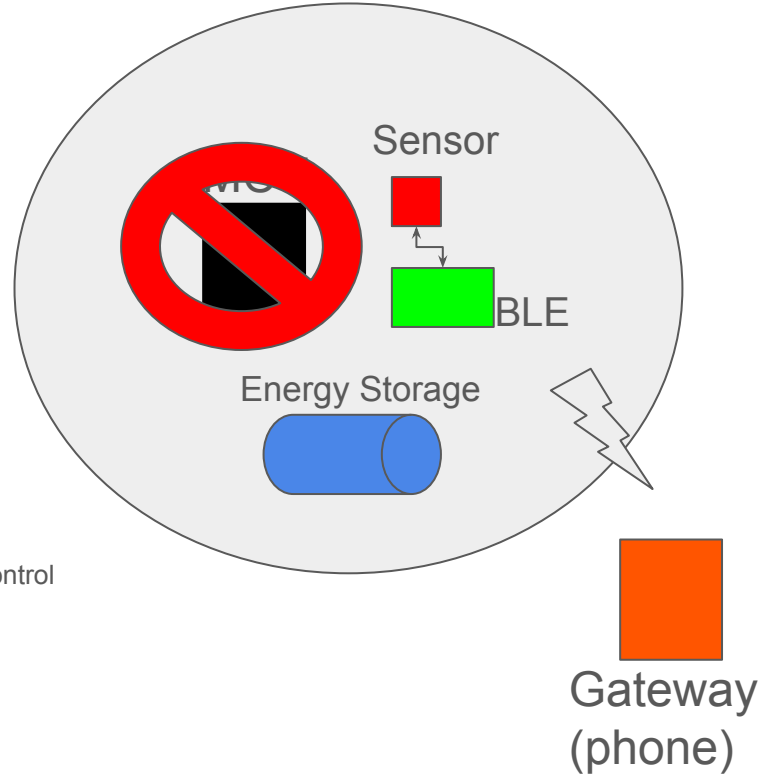


Reference: NXP

MCU free systems

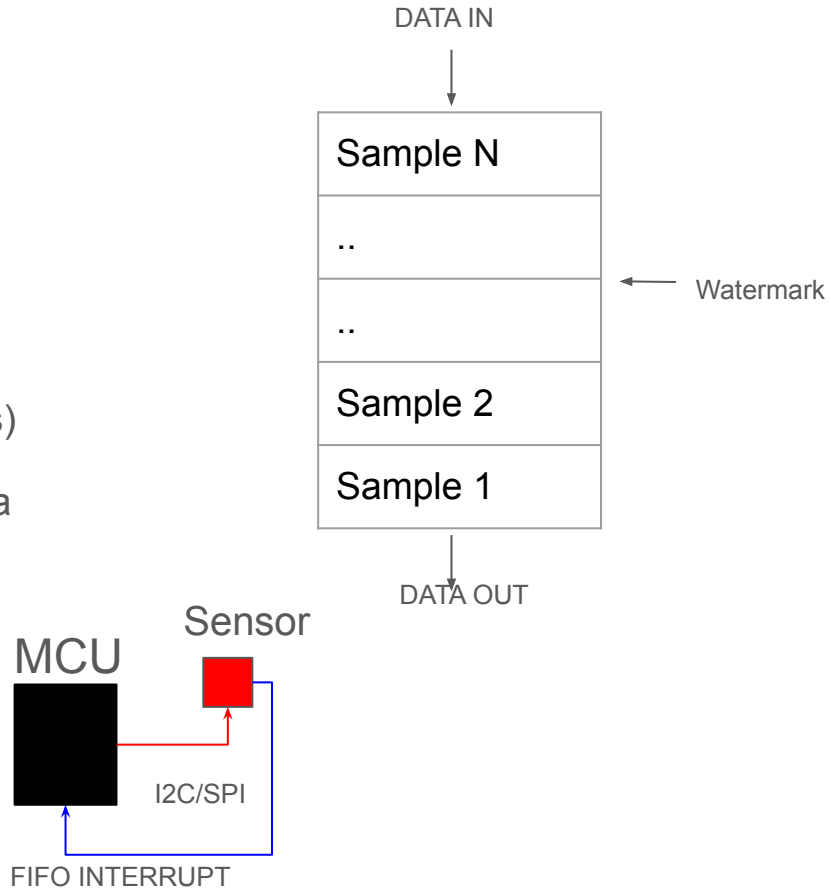
- Tilt switch / Motion activated switch
- One wire interface (bidirectional)
  - Configuration (thresholds, data rate)
  - Control
- Output can be configured to latch or have pulsating behavior





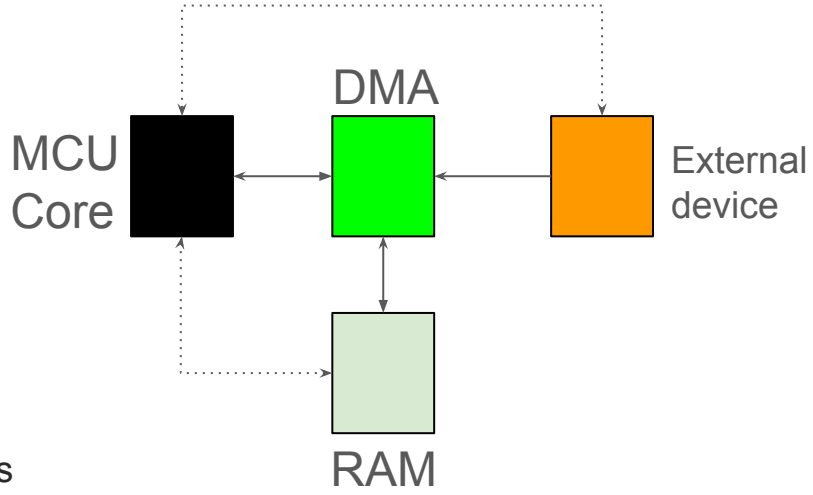
FIFO Buffers

- FIFO - First In First Out buffer
- Localized storage in sensor. (Typically few kB)
- MCU can be in deep sleep mode, until it needs to process data from sensor (when buffer overflows watermark level is reached or trigger event occurs)
- No need to interrupt the MCU every time there is a new sample from sensor
- MCU can perform burst data read - reduced protocol overhead (I2C/SPI or other)



DMA

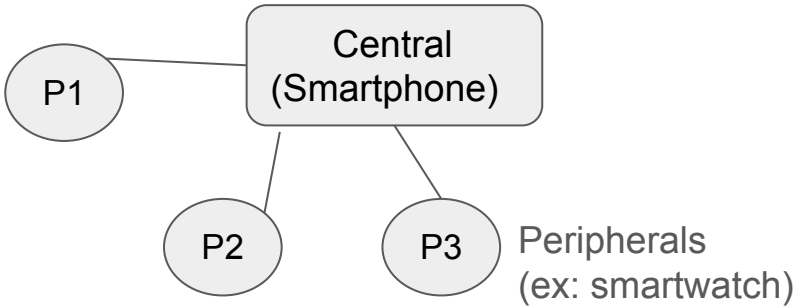
- DMA - Direct Memory Access
- Efficient way to transfer data around the microcontroller without the CPU Core intervention.
- Suited for resource constrained applications,
- Examples:
  - reading in data bytes from a UART and placing them in memory for later processing while CPU in deep sleep mode.
  - ADC conversion and storage for analog sensors
    - LPTMR resource is used to initiate ADC conversion



BLE

- Bluetooth Low Energy - low power variant of classic bluetooth (complimentary, not a replacement!)
- Optimizations
  - Advertising interval (Beacons)
  - Advertising data length
  - Connection interval and payload
  - Peripheral latency - skip connection events

State	Current (Avg)
Idle	< 20 uA
Advertising	~10 mA
Connection	~ 30 mA



Energy Harvesting / Free energy

- The energy harvested from the actuation of the switch is sufficient to communicate the switch actuation state via BLE beacons reliably without the need for any additional battery.
- Applications
  - Door state sensing
  - Indoor lighting & wireless actuation

Reference: ON Semiconductor