FCC ID: UYHTD-7UX157EHPWN

Tux droid and Fux (USB fish dongle) operation theory

1. Power supply

Tux can use two sources of power supply. One source is the 4.8V battery (H11 connector). The second source is an external sector adaptor (H9 connector). The external sector adaptor is used by the charger of battery block (U6 BQ2002T). Battery can be disconnected with a general switch (H10 connector). From one of the two source of power supply, a 3V3 regulator (U1 APE8800A) supplies the power for all the Tux.

Fux (dongle) is supplied by the USB connector (J1 connector). A 3V3 regulator (U2 APE8800A) supplies the power for the RF module.

2. Tux and Fux basic decription

At the start, Tux search to connect with Fux (dongle). When Fux is connected to a PC, it starts the RF connection procedure. When the RF initialisation is completed, Tux and Fux can exchange sound and data command.

When connected to the PC, Fux search to connect with Tux. When Fux and Tux are RF connected, the status led bright (D1). Fux takes sound and data command from USB and sends it to Tux through RF link and takes sound and data command from RF link and sends it to PC through USB.

3. Sound MCU description

On Tux, a microphone (H15 connector) is connected to a preamplifier block based on Q24 BC817 transistor. The signal from preamplifier is sampled by the Sound MCU (U7 ATmega 88) via ADC6 pin. This sound is send to the RF module via SPI bus (pin SS, MISO, MOSI, SCK). The RF module transmits the sound to the Fux. Fux transmits the sound to PC through USB.

The sound from the PC is transmitted through USB to the RF module of Fux. The Fux's RF module sends this sound to the Tux's RF module. Tux's RF module sends the sound to the sound MCU (U7 ATmega88) via SPI bus (pin SS, MISO, MOSI, SCK). The Sound MCU (U7 ATmega88) sends the sound via PD5 to the filter block based on Q1 BC817 transistor. At the output of the filter block, sound is send to the power amplifier (U4 TPA 6203) and the speaker (H12 connector).

Sound MCU (U7 ATmega88) have an external flash (U2 AT26F004) to save pre-recorded sound. This flash can be programmed by SPI bus (pin PB1, MISO, MOSI, SCK). Data to program the flash are received from the RF module to the Sound MCU (U7 ATmega88) via the SPI bus (pin SS, MISO, MOSI, SCK). The Sound MCU (U7 ATmega88) resend data to the flash (U2 AT26F004) via the SPI bus (pin PB1, MISO, MOSI, SCK). To read sound in the flash (U2 AT26F004), the Sound MCU (U7 ATmega88) uses SPI bus (pin PB1, MISO, MOSI, SCK). Sound MCU sends sound to the power amplifier (U4 TPA 6203) via PD5, like for audio from RF module.

4. Behavior MCU description

Behavior MCU (U3 ATmega88) can read information from a lot of push button (H3 connector).

Behavior MCU (U3 ATmega 88) can control a lot of motor inside Tux. The motors are controlled by PD0, PD1, PD4, PB0, PB1, PB2 pins. This pins drive transistors motor drivers (Q2, Q3, Q6, Q7, Q28, Q14, Q15, Q10, Q11, Q29, Q20, Q21, Q16, Q17, Q30 transistors). Motor position switches are also controlled by Behavior MCU (U3 ATmega88). The position switches are connected on H2 connector and H4 connector.

Behavior MCU can control led inside (H1 connector) via pin PC2 and PC3.

Behavior MCU (U3 ATmega 88) can read information from an Ir Receiver (H1 connector) via pin PD2. Behavior MCU (U3 ATmega 88) can send Ir information through Ir Transmitter (H1 connector) via PD5 pin.

Tux. Motor, led and Ir controlling is done with RF data command from the PC. Data commands are received by RF of the Tux. RF module send it to Sound MCU (U7 ATmega 88) by SPI bus (pin SS, MISO, MOSI, SCK). Sound MCU (U7 ATmega88) forward the data commands to Behavior MCU (U3 ATmaga 88) via I2C bus (pin SDA, SCL).
Push button statement and Ir receive code are send to the PC through the RF link using data command. Data commands are send by I2C bus (pin SDA, SCL) from Behavior MCU (U3 ATmega 88) to Sound MCU (U7 ATmega 88). Sound MCU (U7 ATmega 88) sends data commands by SPI bus (pin SS, MISO, MOSI, SCK) to the RF module.

5. Reprogramming mode

All MCU of Tux and Fux are reprogramming. To reprogram USB MCU (U1 AT89C5130), there is a push button on the Fux (S1). Programming code is send by the PC through the USB. To reprogram RF MCU (IC1 ATmega48) of the Fux, programming code is send by the PC through the USB. The USB MCU (U1 AT89C5130) send programming code to the RF MCU (IC1 ATmega48) via the I2C bus (pin SDA, SCL)

To reprogram Sound, Behaviour and RF MCU, a small cable must be connected between Tux (H5 connector) and Fux (J3 connector). When this cable is connected, you must push on the head button of the Tux (H1 connector) and turn on the Tux. Programming code is send by the PC through the USB. The USB MCU (U1 AT89C5130) sends programming code to the RF MCU (IC1 ATmega48) or Sound MCU (U7 ATmega88) or Behavior MCU (U3 ATmega88) via the I2C bus (pin SDA, SCL)

6. RF link description

RF module uses an MCU (IC1 ATMega 48) and an RF processor (IC2 ATR2406). The RF processor modulates in GFSK the digital data. The RF processor uses 2.4 GHz band. RF processor is connected to an F antenna. This antenna is printed on the PCB.

RF link use a timing that is described on the next pages. At the start dongle emit an init frame on the 16 frequencies of this table.

Init frequency schema

Frequency	Unit	Channel	Frequency	Unit	Channel
2401,056	MHz	0	2442,528	MHz	48
2406,24	MHz	6	2447,712	MHz	54
2411,424	MHz	12	2452,896	MHz	60
2416,608	MHz	18	2458,08	MHz	66
2421,792	MHz	24	2463,264	MHz	72
2426,976	MHz	30	2468,448	MHz	78
2432,16	MHz	36	2473,632	MHz	84
2437,344	MHz	42	2478,816	MHz	90

When Tux receives an init frame, the frequency hopping starts. Tux and Fux use normal frame. Frame structure of the init and normal frame are on the next pages.

Frequency hopping use 20 frequencies there are randomly choice. The table of used frequencies for this choice is on the next pages. This is an adaptativ frequency hopping. When one frequency has a big error rate, this frequency is replaced. The new frequency is randomly computed.

7. RF receive and transmit description

On receive mode, a 2.4 GHz GFSK signal will be received by a F-antenna (permanent integrated on PCB) and passes through the 2.4 GHz microstrip-lowpass filter (C8, C22) to the RF_IN of IC2 (ATR2406). This RF signal is differently fed through the LNA to the image rejection mixer driving the integrated LowIF bandpass filter. The IF frequency is 864 kHz. The limiting IF_AMP with an integrated RSSI function feeds the signal to the digital demodulator.This demodulated signal from RX_Data will send to IC1 (ATmega48). The digital data are send by IC1 (ATmega 48) via the SPI bus (pin SS, MISO, MOSI, SCK) to the Tux or the Fux.

On transmit mode, data come from the SPI bus (pin SS, MISO, MOSI, SCK) of Tux or Fux. IC1 (ATmega 48) send data to IC2 (ATR2406) for modulation via pin TX_DATA. The transmit data is filtered by an integrated Gaussian filter (GF) and fed to the fully integrated VCO operating at twice the output frequency. After modulation, the signal is frequency divided by 2 and fed to the internal preamplifier PA. This preamplifier supplies typically +4 dBm output power at a micro strip via pin TX_OUT. The RF signal is send by C9 to a microstrip -lowpass with C8 and C22. The 2.4 GHz GFSK signal will be transmit by a F-antenna. permanent integrated on PCB)

8. Frequency channels

Both Fux and Tux droid have 95 physical channels and 20 logical channels. Please see the frequency table in below.

In normal operation (traffic), a list of 20 frequencies is randomly chosen and both Fux and Tux droid will operate on these 20 frequencies. The sequence of frequencies is just following the list, so it will always be the same sequence order unless one frequency is changed. When one frequency of the list is found to fail the transmission a couple of times, it is removed from the list and another frequency is chosen randomly within the 95 available channels. The list of the 20 frequencies on which the module operates will change continuously, but at a slow rate.

In initialization mode (i.e. the Fux is powered on, but the Tux droid is powered off), the Fux will transmit on 16 fixed frequencies listed above, the order is always the same.

If the Tux droid is powered on and the Fux is powered off, the Tux droid will in reception all the time and just waits for any signal, it never transmits.

Frequency table

Frequency	Unit	Channel	Frequency	Unit	Channel
2401,056	MHz	0	2442,528	MHz	48
2401,92	MHz	1	2443,392	MHz	49
2402,784	MHz	2	2444,256	MHz	50
2403,648	MHz	3	2445,12	MHz	51
2404,512	MHz	4	2445,984	MHz	52
2405,376	MHz	5	2446,848	MHz	53
2406,24	MHz	6	2447,712	MHz	54
2407,104	MHz	7	2448,576	MHz	55
2407,968	MHz	8	2449,44	MHz	56
2408,832	MHz	9	2450,304	MHz	57
2409,696	MHz	10	2451,168	MHz	58
2410,56	MHz	11	2452,032	MHz	59
2411,424	MHz	12	2452,896	MHz	60
2412,288	MHz	13	2453,76	MHz	61
2413,152	MHz	14	2454,624	MHz	62
2414,016	MHz	15	2455,488	MHz	63
2414,88	MHz	16	2456,352	MHz	64
2415,744	MHz	17	2457,216	MHz	65
2416,608	MHz	18	2458,08	MHz	66
2417,472	MHz	19	2458,944	MHz	67
2418,336	MHz	20	2459,808	MHz	68
2419,2	MHz	21	2460,672	MHz	69
2420,064	MHz	22	2461,536	MHz	70
2420,928	MHz	23	2462,4	MHz	71
2421,792	MHz	24	2463,264	MHz	72
2422,656	MHz	25	2464,128	MHz	73
2423,52	MHz	26	2464,992	MHz	74
2424,384	MHz	27	2465,856	MHz	75
2425,248	MHz	28	2466,72	MHz	76
2426,112	MHz	29	2467,584	MHz	77
2426,976	MHz	30	2468,448	MHz	78
2427,84	MHz	31	2469,312	MHz	79
2428,704	MHz	32	2470,176	MHz	80
2429,568	MHz	33	2471,04	MHz	81
2430,432	MHz	34	2471,904	MHz	82
2431,296	MHz	35	2472,768	MHz	83
2432,16	MHz	36	2473,632	MHz	84
2433,024	MHz	37	2474,496	MHz	85
2433,888	MHz	38	2475,36	MHz	86
2434,752	MHz	39	2476,224	MHz	87
2435,616	MHz	40	2477,088	MHz	88
2436,48	MHz	41	2477,952	MHz	89
2437,344	MHz	42	2478,816	MHz	90
2438,208	MHz	43	2479,68	MHz	91
2439,072	MHz	44	2480,544	MHz	92
2439,936	MHz	45	2481,408	MHz	93
2440,8	MHz	46	2482,272	MHz	94
2441,664	MHz	47			

9. <u>Frame Structure</u>

The frame structure is shown below. Both initialization mode and normal mode have frame structure in 2 ms long. It is divided into 2 slots, each has 1 ms long.

In normal frame, this is always 64 bytes of preamble and useful data per slot and in both directions with exactly the same structure. The active transmission time is 575 us. The USB fish dongle is allowed to transmit during the first slot and the Tux droid is allowed to transmit during the second slot.

In initialization frame, the preamble and data is 19 bytes and the active transmission time is 183 us. When the USB fish dongle is powered on and the Tux droid is powered off, the USB fish dongle will transmit during the first slot, but the second slot is empty as the Tux droid cannot reply. If the Tux droid is turned on, it will reply for initialization in the second slot, then they will switch to normal operation mode.

Frame Structure

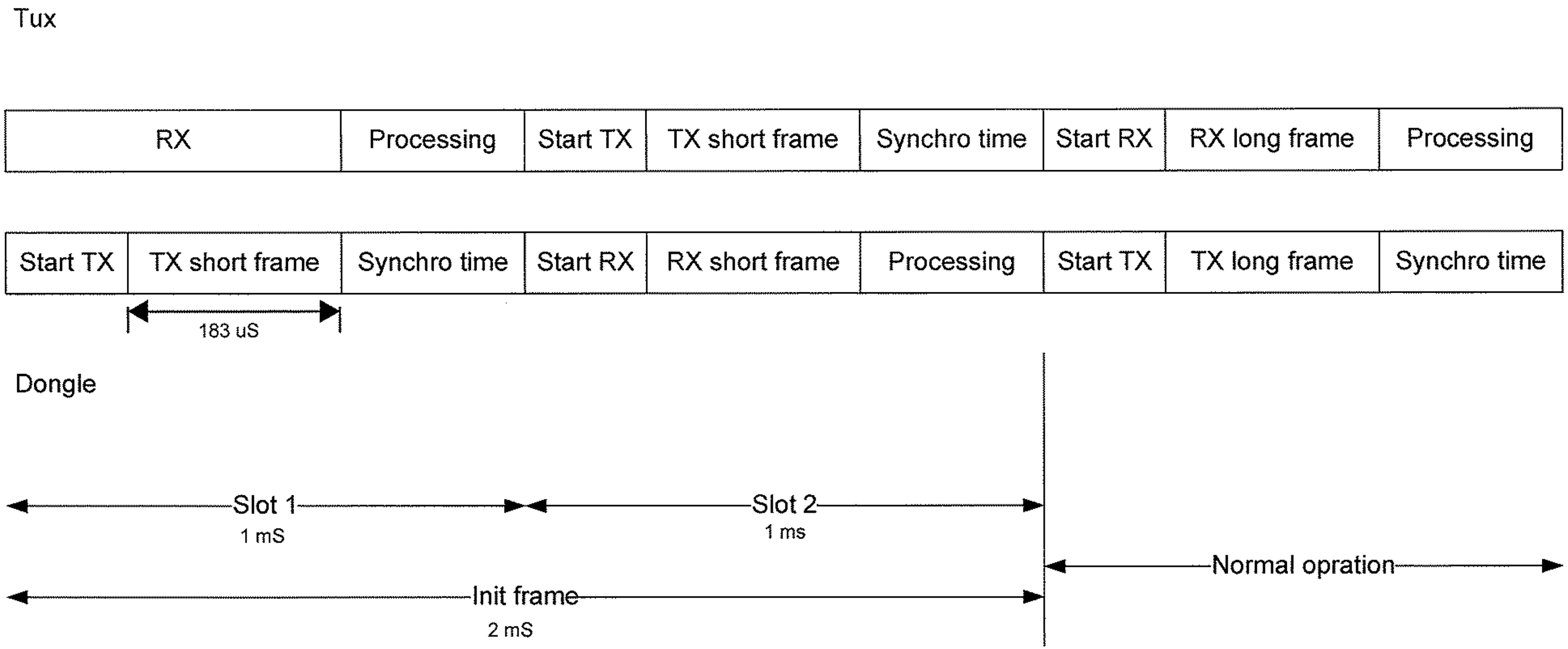
Init frame

[0-5] Preamble	[6-7] Synchro	[8-11] SOF	[12] Frame size	[13-14] Header	[15-16] Hopping parameter	[17] Frame counter	[18] CRC

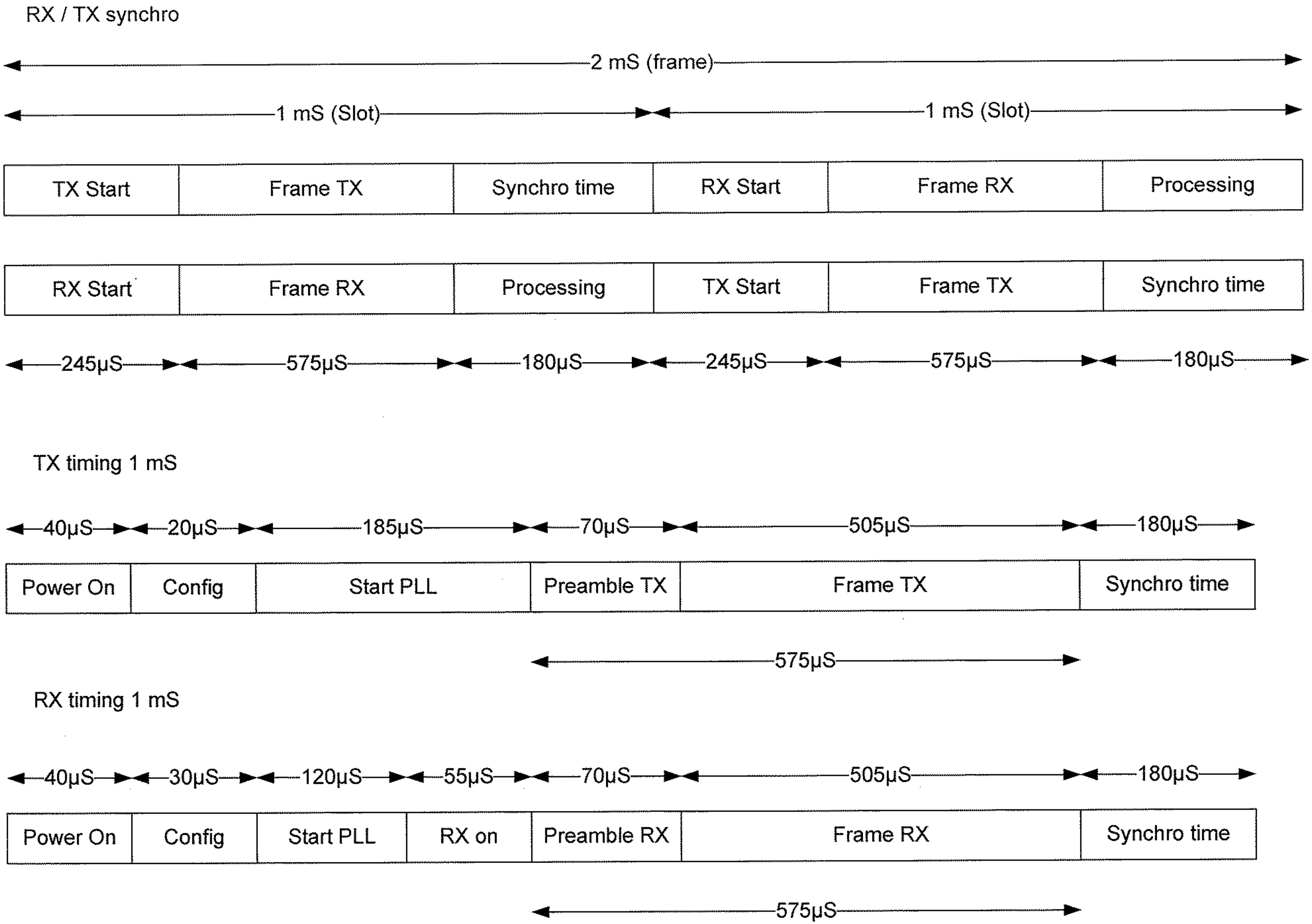
Normal frame

[0-5] Preamble	[6-7] Synchro	[8-11] SOF	[12] Frame size	[13-14] Header	[15-16] Hopping parameter	[17] Frame counter	[18-21] Command	[22-38] Audio 0	[39-44] Reserved	[45-61] Audio 0	[62] Reserved	[63] CRC

Initialization Frame



Normal Frame



Appendix

IC specification for ATR2406 2.4 GHz RF Transceiver

Features

- Fully Integrated Low IF Receiver
- Fully Integrated GFSK Modulator for 72, 144, 288, 576 and 1152 Kbit/s
- High Sensitivity of Typically –93 dBm Due to Integrated LNA
- High Output Power of Typically +4 dBm
- Multi-channel Operation
  - 95 Channels
  - Support Frequency Hopping (ETSI) and Digital Modulation (FCC)
- Supply-voltage Range 2.9V to 3.6V (Unregulated)
- Auxiliary-voltage Regulator on Chip (3.2V to 4.6V)
- Low Current Consumption
- Few Low Cost External Components
- Integrated Ramp-signal Generator and Power Control for an Additional Power Amplifier
- Low Profile Lead-free Plastic Package QFN32 (5 mm × 5 mm × 0.9 mm)
- RoHs Compliant

Applications

- Hightech Multi-user Toys
- Wireless Game Controllers
- Telemetry
- Wireless Audio/Video
- Electronic Point of Sales
- Wireless Head Set
- FCC CFR47, Part 15, ETSI EN 300 328, EN 300 440 and ARIB STD-T-66 Compliant Radio Links

Low IF 2.4 GHz ISM Transceiver

ATR2406

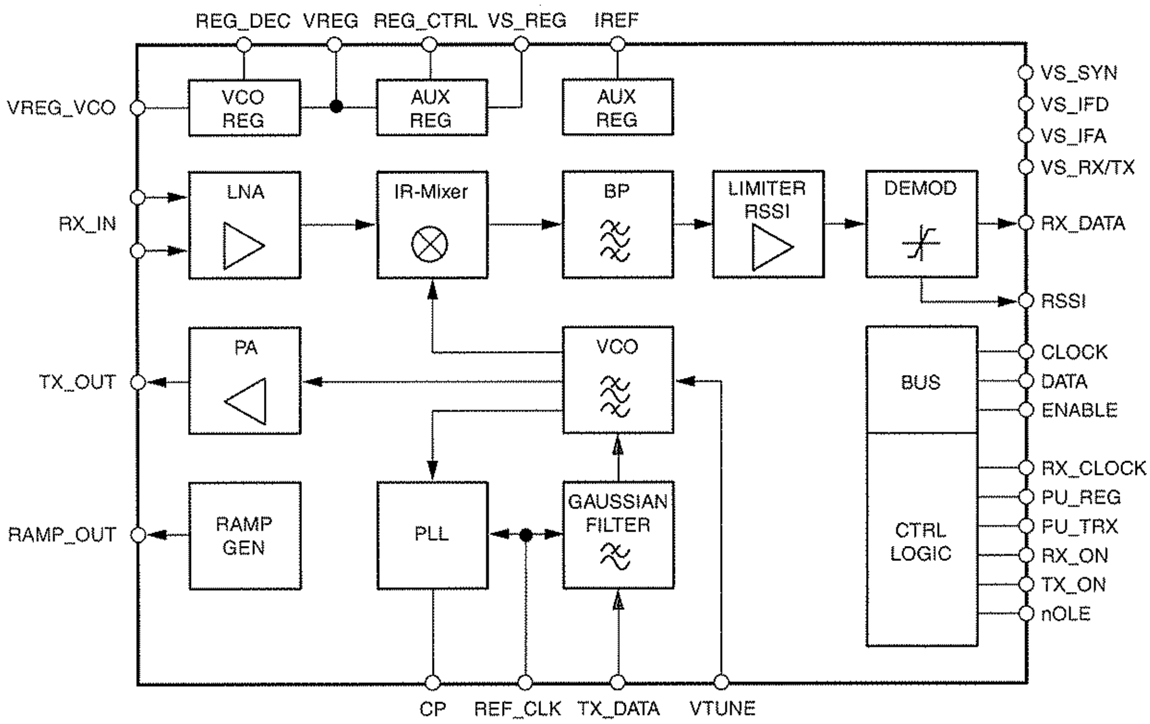
1. Description

The ATR2406 is a single chip RF-transceiver intended for applications in the 2.4 GHz ISM band. The QFN32 packaged IC is a complete transceiver including image rejection mixer, low IF filter, FM demodulator, RSSI, TX preamplifier, power-ramping generator for external power amplifier, integrated synthesizer, and a fully integrated VCO and TX filter. No mechanical adjustment is necessary in production.

The RF-transceiver offers a clock recovery function on-chip.

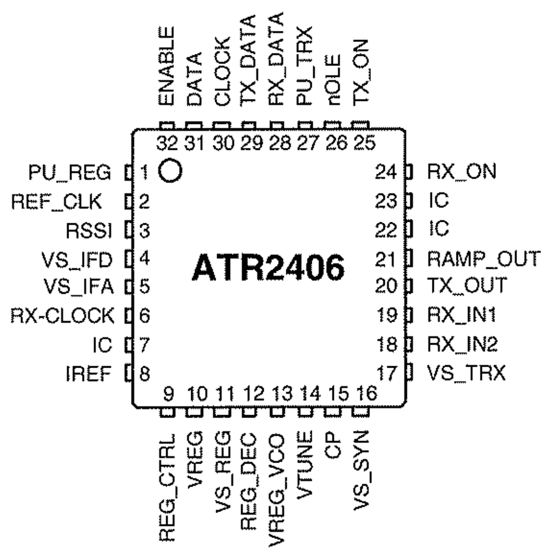
4779K–ISM–06/06

Figure 1-1. Block Diagram



2. Pin Configuration

Figure 2-1. Pinning QFN32 - 5 × 5



3. Functional Description

3.1 Receiver

The RF signal at RF_IN is differently fed through the LNA to the image rejection mixer IR_MIXER driving the integrated LowIF bandpass filter. The IF frequency is 864 kHz.The limiting IF_AMP with an integrated RSSI function feeds the signal to the digital demodulator DEMOD. No tuning is required. Datasling is handled internally.

3.2 Clock Recovery

For 1152 kBit/s data rate the receiver has a clock recovery function on-chip.

The receiver includes a clock recovery circuit which regenerates the clock out of the received data. The advantage is that this recovered clock is synchronous to the clock of the transmitting device (and thus to the transmitted data) which allows to reduce the load of the processing microcontroller significantly.

The falling edge of the clock gives the optimal sampling position for the RX_Data signal so at this event the data must be sampled by the microcontroller. The recovered clock is available at pin 6.

3.3 Transmitter

The transmit data at TX_DATA is filtered by an integrated Gaussian Filter GF and fed to the fully integrated VCO operating at twice the output frequency. After modulation the signal is frequency-divided by 2 and fed to the internal preamplifier PA. This preamplifier supplies typically +4 dBm output power at TX_OUT.

A ramp-signal generator RAMP_GEN, providing a ramp signal at RAMP_OUT for the external power amplifier, is integrated. The slope of the ramp signal is controlled internally so that spurious requirements are fulfilled.

3.4 Synthesizer

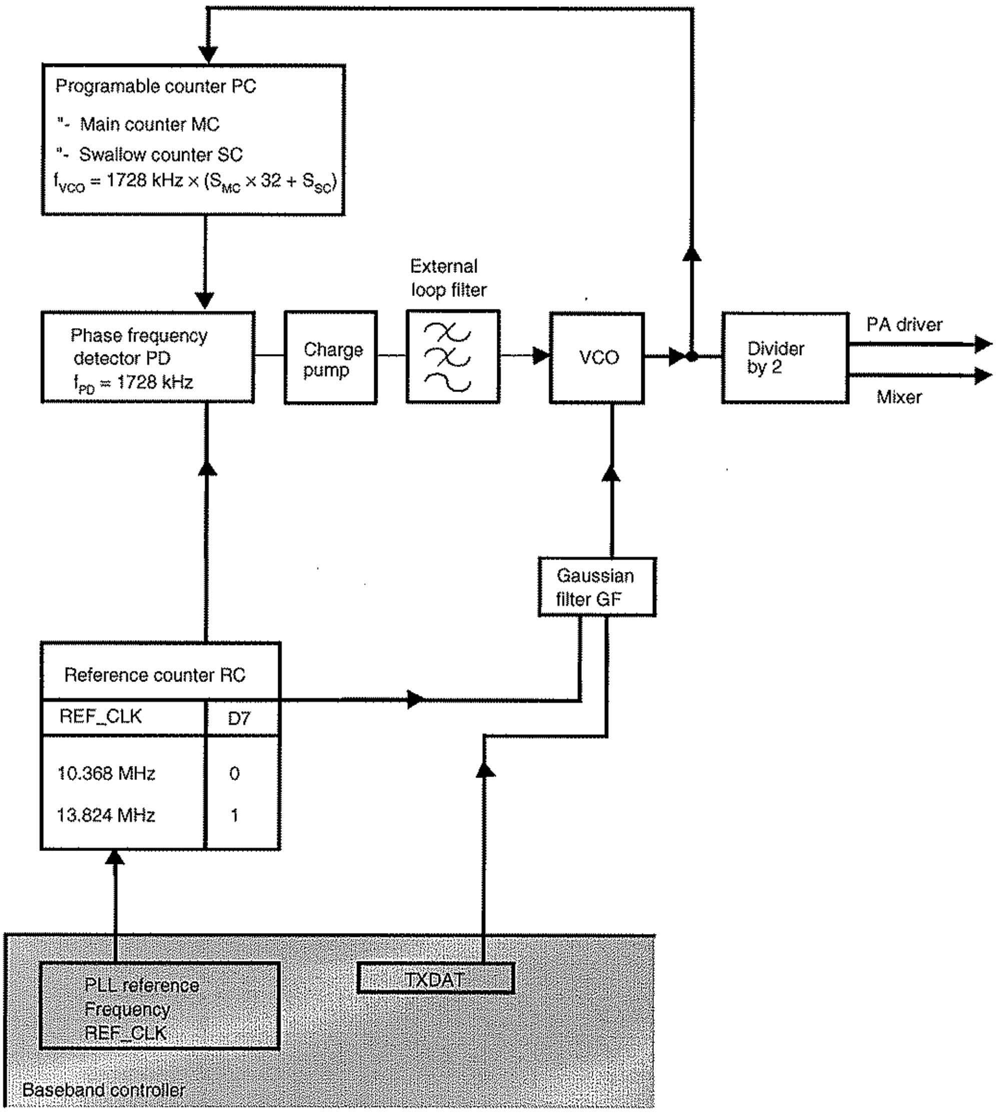
The IR_MIXER, the PA and the programmable counter PC are driven by the fully integrated VCO, using on-chip inductors and varactors. The output signal is frequency divided to supply the desired frequency to the TX_DRIVER, 0/90 degree phase shifter for the IR_MIXER and to be used by the PC for the phase detector PD (f_{PD} = 1.728 MHz). Open loop modulation is supported.

3.5 Power Supply

An integrated bandgap-stabilized voltage regulator for use with an external low-cost PNP transistor is implemented. Multiple power-down and current saving modes are provided.

7. PLL Principle

Figure 7-1. PLL Principle



The following table shows the LO frequencies for RX and TX in the 2.4 GHz ISM band. There are 95 channels available. Since the ATR2406 supports wideband modulation with 400 kHz deviation, every second channel can be used without overlap in the spectrum.

Table 7-1. LO Frequencies

Mode	f_{IF}/kHz	Channel	f_{ANT}/MHz	f_{VCO}/MHz	S_{MC}	S_{SC}	N
TX		C0	2401.056	2401.056	86	27	2779
		C1	2401.920	2401.920	86	28	2780
		...	...	...	...	...	...
		C93	2481.408	2481.408	89	24	2872
		C94	2482.272	2482.272	89	25	2873
RX	864	C0	2401.056	2401.920	86	28	2780
		C1	2401.920	2402.784	86	29	2781
		...	...	...	...	...	...
		C93	2481.408	2482.272	89	25	2873
		C94	2482.272	2483.136	89	26	2874

7.1 TX Register Setting

The following 16-bit word has to be programmed for TX.

MSB															LSB
Data bits															
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	1	PA		GFCS			1	RC	MC		SC				

Note: D12 and D13 are only relevant if ramping generator in conjunction with external PA is used, otherwise it can be programmed 0 or 1.

Table 7-2. Output Power Settings with Bits D12 - D13

PA (Output Power Settings)		
D13	**D12**	**RAMP_OUT (Pin 21)**
0	0	1.3 V
0	1	1.35 V
1	0	1.4 V
1	1	1.75 V

The VRAMP voltage is used to control the output power of an external power amplifier. The voltage ramp is started with the TX_ON signal.

These bits are only relevant in TX mode.