AN11017

Transceiver OL2381 using wireless M-BUS

Rev. 2 — 10 May 2011 Application note

Document information

Info	Content
Keywords	OL2381, Transceiver, 868 MHz, wireless M-BUS, OMS.
Abstract	This document describes how to use OL2381 in Wireless M-BUS applications.

Revision history

Rev	Date	Description
v.2	20110510	second issue Modifications: • Values added to the register address 0x01 column in table 13.
v.1	20110422	first issue

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1. Introduction

This application note describes how to use the NXP transceiver OL2381 in a wireless M-Bus application.

Wireless M-Bus is a European standard Ref. 5 for the transmission of data from utility meters such as gas, heat and water. Its primary use is in the Short Range Devices (SRD) unlicensed telemetry band at 868 MHz. As a broad definition, this standard can be applied to various applications.

This application note only describes the physical layer.

The OL2381 is a highly integrated and fully software configurable, single-chip transceiver operating in ISM/SRD band. The OL2381 has a small form factor, low power consumption, and a wide supply voltage range. These features make it suitable for use in battery powered handheld devices and their counterparts.

OL2381 value propositions for wireless M-Bus are:

- Full wireless M-Bus compliance (except N-mode)
- Efficient RF power amplifier with programmable power output
- Highly sensitive receiver with programmable gain
- Programmable data rate
- Programmable center frequency; on-the-fly and multi-channel operation
- Intelligent state machine reduces microcontroller load and power consumption
- Several automatic signal monitors allow long system battery life
  - wake-up search timer
  - RSSI level checker
  - coding checker
  - baud rate checker
  - preamble detection
- Programmable IF filter for different bandwidth requirements:
  - narrowband for long range with low data rate
  - wideband for short range with high data rate

This application note focuses on the 868 MHz application, however, the 433 MHz (F-Mode) frequency is also supported (refer to draft version of Ref. 3).

For a specific wireless M-BUS solution, refer to Ref. 6 which provides a complete energy metering solution with software, hardware and data sheets. The internet solution uses a 3-wire SPI interface, whereas this document describes the 7-wire interface.

1.1 OL2381 Block diagram

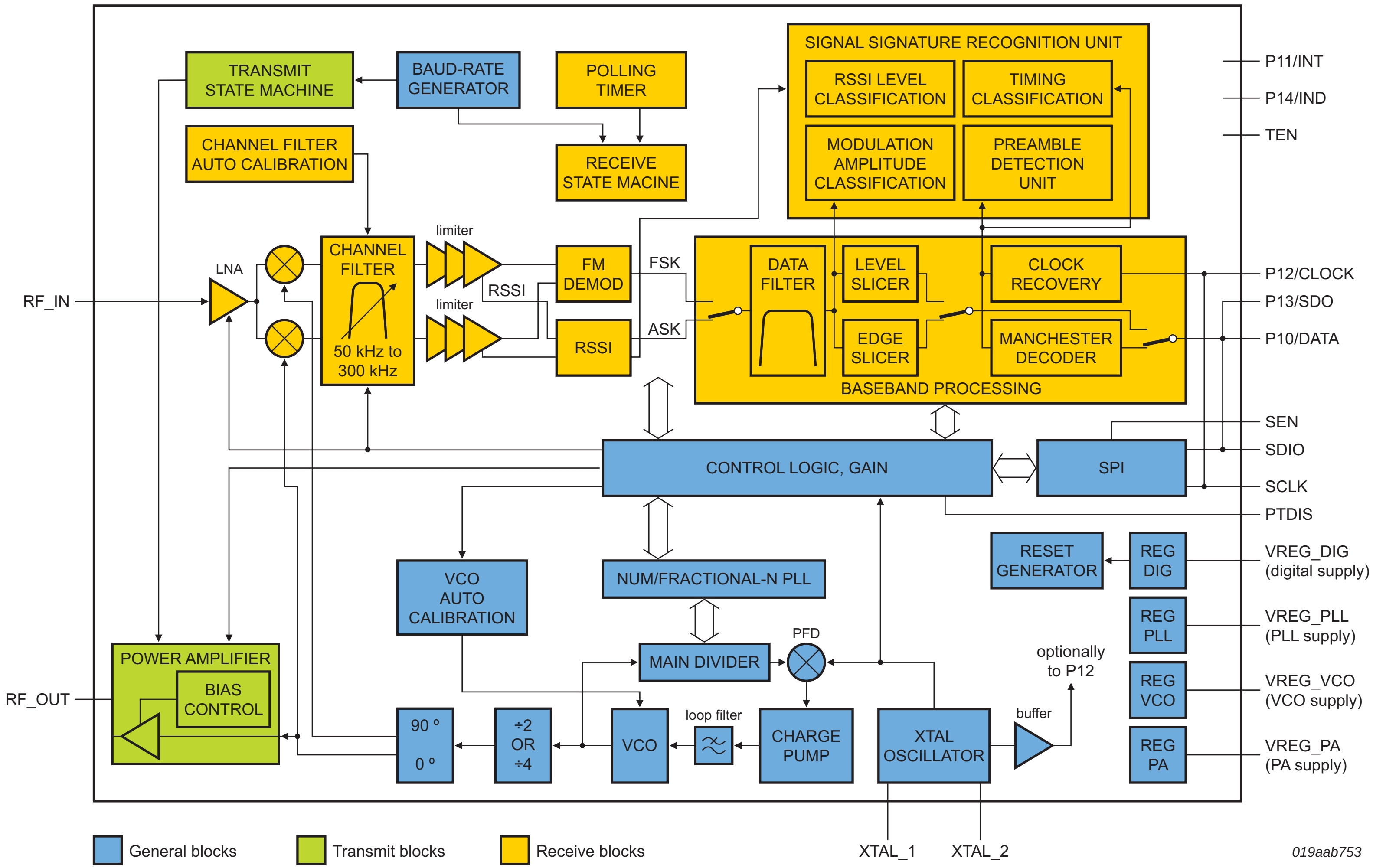

Fig 1. Block diagram of the OL2381 transceiver.

1.2 Document overview

This application note comprises the following sections:

- Section 2 - Reasoning behind the wireless M-BUS
- Section 3 - Details of the physical layer
- Section 4 - Programming information for the general registers
- Section 5 - Programming information for the transmit registers
- Section 6 - Programming information for the receive registers
- Section 7 - Transmit/receive operation procedures
- Section 8 - A hardware example is detailed
- Section 9 - A representation of the software in a block diagram

2. Wireless M-BUS

To help protect against climate change, the EU passed a directive in 2006 which commits its members to reduce their energy consumption. The directive was intended to raise awareness of climate change due to energy consumption by promoting reduction in heat, gas, electricity, water and so on. Smart meters can make this information readily accessible and are key to realizing this goal.

Since 2010, it is compulsory to equip new buildings with smart metering devices that are able to resend their data.

The 868 MHz SRD band was chosen because it has good data transmission range characteristics. In this European license-free band, all users must follow regulating rules intended to prevent overloading. These rules limit output power, duty cycle, and spectral emissions. This regulation enables many transmitters to work in parallel within a finite area.

The physical and data link layer for wireless M-BUS is specified in the European Standard (Ref. 5). Different modes are specified for various applications in this standard. The modes are described in the following chapters (as of February 2011, the C-, F- and N-modes have not yet been released).

2.1 Wireless M-Bus mode S1

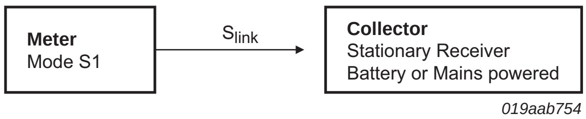

Fig 2. Mode S1

Table 1. Mode S1

Title	Description[1]
Application	transmit only meter for stationary receiving readout
Sending rate	six times a day - the battery receiver needs only to be active during these time slots, or it is periodically searching for the long header.
Center Frequency	868.30 MHz
FSK Deviation	±50 kHz
Data Encoding	Manchester
Chip Rate	32.768 kchip/s (data rate = 16,384 bps)
Frame	long header (576 chips)

[1] All values provided are typical values unless otherwise stated.

The metering devices only send their data to the data collector several times per day. Consequently, the data collector is in the sleep mode for most of the day and only needs to be awakened to receive the metering data. Alternatively, it periodically searches for a valid transmission that typically starts with a long header. Read-out on request is not possible in this mode.

2.2 Wireless M-Bus mode S1-m

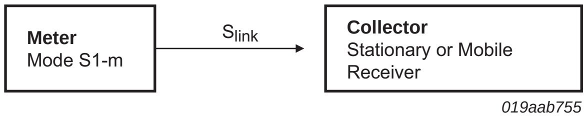

Fig 3. Mode S1-m

Table 2. Mode S1-m

Title	Description[1]
Application	Stationary mode - transmit only meter, for stationary or mobile receivers
Sending rate	30 times per hour - the receiver must be continuously enabled
Center Frequency	868.30 MHz
FSK Deviation	±50 kHz
Data Encoding	Manchester
Chip Rate	32.768 kchip/s (data rate = 16,384 bps)
Preamble	short header (48 chips)

[1] All values provided are typical values unless otherwise stated.

S1-m is same as S1, but transmit interval is shorter. So mobile receivers can await this time.

2.3 Wireless M-Bus mode S2

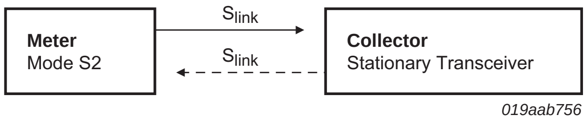

Fig 4. Mode S2

Table 3. Mode S2

Title	Description[1]
Application	Stationary mode - bidirectional communication in S1 or S1-m mode.
Sending rate	same as S1/S1-m, depending on the mode used
Center Frequency	868.30 MHz (both directions)
FSK Deviation	±50 kHz
Data Encoding	Manchester
Chip Rate	32.768 kchip/s (data rate = 16,384 bps)
Preamble	short header or optional long header (48 chips)

[1] All values provided are typical values unless otherwise stated.

The meter periodically sends data and its receiver is only enabled for a short period after each transmission. A bidirectional communication is established only if the stationary transceiver asks for a request within this short period.

2.4 Wireless M-Bus mode T1

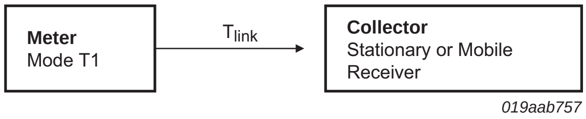

Fig 5. Mode T1

Table 4. Mode T1

Title	Description[1]
Application	frequent transmission, short telegrams
Sending rate	same as S1/S1-m, depending on the mode used
Center Frequency	868.95 MHz
FSK Deviation	(±40 kHz to ±80 kHz)
Data Encoding	3 out of 6
Chip Rate	100 kchip/s (data rate = 66.67 bps)
Preamble	short header (48 chips)

[1] All values provided are typical values unless otherwise stated.

2.5 Wireless M-Bus mode T2

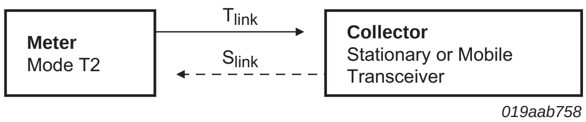

Fig 6. Mode T2

Table 5. Mode T2

Title	Description[1]
Application	frequent transmission, bidirectional
Sending rate	short data burst <5 ms every few seconds
Center Frequency	868.95 MHz (T)
	868.30 MHz (S)
FSK Deviation	(±40 kHz to ±80 kHz)
Data Encoding	3 out of 6 (T) / Manchester (S)
Chip Rate	100 kchip/s (T) / 32.768 kchip/s (S)
Preamble	short header (48 chips)
Response delay	3 ms

[1] All values provided are typical values unless otherwise stated.

Meter unit transmits on a regular basis similar to Type T1. Its receiver is enabled for a short period after the end of each transmission and locks on if an acknowledge is received (at 32.768 kchip/s). Further bidirectional communication in the 0.1 % frequency band using 100 kchip/s (meter transmit) and 32.768 kchip/s (meter receive) can follow.

Note that communication from the meter to collector uses the physical layer of the T-mode. The physical layer parameters for the reverse direction are identical to the S-mode.

2.6 Wireless M-Bus mode C1

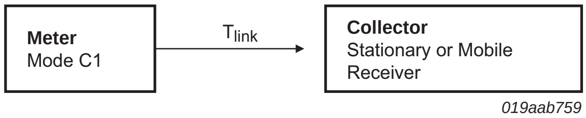

Fig 7. Mode C1

Table 6. Mode C1

Title	Description[1]
Application	Compact mode - frequent transmission, short telegrams
Sending rate	short data burst <22 ms on regular basis
Center Frequency	868.95 MHz
FSK Deviation	±45 kHz
Data Encoding	NRZ
Chip Rate	100 kchip/s (data rate = 100 bps)
Preamble	short header (32 chips)

[1] All values provided are typical values unless otherwise stated.

2.7 Wireless M-Bus mode C2

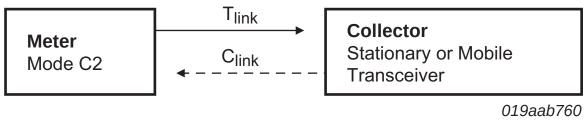

Fig 8. Mode C2

Table 7. Mode C2

Title	Description[1]
Application	Compact mode - frequent transmission, bidirectional
Sending rate	short data burst <22 ms on regular basis
Center Frequency	868.95 MHz (T)
	869.525 MHz (C)
FSK Deviation	±45 kHz
Data Encoding	NRZ
Chip Rate	100 kchip/s (data rate = 100 bps)
Preamble	short header (32 chips)

[1] All values provided are typical values unless otherwise stated.

Meter unit transmits on a regular basis similar to type C. Its receiver is enabled for a short period after the end of each transmission and if an acknowledge is received it locks on. Further bidirectional communication in the 0.1 % frequency band can follow.

The same receiver can receive T-mode and C-mode. Because of the use of GFSK modulation at C-link, the transmission allows more data with the same energy budget.

2.8 Wireless M-Bus mode R2

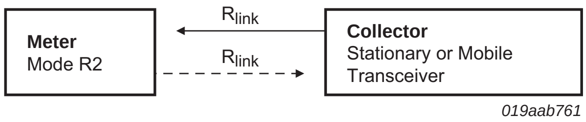

Fig 9. Mode R2

Table 8. Mode R2

Title	Description[1]
Application	frequent reception, bidirectional, long range
Sending rate	meter transmit only on request
Center Frequency	868.33 MHz (collector to meter)
	868.03 + n*0.06 MHz (meter to collector)
FSK Deviation	±6 kHz
Data Encoding	Manchester
Chip Rate	4.8 kchip/s (data rate = 2.4 bps)
Frame	medium header (96 chip)
Response delay	3 ms (collector) / 10 ms (meter)

[1] All values provided are typical values unless otherwise stated.

In mode R2, the meter periodically listens for a request. If a request is received, the meter data is sent to the collector. Due to frequency multiplexing, several metering devices can be read at the same time. The communication settings for each direction are different. The communication devices must support fast switching between these settings.

The OL2381 is unable to receive multiple channels at the same time. However, due to a medium header, and OL2381 fast switching frequency, it is possible to poll several channels and read the channel that contains data.

2.9 Wireless M-Bus mode F2a

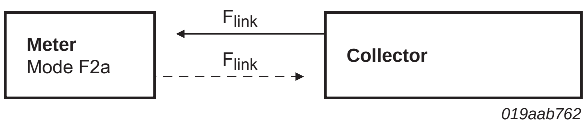

Fig 10. Mode F2a

Table 9. Mode F2a

Title	Description[1]
Application	frequent receive and transmit mode long range two-way communication, readout on demand
Sending rate	meter listens every few seconds
Center Frequency	433.82 MHz
FSK Deviation	±5.5 kHz
Data Encoding	NRZ
Chip Rate	2.4 kchip/s (data rate = 2.4 bps)
Preamble	extended preamble for wake-up
Response delay	2 ms

[1] All values provided are typical values unless otherwise stated.

2.10 Wireless M-Bus mode F2b

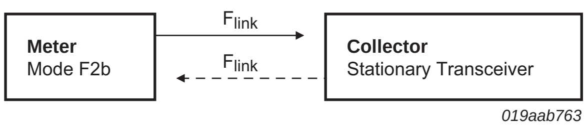

Fig 11. Mode F2b

Table 10. Mode F2b

Title	Description[1]
Application	frequent transmit and receive mode long range two-way communication for stationary readout
Sending rate	meter transmits a number of times per day communication is possible after transmission
Center Frequency	433.82 MHz
FSK Deviation	±5.5 kHz
Data Encoding	NRZ
Chip Rate	2.4 kchip/s or 4.8 kchip/s (data rate = 2.4 bps or 4.8 bps)
Preamble	-
Response delay	2 ms

[1] All values provided are typical values unless otherwise stated.

2.11 Wireless M-Bus mode N1, N2a-g

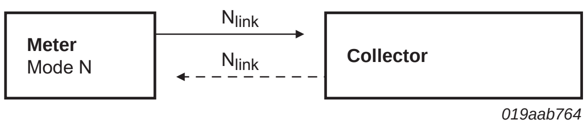

Fig 12. Mode N1, N2a-g

Table 11. Mode N1, N2a-g

Title	Description[1]
Application	narrowband communication long range communication in VHF frequency band
Center Frequency	169.4 MHz

[1] All values provided are typical values unless otherwise stated.

Because the center frequency does not comply with the working range of OL2381, this mode is not supported by OL2381.

3. Physical layers

There are five different physical radio links identified in Section 2. These links are named S, T, C, R, and F radio links, in the following chapters.

Table 12. Physical Radio links

Radio Link	Used in the following modes		Frequency MHz[1]	FSK Dev. kHz[1]
S	meter S1	→ collector	868.3	±50
	meter S1-m	→ collector		
	meter S2	→ collector		
	collector	→ meter S2		
	collector	→ meter T2		
T	meter T1	→ collector	868.95	±45
	meter T2	→ collector		
	meter C1	→ collector		
	meter C2	→ collector		
C	collector	→ meter C2	869.525	±45
R	collector	→ meter R2	868.03 + n × 60 kHz	±6
	meter R2	→ collector		
F	meter F2a	→ collector	433.82	±5.5
	collector	→ meter F2a		
	meter F2b	→ collector		
	collector	→ meter F2b		

[1] All values provided are typical values unless otherwise stated.

4. General register settings

This section briefly explains the settings of the receiver and transmitter common registers; see Figure 13. Not all registers are described in this application note, for more information please refer to data sheet Ref. 1 or application note Ref. 2.

Frequency register (FC0L+FC0M+FC0H) is used as an example in the flow chart provided by Figure 13. It is possible to have up to four different frequency setups for applications using different frequencies and to switch easily between them.

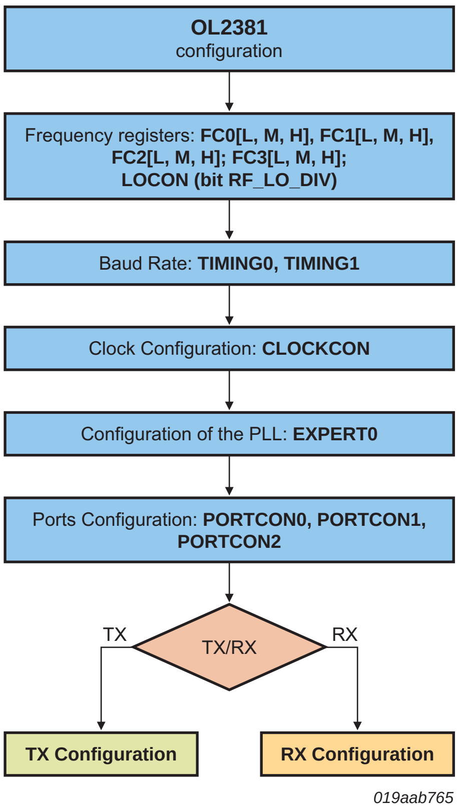

Fig 13. Register settings flow chart

4.1 Frequency settings

Four frequencies can be preset into OL2381 registers 0x00 to 0x0b. For the simplicity of this document only one frequency is set in registers 0x00 to 0x02. Figure 14 shows an example of the settings for 868.3 MHz in the general registers and the equations to calculate them. To set frequencies above 500 MHz, the VCO frequency is divided by 2 and bit RF_LO_DIV is set to logic 0.

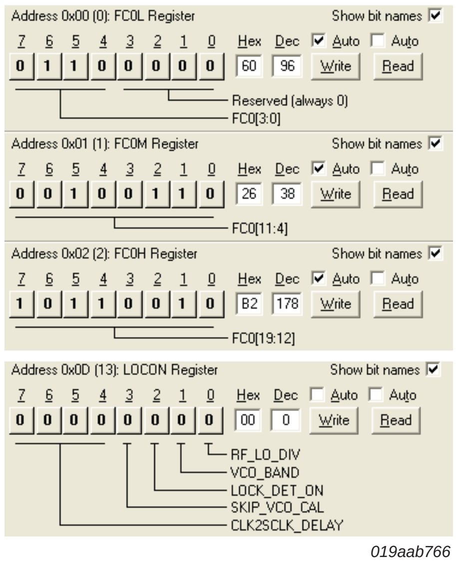

Fig 14. Frequency configuration

$$FCx[19:15] = \left\lfloor \frac{f_{RF}}{f_{ref}} \times (1 + RF\_LO\_DIV) - 32.5 \right\rfloor \quad (1)$$

$$FCx[14:0] = \left\lfloor \frac{f_{RF}}{f_{ref}} \times (1 + RF\_LO\_DIV) - (32 - FCx[19:15]) \times 16384 \right\rfloor \quad (2)$$

Where:

f_{RF} = required center frequency.

f_{ref} = 16 MHz [quartz].

RF_LO_DIV = 0 (for S, T, C and R).

RF_LO_DIV = 1 (for F).

$$\lfloor\ \rfloor = floor\ ()\ function\ (e.g. 2.8 \rightarrow 2) \quad (3)$$

Table 13. M-Bus register frequency settings

M-Bus radio link	OL2381 register address				Frequency (f)
	FCOL (0x00)	FCOM (0x01)	FCOH (0x02)	LOCON (0x0d)	
S	0x60	0x26	0xb2	0x00	868.30 MHz
T	0x90	0x79	0xb2	0x00	868.95 MHz
C	0x30	0xc3	0xb2	0x00	869.525 MHz
R	0xd0	0x03	0xb2	0x00	868.03 MHz (n = 0)
	0x80	0x0b	0xb2	0x00	868.09 MHz (n = 1)
	0x30	0x13	0xb2	0x00	868.15 MHz (n = 2)
	0xe0	0x1a	0xb2	0x00	868.21 MHz (n = 3)
	0x80	0x22	0xb2	0x00	868.27 MHz (n = 4)
	0x30	0x2a	0xb2	0x00	868.33 MHz (n = 5)
	0xe0	0x31	0xb2	0x00	868.39 MHz (n = 6)
	0x90	0x39	0xb2	0x00	868.45 MHz (n = 7)
	0x40	0x41	0xb2	0x00	868.51 MHz (n = 8)
	0xf0	0x48	0xb2	0x00	868.57 MHz (n = 9)
F	0xe0	0xd1	0xb1	0x01	433.82 MHz

4.2 Baud rate

Figure 15 shows the general register settings for chip rate and the equations to calculate them are provided below the figure. The chip rate is equivalent to the symbol. In this example, the watchdog timer is set to 4 ms.

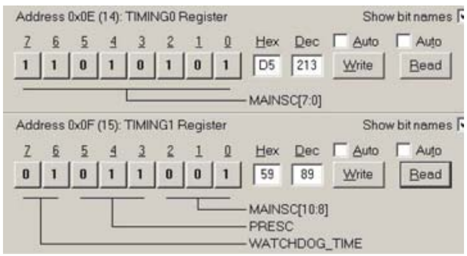

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Fig 15. Baud rate configuration

Where:

$$MAINSC = max(0, min(2047, \lfloor kchip \times 2^{PRESC} - 2047.5 \rfloor)) \quad (4)$$

$$PRESC = \left\lfloor \log_2 \times \frac{8191}{2 \times max(25, min(3000, kchip))} \right\rfloor \quad (5)$$

$$kchip = \frac{\text{chip\_rate} \times 4096 \times 128}{f_{ref}} \quad (6)$$

Chip_rate = desired chip rate.

f_{ref} = reference frequency (16 MHz)

Table 14. M-bus register setting Baud rate

M-bus radio link	OL2381 Register address		Chip rate (Chip/s)
	Timing0 (0x0e)	Timing1 (0x01)	
S	0x63	0x48	32768
T, C	0xcd	0x44	100000
R	0xd5	0x61	4800
F	0xd5	0x69	2400

4.3 PLL

The recommended value for the PLL loop bandwidth is ICP 2, as shown in Figure 16.

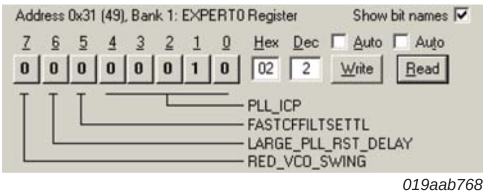

Fig 16. PLL loop bandwidth configuration

Table 15. M-Bus PLL register settings

M-Bus radio link	OL2381 register address	Information
	EXPERT0 (0x31 bank 1)	
S, T, C, R, F	0x02	current = 2 × 15 μA

Remark: This register EXPERT0 is located in Bank1 which means that it is necessary to switch the bank at address 0x3f to 0x01. Afterwards, switch back to 0x00.

4.4 Port configuration

Writing to, and reading from OL2381 registers is always done through SPI ports (green lines in Figure 17). The Host Controller is always clock master.

Sending and receiving RF data is done in this example through separate pins (blue lines in Figure 17) and the OL2381 is always clock master.

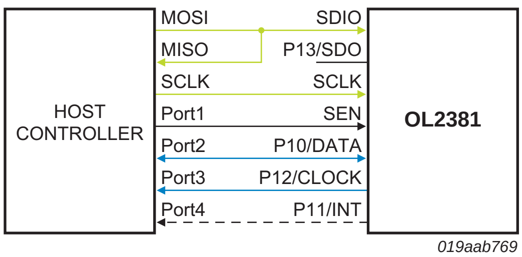

Fig 17. SPI communication and separate TX/RX data, clock port and Interrupt pins

The port register settings for this configuration are shown in the following sections.

Different configurations, such as working with a three wire interface, is explained in data sheet Ref. 1, application note Ref. 2. It is recommended that the SPI controller hardware is used to reduce processing load on the host controller, especially for data.

4.4.1 Port PORTCON0

The settings for register PORTCON0 are shown in Figure 18 which represents the reset condition for OL2381.

The data to the host controller can be inverted by setting bit P10INV to logic 1.

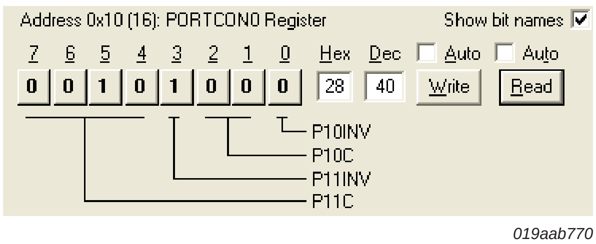

Fig 18. Port configuration PORTCON0

Table 16. M-Bus register PORTCON0 settings

M-Bus radio link	OL2381 Register address	Information
	PORTCON0 (0x10)	
S, T, C, R, F	0x28	reset condition

4.4.2 Port PORTCON1

Register PORTCON1 is set as shown in Figure 19 (P13/SDO is not used, and P12 is set as the clock pin). For applications that require an inverted clock, case bit P12INV is set.

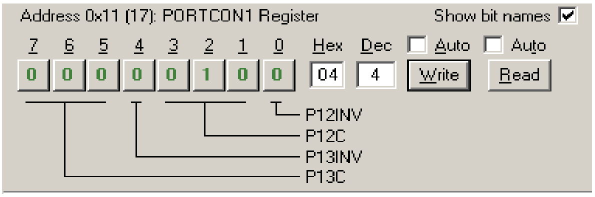

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Fig 19. Port configuration PORTCON1

Table 17. M-Bus register PORTCON1 settings

M-Bus radio link	OL2381 register address	Information
	PORTCON1 (0x11)	
S, T, C, R	0x04	pin 12 is the clock for RX and TX
F	0x05	pin 12 inverts the clock for RX and TX

4.4.3 Port PORTCON2

Register PORTCON2 is set as shown in Figure 20 (bits SEP_TX_LINES and SEP_RX_OUT set to 11).

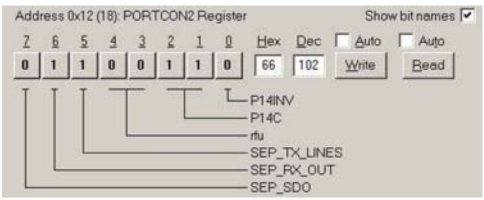

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Fig 20. Port configuration PORTCON2

Table 18. M-Bus register PORTCON2 settings

M-Bus radio link	OL2381 register address	Information
	PORTCON2 (0x12)	
S, T, C, R, F	0x66	7-wire interface

The configuration of P14 depends on the RF switch; details are given in data sheet Ref. 1. In this example it is set to provide “0” for RX-mode and “1” for TX-mode.

5. TX register settings

This section explains how to set the registers used by the transmitter in this application. The full transmitter flow chart is shown in Figure 21. Not all registers are described in this application note. Refer to data sheet Ref. 1 or application note Ref. 2 for more information.

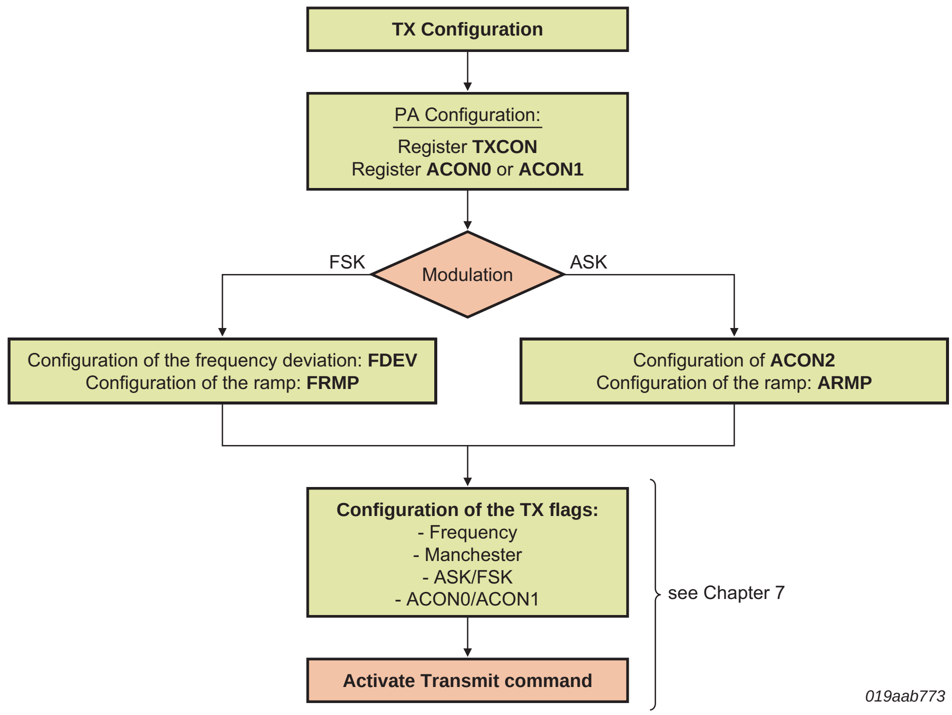

Fig 21. Flow chart of TX registers

5.1 Power Amplifier (PA) configuration

The PAM bits in register TXCON set the voltage for the power amplifier voltage regulator. PAM0 (PAM bits set to 00) is the recommended value for power amplifier operation. The S link and the R link use Manchester data, but there are some non-Manchester data bits in the preamble. As a result, the transmitter should work for all modes in the non-Manchester mode. The Manchester coding of the payload is performed by the host controller. These settings are shown in Figure 22.

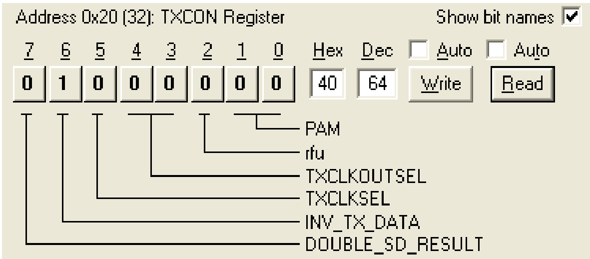

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Fig 22. PA configuration

Table 19. M-Bus PA register settings

M-Bus radio link	OL2381 register address	Information
	TXCON (0x20)	
S, T, C, R, F	0x40	PAM = 0, TXCLKSEL = 0, send inverted data

Output power can be trimmed by setting bits AMH0 in register ACON0. Setting register ACON0 as shown in Figure 23 provides approximately 10 dBm of output power.

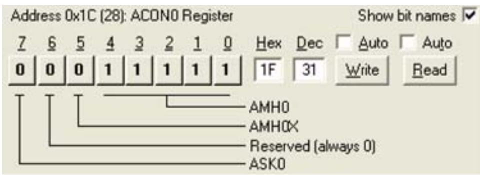

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Fig 23. Output power configuration

Table 20. M-Bus output power register settings for FSK-mode

M-Bus radio link	OL2381 register address	Output power
	ACON0 (0x1C)	
S, T, C, R, F	0x00	approximately −70 dBm (PA off)
S, T, C, R, F	0x01	approximately −20 dBm
...	...	...
S, T, C, R, F	0x1F	approximately +10 dBm

5.2 Modulation type and frequency deviation

ASK0 bit is set to 0 for FSK modulation; see Figure 23.

Register FDEV configures the frequency deviation; see Figure 24.

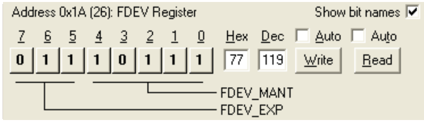

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Fig 24. Frequency deviation configuration

$$\mathrm{FDEV\_EXP} = min\left(7, max\left\{\left\lfloor \frac{1 + \mathrm{DOUBLE\_SD\_RESULT}}{1 + \mathrm{RF\_LO\_DIV}} \right\rfloor, \left\lfloor \log_2 \times \frac{FDEV}{15.75} \right\rfloor\right\}\right) \quad (7)$$

$$\mathrm{FDEV\_MANT} = min\left(31, \left\lfloor 0.5 + \frac{FDEV}{2^{FDEV\_EXP}} \right\rfloor\right) \quad (8)$$

Where:

f_{dev} = wanted frequency deviation.

FDEV = f_{dev} × 65 536 / 16 000 000 [= reference clock].

DOUBLE_SD_RESULT = 0.

$\mathrm{RF\_LO\_DIV}_{[S,T,C,R]}$ = 0.

$\mathrm{RF\_LO\_DIV}_{[F]}$ = 1.

$$\lfloor\ \rfloor = floor\ ()\ function\ (\mathrm{e.g.}\, 2.8 \rightarrow 2) \quad (9)$$

Table 21. M-Bus frequency deviation register settings

M-Bus radio link	OL2381 register address	Output power
	FDEV (0x1A)	
S	0x7A	f_{dev} = 50 kHz
T, C	0x77	f_{dev} = 45 kHz
R	0x2C	f_{dev} = 6 kHz
F	0x17	f_{dev} = 5.5 kHz

5.3 Soft-FSK

To reduce transmit bandwidth in mode C2, the European standard Ref. 3 uses G-FSK for the link collector to meter. The OL2381 reduces transmit bandwidth by a linear interpolation approach, see Figure 25 and Figure 26.

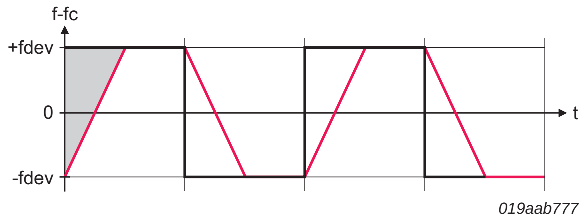

Fig 25. Linear shaping of FSK signal

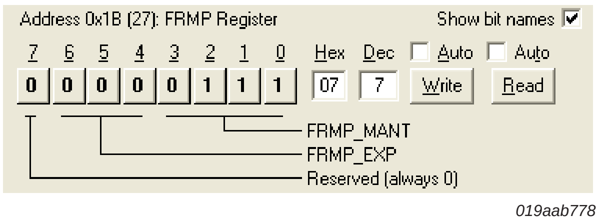

Fig 26. Soft FSK register settings

The settings in Table 22, provide a value of 50 % slope for C-mode.

Table 22. M-Bus soft-FSK register settings

M-Bus radio link	OL2381 register address	Information
	FRMP (0x1B)	
C	0x07	50 % slope at this data rate
S, T, R, F	0x00	rectangular

Remark: This value represents the slew rate of the baseband signal and it must be recalculated for other data rates; see data sheet Ref. 1.

6. RX register settings

This section explains how to set the registers used by the receiver in this application. The full receiver flow chart is shown in Figure 27. Not all registers are described in this application note. Refer to data sheet Ref. 1 or application note Ref. 2 for more information.

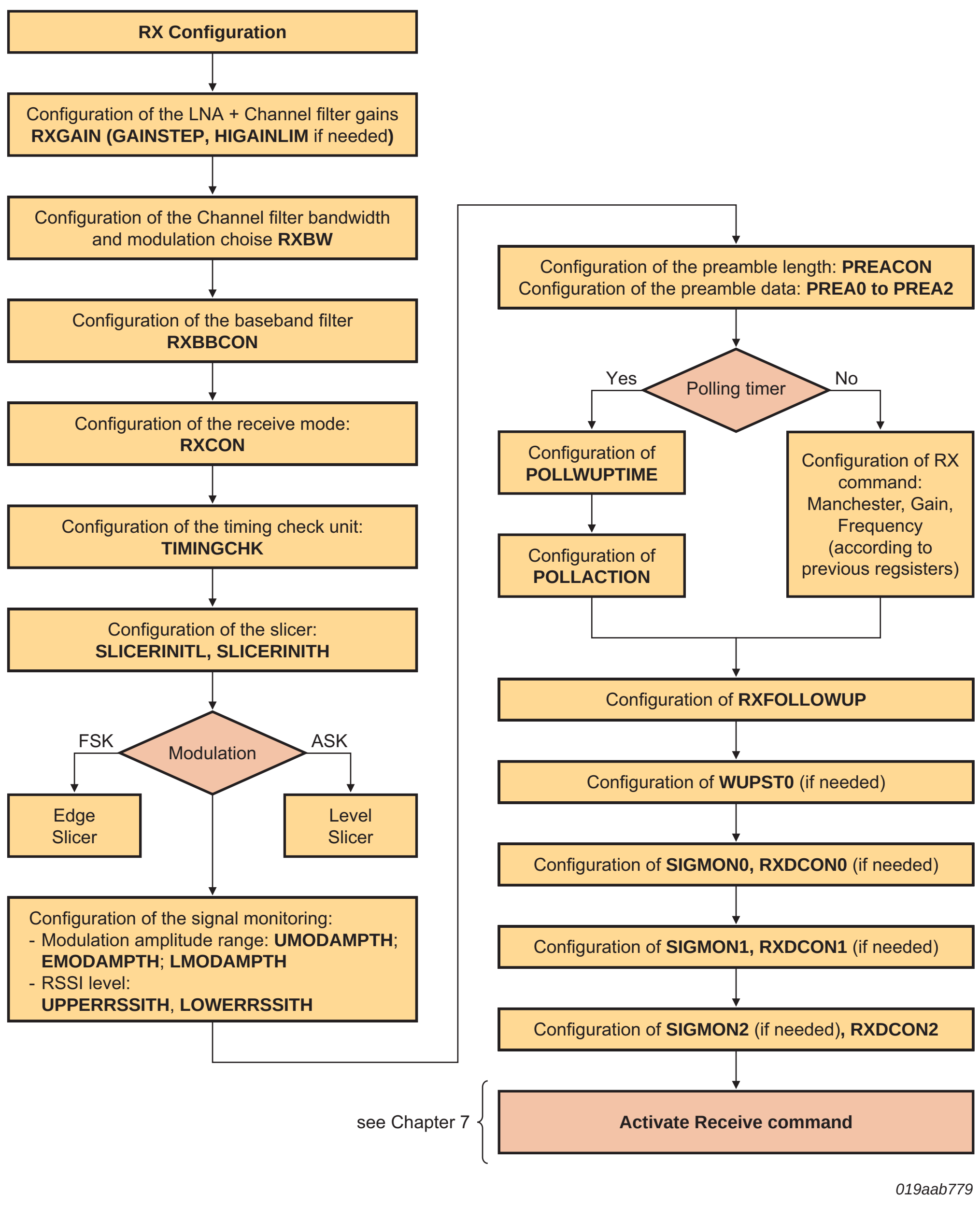

Fig 27. RX registers flow chart

6.1 LNA configuration

The gain of the LNA can be programmed in 16 steps. In WUPS mode, the receiver automatically detects the signal strength and decides to use either the HI_GAIN, or the LOW_GAIN setting. This is important to achieve a large dynamic range.

In this example, HI_GAIN is set to maximum gain and LOW_GAIN is set to minimum gain. This is shown in Figure 28 (default value).

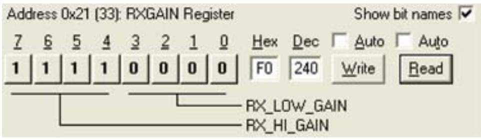

Fig 28. LNA configuration

Table 23. M-Bus LNA configuration register settings

M-Bus radio link	OL2381 register address	Information
	RXGAIN (0x21)	
S, T, C, R, F	0xF0	HI_GAIN = maximum, LOW_GAIN = minimum

If the RSSI exceeds the value given in register HIGAINLIM during wake-up search (see Figure 29), the receiver switches to LOW_GAIN. The GAINSTEP register is set to 0.

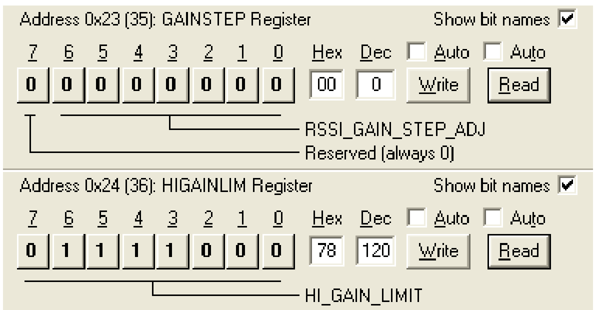

Fig 29. Automatic gain

Table 24. M-Bus automatic gain register settings

M-Bus radio link	OL2381 register address		Information
	GAINSTEP (0x23)	HIGAINLIM (0x24)	
S, T, C, R, F	0x00	0x78	at this input power the LNA switches to LO_GAIN

6.2 Channel bandwidth configuration

Register RXBW sets the demodulation choice (ASK/FSK) and channel filter (IF) bandwidth. If FSK modulation is used, bit DEMOD_ASK is set to logic 0.

To optimize receiver performance, the bandwidth is chosen carefully. It must be close to the bandwidth occupied by the modulated signal including the center frequency tolerances of transmitter and receiver.

The center frequency tolerances are mainly dependent on the crystal used in the receiver and transmitter. This is not calculated in the following example.

RSSI_FILTER_FC is set to 5 which means that the RSSI value is filtered so that the bandwidth value is more stable.

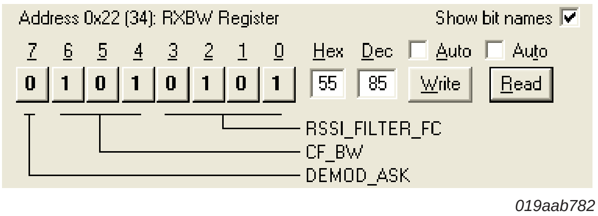

Fig 30. Register RXBW

Table 25. M-Bus channel bandwidth register settings

M-Bus radio link	OL2381 register address RXBW (0x22)	Information
S	0x15	f_{dev} = 80 kHz, f_{mod} = 16.6 kHz → BW = 200 kHz
T, C	0x05	f_{dev} = 80 kHz, f_{mod} = 55 kHz → BW = 300 kHz
R, F	0x55	f_{dev} = 7.2 kHz, f_{mod} = 2.4 kHz → BW = 50 kHz

$BW \geq 2 \times (f_{dev} + f_{mod})$ (as a rule of thumb, crystal tolerance is not considered).

Where:

f_{dev} = maximum displayed frequency deviation.

f_{mod} = maximum displayed modulation frequency.

If higher bandwidth is required, set register EXPERT2 (0x33 bank 1) to 0xC2.

Table 26. M-Bus channel register settings for EXPERT2 register

M-Bus radio link	OL2381 register address EXPERT2 (0x33 bank 1)	Information
S, T, C	0xc2	set bit 6 and bit 7 for BW > 200 kHz
R, F	0x02	default

6.3 Baseband filter configuration

Register RXBBCON sets the baseband filter cut-off frequency. It must be appropriate to the selected chip rate; see Figure 31.

DEGLITCHER_WINDOW_LEN is set to 01 to reduce noise.

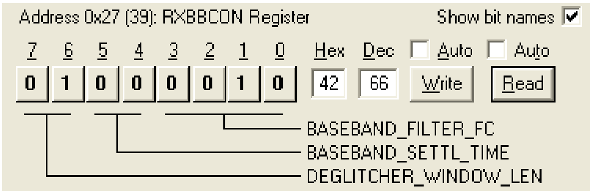

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Fig 31. Baseband filter configuration

Table 27. M-Bus baseband filter cut-off frequency register settings

M-Bus radio link	OL2381 register address	Information ($f_c > 0.5 \times$ chip rate)	
	RXBBCON (0x27)		
S	0x42	chip rate = 32768	$\rightarrow f_c$ = 28.405 kHz
T, C	0x41	chip rate = 100000	$\rightarrow f_c$ = 57.174 kHz
R	0x45	chip rate = 4800	$\rightarrow f_c$ = 3.5400 kHz
F	0x46	chip rate = 2400	$\rightarrow f_c$ = 1.7701 kHz

6.4 Manchester decoder and clock recovery

The Manchester decoder is activated in register RXCON as shown in Figure 32. The Manchester decoder is used for S and R radio links (→ Manchester violations during preamble are supported). CLOCK_RECOV_TC for clock rate deviation is set to 01 supporting a maximum TX baud rate frequency tolerance of 4 %.

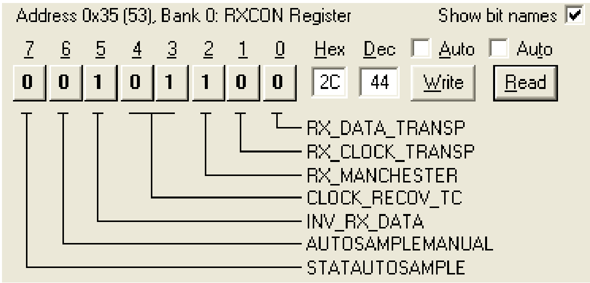

Fig 32. Manchester decoder

Table 28. M-Bus Manchester decoder register settings

M-Bus radio link	OL2381 register address	Information
	RXCON (0x35)	
S, R	0x2C	Manchester 4 % clock deviation inverted at RX
T, C, F	0x29	no Manchester 4 % clock deviation inverted at RX; transparent

6.5 Slicer configuration

The edge slicer is recommended for FSK modulation as shown in Figure 33 (SLICERSEL_D[5:4] set to 00). Registers 0x2B, 0x2C and 0x2D are set to 00.

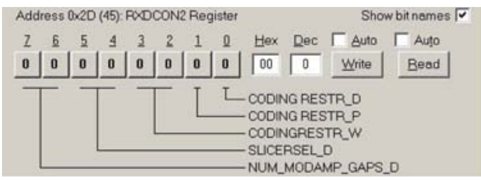

Fig 33. Slicer configuration

Table 29. M-Bus slicer configuration register settings

M-Bus radio link	OL2381 register address			Information
	RXDCON0 (0x2B)	RXDCON1 (0x2C)	RXDCON2 (0x2D)	
S, T, C, R, F	0x00	0x00	0x00	edge slicer

6.6 Expected modulation amplitude configuration

The expected peak modulation is configured to obtain the optimum receiver settings. Register EMODAMPTH (see Figure 34) holds the expected peak deviation value which is compared with the actual received baseband signal. Good results can be found if calculated with an f_{dev} of 70 %. If a higher bandwidth is required, set register EXPERT2 (see Section 6.2). The formula to calculate the expected modulation amplitude configuration is then different.

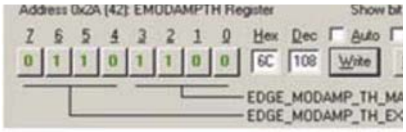

Fig 34. Expected modulation amplitude configuration

$$\text{EDGE\_MODAMP\_TH\_EXP} = min\left(15, \left\lfloor \log_2\left(\frac{max(15, x)}{7.75}\right) \right\rfloor\right) \quad (10)$$

$$\text{EDGE\_MODAMP\_TH\_MANT} = min\left(15, \left\lfloor \frac{x}{2^{EDGE\_MODAMP\_TH\_EXP}} + 0.5 \right\rfloor\right) \quad (11)$$

Where:

f_{dev} = desired modulation deviation

X = 33256 * f_{dev} / 600 kHz (for S,T and C)

X = 33256 * f_{dev} / 200 kHz (for R and F)

EDGE_MODAMPTH_TH_MANT = 1100b.

Table 30. M-Bus edge slicer configuration register settings

M-Bus radio link	OL2381 register address EMODAMPTH (0x2A)	Information
S, T, C	0x7C	$f_{dev(min)}$ = 40 kHz, X = 2217, $X_{70\,\%}$ = 1552 ~ 12 × 2^7
R, F	0x68	$f_{dev(min)}$ = 4.8 kHz, X = 798, $X_{70\,\%}$ = 559 ~ 8 × 2^6

6.7 RX sequence

The following RX sequence (see Figure 35) is used in this example:

- WUPS (Wake-UP Search)
- Preamble detection (find synchronization word)
- Data reception

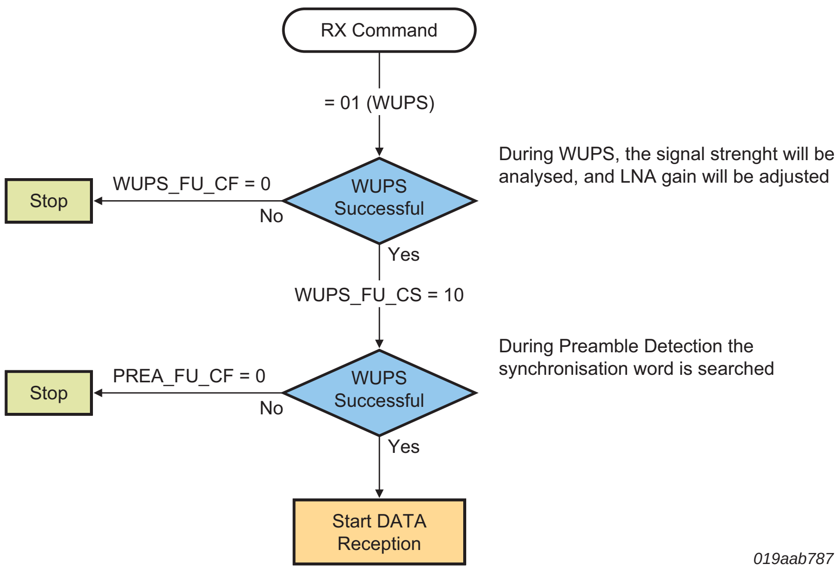

Fig 35. RX sequence

Remark: In this example, all signal monitors (see Section 6.8) are disabled. Therefore the "stop condition" never occurs. However, the advantage of WUPS in this example is that the LNA gain is selected automatically; see Section 6.1.

The previous sequence can be set with register RX_FOLLOWUP; see Figure 36.

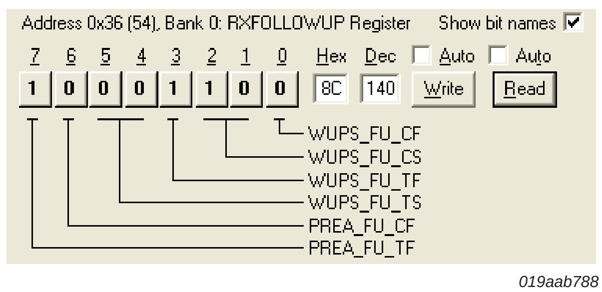

Fig 36. Register RX_FOLLOWUP

Table 31. M-Bus RX_FOLLOWUP register settings

M-Bus radio link	OL2381 register address RX_FOLLOWUP (0x36)	Information
S, T, C, R, F	0x8C	see Figure 35

6.8 Signal monitors

Signal monitors are not used in this example. Signal monitors can be used to analyze the reception signal regarding strength, coding, and timing without involving the host controller. The use of signal monitors is explained in application note Ref. 2.

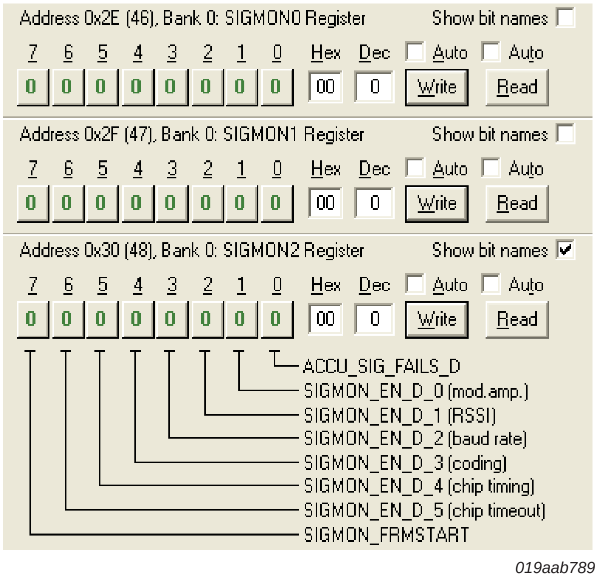

Fig 37. Signal monitors

Table 32. M-Bus signal monitors register settings

M-Bus radio link	OL2381 register address			Information
	SIGMON0 (0x2E)	SIGMON1 (0x2F)	SIGMON2 (0x30)	
S, T, C, R, F	0x00	0x00	0x00	signal monitors not used

6.9 Preamble detection

The OL2381 has preamble pattern recognition. The value of the preamble (synchronization word) is known in advance so the value of the preamble in the receiver is configured according to this value. Five registers are used to configure the preamble; see Figure 38. Register PREACON (address: 0x3A) configures the preamble length and the number of chip errors allowed during preamble detection. The value of the preamble that the receiver must recognize, is set in registers PREA0 to PREA3 (addresses: 0x3B to 0x3E).

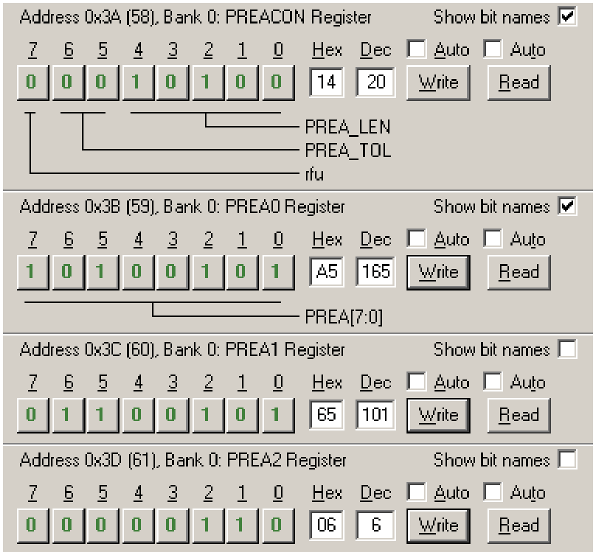

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Fig 38. Preamble configuration registers

Table 33. M-Bus preamble structure

M-Bus radio link	Preamble		Information
	Header	Synchronization word	
S, R	n × (01)	0001110110100101 10	n ≥ 15 or n ≥ 39 or n ≥ 279
T, C	n × (01)	0000111101	n ≥ 19
F	n × (01)	0001110101001011 0	n ≥ 39

Table 34. M-Bus preamble length and value register settings

M-Bus radio link	OL2381 register addre					Information
	PREACON (0x3A)	PREA0 (0x3B)	PREA1 (0x3C)	PREA2 (0x3D)	PREA3 (0x3E)	
S, R	0x12	0x96	0x76	0x54	0x55	length = 18, no chip errors
T, C	0x0A	0x3D	0x54	0x55	0x55	length = 10, no chip errors
F	0x11	0x96	0x3A	0xAA	0xAA	length = 17, no chip errors

To avoid too many fail recognitions due to noise, increase the value in register 0x3A. Good results can be found by setting register 0x3A to a value of 0x14 (length = 20).

7. Activate transmit or receive operation

7.1 TX command

To enter the transmit mode, a transmit command is sent to OL2381 on the SPI line. It is activated by sending the ninth clock edge (eight clock edges for D0 to D7and the ninth clock for activating the transmitter). Table 35 shows the transmit command packet.

Table 35. Transmit packet

D0	D1	D2	D3	D4	D5	D6	D7
1	1	transmitter frequency selection bits		data and power amplifier synchronization bit	power amplifier control bit	Manchester generation bit	amplitude selection bit
1	1	0	0	0	0	0	0

Table 36. M-Bus transmit command

M-Bus radio link	OL2381 transmit command	Information
	Address is the command	
S, T, C, R, F	0xC0	frequency 0, FSK, no Manchester

Due to Manchester violations in the preamble, the host controller for links S and R must create the Manchester data. Therefore, all wireless M-Bus modes must use the "no Manchester" setup.

7.2 RX command

To enter the receive mode, a receive command is sent to OL2381 on the SPI line. It is activated by sending the ninth clock edge (eight clock edges for D0 to D7, and the ninth clock for activating the receiver). Table 37 shows the receive command packet.

Table 37. Receive packet

D0	D1	D2	D3	D4	D5	D6	D7
1	0	receiver frequency selection bits		WUPS/PRDA or data reception		gain setting	
1	0	0	0	0	1	0	1

Table 38. M-Bus receive command

M-Bus radio link	OL2381 receive command	Information
	Address is the command	
S, T, C, R, F	0x85	frequency 0, WUPS, automatic gain

7.3 RX current reduction

The current consumption of battery powered receivers is an issue. To prolong battery life, the OL2381 implements several automatic functions, most of which run without the host controller and with reduced current consumption.

An example of the following functions can be found in the general application note AN11039; refer to Ref. 2

- **Polling timer**

  The host controller and OL2381 are in Power-down mode. The OL2381 awakes automatically at the desired time and goes into → WUPS mode. If no valid telegram is recognized, it re-enters the Power-down mode. The use of signal monitors is recommended to enable fast recognition. The host controller is not involved.

- **WUPS**

  If OL2381 is awake, the signal is analyzed regarding strength, coding, and timing. During this state, the gain of the LNA is set to HI_GAIN or LO_GAIN. If conditions are satisfied, the OL2381 enters → preamble detection mode. If no conditions are set, the OL2381 enters → preamble detection mode The host controller is not involved.

- **Preamble detection**

  If the signal is in the correct range, the preamble is sought. If the preamble is found, an interrupt starts the host controller. The OL2381 enters → data reception mode.

- **Data reception**

  If preamble is found, the host controller obtains data from the OL2381.

Using this mechanism, the mean current consumption could be reduced. The reduction depends mainly on the setup of the polling timer.

8. Hardware

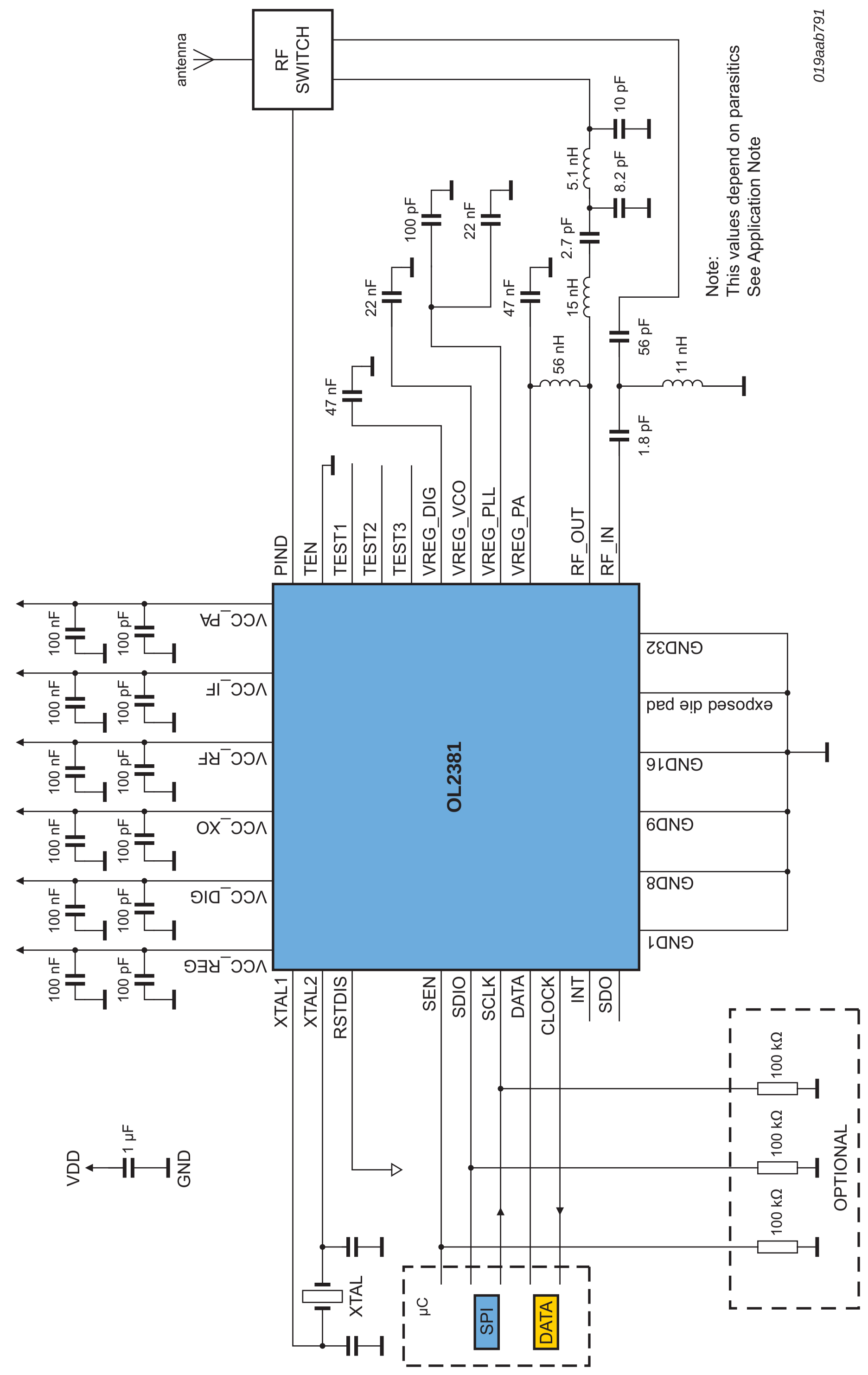

Fig 39. OL2381 typical schematic for 868 MHz

Figure 39 shows a typical application schematic for the OL2381 operating in the 868 MHz telemetry band.

Note the following:

- At layout, there must be one whole ground plane on the underside.
- A transitional ground plane must be below the RF signal path.
- All components that have a ground pin, must have a via to the ground plane as short as possible.
- The resistors can be removed if the microcontroller always drives the inputs to a legal state. Floating inputs can lead to increased current consumption.
- The inductance and capacitance values at the RF_IN and RF_OUT path depend on the parasitic of the layout. To ensure a good RF performance, verify these values after board layout.
- The capacitors connected to the V_{CC} pins depend on the layout. The 100 pF capacitor types must be as close as possible to the pin. If the pin has another 100 nF capacitor nearby, some 100 nF capacitors can be removed.

9. Software

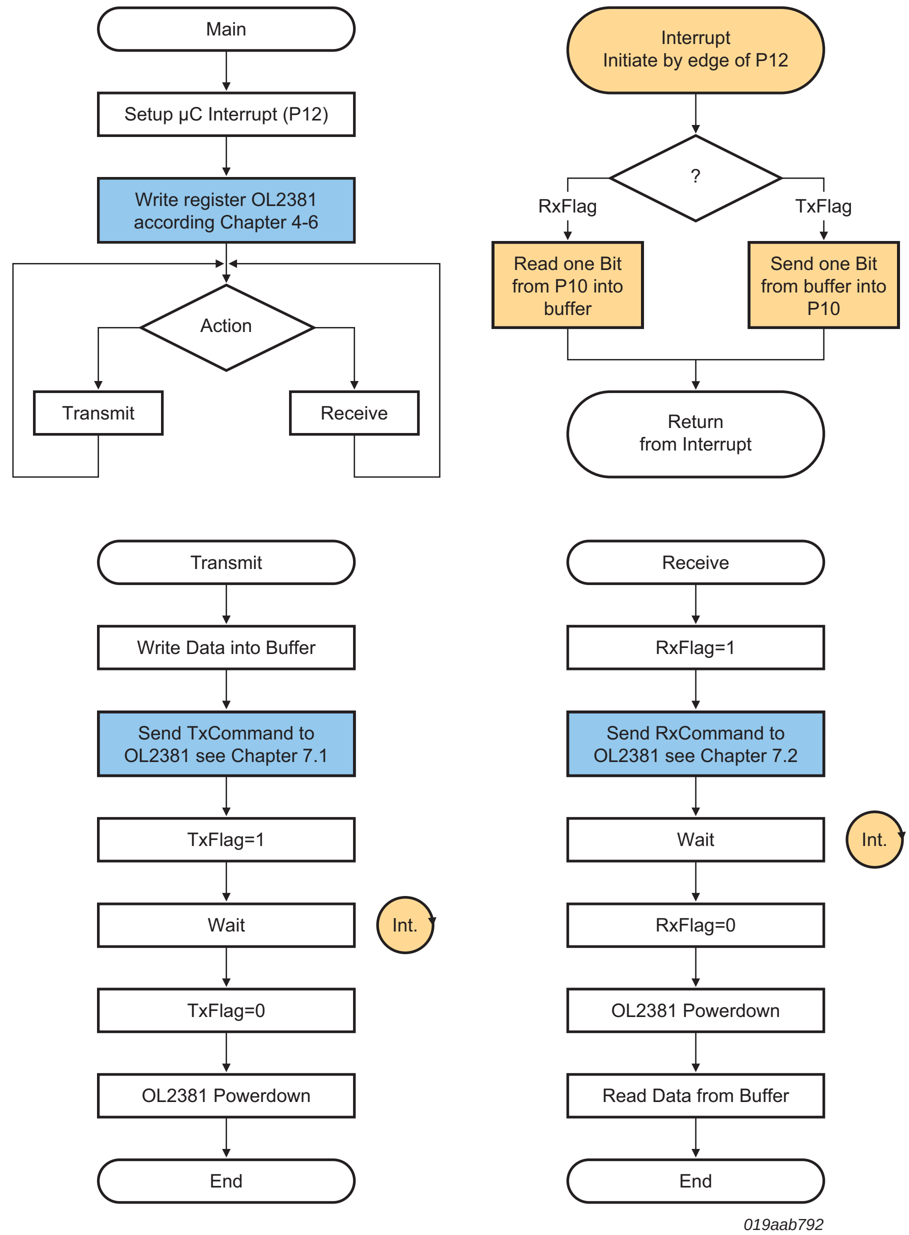

Fig 40. Software example

Figure 40 shows an example of how the software can be configured to operate.

The blue blocks show the communication to OL2381 via the SPI interface; see Figure 39.

The yellow blocks represent data transfers to and from OL2381 via the data interface; see Figure 39.

If the hardware SPI is used, the ‘yellow function’ is not needed. Instead, the hardware automatically reads bits in and sends bits out. The interrupt load shown in the application, can be very high, so the use of a hardware SPI is especially recommended for the data interface. For example, at a data rate of 100 kchip/s there is one interrupt every 10 μs.

10. Register configuration

Figure 41 to Figure 45 show configurations for S, T, C, R and F radio links.

```
;       x0 x1 x2 x3 x4 x5 x6 x7 x8 x9 xa xb xc xd xe xf
; visible in bank 0,1
01_0x = 60 26 b2 00 00 00 00 00 00 00 00 00 20 00 63 48
01_1x = 28 04 66 00 00 01 ff 00 04 01 7a 00 1f 00 00 00
01_2x = 40 f0 15 00 78 00 00 42 00 00 99 00 00 00 -- --
01_3x = -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00
; visible in bank 0
0_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
0_3x  = 00 00 00 00 00 2c 8c 00 00 00 00 96 76 54 55 --
; visible in bank 1
1_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 80 00
1_3x  = 00 02 49 02 00 60 00 00 00 00 00 00 00 00 00 –
```

019aab793

Fig 41. OL2381 register settings for S-mode

```
;       x0 x1 x2 x3 x4 x5 x6 x7 x8 x9 xa xb xc xd xe xf
; visible in bank 0,1
01_0x = 90 79 b2 00 00 00 00 00 00 00 00 00 20 00 cd 44
01_1x = 28 04 66 00 00 01 ff 00 04 01 7a 00 1f 00 00 00
01_2x = 40 f0 05 00 78 00 00 41 00 00 99 00 00 00 -- --
01_3x = -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00
; visible in bank 0
0_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
0_3x  = 00 00 00 00 00 29 8c 00 00 00 00 3d 54 55 55 --
; visible in bank 1
1_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 80 00
1_3x  = 00 02 49 02 00 60 00 00 00 00 00 00 00 00 00 --
```

019aab794

Fig 42. OL2381 register settings for T-mode

```
;       x0 x1 x2 x3 x4 x5 x6 x7 x8 x9 xa xb xc xd xe xf
; visible in bank 0,1
01_0x = 30 c3 b2 00 00 00 00 00 00 00 00 00 20 00 cd 44
01_1x = 28 04 66 00 00 01 ff 00 04 01 7a 07 1f 00 00 00
01_2x = 40 f0 05 00 78 00 00 41 00 00 99 00 00 00 -- --
01_3x = -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00
; visible in bank 0
0_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
0_3x  = 00 00 00 00 00 29 8c 00 00 00 00 3d 54 55 55 --
; visible in bank 1
1_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 80 00
1_3x  = 00 02 49 02 00 60 00 00 00 00 00 00 00 00 00 --
```

019aab795

Fig 43. OL2381 register settings for C-mode

```
;       x0 x1 x2 x3 x4 x5 x6 x7 x8 x9 xa xb xc xd xe xf
; visible in bank 0,1
01_0x = d0 03 b2 00 00 00 00 00 00 00 00 00 20 00 d5 61
01_1x = 28 04 66 00 00 01 ff 00 04 01 2c 00 1f 00 00 00
01_2x = 40 f0 55 00 78 00 00 45 00 00 68 00 00 00 -- --
01_3x = -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00
; visible in bank 0
0_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
0_3x  = 00 00 00 00 00 2c 8c 00 00 00 00 96 76 54 55 --
; visible in bank 1
1_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 80 00
1_3x  = 00 02 49 02 00 60 00 00 00 00 00 00 00 00 00 –
```

019aab796

Fig 44. OL2381 register settings for R-mode

```
;       x0 x1 x2 x3 x4 x5 x6 x7 x8 x9 xa xb xc xd xe xf
; visible in bank 0,1
01_0x = e0 d1 b1 00 00 00 00 00 00 00 00 00 20 01 d5 69
01_1x = 28 05 66 00 00 01 ff 00 04 01 17 00 1f 00 00 00
01_2x = 40 f0 55 00 78 00 00 46 00 00 68 00 00 00 -- --
01_3x = -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00
; visible in bank 0
0_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
0_3x  = 00 00 00 00 00 29 8c 00 00 00 1a 96 3a aa aa --
; visible in bank 1
1_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 80 00
1_3x  = 00 02 49 02 00 60 00 00 00 00 00 00 00 00 00 --
```

019aab797

Fig 45. OL2381 register settings for F-mode

The OL2381 implements all calibrations automatically in these examples.

Take care when writing to addresses 0x0C, 0x18, bank 0 and 0x2F, 0x30, 0x34, 0x39 bank 1. These writes can start calibration processes or change calibration data. The best solution is not to write to these addresses in simple applications.

In time-critical applications where the time between RX and TX is important, the calibration can be skipped. In this case, the user must handle the calibration.

To obtain the repeatable register settings shown in Figure 41 to Figure 45, the following steps are executed:

- write all OL2381 registers to 0x00
- reset OL2381 by writing 0x01 to register 0x13 (this puts most registers into the default state, the remainder stay at 0x00)
- program the registers described in Section 4 to Section 6

11. Abbreviations

Table 39. Abbreviations

Acronym	Description
FSK	Frequency Shift-Keying
GFSK	Gaussian FSK
LNA	Low-Noise Amplifier
NRZ	Not Return to Zero
PLL	Phase-Locked Loop
RSSI	Residual Signal Strength Indicator
SPI	Serial Peripheral Interface
SRD	Short Range Device
VCO	Voltage Controlled Oscillator
WUPS	Wake-UP Search

12. References

[1] **Data sheet —** OL2381.

[2] **Application note —** AN11039.

[3] **European Standard [EN 13757-4] —** Working draft dated 2010-09-09.

[4] **Electromagnetic compatibility and Radio spectrum Matters (ERM) —** ETSI EN 300 220.

[5] **European Standard [EN 13757-4] —** Release date, June 2005.

[6] **URL —** http://www.nxp.com/smartmetering.

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14. Contents

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