RF2401: High Sensitivity, 1.5-72kbps, 2.4GHz FSK Transceiver

Description

The RF2401 is a 1.5kbps to 72kbps low-power, low-voltage, single chip 2.4GHz ISM band RF transceiver ideal for battery operated wireless applications such as wireless sensors and control, gaming, human interface devices, and security networks.

The RF2401's built-in custom low power micro-controller supports the proprietary wireless protocol links in the license-free 2.4000GHz to 2.4835GHz ISM band. It includes a low-IF receiver architecture and uses FSK modulation. A SPI interface provides a simple control of the baseband using an external host controller.

The RF2401 provides two communication modes with normal or high sensitivity and programmable bit rate from 1.5kbps to 72kbps.

The RF2401 provides a divided clock output programmable at either 32.5kHz, 325kHz or 3.25MHz to drive external micro-controllers time reference.

Typical Applications

Remote sensing and control

Wireless mice, keyboards, toys etc…

Wireless watch sensors, sports equipment

Alarm and security systems

Features

- Low Voltage:
  - 1.9V to 3.6V battery operation
- Low Power:
  - 7mA in RX normal sensitivity mode (NS)
  - 8mA in RX high sensitivity mode (HS)
  - TX Mode: 11mA @-1dBm, 36mA @+10dBm
  - <150μA in Stand-by Mode
  - <10nA in Power Down Mode
- High Performance:
  - -115dBm sensitivity at 1.5kbps
  - +10dBm maximum received input signal
  - Programmable output power from -20dBm to +10dBm
- Ultra compact radio design with low BOM cost:
  - COB with 4mm x 4mm footprint
  - Operating Temperature: -40°C to +85°C
  - Direct antenna interface (200 Ω differential)
  - Low-cost 26MHz crystal oscillator, frequency tolerance over temperature and aging of ±20ppm, with adjusted initial value
- Flexible interface:
  - SPI interface for micro controllers
  - Fully programmable link layer
  - External PA and LNA control signal available on 2 pads

Simplified Application Schematic

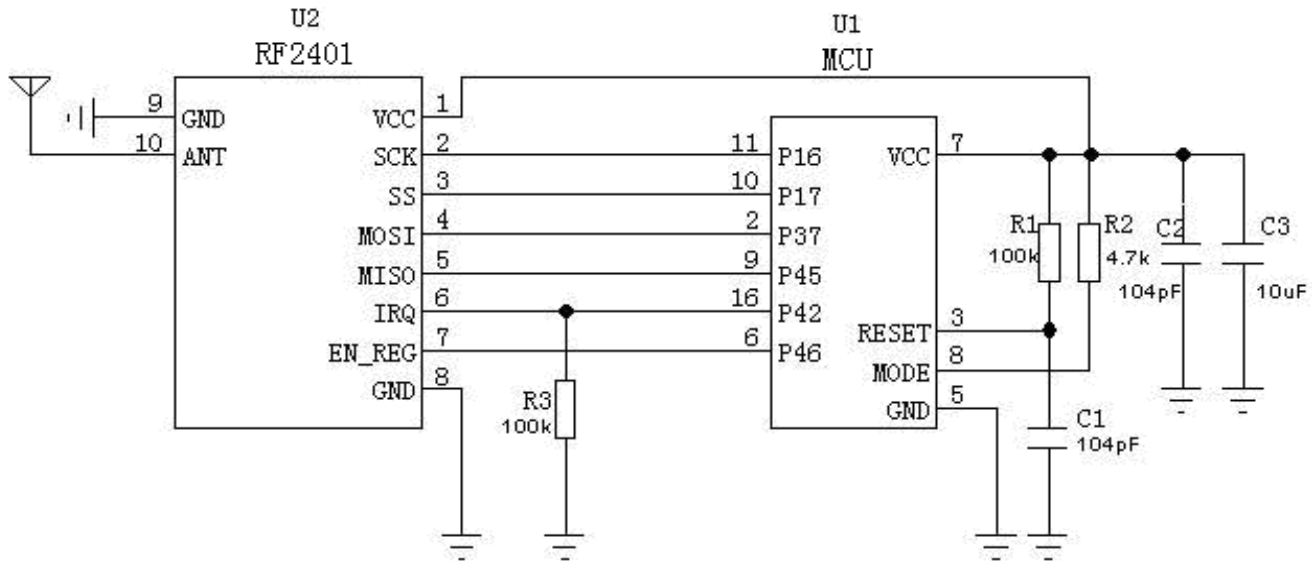


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Writing Conventions

This product specification follows a set of typographic conventions that make the document consistent and easy to read. The following writing conventions are used:

Commands, bit state conditions, and register names are written in **`Courier New bold`**.

Pin names and pin signal conditions are written in `Courier New`.

Cross references are underlined and highlighted in blue.

All numerical values are given in decimal base, unless specified.

1. Introduction

1.1 Overview

The RF2401 is a low-power, low-voltage, single chip 2.4GHz RF transceiver ideal for battery operated wireless applications such as wireless sensors or control, gaming, human interface devices and security networks.

The RF2401 employs a FSK modulation scheme which is directly applied to the 2.4GHz transmitter. RF output power is digitally tuned over a wide range (-20dBm to +10dBm) to optimize current consumption and transmitted power for the application. The on-air transmission rate is digitally programmable from 1.5kbps to 72kbps.

The RF2401 features a fully integrated low-noise, high-sensitivity 2.4GHz front end with -115dBm at 1.5kbps in high sensitivity mode. Due to its robust low-IF receiver architecture, the RF2401 does not require expensive external filters to block undesired RF signals. Additionally, the integration of an agile frequency synthesizer makes the RF2401 well suited for frequency hopping applications.

The RF2401 provides a divided clock output programmable between 32.5kHz and 3.25MHz allowing external RC clocked micro-controllers to get a precise time reference.

The RF2401 is an attractive choice for a broad range of wireless high sensitivity and low data rate applications. In addition, the low bill-of-materials (BOM) required implementing a complete solution with the RF2401 results in minimal overall system cost.

1.2 Applications schematic and block diagram

A simplified applications schematic and block diagram of the RF2401 (Die Version) is shown in Figure 1. Required external components include only a crystal for the frequency . The major blocks that build the RF2401 are the RF transceiver, the digital interface including custom micro-controller and the power management circuitry. An overview of each of these blocks is provided in this section.

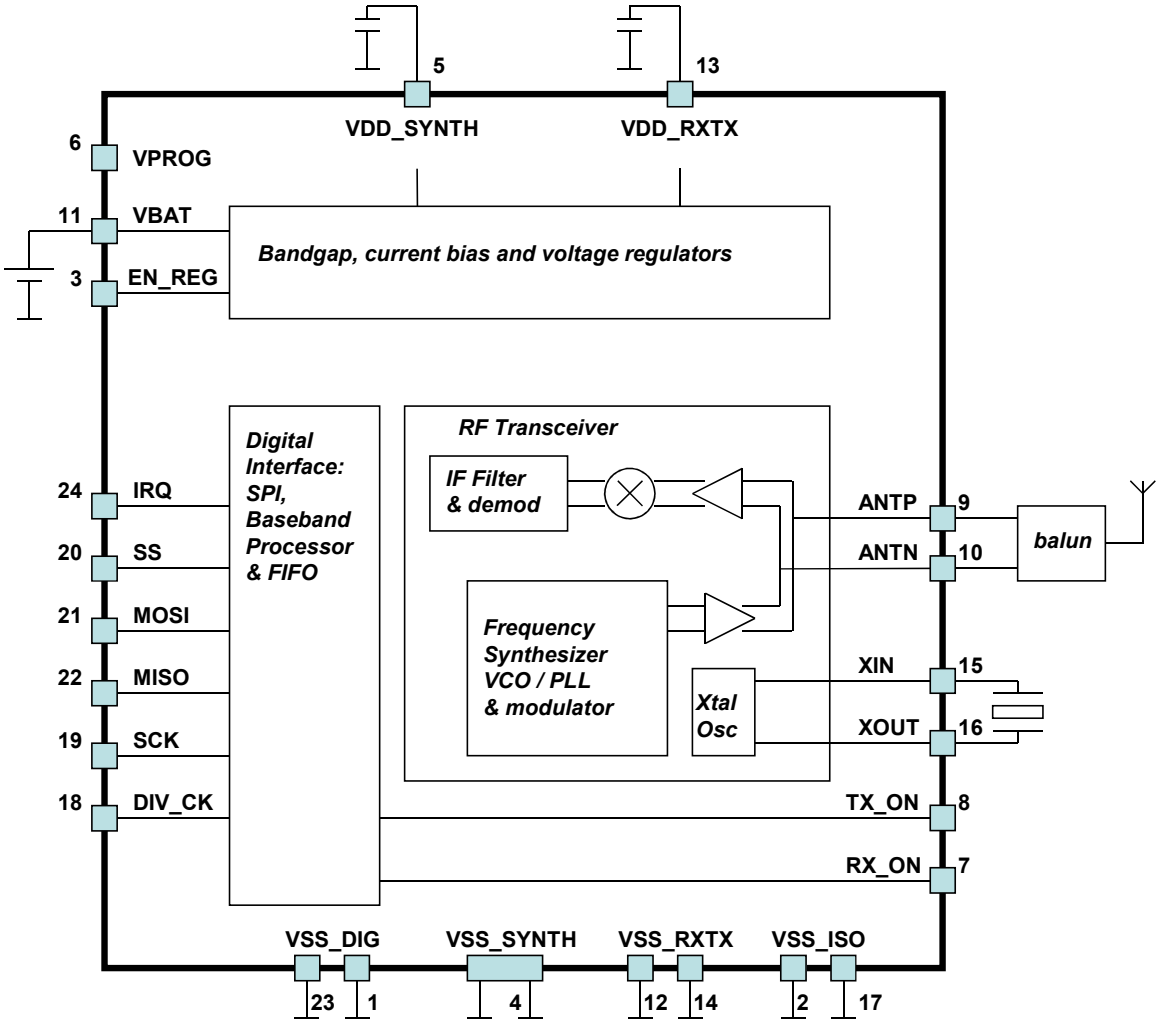


Figure 1: Simplified block diagram, die pin-out

1.3 RF transceiver

The highly integrated multi-channel RF transceiver is ideal for wireless applications in the world-wide, license-free, ISM frequency band at 2.4000GHz to 2.4835GHz. Its robust low-IF architecture and direct FSK modulation scheme are designed for proprietary communication protocols. The RF2401 sup ports data transmission rates of 1.5kbps to 72kbps for up to 20 channels.

The RF transceiver can be programmed to one of two primary modes:

Transmit mode: the entire transmit-chain is active and the digital baseband data can be up-converted to a 2.4GHz FSK modulated signal.

Receive mode: the frequency synthesizer and the entire receive-chain are active and ready to receive a packet.
The RF transceiver consists of three major subsystems: the frequency synthesizer/phase-locked loop (PLL), the receiver and the transmitter. Each of these is described below.

1.3.1 Frequency synthesizer / Phase-Locked Loop (PLL)

The frequency synthesizer provides an accurate, low jitter (-100 dBc @ 1MHz offset) 2.4GHz RF signal used for both up-conversion (in Transmit mode) and down-conversion (in Receive mode). Up to 20 different RF channel frequencies can be synthesized in high sensitivity mode. Additionally, the PLL supports direct FSK modulation for use in the Transmit mode.

An auto-calibration mechanism is included in the PLL (see Section 5.2.4) to center the VCO control voltage.

1.3.2 Receiver

The receiver achieves high sensitivity (-115dBm at 1.5kbps in high sensitivity mode) and supports a wide input signal range (up to +10dBm at 2.4GHz). It is comprised of a low noise amplifier (LNA), followed by a down-conversion mixer and an IF-filter. The output of the IF-filter is fed to a limiting-amplifier which feeds the digital FSK demodulators (normal and high sensitivity). The received data or IF are available in a special “Transparent mode” (see Section 5.2.25).

The receiver includes a Received Signal Strength Indicator (RSSI), which can measure the down-converted RF power after the IF filter. The average power on the channel or burst power of a packet can be read via the SPI after the single-shot RSSI measurement has been completed (see Section 5.2.24).

1.3.3 Transmitter

The transmitter consists of an FSK modulator with a programmable bit-rate (1.5kbps to 72kbps) which is included in the frequency synthesizer (see Section 1.3.1) and a programmable Power Amplifier (PA) output stage. Eight power level from -20dBm to +10dBm, optimized for efficiency, are proposed among the2^10 (10 bit) possible power levels.

1.4 Digital interface

The Digital Interface is shown in Figure 2. It includes:

- A four pin Serial Peripheral Interface (SPI).
- A Custom Micro-Controller with built in CODEC, FIFO’s and timers.
- Two **RAMs** (Program and Registers).
- One **ROM** and its Boot machine.

The SPI can operate at up to 10MHz (at a typical 25pF load) for reading and writing to the configuration (**RAM2**) and program (**RAM1**) memories.

The Custom Micro-Controller drives an interrupt pin (IRQ) which can be programmed to indicate the status of the RF2401(e.g., that a packet has been sent or received or that auto-calibration has finished). This functionality allows the host controller to complete other operations or even enter its own low power mode. Additionally, a DIV_CK output pad allows the user to output a divided version of the internal crystal clock (26MHz). This divided frequency can be disabled or chosen @ 3.25MHz, 325kHz or 32.5kHz. Two other pins, RX_ON and TX_ON, allow the user to command an external PA or/and LNA.

The RAM memories are reset through internal POR on internal VDD_DIG digital supply.

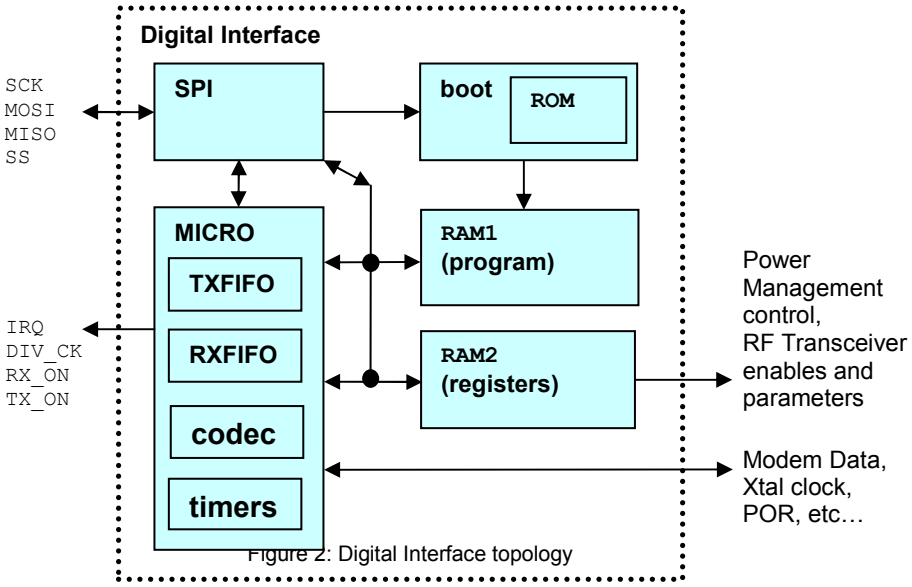


Figure 2: Digital Interface topology

1.4.1 Baseband micro-controller

The baseband custom micro-controller is the central digital control system of the RF2401. It manages all modes of the RF2401 through **RAM2** register memory and controls the RF transceiver and **TXFIFO** or **RXFIFO** operations. Furthermore, it configures digital data for transmission and processes packets received from the demodulator (what is commonly referred to as the link layer). The micro-controller is able to execute different subroutines which are handling production test, auto-calibration, communication (and FIFO control). Those different subroutines are stored in a **ROM** memory and are loaded in the **RAM1** program memory and activated through SPI interface.

There are various communication subroutines available for RF2401 (either high sensitivity or normal sensitivity). Most communication subroutines will set the RF2401 frequency synthesizer in Receive mode and turn on the Receiver. A simple communication subroutine allows the RF2401 to transmit and to go back to Standby mode with crystal oscillator enabled.

1.4.1.1 In Communication mode:

The **TXFIFO** can be written at any time by the host controller. When the SPI command **Send_TXFIFO** is activated, the internal micro-controller will transmit all the content of the **TXFIFO** (or, depending on the subroutine used, a predefined number of bytes, stored in **RAM2**) on the selected channel at the selected data rate.

The RF2401 will wait for any packet on the selected channel at the selected data rate. When a packet is received, the RF2401 examines the packet size header, and stores the corresponding number of bytes in the **RXFIFO** (or, depending on the subroutine used, a predefined number of bytes, stored in **RAM2**) and sets the IRQ signal Pin high.

The RF2401 **RXFIFO** and **RXFIFO_Size** can be read through SPI. The IRQ bit can be reset through the SPI **Clear_IRQ** command.

1.4.1.2 In Auto-calibration mode:

The center frequency of the VCO is tuned for a chosen channel frequency.

The result of the auto-calibration is directly written in the VCO center frequency register **VCO_Code[3:0]**.

1.4.1.3 In Standby mode:

The RF2401 control registers (**RAM2**) can be read or written.

1.4.1.4 In RAM2 initialization mode

The RF2401 configures it's **RAM2** to default value and sets IRQ pin high when this action is finished.

1.5 Power management

The power management system of the RF2401 provides the necessary supplies, voltage and current references for reliable operation in all modes. It includes low drop-out voltage regulators (LDO) for the RF transceiver and all digital circuitry, a low noise bandgap, and a bias-generator. These circuits are powered through the VBAT pin.

1.5.1 RF transceiver supply

There are 2 on-chip regulators, for the transceiver and the synthesizer's analog part, which supply all analog circuits in the RF transceiver. The voltage reference for these regulators is derived from a low noise bandgap circuit. The regulators are enabled individually when needed.

1.5.2 Digital supply

A low power regulator generates the supply (VDD_dig) for all digital parts in the system (base-band, frequency synthesizer logic and demodulator). VDD_dig supply is fully internal and this regulator requires no external decoupling capacitor.

1.5.3 Bias generator

The RF2401 features a bias generator that utilizes on-chip bandgap (temperature compensated) and PTAT (temperature dependent) references.

2. Pin information

Table 1: RF2401 pinout (die version only)

Bond pad	Name	Notes	I/O	Pin Function	Description
1	VSS_DIG	1		Ground	Digital Ground
2	VSS_ISO	1		Ground	Isolation Ground
3	EN_REG		I	Digital Input	Master chip enable signal
4	VSS_SYNTH	1		Ground	Synthesizer Ground
5	VDD_SYNTH			Power Output	Regulated output voltage of synthesizer supply provided for external decoupling; not to be loaded by any external circuitry
6	VPROG		I	Prog voltage	Programing voltage. This terminal must be left floating
7	RX_ON		O	Open Drain	Digital Output for external LNA
8	TX_ON		O	Open Drain	Digital Output for external PA
9	ANTP		I/O	RF	Positive antenna terminal
10	ANTN		I/O	RF	Negative antenna terminal
11	VBAT			Power Input	Positive RF2401 supply: connect to 3V battery
12	VSS_RXTX	1		Ground	RF Ground
13	VDD_RXTX		I	Power Output	Regulated output voltage of transceiver supply provided for external decoupling; not to be loaded by any external circuitry
14	VSS_RXTX	1		Ground	RF Ground
15	XIN		I	Analog Input	Crystal oscillator input
16	XOUT		O	Analog Output	Crystal oscillator output
17	VSS_ISO	1		Ground	Insulation Ground
18	DIV_CK		O	Digital output	Programmable Clock output
19	SCK		I	Digital Input	SPI clock input
20	SS		I	Digital Input	SPI Slave Select, active high
21	MOSI		I	Digital Input	SPI data input
22	MISO		O	Digital output	SPI data output
23	VSS_DIG	1		Ground	Digital Ground
24	IRQ		O	Digital Output	Interrupt output for external host controller

Note 1: For a proper operation of the chip, this terminal shall be connected to a common ground plane.

3. Electrical specifications

3.1 Handling procedures and absolute maximum ratings

This device has built-in protection against high static voltages or electric fields; however, anti-static precautions must be taken as with any CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the specified voltage range. Unused inputs must always be tied to a defined logic voltage level.

Table 2: Absolute maximum ratings

Parameter	Symbol	Min	Max	Unit
Supply Voltage VBAT - VSS	V_{BAT}	-0.3	3.8	V
Input Voltage	V_{IN}	VSS - 0.2	VBAT + 0.2	V
Electrostatic discharge to Mil-Std-883 method 3015.7 with ref. to VSS_DIG	V_{ESD}	-1500	+1500	V
Maximum soldering conditions		As per Jedec J-STD-020		

Stresses above these listed maximum ratings may cause permanent damage to the device. Exposure beyond specified operating conditions may affect device reliability or cause malfunction

3.2 General operating conditions

Table 3: General operating conditions

Parameter	Symbol	Min	Typ	Max	Unit
Supply voltage VBAT	V_{BAT}	1.9	2.5	3.6	V
Temperature range	T_A	-40		+85	°C

3.3 Electrical characteristics

The electrical characteristics of the RF2401 are su mmarized in this section. The electrical characteristics are summarized in the following tables.

Unless otherwise specified: VBAT = 1.9V to 3.6V, TA=-40 to +85°C. Typical values are generally stated at room temperature (T=25°C) with a supply voltage of VBAT = 2.5V.

Table 4: Supply currents on VBAT

Operating mode		Notes	Symbol	Conditions	Min	Typ	Max	Unit
Power Down			I_{VBAT_PWDOWN}	EN_REG = 0			1	μA
Standby			I_{VBAT_STDBY}	26MHz crystal oscillator disabled		140		μA
Transmit		1	I_{VBAT_TX3}	P_{OUT} = -1.1dBm, 2440 MHz		11		mA
			I_{VBAT_TX7}	P_{OUT} = 10dBm, 2440 MHz		36		mA
Receive	normal sensitivity		I_{VBAT_RX1}	2440 MHz		7		mA
	high sensitivity		I_{VBAT_RX2}	2440 MHz		8		mA

Conditions: VBAT = 2.5V.

Note 1: See Table 14 for more detailed PA power settings.

Table 5: DC characteristics

Parameter	Symbol	Condition	Min	Typ	Max	Unit
HIGH level input voltage	V_{IH}		0.7 * VBAT		VBAT+0.2	V
LOW level input voltage	V_{IL}		-0.2		0.3 * VBAT	V
HIGH level output voltage	V_{OH}	I_{OH}=100μA	VBAT-0.3		VBAT	V
LOW level output voltage	V_{OL}	I_{OL}=100μA	0		0.3	V

Table 6: RF characteristics

Parameter	Conditions	Notes	Symbol	Min	Typ	Max	Unit
General RF conditions							
Operating frequency			f_{OP}	2400		2484	MHz
Differential antenna impedance					200		Ohm
Data rate	HS 1.5	2	DR_1	1.2	1.5		kbps
	HS 3	2	DR_2	2.4	3		kbps
	HS 6	2	DR_3	4.8	6		kbps
	HS 12	2	DR_4	9.6	12		kbps
	NS 24	2	DR_5	19.2	24		kbps
	NS 48	2	DR_6	38.4	48		kbps
	NS 72	2	DR_7	57.6	72		kbps
Channel spacing			F_{CHW}		4		MHz
Crystal frequency			f_{XTAL}		26		MHz
Crystal frequency accuracy		1				±20	ppm
Transmitter Operation							
Output Power	Power Level = 7	3	P_{RF7}		+10		dBm
	Power Level = 6	3	P_{RF6}		+9.3		dBm
	Power Level = 5	3	P_{RF5}		+6.6		dBm
	Power Level = 4	3	P_{RF4}		+2.7		dBm
	Power Level = 3	3	P_{RF3}		-1.1		dBm
	Power Level = 2	3	P_{RF2}		-3.1		dBm
	Power Level = 1	3	P_{RF1}		-10.4		dBm
	Power Level = 0	3	P_{RF0}		-21.7		dBm
RF power accuracy			P_{RFAC}	-4		+4	dB
Receiver Operation							
Sensitivity for 0.1% BER at room temperature	HS 1.5	4			-115		dBm
	HS 3	4			-113		dBm
	HS 6	4			-111		dBm

Parameter	Conditions	Notes	Symbol	Min	Typ	Max	Unit
	HS 12	4			-107		dBm
	NS 24	4			-102		dBm
	NS 48	4			-98		dBm
	NS 72	4			-96		dBm
Maximum input power for 0.1% BER	HS 1.5	4,5			+10		dBm
	HS 3	4,5			+10		dBm
	HS 6	4,5			+10		dBm
	HS 12	4,5			+10		dBm
	NS 24	4			+10		dBm
	NS 48	4			+10		dBm
	NS 72	4			+10		dBm

Note 1: Frequency accuracy includes stability over temperature range and aging of the quartz. Initial correction including the effect of printed circuit and crystal capacitors, must be stored in the Host in a Non Volatile Memory as a fixed correction to be added on the channel frequency code (see Section 5.2.7). Alternatively, an on-chip OTP (One Time Programmable) memory can be used. Please refer to the application note.

Note 2: Data rate "on air". Bit stuffed data bit rate (maximum 4 consecutive same symbols) is between 80 and 100% of this value.

Note 3: See Table 14 for more detailed PA power settings.

Note 4: BER (Bit Error Rate) is measured in Transparent mode (see Section 5.2.25) with demodulated data on `MISO` and fixed data clock coupled from Data PN15 generator. Because of long preamble (internally fixed at 3 * **`Address[7:0]`** byte) used in RF2401 communication protocol, the PER corresponds to about BER + 3 dB sensitivity.

Note 5: Under certain crystal clock offset conditions and on specific channels, this parameter can be reduced to -35 dBm. Please ask for the corresponding application note.

3.4 Target RF characteristics

The RF characteristics of the RF2401 are provided a s indicative information. These parameters are not measured on production units and are not guaranteed.

Typical values are generally stated at room temperature (T=25°C) with a supply voltage of `VBAT` = 2.5V.

Table 7: Target RF characteristics

Parameter	Conditions	Notes	Symbol	Min	Typ	Max	Unit
General RF conditions							
Synthesizer frequency step size			F_{Cstep}		793		Hz
Transmitter Operation							
Frequency deviation for 01010101 repeating sequence		1	Δf_{M1}	±45	±50	±55	kHz
Frequency drift for any packet length					0		kHz
Power transmitted at freq offset $\lvert f_{offs} \rvert$ = 2MHz	72kbps		P_{RF12}			-20	dBm
Power transmitted at freq offset $\lvert f_{offs} \rvert$ = 3MHz	72kbps		P_{RF13}			-30	dBm
Power transmitted at freq offset $\lvert f_{offs} \rvert$ = 4MHz	72kbps		P_{RF24}			-45	dBm
Power transmitted at freq offset $\lvert f_{offs} \rvert$ ≥ 6MHz	72kbps		P_{RF26}			-50	dBm
Spurious emission in operating mode $f \leq 1GHz$		2				-57	dBm

Parameter	Conditions	Notes	Symbol	Min	Typ	Max	Unit
Spurious emission in operating mode for f = n * (f_{OP} / 2), n is integer > 0		2,4				-20	dBc
Spurious emission in operating mode for other f > 1GHz		2,4				-47	dBc
Receiver Operation							
Spurious emission for 25MHz < f < 1GHz						-57	dBm
Spurious emission for f > 1GHz						-47	dBm

Conditions: VBAT = 2.5V

Note 1: Positive frequency deviations are represented by a logic level '1', and negative frequency deviations are represented by a logic level '0'.

Note 2: Measuring conditions and signals specifications as described in ETSI EN 300 440-1 V1.6.1, TX §7.3.

Note 3: Measuring conditions and signals specifications as described in ETSI EN 300 328 V1.8.1, TX §4.3; RX §8.4.

Note 4: Depending on the setting of the output power an additional harmonic filter may be needed to comply with local regulations.

The RF2401 was designed for compliance with the following standards:

1. ETSI EN 300 440-1 V1.6.1
2. ETSI EN 300 328 V1.8.1,
3. FCC Regulations Part 15, §15.247

Customers are however recommended to test compliance of their final systems incorporating or embedding the RF2401 with these or others standards as they may apply and to obtain all necessary licenses and authorizations.

3.5 Timing characteristics

Table 8: Timing Characteristics

Parameter	Notes	Symbol	Conditions	Min	Typ	Max	Unit
RX↔TX in same channel		t_{RX_TX}			200		μs
Standby mode → TX/RX mode	1	t_{STDBY_RF}		0.8	1	10	ms
Power-down → Standby mode		t_{PD_STDBY}			600	1000	μs
Standby mode → Power-down		t_{PD_STDBY}			10		μs
Power-down dwell time	2	t_{PD_DWELL}			20		ms
Auto-calibration		$t_{AUTOCAL}$			320		μs

Conditions: VBAT = 2.5V.

Note 1: Dominated by the crystal oscillator start-up time, which strongly depends on the quartz Q-factor. Typical values are for TSS-3225J, CL=10pF. Maximum is for TSS-3225J with significant margin for Q-factor spreading.

Note 2: Minimal timing necessary to generate correctly internal VDD_DIG POR.

4. Functional modes

4.1 Operational modes

This section describes the operational modes of the RF2401. An example state diagram is given in Figure 2, and each mode is described below. Custom modes are available on special request. The SPI interface is used to set or change the mode by loading and running the corresponding subroutine.

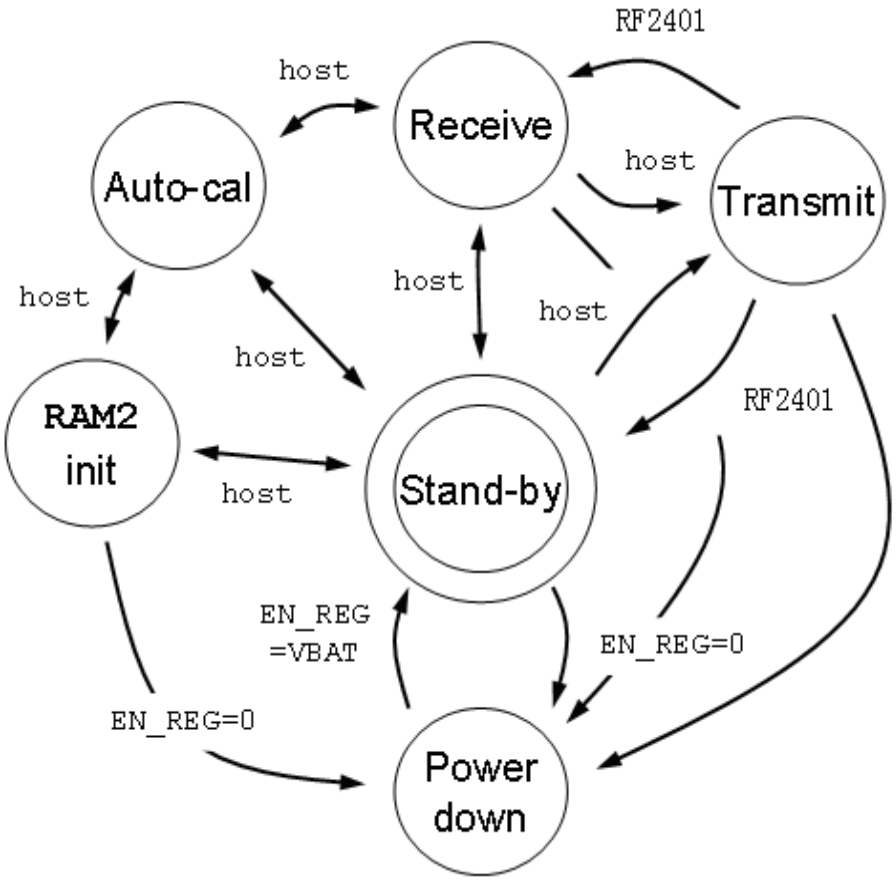


Figure 3: Example of state diagram of RF2401 modes

4.1.1 Power down

This mode is enabled when EN_REG terminal is tied to VSS or left floating (internal 3uA pull down). All regulators and the voltage reference are disabled and supply current on VBAT is in the nA range.

4.1.2 Standby mode

Upon connecting a battery to the VBAT pin and setting the pin EN_REG = VBAT, the regulated digital supply ramps up quickly (see Table 8). The SPI Register Memory is then set to 0 and the SPI waits the HOST programming.
In Standby mode, all internal circuits are disabled and can be accessed, including the crystal oscillator. The host can program the RF2401 for any operational mode at any time.

4.1.3 RAM2 Init mode

The RF2401 is configured through a 16x12 bit RAM memory **RAM2**. This RAM is reset to 0 when EN_REG signal is set from VSS to VBAT. In order to avoid 16 SPI **Write_RAM2** operations (see Section 5.1.1.9), a dedicated micro controller subroutine located at **ROM_BOOT_Address = 0** will initialize most **RAM2** addresses to their default value.

4.1.4 Auto-calibration modes

Global PTAT current
The internally generated PTAT current can be self-calibrated using an internal switch cap PTAT generator. This is usefull to get rid of the lousy poly resistor value tolerance (+- 30 %).

VCO center frequency
The RF2401 frequency synthesizer has an Auto-calibration mode that must be run periodically by the host. This keeps the channel frequency and FSK modulator operating within specification. Analog components in this block are sensitive to temperature variation, therefore performance may degrade or the link may fail if not run periodically. See Section 5.2.4 for programming details.

4.1.5 Transmit (TX) mode

In TX mode, the RF2401 outputs a FSK-modulated packet to the antenna pins, returns to Receive mode or to Standby mode with crystal oscillator enabled and sets the interrupt pin `IRQ` high. Depending on the chosen subroutine, the RF2401 can either transmit the whole **`TXFIFO`** (till **`TXFIFO`** size = 0) or a predefined number of bytes (packet size including the header) programmed in **`RAM2`**.

TX mode is activated from Receive mode or from Standby mode with crystal oscillator enabled using the SPI command **`Send_TXFIFO`**.

4.1.6 Receive (RX) mode

In RX mode, the RF2401 is ready to receive a FSK-modulated packet from the antenna. After receiving a packet, the RF2401 sets interrupt pin `IRQ` high. Depending on the chosen subroutine, the RF2401 can either read the size of the packet to be received in the packet header or in **`RAM2`** (see Section 5.2.12).

5. User interface

This section describes information the user needs for programming and interfacing the RF2401. The major subsections include the digital interface, the programming interface and register descriptions.

5.1 Digital interface

The RF2401 can be controlled with a 4-wire serial peripheral interface (SPI). The four wires are:

SS: Slave select

SCK: Serial clock

MOSI: Serial data in to RF2401

MISO: Serial data out of RF2401

Details of the SPI interface are provided in Section 5.1.1.

The RF2401 has a programmable interrupt pin (IRQ). The IRQ pin is activated or disabled by the micro-controller.

The RF2401 has 2 programmable open drain type outputs RX_ON and TX_ON in order to connect external PA or LNA. Those outputs polarity can be set independently.

A more detailed description of setting the IRQ, RX_ON & TX_ON pins is available upon special request.

The RF2401 also has a dedicated DIV_CK output pin to output a divided version of the internal crystal clock (26MHz). This divided frequency can be disabled or chosen @ 3.25MHz, 325kHz or 32.5kHz (see Section 5.2.5).

All internal enables signals and parameters of the RF2401 are mapped in a small 16x12 bits memory called **RAM2**. **RAM2** can directly be accessed through SPI and no crystal clock is required. See Section 5.3 for **RAM2** mapping description.

5.1.1 SPI operations

The SPI interface is used to read from and to write into all the registers of the RF2401.

SPI operations allow various accesses:

- Memories Write and Read actions
- Micro-controller commands
- Loading of subroutines in **RAM1**
- Test instructions (used in production)

A SPI transaction is defined as all of the activity on SCK, MOSI and MISO that occurs between one rising edge of SS and its next falling edge (see Figure 4 below). All the data shall be sent starting with the most-significant bit (MSB) first.
Not all the commands are encoded on a number of bits multiple of 8. Additional clocks can be sent after the command with no impact on the command decoding. Thus, the chip can be accessed without problems using an 8-bit wide SPI interface.
Each change to MOSI is latched on the rising edge of SCK, and each change to MISO is available on the falling edge of SCK. A timing diagram is shown in Figure 4. Complete timing specifications are given in Table 9.

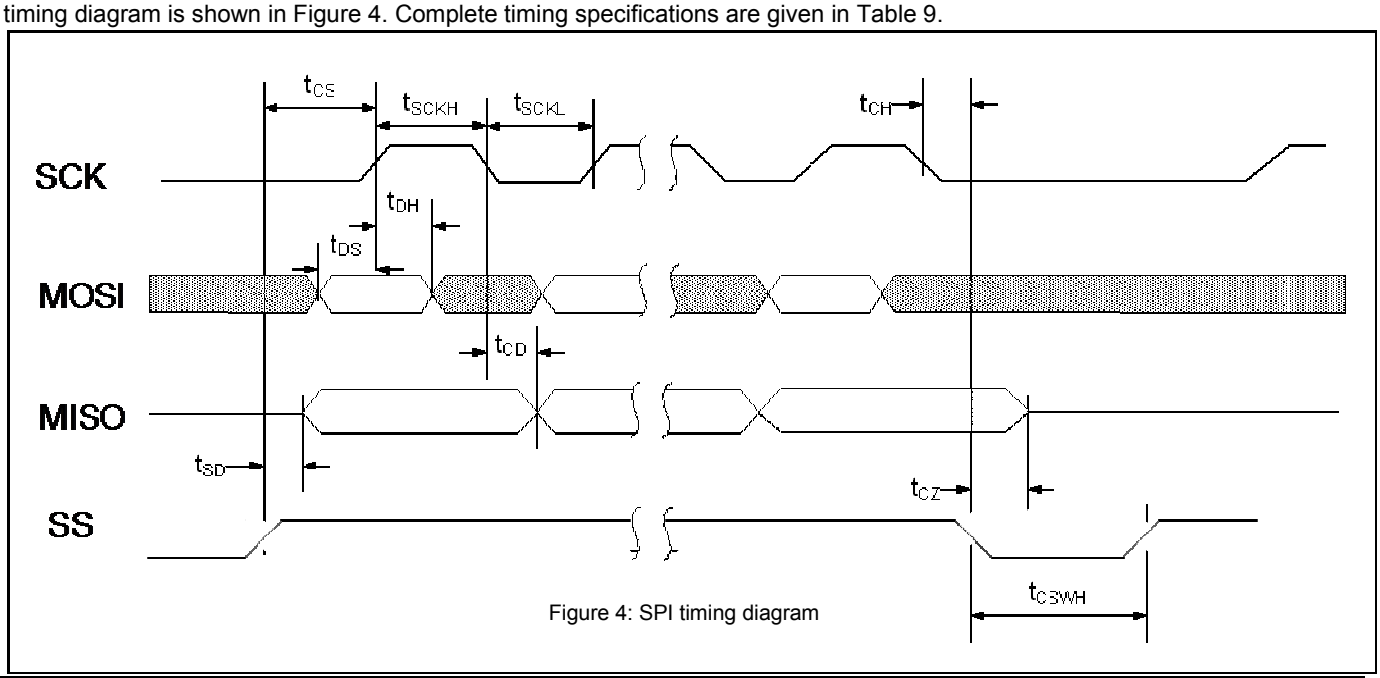


Figure 4: SPI timing diagram

Table 9: SPI timing values.

Condition: 25°C, 2.5V, 25pF.

Symbol	Parameters	Min	Max	Units
t_{DS}	MOSI to SCK Setup	5		ns
t_{DH}	SCK to MOSI Hold	5		ns
t_{SD}	SS to SDO Valid		30	ns
t_{CD}	SCK to MISO Valid		30	ns
t_{SCKL}	SCK Low Time	40		ns
t_{SCKH}	SCK High Time	40		ns
f_{SCK}	SCK Frequency	0	10	MHz
t_{CS}	SS to SCK Setup	20		ns
t_{CH}	SCK to SS Hold	20		ns
t_{CSWH}	SS Inactive Time	20		ns
t_{CZ}	SS to MISO High Z		30	ns

5.1.1.1 Status bits: `Status[2:0]`

For each SPI command, MISO will always give 3 status bits on the first 3 SCK cycles.

- As soon as SS goes high, the first status bit (**`Status[2]`**) is available on the MISO terminal. This bit is called "Previous_FIFO_Order_Pending" and is high when the micro controller has not yet processed the previous FIFO order. This process takes a maximum of 8 sck cycles and starts on the falling edge of the SS signal.
- **`Status[1]`** reflects the inactivity of the crystal oscillator (**`Status[1]`** = '0' means the crystal oscillator is running)
- **`Status[0]`** shows the unlock state of the 2.4GHz LO frequency synthesizer (**`Status[0]`** = 0 means the main LO PLL is locked).

For correct transmission operation, status[2:0] must be equal to '000'.

The possible SPI actions are described in the following chapters:

5.1.1.2 SPI command: `Read_RXFIFO`

MOSI	1	1	0	0	x	x	x	x	x	x	x	x	x	x	x	x
MISO	**`Status[2..0]`**			**`RXFIFO_Size[4..0]`**					**`RXFIFO_Data[7..0]`**							

This command returns the next byte out of the **`RXFIFO`**. It also returns the total number of bytes currently available in the **`RXFIFO`** (including this one / the one being read).
This SPI operation works together with the internal micro-controller and is functional only when this latter has been started (SPI command **`Start_Micro`**) and when the master clock is active (Crystal oscillator must be enabled). The order is taken into account only when SS signal goes down and the **`RXFIFO`** size information are sampled by mck when SS is low.
The general timing is illustrated in Figure 5.

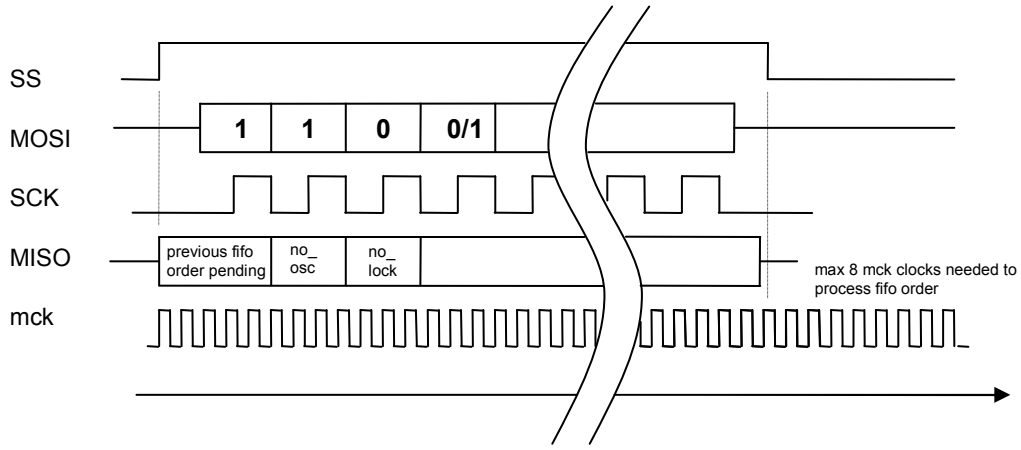


Figure 5 : timing of the SPI **Read_RXFIFO** / **Write_TXFIFO** command

5.1.1.3 SPI command: Write_TXFIFO

MOSI	1	1	0	1	**TXFIFO_Data[7..0]**		x	x	x	x
MISO	**Status[2..0]**			**RXFIFO_Size[4..0]**		**TXFIFO_Size[4..0]**		x	x	x

This command writes a byte to the **TXFIFO**. It also returns the total number of bytes in both FIFOs, not including this one.
This SPI operation works together with the internal micro-controller and is functional only when this latter has been started (SPI command **Start_Micro**) and when the master clock is active (Crystal oscillator must be enabled). The order is taken into account only when SS signal goes down and the **FIFO** size information are sampled by mck when SS is low.
The general timing is illustrated in Figure 5.

5.1.1.4 SPI command: Read_RXFIFO_Size

MOSI	1	1	1	0	0	0	0	x	x	x	x	x
MISO	**Status[2..0]**			x	x	x	x	**RXFIFO_Size[4..0]**				

This command reads the total number of bytes currently available in the **RXFIFO**.

5.1.1.5 SPI command: Read_TXFIFO_Size

MOSI	1	1	1	0	0	0	1	x	x	x	x	x
MISO	**Status[2..0]**			x	x	x	x	**TXFIFO_Size[4..0]**				

This command reads the total number of bytes currently available in the TXFIFO.

5.1.1.6 SPI command: `Read_RAM1`

MOSI	0	0	1	address[5..0]						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MISO	**Status[2..0]**			x	x	x	x	x	x	data_read[11..0]													x	x	x

This command reads the 12-bits word from the specified address (6 bits) of **RAM1**. This command will put the micro controller on hold until last bit has been processed.

5.1.1.7 SPI command: `Write_RAM1`

MOSI	0	0	0	address[5..0]						data_write[11..0]													x	x	x
MISO	**Status[2..0]**			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

This command writes a 12-bits word to the specified address (4 bits) of **RAM1**. This command will put the micro controller on hold until last bit has been processed.

5.1.1.8 SPI command: `Read_RAM2`

MOSI	0	1	1	address[3..0]				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
MISO	**Status[2..0]**			x	x	x	x	data_read[11..0]															x	x	x	x	x

This command reads the 12-bits word from the specified address (4 bits) of **RAM2**. This command will put the micro controller on hold until last bit has been processed.

5.1.1.9 SPI command: `Write_RAM2`

MOSI	0	1	0	address[3..0]				data_write[11..0]															x	x	x	x	x
MISO	**Status[2..0]**			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

This command writes a 12-bits word to the specified address (4 bits) of RAM2. This command will put the micro controller on hold until last bit has been processed.

5.1.1.10 SPI command: `Reset_Micro`

MOSI	1	1	1	0	0	1	0	x
MISO	**Status[2..0]**			x	x	x	x	x

This instruction allows an asynchronous reset of the micro controller. Never use this command when the Micro is running (RAM2 and FIFO's content could be corrupted). Always first stop the Micro using SPI command **Stop_Micro** prior to use **Reset_Micro**.

5.1.1.11 SPI command: `Stop_Micro`

MOSI	1	1	1	0	0	1	1	x
MISO	**Status[2..0]**			x	x	x	x	x

This command stops the micro-controller.

5.1.1.12 SPI command: `Start_Micro`

MOSI	1	1	1	0	1	0	0	x
MISO	**Status[2..0]**			x	x	x	x	x

This command starts the micro-controller and executes the program currently stored in **RAM1**.

5.1.1.13 SPI command: `Clear_IRQ`

MOSI	1	1	1	0	1	0	1	x
MISO	**Status[2..0]**			x	x	x	x	x

Use this command to reset the IRQ signal. It works only when micro-controller is running.

5.1.1.14 SPI command: Send_TXFIFO

MOSI	1	1	1	0	1	1	0	x
MISO	Status[2..0]			x	x	x	x	x

This command will send the current contents of the **TXFIFO**. Depending on the selected subroutine, the program either send the full content of the FIFO, or the number of bytes specified in **RAM2**.

5.1.1.15 SPI command: Command2

MOSI	1	1	1	0	1	1	1	x
MISO	Status[2..0]			x	x	x	x	x

This command allows the Channel RSSI to be read and stored to **Limit_RSSI[3:0]**.

5.1.1.16 SPI command: ROM_Boot

MOSI	1	1	1	1	0	0	0	ROM_Boot_Address[8..0]							
MISO	Status[2..0]			x	x	x	x	x	x	x	x	x	x	x	x

This command copies the 64 12-bits instructions from the specified **ROM** address to **RAM1**. This allows for fast initialization of the micro-controller subroutines.
The crystal oscillator must be enabled to perform this operation. Additionally, **ROM_Boot** command stops and resets the micro-controller.

5.1.1.17 SPI command: ROM_Boot0_and_Start

MOSI	1	1	1	1	1	1	1	x
MISO	Status[2..0]			x	x	x	x	x

This command copies the 64 12-bits instructions from the **ROM** address **0** to **RAM1**. This allows for fast initialization of the micro-controller subroutines.
The crystal oscillator must be enabled to perform this operation. Additionally, **ROM_Boot0_and_Start** command resets and starts the micro-controller.

5.2 Programming interface

The Programming interface section describes how to program the RF2401 by writing to the RF2401 **RAM2** or by booting and running in **ROM** stored subroutines. The complete **RAM2** description can be found in Section 5.3.

5.2.1 RAM2, RAM1 reset

The RF2401 automatically performs a power on reset to **RAM1, RAM2** when internal VDD_DIG voltage is established (after EN_REG terminal is set to VBAT from VSS) → see Section 3.5 for minimal timing.

After reset, all RF communication setup parameters (RF channel, etc.) must be reconfigured (see Section 5.2.2), and the PLL auto-calibration cycle must be initiated again.

5.2.2 RAM2 Initialization

The RF2401 has a dedicated subroutine located at the **ROM_Boot_Address = 0** which will initialize the **RAM2** memory to its default state (see Section 5.3).
To request the **RAM2** initialization, EN_REG terminal must be enabled. VDD_SYNTH, VDD_RXTX regulators and crystal oscillator must be started by writing "111000000100" in the **RAM2** at the address **0** (see Section 5.1.1.9). Quartz activity can be monitored through **Status[1]** (see Section 5.1.1.1) by using a simple **Stop_Micro** SPI command, for example. When **Status[1]** has gone low, the **RAM2** initialization subroutine can be executed. This is achieved by the SPI command **ROM_Boot** described in Section 5.1.1.16 with argument **ROM_Boot_Address = 0**.
There are then 2 possibilities to start the subroutine:

Manual Boot (only RAM2 initialization subroutine is executed):
→In this case, the ROMboot instruction of the micro controller must be disabled. Use SPI command **Write_RAM1** with address = **13** and data_write = **1184** (this will initialize **RAM2** with **RB_Inst_Dis = 1**, see Section 5.2.27).
Use then the SPI command **Start_Micro** described in Section 5.1.1.12.The end of initialization will be signaled with IRQ going high. SPI command **Clear_IRQ** (see Section 5.1.1.13) allows clearing the interrupt.

Automatic Boot (Following in ROM chained subroutines will be successively booted and executed):
→ Use then the SPI command **Start_Micro** described in Section 5.1.1.12. In this case, RAM2 initialization subroutine is executed and following subroutines will be automatically booted and executed. The default chain stored in **ROM** is:

- RAM2 Initialization(located @ **ROM_Boot_Address = 0**)
- Internal PTAT current value auto-calibration(located @ **ROM_Boot_Address = 33**)
- VCO code auto-calibration on center band frequency (2440 MHz) (located @ **ROM_Boot_Address = 64**)
- High Sensitivity Communication Subroutine with payload defined in **RAM2** (located @ **ROM_Boot_Address = 128**).

Note 1: Using SPI short command **ROM_Boot0_and_Start** will also result in Automatic Boot.

5.2.3 Internal PTAT current value auto-calibration

This auto-calibration is used to calibrate the current delivered by the internal PTAT generator. It refers to the internally generated switch cap current of the IF filter which also takes into account the general process variation through body effect coefficient.
To load the auto-calibration in **RAM1** memory, EN_REG terminal must be enabled. VDD_SYNTH, VDD_RXTX regulators must be enabled and crystal oscillator must be running (see Section 5.2.2). Use then the SPI command **ROM_Boot** (Section 5.1.1.16) with argument **ROM_Boot_Address = 33** (location of the auto-calibration subroutine in the **ROM**).
There are then 2 possibilities to start the subroutine:

Manual Boot (only internal PTAT current value auto-calibration subroutine is executed):
→Set the ROOMBOOT instruction disable bit **RB_Inst_Dis = 1** using SPI command **Write_RAM2** (see Section 5.2.27). If **RB_Inst_Dis** has been previously set = **1**, this step can be omitted. Use then the SPI command **Start_Micro** described in Section 5.1.1.12.The end of auto-calibration will be signaled with IRQ going high. SPI command **Clear_IRQ** (see Section 5.1.1.13) allows clearing the interrupt.

Automatic Boot (Following in ROM chained subroutines will be successively booted and executed):
→Set the ROOMBOOT instruction disable bit **RB_Inst_Dis = 0** using SPI command **Write_RAM2** (see Section 5.2.27). If **RB_Inst_Dis** has been previously set = **0**, this step can be omitted. Use then the SPI command **Start_Micro** described in Section 5.1.1.12. In this case, internal PTAT current value auto-calibration subroutine is executed and following chained subroutines will be automatically booted and executed. The default chain stored in **ROM** is:

- Internal PTAT current value auto-calibration(located @ **ROM_Boot_Address = 33**)
- VCO code auto-calibration on center band frequency (2440 MHz) (located @ **ROM_Boot_Address = 64**)
- High Sensitivity Communication Subroutine with payload defined in **RAM2** (located @ **ROM_Boot_Address = 128**).

The calibration of the PTAT should be independent of temperature and only needs to be executed once when chip is powered. Because this value should be constant during product life, it is possible to do calibration only once and to store **RAM2@5<3:0>**

value somewhere in a non volatile memory. **Write_RAM2** SPI command with this prestored value could then be used to set the correct internal PTAT current.

5.2.4 VCO code auto-calibration

This auto-calibration is used to calibrate the analog circuits of the PLL. For correct transmission and reception, the PLL should be calibrated at each channel frequency to be used before the link is established.
To load the auto-calibration in **RAM1** memory, EN_REG terminal must be enabled. VDD_SYNTH, VDD_RXTX regulators must be enabled and crystal oscillator must be running (see Section 5.2.2). Use then the SPI command **ROM_Boot** (Section 5.1.1.16) with argument **ROM_Boot_Address = 64** (location of the auto-calibration subroutine in the **ROM**).

Auto-calibration frequency is set trough register **VcoCalibFreq[11:0]** which is located in **RAM1** at the address **53** (default value of **VcoCalibFreq[7:0] = 128** when VCO frequency auto-calibration subroutine is loaded). It must be programmed through the SPI **Write_RAM1** command to fit the required frequency operation. **VcoCalibFreq[11:0]** is:

VcoCalibFreq[7:0] = (round(4'259'840 / Fo) – 1'618); where Fo is the RF operating frequency in MHz.

VcoCalibFreq[11:8] = "1011".

Examples: Fo = 2480, hex **VcoCalibFreq[11:0]** = 'B64'.

Fo = 2440, hex **VcoCalibFreq[11:0]** = 'B80'.

Fo = 2400, hex **VcoCalibFreq[11:0]** = 'B9D'.

There are then 2 possibilities to start the subroutine:

Manual Boot (only VCO code auto-calibration subroutine is executed):
→Set the ROOMBOOT instruction disable bit **RB_Inst_Dis = 1** using SPI command **Write_RAM2** (see Section 5.2.27). If **RB_Inst_Dis** has been previously set = **1**, this step can be omitted. Use then the SPI command **Start_Micro** described in Section 5.1.1.12.The end of initialization will be signaled with IRQ going high. SPI command **Clear_IRQ** (see Section 5.1.1.13) allows clearing the interrupt.

Automatic Boot (Following in ROM chained subroutines will be successively booted and executed):
→Set the ROOMBOOT instruction disable bit **RB_Inst_Dis = 0** using SPI command **Write_RAM2** (see Section 5.2.27). If **RB_Inst_Dis** has been previously set = **0**, this step can be omitted. Use then the SPI command **Start_Micro** described in Section 5.1.1.12. In this case, VCO code auto-calibration subroutine is executed and following chained subroutines will be automatically booted and executed. The default chain stored in **ROM** is:

- VCO code auto-calibration on chosen frequency (located @ **ROM_Boot_Address = 64**)
- High Sensitivity Communication Subroutine with payload defined in **RAM2** (located @ **ROM_Boot_Address = 128**).

In both manual and automatic Boot, the end of the VCO code auto-calibration routine will be signaled with IRQ going high. SPI command **Clear_IRQ** (see Section 5.1.1.13) allows clearing the interrupt.

The calibration of the PLL may vary if the external conditions change (e.g., temperature), therefore calibration should be repeated periodically.

5.2.5 External Clock frequency (on DIV_CK terminal)

The Frequency of the optional clock output can be set through the register **Ck_Pad[1:0]** (**RAM2@0[4:3]**) as shown in Table 10.

Table 10: **Ck_Pad** Frequencies

Control Bits **Ck_Pad[1:0]**	**Outputted Clock Frequency on Div_Ck**
'00'	no clock
'01'	3.25 MHz
'10'	325 kHz
'11'	32.5 kHz

5.2.6 Channel Data rate

The RF2401 has a programmable channel data rate of 1.5kbps to 72kbps for transmission and reception in normal sensitivity mode. The channel data rate is set by **R_Bit_Clk[8:0]** (**RAM2@12[8:0]**) and **Ch_Rate[2:0]** (**RAM2@12[11:9]**) as shown in Table 11. The complete typical values **RAM2@12[11:0]** is also reported. In high sensitivity mode, only the 4 slower data rates are available (**Ch_Rate[2:0]** = '000' to '011').

Table 11: Channel Data Rate

On air bit rate [kbps]	minimum data bit rate[kbps]	Ch_Rate[2:0]	R_Bit_Clk[8:0]	RAM2@12[11:0] [hex]
1.5	1.2	'000'	'110000000'	0x180
2.99	2.392	'001'	'011000000'	0x2C0
6.02	4.816	'010'	'001011111'	0x45F
12.037	9.629	'011'	'000101111'	0x62F
24.074	19.26	'100'	'000010111'	0x817
48.15	38.52	'101'	'000001011'	0xA0B
72.22	57.77	'110'	'000000111'	0xC07

The exact recovered and transmitted bit rate is given by:

On air bit rate = 26e6 / 45 / (unsigned(**R_Bit_Clk[8:0]**)+1) [bit/sec]

To establish a communication, both linked devices must be set to the same data rate.

5.2.7 RF Frequency of operation

The channel register sets the center frequency of the transmission channel used by the RF2401. The channel is set by the **Frequ[16:0]** register. Each time RF frequency is defined, VCO code auto-calibration subroutine must be executed with corresponding frequency parameter (see Section 5.2.4).

The RF center frequency is defined as:

Frequency should be between 2400MHz and 2484MHz

Frequency = fref * (92 + unsigned(**Frequ[16..0]**) / 2^15), with fref = 26MHz.

The channel step is given by 26MHz / 32768 and is about equal to 793Hz.

The RF frequency must be corrected to compensate the initial crystal oscillator deviation. After printed circuit board assembly and frequency measurement, a value must be stored in the Host in a Non Volatile Memory as a fixed correction to be added on the channel frequency code. Alternatively, an on-chip OTP (One Time Programmable) memory can be used. Please refer to the application note for the frequency measurements and correction methods.

To establish a communication, both linked devices must be set to the same channel. The host can program a channel change, which is validated when SPI signal SS goes down.

Channel spacing of 4 MHz is recommended to limit interference with other RF2401 devices operating on adjacent channels. The table below describes a possible definition of the channels.

Table 12: Channel Frequency Selection

Channel	Frequency [MHz]	Frequ[16:5] [hex]	Frequ[4:0] [hex]	VcoCalibFreq[11:0] [hex]
0	2401.5	0x176	0x11	0xB9C
1	2405.5	0x213	0x16	0xB99
2	2409.5	0x2B1	0x07	0xB96
3	2413.5	0x34E	0x18	0xB93
4	2417.5	0x3EC	0x09	0xB90
5	2421.5	0x489	0x1B	0xB8D
6	2425.5	0x527	0x0C	0xB8A

7	2429.5	0x5C4	0x1D	0xB87
8	2433.5	0x662	0x0E	0xB84
9	2437.5	0x700	0x00	0xB82
10	2441.5	0x79D	0x11	0xB7F
11	2445.5	0x83B	0x02	0xB7C
12	2449.5	0x8D8	0x13	0xB79
13	2453.5	0x976	0x04	0xB76
14	2457.5	0xA13	0x16	0xB73
15	2461.5	0xAB1	0x07	0xB71
16	2465.5	0xB4E	0x18	0xB6E
17	2469.5	0xBEC	0x09	0xB6B
18	2473.5	0xC89	0x1B	0xB68
19	2477.5	0xD27	0x0C	0xB65

5.2.8 Address Byte

The Address byte is used in the packet preamble in order to set the byte start in the bit to byte built in reconstruction algorithm. Decimal value of **`Address[7:0]`** must be different from **`0, 48, 51, 99, 102, 146, 153, 204`**. For proper communication between two devices the receiving device must set the **`Address[7:0]`** register to match the transmitting device's **`Address[7:0]`** register.

5.2.9 Bit stuffing

To make the clock recovery procedure easier for the receiver, the data transmitted is automatically bit stuffed with a hardwired algorithm. The internal bit stuffing procedure is allowing a maximum of 4 consecutive same symbols to be transmitted. It corresponds to a minimum efficiency of 80%, or a minimum bit rate described by Table 13.

Table 13: "On air" versus Minimum Bit stuffed Bit Rates

Selected "on air" bit rate[kbps]	Minimum bit stuffed data bit rate [kbps]
1.5	1.2
3	2.4
6	4.8
12	9.6
24	19.2
48	38.4
72	57.6

5.2.10 TX power level

The PA output power can be adjusted to many different levels from -20dBm to +10 dBm with different efficiencies.

Table 14 shows 8 typical levels with optimum efficiency. These levels are set by **`I_Pre_PA[4:0]`** and **`I_PA[4:0]`** register bits. Typical current consumption and PA efficiency for each of these power levels are also shown.

Table 14: RF power settings for the RF2401

Power Level	`I_Pre_PA[4:0]` [unsigned decimal]	`I_PA[4:0]` [unsigned decimal]	Output Power [dBm]	PA Power efficiency [%]	DC total Current Consumption [mA]
7	29	18	+10	27.3	36.3

6	21	5	+9.3	29.7	29.5
5	10	2	+6.6	24.2	20,7
4	7	1	+2.7	15.8	14.4
3	4	1	-1.1	9.4	11.2
2	3	1	-3.1	7	10.2
1	1	1	-10.4	1.9	8.1
0	16	0	-21.7	0.2	6.9

Measurement conditions: 72kbps, f0=2440MHz, VBAT = 2.45V, VSS=0V, T=25 °C, load impedance = 100Ω differential (BALUN type: 2450FB15A0100E 2.45GHZ 1:2BALUN T&R JOHANSON), other **RAM2** parameters set to default values. Output Power is measured at the output of the BALUN.

5.2.11 External PA and LNA control

A control signal for an external Power Amplifier or low noise Amplifier is available if a higher transmit output power is required than the RF2401 can output or when a higher sensiti vity is needed. The TX_ON & RX_ON pins provide open drains controlled through the internal software. It is possible to control the polarity by programming the **RAM1** memory accordingly. Inverted polarity can be obtained on special request. When using an external Power Amplifier, the user is requested to comply with all ISM band regulations.

5.2.12 Packet (TX and RX) payload

5.2.12.18 Mode payload size in the header:

In this mode (defined by the SPI Command **ROM_Boot** @256 or 320), the transmit payload can be up to 31 bytes. A header byte which defines the packet size is added (See Section 6). The payload (and header) are read and written through the SPI command **Read_RXFIFO** and **Write_TXFIFO** (See Section 5.1.1).

5.2.12.19 Mode payload size in RAM2:

In this mode (defined by the **ROM_Boot** @128 or 192), the transmit payload can be up to 32 bytes, but the first byte following the Address byte has to be different from **Address[7:0]**. Payload size is defined in the register **N_Pay[4:0]** (**RAM2@14[4:0]**). The payload is read and written through the SPI command **Read_RXFIFO** and **Write_TXFIFO** (See Section 5.1.1).

5.2.13 Registers: TXFIFO and RXFIFO

RF2401 has two 32 bytes FIFO's (**TXFIFO** and **RXFIFO**). The transmit **TXFIFO** can be accessed through the SPI command **Write_TXFIFO**. The receive **RXFIFO** can be accessed through the SPI command **Read_RXFIFO**.

The transmit FIFO must be loaded prior to transmission. The size of the transmit **TXFIFO** is monitored at each write FIFO command or can be viewed at any time through the command **Read_TXFIFO_Size** (see Section 5.1.1.5).

The receive **RXFIFO** can be read after an incoming packet has been received. The size of the receive **RXFIFO** is monitored at each **Read_FIFO** command or can be viewed at any time through the command **Read_RXFIFO_Size** (see Section 5.1.1.4).

Note: Both **TXFIFO** and **RXFIFO** are managed by the micro controller, which means that this latter must be enabled (**Start_Micro**) and running (crystal oscillator enabled, **Status[1]** = '0'). Also, the SPI command **Reset_Micro** will reset all internal **TXFIFO** and **RXFIFO** pointers to 0.

5.2.14 Transmission flow, "high sensitivity", mode payload defined in RAM2, quick control (automatic ROMboot).

This section describes the entire flow for transmitting data on the RF2401 in high sensitivity mode (w hole **TXFIFO** is transmitted):

1. Start the RF2401 by setting EN_REG terminal equa l to VBAT.
2. Perform a first **RAM2** initialization:
   a. Start both VDD_SYNTH and VDD_RXTX regulators + crystal oscillator by writing (SPI command **Write_RAM2**) "111000000100" in **RAM2@0** (see Section 5.1.1.9).
   b. Wait 1 to 10ms for the crystal to start. Oscillator activity can be poled trough **Status[1]** (see Section 5.2.2).

c. Use the SPI command **ROM_Boot0_and_Start** (see Section 5.1.1.17). RF2401 will set default initialization parameters, auto calibrate internal PTAT and VCO on 2440 MHz band, set IRQ pin high and boot the Communication subroutine located at **ROM_BOOT_address = 128**.

d. Use the SPI command **Clear_IRQ** (see Section 5.1.1.13) to clear the interrupt.

3. Write the **TXFIFO** through SPI **Write_TXFIFO** (see Section 5.1.1.3).
4. Use SPI **Send_TXFIFO** command to transmit the packet.
5. The RF2401 will:
   a. Send the Packet with payload size defined in **RAM2**.
   b. Set the IRQ pin high when transfer is complete.
6. User can reset the IRQ signal by using the SPI command **Clear_IRQ**.
7. Next Packet transmission only implies steps 3 to 6 to be repeated.

Note 0: The Data Bit Rate, transmit power and carrier frequency are now default like defined in the default of Section 5.3. Use SPI command **Write_RAM2** to redefine those parameters if needed.

Note 1: Transmission mode is started from reception mode. So, it is not possible to exclude that an incoming packet has triggered the IRQ before Sent Packet IRQ is activated (IRQ is the same for all operational modes). The SPI command **Read_TXFIFO_Size** and **Read_RXFIFO_Size** allows the user to look at both **TXFIFO** and **RXFIFO** to determine the origin of the interruption.

Note 2: Transmission mode is operated by the internal micro controller. This latter operates by taking control of **RAM2** and **TXFIFO**. Read and Write SPI accesses to **RAM2** will put the micro controller on hold and possibly corrupt the correct transmission operation if SPI transaction time is too long (if SCK frequency is close to channel data rate). To retrieve **RAM2** values (like **Limit_RSSI[3:0]** or **DFT_Mes[7:0]** for example), the best is to proceed (with SPI command **Read_RAM2**) just after IRQ signal has gone high and not just after a **Send_TXFIFO** request.

5.2.15 Reception flow, “high sensitivity”, mode payload defined in RAM2, quick control (automatic ROMboot).

This section describes the entire flow for receiving data on the RF2401 in high sensitivity mode with payload size defined in header:

1. Start the RF2401 by setting EN_REG terminal equal to VBAT.
2. Perform a first **RAM2** initialization:
   a. Start both VDD_SYNTH and VDD_RXTX regulators + crystal oscillator by writing (SPI command **Write_RAM2**) “111000000100” in **RAM2@0** (see Section 5.1.1.9).
   b. Wait 1 to 10ms for the crystal to start. Oscillator activity can be poled trough **Status[1]** (see Section 5.1.1.1).
   c. Use the SPI command **ROM_Boot0_and_Start** (see Section 5.1.1.17). RF2401 will set default initialization parameters, auto calibrate internal PTAT and VCO on 2440 MHz band, set IRQ pin high and boot the Communication subroutine located at **ROM_BOOT_address = 128**.
   d. Use the SPI command **Clear_IRQ** (see Section 5.1.1.13) to clear the interrupt.
3. The RF2401 will:
   a. Wait an incoming Packet with payload size defined in **RAM2** and store it in the **RXFIFO** (including the header).
   b. Set the IRQ pin high when packet has been stored in the **RXFIFO**.
4. User can reset the IRQ signal by using the SPI command **Clear_IRQ**.
5. User can read the **RXFIFO** using the SPI command **Read_RXFIFO** (see Section 5.1.1.2).

Note 0: The Data Bit Rate, transmit power and carrier frequency are now default like defined in the default of Section 5.3. Use SPI command **Write_RAM2** to redefine those parameters if needed.

Note 1: Transmission mode is normally started from reception mode. So, it is not possible to exclude that an incoming packet has triggered the IRQ before Sent Packet IRQ is activated (IRQ is the same for all operational modes). The SPI command **Read_TXFIFO_Size** and **Read_RXFIFO_Size** allow the user to look at both **TXFIFO** and **RXFIFO** to determine the origin of the interruption.

Note 2: Reception mode is operated by the internal micro controller. This latter operates by taking control of **RAM2** and **RXFIFO**. Read and Write SPI accesses to **RAM2** will put the micro controller on hold and possibly corrupt the correct reception operation if SPI transaction time is too long (if SCK frequency is close to channel data rate). To retrieve **RAM2** values (like

Limit_RSSI[3:0] or **DFT_Mes[7:0]** for example), the best is to proceed (with SPI command **Read_RAM2**) just after IRQ signal has gone high.

5.2.16 Transmission flow, "high sensitivity", mode entire TXFIFO, manual control (step by step).

This section describes the entire flow for transmitting data on the RF2401 in high sensitivity mode (whole **TXFIFO** is transmitted):

1. Start the RF2401 by setting EN_REG terminal equal to VBAT.
2. Perform a first **RAM2** initialization:
   a. Start both VDD_SYNTH and VDD_RXTX regulators + crystal oscillator by writing (SPI command **Write_RAM2**) "111000000100" in **RAM2@0** (see Section 5.1.1.9).
   b. Wait 1 to 10ms for the crystal oscillator to start. Oscillator activity can be poled trough **Status[1]** (see Section 5.1.1.1).
   c. Use the SPI command **ROM_Boot** with **ROM_Boot_Address = 0** (see Section 5.1.1.16).
   d. Use SPI command **Write_RAM1** with address = **13** and data_write = **1184** (to set RB_Inst_Dis = **1**, see Section 5.2.27).
   e. Use the SPI command **Start_Micro** (see Section 5.1.1.12).
   f. Wait the interrupt IRQ signal to go high (this will mean that crystal oscillator has started and that **RAM2** initialization subroutine has been executed).
   g. Clear IRQ using the SPI command **Clear_IRQ** (see Section 5.1.1.13).
3. Perform a PTAT auto-calibration sequence:
   a. Use the SPI command **ROM_Boot** with **ROM_Boot_Address = 33**.
   b. Use the SPI **Start_Micro** command.
   c. Wait the interrupt IRQ signal to go high (this will mean that PTAT auto-calibration subroutine has been executed).
   d. Clear IRQ using the SPI command **Clear_IRQ**.
4. Use SPI write **RAM2** command to configure:
   a. The data rate (**R_Bit_Clk[8:0]** (and **Ch_Rate[2:0]** for normal sensitivity), see Section 5.2.6).
   b. The output power (**I_Pre_PA[4:0]** and **I_PA[4:0]**, see Section 5.2.10).
   c. The Address byte **Address[7:0]** (see Section 5.2.8).
   d. The channel frequency **Frequ[16:0]** (see Section 5.2.7).
5. Perform a VCO auto-calibration sequence:
   a. Use the SPI command **ROM_Boot** with **ROM_Boot_Address = 64**.
   b. Program the center frequency for the auto-calibration via SPI command **Write_RAM1** (see Section 5.2.4)
   c. Use the SPI **Start_Micro** command.
   d. Wait the interrupt IRQ signal to go high (this will mean that VCO auto-calibration subroutine has been executed).
   e. Clear IRQ using the SPI command **Clear_IRQ**.
6. Boot high sensitivity communication software
   a. Use SPI command **ROM_Boot** with **ROM_Boot_Address = 256**.
   b. Start the micro controller with the SPI command **Start_Micro**
7. Write the **TXFIFO** through SPI **Write_TXFIFO** (see Section 5.1.1.3). The first byte written is the header and contents the payload size in its 5 LSBs.
8. Use SPI **Send_TXFIFO** command to transmit the packet.
9. The RF2401 will:
   a. Send the Packet until **TXFIFO** is empty.
   b. Set the IRQ pin high when transfer is complete.
10. User can reset the IRQ signal by using the SPI command **Clear_IRQ**.
11. Next Packet transmission only implies steps 6 to 9 to be repeated.

Note 1: Transmission mode is started from reception mode. So, it is not possible to exclude that an incoming packet has triggered the IRQ before Sent Packet IRQ is activated (IRQ is the same for all operational modes). The SPI command **Read_TXFIFO_Size** and **Read_RXFIFO_Size** allows the user to look at both **TXFIFO** and **RXFIFO** to determine the origin of the interruption.

Note 2: Transmission mode is operated by the internal micro controller. This latter operates by taking control of **RAM2** and **TXFIFO**. Read and Write SPI accesses to **RAM2** will put the micro controller on hold and possibly corrupt the correct transmission operation if SPI transaction time is too long (if SCK frequency is close to channel data rate). To retrieve **RAM2** values (like **Limit_RSSI[3:0]** or **DFT_Mes[7:0]** for example), the best is to proceed (with SPI command **Read_RAM2**) just after IRQ signal has gone high and not just after a **Send_TXFIFO** request.

5.2.17 Reception flow, "high sensitivity", mode payload size in header, manual control (step by step).

This section describes the entire flow for receiving data on the RF2401 in high sensitivity mode with payload size defined in header:

1. Start the RF2401 by setting EN_REG terminal equal to VBAT.
2. Perform a first **RAM2** initialization:
   a. Start both VDD_SYNTH and VDD_RXTX regulators + crystal oscillator by writing (SPI command **Write_RAM2**) "111000000100" in **RAM2@0** (see Section 5.1.1.9).
   b. Wait 1 to 10ms for the crystal oscillator to start. Oscillator activity can be poled trough **Status[1]** (see Section 5.1.1.1).
   c. Use the SPI command **ROM_Boot** with **ROM_Boot_Address** = **0** (see Section 5.1.1.16).
   d. Use SPI command **Write_RAM1** with address = **13** and data_write = **1184** (to set RB_Inst_Dis = **1**, see Section 5.2.27).
   e. Use the SPI command **Start_Micro** (see Section 5.1.1.12).
   f. Wait the interrupt IRQ signal to go high (this will mean that crystal oscillator has started and that **RAM2** initialization subroutine has been executed).
   g. Clear IRQ using the SPI command **Clear_IRQ** (see Section 5.1.1.13).
3. Perform a PTAT auto-calibration sequence:
   a. Use the SPI command **ROM_Boot** with **ROM_Boot_Address** = **33**.
   b. Use the SPI **Start_Micro** command.
   c. Wait the interrupt IRQ signal to go high (this will mean that PTAT auto-calibration subroutine has been executed).
   d. Clear IRQ using the SPI command **Clear_IRQ**.
4. Use SPI write **RAM2** command to configure:
   a. The data rate (**R_Bit_Clk[8:0]** (and **Ch_Rate[2:0]** for normal sensitivity), see Section 5.2.6).
   b. The output power (**I_Pre_PA[4:0]** and **I_PA[4:0]**, see Section 5.2.10).
   c. The Address byte **Address[7:0]** (see Section 5.2.8).
   d. The channel frequency **Frequ[16:0]** (see Section 5.2.7).
5. Perform a VCO auto-calibration sequence:
   a. Use the SPI command **ROM_Boot** with **ROM_Boot_Address** = **64**.
   b. Program the center frequency for the auto-calibration via SPI command **Write_RAM1** (see Section 5.2.4).
   c. Use the SPI **Start_Micro** command.
   d. Wait the interrupt IRQ signal to go high (this will mean that VCO auto-calibration subroutine has been executed).
   e. Clear IRQ using the SPI command **Clear_IRQ**.
6. Boot high sensitivity communication software
   a. Use SPI command **ROM_Boot** with **ROM_Boot_Address** = **256**.
   b. Start the micro controller with the SPI command **Start_Micro**
7. The RF2401 will:
   a. Wait an incoming Packet and store the number of byte stored in the header in the **RXFIFO** (including the header).

b. Set the IRQ PIN high when packet has been stored in the **RXFIFO**.

8. User can reset the IRQ signal by using the SPI command **Clear_IRQ**.
9. User can read the **RXFIFO** using the SPI command **Read_RXFIFO** (see Section 5.1.1.2).

Note 1: Transmission mode is normally started from reception mode. So, it is not possible to exclude that an incoming packet has triggered the IRQ before Sent Packet IRQ is activated (IRQ is the same for all operational modes). The SPI command **Read_TXFIFO_Size** and **Read_RXFIFO_Size** allow the user to look at both **TXFIFO** and **RXFIFO** to determine the origin of the interruption.

Note 2: Reception mode is operated by the internal micro controller. This latter operates by taking control of **RAM2** and **RXFIFO**. Read and Write SPI accesses to **RAM2** will put the micro controller on hold and possibly corrupt the correct reception operation if SPI transaction time is too long (if SCK frequency is close to channel data rate). To retrieve **RAM2** values (like **Limit_RSSI[3:0]** or **DFT_Mes[7:0]** for example), the best is to proceed (with SPI command **Read_RAM2**) just after IRQ signal has gone high.

5.2.18 Transmission flow, “high sensitivity”, mode payload size defined in RAM2

This section describes the entire flow for transmitting data on the RF2401 in high sensitivity mode with payload size defined in **RAM2**.

The steps are the same as described in Section 5.2.16, excepted:

The Payload size **N_Pay[4:0]** must be defined in step 4.

The header byte no longer defines the number of byte of the payload.

The **ROM_Boot_Address** must be set to **128** in step5.

5.2.19 Reception flow, “high sensitivity”, mode payload size defined in RAM2

This section describes the entire flow for receiving a packet with the RF2401 in high sensitivity mode, with payload size defined in **RAM2**.

The steps are the same as described in Section 5.2.17, excepted:

The Payload size **N_Pay[4:0]** must be defined in step 4.

The header byte no longer defines the number of byte of the payload.

The **ROM_Boot_Address** must be set to **128** in step5.

5.2.20 Transmission flow, “normal sensitivity”, mode entire TXFIFO

This section describes the entire flow for transmitting data on the RF2401 in normal sensitivity mode (whole **TXFIFO** is transmitted):

The steps are the same as described in Section 5.2.16, excepted:

The **ROM_Boot_Address** must be set to **320** in step 5.

5.2.21 Reception flow, “normal sensitivity”, mode payload size in header

This section describes the entire flow for receiving a packet with the RF2401 in normal sensitivity mode, with payload size defined in header.

The steps are the same as described in Section 5.2.17, excepted:

The **ROM_Boot_Address** must be set to **320** in step 5.

5.2.22 Transmission flow, “normal sensitivity”, mode payload size defined in RAM2

This section describes the entire flow for transmitting data on the RF2401 in normal sensitivity mode with payload size defined in **RAM2**.

The steps are the same as described in Section 5.2.16, excepted:

The Payload size **N_Pay[4:0]** must be defined in step 4.

The header byte no longer defines the number of byte of the payload.

The **ROM_Boot_Address** must be set to **192** in step 5.

5.2.23 Reception flow, "normal sensitivity", mode payload size defined in RAM2

This section describes the entire flow for receiving data on the RF2401 in normal sensitivity mode with payload size defined in **RAM2**.

The steps are the same as described in Section 5.2.17, excepted:

The Payload size **N_Pay[4:0]** must be defined in step 4.

The header byte no longer defines the number of byte of the payload.

The **ROM_Boot_Address** must be set to **192** in step 5.

5.2.24 Received Signal Strength Indicator (RSSI)

A received signal strength indicator (RSSI) is available through the register **Limit_RSSI[3:0]** located in **RAM2@8[3:0]**. A RSSI measurement can be activated in two different ways:

Packet RSSI

→The communication subroutines defined by SPI command **ROM_Boot** with **ROM_Boot_Address = 128, 192, 256** and **320** will write the RSSI measured during the packet reception to **RAM2** register **Limit_RSSI[3:0]**. Header + Payload size (see Section 6.1) must be greater than 1 byte to get a correct **Limit_RSSI[3:0]** value.

Channel RSSI

→The special subroutine defined by **ROM_Boot** with **ROM_Boot_Address = 248** will write the measured RSSI value to **RAM2** register **Limit_RSSI[3:0]** when SPI **command2** is activated. This allows the user to determine the amount of RF activity on a given channel. This is useful for determining if there is other RF activity on the channel (e.g., WiFi).

The relationship between the applied RF power, P_{IN} at the antenna **Limit_RSSI[3:0]** pins and the value given by the RSSI can be expressed as:

P_{IN} [dBm] = -120dBm + unsigned (**Limit_RSSI[3:0]**) * 8dB, for -105 dBm < P_{IN} < -60 dBm.

The accuracy of the RSSI is not guaranteed, and is provided for test purposes only. This accuracy could be improved by calibration means.

5.2.25 Transparent mode

The RF2401 can be configured in Transparent mode. This mode allows the users to directly control the data-stream by FSK Modulating the data present on MOSI in Transmit mode and to get the data directly at the output of the FSK demodulator in Receive mode. Some other configurations are used in testing phase. Information on transparent mode operation could be obtained on special request.

5.2.26 Frequency Error Register: DFT_Mes[7:0]

This Register located in **RAM2@9[7:0]** is updated by the subroutine in High Sensitivity communication mode each time that a Packet is received. **DFT_Mes[7:0]** contains the signed frequency error between the Transmitter and the Receiver RF frequencies. 1LSB corresponds to an offset frequency of 26MHz/32768 = 793Hz.

5.2.27 Micro controller ROMboot Instruction Disable: RB_Inst_Dis

In order to present a very simple programming interface, the subroutines are able to call each other trough an internal micro controller instruction ROMboot. This instruction is disabled when bit **RB_Inst_Dis = 1**. This allows the user to manually select the subroutine to be stored in **RAM1** memory.

Note 1: When default values initialization subroutine located at ROM address 0 is started, **RB_Inst_Dis** is set = **0** and next subroutine is automatically called, even if **RB_Inst_Dis** was set equal to **1** before starting the micro controller. Use SPI command **Write_RAM1** @address **13** with value = **1184** (after SPI command **ROM_Boot** and prior to start the micro controller) to force **RB_Inst_Dis = 1**.

5.3 Description of RAM2 and registers mapping

In this section all basic functionality and reset values for relevant registers of the RF2401 are described. Any register not specifically mentioned here is reserved and its contents must be set according to defined Default value.

5.3.1 Memory RAM2[11:0] @ address 0

Mnemonic	Bit	Default Value	Reset Value	Description
VDD_Synth_En	11	1	0	VDD_Synth Voltage Regulator enable
VDD_RXTX_En	10	1	0	VDD_RXTX Voltage Regulator enable
Xtal_En	9	1	0	Crystal oscillator enable
Reserved	8	1	0	Reserved.
Reserved	7	1	0	
Reserved	6	1	0	
Reserved	5	0	0	
Div_Ck_Freq[0]	4	0	0	Selects the frequency of the clock output on DIV_CK
Div_Ck_Freq[1]	3	0	0	
Reserved	2	1	0	Reserved.
Reserved	1	0	0	
Reserved	0	0	0	

5.3.2 Memory RAM2[11:0] @ address 1

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	0	0	
Reserved	9	0	0	
Reserved	8	0	0	
Reserved	7	0	0	
Reserved	6	0	0	
Reserved	5	0	0	
Reserved	4	0	0	
Reserved	3	0	0	
TX_On_Pad	2	0	0	TX_On Pad control. Set by internal Micro-Controller.
RX_On_Pad	1	0	0	RX_On Pad control. Set by internal Micro-Controller.
Reserved	0	0	0	Reserved.

5.3.3 Memory RAM2[11:0] @ address 2

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	1	0	Reserved.
Reserved	10	0	0	
Reserved	9	1	0	
Reserved	8	0	0	
Reserved	7	0	0	
Reserved	6	0	0	
Reserved	5	0	0	
Reserved	4	1	0	
Reserved	3	0	0	
Reserved	2	1	0	
Reserved	1	0	0	
Reserved	0	1	0	

5.3.4 Memory RAM2[11:0] @ address 3

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	0	0	
Reserved	9	1	0	
Reserved	8	0	0	
Reserved	7	1	0	
Reserved	6	1	0	
Reserved	5	0	0	
Reserved	4	0	0	
VCO_Code[3]	3	1	0	The VCO tuning code is determined automatically by auto-calibration procedure
VCO_Code[2]	2	0	0	
VCO_Code[1]	1	0	0	
VCO_Code[0]	0	0	0	

5.3.5 Memory RAM2[11:0] @ address 4

Mnemonic	Bit	Default Value	Reset Value	Description
I_Pre_PA[4]	11	0	0	Current bias of the PA preamplifier. Defines RF Output Power in Transmit mode.
I_Pre_PA[3]	10	1	0	
I_Pre_PA[2]	9	1	0	
I_Pre_PA[1]	8	0	0	
I_Pre_PA[0]	7	1	0	
Reserved	6	0	0	Reserved.
Reserved	5	0	0	
Reserved	4	0	0	
Reserved	3	0	0	
Reserved	2	0	0	
Reserved	1	0	0	
Reserved	0	0	0	

5.3.6 Memory RAM2[11:0] @ address 5

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	1	0	
Reserved	9	0	0	
Reserved	8	0	0	
Reserved	7	0	0	
Reserved	6	1	0	
Reserved	5	0	0	
Reserved	4	0	0	
Main_PTAT[3]	3	1	0	Control of the main chip PTAT current bias.
Main_PTAT[2]	2	0	0	
Main_PTAT[1]	1	0	0	
Main_PTAT[0]	0	0	0	

5.3.7 Memory RAM2[11:0] @ address 6

Mnemonic	Bit	Default Value	Reset Value	Description
I_PA[4]	11	0	0	Current bias of the PA. Defines RF Output Power in Transmit mode.
I_PA[3]	10	1	0	
I_PA[2]	9	0	0	
I_PA[1]	8	1	0	
I_PA[0]	7	1	0	
Reserved	6	0	0	Reserved.
Reserved	5	0	0	
Reserved	4	0	0	
Reserved	3	0	0	
Reserved	2	0	0	
Reserved	1	0	0	
Reserved	0	0	0	

5.3.8 Memory RAM2[11:0] @ address 7

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	1	0	Reserved.
Reserved	10	0	0	
Reserved	9	0	0	
Reserved	8	1	0	
Reserved	7	0	0	
Reserved	6	0	0	
Reserved	5	0	0	
Reserved	4	0	0	
Reserved	3	0	0	
Reserved	2	0	0	
Reserved	1	0	0	
Reserved	0	0	0	

5.3.9 Memory RAM2[11:0] @ address 8

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	1	0	
Reserved	9	0	0	
Reserved	8	0	0	
Reserved	7	1	0	
Reserved	6	0	0	
RB_Inst_Dis	5	0	0	ROMboot Instruction Disable.
Reserved	4	0	0	Reserved.
Limit_RSSI[3]	3	0	0	RSSI value.
Limit_RSSI[2]	2	0	0	
Limit_RSSI[1]	1	0	0	
Limit_RSSI[0]	0	0	0	

5.3.10 Memory RAM2[11:0] @ address 9

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	1	0	Reserved.
Reserved	10	0	0	
Reserved	9	1	0	
Reserved	8	0	0	
DFT_Mes[7]	7	0	0	Error frequency measured by DFT in High Sensitivity mode.
DFT_Mes[6]	6	0	0	
DFT_Mes[5]	5	0	0	
DFT_Mes[4]	4	0	0	
DFT_Mes[3]	3	0	0	
DFT_Mes[2]	2	0	0	
DFT_Mes[1]	1	0	0	
DFT_Mes[0]	0	0	0	

5.3.11 Memory RAM2[11:0] @ address 10

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	0	0	
Reserved	9	1	0	
Reserved	8	0	0	
Reserved	7	1	0	
Reserved	6	0	0	
Reserved	5	0	0	
Reserved	4	0	0	
Reserved	3	0	0	
Reserved	2	1	0	
Reserved	1	0	0	
Reserved	0	0	0	

5.3.12 Memory RAM2[11:0] @ address 11

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	0	0	
Reserved	9	0	0	
Reserved	8	0	0	
Reserved	7	1	0	
Reserved	6	0	0	
Reserved	5	1	0	
Reserved	4	0	0	
Reserved	3	0	0	
Reserved	2	0	0	
Reserved	1	0	0	
Reserved	0	0	0	

5.3.13 Memory RAM2[11:0] @ address 12

Mnemonic	Bit	Default Value	Reset Value	Description
Ch_Rate[2]	11	0	0	Bandwidth of the normal sensitivity demodulator.
Ch_Rate[1]	10	0	0	
Ch_Rate[0]	9	0	0	
R_Bit_Ck[8]	8	1	0	CODEC Bit clock frequency.
R_Bit_Ck[7]	7	1	0	
R_Bit_Ck[6]	6	0	0	
R_Bit_Ck[5]	5	0	0	
R_Bit_Ck[4]	4	0	0	
R_Bit_Ck[3]	3	0	0	
R_Bit_Ck[2]	2	0	0	
R_Bit_Ck[1]	1	0	0	
R_Bit_Ck[0]	0	0	0	

5.3.14 Memory RAM2[11:0] @ address 13

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	0	0	
Reserved	9	0	0	
Reserved	8	0	0	
Address[7]	7	1	0	Address Byte Value.
Address[6]	6	0	0	
Address[5]	5	1	0	
Address[4]	4	0	0	
Address[3]	3	1	0	
Address[2]	2	0	0	
Address[1]	1	0	0	
Address[0]	0	1	0	

5.3.15 Memory RAM2[11:0] @ address 14

Mnemonic	Bit	Default Value	Reset Value	Description
Reserved	11	0	0	Reserved.
Reserved	10	0	0	
Frequ[4]	9	0	0	Synthesizer's RF Frequency LSB's.
Frequ[3]	8	1	0	
Frequ[2]	7	1	0	
Frequ[1]	6	1	0	
Frequ[0]	5	0	0	
N_Pay[4]	4	0	0	Payload size of the Packet.
N_Pay[3]	3	0	0	
N_Pay[2]	2	0	0	
N_Pay[1]	1	1	0	
N_Pay[0]	0	1	0	

5.3.16 Memory RAM2[11:0] @ address 15

Mnemonic	Bit	Default Value	Reset Value	Description
Frequ[16]	11	0	0	Synthesizer's RF Frequency MSB's.
Frequ[15]	10	1	0	
Frequ[14]	9	1	0	
Frequ[13]	8	1	0	
Frequ[12]	7	0	0	
Frequ[11]	6	1	0	
Frequ[10]	5	1	0	
Frequ[9]	4	0	0	
Frequ[8]	3	0	0	
Frequ[7]	2	0	0	
Frequ[6]	1	1	0	
Frequ[5]	0	0	0	

6. Packet information

The following details on the packet are provided for informational purposes only. Knowledge of the information contained here is not necessary for proper usage of the RF2401.

6.1 Packet format

In normal sensitivity mode, each packet contains the following information:

Preamble	3 * Address Byte	Header	Payload

Table 15: Packet format, normal sensitivity mode

Packet Information	Length	Description
Preamble = 5 * "11001100"	5 byte	Clock recovery and data-slicer initialization.
3 * Address Byte	3 byte	The preamble consists of 3 Address byte **Address[7:0]**.
Header	0 or 1 byte	The 5 LSB's of the header represent the payload size of the packet for communication subroutine available @ **ROM_Boot_Address = 320**. For communication subroutine available @ **ROM_Boot_Address = 128**, header is not existing.
Payload	0-32 bytes	Data

In high sensitivity mode, each packet contains the following information:

Marking	Preamble	3 * Address Byte	Header	Payload

Table 16: Packet format, high sensitivity mode

Packet Information	Length	Description
Marking	20 bit	Initial frequency step used to lock high sensitivity demodulator.
Preamble = N * "11001100"	2 byte	Clock recovery initialization.
3 * Address Byte	3 byte	The preamble consists of 3 Address byte **Address[7:0]**.
Header	0 or 1 byte	The 5 LSB's of the header represent the payload size of the packet for communication subroutine available @ **ROM_Boot_Address = 256**. For communication subroutine available @ **ROM_Boot_Address = 192**, header is not existing.
Payload	0-32 bytes	Data

The size of the received packet including header and payload (stored in **RXFIFO**) can be read with the SPI command **Read_RXFIFO_Size** (see Section 5.1.1.4). When **RXFIFO** has been completely read (until **RXFIFO_Size[4..0]** = 0) after the previous reception, **RXFIFO_Size[4..0]** of the current packet is then the total packet size including the header.

The header byte is treated like a standard payload byte and must be stored in the **TX_FIFO** before the payload data prior to transmit the packet in any mode.

For each byte, the MSBit is sent first.