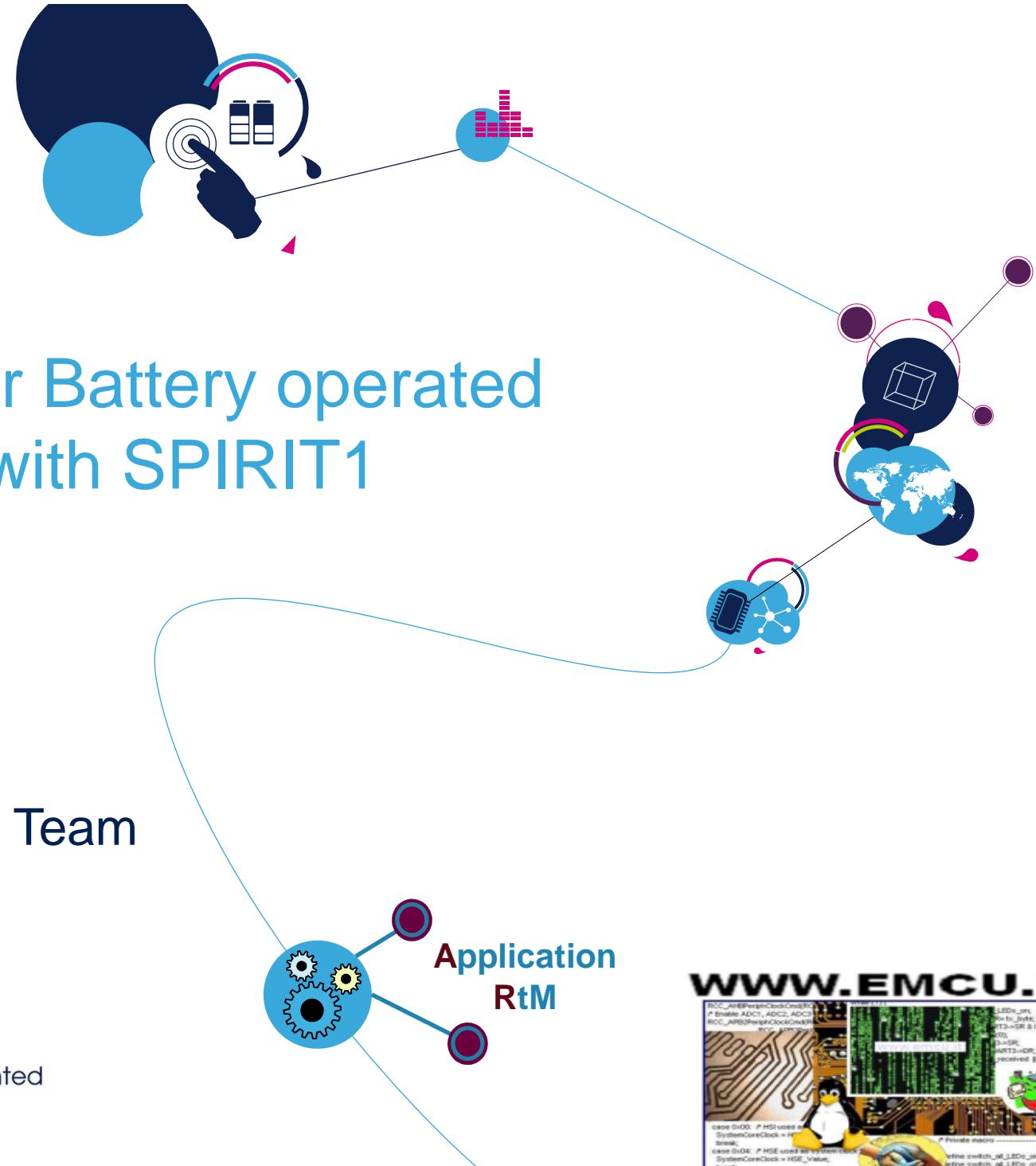


# Guidelines for Battery operated applications with SPIRIT1

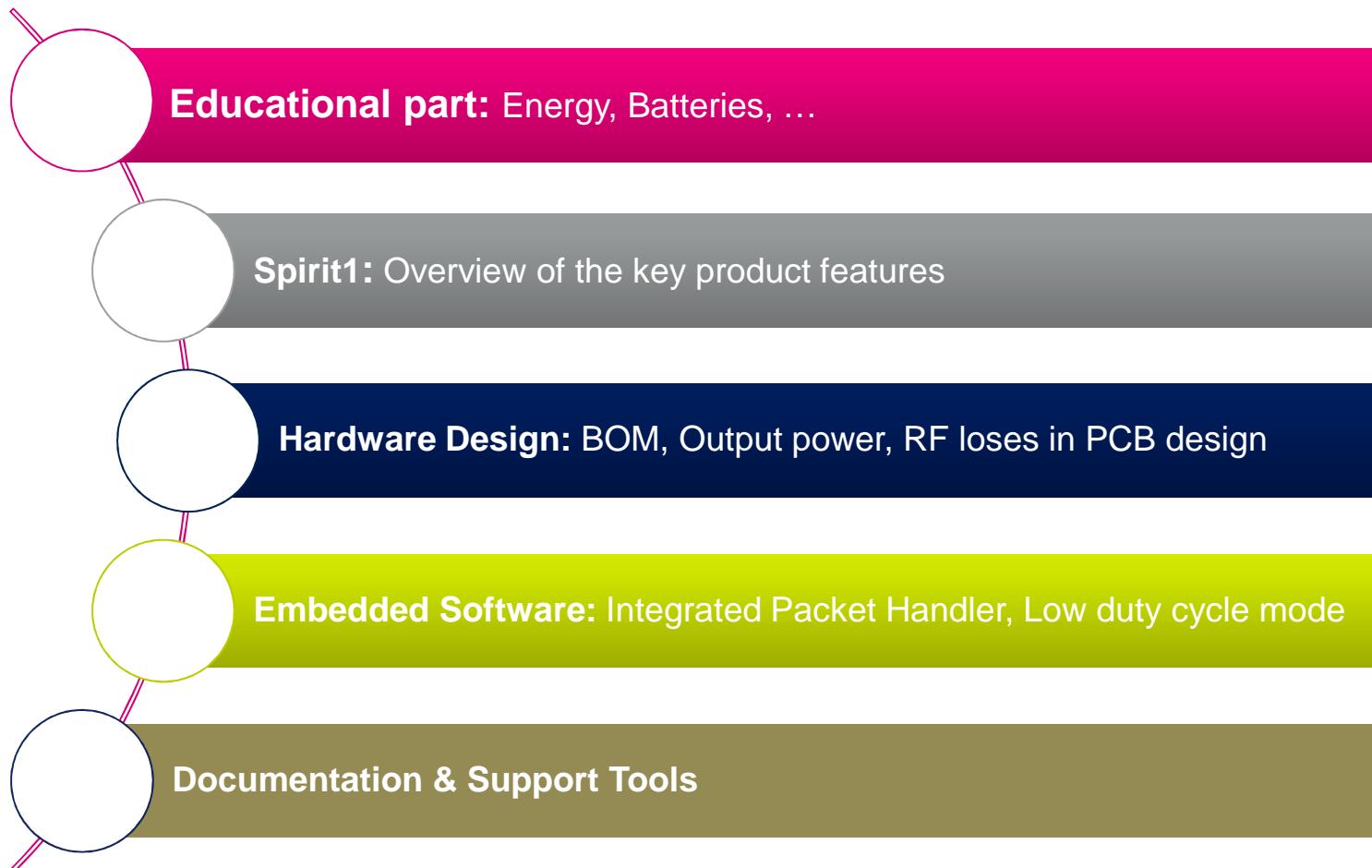
July 1<sup>st</sup> 2013

AMS Application Team



# Agenda

2



- Used to describe energy absorbed or delivered by an electrical circuit. This energy is supplied by the combination of electric current and electrical potential in the time
  - Equations
    - Joule = Watts x Seconds
    - Watt = Volt x Ampere (Ohms law)
      - Joule = Volt x Ampere x Seconds
  - Our focus in low power designs
    - Power source voltage
    - Current consumption
    - Time necessary to perform an operation

# Batteries

4

- Primary, disposable

- Alkaline (-Zn +MnO<sub>2</sub>; KOH), 1.5 V, 0.4-0.6 MJ/kg (quality standard)
- Lithium (-Li +MnO<sub>2</sub>, ...), 3.0 V, 0.8-1.0 MJ/kg (long shelf life)
- Silver-oxide (-Zn +Ag<sub>2</sub>O), 1.5 V, 0.47 MJ/kg (very expensive)
- Zinc-carbon (-Zn +MnO<sub>2</sub>; NH<sub>4</sub>Cl), 1.5 V, 0.13 MJ/kg (common, cheap)



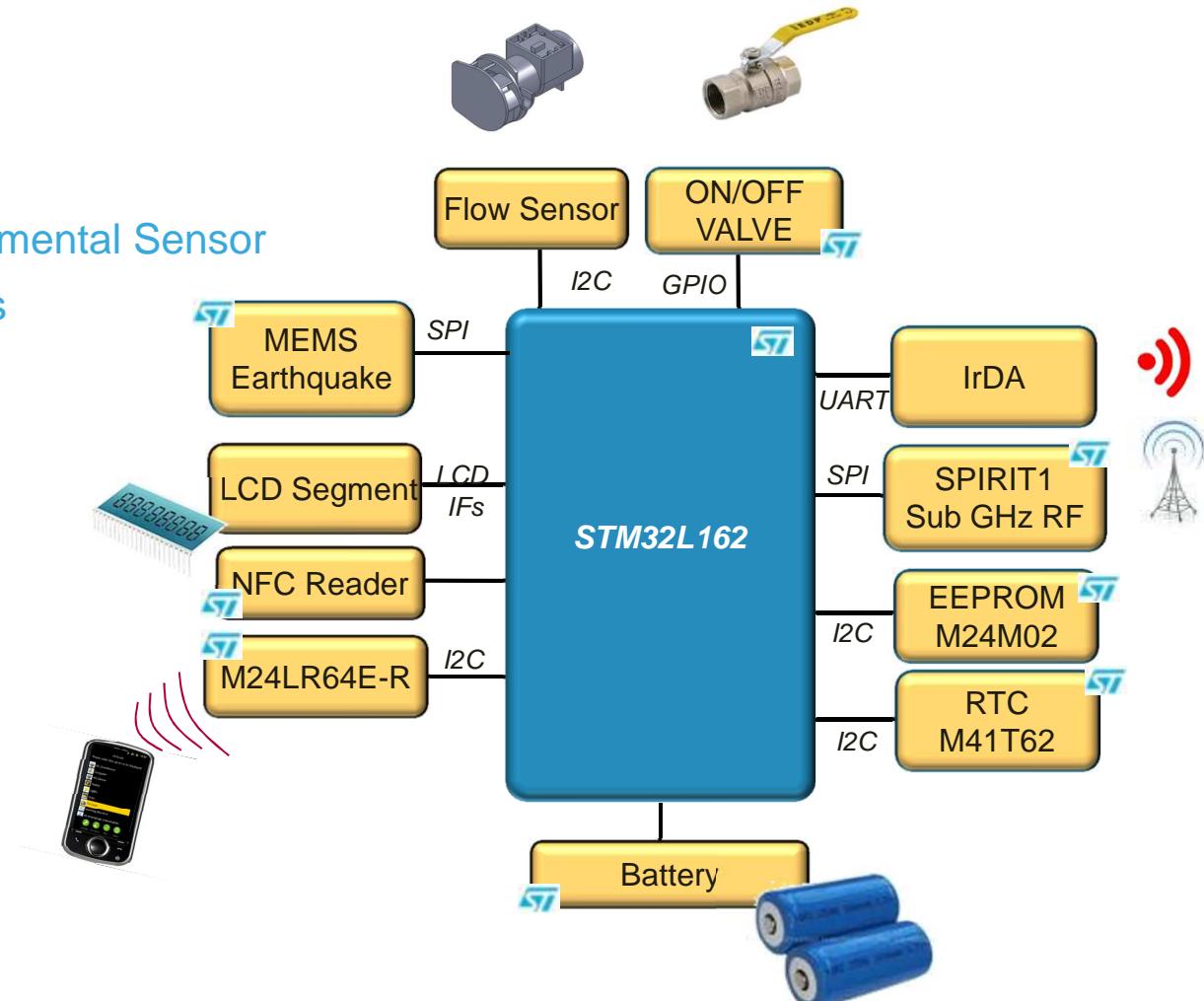
- Secondary, rechargeable

- NiCd, 1.2 V, 0.14 MJ/kg
- Pb-acid, 2.1 V, 0.14 MJ/kg
- NiMH, 1.2 V, 0.3 MJ/kg
- NiZn, 1.6 V, 0.36 MJ/kg
- Li-Ion, 3.6 V, 0.7 MJ/kg
- Li-Po, 3.7 V, 0.65 MJ/kg



# Typical application schematics

- Spirit1 + Microcontroller + Sensing Element (+ Actuator)
  - Gas meter
  - Water meter
  - Heat meter
  - Wireless Environmental Sensor
  - Internet of Things



# Spirit1 Key Product Features

- Frequency bands: 169, 315, 433, 868, 915, 920 MHz
- Configurable data rate from 1 to 500 kbps
- SPI, GPIO interface
- Supply voltage: 1.8 V to 3.6V
- QFN20 4x4mm, thickness 0.9mm
- Modulation schemes: 2-FSK, GFSK, MSK, GMSK, OOK, ASK
- Suitable for Systems targeting compliance
  - Wireless MBUS standard
  - ETSI EN 300 220, FCC CFR47 Part 15, ARIB STD-67

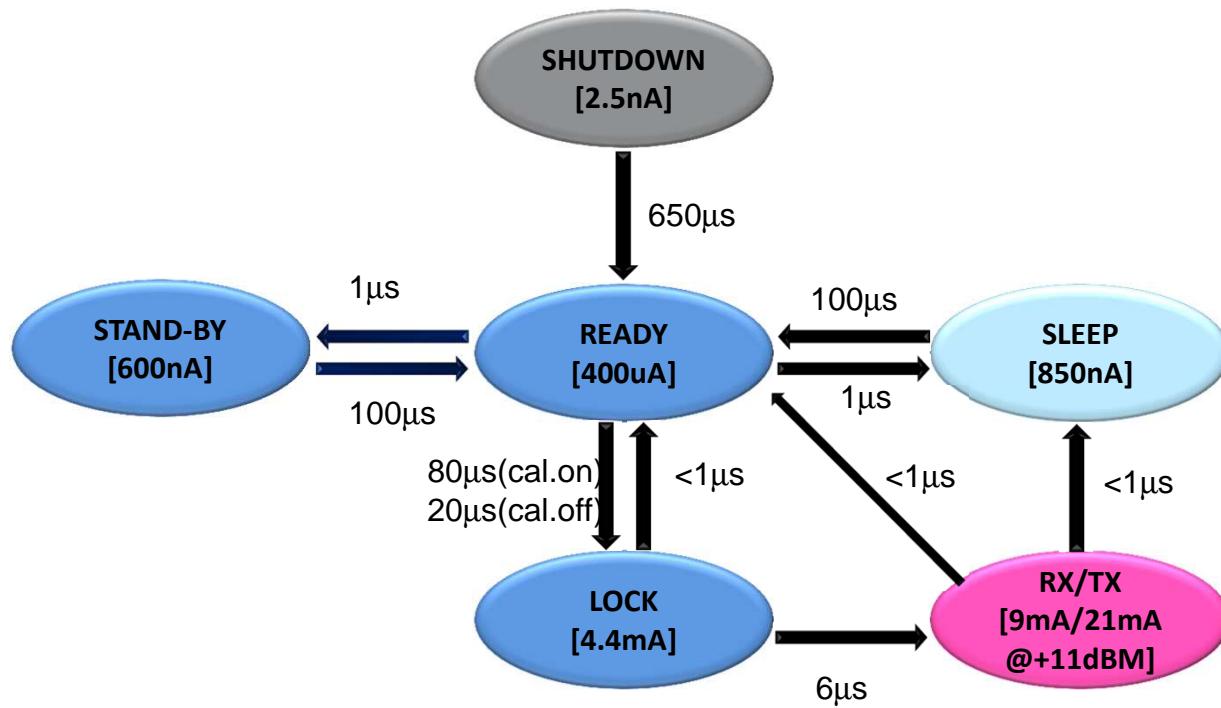


# Spirit1 Key Product Features

- Output Power: -36 dBm to +11 dBm (16dBm in boost mode)
- Receiver sensitivity: -123 dBm (1.2 kbps, 169MHz, SMPS OFF)  
-117 dBm (1.2 kbps, 169MHz, SMPS ON)
- Integrated SMPS allows very low power consumption

<b>RX</b>	<b>9 mA</b>	<b>SPI on, XTAL on, Synth on</b>
<b>TX</b>	<b>21 mA</b>	SPI on, XTAL on, Synth on
<b>Ready</b>	<b>400 uA</b>	SPI on, XTAL on
<b>Sleep</b>	<b>850 nA</b>	SPI on, register retention, RC oscillator
<b>Standby Mode</b>	<b>600 nA</b>	SPI on, register retention
<b>Shutdown Mode</b>	<b>2.5 nA</b>	Everything OFF

# Operating Modes/Consumption

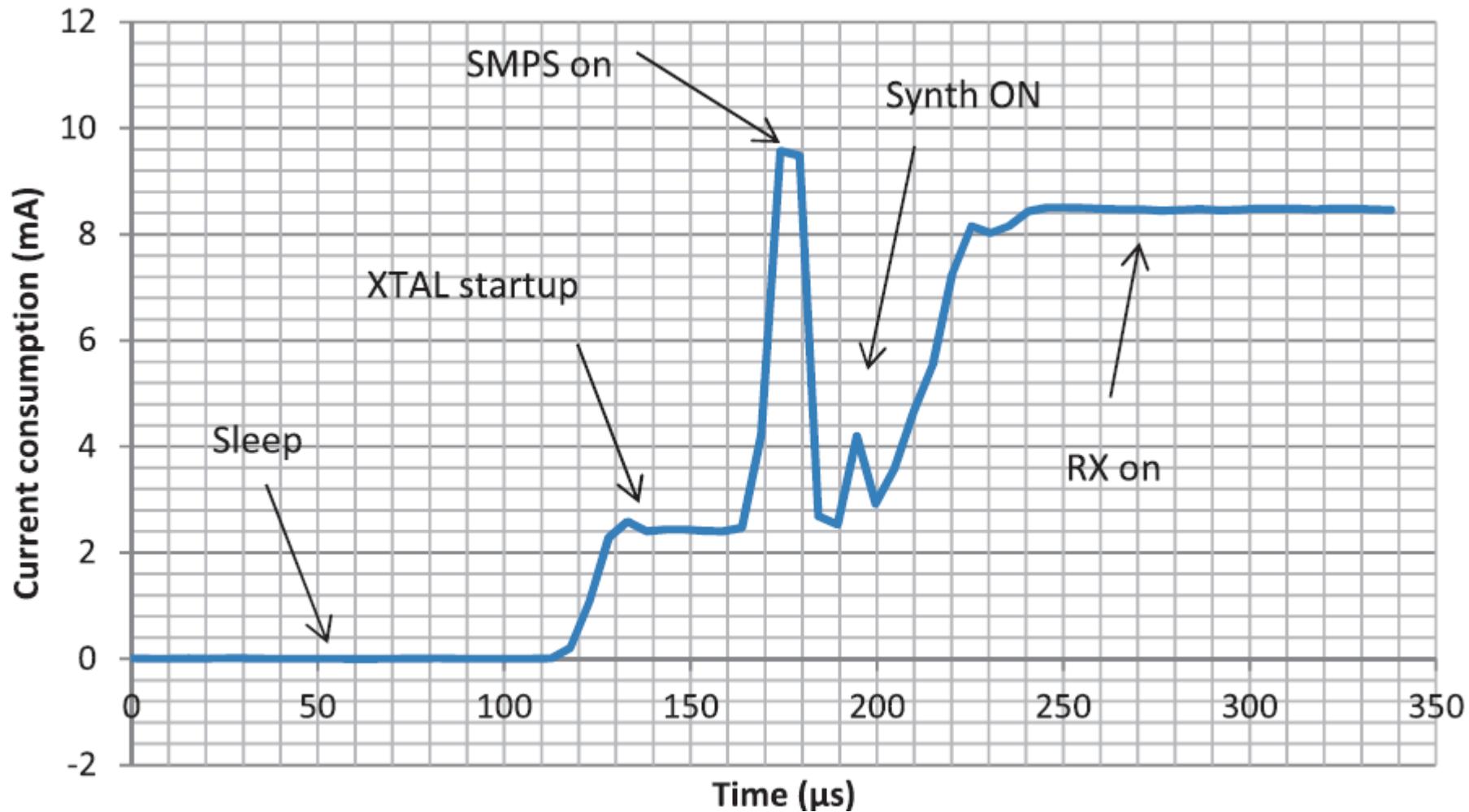


Mode	Description
Shutdown	Off, no register retention
Standby	SPI On, register retention
Sleep	SPI on, register retention, Wakeup timer on
Ready	SPI on, XTAL on
RX	SPI on, XTAL on, RF Synth on
TX	SPI on, XTAL on, RF Synth on

Built-in main controller handles operating mode transitions

# Typical Current Profiles (Rx)

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# Batteries lifetime

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- Basic model (example: packet sniff rate 500 ms, 100 frames / day)

State	Current (uA)	Time (ms)
Polling Rx	9000	6
Sleep Mode	3.8	494
Frame reception	10500	250
Frame analysis	1500	3.5

Rx Frame / day	100
Battery capacity	1250 mAh
Capacity available	50%
Lifetime	227 days, 0.62 years

- Advanced model
  - Step-by-step current & time analysis in order to get realistic battery lifetime estimation

# Hardware Design

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Application Diagram & BOM benefits

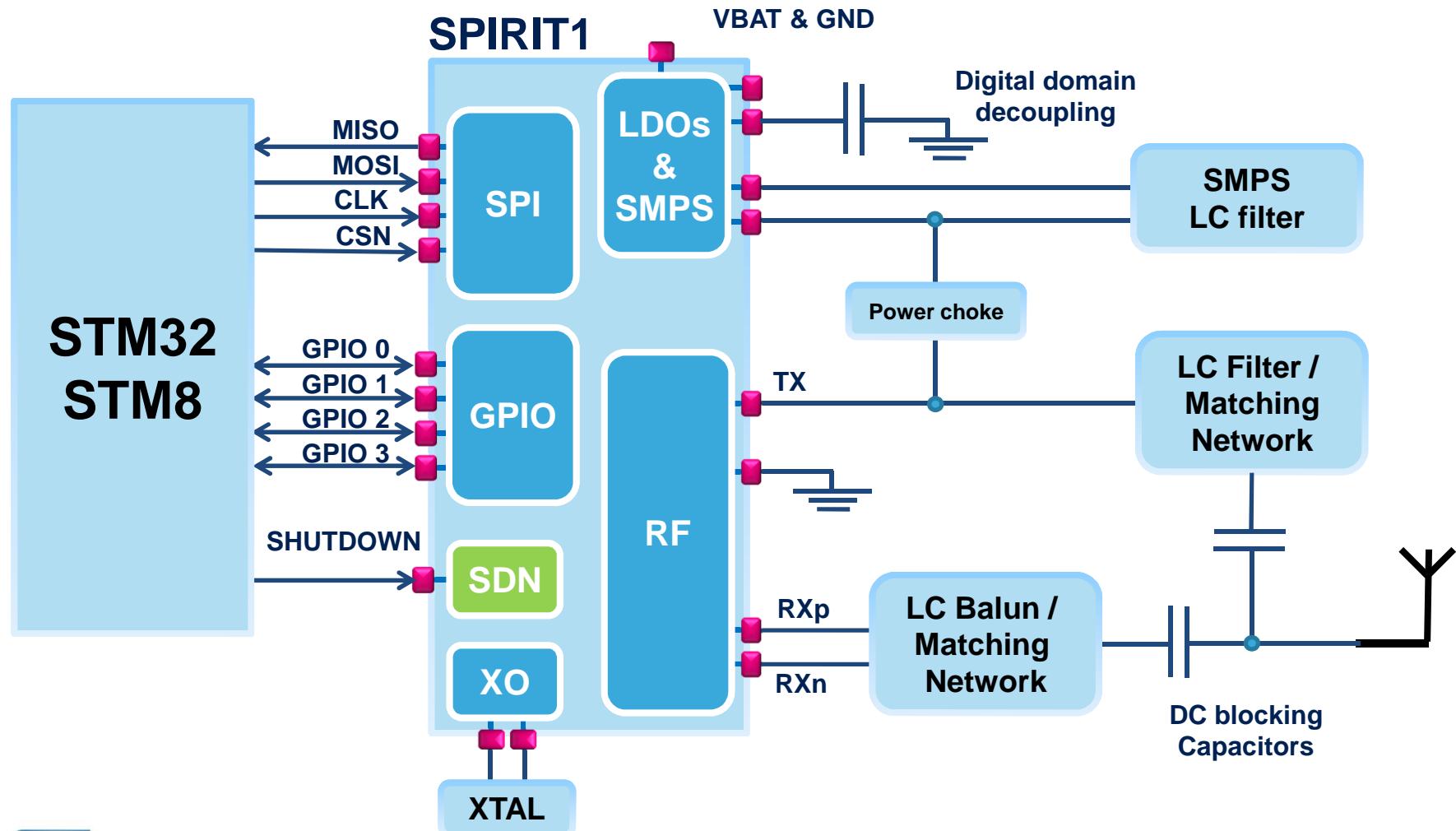
Output power

PCB Design

Spirit1 Companion chip

# SPIRIT1 Application Diagram

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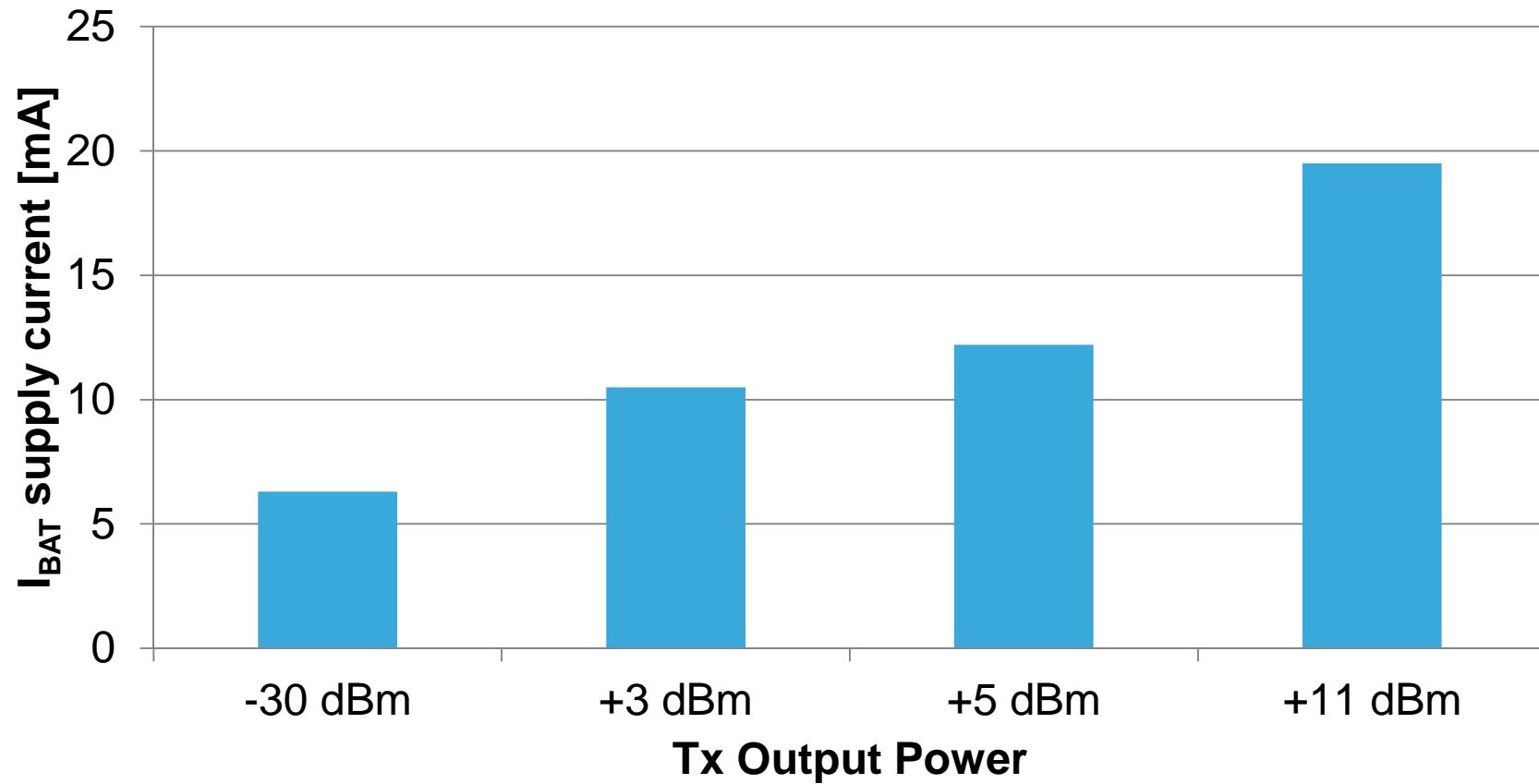
# SPIRIT1 hw design benefits

- No need an external PLL loop filter
  - No need an external tank for the VCO
  - No need an external TX SAW filter to reduce spurious emissions
    - SAW filter – Surface Acoustic Wave
    - ~ 1.5 mA up to 8 mA (Pout dependent)
  - No need any external SAW filter in RX to obtain good image rejection
    - ~ 1.5 mA
  - No need for TCXO
    - TCXO – temperature compensated XO
    - ~ 1.5 mA
  - Single ended TX - lower current consumption than the differential TX output
    - Single ended TX is more practical for attachment to external PAs available in the market

# Output power

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**PN9 @ 868MHz**



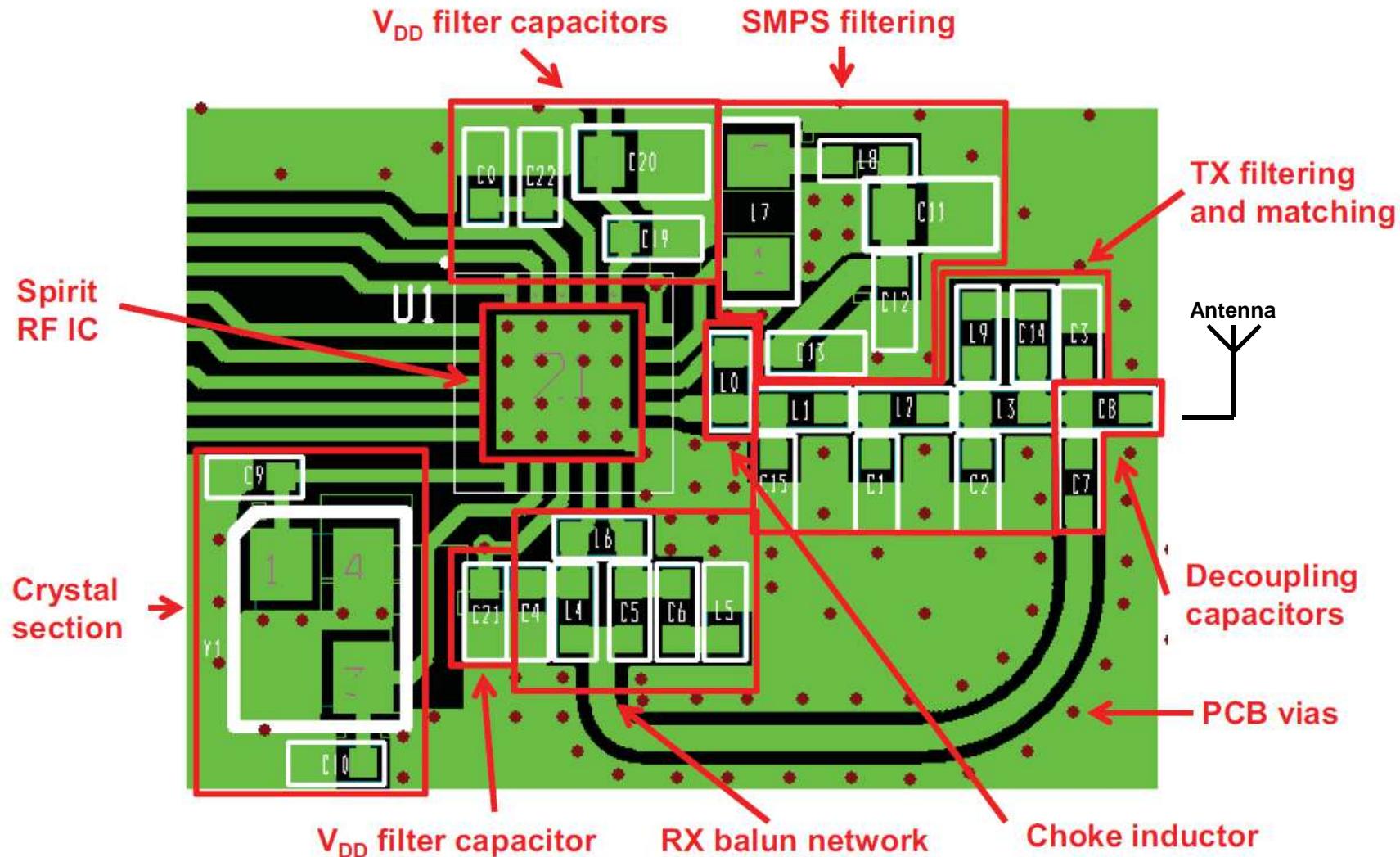
- Dielectric constant (relative permittivity), dissipation factor (loss tangent)
  - “standard loss”
    - FR4 (DK 4, DF 0.01)
  - “low loss”
    - Rogers R04003 (DK 3.38, DF 0.0027)
    - Roger RT/Duroid (DK 2.2, DF 0.0009)

# Two or multi-layer board design

- The advantage of N-layer designs over 2-layer designs
    - Distributed RF decoupling of a DC power plane by a ground plane
    - Ground layer very near to the RF plane to reduce the parasitic effects (Tx spurious emissions)
  - Typical 4-layer board stack
    1. TOP layer, used for the RF signals
    2. GROUND layer, used only as ground plane
    3. POWER layer, used for DC power plane
    4. BOTTOM layer, used for the low frequency and digital signals

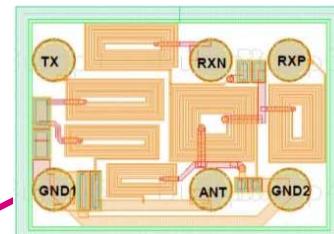
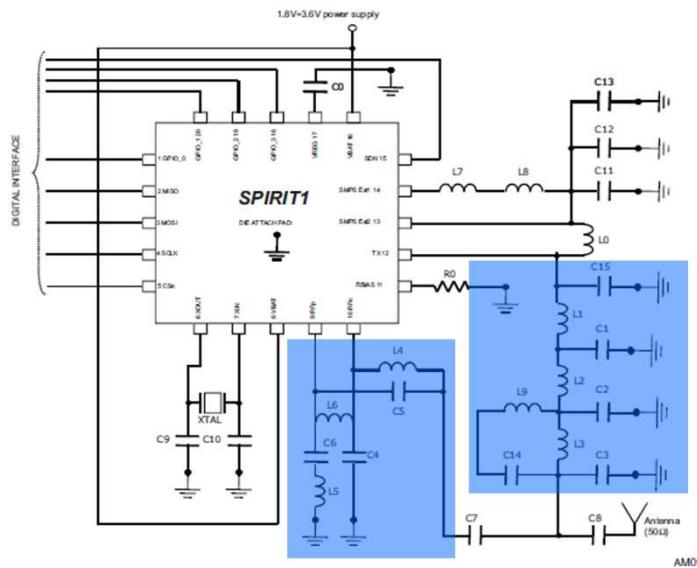
# SPIRIT1 PCB layout

17

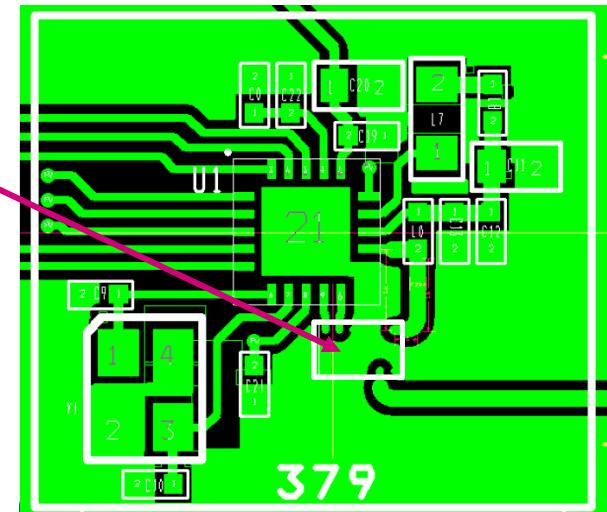


\* AN4169 - PCB design guidelines for the SPIRIT1 transceiver

# BALF-SPI-01D3 SPIRIT1 Companion chip



Balun+Filter into 1 die



SPIRIT1 EVB with BALF-SPI-01D3

- ST IPD Technology on Glass
- Covers all ETSI, FCC & ARIB : 868 to 920 MHz frequency range
- Reduced Size (< 3mm<sup>2</sup>, up to 70% vs discrete solution)
- Reduced Cost (-60% from BOM+PCB)
- No components dispersion or temperature variation
- Higher Reliability - better Performance (Insertion Losses)
- Reduced PCB sensibility

# Embedded Software

19

Autonomous functionalities

Software Design and  
Programming considerations

Low Duty Cycle Mode

# Where Spirit1 works for MCU

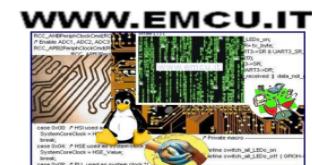
20

- Integrated packet handler
  - Support for automatic acknowledgment, retransmission, low duty cycle protocol and timeout protocol
  - Automatic Packet Filtering (Source/Destination address, CRC, Control field)
  - The Host MCU can stay in power down until a valid RF packet has been received, and then burst read the data
- Automatic clear channel assessment (CCA) engine
  - Channel access mechanism, based on the rule “Listen-before-talk” systems. Embedded CSMA/CA protocol
- Automatic antenna selection
  - Integrated antenna diversity switching mechanism
- Separate 96-byte RX/TX FIFOs

# Where software saves

- Receiver Quality Indicators & Timeout Mechanisms
  - Received signal strength indicator (RSSI) threshold leveling
    - Measured received signal power
  - Carrier Sense (CS), timeout
    - Based on RSSI (threshold, static/dynamic mode)
  - Link quality indicator (LQI)
    - Level of noise power on the demodulated signal
  - Preamble quality indicator (PQI), IRQ & timeout
    - The best correlation between the received preamble and the expected one
    - Packet demodulation can be stopped when PQI is below threshold
  - Synchronization quality indicator (SQI), IRQ & timeout
    - The best correlation between the received synchronization word and the expected one
    - Packet demodulation can be stopped when SQI is below threshold
- VCO calibration
  - temperature/VBAT variation
  - automatic (80 us) or manual (20 us, when MCU stores the calibration words)

The value of the  
Time out can be  
programmed up to  
~3 seconds!

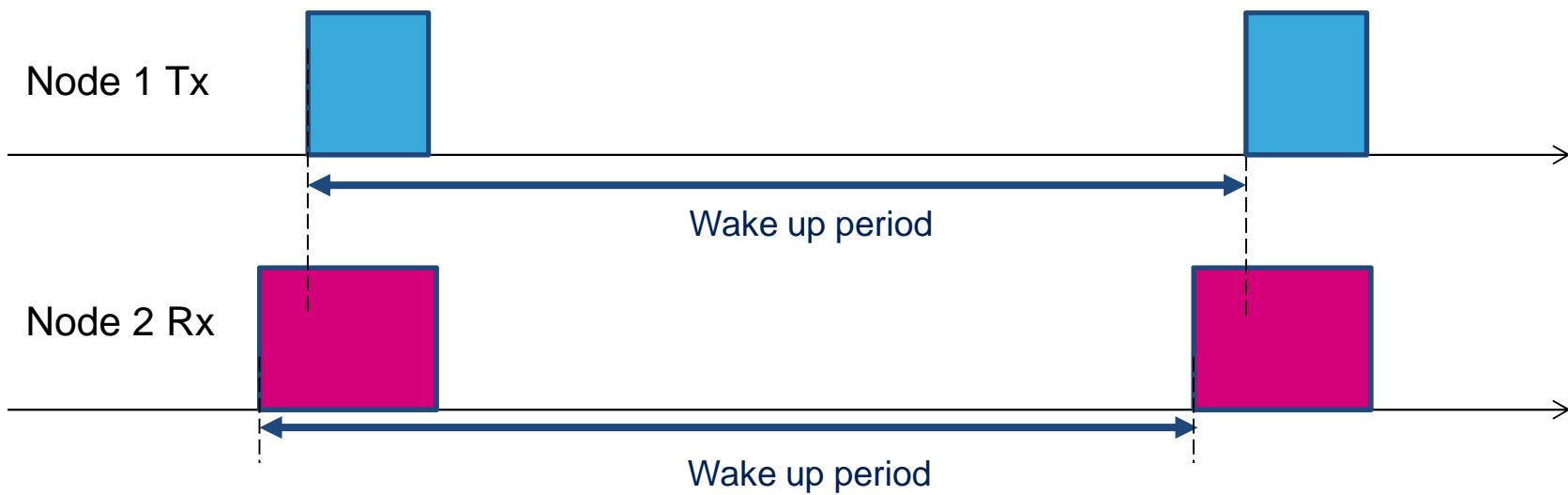


# Where to pay attention

- Packet format
  - short preamble and synchronization fields, payload optimization, CRC
- Communication protocol
  - Data rate
  - Limited number of channels to monitor in Rx
  - FEC/Viterbi and interleaving
    - Convolutional coding in transmitter and on the receiver side - error correction is performed using soft Viterbi decoding
    - Number of transmitted bits is roughly doubled, hence the on-air packet duration in time is roughly doubled as well (~1dB link budget increase)
  - Data whitening / dewhitening
    - To prevent short repeating sequences that create spectral lines, which may complicate symbol tracking at the receiver or interfere with other transmissions

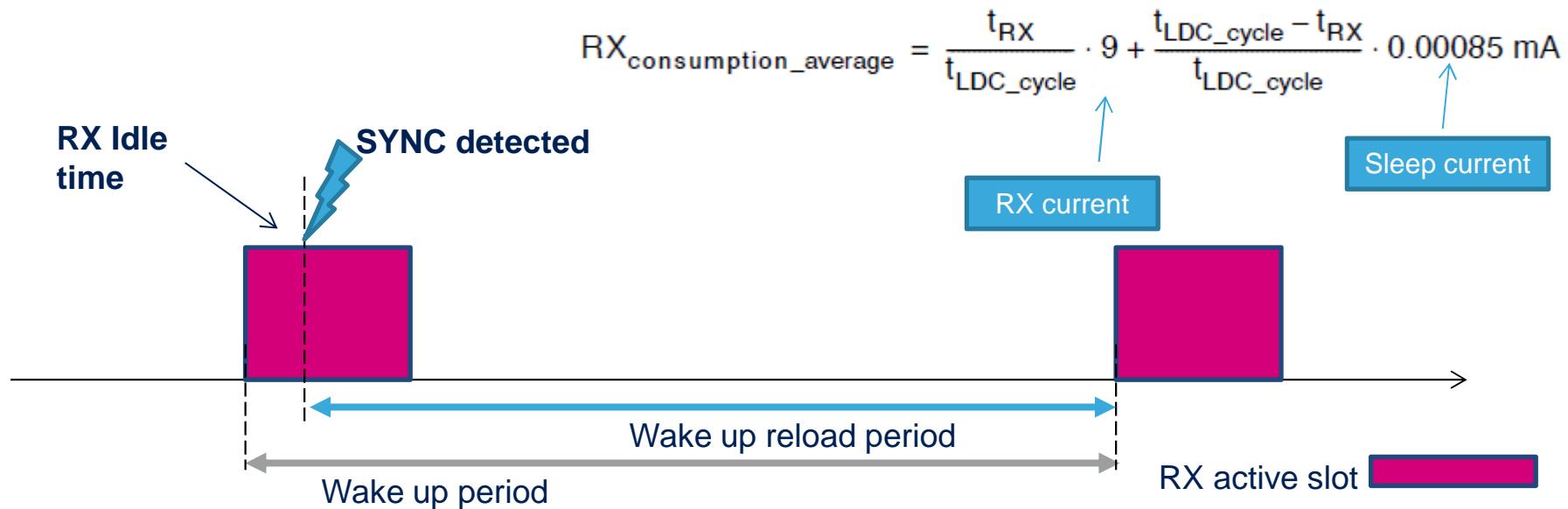
# Low Duty Cycle mode

- The Low Duty Cycle (LDC) mode allows operations with very low power consumption, while still keeping an efficient communication link
  - WAKE\_UP timer is used in LDC mode. It periodically wakes up the SPIRIT1 to perform a transmission or a reception
  - To maintain the correct synchronization between the receiver and a transmitter, the value of the wake-up timer can be automatically reloaded at the time the SYNC is detected



# SPIRIT1 Low Duty Cycle mode

- LDC mode with wake-up timer reload on SYNC allows a better synchronization with the transmitter
- RX Idle time - Settling time of the analog RF circuits



The value of the Wake up period can be programmed up to ~2 sec  
(RC Oscillator)

# Documentation & Support Tools

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Datasheet, Application /  
Design Notes & Tips

Evaluation Boards

Software Development Kits

Technical Support



# SPIRIT1 on Internet

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- Product RTM with All Documentation available at  
[http://www.st.com/web/catalog/sense\\_power/FM1968/CL1976/SC1845/PF253167](http://www.st.com/web/catalog/sense_power/FM1968/CL1976/SC1845/PF253167)



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## SPIRIT1 Low data rate, low power Sub 1GHz transceiver

 Active

The SPIRIT1 is a very low-power RF transceiver, intended for RF wireless applications in the sub-1 GHz band. It is designed to operate both in the license-free ISM and SRD frequency bands at 169, 315, 433, 868, and 915 MHz, but can also be programmed to operate at other additional frequencies in the 300-348 MHz, 387-470 MHz, and 779-956 MHz bands. The air interface is programmable from 1 to 50 kbps, and the SPIRIT1 can be used in systems with channel spacing of 12.5/25 kHz, complying with the EN 300 220 standard. It uses a very small number of discrete external components and integrates a configurable baseband modem, which supports data management, modulation, and demodulation. The data management handles the data in the proprietary fully programmable packet format also allows the M-Bus standard compliance format (all performance classes).

Moreover, the SPIRIT1 can perform cyclic redundancy checks on the data as well as FEC encoding/decoding on the packets. The SPIRIT1 provides an optional automatic acknowledgement, retransmission, and timeout protocol engine in order to reduce overall system costs by handling all the high-speed link layer operations.

Moreover, the SPIRIT1 supports an embedded CSMA/CA engine. An AES 128-bit encryption co-processor is available for secure data transfer. The SPIRIT1 fully supports antenna diversity with an integrated antenna switch/cell control algorithm. The SPIRIT1



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## SPIRIT1 Low data rate, low power Sub 1GHz transceiver

 Active

Quick Links [Product Specifications](#) 

Technical Documentation

 Product Specifications

Online Support

[Online Support](#)

FAQ

[E2E Communities](#)

Learning

- Application Notes, Schematics, BOM, Gerber Files, ...
  - SW Development Kit (SDK) for STM32L, includes WM-Bus library, Set of examples, Thingsquare MIST (6lowPAN, MESH)

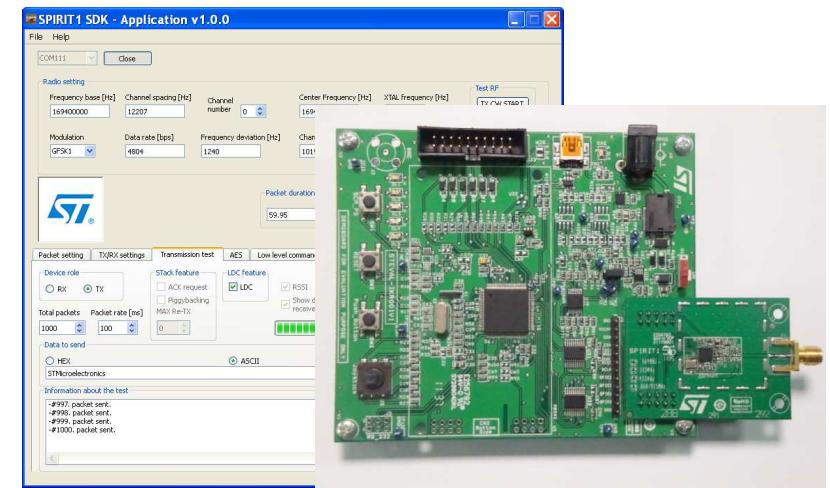
# Development Kits

- **SPIRIT1 Development Kits**

- **STEVAL-IKR001V1 – 169 MHz**
- **STEVAL-IKR001V2 – 315 MHz**
- **STEVAL-IKR001V3 – 433 MHz**
- **STEVAL-IKR001V4 – 868MHz**
- **STEVAL-IKR001V5 – 915 MHz**
- **STEVAL-IKR001V6 – 920 MHz**

- **Development kit content**

- **2 x STM32L based motherboard**
- **2 x SPIRIT1 RF modules**
- **2 x Antennas**
- **2 x USB cables**
- **Software development kit (SDK) has to be downloaded from <http://www.st.com>**
  - Includes ST Wireless MBUS stack, Examples, Documentation
- **Kit boards are preprogrammed with a firmware for GUI evaluation (DFU for firmware upgrade over USB)**



**COMING SOON: STEVAL-IKR002Vx**

# RF module boards

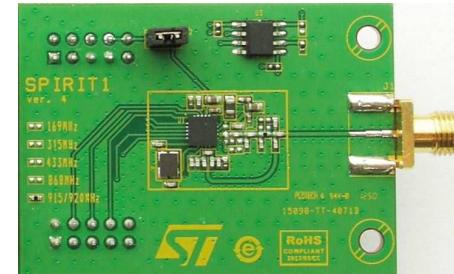
28

- SPIRIT1 RF module boards

- STEVAL-IKR001V1D – 169 MHz
  - STEVAL-IKR001V2D – 315 MHz
  - STEVAL-IKR001V3D – 433 MHz
  - STEVAL-IKR001V4D – 868MHz
  - STEVAL-IKR001V5D – 915 MHz

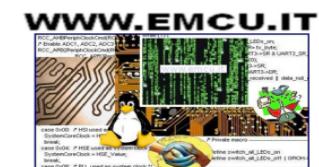


COMING SOON: STEVAL-IKR002VxD



- Package content

- 1 x SPIRIT1 RF module
  - The RF module is compatible with STM32L mother board from the development kit



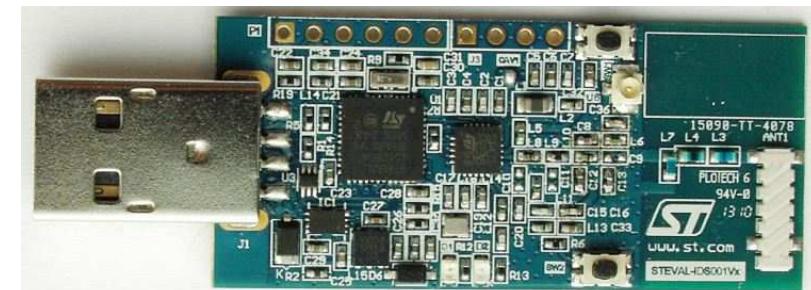
# STEVAL-IDS001Vx

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- **STEVAL-IDS001Vx demo kit RF Dongle**

- SPIRIT1 RF transceiver
- STM32L151CBU6 MCU
- Ceramic antenna + U.FL connector
- LDS3985PU33R, LDO
- USBLC6-2P6, protection
- M95256-RMC6TG - EEPROM
- SWD connector for debugging

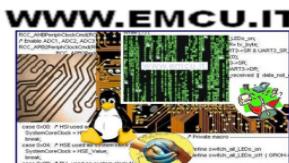
Coming soon!



# SDK content

30

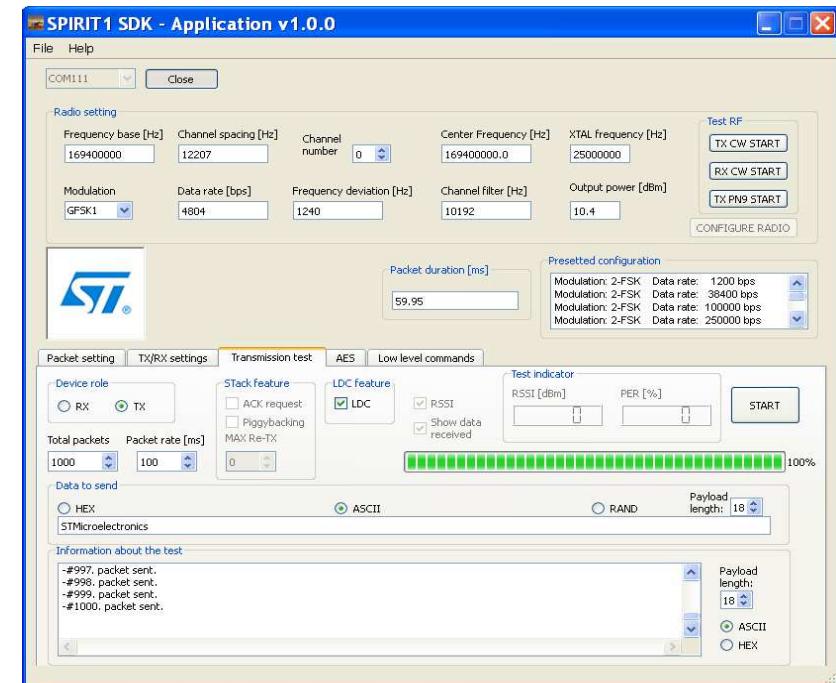
- SPIRIT1 Library (STM32L, STM8L)
  - Spirit1 low level drivers: APIs to manage the features the device offers (platform independent
    - Radio, GPIO, IRQ, Calibration, CSMA etc.
  - SDK\_EVAL Libraries: APIs to manage the main features of the motherboard
  - Examples: BasicGeneric, LDCGeneric, StackGeneric, ...
- WMBUS Library (Binary for STM32L)
  - library files with the PHYSICAL and LINK layer of the WMBUS STACK
  - Examples: 169 or 868 bands and meter or concentrator
- SPIRIT1 SDK Virtual Com port
  - VirtualCom Libraries for the STM32L motherboard.
- MCU Standard Peripheral Library
  - Standard peripheral library for the STM32L + STM8L microcontroller
- STM32 USB-FS-Device Library:
  - USB library for STM32L microcontroller



# SPIRIT1 SDK Suite GUI

- SPIRIT1 SDK contains PC application (GUI) allowing:
  - Radio configuration
  - RF tests (TX of unmodulated carrier, TX PN9 sequence, RX activation)
  - Packet transmission/reception test with PER evaluation
  - AES engine encryption/decryption tests
  - Register read/write and dump
  - Store/load radio and packet configuration
  - Automatic Firmware Upgrade
  - Windows XP, 7

**SPIRIT1 RF performance evaluation**



# Analog, MEMS & Sensors (AMS) Application Support Team

... is providing technical application support for customers, designing in ST Analog, MEMS & Sensors products, in projects agreed with local EMEA ST sales office / Technical marketing team

- Solving
  - Product and Application problems – answering detailed technical questions
  
- Providing
  - Design consulting (Schematic, PCB and Software)
  - Technical Trainings

## Application Support Service Card

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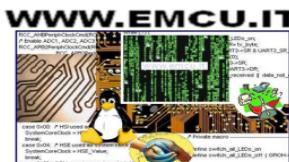
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## Application Support Team Focus

AMS Applications Help Desk

		
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... and RF IPD/IPAD RF Baluns



Contact email: [AMS-support-EMEA@st.com](mailto:AMS-support-EMEA@st.com)