

CC112x/CC120x RX Sniff Mode

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ABSTRACT

This application report shows how the RX Sniff Mode can be configured for different TX configurations and discusses how average power consumption can be estimated for a receiver implementing this mode. You are expected to have basic knowledge on how the enhanced Wake on Radio (eWOR) and the RX Sniff Mode are implemented in TI's Performance Line Sub-1 GHz RF family of devices [1], [2].

Project collateral associated with this application report can be downloaded from the following URL: http://www.ti.com/lit/zip/swra428.



Contents

1	Introduction	2
2	Notation	3
3	Configuring the Radio for RX Sniff Mode	3
4	Code Examples	11
5	Conclusion	26
6	References	26
Appen	dix A Revision History	27

List of Figures

1	Event 0 and Event 1	4
2	MCU Controlled RX Timeout	7
3	Total RX Consumption in a Noise Free Environment	8
4	Total RX Current Consumption in Presence of Noise	9
5	Typical Settings (CC1120, 1.2 kbps, 50 kHz RX filter BW)	11
6	Code Configurations	13
7	CS Response Time (CC1120, 1.2 kbps, 50 kHz RX filter BW)	18
8	Current Profile (CC1120, 1.2 kbps, 50 kHz RX filter BW)	18
9	Average Current Consumption (CC1120, 1.2 kbps, 50 kHz RX Filter BW, RX config. 1)	19
10	CC112x_RX_Sniff_Mode.xlsx Dashboard (RX config. 1)	19
11	CC112x_RX_Sniff_Mode.xlsx Dashboard (RX config. 2)	20
12	4 Bytes Sync Word vs. 11 Bits Sync Word	20
13	CC112x_RX_Sniff_Mode.xlsx Dashboard (RX config. 3)	20
14	Typical Settings (CC1200, 38.4 kbps, ETSI standard)	21
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16 17	CC120x_RX_Shill_Mode.xlsx Dashboard (3 bytes preamble) CC120x_RX_Sniff_Mode.xlsx Dashboard (24 bytes preamble) Average Current Consumption (CC1200, 38.4 kbps, ETSI standard, 24 bytes preamble)	23 23 25
	List of Tables	
1	Abbreviations	2

1	Abbreviations	2
2	WOR_CFG1 - eWOR Configuration Reg. 1	3
3	Register Fields Used by RX Sniff Mode	3
4	Resolution and Max t _{Event0} for Different Values of WOR_RES	8
5	Register Fields to be Changed When Running RX Sniff Mode (RX config. 1)	15
6	SPNU428A Revisions	27

1 Introduction

Introduction

The RX Sniff Mode is a novel feature enabled by the TI Performance Line WaveMatch technology. The receiver only needs 4 bits of preamble for settling, as opposed to legacy receivers that often need 3 - 4 bytes. In a typical RF protocol where several preamble bytes are transmitted, TI Performance Line can autonomously duty cycle the receiver while waiting for a packet. Therefore, the RX Sniff Mode can be used fully transparent to you, while offering greatly reduced average current without sacrificing RF performance. The RX Sniff Mode is enabled by using the eWOR timer together with the RX termination based on carrier sense (CS) or preamble quality threshold (PQT).

AGC	Automatic Gain Control
CRC	Cyclic Redundancy Check
CS	Carrier Sense
eWOR	Enhanced Wake on Radio
FIFO	First-In-First-Out
GPIO	General-purpose input/output
OSC	Oscillator
PQT	Preamble Quality Threshold
RC	Resistor-Capacitor
RSSI	Received Signal Strength Indicator
RX	Receive Mode

Table 1. Abbreviations

2 Notation

Throughout this document, mapped register values are used. $m(\text{REGISTER}_NAME.REGISTER_FIELD)$ equals the value in the description field that matches the bit pattern. If a register is not part of a m()-construct, it means that the bit pattern value is used. After a reset, $m(WOR_CFG1.EVENT1) = 4$ while $WOR_CFG1.EVENT1 = 0$.

Bit No	Name	Reset	R/W	Description	
2:0	EVENT1	0x00	R/W	Event 1 timeout	
				EVENT1	WOR_EVENT1
				000	4
				001	6
				010	8
				011	12
				100	16
				101	24
				110	32
				111	48

Table 2. WOR_CFG1 - eWOR Configuration Reg. 1

3 Configuring the Radio for RX Sniff Mode

This section explains all the different parameters and register fields involved when configuring the radio for the RX Sniff Mode. Table 3 shows the different register fields discussed and in which section they are covered.

Table 3. Register Fields Used by RX Sniff Mode

Register Name	Register Field	Section
WOR_CFG1	WOR_RES	Section 3.2 and Section 3.8
	WOR_MODE	Section 3.10 and Section 3.11
	EVENT1	Section 3.3
WOR_CFG0	DIV_256HZ_EN	Section 3.12
	EVENT2_CFG	Section 3.1 and Section 3.4
	RC_MODE	Section 3.5
	RC_PD	Section 3.5
WOR_EVENT0_MSB	EVENT0_15_8	Section 3.2 and Section 3.7
WOR_EVENT0_LSB	EVENT0_7_0	Section 3.2 and Section 3.7
SETTLING_CFG	FS_AUTOCAL	Section 3.6
RFEND_CFG1	RXOFF_MODE	Section 3.10 and Section 3.11
	RX_TIME	Section 3.7
	RX_TIME_QUAL	Section 3.7
RFEND_CFG0	TERM_ON_BAD_PACKET	Section 3.10, Section 3.10.2, and Section 3.11
	ANT_DIV_RX_TERM_CFG	Section 3.9, Section 3.9.1, and Section 3.9.2
AGC_CS_THR	AGC_CS_THRESHOLD	Section 3.9.1
AGC_CFG1	AGC_WIN_SIZE	Section 3.9.1
	AGC_SETTLE_WAIT	Section 3.9.1
AGC_CFG0	RSSI_VALID_COUNT	Section 3.9.1

Register Name	Register Field	Section				
PREAMBLE_CFG0	PQT_EN	Section 3.9.2				
	PQT	Section 3.9.2				
FIFO_CFG	CRC_AUTOFLUSH	Section 3.10.1				
PKT_CFG1	CRC_CFG	Section 3.10.1				
PKT_CFG0	LENGTH_CONFIG	Section 3.10.2				
PKT_LEN	PACKET_LENGTH	Section 3.10.2				
IOCFGx	GPIOx_CFG	Section 3.1 and Section 3.10				
MDMCFG1	CARRIER_SENSE_GATE	Section 3.2				
SYNC_CFGx ⁽¹⁾	PQT_GATING_EN	Section 3.2				

Table 3. Register Fields Used by RX Sniff Mode (continued)

⁽¹⁾ PQT_GATING_EN is in the SYNC_CFG1 register for CC112x and SYNC_CFG0 register for CC120x.

3.1 Event 0, Event 1 and Event 2

The eWOR timer has three events: Event 0, Event 1, and Event 2. The relationship between Event 0 and Event 1 is shown in Figure 1. Event 2 is not used in the RX Sniff Mode (see Section 3.4) and is, therefore, not shown in the figure.



Figure 1. Event 0 and Event 1

All three events can be monitored on the general-purpose input/output (GPIO) pins by setting $IOCFGx.GPIOx_CFG = WOR_EVENT0/1/2$ (54/55/56). If $IOCFGx.GPIOx_CFG = WOR_EVENT2$ (56), $WOR_CFG0.EVENT2_CFG$ must be $\neq 00_b$. Event 2 is not shown in Figure 1 as it will not be used in most RX Sniff Mode applications. For more details, see Section 3.4.

3.2 Event 0 and t_{Event0}

The RX Sniff Mode Event 0 is the event used when the crystal oscillator and the digital regulator are turned on (when the radio is in SLEEP state). The time between two Event 0's are called t_{Event0} and there are several factors to take into account when determining this time. It is recommended that both MDMCFG1.CARRIER_SENSE_GATE and SYNC_CFGx.PQT_GATING_EN = 0 when using the RX Sniff Mode to simplify how t_{event0} should be determined.

• Termination based on CS (see Section 3.9.1)

Before the radio can detect a sync word, a minimum of 4-bit preamble is needed for AGC settling (including frequency offset compensation). This means that the maximum time between two Event 0's can be calculated as shown in Equation 1 when RX is terminated based on CS.

 t_{Event0} [Desired] = $\frac{\# \text{ of Preamble Bits - 4}}{\text{Data Rate [bps]}}$ [s]

(1)



Termination based on PQT (see Section 3.9.2)

If termination based on PQT is used, the radio needs a maximum of 10 bits of preamble to be sure that a preamble is detected (AGC settling and frequency offset compensation is included). The preamble quality estimator uses an 8-bit wide correlation filter to detect a preamble and 2 extra bits might be necessary to align the transmitter and receiver. In addition, the radio needs some time, T0, before starting to look for the preamble. For more information on how to calculate T0, see the device-specific user's guides, [1] and [2]. This means that the max time between two Event 0's can be calculated as shown in Equation 2 when RX is terminated based on PQT. Equation 2 is not valid when using OOK, feedback to PLL, or when TOC_LIMIT $\neq 0$.

 t_{Event0} [Desired] = $\frac{\text{# of Preamble Bits - 10}}{\text{Data Rate [bps]}}$ - T0[s]

 t_{Event0} is given by the WOR_CFG1.WOR_RES, WOR_EVENT0_MSB, and WOR_EVENT0_LSB registers together with the frequency of the low-power RC oscillator as shown in Equation 2. For more details on WOR_RES, see Section 3.8.

 $t_{Event0}[Programmed] = \frac{1}{f_{RCOSC}} \cdot EVENT0 \cdot 2^{5 \cdot WOR} RES [s]$

The RC oscillator has a tolerance of 0.1% after calibration (see [3] or [4]). This means that when programming t_{event0} , Equation 4 should be used.

 $t_{Event0}[Programmed] = \frac{100}{100.1} \cdot t_{Event0}[Desired]$

3.3 Event 1 and t_{Event1}

 t_{Event1} is the time between Event 0 and Event 1. If t_{Event1} is larger than the crystal start-up time, an SRX strobe is issued on this event. Setting t_{Event1} larger than the crystal start-up time is useful in applications where the transmitter and receiver are in sync and one needs to put the radio in RX mode at a known time. In a typical RX Sniff Mode application, t_{Event1} should be set shorter than the crystal start-up time. In these cases, the SRX strobe will be issued as soon as the crystal is stable (CHIP_RDYn is asserted). This way the radio enters RX mode as fast as possible, reducing the power consumption. t_{Event1} can be calculated as shown in Equation 5.

$$t_{Event1} = \frac{1}{f_{RCOSC}} \cdot m(WOR_CFG1.WOR_EVENT1)[s]$$

3.4 Event 2 and t_{Event2}

At Event 2, the radio can autonomously be taken out of SLEEP mode to perform RC oscillator calibration and improve the accuracy of the eWOR timer. The time between two Event 2's are called t_{Event2} and is given by Equation 6.

$$t_{Event2} = \frac{2^{m(WOR_CFG0.WOR_EVENT2)}}{f_{RCOSC}} [s]$$

(6)

5

(5)

(2)

(3)

(4)



Configuring the Radio for RX Sniff Mode

When enabling calibration at Event 2 by setting WOR_CFG0.WOR_EVENT2 $\neq 0$, t_{Event0} must be greater than t_{Event2} [1], [2]. Using the RX Sniff Mode does in most cases mean that t_{Event0} is much smaller than the minimum t_{Event2} (~1 s when f_{RCOSC} = 32 kHz and ~0.82 s when f_{RCOSC} = 40 kHz), therefore, WOR_EVENT2 should in most RX Sniff Mode applications be set to 0.

3.5 RC Oscillator

To run the RX Sniff Mode, the internal RC oscillator must be enabled by setting WOR_CFG0.RC_PD = 0. In order to keep the frequency as accurate as possible, the RC oscillator needs to be calibrated. How often the RC oscillator should be calibrated is controlled through the WOR_CFG0.RC_MODE register field.

In an RX Sniff Mode application, the radio typically wakes up several times every second; it is recommended to do an initial calibration at start-up and then turn off the RC oscillator calibration ($RC_{MODE} = 0$). Re-calibration can then be initialized by the MCU.

The function found in Example 1 can be used to run a single RX oscillator calibration. In Example 1, cc112x should be replaced with cc120x in the function calls if the radio is a CC120X, and the register prefixes should be CC120X instead of CC112X.

Example 1. RC Oscillator Calibration (CC112x)

```
* @fn
             calibrateRcOsc
*
 @brief
           Calibrates the RC oscillator used for the eWOR timer. When this
            function is called, WOR_CFG0.RC_PD must be 0
* @param
            none
* @return
            none
* /
static void calibrateRCOsc (void) {
 uint8 temp;
 // Read current register value
 cc112xSpiReadReg(CC112X_WOR_CFG0, &temp,1);
 // Mask register bit fields and write new values
 temp = (temp & 0xF9) | (0x02 << 1);
 // Write new register value
 ccll2xSpiWriteReg(CCll2X_WOR_CFG0, &temp,1);
 // Strobe IDLE to calibrate the RCOSC
 trxSpiCmdStrobe(CC112X_SIDLE);
 // Disable RC calibration
 temp = (temp & 0xF9) | (0x00 << 1);
 ccll2xSpiWriteReg(CCll2X_WOR_CFG0, &temp, 1);
}
```

3.6 Frequency Synthesizer Calibration

The internal on-chip FS characteristics varies with temperature and supply voltage changes as well as the desired operating frequency and must be calibrated regularly. Calibration can be done automatically when going to or from active states (RX and TX) by setting SETTLING_CFG.FS_AUTOCAL \neq 1. Since the radio goes from IDLE to RX (and back to IDLE) several times a second when using the RX Sniff Mode, it is recommended to disable auto calibration FS_AUTOCAL = 0 and do a manual calibration instead (when needed) to reduce current consumption. A manual calibration is performed by issuing an SCAL strobe command (for CC112x, see [7]).



3.7 RX Timeout

When using the RX Sniff Mode, RX is terminated when there is no carrier on the air or when no preamble is present, depending on the RFEND_CFG0.ANT_DIV_RX_TERM setting. For more details, see Section 3.8. Assume the radio wakes up in the beginning of the preamble and detects that a signal is present (CS or PQT). This means that ideally it should stay awake for a minimum time given by the preamble length plus the sync word length to be able to detect a sync word. The wakeup period, t_{Event0} , is programmed to be 4 bits or T0 + 10 bits shorter than the preamble length (see Section 3.2). It is not possible to program the RX timeout to be larger than t_{Event0} , therefore, the RX timeout must be disabled when running the RX Sniff Mode (RFEND_CFG1.RX_TIME = 111b).

The RX_TIME_QUAL bit in the RFEND_CFG1 register determines what happens when the RX timer expires. Since the RX Sniff Mode does not implement the RX timeout, this bit is don't care.

In a noisy environment, the MCU can be programmed to wake up if the radio detects a signal (CARRIER_SENSE or PQT_REACHED asserted). It can then start a timer before going back to sleep and wake up when the timer expires. If no sync is found, the MCU should put the radio back in SLEEP Mode by issuing an SIDLE strobe followed by an SWOR strobe (see Figure 2). Note that the radio needs to reach the IDLE state before the SWOR strobe can be issued.

Case A shows the format of the desired packet while case B shows how the MCU forces the radio back to SLEEP after a timeout equal to the preamble + sync length of the desired packet. In Case A, RX is terminated automatically after a packet is received ($RFEND_CFG1.RXOFF_MODE = 0$).



Figure 2. MCU Controlled RX Timeout



Configuring the Radio for RX Sniff Mode

3.8 eWOR Timer Resolution

WOR_CFG1.WOR_RES is used to configure the eWOR timer resolution and the resolution of t_{Event0} (see Section 3.2).

	f _{RCOSC} :	= 32 kHz	f _{RCOSC} :	= 40 kHz
WOR_RES	Resolution Max t _{Event0}		Resolution	Max t _{Event0}
0	31.25 µs	2.048 s	25 µs	1.638 s
1	1 ms	65.536 s	0.8 ms	52.429 s
2	32 ms	2097.152 s	25.6 ms	1677.722 s
3	1.024 s	67108.864 s	819.2 ms	53687.091 s

Table 4	. Resolution	and Max	t _{Event0} for	Different	Values	of w	OR_RES
---------	--------------	---------	-------------------------	-----------	--------	------	--------

3.9 RX Termination

When implementing the RX Sniff Mode, the radio should terminate RX as fast as possible if there is no signal on the air to minimize the current consumption. The radio can terminate the RX mode in lack of a carrier (RFEND_CFG0.ANT_DIV_RX_TERM_CFG = 1) or in lack of preamble

 $(RFEND_CFG0.ANT_DIV_RX_TERM_CFG = 100_b)$. Detecting a carrier takes less time compared to detecting a preamble and t_{Event0} is shorter when RX termination is based on PQT compared to CS. Which RX termination to use (CS or PQT) depends on the system requirements and the environment the system is operating in. Consider the scenario shown in Figure 3. When the radio never triggers on noise, termination on CS gives the lowest total RX current. Figure 4 shows a scenario where noise is present in the channel and terminating on PQT gives the lowest RX current even if detecting a preamble takes longer than detecting a carrier. A third case is also shown in Figure 4. Here the MCU terminates RX after a timeout equal to the length of the preamble and sync word (the sync word is in this case half the length of the preamble). As seen from the figure, this leads to an even lower current consumption on the radio, but the MCU will draw some more current compared to case A and case B.











Figure 4. Total RX Current Consumption in Presence of Noise

3.9.1 Termination Based on CS

When termination based on CS is implemented (RFEND_CFG0.ANT_DIV_RX_TERM_CFG = 1), the CS threshold has to be set to a proper value. The CS threshold is programmed through the AGC_CS_THRESHOLD register field found in the AGC_CS_THR register. AGC_CS_THRESHOLD is a two's complement number with 1 dB resolution and is given by Equation 7. For details regarding the RSSI offset, see the device-specific user's guides [1], [2].

CS Threshold = AGC_CS_THR + RSSI Offset

(7)

9

Setting the optimal threshold is a trade-off between sensitivity and current consumption. The CS threshold determines the sensitivity limit of the application as only packets with a signal strength above the threshold will be received. The CS threshold should be set as low as possible to achieve good sensitivity (close to the sensitive limit given in the radio's data sheet [3], [4], [5], [6]. However, setting the threshold too low causes more wake-ups due to noise and interference, and the current consumption will increase.



Configuring the Radio for RX Sniff Mode

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The carrier sense response time is the time it takes from when the radio enters RX mode until it can determine if there is a signal on the air or not. There are several registers that determines the CS response time and they are all discussed in the *RSSI* section of the user's guides [1], [2]. Two Excel sheets are available for calculating the CS response time for both CC112x and CC120x [9], [10]. It is recommended to use typical settings from SmartRF[™] Studio [8] when implementing the RX Sniff Mode and then set AGC_CFG1.AGC_SETTLE_WAIT, AGC_CFG1.AGC_WIN_SIZE, and AGC_CFG0.RSSI_VALID_COUNT to 0. When doing this, there will be a trade-off between CS response time and accuracy. Note that changing registers from the recommended settings to reduce the CS response time might reduce the sensitivity, so testing must be done to assure satisfying RF performance.

3.9.2 Termination Based on PQT

When termination based on PQT is implemented (RFEND_CFG0.ANT_DIV_RX_TERM_CFG = 100_{b}), the preamble detector must be enabled by setting PREAMBLE_CFG0.PQT_EN = 1. The preamble threshold is configured with the register field PREAMBLE_CFG0.PQT. The PQT response time is the time it takes from the radio enters RX mode until it can determine if there is a valid preamble on the air or not. For more info on PQT, see the *Preamble Detection* section in the device-specific user's guide [1], [2].

3.10 Termination Due to Bad Packets

What happens after a bad packet has been received is determined by the TERM_ON_BAD_PACKET bit in the RFEND_CFG0 register (in this context, a bad packet is a packet with the wrong length, wrong address, or with CRC error). When TERM_ON_BAD_PACKET = 0, the radio stays in RX regardless of the RFEND_CFG1.RXOFF_MODE when a bad packet has been discarded. When TERM_ON_BAD_PACKET = 1, the radio will go back to SLEEP after rejecting a bad packet given that WOR_CFG1.WOR_MODE = 0 or 1. For more details, see Section 3.11. When a good packet is received, the radio will enter the state indicated by the RFEND_CFG1.RXOFF_MODE setting.

When making a low power system, it is not just the radio that should minimize its current consumption. The MCU running the application should also reduce its current consumption as much as possible. One thing that can be done is to only wake up the MCU when there is a good packet in the RX FIFO and let the radio go back to SLEEP automatically otherwise. This means that TERM_ON_BAD_PACKET should be 1.

Since the radio only wants to wake up the MCU when there is a good packet in the RX FIFO, the PKT_CRC_OK should be used to wake up the MCU (IOCFGx.GPIOx_CFG = PKT_CRC_OK (19)). On the CC112x, the GPIO2 pin is the only GPIO pin that will be 0 also in SLEEP state when configured as PKT_CRC_OK, while on the CC120x, both GPIO0 and GPIO2 will be low in SLEEP state.

3.10.1 CRC Filtering

Since the radio is configured to go back to SLEEP if a packet is discarded (see Section 3.10), CRC filtering needs to be enabled. This is done by setting FIFO_CFG.CRC_AUTOFLUSH = 1. When this bit is set, it is important that the CRC check is enabled (PKT_CFG1.CRC_CFG \neq 0).

3.10.2 Maximum Packet Length Filtering

If the application uses variable packet length (PKT_CFG0.LENGTH_CONFIG = 1), maximum packet length filtering must be enabled. Maximum packet length filtering keeps the radio from entering RXFIFO_OVERFLOW state and also makes sure that packets that are too big for the RX FIFO are discarded so that the radio goes back to SLEEP (since RFEND_CFG0.TERM_ON_BAD_PACKET = 1).

The maximum allowed packet length must allow the complete packet, including optional status bytes, room in the RX FIFO. If <code>PKT_CFG1.APPEND_STATUS = 0</code>, max packet length is 127 and if <code>APPEND_STATUS = 1</code> max packet length is 125. The maximum allowed packet length is written to the <code>PKT_LEN.PACKET_LENGTH</code> register field.

In an application where the radio does not expect packets longer than 20 bytes (length byte + payload), PACKET_LENGTH should be set to 19 even if there are room for longer packet in the RX FIFO.



3.11 eWOR Mode

There are five different eWOR modes to select from, but only two that can be used if the radio should return to SLEEP automatically on the reception of a bad packet, as discussed in Section 3.10. These two are Feedback Mode (WOR_CFG1.WOR_MODE = 0) and Normal Mode (WOR_CFG1.WOR_MODE = 1). For both modes, the radio enters the state indicated by the RFEND_CFG1.RXOFF_MODE setting when a good packet is received, and enter SLEEP if a bad packet is received (since RFEND_CFG0.TERM_ON_BAD_PACKET_EN = 1). Using Feedback Mode, the radio enters IDLE instead of SLEEP if 16 bad packets are received in a row. For more details, see [1] and [2].

3.12 eWOR Clock Division

Setting $WOR_CFG0.DIV_256HZ_EN = 1$ lowers the current consumption in SLEEP mode, but when this bit is set, the radio should not be woken from SLEEP by pulling CSn low. The setting of this bit depends on the application's need to manually wake up the radio.

4 Code Examples

There is one code example for the CC1120 and one for the CC1200 to supplement this application report. Both code examples can be downloaded from the web [11], [12].

4.1 CC1120 Code Example

The CC1120 code example uses the 1.2 kbps, 50 kHz RX filter BW typical settings from SmartRF Studio [8], version 1.13.0 as a starting point (see Figure 5).

CC1120 - Device Control Panel (offline) File Settings View Evaluation Board Help					
E Easy Mode	Register View 🗹 RF Param	stors		CC1120 - Register View (offline)	8
Typical settings				Register export	1
Cetegory Setting name					-
▼ Generic 868/915/920MHz				h locrea	Value (Her
Bt rate: 1.2 kbps, 24 Bt rate: 1.2 kbps, 24	FSK, RX B/V. 20 8R2 (000) FSK, RX B/V. 50 8R2 (868)			IOCFG2	06
Bit rate: 300 bps, 2-F Bit rate: 1 3ktore 3-F	FSK, RX BW. 10 kHz, narrow band, optimized	for sensitivity (868) 39)		IOCFG1	BO
Bit rate: 4.8 kbps, 00	OK, RX BW 66 kHz (868)	~,		► IOCFG8	40
Bit rate: 38.4 kbps, 2 Bit rate: 50kbps, 2-9	2-GFSK, RX BW 100 kHz (868) FSK IFFF 802 15 4G (868)			SYNC2	08
Bit rate: 200kbps, 4-	GFSK, max throughput (868)			SYNC1	51
Generic 950MHz Generic 434MHz				SYNC0	DE
Generic 169MHz				SYNC_CFG0	17
				BEVIATION_M	48
				MOBCFG_DEV_E	05
				▶ PREAMBLE_CFG1	14
RI- Parameters				PREAMELE_CFG0	2A
Carrier frequency	Xtal frequency	Symbol rate	Bit rate	▶ FREQ_F_CFG	40
868.000000 🔒 MHz	32.000000 💉 MHz	1.2 ksps	1.2 kbps	CHAN_BW	04
		2010 C		MDMCFG1	46
RX filter B/V	Modulation format	Deviation	ix power	MUMCFG0	05
50.000000 kHz	2-FSK	20.019531 kHz	15 M dBm	SYMBOL_RATE1	A9
			Performance mode	SYMBOL_RATED	2A
Manchester enable	PA rempine	Whitening	High Performance	AGC_REF	36
				AGC_GAIN_ADJUST	00
Preser Friday day Name				AGC_CFG3	91
Raige Extender Rore				AGC_CFG2	20
	- · · · · · · · · · · · · · · · · · · ·			AGC_CFG0	CF
Continuous TX Continuous RX Packet TX Packet R	X RF Device Commands RX Shiff mode			FIFO_CFG	00
Expected packet count 100 Infinite				DEV_ADOR SETTLING CEG	00
Viewing format				FS_CFG	12
			1 N	WOR_CFG1	08
Seq. number included in payload.				WOR_CFG0	21
				WOR_EVENT0_LSB	00
			RX	PKT_CFG2	04
				P PKT_CEG8	20
				RFEND_CFG1	OF
				RFEND_CFG0	00
				P PA_CF02 PA_CF01	56
				► PA_CFG0	7C
				PKT_LEN	FF
				FREQOFF CFG	22
				TOC_CFG	08
				MARC_SPARE	00
				CFM_DATA_CFG	00
				EXT_CTRL	01
			Average RSSt -	RCCAL_FINE BCCAL_COARSE	00
			Received ok: 0	RCCAL_OFFSET	00
			Received not ok: 0	FREQOFF1	00
2			Packet error rate: -	FREQ2	6C 🗸
Lump data to file:				<	2
Advanced			Start Stop	Register reset Help	Refresh
Not consert	ad	Off Ins.	node	Partie state N.A.	

Figure 5. Typical Settings (CC1120, 1.2 kbps, 50 kHz RX filter BW)

Code Examples

The register settings obtained by using the code export feature is shown in Example 2.

Example 2. Code Export (CC1120, 1.2 kbps, 50 kHz RX filter BW)

```
// RX filter BW = 50.000000
// Address config = No address check
// Packet length = 255
// Symbol rate = 1.2
// PA ramping = true
// Performance mode = High Performance
// Carrier frequency = 868.000000
// Bit rate = 1.2
// Packet bit length = 0
// Whitening = false
// Manchester enable = false
// Modulation format = 2-FSK
// Packet length mode = Variable
// Device address = 0
// TX power = 15
// Deviation = 20.019531
// Rf settings for CC1120
static const registerSetting_t preferredSettings[] = {
  {CC112X_IOCFG3, 0xB0},
  {CC112X_IOCFG2,
                       0x06},
  {CC112X_IOCFG1,
                       0xB0},
  {CC112X_IOCFG0,
                      0x40},
                       0x0B},
  {CC112X_SYNC_CFG1,
  {CC112X_DEVIATION_M,
                        0x48},
  {CC112X_MODCFG_DEV_E, 0x05},
  {CC112X_DCFILT_CFG,
                        0x1C
  {CC112X_IQIC,
                        0x00},
  {CC112X_CHAN_BW,
                       0x04},
  {CC112X MDMCFG0,
                       0 \ge 0 \le 1
  {CC112X_AGC_CFG1,
                       0xA9},
  {CC112X_AGC_CFG0,
                       0xCF}
  {CC112X_FIFO_CFG,
                        0x00},
  {CC112X_SETTLING_CFG, 0x03},
  {CC112X_FS_CFG,
                        0x12\},
  {CC112X_PKT_CFG0,
                        0x20},
  {CC112X_PKT_LEN,
                        0xFF},
  {CC112X_IF_MIX_CFG, 0x00},
  {CC112X_FREQOFF_CFG 0x22},
  {CC112X_FREQ2,
                        0x6C},
  {CC112X_FREQ1,
                        0x80},
  {CC112X_FS_DIG1,
                      0x00},
  {CC112X_FS_DIG0,
                        0x5F},
  {CC112X_FS_CAL1,
                        0x40},
  {CC112X_FS_CAL0,
                        0x0E},
  {CC112X_FS_DIVTWO,
                        0x03},
  {CC112X_FS_DSM0,
                       0x33},
                       0x17},
  {CC112X FS DVC0,
  {CC112X_FS_PFD,
                       0x50},
  {CC112X_FS_PRE,
                       0x6E},
  {CC112X_FS_REG_DIV_CML 0x14},
  {CC112X_FS_SPARE, 0xAC},
                        0xB4},
  {CC112X_FS_VC00,
  {CC112X_XOSC5,
                        0x0E},
  {CC112X_XOSC1,
                        0x03},
};
```



(8)

Three different configurations (see Figure 6) are available for this example and they are discussed in the following sections (Section 4.1.1, Section 4.1.2, and Section 4.1.3).

Configurations for "cc1120_rx_sniff_mo 🔀				
Configurations: RX (Config 1) RX (Config 2) RX (Config 3) TX (Config 1) TX (Config 2 and 3)	OK New Remove			

Figure 6. Code Configurations

4.1.1 RX Config. 1

In this configuration, three preamble bytes are used since this is the preamble configuration given by SmartRf Studio (see Figure 5).

• t_{Event0} Configuration

Equation 8 shows t_{Event0} as maximum 16.67 ms.

 $t_{Event0} = \frac{\text{\# of Preamble Bits - 4}}{\text{Data Rate [bps]}} = \frac{3 \cdot 8 - 4}{1200} = 16.67 \cdot 10^{-3} \text{ s}$

This means that WOR_RES should be 0 (see Table 4). Solving Equation 9 with respect to EVENT0, you get EVENT0 to be 532.80.

 $EVENT0 = t_{Event0}[Programmed] \cdot f_{RCOSC} = \frac{100}{100.1} \cdot t_{Event0}[Desired] \cdot f_{RCOSC} = \frac{100}{100.1} \cdot 16.67 \cdot 10^{-3} \cdot 32 \cdot 10^{-3} = 532.80$ (9)

EVENT0 = 532.80 means that EVENT0_15_8 = 0x02 and EVENT0_7_0 = 0x14.

In addition, MDMCFG1.CARRIER_SENSE_GATE = 0 and SYNC_CFG1.PQT_GATING = 0 as discussed in Section 3.2.

• t_{Event1} Configuration

According to the CC1120 data sheet [3], the start-up time of the crystal is typical 400 μ s, therefore, EVENT 1 should be less than 100_b. In the CC1120 RX Sniff Mode code example [11] EVENT1 = 000_b.

• t_{Event2} Configuration

Since t_{Event0} is 16.67 ms, t_{Event0} is less than the minimum t_{Event2} (1 s) and WOR_EVENT2_CFG should be set to 0 (see Section 3.4).

RC Oscillator Configuration

WOR_CFG0.RC_PD and WOR_CFG0.RC_MODE both set to 0 as described in Section 3.5.

• FS Calibration

SETTLING_CFG.FS_AUTOCAL = 0 as stated in Section 3.6.

• RX Timeout Configuration



Code Examples

 $RFEND_CFG1.RX_TIME = 111_{b}$ and $RFEND_CFG1.RX_TIME_QUAL = x$ as described in Section 3.7 ($RX_TIME_QUAL = 1$ in the code example [11] since this is the default value of this bit). No timeout is implemented, meaning the radio will stay in RX as long as there is a signal on the air.

RX Termination Configuration

In the code example [11], termination based on carrier sense is implemented. This means that RFEND_CFG0.ANT_DIV_RX_TERM_CFG = 1. Because of this, PREAMBLE_CFG0.PQT_EN and PREAMBLE_CFG0.PQT are don't care and the default values are being used (PREAMBLE_CFG0.PQT_EN = 1 and PREAMBLE_CFG0.PQT = 1010_b)

When $ANT_DIV_RX_TERM_CFG = 1$, the CS threshold must be set to something other than default. The sensitivity limit for the chosen RF settings is -114 dBm [3]. In the code example [11], CS threshold is set 1 dB higher, at -113 dBm, to avoid too many wake-ups due to noise.

The RSSI offset is -102 dBm [1]. To get a CS threshold of -113 dBm, AGC_CS_THR must be set to 0xF5 (see Equation 10).

CS Threshold = AGC_CS_THR + RSSI Offset AGC_CS_THR = CS Threshold - RSSI Offset = -113 - (-102) = -11

(10)

To reduce the CS response time, AGC_CFG1.AGC_WIN_SIZE, AGC_CFG1.AGC_SETTLE_WAIT and AGC_CFG0.RSSI_VALID_COUNT are all set to 0.

"Bad Packet" Termination

To save as much power as possible, the radio is configured to return to SLEEP if a bad packet is received and to only wake up the MCU if a good packet is received, therefore, RFEND_CFG0.TERM_ON_BAD_PACKET = 1 and IOCFG2.GPIO2_CFG = 010011_{b} (see Section 3.10). ⁽¹⁾

In addition, FIFO_CFG.CRC_AUTOFLUSH must be 1 and PKT_CFG1.CRC_CFG \neq 0. In the code example [11], CRC_CFG = 01_b as this is the default value of this register field.

RFEND_CFG1.RXOFF_MODE is set to 0 (IDLE) making the radio enter IDLE state when a good packet is received.

Since the radio should only wake up the MCU when a good packet is received, the radio must be configured to avoid entering RX FIFO ERROR state. The settings given in Example 2 indicates variable packet length mode $PKT_CFGO.LENGTH_CFG = 01_b$ and $PKT_CFGI.APPEND_STATUS = 1$, therefore, PKT_LEN should be set to 125 (0x7D) (see Section 3.10.2)

• eWOR Mode

To make the receiver SW as simple as possible, Normal mode (WOR_CFG1.WOR_MODE = 1) is selected for this code example [11].

eWOR Clock Division

 $WOR_CFG0.DIV_256HZ_EN = 1$ to make the current consumption as low as possible. (1) IOCFG0.GPIO0_CFG = 000110b and is used by the TX to determine when a packet has been sent.

Table 5. Register Fields to be Changed When Running RX Sniff Mode (RX config. 1)

Register Name	Register Field	Value	Register Value
WOR_CFG1	WOR_RES	00 _b	WOR_CFG1 = 0x08
	WOR_MODE	001 _b	
	EVENT1	000 _b	
WOR_CFG0	WOR_CFG_NOT_USED	00 _b	$WOR_CFG0 = 0x20$
	DIV_256HZ_EN	1 _b	
	EVENT2_CFG	00 _b	
	RC_MODE	00 _b	
	RC_PD	O _b	
WOR_EVENT0_MSB	EVENT0_15_8	0x02	WOR_EVENT0_MSB = 0x02
WOR_EVENT0_LSB	EVENT0_7_0	0x15	WOR_EVENT0_LSB = 0x15
SETTLING_CFG	SETTLING_CFG_NOT_USED	000 _b	SETTLING_CFG = 0×03
	FS_AUTOCAL	00b	
	LOCK_TIME	01 _b	
	FSREG_TIME	1 _b	_
RFEND_CFG1	RFEND_CFG1_NOT_USED	00 _b	$RFEND_CFG1 = 0 \times 0F$
	RXOFF_MODE	00 _b	
	RX_TIME	111 _b	
	RX_TIME_QUAL	1 _b	
RFEND_CFG0	RFEND_CFG0_NOT_USED	0,	$RFEND_CFG0 = 0x09$
	CAL_EN_WAKE_UP_EN	O _b	-
	TXOFF_MODE	00 _b	_
	TERM_ON_BAD_PACKET	1 _b	
	ANT_DIV_RX_TERM_CFG	001 _b	
AGC_CS_THR	AGC_CS_THRESHOLD	0xF5	$AGC_CS_THR = 0xF5$
AGC_CFG1	AGC_SYNC_BEHAVIOUR	101 _b	AGC_CFG1 = 0xA0
	AGC_WIN_SIZE	000 _b	
	AGC_SETTLE_WAIT	00 _b	
AGC_CFG0	AGC_HYST_LEVEL	11 _b	$AGC_CFG0 = 0xC3$
	AGC_SLEWRATE_LIMIT	00 _b	
	RSSI_VALID_COUNT	00 _b	_
	AGC_ASK_DECAY	11 _b	-
PREAMBLE_CFG0	PREAMBLE_CFG0_NOT_USED	00 _b	$PREAMBLE_CFG0 = 0x2A$
	PQT_EN	1 _b	
	PQT_VALID_TIMEOUT	O _b	
	PQT	1010 _b	
FIFO_CFG	CRC_AUTOFLUSH	1 _b	$FIFO_CFG = 0x80$
	FIFO_THR	0000000 _b	1

Register Name	Register Field	Value	Register Value
PKT_CFG1	PKT_CFG1_NOT_USED	0 _b	$PKT_CFG1 = 0x05$
	WHITE_DATA	0 _b	
	ADDR_CHECK_CFG	00 _b	
	CRC_CFG	01 _b	
	BYTE_SWAP_EN	0 _b	
	APPEND_STATUS	1 _b	
PKT_CFG0	PKT_CFG0_RESERVED7	0 _b	$PKT_CFG0 = 0x20$
	LENGTH_CONFIG	01 _b	
	PKT_BIT_LEN	000 _b	_
	UART_MODE_EN	O _b	-
	UART_SWAP_EN	0 _b	-
PKT_LEN	PACKET_LENGTH	0x7D	$PKT_LEN = 0x7D$
IOCFG2	GPIO2_ATRAN	0 _b	IOCFG2 = 0x13
	GPIO2_INV	O _b	-
	GPIO2_CFG	010011 _b	
MDMCFG1	CARRIER_SENSE_GATE	0	MDMCFG1 = 0x46
	FIFO_EN	1	
	MANCHESTER_EN	0	-
	INVERT_DATA_EN	0	-
	COLLISION_DETECT_EN	0	-
	DVGA_GAIN	11b	
	SINGLE_ADC_EN	0	-
SYNC_CFG1	SYNC_CFG1_RESERVED7	0	SYNC_CFG1 = 0x0B
	PQT_GATING_EN	0	1
	SYNC_CFG1_RESERVED5	0	1
	SYNC_THR	1011b	1

Table 5. Register Fields to be Changed When Running RX Sniff Mode (RX config. 1) (continued)

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Example 3. RX Sniff Mode Settings (CC1120, 1.2 kbps, 50 kHz RX filter BW, RX config. 1)

```
// RX filter BW = 50.000000
// Address config = No address check
// Packet length = 125
// Symbol rate = 1.2
// PA ramping = true
// Performance mode = High Performance
// Carrier frequency = 868.000000
// Bit rate = 1.2
// Packet bit length = 0
// Whitening = false
// Manchester enable = false
// Modulation format = 2-FSK
// Packet length mode = Variable
// Device address = 0
// TX power = 15
// Deviation = 20.019531
// Rf settings for CC1120
static const registerSetting_t preferredSettings[] = {
  {CC112X_IOCFG3, 0xB0},
                         0x13},
  {CC112X_IOCFG2,
  {CC112X_IOCFG1,
                         0xB0},
  {CC112X_IOCFG0,
                         0x06},
                        0x0B},
  {CC112X_SYNC_CFG1,
  {CC112X_DEVIATION_M,
                         0x48},
  \{CC112X\_MODCFG\_DEV\_E, 0x05\},
  CC112X_DCFILT_CFG,
                          0x1C},
                          0x00},
  {CC112X_IQIC,
  {CC112X_CHAN_BW,
                          0x04},
  {CC112X_MDMCL.CC,
{CC112X_AGC_CS_THR, 0xF5},
CC112X_AGC_CS_THR, 0xF5},
(0xA0},
                         0x05},
  {CC112X_SETTLING_CFG, 0x03},
                     0x12},
  {CC112X_FS_CFG,
                          0x20},
  {CC112X_WOR_CFG0,
  {CC112X_WOR_EVENT0_MSB, 0x02},
  {CC112X_WOR_EVENT0_LSB, 0x14},
  {CC112X_PKT_CFG0,
                          0x20},
                         0x09},
  {CC112X_RFEND_CFG0,
                         0x7D},
  {CC112X_PKT_LEN,
  {CC112X_PR1_LEN, 0x7D},
{CC112X_IF_MIX_CFG, 0x00},
  {CC112X_FREQOFF_CFG, 0x22},
  {CC112X_FREQ2,
                         0x6C},
  {CC112X_FREQ1,
                         0x80},
  {CC112X_FS_DIG1,
                         0x00},
  {CC112X_FS_DIG0,
                          0x5F
  {CC112X_FS_CAL1,
                          0x40},
  {CC112X_FS_CAL0,
                          0x0E},
                         0x03},
  {CC112X_FS_DIVTWO,
                         0x33},
  {CC112X_FS_DSM0,
  {CC112X_FS_DVC0,
                         0x17},
  {CC112X_FS_PFD,
                         0x50},
  {CC112X_FS_PRE,
                         0x6E},
  {CC112X_FS_REG_DIV_CML, 0x14},
  {CC112X_FS_SPARE,
                          0 \times AC
  {CC112X_FS_VC00,
                           0xB4},
  {CC112X_XOSC5,
                          0x0E},
  {CC112X_XOSC1,
                           0x03},
};
```



Code Examples

4.1.1.1 Measurements and Estimates (RX Config. 1)

Using the CC112x_RX_Sniff_Mode Excel sheet [9] to estimate the CS response time, you get ~540 μ s (see Figure 7).

	А	В
1	Settings	
2	f _{xosc} [MHz]	32
3	DCFILT_CFG.DCFILT_BW	4
4	DCFILT_CFG.DCFILT_FREEZE_COEFF	0
5	MDMCFG1.CARRIER_SENSE_GATE	0
6	CHAN_BW.BB_CIC_DECFACT	4
7	CHAN_BW.ADC_CIC_DECFACT	0
8	Decimation factor	20
9	CHAN_BW.CHFILT_BYPASS	0
10	AGC_CFG1.AGC_WIN_SIZE	0
11	AGC_CFG1.SETTLE_WAIT	0
12	AGC_CFG0.RSSI_VALID_CNT	0
13	# of AGC_UPDATE pulses	1
14	Results	
15	D0 [us]	12,31 µs
16	D1 [us]	77,50 μs
17	D2 [us]	77,50 μs
18	D3 [us]	77,50 μs
19	D4 [us]	43,75 μs
20	D5 [us]	170,00 μs
21	D6 [us]	2,50 µs
22	T0 = D0+D1+D3+D5	337,31 μs
23	Τ1	120,00 μs
24	T2	41,44 μs
25	CS response time (# of AGC_UPDATE pulses is known)	540,19 μs
26	Max CS Response Time	660,19 µs

Figure 7. CS Response Time (CC1120, 1.2 kbps, 50 kHz RX filter BW)

Figure 8 shows the current profile when running the CC1120 RX Sniff Mode code . The RX time is measured to be 540 μ s, the same as the estimated CS response time found using the Excel sheet [9] (see Figure 7).



Figure 8. Current Profile (CC1120, 1.2 kbps, 50 kHz RX filter BW)



Figure 9 shows the measurement of the average current consumption when running the RX Sniff Mode (RX config. 1). The average current consumption (when there is no data on the air) is 0.905 mA (905 μ V measured over a 1 Ω resistor). This is almost the same as estimated in CC112x_RX_Sniff_Mode.xlsx [9] (see Figure 10).

Tek Stop			
			Ţb (a) −16.0ms
			622μs Δ16.62 ms
i g <mark>en</mark> i i se i i se i se i se i se i se i se			
The second states and second sec			and at an and the set of a set of the set of
	a da da manda da ser altra di Sasa da se angenera d		
			· · · · · · · · · · · · · · · · · · ·
			· · · ·
e e e e e e e e e e e e e e e e e e e			
10.0mVΩ [®] //	· · · ·		
Value Mean Area 15-04µVs 15.04µ Mean 905µV 905µ	Min Max St 15.04µ 15.04µ 0. 905µ 905µ 0.	2.00ms 000 1→ ▼−7.68000ms	500kS/s 10k points

Figure 9. Average Current Consumption (CC1120, 1.2 kbps, 50 kHz RX Filter BW, RX config. 1)

1	Input Parameters:	
2	Number of Preamble Bytes	3
3	SYMBOL_RATE2	43
4	SYMBOL_RATE1	A9
5	SYMBOL_RATE0	2A
6	Data Rate [sps]	1200
7	f _{xosc} [MHz]	32
8	f _{RCOCS} [kHz]	32
9	DCFILT_CFG	1C
10	MDMCFG1	46
11	CHAN_BW	04
12	AGC_CFG1	A0
13	AGC_CFG0	C3
14	PREAMBLE_CFG0	2A
15	Termination Based on:	CS
16		
17	Average Current Consumption	0,904 mA
18	t _{Event0}	16,63 ms
19	EVENTO (bex)	021/

Figure 10. CC112x_RX_Sniff_Mode.xlsx Dashboard (RX config. 1)



4.1.2 RX Config. 2

Many existing protocols use 4 bytes of preamble and 4 bytes sync. When increasing the preamble from 3 (RX config. 1) to 4 bytes, the average current consumption is reduced from 0.904 mA to 0.646 mA as shown in Figure 11, as t_{Event0} can be increased from 16.63 ms to 23.28 ms.

1	Input Parameters:	
2	Number of Preamble Bytes	4
3	SYMBOL_RATE2	43
4	SYMBOL_RATE1	A9
5	SYMBOL_RATE0	2A
6	Data Rate [sps]	1200
7	f _{xosc} [MHz]	32
8	f _{RCOCS} [kHz]	32
9	DCFILT_CFG	1C
10	MDMCFG1	46
11	CHAN_BW	04
12	AGC_CFG1	A0
13	AGC_CFG0	C3
14	PREAMBLE_CFG0	2A
15	Termination Based on:	CS
16		
17	Average Current Consumption	0,646 mA
18	t _{Event0}	23,28 ms
19	EVENT0 (hex)	02E9

Figure 11. CC112x_RX_Sniff_Mode.xlsx Dashboard (RX config. 2)

4.1.3 RX Config. 3

Assume a system using 4 bytes of preamble and a 4 bytes long sync word. The CC112x (and CC120x) can be configured to look for an 11 bits sync word. This means that the receiver can sleep for part of the sync word as well (see Figure 12), increasing t_{Event0} and reducing the current consumption.



Figure 12. 4 Bytes Sync Word vs. 11 Bits Sync Word

In this case, the effective preamble is 4 bytes + (32 - 11 bits) = 53 bits = 6.625 bytes and the average current consumption is estimated to be 0.369 mA (see Figure 13).

1	Input Parameters:	
2	Number of Preamble Bytes	6,625
3	Data Rate [sps]	1200
4	f _{xosc} [MHz]	32
5	f _{RCOCS} [kHz]	32
6	DCFILT_CFG	10
7	MDMCFG1	46
8	CHAN_BW	4
9	AGC_CFG1	AO
10	AGC_CFG0	C3
11		
12	Average Current Consumption	0,369 mA
13	t _{Event0}	40,83 ms
14	EVENT0 (hex)	051A

Figure 13. CC112x_RX_Sniff_Mode.xlsx Dashboard (RX config. 3)



4.2 CC1200 Code Example

The CC1200 code example [12] uses the 38.4 kbps typical settings from the SmartRF Studio [8] version 1.13.0 as a starting point (see Figure 14). The register settings will be altered to achieve a 1.5 mA average current consumption.

🏘 CC1 200 - Device Control Par	met (offline)								
Eile Settings View Evaluation	ion Board Help								
E Easy Mode Expert Mod	ode 🗹 Registe	er View 🔽 RF Paramete	rs					CC1200 - Register View (off	line) 🗗 🤇
Typical settings								📳 Register exp	port
Category	Setting name							_	
▼ Generic 868/915/920MHz	Sushalizate: 1 Oktober 2 ESK	12 E Mit Charge Lengths, onlinized to	constitute (PC0MUz)					Register	Value (Hex)
	Symbol rate: 4.8kbps, OOK, F	RX BW 128 kHz (868MHz)	a sensimily: (coomitz)					IOCFG2	06
	Symbol rate: 50kbps, 2-GFSk	SK, RX EW 100 kHz (868MHz) K, IEEE 802.15.4g compliant, Dual sync v	vord (868MHz)		Non-Address Constant and State Street			IOCFG1 IOCFG0	30
	Symbol rate: 100kbps, 2-FSK Symbol rate: 100kbps, 2-GES	(, RX BW 277 kHz (868MHz) SK. narrow band (868MHz)						SYNC3	93
	Symbol rate: 200kbps, 2-GFS	SK, max throughput (868MHz)						SYNC2	08
E	Symbol rate: 500ksps, 4-6FS Symbol rate: 500ksps, 2-FSK	(, narrow band (868MHz)						SYNC0	DE
 Generic 434MHz Generic 169MHz 								SYNC_CEG1	A9 03
								DEVIATION_M	06
								MODCFG_DEV_E	08
RF Parameters		Mal formula and						PREAMBLE_CFG1	14
Carrier frequency		Autor meduancy	Symbo	rate	Bit rate			PREAMBLE_CFG0	8A C9
867.999878 6 MHZ	2	40.000000 Mmz	36.4	ksps	38.4 800	5		CHAN_BW	10
104 169667 Max			Levial 10.001	2014 644	14	n		MDMCFG1	42
104.100007 1112			18.80	014 812				SYMBOL_RATE2	8F
Manchester enable		PA ramping	□ we	itening				SYMBOL_RATE1	75
				-				AGC_REF	27
Range Extender None	~							AGC_CS_THR	E
							_	AGC_CF03	B1
Continuous TX Continuous RX Pa	Packet TX Pocket RX RF D	Device Commands						AGC_CFG2	20
Executed exclud exacts 400						ř.		AGC_CFG0	94
Expected packet court.	make							FFO_CFG	00
Viewing format: Hexadecin	mai 💌					58	1	SETTLING_CFG	08
□ 802.15.4g mode 🗹 Seq. numb	ber included in payload.					47		FS_CFG	12
						4		WOR_CFG0	21
							RX	WOR_EVENT0_MSB MOR_EVENT0_LSB	00
								RXDCM_TIME	00
								PKT_OFG2	00
								PKT_CFG0	20
								RFEND_CFG1	OF
								PA_CFG1	7F
								PA_CFG0	56
								PKT_LEN	FF
								F_MX_CFG	10
								TOC_CFG	20
								MARC_SPARE	00
								MDMCFG2	02
								EXT_CTRL	01
						Average RSSt -		ROCAL_FINE ROCAL_COARSE	00
						Received ok: 0		RCCAL_OFFSET	00
						Packet error rate: -		 FREQOFF1 FREQOFF0 	00
Dump data to file:								FREQ2	56 💌
Advanced						Start	Stop	Register reset Help	Retresh

Figure 14. Typical Settings (CC1200, 38.4 kbps, ETSI standard)

Code Examples

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The register settings obtained by using the code export feature is shown in Example 4.

Example 4. Code Export (CC1200, 38.4 kbps, ETSI standard)

```
// RX filter BW = 104.166667
// Address config = No address check
// Packet length = 255
// Symbol rate = 38.4
// Carrier frequency = 867.999878
// Bit rate = 38.4
// Packet bit length = 0
// Whitening = false
// Manchester enable = false
// Modulation format = 2-GFSK
// Packet length mode = Variable
// Device address = 0
// Deviation = 19.989014
// Rf settings for CC1200
static const registerSetting_t preferredSettings[] = {
  {CC120X_IOCFG2, 0x06},
{CC120X_SYNC_CFG1, 0xA9},
  {CC120X_MODCFG_DEV_E, 0x0B},
  {CC120X_PREAMBLE_CFG0, 0x8A},
  {CC120X_IQIC,
                           0xC8},
                          0x10},
  {CC120X_CHAN_BW,
  {CC120X_MDMCFG1,
{CC120X_MDMCFG0
                          0x42},
                           0x05},
  {CC120X_MDMCFG0,
  {CC120X_SYMBOL_RATE2,
                            0x8F},
  {CC120X_SYMBOL_RATE1,
                             0x75},
  {CC120X_SIMBOL_RATE0,
{CC120X_SYMBOL_RATE0,
                            0x10},
  {CC120X_AGC_REF,
                            0x27},
                         0xEE } ,
  CC120X_AGC_CS_THR,
  {CC120X_AGC_CFG1,
                          0x11},
  {CC120X_AGC_CFG0,
                           0x94},
  {CC120X_FIFO_CFG,
                           0x00},
  {CC120X_FS_CFG,
                           0x12},
  {CC120X_PKT_CFG2,
                           0x00},
  {CC120X_PKT_CFG0,
                            0x20},
  {CC120X_PKT_LEN, UXFF;,
{CC120X_PKT_LEN, 0xFF;,
{CC120X_IF_MIX_CFG, 0x1C},
UXFF;,
{CC120X_IF_MIX_CFG, 0x03},
  {CC120X_TOC_CFG,
                          0x02},
  {CC120X_MDMCFG2,
  {CC120X_FREQ2,
                          0x56},
  {CC120X_FREQ1,
                           0xCC},
  {CC120X_FREQ0,
                           0xCC},
                            0xEE } ,
  {CC120X_IF_ADC1,
  {CC120X_IF_ADC0,
                             0x10},
  {CC120X_FS_DIG1,
                             0x07},
  {CC120X_FS_DIG0,
                            0xAF},
  {CC120X_FS_CAL1,
                            0x40},
                           0 \ge 0 \ge 
  {CC120X FS CAL0,
  {CC120X_FS_DIVTWO,
                           0x03},
  {CC120X_FS_DSM0,
                           0x33},
  {CC120X_FS_DVC0,
                           0x17},
  {CC120X_FS_PFD,
                           0x00},
                            0x6E},
  {CC120X_FS_PRE,
                           0x1C},
  {CC120X_FS_REG_DIV_CML,
  {CC12UX_F5_XE____
{CC12UX_F5_SPARE, 0xAC},
______0xB5},
                           0x09},
  {CC120X_IFAMP,
  {CC120X_XOSC5,
                            0x0E},
  {CC120X_XOSC1,
                             0x03},
};
```



AGC_WIN_SIZE, AGC_SETTLE_WAIT, and RSSI_VALID_COUNT were all set to 0 (see Section 3.9.1) and FS auto calibration was turned off (SETTLING_CFG.FS_AUTOCAL = 0). The register values were input to the CC120x_RX_Sniff_Mode Excel sheet [10] as shown in Figure 15. Figure 15 also shows that the number of preamble bytes is too low to be able to run the RX Sniff Mode. ⁽¹⁾



Figure 15. CC120x_RX_Sniff_Mode.xlsx Dashboard (3 bytes preamble)

To be able to run the RX Sniff Mode and achieve an average current consumption of ~1.5 mA, the number of preamble bytes transmitted must be increased to 24 bytes, as shown in Figure 16. It can easily be seen that reducing the current on the RX side means increased current consumption on the TX side.

1	Input Parameters:	
2	Number of Preamble Bytes	24
3	SYMBOL_RATE2	8F
4	SYMBOL_RATE1	75
5	SYMBOL_RATE0	10
6	Data Rate [sps]	38400
7	f _{xosc} [MHz]	40
8	f _{RCOSC} [kHz]	40
9	MDMCFG2	2
10	MDMCFG0	5
11	IQIC	C8
12	SYNC_CFG0	3
13	CHAN_BW	10
14	DCFILT_CFG	4C
15	IF_MIX_CFG	1C
16	AGC_CFG1	0
17	AGC_CFG0	90
18	PREAMBLE_CFG0	8A
19	Termination Based on:	CS
20		
21	Average Current Consumption	1,518 mA
22	t _{Event0}	4,88 ms
23	EVENT0 (hex)	00C3

Figure 16. CC120x_RX_Sniff_Mode.xlsx Dashboard (24 bytes preamble)

The sensitivity limit for the chosen RF settings is -110 dBm (see the CC1200 data sheet [6]). In the code example [12], the CS threshold is set 1 dB higher, at -109 dBm, to avoid too many wake-ups due to noise.

The RSSI offset is -81 dBm (see the CC120x user's guide [2]). To get a CS threshold of -109 dBm, AGC_CS_THR must be set to 0xE4 (use Equation 11).

CS Threshold = AGC_CS_THR + RSSI Offset AGC_CS_THR = CS Threshold - RSSI Offset = -109 - (-81) = -28

(11)

The rest of the relevant register fields were changed in the same manner as explained for the CC1120 example [11] (see Section 4.1) and the registers settings used by the CC1200 RX Sniff Mode code example [12] are shown in Example 5.

¹⁾ A solution might be to use the RX Duty Cycle Mode as the RX duty cycle timer provides smaller timeouts on the time not spent in RX, but this application report does not go into details on this topic. The CC120x user's guide [2] provides more info on this mode.

Example 5. RX Sniff Mode Settings (CC1200, 38.4 kbps, ETSI standard)

```
// RX filter BW = 104.166667
// Address config = No address check
// Packet length = 125
// Symbol rate = 38.4
// Carrier frequency = 867.999878
// Bit rate = 38.4
// Packet bit length = 0
// Whitening = false
// Manchester enable = false
// Modulation format = 2-GFSK
// Packet length mode = Variable
// Device address = 0
// Deviation = 19.989014
// Rf settings for CC1200
static const registerSetting_t preferredSettings[] = {
  {CC120X_IOCFG2, 0x13},
  {CC120X_IOCFG0,
                           0x06},
  {CC120X_10CFG0, 0xA0},
{CC120X_SYNC_CFG1, 0xA9},
{CC120X_MODCFG_DEV_E, 0x0B},
  {CC120X_PREAMBLE_CFG1, 0x30},
  {CC120X_PREAMBLE_CFG0, 0x8A},
  {CC120X_IQIC,
                           0xC8},
  {CC120X_CHAN_BW,
                          0x10},
  {CC120X_MDMCFG1,
                          0x42},
                           0x05},
  {CC120X_MDMCFG0,
  CC120X_SYMBOL_RATE2,
                            0x8F},
  {CC120X_SYMBOL_RATE1,
                            0x75},
  {CC120X_SYMBOL_RATE0,
                        0x27},
                           0x10},
  {CC120X_AGC_REF,
                          0xE4},
  {CC120X_AGC_CS_THR,
 {CC120X_AGC_CFG1, UXUUJ,
{CC120X_AGC_CFG1, UXUUJ,
~~ CPG0, 0x90},
  {CC120X_SETTLING_CFG, 0x03},
  CC120X_FS_CFG,
                           0x12},
  {CC120X_WOR_CFG0,
                           0x20},
                          0xC3},
  {CC120X_WOR_EVENT0_LSB,
  {CC12UX_WUN_2...
{CC12UX_PKT_CFG2, 0x0U},
_____OFG0, 0x20},
  {CC120X_RFEND_CFG0,
                          0x09},
  {CC120X_PKT_LEN,
                          0x7D},
                         0x1C},
  {CC120X_IF_MIX_CFG,
  {CC120X_TOC_CFG,
                          0x03},
  {CC120X_MDMCFG2,
                           0x02},
  {CC120X_FREQ2,
                           0x56},
  {CC120X_FREQ1,
                            0xCC},
  {CC120X_FREQ0,
                            0xCC},
  {CC120X_IF_ADC1,
                           OxEE},
  {CC120X_IF_ADC0,
                           0x10},
  {CC120X_FS_DIG1,
                          0x07},
  {CC120X_FS_DIG0,
                          0xAF},
  {CC120X_FS_CAL1,
                          0x40},
  {CC120X_FS_CAL0,
                          0x0E},
  {CC120X_FS_DIVTWO,
                          0x03},
  {CC120X_FS_DSM0,
                           0x33},
  {CC120X_FS_DVC0,
                           0x17},
  {CC120X_FS_PFD,
                           0x00},
                   0x6E},
  {CC120X_FS_PRE,
  {CC120X_FS_REG_DIV_CML, 0x1c},
                            0xAC},
  {CC120X FS SPARE,
  {CC120X_FS_VC00,
                            0xB5},
  {CC120X_IFAMP,
                            0x09},
  {CC120X_XOSC5,
                            0 \times 0 E},
  {CC120X_XO<u>SC1</u>,
                            0x03},
```



Example 5. RX Sniff Mode Settings (CC1200, 38.4 kbps, ETSI standard) (continued)

};

Figure 17 shows the current profile when running the CC1200 RX Sniff Mode code [12]. The average current consumption is measured to be 1.50 mA, very close to the estimated current consumption found using the 120x_RX_Sniff_Mode Excel sheet [10] (see Figure 16).



Figure 17. Average Current Consumption (CC1200, 38.4 kbps, ETSI standard, 24 bytes preamble)



5 Conclusion

This application report has shown which registers to configure when implementing the RX Sniff Mode and also provides two Excel sheets, which provide a good estimation of the average current consumption when using this mode. The code examples can be used as starting points when implementing the RX Sniff Mode in a real-life application.

From the examples one can see that the average current consumption decreases when the preamble length increases. For very long preamble sequences it is recommended to use SmartPreamble. This concept is described in details in [13].

6 References

- 1. CC112X/CC1175 Low-Power High Performance Sub-1 GHz RF Transceivers/Transmitter User's Guide (SWRU295)
- 2. CC120x Low-Power High Performance Sub-1 GHz RF Transceivers User's Guide (SWRU346)
- 3. CC1120 High Performance RF Transceiver for Narrowband Systems Data Sheet (SWRS112)
- 4. CC1121 High Performance Low Power RF Transceiver Data Sheet (SWRS111)
- 5. CC1125 Ultra-High Performance RF Narrowband Transceiver Data Sheet (SWRS120)
- 6. CC1200 Low Power, High Performance RF Transceiver Data Sheet (SWRS123)
- 7. CC112x/CC1175 High Performance RF Transceiver/Transmitter for Narrowband Systems Errata Note (SWRZ039)
- 8. SmartRF Studio (SWRC176)
- 9. CC112x_RX_Sniff_Mode.xlsx (SWRA428)
- 10. CC120x_RX_Sniff_Mode.xlsx (SWRA428)
- 11. CC112x Software Examples (SWRC253)
- 12. CC120x Software Examples (SWRC274)
- 13. CC112x/CC120x RX Sniff Mode With Smart Preamble (SWRA438)



Appendix A Revision History

This document has been revised from SWRA428 to SWRA428A because of the following technical change(s).

Table 6. SPNU428A Revisions

Location	Additions, Deletes, and Edits
Table 3	Added two registers (MDMCFG1 and SYNC_CFGx)
Section 3.2	Added Info on how to determine t_{Event0} when using PQT termination. Also added info on how the RC oscillator tolerance should be accounted for.
Section 3.7	Added info on t _{Event0} when PQT termination is enabled
Section 3.9	Added info saying that t_{Event0} is shorter when PQT termination is enabled compared to when using CS termination.
Figure 4	Added case C showing the current consumption for the radio when MCU is used to terminate RX (and CS termination is enabled on the radio).
Section 3.9.2	Added explanation of PQT response time and reference to user's guides.
Section 4.1	SmartRF Studio version changed from 1.12.0 to 1.13.0.
Section 4.1.1.1	New value for EVENT0 since the RC oscillator tolerance is accounted for in the equation.
Figure 5	Added MDMCFG1 and SYNC_CFG1
Example 3	Changed value of WOR_EVENT0_LSB
Figure 9	Updated with new measurements
Figure 10	Updated due to new revision of excel sheet
Figure 11	Updated due to new revision of excel sheet
Section 4.1.2	Changes numbers in the text related to Figure 11
Figure 13	Updated with new measurements
Example 4	Changed value FS_REG_DIV_CML
Figure 15	Updated due to new revision of excel sheet
Figure 16	Updated due to new revision of excel sheet
Example 5	Changed value FS_REG_DIV_CML
Figure 17	Updated with new measurements
Section 5	Added reference to [13]

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