CMOSTEK

AN138

CMT2219A Configuration Guideline

Introduction

The purpose of this document is to provide the guidelines for the users to configure the CMT2219A on the RFPDK. The part number covered by this document is shown in the table below.

Table 1. Part Number Covered in this Document

Product	Modulation/ Frequency	Sensitivity	Rx Current	Embedded EEPROM	Operation Mode
CMT2219A	(G)FSK/OOK 300-960 MHz	-109 dBm (868.35 MHz, 1 ksps, 0.1% BER/FSK)	5.7 mA (868.35 MHz/FSK)	√	Active / Passive

The RFPDK (RF Products Development Kit) is a PC application developed by CMOSTEK for the NextGenRF^{TM} product line. Differing from traditional RF chip configuration methods, which usually require complex software programming and register-based controlling, the RFPKD revolutionarily simplifies the NextGenRF^{TM} product configurations. The user can easily complete the product configuration by just clicking and inputting a few parameters. After that, the product can be directly used in the RF system without performing any further configurations.

This document describes the details of how to configure the features/parameters of the CMT2219A with the RFPDK.

To help the user develop their application with CMT2119A and CMT2219A easily, CMOSTEK provides **CMT2119A/2219A One-Way RF Link Development Kits** that enables the user to quickly evaluate the performance, demonstrate the features and develop the application. The Development Kits includes:

- RFPDK
- USB Programmer
- RF-EB (evaluation board for NextGenRF^{TM} products)
- CMT2119A-EM (Tx module)
- CMT2219A-EM (Rx module)

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1. Getting Started

Install RFPDK on the computer. The detail of the installation can be found in Chapter 7 of “AN103 CMT211xA/221xA One-Way RF Link Development Kits User’s Guide”.

Setup the development kits as shown in Figure 1 before configuring the CMT2219A. The Application with CMT2219A can be CMT2219A-EM provided by CMOSTEK, or the PCB designed by the user with CMT2219A.

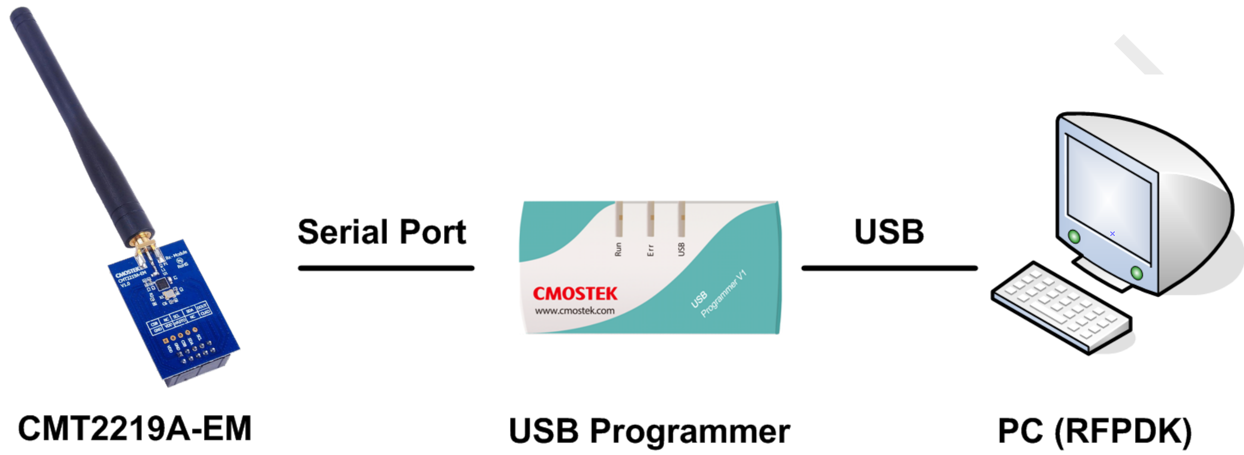

Figure 1. CMT2219A Configuration Setup

Start the RFPDK from the computer’s desktop and select CMT2219A in the Device Selection Panel shown in Figure 2. Once a device is selected, the Device Control Panel appears as shown in Figure 3. Because the Advanced Mode covers all the configurable features/parameters while the Basic Mode only contains a subset, the Advanced Mode is described in this document.

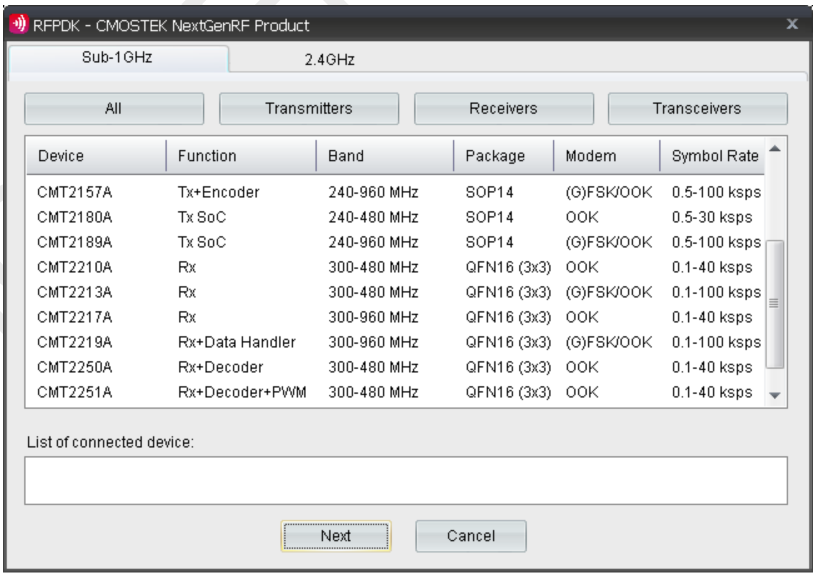

Figure 2. Device Selection Panel

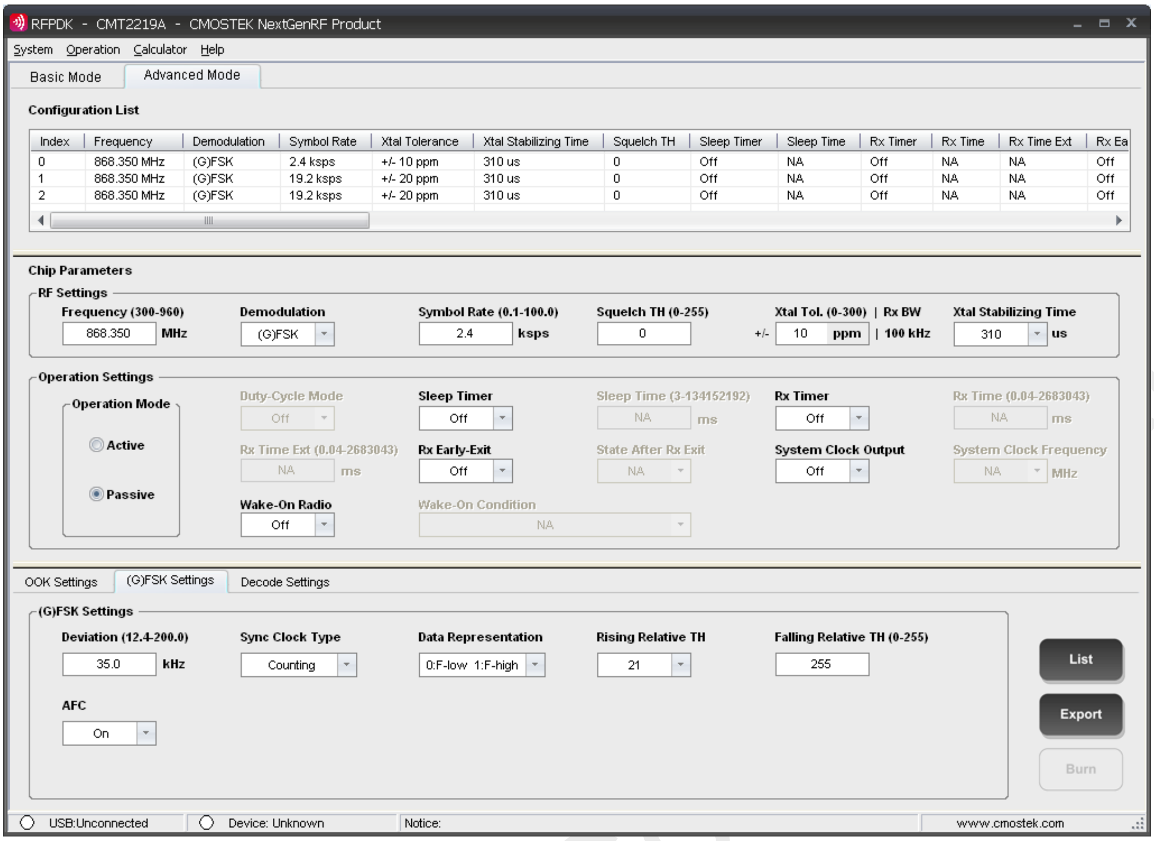

Figure 3. Advanced Mode of Device Control Panel

2. RF Settings

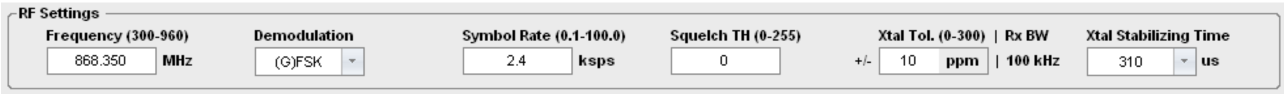

Figure 4. RF Settings

Table 2. RF Settings Parameters

Parameters	Descriptions	Default	Mode
Frequency	The receive radio frequency, the range is from 300 to 960 MHz, with resolution of 0.001 MHz.	868.350 MHz	Basic Advanced
Demodulation	The demodulation type, the options are: OOK or (G)FSK demodulation.	(G)FSK	Basic Advanced
Symbol Rate	The receiver symbol rate, the range is from 0.1 to 40 ksps for OOK and from 0.1 to 100.0 ksps for (G)FSK, with resolution of 0.1 ksps.	2.4 ksps	Basic Advanced
Squelch TH	The threshold of the squelch circuit to suppress the noise, the range is from 0 to 255.	0	Basic Advanced
Xtal Tol. | Rx BW	The sum of the crystal frequency tolerance of the Tx and the Rx, the range is from 0 to ±300 ppm. And the calculated BW is configured and displayed.	±10 ppm | 100 kHz	Basic Advanced
Xtal Stabilizing Time	Time for the device to wait for the crystal to get settled after power up. The options are: 78, 155, 310, 620, 1240 or 2480 us.	310 us	Basic Advanced

2.1 Frequency

CMT2219A covers a wide range of the receive radio frequency from 300 to 960 MHz. The frequency is accurate to three decimal places on the RFPDK.

2.2 Demodulation

CMT2219A supports OOK, FSK and GFSK demodulation.

2.3 Symbol Rate

With OOK demodulation, CMT2219A supports 0.1 – 40.0 ksps symbol rate. The symbol rate tolerance of the device is from –25% to +25% of the “Symbol Rate” configured on the RFPDK. For example, if the user set the symbol rate to 9.6 ksps on the RFPDK, the covered symbol rate of the transmitted data is from 7.2 to 12 ksps. If the user set it to 40 ksps, the covered range is from 30 to 40 ksps. Any symbol rate outside the range of 0.1 – 40 ksps is not supported.

With (G)FSK demodulation, CMT2219A supports 0.1 – 100.0 ksps symbol rate. Normally, the symbol rate tolerance of the device is from –30% to +30% of the “Symbol Rate” configured on the RFPDK. For example, the user set the symbol rate to 9.6 ksps on the RFPDK, the covered symbol rate of the transmitted data is from 6.7 to 12.5 ksps. If the user set it to 100 ksps, the covered range is from 70 to 100 ksps. Any symbol rate outside the range of 0.1 – 100 ksps is not supported. The less symbol rate offset exists between the transmitter and the receiver, the less sensitivity is lost. The following data can be used as a reference. Please note that when the “Tracing” method is used to recover the sync clock (see Chapter 5.4.2), the symbol rate tolerance is from –9% to +9%.

2.4 Squelch TH

The Squelch Threshold is used to mute the receiver output in the absence of the desired radio signal. Since the RSSI is digitized to an 8-bit binary value that has the range from 0 to 255, the squelch threshold is designed to be an 8-bit binary value that is comparable to the digitized RSSI.

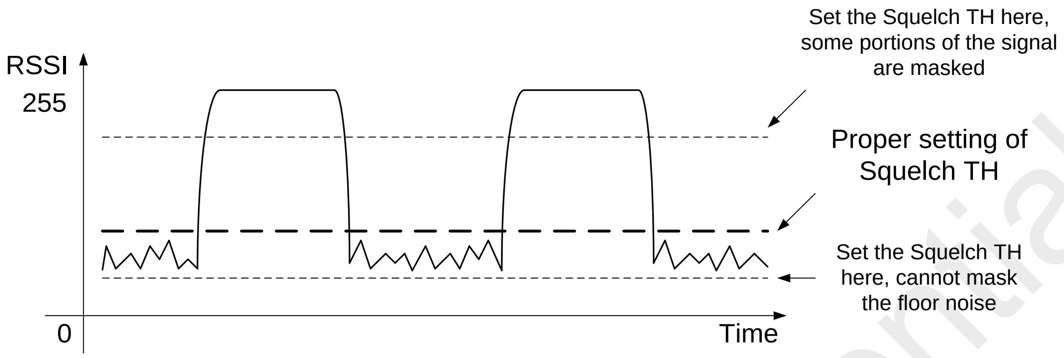

Figure 5. Squelch Threshold

When the received signal strength falls below this threshold the output of the receiver is muted. The user shall set the squelch threshold just above the background radio noise level. Setting a larger threshold requires higher received signal strength to un-mute the receiver, which also means the receiving sensitivity becomes lower. When the radio muting is not required, the squelch threshold can be set to 0 to avoid any potential lost in the sensitivity.

The best way to find the proper value of the Squelch TH is to observe the demodulation output on DOUT. Without any effective signal being transmitted in the channel, the DOUT stays logic 0 while the threshold is set over the noise floor, and outputs random sequence of 0 and 1 while the threshold is set below the noise floor. The user is able to find a value that is just over the noise floor by try and error.

2.5 Xtal Tol. | Rx BW

This is the sum of the crystal frequency tolerance of the transmitter and receiver. The input range is from 0 to ±300 ppm. The wide range of crystal tolerance allows very low cost crystal to be used in the applications.

Assuming the crystal tolerance of the transmitter is ±10 ppm, and the crystal tolerance of the receiver is ±20 ppm, the user shall enter the total tolerance of ±30 ppm on the RFPDK. The RFPDK takes this into account to calculate the receiving bandwidth, which is displayed on the right hand side of the input Xtal tolerance. When the crystal tolerance increases, the bandwidth is increased and the sensitivity is reduced. However, the powerful AFC function can minimize the frequency error due to the crystal tolerance and therefore maintains the highest sensitivity performance.

It is also recommended for the user to perform on-field testing of the sensitivity with the desired setting of the Xtal Tolerance.

2.6 Xtal Stabilizing Time

This defines the time for the device to wait for the crystal to get stable after it is powered up. The user shall select one of the six options provided on the RFPDK that is most suitable for the crystal used in the applications.

3. Operation Settings

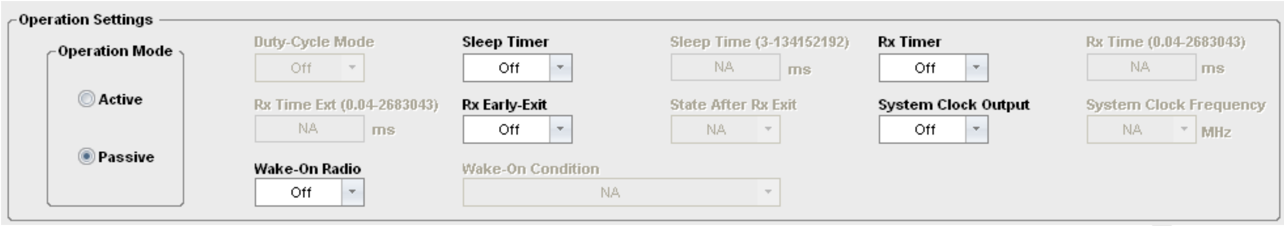

Figure 6. Operation Settings

The available operating options for the radio control are listed in the table below.

Table 3. Operation Settings Parameters

Parameters	Descriptions	Default	Mode
Operation Mode	This determines that the chip works in Active mode by using off-line configuration or works in Passive mode by using on-line configuration.	Passive	Basic Advanced
Duty-Cycle Mode	Turn on/off the duty-cycle mode, the options are: on or off. It is only available when Active mode is selected.	On	Basic Advanced
Sleep Timer	This turns on/off the sleep timer.	Off	Basic Advanced
Sleep Time	This parameter is only available when the Sleep Timer is turned on. The sleep time has the range from 3 to 134,152,192 ms.	10 ms	Basic Advanced
Rx Timer	This turns on/off the receive timer.	Off	Basic Advanced
Rx Time	This parameter is only available when the Rx Timer is turned on. The receive time has the range from 0.04 to 2,683,043.00 ms.	1 ms	Basic Advanced
Rx Time Ext	The extended receive time has the range from 0.04 to 2,683,043.00 ms. It is only available when Wake-On Radio is turned on and the Rx Timer is turned on.	200.00 ms	Advanced
Rx Early-Exit	Turn on/off the Rx early exit function, the options are: on or off.	Off	Advanced
State After Rx Exit	This defines the state to which the device will switch after the Rx Early-Exit. The options are: STBY or TUNE.	STBY	Advanced
Wake-On Radio	Turn on/off the wake-on radio function, the options are: on or off.	Off	Advanced
Wake-On Condition	The condition to wake on the radio, the option is: Extended by Preamble, or Extended by Preamble then Sync Word. It is only available when Wake-On Radio is turned on.	Extended by Preamble	Advanced
System Clock Output	Turn on/off the system clock output on CLKO, the options are: on or off.	Off	Advanced
System Clock Frequency	The system clock output frequency, the options are: 13.000, 6.500, 4.333, 3.250, 2.600, 2.167, 1.857, 1.625, 1.444, 1.300, 1.182, 1.083, 1.000, 0.929, 0.867, 0.813, 0.765, 0.722, 0.684, 0.650, 0.619, 0.591, 0.565, 0.542, 0.520, 0.500, 0.481, 0.464, 0.448, 0.433, 0.419 or 0.406 MHz. It is only available when System Clock Output is turned on.	6.500 MHz	Advanced

3.1 Operation Mode

When works in Active mode, the device is configured by the contents stored in the embedded EEPROM, which is programmed off-line. When works in Passive mode, the device is configured by the external MCU through on-line register accessing.

3.2 Passive Operation Mode

3.2.1 Sleep Timer, Sleep Time

The sleep time has the range is from 3 to 134,152,192 ms. Please note that the sleep timer which is driven by the LPOSC has ±1% frequency tolerance.

3.2.2 Rx Timer, Rx Time, Rx Time Ext

The Rx Time is the receive time that has the range from 0.04 to 2,683,043.00 ms. The Rx Time Ext is the extended receive time that has the same range as the Rx Time. It must be configured when Wake-On Radio (WOR) is turned on. The receive timer is driven by the crystal oscillator therefore the timer accuracy is crystal-dependent.

3.2.3 Rx Early-Exit, State After Rx Exit

Once the Rx Early-Exit is turned on, the device will automatically exit the RX state as soon as a valid packet is received. This saves the work of the external MCU program and the system power consumption. After the existing the RX state, the parameter "State After Rx Exit" tells the device to which state it will automatically switch.

3.2.4 Wake-On Radio, Wake-On Condition

The wake-on radio (WOR) function is an effective power consumption saving technique that minimizes the receive time while it guarantees that the device can successfully capture the transmitted data. See the section 3.6.4, 3.6.5 and 3.6.6 for details of WOR.

3.2.5 Passive Operation Mode Application Examples

The following application examples are provided for good understanding of how to control the device operating state, timers and WOR with the external MCU.

3.2.5.1 Example 1: Sleep Timer Only

Table 4. Sleep Timer Only Configurations

Options	Value	Options	Value
Sleep Timer	On	Sleep Time	500 ms
RX Timer	Off	RX Time, RX Time Ext	Ignored, Ignored
RX Early-Exit	Off	State After Rx Exit	Ignored
Wake-On Radio	Off	Wake-On Condition	Ignored

The sleep time is fixed to 500 ms. The RX state entering and exiting is totally under the MCU's control.

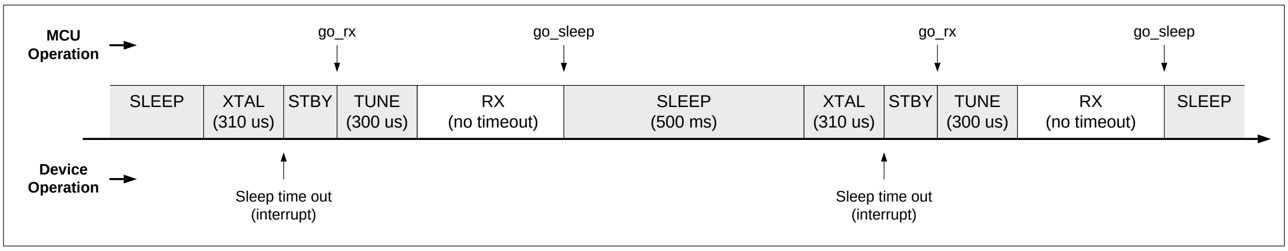

Figure 7. Sleep Timer Only Operation

Once the radio wakes up from SLEEP, it switches to STBY and generates an interrupt to notify the MCU. The MCU issued a 'go_rx' command to switch the radio into the RX state. Before entering the RX state, it takes about 300 us for the device to perform the frequency calibrations.

During the RX state, as usual the MCU uses the different data acquisition mode to obtain the data. The MCU issues a 'go_sleep' command to switch the radio back to SLEEP whenever it wants to.

3.2.5.2 Example 2: Fixed Duty

Table 5. Fixed Duty Configurations

Options	Value	Options	Value
Sleep Timer	On	Sleep Time	500 ms
RX Timer	On	RX Time, RX Time Ext	50 ms, Ignored
RX Early-Exit	Off	State After Rx Exit	Ignored
Wake-On Radio	Off	Wake-On Condition	Ignored

The sleep and receive time is fixed to 500 ms and 50 ms, respectively.

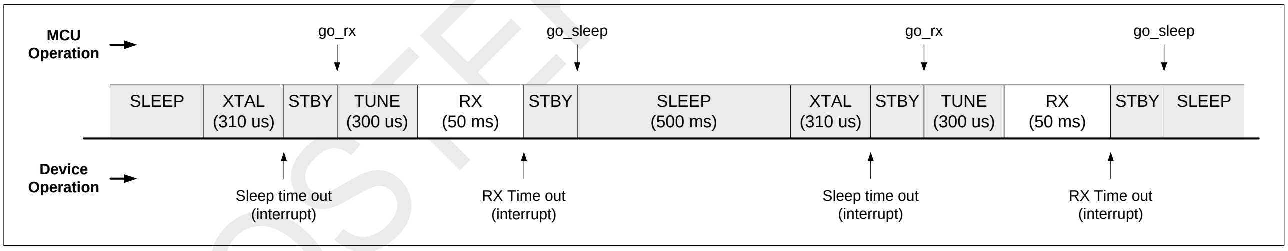

Figure 8. Fixed Duty Operation

Once the radio wakes up from SLEEP, it switches to STBY and generates an interrupt to notify the MCU. The MCU issued a 'go_rx' command to switch the radio into the RX state. Before entering the RX state, it takes about 300 us for the device to perform the frequency calibrations.

During the RX state, as usual the MCU uses the different data acquisition mode to obtain the data. Once the radio exits the RX state, it switches to STBY and waits for the MCU's command. At the same time, it generates an 'rx_timeout' interrupt to notify the MCU.

The MCU is also able to read the FIFO in the STBY state. Also, during the time when the radio is switched from RX to STBY, the FIFO read operation can be performed as usual. However, the FIFO content will be cleared in the SLEEP state.

At the end of the cycle, the MCU issues a 'go_sleep' command to switch the radio back to the SLEEP state.

3.2.5.3 Example 3: Fixed Duty + Early Exit

Table 6. Fixed Duty + Early Exit Configurations

Options	Value	Options	Value
Sleep Timer	On	Sleep Time	500 ms
RX Timer	On	RX Time, RX Time Ext	50 ms, Ignored
RX Early-Exit	On	State After Rx Exit	STBY
Wake-On Radio	Off	Wake-On Condition	Ignored

Based on the Example 2, the Early Exit function is turned on in this example. The Early Exit means that whenever the device received a valid packet, it automatically leaves the RX state. This option is only functional in the Packet Mode, since in Direct Mode and Buffer Mode the device does not recognize a packet.

The sleep time is fixed at 500 ms, while the receive time is either 50 ms, or being shorter due to an early exit by receiving a valid packet.

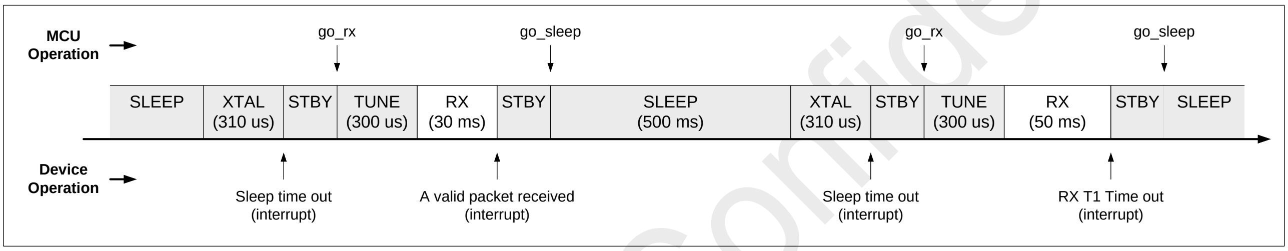

Figure 9. Fixed Duty + Early Exit Operation

When a valid packet is received, the 'pkt_done' interrupt is generated to notify the MCU as soon as the device switches to the STBY from the RX. If no packet is received, an 'rx_timeout' interrupt is generated at the switch from RX to STBY to notify the MCU.

3.2.5.4 Example 4: Wake on Preamble

Table 7. Wake on Preamble Configurations

Options	Value	Options	Value
Sleep Timer	On	Sleep Time	500 ms
RX Timer	On	RX Time, RX Time Ext	10 ms, Ignored
RX Early-Exit	Off	State After Rx Exit	Ignored
Wake-On Radio	On	Wake-On Condition	Extended by Preamble

The wake-on radio function provides a more powerful scheme to save the power. In this example, the receiver time is set to 10 ms which is much shorter than the packet length. The sleep time is still 500 ms.

When there is no effective signal received, the radio acts like the one introduced in the Example 1. Because the RX Time is much shorter, more power is saved.

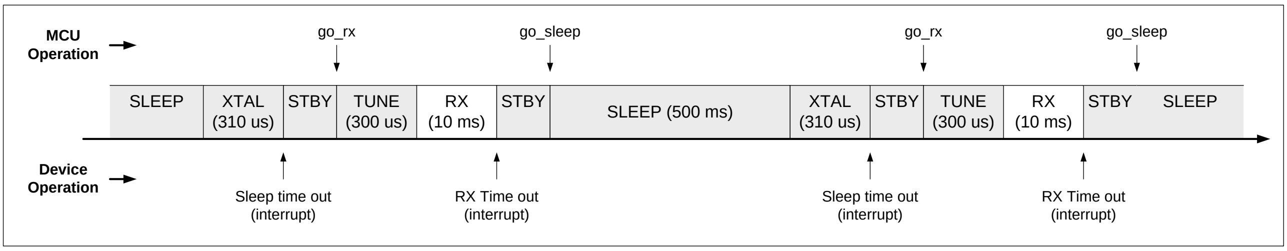

Figure 10. Wake on Preamble without Valid Signal Operation

If a valid preamble is received, the RX state is extended from RX Time to manual control (the RX Timer is off). The extension of the RX state allows the entire packet to be received. The MCU issues a 'go_sleep' command to switch the device back to SLEEP at the end of the cycle.

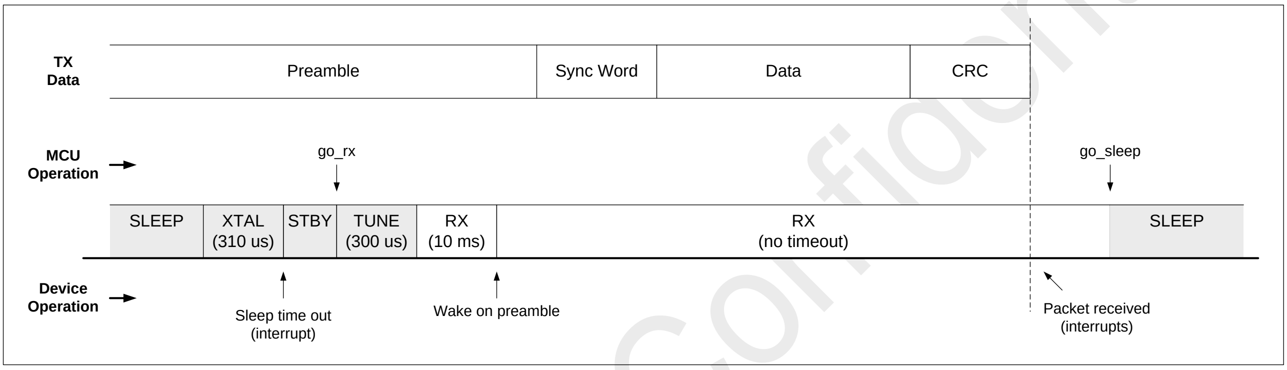

Figure 11. Wake on Preamble with Valid Signal Operation

3.2.5.5 Example 5: Wake on Preamble then Sync Word

Table 8. Wake on Preamble then Sync Word Configurations

Options	Value	Options	Value
Sleep Timer	On	Sleep Time	500 ms
RX Timer	On	RX Time, RX Time Ext	10 ms, 30 ms
RX Early-Exit	Off	State After Rx Exit	Ignored
Wake-On Radio	On	Wake-On Condition	Extended by Preamble then Sync Word

Compared to the Example 4, this example can even save more power by providing two stages of RX extension.

When there is no effective signal received, the radio acts like the one introduced in the Example 1.

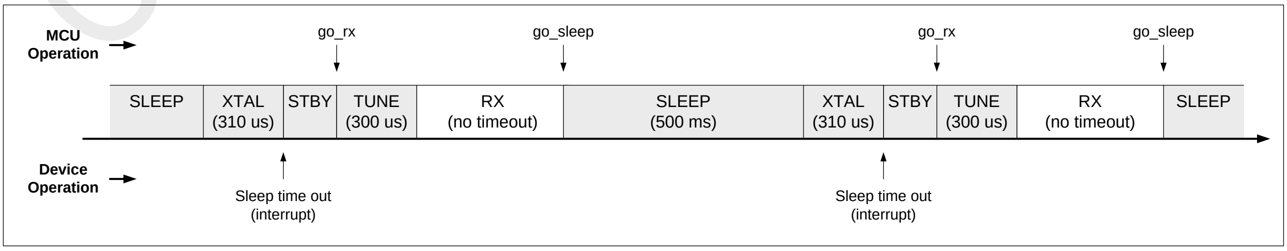

Figure 12. Wake on Preamble then Sync Word without Valid Signal Operation

If a valid preamble is received, the RX is switched to RX EXT. The RX EXT is just long enough to receive the sync word. Later on, if the sync word validation is failed, the radio switches from RX to STBY on the RX EXT timeout.

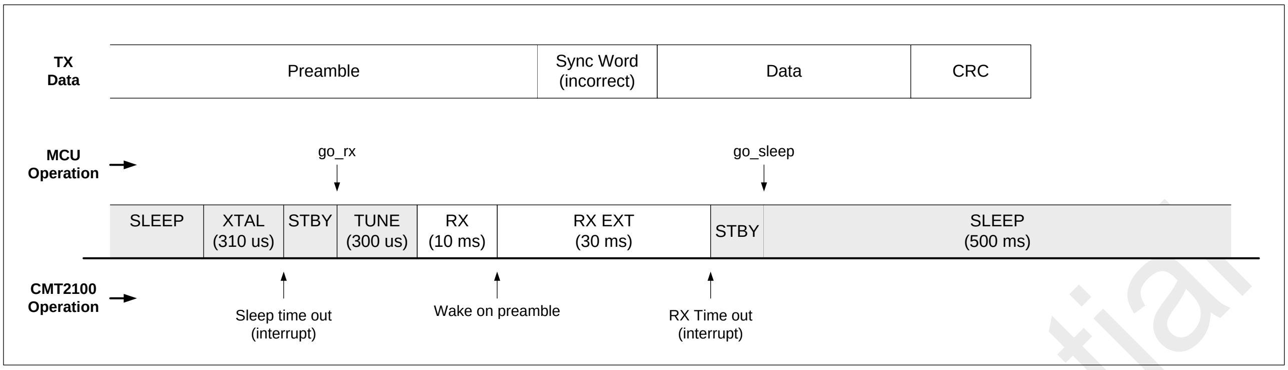

Figure 13. Wake on Preamble then Sync Word with Invalid Sync Word Operation

If the sync word validation is successful, the receive time is extended from RX EXT to manual control (the RX timer is off). The extension of the RX state allows the entire packet to be received. The MCU issues a 'go_sleep' command to switch the device back to SLEEP at the end of the cycle.

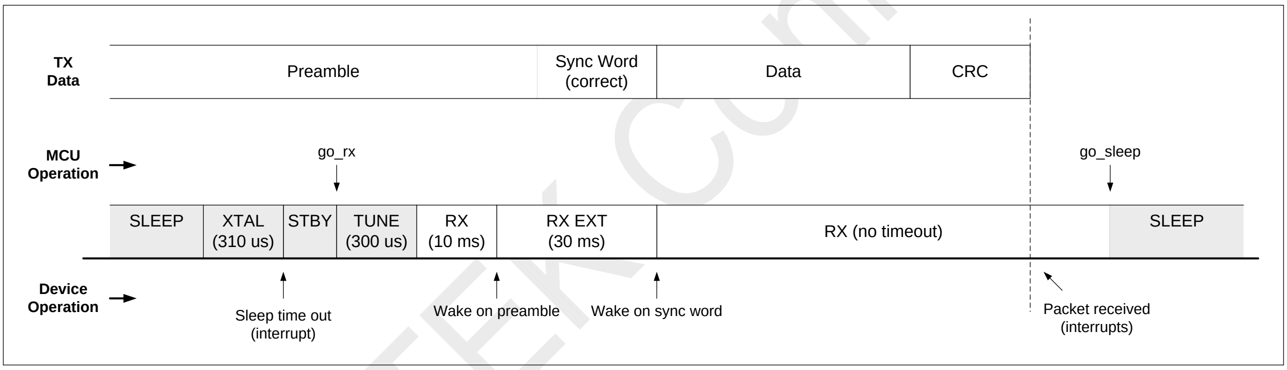

Figure 14. Wake on Preamble then Sync Word with Valid Sync Word Operation

3.2.5.6 Example 6: Wake on Preamble then Sync Word + Early Exit

Table 9. Wake on Preamble then Sync Word + Early Exit Configurations

Options	Value	Options	Value
Sleep Timer	On	Sleep Time	500 ms
RX Timer	On	RX Time, RX Time Ext	10 ms, 30 ms
RX Early-Exit	On	State After Rx Exit	STBY
Wake-On Radio	On	Wake-On Condition	Extended by Preamble then Sync Word

This example is based on the Example 5. With the RX Early-Exit option turned on, the radio automatically switches from RX to STBY as soon as a valid packet is received. This further saves the power.

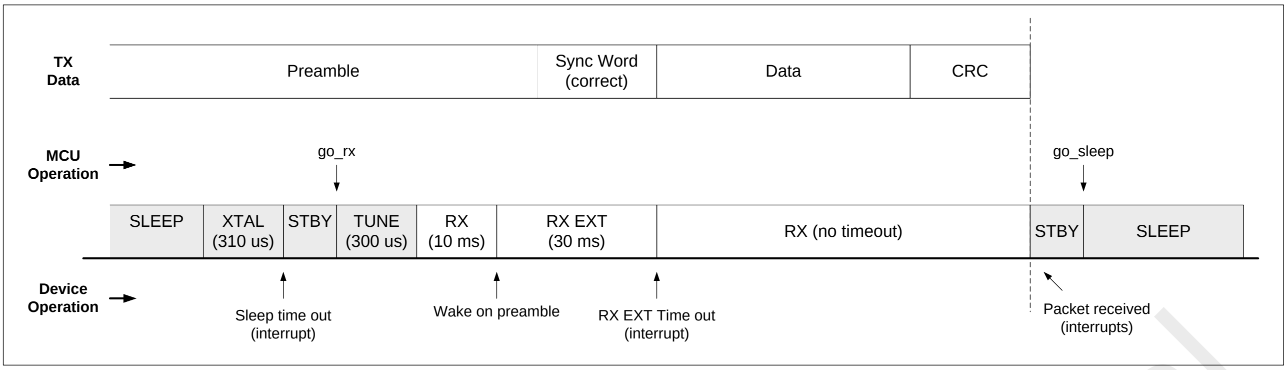

Figure 15. Wake on Preamble then Sync Word + RX Early-Exit Operation

This example is only applied to the **Packet Mode**.

3.3 Active Operation Mode

3.3.1 Duty-Cycle Mode

When Active operation mode is selected, the Duty-Cycle Mode option allows the user to determine how the radio is controlled, as shown in the figure below.

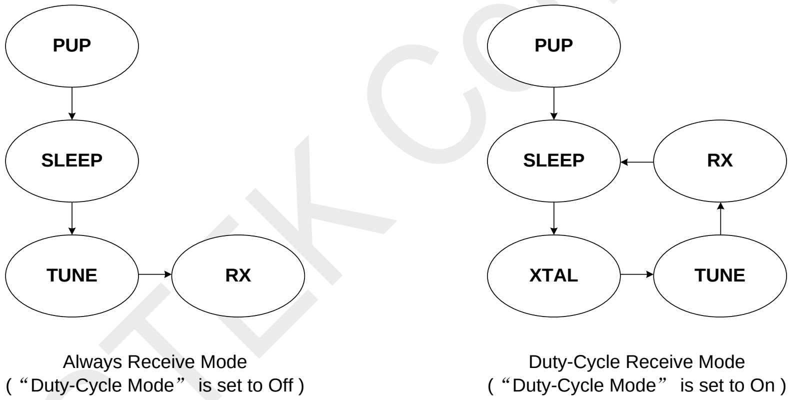

Figure 16. Radio Operation with Duty-Cycle Mode On and Off

3.3.1.1 Always Receive Mode

If the duty-cycle mode is turned off, the device will go through the Power Up (PUP) sequence, stay in the SLEEP state for about 3 ms, tune the receive frequency, and finally stay in the RX state until the device is powered down. The power up sequence, which takes about 4 ms to finish, includes the task of turning on the crystal and calibrating the internal blocks. The device will continuously receive the incoming RF signals during the RX state and send out the demodulated data on the DOUT pin. The configurable system clock is also output from the CLKO pin if it is enabled in the Advanced Mode on the RFPDK. The figure below shows the timing characteristics and current consumption of the device from the PUP to RX.

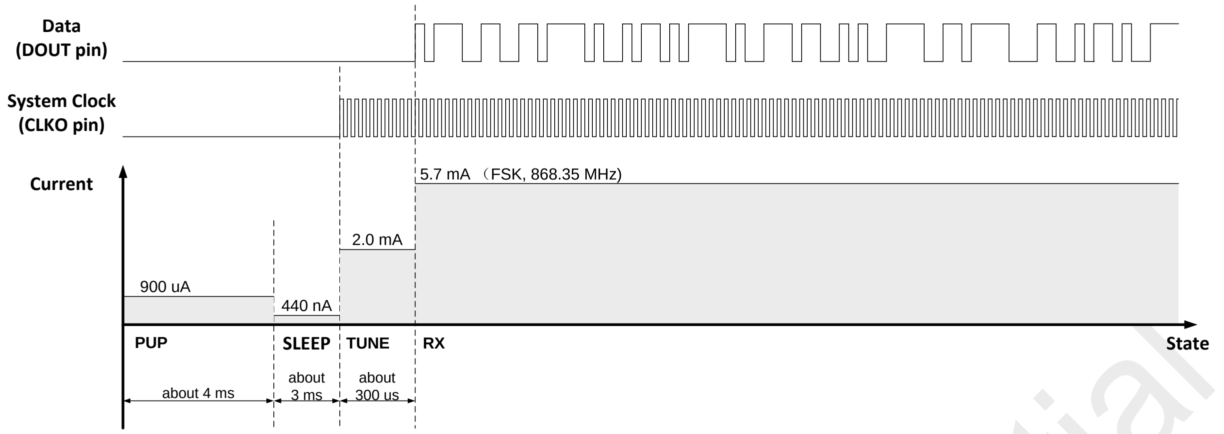

Figure 17. Timing and Current Consumption for Always Receive Mode

3.3.1.2 Duty-Cycle Receive Mode

If the duty-cycle mode is turned on, after the PUP the device will automatically repeat the sequence of SLEEP, XTAL, TUNE and RX until the device is powered down. This allows the device to re-tune the synthesizer regularly to adept to the changeable environment and therefore remain its highest performance. The device will continuously receive any incoming signals during the RX state and send out the demodulated data on the DOUT pin. The configurable system clock output is output from the CLKO pin during the TUNE and RX state. The PUP sequence consumes about 9.5 ms which is longer than the 4 ms in the Always Receive Mode. This is because the LPOSC, which drives the sleep timer, must be calibrated during the PUP.

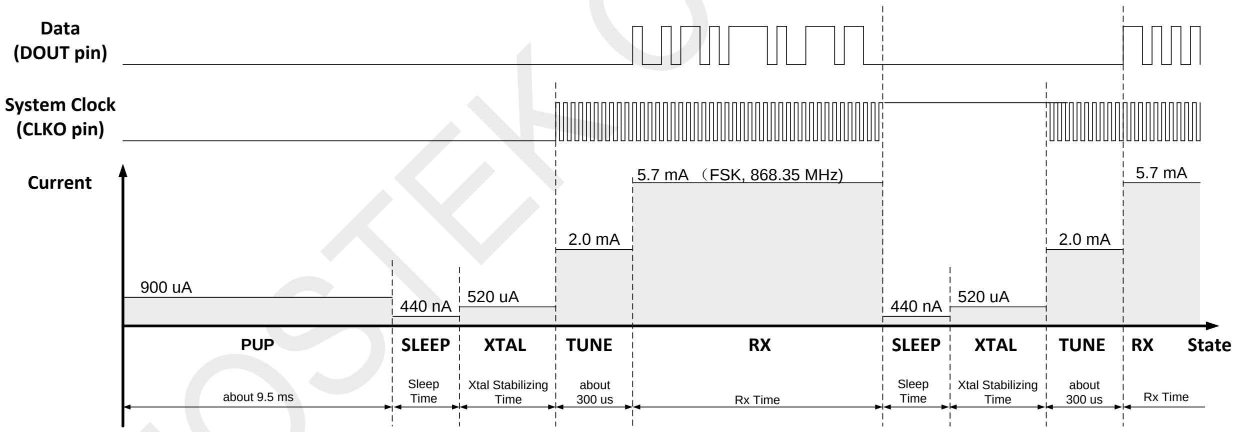

Figure 18. Timing and Current Consumption for Duty-Cycle Receive Mode

It is strongly recommended for the user to turn on the duty-cycle mode option. The advantages are:

- Maintaining the highest performance of the device by regular frequency re-tune.
- Increasing the system stability by regular sleep (resetting most of the blocks).
- Saving power consumptions of both of the Tx and Rx device.

As long as the Sleep Time and Rx Time are properly configured, the transmitted data can always be captured by the device.

3.3.2 Sleep Time, Rx Time in Active Operation Mode

When the Duty-Cycle Mode is turned on, the Sleep Time and Rx Time is opened to the user to configure. Proper setting of these two values is important for the device to work in an expected scenario.

3.3.2.1 Easy Configuration

When the user wants to take the advantage of maintaining the highest system stability and performance, and the power consumption is not the first concern in the system, the Easy Configuration can be used to let the device to work in the duty-cycle mode without complex calculations, the following is a good example:

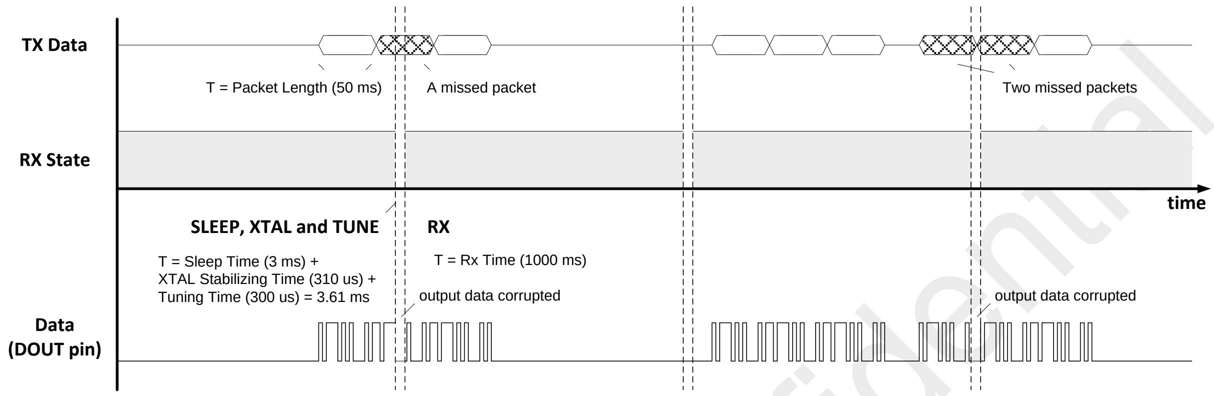

Figure 19. Tx and Rx relationship of Easy Configuration

In this example, the Tx device transmits the data at 1.2 ksps and there are 60 symbols in one data packet. Thus, the packet length is 50 ms. The user can do the following:

- Set the Sleep Time to the minimum value of 3 ms.
- Set the Rx Time to 1 second which is much longer than the packet length.
- Let the Tx device to send out 3 continuous data packets in each transmission.

Because the Sleep Time is very short, the non-receive time is only about 3.61 ms (the sum of the Sleep Time, XTAL stabilizing time and the tuning time), which is much shorter than the packet length of 50 ms. Therefore, this non-receive time period will only have a chance to corrupt no more than 2 packets receiving. During the non-receive time period, the DOUT pin will output logic 0.

Because the Rx Time is very long, and 3 continuous data packets are sent in each transmission, there is at least 1 packet that can be completely received by the device and sent out via the DOUT pin with no corruption. The external MCU will only need to observe the DOUT pin status to perform data capturing and further data processing.

3.3.2.2 Precise Configuration

If the system power consumption is a sensitive and important factor in the application, the Precise Configuration can be used.

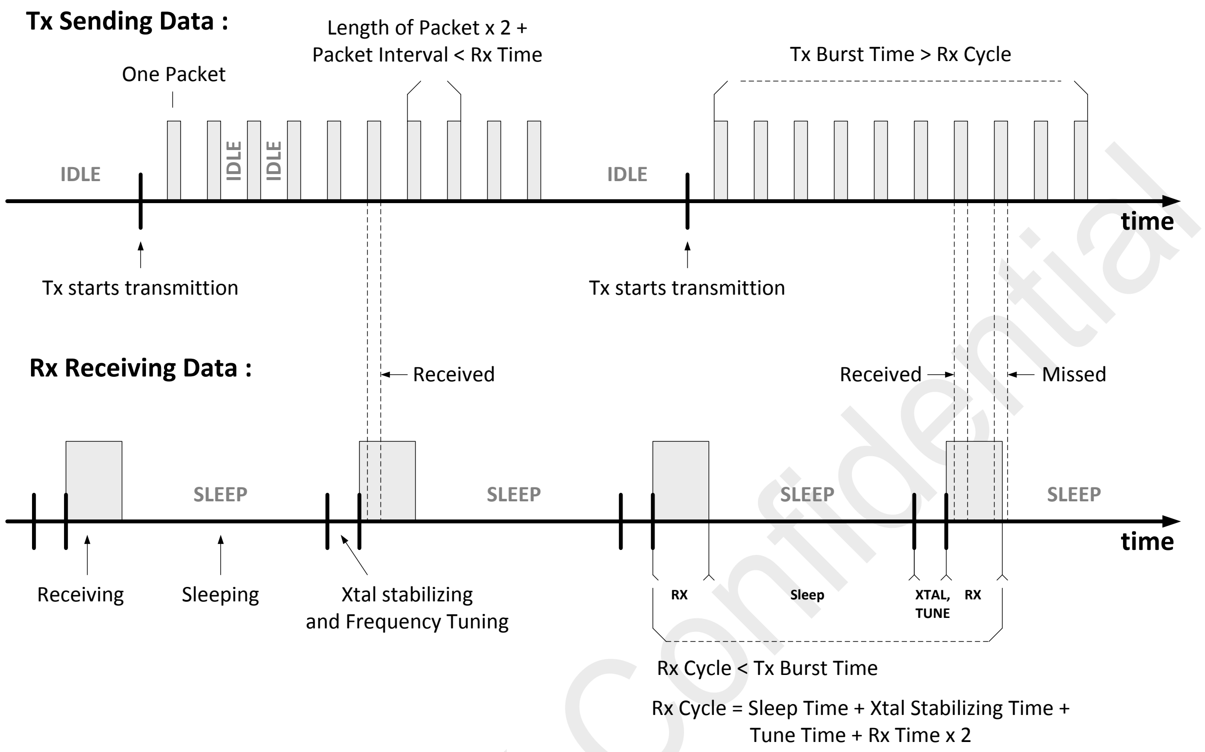

Figure 20. Tx and Rx Relationship of Precise Configuration

The above figure is a conceptual diagram to explain the timing relationships between the Tx and the Rx device. The user will have to make some trade-off amount the packet length, packet interval, Tx burst time, Rx receive time and Rx sleep time, to optimize the power consumption of the Rx device. Two requirements must be fulfilled:

- Length of Packet x 2 + Packet Interval < Rx Time
- Tx Burst Time > Rx Cycle, where Rx Cycle = Xtal Stabilizing Time + Tune Time + Rx Time x 2 + Sleep Time

The Rx Time must always be longer than the packet length times two plus the packet interval which is determined by the Tx setting (symbol rate, number of symbol per packet, etc). This ensures that the receiver always has a chance to capture at least 1 packet within a Tx Burst. Normally, it is recommended for the user to set the Rx Time to be longer than 2 or more packets plus the intervals, especially when the application environment is noisy and interferential. The user must also ensure that the Rx Cycle is shorter than the Tx Burst Time. In another words, it must be ensured that at least 1 RX state happens during 1 Tx Burst.

3.3.3 Wake-On Radio, Wake-On Condition in Active Operation Mode

The following application examples are provided for good understanding of Wake-on Radio in Active Operation Mode.

Please note that the sleep timer which is driven by the LPOSC has ±1% frequency tolerance. The receive timer is driven by the crystal oscillator therefore the timer accuracy is crystal-dependent.

3.3.3.1 Application Example 1: Fixed Duty

Table 10. Fixed Duty Configurations

Options	Value
Sleep Time	5,000 ms
Rx Time	400 ms
Rx Time Ext	NA
Wake-On Radio	Off
Wake-On Condition	NA
Preamble Size	NA

The sleep and receive time is fixed to 5,000 ms and 400 ms, respectively.
The Xtal Stabilizing Time is set to 310 us.

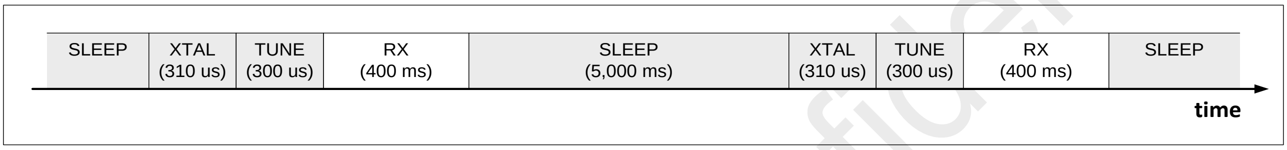

Figure 21. Fixed Duty Operation

After a successful power up, the device enters the SLEEP state. When it reaches the sleep timeout of 5,000 ms, it switches to XTAL state to wait for the crystal to get stable. Subsequently it takes about 300 us to tune the frequency synthesizer to the desired frequency. Once the frequency synthesizer is locked, the device starts receiving. When the Rx timer is timeout at 400 ms, the device switches back to the SLEEP state and repeat the same cycle continuously until it is powered down.

In this example, the non-receive time is 5,000 + 0.31 + 0.3 = 5,000.61 ms. The receive time is 400 ms. Therefore, according to the principle introduced in the “Precise Configuration”, the Tx burst time must be longer than 5,400.61 ms, and 2 data packets must appear during the RX state for safety.

3.3.3.2 Application Example 2: Wake on Preamble

Table 11. Wake on Preamble Configurations

Options	Value
Sleep Time	800 ms
Rx Time	20 ms
Rx Time Ext	200 ms
Wake-On Radio	On
Wake-On Condition	Extended by Preamble
Preamble Size	2-byte

The wake-on radio function provides a powerful scheme to save the power. In this example, the receive time is set to 20 ms which is much shorter than the packet length. The sleep time is 800 ms.

When there is no effective signal received, the radio acts like the one introduced in the Application Example 1. Because the Rx time is much shorter, more power is saved.

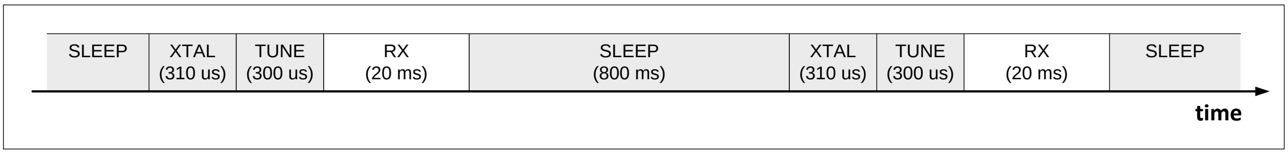

Figure 22. Preamble Wake-On Operation without Preamble Detected

If a valid preamble is received, the RX state is extended to RX EXT which is long enough for more than 2 data packets reception. A valid preamble means the preamble of the size (2-byte in this example) defined on the RFPDK. Please note that the preamble size defined for the Rx device is not necessarily the entire preamble length that is transmitted by the Tx device.

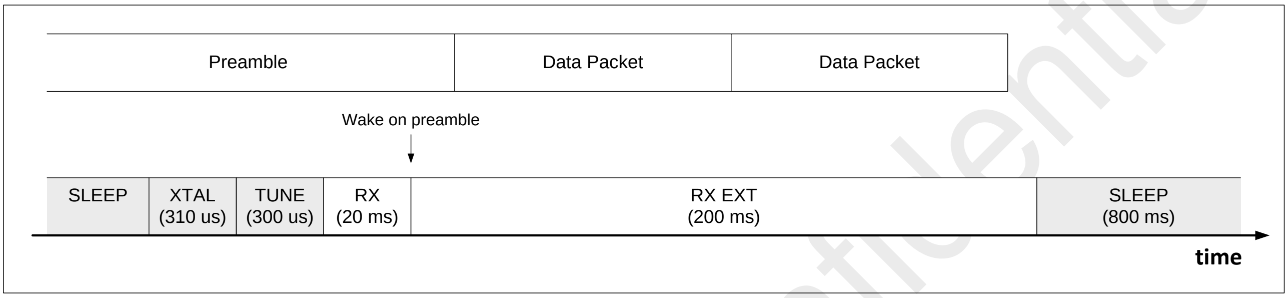

Figure 23. Preamble Wake-On Operation with Preamble Detected

In order to ensure that the preamble can be captured by the Rx, the RX EXT must be longer than the valid preamble size which is 2-byte.

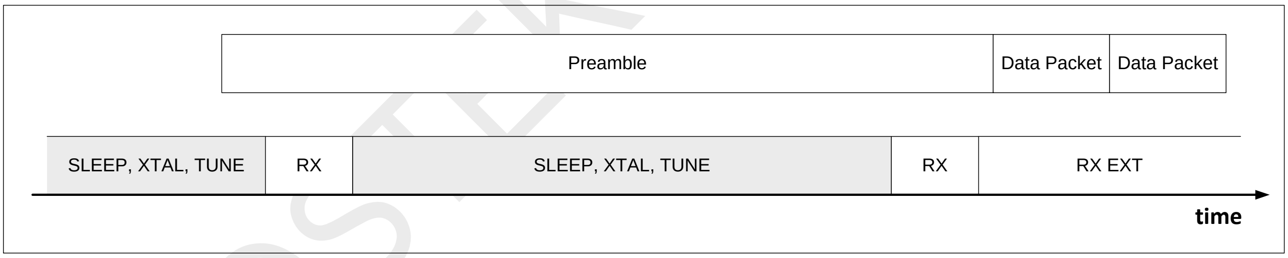

Figure 24. The Transmitted Preamble Length

Also, as shown in the above figure, for the Tx device, the transmitted preamble length must be long enough to ensure the Rx reception:

Preamble Length > RX + SLEEP + XTAL + TUNE + RX

The longer the transmitted preamble length is, the more power the Tx device consumes in each transmission. Therefore, this example is suitable for the application where the Tx device does not send out data very often, and the Rx device is very sensitive about the current consumption.

3.3.3.3 Application Example 3: Wake on RSSI

Table 12. Wake on RSSI Configurations

Options	Value
Sleep Time	800 ms
Rx Time	20 ms
Rx Time Ext	200 ms
Wake-On Radio	On
Wake-On Condition	Extended by RSSI
Preamble Size	NA

This is similar to the Application Example 2, but the wake-on condition is changed to a valid RSSI. Once a valid RSSI is detected, the RX state is extended to RX EXT which is long enough for more than 2 data packets reception.

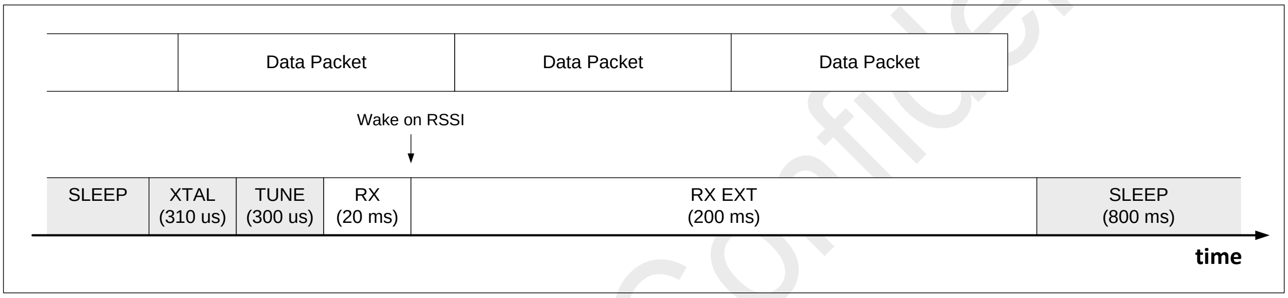

Figure 25. RSSI Wake-On Operation with RSSI Detected

The timing requirement obeys the rules introduced in the "Precise Configuration".

This example is only suitable for the application where the noise level is known and the squelch threshold is properly set to mask the noise. This is because any incoming noise higher than the squelch threshold leads to a valid RSSI produced that can wake on the radio. As a result, the goal of saving the power consumption cannot be reached.

3.4 System Clock Output, System Clock Frequency

If the system clock output is enabled on the RFPDK, a continuous clock signal divided down from the 26 MHz crystal clock is output via the CLKO pin to drive the external MCU or other devices. The selectable clock frequency has a wide range from 0.406 to 13 MHz. This clock is only available when the device is not in the SLEEP or PUP state.

The user can either use this clock to drive the external MCU, or as an indication of the device working status. In some circumstances, the MCU can treat this clock as an interrupt to synchronize the working status to that of the device.

4. OOK Settings

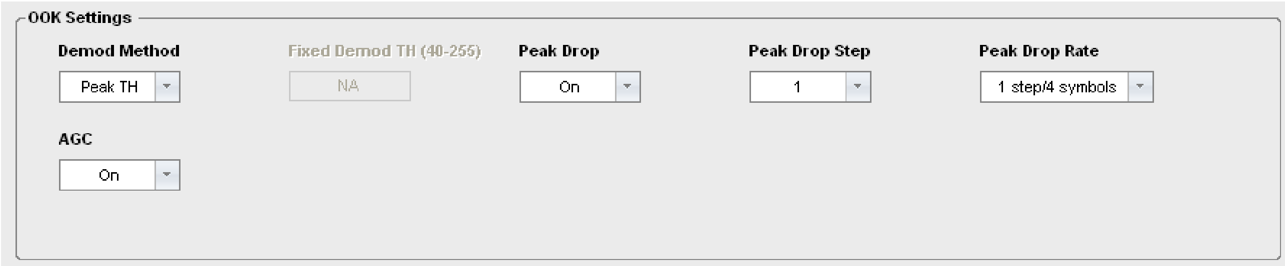

Figure 26. OOK Settings

Table 13. OOK Settings

Parameters	Descriptions	Default	Mode
Demod Method	The OOK demodulation methods, the options are: Peak TH, or Fixed TH.	Peak TH	Advanced
Fixed Demod TH	The threshold value when the Demod Method is "Fixed TH", the minimum input value is the value of Squelch Threshold set on the RFPDK, the maximum value is 255.	50	Advanced
Peak Drop	Turn on/off the RSSI peak drop function, the options are on, or off.	On	Advanced
Peak Drop Step	The RSSI peak drop step size, the options are: 1, 2, 3, 5, 6, 9, 12 or 15.	1	Advanced
Peak Drop Rate	The RSSI peak drop rate, the options are: 1 step/4 symbols, 1 step/2 symbols, 1 step/1 symbol, or 1 step/0.5 symbol.	1 step/4 symbols	Advanced
AGC	Automatic Gain Control, the options are: on or off.	On	Advanced

4.1 Demod Method

The OOK demodulation is done by comparing the RSSI to a demodulation threshold. The threshold is an 8-bit binary value that is comparable to the 8-bit digitized RSSI.

4.1.1 Fixed Threshold Method

When the "Demod Method" is set to Fixed TH, once the RSSI goes above the threshold, logic 1 is output as the demodulated signal, otherwise logic 0 is output.

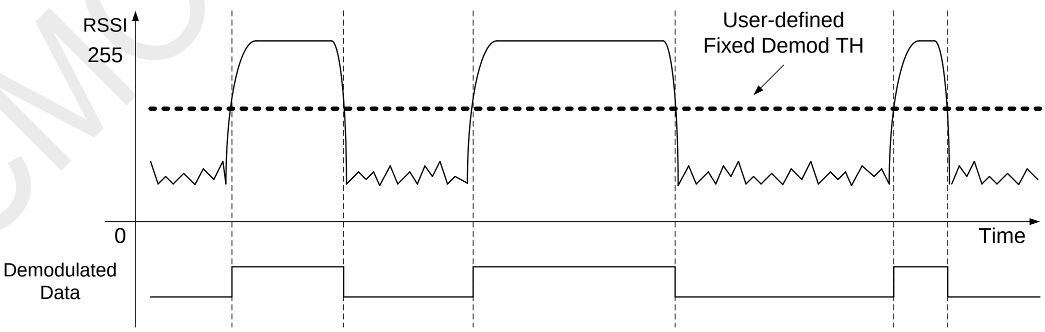

Figure 27. OOK Demodulation Using Fixed Threshold

The minimum value of the Fixed Demod TH is always higher than the Squelch Threshold, because anything lower than the squelch threshold is muted, and therefore setting the Fixed Demod TH lower than the squelch threshold is meaningless.

4.1.2 Peak Threshold Method

When the “Demod Method” is set to “Peak TH”, the demodulator dynamically detects the peak value of the RSSI. The comparison threshold (Demod TH) is then obtained by reducing N dB from the peak. The magnitude of N is internally calculated according to the different bandwidths, symbol rates and filtering settings.

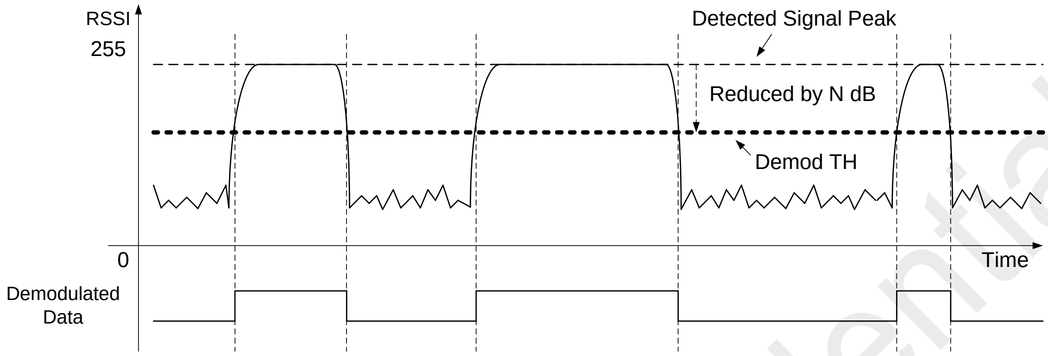

Figure 28. OOK Demodulation Using Peak - N Threshold

When the signal disappears, the peak is detected on the noise floor (see more descriptions in the Section 4.3). A proper setting of Squelch Threshold holds its functionality of muting the floor noise when there is no valid signal being received.

To compare the two different modes, the Peak TH mode is used by default on the RFPDK, due to its high adaptability to the different environments and it is carefree for the user. The Fixed TH mode allows the system to only receive the signals whose strength is above a preset value, which is helpful for the user to control the communication distance between the Tx and the Rx.

4.2 Fixed Demod TH

This parameter defines the value of the fixed threshold. The minimum value of this parameter can be set is the value of the Squelch Threshold. This is because anything below the Squelch Threshold is muted. Setting the demodulation threshold below the Squelch Threshold is insignificant. It is unused when the demodulation method is set to Peak TH.

4.3 Peak Drop Step, Peak Drop Rate

When using the Peak TH mode, the Peak Drop function is very useful to deal with the long string of logical “0” on the received data.

When the Peak Drop function is turned off, the dynamically detected peak remains 8 symbols. This means within a moving 8-symbol time window the peak value of the RSSI will be recorded to calculate the demodulation threshold. This might have problem when a string longer than 8 symbols of logical “0” appears, as shown in the below figure.

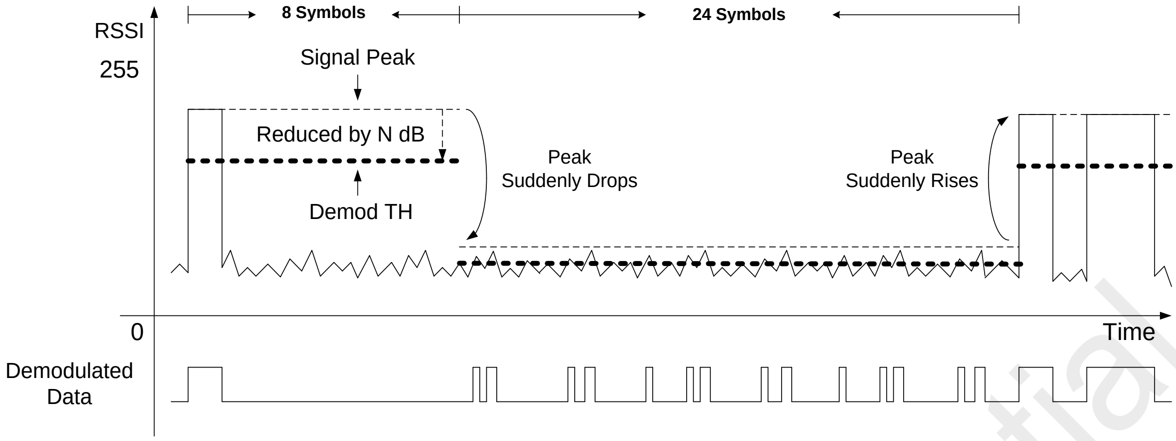

Figure 29. OOK Demodulation Using Peak - N Threshold, with Peak Drop Off

As shown in the above figure, the transmitter sends out a "1" symbol followed by thirty-one "0" symbols. After the signal peak stands for 8 symbols, it suddenly drops to just above the floor noise. From that point the detected peak is actually the floor noise peak and the demodulated data is unpredictable. The last 24 symbols of "0" are then lost or partially lost. Practically, the similar situation does exist and this will lead to failure of demodulation.

The problem can be resolved by turning on the Peak Drop function. It allows the detected peak to drop slowly in order to recognize more symbols of "0". The following figure gives an example. In this example, the Peak Drop Step parameter is set to 12 (RSSI code) on the RFPDK, with the Peak Drop Rate set to 1 step per 2 symbols.

The value of the Peak Drop Step defines how many RSSI codes the signal peak drops each time. The value of Peak Drop Rate defines how fast the peak drop is performed.

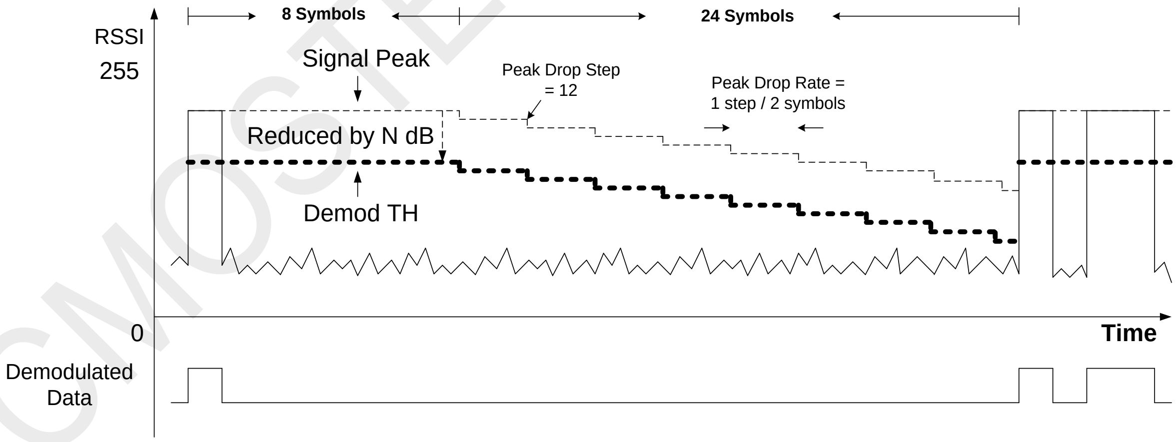

Figure 30. OOK Demodulation Using Peak - N Threshold, with Peak Drop On

As shown in the above figure, after remaining 8 symbols, the peak drops step by step until the next '1' symbol comes. The demodulation threshold drops accordingly to the peak and stays above the noise floor during the long '0' sequence, and therefore allows the device to produce the correct demodulation result. The longer it takes for the peak to drop to the noise floor, the more "0" the system can demodulate. In practice, the bottom of the dropping is either the Squelch Threshold defined on the RFPDK when all the noise are muted by the threshold, or the noise floor which varies depending on the different environments. Below is an example to calculate the total drop time:

Assuming the signal peak is 240, to drop from 239 to 0, the total drop time is computed by:

Drop Time = 240 / Peak Drop Step / Peak Drop Rate, units in Rx symbols

Since the maximum step size is 15 (in terms of RSSI code) and the highest rate is 1 step per 0.5 symbol, the fastest peak drop from 239 to 0 is: 240 / 15 / (1/0.5) = 8-symbol time. Since the minimum step is 1 and the lowest rate is 1 step per 4 symbols, the slowest peak drop from 239 to 0 is: 240 / 1 / (1/4) = 960-symbol time.

It should be noticed that, in the above computations the “time” is measured in “numbers of the Rx symbol” according to the symbol rate configured on the RFPDK. The user should take the symbol rate offset into account during the calculations. For instance, if the Rx symbol rate is set to 4.8 ksps while the Tx actually transmits the data at 2.4 ksps, the signal peak only stands for 4 symbols (at 2.4 ksps) instead of 8 symbols before starting the dropping. Also, the peak drop rate doubles.

CMOSTEK recommends turning on the peak drop function on the RFPDK. By default, the step is set to 2 and the rate is set to 1 step per 4 symbols, and thus it takes 480 symbols to drop from 239 to 0. This default setting fulfills the requirements in most of the wireless applications using OOK. The user does not have to change them unless particular situation are found, such as, the transmitted signals are very small, symbol rate offset is too large, or the string of ‘0’ is too long.

4.4 AGC

The Automatic Gain Control option is available for the device to have better blocking immunity performance for OOK demodulation. It is recommended to turn on the AGC during the normal operation.

5. (G)FSK Settings

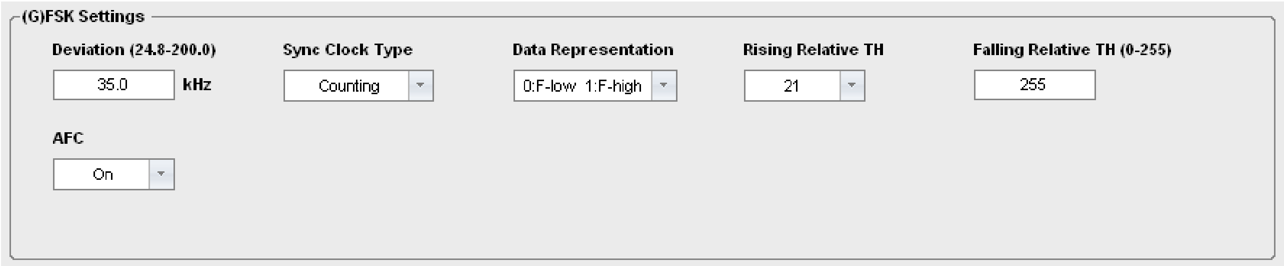

Figure 31. (G)FSK Settings

Table 14. (G)FSK Settings Parameters

Parameters	Descriptions	Default	Mode
Deviation	The (G)FSK frequency deviation. The minimum value of the deviation is equal to Xtal Tolerance (ppm) x Frequency (MHz) / 0.7. The maximum value of deviation is equal to 220 kHz - Xtal Tolerance (ppm) x Frequency (MHz).	35.0 kHz	Basic Advanced
Data Representation	To select whether the frequency "F-high" represent data 0 or 1. The options are: 0: F-high 1:F-low, or 0: F-low 1:F-high.	0: F-low 1:F-high	Basic Advanced
Sync Clock Type	This parameter allows the user to select the method to perform the clock data recovery. The options are: tracing or counting.	Counting	Advanced
Rising Relative TH	This is the relative threshold to trigger the (G)FSK demodulation. It is measured in terms of RSSI code. The options are: 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 36, 42, 54, 66, or 90.	21	Advanced
Falling Relative TH	This is the relative threshold to shut down the (G)FSK demodulation. It is measured in terms of RSSI code. The range is from 0 to 255.	255	Advanced
AFC	Turn on/off the Automatic Frequency Control function. The options are: On or Off.	On	Advanced

5.1 Deviation

The device supports a wide range of deviations. The deviation is the maximum instantaneous difference between the modulated frequency and the nominal carrier frequency Fo.

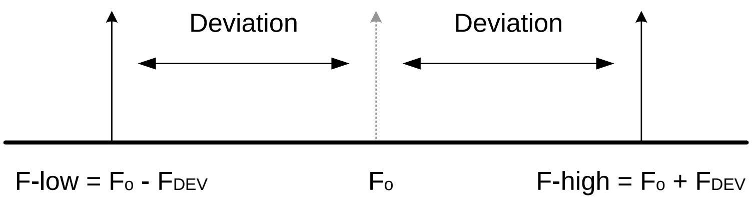

Figure 32. (G)FSK Deviation

A proper selection of the deviation is regarding to the modulation index and the frequency error between the TX and the RX. The modulation index is given by:

$$\text{Modulation Index} = \frac{\text{Deviation x 2}}{\text{Symbol Rate}}$$

The value of crystal tolerance dominates the frequency error:

$$\text{Frequency Error} >= \text{Xtal Tolerance x Frequency}$$

By obeying the following rules, the RFPDK automatically computed the minimum value of the deviation that can be configured.

$$\text{Deviation} >= \text{Symbol Rate x 2}$$

$$\text{Deviation} >= \frac{\text{Frequency Error}}{0.7}$$

This means the Modulation Index cannot be less than 1. Also, the deviation must be larger than the frequency error in order to guarantee the reception.

The RFPDK also computes the maximum value of the deviation that can be configured. The following rule is obeyed:

$$\text{Deviation} <= \text{220 kHz} - \text{Frequency Error}$$

Therefore, once the Symbol Rate and Xtal Tolerance are configured on the RFPDK, the configurable range of the Deviation is automatically obtained.

5.2 Data Representation

This parameter determines whether the frequency “F-high” modulated frequency represent data 1, or data 0. It should be set according to the transmitter’s configurations.

5.3 Rising Relative TH, Falling Relative TH

When the device is in the RX state, the RF front end continuously passes signals and noises into the digital (G)FSK demodulator.

The (G)FSK demodulator is turned on when the RSSI has increased a certain value (defined by the Rising Relative TH) in a short time window, and turned off when RSSI has decreased a certain value (defined by the Falling Relative TH) in the same time window. The short time window is either 1-symbol or 2-symbol time, which is automatically determined by the device according to different symbol rates. This design has the advantage of detecting valid signals in environments with time varying noise floor.

The default value of the ‘Rising Relative TH’ is 21, which is approximately 7 dB. It determines how sensitive the demodulator is triggered by the increasing RSSI. In the application where the noise level fluctuate more than 7 dB, it should be set larger to avoid mistakenly triggering. The mistakenly triggering does not affect the receiving performance, but only consumes more power.

The default value of the ‘Falling Relative TH’ is set to 255. It determines how sensitive the demodulator is turned off by decreasing RSSI. Setting this value maximum indicates that the demodulator cannot be turned off by the RSSI, but it will be turned off when the chip goes to SLEEP state.

At the instance that the device is switched into the RX state, if it is the valid signal being transmitted by the TX and the increasing amount is larger than the Rising Relative TH, the demodulator is turned on and starts sending out the valid demodulated data, as shown in the below figure.

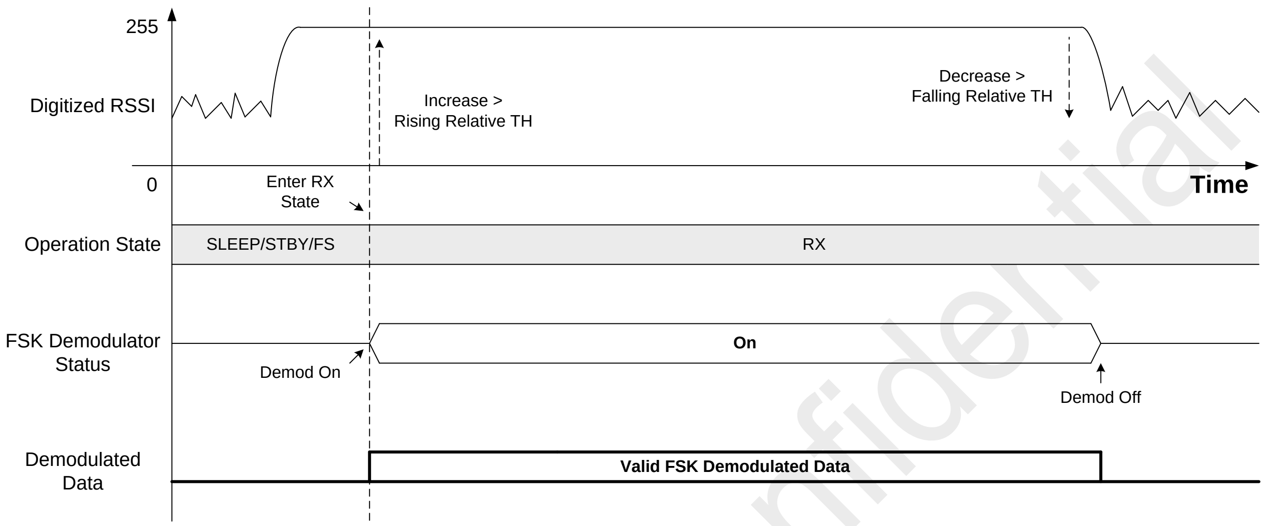

Figure 33. Entering RX with Signal Being Transmitted

At the instance that the device is switched into the RX state, if the incoming signal is the noise and the increasing amount from 0 to the noise level has exceeded the Rising Relative TH, the demodulator is also turned on. As a result, the noise is demodulated and output from the beginning of the RX state till the first bit of the valid transmitted signal comes, as shown in the below figure.

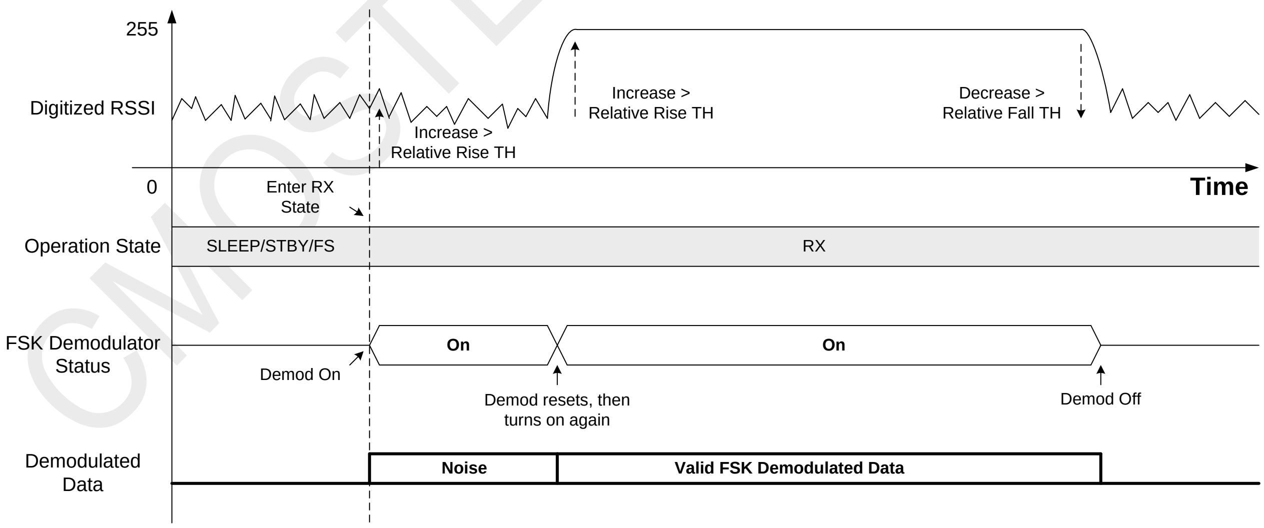

Figure 34. Entering RX with Noise

Once the valid signal comes, the demodulator will reset itself immediately and restart to receive the data. In the subsequent data transmission in the same RX cycle, this will not happen again since the decreasing from valid signal to noise will turn off the demodulator if the Falling Relative TH is properly set. The user program on the external MCU shall ignore this “noise” period at the beginning of the RX state. On the other hand, if a proper value of the “Squelch Threshold” is set above the noise floor, the noise is muted.

When the incoming RF signal is sourced from an instrument, such as a signal generator, the (G)FSK demodulator might not be able to turn on/off effectively while the signal magnitude is changed. This is because the short time window to detect the RSSI change is only 1-symbol or 2-symbol time, but the signal sourced from the instrument might take a longer time to change from one level to another, which is determined by the characteristics of the instruments. This might lead to misunderstanding of the device behavior while testing the device in the lab.

To overcome this problem, it is suggested for the user to reset the chip every time the signal magnitude on the instrument is set to a new value. As introduced above, if the Rising Relative TH is properly set, every time the device enters to RX state, the detected RSSI change is dramatic from 0 to the current RSSI (a lot shorter than the time window) and will always trigger the demodulator and therefore output the demodulated data.

5.4 Sync Clock Type

The optional types of the sync clock are: No Sync Clock, Counting and Tracing. When the AFC is turned on (see Section 5.5), the sync clock must be set to either counting or tracing.

5.4.1 Counting

The counting method has the advantage of having a +/- 30%(GFSK/FSK) or +/- 25%(OOK) tolerance of symbol rate error, while it has a drawback of requiring frequent transitions on the data to adjust the sync clock rate. If there is no transition happens in 3-4 symbols and the symbol rate error is significantly large, the clock recovery and data capturing will start to go wrong.

5.4.2 Tracing

The tracing method has a different principle. Acting like a DPLL, it takes a few symbols for the sync clock generator to “trace” the TX symbol rate and eventually lock to the same symbol rate. It can only tolerate +/- 9% of symbol rate error. However, with the same symbol rate error, tracing method allows the receiver to correctly sample a much longer string of “0” than the counting method.

Using the tracing method, the default characteristic of the receiver allow 10 – 15 symbols of the consecutive “0” to be correctly sampled, while tolerating +/- 9% of symbol rate error. It is always recommended for the user to avoid transmitting long string of “0” by encoding the data using the Manchester, data-whitening or similar encoding techniques.

5.4.3 No Sync Clock

When the Sync Clock is turned off by choosing “No Sync Clock”, the receiver does not suffer from the long string “0” because the demodulated data is only transparently sent out to the data pin without any internal capturing. However, in this case, since the preamble detection cannot be performed without the sync clock, the AFC must be turned off. Also, the WOR condition of “Extended by Preamble” cannot be used. The symbol rate tolerance is also +/- 30%(GFSK/FSK) or +/- 25%(OOK).

5.5 AFC

The Automatic-Frequency-Control (AFC) is useful to minimize the RF frequency error between the TX and the RX. The frequency error is usually caused by the crystals tolerance on the two sides. The AFC on the receiver improves the sensitivity performance during the transmission. The increased sensitivity can vary from 1 – 3 dB in different receiver settings. If AFC is turned on, the Sync Clock Type must be set to either “Tracing” or “Counting” because the synchronization clock is required to detect the preamble which is used to trigger the AFC. By default the AFC is turned off to allow “No Sync Clock” to be used.
The AFC is triggered by detecting a valid preamble. The preamble size is defined in the Decoding Setting (see Chapter 6.

Decode Settings). After detecting a valid preamble, it takes 4 – 8 symbols for the AFC circuit to remove most of the frequency error. It is recommended for the user to transmit at least 8-symbol of preamble more than the preamble size defined on the RFPDK, so that the AFC can be done during the reception of the preamble and increase the sensitivity during the subsequent sync or data receptions. The figure below shows the AFC timing characteristics with the preamble size is set to 16-symbol.

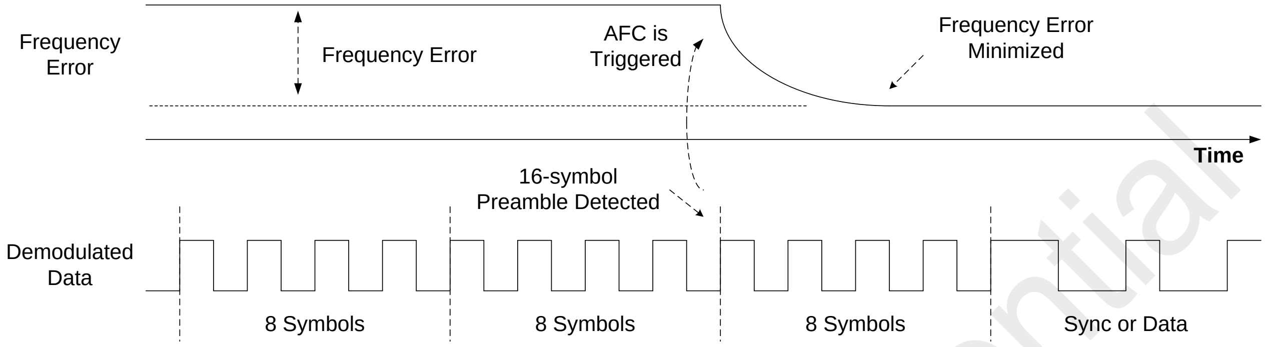

Figure 35. AFC Timing Characteristics

When the tracing method is used to recover the sync clock and the transmitted data is encoded to avoid long string of "0", turning on the AFC can achieve the highest sensitivity performance of the device.

6. Decode Settings

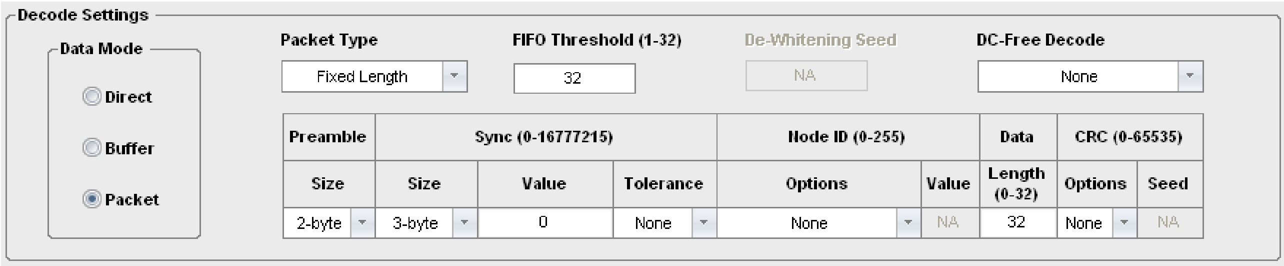

Figure 36. Decode Settings

Direct data mode, which is required in this product, means that the demodulated data is output via the DOUT, which can be mapped to GPO 1, 3 or 4. The available options of Data Mode are shown in the table below.

Table 15. Decode Settings Parameter

Parameter	Descriptions	Default	Mode
Data Mode	The data acquisition mode, the options are: Direct, Buffer or Packet. Table 17, Table 18 and Table 19 respectively shows the available parameters for each data mode.	Packet	Basic Advanced

The table below shows the digital pins used to connect to the external MCU. The selection of the pin functions are not done on the RFPDK, instead it is done by writing the control registers in the external MCU program. The subsequent sections will refer to some of the contents in this table while explaining the behavior of the device.

Table 16. Digital Pin Functions

Pin	Name	I/O	Functions
1	CSB	I	4-wire SPI chip register select input.
2	SDA	IO	4-wire SPI data input and output.
3	SCL	I	4-wire SPI clock input.
4	FCSB	I	4-wire SPI chip FIFO select input, active low. Internally pulled high, leave floating when programming the EEPROM.
5	GPO4	O	Programmable output, options are: DOUT (default), INT1, INT2 and DCLK.
6	GPO3	O	Programmable output, options are: CLKO (default), INT1, INT2 and DOUT.
9	GPO2	O	Programmable output, options are: INT1 (default), INT2 and DCLK.
10	GPO1	O	Programmable output, options are: nRSTO (default), INT1, INT2 and DOUT.

6.1 Direct Mode

In direct mode, the data from the demodulator's output can be directly captured by the MCU on the DOUT. The synchronization clock is output on the DCLK. The optional preamble and sync word detection interrupt is supported.

The available options of data decoding in the direct mode are shown in the table below.

Table 17. Configurable parameters in Direct Mode

Parameter	Descriptions	Default	Mode
Preamble	The size of the valid preamble, the options are: None, 1-byte, 2-byte, 3-byte, or 4-byte.	2-byte	Basic Advanced
Sync Size	The size of the Sync Word, the options are: None, 1-byte, 2-byte, 3-byte, or 4-byte.	2-byte	Basic Advanced
Sync Value	The value of the Sync Word, the range is from 0 to $2^{Sync\_Size}-1$.	0	Basic Advanced
Sync Tolerance	The number of bits tolerated for the Sync Word recognition. The options are: None, 1 Error, 2 Errors or 3 Errors.	None	Basic Advanced

6.1.1 Preamble

The preamble detection is optional in direct mode. It is used when the wake-on radio is turned on and the wake-on condition is set to “Extended by Preamble”, or when the AFC is turned on. Once the preamble detection is used, the Sync Clock Type must be set to either Counting or Tracing. When using FSK demodulation, it is always recommended to include the preamble in a packet.

6.1.2 Sync Word

The sync word detection is optional in direct mode. The sync word is defined by the parameters of Sync Size and Sync Value. A successful detection of a sync word generates an active-high interrupt that can be assigned to INT1 or INT2. The external MCU can use this information to filter the received data. For example, if the Sync Tolerance is set to 2 Errors, it means that less or equal to 2 bits of error in the sync word are allowed.

6.1.3 Application Information

The figure below shows the data path from the demodulator to the I/Os in the direct mode.

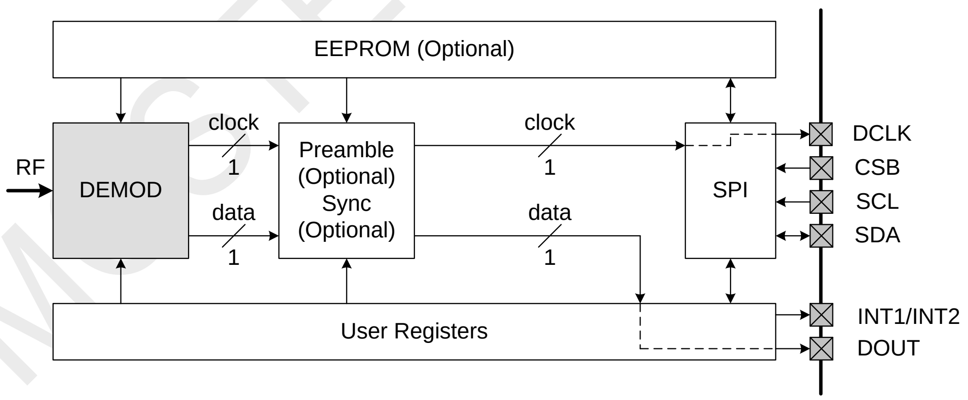

Figure 37. Data Path of Direct Mode

It can be seen that the data and clock output of the demodulator are sent out to the DOUT and DCLK pin, respectively. The preamble and sync word detection are both optional.

The sync clock recovery is also optionally enabled by the parameter “Sync Clock Type”. If it is enabled, the rising edge of the DCLK always locates at the centre of a symbol of the DOUT, as shown in the figure below. The MCU can use the DCLK as an interrupt to sample the DOUT if it is required.

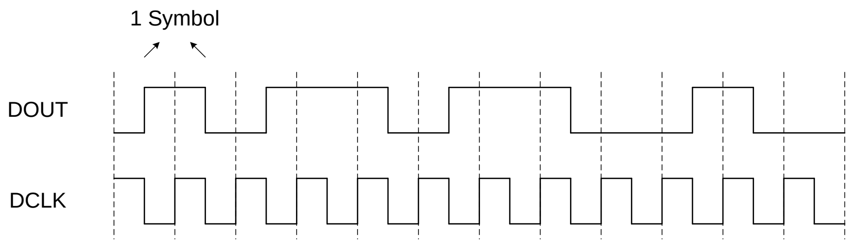

Figure 38. Timing Characteristic of DOUT and DCLK

The data receiving works independently of the preamble and sync word detection in the direct mode. This means, no matter a valid preamble or a sync word is detected or not, the demodulated data will be output via DOUT.

Application Flow Example 1:

- Use the IO_SEL user register to output DOUT to the desired GPO.
- Use the OP_CTRL user register to switch the device to RX state, wait for the required time.
- Get the data on DOUT pin and perform software synchronization on the MCU.
- After data acquisition is done, use the OP_CTRL user register to switch the device to SLEEP state.

Application Flow Example 2:

- Use the IO_SEL user register to output DOUT and DCLK to the desired GPOs.
- Use the OP_CTRL user register to switch the device to RX state, wait for the required time.
- Get the data on DOUT pin synchronously with the DCLK signal as an interrupt to the MCU.
- After data acquisition is done, use the OP_CTRL user register to switch the device to SLEEP state.

Since all the GPOs are configurable, for those are not used in the applications, the user can use the IO_SEL user register to set it to either INT1 or INT2, then leave it float. By default, INT1 and INT2 will output logical 0.

6.2 Buffer Mode

In buffer mode, the data from the demodulator's output is shifted into a 32 x 8-bit FIFO. The sync clock recovery is always enabled. The MCU can use the SPI to read the FIFO. The FIFO will retain its content and be readable in the STBY, TUNE and RX state. The optional preamble and sync word detection is supported. The interrupts are output to the INT1 or INT2.

The available options of data decoding in the buffer mode are listed in the table below.

Table 18. Configurable parameters in Buffer Mode

Parameter	Descriptions	Default	Mode
Preamble	The size of the valid preamble, the options are: None, 1-byte, 2-byte, 3-byte, or 4-byte.	2-byte	Basic Advanced
Sync Size	The size of the Sync Word, the options are: 1-byte, 2-byte, 3-byte, or 4-byte.	2-byte	Basic Advanced
Sync Value	The value of the Sync Word, the range is from 0 to $2^{Sync\_Size}-1$.	0	Basic Advanced
Sync Tolerance	The number of bits tolerated for the Sync Word recognition. The options are: None, 1 Error, 2 Errors or 3 Errors.	None	Basic Advanced
FIFO Threshold	This defines the FIFO threshold that once it is reached, an interrupt is generated to notify the external MCU. The range is from 1 to 32, in terms of the FIFO address.	32	Basic Advanced

6.2.1 Preamble

The preamble detection is optional in buffer mode. It is used when the wake-on radio is turned on and the wake-on condition is set to “Extended by Preamble”, or when the AFC is turned on. When using (G)FSK demodulation, it is always recommended to include the preamble in a packet. The preamble will be taken off after the chip has detected it. It will not be shifted into the FIFO.

6.2.2 Sync Word

The sync word detection must be enabled in buffer mode. The sync word is defined by the parameters of Sync Size and Sync Value. A successful detection of a sync word generates an active-high interrupt that can be assigned to INT1 or INT2. The received data is only shifted into the FIFO after a valid sync word is detected. For example, if the Sync Tolerance is set to 2 Errors, it means that less or equal to 2 bits of error in the sync word does not stop the subsequence data reception.

6.2.3 FIFO Threshold

This parameter allows the user to choose how many bytes of unread data will set the FIFO_TH interrupt to high. For example, if it is set to 16, it means when the unread data in the FIFO is equal to or more than 16 bytes, the FIFO_TH interrupt stays high.

6.2.4 Application Information

The figure below shows the data path from the demodulator to the I/Os in the buffer mode.

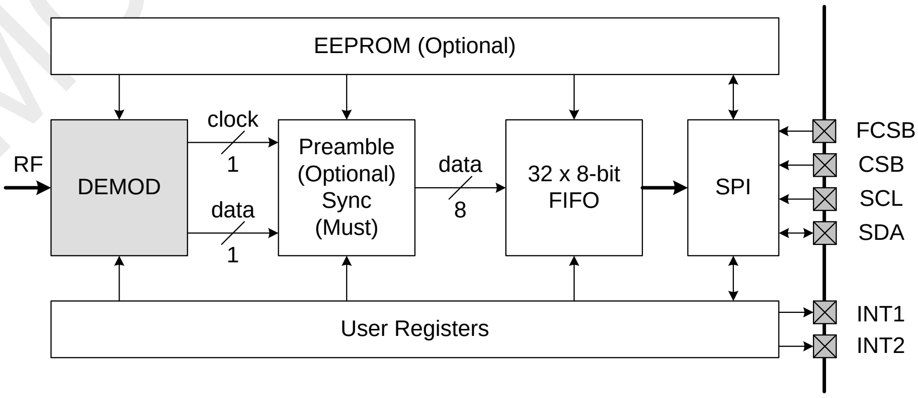

Figure 39. Data Path of Buffer Mode

Because the chip does all the data buffering work, the MCU can spend time on other tasks during the buffering process. Also, it reduces the MCU's performance requirement in terms of speed and reactivity. The Sync Clock Type must be set to either Counting or Tracing in buffer mode.

The data receiving is independent of the preamble detection. This means, no matter a valid preamble is detected or not, the subsequent sync word detection and FIFO filling will be performed.

The sync word detection is compulsory in the buffer mode. The demodulated data will only be shifted into the FIFO while a sync word is detected. Once the sync word is detected, the FIFO will still be continuously filled with noise or data as long as it is not full, until that the MCU sets the FIFO_PKT_CLR bit in the user register INTCTL_D. After the FIFO is cleared, the device is able to detect the next incoming sync word again. Also, the FIFO_PKT_CLR bit clear the current status of the packet handler.

Five interrupts are provided to assist the FIFO reading. Please refer to the user register INTCTL_D for the detailed descriptions for each of them. The interrupts timing characterizes are shown in the figure below.

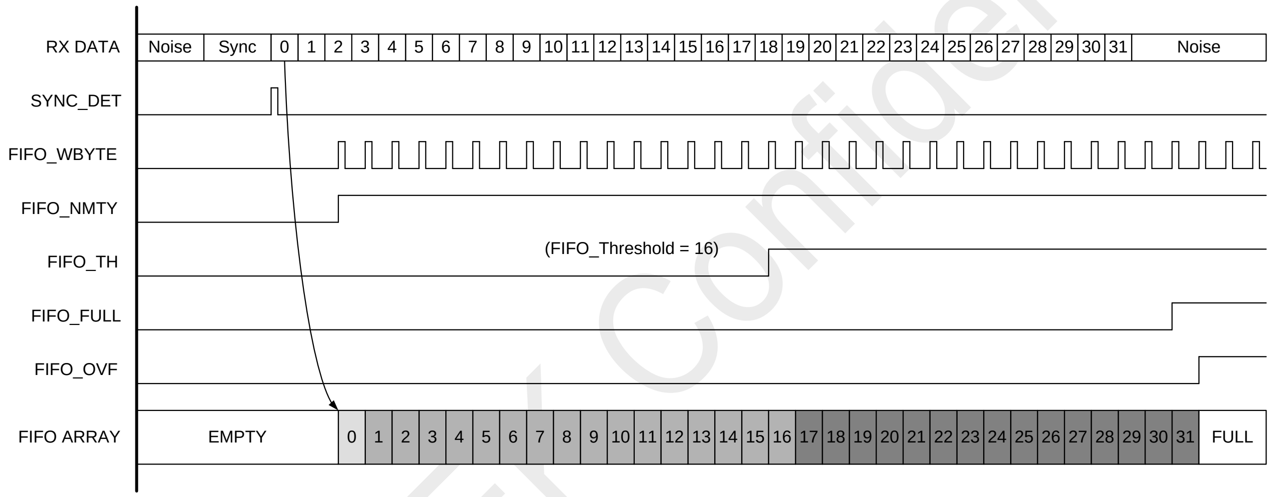

Figure 40. FIFO Interrupts Timing Characteristics

Typical ways to use the different interrupts:

- FIFO_WBYTE: The MCU reads the FIFO once the FIFO_WBYTE goes high, as long as the MCU processing speed is fast enough, byte 0 will always be read out before byte 1 is filled. This is the fastest way to read out the FIFO content.
- FIFO_NMTY: This is the FIFO "Not Empty" interrupt. The MCU starts reading the FIFO once the FIFO_NMTY interrupt goes high. This interrupt will be cleared automatically once the FIFO is found empty.
- FIFO_TH: The "FIFO Threshold" parameter allows the user to choose how many bytes of unread data will set the FIFO_TH interrupt to high. The MCU starts reading the data once the FIFO_TH goes high. This interrupt will be cleared automatically once it is found that the number of unread data bytes is less than the threshold.
- FIFO_FULL: The MCU starts reading the FIFO once the FIFO_FULL goes high. This interrupt will be cleared automatically once the FIFO is found not full. This is the easiest and slowest way to read out the content of the FIFO.
- FIFO_OVF: The FIFO_OVF reflects that the FIFO overflows. Once the FIFO overflows the incoming data cannot be shifted into the FIFO and therefore they will be lost. This interrupt will be cleared automatically once it is found that the FIFO does not overflow.

The user shall consider the speed of FIFO filling and reading to decide which FIFO interrupt is the most suitable one to use in the system. The speed of filling the FIFO is the data rate divided by 8. The speed of reading the FIFO is determined by the MCU and the SPI interface speed.

Application Flow Example:

- Set INT1_CTL<3:0> to 0110 in the user register INTCTL_A to assign the FIFO_NMTY interrupt to INT1.
- Set INT2_CTL<3:0> to 1000 in the user register INTCTL_A to assign the FIFO_TH interrupt to INT2.
- Use the OP_CTRL user register to switch the device to RX state, wait for the required time.
- Use the OP_CTRL user register to switch the device to STBY state once detecting the FIFO_TH interrupt goes high.
- Read out the FIFO contents.
- Use the OP_CTRL user register to switch the device to SLEEP state.

6.3 Packet Mode

In packet mode, the data from the demodulator’s output are first shifted into the packet handler to get decoded, and then filled into the 32 x 8-bit parallel FIFO.

The available options of data decoding in the direct mode are listed in the table below.

Table 19. Configurable parameters in Packet Mode

Parameter	Descriptions	Default	Mode
Packet Type	The device can support two packet types. The options are: Fixed Length or Variable Length.	Fixed Length	Basic Advanced
Preamble	The size of the valid preamble, the options are: None, 1-byte, 2-byte, 3-byte, or 4-byte.	2-byte	Basic Advanced
Sync Size	The size of the Sync Word, the options are: None, 1-byte, 2-byte, 3-byte, or 4-byte.	2-byte	Basic Advanced
Sync Value	This parameter is only available when Sync Size is not set to “None”. It defines the value of the Sync Word, the range is from 0 to 2^N-1, where N is determined by Sync Size. For example, if Sync Size is 1-byte, N is 8; if Sync Size is 2-byte, N is 16, etc.	0	Basic Advanced
Sync Tolerance	The number of bits tolerated for the Sync Word recognition. The options are: None, 1 Error, 2 Errors or 3 Errors.	None	Basic Advanced
Node ID Options	The options for the Node ID detection are: None, Detect Node ID, Detect Node ID and 0x00, or Detect Node ID, 0x00 and 0xFF	None	Basic Advanced
Node ID Value	This parameter is only available when the Node ID Options is not set to “None”. It defines the value of the Node ID. The range is from 0 to 255.	1	Basic Advanced
Data Length	This defines the number of bytes of data in a fixed length packet. The range is from 1 to 32.	32	Basic Advanced
CRC Options	The options for the CRC are: None, CCITT and IBM.	None	Basic Advanced
CRC Seed	This parameter is only available when CRC Options is not set to “None”. It defines the initial seed for the CRC polynomial. The range is from 0 to 65535.	0	Basic Advanced
DC-Free Decode	The options of DC-free data decoding are None, Manchester 1 (01=one, 10=zero), Manchester 2 (10= one, 01=zero), or De-whitening.	None	Basic Advanced
De-Whitening Seed	This parameter is only available when DC-Free Data Decode is not set to “None”. The initial seed for the data de-whitening polynomial. The range is from 0 to 511.	511	Basic Advanced

Parameter	Descriptions	Default	Mode
FIFO Threshold	This defines the FIFO threshold that once it is reached, an interrupt is generated to notify the external MCU. The range is from 1 to 32, in terms of the FIFO address.	32	Basic Advanced

6.3.1 Packet Type

The device supports two packet types: Fixed length and Variable length.

Fixed Length Packet

The pre-defined length means that the payload length is programmed into the device during the RFPDK configuration process and will not be changed during the transmission and reception. The Rx and Tx shall have the same payload length in this case. The payload contains the optional Node ID and the Data. The maximum payload length is limited to the FIFO size which is 32 bytes.

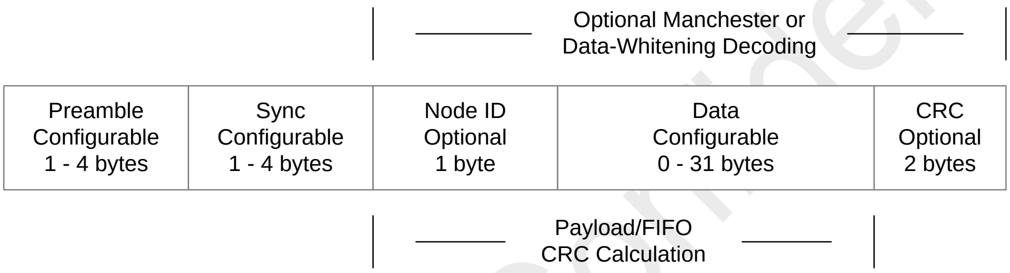

Figure 41. Fixed Length Packet Structure

The sync word detection is compulsory in the packet mode. The size of preamble, sync word and payload (Node ID + Data) are all configurable. The Node ID can be disables by setting the “Node ID Option” to “None”. Only the optional Node ID and the Data will be shifted into the FIFO after the sync word has been detected.

Variable Length Packet

The variable length means that the payload length can vary in each transmission. In this case, an additional “Length” byte is given as a part of the payload to indicate the payload length of the current frame. The maximum payload length can be indicated by the “Length” byte is 31, because the “Length” byte itself is not included in the calculation. For example, if the “Length” byte indicates that the payload is 31 bytes, and the Node ID is supported, it means that there will be 1 byte of Node ID and 30 bytes of Data in the current packet.

If the “Length” byte indicates that the payload length is larger than 31, which exceeds the maximum size of the FIFO minus 1, the current packet will be discarded by the device and the Data will not be shifted into the FIFO.

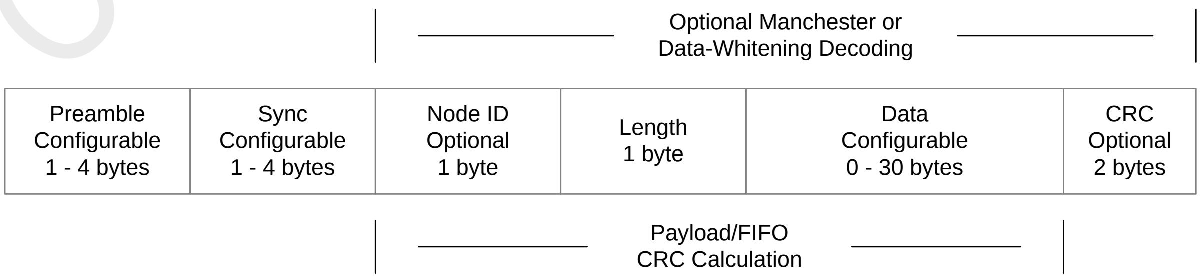

Figure 42. Variable Length Packet Structure

The FIFO filling and reading mechanism is identical to the buffer mode. The FIFO starts being filled once the sync word and optional node ID validation is successful. The CRC validation failure does not clear the FIFO. The automatic state changing from RX to STBY/TUNE (see Chapter 'Radio Control') does not disturb the FIFO reading.

6.3.2 Preamble

The preamble detection is optional in packet mode. It is used when the wake-on radio is turned on and the wake-on condition is set to "Extended by Preamble", or when the AFC is turned on. When using FSK demodulation, it is always recommended to include the preamble in a packet. The preamble will be taken off after the chip has detected it. It will not be shifted into the FIFO.

6.3.3 Sync Word

The sync word detection is optional in packet mode. The sync word is defined by the parameters of Sync Size and Sync Value. A successful detection of a sync word generates an active-high interrupt that can be assigned to INT1 or INT2. The user can introduce some tolerance of the sync word filtering. For example, if the Sync Tolerance is set to 2 Errors, it means that less or equal to 2 bits of error in the sync word does not stop the subsequence data reception.

6.3.4 Node ID

The Node ID detection is an option in packet mode. The Node ID is defined by the parameters of Node ID Value and Node ID Options. A successful detection of a node ID generates an active-high interrupt that can be assigned to INT1 or INT2. Beside the sync word detection, the Node ID allows the user to further filter the incoming data. The parameter of "Node ID Options" provides 4 options for the Node ID filtering as shown below.

- "None": The Node ID filtering is not supported.
- "Detect node ID": The Node ID filtering is supported. Only after the chip has detected that the received Node ID matches the value of the "Node ID" parameter, it will continue to process the frame.
- "Detect node ID, 0x00": The Node ID filtering is supported. Only after the chip has detected that the received Node ID either matches the value of the "Node ID" parameter or 0x00, it will continue to process the frame.
- "Detect Node ID, 0x00, 0xFF": The Node ID filtering is supported. Only after the chip has detected that the received Node ID either matches the value of the "Node ID" parameter, 0x00 or 0xFF, it will continue to process the packet.

6.3.5 CRC Checksum

The CRC validation is optional in the packet mode. The 'CRC Type' parameter is used to select the two types of CRC supported: CCITT or IBM. Please note that the CRC is calculated on the Payload.

The CCITT CRC polynomial is: $X^{16} + X^{12} + X^{5} + 1$

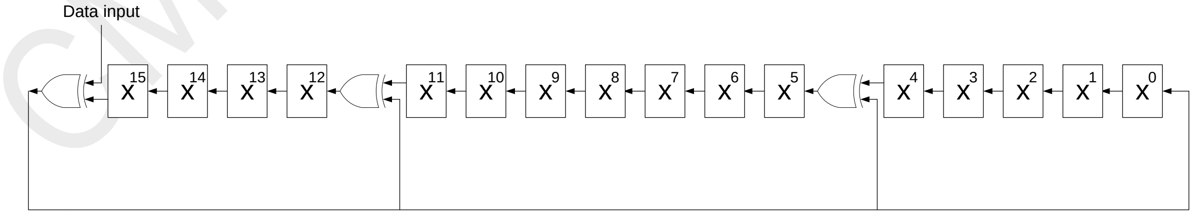

Figure 43. CCITT CRC Structure

The IBM CRC polynomial is: $X^{16} + X^{15} + X^{2} + 1$

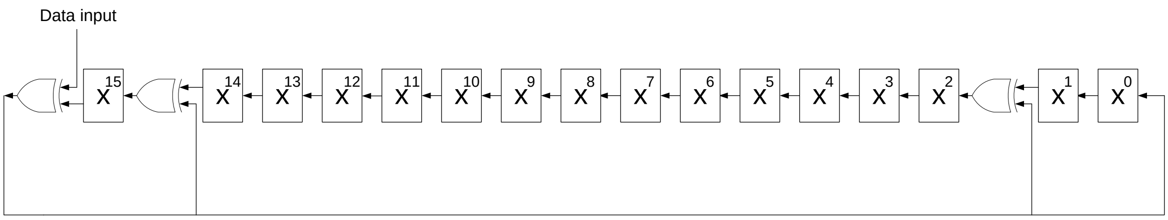

Figure 44. IBM CRC Structure

The ‘CRC Seed’ parameter defines the initial seed of the polynomial.

The chip compares the checksum to the 2-byte CRC in the packet. If they are identical, it means that the payload has been received correctly and the CRC_PS interrupt is asserted. If the CRC check fails, the payload is stilled filled into the FIFO and the PKT_DONE interrupt is asserted. But the CRC_PS interrupt and the corresponding register flag is not generated.

6.3.6 DC-Free Decode

Two DC-Free decoding techniques are supported: Manchester and De-Whitening. They are only supported in Packet Mode.

Manchester

The chip can decode the payload and CRC which has been converted into the Manchester code by the transmitter. This function is only available in the **Packet Mode**. RFPDK allows the user to select 2 types of conventional Manchester Decoding.

For ‘Manchester 1’, logic 1 is converted to “01” and logic 0 is converted to “10”.

Table 20. Encode/Decode Using Manchester 1 Method

	Preamble					Sync Word					Payload & CRC						
Encoded Data	1	0	1	0	…	0	1	1	0	…	0	1	1	0	0	1	…
Decoded Data	1	0	1	0	…	0	1	1	0	…	1		0		1		…

For ‘Manchester 2’, logic 1 is converted to “10” and logic 0 is converted to “01”.

Table 21. Encode/Decode Using Manchester 2 Method

	Preamble					Sync Word					Payload & CRC						
Encoded Data	1	0	1	0	…	0	1	1	0	…	0	1	1	0	0	1	…
Decoded Data	1	0	1	0	…	0	1	1	0	…	0		1		0		…

The receiver converts the encoded data back to the NRZ data. After the decoding, the payload will be filled into the FIFO. Therefore, the Manchester decoding is transparent to the MCU.

De-Whitening

The device can decode the payload and CRC which have been whitening encoded by the transmitter. The whitening or de-whitening process is that the data input is XOR with a specific polynomial, which produces a pseudo-random sequence. The advantage of whitening compare to the Manchester coding is that it does not reduce the actual data rate into a half, so that it saves the power. The de-whitening process is transparent to the MCU. The whitening and the de-whitening shares the same polynomial.

Whitening/De-Whitening polynomial: $X^9 + X^5 + 1$

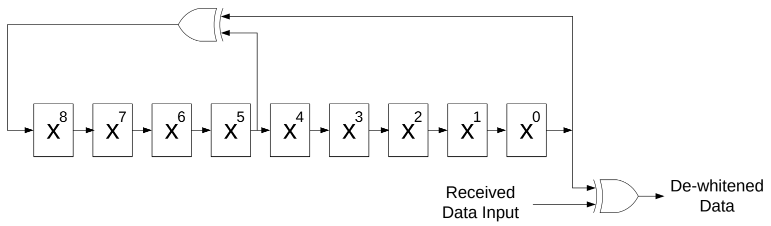

Figure 45. Whitening/De-Whitening Algorithm Structure

The 'De-whitening Seed' allows the user to define the 9-bit initial seed for the polynomial. The seeds on the Tx and the Rx must be identical.

6.3.7 Application Information

The figure below shows the data path from the demodulator to the I/Os in the packet mode.

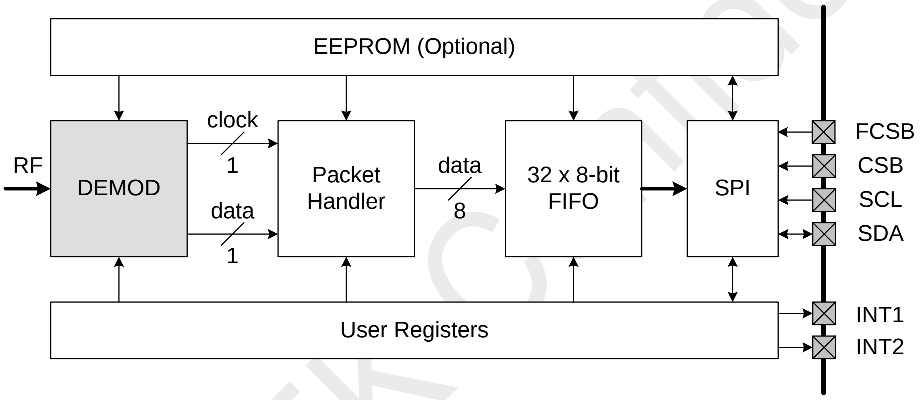

Figure 46. Data Path of Packet Mode

Similar to the buffer mode, the data are obtained by reading the FIFO. The FIFO will retain its content in the STBY, TUNE and RX state. The MCU can use the FIFO interrupts to assist to the FIFO reading. The packet handler provides various functions to decode and validate the incoming data. This can further reduce the work load and user program size of the MCU. The FIFO_PKT_CLR bit clears the current status of the packet handler and the FIFO pointers. The RSSI valid, preamble, sync word, node ID, packet done and CRC interrupt clearing can be done by setting the related bit in the INTCTL_C register, but they do not take effect in the SLEEP state.

Application Flow Example 1:

Note, in this application, the CRC checksum has been enabled; pre-defined payload length has been selected and programmed on the RFPDK.

- Set INT2_CTL<3:0> to 1100 in the user register INTCTL_A to assign the FIFO_ WBYTE interrupt to INT1.
- Use the OP_CTRL user register to switch the device to RX state, wait for the required time.
- Continuously read a byte from the FIFO once detecting that the FIFO_WBYTE goes high, until the entire payload is read.
- Use the OP_CTRL user register to switch the device to SLEEP state.
- Check the CRC_PS_FLAG. If 0, discards the data that has been received; If 1, clear it by setting the CRC_PS_CLR to 1, continue to process the received data.

Application Flow Example 2:

- Set INT1_CTL<3:0> to 0110 in the user register INTCTL_A to assign the FIFO_NMTY interrupt to INT1.
- Use the OP_CTRL user register to switch the device to RX state, wait for the required time.
- Once detecting that the PKT_DONE_FLG goes high, start to read the FIFO until the FIFO_NMTY goes low.
- Use the OP_CTRL user register to switch the device to SLEEP state.
- Check the CRC_PS_FLAG. If 0, discards the data that has been received; If 1, clear it by setting the CRC_PS_CLR to 1, continue to process the received data.

To increase the reliability, it is recommended that the user should enable the CRC check. Because the PKT_DONE_FLG interrupt only indicates that the entire payload has been stored into the FIFO. It does not tell the MCU whether the data is received correctly or not.

7. Document Change List

Table 22. Document Change List

Rev. No	Chapter	Description of Changes	Date
0.2	All	Initial released version.	2014-09-10
0.6	-	-	2014-09-12
0.8	3	Add Active Operation Mode to Chapter 3.	2015-03-18

8. Contact Information

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