Features

- Frequency band: 315/433/470/868/915MHz
- FSK/GFSK modulation
- Supports 3-wire or 4-wire SPI interface
- Wide input voltage range of 2.0V~3.6V
- Programmable data rate: 2Kbps~250Kbps
- Programmable TX output power up to 17dBm
- Low current consumption
  - 0.4μA deep sleep mode current with data retention
  - RX current consumption (AGC on & low data rate) @ 433.92MHz: 13mA
  - RX current consumption (AGC on & low data rate) @ 868.3MHz: 14mA
  - TX current consumption @ 433.92MHz: 31mA@10dBm P_{OUT}, 54mA@17dBm P_{OUT}
  - TX current consumption @ 868.3MHz: 34mA@10dBm P_{OUT}, 62mA@17dBm P_{OUT}
- High RX sensitivity (433.92MHz)
  - -121dBm at 2Kbps on-air data rate
  - -112dBm at 50Kbps on-air data rate
  - -106dBm at 250Kbps on-air data rate
- High RX sensitivity (868.3MHz)
  - -121dBm at 2Kbps on-air data rate
  - -111dBm at 50Kbps on-air data rate
  - -105dBm at 250Kbps on-air data rate
- On-chip VCO and Fractional-N synthesizer with integrated loop filter
- Supports low cost 16MHz crystal
- Programmable digital channel filter for optimum performance at various data rates
- AGC (Auto Gain Control) to achieve wide input range, up to +10dBm
- AFC (Auto Frequency Compensation) for frequency drift due to X'tal aging
- On-chip low power RC oscillator for WOR (Wake-on-RX) and WOT (Wake-on-TX) functions
- Physical TX/RX FIFO buffers: TX 64 bytes, RX 64 bytes
- Simple FIFO/Block FIFO/Extend FIFO (up to 255 bytes)/Infinite FIFO modes
- Programmable threshold for carrier detection
- Frame synchronization recognition for both FIFO mode and Direct mode
- Packet handling
  - FEC (Forward Error Correction)
  - Data whitening
  - Manchester encoding
  - CRC-16 checking
- ATR (Auto-Transmit-Receive)
  - Auto-resend
  - Auto-acknowledgment
  - WOT + Auto-resend
  - WOR + Auto-acknowledgment
- Packet filtering
  - CRC filtering
  - Address filtering
- Package type: 24-pin QFN (3mm×3mm)

General Description

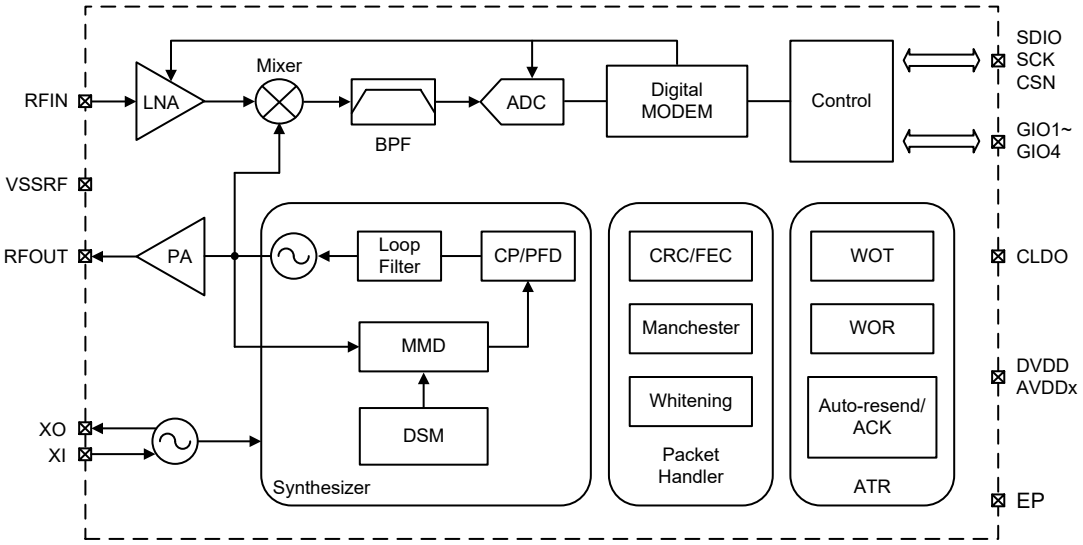
The BC3601 is a high performance and low cost CMOS RF FSK/GFSK transceiver for wireless applications in the 315MHz, 433MHz, 470MHz, 868MHz and 915MHz ISM (Industrial, Scientific and Medical) frequency bands. It incorporates a highly integrated sub-1GHz transceiver and a baseband modem with a programmable data rate from 2Kbps to 250Kbps. Data handling features include 64-byte TX/RX FIFO, packet handling, CRC generation, Forward Error Correction and data whitening, Manchester encoding.

The BC3601 is designed to achieve a high performance sub-1GHz transceiver. A low-noise low-IF receiver can achieve -121dBm sensitivity of 2Kbps data rate for both 433MHz and 868MHz bands. A Class-E Power Amplifier can deliver up to +17dBm output power at 433MHz and 868MHz bands. A fully integrated Fractional-N synthesizer can support a wide frequency range with a fine resolution. The loop filter is integrared to on-chip to minimize the external components.

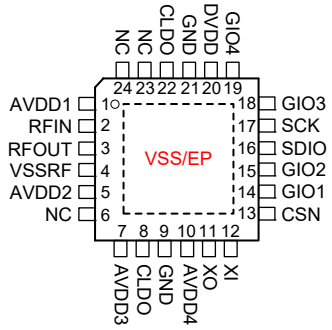
External host MCU can access the BC3601 through a 3-wire or 4-wire SPI interface. The device supports short strobe commands to reduce the loading of the host MCU while maintaining wireless communication link.

Additional link layer features like RSSI for channel assessment, auto-acknowledgement and auto-resend, WOT and WOR, etc., facilitate microcontroller based ISM bands wireless link applications.

Block Diagram



Pin Assignment



BC3601
24 QFN-A

Pin Description

Pin No.	Pin Name	Type	Description
1	AVDD1	PWR	Analog power supply
2	RFIN	AI	RF LNA input
3	RFOUT	AO	RF power amplifier output (It is recommended to be powered by V_{DD} directly)
4	VSSRF	PWR	RF ground
5	AVDD2	PWR	Analog power supply
6	NC	—	Not connected
7	AVDD3	PWR	Analog power supply
8	CLDO	PWR	LDO output
9	GND	PWR	Ground
10	AVDD4	PWR	Analog power supply
11	XO	AO	Crystal oscillator output
12	XI	AI	Crystal oscillator input
13	CSN	DI	SPI chip select input, low active
14	GIO1	DI/O	Multi-function I/O 1
15	GIO2	DI/O	Multi-function I/O 2
16	SDIO	DI/O	SPI data input/output
17	SCK	DI	SPI clock input
18	GIO3	DI/O	Multi-function I/O 3
19	GIO4	DI/O	Multi-function I/O 4
20	DVDD	PWR	Digital power supply
21	GND	PWR	Ground
22	CLDO	PWR	LDO output, connected to a bypass capacitor
23	NC	—	Not connected
24	NC	—	Not connected
—	VSS/EP	PWR	Exposed pad, must be connected to ground

Legend: DI: Digital Input; DO: Digital Output; ID/O: Digital Input/Output;
AI: Analog Input; AO: Analog Output; PWR: Power/Ground.

The backside plate of EP shall be well soldered to ground on PCB, otherwise it will downgrade RF performance.

Absolute Maximum Ratings

Supply Voltage ..... V_{SS}-0.3V to V_{SS} +3.6V

Voltage on I/O Ports..... V_{SS}-0.3V to V_{DD}+0.3V

Storage Temperature .....-50˚C to 125˚C

Operating Temperature .....-40˚C to 85˚C

ESD HBM..... ±2kV

The device is 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 device. Functional operation of this device 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}=3.3V, f_{XTAL}=16MHz, FSK modulation with matching circuit and low/high pass filter, RFOUT is powered by V_{DD} (3.3V), unless otherwise specified.

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
T_{OP}	Operating Temperature	—	-40	—	85	°C
V_{DD}	Supply Voltage	—	2	3.3	3.6	V
Digital I/Os						
V_{IH}	High Level Input Voltage	—	0.7×V_{DD}	—	V_{DD}	V
V_{IL}	Low Level Input Voltage	—	0	—	0.3×V_{DD}	V
V_{OH}	High Level Output Voltage	I_{OH}=-5mA	0.8×V_{DD}	—	V_{DD}	V
V_{OL}	Low Level Output Voltage	I_{OL}=5mA	0	—	0.2×V_{DD}	V
Current Consumption						
I_{Sleep}	Deep Sleep mode Current Consumption		—	0.4	1.0	μA
I_{IL}	Idle Mode Current Consumption	LIRC on, X'tal off	—	1.8	—	μA
I_{Light}	Light Sleep mode Current Consumption	X'tal on	—	0.7	—	mA
$I_{Standby}$	Standby Mode Current Consumption @ 315/433MHz	X'tal on, Synthesizer on	—	5.5	—	mA
	Standby Mode Current Consumption @ 868/915MHz		—	5.5	—	mA
I_{RX} or I_{TX}	315MHz Band Current Consumption	RX mode@2kbps	—	13	—	mA
		RX mode@250kbps	—	13.5	—	
		TX mode @0dBm P_{OUT}	—	19	—	
		TX mode @10dBm P_{OUT}	—	33	—	
		TX mode @13dBm P_{OUT}	—	41	—	
		TX mode @17dBm P_{OUT}	—	60	—	
	433MHz Band Current Consumption	RX mode@2kbps	—	13	—	mA
		RX mode@250kbps	—	13.5	—	
		TX mode @0dBm P_{OUT}	—	20	—	
		TX mode @10dBm P_{OUT}	—	31	—	
		TX mode @13dBm P_{OUT}	—	39	—	
		TX mode @17dBm P_{OUT}	—	54	—	
	868MHz Band Current Consumption	RX mode@2kbps	—	13.5	—	mA
		RX mode@250kbps	—	14	—	
		TX mode @0dBm P_{OUT}	—	20	—	
		TX mode @10dBm P_{OUT}	—	34	—	
		TX mode @13dBm P_{OUT}	—	45	—	
		TX mode @17dBm P_{OUT}	—	62	—	
	915MHz Band Current Consumption	RX mode@2kbps	—	14	—	mA
		RX mode@250kbps	—	14.5	—	
		TX mode @0dBm P_{OUT}	—	21	—	
		TX mode @10dBm P_{OUT}	—	32	—	
		TX mode @13dBm P_{OUT}	—	41	—	
		TX mode @17dBm P_{OUT}	—	61	—	
Pull-high Resistance						
R_{PH}	Pull-high Resistance for I/O Ports	3.3V	—	33	—	kΩ

A.C. Characteristics

Ta=25°C, V_{DD}=3.3V, f_{XTAL}=16MHz, FSK modulation with matching circuit and low/high pass filter, RFOUT is powered by V_{DD}(3.3V), unless otherwise specified.

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
RF Characteristics						
f_{RF}	RF Frequency Band	315MHz band	—	315	—	MHz
		433MHz band	—	433.92	—	
		470~510MHz band	—	490	—	
		868MHz band	—	868.3	—	
		915MHz band	—	915	—	
DR	Data Rate	GFSK modulation	2	—	250	Kbps
f_{LIRC}	Internal Low Frequency RC Oscillator	3.3V	-10%	32.768	+10%	kHz
Transmitter						
P_{OUT}	TX Output Power	433MHz band	0	—	17	dBm
		868MHz band	0	—	17	
S.E.$_{TX}$	TX Spurious Emission (P_{OUT}=10dBm)	f < 1GHz	—	—	-36	dBm
		47MHz<f<74MHz	—	—	-54	
		87.5MHz<f<118MHz				
		174MHz<f<230MHz				
		470MHz<f< 862MHz				
		2nd, 3rd Harmonic	—	—	-30	
Receiver						
$t_{ST,RX}$	RX Settling Time	Light Sleep mode to RX mode	—	150	—	μs
P_{Sens}	315MHz RX Sensitivity @ BER=0.1%	2Kbps (f_{DEV}=8kHz)	—	-121	—	dBm
		10Kbps (f_{DEV}=40kHz)	—	-115	—	
		50Kbps (f_{DEV}=18.75kHz)	—	-112	—	
		125Kbps (f_{DEV}=46.875kHz)	—	-108	—	
		250Kbps (f_{DEV}=93.75kHz)	—	-106	—	
	433MHz RX Sensitivity @ BER=0.1%	2Kbps (f_{DEV}=8kHz)	—	-121	—	dBm
		10Kbps (f_{DEV}=40kHz)	—	-115	—	
		50Kbps (f_{DEV}=18.75kHz)	—	-112	—	
		125Kbps (f_{DEV}=46.875kHz)	—	-108	—	
		250Kbps (f_{DEV}=93.75kHz)	—	-106	—	
	868MHz RX Sensitivity @ BER=0.1%	2Kbps (f_{DEV}=8kHz)	—	-121	—	dBm
		10Kbps (f_{DEV}=40kHz)	—	-114	—	
		50Kbps (f_{DEV}=18.75kHz)	—	-111	—	
		125Kbps (f_{DEV}=46.875kHz)	—	-108	—	
		250Kbps (f_{DEV}=93.75kHz)	—	-105	—	
	915MHz RX Sensitivity @ BER=0.1%	2Kbps (f_{DEV}=8kHz)	—	-121	—	dBm
		10Kbps (f_{DEV}=40kHz)	—	-114	—	
		50Kbps (f_{DEV}=18.75kHz)	—	-111	—	
		125Kbps (f_{DEV}=46.875kHz)	—	-108	—	
		250Kbps (f_{DEV}=93.75kHz)	—	-105	—	
$P_{IN,max}$	Maxmum Input Power	@ BER<0.1%	—	—	10	dBm
IR	Image Rejection	—	—	25	—	dB
S.E.$_{RX}$	RX Spurious	25MHz~1GHz	—	—	-57	dBm
		Above 1GHz	—	—	-47	

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
	RSSI Range	AGC on	-110	—	-10	dBm
LO Characteristics						
f_{LO}	RF Frequency Coverage Range	315MHz band	290	—	340	MHz
		433MHz band	390	—	470	
		470~510MHz band	470	—	510	
		868/915MHz band	830	—	960	
f_{STEP}	LO Frequency Resolution	—	—	—	1	kHz
PN_{LO}	315MHz Phase Noise	@ 100kHz offset	—	-94	—	dBc/Hz
		@ 1MHz offset	—	-118	—	
	433MHz Phase Noise	@ 100kHz offset	—	-93	—	
		@ 1MHz offset	—	-118	—	
	868MHz Phase Noise	@ 100kHz offset	—	-88	—	
		@ 1MHz offset	—	-112	—	
	915MHz Phase Noise	@ 100kHz offset	—	-88	—	
		@ 1MHz offset	—	-112	—	
Crystal Oscillator						
f_{XTAL}	X'tal Frequency	—	—	16	—	MHz
ESR	X'tal Equivalent Series Resistance	—	—	—	100	Ω
C_{LOAD}	X'tal Capacitor Load	—	—	16	—	pF
TOL	X'tal Tolerance	—	-20	—	+20	ppm
t_{SU}	X'tal Startup Time	49US XO	—	—	1	ms

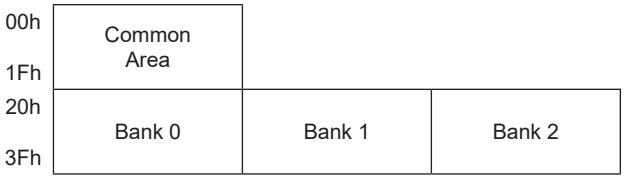
SPI Characteristics

Ta=-40°C~85°C, unless otherwise specified

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
f_{SCK}	SCK frequency	—	—	4	—	MHz
t_{SCKH}	SCK high time	—	$1/f_{XCLK}$	—	—	s
t_{SCKL}	SCK low time	—	$1/f_{XCLK}$	—	—	s
t_{S_SDIO}	SDIO input setup time	—	20	—	—	ns
t_{H_SDIO}	SDIO input hold time	—	20	—	—	ns
t_{S_CSN}	CSN to SCK active	—	30	—	—	ns
t_{H_CSN}	SCK inactive to CSN inactive	—	30	—	—	ns

Note: $f_{XCLK}=f_{XTAL}/(XODIV2+1)$

Memory Mepping

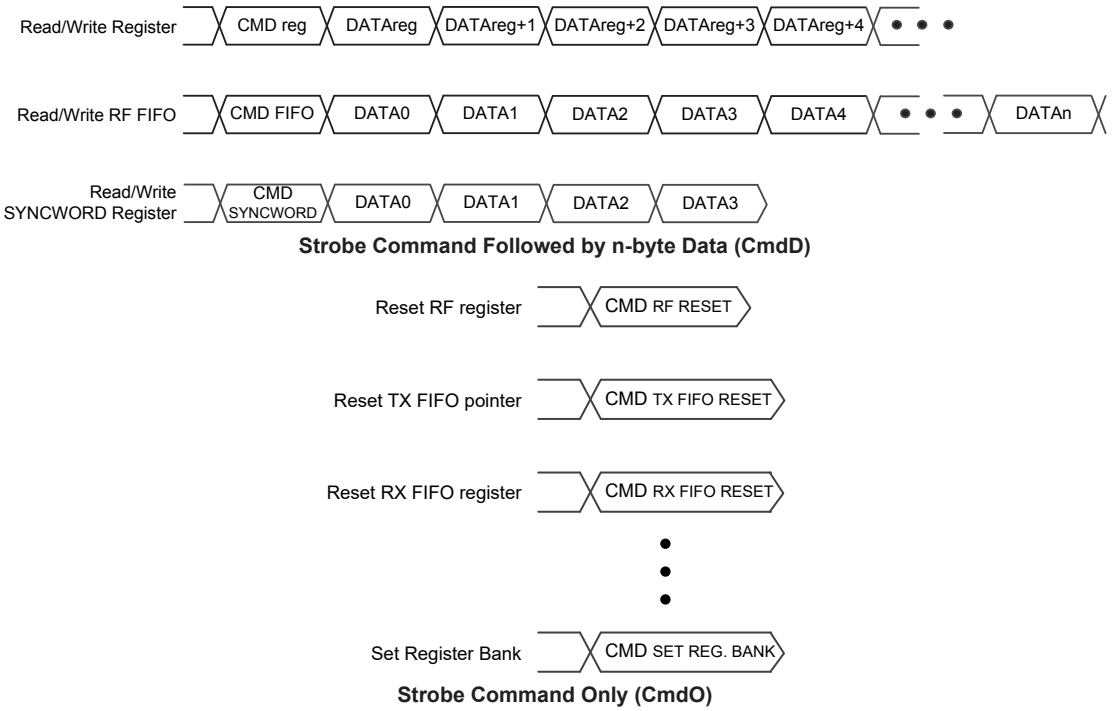


Common Area: It contains 32 bytes space. Accessing addresses 00h~1Fh always means to access the Common Area regardless of Bank Pointer configuration.

Bank 0~2: Each bank contains 32 bytes space. They are selected by the Bank Pointer.

The Bank Pointer, BANK[1:0], which is defined in the Common Area, can be set directly by the Set Register Bank command and read/written by the Control Register command.

Control Register Access



SFR Mapping and Bit Definition

Command Area Control Register

All control registers will be set to their initial value by power-on reset (POR). The software reset will set the control registers to their initial value except the FSYCK_EN, FSYCK_DIV[1:0], PWRON, GIO1S[2:0], GIO2S[2:0], PADDS[1:0], GIO3S[3:0], GIO4S[3:0], GIOPU[5:0], SPIPU, SDO_TEN bits in the RC1, IO1, IO2 and IO3 registers. These bits keep unchanged after software reset.

Addr.	Name	Bit							
		7	6	5	4	3	2	1	0
00h	CFG1	—	AGC_EN	RXCON_EN	DIR_EN	—	—	BANK[1:0]	
01h	RC1	PWRON	FSYCK_RDY	XCLK_RDY	XCLK_EN	FSYCK_DIV[1:0]		FSYCK_EN	RST_LL
02h	IRQ1	RXTO	RXFFOW	—	—	RXDETS[1:0]		IRQCPOR	IRQPOR
03h	IRQ2	ARKTFIE	ATRCTIE	FIFOLTIE	RXERRIE	RXDETIE	CALCMPIE	RXCMPIE	TXCMPIE
04h	IRQ3	ARKTFIF	ATRCTIF	FIFOLTIF	RXERRIF	RXDETIF	CALCMPIF	RXCMPIF	TXCMPIF
06h	IO1	PADDS[1:0]		GIO2S[2:0]			GIO1S[2:0]		
07h	IO2	GIO4S[3:0]				GIO3S[3:0]			
08h	IO3	SDO_TEN	SPIPU	GIOPU[5:0]					
09h	FIFO1	—	—	TXFFSA[5:0]					
0Ah	FIFO2	—	—	—	RXPL2F_EN	FFINF_EN	FFMG_EN	FFMG[1:0]	
0Bh	PKT1	TXPMLEN[7:0]							
0Ch	PKT2	PID[1:0]		—	—	SYNCLEN[1:0]		RXPMLEN[1:0]	
0Dh	PKT3	MCH_EN	FEC_EN	CRC_EN	CRCFMT	PLLEN_EN	PLHAC_EN	PLHLEN	PLH_EN
0Eh	PKT4	WHT_EN	WHTSD[6:0]						
0Fh	PKT5	TXDLEN[7:0]							
10h	PKT6	RXDLEN[7:0]							
11h	PKT7	RXPID[1:0]		DLY_RXS[2:0]			DLY_TXS[2:0]		

Addr.	Name	Bit							
		7	6	5	4	3	2	1	0
12h	PKT8	—		PLHA[5:0]					
13h	PKT9	PLHEA[7:0]							
14h	MOD1	DTR[7:0]							
15h	MOD2	RXIFOS[11:8]				DITHER[1:0]		—	DTR[8]
16h	MOD3	RXIFOS[7:0]							
17h	DM1	—	—	MDIV[5:0]					
18h	DM2	PREAMBLE_CFO_EN1	PREAMBLE_CFO_EN0	SDR[5:0]					
19h	DM3	CSF_SW_EN	FD_MOD[6:0]						
1Ah	DM4	THOLD[3:0]				CFO_DSEL	CFO_OFFSET_EN[2:0]		
1Bh	DM5	FD_HOLD[7:0]							
1Ch	DM6	—	PH_DIFF_MOD	—		—			
1Dh	DM7	PH_DIFF_STEP[7:0]							
1Eh	DM8	M_RATIO[7:0]							

Note: Addresses 05h and 1Fh which are not listed in this table are reserved for future use, it is suggested not to change their initial values by any methods.

The reset value shown in the following register description tables means the software reset results of strobe command.

- **CFG1: Configuration Control Register 1**

Bit	7	6	5	4	3	2	1	0
Name	—	AGC_EN	RXCON_EN	DIR_EN	—	—	BANK[1:0]	
R/W	—	R/W	R/W	R/W	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

Bit 7 Reserved, must be “0”

Bit 6 **AGC_EN**: AGC enable
0: Disable
1: Enable

Bit 5 **RXCON_EN**: RX continue mode enable
0: Disable
1: Enable
Note that this bit only affects normal RX mode and ATR RX mode without ARK function.

Bit 4 **DIR_EN**: Direct mode enable
0: TX/RX data from packet handling hardware
1: TX/RX data from/to external MCU directly

Bit 3~2 Reserved, must be “00”

Bit 1~0 **BANK[1:0]**: Control register bank selection
00: Bank 0
01: Bank 1
10: Bank 2
11: Reserved
This selection can be set by both the Set Register Bank command and Control Register command.

- **RC1: Reset/Clock Control Register 1**

Bit	7	6	5	4	3	2	1	0
Name	PWRON	FSYCK_RDY	XCLK_RDY	XCLK_EN	FSYCK_DIV[1:0]		FSYCK_EN	RST_LL
R/W	R/W	R	R	R/W	R/W		R/W	R/W
POR	1	—	—	—	0	0	0	—
Reset	—	0	0	1	—	—	—	0

Bit 7 **PWRON**: 3.3V power on flag

This bit is only set to 1 by power on reset and not affected by software reset of strobe command. After being set high, this bit should be cleared by software.The firmware can check this flag status and determine whether to execute auto calibration in the Light Sleep mode.

Bit 6 **FSYCK_RDY**: FSYCK clock ready flag (ready only)

0: Not ready

1: Ready

This bit is used to indicate that whether the FSYCK clock is ready for operation. This bit will be automatically cleared when FSYCK_EN=0, when power on reset occurs or when a Deep Sleep command or an Idle command is received.

Bit 5 **XCLK_RDY**: XCLK clock ready flag (ready only)

0: Not ready

1: Ready

This bit is used to indicate whether the XCLK debounce counter is full and XCLK is ready for operation. Note that when exiting the Deep Sleep state, this flag may need a certain period before being set high. This bit will be automatically cleared to zero when XCLK_EN=0, when RST_LL=1, when power on reset or when a software reset command, a Deep Sleep command or an Idle command is received.

Bit 4 **XCLK_EN**: XCLK clock enable

0: Disable

1: Enable

Setting this bit high will enable the XCLK path to the baseband block while clearing this bit to zero can save power if required. The XCLK clock should be enabled when writing data to the FIFO.

Bit 3~2 **FSYCK_DIV[1:0]**: FSYCK clock (XCLK division) selection

00: 1/1 XCLK

01: 1/2 XCLK

10: 1/4 XCLK

11: 1/8 XCLK

Bit 1 **FSYCK_EN**: FSYCK clock enable

0: Disable

1: Enable

Bit 0 **RST_LL**: Low voltage (1.2V) logic reset control

0: Release reset

1: Reset

- **IRQ1: Interrupt Control Register 1**

Bit	7	6	5	4	3	2	1	0
Name	RXTO	RXFFOW	—	—	RXDETS[1:0]		IRQCPOR	IRQPOR
R/W	R	R	—	—	R/W		R/W	R/W
Reset	0	0	0	0	1	0	0	1

Bit 7 **RXTO**: RX time-out flag
0: RX time-out does not occur
1: RX time-out occurs
This flag will be set high by hardware when the RX time-out condition occurs and automatically cleared when a Light Sleep strobe command is received, when the device enters the RX continuous mode, when WOR/WOT wake up occurs or when the device enters the ARK TX/RX mode.

Bit 6 **RXFFOW**: RX FIFO overwrite flag
0: RX FIFO overwrite does not occur
1: RX FIFO overwrite occurs
This flag will be set high by hardware when the RX FIFO overwrite condition occurs and automatically cleared when a RX FIFO reset strobe command or a RX strobe command is received.

Bit 5~4 Reserved, must be "00"

Bit 3~2 **RXDETS[1:0]**: RX detect selection
00: Detect carry
01: Detect preamble
1x: Detect SYNCWORD

Bit 1 **IRQCPOR**: IRQ flags clearing polarity selection
0: IRQ flags are cleared by writing 0 to the corresponding bits
1: IRQ flags are cleared by writing 1 to the corresponding bits

Bit 0 **IRQPOR**: IRQ signal polarity selection
0: Active low
1: Active high
When an IRQ flag in the IRQ3 register is set high and the corresponding IRQ function is enabled, then the active level of the IRQ signal is determined by this configuration.

- **IRQ2: Interrupt Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	ARKTFIE	ATRCTIE	FIFOLTIE	RXERRIE	RXDETIE	CALCMPIE	RXCMPIE	TXCMPIE
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

Bit 7 **ARKTFIE**: ARK TX Failure IRQ Enable
0: Disable
1: Enable

Bit 6 **ATRCTIE**: ATR Cycle Timer IRQ Enable
0: Disable
1: Enable

Bit 5 **FIFOLTIE**: FIFO Low Threshold IRQ Enable
0: Disable
1: Enable

Bit 4 **RXERRIE**: RX Error IRQ Enable
0: Disable
1: Enable

Bit 3 **RXDETIE**: RX Event Detected IRQ Enable
0: Disable
1: Enable

Bit 2 **CALCMPIE**: Calibration Complete IRQ Enable
0: Disable
1: Enable

Bit 1 **RXCMPIE**: RX Complete IRQ Enable
0: Disable
1: Enable

Bit 0 **TXCMPIE**: TX Complete IRQ Enable
0: Disable
1: Enable

- **IRQ3: Interrupt Control Register 3**

Bit	7	6	5	4	3	2	1	0
Name	ARKTFIF	ATRCTIF	FIFOLTIF	RXERRIF	RXDETIF	CALCMPIF	RXCMPIF	TXCMPIF
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	0	0	0	0	0	0

When the individual flag within this register is set high by the hardware, the corresponding IRQ will be generated. These flags can be cleared by writing 0 or 1 to the corresponding flag which is determined by the IRQCPOR bit configuration.

Bit 7 **ARKTFIF**: ARK TX Failure IRQ Flag
0: No request
1: Interrupt request

Bit 6 **ATRCTIF**: ATR Cycle Timer IRQ Flag
0: No request
1: Interrupt request
This flag will be set high when the ATRCT timer is full.

Bit 5 **FIFOLTIF**: FIFO Low Threshold IRQ Flag
0: No request
1: Interrupt request
When in the Burst TX mode, if this flag is set high, it means that TX FIFO data length is less than FFMG setting threshold and there are TX data to be written into the FIFO. When in the Burst RX mode, if this flag is set high, it means that RX FIFO remaining space is less than FFMG setting threshold and the remaining RX data length is longer than FFMG setting threshold.

Bit 4 **RXERRIF**: RX Error IRQ Flag
0: No request
1: Interrupt request
The RX error conditions include CRC failure (CRC_EN=1) or RX FIFO overwrite.

Bit 3 **RXDETIF**: RX Event Detected IRQ Flag
0: No request
1: Interrupt request
The RX events include carry, preamble and syncword and the actual trigger source is determined by the RXDETS[1:0] configuration.

Bit 2 **CALCMPIF**: Calibration Complete IRQ Flag
0: No request
1: Interrupt request
If ACAL_EN=0, the LIRC calibration is enabled by its individual calibration enable bit and the calibration completion will trigger IRQ. If ACAL_EN=1, VCO and RC calibrations are enabled and both completion will trigger IRQ.

Bit 1 **RXCMPIF**: RX Complete IRQ Flag
0: No request
1: Interrupt request
When the RX operation is completed without any error, this flag will be set high by hardware.

Bit 0 **TXCMPIF**: TX Complete IRQ Flag
0: No request
1: Interrupt request

- **IO1: I/O Control Register 1**

Bit	7	6	5	4	3	2	1	0
Name	PADDS[1:0]		GIO2S[2:0]			GIO1S[2:0]		
R/W	R/W		R/W			R/W		
POR	0	1	0	0	0	0	0	0

Bit 7~6 **PADDS[1:0]**: PAD driving strength selection (only reset by POR)
00: 0.5mA
01: 1mA
10: 5mA
11: 10mA

Bit 5~3 **GIO2S[2:0]**: GIO2 pin function selection (only reset by POR)
000/111: No function, input
001: SDO, 4-wire SPI data, output
010: TRXD, direct mode TXD/RXD, input/output
011: TXD, direct mode TXD, input
100: RXD, direct mode RXD, output
101: IRQ, interrupt request, output
110: ROSCi, ATR clock external input

Bit 2~0 **GIO1S[2:0]**: GIO1 pin function selection (only reset by POR)
000/111: No function, input
001: SDO, 4-wire SPI data, output
010: TRXD, direct mode TXD/RXD, input/output
011: TXD, direct mode TXD, intput
100: RXD, direct mode RXD, output
101: IRQ, interrupt request, output
110: ROSCi, ATR clock external input

- **IO2: I/O Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	GIO4S[3:0]				GIO3S[3:0]			
R/W	R/W				R/W			
POR	0	0	0	0	0	0	0	0

Bit 7~4 **GIO4S[3:0]**: GIO4 pin function selection (only reset by POR)
0000/0111/1111: No function, input
0001: SDO, 4-wire SPI data, output
0010: TRXD, direct mode TXD/RXD, input/output
0011: TXD, direct mode TXD, input
0100: RXD, direct mode RXD, output
0101: IRQ, interrupt request, output
0110: ROSCi, ATR clock external input
1000: TBCLK, TX bit (data) clock, output
1001: RBCLK, RX bit (recovery) clock, output
1010: FSYCK, i.e. XCLK 1/1, 1/2, 1/4, 1/8 output
1011: LIRCCLK, internal LIRC clock with debounce, output
1100: EPA_EN, external PA enable, output
1101: ELAN_EN, external LNA enable, output
1110: TRBCLK, TBCLK in TX mode or RBCLK in RX mode, output

Bit 3~0 **GIO3S[3:0]**: GIO3 pin function selection (only reset by POR)
0000/0111/1111: No function, input
0001: SDO, 4-wire SPI data, output
0010: TRXD, direct mode TXD/RXD, input/output
0011: TXD, direct mode TXD, input
0100: RXD, direct mode RXD, output
0101: IRQ, interrupt request, output
0110: ROSCi, ATR clock external input
1000: TBCLK, TX bit (data) clock, output
1001: RBCLK, RX bit (recovery) clock, output
1010: FSYCK, i.e. XCLK 1/1, 1/2, 1/4, 1/8 output
1011: LIRCCLK, internal LIRC clock with debounce, output
1100: EPA_EN, external PA enable, output
1101: ELAN_EN, external LNA enable, output
1110: TRBCLK, TBCLK in TX mode or RBCLK in RX mode, output

- **IO3: I/O Control Register 3**

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

Bit 7 **SDO_TEN**: SDO tri-state enable (only reset by POR)
0: Disable
1: Enable

Bit 6 **SPIPU**: 3-wire SPI pull-up enable (only reset by POR)
0: Disable
1: Enable
When this bit is set high, it only controls the pull-up function for the CSN, SCK and SDIO pins. Note that the pull-up function disable of the SDO pin for the 4-wire SPI is configured using the GIOPU[4:1] bits.

Bit 5 Reserved, must be "1"

Bit 4~1 **GIOPU[4:1]**: GIO pin function pull-up enable control (only reset by POR)
These bits control the pull-high function of the GIO4~GIO1 pins respectively.

Bit 0 Reserved, must be "1"

- **FIFO1: FIFO Control Register 1**

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

Bit 7~6 Reserved, must be "00"

Bit 5~0 **TXFFSA[5:0]**: TX FIFO start address, used for Block FIFO mode

- **FIFO2: FIFO Control Regsiter 2**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	RXPL2F_EN	FFINF_EN	FFMG_EN	FFMG[1:0]	
R/W	—	—	—	R/W	R/W	R/W	R/W	
Reset	0	0	0	0	0	0	0	1

Bit 7~5 Reserved, must be "000"

Bit 4 **RXPL2F_EN**: RX payload length byte to FIFO enable
0: Disable
1: Enable
Setting this bit high will place the payload length byte in the packet to RX FIFO. In the RX continue mode (RXCON_EN=1), this bit should be set to 1 to support multiple payload in single RX FIFO.

Bit 3 **FFINF_EN**: FIFO infinite length mode enable
0: Disable
1: Enable

Bit 2 **FFMG_EN**: FIFO length margin detect enable
0: Disable
1: Enable

Bit 1~0 **FFMG[1:0]**: FIFO length margin selection
Threshold of remaining data in TX FIFO:
00: 4 bytes
01: 8 bytes
10: 16 bytes
11: 32 bytes
Threshold of remaining space in RX FIFO:
00: 4 bytes
01: 8 bytes
10: 16 bytes
11: 32 bytes
After the FIFO length margin detect function has been enabled by setting the FFMG_EN bit high and the required FIFO length margin has been selected by setting these bits, when the selected condition occurs the FIFOLTIF flag will be set high. In this case, an interrupt signal will also be gemerated if the corresponding interrrpt function has been enabled.

- **PKT1: Packet Control Register 1**

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

Bit 7~0 **TXPMLEN[7:0]**: TX preamble length
Transmit preamble length=(TXPMLEN[7:0]+1) bytes

- **PKT2: Packet Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	PID[1:0]		—	—	SYNCLEN[1:0]		RXPMLEN[1:0]	
R/W	R/W		—	—	R/W		R/W	
Reset	0	0	0	0	0	1	1	0

Bit 7~6 **PID[1:0]**: Packet ID
This ID will be placed in the highest two bits of the payload header field when the header option is enabled using the PLH_EN bits.

Bit 5~4 Reserved, must be "00"

Bit 3~2 **SYNCLEN[1:0]**: TX/RX mode SYNCWORD length selection
00: Reserved
01: 4 bytes
10: 6 bytes
11: 8 bytes

Bit 1~0 **RXPMLEN[1:0]**: RX preamble detection length selection
00: 0 byte – no preamble detection
01: 1 byte
10: 2 bytes
11: 4 bytes

- **PKT3: Packet Control Register 3**

Bit	7	6	5	4	3	2	1	0
Name	MCH_EN	FEC_EN	CRC_EN	CRCFMT	PLLEN_EN	PLHAC_EN	PLHLEN	PLH_EN
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset	0	0	1	0	0	0	0	0

Bit 7 **MCH_EN**: Manchester code enable
0: Disable
1: Enable

Bit 6 **FEC_EN**: FEC enable
0: Disable
1: Enable

Bit 5 **CRC_EN**: CRC field enable
0: Disable
1: Enable

Bit 4 **CRCFMT**: CRC format selection
0: CCITT-16-CRC $G(X)=X^{16}+X^{12}+X^{5}+1$
1: IBC-16_CRC $G(X)=X^{16}+X^{15}+X^{2}+1$

Bit 3 **PLLEN_EN**: Payload length field enable
0: Disable
1: Enable

Bit 2 **PLHAC_EN**: Payload header address correction enable control
0: Disable, PLHA[5:0] in the PKT8 register can be used as software flags defined by users
1: Enable, PLHA[5:0] of TX/RX devices must include the same address, otherwise the packet will be regarded as a failed packet.

Bit 1 **PLHLEN**: Payload header length
0: 1 byte
1: 2 bytes

Bit 0 **PLH_EN**: Payload header field enable
0: Disable
1: Enable

- **PKT4: Packet Control Register 4**

Bit	7	6	5	4	3	2	1	0
Name	WHT_EN	WHTSD[6:0]						
R/W	R/W	R/W						
Reset	0	0	1	1	0	1	1	0

Bit 7 **WHT_EN**: Data whitening enable
0: Disable
1: Enable

Bit 6~0 **WHTSD[6:0]**: Data whitening seed

- **PKT5: Packet Control Register 5**

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

Bit 7~0 **TXDLEN[7:0]**: TX data length (unit: byte, used in burst mode only)

- **PKT6: Packet Control Register 6**

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

Bit 7~0 **RXDLEN[7:0]**: RX data length (unit: byte; used in burst mode only)
When the PLLEN_EN bit is cleared to 0, the received data length is determined by this field.
When this register is read, the read value indicates the RX data length in FIFO. The default read value is 00h.

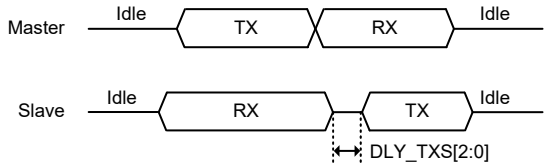
- **PKT7: Packet Control Register 7**

Bit	7	6	5	4	3	2	1	0
Name	RXPID[1:0]		DLY_RXS[2:0]			DLY_TXS[2:0]		
R/W	R		R/W			R/W		
Reset	0	0	1	0	0	0	0	0

Bit 7~6 **RXPID[1:0]**: Received packet PID (read only)

Bit 5~3 **DLY_RXS[2:0]**: RX block stable time after RX is enabled
000: 4μs
001: 8μs
010: 12μs
011: 16μs
100: 20μs
101: 32μs
110: 64μs
111: 100μs
These bits are used to select the waiting time between RX enable and RX stable. This time should be configured to a value greater than the default RX DCOC turbo mode delay time of 6μs.

Bit 2~0 **DLY_TXS[2:0]**: TX start (delay) time before entering the TX mode
000: 0μs
001: 10μs
010: 20μs
011: 40μs
100: 60μs
101: 80μs
110: 100μs
111: 120μs
It is used to align the timing between transmitter and receiver in ARK mode.



- **PKT8: Packet Control Register 8**

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

Bit 7~6 Reserved, must be "00"

Bit 5~0 **PLHA[5:0]**: Payload header address to support broadcast
Address=0 in RX mode means not doing correction check.
Write: write data to TX PLHA[5:0]. Read: read data from RX PLHA[5:0].

- **PKT9: Packet Control Register 9**

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

Bit 7~0 **PLHEA[7:0]**: Payload header extended address to support broadcast
Address=0 means not doing correction check.

- **MOD1: Modulator Control Register 1**

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

Bit 7~0 **DTR[7:0]**:
DTR[8:0]: Data rate divider, DTR[8] is located in the MOD2 register.
Data Rate={FXTAL/[(XODIV2+1)×32×(DTR[8:0]+1)]}, XODIV2=0, here data rate indicates TBCLK.
Note that DTR[8:0] can only be an odd number.

- **MOD2: Modulator Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	RXIFOS[11:8]				DITHER[1:0]		—	DTR[8]
R/W	R/W				R/W		—	R/W
Reset	1	0	0	1	0	0	0	0

Bit 7~4 **RXIFOS[11:8]**:
RXIFOS[11:0]: RX intermediate frequency offset, RXIFOS[7:0] is located in the MOD3 register.
Write RXIFOS[11:8] first and then write RXIFOS[7:0] to fully update RXIFOS[11:0].
RXIFOS[11:0]=Floor $((f_{IF}/f_{XTAL}/(XODIV2+1))\times 2^{17})$

Bit 3~2 **DITHER[1:0]**: Dither value
It is recommended not to change the DITHER[1:0] content.

Bit 1 Reserved, must be "0"

Bit 0 **DTR[8]**:
DTR[8:0]: Data rate divider, DTR[7:0] is loaced in the MOD1 register.
Data Rate=$f_{XTAL}/(XODIV2+1)/32/(DTR[8:0]+1)$, here data rate indicates TBCLK. Note that DTR[8:0] can only be an odd number.

- **MOD3: Modulator Control Register 3**

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

Bit 7~0 **RXIFOS[7:0]**:
RXIFOS[11:0]: RX intermediate frequency offset, RXIFOS[11:8] is located in the MOD2 register.
Write RXIFOS[11:8] first and then write RXIFOS[7:0] to fully update RXIFOS[11:0].
RXIFOS[11:0]= Floor $((f_{IF}/f_{XTAL}/(XODIV2+1))\times 2^{17})$

- **DM1: Demodulator Control Register 1**

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

Bit 7~6 Reserved, must be "00"

Bit 5~0 **MDIV[5:0]**: Demodulator operation clock divider
DMCLK=ADCLK/(MDIV[5:0]+1)
DM1 recommended setting values are summarised in the following.

f_{XTAL}	16MHz
Data Rate=2Kbps	31h
Data Rate=5Kbps	13h
Data Rate=10Kbps	09h
Data Rate=25Kbps	07h
Data Rate=50Kbps	13h
Data Rate=125Kbps	07h
Data Rate=250Kbps	03h

- **DM2: Demodulator Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	PREAMBLE_CFO_EN1	PREAMBLE_CFO_EN0	SDR[5:0]					
R/W	R/W	R/W	R/W					
Reset	0	1	0	0	0	0	0	0

Bit 7 **PREAMBLE_CFO_EN1**: Enable 2nd stage CFO correction in preamble
0: Disable
1: Enable
Note that this bit can only be set if the preamble length is 4 bytes, i.e, RXPMLEN[1:0]=11b.

Bit 6 **PREAMBLE_CFO_EN0**: Enable 1st stage CFO correction in preamble
0: Disable
1: Enable

Bit 5~0 **SDR[5:0]**: Decimator operation clock after phase extract
SDR[5:0]+1=DMCLK/(8×DATA_RATE), here DATA_RATE indicates RBCLK.
DM2 recommended setting values are summarised in the following.

f_{XTAL}	16MHz		
Rx Preamble / Data Rate	1 Byte	2 Byte	4 Byte
2Kbps	09h	49h	C9h
5Kbps			
10Kbps			
25Kbps	04h	44h	C4h
50Kbps	00h	40h	C0h
125Kbps			
250Kbps			

- **DM3: Demodulator Control Register 3**

Bit	7	6	5	4	3	2	1	0
Name	CSF_SW_EN	FD_MOD[6:0]						
R/W	R/W	R/W						
Reset	1	1	1	0	0	0	0	0

Bit 7 **CSF_SW_EN**: Channel selection filter and auto bandwidth switch enable
0: Disable
1: Enable

Bit 6~0 **FD_MOD[6:0]**: Frequency deviation modifier
FD_MOD=Round ((h/(SDR[5:0]+1))×128)
h=modulation index
SDR[5:0]+1=DMCLK/(8×DATA_RATE)
DM3 recommended setting values are summarised in the following.

f_{XTAL}	16MHz
Data Rate=2Kbps	E6h
Data Rate=5Kbps	
Data Rate=10Kbps	
Data Rate=25Kbps	
Data Rate=50Kbps	E0h
Data Rate=125Kbps	
Data Rate=250Kbps	

- **DM4: Demodulator Control Register 4**

Bit	7	6	5	4	3	2	1	0
Name	THOLD[3:0]				CFO_DSEL	CFO_OFFSET_EN[2:0]		
R/W	R/W				R/W	R/W		
Reset	0	0	0	1	1	0	0	0

Bit 7~4 **THOLD[3:0]**: Detection errors threshold
THOLD[3:2]: Preamble detection errors bit number threshold
THOLD[1:0]: SYNCWORD detection errors bit number

Bit 3 **CFO_DSEL**: CFO correction domain selection
0: Analog domain
1: Digital domain

Bit 2~0 **CFO_OFFSET_EN[2:0]**: Enable extra CFO offset on the CFO_estimate value by the CFO detect hardware
000: No CFO offset, default value
001: Extra 1/16 CFO_estimate offset
010: Extra 1/8 CFO_estimate offset
011: Reserved
100: Extra 1/4 CFO_estimate offset
101: Reserved
110: Reserved
111: Reserved
Note that the extra CFO offset is only used for ultra-low data rate (≤10K) cases.

f_{XTAL}	16MHz		
Rx Preamble / Data Rate	1 Byte	2 Byte	4 Byte
2Kbps~250Kbps	08h	08h	48h

- **DM5: Demodulator Control Register 5**

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

Bit 7~0 **FD_HOLD[7:0]**: Frequency deviation threshold for preamble detection
DM5 recommended setting values are summarised in the following.

f_{XTAL}	16MHz		
Rx Preamble / Data Rate	1 Byte	2 Byte	4 Byte
2Kbps	1Fh	1Ah	
5Kbps			
10Kbps			
25Kbps			
50Kbps	3Ah	30h	
125Kbps			
250Kbps			

- **DM6: Demodulator Control Register 6**

Bit	7	6	5	4	3	2	1	0
Name	—	PH_DIFF_MOD	—	—	—	—	—	—
R/W	—	R/W	—	—	—	—	—	—
Reset	0	0	0	0	0	0	0	0

Bit 7 Reserved, must be "0"

Bit 6 **PH_DIFF_MOD**: Phase difference extract mode setting
0: Phase extract range [-pi/2, pi/2]
1: Phase extract range [-pi, pi]

Bit 5~0 Reserved, must be "000000"
DM6 recommended setting values are summarised in the following.

f_{XTAL}	16MHz
Data Rate=2Kbps	40h
Data Rate=5Kbps	
Data Rate=10Kbps	00h
Data Rate=25Kbps	
Data Rate=50Kbps	40h
Data Rate=125Kbps	00h
Data Rate=250Kbps	

- **DM7: Demodulator Control Register 7**

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

Bit 7~0 **PH_DIFF_STEP[7**:0]: Incremental phase step per ADCLK for IF digital clock synthesizer
For different data rates, different ADCLK clocks are used.
If (Data rate < 200K)
Fif=200kHz;
Else Fif=300kHz;
Phase_diff_step=round ((Fif×8/Fadclk)×2^9);
DM7 recommended setting values are summarised in the following.

f_{XTAL}	16MHz
Data Rate=2Kbps	66h
Data Rate=5Kbps	
Data Rate=10Kbps	
Data Rate=25Kbps	
Data Rate=50Kbps	
Data Rate=125Kbps	9Ah
Data Rate=250Kbps	

- **DM8: Demodulator Control Register 8**

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

Bit 7~0 **M_RATIO[7:0]**: For CFO calulation

M_RATIO=round(1/(MDIV+1)×2^8)

DM8 recommended setting values are summarised in the following.

f_{XTAL}	16MHz
Data Rate=2Kbps	05h
Data Rate=5Kbps	0Dh
Data Rate=10Kbps	1Ah
Data Rate=25Kbps	20h
Data Rate=50Kbps	0Dh
Data Rate=125Kbps	20h
Data Rate=250Kbps	40h

Bank 0 Control Registers

All control registers will be set to their initial value by power-on reset (POR). The software reset will set the control registers to their initial value except the LIRC_EN, LIRC_OP[4:0], LIRC_OW and LIRCCAL_EN bits in the XO3 register. These bits keep unchanged after software reset.

Addr.	Name	Bit							
		7	6	5	4	3	2	1	0
20h	OM	PWR_SOFT	BAND_SEL[1:0]		—	ACAL_EN	RTX_EN	RTX_SEL	SX_EN
22h	SX1	—	D_N[6:0]						
23h	SX2	D_K[7:0]							
24h	SX3	D_K[15:8]							
25h	SX4	—	—	—	—	D_K[19:16]			
26h	STA1	—	—	—	CD_FLAG	—	OMST[2:0]		
28h	RSSI2	—				RSSI_CTHD[3:0]			
29h	RSSI3	RSSI_NEGDB[7:0]							
2Ah	RSSI4	RSSI_SYNC_OK[7:0]							
2Bh	ATR1	ATRCLK_DIV[1:0]		ATRCLKS	ATRTU	ATRCTM	ATRM[1:0]		ATR_EN
2Ch	ATR2	ATRCYC[7:0]							
2Dh	ATR3	ATRCYC[15:8]							
2Eh	ATR4	ATRRXAP[7:0]							
2Fh	ATR5	ATRRXEP[7:0]							
30h	ATR6	ATRRXEP[15:8]							
31h	ATR7	ARKNM[3:0]				—	ATR_WDLY[1:0]		ARK_EN
32h	ATR8	ARKRXAP[7:0]							
33h	ATR9	ATRCT[7:0]							
34h	ATR10	ATRCT[15:8]							
35h	ATR11	—						ATRRXAP[9:8]	
3Ch	XO1	—		—	XO_TRIM[4:0]				
3Dh	XO2	—	—	—	—	XODIV2	XO_SEL[2:0]		
3Eh	XO3	LIRCCAL_EN	LIRC_OW	LIRC_OP[4:0]					LIRC_EN
3Fh	TX2	CT_PAD[7:0]							

Note: Addresses 21h, 27h and 36h~3Bh which are not listed in this table are reserved for future use, it is suggested not to change their initial values by any methods.

The reset value shown in the following register description tables means the software reset results of strobe command.

- **OM: Operation Mode Control Register**

Bit	7	6	5	4	3	2	1	0
Name	PWR_SOFT	BAND_SEL[1:0]		—	ACAL_EN	RTX_EN	RTX_SEL	SX_EN
R/W	R/W	R/W		—	R/W	R/W	R/W	R/W
Reset	0	0	1	0	0	0	0	0

Bit 7 **PWR_SOFT**: RF operation mode selection, this bit must be kept as "0"
0: RF normal operation mode
1: Reserved

Bit 6~5 **BAND_SEL[1:0]**: Band selection (when PWR_SOFT=0)
00: 315MHz band, ODDIV=4
01: 433MHz band, ODDIV=2
10: 470~510MHz band, ODDIV=2
11: 868/915MHz band, ODDIV=1

Bit 4 Reserved, must be "0"

Bit 3 **ACAL_EN**: Auto calibration enable
0: Disable
1: Enable
When this bit is set high, both the VCO and RC calibrations will be enabled. When the VCO and RC calibrations are completed, this bit will be cleared to zero by hardware.

Bit 2 **RTX_EN**: RX or TX mode enable
0: Disable
1: Enable
After the RX or TX mode has been selected by the RTX_SEL bit, setting this bit high will enable the selected mode.

Bit 1 **RTX_SEL**: RX or TX mode selection
0: RX mode
1: TX mode

Bit 0 **SX_EN**: Synthesizer enable (standby mode enable control)
0: Disable
1: Enable
Setting this bit high will enable the PFD, CP and VCO functions.

- **SX1: Fractional-N Synthesizer Control Register 1**

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

Bit 7 Reserved, must be "0"

Bit 6~0 **D_N[6:0]**: RF channel integer number code
D_N[6:0]=floor (f_{RF}×ODDIV/f_{XTAL}/(XODIV2+1))
For example, XO=16MHz and RF band=433.92MHz which are initial setup:
→ (433.92MHz×2)/16MHz=54.24
→ D_N=54
→ Dec2Hex(54)=36
→ Dec2Bin(54)=011_0110

- **SX2: Fractional-N Synthesizer Control Register 2**

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

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

- **SX3: Fractional-N Synthesizer Control Register 3**

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

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

- **SX4: Fractional-N Synthesizer Control Register 4**

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

Bit 7~4 Reserved, must be "0000"

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

D_K[19:0]=floor (f_{RF}×ODDIV/f_{XTAL}-D_N)×2^{20})

For example, XO=16MHz and RF band=433.92MHz which are initial setup:

→ (433.92MHz×2)/16MHz=54.24

→ D_K=0.24×2^{20}=251658

→ Dec2Hex (251658)=3D70A

→ Dec2Bin (251658)=0111_1101_0111_0000_1010

- **STA1: Status Control Register 1**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	CD_FLAG	—	OMST[2:0]		
R/W	—	—	—	R	—	R		
Reset	0	0	0	0	0	0	0	0

Bit 7~5 Reserved, must be "000"

Bit 4 **CD_FLAG**: Carrier detection flag

This flag will be set high by hardware when carrier detection is okey after pulling DEMOD_EN high. Here DEMOD_EN high level is an internal signal which is generated by the internal state machine when in the Direct mode (DIR_EN=1) or after the RX strobe command is received when in the Burst mode (DIR_EN=0). The flag will be automatically cleared when RX_EN rising edge occurs. Here RX_EN rising edge is generated after setting RTX_SEL=0 and RTX_EN=1 when in the Direct mode or by the internal state machine after the RX strobe command is received when in the Burst mode.

Bit 3 Reserved, must be "0"

Bit 2~0 **OMST[2:0]**: Operation mode state indication (read only)

000: Deep Sleep mode
001: Idle mode
010: Light Sleep mode
011: Standby mode
100: TX mode
101: RX mode
110: VCO calibration mode
111: Undefined

- **RSSI2: RSSI Control Register 2**

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

Bit 7~4 Reserved, must be "0000"

Bit 3~0 **RSSI_CTHD[3:0]**: RSSI threshold for carrier detection
(RSSI_CTHD×2+1)+74=RSSI threshold for carrier detection

- **RSSI3: RSSI Control Register 3**

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

Bit 7~0 **RSSI_NEGDB[7:0]**: RSSI value (unit: -dB)
It is a real time measurement value.

- **RSSI4: RSSI Control Register 4**

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

Bit 7~0 **RSSI_SYNC_OK[7:0]**: RSSI snapshot when SYNCWORD is detected OK

- **ATR1: Auto TX/RX Control Register 1**

Bit	7	6	5	4	3	2	1	0
Name	ATRCLK_DIV[1:0]		ATRCLKS	ATRTU	ATRCTM	ATRM[1:0]		ATR_EN
R/W	R/W		R/W	R/W	R/W	R/W		R/W
Reset	1	1	0	0	1	0	0	0

Bit 7~6 **ATRCLK_DIV[1:0]**: ATR clock frequency division
00: 1/1, ATRCLK=32768Hz
01: 1/4, ATRCLK=8192Hz
10: 1/8, ATRCLK=4096Hz
11: 1/16, ATRCLK=2048Hz

Bit 5 **ATRCLKS**: ATRCLK clock source selection
0: From the internal LIRC clock
1: From the external ROSCi clock input on PAD GIOx pin

Bit 4 **ATRTU**: Auto TRX unit time selection
0: 250μs
1: 1ms, used to support low data rate applications
This bit is used to select the unit time for the ATR RX active period (ATRRXAP[9:0]), ATR RX extended period (ATRRXEP[15:0]) and ARK RX active period (ARKRXAP[7:0]).

Bit 3 **ATRCTM**: Auto TRX timer mode selection
0: Single mode, restart ATRCT timer when every ATR transation occurs
1: Continuous mode, start ATRCT timer upon receiving Idle command, stop ATRCT timer when ATR_EN=0 or ATRCTM=0

Bit 2~1 **ATRM[1:0]**: Auto TRX mode selection
00: ATR WOT mode
01: ATR WOR mode
10: ATR WTM mode
11: ATR WTM mode

Bit 0 **ATR_EN**: Auto TRX enable
0: Disable
1: Enable
Note that the ATR functions are activated by operation state transition from standby/sleep mode to Idle mode.

- **ATR2: Auto TX/RX Control Register 2**

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

Bit 7~0 **ATRCYC[7:0]**: ATRCT timer expire value low byte

- **ATR3: Auto TX/RX Control Register 3**

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

Bit 7~0 **ATRCYC[15:8]**: ATRCT timer expire value high byte
Wakeup period= Period (ATRCLK)×(ATRCYC[15:0]) + Period(LIRCCLK), ATRCYC!=0. Default set to about 2 seconds.

- **ATR4: Auto TX/RX Control Register 4**

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

Bit 7~0 **ATRRXAP[7:0]**: ATR RX active period low byte
ATR RX active period high byte ATRRXAP[9:8] is located in the ATR11 register.
Active period=unit time×(ATRRXAP[9:0]+1); the unit time can be 250μs or 1ms which is determined by the ATRTU bit. The default ATR RX active period is 10ms with a default time unit of 250μs.

- **ATR5: Auto TX/RX Control Register 5**

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

Bit 7~0 **ATRRXEP[7:0]**: ATR RX extend period low byte

- **ATR6: Auto TX/RX Control Register 6**

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

Bit 7~0 **ATRRXEP[15:8]**: ATR RX extended period high byte
Extend period=unit time×(ATRRXEP[15:0]+1); the unit time can be 250μs or 1ms which is determined by the ATRTU bit. The default ATR RX extended period is 100ms with a default time unit of 250μs.

- **ATR7: Auto TX/RX Control Register 7**

Bit	7	6	5	4	3	2	1	0
Name	ARKNM[3:0]				—	ATR_WDLY[1:0]		ARK_EN
R/W	R/W				—	R/W		R/W
Reset	0	1	1	1	0	0	1	0

Bit 7~4 **ARKNM[3:0]**: ARK repeat cycle number
Maximum repeat cycle number=ARKNM[3:0]+1

Bit 3 Reserved, must be "0"

Bit 2~1 **ATR_WDLY[1:0]**: Auto wake up delay time
00: 244μs
01: 488μs
10: 732μs
11: 976μs

Bit 0 **ARK_EN**: Auto Resend/ACK enable
0: Disable
1: Enable

- **ATR8: Auto TX/RX Control Register 8**

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

Bit 7~0 **ARKRXAP[7:0]**: ARK RX active period
Active period=unit time×(ARKRXAP[7:0]+1); the unit time can be 250μs or 1ms which is determined by the ATRTU bit. The default ARK RX active period is 10ms with a default time unit of 250μs.

- **ATR9: Auto TX/RX Control Register 9**

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

Bit 7~0 **ATRCT[7:0]**: ATR cycle timer low byte

- **ATR10: Auto TX/RX Control Register 10**

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

Bit 7~0 **ATRCT[15:8]**: ATR cycle timer high byte

Reading ATRCT[15:0] will get the current count value. Due to the limitation of SPI 8-bit data length, reading the ATR9 register will take a snapshot of the whole 16-bit data into the read register buffer. Users should read ATR9 and ATR10 in series (non-interrupted) to get correct data.

Writing to ATRCT[15:0] will update the count value. Write to ATR9 first and then write to ATR10 to trigger the ATRCT write function. This timer update mechanism is used to align the time slot for the master and slave in a two-way RF system.

- **ATR11: Auto TX/RX Control Register 11**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	ATRRXAP[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

Bit 7~0 **ATRRXAP[9:8]**: ATR RX active period high byte

ATR RX active period low byte ATRRXAP[7:0] is located in the ATR4 register.

Active period=unit time×(ATRRXAP[9:0]+1); the unit time can be 250μs or 1ms which is determined by the ATRTU bit. The default ATR RX active period is 10ms with a default time unit of 250μs.

- **XO1: XO Control Register 1**

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

Bit 7~5 Reserved, must be "000"

Bit 4~1 **XO_TRIM[4:0]**: Fine tune value for the internal capacitor load on XO pin

Crystal Oscillator	C_{LOAD}	CL_1=CL_2 (on PCB)	XO_TRIM
49US 16MHz	16pF	22pF	0FH
	20pF	30pF	13H
3225SMD 16MHz	16pF	27pF	0BH

49US 16MHz crystal oscillator

16pF C_{LOAD}: Within ±20ppm frequency error, 1 trim code shifts -2ppm.

20pF C_{LOAD}: Within ±20ppm frequency error, 1 trim code shifts -1.3ppm.

3225SMD 16MHz crystal oscillator

16pF C_{LOAD}: Within ±20ppm frequency error, 1 trim code shifts -0.4ppm.

- **XO2: XO Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	XODIV2	XO_SEL[2:0]		
R/W	—	—	—	—	R/W	R/W		
Reset	0	0	0	0	0	0	1	1

Bit 7~4 Reserved, must be "0000"

Bit 3 **XODIV2**: XO output divided by 2 enable
0: Disable
1: Enable
Note: $f_{XCLK}=f_{XO}$ when XODIV2=0, $f_{XCLK}=f_{XO}/2$ when XODIV2=1.

Bit 2~0 **XO_SEL[2:0]**: XO frequency selection
000: Reserved
001: Reserved
010: Reserved
011: 16MHz
100: Reserved
101: Reserved
110: Reserved
111: Reserved
Note that the XODIV2 bit must be fixed at zero.

- **XO3: XO Control Register 3**

Bit	7	6	5	4	3	2	1	0
Name	LIRCCAL_EN	LIRC_OW	LIRC_OP[4:0]					LIRC_EN
R/W	R/W	R/W	R/W					R/W
POR	0	0	0	1	1	0	1	0

Bit 7 **LIRCCAL_EN**: LIRC calibration enable control
0: Disable
1: Enable

Bit 6 **LIRC_OW**: LIRC overwrite control
0: LIRC_OP[4:0] from calibration engine
1: LIRC_OP[4:0] from control register

Bit 5~1 **LIRC_OP[4:0]**: LIRC trim
After writing data to LIRC_OP[4:0], this trim will become active when the LIRC_OW bit is set high. When reading data from LIRC_OP[4:0], the actual data source is determined by the LIRC_OW bit setting.

Bit 0 **LIRC_EN**: LIRC enable control
0: Disable
1: Enable

- **TX2: TX Control Register 2**

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

Bit 7~0 **CT_PAD[7:0]**: RF output power control

The device offers several power level settings for 10dBm, 13dBm and 17dBm, respectively.

RF Output Power	CT_PAD[7:0]	
	433MHz	868MHz
17dBm	7BH	7BH
13dBm	45H	46H
10dBm	3AH	3AH

Note: The output power level will vary due to different matching components and the PCB placements. These matching variations will significantly impact output power level below +10dBm.

Bank 1 Control Registers

All control registers will be set to their initial value by power-on reset (POR). The software reset will set the control registers to their initial value.

Addr.	Name	Bit							
		7	6	5	4	3	2	1	0
21h	AGC2	SAT_SEL[1:0]		—				AGC_CMP_THD[1:0]	
22h	AGC3	CDRST_THD_SEL[1:0]		ENVAVG_SEL[1:0]		—	IF_DETOK_THD[2:0]		
23h	AGC4	GAIN_SEL[3:0]				—	AGC_ST[2:0]		
24h	AGC5	—						AGC_FSEL[1:0]	
26h	AGC7	GAIN_STB[7:0]							
2Ch	FCF1	—	—	SFRATIO[1:0]		—			
2Dh	FCF2	FSCALE[7:0]							
2Eh	FCF3	—				FSCALE11:8]			
2Fh	FCF4	CF_B12[7:0]							
30h	FCF5	—						CF_B12[9:8]	
31h	FCF6	CF_B13[7:0]							
32h	FCF7	—						CF_B13[9:8]	
33h	FCF8	CF_A12[7:0]							
34h	FCF9	—						CF_A12[9:8]	
35h	FCF10	CF_A13[7:0]							
36h	FCF11	—						CF_A13[9:8]	
37h	FCF12	CF_B22[7:0]							
38h	FCF13	—						CF_B22[9:8]	
39h	FCF14	CF_B23[7:0]							
3Ah	FCF15	—						CF_B23[9:8]	
3Bh	FCF16	CF_A22[7:0]							
3Ch	FCF17	—						CF_A22[9:8]	
3Dh	FCF18	CF_A23[7:0]							
3Eh	FCF19	—						CF_A23[9:8]	

Note: Addresses 25h, 27h~2Bh and 3Fh which are not listed in this table are reserved for future use, it is suggested not to change their initial values by any methods.

The reset value shown in the following register description tables means the software reset results of strobe command.

- **AGC2: AGC Control Register 2**

Bit	7	6	5	4	3	2	1	0
Name	SAT_SEL[1:0]		—	—	—	—	AGC_CMP_THD[1:0]	
R/W	R/W		—	—	—	—	R/W	
Reset	0	1	0	0	0	0	0	0

Bit 7~6 **SAT_SEL[1:0]**: Saturation detection threshold selection
00: -6 dBFS
01: -8 dBFS
10: -10 dBFS
11: -12 dBFS
Note: "FS" indicates the ADC output full-scale.

Bit 5~2 Reserved, must be "0000"

Bit 1~0 **AGC_CMP_THD[1:0]**: AGC comparison number threshold
00: Continuous AGC comparison until ID is detected
01~11: Comparison number threshold

- **AGC3: AGC Control Register 3**

Bit	7	6	5	4	3	2	1	0
Name	CDRST_THD_SEL[1:0]		ENVAVG_SEL[1:0]		—	IF_DETOK_THD[2:0]		
R/W	R/W		R/W		—	R/W		
Reset	0	0	1	0	0	1	0	0

Bit 7~6 **CDRST_THD_SEL[1:0]**: Carrier signal threshold to reset AGC

CDRST_THD_SEL[1:0]	GAIN_SEL[3:0]		
	0010b	0011b	Other Values
00b	-32 dBFS	-41 dBFS	-48 dBFS
01b	-35 dBFS	-44 dBFS	-48 dBFS
10b	-38 dBFS	-47 dBFS	-48 dBFS
11b	-41 dBFS	-48 dBFS	-48 dBFS

If the AGC completion state is reached and the signal strength detected is below the preset threshold, the AGC flow will be reset and then restarted.

Bit 5~4 **ENVAVG_SEL[1:0]**: Envelop detection average ratio selection
00: 1/16
01: 1/32
10: 1/64
11: 1/128

Bit 3 Reserved, must be "0"

Bit 2~0 **IF_DETOK_THD[2:0]**: IF detection OK threshold
After the gain stable time which determined by the AGC7 register, the AGC circuit will wait for (IF_DETOK_THD×8) ADCLK cycles before starting to detect the IF signal strength.

- **AGC4: AGC Control Register 4**

Bit	7	6	5	4	3	2	1	0
Name	GAIN_SEL[3:0]				—	AGC_ST[2:0]		
R/W	R				—	R		
Reset	0	0	0	1	0	0	0	1

Bit 7~4 **GAIN_SEL[3:0]**: Gain curve selection
0000: Gain Curve is not selected.
0001: Maximum gain is selected.
0111: Minimum gain is selected.
The available field value is from 0000 to 0111. The gain will automatically be selected by hardware. Refer to the CDRST_THD_SEL[1:0] bit field description in the AGC3 register.

Bit 3 Reserved, must be "0"

Bit 2~0 **AGC_ST[2:0]**: AGC state machine state
000~001: AGC is not completed
111: AGC is completed

- **AGC5: AGC Control Register 5**

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

Bit 7~2 Reserved, must be "000000"

Bit 1~0 **AGC_FSEL[1:0]**: AGC filter configuration
AGC_FSEL[1]: HPF pass band set point
0: 5/32 ADCLK
1: 6/32 ADCLK
AGC_FSEL[0]: LPF pass band set point
0: 17/320 ADCLK
1: 17/256 ADCLK
ADCLK=0.5×XCLK. It is recommended to set AGC_FSEL[1:0]=00b for XCLK=16MHz.

- **AGC7: AGC Control Register 7**

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

Bit 7~0 **GAIN_STB[7:0]**: Gain stable count
Gain stable count delay in ADCLK period=GAIN_STB[7:0]×2

- **FCF1: Filter Coefficient Control Register 1**

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

Bit 7~6 Reserved, must be "00"

Bit 5~4 **SFRATIO[1:0]**: Smooth filter ratio selection
00: 1/1
01: 1/16
10: 1/64
11: 1/128

Bit 3~0 Reserved, must be "0110"

- **FCF2: Filter Coefficient Control Register 2**

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

Bit 7~0 **FSCALE[7:0]**: Frequency deviation scale parameter low byte.

- **FCF3: Filter Coefficient Control Register 3**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	FSCALE[11:8]			
R/W	—	—	—	—	R/W			
Reset	0	0	0	0	0	1	0	0

Bit 7~4 Reserved, must be "0000"

Bit 3~0 **FSCALE[11:8]**: Frequency deviation scale parameter high byte
If the Data Rate is 100kbps~250kbps, then the FSCALE value can refer to the Lookup Table recommended settings.
If the Data Rate < 100K, then the FSCALE value is calculated as follows:
FSCALE[11:0]=round $((h \times f_S / f_{XTAL} / (XODIV2+1)) \times 2^{15})$,
where h= (2×frequency deviation)/(data symbol rate).
Here "h" is the modulation index calculated from frequency deviation and data symbol rate.

- **FCF4: Filter Coefficient Control Register 4**

Bit	7	6	5	4	3	2	1	0
Name	CF_B12[7:0]							
R/W	R/W							
Reset	1	0	0	0	0	1	0	1

- **FCF5: Filter Coefficient Control Register 5**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_B12[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	1	0

- **FCF6: Filter Coefficient Control Register 6**

Bit	7	6	5	4	3	2	1	0
Name	CF_B13[7:0]							
R/W	R/W							
Reset	1	0	0	0	1	0	1	0

- **FCF7: Filter Coefficient Control Register 7**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_B13[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

- **FCF8: Filter Coefficient Control Register 8**

Bit	7	6	5	4	3	2	1	0
Name	CF_A12[7:0]							
R/W	R/W							
Reset	0	0	0	1	0	0	1	0

- **FCF9: Filter Coefficient Control Register 9**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_A12[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

- **FCF10: Filter Coefficient Control Register 10**

Bit	7	6	5	4	3	2	1	0
Name	CF_A13[7:0]							
R/W	R/W							
Reset	0	0	1	0	1	0	1	1

- **FCF11: Filter Coefficient Control Register 11**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_A13[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	1	1

- **FCF12: Filter Coefficient Control Register 12**

Bit	7	6	5	4	3	2	1	0
Name	CF_B22[7:0]							
R/W	R/W							
Reset	0	0	0	1	0	1	0	0

- **FCF13: Filter Coefficient Control Register 13**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_B22[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	1

- **FCF14: Filter Coefficient Control Register 14**

Bit	7	6	5	4	3	2	1	0
Name	CF_B23[7:0]							
R/W	R/W							
Reset	0	0	1	0	0	0	0	1

- **FCF15: Filter Coefficient Control Register 15**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_B23[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

- **FCF16: Filter Coefficient Control Register 16**

Bit	7	6	5	4	3	2	1	0
Name	CF_A22[7:0]							
R/W	R/W							
Reset	0	1	1	1	1	0	0	0

- **FCF17: Filter Coefficient Control Register 17**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_A22[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

- **FCF18: Filter Coefficient Control Register 18**

Bit	7	6	5	4	3	2	1	0
Name	CF_A23[7:0]							
R/W	R/W							
Reset	0	0	1	0	1	0	0	0

- **FCF19: Filter Coefficient Control Register 19**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CF_A23[9:8]	
R/W	—	—	—	—	—	—	R/W	
Reset	0	0	0	0	0	0	0	0

The FCF4~FCF19 regsiters define eight groups of IIR coefficients, their recommended settings for different XTAL clock conditions are listed (Lookup Table) below.

f_{XTAL}	16M	16M	16M	16M	16M	16M	16M
f_S	250K	125K	50K	25K	10K	5K	2K
f_D	93.75K	46.875K	18.75K	50K	40K	20K	8K
D_K[19:0]=20'h	FC × ODDIV / f_{XTAL} / (XODIV2+1), take decimal number						
D_N[6:0]=7'h	FC × ODDIV / f_{XTAL} / (XODIV2+1), take integer number						
SFRATIO[1:0]=2'b	0	0	0	1	1	3	3
FSCALE[11:0]=12'h	444	119	4C	CD	A4	52	20
CF_B12[9:0]=10'h	285	01D	0	0	0	0	0
CF_B13[9:0]=10'h	8A	346	0	0	0	0	0
CF_A12[9:0]=10'h	12	022	0	310	310	302	302
CF_A13[9:0]=10'h	32B	331	0	0	0	0	0
CF_B22[9:0]=10'h	114	386	0	0	0	0	0
CF_B23[9:0]=10'h	21	012	0	0	0	0	0
CF_A22[9:0]=10'h	78	008	0	0	0	0	0
CF_A23[9:0]=10'h	28	008	0	0	0	0	0

Carry Freq.	ODDIV	PLL Freq.	VCO Freq.
915 MHz	1	915 MHz	1.83 GHz
868 MHz		868 MHz	1.736 GHz
470 MHz	2	940 MHz	1.88 GHz
433 MHz		866 MHz	1.732 GHz
315 MHz	4	1.25 GHz	2.5G Hz

Bank 2 Control Registers

All control registers will be set to their initial value by power-on reset (POR). The software reset will set the control registers to their initial value.

Addr.	Name	Bit							
		7	6	5	4	3	2	1	0
2Ah	RSV1	Reserved							
2Fh	RSV2	Reserved							
34h	RSV3	Reserved							
3Ah	RSV4	Reserved							

Note: The addresses 21h~3Fh except 2Ah, 2Fh, 34h and 3Ah are reserved for future use, it is suggested not to change their initial values by any methods.

The reset value shown in the following register description tables means the software reset results of strobe command.

- **RSV1: Reserved**

Bit	7	6	5	4	3	2	1	0
Name	Reserved							
R/W	R/W							
Reset	0	1	0	1	0	1	0	1

Bit 7~0 Reserved, must be set to 01010111

- **RSV2: Reserved**

Bit	7	6	5	4	3	2	1	0
Name	Reserved							
R/W	R/W							
Reset	0	0	0	1	1	0	0	0

Bit 7~0 Reserved, the recommended setting values are summarised in the following table.

Data Rate < 100Kbps	44h
Data Rate ≥ 100Kbps	54h

- **RSV3: Reserved**

Bit	7	6	5	4	3	2	1	0
Name	Reserved							
R/W	R/W							
Reset	0	1	0	1	0	0	0	0

Bit 7~0 Reserved, must be set to 11010000

- **RSV4: Reserved**

Bit	7	6	5	4	3	2	1	0
Name	Reserved							
R/W	R/W							
Reset	0	1	0	1	0	1	0	0

Bit 7~0 Reserved, must be set to 10010100

Special Function Description

Sub-1GHz RF Transceiver

The BC3601 adopts a fully-integrated, low-IF receiver architrecture. The received RF signal is first amplified by a low noise amplifier (LNA), after which the frequency is down-converted to an intermediate frequency (IF) by a quadrature mixer. The mixer output is filtered by a channel-selected filter which rejects the unwanted out-of-band (OOB) interference and image signals. After filtering, the IF signal levl is adjusted by a analog programmable gain amplifier (PGA). Then the IF signal is digitized by a 10-bit ∑Δ ADC.

The BC3601 features an Automatic Gain Control (AGC) unit to adjust the receiver gain according to the RSSI value, generated at the digital modem. The AGC enables the BC3601 to operate from sensitivity level to +10dBm input power.

The BC3601 adopts a fully integrated fractional-N synthesizer which includes RF VCO, on-chip VCO inductor, loop filter, and digital controlled XO (DCXO). The fractional-N synthesizer architecture allows the users to extend their potential usage to a wider frequency range.

The transmit session is a VCO direct modulation architecture. Different from the conventional direct up-conversion transmitters, the GFSK modulation signal is fed into the VCO directly to take advantange of fractional-N synthesizer. As a result, both layout area and current consumption are much smaller compared with direct up-conversion transmitters. The fine resolution can generate the GFSK signal with a low FSK error. The modulated signal is fed into a Class-E Power Amplifier (PA) and the maximum output power can be up to +17dBm.

Serial Interface

The BC3601 communicates with a host MCU via a 3-wire SPI interface (CSN, SCK, SDIO) or a 4-wire SPI interface (SDO from GIO1 or GIO2) with a data rate up to 4Mbps. An SPI transmission is an (8+8×n) bits sequence which consists of an 8-bit command and n×8 bits of data, where n can be 0 or any natural number. If the number n is greater than the address boundary, the address will return to zero. The host MCU should pull the CSN (SPI chip select) pin low in order to access the BC3601. Using the SPI interface, user can access the control registers and issue Strobe commands. When writing data to the RF chip, the SPI data will be latched into the registers at the rising edge of the SCK signal. When reading data from the RF chip registers, the bit data will be transferred at the falling edge of the SCK signal after inputing the target register address.

Command (8 bits)								Data (8 bits)							
C7	C6	C5	C4	C3	C2	C1	C0	D7	D6	D5	D4	D3	D2	D1	D0

SPI Command Format

Two kinds of command are defined. One is 1-byte command only, named CmdO, and the other is 1-byte command followed by n-byte data, named CmdD.

C7	C6	C5	C4	C3	C2	C1	C0	Description	CmdO	CmdD
0	1	A5	A4	A3	A2	A1	A0	Write to control registers		√
1	1	A5	A4	A3	A2	A1	A0	Read from control register		√
0	0	1	x	x	x	B1	B0	Set register bank	√	
0	0	0	1	x	x	x	0	Write SYNCWORD command		√
1	0	0	1	x	x	x	0	Read SYNCWORD command		√
0	0	0	1	x	x	x	1	TX FIFO write command		√
1	0	0	1	x	x	x	1	RX FIFO read command		√
0	0	0	0	1	0	0	0	Software reset command	√	
0	0	0	0	1	0	0	1	TX FIFO address pointer reset command	√	
1	0	0	0	1	0	0	1	RX FIFO address pointer reset command	√	
0	0	0	0	1	0	1	0	Deep Sleep mode	√	
0	0	0	0	1	0	1	1	Idle mode	√	
0	0	0	0	1	1	0	0	Light Sleep mode	√	
0	0	0	0	1	1	0	1	Standby mode	√	
0	0	0	0	1	1	1	0	TX mode	√	
1	0	0	0	1	1	1	0	RX mode	√	

A5~A0: The address of control registers;

x: Hardware doesn't care but it is recommended to set to 0 by software;

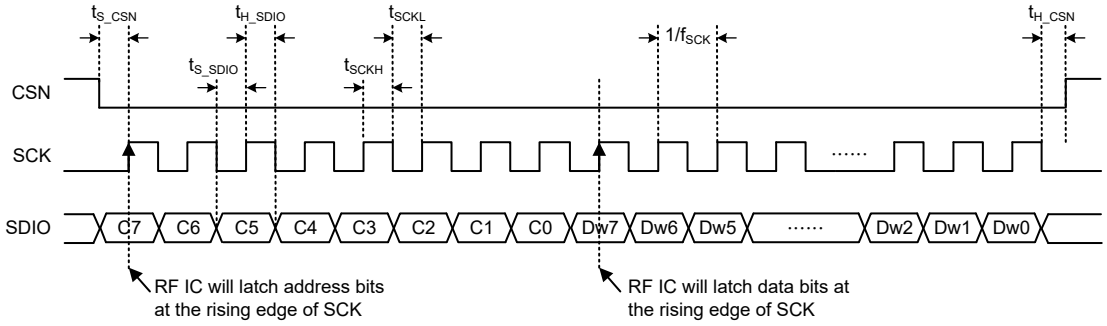
B1~B0: Bank number

Note: 1. The chip supports multi-byte read/write operations and the address is increased automatically after each read or write operation.

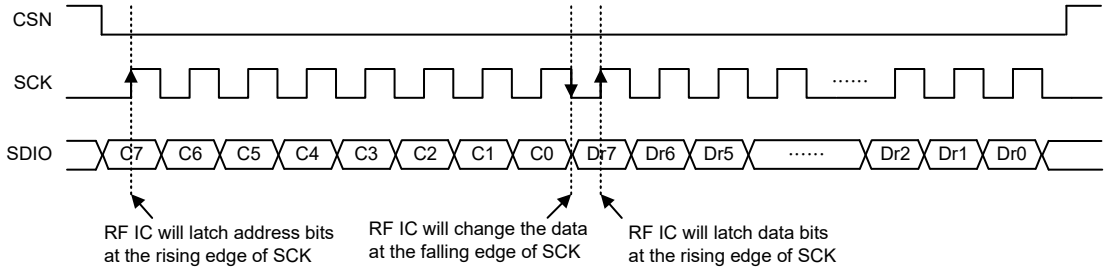
2. Using software to read/write multiple bytes is allowed after one read/write command in a single CSN enabled cycle.

3. In the sleep mode, GIOs will keep the same level of the last operation mode.

SPI Timing



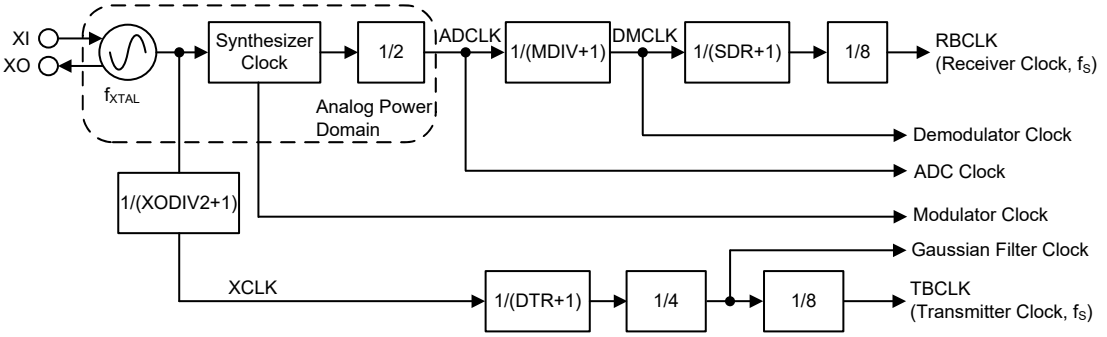
3-Wire SPI Interface Write 1-byte Data Operation



3-Wire SPI Interface Read 1-byte Data Operation

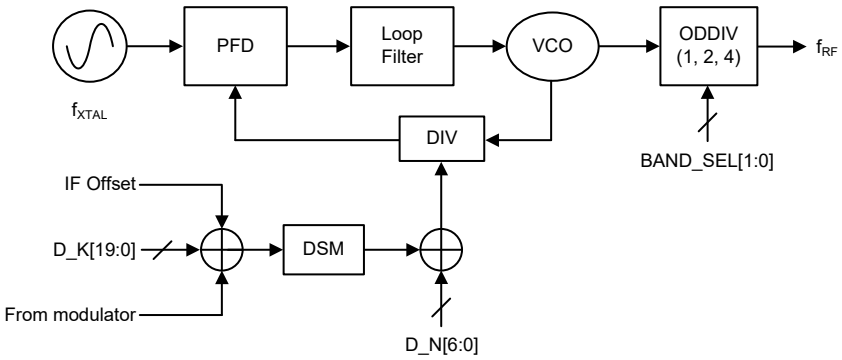
System Clock

The main system clock of the BC3601 comes from the X'tal oscillator. All internal operation clocks of various functional blocks are derived from the X'tal oscillator.



Signal	Constraints	Note
XCLK (Oscillator Clock)	—	Support 16MHz crystal
RBCLK (Receiver Bit Clock)	XTAL=2×(MDIV+1)×(SDR+1)×8×RBCLK	SDR=0, for RBCLK≥50K
TBCLK (Transmitter Bit Clock)	XTAL=(XODIV2+1)×(DTR+1)×4×8×TBCLK	DTR can only be an odd number; Basically, RBCLK=TBCLK=Data Rate

Transceiver Frequency



The RF transceiver frequency is generated by a high resolution fractional-N delta-sigma frequency synthesizer. By appropriate setting on the configuration parameters D_N[6:0] and D_K[19:0], a low-noise LO frequency can be generated to comply with various radio regulatory standards including ETSI EN, FCC, etc. In the RX mode, the synthesizer would generate an LO-IF frequency for the RX mixer operation, RXIFOS[11:0] is used to generate the required IF(Intermedia Frequency) offset. For data rate equal to or larger than 200K, IF should be set to 300K, otherwise IF should be set to 200K. In the TX mode, there is extra input from the modulator to provide extra frequency deviation waveform of baseband data.

$$D\_N[6:0]=Floor\left(\frac{f_{RF}\times ODDIV}{f_{XTAL}/(XODIV2+1)}\right)$$

$$D\_K[19:0]=Floor\left(\left(\frac{f_{RF}\times ODDIV}{f_{XTAL}/(XODIV2+1)}-D\_N[6:0]\right)\times 2^{20}\right.$$

$$RXIFOS[11:0]=Floor\left(\left(\frac{f_{IF}}{f_{XTAL}/(XODIV2+1)}\right)\times 2^{17}\right.$$

For 315MHz band, ODDIV=4 (BAND_SEL[1:0]=00b)

For 433MHz band, ODDIV=2 (BAND_SEL[1:0]=01b)

For 470~510MHz band, ODDIV=2 (BAND_SEL[1:0]=10b)

For 869/915MHz band, ODDIV=1 (BAND_SEL[1:0]=11b)

Modulator

The BC3601 supports GFSK modulation. A BT=0.5 Gaussian filter for pulse smoothing is implemented in the BC3601. The frequency deviation, f_{DEV}, of the transmitter is programmed using the FSCALE[11:0] field. The value of FSCALE[11:0] is determined by the modulation index h, the XO output divided by 2 control bit XODIV2, data rate f_S and f_{XTAL}.

$$h=\frac{2\times f_{DEV}}{f_S}$$

$$FSCALE[11:0]=round\left(\left(h\times\frac{f_S}{f_{XTAL}/(XODIV2+1)}\right)\times 2^{15}\right), \text{ take the least significant 12 bits}$$

For low data rate applications (≤10K), a modulation index of 8 is recommended. For high data rate applications (≥50K), a modulation index of 0.75 is recommended. For applications where data rate is between the aforementioned boundaries, keeping the frequency deviation above 20K is recommended.

The FSCALE bit field needs to multiply a scaling factor for data rate equal to or larger than 100K. The recommended FSACLE values for data rates equal to or larger than 100K are provided in the filter coefficients tables following the Filter Coefficient Control Registers.

State Machine

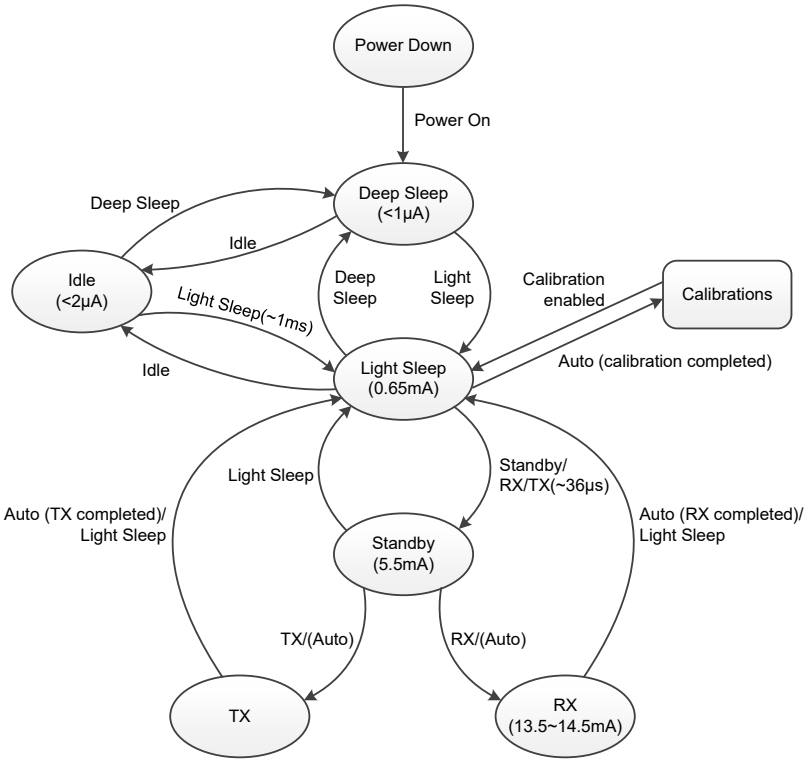
There are seven operating modes in the BC3601 from the viewpoint of current consumption. The operation modes and key funcitons on/off state in the corresponding mode are listed below.

1. Power Down mode
2. Deep Sleep mode
3. Light Sleep mode
4. Standby mode
5. Idle mode
6. TX mode
7. RX mode

Mode	Register Retention	3.3V	LIRC	Regulator	XO	Standby+VCO	TX	RX	Strobe Command
Power Down	No	OFF	OFF	OFF	OFF	OFF	OFF	OFF	—
Deep Sleep	Yes	ON	OFF	OFF	OFF	OFF	OFF	OFF	8'b0000_1010
Light Sleep	Yes	ON	OFF	ON	ON	OFF	OFF	OFF	8'b0000_1100
Idle	Yes	ON	ON	OFF	OFF	OFF	OFF	OFF	8'b0000_1011
Standby	Yes	ON	OFF	ON	ON	ON	OFF	OFF	8'b0000_1101
TX	Yes	ON	OFF	ON	ON	ON	ON	OFF	8'b0000_1110
RX	Yes	ON	OFF	ON	ON	ON	OFF	ON	8'b1000_1110

TX/RX FIFO Mode (DIR_EN=0) State Machine

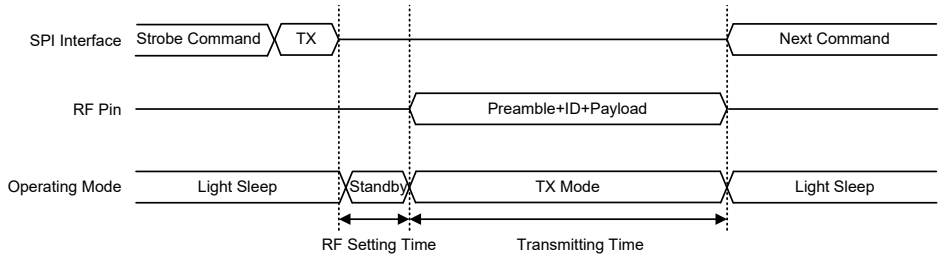
If the DIR_EN bit is cleared to 0, the device mode transactions are implemented by strobe command from the host MCU and the TX/RX data are derived from the packet handling hardware.



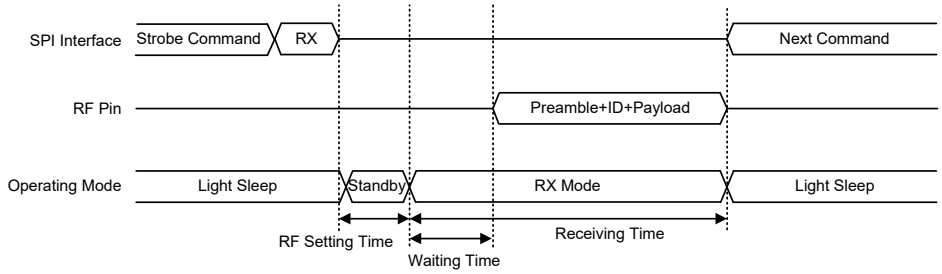
FIFO Mode State Diagram

Initially, the BC3601 is in the Power Down mode. After the device completes the internal power on reset, it will enter the Deep Sleep mode and wait for further strobe commands from the host MCU. If the Light Sleep command is received, the device will enable the internal LDO, oscillate the XO and enter the Light Sleep mode. In this state, the host MCU can have the BC3601 execute calibration process if necessary. For normal TRX operations, the host MCU can issue a RX or TX command to the BC3601. After receiving the TX or RX command, the device will first enter the Standby mode which lasts a certain period known as TX/RX setting time. After the setting time has escaped, the device will finally enter the RX or TX mode. The device will stay in the TX/RX sate until the TX/RX event is completed, after which the device will return to the Light Sleep mode automatically.

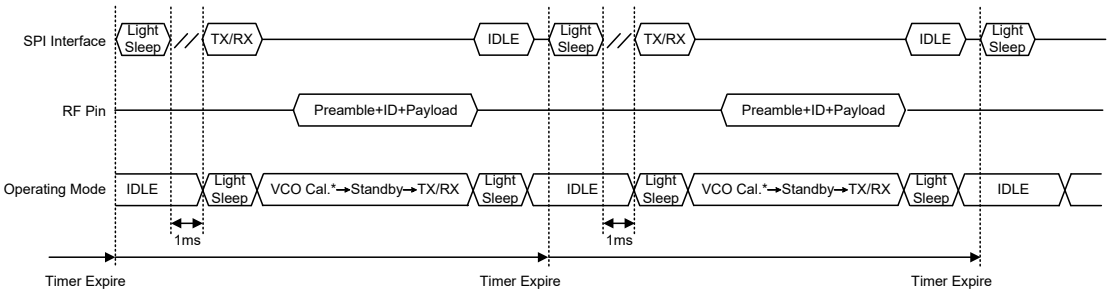
For low power periodically wireless transmission, the device supports low power Idle mode where the LIRC and wake-up timer are turned on. By appropriate timer setting and issuing the Idle mode command, the device will turn off the LDO and XO and enter the Idle mode. The device stays in the Idle mode until the timer expires and then an IRQ will be asserted on the GIO to wake-up the host MCU. Then the host MCU can have the device enter the Light Sleep mode and continue to execute normal TX/RX operations. After TX/RX event is completed, the host MCU can issue the Idle command to have the device return to the Idle mode again.



TX Timing in FIFO Mode



RX Timing in FIFO Mode



Note: VCO Cal.(VCO Calibration) time: ~62μs.

Periodical TX/RX Timing

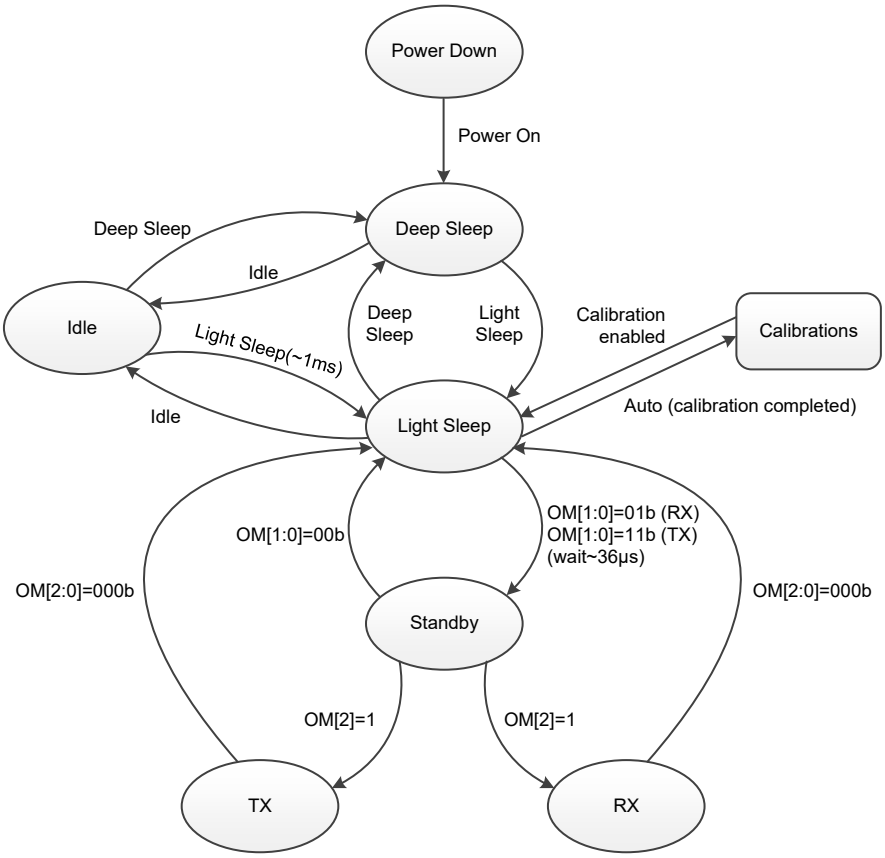
TX/RX Direct Mode (DIR_EN=1) State Machine

If setting DIR_EN=1, TX data is derived directly from the host MCU to BC3601 and RX data is sent directly from the BC3601 to the host MCU. In order to simplify the data bit clock synchronization between the BC3601 and the host MCU, the BC3601 outputs the TBCLK/RCLK from GIO3 or GIO4 by setting GIO3S[3:0] or GIO4S[3:0]. Both TBCLK and RBCLK are in 50/50 duty cycle. In the transmitting mode, the host MCU outputs bit data at the rising edge of the TBCLK signal and the BC3601 samples the TX bit data at the falling edge of the TBCLK signal. In the receiving mode, the host MCU receives data at the rising edge of the RBCLK signal and the BC3601 outputs bit data at the falling edge of the RBCLK signal. The host MCU can select GIO1/GIO2 for the TX/RX bit data transmission by setting GIO1S[2:0]/GIO2S[2:0].

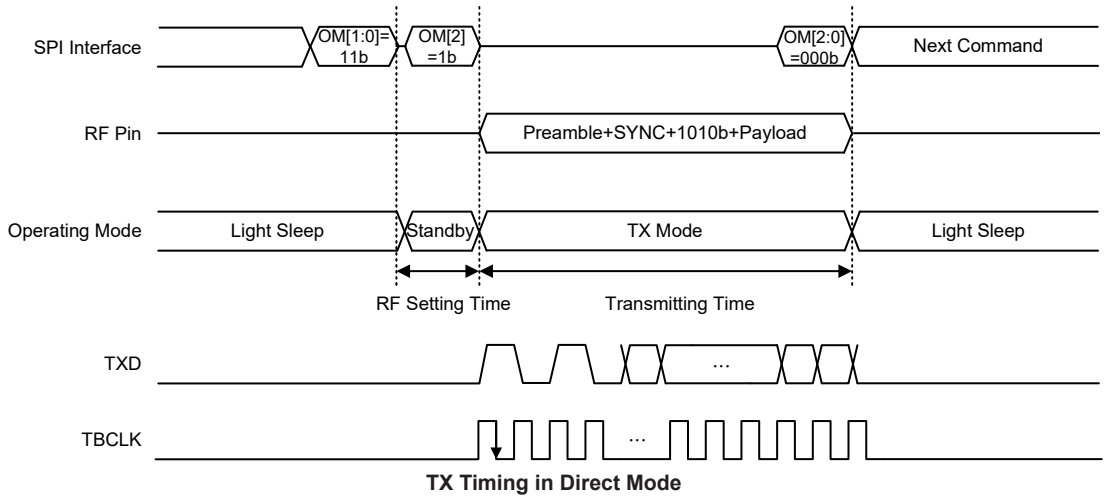
For TX operations in the direct mode, the host MCU needs to set the OM[1:0] bits, i.e. RTX_SEL and SX_EN, to 11b to select the TX mode and have the BC3601 enter standby mode first, then set the OM[2] bit, RTX_EN, to 1 to have the BC3601 start to transmit the TX data. As long as the host MCU sets OM[2:0] to 000b, the BC3601 will return to the Light Sleep mode.

For RX operations in the direct mode, the host MCU needs to set OM[1:0] to 01b first, then set OM[2] to 1 to have the BC3601 start to receive data from the air. After the BC3601 receives the matched SYNCWORD code, it will output the RBCLK clock, receive data bit (payload part) and then transmit to the host MCU.

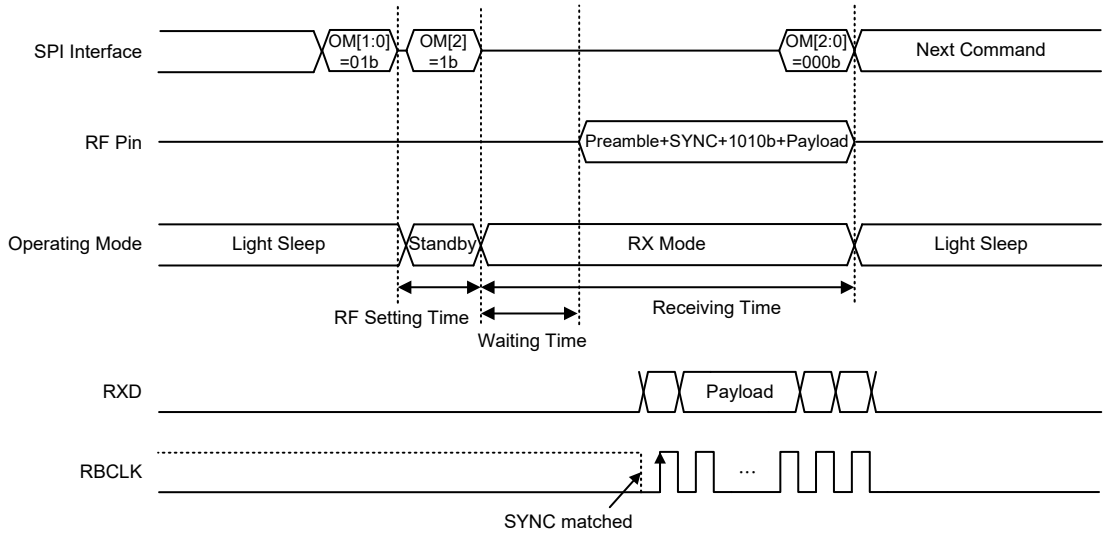
In direct mode, the transmission data length has no limit.



Direct Mode State Diagram



TX Timing in Direct Mode



RX Timing in Direct Mode

Calibration

The device has three calibration functions, VCO, RC and LIRC calibrations, allowing proper setting to compensate the PVT (Process-Voltage-Temperature) variation effect. The control bit, ACAL_EN, is used to enable the VCO and RC calibration functions at the same time and both calibration functions will be automatically implemented after this bit is set high. When the calibrations are completed, the ACAL_EN bit is cleared to zero by hardware. The host MCU can poll the ACAL_EN bit status or use the calibration complete interrupt flag CALCMPF to check the calibration status. The device also has an independent enable bit, LIRCCAL_EN, for the LIRC calibration function, allowing to independently implementing the LIRC calibration function.

LIRC Calibration

There is an internal low frequency RC oscillator in the BC3601 providing a clock source for the wake-up timer in the Idle mode. After calibration, the internal low frequency RC oscillator supports a precision of ±2% for the PVT variation. The calibration process chooses the curve setting of LIRC frequency to an approximation of 32768Hz. Then an extra LIRC correction process is used to tune the wake-up timer accuracy error to be less than ±1%.

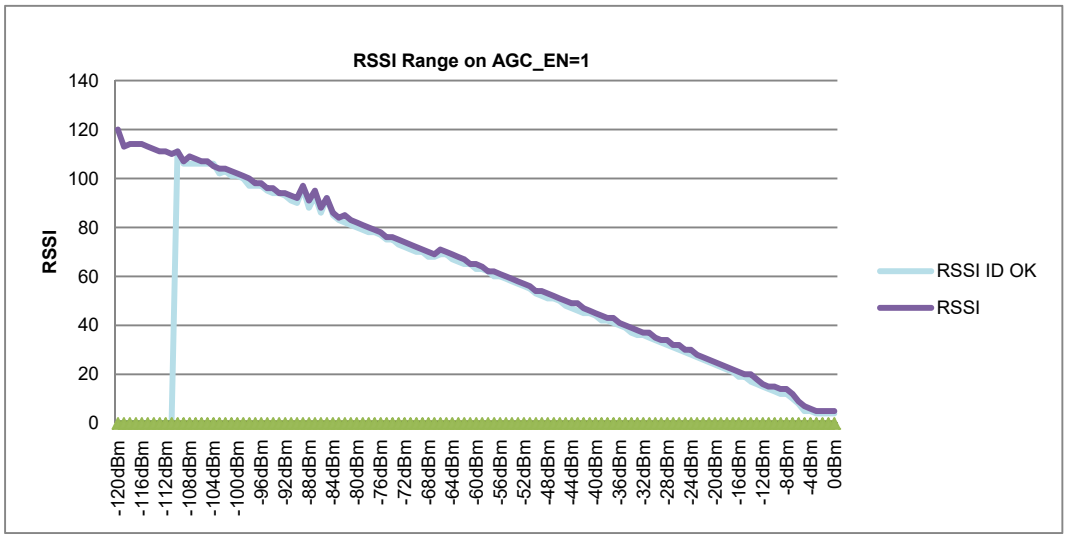
The host MCU need to configure LIRC_OW=0 and LIRC_EN=1 before the LIRC calibration. Then the BC3601 will do LIRC calibration when LIRCCAL_EN is set to 1 by the host MCU during the Light Sleep mode. The LIRCCAL_EN bit is reset to 0 by hardware on the completion of LIRC calibration. The LIRC calibration process would take about 4ms.

AGC & RSSI

In order to enhance the receiving dynamic range and ensure the signal SNR be no less than the demodulator minimum SNR requirement, an AGC (Auto-Gain-Control) function block is embedded. The AGC would tune the receiver gain to get valid signal level before ADC staying between the set point and -26 dBFS. The set point is in the range of -6 dBFS to -12 dBFS which is adjusted by the SAT_SEL[1:0] bit field. FS is the full-scale of the A/D converter.

There is an integrated RSSI (Receiver Signal Strength Indicator) measurement function block in the BC3601. The RSSI calculation engine calculates the receiving signal strength after ADC. By combining the calculated ADC signal strength value and receiver chain total gain, the RSSI value is induced. The valid RSSI reading value is from -110dBm to -10dBm. The RSSI measurement error is normally below ±6dBm. The unit of the reading value is -dBm. Two RSSI reading values are available, one is RSSI_SYNC_OK[7:0] that is a RSSI measurement value snapshot when the valid SYNCWORD is detected OK, the other reading value is RSSI_NEGDB[7:0] that is a real time RSSI calculation result. In the receiving mode, the host MCU can access the RSSI_NEGDB bit field. After the receiving is completed, the host MCU should poll RSSI_SYNC_OK[7:0] for receiving signal strength assessment.

The following RSSI reading curve is measured at a receiving data rate of 250K.



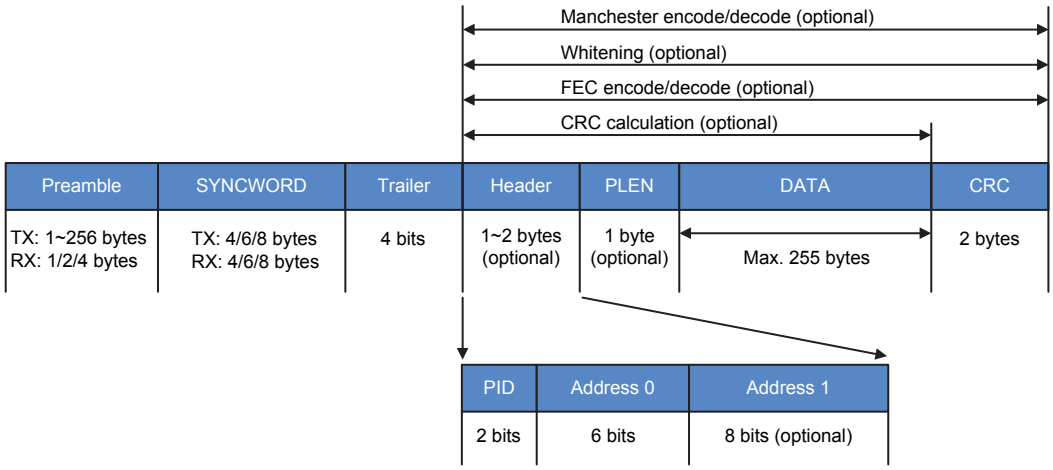
RSSI Reading Curve when AGC Enabled

Packet Handler

In the TX mode, the packet handler is used to move the transmitting data out of FIFO and implement channel coding according to the packet format, then sends the packet to the modulator. In the RX mode, the packet handler is used to implement channel decoding with data from the demodulator and store the payload data into FIFO.

The packet handler performs several tasks such as Preamble and SYNCWORD insertion, Forward Error Correction, CRC calculation/checking, whitening/dewhiteing and Manchester encode/decode.

Packet Format



Preamble	MSB	SYNCWORD	LSB	Trailer
0101···01	0	...	0	1010
1010···10	1	...	1	0101

Note: 1. Preamble format will follow SYNCWORD MSB to inverse.

If MSB=0, Preamble format=0101…01

If MSB=1, Preamble format=1010…10

2. Trailer format will follow SYNCWORD LSB to inverse.

If LSB=0, Trailer format=1010

If LSB=1, Trailer format=0101

Preamble

The packet starts with a preamble with 1~256 bytes set by TXPMLEN[7:0] in the TX mode. In the RX mode, preamble detection length is limited to 1, 2 or 4 bytes selected by RXPMLEN[1:0].

SYNCWORD

The SYNCWORD length which is set by SYNCLEN[1:0] can be 4, 6 or 8 bytes in the TX mode. In the RX mode, the detection length is also 4, 6 or 8 bytes. When the RX side receives a matched SYNCWORD packet, the DATA field will be stored in the FIFO.

Trailer

The trailer field is fixed at 4 bits which is a concatenating field between SYNCWORD and the latter payload.

Header

The header (Payload Header) is optional and enabled by PLH_EN. The payload header length can be 1 or 2 bytes set by PLHLEN. When the PLHLEN bit is 0, only PID[1:0] and PLHA[5:0] (address 0) fields are used in the packet. PID[1:0] is located in bit[7:6] of the payload header field. If PLHAC_EN=0, PLHA[5:0] can be used as software flags and the actual function can be defined by users. If PLHAC_EN=1, the device will compare the local PLHA[5:0] field with the received PLHA[5:0] field. If matched, the receiving data will be moved into the RX FIFO, otherise the following incoming data will be abandoned. The PLHA[5:0] field is used to support broadcast function and PLHA[5:0]=0 is a special preserved address permitting the BC3601 not to implement the address filtering mechanism.

When the PLHLEN bit is set to 1, the address field length is extended to 14 bits which is formed by address 0 (PLHA[5:0]) and address 1 (PLHEA[7:0]).

PLEN (Payload Length)

The PLEN field is optional and is fixed at 1 byte once being enabled by PLLEN_EN. When this bit is set high, the DATA field length is variable and is determined by the PLEN field in each TX/RX packet.

DATA

When in the TX mode, the TX data length is determined by the TXDLEN[7:0]. The maximum length is 255 bytes in the extend FIFO mode. In the special case of infinite FIFO mode, the length can exceed 255 with an infinite length. If PLLEN_EN=1, the PLEN field in the TX packet is enabled and the PLEN content equals to TXDLEN[7:0]. When in the RX mode, the RX data length is set by RXDLEN[7:0] if PLLEN_EN=0 and by PLEN field in the receiving packet if PLLEN_EN=1.

CRC

The CRC field is optional and is enabled by CRC_EN. It is recommend to always set CRC_EN to 1 for data correctness checking. There are two CRC formulas selected by setting the CRCFMT bit.

CRCFMT=0: CCITT-16-CRC $G(X)=X^{16} + X^{12} + X^5 + 1$

CRCFMT=1: IBC-16_CRC $G(X)=X^{16} + X^{15} + X^2 + 1$

Note that the CRC initial value is FFFF.

FEC

The optional data encode/decode function can be enabled by FEC_EN. Use (7,4) Hamming code to correct 1-bit error and more than 1-bit error detect for each 4-bit data. After FEC, the data length for each data will be (4+3)×2=14 bits.

- **Hamming Code Function Table**

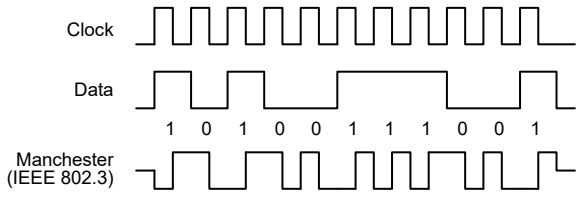
Bit	7	6	5	4	3	2	1
Transmitted Bit	D3	D2	D1	P2	D0	P1	P0
P0	Y	N	Y	N	Y	N	Y
P1	Y	Y	N	N	Y	Y	N
P2	Y	Y	Y	Y	N	N	N

Data Whitening

The optional data whitening/de-whitening function can be enabled by WHT_EN. Use PN7 code to implement XOR operation with the transmitted data. The whitening seed is set by WHTSD[6:0].

Manchester Code

The optional Manchester encode/decode function can be enabled by MCH_EN. Each bit after Manchester encoding will be extended into two bits and recoveried to one bit data after decoding.



Manchester Code Example

FIFO Operation Modes

In Burst mode, data transmission to the RF transmitter is derived from FIFO and is pre-written by the host MCU. There are 4 FIFO modes to support various applications. They are Simple FIFO mode, Block FIFO mode, Extend FIFO mode and Infinite FIFO mode.

FIFO Reset

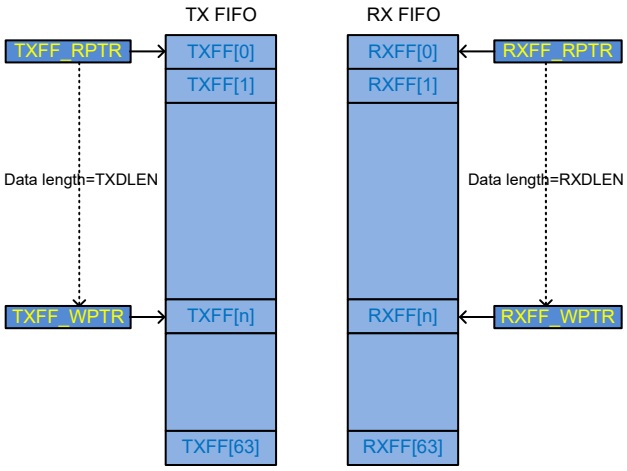
To use the FIFO in the burst mode, issue the TX FIFO address pointer reset command and RX FIFO address pointer reset command to reset the FIFO pointer and buffer first. After this, the FIFO is in the initial state same as reset.

Simple FIFO Mode

This FIFO mode is used for general applications with a TX/RX data length less then or equal to 64 bytes. The data length should not exceed 64 bytes. To use the simple FIFO mode, the host MCU must write the transmitting data to FIFO by the SPI write FIFO command. The transmitting sequence is first written byte first out and the MSB in each byte first out to the transmitter. Users should determine all transmitting data packet format including the preamble, syncword and packet encoding such as FEC, CRC, whiting. After FIFO data filling out is completed, clear the TXFFSA[5:0] field and set TXDLEN[7:0]/RXDLEN[7:0] field to the desired transmitting/receiving length in bytes. Then issue the TX command to start the transmission. After the current transmitting is completed, the data will be kept in FIFO to wait for the next transmission.

Programming procedure

1. Reset TX FIFO by the SPI reset TX FIFO command.
2. Reset RX FIFO by the SPI reset RX FIFO command.
3. TXFFSA[5:0] must be cleared to 0.
4. Fill out TX FIFO by the SPI write FIFO command.
5. Set TXDLEN[7:0]/RXDLEN[7:0] to control the TX/RX length in bytes.
6. Issue the TX command for transmitter and RX command for receiver.
7. TX/RX completion is acknowledged by the TX/RX complete IRQ.
8. Re-transmit TX packet with the same data will auto-reset TXFF_RPTR to 0.

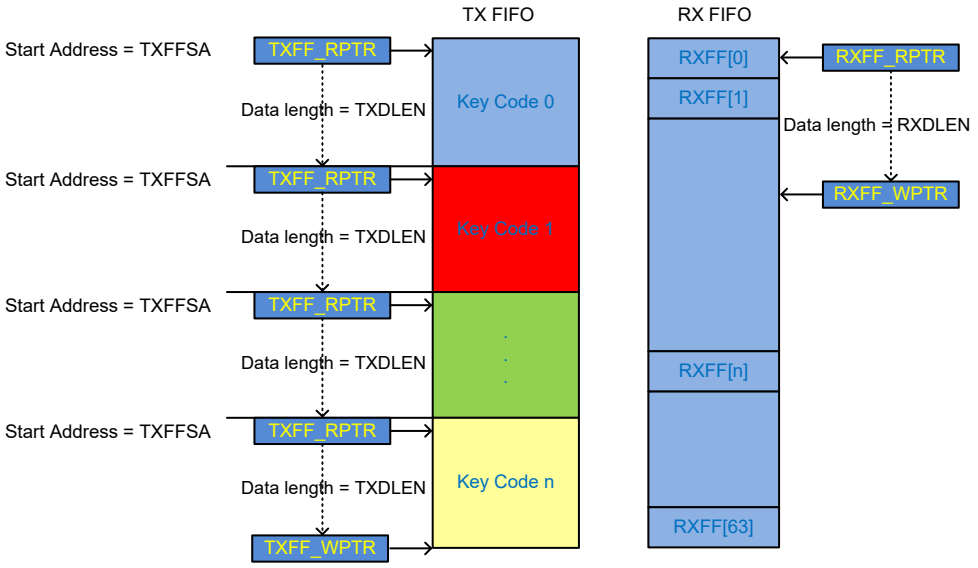


Block FIFO Mode

The Block FIFO mode is used to support multi-key code applications. Users should write all the key codes to FIFO first. When a key is pressed, the host MCU will detect the key and set TXFFSA[5:0] to the target key code start address and set TXDLEN[7:0] to indicate the key code length and issue the TX strobe command to start the transmission. The maximum FIFO length is also limited to 64 bytes.

Programming procedure

1. TX: Write key code 0~n to TX FIFO by SPI write FIFO command.
2. TX: Set TXDLEN[7:0] for key code length.
3. TX: When a key is pressed, the host MCU will set TXFFSA[5:0] to the start address of the corresponding key code.
4. RX: Set the RXDLEN[7:0] to key code length and then enter the RX mode by SPI command.
5. TX: Issue TX command for transmitter.
6. RX: Issue RX command for receiver.
7. TX/RX completion is acknowledged by the TX/RX complete IRQ.



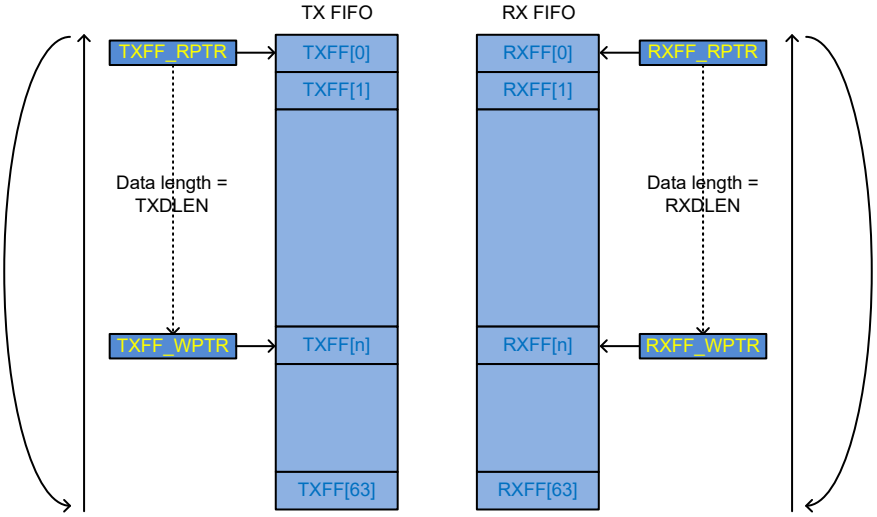
Extend FIFO Mode

The Extend FIFO mode is used for transmissions with a long payload data packet. The maximum length is 255 bytes. As the physical FIFO length is 64 bytes, to extend the available transmitting length in one packet, a handshake mechanism is needed between the host MCU and the FIFO controller.

Set FFMG[1:0] to determine the FIFO data length margin and set FFMG_EN to enable the margin detect function to inform the MCU when the TX FIFO data fullness level is less than the margin. The MCU should write data to TX FIFO fast enough when receiving this reminding signal to avoid transmission being terminated by TX FIFO underflow.

Programming procedure:

1. Set FFMG_EN to enable FIFO depth low threshold detect function and set FFMG[1:0] to select the threshold, 4, 8, 16 or 32 bytes.
2. Set the FIFOLTIE bit to 1 to enable the FIFO low threshold IRQ.
3. Set GIOnS field (n=1~4)=101b to output IRQ on GIO1~4.
4. TX: If MCU detects the FIFO low threshold IRQ signal, it will move data into TX FIFO with a data length less than or equal to (64-FFMG[1:0]). Then the MCU clears the FIFO low threshold IRQ flag FIFOLTIF and repeats the same routine until all TX data are completely written to TX FIFO.
5. RX: If MCU detects the FIFO low threshold IRQ signal, it will read data from RX FIFO with a data length equal to FFMG[1:0]. Then the MCU clears the FIFO low threshold IRQ flag FIFOLTIF and repeats the same routine until receiving the RX completion IRQ to read the remaining data from RX FIFO.



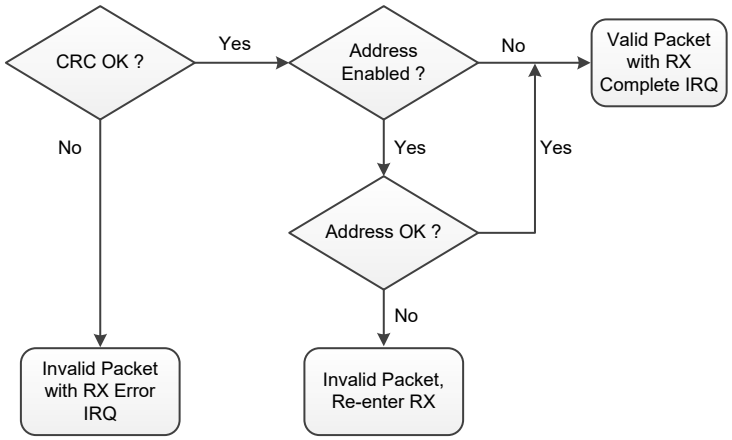
Infinite FIFO Mode

Programming procedure:

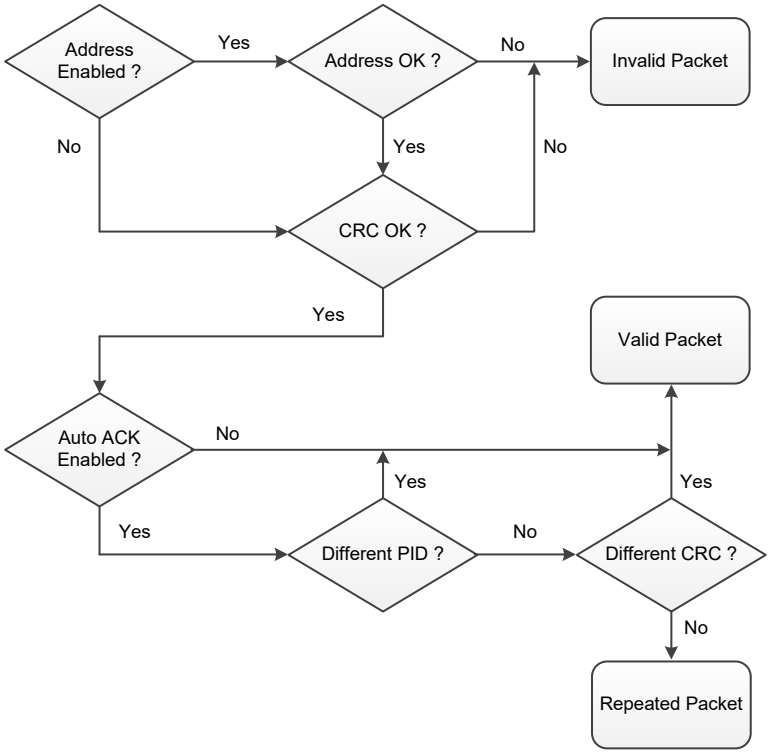
1. Set FFINF_EN to 1 to enable the Infinite FIFO mode.
2. The handshaking and IRQ function are identical with the Extend FIFO mode.
3. TX: If receiving the FIFO low threshold IRQ, the MCU continues to write TX data to TX FIFO with a data length less than or equal to (64-FFMG[1:0]). Then the MCU clears the FIFO low threshold IRQ flag and repeats the same routine until it wants to terminate the infinite FIFO mode. To terminate the infinite FIFO mode, after receiving IRQ and moving data to TX FIFO, the MCU should clear FFINF_EN to zero and set TXDLEN[7:0] to the remaining data length if the remaining transmitting length is less than 192 bytes and longer than 64 bytes. The terminating configuration should be programmed only once for one transmission. The packet will be terminated when all of the target data are transmitted completely.
4. RX: If receiving the FIFO low threshold IRQ, the MCU reads data from RX FIFO with a data length equal to FFMG[1:0]. Then the MCU clears the FIFO low threshold IRQ flag and repeats the same routine until it wants to terminate the infinite FIFO mode. To terminate the infinite FIFO mode, after receiving IRQ and reading data from RX FIFO, the MCU should clear FFINF_EN to zero and set RXDLEN[7:0] to the remaining data length if the remaining receiving length is less than 192 bytes and longer than 64 bytes. The terminating configuration should be programmed only once for one receiption. The packet will be terminated when all of the target data are received completely.

Receiving Packet Judgement

In normal RX operating mode, package reception follows the following judgement criteria.

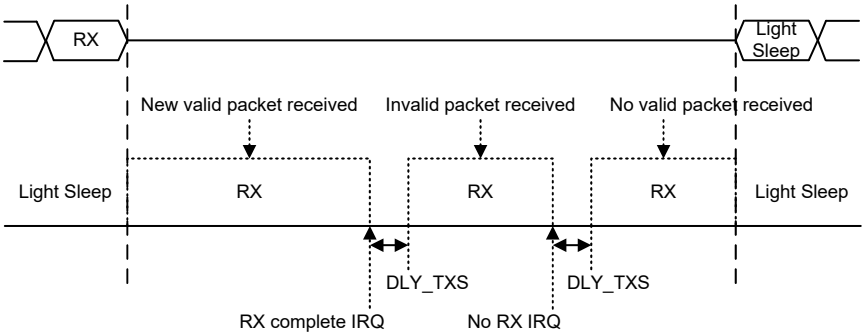


The BC3601 adopts extra receiver packet judgment for the continuous RX mode and auto-acknowledge mode. The main purpose of these special link layer functions are used to alleviate MCU loading when handling TRX packet transaction.



Continuous RX Mode

There is a special continuous RX operating mode supported in the BC3601. The MCU can enable this continuous RX mode by setting the RXCON_EN bit high and start the continuous RX mode by issuing the RX strobe command to the device. If there is a valid RX packet received, the BC3601 will issue a RX completion IRQ to the MCU. The device then repeats the RX operation after a duration defined by DLY_TXS[2:0] to keep listening for incoming packets. If an invalid packet is received, the BC3601 would only repeat the RX operation without issuing the RX completion IRQ to the MCU. The MCU stops the continuous RX by issuing the Light Sleep strobe command to the BC3601. In the continuous RX mode, only simple FIFO mode can be used. In order to prevent the receiving packet data length field from being corrupted by new incoming packets before the MCU reads data from RX FIFO, users should set RXPL2F_EN=1 and PLLEN_EN=1 to have the PLEN information stored into the RX FIFO. Because of the existence of PLEN byte, the maximum packet data length becomes 63 bytes. If a new incoming packet arrives before the MCU reads RX FIFO, a FIFO overflow error will happen, in which condition the BC3601 will issue a RX error IRQ to the MCU. At this moment, the MCU should exit the continuous RX mode and reset the RX FIFO pointer.

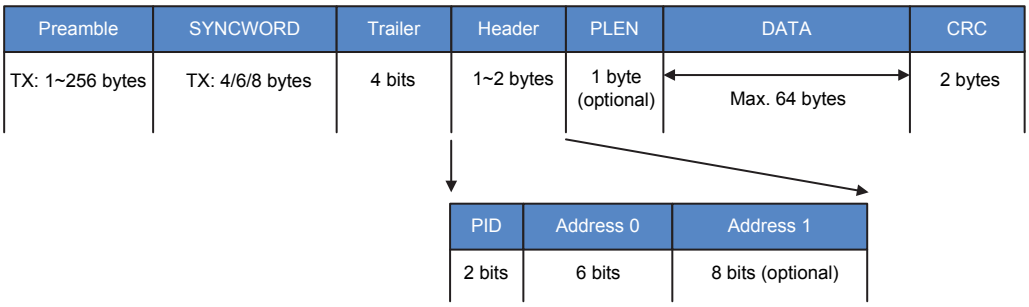


Continuous RX Mode

ARK Mode: Auto-Resend and Auto-Ack

The BC3601 supports auto-resend and auto-ack mechanism by setting the ARK_EN bit high. This mechanism enables an easy two-way communication implementation however can only be operated in the simple FIFO mode.

Set ARK_EN to 1 to enable the device to enter the auto-resend and auto-ack ready mode. Then, auto-resend is triggered by the TX strobe command from the MCU and auto-ack is triggered by RX strobe command from the MCU. Packet format transmitted from the master to the slave in the auto-resend mode are illustrated below.



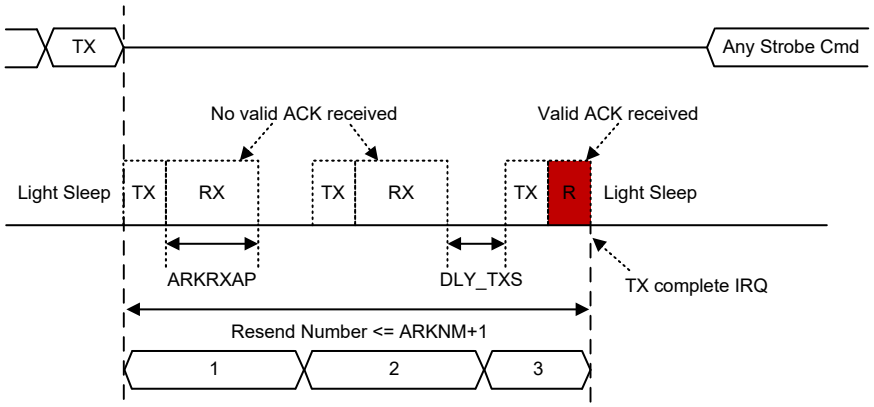
The slave side in the auto_ack mode uses the packet format as the following to be an acknowledge packet transmitted to master. Note that there is no payload data field used in the acknowledge packet.

Preamble	SYNCWORD	Trailer	Header	PLEN	CRC
TX: 1~256 bytes	TX: 4/6/8 bytes	4 bits	1~2 bytes	1 byte (optional)	2 bytes

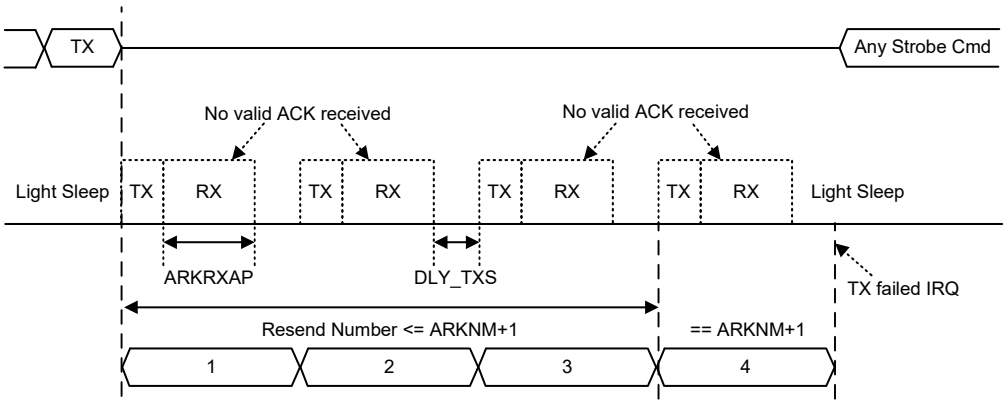
PID	Address 0	Address 1
2 bits	6 bits	8 bits (optional)

If the address field is used for the ARK mode, the auto-resend (master) side should configure the same address as the auto-ack (slave) side.

After configuring ARKNM[3:0], ARK_EN and ARKRXAP[7:0], the MCU starts the auo-resend process by issuing the TX strobe command. The BC3601 starts to transmit data from the TX FIFO and then enters the RX mode after the TX completion. The RX period is in multiples of 250μs which is determined by ARKRXAP[7:0] plusing one. If the BC3601 receives a valid acknowledge packet from the slave side within the RX period with CRC checked correct, it will return to the Light Sleep mode and issue a TX completion IRQ to the MCU. Otherwise, the BC3601 will check if the resend number has reached the limit set by ARKNM[3:0], if not, it will go to the TX mode to transmit the same TX data from the TX FIFO and the resend number will be increased by one.



Auto-resend: ACK Packet Received before ARKNM Limit

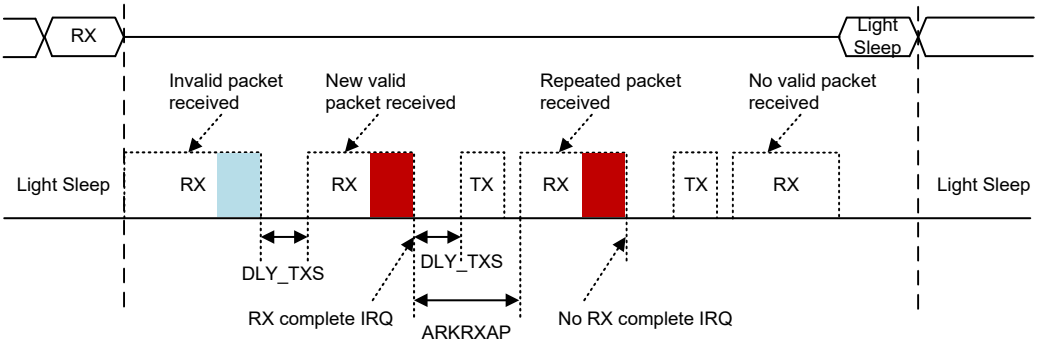


Auto-resend: No Valid Packet Received before ARKNM Limit

Regarding the auto-ack in the slave side, the MCU issues the RX strobe command to start the auto-ack process and issues the Light Sleep strobe command to stop the auto-ack process. In the auto-ack mode, an extra PID/CRC filtering function will be applied for the slave side to check the packet received. If the PID/CRC of the new incoming packet is same as the stored PID/CRC of the last packet, then the newly received packet would be treated as a repeated packet.

During the auto-ack process, if the device receives a valid packet with different PID/CRC and CRC/address checked okey, it will issue a RX completion IRQ to the MCU and auto-transmit the ACK packet to the master. If the device receives a packet with the same PID/CRC and CRC/address checked okey, it will treat this packet as the repeated packet. Then the device will not issue the RX IRQ to the MCU but still auto-transmit the ACK packet to the master. If the device receives a packet with CRC/address checked failed, no IRQ is issued and the device will auto-redo the RX operation to continuely listening for incoming packets.

The gap period for the device to restart the next RX operation after the current RX completion is defined by ARKRXAP[7:0]. In general cases, the MCU should fetch the receiver FIFO data within this period after receiving the RX completion IRQ. Besides, the MCU needs to wait for a same duration if it wants to leave the ARK mode after receiving the RX completion IRQ.



Auto-ACK Process

ATR Mode: Auto-Transmit-Receive

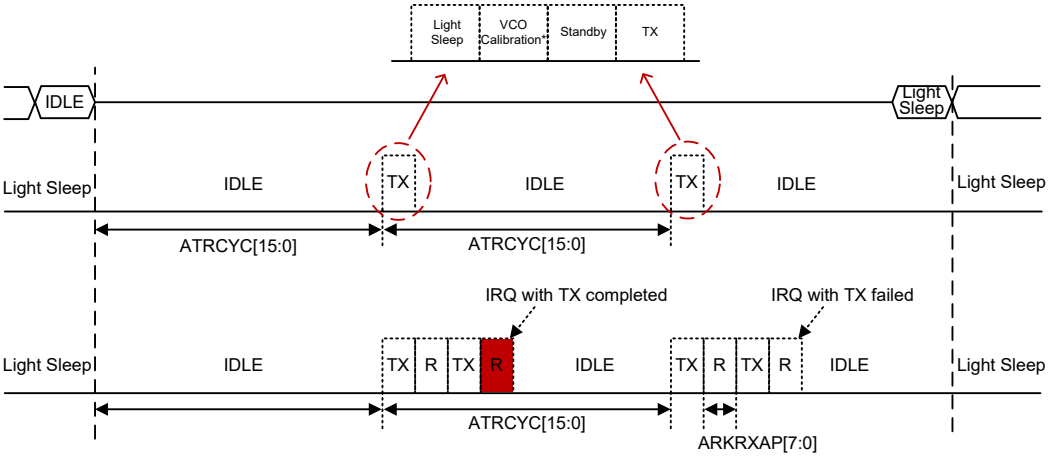
There is a special ATR operation mode in the BC3601 to reduce the external host's loading. Two ATR functions are implemented within the device, one is WOR (Wake-On-RX) and the other is WOT (Wake-On-TX). They can only be operated with simple FIFO mode. These two operating modes need to co-work with an Idle mode timer which operates at a low frequency. The low frequency clock can be sourced from the internal LIRC or from the external ROSCi clock by setting the ATRCLKS bit in the ATR1 register. There are two operation modes for the ATRCT timer which is selected using the ATRCTM bit. Clearing the ATRCTM bit to 0 will select the single mode, where the ATRCT timer will restart upon every ATR transaction when entering the IDLE state. The ATRCT timer will stop and leave the ATR mode upon receiving the Light Sleep command. Setting the ATRCTM bit to 1 will select the continuous mode, where the ATRCT timer will start to operate upon receiving the Idle command and continuously run until the ATR_EN bit or the ATRCTM bit is cleared to zero.

After entering the ATR mode, only the Idle, Light Sleep, Set Register Bank and control register read/write commands can be recognized by the BC3601.

WOT (Wake-On-TX) Function

When the WOT function is enabled by setting the ATR_EN bit to 1 and the ATRM[1:0] bits to 00b, the device will periodically wake-up from the Idle mode and transmit TX FIFO contents without interaction with the host MCU. The device starts the WOT process upon receiving the Idle strobe command from the MCU and stops the WOT process upon receiving the Light Sleep strobe command from the MCU. The ATRCYC[15:0] bits are used to set the wake-up period for the WOT function. At the moment of timer expiration, the wake-up timer will trigger the device to leave the Idle state and enter the active state to transmit data, at the same time the ATRCYC[15:0] content will be reloaded into the timer's down counter. After finishing the TX operation, the device will return to the Idle mode and stay in this state until next wake-up timer expiration occurs. In the active state, the device only implements wake-up transmission once by default. Users can extend the wake-up transmitting mechanism by combining with the ARK function. The repeated transmitting number is controlled by the ARKNM[3:0] bits in the ATR7 register. The time duration between the repeated transmitting packets is inserted with one RX slot and controlled by ARKRXAP[7:0] in the ATR8 register. If the device receives ACK in the RX slot, a TX completion IRQ will be issued to inform the host MCU.

Note: 1. VCO Calibration time: ~62μs.
2. Both new TX and RX need to first go through "Light Sleep → VCO Cal. → Standby".



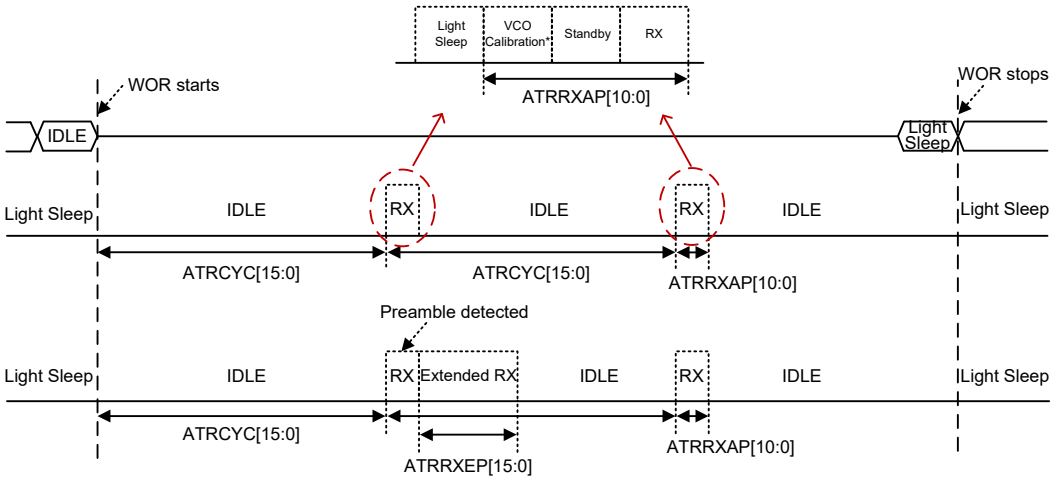
WOT Process

WOR (Wake-On-RX) Function

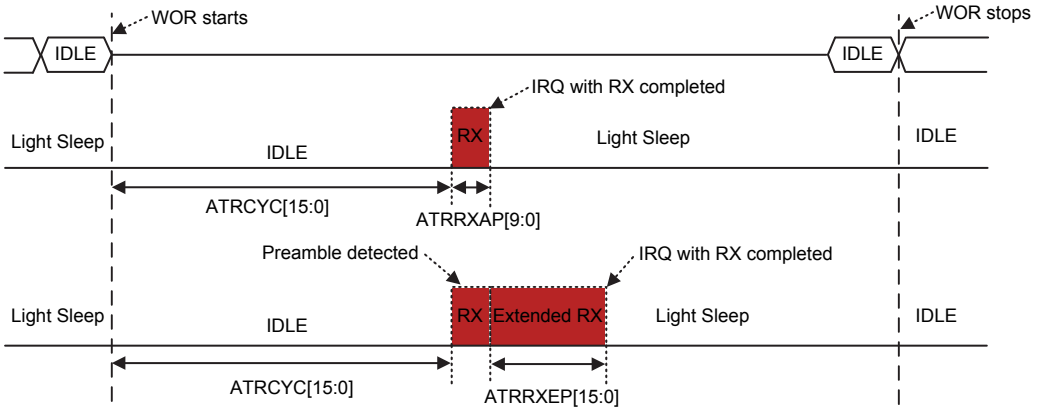
When the WOR function is enabled by setting the ATR_EN bit to 1 and the ATRM[1:0] bits to 01b, the device will periodically wake-up from the Idle mode and listen for the incoming packets without interaction with the host MCU. The device starts the WOR process upon receiving the Idle strobe command from the MCU and stops the WOR process upon receiving the Ligh Sleep strobe command from the MCU. The ATRCYC[15:0] bits are used to set the wake-up period for the WOR function. At the moment of ATR timer expiration, the wake-up timer will trigger the device to leave the Idle mode and enter the active state to listen for the incoming packet, at the same time the ATRCYC[15:0] content will be reloaded into the timer's counter. The receiving active period is defined by the ATRRXAP[9:0] bits. The active period is in multiples of 250μs and starts from 250μs. If there is no incoming packet received in the RX active period, the device will return to the Idle mode and wait for the next WOR cycle.

The active period is auto-extended when the preamble is detected. The extend period is defined by ATRRXEP[15:0]. The extend period is also in multiples of 250μs and starts from 250μs. Once the SYNCWORD is received, the receiving period would be auto-extended until the whole packet is completely received. After the RX receiving is done with CRC checked OK, BC3601 would acknowledge the MCU with RX complete IRQ if RXCMPIE is 1 and stay at light sleep mode. MCU can read the incoming packet from the RX FIFO and then restart the next WOR session by issuing Idle strobe command. If MCU want to leave WOR mode, MCU still need to issue light sleep command to BC3601.

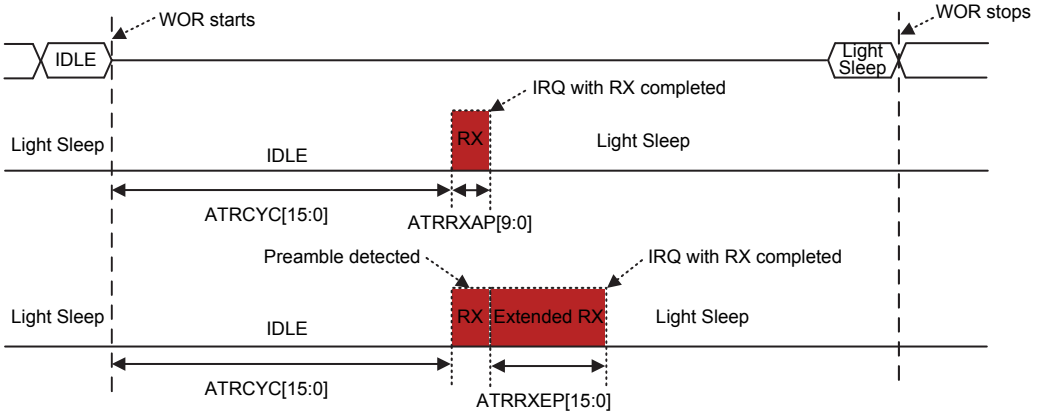
Note: 1. VCO calibration time: ~62μs.
2. Both new RX and TX need to first go through "Light Sleep → VCO Cal. → Standby".



WOR Without Incoming Packet Received

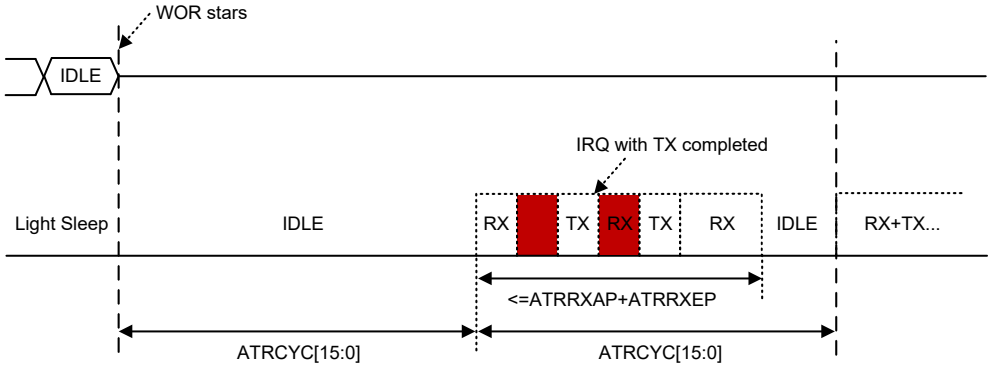


WOR With Incoming Packet Received



WOR Stops after Receiving Incoming Packet

In the WOR active period, the device only implements RX operation once by default. Users can extend the wake-up receiving mechanism by combining with the ARK function. In WOR+ARK mode, the time duration between the repeated receiving packets is inserted with one TX slot for acknowledgement. The TX duration depends on the transmitting symbol rate. The device stays in the RX mode for a maximum period of time defined by ATRRXAP+ATRRXEP. If a valid imcoming packet, with CRC checked OK and a different PID/CRC, is received before the timer expires, the device will issue a RX completion IRQ to the MCU and automatically enter the TX mode. If a repeated packet, with CRC checked OK and a same PID/CRC, is received, the device will only automatically enter the TX mode with no IRQ to the MCU. After the TX completion, the device will return to the RX mode again and listen for the incoming packets until the timer expires if no incoming packet is received.



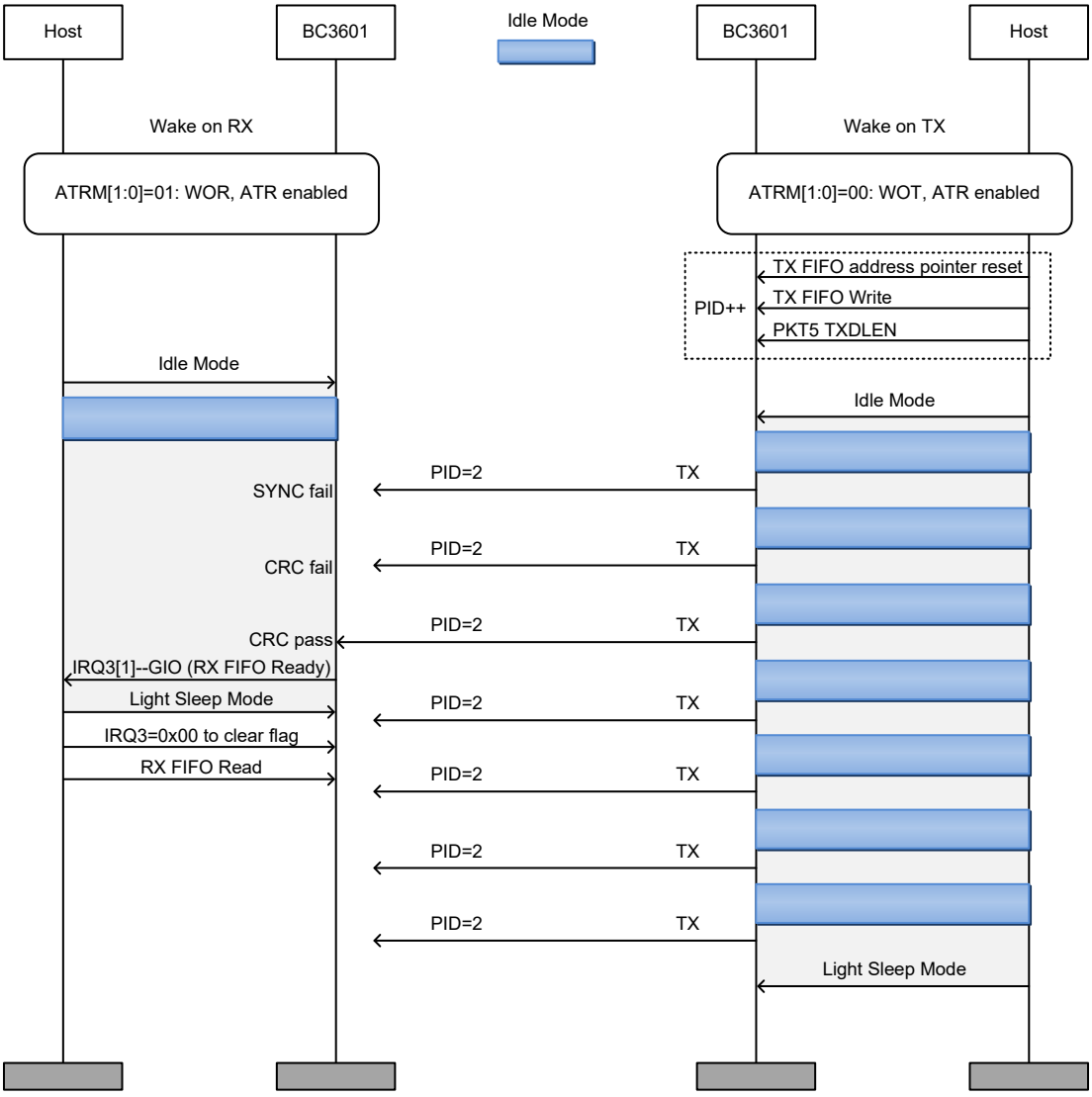
WOR+ARK Process

WTM (Wake up Timer Mode)

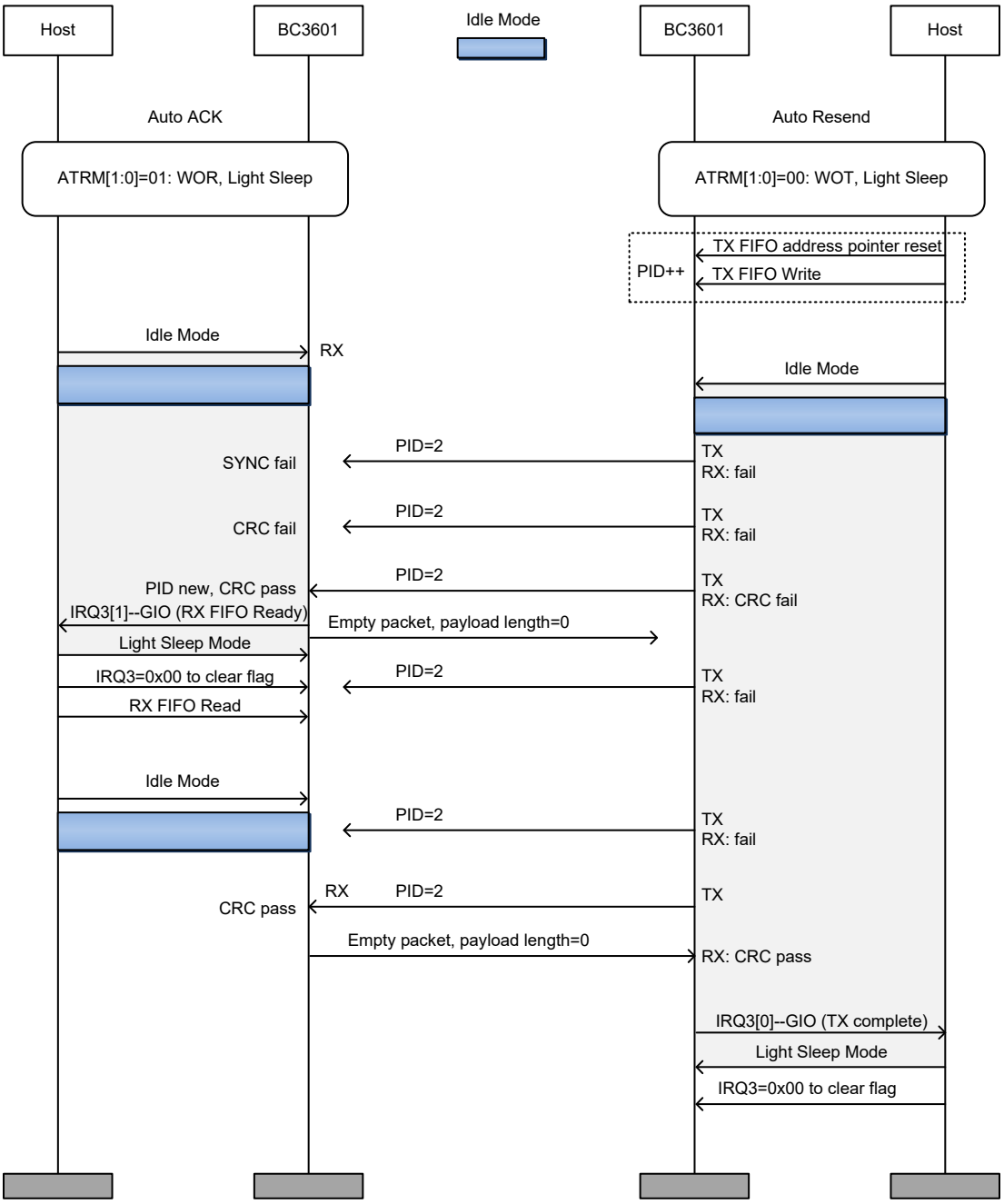
The BC3601 can be set as a programmable timer to output a periodical waveform on GIOs. User can use this signal to wake up the CPU. Set ATR_EN=1 and ATRM=10b to enable the WTM mode. The device starts the WTM mode upon receiving the Idle strobe command from the MCU and stops the WTM mode upon receiving the Light Sleep strobe command. The device will stay in the Idle mode for the whole WTM process.

Message Flowchart Examples

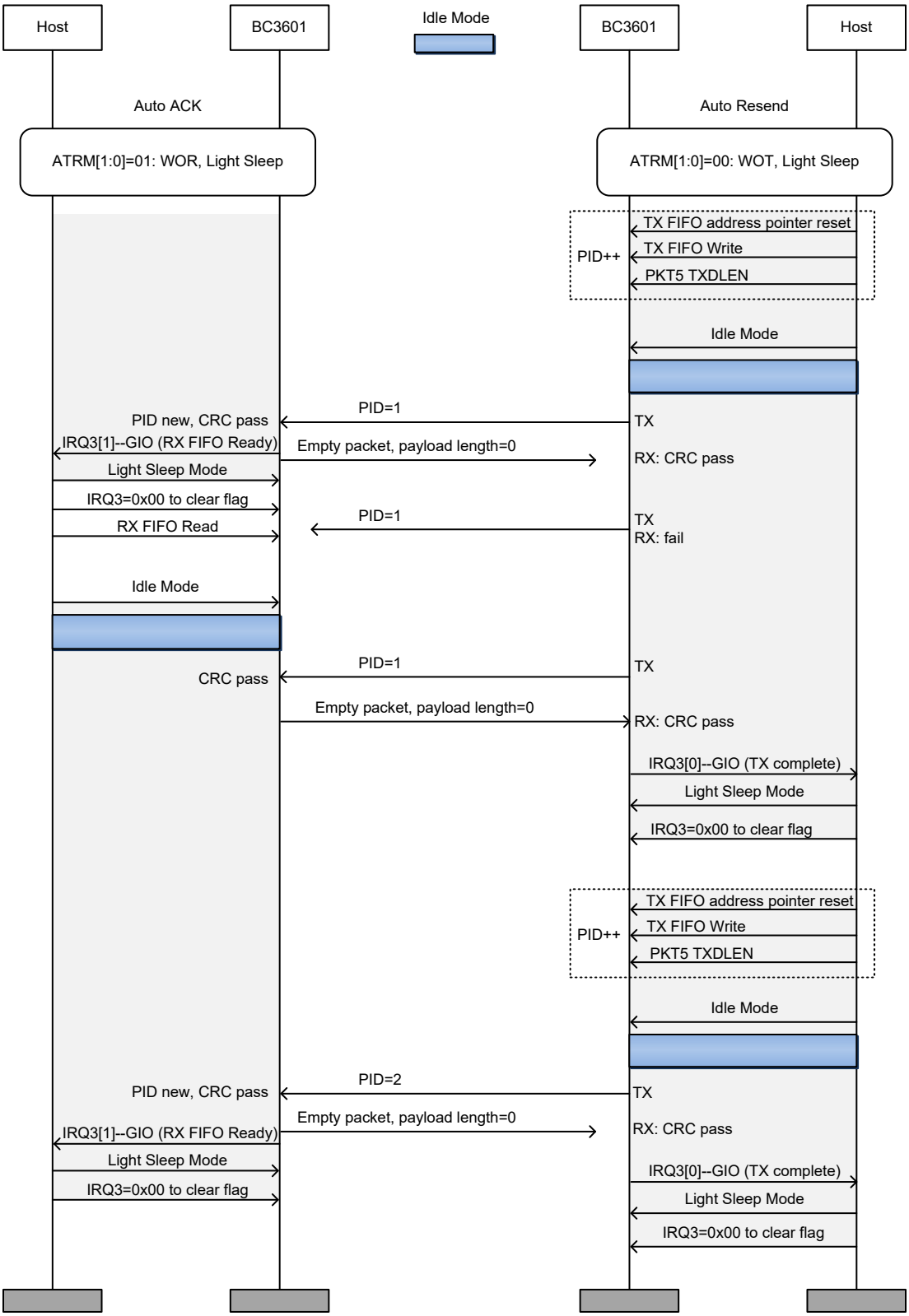
ATR: WOT & WOR



ATR+ARK: WOT+Auto-Resend & WOR+Auto-Ack



ATR+ARK: WOT+Auto-Resend & WOR+Auto-Ack



Abbreviation

AAK: Auto-Ack

ADC: Analog to Digital Converter

AFC: Automatic Frequency Compensation

AGC: Automatic Gain Control

ARK: Auto-Resend and Auto-Ack

ATR: Automatic-Transmit-Receive

BER: Bit Error Rate

CD: Carrier Detect

CFO: Carrier Frequency Offset

CRC: Cyclic Redundancy Check

DCOC: DC Offset Correct

FEC: Forward Error Correction

FIFO: First In First Out

GFSK: Gaussian Frequency Shift Keying

HPF: High-Pass Filter

ID: Identifier

IF: Intermedia Frequency

IIR: Infinite Impulse Response

IRQ: Interrupt Request

ISM: Industrial, Scientific and Medical

LNA: Low-Noise Amplifier

LO: local Oscillator

LPF: Low-Pass Filter

OW: Overwrite

PA: Power Amplifier

PD: Power Down

PFD: Phase Frequency Detector (for PLL)

PLL: Phase Lock Loop

POR: Power On Reset

PVT: Process-Voltage-Temperature

RBCLK: RX Bit Clock

RSSI: Received Signal Strength Indicator

RX: Receiver

SNR: Signal Noise Ratio

SPI: Serial Port Interface

SX: Synthesizer

SYCK: System Clock for digital circuit

SYNC: Synchronization Word

TBCLK: TX Bit Clock

TRX: TX/RX

TX: Transmitter

VCO: Voltage Controlled Oscillator

WOR: Wake-on-RX

WOT: Wake-on-TX

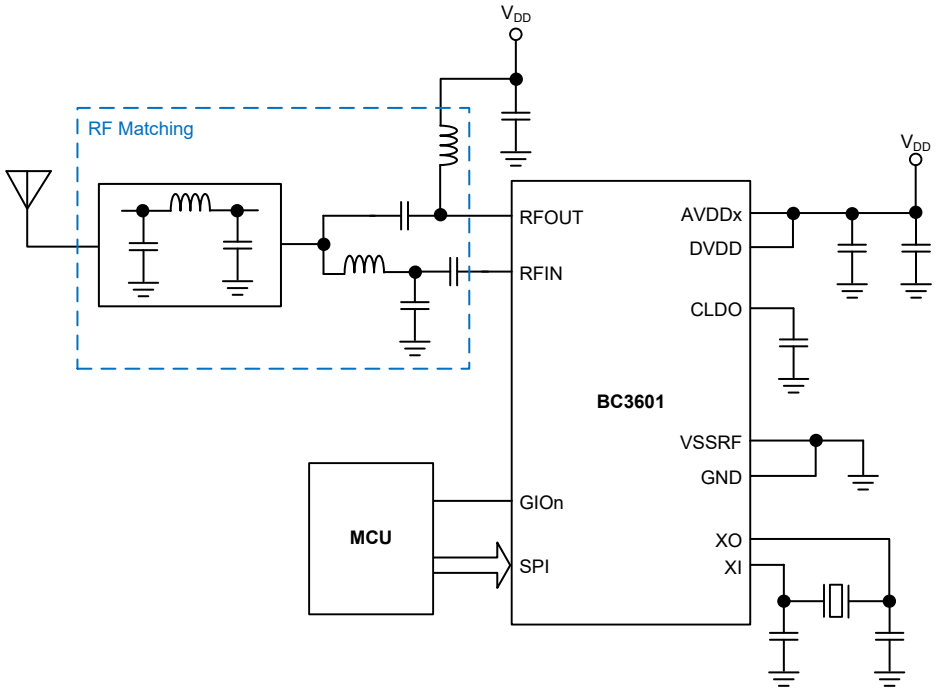
WTM: Wake-up Timer Mode

XCLK: Crystal Clock

XO/XOSC: Crystal Oscillator

XTAL: Crystal

Application Circuits



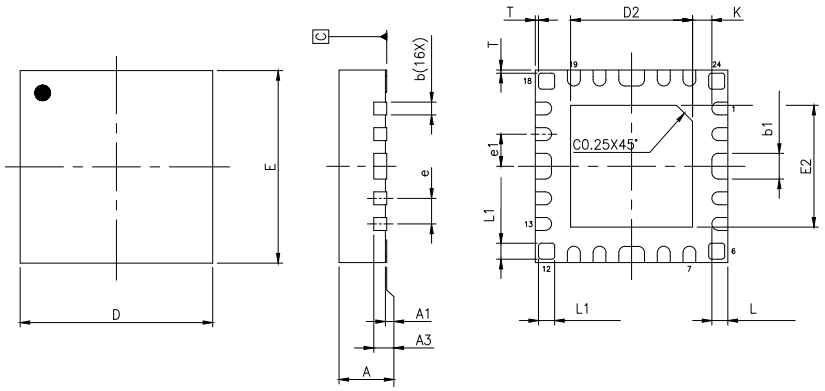
Package Information

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 information.

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

- Further Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- Packing Meterials Information
- Carton information

SAW Type 24-pin QFN (3mm×3mm×0.55mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	0.020	0.022	0.024
A1	0.000	0.001	0.002
A3	—	0.006 BSC	—
b	0.006	0.008	0.010
b1	0.014	0.016	0.018
D	—	0.118 BSC	—
E	—	0.118 BSC	—
e	—	0.016 BSC	—
e1	—	0.020 BSC	—
D2	0.073	0.075	0.077
E2	0.073	0.075	0.077
L	0.006	0.010	0.014
L1	0.008	0.010	0.012
K	0.008	—	—

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	0.50	0.55	0.60
A1	0.00	0.02	0.05
A3	—	0.150 BSC	—
b	0.15	0.20	0.25
b1	0.35	0.40	0.45
D	—	3.00 BSC	—
E	—	3.00 BSC	—
e	—	0.40 BSC	—
e1	—	0.50 BSC	—
D2	1.85	1.90	1.95
E2	1.85	1.90	1.95
L	0.15	0.25	0.35
L1	0.20	0.25	0.30
K	0.20	—	—