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Wireless M-BUS Solutions

SPIRIT1 & STM32L

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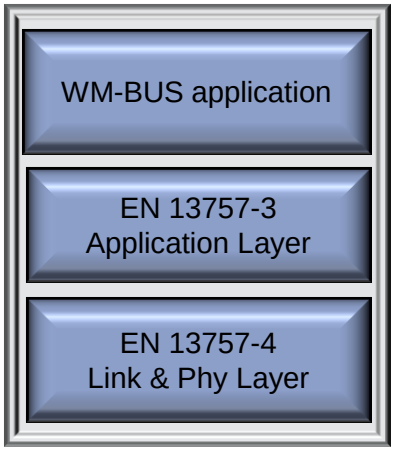
What is Wireless M-BUS?

- Open standard for Automatic Meter Reading at sub 1 GHz
- Metering Bus (or in short "M-Bus ") is a basis for new Advanced Metering Infrastructure (AMI) installations. It defines the communication between meters for water, gas, heat and the data concentrators.
- Wireless M-Bus standard defines the wireless communication between meters.

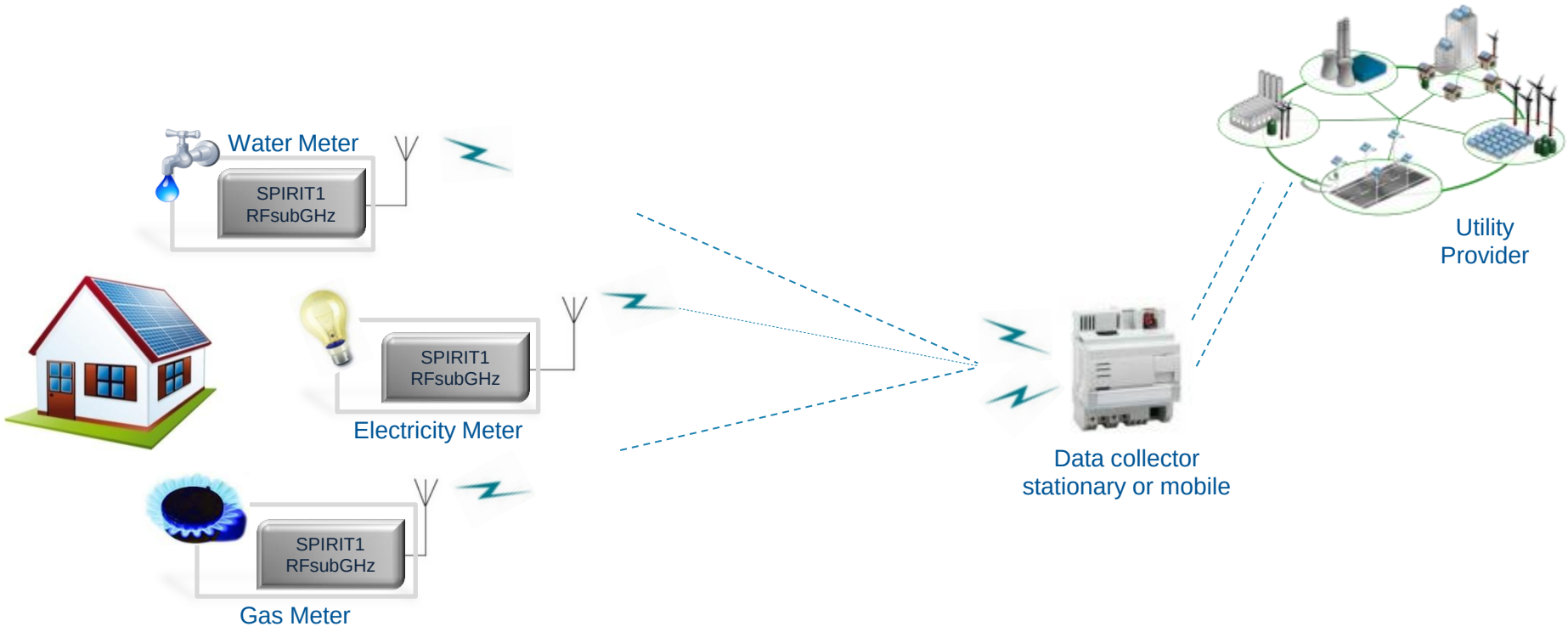
Relevant standards documents are the following:

- European standard prEN13757-4:2011 Wireless meter readout
- European standard EN13757-3:2004 Dedicated application layer
- ETSI EN 300 220 v2.3.1



Wireless M-BUS
protocol stack

Wireless M-BUS scenario

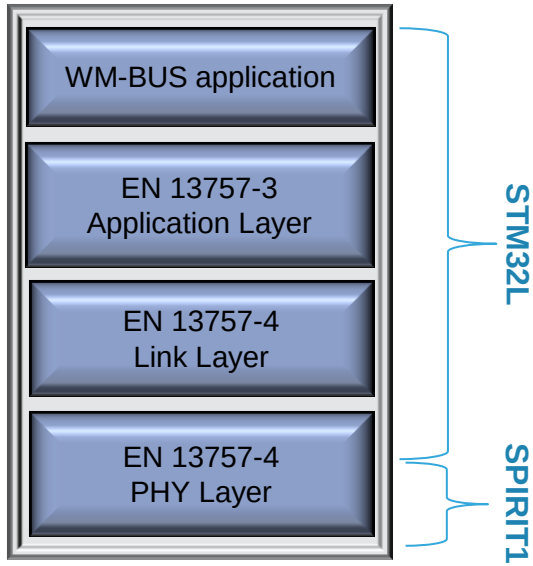


- Automatic meters reading to:
  - Stationary data collectors
  - Mobile data collectors
- Meters are working without any operator's intervention or need for battery replacement.

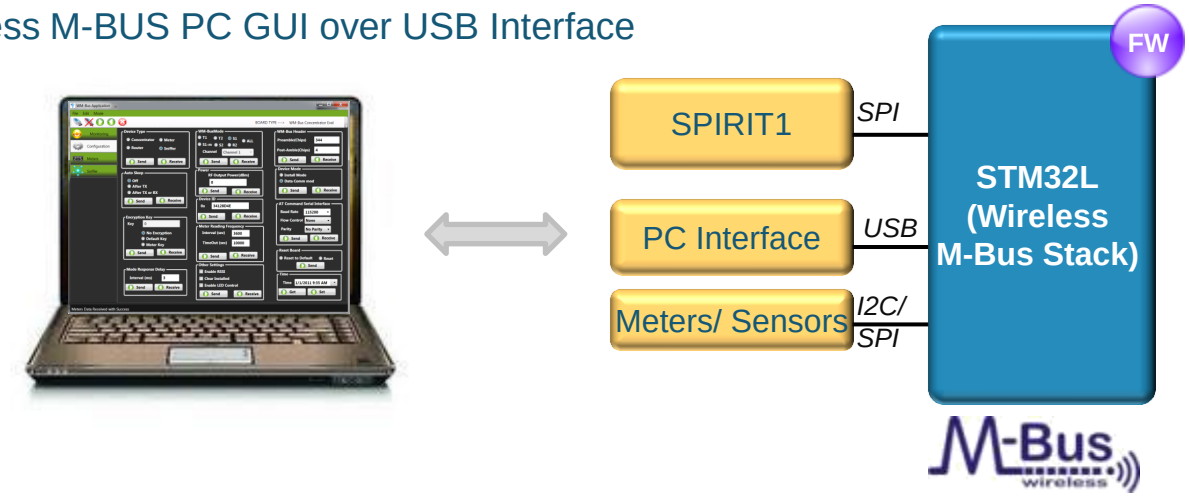
AVAILABLE

ST Wireless M-BUS Stack features (1/2)

- Development based on:
  - STM32L152 MCU ARM 32bit
  - SPIRIT transceiver Sub GHz
- WMBUS protocol stack EN113757-4:2011.10
- Mode supported are: S, T, R, N
  (except N2g which requires 4-GFSK modulation)
- Device Type: Meter and Concentrator
  →PHY and LINK layer implementation provided as binary library for STM32L (ARM Cortex-M3).
  →Example application layer provided in source form for user customization.
  Sniffer Type *under development*
- Wireless M-BUS PC GUI over USB Interface



Wireless M-BUS protocol stack



ST Wireless M-BUS Stack features (2/2)

WMBUS Mode supported are:

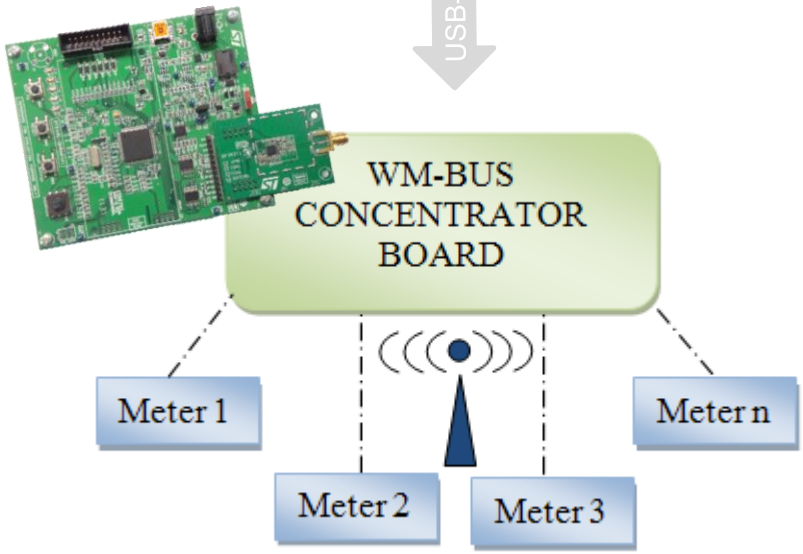
→S, T, R @ 868 MHz

→N @ 169 MHz

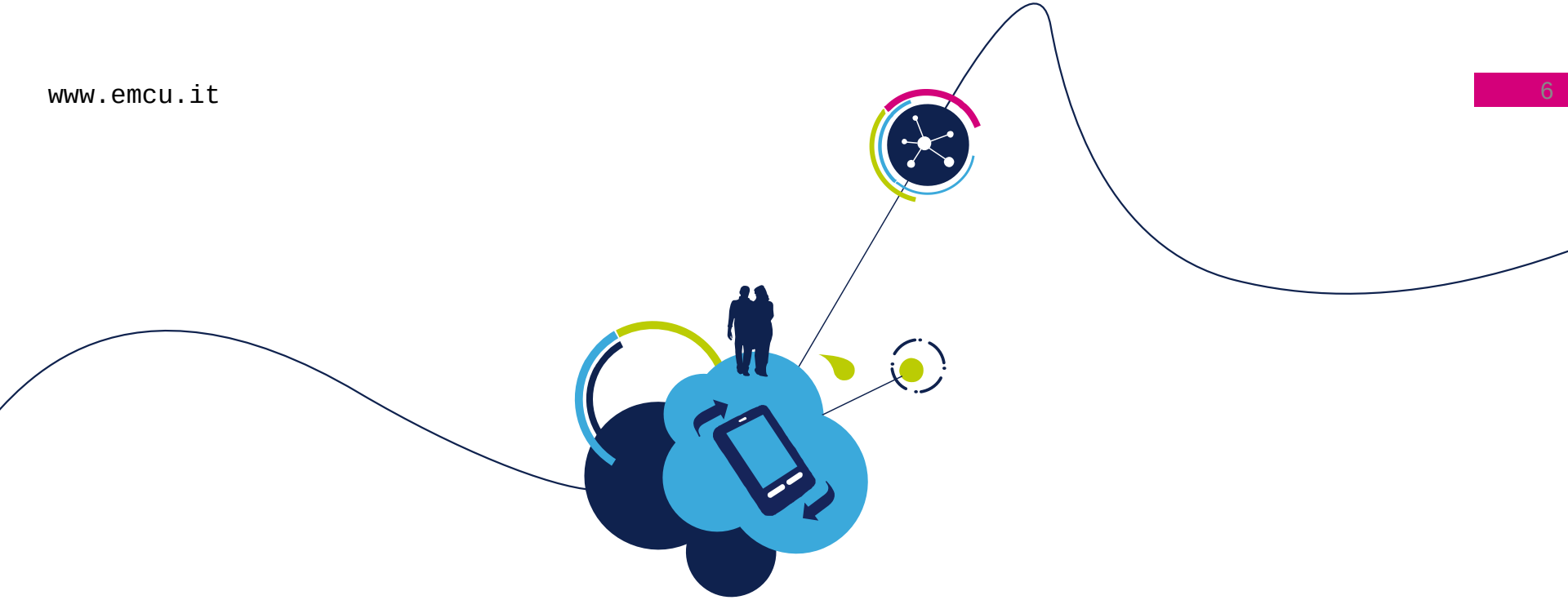
(except N2g (*) which requires 4-GFSK modulation)

Main features are:

- Auto acknowledgment
- CRC check
- Installation mode/data mode
- Management of a simple meter database based on linked list
- Packet filtering based on registered meters
- Meter and Other roles
- Non blocking API
- AES CTR support
- AT Command (**)



Notes : (*) N2g is multi Hop repeater, (**) Underdevelopment, Q1 / ‘13



Wireless M-BUS Modes

Wireless M-BUS modes

Mode	Description	Direction	Frequency band	Usage
S	Stationary mode	One (s1) Two way (S2)	868 MHz	Communication between meter and stationary/mobile concentrator. Manchester encoding
T	Frequent Transmit mode	One(T1) Two way (T2)	868 MHz	The meter transmits a very short frame (typically 3 ms to 8 ms) every few second's Walk-by and/or drive-by readout. Manchester and “3 out of 6 encoding”.
R	Frequent Receive mode	Two way	868 MHz	the meter listens every few seconds for the reception of a wakeup message from a mobile transceiver. Manchester encoding
C (*)	Compact	One/two way	868 MHz	Similar T, but send more info with the same energy
N	Narrowband VHF	One/two way	169 MHz	Optimized for narrowband and long range. NRZ-encoded
F (*)	Frequent TX & RX	Two way	433 MHz	Wake up message from a stationary or mobile device. NRZ-encoded

(*) Not available in current ST WMBUS implementation

Wireless M-BUS submodes S, T, R

Mode	Direction	Usage
S1	One way	Communication between meter and *stationary* concentrator with long header. Single channel. Format A only
S1-m	One way	Communication specialized between meter and *mobile* concentrator with short header. Single channel. Format A only
S2	Two way	Meter unit with a receiver either continuously enabled or synchronized requiring no extended preamble for wakeup. A long header is optional. Single channel. Format A only
T1	One way	Transmit only with short data bursts typically 3.8 ms every few seconds. Single channel. Format A only
T2	Two way	Transmit similar to T1 and establish two way link if ack is received. Single channel, asymmetric. Format A only
R2	Two way	Transmit regularly and wait for a wakeup message which establish a two way communication. Multichannel support. Format A only

Wireless M-BUS submodes C, N, F

Mode	Direction	Usage
C1 (*)	One way	Transmit only, on a regular basis, with short data bursts <22ms. Manchester encoded. Format A and B.
C2 (*)	Two way	Transmits like C1. Its receiver is enabled for a short period after the end of each transmission and locks on if a proper preamble and synchronization word is detected. Format A and B.
N1a-f	One way	Transmit only; transmits on a regular basis to a stationary receiving point. Single hop repeaters are allowed. Format A only.
N2a-f	Two way	Transmits like N1a-f. Its receiver is enabled for a short period after the end of each transmission and locks on if a proper preamble and synchronization word is detected. Format A only.
F2-m (*)	Two way	Meter receiver with possible battery economizer, requiring extended preamble for wake-up. Single Channel. Format A and B.
F2 (*)	Two way	Meter unit transmits on a regular basis. Its receiver is enabled for a short period after the end of each transmission. It locks on if a proper preamble and synchronization word is detected. Single Channel. Format A and B.

(*) Not available in current ST Wireless M-BUS implementation

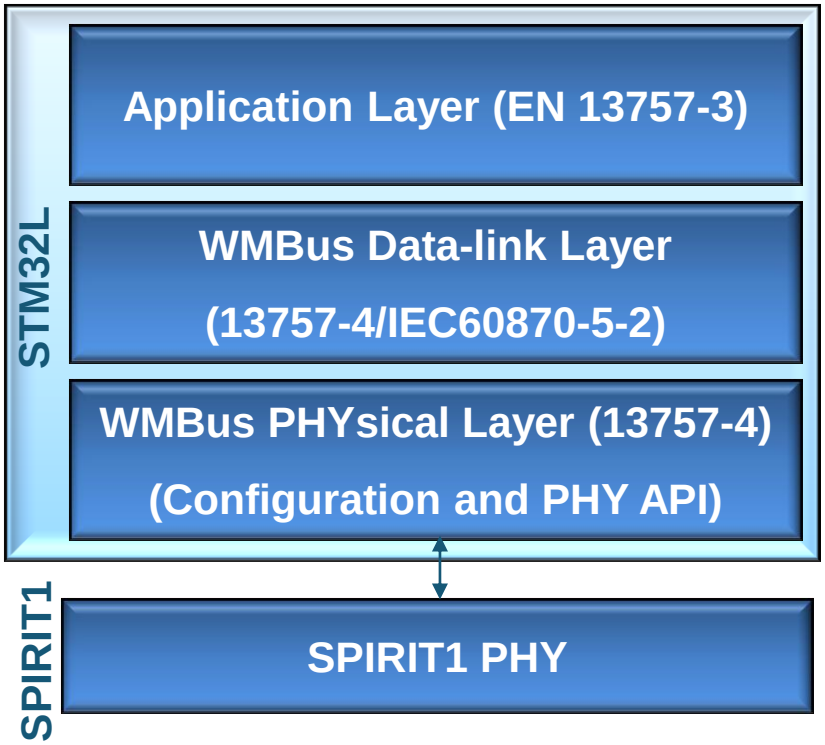
STM32L & SPIRIT1 WMBUS Protocol Layer implementation

STM32L role:

- Wireless M-Bus (WMBUS) Application Layer
- Wireless M-Bus Link Layer
  - MAC packet
  - CRC handling
  - Encryption/ Decryption initiate/read.
  - Services to application layer
- Wireless M-Bus PHY API
  - Init PHY for Wireless M-Bus
  - Command/Data exchange APIs
  - Interrupt Services
  - Power Management
  - SPIRIT Mode Management

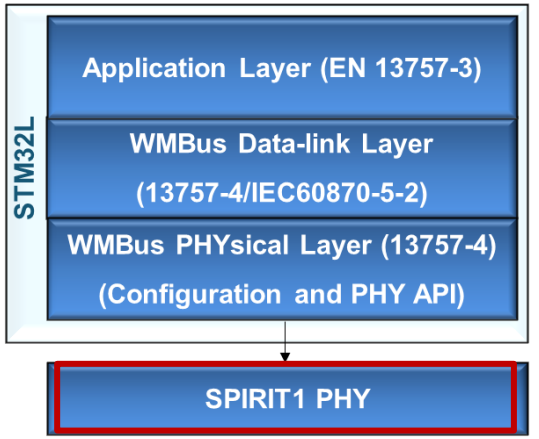
SPIRIT1 role:

- Wireless M-Bus Modes
- Header, Sync and trailer fields
- Manchester/3-out-of-6-encoding
- Sync detection
- Tx and RX FIFO



PHY Layer: SPIRIT1 WMBUS packet structure

1. The PHY payload block will be implemented in Firmware.
2. Header, Sync and Post-amble will be only configured using STM32L.
3. Data encoding and decoding at PHY level is managed by SPIRIT depending on mode selection.
4. Manchester and 3-out of 6 encoding



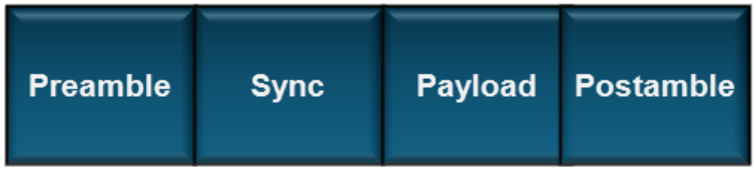
Manchester or 3 out 6 encoding

PHY Layer: SPIRIT1 Packet Handler Engine

SPIRIT1 Embedded packet format:

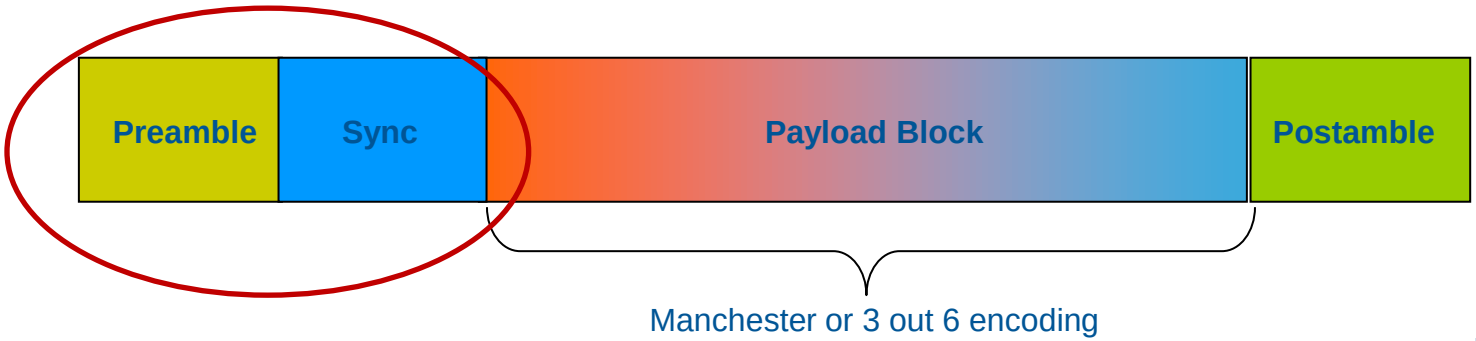
- **STack**

- **WM-Bus**

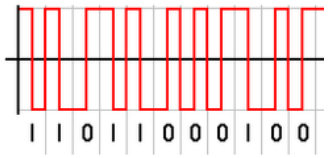


- **BASIC**

PHY Layer: SPIRIT1 WMBUS packet structure



Manchester



The WM-Bus protocol is chosen by the sub-mode selected:

- Sub-mode 0: Manchester code; preamble length = 279*; sync at 0x7696 (18 bits);

  Supports the modes **S1**, **S2** long header .
- Sub-mode 1: Manchester code; preamble length = 15* ; sync at 0x7696 (18 bits).

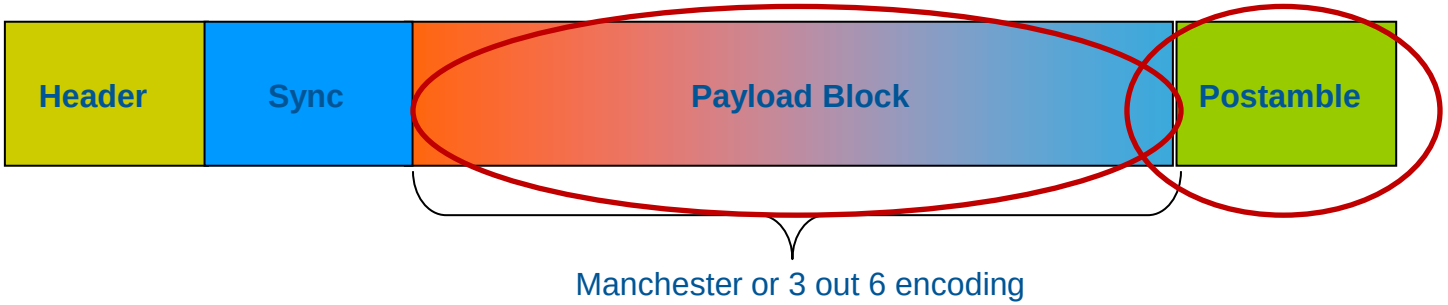
  Supports the modes **S1-m**, **S2**, **T2** other to meter.
- Sub-mode 3: uses 3-out-of-6 code; preamble length = 19*; sync at 0x3D (in 10 bits)

  Supports the modes **T1**, **T2** meter to other.
- Sub-mode 5: Manchester code; preamble length = 39*; sync at 0x7696 (in 18 bits).

  Supports the mode **R2** short header .
- Through the direct mode and specific configuration of the BASIC packet format (NRZ data coding), the SPIRIT1 supports the last sub mode: **C1**, **C2**, **N1a-f**, **N2a-f**, **F2**, **F2m**.

(*) = in ‘01’ sequence

PHY Layer: SPIRIT1 WMBUS packet structure



PAYLOAD

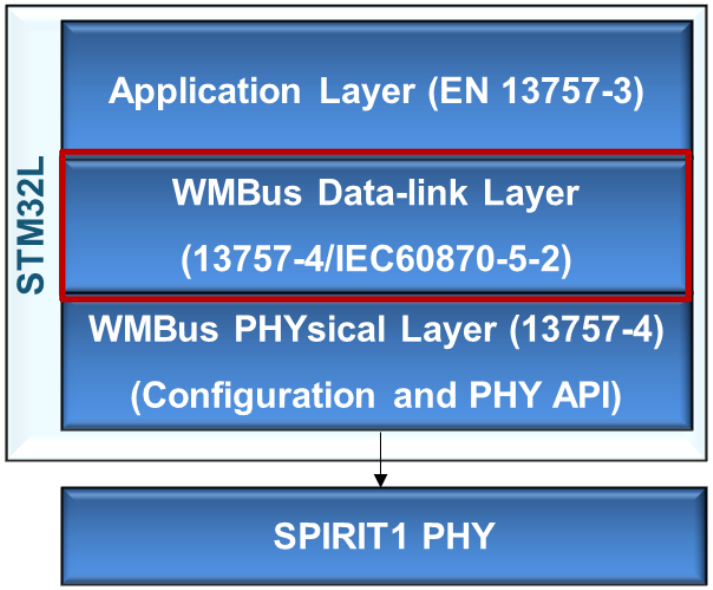
- The data to transmit are stored in this field. The length is from 0 to 65536 bytes.
- The payload length is set as: *PCKTLEN1* * 256 + *PCKTLEN0*.

POSTAMPLE

- The postamble added at the end of the packet according to the WMBus standard.
- The number of ‘01’ sequences added to the postamble is set with the *MBUS_PSTMBL_CTRL*

WM-BUS Link Layer

- The WM-Bus link layer is compliant with 13757-4:2011.10
- Provides services that transfer data between PHY and Application layer
- Generate Outgoing CRC and verify CRCs for incoming messages
- Provide WM-Bus addressing
- Acknowledge transfers for bidirectional communication modes
- WM-Bus frame formation and verification of incoming frames
- Two frame formats exists A and B and they are identified by the preamble/synch bits sequence.



Frame Formats

Packets in format A and B are composed of several blocks:

- First block which contains frame length (L-field), the control information (C-field), and the senders address (Link Layer Address)
- Second block which contains CI field and payload information
- Other(s) optional blocks (max 1 for format B)

Frame Format A

First Block

L-field	C-field	M-field	A-field
1 byte	1 byte	2 bytes	6 bytes

Second Block

CI-field	Data-field	CRC-field
1 byte	15 or if it is the last block (((L-9) modulo 16) –1) bytes	2 bytes

Optional Block

Data-field	CRC-field
(L-129) bytes	2 bytes

Frame Format B

First Block

L-field	C-field	M-field	A-field
1 byte	1 byte	2 bytes	6 bytes

Second Block

CI-field	Data-field	CRC-field
1 byte	115 or if it is the last block (L-12) bytes	2 bytes

Optional Block

Data-field	CRC-field
16 or if it is the last block ((L-9) modulo 16) bytes	2 bytes

- L-field = frame Length
- C-filed = control field
- M-field = Manufacturer ID
- A-field = Address sender
- CI-Field = Control Information field, specifics the type of data-filed
- CRC-field = Cyclic redundancy check

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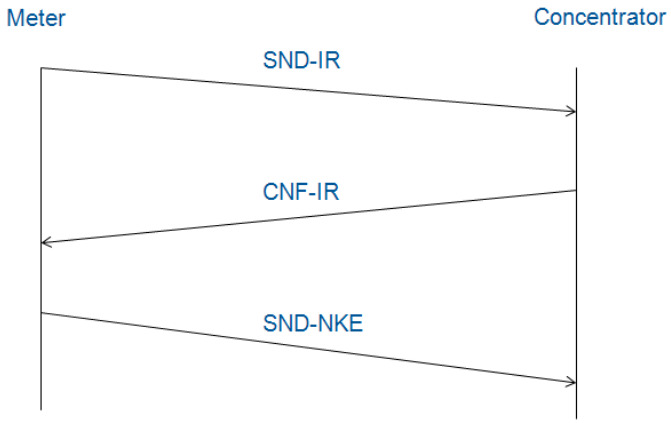
Meter installation example

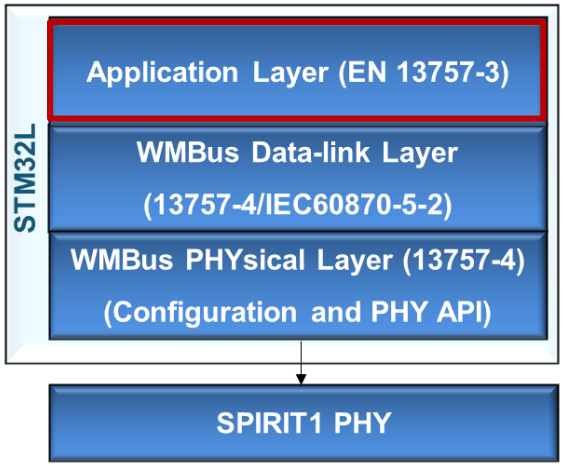
- Concentrator should be in installation mode (manually initiated).
- Meter send SND-IR messages to concentrator (manually initiated). The meter is doing retries in case of no response.
- Concentrator send CNF-IR to meter, subject to approval policy. A message can be also sent to the installer
- From now on the meter is registered with concentrator and it can leave installation mode.
- Concentrator is requiring manual intervention or timeout to leave installation mode

Note: Meter can be also preinstalled requiring no installation messages



Meter sending data example (unidirectional mode)

- Applicable to S1, T1, C1, N1
- SND/NR Send unsolicited/periodical application data without request



Wireless MBus Example Frame

Application

Ident. Nr.	Manufr.	Version	Device type	Access No.	Status	Signature
4 Byte	2 Byte	1 Byte	1 Byte	1 Byte	1 Byte	2 Byte

DIF	DIFE	VIF	VIFE	Data
1 Byte	0 ... 10 (1 Byte each)	1 Byte	0 ... 10 (1 Byte each)	0 ... N Byte
Data Information Block DIB		Value Information Block VIB		
Data Record Header DRH				

Data Header(Req.)	Variable Data Blocks (Records)	MDH(opt)O	Opt.Mfg.specific data Opt)
0 byte (CI = 78h) 4 byte (CI = 7Ah) 12 byte (CI = 72h)	variable number	1 Byte	variable number

Link Layer

Block 1

L-field	C-field	M-field	A-field	CRC-field
1 byte	1 byte	2 bytes	6 bytes	2 bytes

Block 2

CI-field	Data-field	CRC-field
1 byte	15 or if it is the last block (((L-9) modulo 16) –1) bytes	2 bytes

Data-field	CRC-field
16 or if it is the last block ((L-9) modulo 16) bytes	2 bytes

Optional Block

PHY Layer

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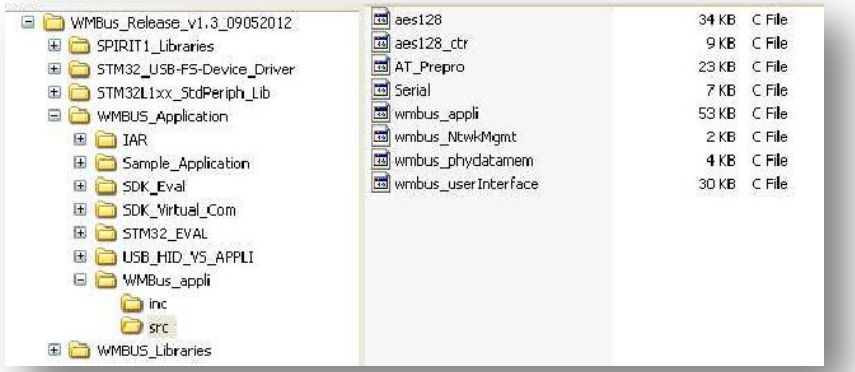
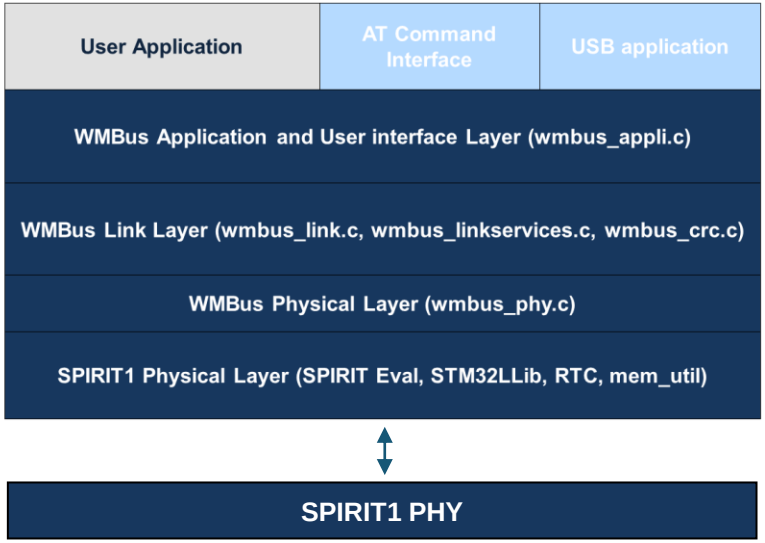
STM32L WM-BUS Firmware library

- **wmbus_appli.c**
  - Application layer provided as an example in source code
- **wmbus_link.c**
  - Link layer provided in library format
- **wmbus_phy.c**
  - PHY layer provided in library format





MEM Footprint:

- 2.1K RAM, 9.1KBytes FLASH (IAR optimization high (size))
- 2.1K RAM, 18 KB Flash (not optimized)

ST WM-BUS library LINK Layer APIs

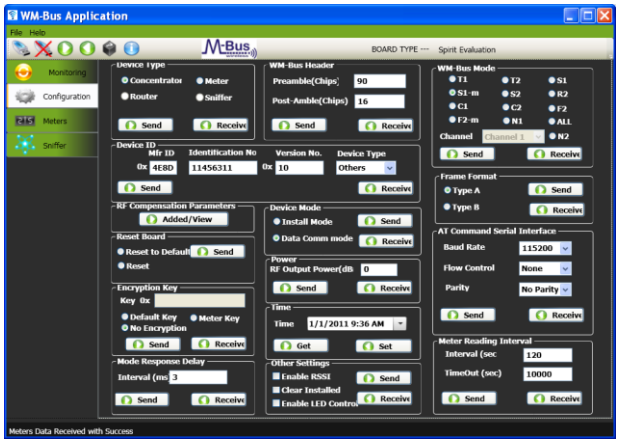
Name	Description
WMBus_LinkGetAttribute	Read attribute from link layer
WMBus_LinkSetAttribute	Set attribute in link layer
WMBus_LinkServicesInit	Init the link service layer
WMBus_LinkServicesReset	Reset the link service layer
WMBus_LinkRadioPowerOn	Power on radio
WMBus_LinkRadioPowerOff	Power off radio
WMBus_LinkRadioStandby	Put the radio in standby
WMBus_LinkRadioResume	Resume radio from standby
WMBus_LinkServicesRequestsCallbackMode (…)	This function processes a request service primitive, generates a valid C-field by setting the FCV, FCB, and PRM bits, transmits the request frame, checks for confirm/response is applicable, and retries data transmission when appropriate (Send/Confirm, Request/Respond when valid ack/nack is not received).
WMBus_LinkServicesIndicationCallbackMode	Receive message within a specific timeout
WMBus_LinkServicesResponseCallbackMode	This function attempts to transmit the response to the indication frame received.

WMBUS PC GUI application

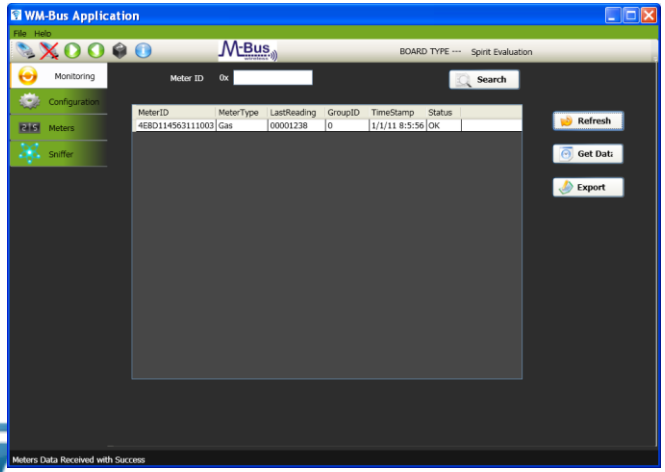
The PC GUI is available in different windows:

- Device Configuration
- Meter Application
- Monitoring

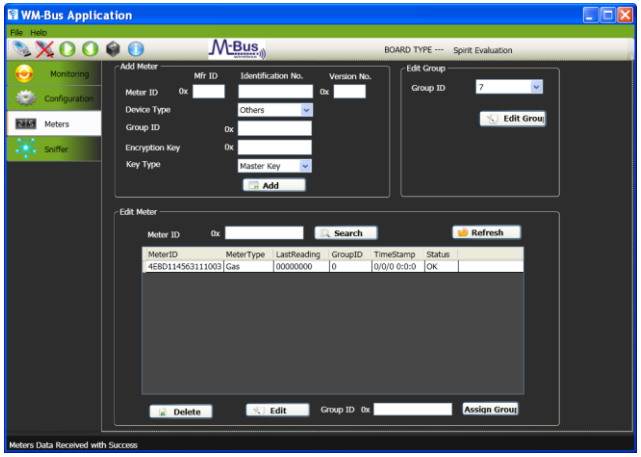
WMBUS GUI application (Configuration)



WMBUS GUI application (Monitoring)



WMBUS GUI application (Meters)



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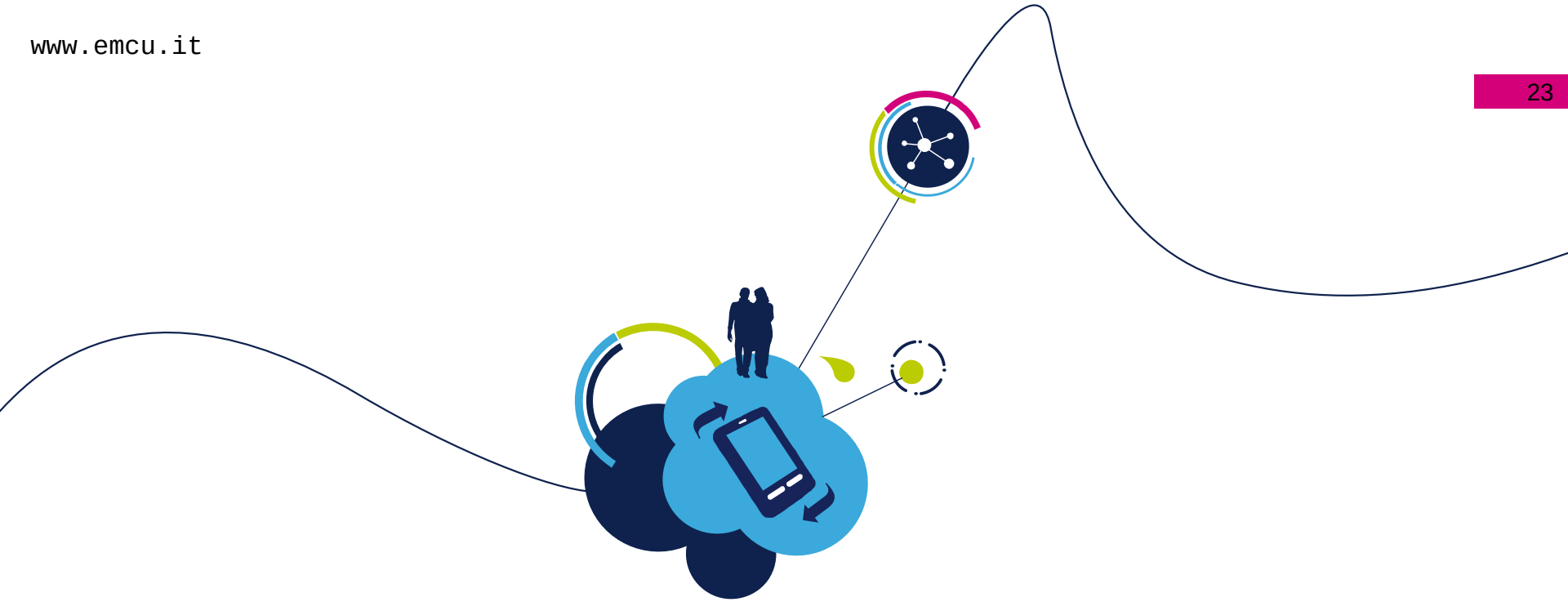
References

- EN 13757-4:2005, *Communication systems for meters and remote reading of meters - Part 4: Wireless meter readout (Radio meter reading for operation in the 868 MHz to 870 MHz SRD 10 band)*

- prEN 13757-4:2011, *Communication systems for meters and remote reading of meters — Part 4: Wireless meter readout (Radio meter reading for operation in SRD bands)*

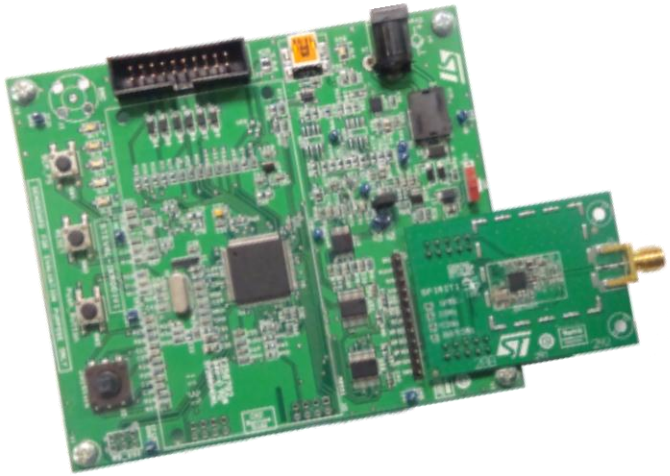


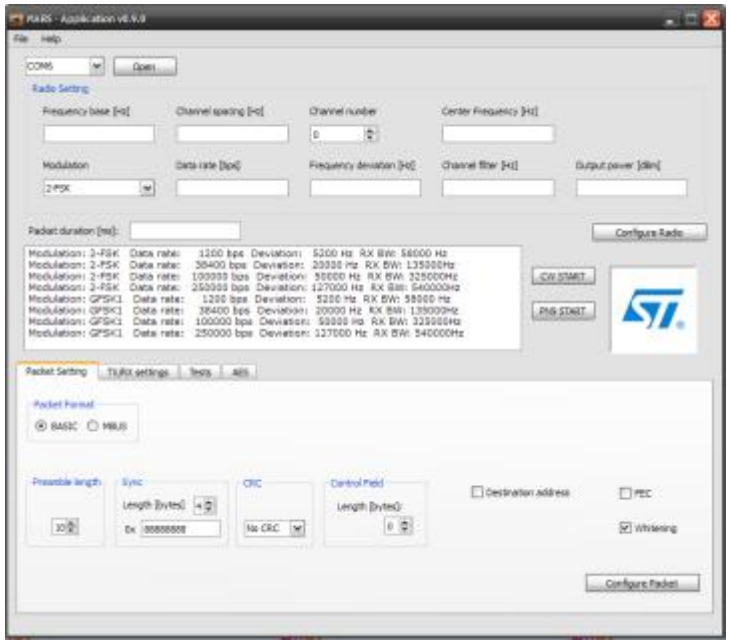
WMBUS ST tools:

1) SPIRIT1 development kit
2) Smart GAS Meter evaluation board

SPIRIT1 development kit

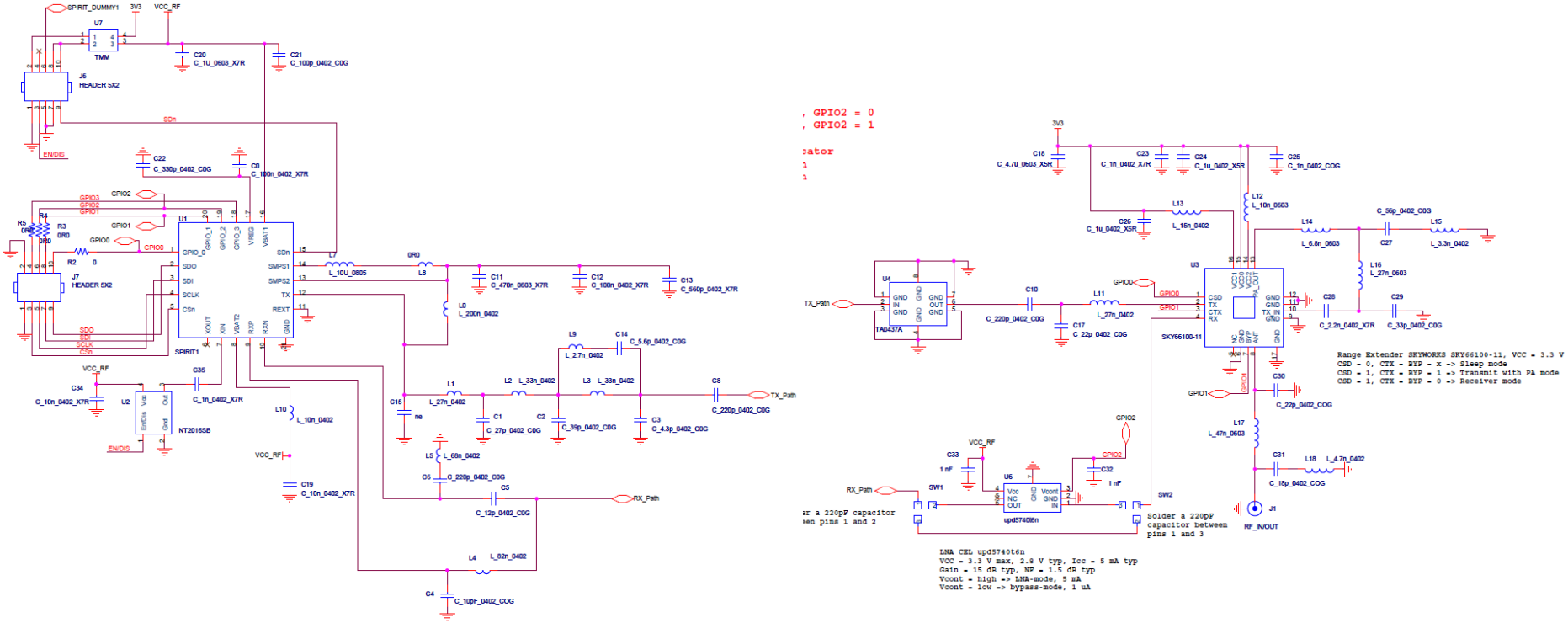
- Hardware:
  - 2 Motherboards (STM32L)
  - 2 SPIRIT1 modules, antenna connector
  - 2 antennas
- Programmable through GUI
  - SPIRIT1 performance can be easily checked/tested
- Highly portable driver available
  - Examples
  - Documentation
  - User manual





ST evaluation board at 169 MHz +27 dBm

- Specifically designed to meet Wireless-MBUS requirements @ 169 MHz.
- Reference design based on external PA SkyWorks SKY66100-11
- Saw Filter TAI-SAW Technology TA0437A to respect emission regulations
  - Fc = 169 MHz, BW = 8.8 MHz typ.
  - IL = 1.5 dB typ., Atten = 52 dB typ.
- CEL uPD5740T6N external LNA to improve sensitivity about 9 dB
- TCXO 25 MHz NDK NT2016SB



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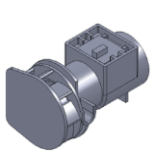
Smart GAS Meter evaluation board

- STM32L162: 32-bit MCU (ARM Cortex-M3) Ultra Low Power
- SPIRIT1: Sub GHz RF transceiver
- LIS3DH: Accelerometer for Earthquake
- M24LR64:DUAL EEPROM RFID/I2C
- M24M02: EEPROM
- M41T62: external RTC
- STTS751: Temperature Sensor
- Omron GAS Sensor (OMRON and ST co-development)

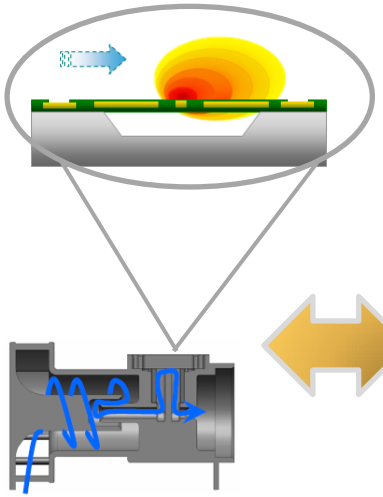


Solution Under Development

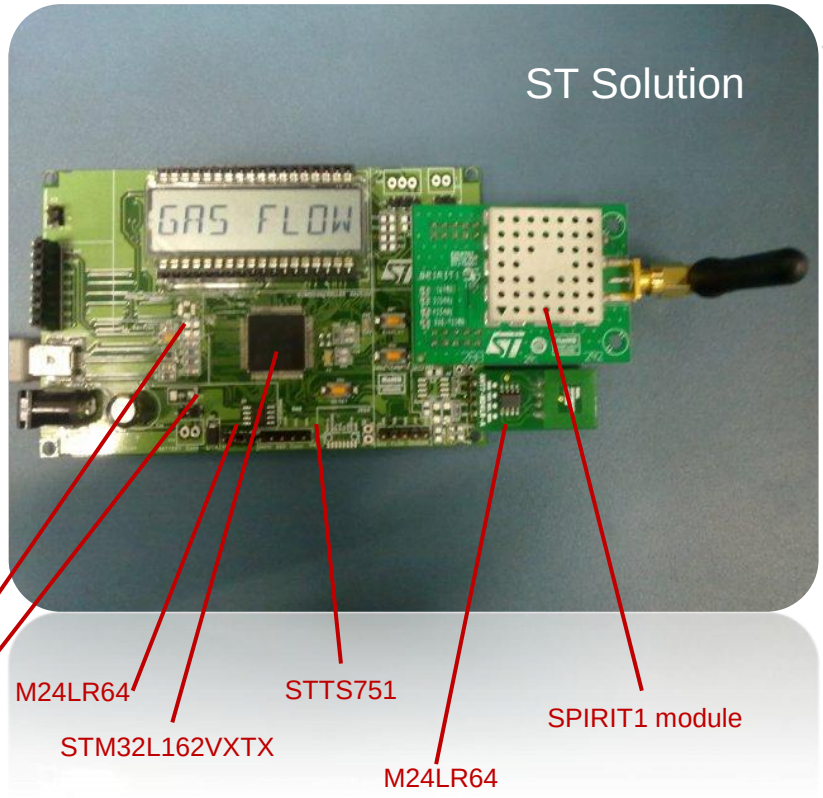
Android Application is available to read/write gas mater parameter by RFID/NFC

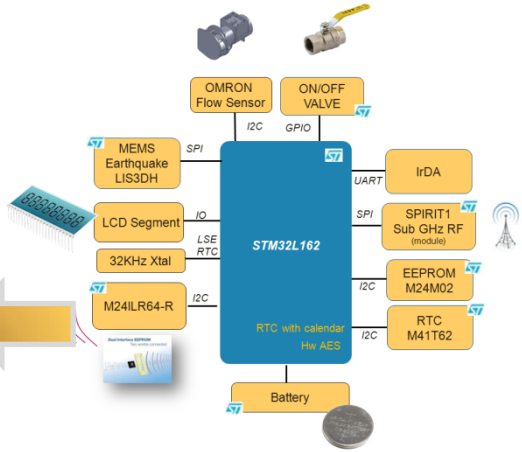
Smart GAS Meter – Evaluation Board

preliminary



OMRON sensor

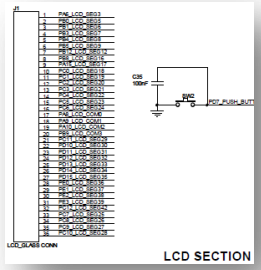


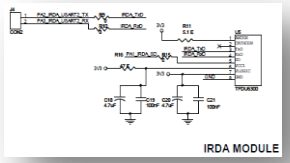


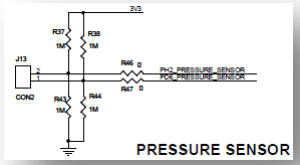
Solution
Under Development

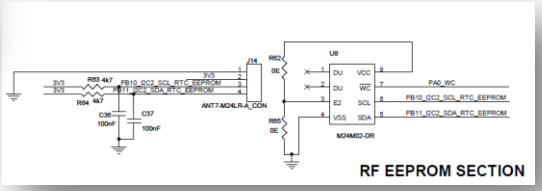
Smart GAS Meter Schematic

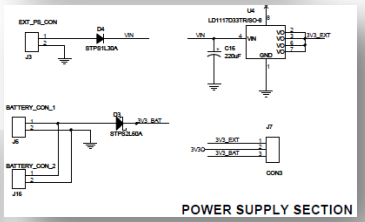
Solution
Under Development

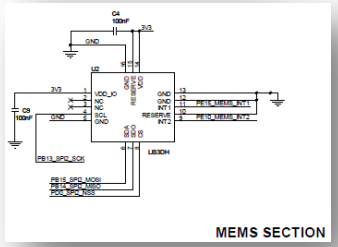


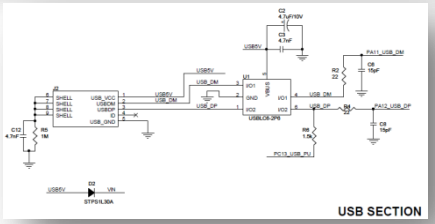


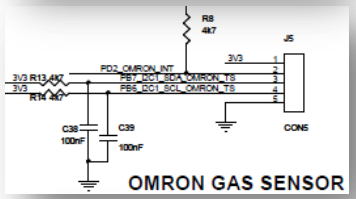


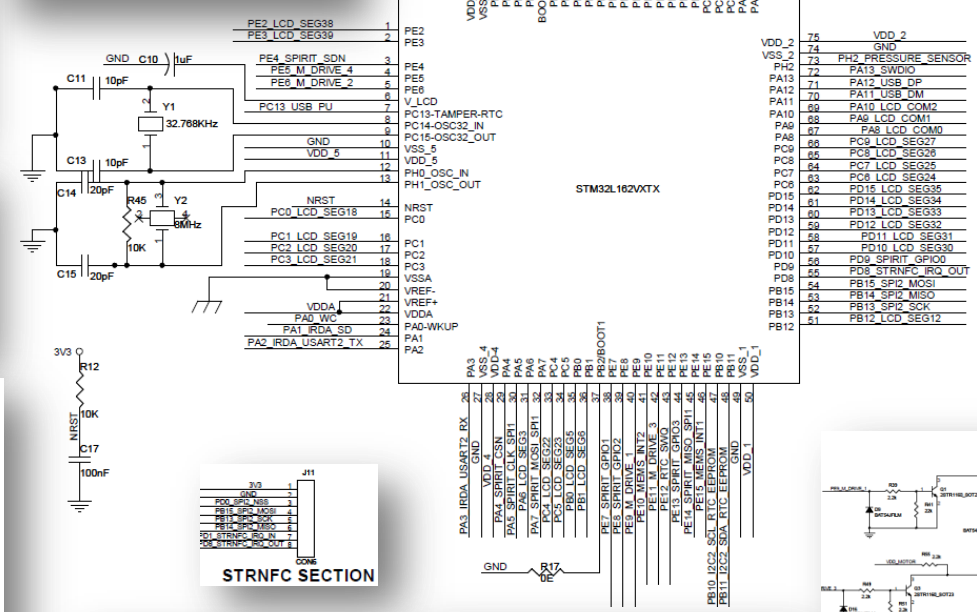


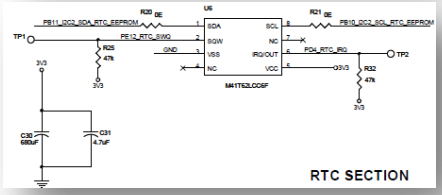


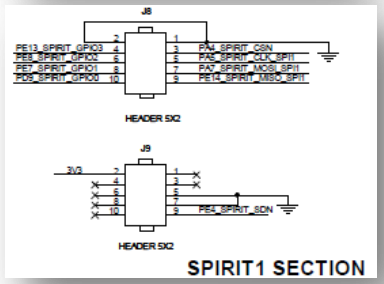


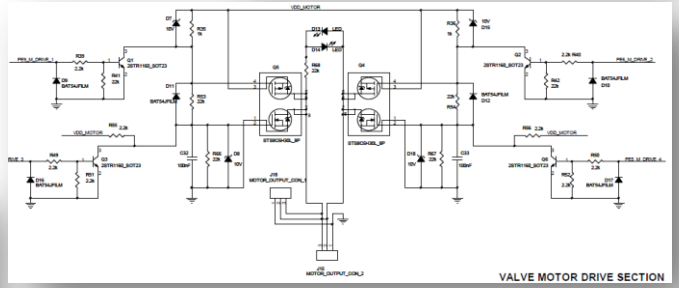


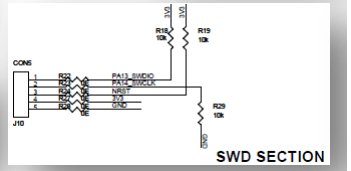


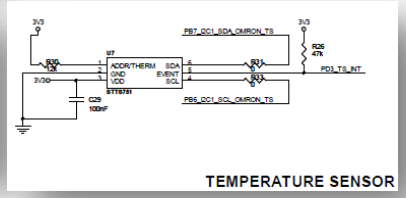


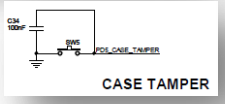












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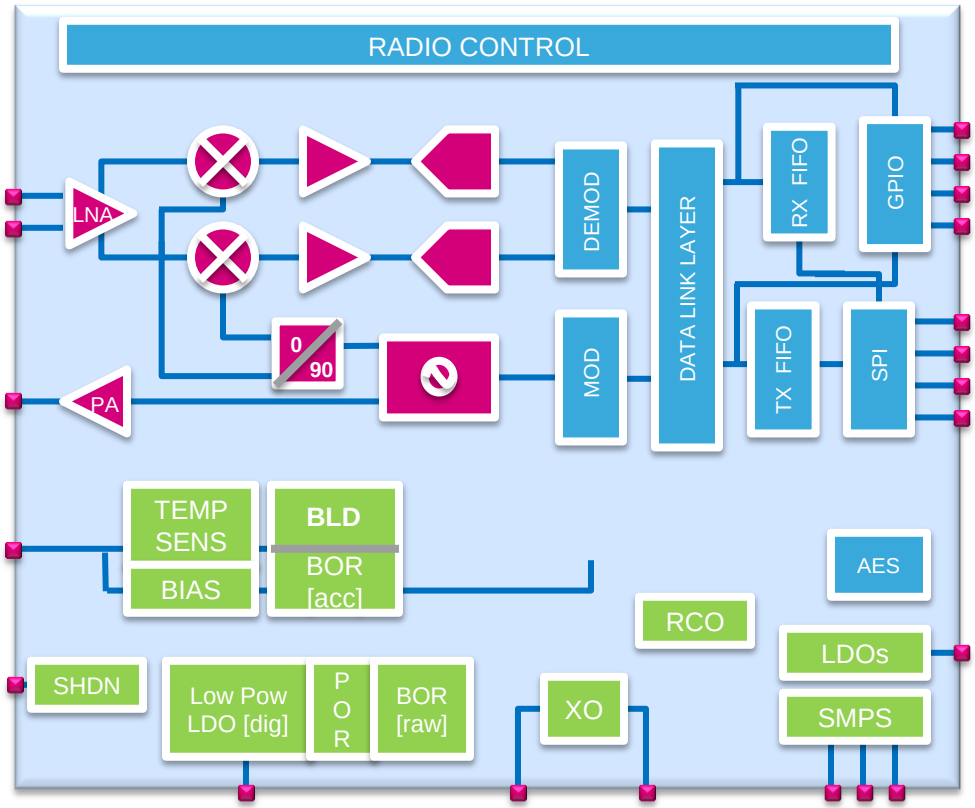
SPIRIT1 – Sub 1-GHz RF Transceiver

- **Frequency bands**: 300-348 MHz, 387-470 MHz, 779-956 MHz
- **Modulation schemes**: FSK, GFSK, MSK, OOK,and ASK
- **Air data rate** from 1 to **500 kbps**
- Programmable **output power**: from -30dBm to +12dBm
- Low current consumption (8mA RX, 433 MHz, FSK, 38.4kbps)
- **Programmable channel spacing** (12.5 kHz
- min). Compatibility with **narrow band system**
- **Frequency Hopping** is allowed
- Automatic acknowledgement, retransmission, and timeout protocol engine
- **AES 128-bit encryption** co-processor
- **Antenna diversity** algorithm
- Package: **QFN20 4x4 mm**

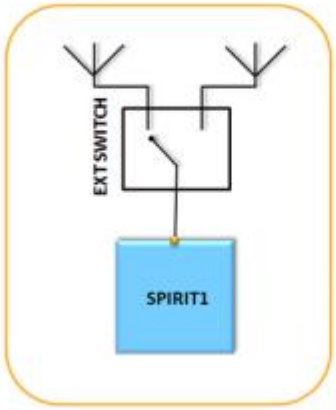
- Three packet configurations
  - Basic
  - STack
  - Wireless M-BUS
- Link quality indicators and received signal qualifier (RSSI, LQI, PQI, SQI, CS)
- Supports CSMA/CA



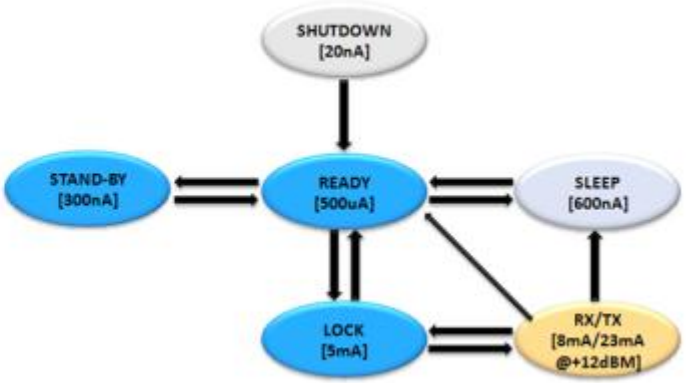
SPIRIT1: Key features

Antenna Diversity Algorithm

- An external switch is controlled to select the antenna with the highest RSSI
- While receiving the preamble, the antennas are repeatedly switched until the RSSI> threshold.
- The switch is then disabled and the selected antenna is used.



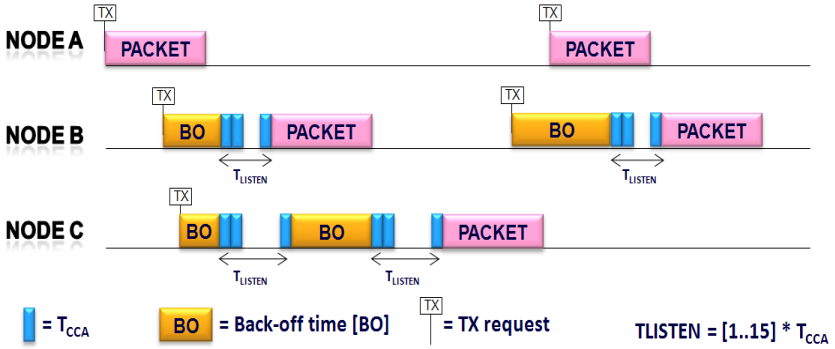
Operating Modes/Consumption



COMPETITION BENCHMARKING

	SPIRIT1	BEST IN CLASS COMPETITOR		NOTE
POWER CONSUMPTION (@3V)	24mW	W/O DC-DC converter	45mW	from 30% to 50% power saving
		W/ EXT DC-DC converter	32mW	
SENSITIVITY (@ 1.2kbps)	-120dBm	-111dBm		
PROGRAMMABLE CHANNEL SPACING	YES, 12.5KHz	YES but 200kHz only →		Can't design NARROW BAND SYSTEMS
ANTENNA DIVERSITY	YES	NO		
Automatic ACK, retransmission and timeout protocol engine	YES	NO		

CSMA/CA algorithm



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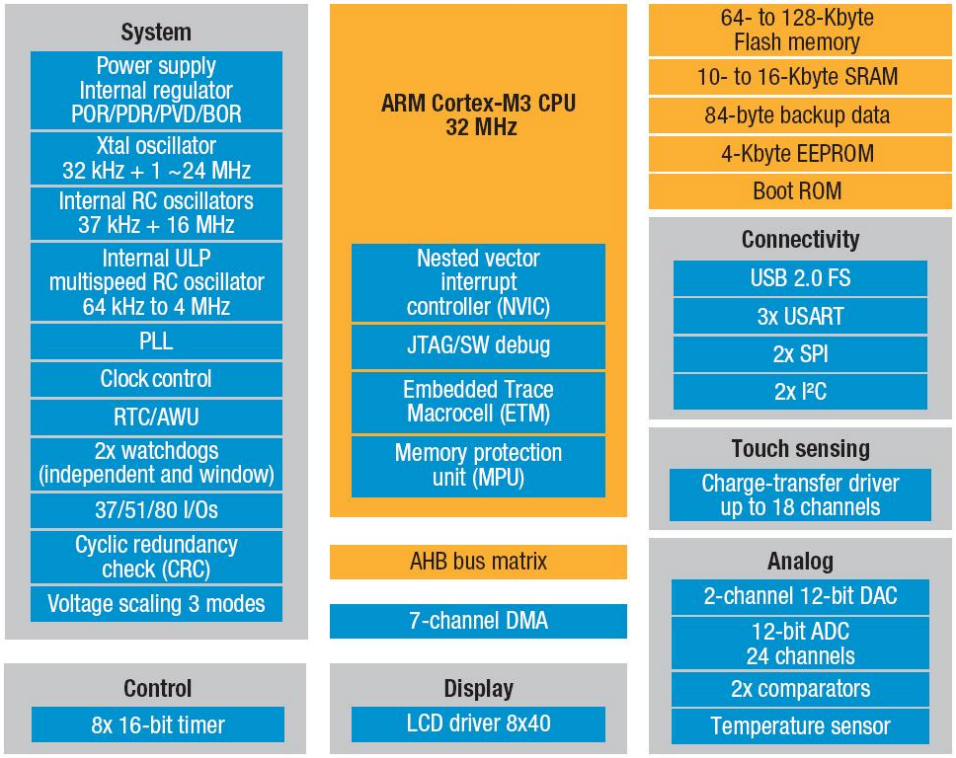
STM32L - Ultra-low power STM32

- Energy saving
  - ARM Cortex-M3 core @ 32 MHz
  - -40 to 125 °C
  - Ultra-low power in dynamic and static modes
- Power supply:
  - 1.65 to 3.6V without BOR
  - 1.8 to 3.6V with BOR
- Special features
  - 32 to 128-Kbyte Flash
  - 10 to 16-Kbyte SRAM
  - 4-Kbyte data EEPROM
  - Segment LCD 8x40
  - Comparator
- Pin-to-pin compatible with STM32 family



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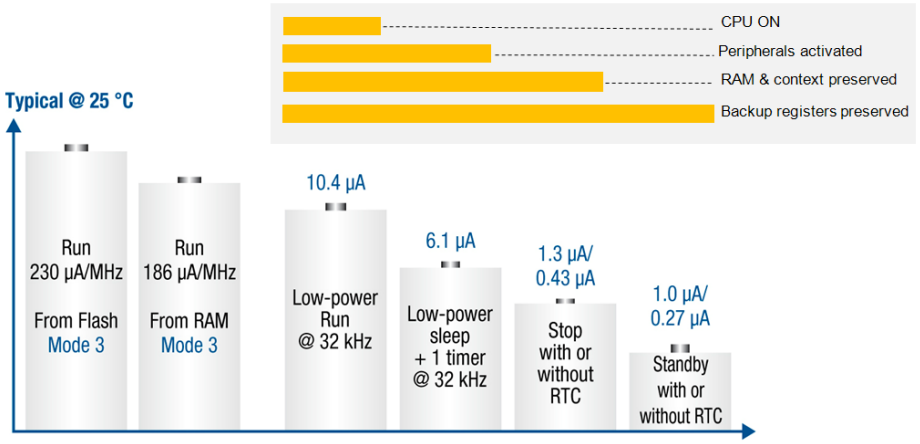
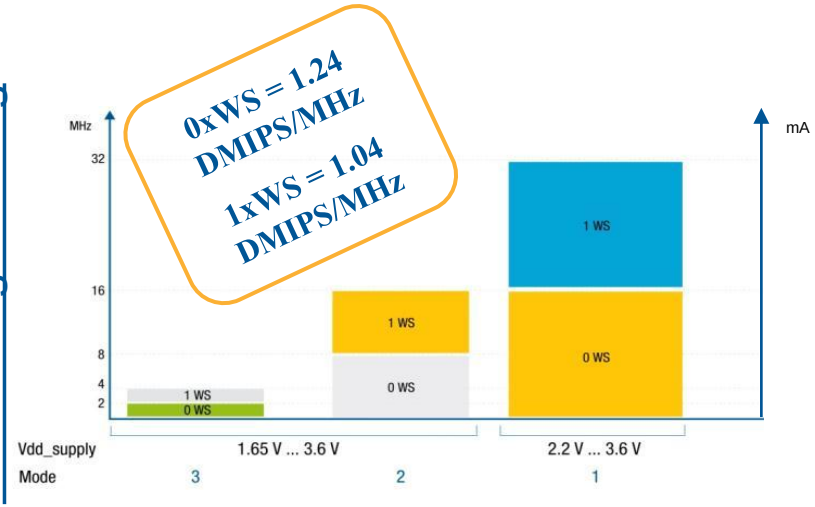
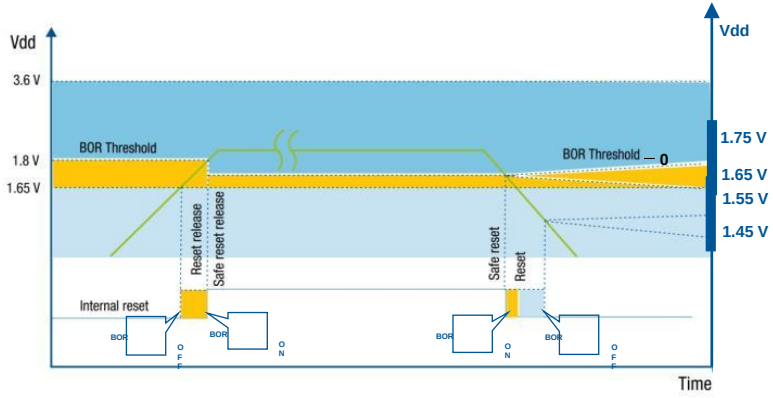
STM32L: Advanced ultra-low-power MCU



Optimized Run mode with Voltage scaling



Safe start-up with BOR



Security & Safety

- Memory Protection Unit
- Anti tamper
- Reset circuitry
- CRC 32-bit
- Back-up clock
- Back-up registers
- Flash protection
- Dual watchdog
- Unique ID
- I/O looking
- Supply monitoring
- Dual stack pointer
- NV memories with ECC
- JTAG fuse

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