Redes de sensores inalámbricos (RSI)

Plataformas de hardware

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NEON
Network of Competence on Internet of Things

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FACULTAD DE INGENIERÍA

UNIVERSIDAD DE LA REPÚBLICA URUGUAY

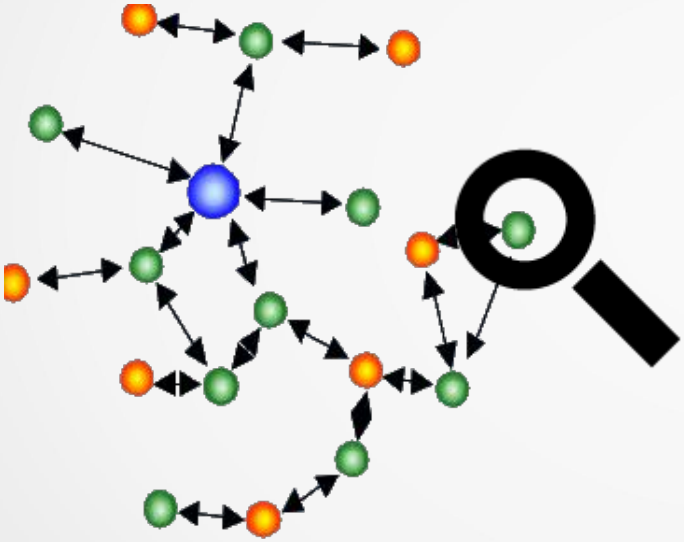
Objetivos

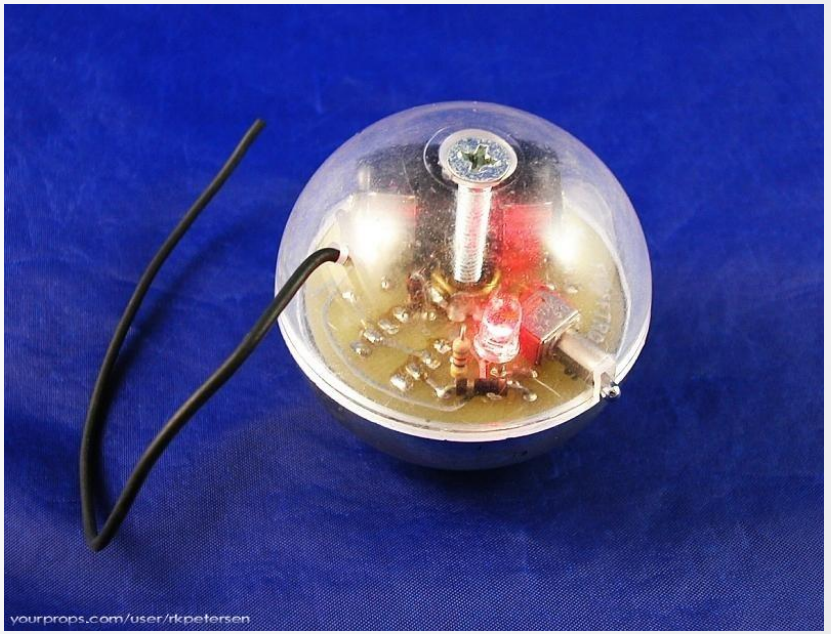
- Introducir la arquitectura de hardware de un nodo.
- Describir las funciones de cada subsistema.
- Dar ejemplos de implementación de cada uno.
- Describir soluciones concretas de nodo, especialmente las utilizadas en el curso.

Agenda

- Introducción: nodo
- Subsistemas o bloques constitutivos del nodo
  - Radio
  - Sensores
  - Alimentación
  - Microcontrolador
- Plataformas de hardware
  - utilizadas en el curso (kits)
  - otras (proyectos y productos)

Introducción





Nodos: requerimientos

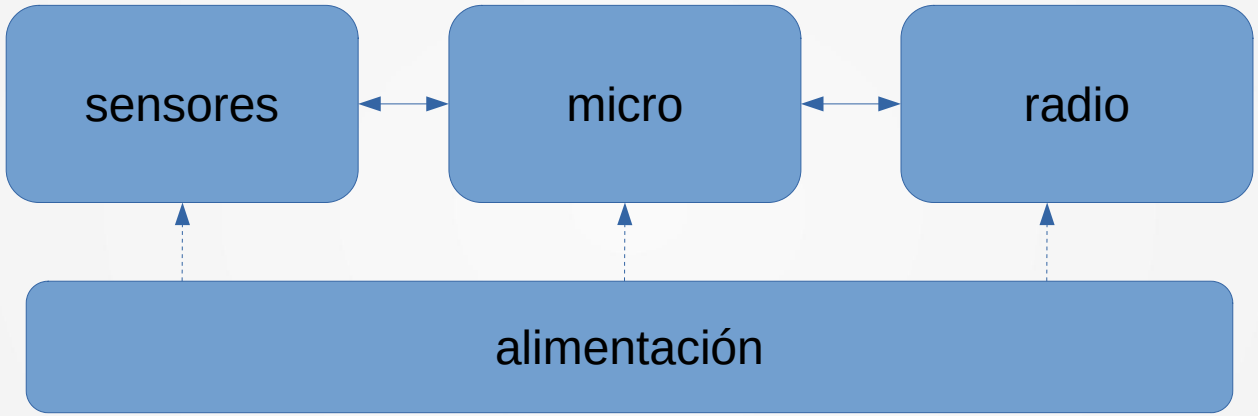
- Características
  - bajo *todo*

costo

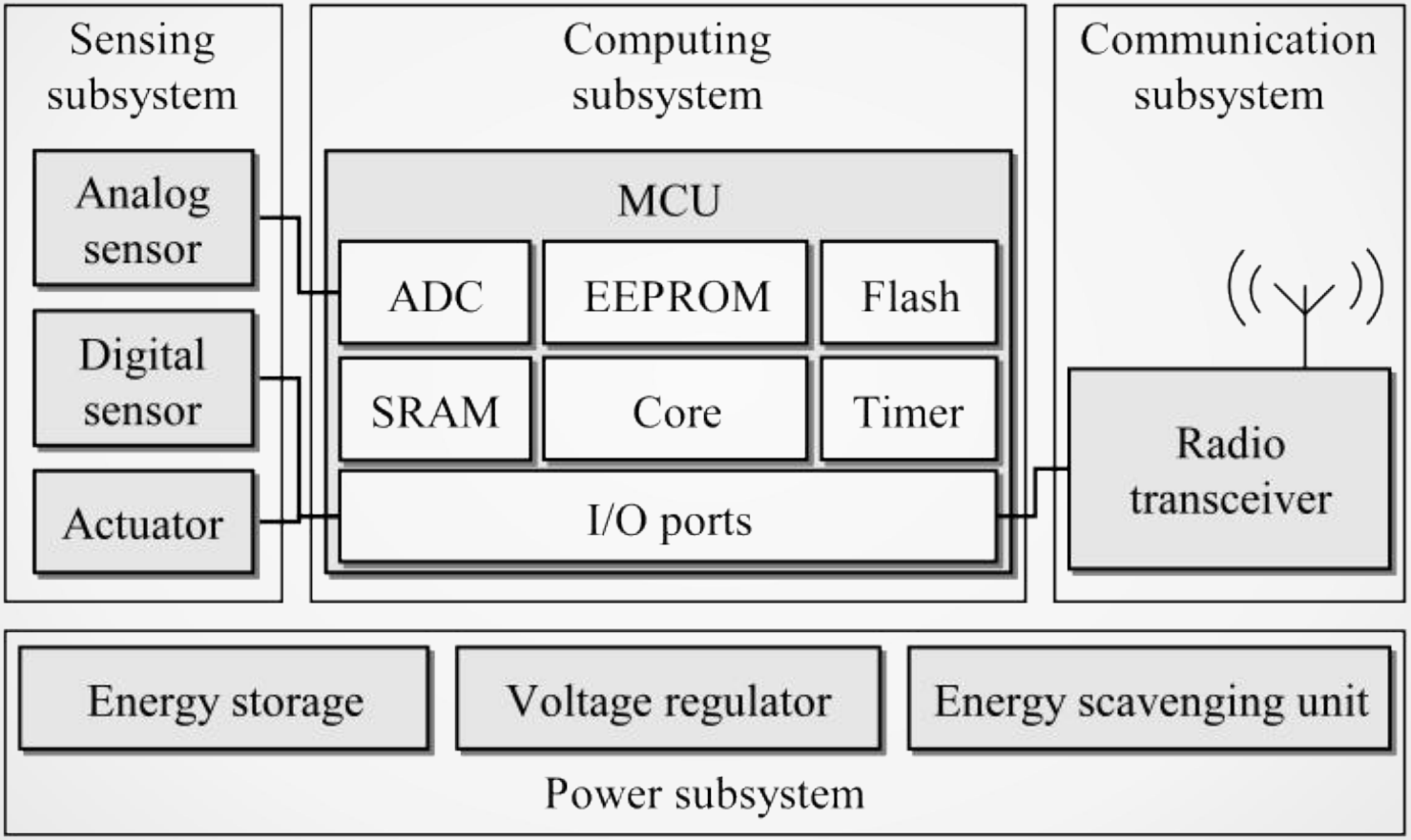
tamaño

consumo

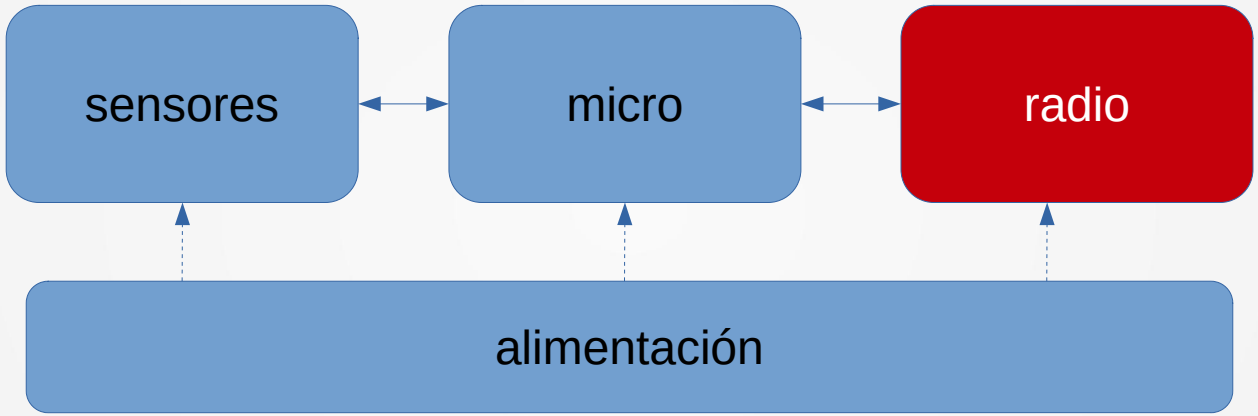
Nodo: diagrama de bloques



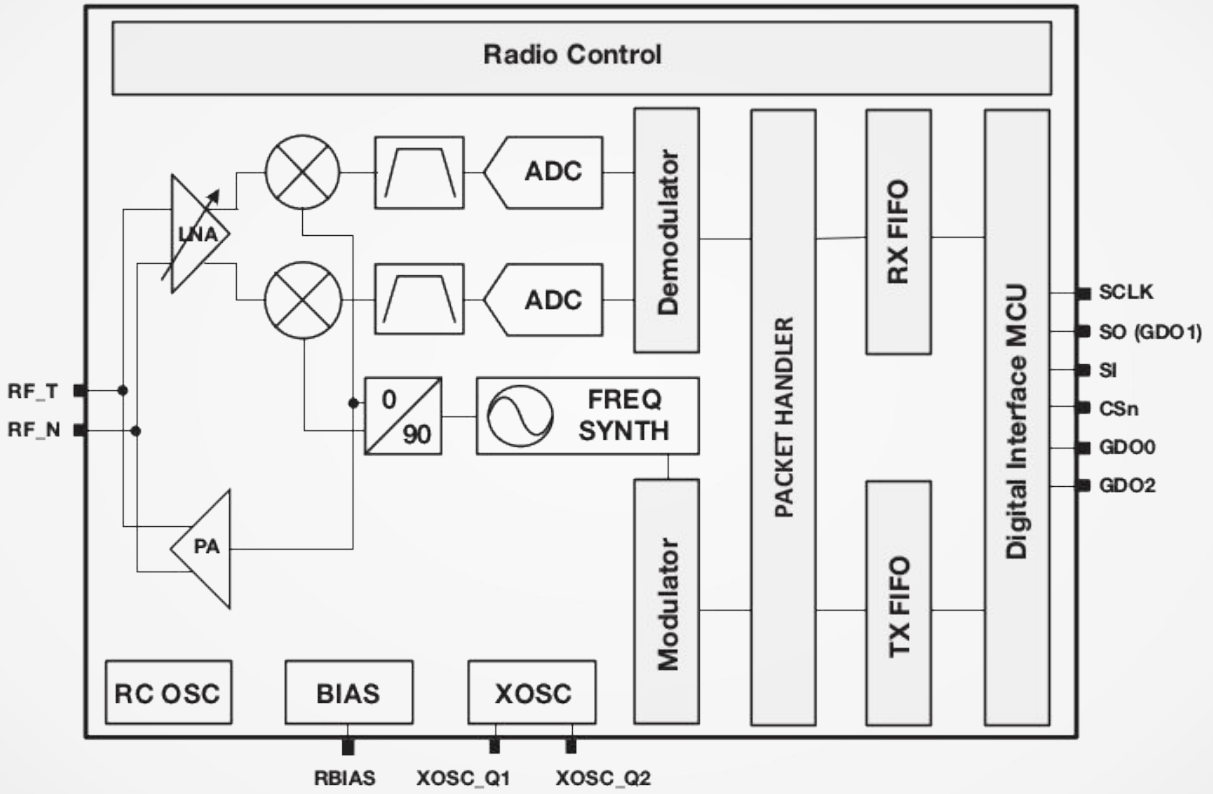
Nodo: diagrama de bloques detallado



Nodo: radio

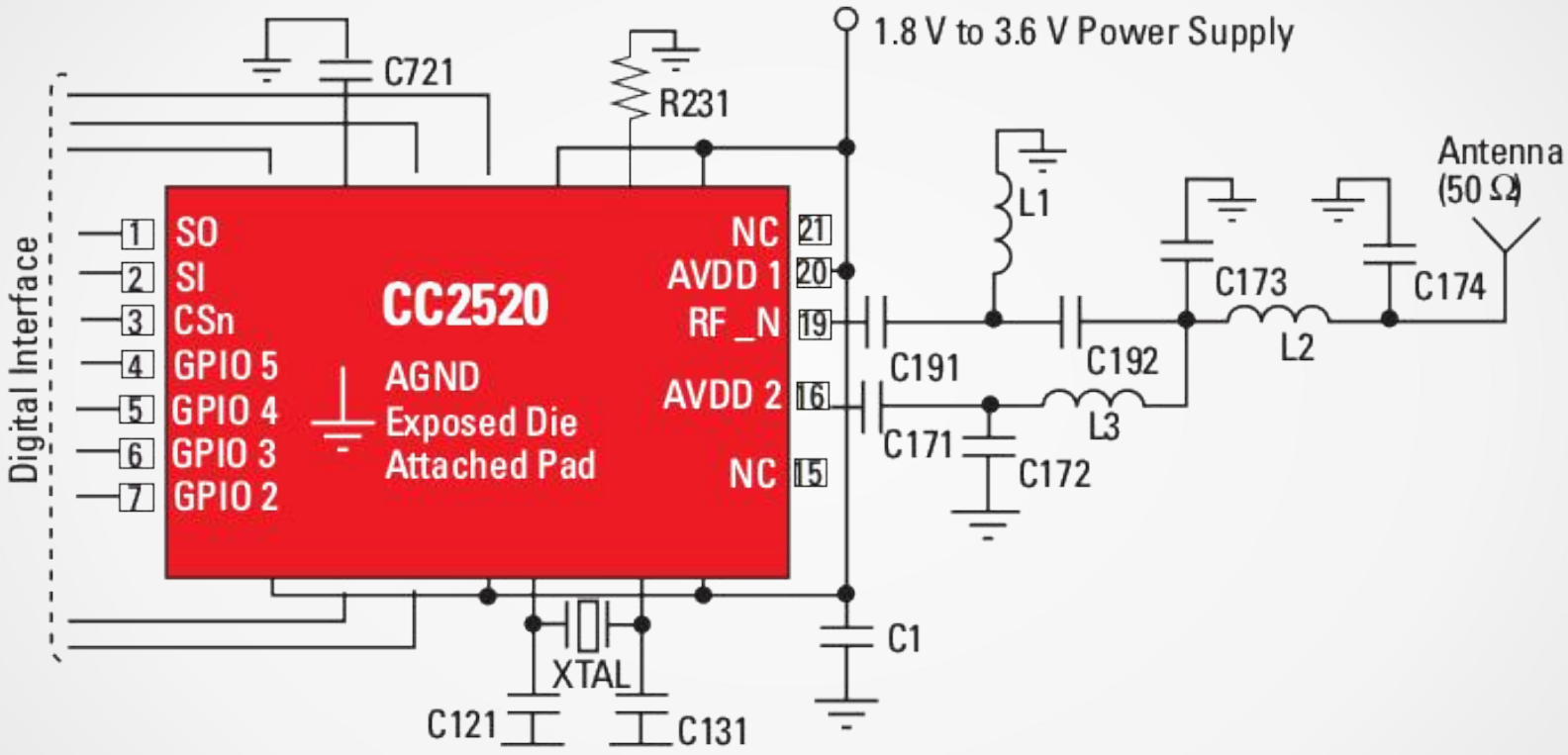


Radio: diagrama de bloques



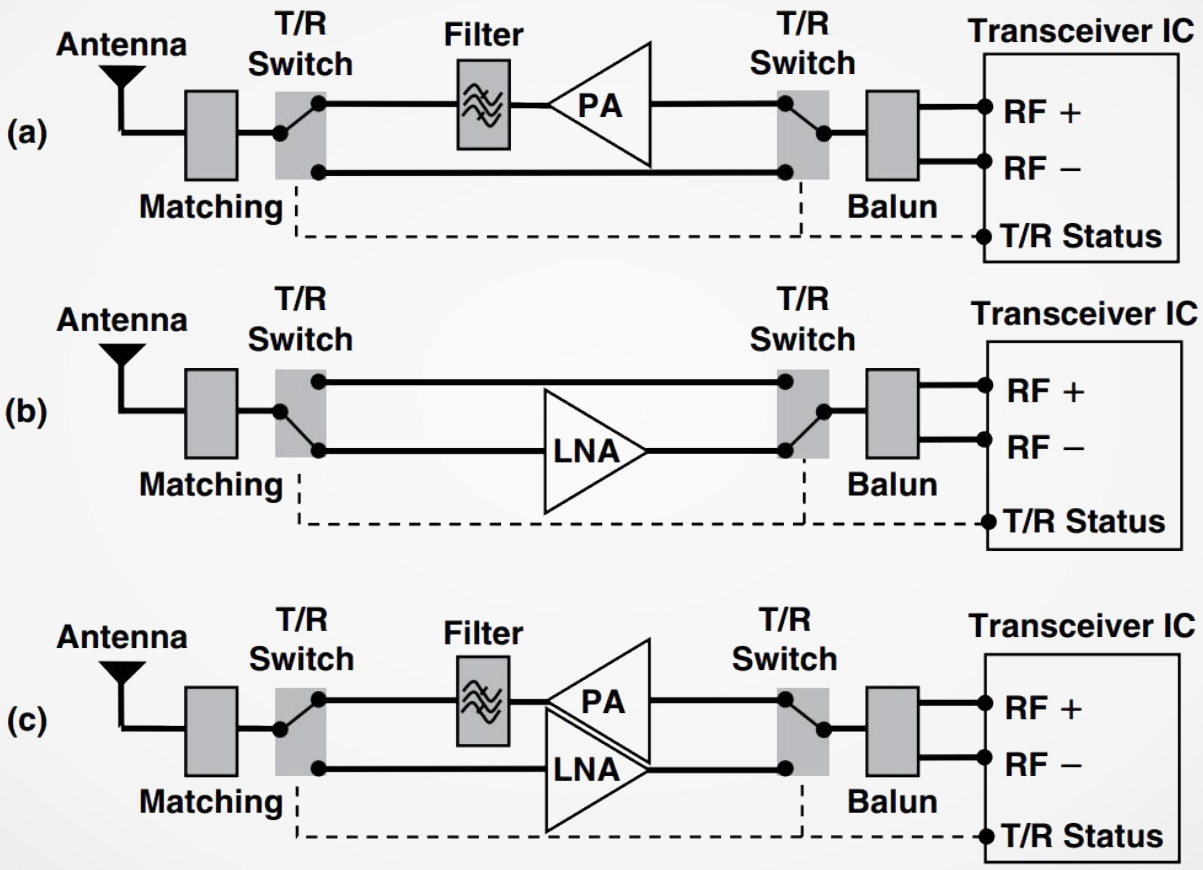
CC110L block diagram.

Radio: circuito de aplicación (CC2520)

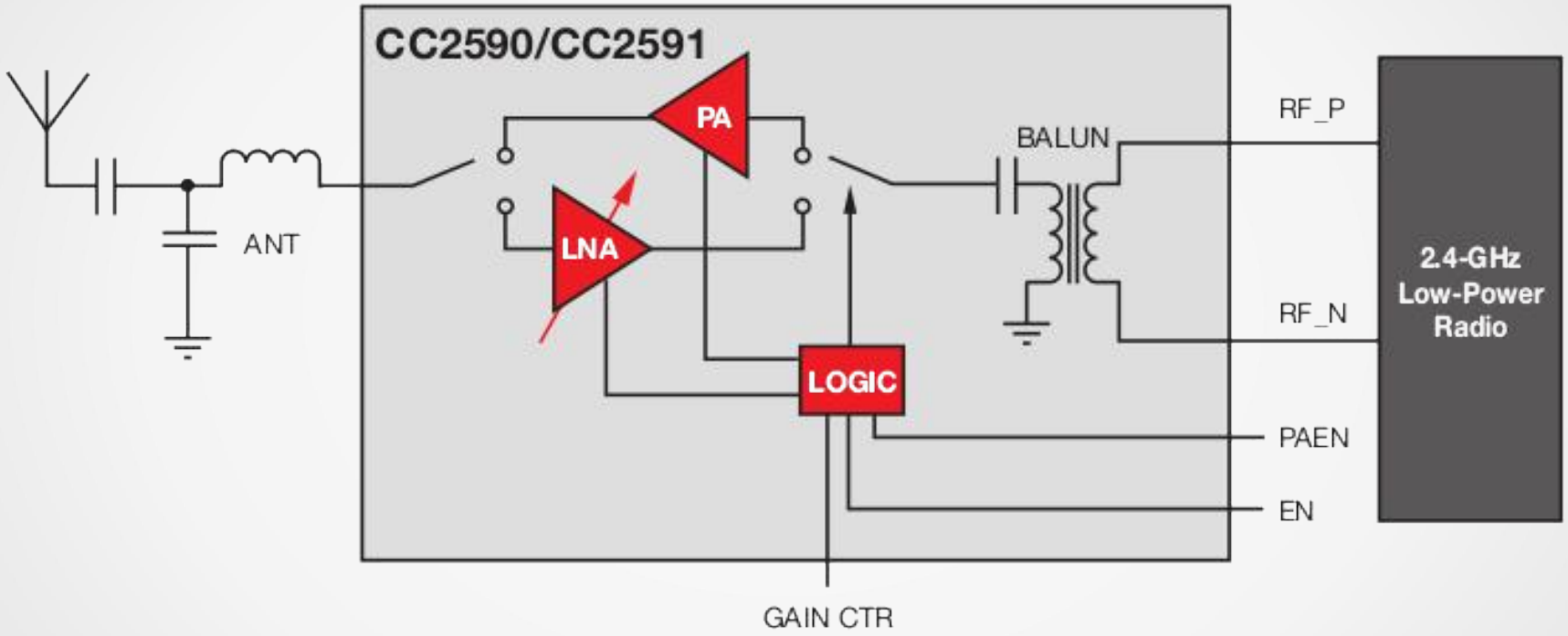


CC2520 application circuit.

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

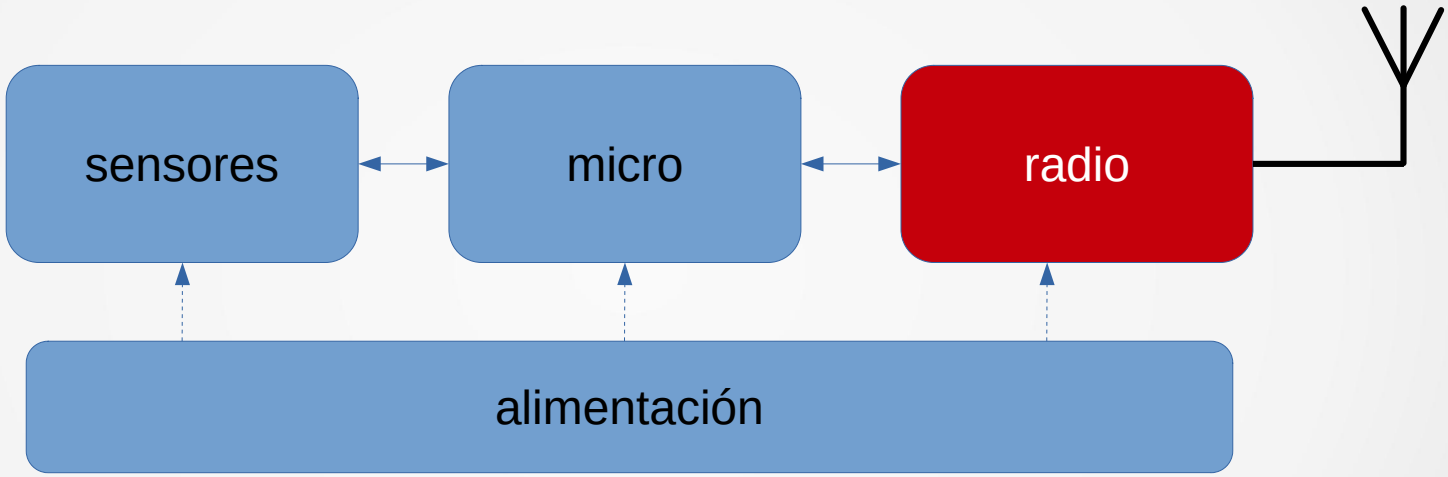


Radio: PA/LNA ejemplo

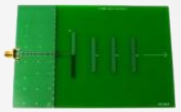


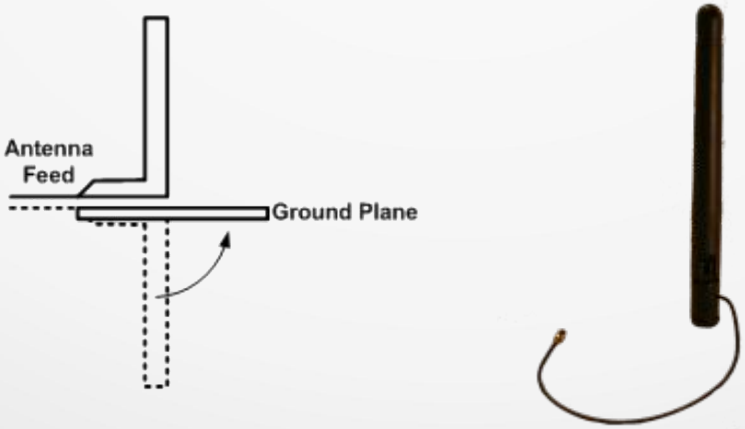
CC2590/CC2591 block diagram.

Nodo: antena

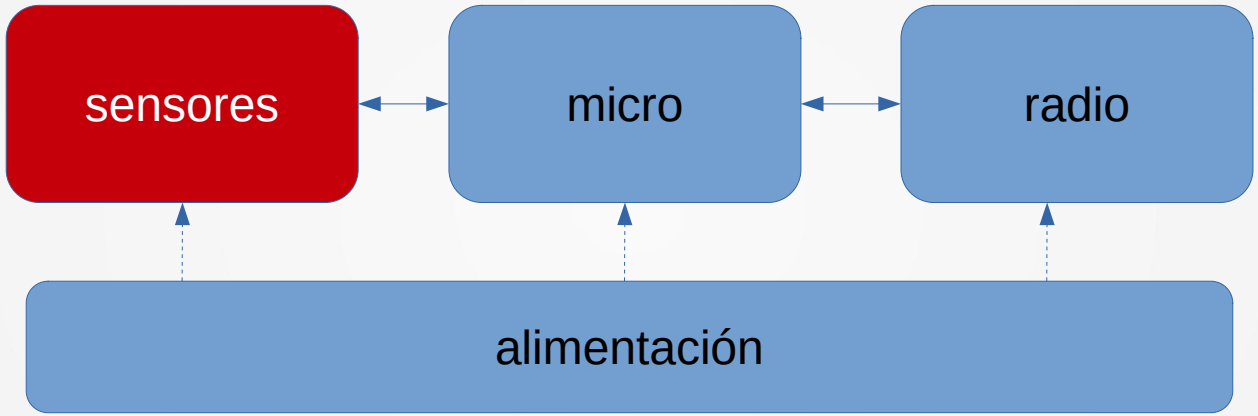


Antenas

Texas Instruments	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



Nodo: sensores



Sensores: clasificación

- 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: temp. & humedad (SH11)

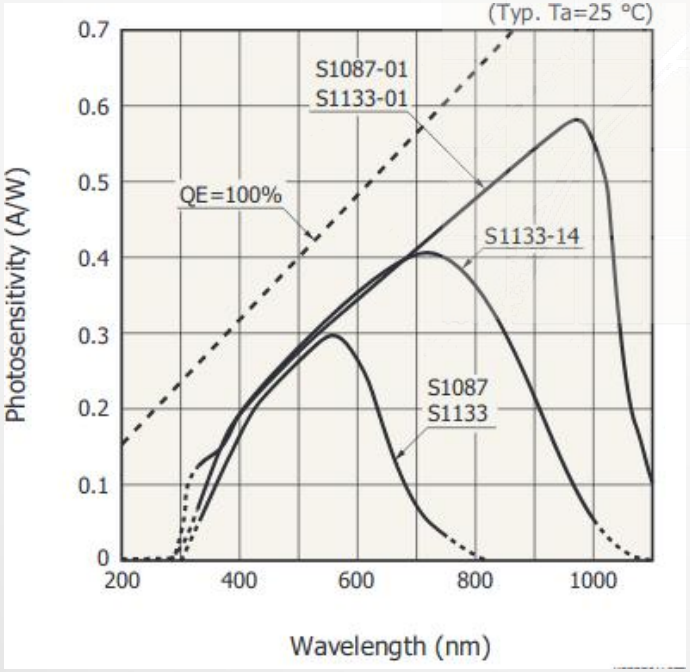
- Temperature & Humidity: Sensirion® SHT11
  - Temperature
    - Range: -40 ~ 123.8 °C
    - Resolution: : ± 0.01(typical)
    - Accuracy: ± 0.4 °C (typical)
  - Humidity
    - Range: 0 ~ 100% RH
    - Resolution: 0.05 (typical)
    - Accuracy: ± 3 %RH (typical)

SHT11
Sensirion

TMP75C
Texas Instruments

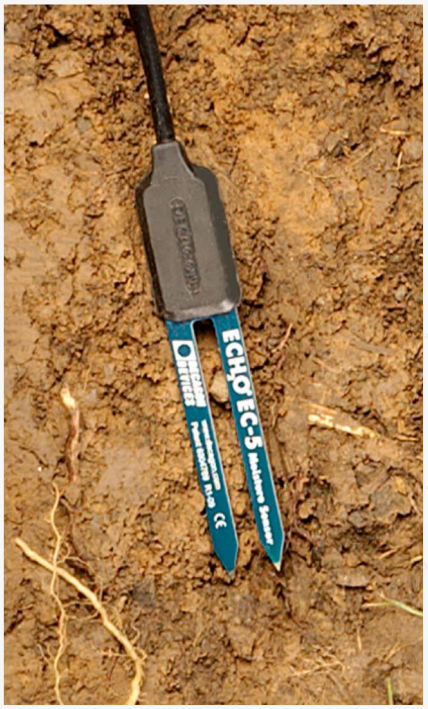
Sensores: luz (S1087)

- Light: Hamamatsu® S1087 Series
  - Visible & Infrared Range
  - 560 nm & 960 nm peak sensitivity wavelength



Sensores: humedad de suelo (decagon)

- Decagon
  - EC-05
  - 10-HS

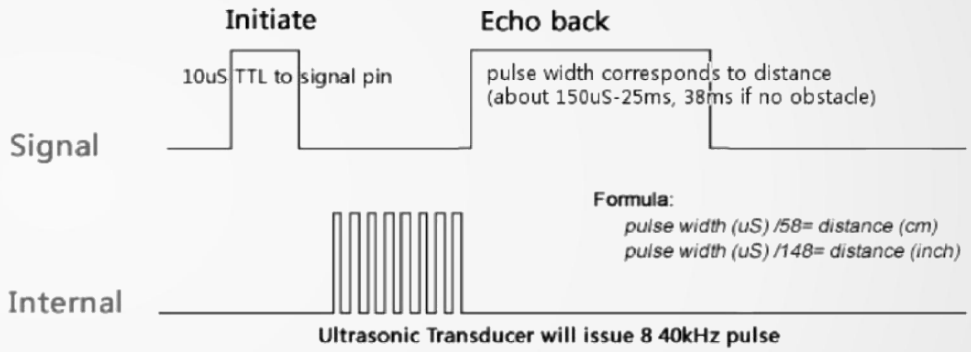


EC-05 (Decagon)

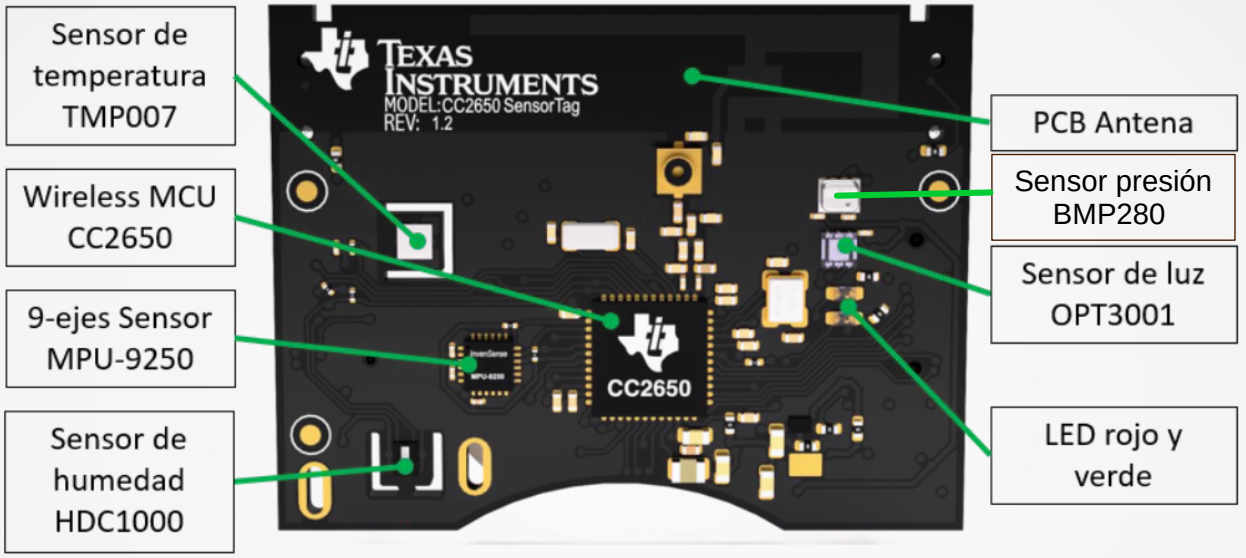
10-HS (Decagon)

Sensores: distancia (ultrasonido)

- HC-SR04
  - 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



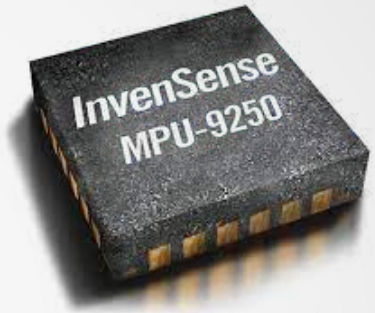
Sensores: kit Sensortag (TI)



- TMP007 (TMP007)
- MPU-9250 (TDK Invens.)
- HDC1000 (Texas Inst.)
- BMP280 (Bosh)
- OPT3001 (Texas Inst.)

Sensor: MPU-9250

- System in Package (SiP con dos chips)
  - MPU-6500
    - 3-axis gyroscope
    - 3-axis accelerometer
    - onboard Digital Motion Processor™ (DMP™)
      - MotionFusion algorithms
  - AK8963
    - 3-axis digital compass.



Sensor: barométrico (presión)

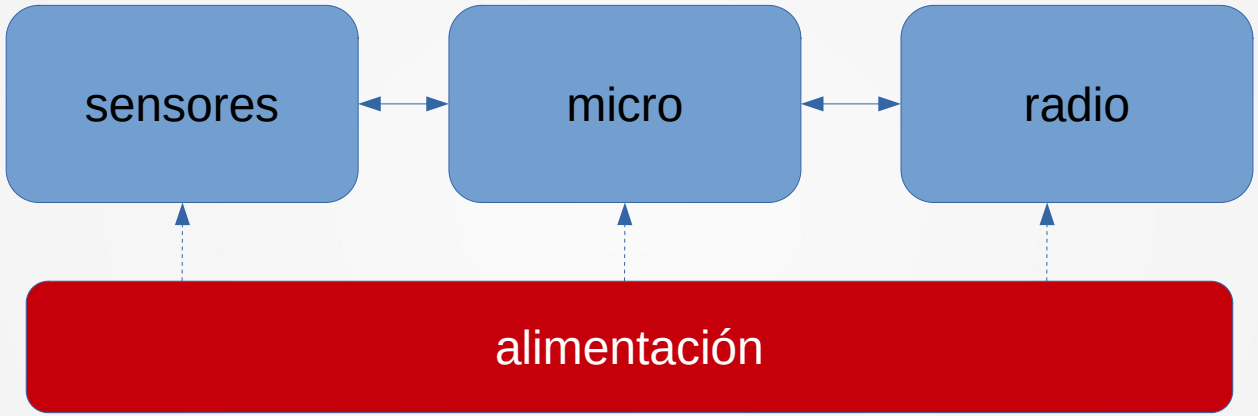
- BMP280 (Bosh)

BMP280 TARGET APPLICATIONS

- Enhancement of GPS navigation (e.g. time-to-first-fix improvement, dead-reckoning, slope detection)
- Indoor navigation (floor detection, elevator detection)
- Outdoor navigation, leisure and sports applications
- Weather forecast
- Vertical velocity indication (e.g. rise/sink speed)

BMP280 (preliminary) Technical data	
Package dimensions	8-pin LGA with metal 2.0 x 2.5 x 0.95 mm³
Operation range (full accuracy)	Pressure: 300 ... 1100 hPa Temperature: 0 ... +65 °C
Supply voltage V_{DDIO} Supply voltage V_{DD}	1.2 ... 3.6 V 1.71 ... 3.6 V
Interface	I²C and SPI
Average current consumption (typ.) (1 Hz data refresh rate)	2.74 µA (ultra-low power mode)
Average current con- sumption in sleep mode	0.1 µA
Average measurement time	5.5 msec (ultra-low power preset)
Resolution of data	Pressure: 0.18 Pa (eqiuv. to <10 cm) Temperature: 0.01 K
Absolute accuracy P = 950 ... 1100 hPa (T = 0 ... +65 °C)	~ ±1 hPa
Relative accuaracy pressure (typ.) p=950 ... 1050 hP (+25 °C)	± 0.12 hPa (equiv. to ±1 m)
Temperature coefficient offset (+25° ... +40 °C @900hPa)	1.5 Pa/K (equiv. to 12.6 cm/K)

Nodo: alimentación



Alimentación: soluciones

- Pilas (baterías primarias)
  - autonomía limitada, sin embargo
  - si muy bajo consumo: pila ~ dispositivo
- Recolección + almacenamiento + conversor tensión
  - funcionamiento sin interrupciones
  - computación intermitente
- Alimentación de red electrica

Alimentación: pilas (battery)

PRODUCT DATASHEET

ENERGIZER E91

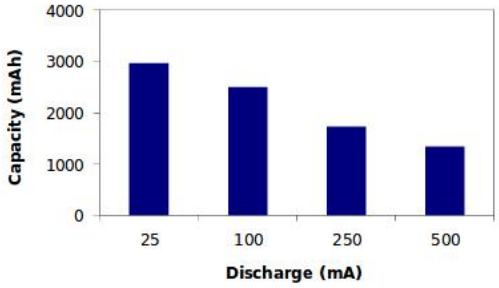
AA

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

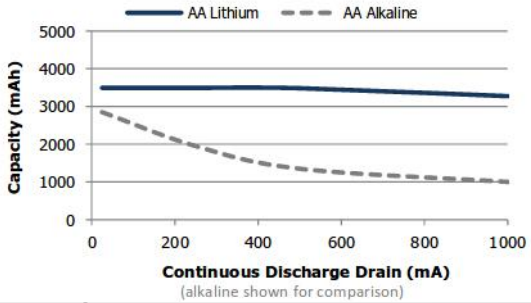
Specifications

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

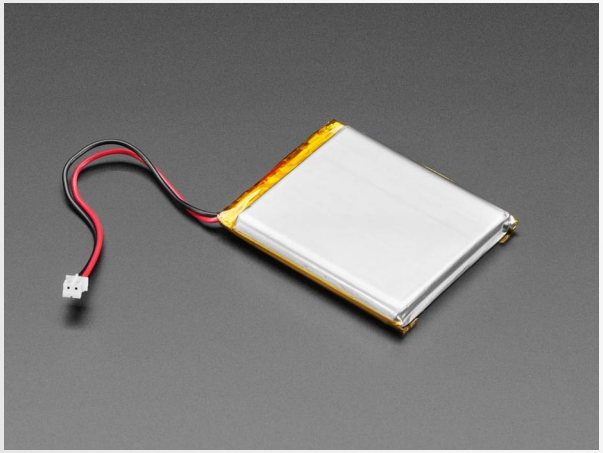


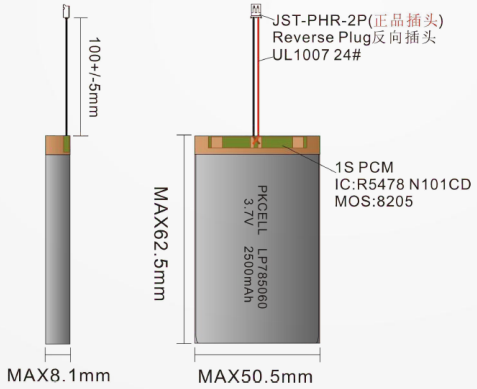
Alimentación

- Recolección de energía
  - solar
  - vibraciones
  - temperatura (diferencia)
  - eólica (micro molinos)
- Almacenamiento de energía
  - baterías recargables
  - supercondensadores
- Conversión de tensión / cargador
  - Vo (almacenamiento) → Vin (dispositivo)

Alimentación: batería recargable

- Ejemplo
  - Lithium Ion Polymer Battery 3.7V 2500mAh





https://www.adafruit.com/category/574

https://www.adafruit.com/product/328

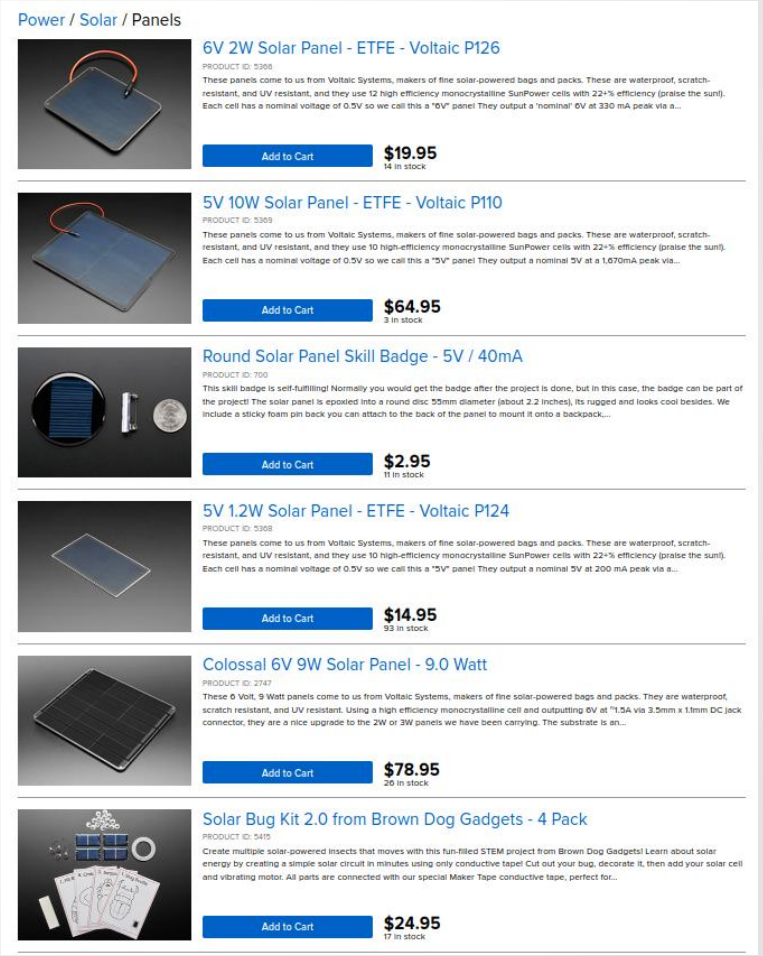
Alimentación: panel solar

- Ejemplo:
  - Small 6V 1W Solar Panel

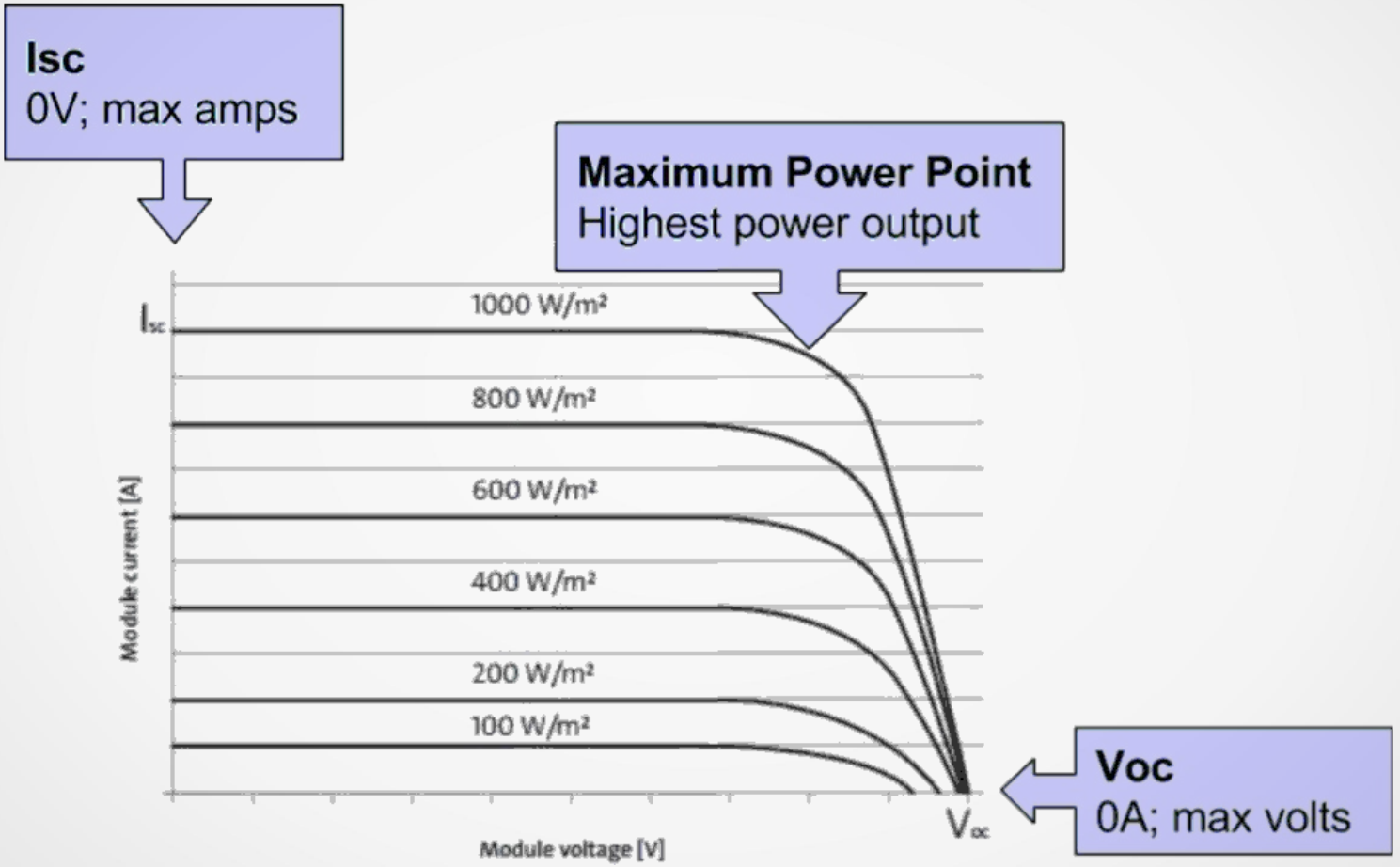
Output

- Open Circuit Voltage: 7.7V
- Peak Voltage: 6.5V
- Peak Current: 180mA
- Peak Power: 1.2W
- Power Tolerance: +/-10%

https://www.adafruit.com/product/3809

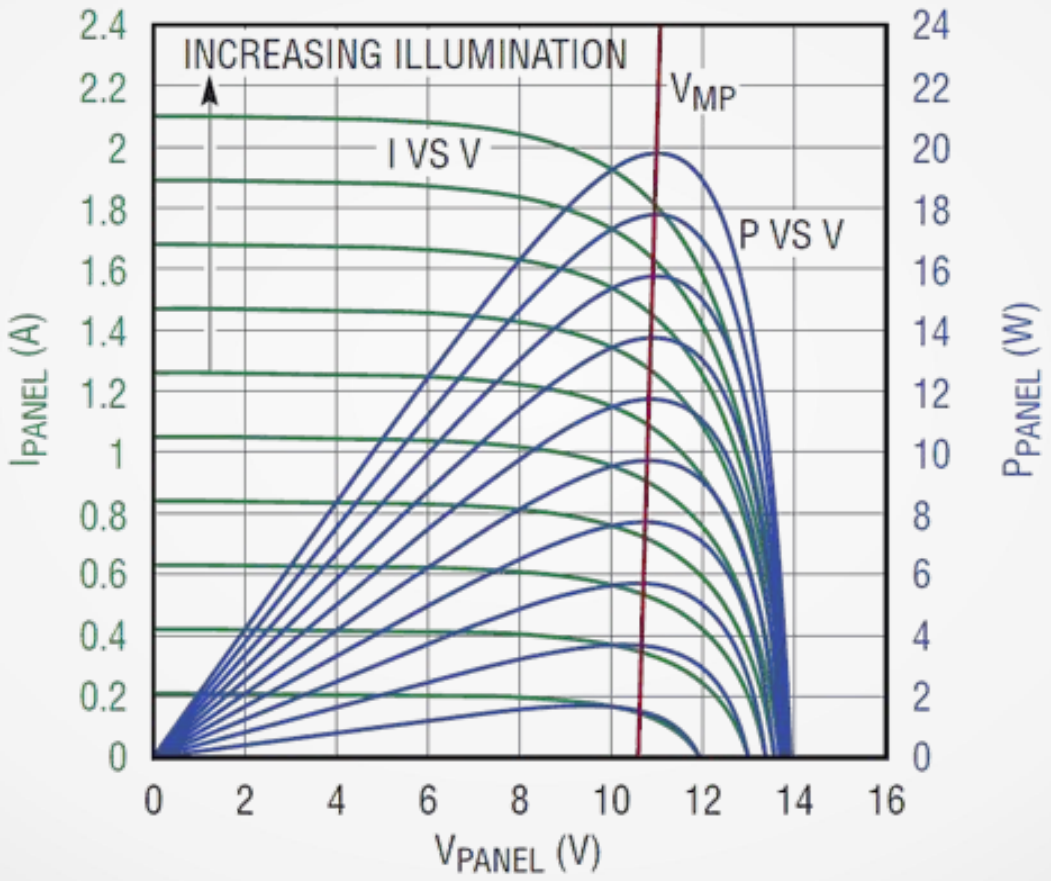


Alimentación: panel solar



https://www.altestore.com/blog/2016/04/how-do-i-read-specifications-of-my-solar-panel/

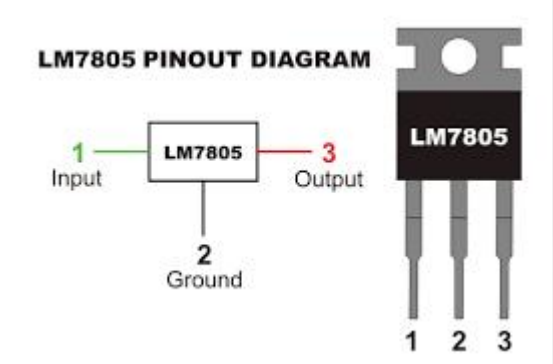
Alimentación: panel solar



https://learn.adafruit.com/usb-dc-and-solar-lipoly-charger/design-notes

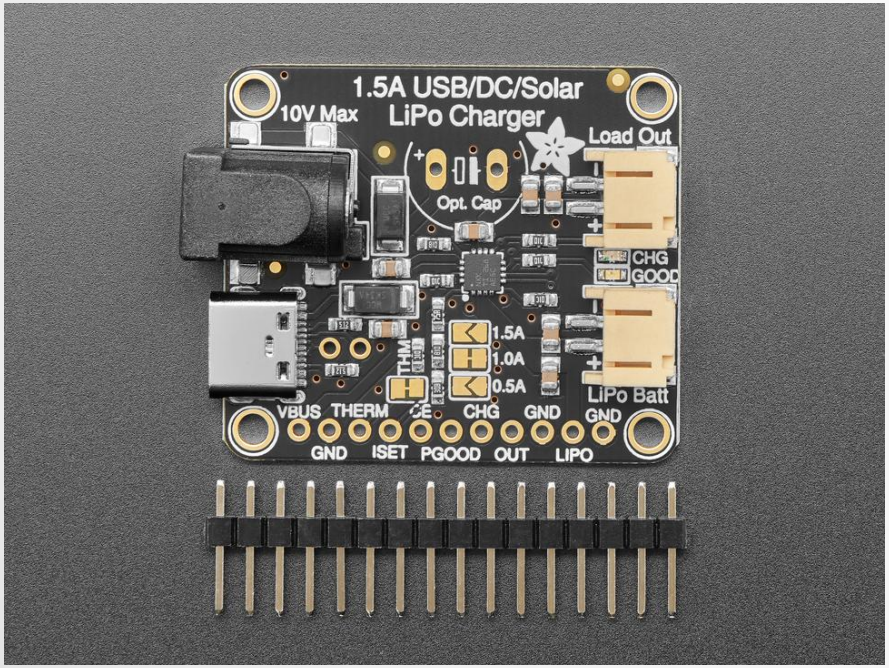
Alimentación: conversores de tensión

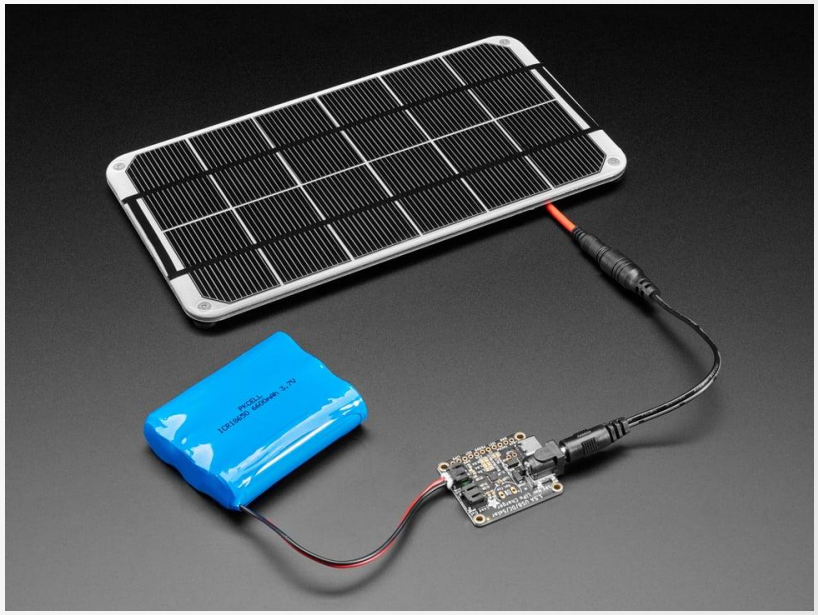
- Tipos
  - Reguladores lineales
  - Conmutados (DC-DC)
    - up, down, up-down
  - Cargadores (funcional. MPTT)
- Consideraciones
  - límites de tensiones
  - salida/s: fija, programables
  - eficiencia



Alimentación: solución

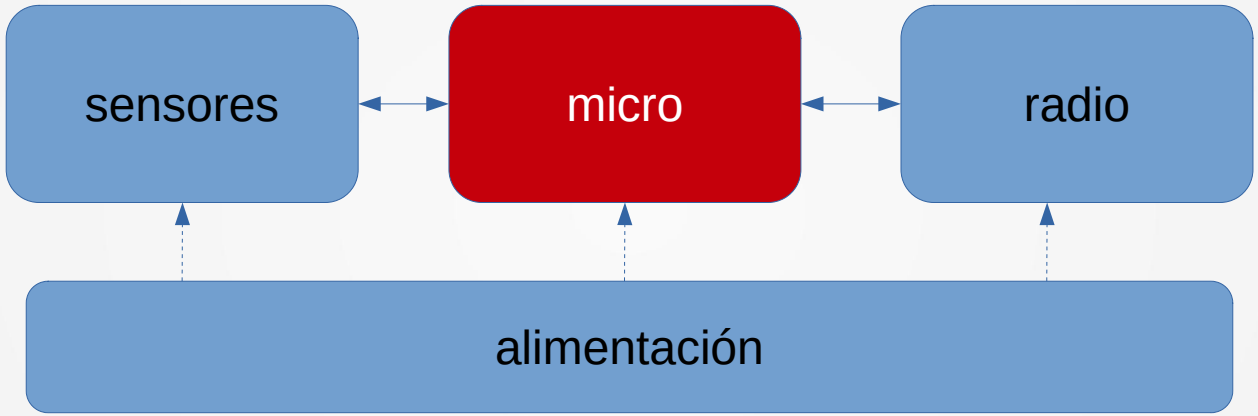
- Ejemplo: bq24074
  - Universal USB / DC / Solar Lithium Ion/Polymer charger





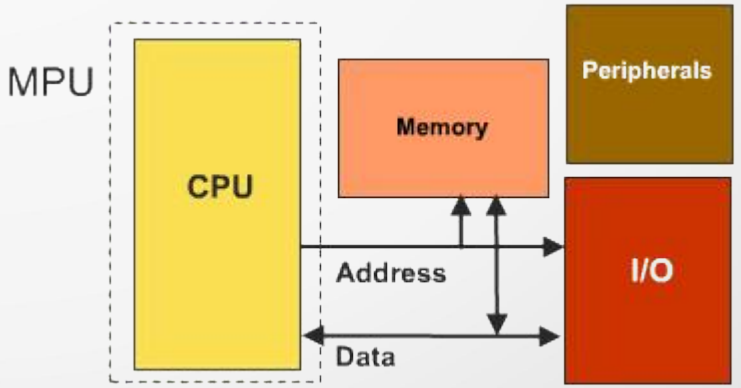
https://www.adafruit.com/product/4755

Nodo: microcontrolador



Microcontrolador: requerimientos

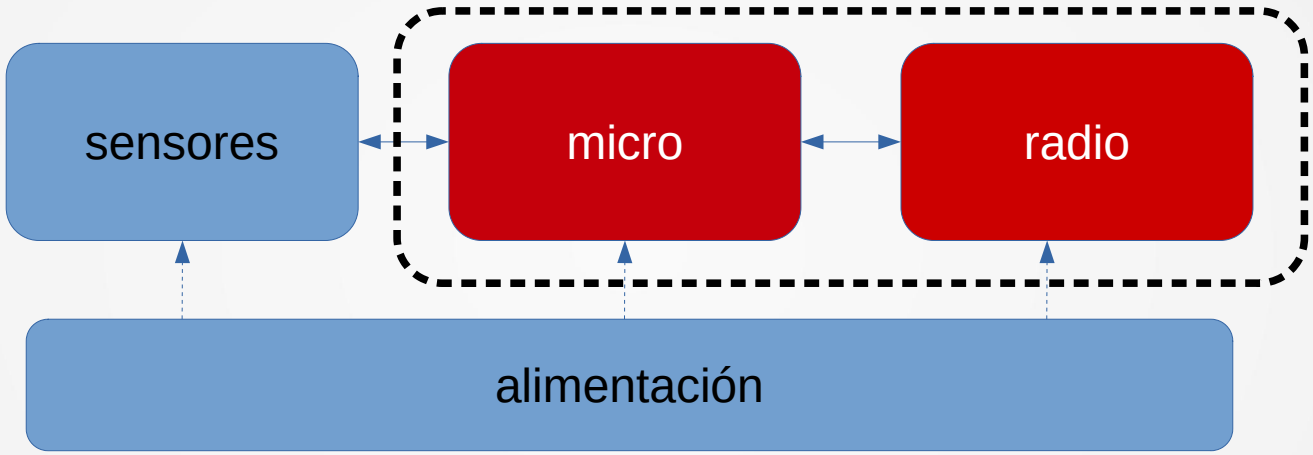
- Memoria de código: Flash, FRAM
- Memoria de datos: RAM (FRAM+cache)
- Memoria datos bulk: logs, datos, file system
- Potencia de procesamiento:
  - velocidad de reloj, arquitectura N-bits, FPU (necesario?)
- Consumo
  - modos de operación



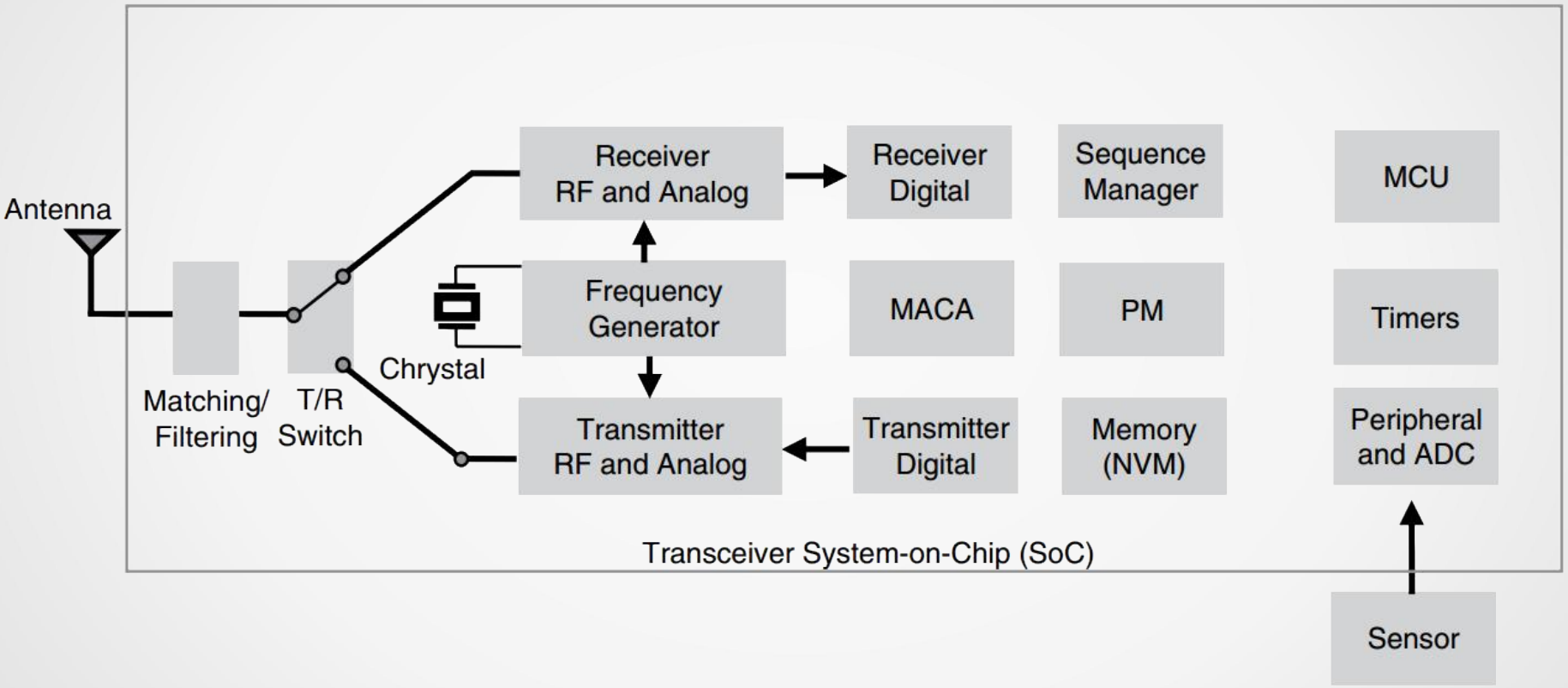
Microcontrolador

- 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)



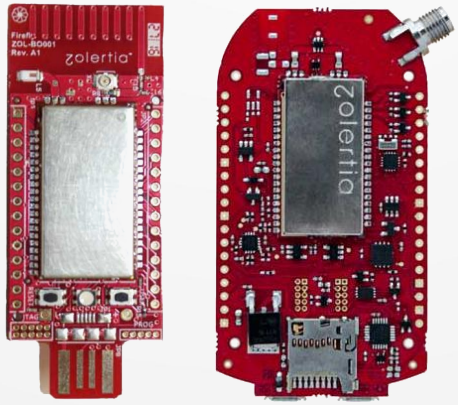
Hardware: opciones “core”

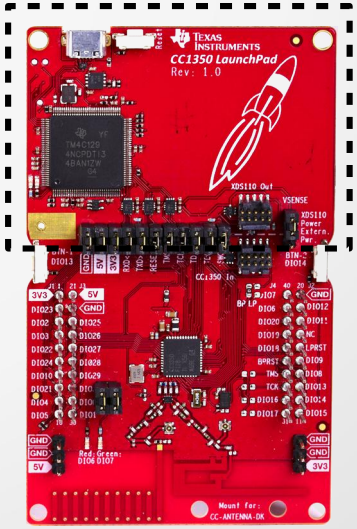
- chips
  - MCU + radio
  - SoC (system-on-chip)
  - SiP (system-in-package)
- módulo
- board / kit
  - evaluation
  - developing
  - prototiping

chips

módulos

boards / kits





prog. JTAG

Recomendaciones

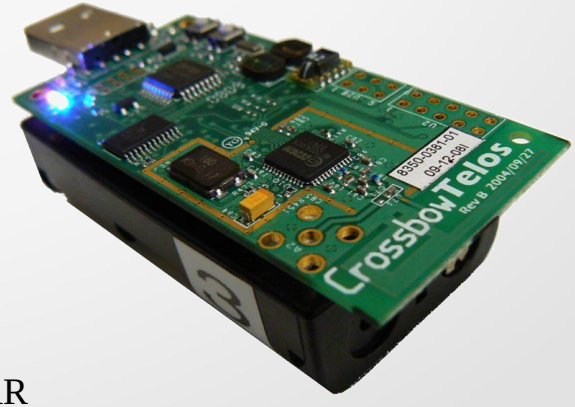
- Características
  - Generales
    - tensión de alimentación
    - corriente / potencia de consumo (modos)
    - duty cycle (tiempo “on” / “período”)
  - RF
    - link budget: PTx (dB), Sensibilidad
  - microcontroladores
    - memoria SRAM / Flash
    - periféricos

Nodos: ejemplos

- Plataformas de hardware: nodos/kits
  - sky (2011-2022?)
  - remote-b (2017-2022?)
  - launchpad sensortag (2023-...)
- Proyectos
  - Proyecto INIA-FPTA
    - Monitoreo microclimático
  - Proyecto fin de carrera:
    - Sistema de Monitoreo y Control de Cultivo Indoor de Cannabis

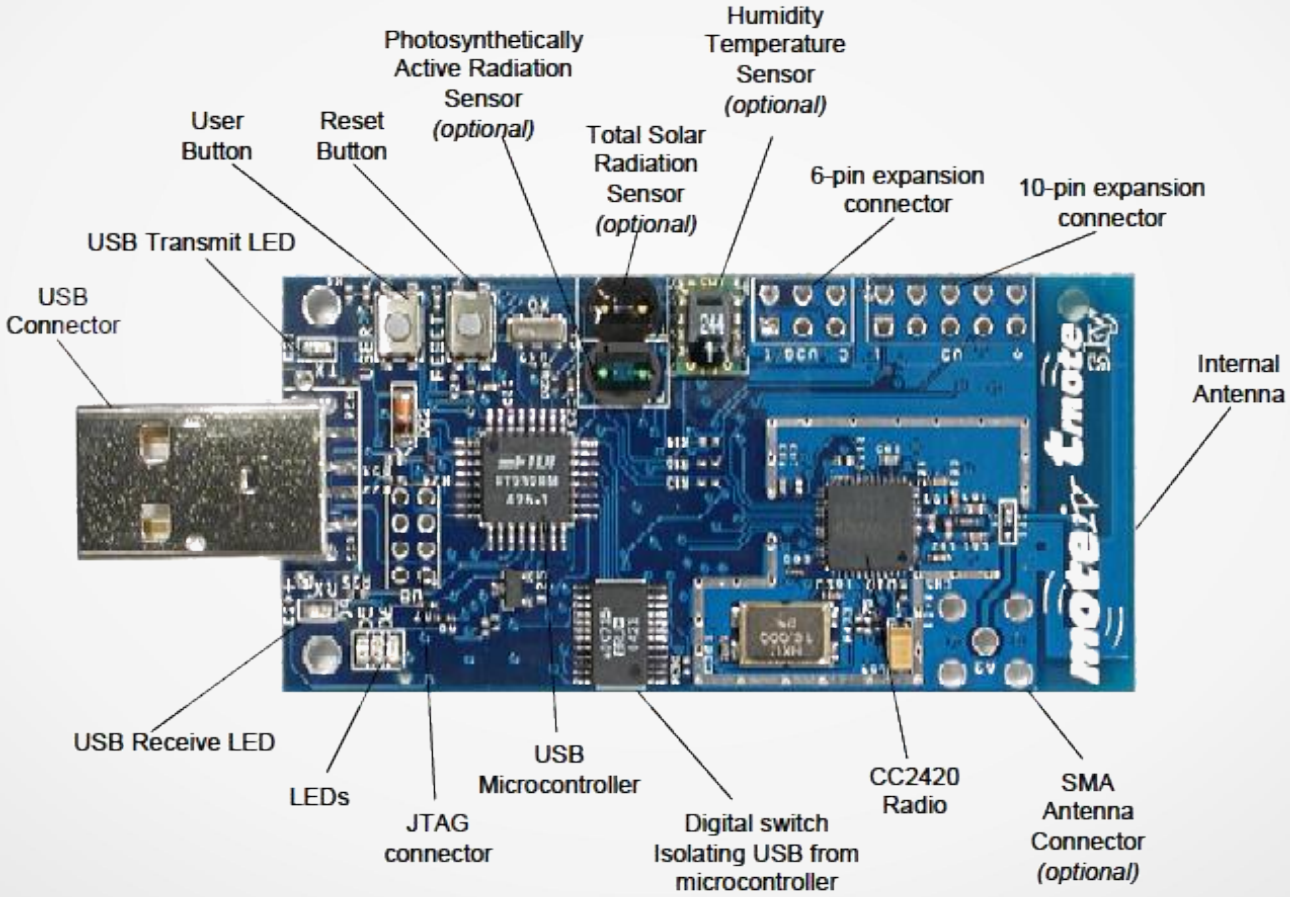
Nodo: sky

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



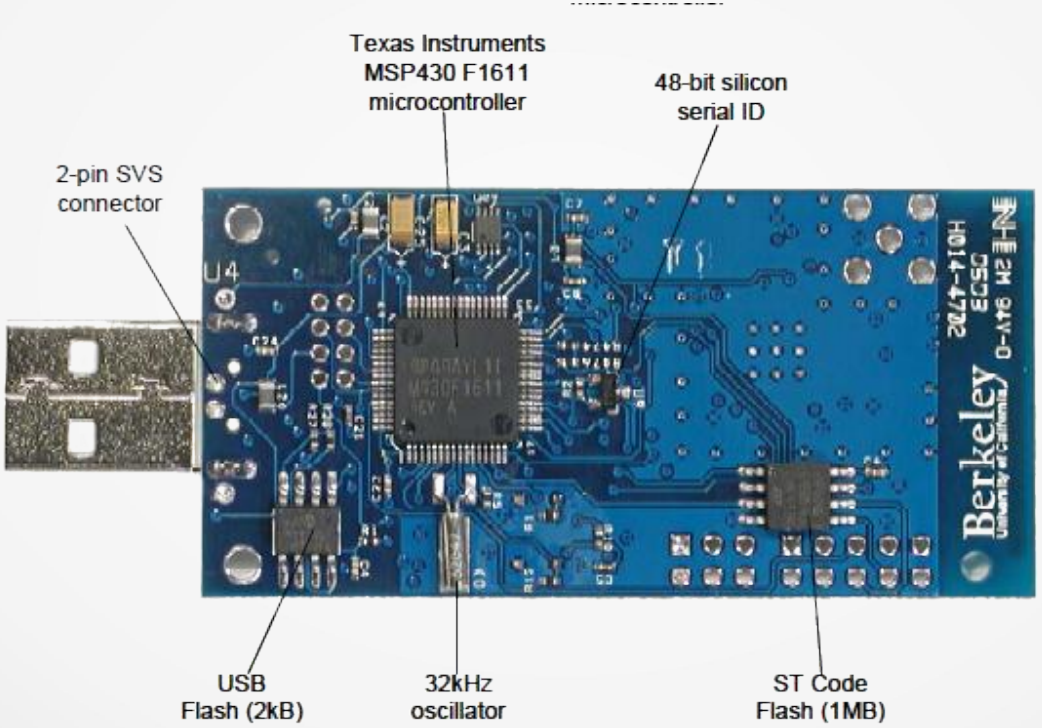
Nodo: sky

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



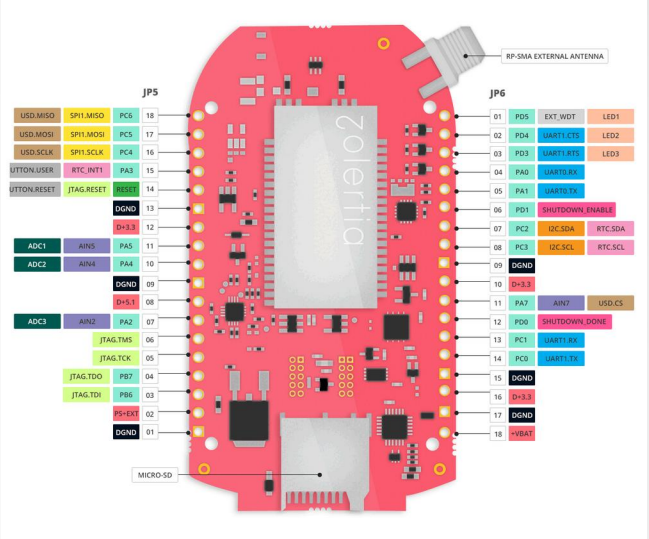
Nodos: ejemplos

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



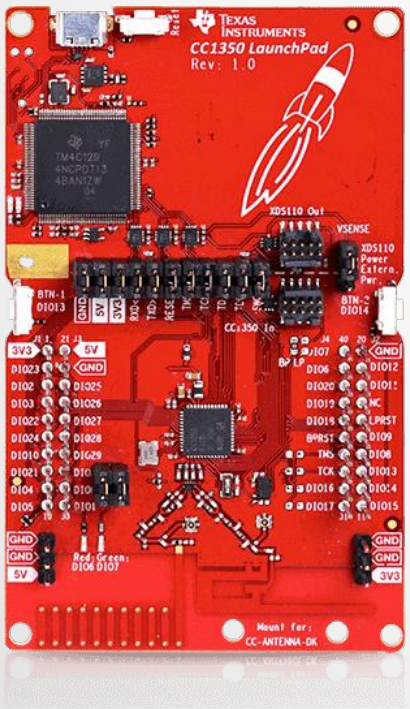
Nodo: remote-b

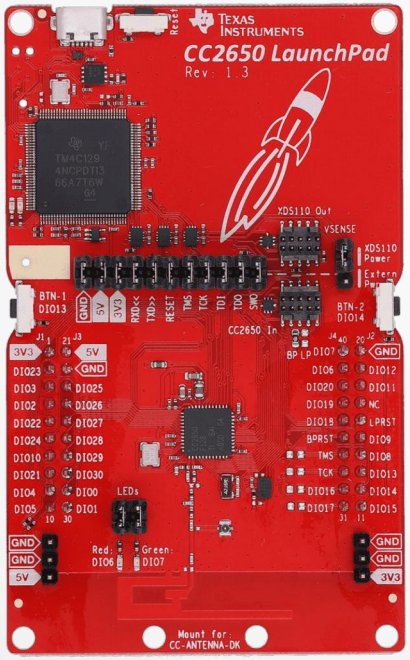
- CC2538 system on chip (SoC)
  - ARM Cortex-M3
  - up to 32 MHz
  - FLASH: 512 kB
  - RAM: 32 kB
  - 2.4 GHz IEEE 802.15.4 RF interface,
- CC1200 868/915 MHz RF transceiver
- LEDs
- Botones



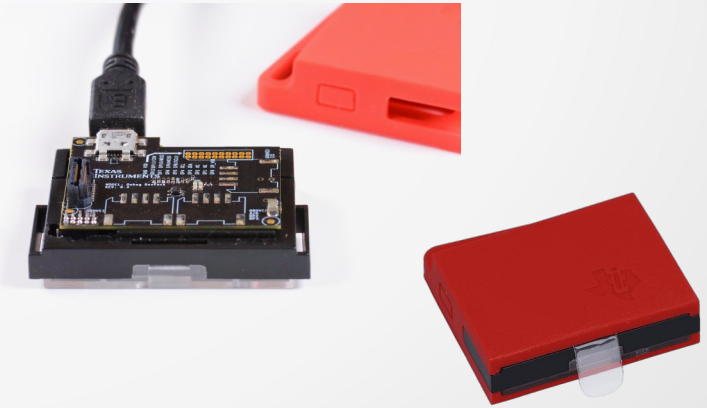
Nodos: LaunchPad & Sensortags

	CC1350	CC2650
LaunchPad	CC1350 LaunchPad	CC2650 LaunchPad
sensortag	CC1350 Sensortag	CC2650 Sensortag





Launchpad



Sensortag

CC1350 vs. CC2650: similitudes

- **Microcontroller**
  - Powerful ARM® Cortex®-M3
  - Up to 48-MHz Clock Speed
  - 128KB of In-System Programmable Flash
  - 8KB of SRAM for Cache
  - 20KB of Ultralow-Leakage SRAM
  - 2-Pin cJTAG and JTAG Debugging
  - Supports Over-The-Air Upgrade (OTA)
- **Ultralow-Power Sensor Controller**
  - Can Run Autonomous from the rest
  - 16-Bit Architecture
  - 2KB of Ultralow-Leakage SRAM for Code and Data
- **Low Power**
  - Normal Operation: 1.8 to 3.8 V
- **Peripherals**
  - All digital pins can be routed to any GPIO
  - Four General-Purpose Timer Modules
  - 12-Bit ADC, 200-ksamples/s, 8-Channel Analog MUX Continuous Time Comparator
  - Ultralow-Power Analog Comparator
  - Programmable Current Source
  - UART / I2C / I2S
  - 2× SSI (SPI, MICROWIRE, TI)
  - Real-Time Clock (RTC)
  - AES-128 Security Module
  - True Random Number Generator (TRNG)
  - Integrated Temperature Sensor
  - etc.

CC1350 vs. CC2650: diferencias

- CC1350 dual-band wireless MCU
  - Bluetooth Low Energy (BLE) 4.2 Specification (2.4GHz)
  - Sub-1 GHz Long Range
    - Wireless M-Bus (EN 13757-4) and IEEE® 802.15.4g
    - versiones: CC1350US 915 MHz, CC1350EU 868 MHz
- CC2650 multiprotocol 2.4 GHz wireless MCU
  - Bluetooth Low Energy (BLE) 4.2 Specification (2.4GHz)
  - IEEE 802.15.4 PHY and MAC (2.4-GHz)
    - ZigBee® and 6LoWPAN, and ZigBee RF4CE remote.

Launchpad vs. sensortag

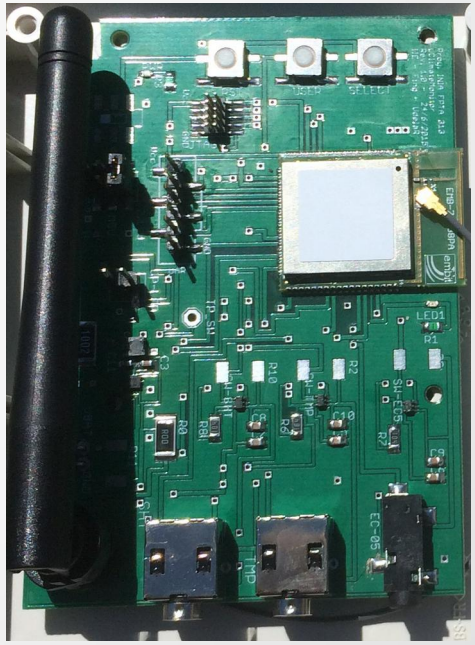
- Lauchpad
  - Wireless MCU (CCxxxx)
  - LEDs / BTN
  - Program. / debug (incluido en placa)
- Sensortag
  - sensores :)

	Sensortag	BoosterPack
Humididty	HDC1000 (TI)	BME280
Temperature	BMP280 (Bosh)	BMP280
Pressure	BMP280	BMP280
Light	OPT3001 (TI)	OPT3001
Internal	TMP007 (TI)	TMP007
External	TMP007	TMP007
Accelerometer	MPU-9250 (TDK)	BMI160
Gyroscope	MPU-9250	BMI160
Magnetometer	MPU-9250	BMM150

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

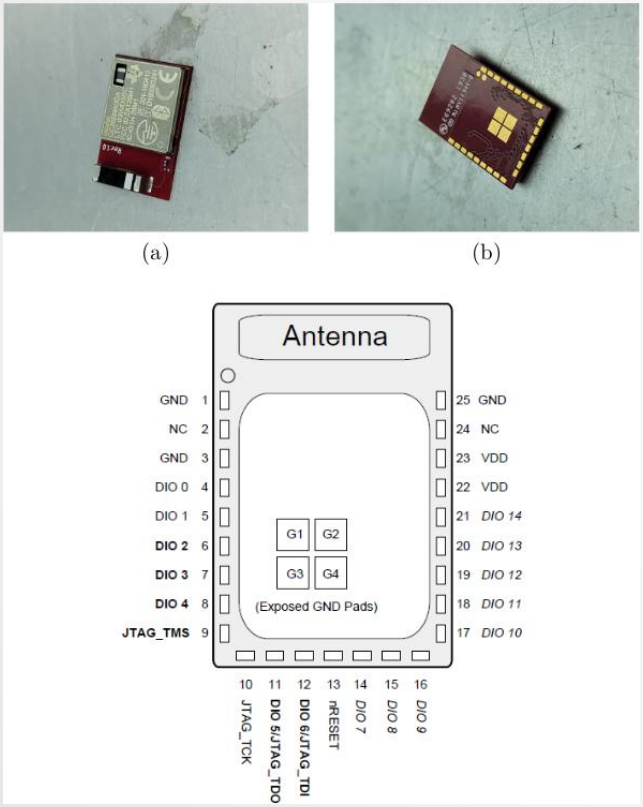


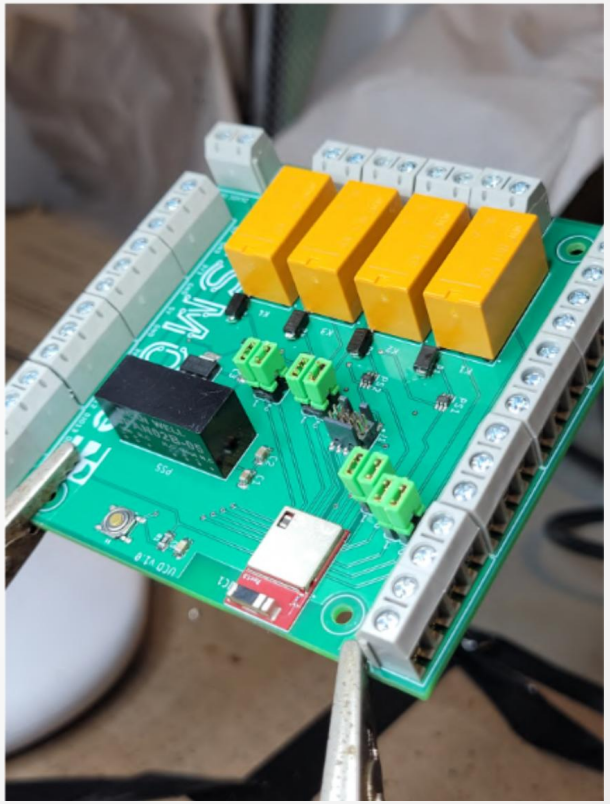
Ejemplos: SMC

- **Sistema de Monitoreo y Control de Cultivo Indoor de Cannabis**
  - Nodos:
    - control distribuido
    - sensor (“maceta”)

Ejemplos: SMC

- **Control distribuido**





módulo CC2650MODA (Texas Inst.)

Ejemplos: SMC

- **Nodo sensor (maceta)**

Planificación clases

1) Introducción RSI
2) **Plataformas de hardware**
3) Arquitectura 6LoWPAN (IPv6)
4) Plataforma de software: Contiki-NG (parte 1)
5) Plataforma de software: Contiki-NG (parte 2)
6) Capa de aplicación: CoAP / MQTT
7) Capa de red: RPL
8) MAC
9) IEEE 802.15.4 / 6lowpan
10) Capa Fisica & antenas
11) IoT y las RSI

gracias... ¿más preguntas?