Sub-1GHz Low-IF OOK RF Receiver

BC2302C/BC2302D

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www.holtek.com

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Features

- Frequency bands
  - BC2302C: 315MHz, 433MHz
  - BC2302D: 315MHz, 433MHz, 868MHz, 915MHz
- Operating voltage range: 2.4V~5.5V
- 0.5μA deep sleep current with data retention
- Low RX current
  - 4.0mA @ 433MHz
  - 5.5mA @ 868MHz
- Good reception sensitivity under 0.1% BER
  - -108dBm at 10Ksps @ 433MHz
  - -107dBm at 10Ksps @ 868MHz
- Wide RF input power range: from sensitivity to +10dBm
- Up to 40Ksps symbol rate
- Support 2-wire I^2C interface for operation configuration
- Support sniff application for lower power application
- Package type: 8-pin SOP-EP

Applications

- RF wireless ceiling lights/fans
- Keyless entry systems
- Smart home appliances
- Door remote controllers
- Other wireless products

General Description

The BC2302x receiver devices adopt a fully-integrated, low-IF OOK receiver with an automatic gain control (AGC) function and a fully-integrated OOK demodulator. The synthesizer is formed by an integrated VCO and a fractional-N PLL to support the 315, 433, 868, and 915MHz frequency bands. The devices only require a crystal and a minimum number of passive components to fully implement an OOK receiver. With this high level of functional integration, these devices provide excellent solutions for low power wireless applications.

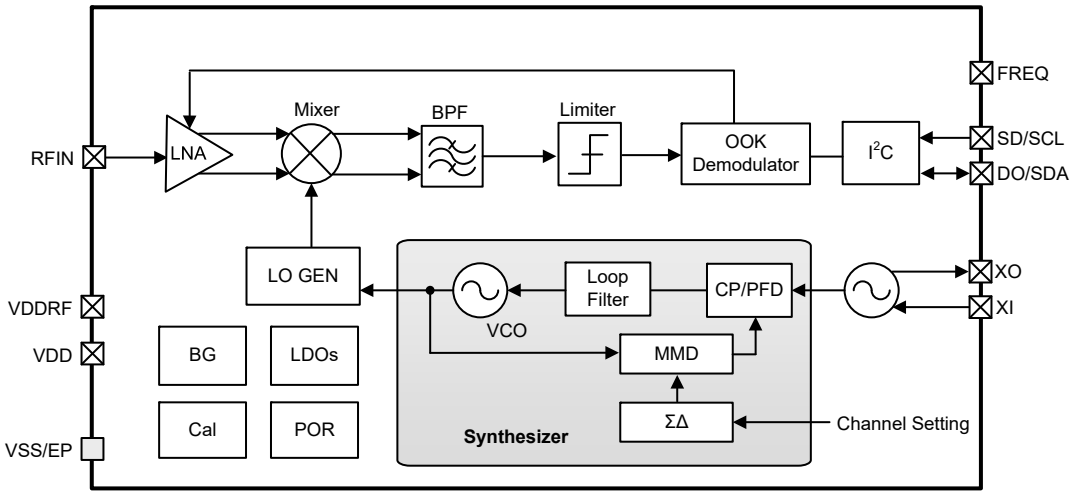
The devices achieve -108dBm and -107dBm sensitivity for the 433.92MHz and 868MHz bands, respectively. They operate from a supply voltage of 2.4 to 5.5V and typically require 4.0mA and 5.5mA at 433.92MHz and 868MHz, respectively. An agile RSSI threshold detection mechanism can further alleviate the impact of interference on OOK reception. There are two operation modes, one of which is the Auto RX mode. By properly setting certain PCB wirings, they can directly enter the RX mode. The devices also support a sniff RX mode, where the on/off RX mode function can be controlled by an MCU to achieve a lower than average power consumption using duty RX mode operation.

The BC2302 series offers two types of ICs. One is the BC2302C which covers the 315 and 433MHz bands while the BC2302D offers a choice of four frequency bands.

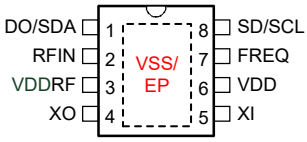
Selection Table

Part Number	Frequency Band
BC2302C	315MHz, 433MHz
BC2302D	315MHz, 433MHz, 868MHz, 915MHz

Block Diagram



Pin Assignment



BC2302C/BC2302D
8 SOP-EP-A

Pin Description

Pin No.	Pin Name	I/O	Description
1	DO/SDA(1)	DO	Demodulated data output in RX Mode
		DI/DO	I²C data line in Configuration Mode
2	RFIN	AI	RF LNA signal input
3	VDDRF	PWR	Analog positive power supply
4	XO	AO	Crystal oscillator output
5	XI	AI	Crystal oscillator input
6	VDD	PWR	Digital positive power supply
7	FREQ	DI	Pin option for frequency selection: • GND: 315MHz (BC2302C/BC2302D) • Floating: 433.92MHz (BC2302C/BC2302D) • VDD: 868.35MHz (BC2302D only)
8	SD/SCL(1)	DI	RX mode shut-down control, should be pulled low in RX Mode
		DI	I²C clock input line in Configuration Mode

Pin No.	Pin Name	I/O	Description
—	VSS/EP(2)	PWR	Exposed pad, must be connected to ground

Legend: DI: Digital Input; DO: Digital Output; AI: Analog Input;
AO: Analog Output; PWR: Power.

Note: 1. The DO/SDA & SD/SCL pins are default connected to a pull-high resistor after a power on reset. After entering the RX mode, these pull-high resistors are disconnected automatically. An analog debounce function is added to these two pins.
2. The VSS/EP is located at the exposed pad.

Absolute Maximum Ratings

Supply Voltage ..... V_{SS}-0.3V to 5.5V
Input Digital Voltage ..... V_{SS}-0.3V to V_{DD}+0.3V
Storage Temperature ..... -60°C to 150°C
Operating Temperature ..... -40°C to 85°C
ESD HBM ..... > ±2kV

*Devices being ESD sensitive. HBM (Human Body Mode) is based on MIL-STD-883.

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the devices. Functional operation of these devices at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

D.C. Characteristics

Ta=25°C, V_{DD}=5.0V, f_{XTAL}=16MHz, OOK demodulation with matching circuit, unless otherwise noted

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
T_{OP}	Operating Temperature	—	-40	—	85	°C
V_{DD}	Operating Voltage	—	2.4	5.0	5.5	V
Current Consumption						
I_{SLP}	Current Consumption, Deep Sleep Mode	—	—	0.5	—	μA
I_{RX}	Current Consumption, RX Mode	@315MHz	—	4.4	—	mA
		@433MHz	—	4.0	—	
		@868MHz	—	5.5	—	
		@915MHz	—	5.5	—	
R_{PH}	Pull-high Resistance for I/O Ports	—	—	100	—	kΩ

A.C. Characteristics

Ta=25°C, V_{DD}=5V, f_{XTAL}=16MHz, OOK demodulation with matching circuit, unless otherwise noted

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Receiver Characteristics						
f_{RF}	RF Frequency Range	BC2302C/BC2302D	—	315	—	MHz
		BC2302C/BC2302D	—	433.92	—	
		BC2302D only	—	868.35	—	
		BC2302D only	—	915	—	
SR	Symbol Rate	Sniff RX Mode	0.5	—	40	Ksps
		Auto RX Mode	0.5	—	19	

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
P_{SENS}	RX Sensitivity – 315MHz (Instrument: Keysight E4438C)	SR=1Ksps, BER=0.1%	—	-109	—	dBm
		SR=10Ksps, BER=0.1%	—	-109	—	
	RX Sensitivity – 433.92MHz (Instrument: Keysight E4438C)	SR=1Ksps, BER=0.1%	—	-108	—	
		SR=10Ksps, BER=0.1%	—	-108	—	
	RX Sensitivity – 868.35MHz (Instrument: Keysight E4438C)	SR=1Ksps, BER=0.1%	—	-107	—	
		SR=10Ksps, BER=0.1%	—	-107	—	
	RX Sensitivity – 915MHz (Instrument: Keysight E4438C)	SR=1Ksps, BER=0.1%	—	-106	—	
		SR=10Ksps, BER=0.1%	—	-106	—	
BW	RX Bandwidth	Auto RX Mode	—	100	—	kHz
SE_{RX}	Receiver Spurious Emission	25MHz ~ 1GHz	—	—	-57	dBm
		Above 1GHz	—	—	-47	
	Blocking Immunity	±2MHz offset	—	42	—	dBc
		±10MHz offset	—	61	—	
Cof_{ST}	Configuration Mode Settling Time (Deep Sleep to Configuration Mode)	49US XO	—	2	—	ms
		SMD3225 XO	—	3	—	ms
RX_{ST}	RX Mode Settling Time (Deep Sleep Mode to RX Mode Data Out)	49US XO	—	2	—	ms
		SMD3225 XO	—	3	—	
LO Characteristics						
f_{LO}	Frequency Coverage Range	BC2302C/BC2302D	300	—	360	MHz
		BC2302C/BC2302D	390	—	450	
		BC2302D only	850	—	935	
	Frequency Resolution	—	—	—	0.1	kHz
	Synthesizer Locking Time	—	—	130	—	μs
	RX Input Impedance	315MHz	1.8-j82.4			Ω
		433MHz	1.5-j54.5			
		868MHz	2-j8			
		915MHz	2.1-j5.3			
Crystal Oscillator Characteristics						
f_{XTAL}	Crystal frequency	General case	—	16	—	MHz
t_{SU}	X'tal Startup Time	f_{XTAL}=16MHz(1)	—	0.5	—	ms
ESR	X'tal Equivalent Series Resistance	—	—	—	100	Ω
C_L	X'tal Load Capacitance	—	—	16	—	pF
TOL	X'tal Tolerance(2)	—	-20	—	+20	ppm

Note: 1. X'tal start-up time is characterized by a reference design using the 49US XO.

2. This is the total tolerance including Initial tolerance, Crystal loading, Aging and Temperature dependence.

I²C Characteristics

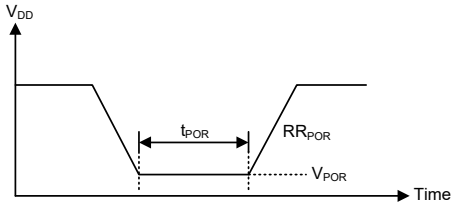
Ta=25°C

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
f_{SCL}	Serial Clock Frequency	—	—	—	1	MHz
t_{BUF}	Bus Free Time between Stop and Start Condition	SCL=1MHz	250	—	—	ns
t_{LOW}	SCL Low Time	SCL=1MHz	500	—	—	ns
t_{HIGH}	SCL High Time	SCL=1MHz	500	—	—	ns
$t_{su(DAT)}$	Data Setup Time	SCL=1MHz	100	—	—	ns
$t_{su(STA)}$	Start Condition Setup Time	SCL=1MHz	250	—	—	ns
$t_{su(STO)}$	Stop Condition Setup Time	SCL=1MHz	250	—	—	ns
$t_{h(DAT)}$	Data Hold Time	SCL=1MHz	100	—	—	ns
$t_{h(STA)}$	Start Condition Hold Time	SCL=1MHz	250	—	—	ns
$t_{r(SCL)}$	Rise Time of SCL Signal	SCL=1MHz	—	—	100	ns
$t_{f(SCL)}$	Fall Time of SCL Signal	SCL=1MHz	—	—	100	ns
$t_{r(SDA)}$	Rise Time of SDA Signal	SCL=1MHz	—	—	100	ns
$t_{f(SDA)}$	Fall Time of SDA Signal	SCL=1MHz	—	—	100	ns

Power on Reset Characteristics

Ta=25°C

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{POR}	V_{DD} Start Voltage to Ensure Power-on Reset	—	—	—	100	mV
RR_{POR}	V_{DD} Rising Rate to Ensure Power-on Reset	—	0.035	—	—	V/ms
t_{POR}	Minimum Time for V_{DD} Stays at V_{POR} to Ensure Power-on Reset	—	1	—	—	ms



Functional Description

The BC2302x devices are ultra-low power, high performance OOK receivers suitable for use in wireless applications with a frequency of 315, 433, 868, 915MHz respectively. The devices are formed by a low-IF receiver, followed by an OOK demodulator and a fractional-N synthesizer. They only require a crystal and a minimum number of passive components to implement an OOK receiver. These devices provide two operation modes. One is the Auto RX mode. By properly setting the PCB pin wirings, they can directly enter the RX mode. Another is the sniff RX mode where the on/off RX mode function can be controlled by an MCU to achieve a lower than average power consumption.

OOK RF Receiver

The BC2302x devices adopt a fully-integrated, low-IF receiver architecture. The received RF signal is first amplified by a low noise amplifier (LNA), after which the frequency is reduced to an intermediate frequency (IF). The IF signal is filtered by a channel-selected filter which rejects the unwanted out-of-band interference signals and image signal. After the BPF stage, the desired IF signal is amplified by the limiter amplifier which generates a received-signal-strength-indicator (RSSI) signal.

The devices feature an automatic gain control (AGC) unit which adjusts the front-end gain according to the RSSI. The AGC can increase the dynamic range of the RSSI and enable the devices to receive a wide dynamic range RF signal.

The OOK one/zero type data is generated by comparing the RSSI signal to a manipulated threshold. This threshold is crucial to the performance of OOK demodulation. The devices adopt an agile threshold detection mechanism. It can alleviate the impact of the interference on OOK reception quality. The agile threshold detection mechanism can reduce glitches when there is no RF signal or when long zero data streams are received. It also includes a fast tracking threshold to offer good immunity from co-channel interferences.

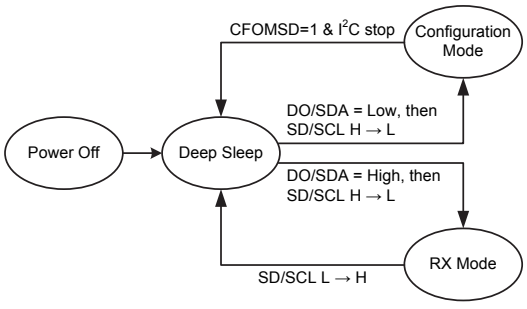
Operation Modes

The devices provide four operation modes, power off mode, deep sleep mode, RX mode and configuration mode.

In the deep sleep mode, there is less than 1μA of sleep mode leakage current with register data retention.

In the RX Mode, the devices execute normal RX operations that receive incoming RF signals from the antenna and then output the demodulated data onto the DO/SDA pin. There are two types of RX mode, one is the Auto RX mode and the other is the sniff RX mode.

In the Configuration Mode, the devices are operated as I²C slaves and are programmed by an external MCU. Users can select the desired RX channel by configuring the internal registers. After the configuration has completed, the devices will return to the deep sleep mode by setting the CFOMSD bit high.



Operation Mode Switching

Note: The CFOMSD bit will be cleared to zero automatically when the devices leave the configuration mode.

Mode	Register Retention	5V	Crystal Oscillator	Synthesizer & VCO	RX
Power Off	No	OFF	OFF	OFF	OFF
Deep Sleep Mode	Yes	ON	OFF	OFF	OFF
RX Mode	Yes	ON	ON	ON	ON
Configuration Mode	Yes	ON	ON	OFF	OFF

Auto RX Mode

The devices provide an Auto RX Mode. After power-on, the devices will enter the RX mode after a 30ms delay from the power-on reset. In this mode, frequency selection is achieved using a pin option together with external PCB wirings as shown in the following table.

FREQ Pin	Selected Frequency for BC2302C	Selected Frequency for BC2302D
GND	315MHz	315MHz
Floating	433.92MHz	433.92MHz
V_{DD}	Unavailable	868.35MHz

To directly enter this mode, the SD/SCL pin should be connected to ground and the FREQ pin should be connected to the required level before power is applied.

Note that there is only one method for the devices to leave the RX mode which is to remove the power.

Sniff RX Mode

The devices also provide a Sniff RX mode as it is controlled by an MCU. The SD/SCL pin defaults to a pull-high state. After power-on the devices will enter the deep sleep mode. An MCU could control the SD/SCL pin to make it enter or leave the RX mode. With additional SD/SCL control, users can optimize the average power consumption based on their applications.

Configuration Mode

The devices include an I^2C serial interface, which is used for bidirectional, two-line communication between multiple I^2C devices. The two lines of this interface are the serial data line, SDA, and the serial clock line, SCL. Both lines are equipped with analog de-bounce functions. After a power on reset, these two pins are pulled to VDD by default using internal pull-high resistors. When entering the RX mode, the pull-high resistors are disconnected.

The devices support the I^2C format for byte write, page write, byte read and page read formats. Every byte placed onto the SDA line must be 8-bits long. The number of bytes that can be transmitted per transfer is unrestricted. Each byte has to be followed by an acknowledge bit. Data is transferred with the most significant bit, MSB, first.

It should be noted that the I^2C is a non-standard I^2C interface, which only supports a single device for connection.

Byte Write

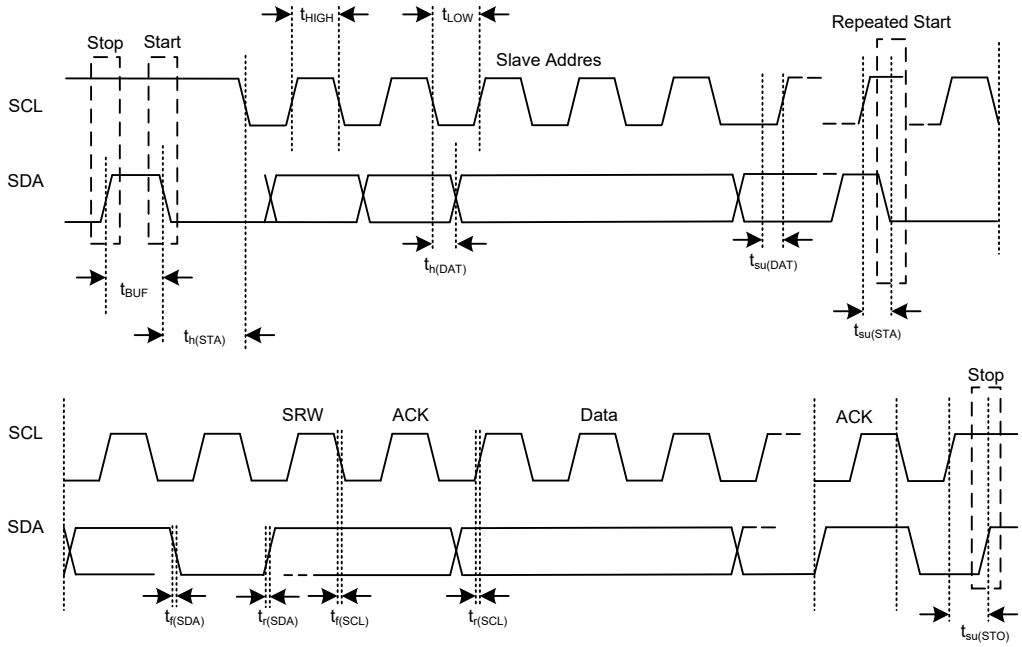
Page Write

Byte Read

Page Read

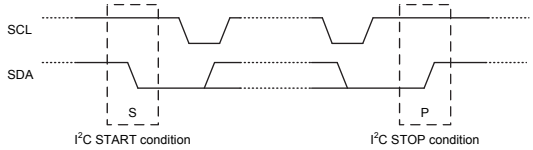
Bus Direction: : Host to device; : Device to host;

Symbol Definitions: S: Start; RS: Repeated Start; P: Stop;
DADDR[6:0]: Device Address, 23h; R:Read(1); W: Write(0);
RADDR[7:0]: register address; A: ACK(0); NA: NAK(1)



I²C Communication Timing Diagram

I²C START and STOP Conditions

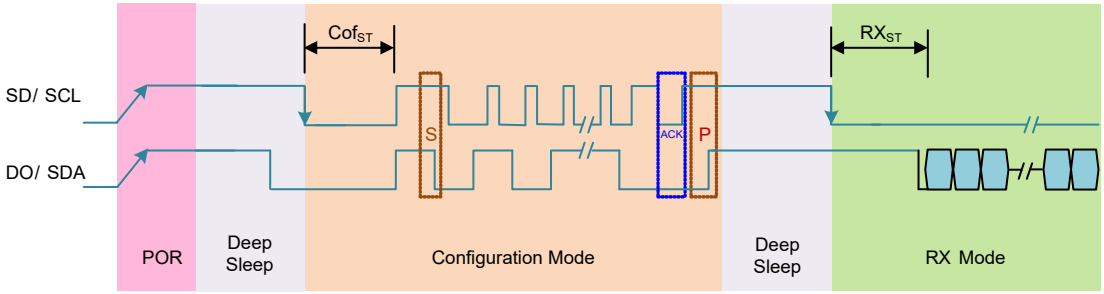


- A high to low transition on the SDA line while SCL is high defines a START condition.
- A low to high transition on the SDA line while SCL is high defines a STOP condition.
- START and STOP conditions are always generated by the master. The bus is considered to be busy after the START condition. The bus is considered to be free again a certain time after the STOP condition.
- The bus remains busy if a Repeated START (RS) is generated instead of a STOP condition. The START (S) and Repeated START (RS) conditions are functionally identical.

Configuration Mode Switching and Timing

As shown in the following diagram, when SDA is low and a SCL falling edge occurs, the devices change from the Deep Sleep Mode to the Configuration Mode after a Cof_{ST} delay time. If the SCL level remains high for a time greater than or equal to 20ms, the devices will be forced to leave the Configuration Mode.

If the devices are connected to an MCU through an I²C interface, users can set the CFOMSD bit of the register, at address 42h, to leave the Configuration Mode.



Entering and Leaving Configuration Mode Timing Diagram

Register Map

When connected to an external MCU, the device's RF frequency can be setup using a series of internal registers in the Configuration Mode. The register data is written to and read from the devices using their internal I²C interface. The following table provides a summary of all internal registers and their detailed descriptions.

Address	Register Name	Bit							
		7	6	5	4	3	2	1	0
05h	CFG0	Reserved							
10h	OM	—	BAND_SEL[1:0]		—	—	—	—	—
11h	CFG1	Reserved							
12h	SX1	—	D_N[6:0]						
13h	SX2	D_K[7:0]							
14h	SX3	D_K[15:8]							
15h	SX4	—	—	—	—	D_K[19:16]			
17h	CFG2	Reserved							
18h	CFG3	Reserved							
19h	CFG4	Reserved							
1Bh	CFG6	Reserved							
39h	CFG5	Reserved							
42h	I2C1	—	—	—	—	—	—	—	CFOMSD

Note: The addresses which are not listed in this table are reserved for future use, it is suggested not to change their initial values by any methods.

Control Register Map

The recommended values for the registers are listed below:

Register \ Frequency	315MHz	433.92MHz	868.35MHz	915MHz
CFG0	07h @ symbol rate < 20Ksps; 03h @ symbol rate ≥ 20Ksps			
CFG1	71h			
CFG2	7Fh @ symbol rate < 20Ksps; 66h @ symbol rate ≥ 20Ksps			
CFG3	B8h		B4h	
CFG4	8Dh			
CFG6	61h			
CFG5	82h			

- **OM – Operation Mode Control Register (Addr: 10H)**

Bit	7	6	5	4	3	2	1	0
Name	—	BAND_SEL[1:0]		—	—	—	—	—
R/W	—	R/W		—	—	—	—	—
POR	0	0	1	0	0	0	0	0

Bit 7 Reserved bit, cannot be changed

Bit 6~5 **BAND_SEL[1:0]**: Band selection
00: 300~360MHz Band
01: 390~450MHz Band
10: Reserved
11: 850~935MHz Band – BC2302D only
Note that for the BC2302C, these two bits cannot be set to "10"/"11"

Bit 4~0 Reserved bit, cannot be changed

- **SX1 – Fractional-N Synthesizer Control Register 1 (Addr: 12H)**

Bit	7	6	5	4	3	2	1	0
Name	—	D_N[6:0]						
R/W	—	R/W						
POR	1	0	0	1	0	1	0	1

Bit 7 Reserved bit, cannot be changed

Bit 6~0 **D_N[6:0]**: RF channel frequency integer number code

$$D\_N[6:0]=\text{Floor}\left(\frac{f_{RF}-f_{IF}}{f_{XTAL}}\times 0.8\right)\times M,\ (315MHz:\ M=2,\ \text{Other Bands: } M=1)$$

For example:

f_{XTAL}=16MHz, RF channel frequency(f_{RF})=315MHz, Intermediate Frequency (f_{IF})=200kHz
→ (315MHz-0.2MHz)/16MHz×0.8×2=31.48
→ D_N=31
→ Dec2Bin(31)=001_1111

f_{XTAL}=16MHz, RF channel frequency(f_{RF})=433.92MHz, Intermediate Frequency (f_{IF})=200kHz
→ (433.92MHz-0.2MHz)/16MHz×0.8=21.686
→ D_N=21
→ Dec2Bin(21)=001_0101

• **SX2 – Fractional-N Synthesizer Control Register 2 (Addr: 13H)**

Bit	7	6	5	4	3	2	1	0
Name	D_K[7:0]							
R/W	R/W							
POR	1	1	0	1	1	0	1	1

Bit 7~0 **D_K[7:0]**: RF channel frequency fractional number code lowest byte

• **SX3 – Fractional-N Synthesizer Control Register 3 (Addr: 14H)**

Bit	7	6	5	4	3	2	1	0
Name	D_K[15:8]							
R/W	R/W							
POR	1	1	1	1	1	0	0	1

Bit 7~0 **D_K[15:8]**: RF channel frequency fractional number code medium byte

• **SX4 – Fractional-N Synthesizer Control Register 4 (Addr: 15H)**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	D_K[19:16]			
R/W	—	—	—	—	R/W			
POR	0	1	1	0	1	0	1	0

Bit 7~4 Reserved bit, cannot be changed

Bit 3~0 **D_K[19:16]**: RF channel frequency fractional number code highest byte

D_K[19:0]=Floor $\{(\frac{f_{RF}-f_{IF}}{f_{XTAL}} \times 0.8\times M - D\_N[6:0]\times 2^{20}\}$, (315MHz: M=2, Other Bands: M=1)

For example:

f_{XTAL}=16MHz, RF channel frequency(f_{RF})=315MHz, Intermediate Frequency (f_{IF})=200kHz

→ (315MHz-0.2MHz)/16MHz×0.8×2=31.48

→ D_K=0.48×2^{20}=503316

→ Dec2Bin(503316)=0111_1010_1110_0001_0100

f_{XTAL}=16MHz, RF channel frequency(f_{RF})=433.92MHz, Intermediate Frequency (f_{IF})=200kHz

→ (433.92MHz-0.2MHz)/16MHz×0.8=21.686

→ D_K=0.686×2^{20}=719323

→ Dec2Bin(719323)=1010_1111_1001_1101_1011

• **I2C1 – I²C Control Register 1 (Addr: 42H)**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	—	CFOMSD
R/W	—	—	—	—	—	—	—	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~1 Reserved bit, cannot be changed

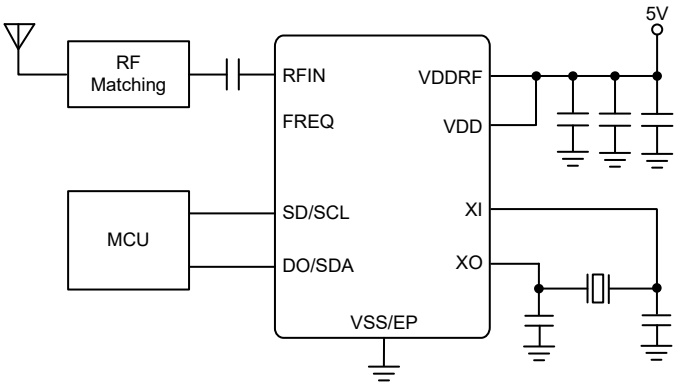
Bit 0 **CFOMSD**: Configuration Mode shut down control

0: No operation

1: Exit Configuration Mode

In the configuration mode the devices can be forced to leave this mode by first setting the CFOMSD bit high and then followed by an I²C stop condition. After leaving the Configuration Mode the CFOMSD bit will be reset to zero automatically.

Application Circuits



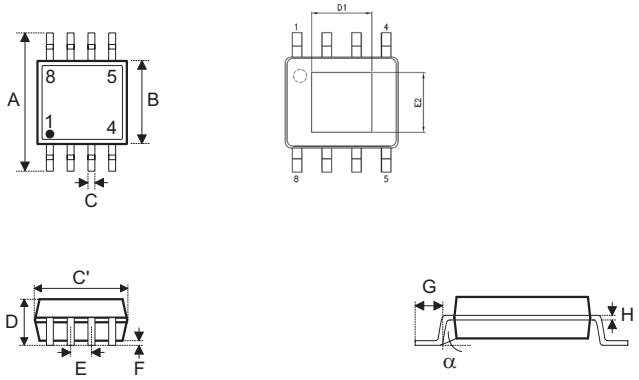
Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the Holtek website for the latest version of the Package/Carton Information.

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- The Operation Instruction of Packing Materials
- Carton information

8-pin SOP-EP (150mil) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.236 BSC	—
B	—	0.154 BSC	—
C	0.012	—	0.020
C'	—	0.193 BSC	—
D	—	—	0.069
D1	0.076	—	0.090
E	—	0.050 BSC	—
E2	0.076	—	0.090
F	0.000	—	0.006
G	0.016	—	0.050
H	0.004	—	0.010
α	0°	—	8°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	6.00 BSC	—
B	—	3.90 BSC	—
C	0.31	—	0.51
C'	—	4.90 BSC	—
D	—	—	1.75
D1	1.94	—	2.29
E	—	1.27 BSC	—
E2	1.94	—	2.29
F	0.00	—	0.15
G	0.40	—	1.27
H	0.10	—	0.25
α	0°	—	8°

Note: For this package type, refer to the package information provided here, which will not be updated by the Holtek website.