Redes de sensores inalámbricos (RSI)

Plataformas de hardware

Leonardo Steinfeld

Inst. de Ingeniería Eléctrica, Fac. de Ingeniería
Universidad de la República (Uruguay)

Objetivos

- Introducir la arquitectura de hardware de un nodo.

- Describir las funciones de cada subsistema.

- Dar ejemplos de implementación de cada uno.

- Describir soluciones concretas de nodo, especialmente las utilizadas en el curso.

Agenda

- Introducción: nodo

- Subsistemas o bloques constitutivos del nodo

  - Radio

  - Sensores

  - Alimentación

  - Microcontrolador

- Soluciones

Introducción
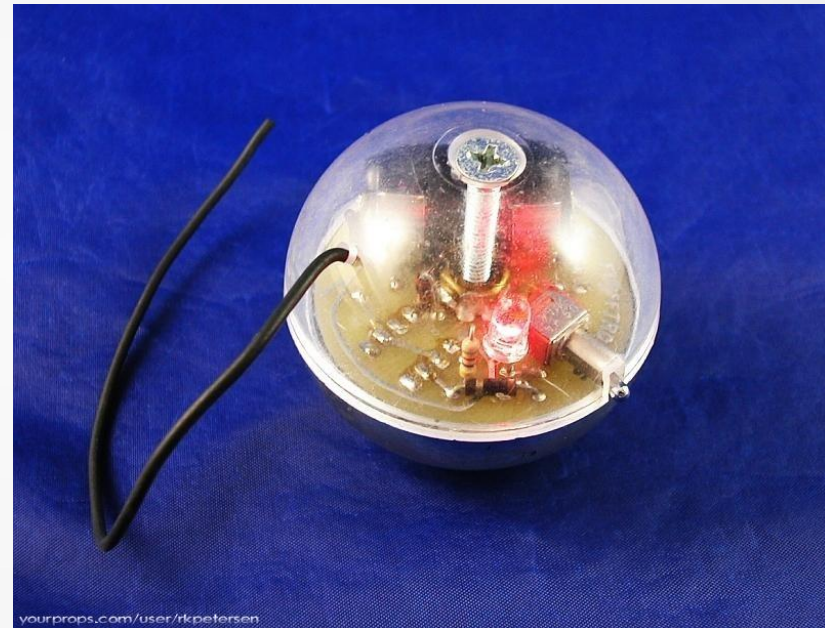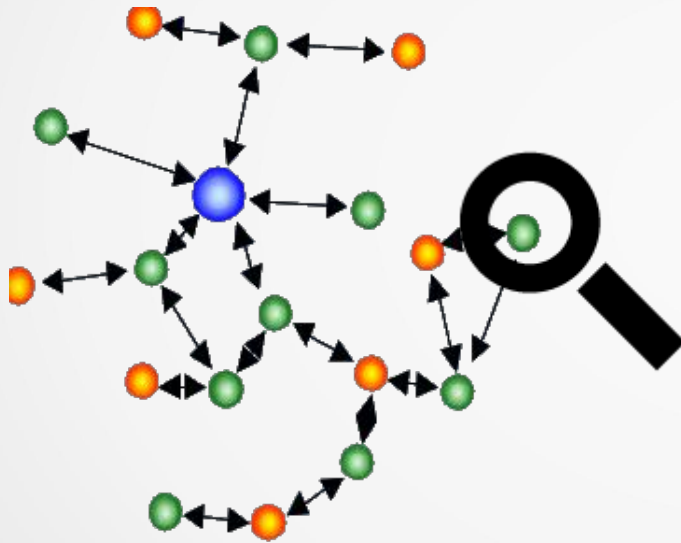
Nodos: requerimientos

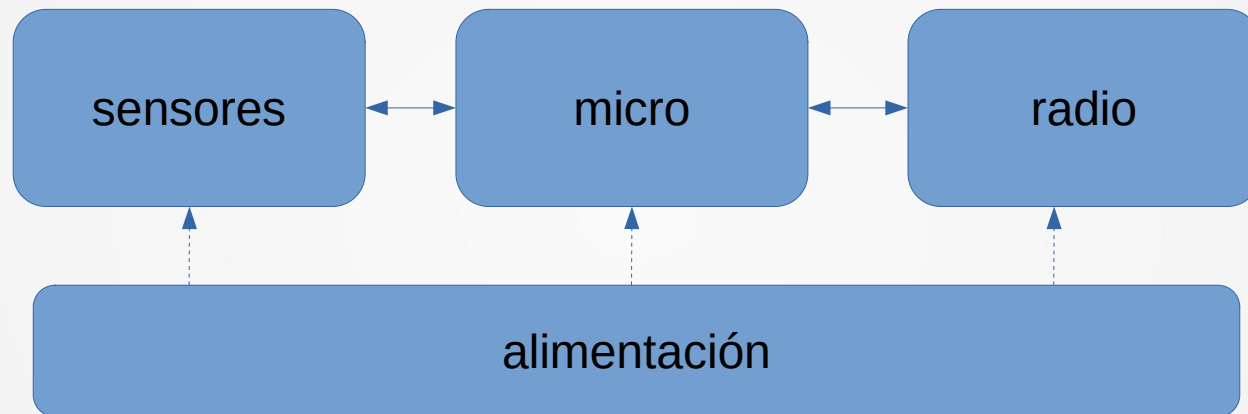- Características
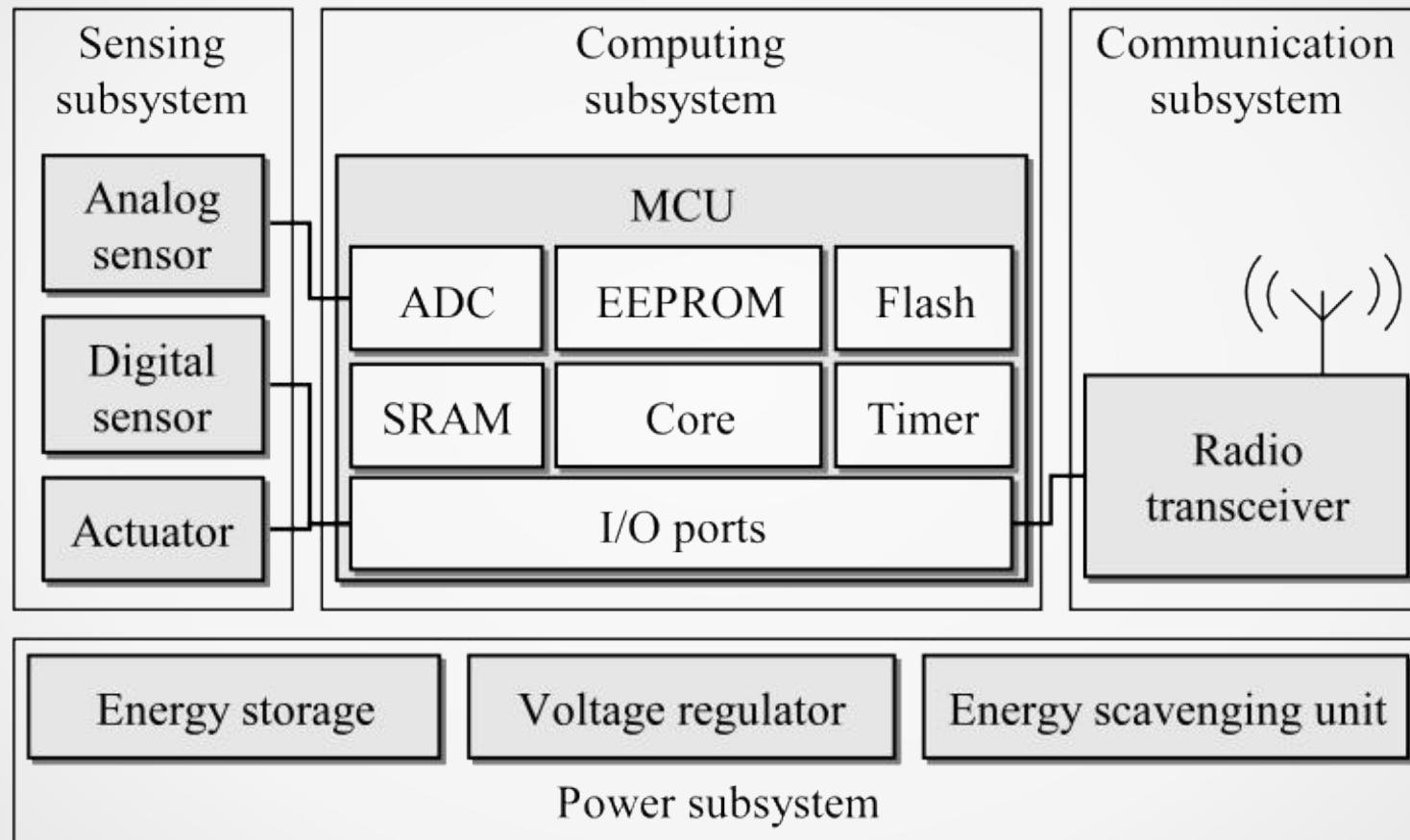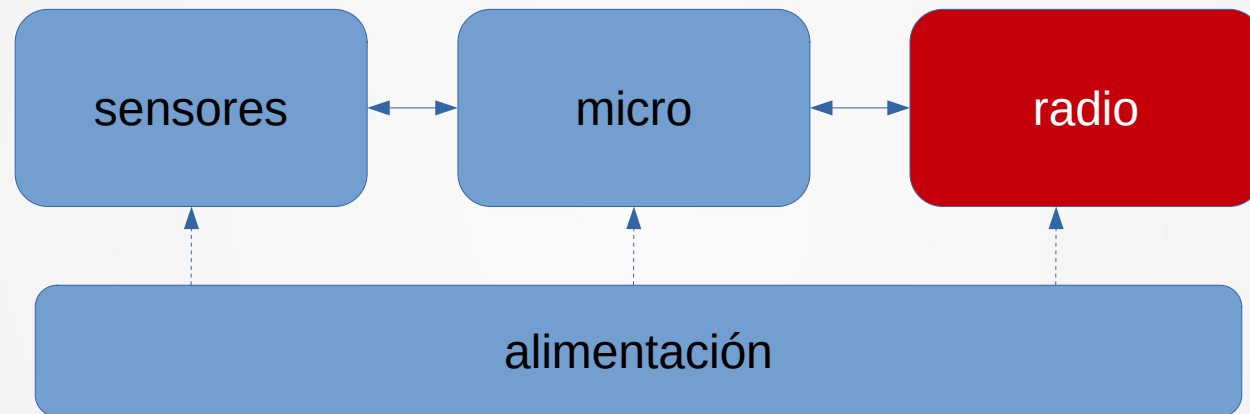 - bajo *todo*

costo   tamaño   consumo

Nodo: diagrama de bloques

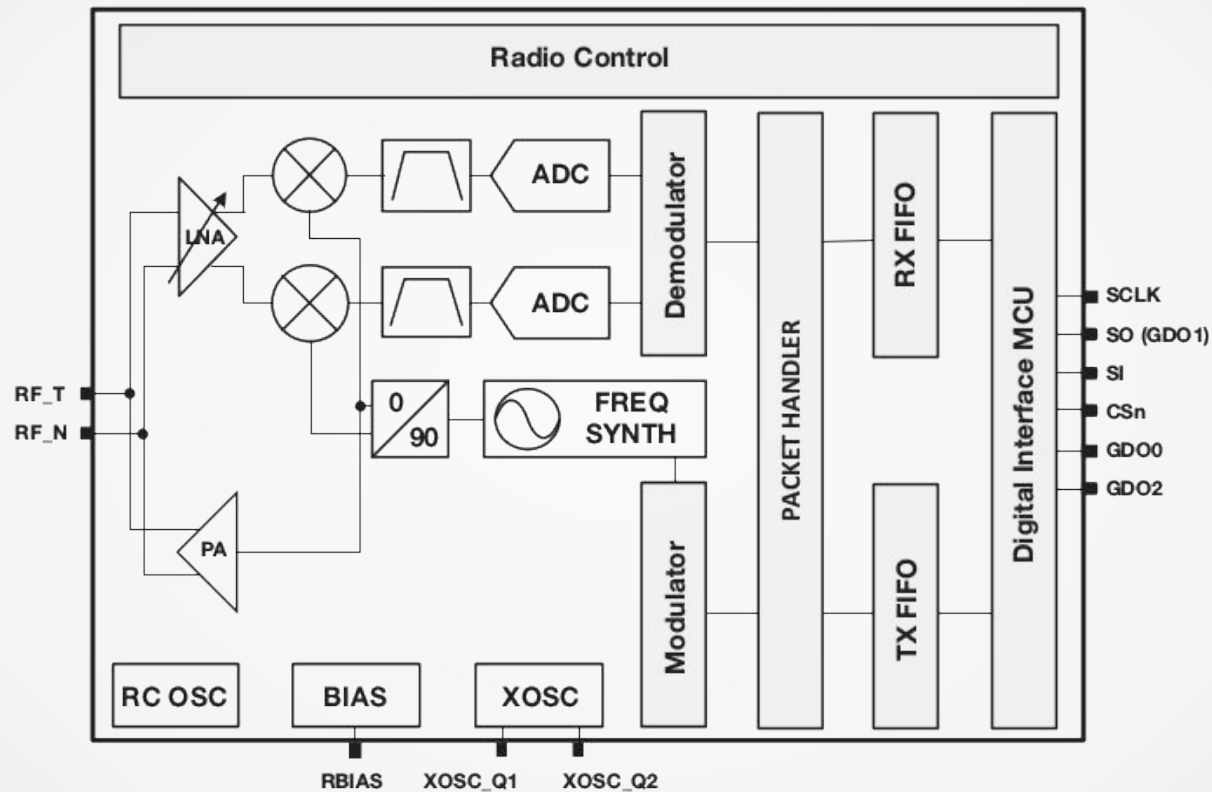# Nodo: diagrama de bloques detallado
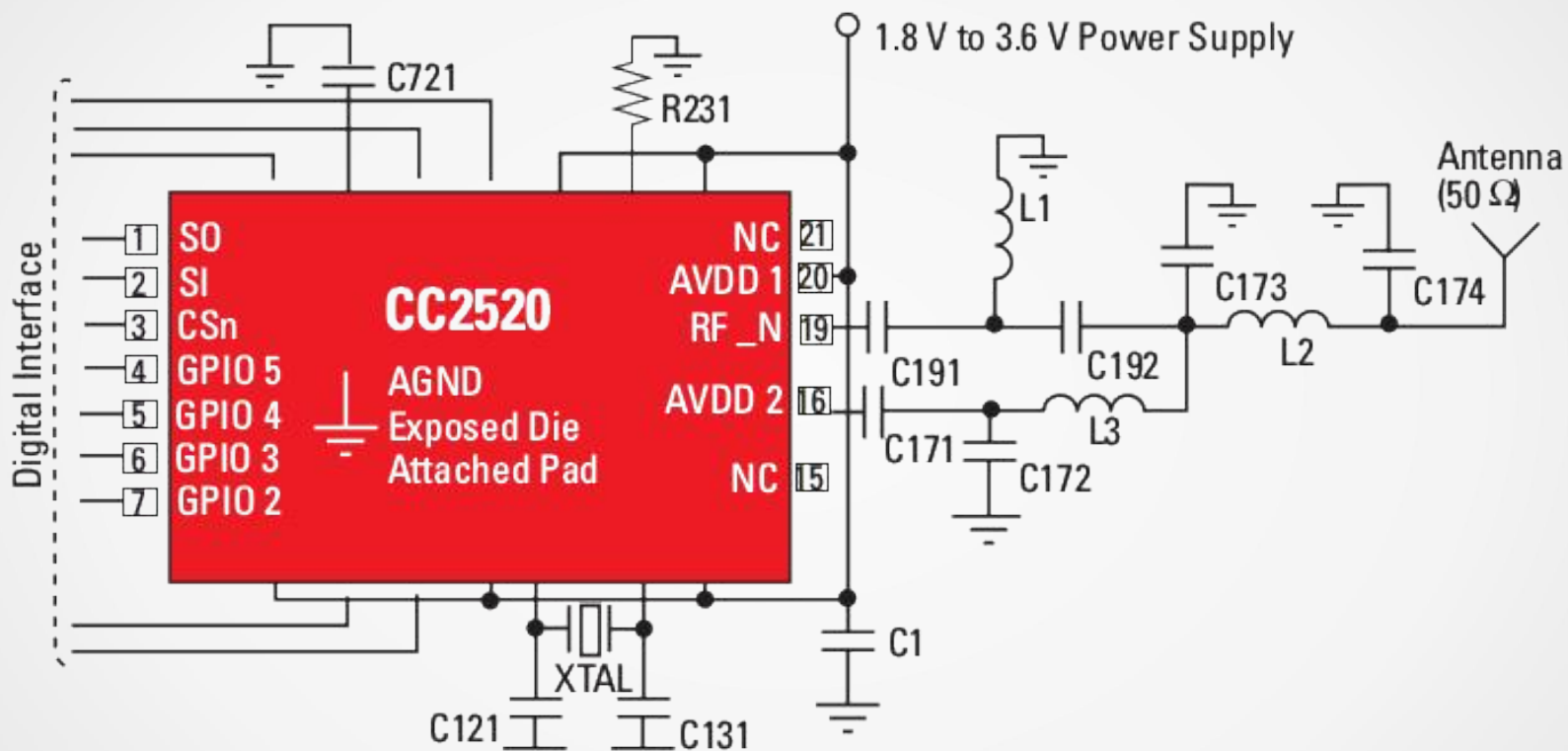
Nodo: radio

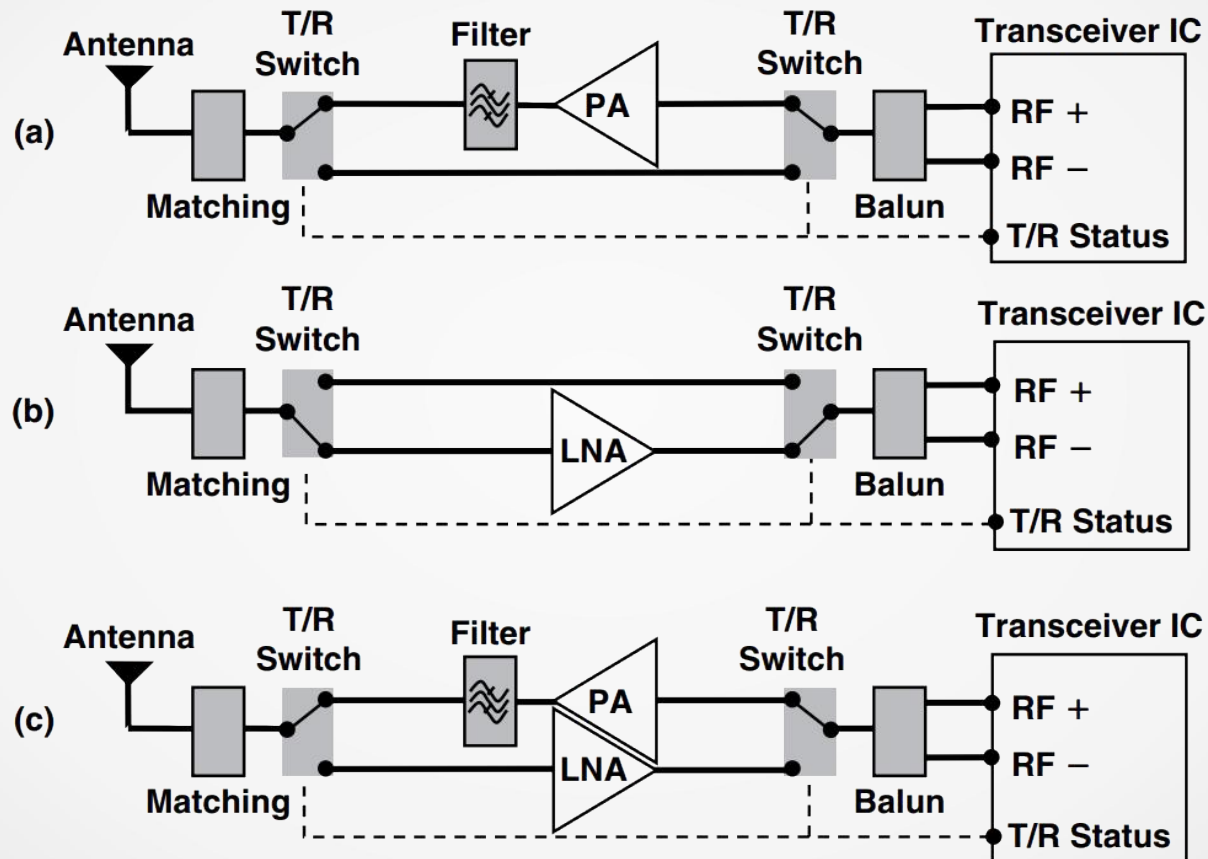# Radio: diagrama de bloques

CC110L block diagram.

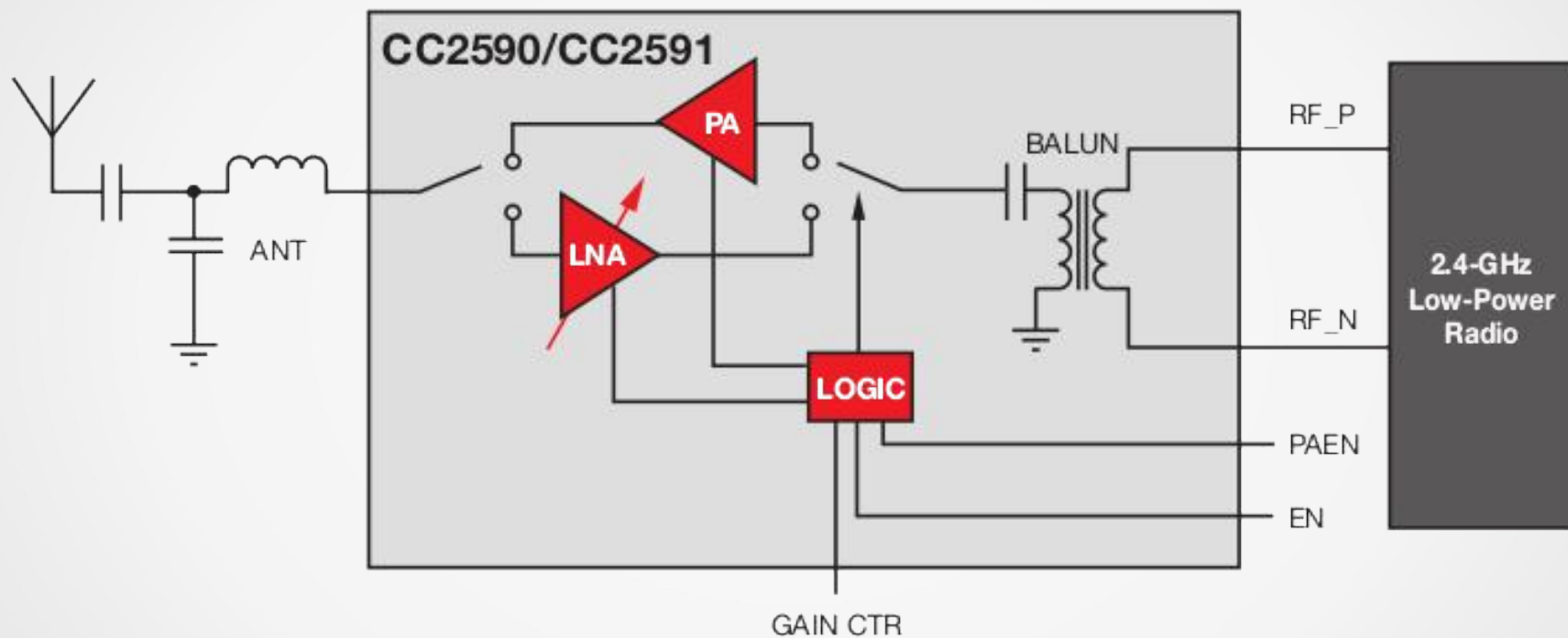# Radio: circuito de aplicación (CC2520)

CC2520 application circuit.

Radio: PA/LNA (power & low noise amp.)

Radio: PA/LNA ejemplo
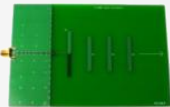
CC2590/CC2591 block diagram.

Antenas

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

Nodo: sensores

© IIE - Facultad de Ingeniería - UDELAR
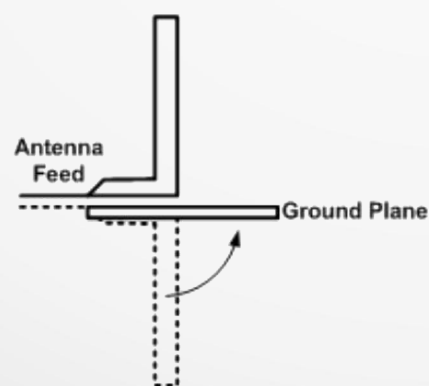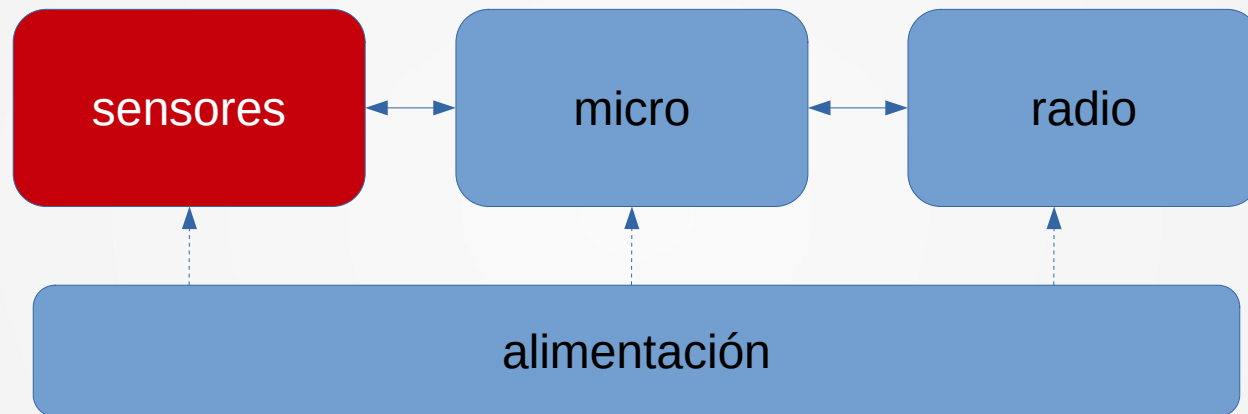
Sensores

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

Sensores: ejemplos

- Temperature & Humidity: Sensirion® SHT11

  - Temperature

    - Range: -40 ~ 123.8 °C

    - Resolution: : ± 0.01(typical)

    - Accuracy: ± 0.4 °C (typical)

  - Humidity

    - Range: 0 ~ 100% RH

    - Resolution: 0.05 (typical)

    - Accuracy: ± 3 %RH (typical)

SHT11
Sensirion

TMP75C
Texas Instruments

Sensores: ejemplos

- Light: Hamamatsu® S1087 Series

  – Visible & Infrared Range

  – 560 nm & 960 nm peak sensitivity wavelength
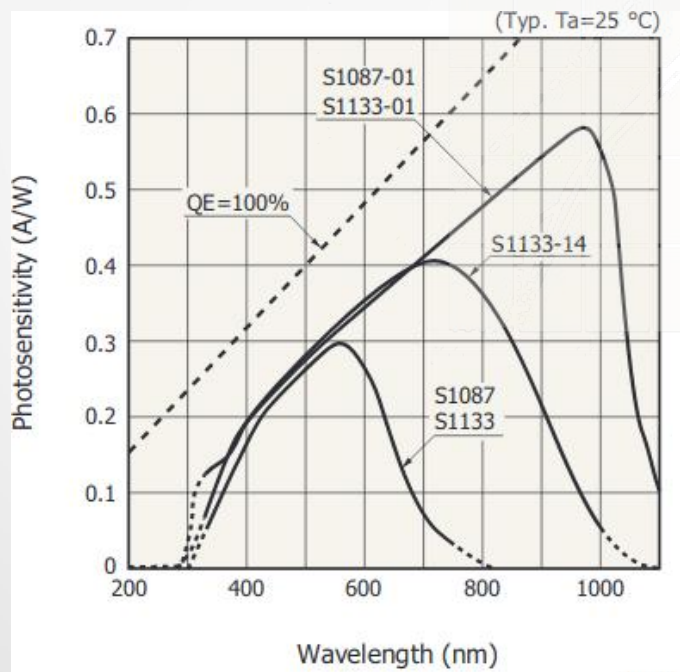
Sensores: ejemplos

- Humedad de suelo
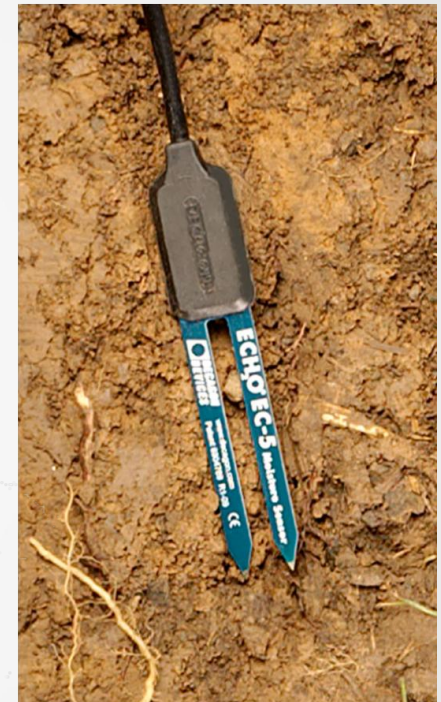
EC-05 Decagon

Sensores: ejemplos

- Sensor de distancia (ultrasonido)

  – Power Supply :+5V DC

  – Current:

    - Quiescent<2mA;

    - Working: 15mA

  – Effectual Angle: <15°

  – Ranging Distance : 2cm – 400 cm

  – Resolution : 0.3 cm

  – Trigger Input Pulse width: 10uS

Initiate   Echo back

10uS TTL to signal pin   pulse width corresponds to distance (about 150uS-25ms, 38ms if no obstacle)

Signal

Formula:
pulse width (uS) /58= distance (cm)
pulse width (uS) /148= distance (inch)

Internal

Ultrasonic Transducer will issue 8 40kHz pulse
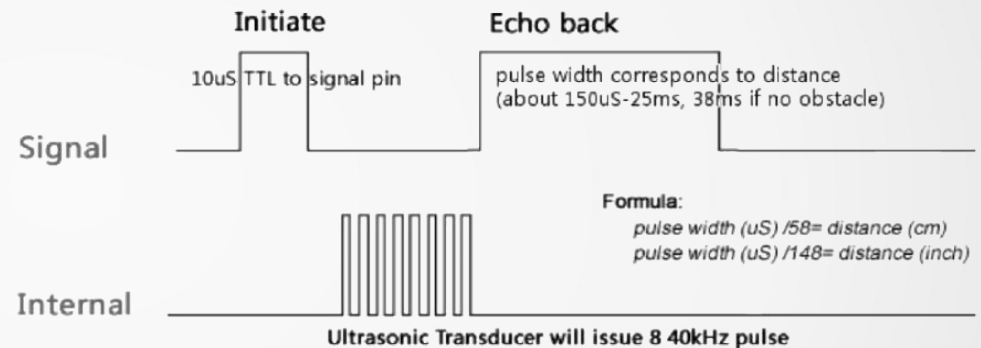
Sensores ejemplos

- Acelerómetro / Magnetómetro: LSM303D

  - 3 magnetic field 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
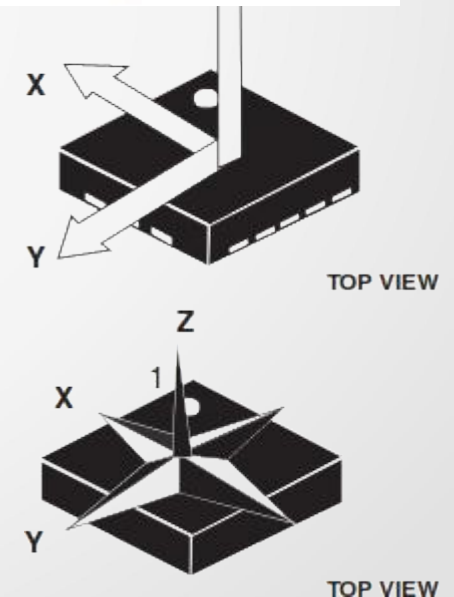
Sensores: ejemplos

- GPS: 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	
SQI Flash	AssistNow Offline	

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

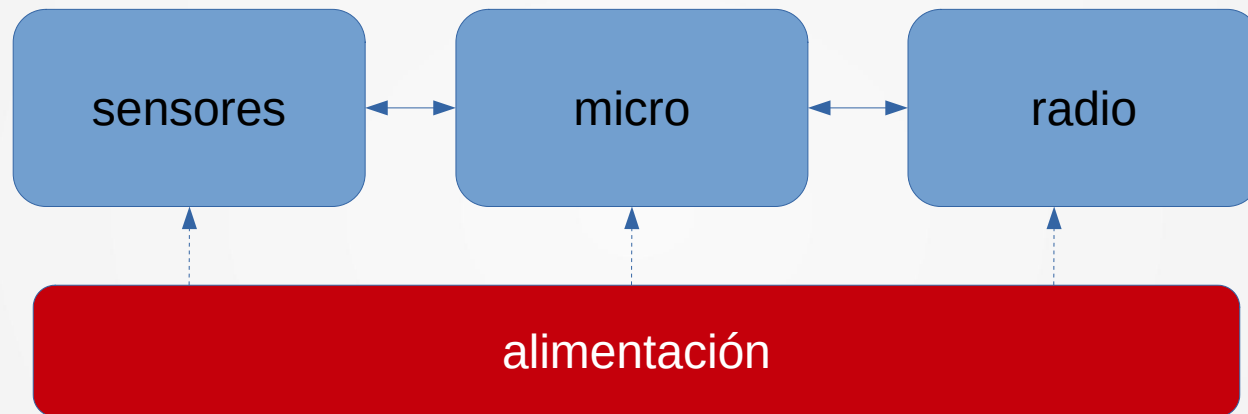**Interfaces**

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
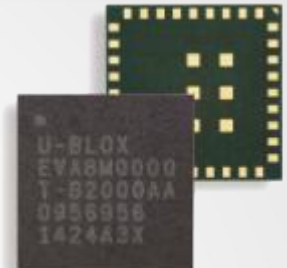
7.0 × 7.0 × 1.1 mm

Nodo: alimentación

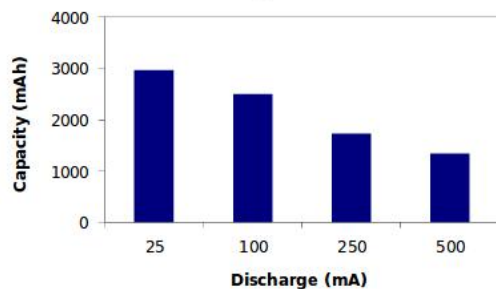# Alimentación: pilas (battery)

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

— AA Lithium   - - - AA Alkaline

(alkaline shown for comparison)
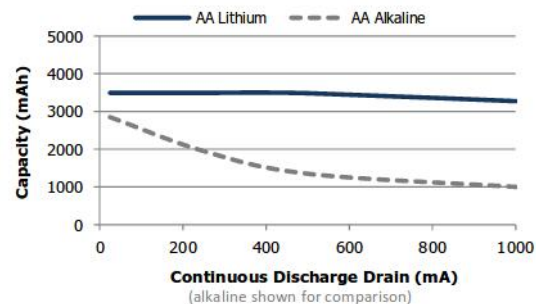
Alimentación: energy scavenging

| Energy source	Power density	Duration
Solar cell (direct sun light)	$15\,\mathrm{mW/cm^2}$	Continuous
Solar cell (well illuminated room)	$10\,\mu\mathrm{W/cm^2}$	Continuous
Piezoelectric	$200\,\mu\mathrm{W/cm^3}$	Operation (e.g. button push)
Temperature difference	$40\,\mu\mathrm{W/cm^3}\,/\,5\,^\circ\mathrm{C}$	Continuous
Air flow	$380\,\mu\mathrm{W/cm^3}\,/\,5\,\mathrm{m/s}$	Continuous

Alimentación

- Conversores de tensión

- Tipos
  - Reguladores lineales
  - Conmutados (DC-DC)
    - up, down, up-down
  - Consideraciones
    - límites de tensiones
    - salida/s: fija, programables
    - eficiencia

LM7805 PINOUT DIAGRAM

1 Input — LM7805 — 3 Output
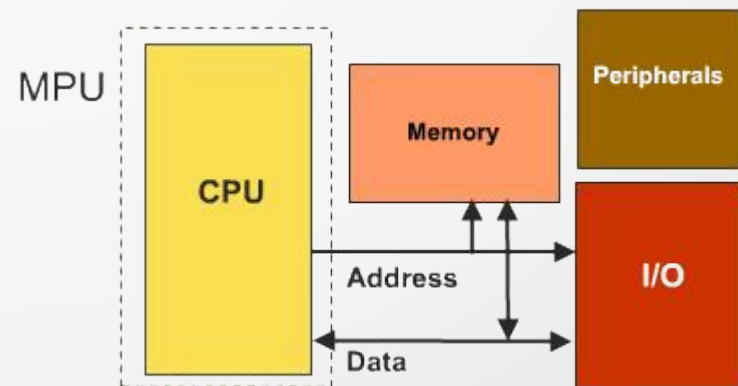
2 Ground

LM7805

1 2 3
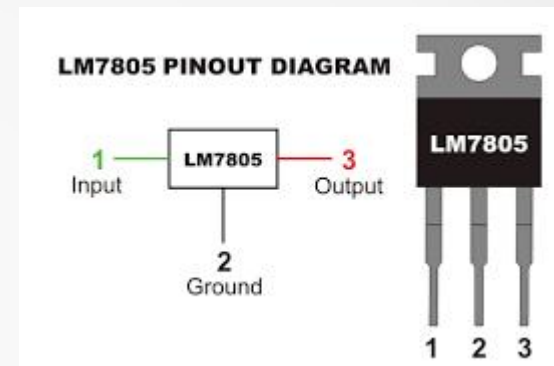
Nodo: microcontrolador
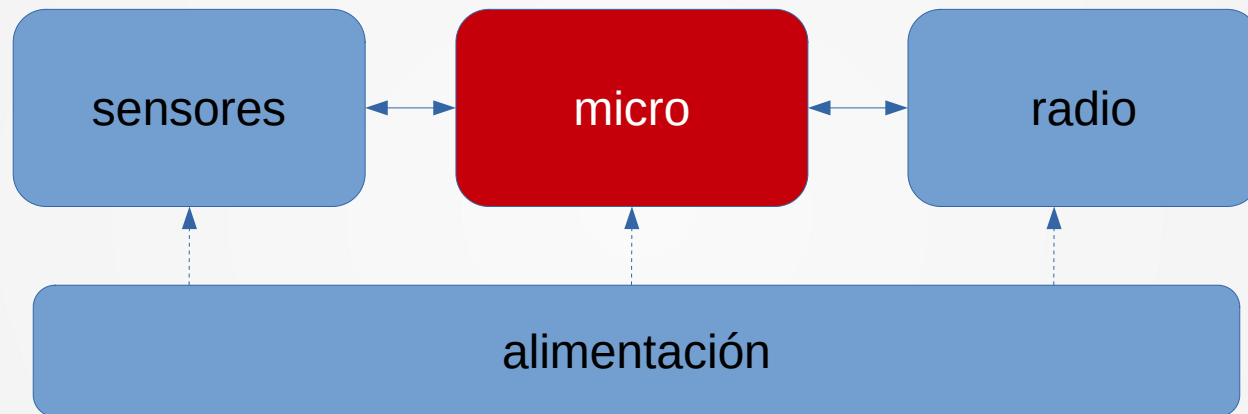
Microcontrolador: requerimientos

- Memoria de código: Flash, FRAM

- Memoria de datos: RAM (FRAM+cache)

- Memoria datos bulk: logs, datos, file system

- Potencia de procesamiento:

  - velocidad de reloj, arquitectura N-bits, FPU (necesario?)

- Consumo

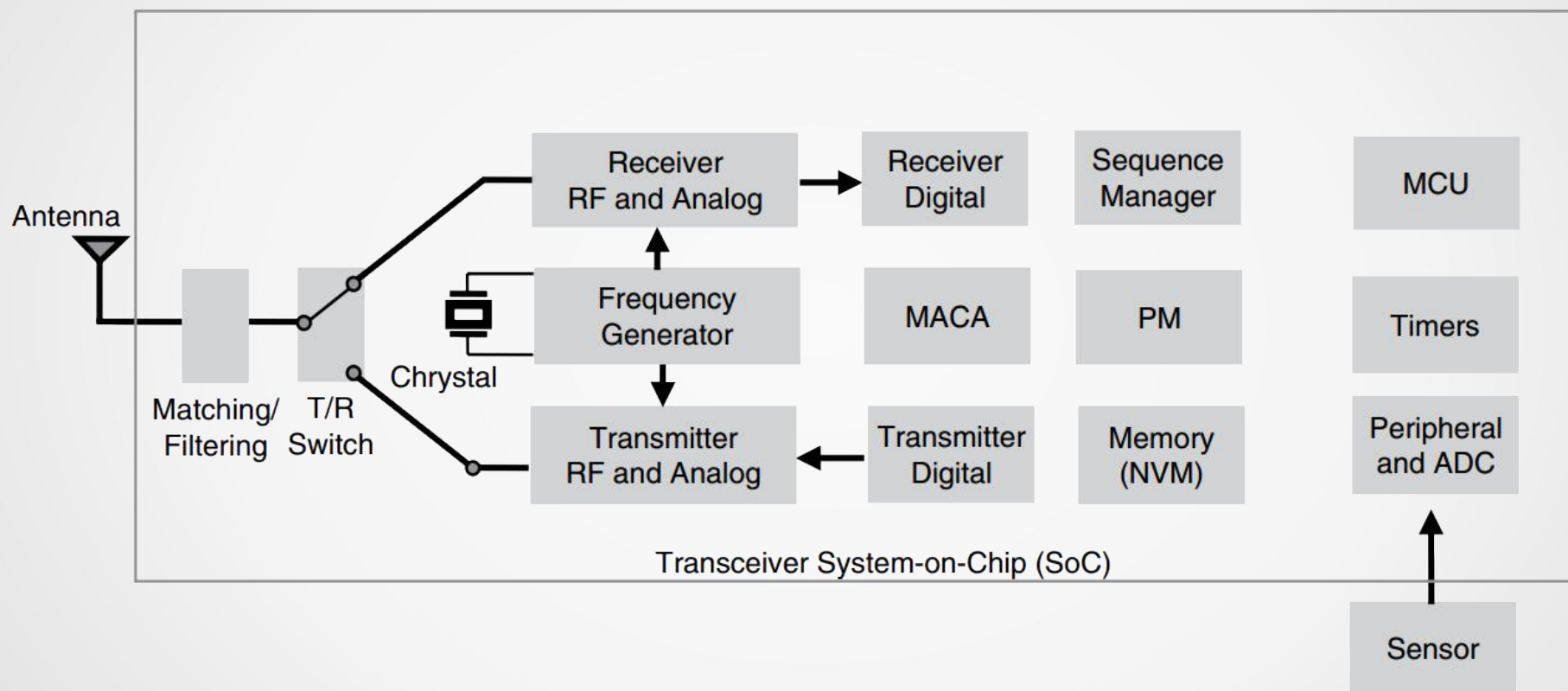 - modos de operación

Microcontrolador

- Funciones

  - Ejecutar aplicación de usuario

  - Sistema operativo

  - Pila de comunicaciones

- Periféricos básicos y comunes

  - SPI, I2C, UART, ADC, DAC (PWM), I/O digitales

  - Otros:

  - DMA, Security Engine, MPU...

Nodo: system-on-chip (SoC)
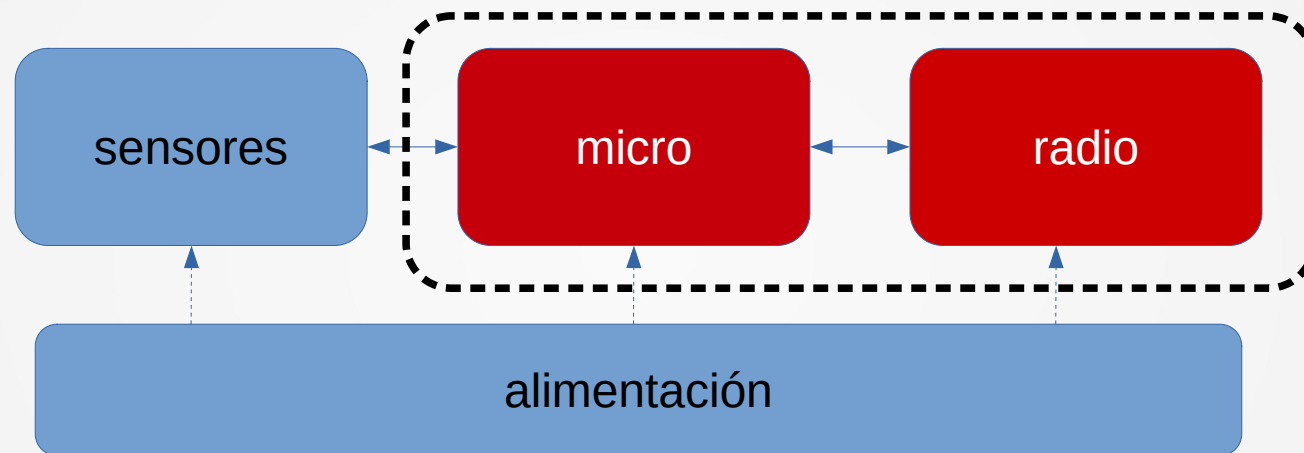
Radio: diagrama de bloques (SoC)

Hardware: opciones "core"

- chips
  - MCU + radio
  - SoC (system-on-chip)
  - SiP (system-in-package)
- módulo
- board / kit
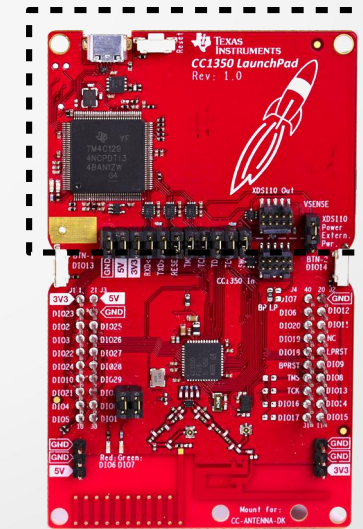 - evaluation
  - developing
  - prototiping

chips

módulos

boards / kits

prog. JTAG

Nodos: opciones chipset (micro + radio)

| Complete ZigBee Solutions		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
	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

Recomendaciones

- Cuidado!

 - Folletos de fabricantes (especialmente)
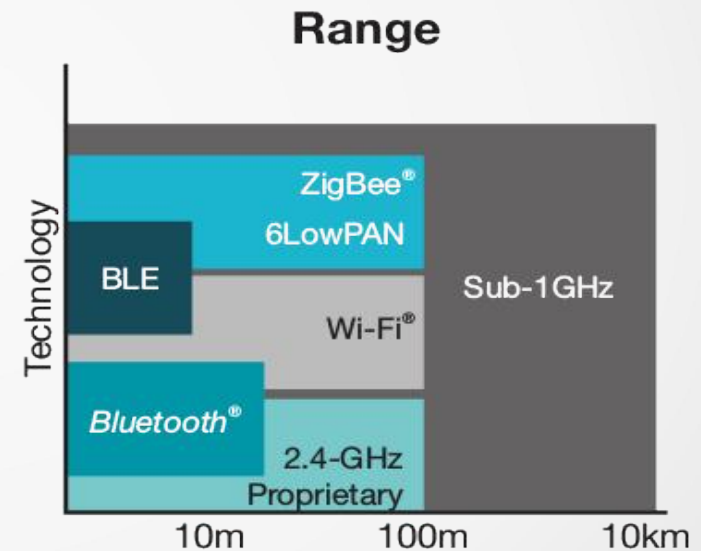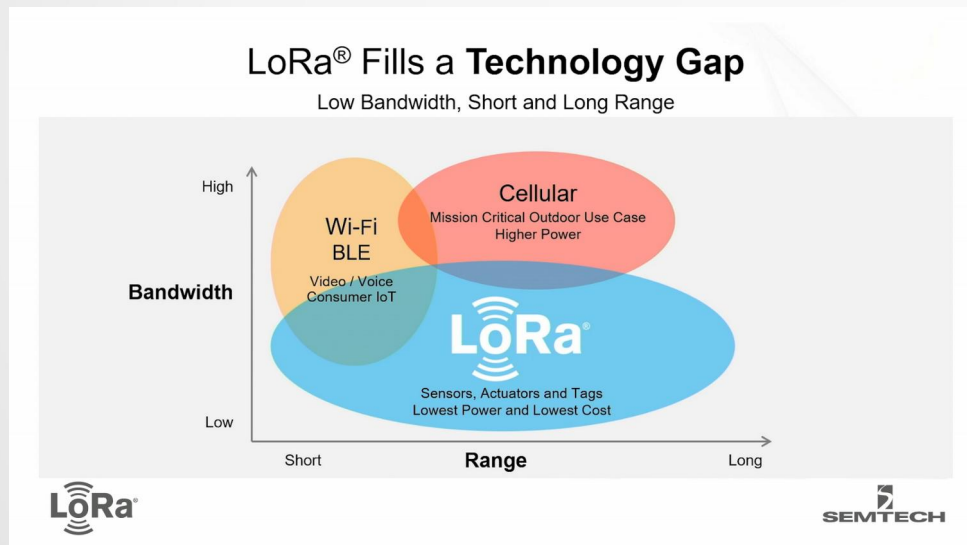
Recomendaciones

- Características
  - Generales
    - tensión de alimentación
    - corriente / potencia de consumo (modos)
    - duty cycle (tiempo "on" / "período")
  - RF
    - link budget: PTx (dB), Sensibilidad
  - microcontroladores
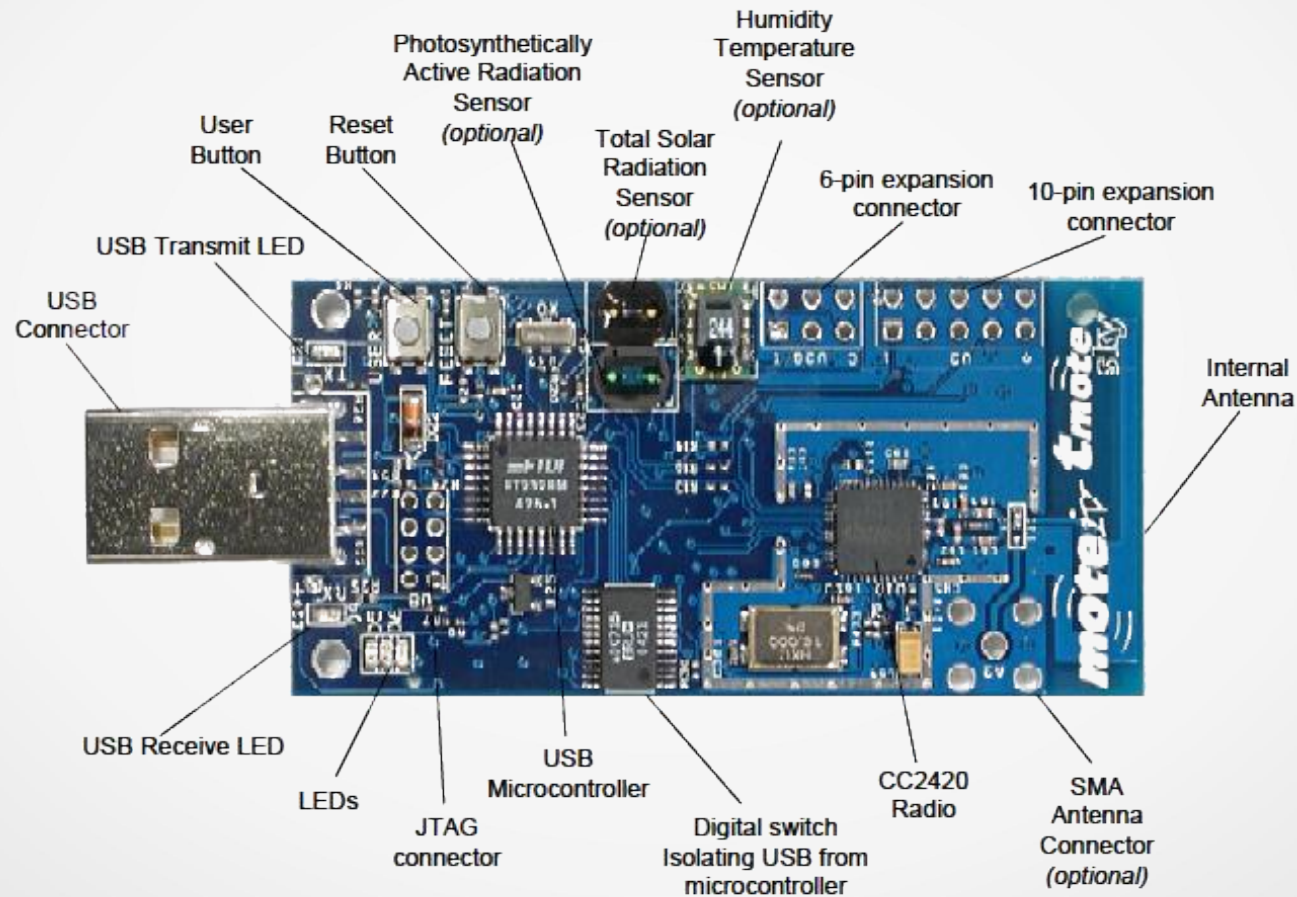   - memoria SRAM / Flash
    - periféricos

Nodo: ejemplos

- **sky / telosB compatible (tmotesky, CM5000)**
  - Micro: MSP430F1611
  - Radio: CC2420
  - Sensores:
    - Light 1: Visible Range
    - Light 2: Visible & Infrared Range
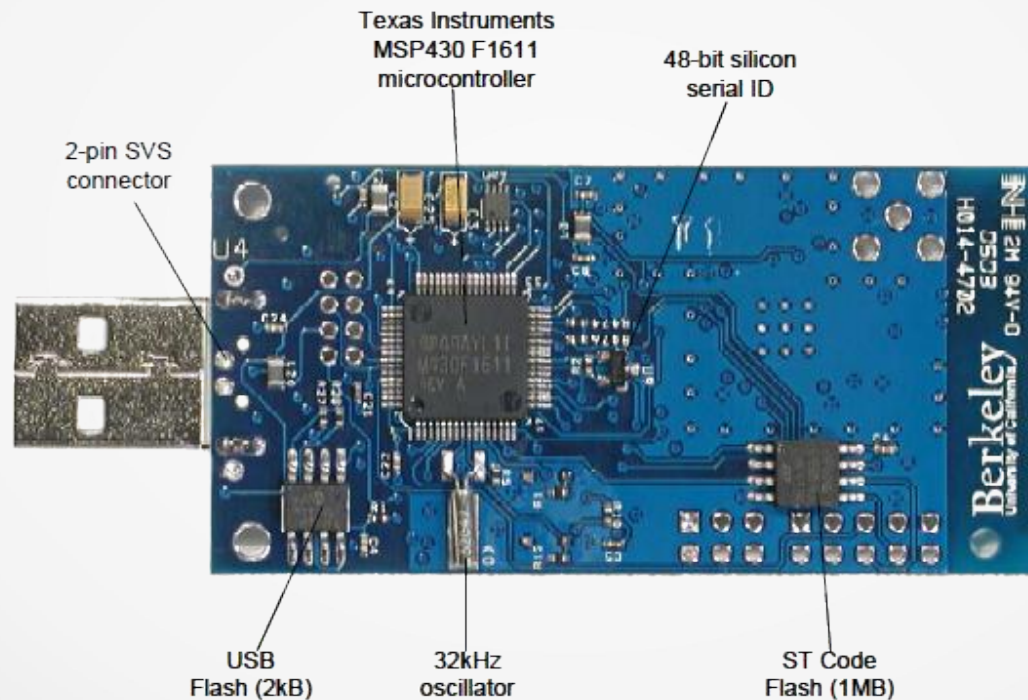   - Temperature & Humidity Sensirion® SHT11
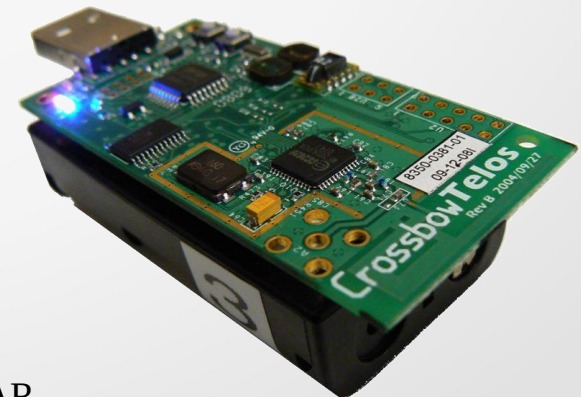
Nodos: ejemplos

- **sky / telosB compatible (tmotesky, CM5000)**

Nodos: ejemplos

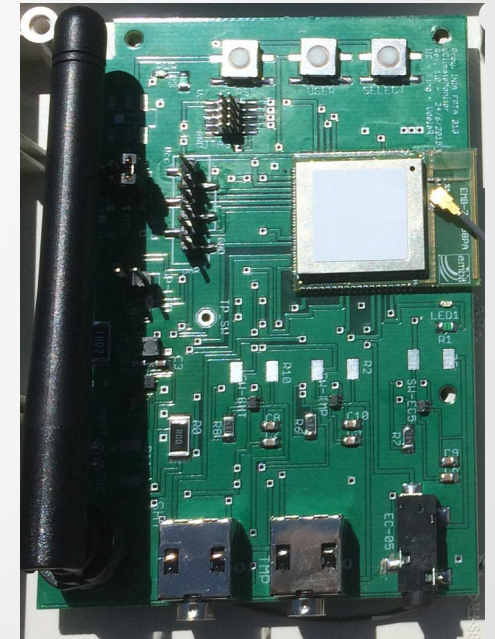- **sky / telosB compatible (tmotesky, CM5000)**

Nodo: ejemplos

- **uclim – IIE (Proyecto INIA-FPTA)**

  - CCC2538 (Cortex M + tranceiver) + CC2592 (PA/LNA)

    - 32 KB RAM

    - 256 KB Flash

    - ~10 mA active / ~1uA sleep

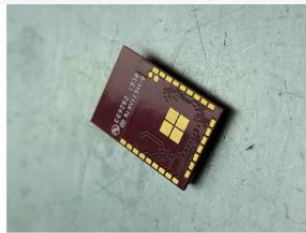 - DC/DC Switching reg. (2.1 & 2.5 VDC)

EMB-Z2538PA

Ejemplos: SMC

- **Sistema de Monitoreo y Control de Cultivo Indoor de Cannabis**

  - Nodos:

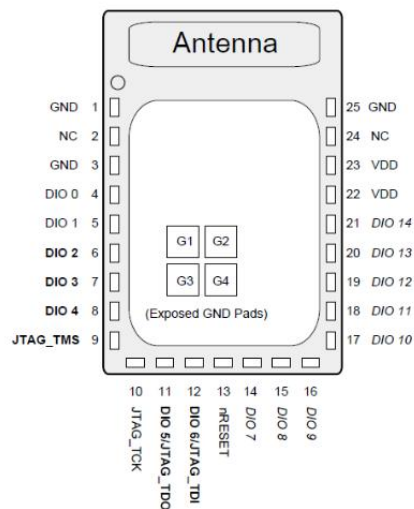   - control distribuido
    - sensor ("maceta")

Ejemplos: SMC

- **Control distribuido**

Ejemplos: SMC

- **Nodo sensor (maceta)**

Contiki hardware (selección)[(*)]

(*) http://www.contiki-os.org/hardware

Platforms	MCU/SoC	Radio	Cooja simulation support
sky	TI MSP430	TI CC2420	Yes
RE-Mote (zolertia)	TI CC2538	Integrated / CC1200	-
cc2538dk	TI CC2538	Integrated	-
z1 (zolertia)	TI MSP430x	TI CC2420	Yes
avr-raven, avr-rcb, avr-zigbit, iris	Atmel AVR	Atmel RF230	-
micaz	Atmel AVR	TI CC2420	Yes
redbee-dev, redbee-econotag	Freescale MC1322x	Integrated	-
wismote	TI MSP430x	TI CC2520	Yes
nRF52 DK	nRF52832	Integrated	-
EVAL-ADF7023DB1	RL78	ADF7023	-

Material

- Zolertia (sitio de la empresa):

  – https://zolertia.io/

- RE-Mmote (remote, remote-b):

  – https://github.com/Zolertia/Resources/wiki/RE-Mote

- Z1

  – https://github.com/Zolertia/Resources/wiki/RE-Mote

- "IoT in 5 days" (libro)

  – https://github.com/marcozennaro/IPv6-WSN-book/

Planificación clases

1. Introducción RSI

2. **Plataforma de hardware**

3. IPv6

4. Plataforma de software: Contiki OS I

5. Plataforma de software: Contiki OS II

6. Capa de aplicación: CoAP / MQTT

7. Capa de red: RPL

8. Subcapa MAC

9. IEEE 802.15.4 / 6lowpan

10. Capa Fisica & antenas

11. IoT y las RSI

gracias... ¿más preguntas?