A Technical Introduction to The Internet of Things

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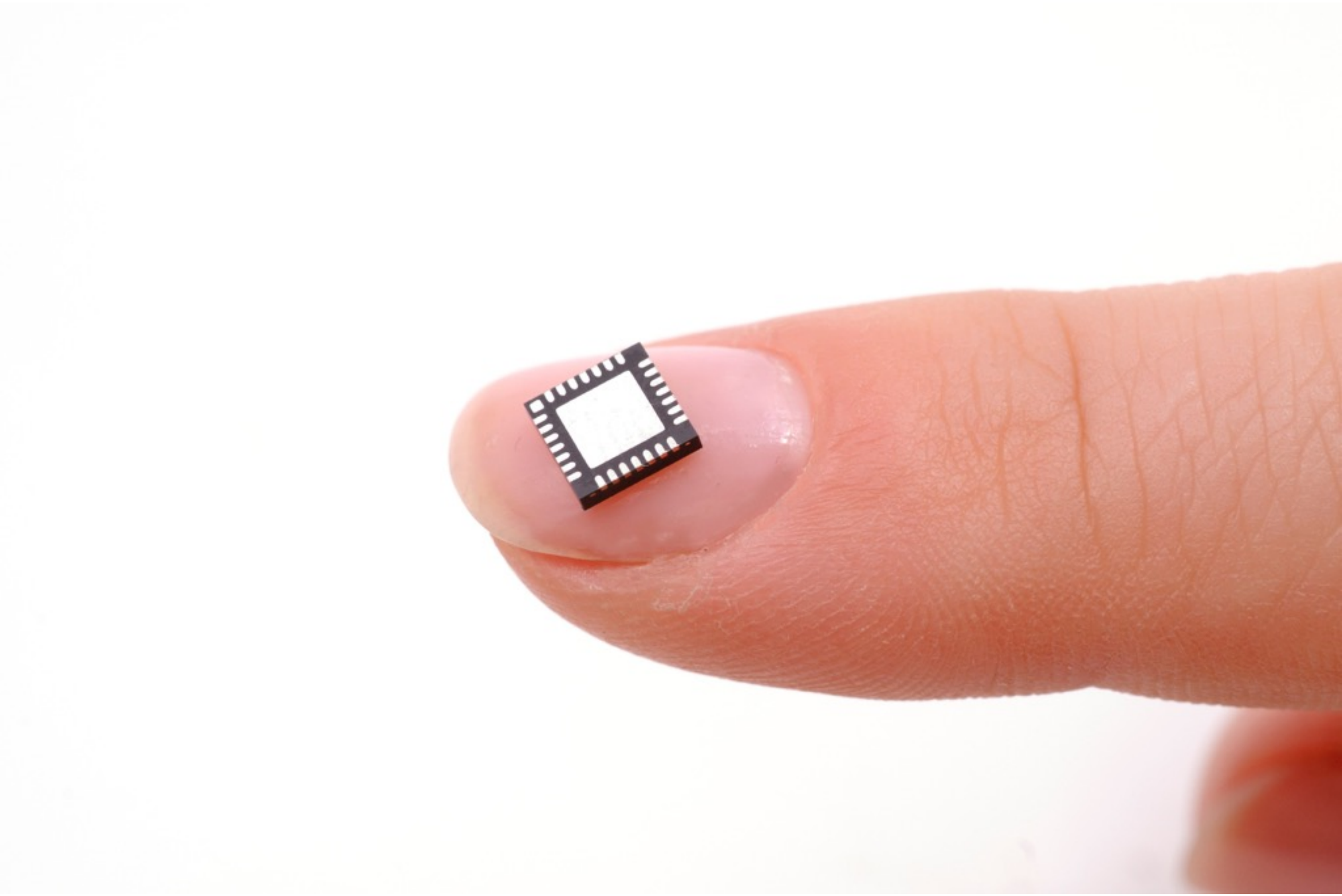
We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory.

Kevin Ashton, RFID Journal, June 2009



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The Internet of Things is Small

- Small Microprocessors
- Small Sensors
- Small amounts of memory
- Small messages
- Small antennas
- Small wireless transactions

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The Internet of Things is Big

Your **microwave oven**, washer, **dryer**, dishwasher, **coffee maker**, refrigerator, **VCR**, television, **video game console**, stereo receiver, **CD player**, DVD player, **remote controls**, garage door openers, **sprinkler systems**, phones, **answering machines**.

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The Cliché of the Connected Fridge

- It knows what you put in
- And what you take out
- It will tell you when you run low
- It can order more food for you
- Your fridge knows how healthy you are

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The Reality of the Connected Fridge

- Commercial & Industrial Refrigerators
- Every shop, warehouse, & commercial kitchen
- Critical to the safety of the food system
- Governments are starting to regulate them
- IoT “connected fridge” will save time & money

Heating Houses & Buildings

- Major use of Electricity & Gas
- Very uneconomic & unscientific use
- Can we do this better with IoT?

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The Common Thermostat

- Requires daily human intervention
- Relies on limited data
- Works sometimes, approximately
- Nest IoT thermostat learns behaviour
- Acquired by Google for a billion dollars

Utilities: Smart Metering is IoT

- Mechanical meters have no power
- Frequently have no sunlight
- Hard for humans to read & maintain
- New batteries & wireless solve problems

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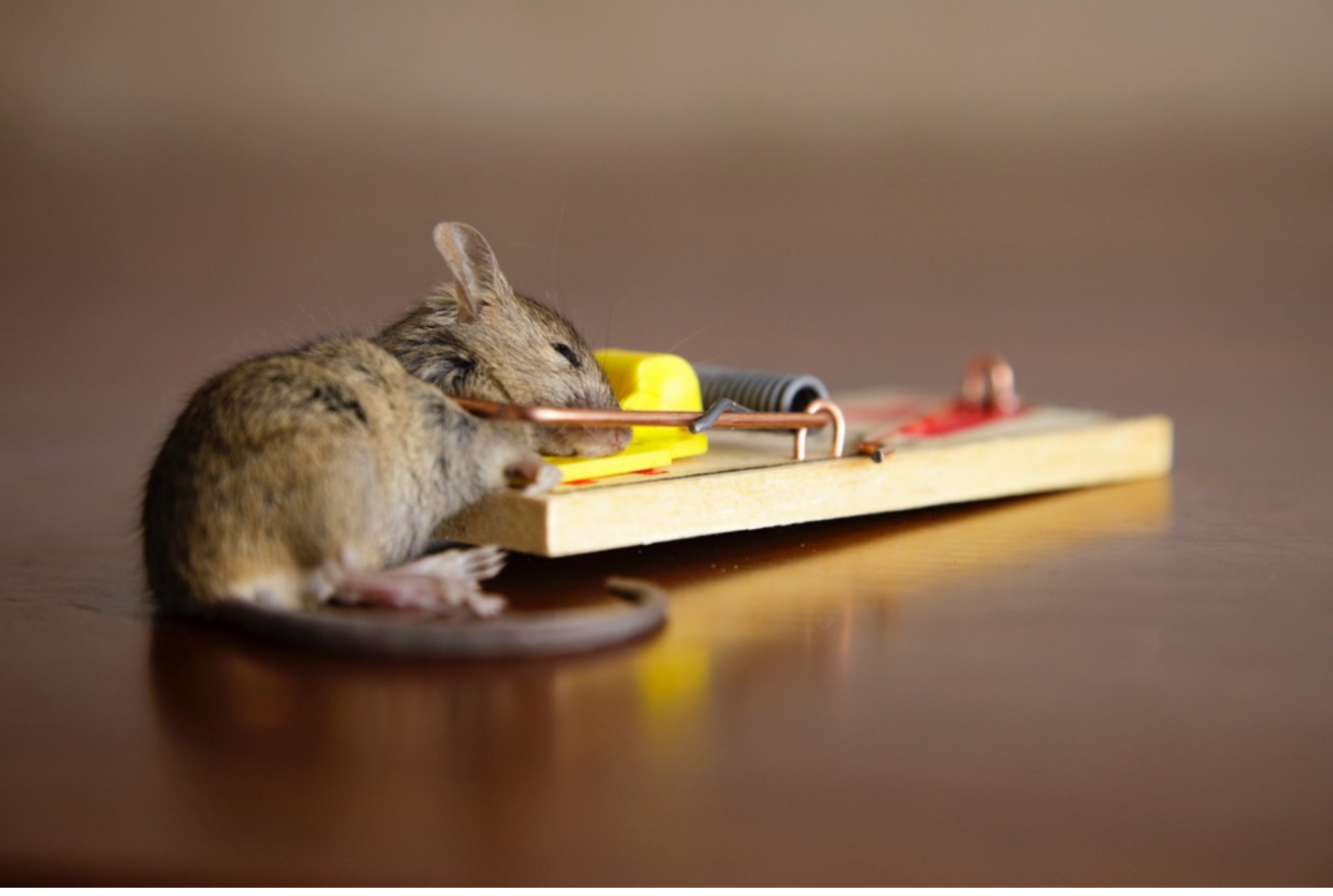
Utilities: IoT for Infrastructure

- Not just for automated meter reading
- Transformers last 20+ years
- Take them out too early, you lose money
- Leave them in too long, they fail in place
- Monitor their temperature & voltages with IoT!



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Retail & Food: IoT for Safety & Compliance

- Traps are under shelves, behind counters, in the dark
- UK law says clear traps within 24 hours
- Supermarket employees spent a lot of time checking
- Neul (Huawei) & Rentokil designed an IoT mousetrap
- Saves hours of employee time every day

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City Maintenance: IoT Saves Time & Money

- Smart trash cans in Milton Keynes
- City employees used to check them every day
- Now sensors alert the city to full trash cans
- Saves time, diesel fuel, people hours

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City Maintenance: IoT Saves Time & Money

- Streetlights are on light sensors or timers
- They only turn on at night
- Check, at night, to see if they're working
- Or wait for a report from the public
- Inexpensive IoT sensor solves this problem!

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IoT for Traffic Management

- What does parking have to do with traffic?
- Better parking information, less driving around
- less driving around = less traffic!
- Garages can display number of free parks
- IoT light sensors can help

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IoT for Shipping Containers

- What's in that container?
- Timber? Milk Powder? Coffee? Electronics?
- Can it get hot? Damp? Can it be shaken?
- IoT Sensors can record conditions
- Assurance for customers of proper shipping

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IoT for Tracking Containers

- Where's your container?
- Tracking used to be thousands of dollars
- GSM tracking now < $100
- Satellite tracking < $500
- If tracked, use for sensor telemetry too

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IoT for Maritime Safety

- Maritime lights are like streetlights
- Except they're much harder to check!
- IoT can provide assurance lights are working
- Weather data, tide height, tsunami warning

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IoT for Pivot Irrigators

- The pivot irrigator enables modern agriculture
- & has helped deplete aquifers around the world
- New irrigators sense dry areas as they roll over
- & vary nozzle size to deliver more or less water

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IoT for Drip Irrigation

- Soil types and drainage varies across fields
- How do you adjust on a granular level?
- New moisture sensors will enable high detail
- Water savings can come at the drip level

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IoT for Greenhouses

- Water delivery: where, when, and how much
- Heating and ventilation with precision
- IoT drops the cost of industrial systems
- Opens fine control for developing markets

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IoT for Water Tanks

- Water Storage is important for farms
- Checking tanks a manual process: hours per week
- Fail to check tanks, livestock can die
- < $100 for tank monitor w/ solar + 3g
- < $200 for tank monitor w/ solar + satellite

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IoT for Water Tanks

- Water tanks help where supply intermittent
- NextDrop in India texts when water will be on
- IoT meters can tell users when they'll run out
- Connected meters can tell cities about supply
- What neighbourhoods need water today?

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IoT for Water Delivery

- Water runs out!
- Trucks deliver more
- Where and when should the trucks go?
- Connected meters = less time & fuel
- Connected meters = no running out
- This works for anything in a tank (fuel, feed, etc.)

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IoT for Weather & Public Safety

- IoT is inexpensive flood monitoring
- Project NOAH in Philippines = 1,000+ IoT stations
- Know before the floods come
- Know before mudslides & bridge outages
- IoT can save money & save lives

DOST - Project NOAH

HOW TO CITE | TOOLS | LEGEND | BLOG | ABOUT | HELP | REPORT A FLOOD

SEARCH: Enter a location

OVERVIEW: Select layer

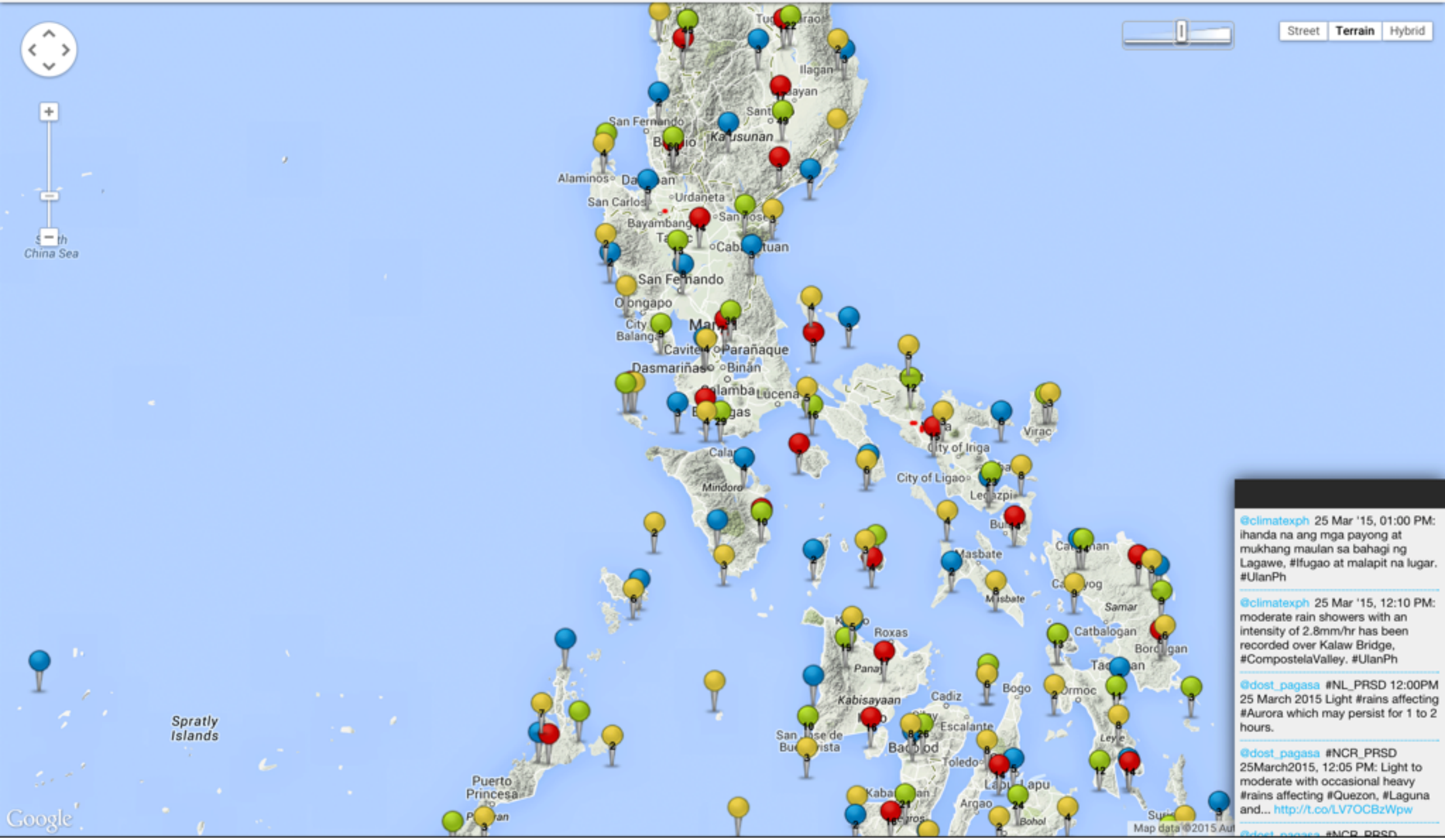
WEATHER OUTLOOK: Select layer

DOPPLER: Select layer

WEATHER STATIONS: Weather Stations, St...

FLOOD MAP: Select layer

HEALTH: Select layer



@climatexph 25 Mar '15, 01:00 PM: ihanda na ang mga payong at mukhang maulan sa bahagi ng Lagawe, #Ifugao at malapit na lugar. #UlanPh

@climatexph 25 Mar '15, 12:10 PM: moderate rain showers with an intensity of 2.8mm/hr has been recorded over Kalaw Bridge, #CompostelaValley. #UlanPh

@dost_pagasa #NL_PRSD 12:00PM 25 March 2015 Light #rains affecting #Aurora which may persist for 1 to 2 hours.

@dost_pagasa #NCR_PRSD 25March2015, 12:05 PM: Light to moderate with occasional heavy #rains affecting #Quezon, #Laguna and... http://t.co/LV7OCBzWpw

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Sensing & Actuating The Internet of Things

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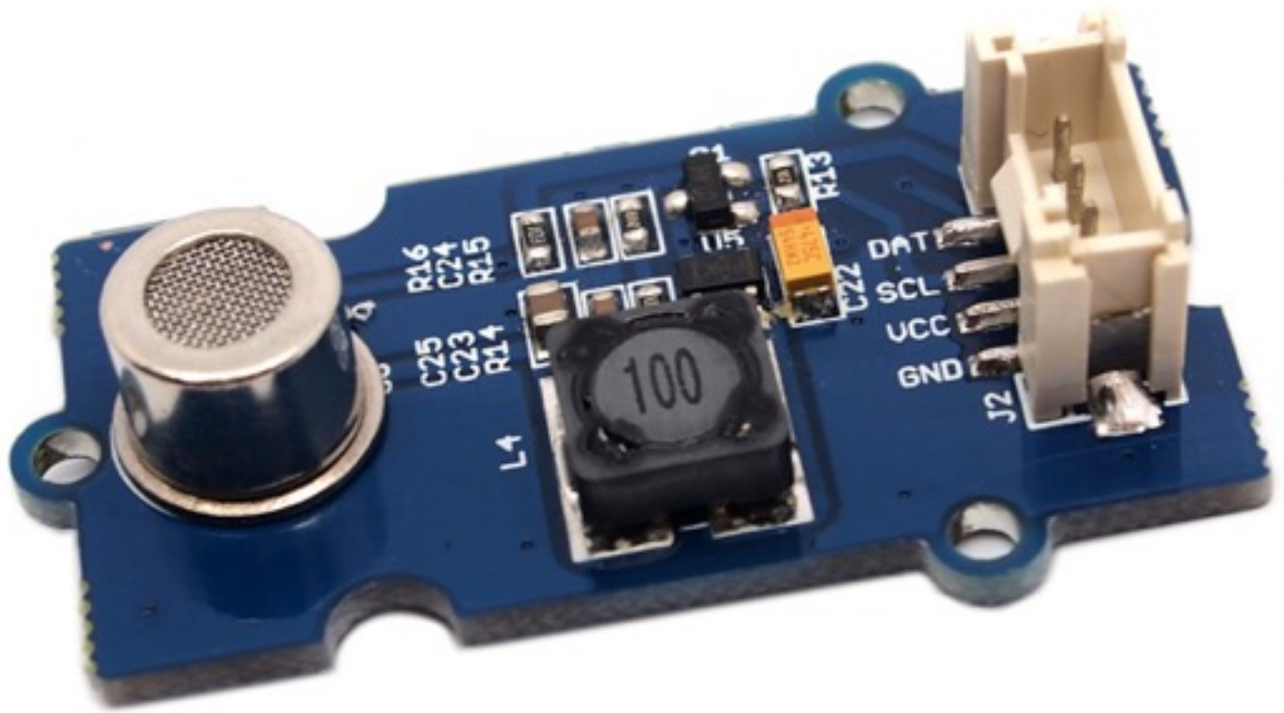
Analogue and Digital Sensors

- RS232, RS485, I2C, SPI, CAN, USB
- Accuracy typically varies with price
- Some need warm-up, others need calibration
- Power requirements vary widely
- Wrong data can be worse than no data at all!

Accelerometer

Air Quality Sensor

Alcohol Sensor



Barometric Pressure

Camera

Collision Sensor

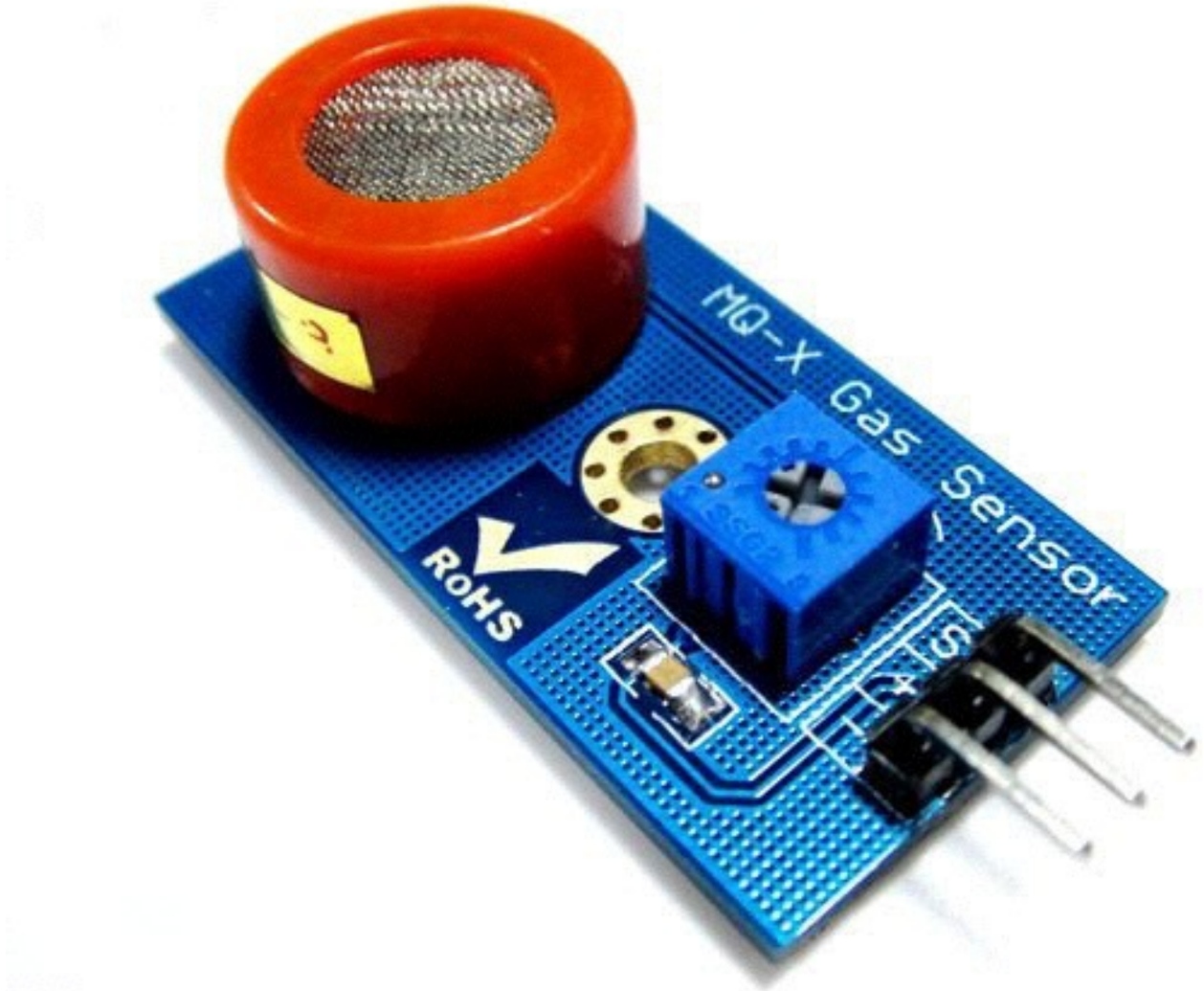
Colour Sensor

Compass: Digital

Formaldehyde Sensor

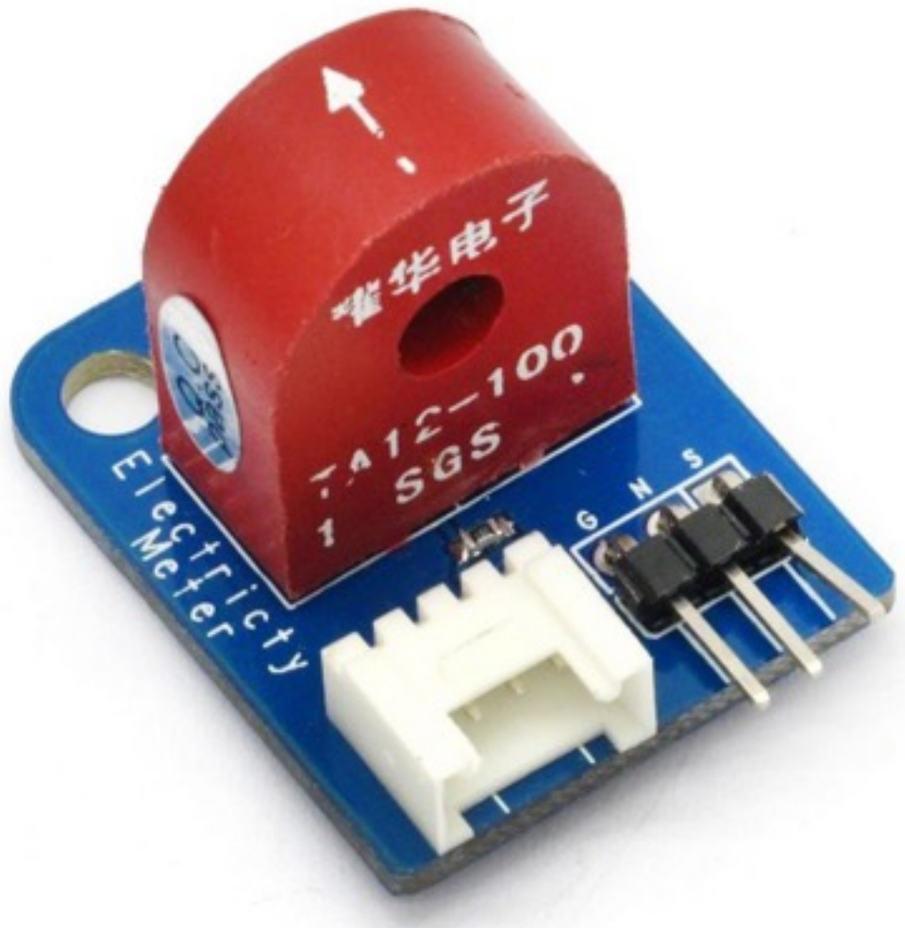
Galvanic Skin Response

Gas Sensor



Global Positioning System

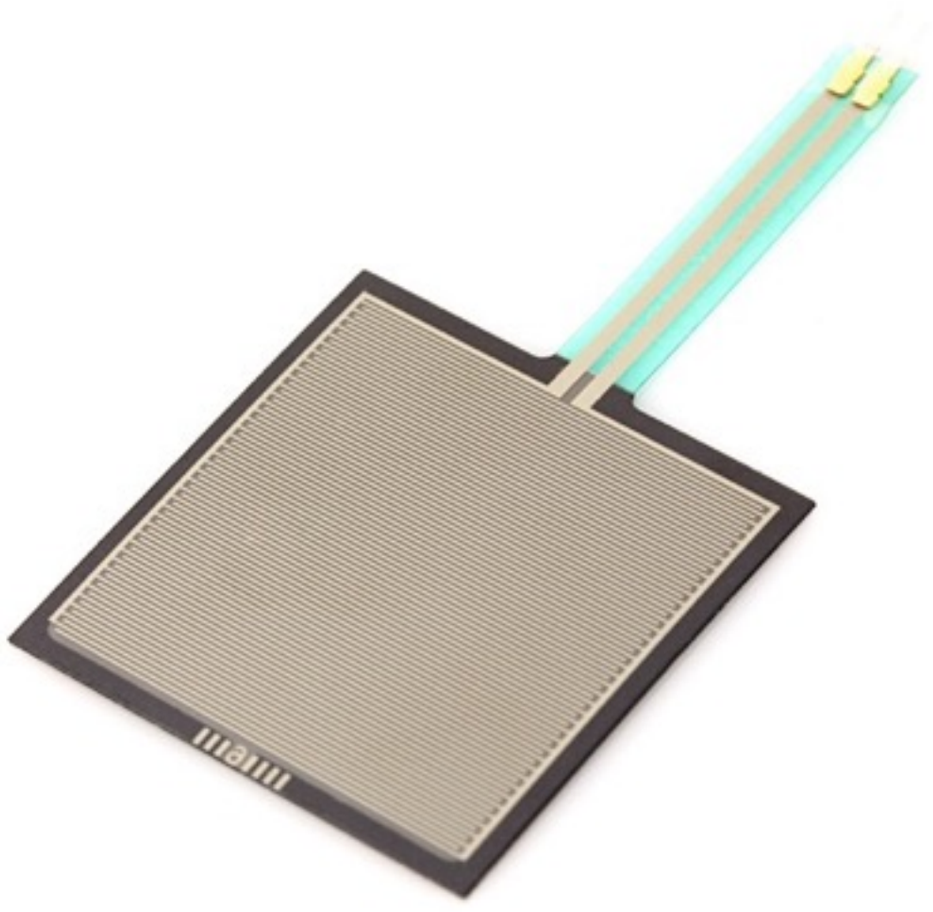
Electrical Current Sensor



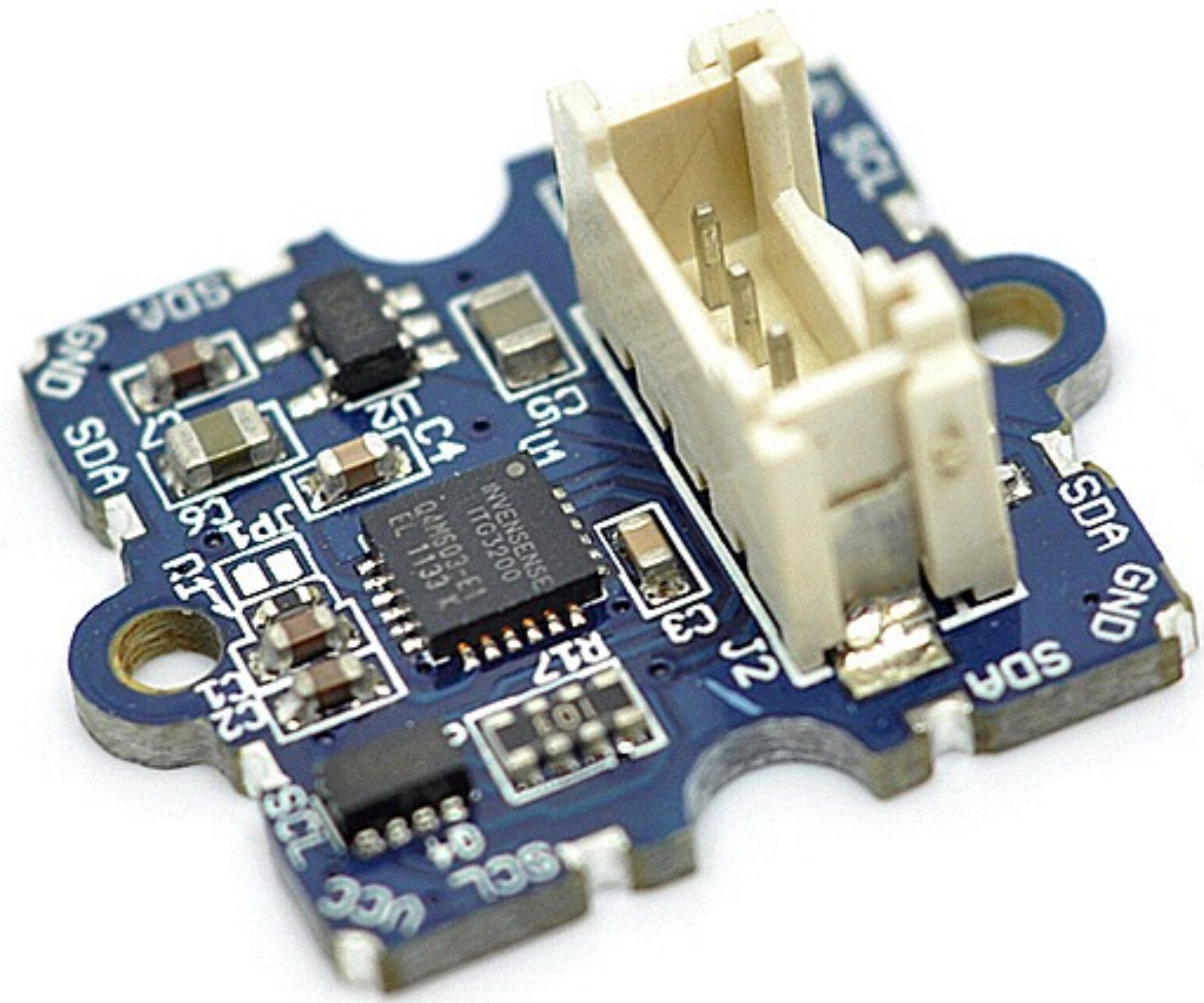
Flow Sensor

Flow Switch

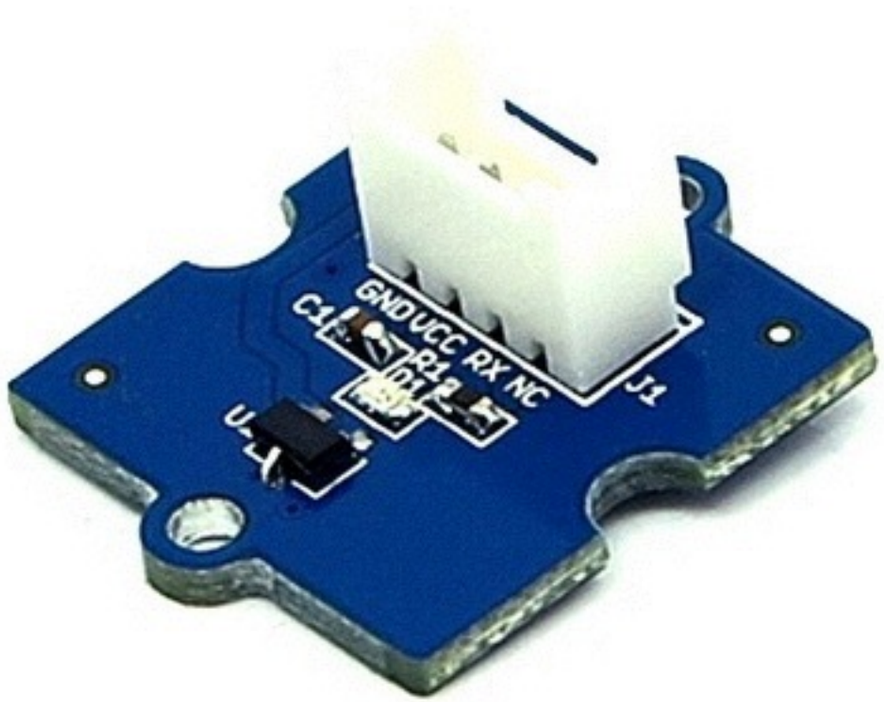
Force Sensitive Resistor



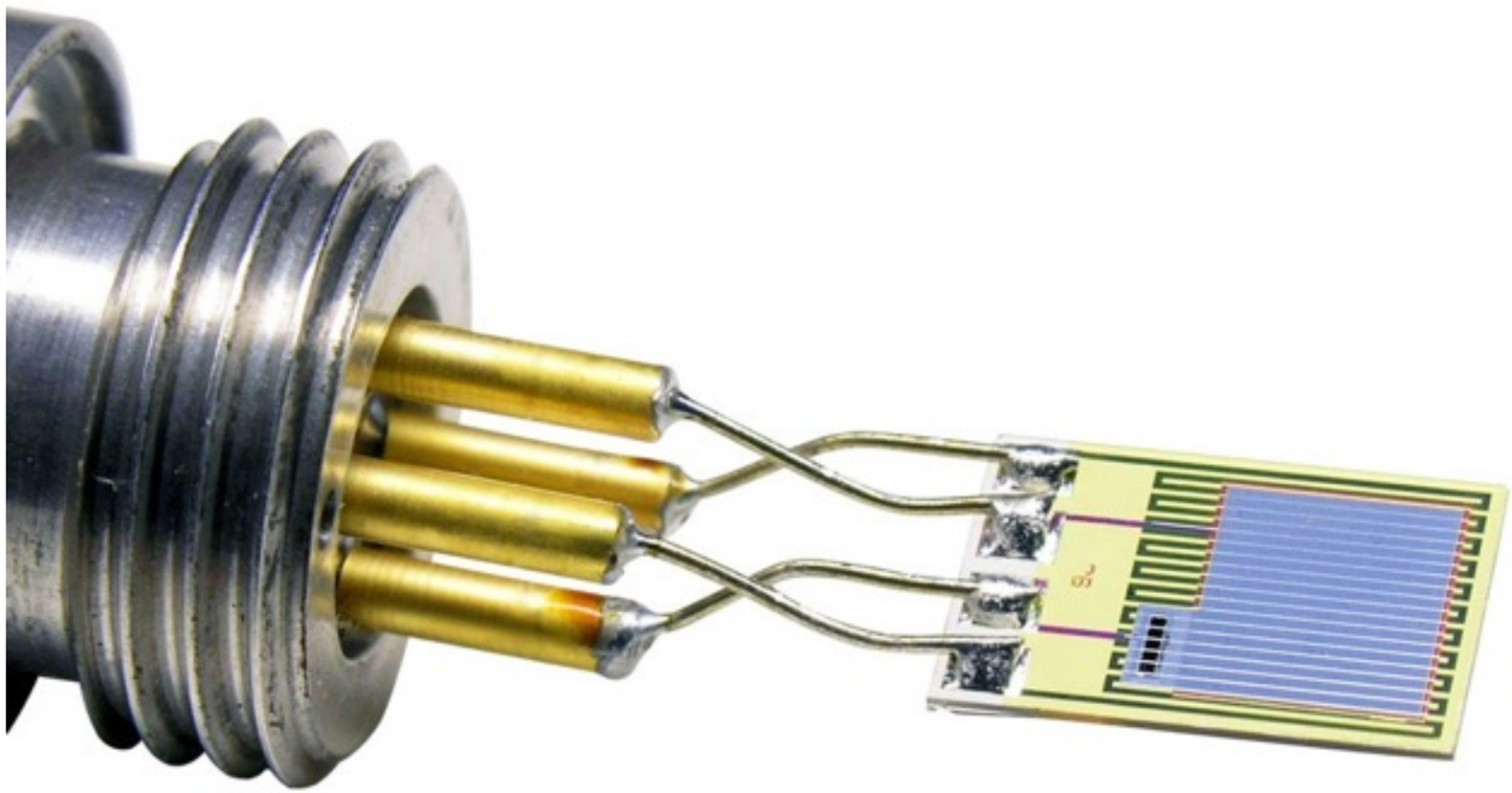
Gyroscope



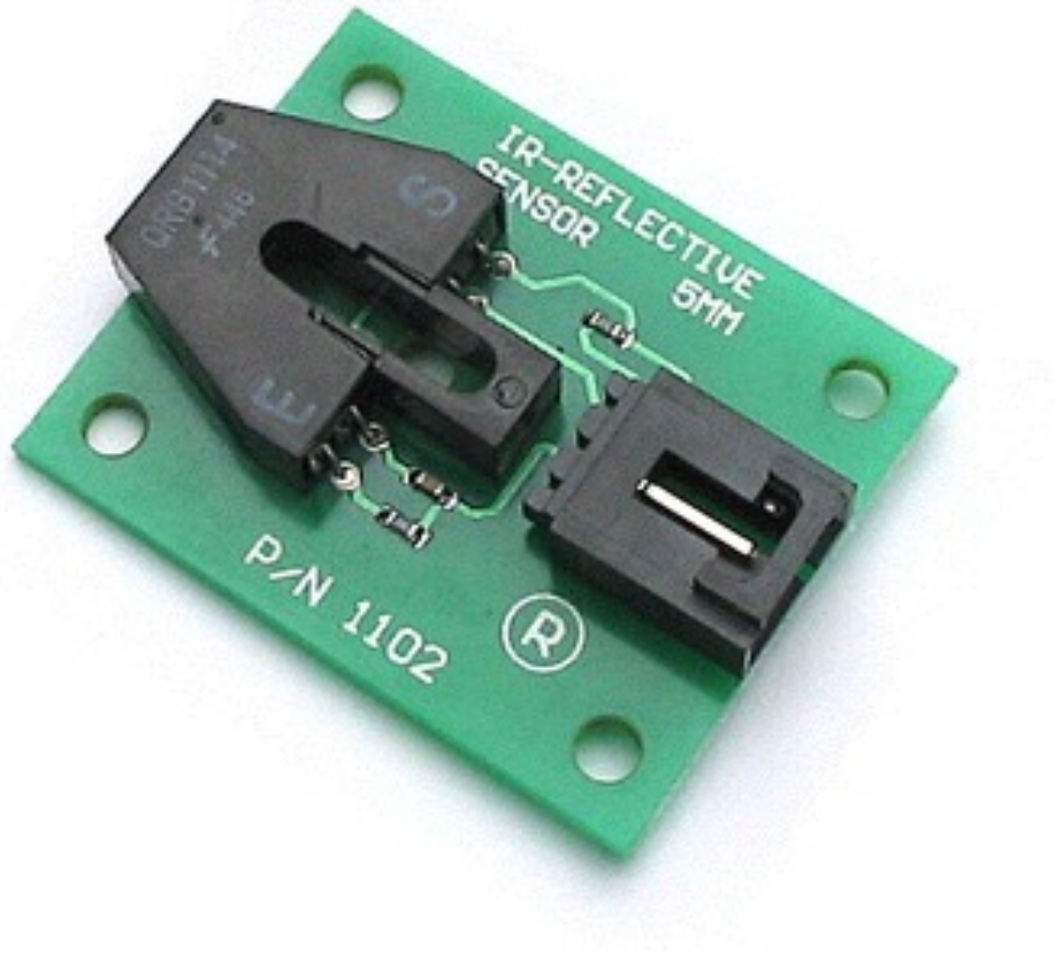
Hall Sensor



Humidity Sensor

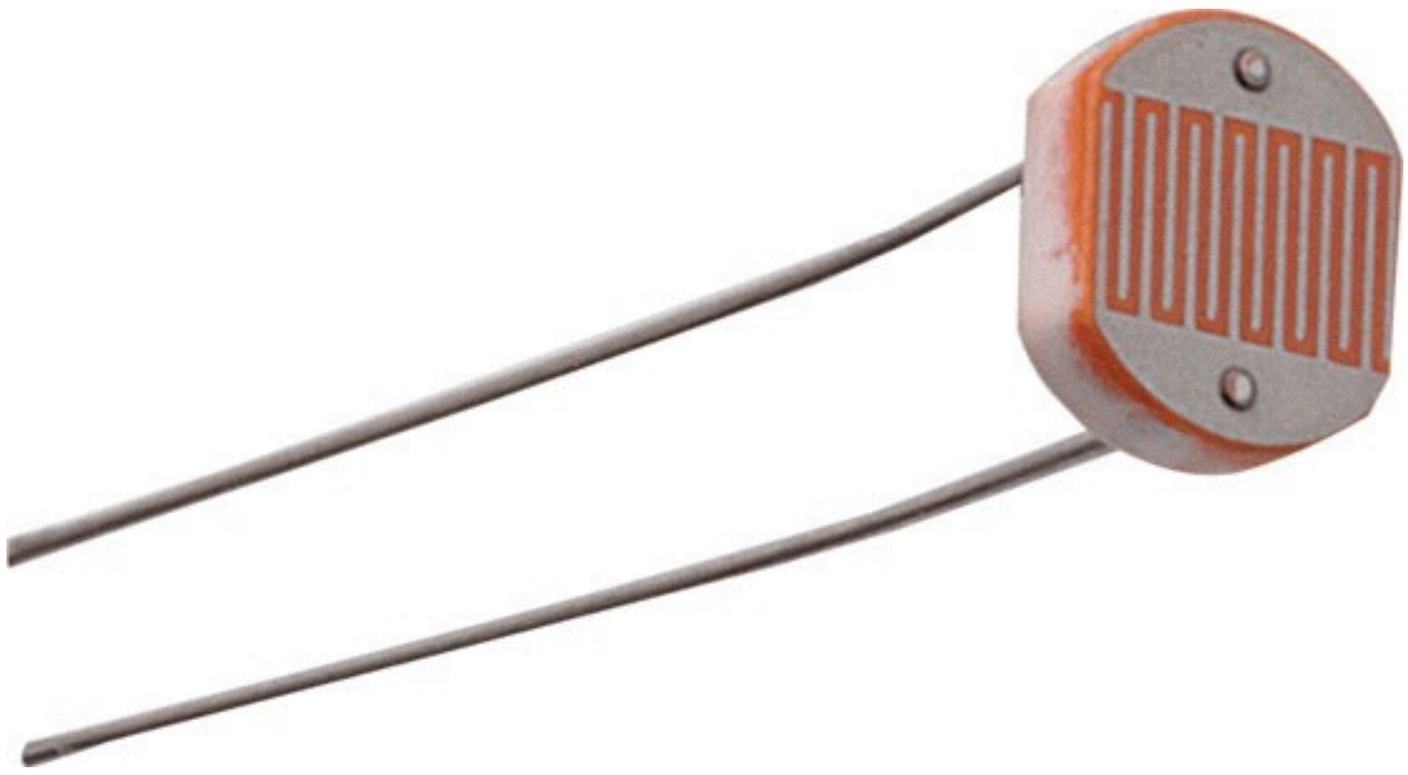


Infrared Reflection



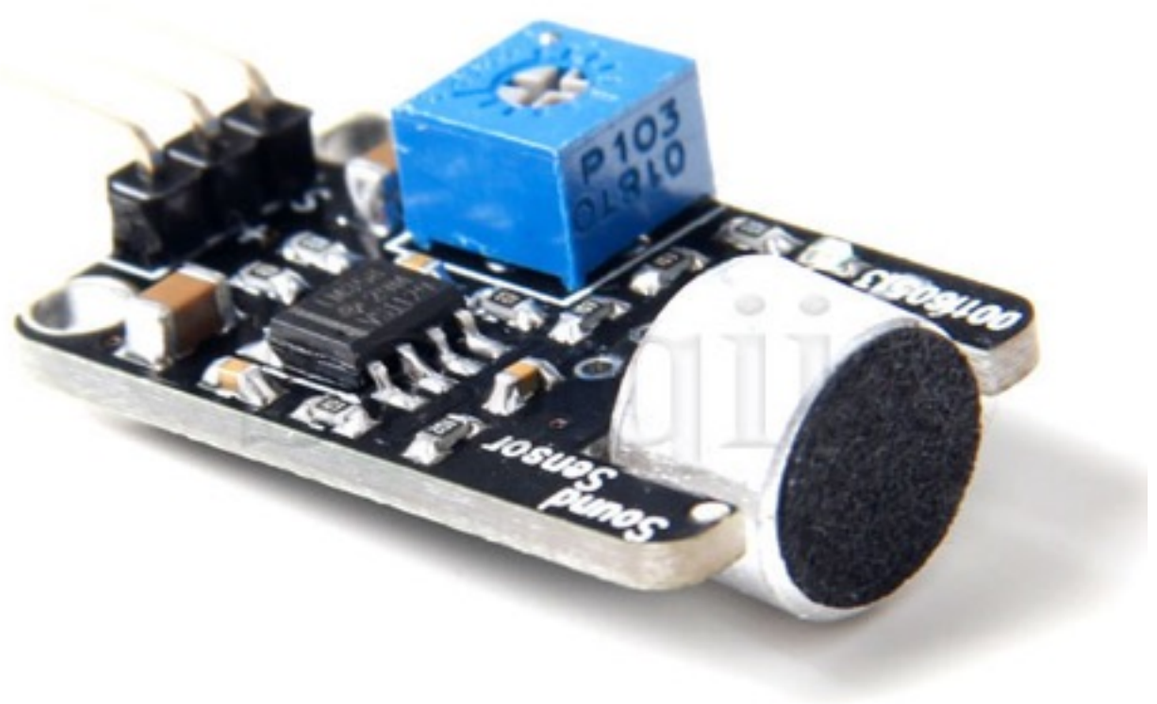
Infrared Sensor: Passive

Light Sensor



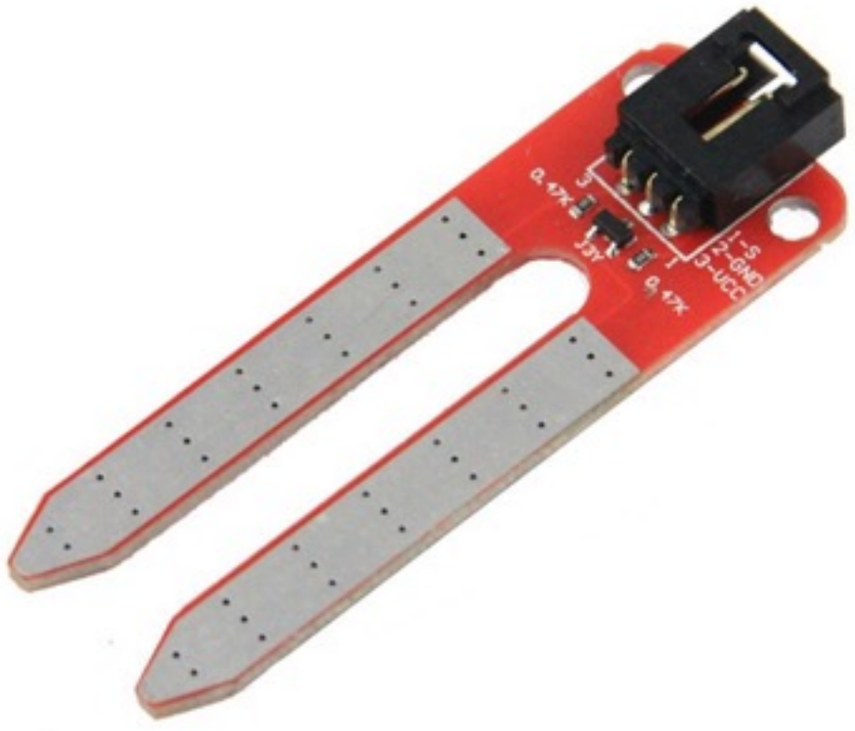
Load Sensor

Loudness Sensor

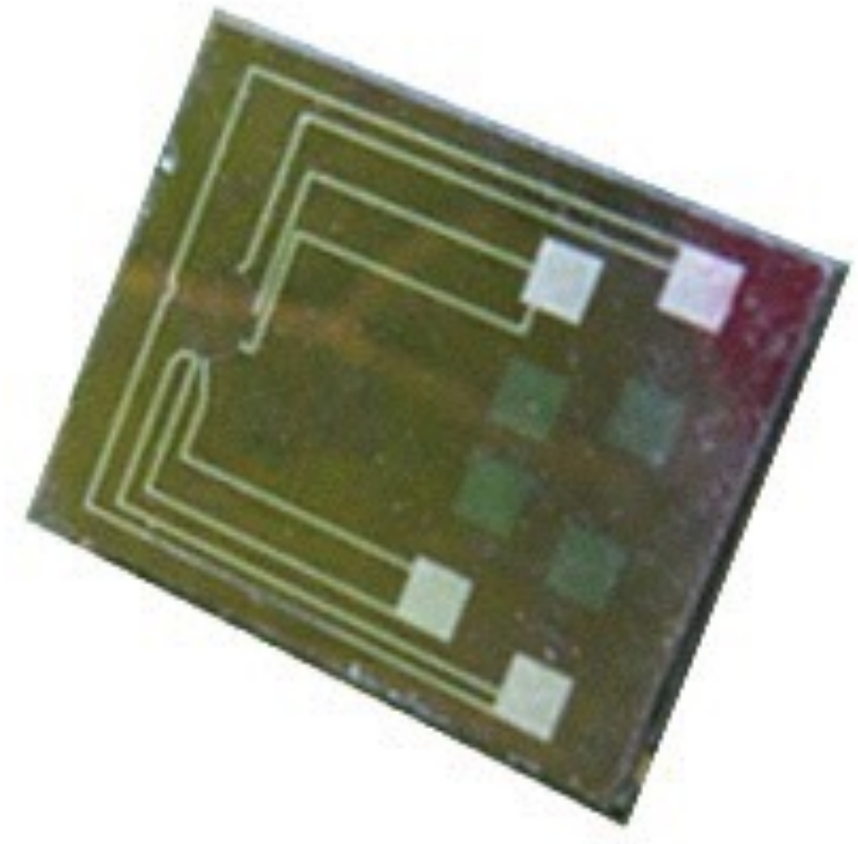


Microphone

Moisture Sensor

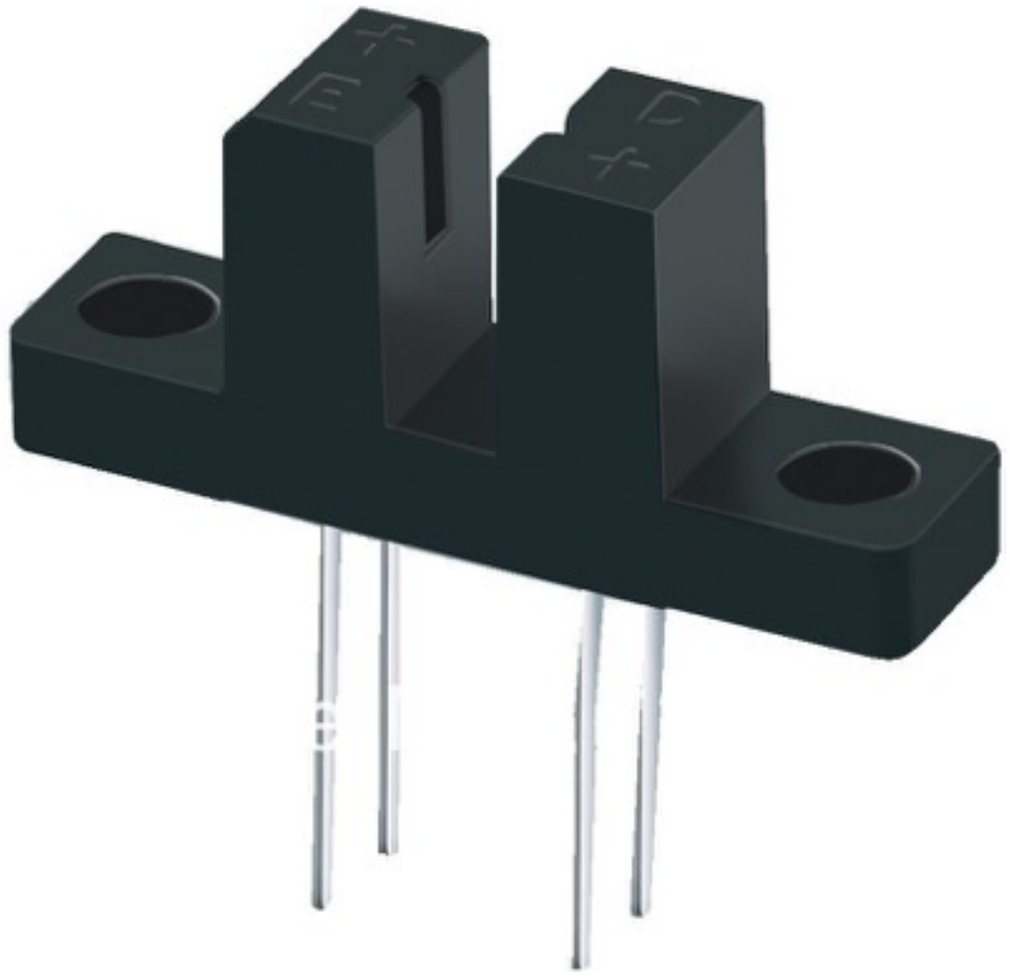


Moisture Sensor Chip (Cornell)

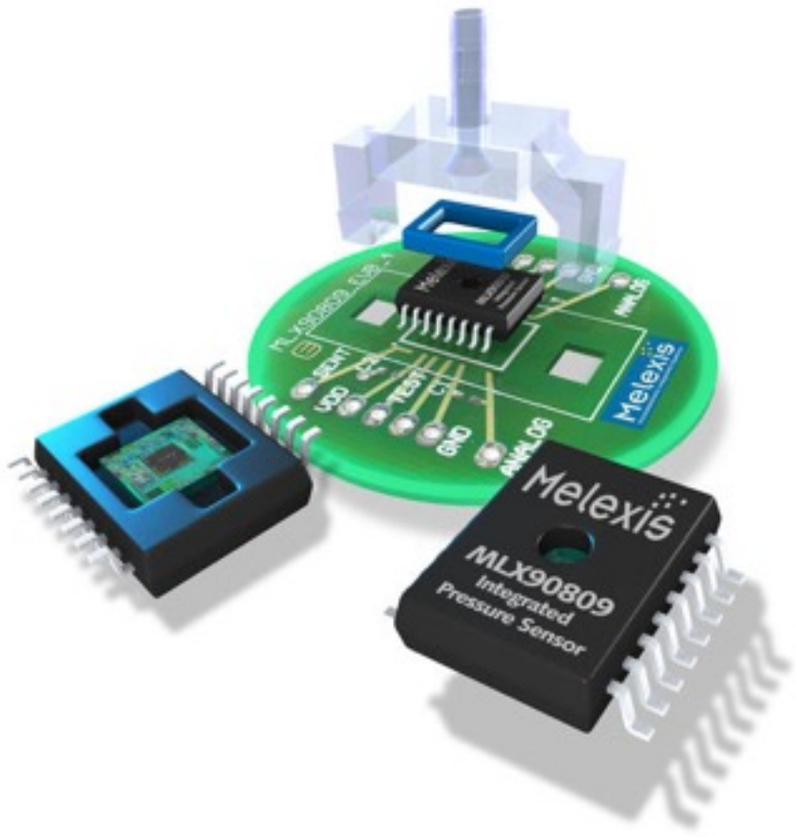


Optical Dust Sensor

Photo Interruptor



Pressure Sensor (MEMS)

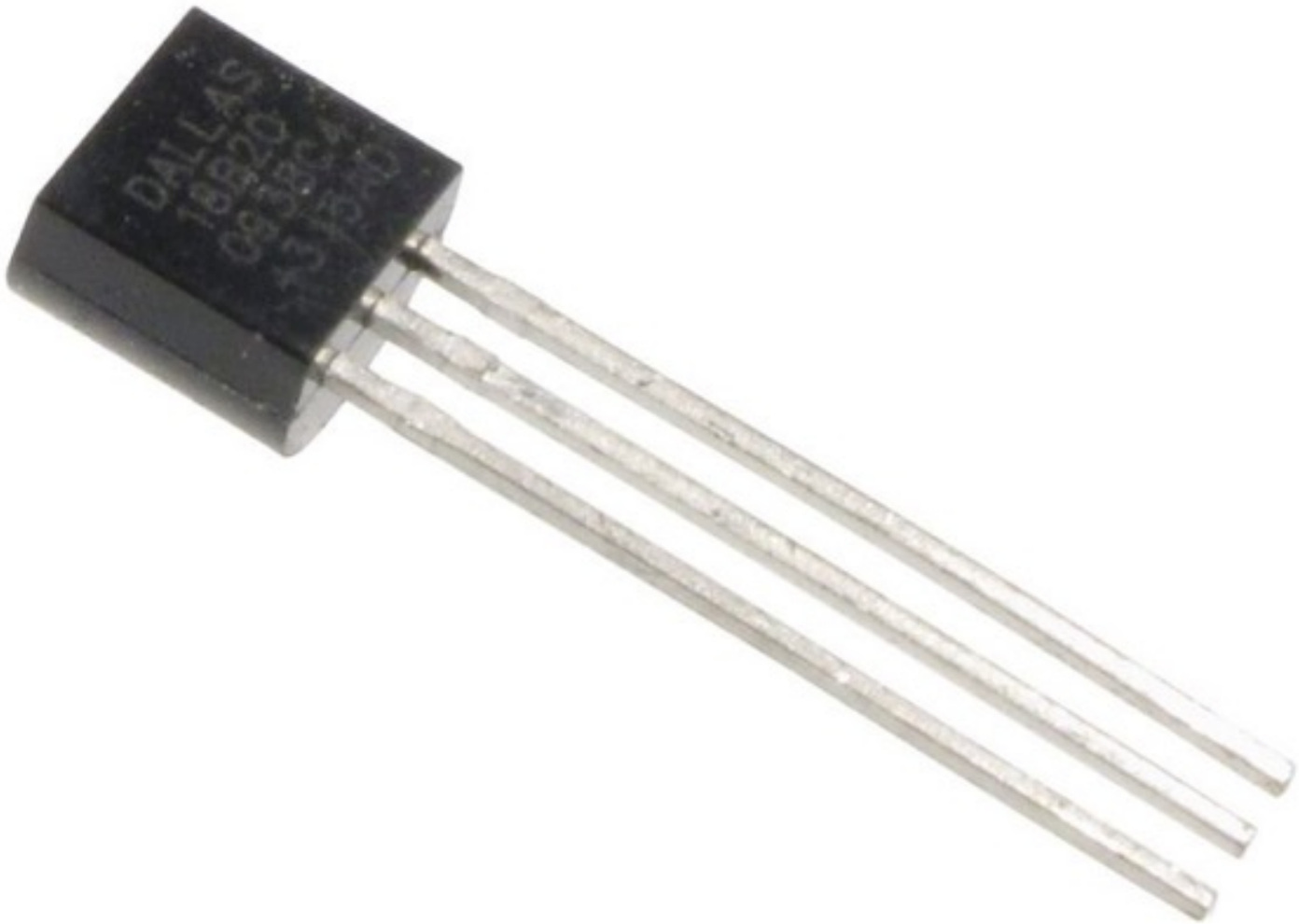


Real Time Clock

Reed Switch

Solar Radiation Sensor

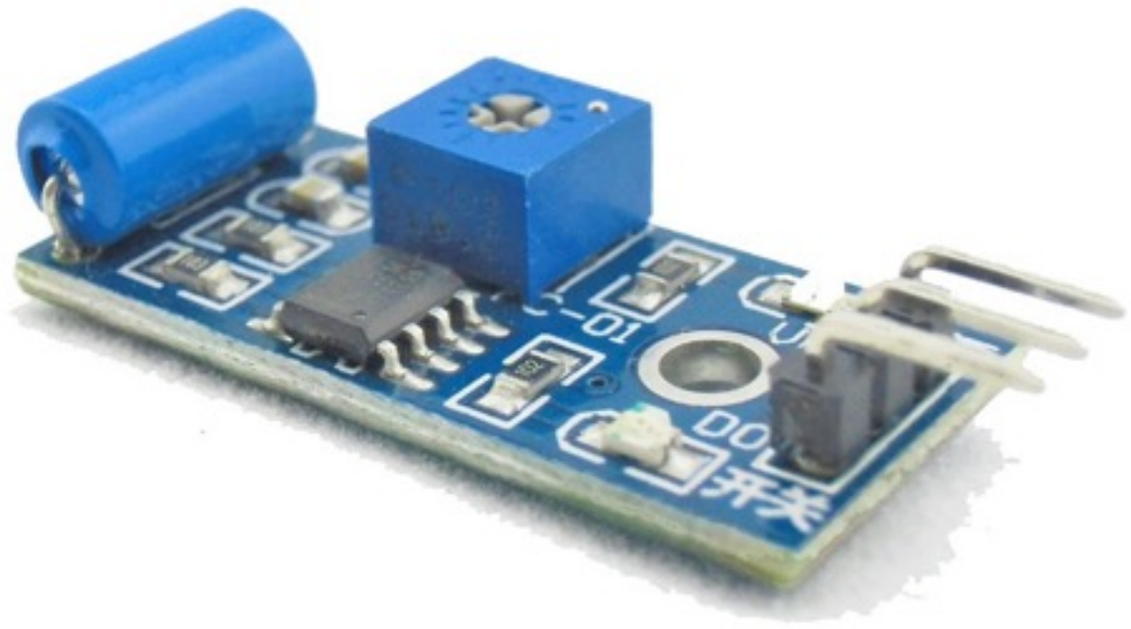
Temperature Sensor



Thermistor

Touch Sensor: Capacitive

Vibration Sensor



Ultrasonic Range Finder

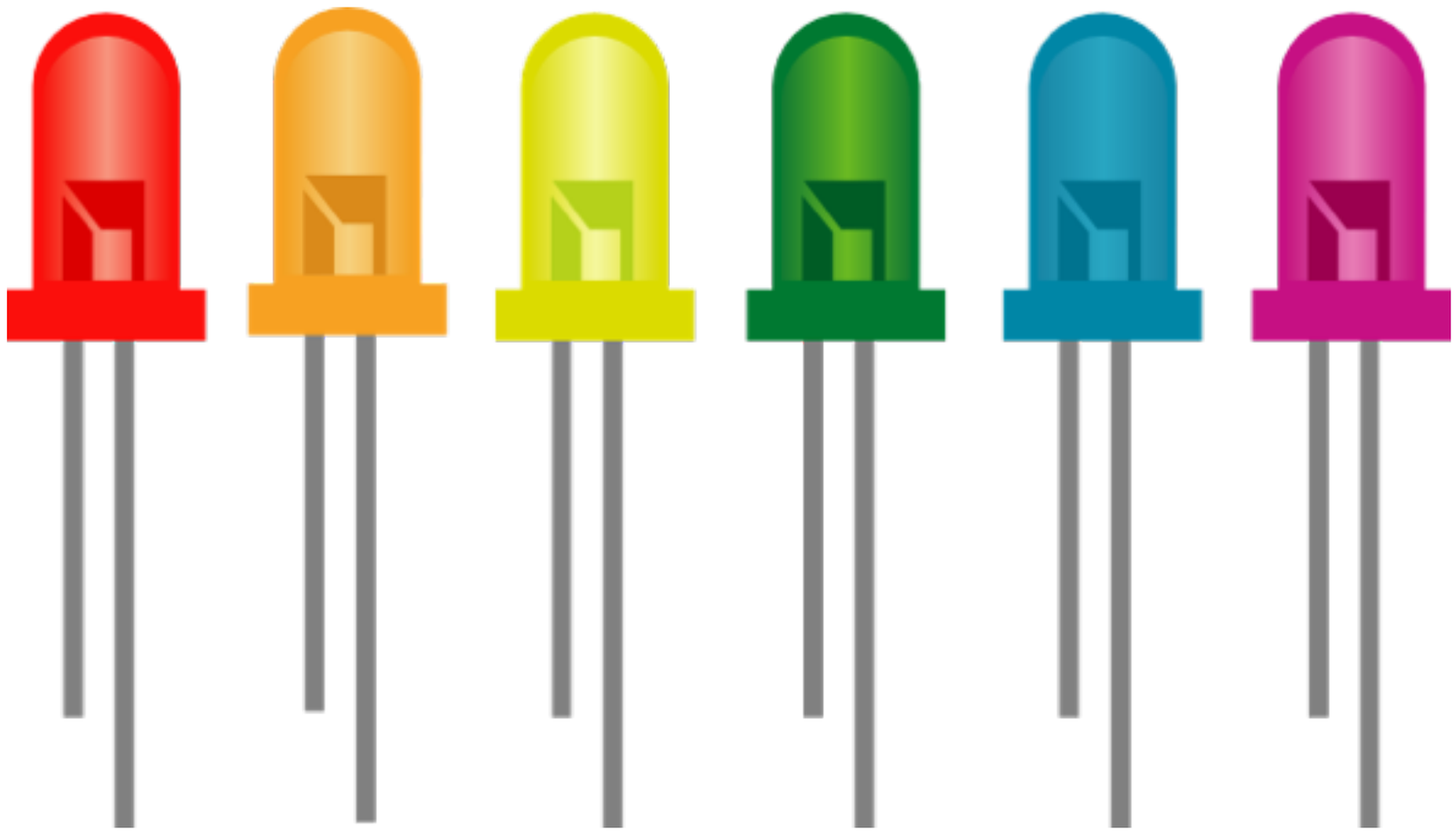
Ultraviolet Radiation Sensor

Actuating the Internet of Things

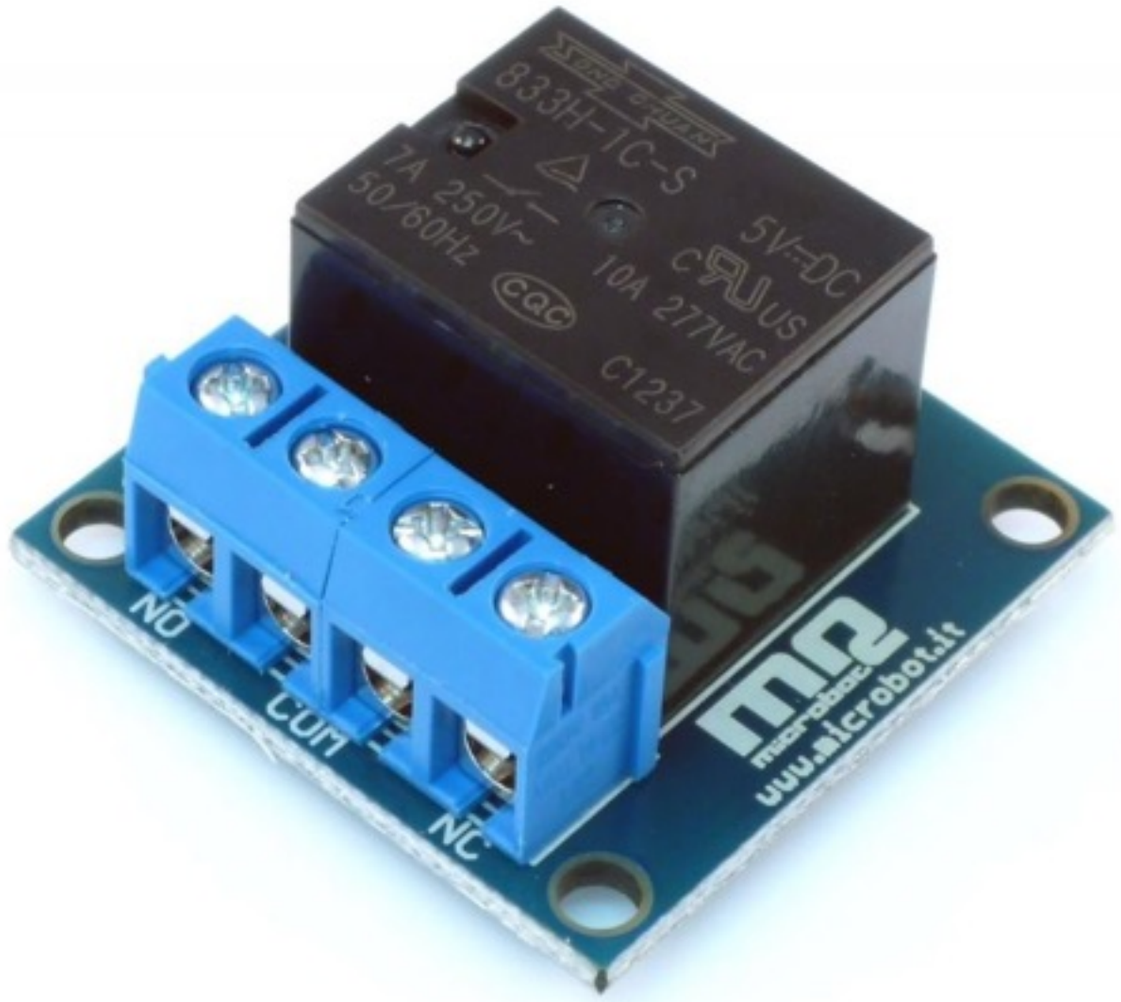
- Consider Power Use: Both Voltage & Amperage
- Interfaces
- Accuracy and Cost
- Availability
- Documentation, Support, & Community Involvement

Buzzer

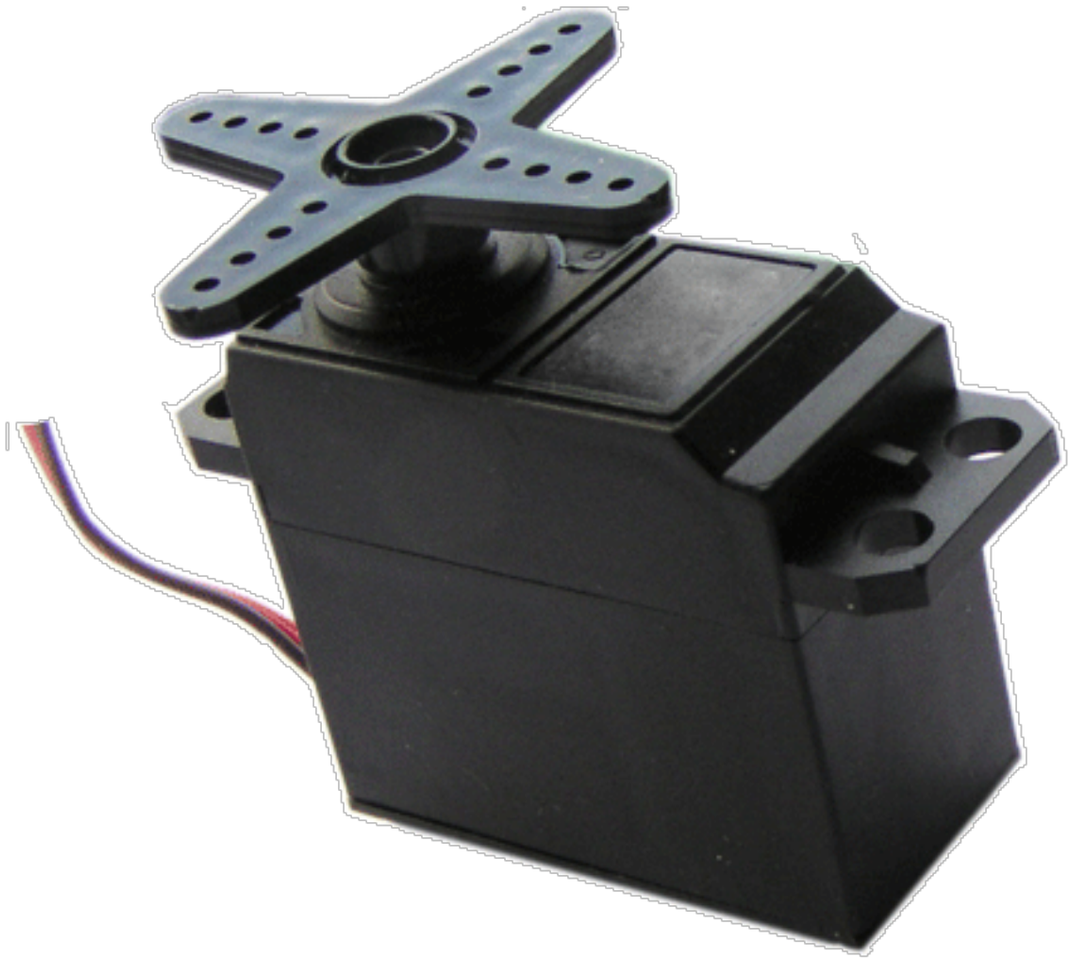
Light Emitting Diodes



Relay


833H-1C-S
7A 250V~
50/60Hz
10A 277VAC
C1237
5V⎓DC
NO
COM
NC
www.microbot.it

Servo



Solenoid

Transistor

Energy System Considerations

- Amount of Power Required
- Stationary or Mobile Application
- Robustness
- Physical Size
- Level of Human Interaction Required
- Technological Maturity

Generating Electricity

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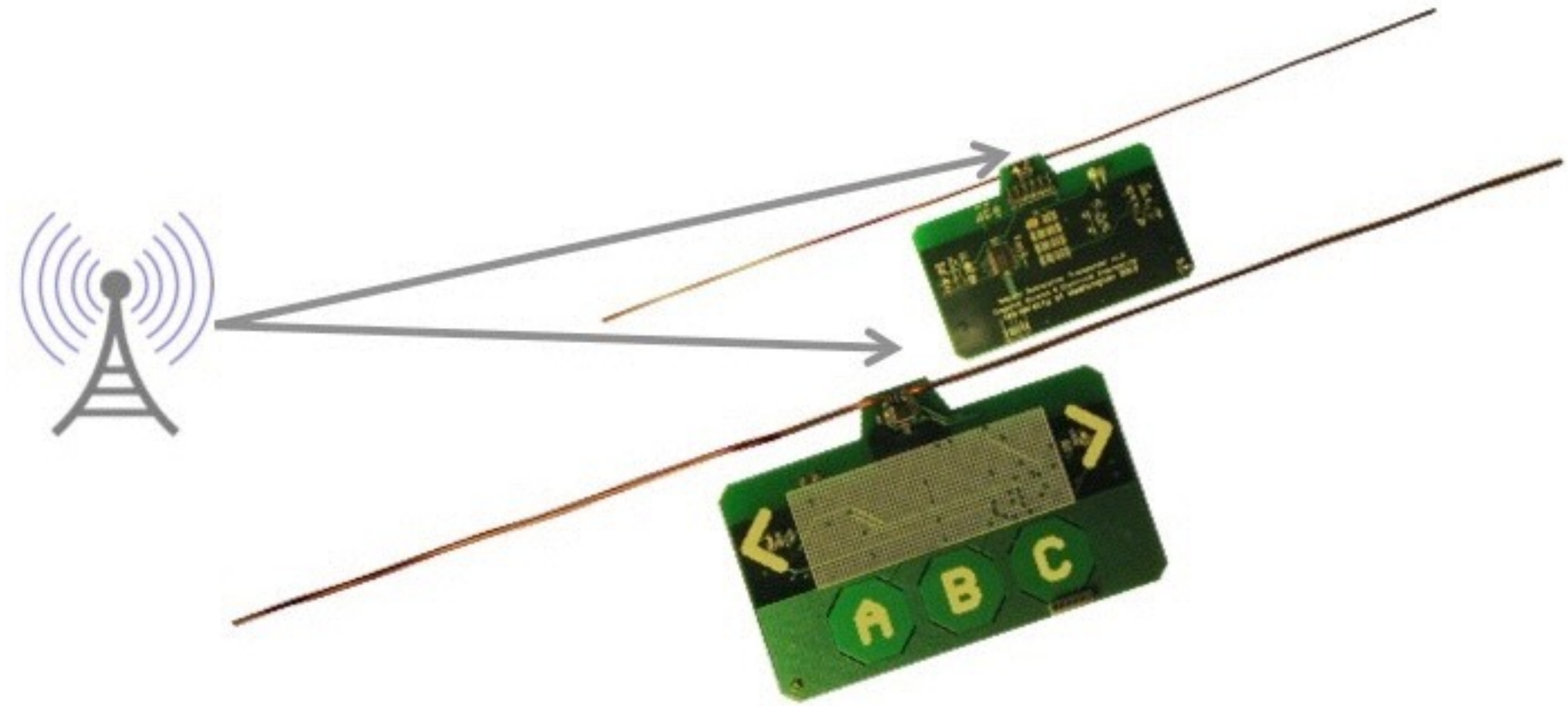
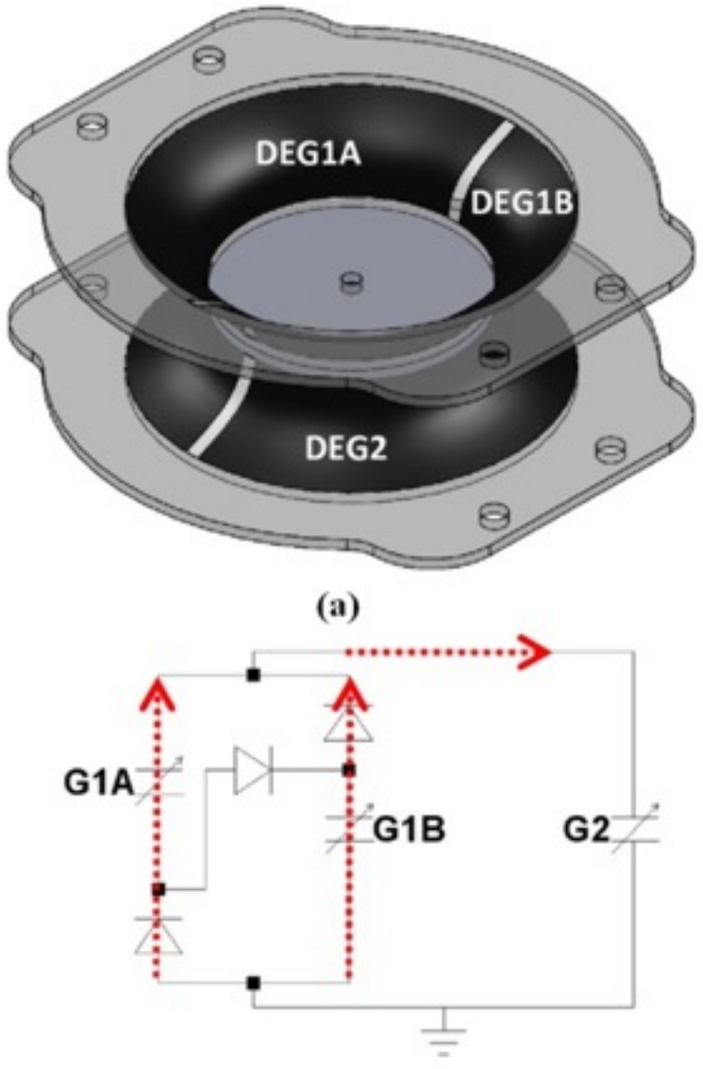
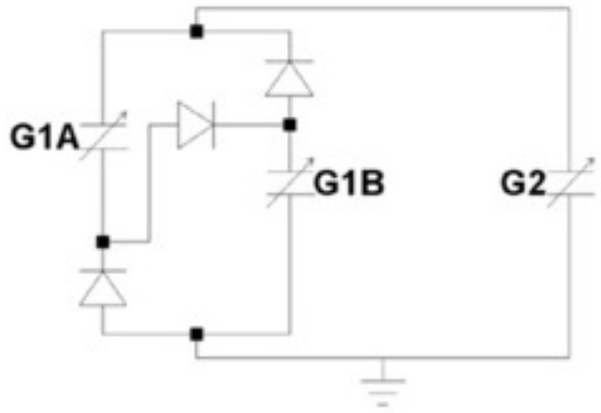
Ambient Backscatter



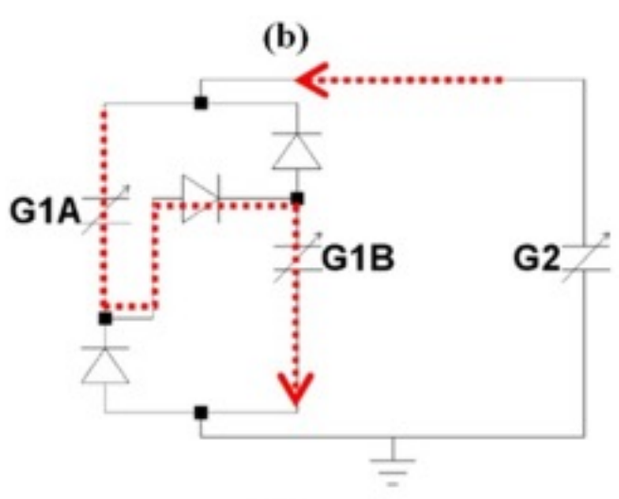
Biomechanical





(a)

(b)

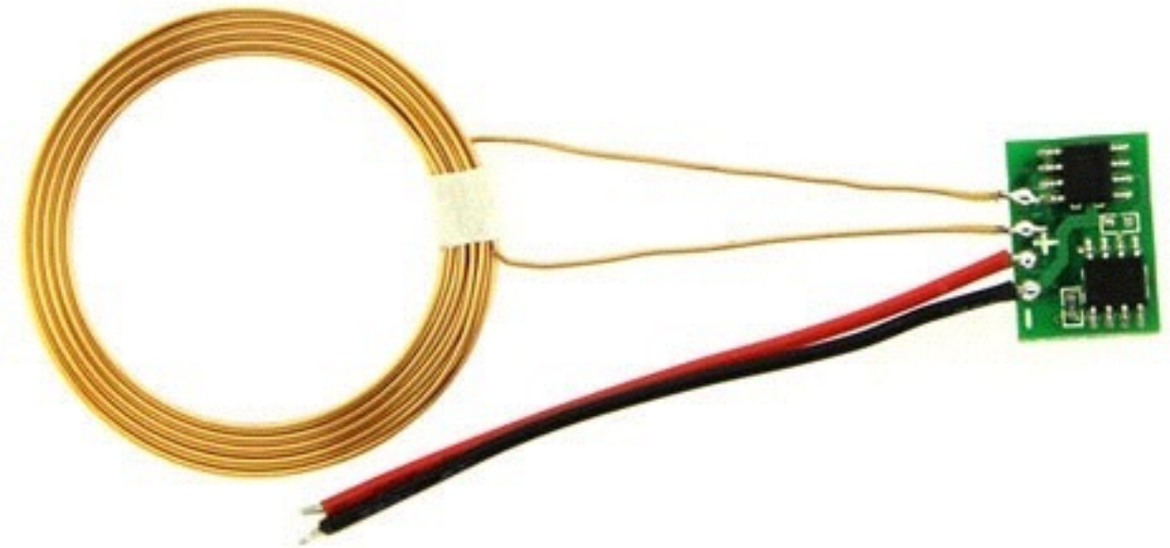


(c)

(d)

Biomechanical

Induction



Induction


oyster
Hackney Wick
Stratford
Bethnal Green
Hoxton
Shoreditch
Old Street
Liverpool Street
Angel
Farringdon
Russell Square
Barbican
Moorgate
Chancery Lane
St. Paul's
Bank
Aldgate
Aldgate East
Whitechapel
Stepney Green
Bow Road
Bow Church
Bromley-by-Bow
Devons Road
Langdon Park
All Saints
Poplar
East India
Blackwall
Canning Town
Royal Victoria
Custom House for ExCeL
Prince Regent
Royal Albert
Beckton Park
Cyprus
Gallions Reach
Beckton
Pontoon Dock
West Silvertown
London City Airport
King George V
Woolwich Arsenal
Pudding Mill Lane
Plaistow
West Ham
Upney
Barking
East Ham
Becontree
Shadwell
Westferry
Limehouse
Wapping
West India Quay
Canary Wharf
North Greenwich for the O2
Heron Quays
South Quay
Crossharbour
Mudchute
Island Gardens
Cutty Sark for Maritime Greenwich
Greenwich
Deptford Bridge
Elverson Road
Lewisham
Rotherhithe
London Bridge
Bermondsey
Canada Water
Surrey Quays
New Cross
New Cross Gate
Tower Gateway
Tower Hill
Monument
Mansion House
Cannon Street
Blackfriars
Temple
Embankment
Southwark
Borough
Elephant & Castle
River Thames
2
1
3
4

Electro-Magnetic

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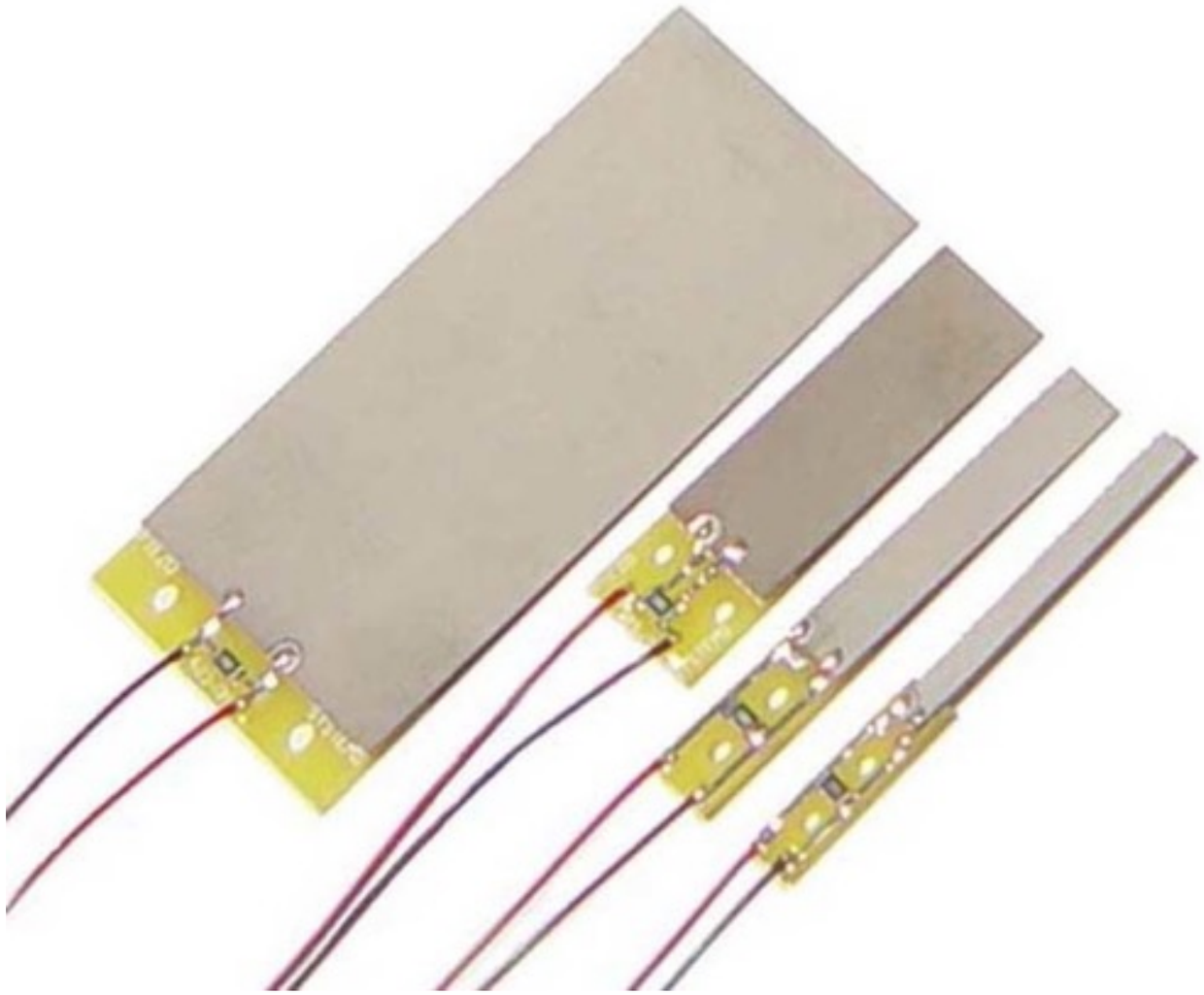
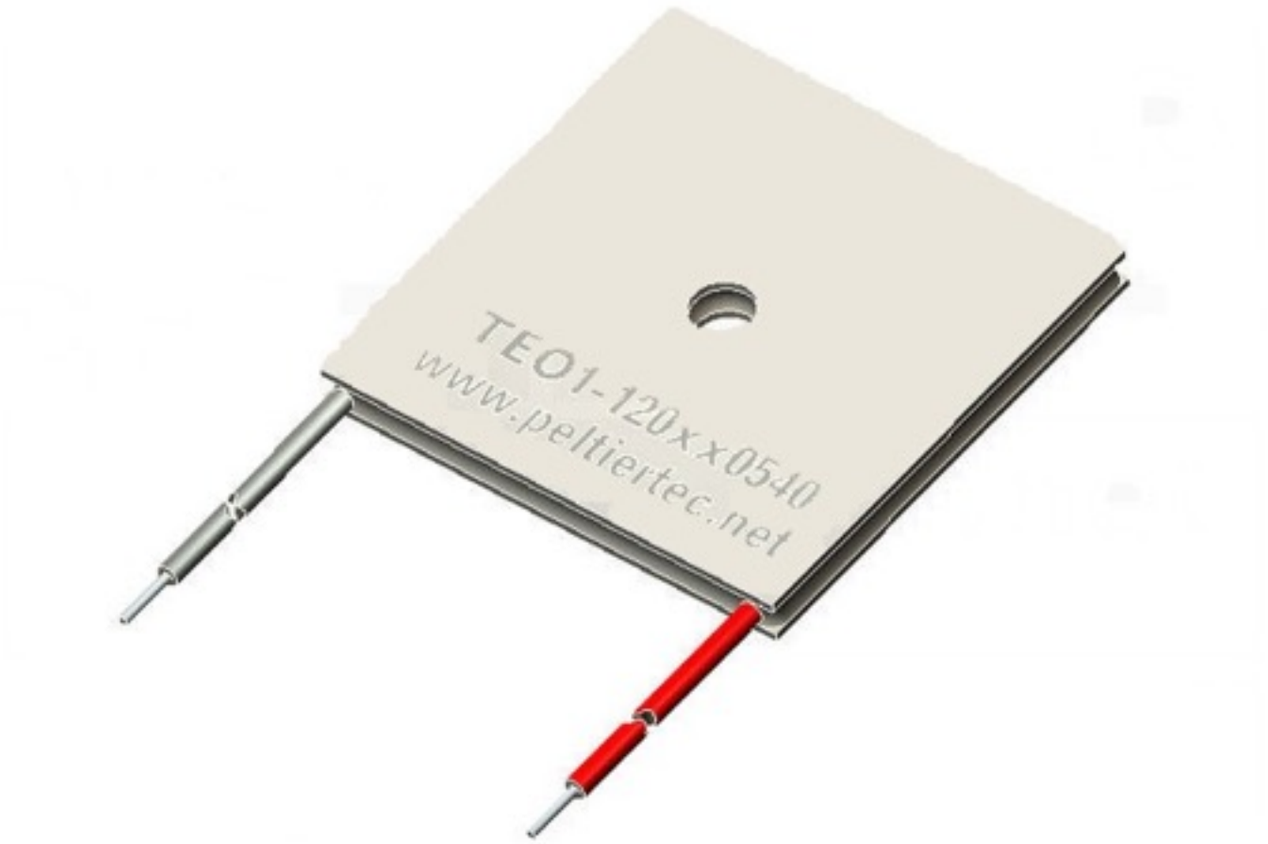
Electro-Magnetic

Micro-Hydro (Electro-Magnetic)

Piezoelectric



Thermoelectric



Thermoelectric

Solar

Solar

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Storing Electricity

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Power Storage Considerations

- One-Use or Renewable
- Capacity of Storage
- Lifetime / Charge Cycles
- Current Required
- Physical Size
- Environmental Impact

Alkaline Battery

Lead Acid Battery

Lithium Battery

Lithium Ion Battery

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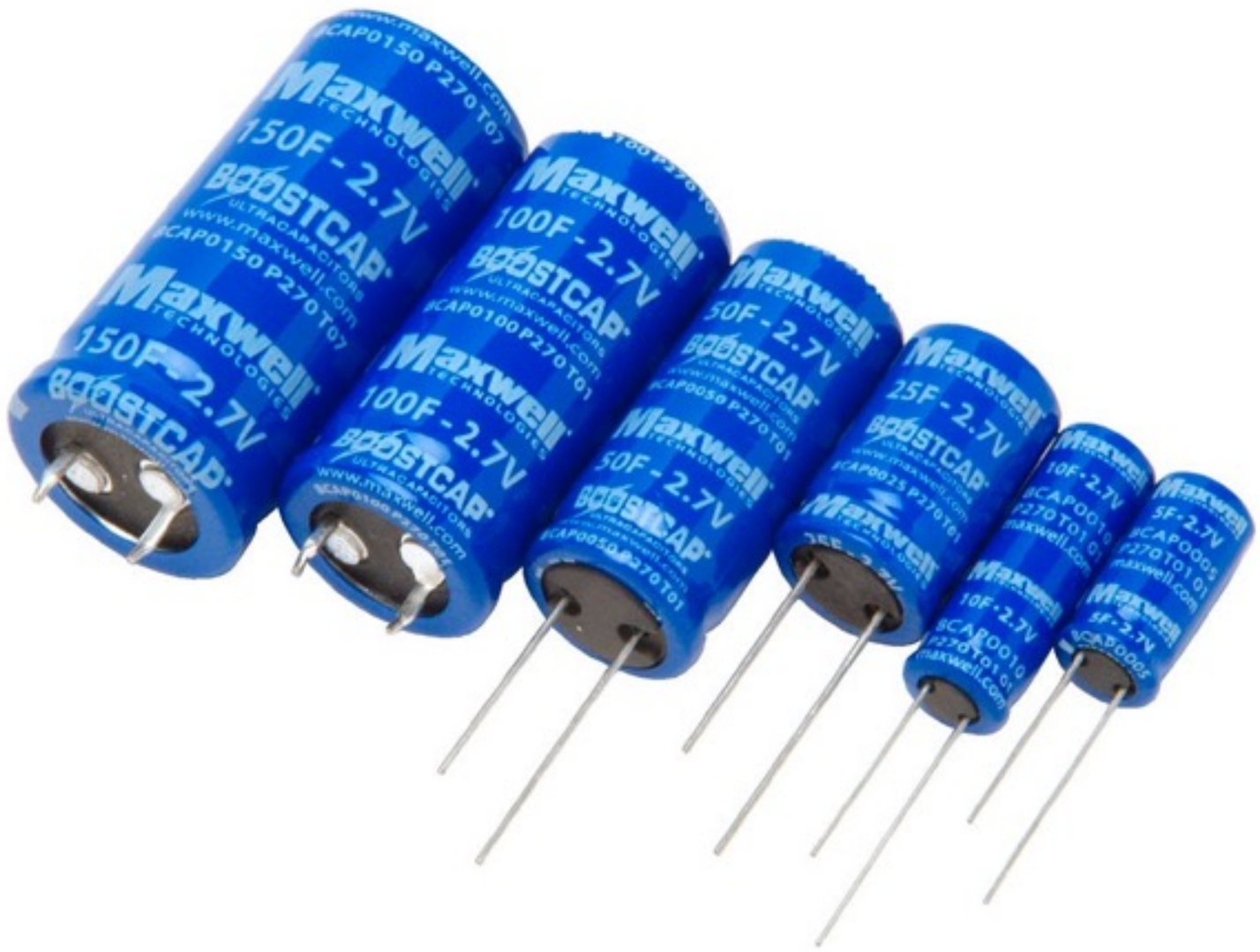
Super/Ultra Capacitor



Radio Frequency Protocols of The Internet of Things

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IoT Protocols for IoT Problems

- Device Constraints
  - Low Power
  - Low CPU
  - Small Size
- Network Constraints
  - Radio Propagation Issues
  - Radio Power Utilisation
  - Interference from Self, Other Devices

Radio Protocols: Wi-Fi

- 802.11b/g/n is pervasive and low cost
- Microprocessor + WiFi module at US $7 each.
- Default protocol for “connected devices”
- Where power is available, Wi-Fi works, but…
- Wi-Fi doesn’t solve many IoT problems

Radio Protocols: 802.15.n

- Includes Zigbee, Bluetooth, BLE
- 868 MHz, 915 MHz, 2.4GHz
- 20kbps – 1mbps depending on spectrum available
- Star, tree, mesh topologies
- Low power consumption
- Low cost - at least in 2.4GHz band
- 128-bit encryption keys
- Several network simulators available

IoT Wireless: Lo-Fi, Motenio, Etc.

- Serial across 433, 868, 915 MHz MHz
- Open Source RFM69 Libraries
- 1.2-300 kbps
- Rx Sensitivity to -120dBm at 1.2kbps
- Some support encryption using RFM69W chip
- Star topology
- Other Similar chips / protocols available
- Very inexpensive – US $3.50 per module

Radio Protocols: Dash7

- RFID standard for Wireless Sensor Networking
- BLAST: bursty, light, asynchronous, stealth, transitive
- 433 MHz ISM (industrial, scientific, medical) band
- Open Source Protocol Stack
- Shared key AES encryption
- Data transfer 10-200kbps
- 1-10km range
- Low cost hardware

Radio Protocols: Z-Wave

- Proprietary across multiple frequency bands
- 9.6-100kbps
- Very low power use for end devices, 0.1% duty cycle
- Mesh topology - devices individually added to mesh
- Mesh repeaters cannot sleep (so not battery powered)
- 32 bit addressing limits use to homes / businesses

Radio Protocols: SigFox

- Proprietary at 868MHz & 915MHz in the US
- Low power consumption
- SigFox owns/operates the Receiver network
  - European, USA, and AU/NZ Networks.
- Up to 140 12-byte messages a day
- 10-1000 bits per second
- Encryption?
- Target pricing US $1/device/year

Radio Protocols: LoRa

- Low Power Wide Area Network
- Designed for wireless, battery operated devices
- Supports bi-directional comms, mobility, localisation
- Star or star of stars topology (not mesh or p2p)
- 0.3-50kbps via adaptive data rate scheme
- Multiple levels of encryption (Net/App/Device)
- Supports time slot scheduling of device transmission

Radio Protocols: Weightless / nbIoT

- Open Standard at Multiple Frequency Bands
  - Standards for TVWS & now Narrowband 868MHz
  - Integrates w/ Cellular as nbIoT using re-farmed GSM
  - Low power consumption - nodes can sleep for days
  - From bits per second to megabits per second
  - Intelligent scheduling at the tower end
  - Public Key Encryption
  - Supports itinerant nodes

Radio Protocols LTE-MTC / LTE IoT

- MTC = “Machine Type Communications”
- Cat-M1 version to be included in 3GPP Release 13
- Uses existing LTE base stations w/ software upgrade
- Six 230 KHz channels per 1.4 MHz carrier
- Data transmissions can be repeated at intervals
- Endpoints tell towers how often they want to talk
  - extended discontinuous repetition cycle (DRX)

Software Protocols & Platforms
The Internet of Things

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Network Protocols: 6LoWPAN

- IPv6 (globally addressable sensors) for
  - Low Power
  - Wireless
    - Personal Area Networks
- Header compression
- Can have a smaller address space
- Allows for ad-hoc and mesh topologies
- Operates over 802.15.4

Network Protocols: LoRaWAN

- Centralised Controller & Device Management
- Handling of Radio Frequencies
- Routing of Traffic between Devices & Apps
- Network to Itinerant / Nomadic Device Comms
- Multiple levels of encryption (Net/App/Device)

Network Protocols: Websockets

- Full-Duplex comms over a single TCP socket
- Can be used by any client or server
- Uses TCP ports 80 / 443
- Supports TLS Encryption
- IETF Standard RFC 6455 in 2011

Network Protocols: MQTT

- Message Queue Telemetry Transport
- Publish-Subscribe Messaging Protocol
- Lightweight & Suitable for IoT Devices
- ISO/IEC Standard
- Very Popular / Useful for Wireless Sensor Networks

PN Realtime Apps Made Simple | P

Jon Brewer

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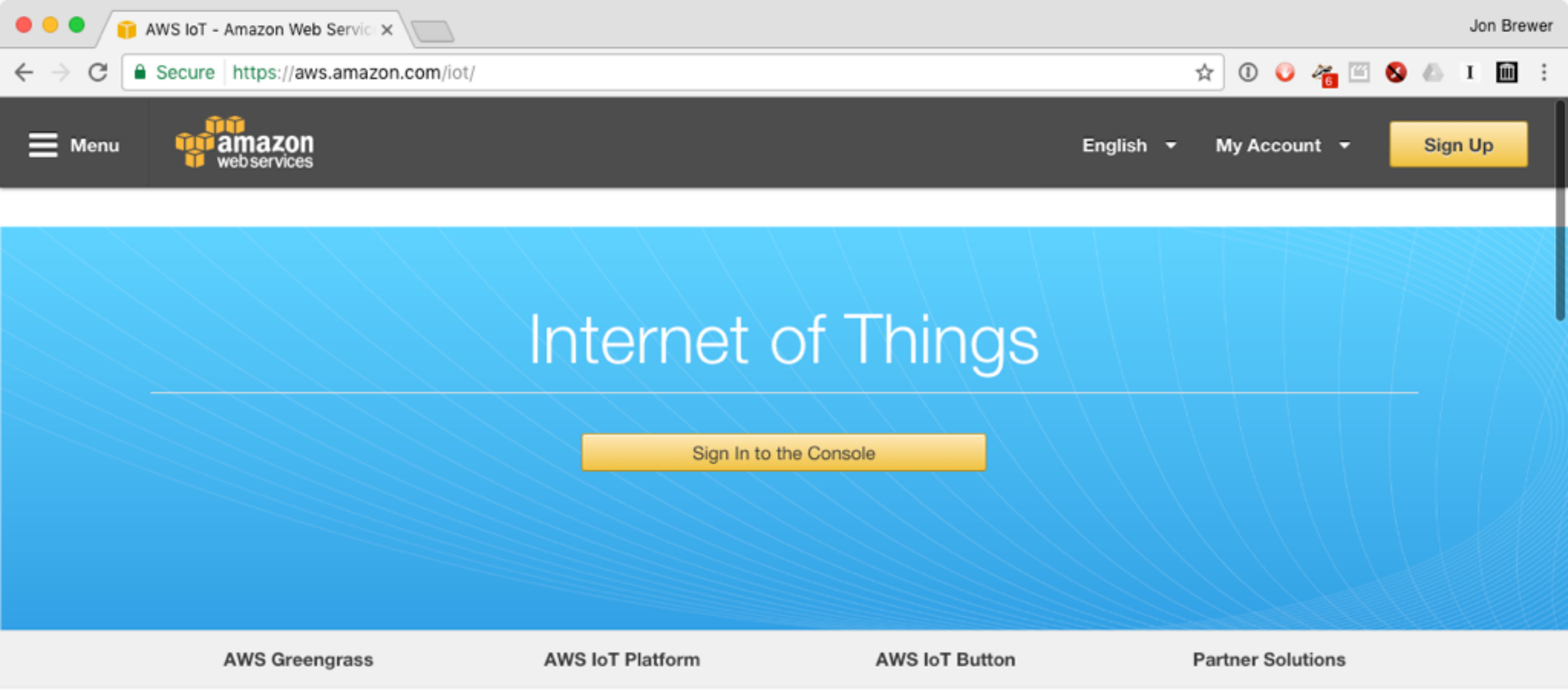

The Internet of Things (IoT) is a term coined by Kevin Ashton, a British technology pioneer working on radio-frequency identification (RFID) who conceived a system of ubiquitous sensors connecting the physical world to the Internet. Although things, Internet, and connectivity are the three core components of IoT, the value is in closing the gap between the physical and digital world in self-reinforcing and self-improving systems.

If you knew the state of every thing in the world, and could reason on top of the data: What problems would you solve?

AllThingsTalk | Make IoT ideas

Jon Brewer

www.allthingstalk.com

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What we do

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Creators of Cayenne IoT Proje

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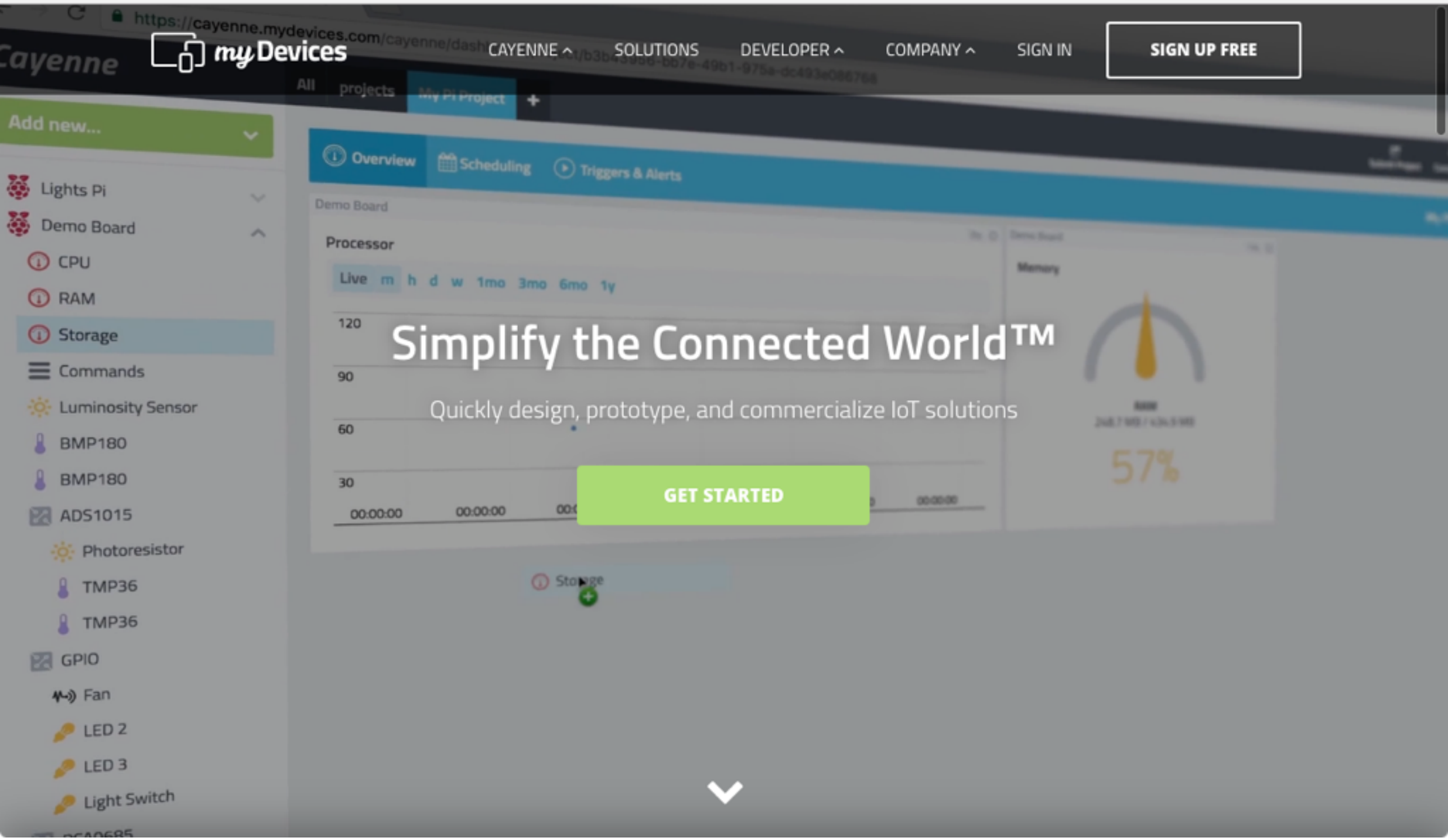

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Stream Technologies - IoT-X

Jon Brewer

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