Plataformas de Hardware

Leonardo Steinfeld

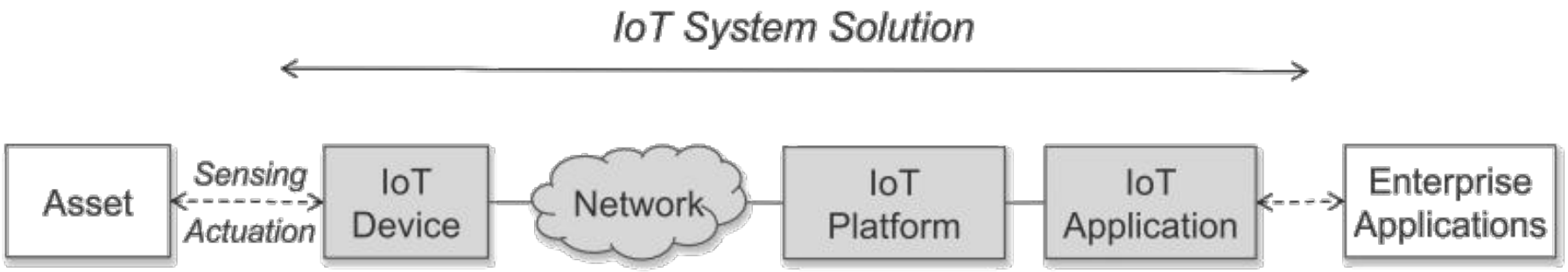
Objetivos

- Introducir la arquitectura de hardware de dispositivos de IoT
- Describir las funciones de cada subsistema
- Dar ejemplos de implementación
- Enumerar soluciones concretas, especialmente:
  - LoRaWAN
  - NB-IoT
  - 6LoWPAN (IEEE 802.15.4)

Agenda

- Introducción
- Dispositivos de IoT: bloques constitutivos
  - Microcontrolador
  - Radio
  - Sensores
  - Alimentación
- Soluciones
  - Opciones de hardware generales
  - Tecnologías de comunicación
- Conclusiones

Introducción



- *IoT Device ~ Plataformas de hardware*
  - “instrumenta” el activo
  - capacidad de sensado (medir) y actuación
  - realización simple o compleja

Introducción

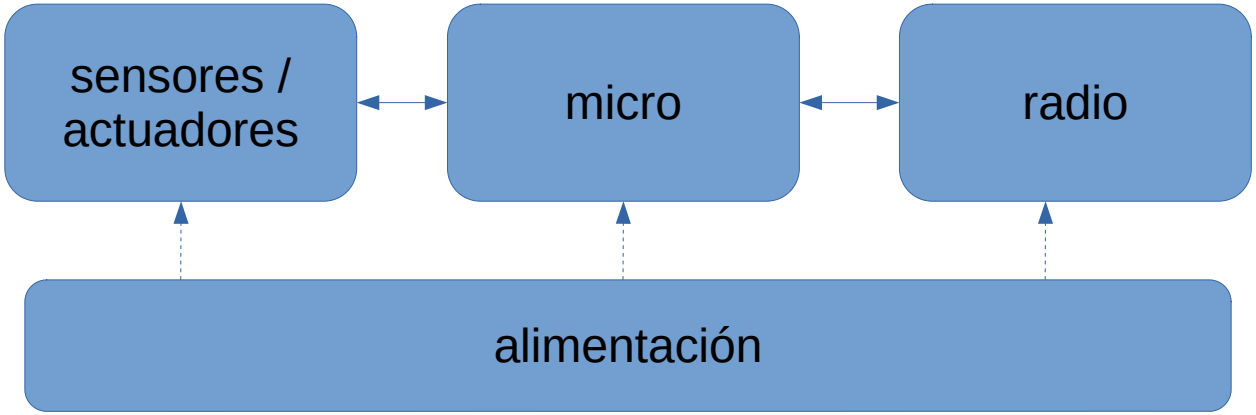
- Requerimientos generales
  - bajo todo

costo tamaño consumo

- Requerimientos funcionales

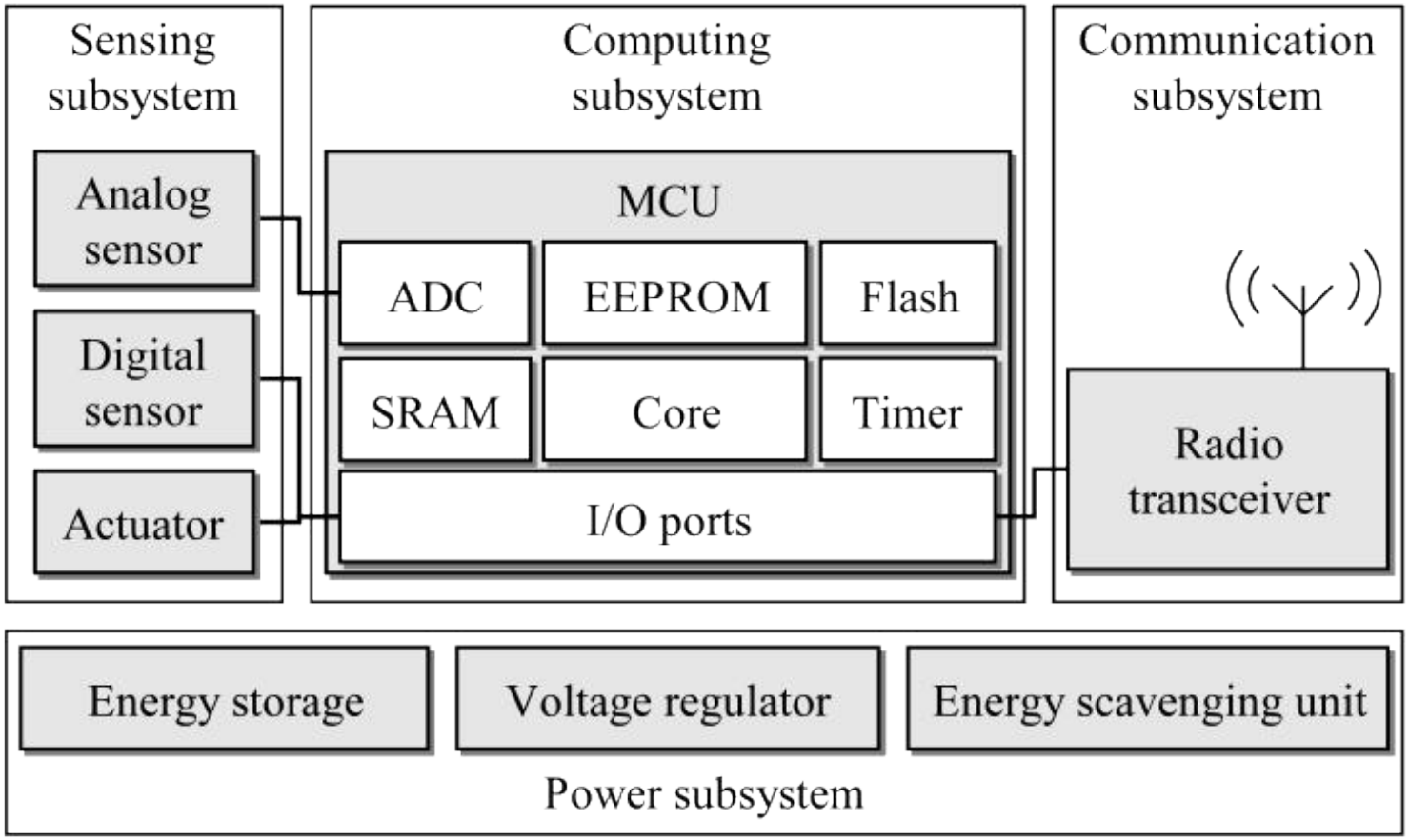
Introducción

- Dispositivo: diagrama de bloques

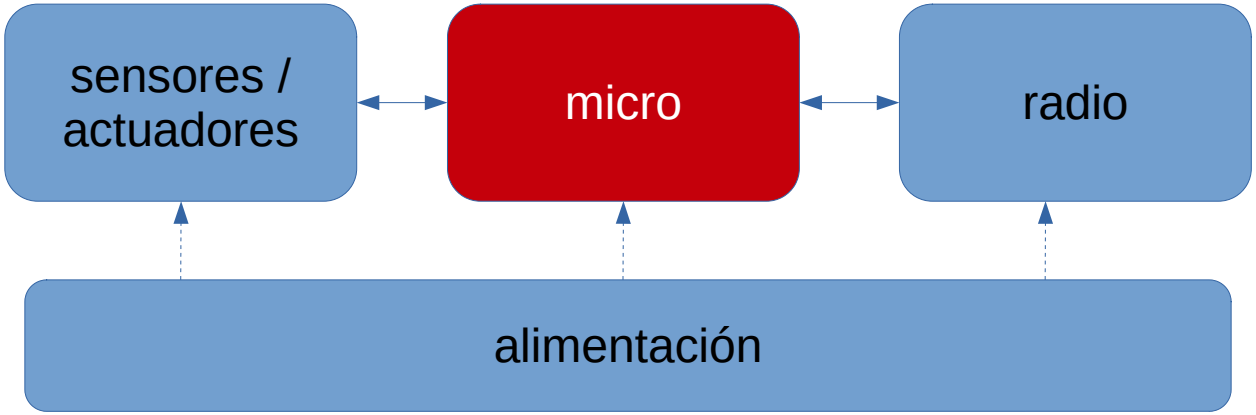


Introducción

- Dispositivo: diagrama de bloques detallado

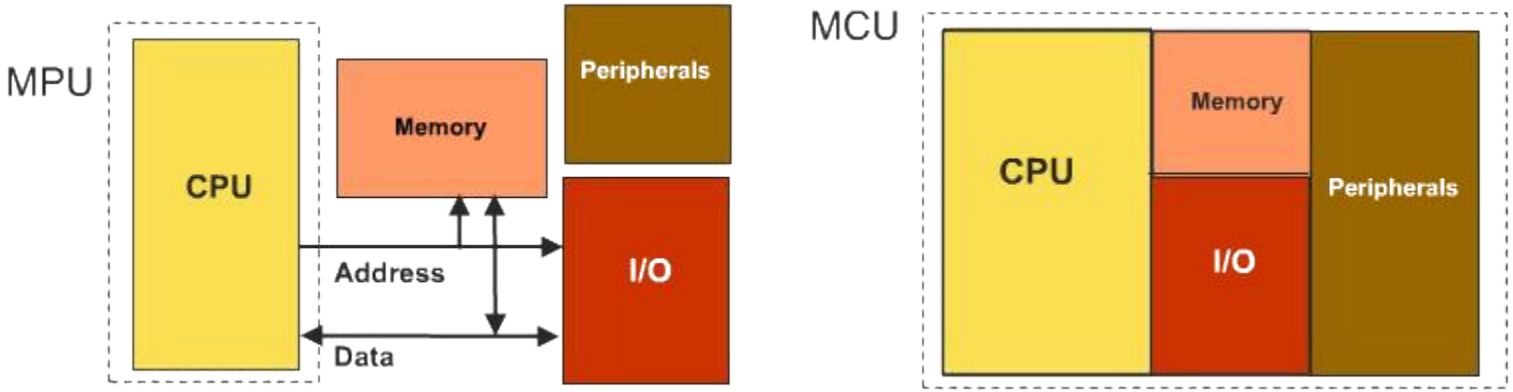


Microcontrolador



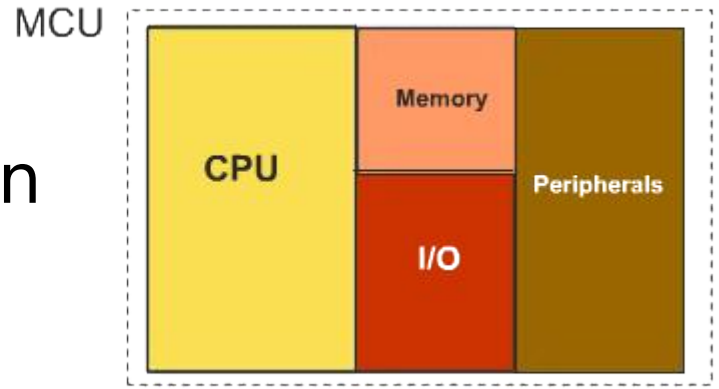
Microcontrolador

- Procesador:
  programable, periféricos y memoria integrada
- Funciones
  - *input*: sensores
  - *output*: actuadores
  - procesado local de datos



Microcontrolador

- Requerimientos
  - Memoria de código: Flash, FRAM
  - Memoria de datos: SRAM (FRAM+cache)
  - Memoria datos *bulk*:
    - *logs*, datos, *file system*
  - Potencia de procesamiento:
    - velocidad de reloj, arquitectura N-bits, FPU (necesario?)
  - Consumo
    - modos de operación

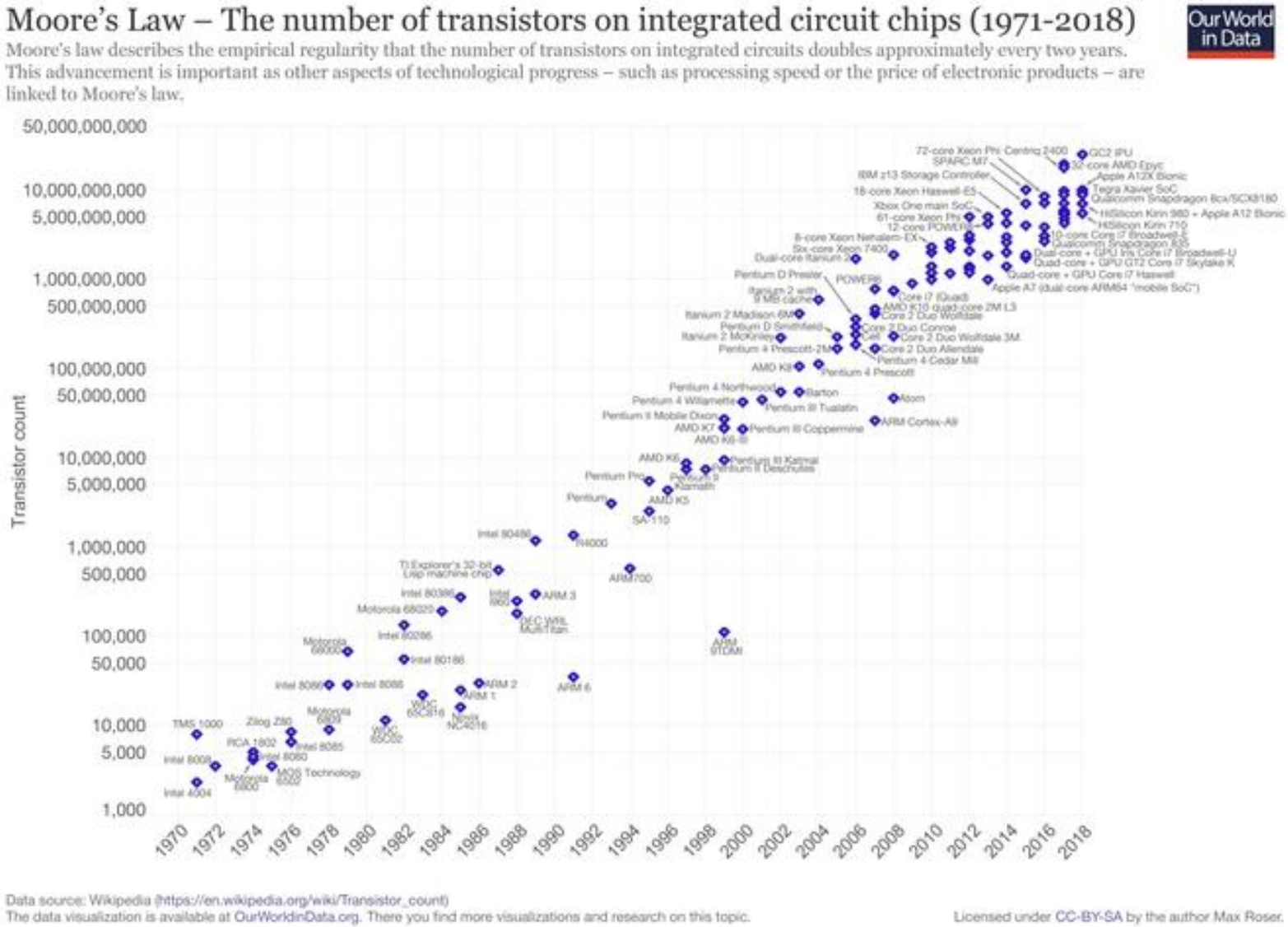


Microcontrolador

- Programa
  - Aplicación de usuario: lógica y procesamiento
  - Sistema operativo / arquitectura de software
  - Pila de comunicación

- Opciones
  - microcontrolador único
  - separados: aplicación + pila de comunicación

Microcontrolador

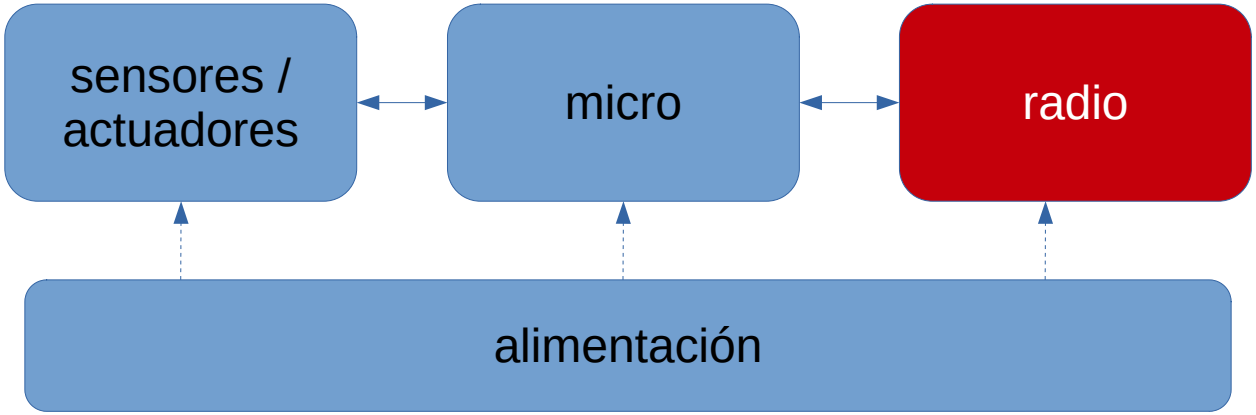


Microcontrolador (caso TI)

- TelosB /sky (**2005**)
  - MSP430F1611 (8 MHz)
    - 10 KB RAM
    - 48 KB Flash
    - 4mA active / 10 uA sleep
  - CC2420
- CCC2538 SoC (**2013**)
  - Cortex M (32 MHz)
    - 32 KB RAM
    - 256 KB Flash
    - ~10 mA active / ~1uA sleep
  - “CC2520” integrado

¿Dónde se han volcado los **beneficios** de la “Ley de Moore”?

Radio

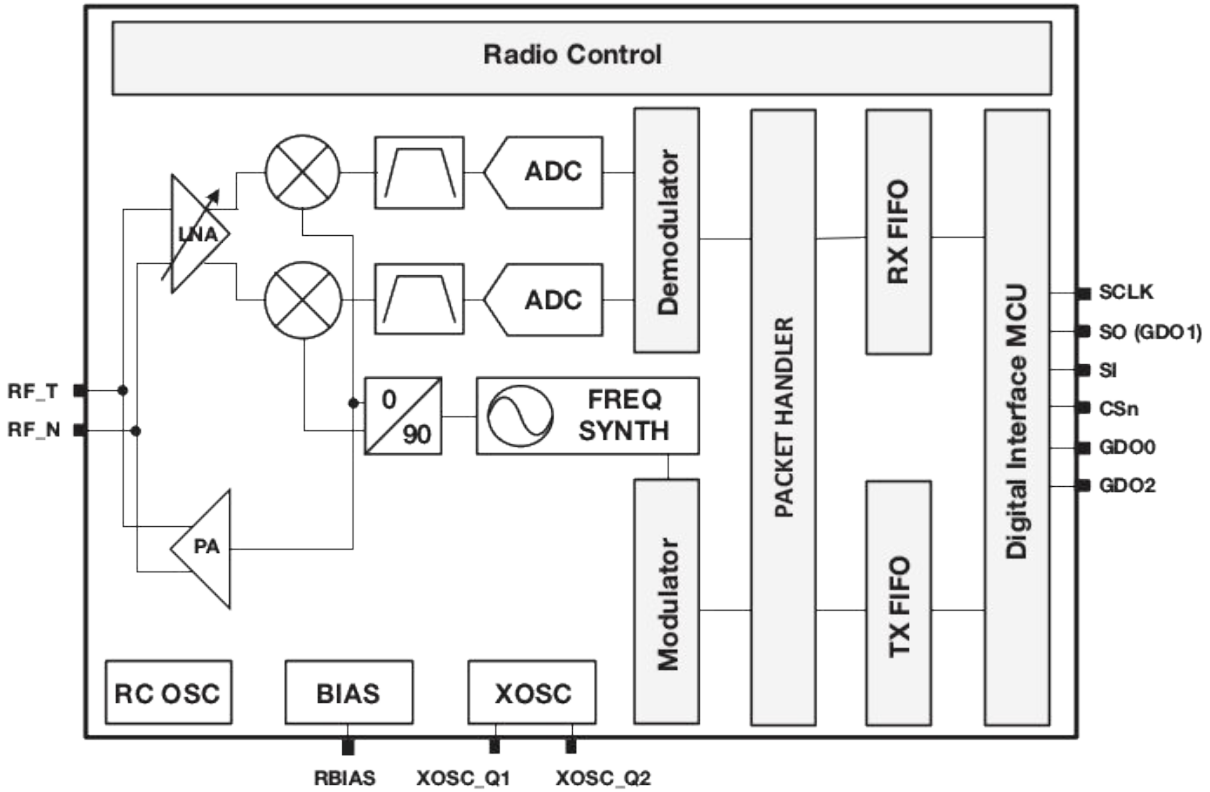


Radio

- Nombres: transceiver / trasceptor
- Tipos
  - modem (modulador / demodulador)
  - packet-radio
- Bandas
  - ISM
    - sub-GHz
    - 2.4 Ghz
  - Licenciadas (NB-IoT)

Radio

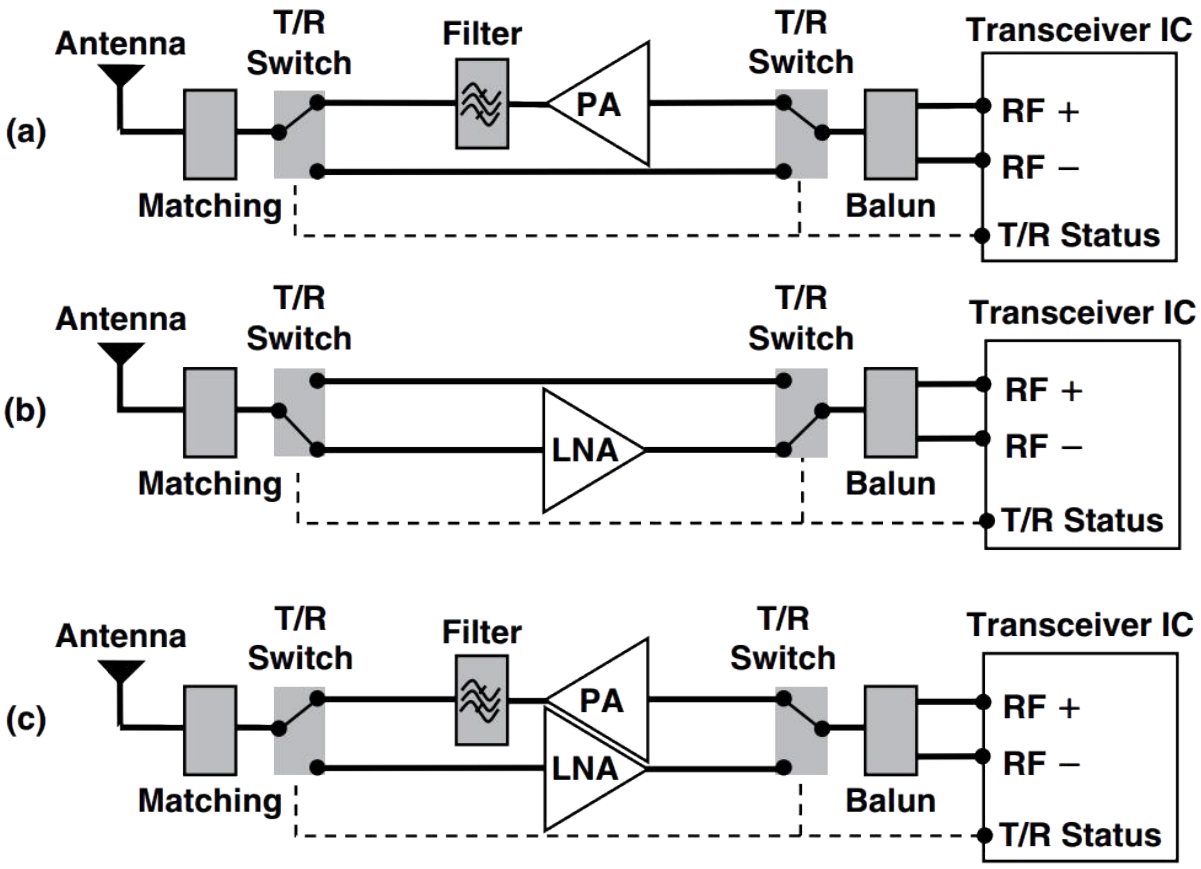
- Diagrama de bloques (sub-GHz)



CC110L block diagram.

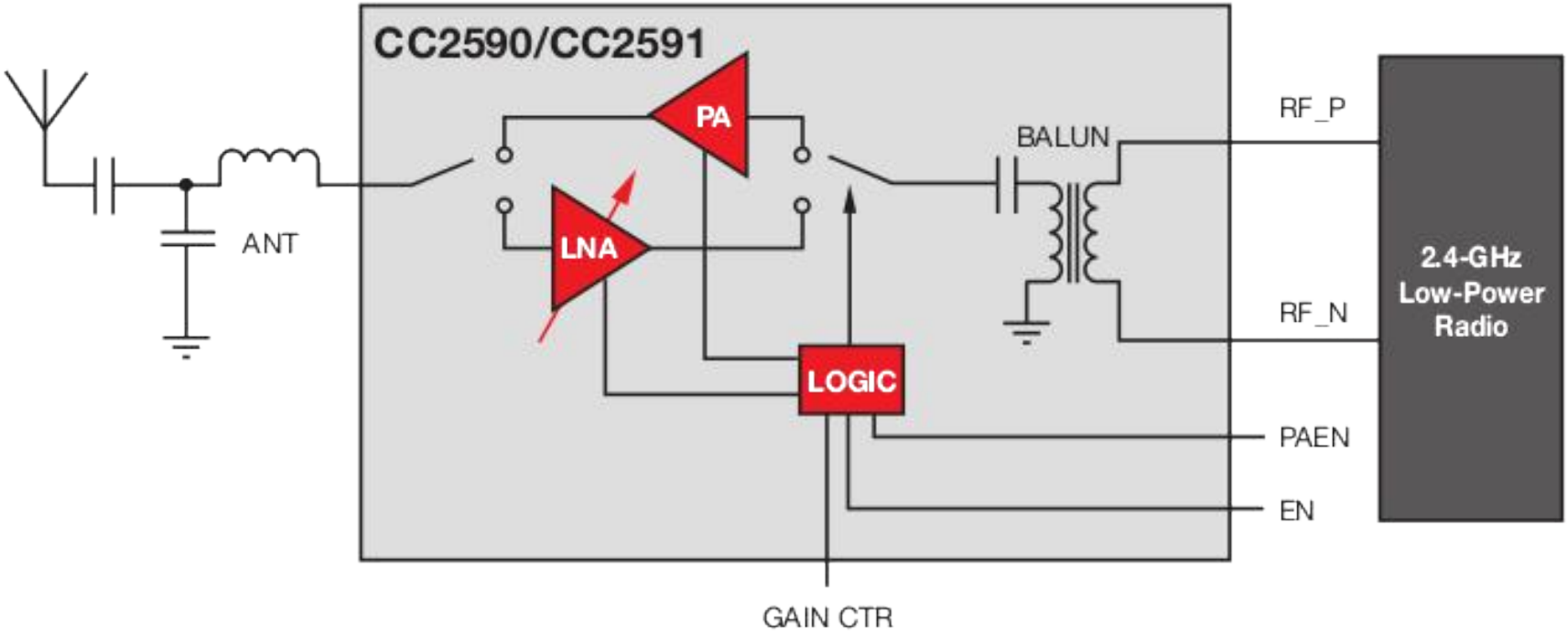
Radio

- PA/LNA: *Power & Low Noise Amplifier*



Radio

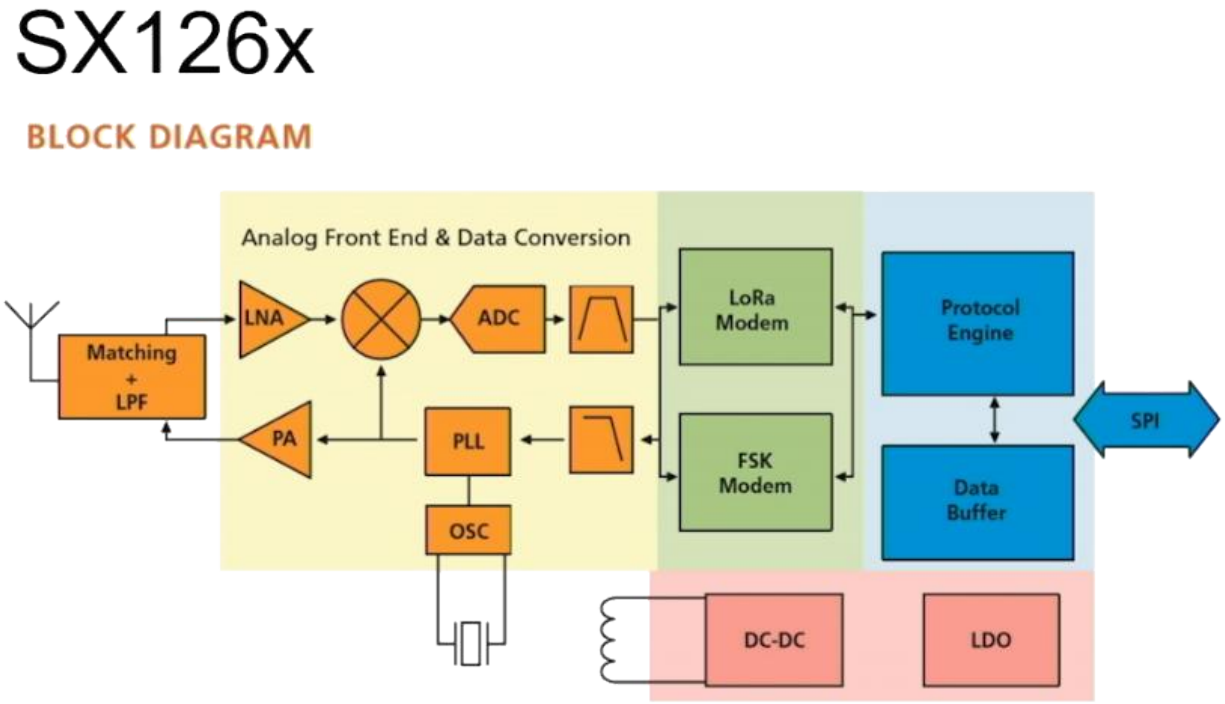
- PA/LNA ejemplo (2.4 GHz)



CC2590/CC2591 block diagram.

Radio

- Diagrama de bloques (LoRa)



Radio

LoRa® Products

LoRa Products							
Part Number	Frequency Range (MHz)	Link Budget (dB)	RXCurrent (mA)	FSK Max DR (kbps)	LoRa DR (kbps)	Max Sensitivity (dBm)	TX Power (dBm)
NEW **SX1261**	150–960	163	4.6	300	0.018–62.5	-148	+15
NEW **SX1262**	150–960	170	4.6	300	0.018–62.5	-148	+22
NEW **SX1268**	410–810	170	4.6	300	0.018–62.5	-148	+22
SX1272	862–1020	158	10	300	0.3–40	-138	+ 20
SX1273	862–1020	150	10	300	1.7–40	-130	+ 20
SX1276	137–1020	168	11	300	0.018–40	-148	+ 20
SX1277	137–1020	158	11	300	1.7–40	-138	+ 20
SX1278	137–525	168	11	300	0.018–40	-148	+ 20
SX1279	137–960	168	11	300	0.018–40	-148	+20

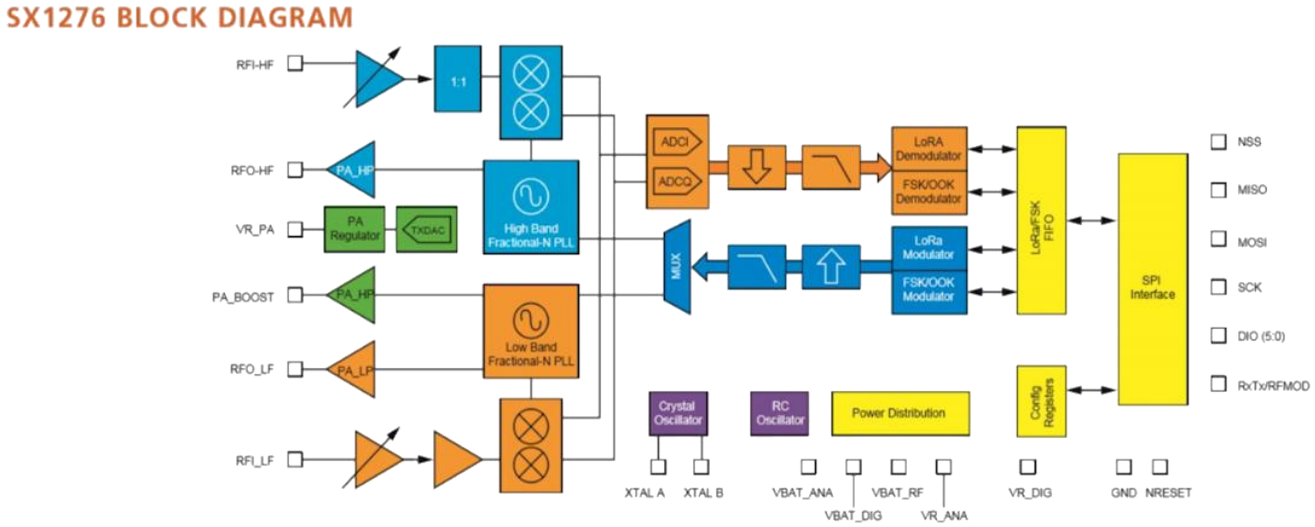
Wireless & RF Selector Guide www.semtech.com/uploads/design-support/SG-SEMTECH-WIRELESSRF.pdf

LoRa®

SEMTECH

Radio

SX127x



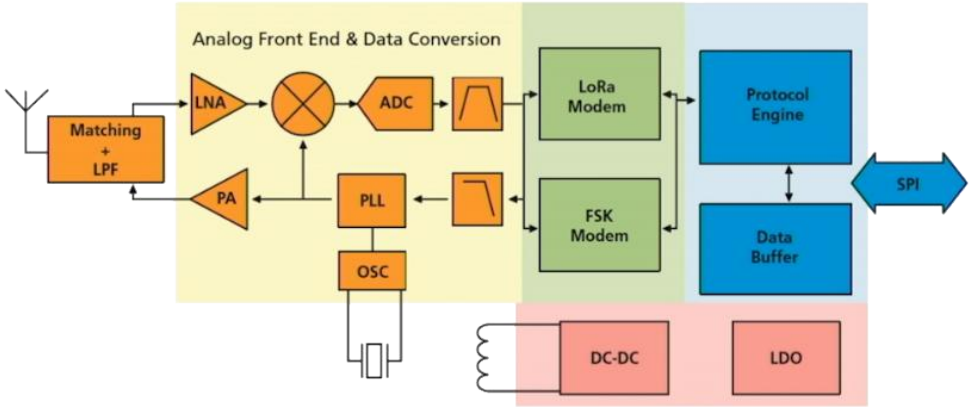
Features

- 1st Gen LoRa radio transceivers in > 80M products
- LoRaWAN™, IEEE802.15.4g and WMBus compliant
- Programmable registers for maximum flexibility

Radio

SX126x

BLOCK DIAGRAM



SX127x Comparison

- 50% less power in RX
- 25% less power in TX
- 45% reduction in size
- (QFN 4x4mm vs QFN 6x6mm)

Features

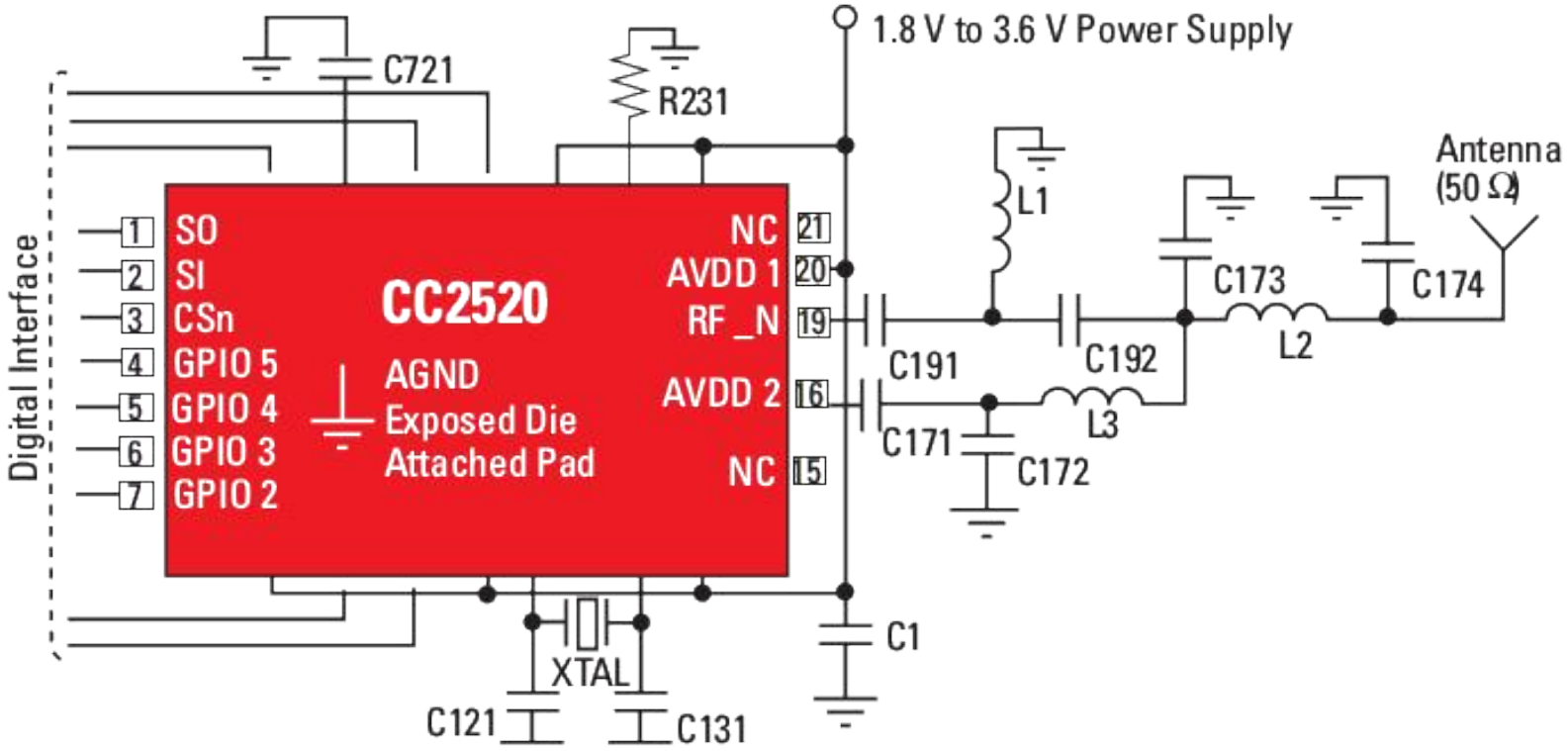
- Higher TX power (22dBm)
- Global continuous frequency coverage (150-960MHz)
- New spreading factor SF5
- Simplified command based API interface
- Integrated PMU (includes dc-dc and LDO)

LoRa®

SEMTECH

Radio

- Circuito de aplicación (CC2520, 2.4 GHz)

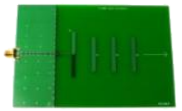


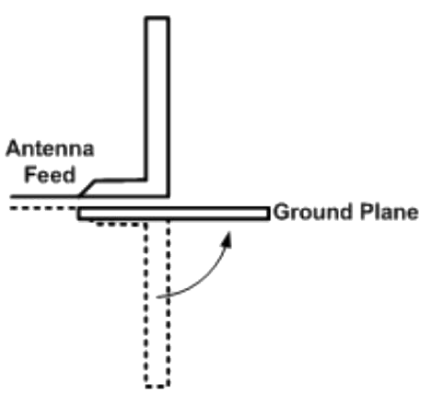
CC2520 application circuit.

Radio

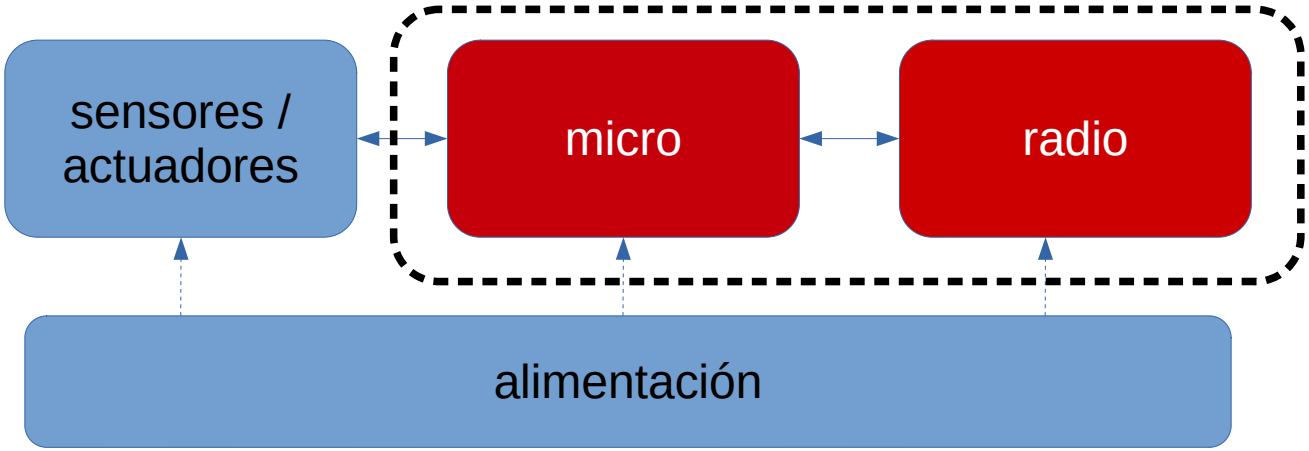
Antenas

Antenna Selection Quick Guide — DN035

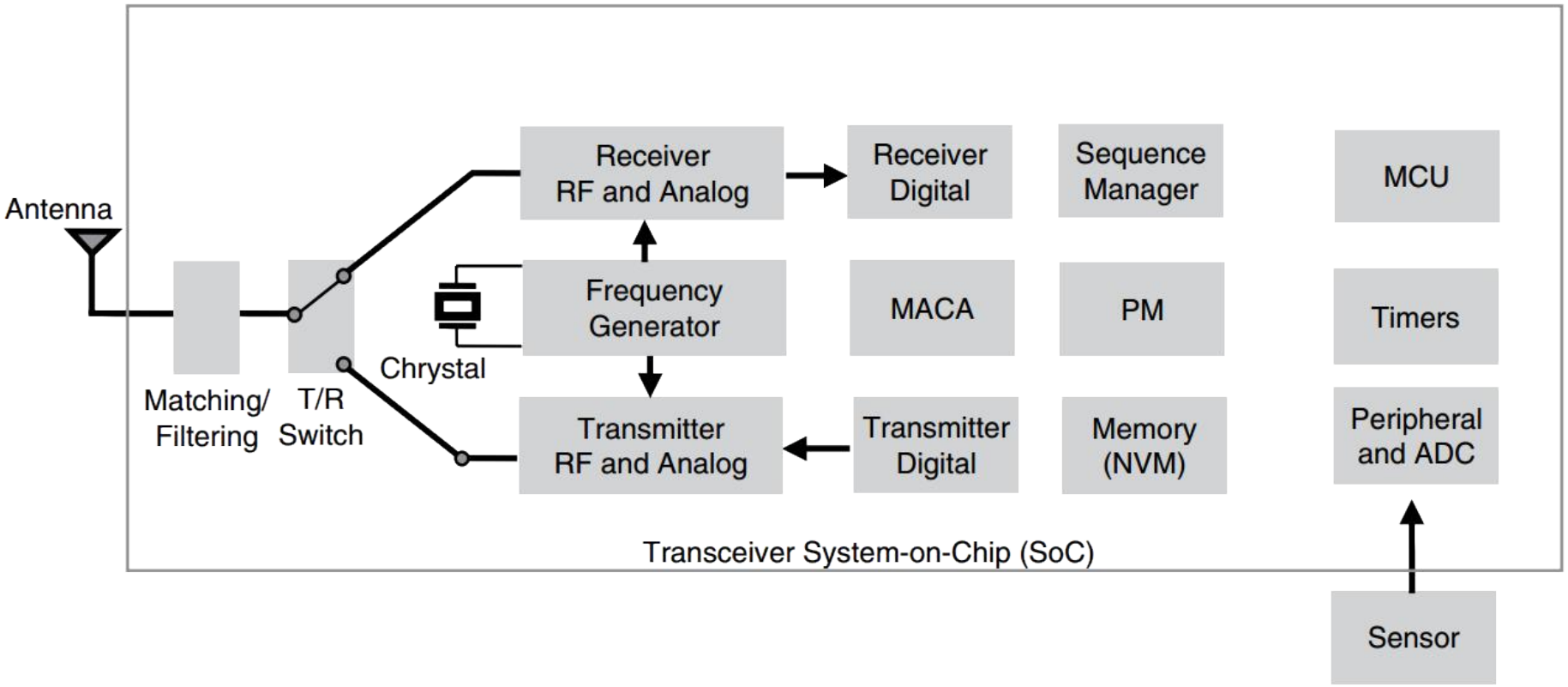
							
Design / Application Note	DN007 *1	AN043 *2	DN004	DN041	DN024	DN034	AN048
Frequency	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz
Typical Efficiency	80%(EB) 94%(SA)	68%(EB)	80%(EB)	65%(Zlight2)	76%(EB) 94%(SA)	72%(SA)	55%(USB)
Bandwidth@ VSWR 2:0	280 MHz	101 MHz	100 MHz	150 MHz	354 MHz (SA)	497 MHz	150 MHz
Dimensions (mm)	26 x 8	15 x 6	46 x 9	45 x 2.5	38 x 25	150 x 100	7 x 3



System-on-chip (SoC)



System-on-chip (SoC)



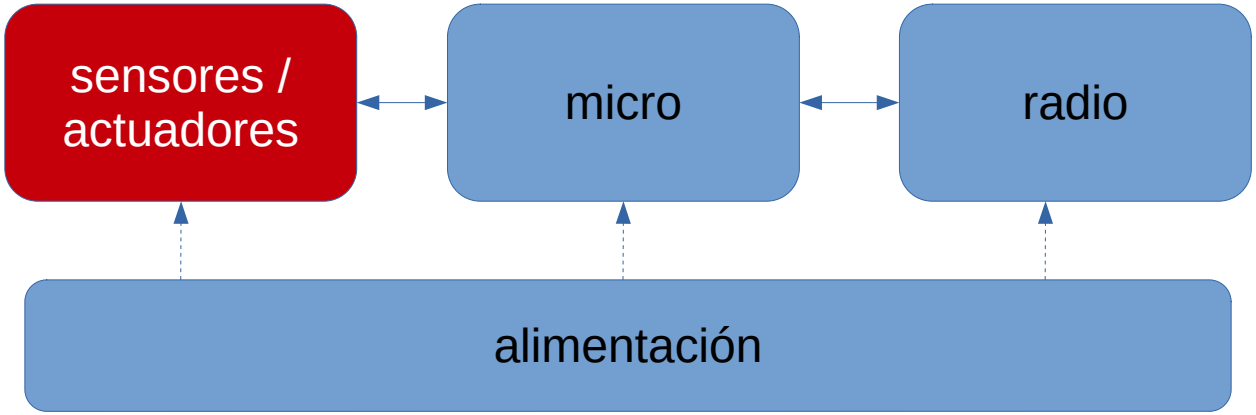
System-on-chip (SoC)

		SoC small footprint, high integration, low cost	Co-processor flexible, easy to use and reduced time to market	Dual-chip ultra-low power or high performance
Complete ZigBee Solutions	Application	**CC2530** or **CC2538**	Any MCU (**MSP430™**, **Tiva™**) Any MPU (**Sitara™**)	**MSP430**
	Protocol stack		CC253x-based coprocessors with UART/SPI/USB interface: • Stack and application profile • Protocol stack • MAC only 	 Three paths to ZigBee
	Radio			**CC2520**
	RF front end (optional)	**CC2590 / CC2591**	**CC2590 / CC2591**	**CC2590 / CC2591**

TI's three paths to ZigBee.

www.ti.com/zigbee

Sensores / Actuadores



Sensores

- transductor: magnitud física
  - Temperatura y humedad del aire
  - Luz
  - etc.
- interfaz eléctrica
  - analógica: 0-5V, 4-20mA, etc.
  - digital: SPI, I2C, etc.
- diferentes “gama”
  - aficionado (*hobbyist*)
  - industrial

Sensores: ejemplos

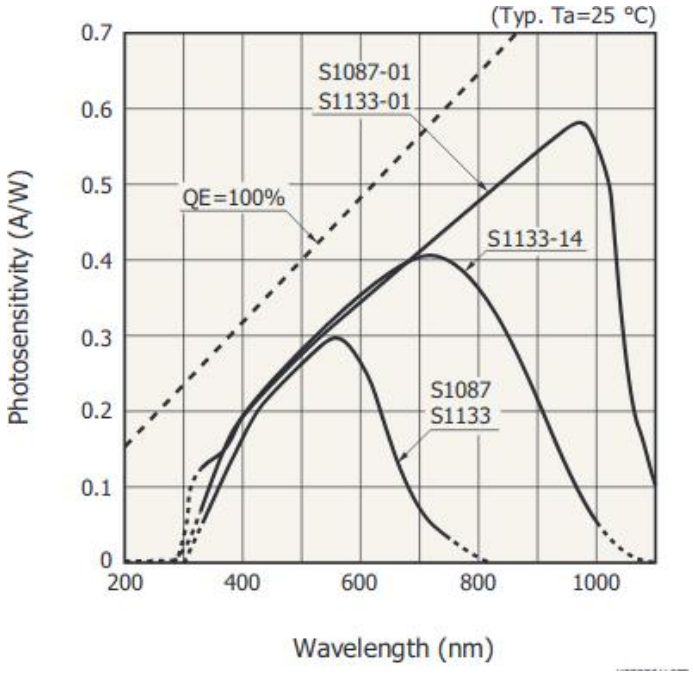
Temperature & Humidity: Sensirion® SHT11

- Humidity
  - Range: 0 ~ 100% RH
  - Resolution: 0.05 (typical)
  - Accuracy: ± 3 %RH (typical)
- Temperature
  - Range: -40 ~ 123.8 °C
  - Resolution: : ± 0.01(typical)
  - Accuracy: ± 0.4 °C (typical)

Sensores: ejemplos

- Light: Hamamatsu® S1087 Series
  - Visible & Infrared Range

    560 nm & 960 nm peak sensitivity wavelength



Sensores: ejemplos

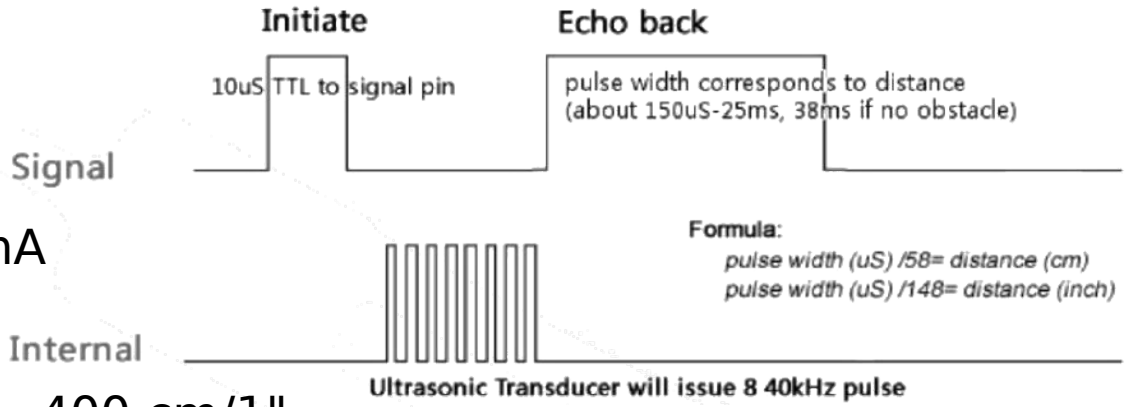
- Humedad de suelo
  - Decagon: EC-05 / 10HS

Sensores: ejemplos

- Sensor de distancia (ultrasonido)

<u>Features:</u>

Power Supply :+5V DC
Quiescent Current : <2mA
Working Currnt: 15mA
Effectual Angle: <15°
Ranging Distance : 2cm – 400 cm/1" 13ft
Resolution : 0.3 cm
Measuring Angle: 30 degree
Trigger Input Pulse width: 10uS
Dimension: 45mm x 20mm x 15mm

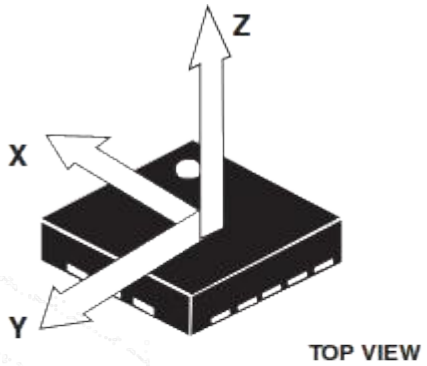


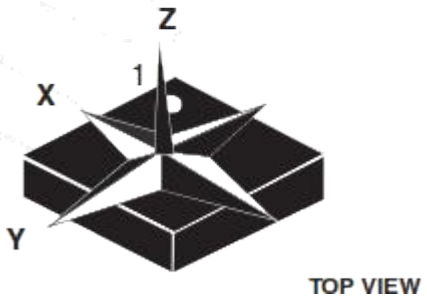
Sensores: ejemplos

- Acelerómetro / Magnetómetro
  - LSM303D

Features:

3 magnetic field channels and 3 acceleration channels
±2 to ±12 gauss magnetic
±2 to ±16 g dynamically acceleration
16-bit data output
SPI / I2C serial interfaces
Analog supply voltage 2.16 V to 3.6 V
Power-down mode / low-power mode
Programmable interrupt generators for free-fall, motion detection and magnetic field detection
Embedded temperature sensor
Embedded FIFO





Sensores: ejemplos

- GPS
  - GPS EVA 8M

Features

Receiver type	72-channel u-blox 8 GNSS engine GPS/QZSS L1 C/A, GLONASS L1 FDMA, SBAS: WAAS, EGNOS, MSAS	
Nav. update rate	up to 18 Hz	
Position accuracy Autonomous:	GPS 2.5 m CEP	GLONASS 4.0 m CEP
Acquisition Cold starts: Aided starts: Reacquisition:	 30 s 3 s 1 s	 33 s 3 s 1 s
Sensitivity Tracking & Nav: Cold starts: Hot starts:	 –164 dBm –147 dBm –156 dBm	 –163 dBm –145 dBm –155 dBm
Assistance GNSS	AssistNow Online AssistNow Offline (up to 35 days) AssistNow Autonomous (GPS only, up to 3 days) OMA SUPL & 3GPP compliant	
Oscillator	Crystal	
Real time clock (RTC)	Can be derived either from onboard GNSS crystal (for lowest system costs and smallest size) or from external RTC Clock (Default mode, for lower battery current)	
Anti jamming	Active CW detection and removal	
Memory	Onboard ROM	

Package

43 pin LGA (Land Grid Array): 7.0 x 7.0 x 1.1 mm, 0.13 g

Electrical data

Supply voltage	1.65 V to 3.6 V
Digital I/O voltage level	1.65 V to 3.6 V
Power consumption[3]	16 mA @ 3 V (Continuous) 3.7 mA @ 3 V Power Save mode (1 Hz)
Backup Supply	1.4 V to 3.6 V

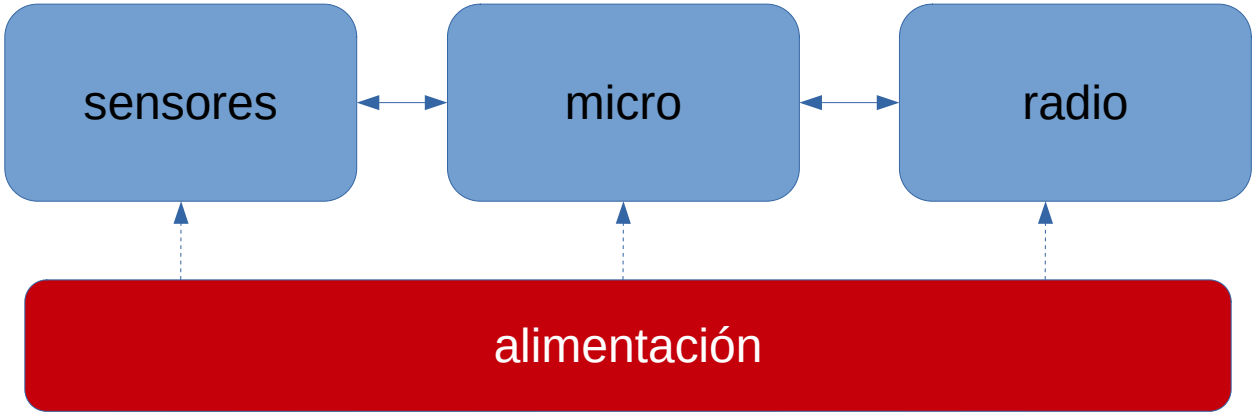
3 For default mode: GPS incl. QZSS, SBAS

Interfaces

Serial interfaces	1 UART 1 USB 1 SPI (optional) 1 DDC (I²C compliant) 1 SQI interface (For optional external Flash)
Digital I/O	Configurable timepulse 1 EXTINT input for Wakeup
Timepulse	Configurable 0.25 Hz to 10 MHz
Protocols	NMEA, UBX binary, RTCM

7.0 × 7.0 × 1.1 mm

Alimentación



Alimentación

- Pilas (*battery*)
- Consideraciones
  cap. nominal
  efecto temp.

PRODUCT DATASHEET

ENERGIZER E91

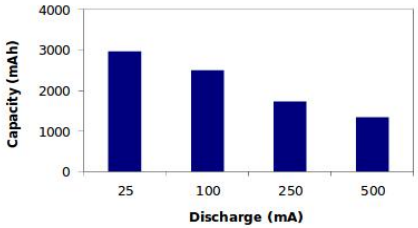
AA

Specifications

Classification:	Alkaline
Chemical System:	Zinc-Manganese Dioxide (Zn/MnO_2)
	No added mercury or cadmium
Designation:	ANSI-15A, IEC-LR6
Nominal Voltage:	1.5 volts
Nominal IR:	150 to 300 milliohms (fresh)
Operating Temp:	-18°C to 55°C (0°F to 130°F)
Typical Weight:	23.0 grams (0.8 oz.)
Typical Volume:	8.1 cubic centimeters (0.5 cubic inch)
Jacket:	Plastic Label
Shelf Life:	10 years at 21°C
Terminal:	Flat Contact

Milliamp-Hours Capacity

Continuous discharge to 0.8 volts at 21°C



PRODUCT DATASHEET

ENERGIZER L91

Ultimate Lithium

AA

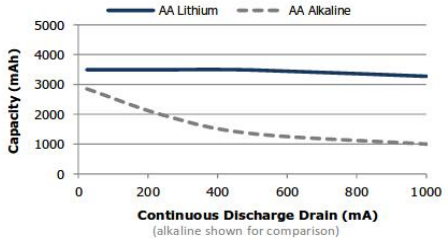
Specifications

Classification:	"Cylindrical Primary Lithium"
Chemical System:	Lithium/Iron Disulfide (Li/FeS_2)
Designation:	ANSI 15-LF, IEC-FR14505 (FR6)
Nominal Voltage:	1.5 Volts
Sizing Compatibility	E91 NH15 1215
Storage Temp:	-40°C to 60°C (-40°F to 140°F)
Operating Temp:	-40°C to 60°C (-40°F to 140°F)*
Typical Weight:	15 grams (0.5 oz.)
Typical Volume:	8.0 cubic centimeters (0.49 cubic inch)
Max Discharge:	2.5 amps continuous
(single battery only)	4.0 amps pulse (2 sec on / 8 sec off)
Lithium Content:	Less than 1 gram
Typical IR:	120 to 240 milliohms (depending on method)
Shelf Life:	20 years at 21°C
More Details:	On-Line Catalog-Application Manual (Li/FeS_2)
Shipping:	Please refer to PSDS Document
Certifications:	This battery has Underwriters Laboratories component recognition (MH29980) · II 1G Ex ia IIC Ga Baseefa 14ATEX0107U

***All data shown tested at 21°C unless otherwise stated.**

Milliamp-Hours Capacity

Constant Current Discharge to 0.8 Volts



Alimentación

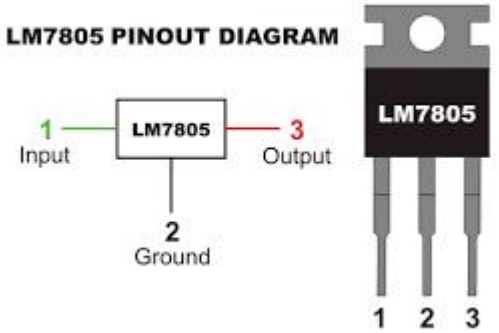
- Recolección de energía (*energy scavenging*)

Energy source	Power density	Duration
Solar cell (direct sun light)	15 mW/cm^2	Continuous
Solar cell (well illuminated room)	10 μW/cm^2	Continuous
Piezoelectric	200 μW/cm^3	Operation (e.g. button push)
Temperature difference	40 μW/cm^3 / 5 °C	Continuous
Air flow	380 μW/cm^3 / 5 m/s	Continuous

Alimentación

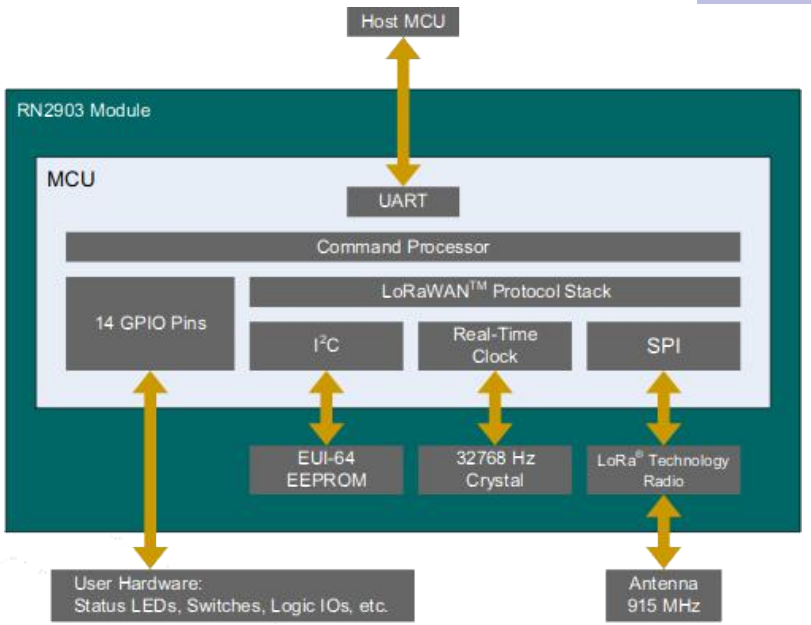
- Conversores de tensión

- Tipos
  - Reguladores lineales
  - Conmutados (DC-DC)
    - up, down, up-down
- Consideraciones
  - limites de tensiones
  - salida: fija, programable
  - eficiencia

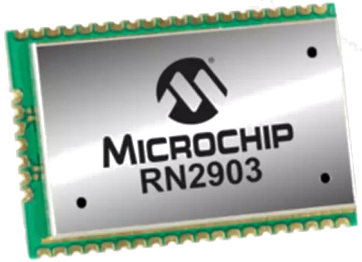


Soluciones

- Opciones
  - chip
  - SoC / SiP
  - módulo
  - kit / *prototyping board*



Ejemplos: LoRaWAN

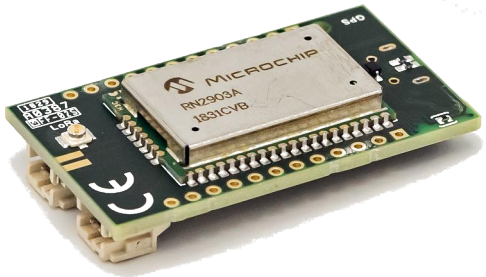


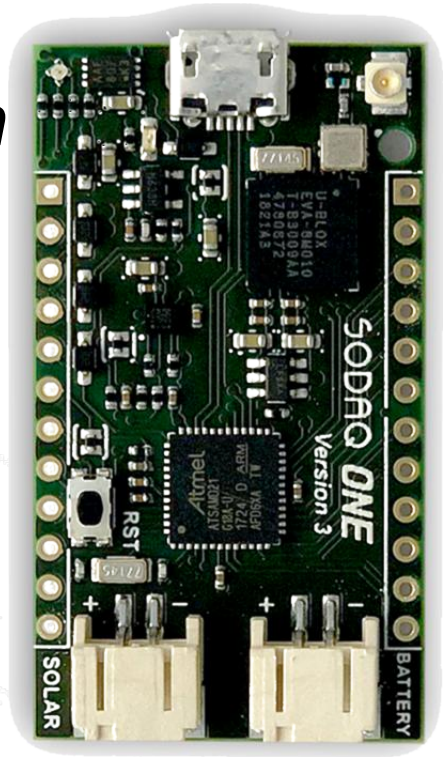
Soluciones

- Tecnologías de comunicación
  - LoRaWAN
  - NB-IoT
  - 6LoWPAN (IEEE 802.15.4)
  - Otras: Sigfox, BT, ...

Soluciones

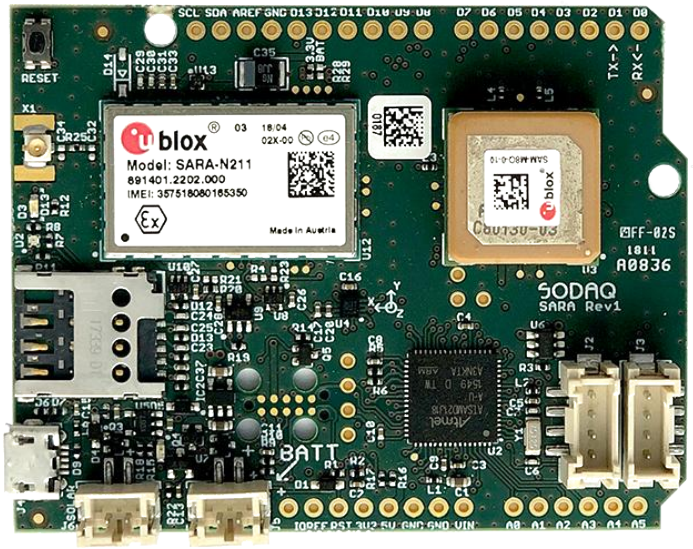
- LoRa: SODAQ ONE
  - LoRa module: RN2903
  - *Accelerometer and Magnetom* (LSM303AGR)
  - GPS EVA 8M

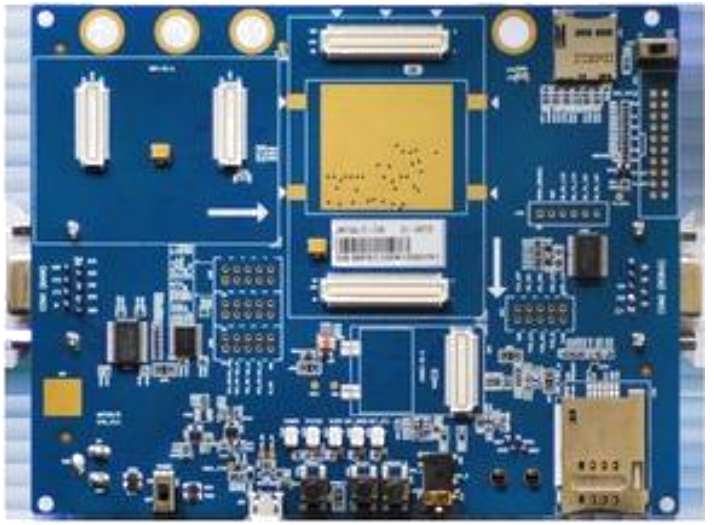




Soluciones

- NB-IoT
  - SODAQ
  - Quectel



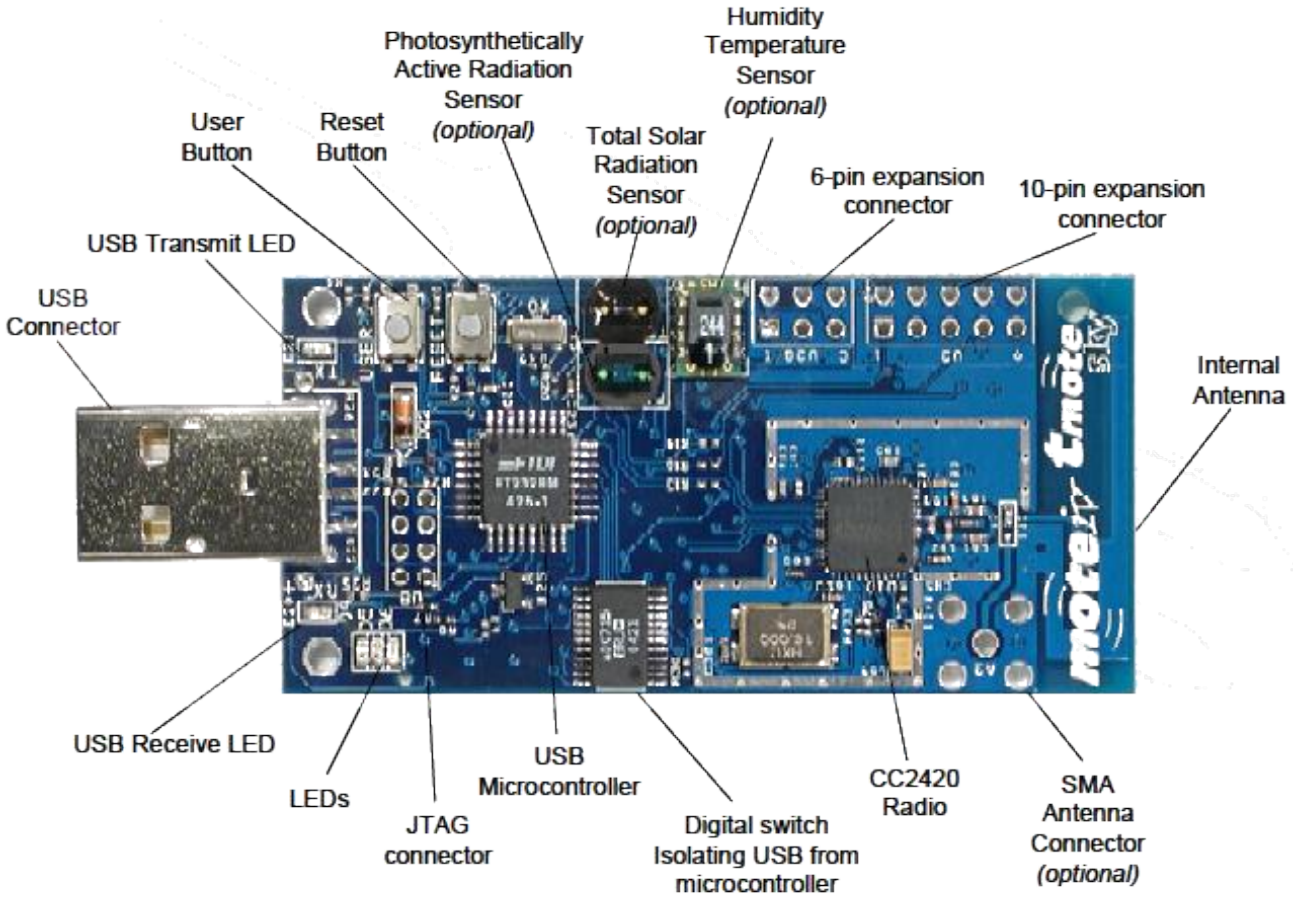


Soluciones

- 6LoWPAN (IEEE 802.15.4, 2.4 GHz): sky / telosb compatible
  - Micro: MSP430F1611
  - Radio: CC2420
  - Sensores:
    - Light 1: Visible Range
    - Light 2: Visible & Infrared Range
    - Temperature & Humidity Sensirion® SHT11

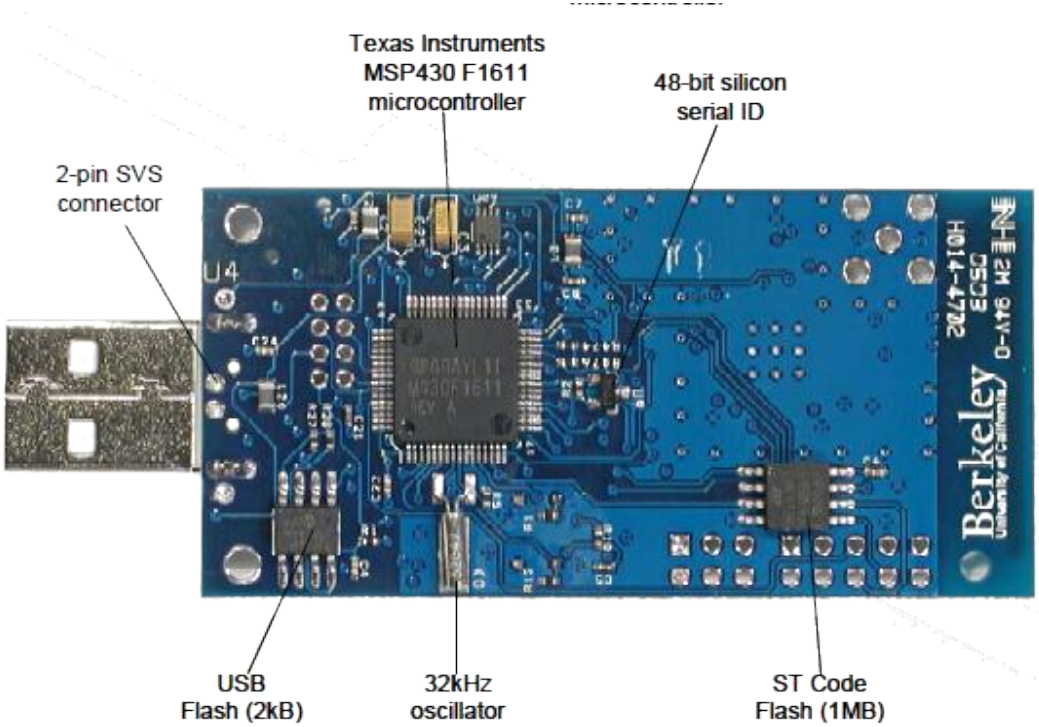
Soluciones

- 6LoWPAN (IEEE 802.15.4, 2.4 GHz): sky / telosb compatible



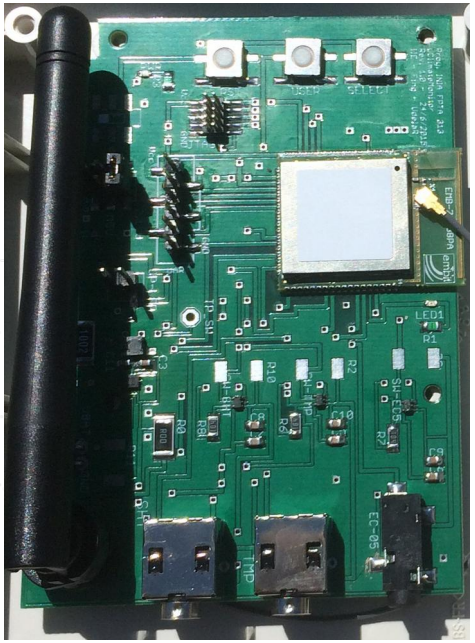
Soluciones

- 6LoWPAN (IEEE 802.15.4, 2.4 GHz): sky / telosb compatible



Soluciones

- 6LoWPAN (IEEE 802.15.4, 2.4 GHz): uclim – IIE (Proyecto INIA-FPTA)
  - CCC2538 (Cortex M + transceiver) + CC2592 (PA/LNA)
    - 32 KB RAM
    - 256 KB Flash
    - ~10 mA active / ~1uA sleep
    - DC/DC Switching reg. (2.1 & 2.5 VDC)



EMB-Z2538PA

Soluciones

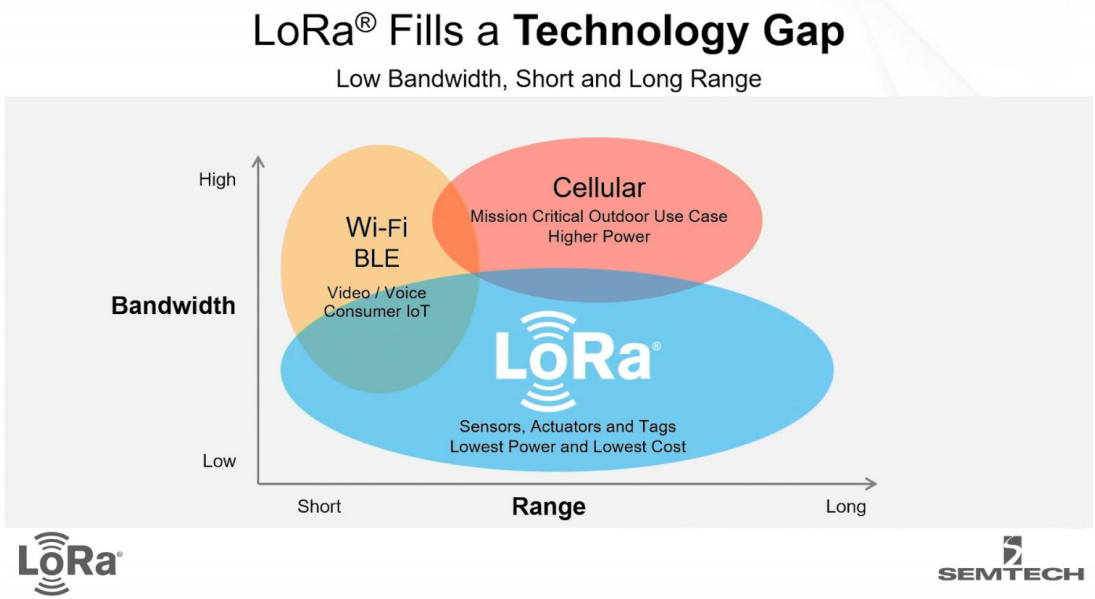
- Sigfox: Loka RC24

SPECIFICATIONS

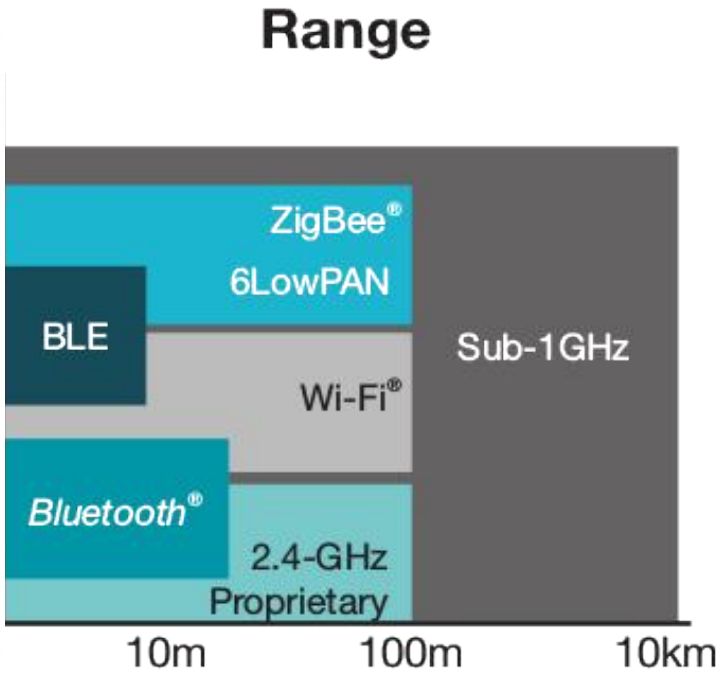
Connectivity	Sigfox, Wi-Fi, Bluetooth
Sensors	Temperature; Accelerometer; (Optional: GPS, External Temperature sensor)
Expansion	24 pins header – Breakout board – SDK
Batteries	2 x AA Alkaline / Lithium / Rechargeable Lithium
Dimensions	L: 92mm; W: 35mm; H: 26mm
IP Certification	IP65
Sigfox Regions	Available for RCZ1 | RCZ2 | RCZ4

Recomendaciones

- ¡Cuidado!
  - Folletos de fabricantes (especialmente)



Semtech / LoRa



Texas Instr.

Recomendaciones

- Características (generales)
  - Generales
    - Tensión de alimentación
    - Corriente/Potencia de consumo
    - Duty cycle (tiempo “on” / “período”)
  - RF
    - *link budget*: PTx (mA), Sensibilidad
  - microcontroladores
    - memoria SRAM / Flash
    - periféricos

Laboratorios

- Microcontrolador (kit): **Arduino Zero**
  - https://docs.arduino.cc/hardware/zero
- Modulo comunicación
  - LoRaWAN: **LR 2 click (RN2903)**
    - https://www.mikroe.com/lr-2-click
  - NB-IoT: **LTE IoT 2 Click (BG96)**
    - https://www.mikroe.com/lte-iot-2-click
- Placa adaptación: **Arduino UNO click shield**
  - https://www.mikroe.com/arduino-uno-click-shield

Gracias!