High Performance Transceiver for Sub 1-GHz Applications

SPIRIT1
SPIRIT1 application focus

HOME/BUILDING AUTOMATION

SMART METERING

WIRELESS SENSOR NETWORKS

RM SYSTEMS

INDUSTRIAL MONITORING & CONTROL
<table>
<thead>
<tr>
<th>Радиочастота</th>
<th>Основные технические характеристики (Выходная мощность, ЭИМ* и др.)</th>
<th>Назначение</th>
<th>Регламентирующий документ</th>
</tr>
</thead>
<tbody>
<tr>
<td>433,075-434,79 МГц</td>
<td>10 мВт (EN 300 220) (Рабочий цикл неограничен)</td>
<td>Неспециализированные (любого назначения) устройства — устройства малого радиуса общего применения, включая устройства дистанционного управления и передачи телеметрии, телемедицины, сигнализации, передачи данных и других подобных передач. Допускается использование маломощными радиостанциями и устройствами для обеспечения безопасности.</td>
<td>Приложение 1 к решению ГНЧ от 7 мая 2007 г. № 07-20-03-001</td>
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<tr>
<td>433,05-434,79 МГц</td>
<td>5 мВт (Рабочий цикл &lt; 10%)</td>
<td>Устройства охранной радиосигнализации — системы радиосигнализации, включающие системы общественной радиосигнализации и системы радиосигнализации для обеспечения безопасности.</td>
<td>Приложение 3 к решению ГНЧ от 7 мая 2007 г. № 07-20-03-001</td>
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<tr>
<td>868-868,2 МГц</td>
<td>10 мВт (Рабочий цикл &lt; 10%)</td>
<td>Устройства охранной радиосигнализации — системы радиосигнализации, включающие системы общественной радиосигнализации и системы радиосигнализации для обеспечения безопасности.</td>
<td>Приложение 3 к решению ГНЧ от 7 мая 2007 г. № 07-20-03-001</td>
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<tr>
<td>868.7-869.2 МГц</td>
<td>22 мВт (EN 300 220)</td>
<td>Неспециализированные (любого назначения) устройства — устройства малого радиуса общего применения, включая устройства дистанционного управления и передачи телеметрии, телемедицины, сигнализации, передачи данных и других подобных передач.</td>
<td>Приложение 11 к решению ГНЧ от 07.05.2007 № 07-20-03-001</td>
</tr>
<tr>
<td>868-868.5 МГц</td>
<td>10 мВт (EN 301 357) (Рабочий цикл 100%)</td>
<td>Беспроводное радиооборудование — устройства малого радиуса действия, используемые для передачи данных между антеннами системами, наушниками, микрофонами и другими радиоустройствами.</td>
<td>Приложение 14 к решению ГНЧ от 07.05.2007 № 07-20-03-001</td>
</tr>
<tr>
<td>2400-2483,5 МГц</td>
<td>2,5 мВт (ЭИМ) [Bluetooth Class 2]</td>
<td>Устройства с псевдослучайной перестройкой рабочей частоты (ПРЧ). Ширина канала не менее 1 МГц. Время прекращения (работы) на одной несущей, выбор которой осуществляется по псевдослучайному закону, не более 0,4 сек. Количество используемых каналов ПРЧ — 79</td>
<td>Приложение к решению ГНЧ от 15 декабря 2009 г. № 09-05-09</td>
</tr>
<tr>
<td>2400-2483,5 МГц</td>
<td>100 мВт (ЭИМ) [Bluetooth Class 1]</td>
<td>Устройства с псевдослучайной перестройкой рабочей частоты (ПРЧ). Ширина канала не менее 1 МГц. Время прекращения (работы) на одной несущей, выбор которой осуществляется по псевдослучайному закону, не более 0,4 сек. Количество используемых каналов ПРЧ — 79. Допускается применение РЭС вне закрытых помещений только при высоте установки РЭС не более 10 м от поверхности Земли. Для целей сбора информации телеметрии в составе автоматизированных систем контроля и учета ресурсов или систем охраны допускается применение без ограничений по высоте установки РЭС.</td>
<td>Приложение к решению ГНЧ от 15 декабря 2009 г. № 09-05-09</td>
</tr>
<tr>
<td>2400-2483,5 МГц</td>
<td>100 мВт (ЭИМ), Максимальная спектральная плотность ЭИМ не более 2 мВт/МГц [802.15.4/ZigBee и др.]</td>
<td>Устройства с прямым расширением спектра и другими видами модуляции.</td>
<td>Приложение к решению ГНЧ от 15 декабря 2009 г. № 09-05-09</td>
</tr>
<tr>
<td>2400-2483,5 МГц</td>
<td>100 мВт (ЭИМ), Максимальная спектральная плотность ЭИМ не более 20 мВт/МГц [802.15.4/ZigBee и др.]</td>
<td>Устройства с прямым расширением спектра и другими видами модуляции. Допускается применение РЭС вне закрытых помещений только для целей сбора информации телеметрии в составе автоматизированных систем контроля и учета ресурсов или систем охраны.</td>
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<td>2400-2483,5 МГц</td>
<td>100 мВт (ЭИМ), Максимальная спектральная плотность ЭИМ не более 10 мВт/МГц</td>
<td>Устройства с прямым расширением спектра и другими видами модуляции. Для применения внутри закрытых помещений.</td>
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</tbody>
</table>
SPIRIT1: Best in class transceiver

Cuts power budget up to 30% over competing devices

Design focused on Power Savings
- RX 9 mA
- TX 21 mA (+11 dBm)
- Shutdown 2.5 nA

Excellent Sensitivity -120 dBm
SPIRIT1: Description

- Frequency bands: 169, 315, 433, 868, 915, 920 MHz
- Configurable data rate from 1 to 500 kbps
- SPI interface
- Supply voltage: 1.8 V to 3.6V
- 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 Features

- **Output Power:** -36 dBm to +11 dBm, in 0.5 dB steps
- **Excellent receiver sensitivity:** -120 dBm (1.2 kbps – 169MHz)
- **Integrated SMPS allows** very low power consumption

<table>
<thead>
<tr>
<th>Mode</th>
<th>Current (mA)</th>
<th>Power Consumption Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX</td>
<td>9 mA</td>
<td>SPI on, XTAL on, Synth on</td>
</tr>
<tr>
<td>TX</td>
<td>21 mA</td>
<td>SPI on, XTAL on, Synth on</td>
</tr>
<tr>
<td>Ready</td>
<td>400 uA</td>
<td>SPI on, XTAL on, Synth on</td>
</tr>
<tr>
<td>Sleep</td>
<td>950 nA</td>
<td>SPI on, register retention, RC oscillator</td>
</tr>
<tr>
<td>Standby Mode</td>
<td>650 nA</td>
<td>SPI on, register retention</td>
</tr>
<tr>
<td>Shutdown Mode</td>
<td>2.5 nA</td>
<td>Everything OFF</td>
</tr>
</tbody>
</table>
SPIRIT1: Operation lifetime increases

- RX Current consumption cut >30%
- Sensitivity performances are not sacrificed

TX Current consumption cut >28% @ max o/p power
SPIRIT1: Key Features

- Integrated packet handler
  - Support for automatic acknowledgment, retransmission, low duty cycle protocol and timeout protocol

- Automatic clear channel assessment (CCA) engine
  - Channel access mechanism, based on the rule “Listen-before-talk” systems. Embedded CSMA/CA protocol

- Fully integrated ultra low power RC oscillator

- AES 128-bit encryption co-processor for secure data transfer
SPIRIT1: Key Features

- Frequency Hopping under MCU control
  - Calibration can be made each time the MCU decide to change frequency or MCU can save and restore calibration data to make the frequency hopping faster

- Separate 96-byte RX/TX FIFOs
  - accessible via the SPI interface for host processing

- Supports automatic antenna selection through an integrated antenna diversity switching mechanism
Main Block Description

• Receiver
  • Architecture based on LOW IF conversion
  • The received RF signal is amplified by a two-stage low noise amplifier (LNA) and down-converted in quadrature (I and Q) to the intermediate frequency (IF). At IF, the I/Q signals are digitized by high dynamic range ADCs.
  • The Demodulator data is then provided to an external MCU either through the 96-byte RX FIFO, readable via SPI, or via a GPIO pin

• Transmitter
  • Architecture is based on direct synthesis of the RF frequency
  • The data to be transmitted are provided by an external MCU either through the 96-byte TX FIFO writable via SPI, or directly using a programmable GPIO pin

• Power Management
  • Integrates a high efficiency step-down converter (SMPS) cascaded with LDOs to supply both analog and digital parts.
  • Operates from a battery voltage ranging from 1.8 V to 3.6V, with high power efficiency
Main Block Description

• **Clock Signal : External crystal**
  - An external 24, 25, 26, 48, 50 or 52 MHz Crystal (between XIN and XOUT) or an external clock signal can be used
  - An integrated low-power RC oscillator, generating the 34.7 kHz signal is used as a clock for the slowest timeouts (i.e low duty cycle protocol or CSMA/CA protocol)

• **Digital Interface**
  - A 4-wire SPI serial interface is used to communicate with the external MCU.
  - 4 GPIOs that can be registered through the SPI registers to perform various functions, including
    - MCU clock output
    - FIFO status flags
    - Wake-up input
    - Battery level detector
    - TX-RX external switch control
    - Antenna diversity control
    - Temperature sensor output
    - Interrupts
Main Block Description

- **Data link layer**
  - Support for channel configuration, packet handling and data buffering
  - Support Packet Formats (Basic, STack and Wireless M-BUS)
  - The Host MCU can stay in power down until a valid RF packet has been received, and then burst read the data, greatly reducing the power consumption and computing power required from the host MCU

- **AES encryption co-processor**
  - Provides data security support as it embeds an advanced encryption standard (AES128) core which implements a cryptographic algorithm

- **Analog temperature sensor**
  - The Host MCU can be used to read the chip temperature (e.g. it can be used to force radio recalibration)

- **Battery indicator and low battery detector**
SPIRIT1 PCB layout

- **V_{DD} filter capacitors**
- **SMPS filtering**
- **TX filtering and matching**
- **Decoupling capacitors**
- **PCB vias**
- **Choke inductor**
- **RX balun network**
- **V_{DD} filter capacitor**
- **Spirit RF IC**
- **Crystal section**
- **Antenna**
SPIRIT1 on Internet

- Product RTM with All Documentation available at

- Application Notes, Schematics, BOM, Gerber Files, ...

Development Kit (SDK) for STM32L, includes WM-Bus library, Set of Thingsquare MIST (6lowPAN, MESH)
• SPIRIT1 Development Kits
  • STEVAL-IKR001V1 – 169 MHz
  • STEVAL-IKR001V2 – 315 MHz
  • STEVAL-IKR001V3 – 433 MHz
  • STEVAL-IKR001V4 – 868 MHz
  • 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](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)
SPIRIT1 Development kit description

5 user leds

JTAG interface

USB

External power supply (optional)

STM32L based motherboard

1 reset, 2 user button, 1 joystick

Power supply switch

SMA connector

SPIRIT1 RF module (available in 4 bands)
**RF module boards**

- **SPIRIT1 RF module boards**
  - STEVAL-IKR001V1D – 169 MHz
  - STEVAL-IKR001V2D – 315 MHz
  - STEVAL-IKR001V3D – 433 MHz
  - STEVAL-IKR001V4D – 868 MHz
  - STEVAL-IKR001V5D – 915 MHz

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

STEVAL-IDS001V2 – 315 MHz
STEVAL-IDS001V3 – 433 MHz
STEVAL-IDS001V4 – 868 MHz
STEVAL-IDS001V5 – 915 MHz
Why SPIRIT1 is better?

- SPIRIT1 does not need an external PLL loop filter
- SPIRIT1 does not need an external tank for the VCO
- SPIRIT1 does not need an external TX SAW filter to reduce spurious emissions
- SPIRIT1 does not need any external SAW filter in RX to obtain good image rejection
- SPIRIT1 has 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
- SPIRIT1 differential RX input is less sensitive to noise
  - Configuration with TX and RX connected together does not allow to use an external range extender and/or an antenna switch, with SPIRIT1 it is possible
- SPIRIT1 has an excellent RX time-out management
  - Any AND/OR combination of CS, SQI and PQI valid signals can be used to guarantee that the receiving of a valid packet will be not interrupted by time-out

15/11/2013
Sub 1GHz RF Transceiver: STS2001

- **Frequency bands**: 150-174MHz, 300-348 MHz, **400-512 MHz**, 779-956 MHz
- **Modulation schemes**: 2-FSK, 2-GFSK, **4-FSK**, 4-GFSK, MSK, OOK and ASK
- **Air data rate** from 0.1 to **500** kbps (2 levels modulation). From **0.2** to **1000** kbps (4 levels modulation)
- **Programmable output power**: from -30dBm to +20 dBm
- **Receiver Sensitivity**: -122dBm @ 1.2kbps
- **Low current consumption**
  - Shutdown: 2.5nA
  - Stand-by: 600nA
  - Sleep: 900nA
  - RX: 10mA
  - TX: 24 mA @+11dBm
- **Frequency Hopping**, Antenna diversity algorithm
- **Automatic acknowledgement**, retransmission, and timeout protocol engine
- **Embedded packet handler**
- **Wireless M-BUS** including the **N2g sub mode**, 6LoWPAN
STS1TX Sub 1GHz RF Transmitter

- Sub 1GHz Transmitter
- Pin to pin and footprint compatible with the SPIRIT1
- RF/ANALOG performance = SPIRIT1
- Link Layer and Packet handler support = SPIRIT1

Main Characteristics:

- Frequency bands: 150-174MHz, 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 +16dBm (boost mode)
- Low current consumption
- Programmable channel spacing (12.5 kHz min).
- Frequency Hopping
- AES 128-bit encryption co-processor
- Embedded packet handler
- Wireless M-BUS, 6LoWPAN
- EN 300 220, FCC CFR47 15 (15.205, 15.209, 15.231, 15.247, 15.249), and ARIB STD T-67, T-108 compliant

QFN20 4*4

Samples and mass production: June 2013
SPIRIT1: Summary

- Multi Band Transceiver, Targeting the Following Applications:
  - Wireless Metering and Wireless Smart Grid
  - Home & Building Automation
  - Industrial Monitoring and Control
  - Wireless Fire and Security Alarms

- Best in Class Solution in Power Saving: Cuts power budget by 30% over competing devices

- Excellent RF performances: High Sensitivity, High Selectivity, Antenna Diversity ensuring reliability & robustness performances

- Compliant Wireless MBus standard

- Demo Kit @ All frequency Band available NOW

- Product in Mass Production
RF Basics
Basic Terminology 1/2

• dBm – is a measure of RF Power referred to 1 mW (0 dBm)
  • 10mW(10dBm), 500 mW (27dBm)

• PER – Packet Error Rate [%] – percentage of the packets not successfully received over a period of time
  • Used to measure the RF transceiver performance

• BER – Bit Error Rate [%] - percentage of the Bits not successfully received over a period of time
  • Used to measure the RF transceiver performance

• Sensitivity (RX) – it is the lowest input power of the receiver acceptable to receive packets with 1% PER

• Blocking (RX) – The receiver ability to work in the presence of a interfering RF signal in a frequency band relatively close to the signal of interest
Basic Terminology 2/2

• Dynamic range - the maximum received power variation at the receiver input pins which result in a correct demodulated signal

• Adjacent Channels – channel(s) closest to the active signal channel

• Alternate Channel – second next channel(s) to the active signal channel

• Payload – application data

• Modulation – superimposing algorithm of a low frequency signal (payload) onto a high frequency signal (Carrier)
  • ASK, OOK, FSK, GFSK, GMSK
RF system

- **Radio IC**
  - Transmitter (only TX)
  - Receiver (only RX)
  - Transceiver (both TX & RX)
  - SoC (Transceiver + MCU)

- **Crystal**
  - Clocks the Radio IC crystal oscillator which generates the reference frequency for the RF synthesizer

- **Balun**
  - Converts balanced (differential) signal to unbalanced (single-ended) signal and the vice versa.

- **Matching network**
  - Whenever a source of power with a fixed output impedance such as a radio transmitter operates into a load, the maximum possible power is delivered to the load when the impedance of the load is equal to the complex conjugate of the impedance of the source.

- **Filter**
  - Attenuates out of band signals

- **Antenna switching**
  - Either can be used to switch from antenna to antenna with a better RSSI value, or is switching the antenna either to the RX to TX chain between the antenna and the radio IC.

- **Range Extender**
  - Can be used to increase the radiated output power

- **Antenna**
  - Converts electric power into radio waves
Complete RF communication environment

- **Signal encoder / decoder**
  - converts information from one format or code to another, for the purposes of standardization, speed, security or saving space by shrinking size (e.g. Manchester), decoder does the opposite

- **Modulator**
  - process of varying one or more properties (amplitude, frequency, ..) of a high-frequency periodic waveform, called the carrier wave, with a modulating signal which typically contains information to be transmitted (Application Data)

- **Communication channel**
  - is the physical transmission medium as a wire or, as in our case, a radio channel

- **Demodulator / Detector**
  - Recovers the information content from the modulated carrier wave
Digital Amplitude modulation methods

- **ASK (Amplitude Shift Keying)**
  - The amplitude of an analog carrier signal varies in accordance with the digital bit stream
  - The amplitude of the carrier is set to a max level when a 1 is sent and a min level when a 0 is sent
  - Simple, duty cycling, lower transmit current
  - Susceptible to noise, wide spectrum

- **OOK (ON OFF Keying)**
  - It is the simplest form of ASK
  - It represents digital data as the presence or absence of a carrier
Digital frequency modulation method (1/2)

• FSK
  • The digital information is transmitted through discrete frequency changes of a carrier
  • Less susceptible to noise
  • Theoretically it requires larger bandwidth than ASK

• 2-FSK (Two level or binary FSK)
  • A pair of discrete frequencies is used to transmit 1/0
Digital frequency modulation method (2/2)

- **GFSK (Gaussian FSK)**
  - A Gaussian filter smoothes baseband data (1/0) to make the pulse smoother
  - It has better spectral width than 2-FSK

- **MSK and GMSK**
  - **MSK (Minimum Shift Keying)**
    - Is a type of continuous-phase frequency-shift keying (CP-FSK)
    - Is implemented as a fast frequency-shift keying (FFSK)
    - The result is a constant-modulus signal => reduces problems caused by distortion
  - **GMSK (Gaussian Minimum Shift Keying)**
    - A Gaussian filter is applied to smooth the incoming digital data
SPIRIT1
Technical Details
State Machine, MCU Control Interface & AES128
Operating Modes/Consumption

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shutdown</td>
<td>Off, no register retention</td>
</tr>
<tr>
<td>Standby</td>
<td>SPI On, register retention</td>
</tr>
<tr>
<td>Sleep</td>
<td>SPI on, register retention, Wakeup timer on</td>
</tr>
<tr>
<td>Ready</td>
<td>SPI on, XTAL on</td>
</tr>
<tr>
<td>RX</td>
<td>SPI on, XTAL on, RF Synth on</td>
</tr>
<tr>
<td>TX</td>
<td>SPI on, XTAL on, RF Synth on</td>
</tr>
</tbody>
</table>

Transition times using 26MHz Xtal

- SHUTDOWN [2.5nA]
- STAND-BY [600nA]
- READY [400uA]
- SLEEP [850nA]
- LOCK [4.4mA]
- RX/TX [9mA/21mA @+11dBm]
**SPI communication**
- Write registers or FIFOs
- Read registers or FIFOs
- 17 Commands (State diagram, AES, FIFO flush)

**GPIO communication**
- Interrupt signals
- Monitoring signals (Valid preamble detected, valid sync word detected, …)
- Commands (TX/RX mode, Wake-up from external input, …)
- Input/output data (direct mode)
- Input/output reference clock (MCU clock out, 34.7 kHz for LDC mode input)
- Analog output: temperature sensor (GPIO 0)

**SDN pin**
- Shutdown signal
GPIO communication

- Monitoring signals

### Packet oriented
- Valid preamble detected
- Sync word detected
- RSSI above threshold

### FIFOs oriented
- TX FIFO almost full
- TX FIFO almost empty
- RX FIFO almost full
- RX FIFO almost empty

### Status oriented
- Device in READY state
- Device in SLEEP or STANDBY states
- TX state indication
- RX state indication
- TX or RX mode indicator
- Device in LOCK state

### Status oriented
- Low battery level
- Power-On Reset
- Antenna switch used for antenna diversity

### Other
- VDD/GND (to emulate an additional GPIO of the MCU)
- Wake-Up timeout in LDC mode
## SPIRIT1

### Interrupts

#### GPIO communication

• Interrupt signals

<table>
<thead>
<tr>
<th>Packet oriented</th>
<th>FIFOs oriented</th>
<th>Protocol oriented</th>
<th>Status oriented</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX data ready</td>
<td>TX FIFO underflow/overflow error</td>
<td>Max re-TX reached</td>
<td>READY state in steady condition</td>
</tr>
<tr>
<td>RX data discarded</td>
<td>RX FIFO underflow/overflow error</td>
<td>Max number of back-off during CCA</td>
<td>STANDBY state switching in progress</td>
</tr>
<tr>
<td>TX data sent</td>
<td>TX FIFO almost full</td>
<td>Wake-up timeout in LDC mode</td>
<td>Low battery level</td>
</tr>
<tr>
<td>CRC error</td>
<td>TX FIFO almost empty</td>
<td>AES End–Of – Operation</td>
<td>Power-On Reset</td>
</tr>
<tr>
<td>Valid preamble detected</td>
<td>RX FIFO almost full</td>
<td></td>
<td>RX operation timeout</td>
</tr>
<tr>
<td>Sync word detected</td>
<td>RX FIFO almost empty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSSI above threshold</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

SPIRIT1 diagram showing GPIO, SPI, SDN, and SHUTDOWN signals.
SPIRIT1 AES-128 Engine

The SPIRIT1 provides data security support as it embeds the Advanced Encryption Standard (AES) 128-bit core.

The AES-128 engine can be used at anytime.

- The SPIRIT1 provides 3 banks of 128 bits registers:
  - Input register (AES_DATA_IN)
  - Output register (AES_DATA_OUT)
  - Key register (AES_KEY_IN).

- Four operations are available:
  - Encryption using a given encryption key.
  - Decryption key derivation starting from an encryption key.
  - Data decryption using a decryption key.
  - Data decryption using a encryption key.
Transmission & Reception

RF Related Features
SPIRIT1 Oscillator and RF synthesizer

• An external XTAL (24, 25, 26, 48, 50, 52 MHz), provide a clock signal to the RF frequency synthesizer.
  • The digital part of the silicon always requires clock in the range (24-26 MHz), so the clock must be divided when using 48-52 MHz XTAL.

• RF Frequency Synthesizer
  • has fractional sigma delta architecture for fast settling and narrow channel spacing
  • contains an integrated PLL capable to synthesize frequencies in the bands (150÷174) MHz, (300÷348) MHz, (387÷470) MHz, (779÷956) MHz, providing the LO signal for the RX chain and the input signal for the PA in the TX chain. **No external PLL loop filter is needed.**
  • uses a multi-band VCO to cover the whole frequency range

• The base Carrier frequency is programmed using SYNT0-SYNT3 registers of SPIRIT1 (easiest way is to use SPIRIT1 SW library)

• Calibration can be automatic (80 us) or manual (20 us), in the latter case the micro should save/restore the calibration words and take into account for temperature/VBAT variation which could require recalibration.
Receiver Quality Indicators

• **Received signal strength indicator** (RSSI) – 8 bits
  • Measured received signal power. RSSI reading is available after the reception of a packet in a register

• **Carrier Sense** (CS) – 1 bit
  • Based on RSSI (threshold, static/dynamic mode)

• **Link quality indicator** (LQI) – 4 bits
  • Level of noise power on the demodulated signal

• **Preamble quality indicator** (PQI) – 8 bits
  • Best correlation between the received preamble and the expected one
  • Preamble valid IRQ can be used
  • Packet demodulation can be stopped when PQI is below threshold

• **Synchronization quality indicator** (SQI) – 7 bits
  • Measurement of the best correlation between the received synchronization word and the expected one
  • Sync word detected IRQ can be used
  • Packet demodulation can be stopped when SQI is below threshold
Automatic Antenna diversity algorithm

- An external switch is controlled to select the antenna with the highest RSSI (through programmable SPIRIT1 GPIO)

- While receiving the packet preamble, the antennas are repeatedly switched until the RSSI > threshold.

- The switch is then disabled and the selected antenna is used.
Transmission & Reception
Packet handler Engine
### SPIRIT1 Packet Handler Engine

#### Embedded packet formats

**STack**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Sync</th>
<th>Length</th>
<th>Destination Address</th>
<th>Source Address</th>
<th>Control</th>
<th>Seq. No.</th>
<th>No ACK</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 32 Bytes</td>
<td>1 – 4 Bytes</td>
<td>0 – 16 Bits</td>
<td>1 Byte</td>
<td>1 Byte</td>
<td>0 – 4 Bytes</td>
<td>2 bits</td>
<td>1 bit</td>
<td>0, 8, 16, 24 bits</td>
<td></td>
</tr>
</tbody>
</table>

**WM-Bus**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Sync</th>
<th>Payload</th>
<th>Postamble</th>
</tr>
</thead>
</table>

**BASIC**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Sync</th>
<th>Length</th>
<th>Destination Address</th>
<th>Control</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
</table>
SPIRIT1 Direct mode

The purpose of the direct modes is to by-pass completely the packet handler engine and to give the user more flexibility. The direct modes are available both for RX and TX

- **Direct mode through FIFO (SPI)**
  - In the direct mode through FIFO the data are continuously read from the TX FIFO and transmitted without any processing of the packet handler for the transmitter and the data are continuously received in the RX FIFO without any processing.

- **Direct mode through GPIO**
  - In the direct mode through GPIO the data are sampled by the device on the rising edge of the clock signal and send on air without any processing of the packet handler for the transmitter and the data are continuously written to one GPIO together with the clock in another GPIO.

- **PN9 mode (for TX)**
  - A pseudo-random binary sequence is generated internally for test purpose only.
SPIRIT1 Automatic Packet Filtering

Embedded automatic packet filtering

- **CRC** (Packet discarded if CRC check do not pass)
- **Destination address** (My own address, Broadcast, Multicast)
- **Source address** (reference address in AND bitwise with the source mask)
- **Control field** (reference address in AND bitwise with the control mask)

The automatic packet filtering engine works in STack and BASIC packet formats

More than one automatic filtering feature can be enabled at the same time
SPIRIT1 Link Layer Protocol

Available through the STack packet format, with following features

- **Automatic acknowledgment**
  - The receiver sends an ACK packet, if a packet is received with success and bit NO_ACK = 0. The transmitter goes in RX state to wait the ACK packet. If the transmitter does not receive any ACK packet when it should, the packet transmitted before is considered lost.

- **Automatic acknowledgment with piggybacking**
  - The receiver can fill the ACK packet with data (as payload field of the packet). The data to send is stored in the TX FIFO (up to 96 bytes without any additional interaction from the MCU !!!)

- **Automatic retransmission**
  - If the transmitter does not receive the ACK packet within the RX timeout programmed, it can be configured to do another transmission. Up to 15 retransmissions.
SPIRIT1 Data coding and integrity check

Error correction and detection methods

- **FEC/Viterbi and interleaving**
  - Convolutional coding in transmitter and on the receiver side - error correction is performed using soft Viterbi decoding
  - Controls errors in data transmission over unreliable/noisy communication channels. The 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/ dewhitenening**
  - To prevent short repeating sequences that create spectral lines, which may complicate symbol tracking at the receiver or interferer with other transmissions

- **CRC (Cyclic Redundancy Check)**
  - CRC polynomials can be selected (4 options). Programmable to 8, 16, or 24 bits

CRC and whitening is applied over all fields excl. preamble and synchronization word
In order to reduce power consumption, many automatic RX timeout modes are supported

- **Infinite timeout** – RX stops when the packet ends or when the SABORT SPI command comes from the microcontroller.

- **Carrier sense (CS) timeout** - RX is aborted if the RSSI never exceeds a programmed threshold within preset timeout (TIMER).

- **SQI timeout** - RX is aborted if the synchronization quality indicator (SQI) does not exceed a programmed threshold within preset timeout.

- **PQI timeout** - RX is aborted if the preamble quality indicator (PQI) does not exceed the programmed threshold within preset timeout.

The value of the Time out can be programmed up to ~3 seconds.
Power consumption Efficient use of the RX timeout mechanism [2/3]

• CS, SQI and PQI can be combined together, both 'AND' or 'OR' Boolean relationships among them are allowed to avoid the reception to be interrupted

<table>
<thead>
<tr>
<th>AND / OR SELECT</th>
<th>CS</th>
<th>SQI</th>
<th>PQI</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Time out not stopped</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Timeout always stopped (default)</td>
</tr>
<tr>
<td>x</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>CS (RSSI above threshold)</td>
</tr>
<tr>
<td>x</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>SQI above threshold</td>
</tr>
<tr>
<td>x</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>PQI above threshold</td>
</tr>
<tr>
<td>0 (AND)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Both RSSI AND SQI above threshold</td>
</tr>
<tr>
<td>0 (AND)</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Both RSSI AND PQI above threshold</td>
</tr>
<tr>
<td>0 (AND)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Both SQI AND PQI above threshold</td>
</tr>
<tr>
<td>0 (AND)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>ALL above threshold</td>
</tr>
<tr>
<td>1 (OR)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>RSSI OR SQI above threshold</td>
</tr>
<tr>
<td>1 (OR)</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>RSSI OR PQI above threshold</td>
</tr>
<tr>
<td>1 (OR)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>SQI OR PQI above threshold</td>
</tr>
<tr>
<td>1 (OR)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>ANY above threshold</td>
</tr>
</tbody>
</table>

• It is up to the programmer to effectively set the timeout value (time) according to the application needs (i.e. preamble and sync word length, data rate etc.)
Power consumption Efficient use of the RX timeout mechanism [3/3]

3 examples

#1
- Preamble
- Sync
- ... Rest of the packet ...

1# CS, PQI, SQI being tested in the app. All above threshold, timeout stopped. Packet received.

#2
- Preamble
- Sync

#2 CS, PQI, SQI being tested in the app. SQI below threshold, timeout was not stopped. Packet not received - demodulation stopped.

#3
- Preamble
- Sync

#3 CS, SQI above threshold, timeout was stopped. PQI test was not set in the app. Packet received.

Packet analysis:
- TX active slot
- RX active slot
- Timeout
- PQI detected
- CS detected
- SQI detected
SPIRIT1 CSMA/CA Engine

The CSMA/CA engine is a channel access mechanism based on the LBT rule “listen before talk”. This avoids the simultaneous use of the channel by different transmitters.

Clear Channel Assessment (CCA)
SPIRIT1 @ 868MHz with external PA for +27dBm Output Power
STEVAL-IKR001V8D demo kit RF board content

- SPIRIT1 RF transceiver
- Tai-Saw Technology – TA801A 868 MHz SAW filter
- FEM (PA + LNA + RF Switch) - Skyworks SE2435L
- EEPROM – M95640
SPIRIT1 Development Kit
Software Package
SPIRIT1 Development Kit content [1/3]

• 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: The example has four configurations to differentiate between these combination: 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 Development Kit content [3/3]

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
The firmware package of the Spirit Development Kit provides in addition to the SPIRIT1 Library:

- **SDK Eval**: a set of API functions to manage the motherboard of the SDK (STM32L microcontroller) including USB library and DFU project files for firmware upgrade.
- **STM32L library**: the standard peripheral library for the STM32L microcontroller.
- **SPIRIT1 Examples**: BasicGeneric, LDCGeneric, StackGeneric etc.
- Developed under EWARM IAR v.6.40 IDE (ST-Link, J-Link required for debugging).
The firmware package of the Spirit Development Kit provides in addition to the SPIRIT1 Library:

- SDK Eval: a set of API functions to manage the STM8L discovery board (STM8L microcontroller)
- STM8L library: the standard peripheral library for the STM8L microcontroller.
- SPIRIT1 Examples: BasicGeneric, LDCGeneric, StackGeneric etc.
- Developed under EWARM IAR v.6.40 IDE (ST-Link, J-Link required for debugging)
SPIRIT1 library Memory Foot print STM32L

<table>
<thead>
<tr>
<th></th>
<th>Flash (KBytes)</th>
<th>Ram (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIRIT1 Library (on STM32L)</td>
<td>20</td>
<td>28</td>
</tr>
</tbody>
</table>

- Maximum usage using all the driver features (Typical application will use much lower flash, e.g 4K)
- Preliminary data

<table>
<thead>
<tr>
<th></th>
<th>Flash (KBytes)</th>
<th>Ram (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM-BUS protocol stack</td>
<td>9.1</td>
<td>2148</td>
</tr>
</tbody>
</table>

- Maximum usage of the Wireless M-Bus library
- Both data are referred from libraries in SPIRIT1 Dev Kit version 1.0.6 compiled with IAR with high optimization on the code size
Getting Started with the SPIRIT1 Development Kit (DK)
SPIRIT1 Development Kits

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

*DK – Development Kit
SDK Download

- Go to SPIRIT1 website
  http://www.st.com/internet/imag_video/product/253167.jsp
- Under Design Support TAB, click on the link of the board you have,
  - i.e. STEVAL-IKR001V1
- In the Design Support TAB click download and install the latest SPIRIT1 DK Setup

*SDK – Software Development Kit*
Run the SPIRIT1 DK-Setup-1.0.x.exe downloaded from www.st.com

- Follow the instruction given in the dialog box
- You will be prompted to accept device driver installation (VCOM driver). Click next and follow the instructions to install it
- Microsoft SQL Server Compact installation will be started automatically. Proceed with the installation in case you want to use the W-Mbus (optional)
- Finally, accept to install the W-Mbus Application (optional)
HW & SW set-up

1. Connect both STM32L motherboards to the PC

2. Check the device manager, two devices with different VCOM numbers should be visible

3. Run two instances of the SPIRIT1 DK GUI (Start -> Programs -> STMicroelectronics -> SPIRIT DK_1.0.x -> SPIRIT1 DK)

4. In each SPIRIT1 DK GUI, select one of the COM ports

   - Click Open port in both GUIs -> you are ready to test SPIRIT1
Test RF – generates Carrier Wave or pseudorandom binary sequence

Click CONFIGURE RADIO button when you change any Radio settings

Details on next slides

Tools, firmware flasher

Connection panel COM port

Radio settings

Non-RADIO SPIRIT1 set-up, register access, Communication test

SPIRIT1 supply voltage
Tools

- **Firmware Upgrade**
  - Uses DFU boot loader (read details in the board user manual about how to put DK board in the DFU mode)

- **Firmware Version**
  - Reads the board firmware version, in case it does not correspond to the DK GUI version, it is recommended to flash the corresponding one (you can find it at $...\text{Firmware}\text{\_}\text{Binary file}\text{\_}SPIRIT1_{DK}.hex$) - Firmware Upgrade

- **Save the Current Configuration**
  - Stores the SPIRIT1 DK GUI configuration you made

- **Load the Saved Configuration**
SPIRIT1 DK GUI - 3/5

Packet Setting
- Preamble Length: 1 – 32 Bytes
- Sync Word, Length: 1- 4 Bytes

Packet Format
- Basic
- WMBUS

CRC Polynomial selection
- Forward Error Correction
- Data Whitening

Similar for WMBUS packet format

15/11/2013
Transmission Test

Select the device Role (different for each board)

Number of packets to transmit (0 = infinite nbr)

Packet rate; set the same for TX and RX role

Payload data format

Payload data for transmitting

Overview of the received or transmitted packets

Packet duration – calculated from the data rate and number of bytes transmitted

Start Receiving or transmitting

Packet Error Rate Statistic

Number of Bytes to send as payload

Number of Bytes expected in the receiver
Low level Commands

- **Read the register content**
- **Save register content (e.g. to copy it to your C code)**
- **Write any particular register**
- **Set the supply voltage (1.8 – 3.4V)**
- **Set the Direct mode RX/TX through GPIOs**

Reads the current state of SPIRIT1

Information block

SPIRIT1 silicon version

SPIRIT Status: READY

**Low level Commands**

**Read registers**
- First Register
- No. registers
- 0: 5
- Read

**Write registers**
- Register to change
- New value
- 0x: 0x
- Write

**Save register values**
- Register bit
- Save

**Set the supply voltage (1.8 – 3.4V)**

**SPIRIT1 information**
- SPIRIT state
- SPIRIT version

**SPIRIT1 silicon version**

15/11/2013
SPIRIT1 Application Hints
AN4198: Increasing the radiated Output Power up to +16dBm

- In the default configuration the transmitter internal power amplifier output (pin 12) is biased by the 1.4V SMPS voltage output through the L0 external inductor.

- Biasing the PA output through the inductor L0 directly connected to the battery, instead of the SMPS output allows to increase the maximum output power delivered to the antenna.

- Example

<table>
<thead>
<tr>
<th>Voltage supply $V_{\text{BAT}}$</th>
<th>Maximum output power (measured at connector)</th>
<th>Current consumption (TX mode)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6 V</td>
<td>+16.1 dBm</td>
<td>54 mA</td>
</tr>
<tr>
<td>3.0 V</td>
<td>+15.6 dBm</td>
<td>51 mA</td>
</tr>
<tr>
<td>2.4 V</td>
<td>+14.8 dBm</td>
<td>44 mA</td>
</tr>
<tr>
<td>1.8 V</td>
<td>+13.0 dBm</td>
<td>27 mA</td>
</tr>
</tbody>
</table>
AN4193: Low duty cycle operation with SPIRIT1 transceiver [1/X]

Why?

• To reduce average power consumption during RX and TX operation

• To build a synchronized star network where both transmitter and receiver can sleep periodically to reduce average power consumption

• LDC mode is controlled by two timers:
  • The LDC timer which defines the window where the duty cycle operation take place (t_{LDC\_cycle})
  • The RX\_TIMEOUT timer which defines the amount of time that the receiver is active (t_{RX})

\[
RX_{consumption\_average} = \frac{t_{RX}}{t_{LDC\_cycle}} \cdot 9 + \frac{t_{LDC\_cycle} - t_{RX}}{t_{LDC\_cycle}} \cdot 0.00085 \text{ mA}
\]

How to define t_{RX}?
AN4193: Low duty cycle operation with SPIRIT1 transceiver [2/X]

How to define $t_{RX}$?

• RX timeout using the Sync detection
  • When valid Sync is detected, we are receiving a valid data packet
  • RX timeout is stopped when a valid SYNC word is detected and the receiver is expected to receive a complete packet

• RX timeout using the RSSI detection
  • RX timeout is stopped upon detection of signal energy above a certain user defined threshold
  • This mode will further reduce average power consumption by decreasing the time when receiver must be on. On the other hand the MCU needs to check that a valid message is received within a user defined timeout.
  • The time to measure RSSI of the incoming signal will vary according to the RX filter bandwidth
AN4193: SPIRIT1 Current consumption profile during wake up to RX

![Graph showing current consumption profile with key events: SMPS on, Synth ON, XTAL startup, Sleep, RX on.](image)
Wireless M-BUS Solutions
STM32L & SPIRIT1
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:
- 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 scenario

- Automatic meters reading to:
  - Stationary data collectors
  - Mobile data collectors
- Meters are working without any operator’s intervention or need for battery replacement
ST Wireless M-BUS Stack features (1/2)

- Development based on:
  - STM32L152 MCU ARM 32bit
  - SPIRIT transceiver SubGHz
- 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 ARM Cortex-M3 (STM32L).
  → Example application layer provided in source code form for user customization.
  Sniffer Type under development
- WMBUS PC GUI over USB Interface
ST Wireless M-BUS Stack features (2/2)

WMBUS Mode supported are:
- S, T, R @ 868Mhz
- N @ 169MHz
  (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 (under development)
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 K flash (not optimized)
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMBus_LinkGetAttribute</td>
<td>Read attribute from link layer</td>
</tr>
<tr>
<td>WMBus_LinkSetAttribute</td>
<td>Set attribute in link layer</td>
</tr>
<tr>
<td>WMBus_LinkServicesInit</td>
<td>Init the link service layer</td>
</tr>
<tr>
<td>WMBus_LinkServicesReset</td>
<td>Reset the link service layer</td>
</tr>
<tr>
<td>WMBus_LinkRadioPowerOn</td>
<td>Power on radio</td>
</tr>
<tr>
<td>WMBus_LinkRadioPowerOff</td>
<td>Power off radio</td>
</tr>
<tr>
<td>WMBus_LinkRadioStandby</td>
<td>Put the radio in standby</td>
</tr>
<tr>
<td>WMBus_LinkRadioResume</td>
<td>Resume radio from standby</td>
</tr>
<tr>
<td>WMBus_LinkServicesRequestsCallbackMode (...)</td>
<td>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).</td>
</tr>
<tr>
<td>WMBus_LinkServicesIndicationCallbackMode</td>
<td>Receive message within a specific timeout</td>
</tr>
<tr>
<td>WMBus_LinkServicesResponseCallbackMode</td>
<td>This function attempts to transmit the response to the indication frame received.</td>
</tr>
</tbody>
</table>
Gas Meter ref Design

- STM32L162: 32bit MCU ARM CM3 ULP
- 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

Android Application is available to read/write gas meter parameter by RFID/NFC
GAS Meter – Evaluation Board

- GAS Meter
- Evaluation Board
- STM32L162
- M24LR64
- SPIRIT1 module
- LIS3DH
- M41T62
- M24LR64
- STTS751
SPIRIT1 compliancy test reports

- **AN4110** EN 300 220 at 868 MHz
- **AN4174** ARIB STD-T67 standard in the 426 MHz band
- **AN4126** FCC title 47 part 15 in the 902 - 928 MHz band
- **AN4147** FCC title 47 part 15 in the 315 MHz band
- **AN4117** EN 300 220 at 434 MHz
- **AN4148** ARIB STD-T93 in the 315 MHz band
- **AN4133** ARIB STD-T108 in the 920 MHz band
Thingsquare MIST Solutions
STM32L & SPIRIT1
6LoWPAN and Internet of Things

• Spirit1 + STM32L based platform
  • Availability: March 2013

• Developed and provided by Thingsquare
  • A pioneering provider of open-source software

• To connect SPIRIT1 to Internet or any other IP network
  • Adapting the packet size of the two networks
  • Adaptation layer for interoperability and packet form
  • Mesh Routing in the personal area network
  • ...

• Open source based on Contiki OS
  • Modest resources requirements
  • Over-the-air secure software updates
Enter Thingsquare

**Things**
With the Thingsquare firmware, things connect to the Internet

**The Cloud**
The things talk to the Thingsquare cloud via the Internet

**Apps**
Smartphone apps talk to the things via the Thingsquare cloud
- Thingsquare Mist: the open source firmware that connects things to the Internet
  - Runs on SoCs, microcontrollers
  - Leverages the Contiki OS
  - IPv6 mesh + seamless IPv4 connectivity
• **Thingsquare Cloud backend:**
  – Rendezvous, pairing, monitoring, data collection
• Smartphone / web apps
  – Reaches the things via the Thingsquare cloud API
Building an IoT product

• The Idea
  – "Everyone wants to have a smartphone-controlled lightbulb! I can sell millions of them!"

• What do you need?
  – An app
  – A chip
One possible solution

- Phone talks directly to chip
  - E.g. Bluetooth, BTLE, Ant+, ...
- The problem
  - Every user must configure their phone
  - Everyone must be in range
  - Chip must be compatible with x types of phones
    - Most of which don’t have BTLE/Ant+...
The IoT solution

- Phone and chip talks to cloud backend
  - Works with every phone, easy to extend, remote connectivity, new innovations, etc

- The problem
  - Connect the chip to the Internet
Thingsquare Mist features

- World’s smallest IPv6 stack
- The world’s smallest IPv4/IPv6 router
  - NAT64 and DNS64
- AES encryption
  - Software, may use hardware accelleration
- Network sniffer
- Frequency hopping protocol
  - Needed for sub-GHz legal requirements
- Portable duty cycling (ContikiMAC, Drowsie)
- WebSocket protocol
- Nicer UDP and TCP socket APIs
Write code in your browser, compile in the cloud, upload instantly to your devices
BALF-SPI-01D3
Companion chip to SPIRIT1 @ 868MHz
• ST IPD Technology on Glass: already used by main RF players
• Cover all ETSI, FCC & ARIB recommendation: 868 to 920 MHz frequency range
• < 3mm²: Reduce Size (up to 70% vs discrete solution) and Cost (-60% from BOM+PCB)
• Dedicated companion chip: No validation needed at customer for faster design time
  ➢ Validation on-going in SPIRIT1 evaluation board
• No components dispersion or temperature variation: Function is guaranteed
• Integrated solution: Higher Reliability, better Performance (IL) thanks to low parasitic Glass wafer, greatly reduce PCB sensibility
SPIRIT1 from 800MHz to 930MHz
Balun Flatness

Output Power measured (dBm)

- SMD (0dBm)
- SMD (10dBm)
- V5 Balun (0dBm)
- V5 Balun (10dBm)

Frequency (MHz)

868 MHz
915-920 MHz
SPIRIT1 @ 868MHz
Harmonics @ 10dBm

H2 SMD @ -36dB
H2 V5 Balun @ -40dB

Improved Harmonics Filtering
THIN FILM IPD BALUN
Custom device for Texas Instrument CC25xx
SMD vs. Thin Film IPD BALUN

Passive integration

Flip chip

Smaller
# Texas Instrument
## 2.4 GHz Wireless radio

<table>
<thead>
<tr>
<th>TI CHIPSET</th>
<th>APPLICATION</th>
<th>POSITIONING</th>
<th>ST BALUN PROPOSAL</th>
<th>DIFFERENTIAL LOAD IMPEDANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC2530</td>
<td>ZigBee</td>
<td>SOC RF + MCU</td>
<td></td>
<td>69 + j 29 Ω</td>
</tr>
<tr>
<td>CC2531</td>
<td></td>
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<tr>
<td>CC2533</td>
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<td></td>
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</tr>
<tr>
<td>CC2540</td>
<td>Bluetooth</td>
<td>BT LE + proprietary SOC</td>
<td>BAL-CC25-01D3</td>
<td>70 + j 30 Ω</td>
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<tr>
<td>CC2541</td>
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<tr>
<td>CC2541S</td>
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<td>CC2543</td>
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<td>CC2545</td>
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<tr>
<td>CC2570</td>
<td>ANT</td>
<td>ANT™ RF (no MCU) Network processors</td>
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<td>Same discrete network &amp; values than CC2530</td>
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<td>CC2571</td>
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<tr>
<td>CC8520</td>
<td>Wireless Audio</td>
<td>RF SOC + Audio + USB</td>
<td>BAL-CC25-02D3</td>
<td>70 + j 30 Ω</td>
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<tr>
<td>CC8521</td>
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<tr>
<td>CC8531</td>
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</tbody>
</table>
Texas Instrument
2.4 GHz Antenna interface

PCB layout with SMD components
- Component count: 9 (0402)
- Solder joints: 18
- Component tolerance: ±10%
- RF Performance will vary as SMD tolerance can vary in opposite direction.
- Reliability & assembly cost directly impacted by number of solder joints

PCB layout with ST Balun
- Component count: 1
- Solder joints: 4
- Component tolerance: NA
- Stable & Repeatable RF Performance using custom impedance balun.
- Better Reliability & lower assembly cost thanks to Thin Film Semiconductor process
ST Balun Measurement on Texas Instrument daughter board

DAUGHTER BOARDS
Include ST balun

ST daughter board for CC2540 / CC2544 with BALCC25-01D3

ST daughter board for CC2540 / CC2544 with BALCC25-02D3
### Texas instrument CC2544 (TX)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>0 dBm</th>
<th>4 dBm</th>
<th>0 dBm</th>
<th>4 dBm</th>
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</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>2390 MHz</td>
<td>0.82 dBm</td>
<td>2.11 dBm</td>
<td>5.21 dBm</td>
<td>5.84 dBm</td>
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<tr>
<td></td>
<td>2440 MHz</td>
<td>0.13 dBm</td>
<td>1.74 dBm</td>
<td>4.62 dBm</td>
<td>5.63 dBm</td>
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<tr>
<td></td>
<td>2495 MHz</td>
<td>0.03 dBm</td>
<td>0.90 dBm</td>
<td>4.52 dBm</td>
<td>4.92 dBm</td>
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<tr>
<td>H2</td>
<td>4880 MHz span 400MHz</td>
<td>-51.3 dBm</td>
<td>-58.9 dBm</td>
<td>-47.2 dBm</td>
<td>-52.1 dBm</td>
</tr>
<tr>
<td>H3</td>
<td>7320 MHz span 400MHz</td>
<td>-46.6 dBm</td>
<td>-48.4 dBm</td>
<td>-38.7 dBm</td>
<td>-36.4 dBm</td>
</tr>
<tr>
<td>H4</td>
<td>9758 MHz span 400MHz</td>
<td>-57.9 dBm</td>
<td>-66.2 dBm</td>
<td>-52.4 dBm</td>
<td>-61.8 dBm</td>
</tr>
</tbody>
</table>
SPIRIT1 module
868 and 915MHz SPIRIT1 based module

- SPIRIT1 based Module

  Supported bands 868MHz and 915MHz

  Using BALF-SPI-01D3 868/915MHz IPD balun and filter

  STM32L151RH6 MCU on board

  Surface Mount antenna

  AT Command set interface via UART
Thank you!