# AN10996

## OL2381 Quick set-up

Rev. 1 — 5 July 2011 Application note

### Document information

| Info | Content |
|---|---|
| **Keywords** | OL2381, registers, set-up |
| **Abstract** | This application note describes how to quickly set-up the OL2381 registers for transmit and receive communication. |

### Revision history

| Rev | Date | Description |
|---|---|---|
| v.1 | 20110705 | initial version |

## Contact information

For more information, please visit: **http://www.nxp.com**

For sales office addresses, please send an email to: **salesaddresses@nxp.com**

# 1. Introduction

This application note describes how to quickly set-up the OL2381 registers for transmit and receive communication.

This application note describes how to set the transmitter and receiver to the following:

- Modulation: FSK (Frequency-Shift Keying)
- Operating frequency: 868 MHz
- Baud rate: 4.8 kbit/s
- Frequency deviation: 4.8 kHz
- Data encoding: Manchester

The receiver is set for data reception.

Polling, wake-up search and preamble detection are not used.

The application settings used in this application note apply to a basic application and many important OL2381 features are not used. More detailed evaluation information is available in the data sheet, application note and user guide for the OL2381. Register settings which require to be set to values that are different to their reset are described. The settings used in this application note are provided in a configuration file in Section 4.8 on page 17.

A Graphical User Interface (GUI)[1] is used to show register settings for both transmitter and receiver. Figure 12 on page 12 and Figure 13 on page 12 (transmitter results) show only the use of Manchester encoding to send data (10101010…)

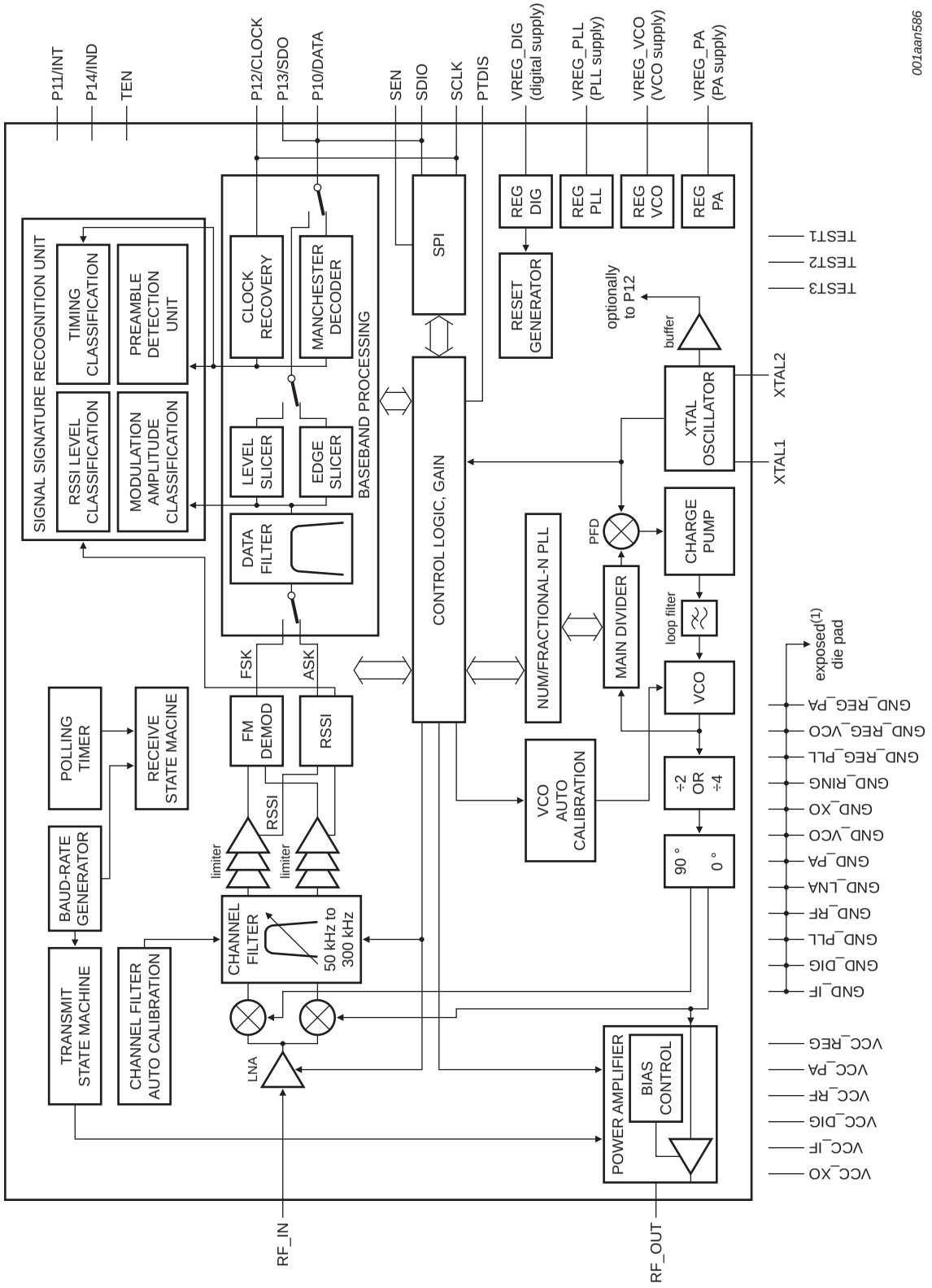
In all examples, except Figure 22 on page 17, the OL2381 pseudo-random generator is disabled: register PORTCON0[2:1] is set to 00; see Figure 23 on page 18. The waveforms in Figure 22 on page 17 show the OL2381 pseudo-random generator enabled to send data.

The general registers shown in the following graphics that are required for receiver and transmitter functions are colored blue; registers required only for receiver operation are yellow, and registers required only for transmitter operation are green.

Once this simple application has been setup and running, more complex applications can be built on this one by adding more useful built-in features.

A block diagram of the OL2381 is shown in Figure 1.

1. The OL2381 GUI is available from NXP on request.




(1) All internal domain grounds including external GND pins 1, 8, 9, 16 and 32 are connected to the exposed die pad.

**Fig 1. OL2381 block diagram**

# 2. General registers

This section briefly explains how to set the common registers used by the receiver and transmitter. This setting is explained in the flow chart Figure 2.

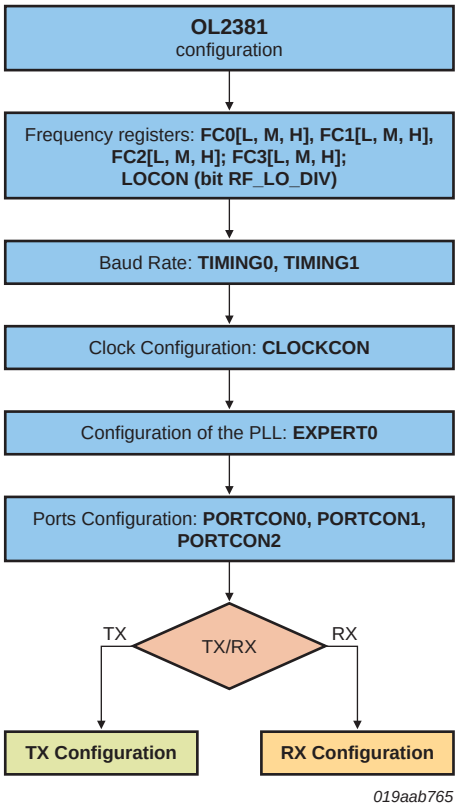



**Fig 2. General registers flow chart**

## 2.1 Frequency

The OL2381 registers allow up to four frequencies to be set. In this application note, only one frequency is set for simplicity. Figure 3 shows the register settings for 868 MHz and the equations to calculate them. Frequencies above 500 MHz require the VCO frequency to be divided by 2 (bit RF_LO_DIV set to logic 0).

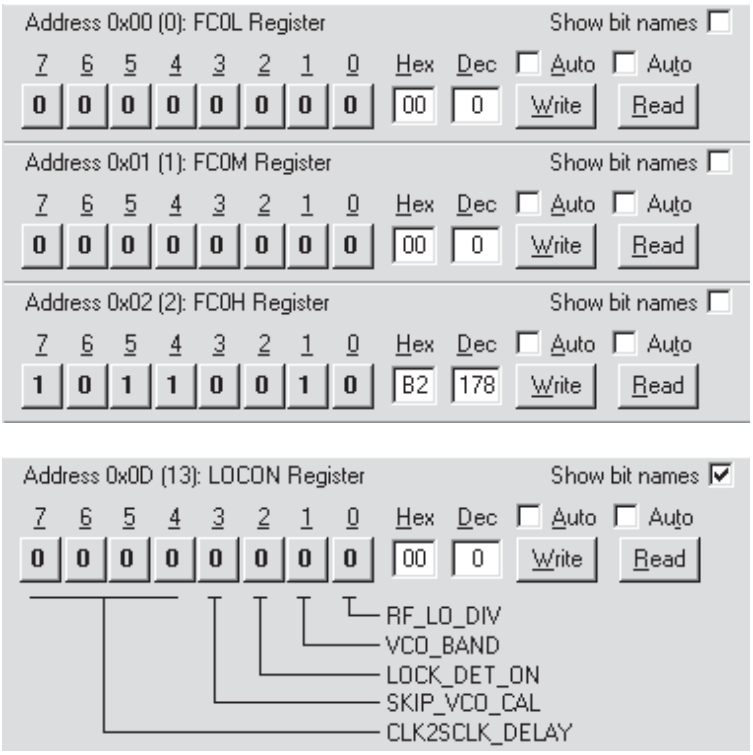



**Fig 3. Frequency configuration**

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

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

Where:

RF_LO_DIV = 0.

$f_{ref}$ = 16 MHz.

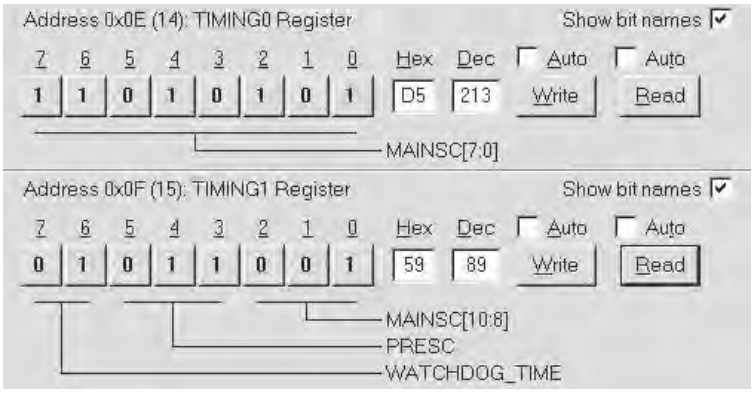
$f_{RF}$ = 868 MHz.

FCx[19:15] = 00110b.

FCx[14:0] = 010000000000000b.

## 2.2 Baud rate

Figure 4 shows the register settings for a baud rate of 4.8 kbit/s and the equations to calculate them. Note that the chip rate is set to 9.6 kbit/s because the data is Manchester encoded.




019aac369

**Fig 4. Baud rate configuration**

$$kchip = \frac{\text{chip\_rate} \times 4096 \times 128}{f_{ref}} = \frac{2048 + MAINSC}{2^{PRESC}} \quad (3)$$

$$PRESC = \left\lfloor \log 2\left(\frac{8191}{2 \times max(25, min(3000, kchip))}\right) \right\rfloor \quad (4)$$

Where:

chip rate = 9600 bit/s.

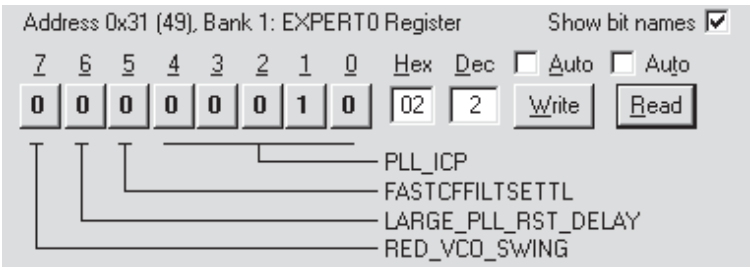
$f_{ref}$ = 16 MHz.

PRESC = 011b.

MAINSC = 00111010101b.

## 2.3 PLL

The recommended value for PLL bandwidth is ICP 2 as shown in Figure 5.




019aac370

**Fig 5. PLL bandwidth configuration**

### 2.4 Ports configuration

Writing to (and reading from) OL2381 registers is always done via the SPI ports. Data can be sent and received either via the SPI or OL2381 ports P10, P11, and P12. In this example, ports are used and register PORTCON2 must be set as shown in Figure 6 (bits SEP_TX_LINES and SEP_RX_OUT set to 11).

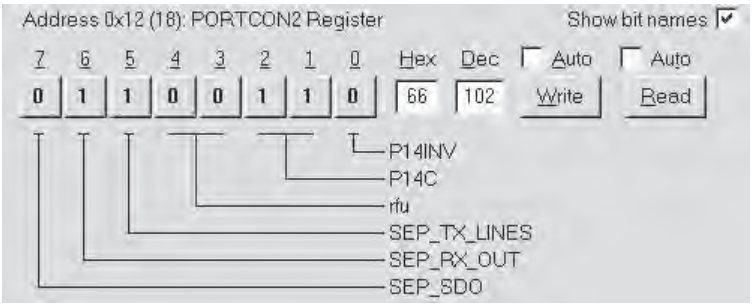



**Fig 6. Ports configuration**

The configuration of P14 depends on the RF switch; details are given in the data sheet.

## 3. TX registers

This section explains how to set the registers used by the transmitter for this application.

The complete transmit flow chart is shown in Figure 7.

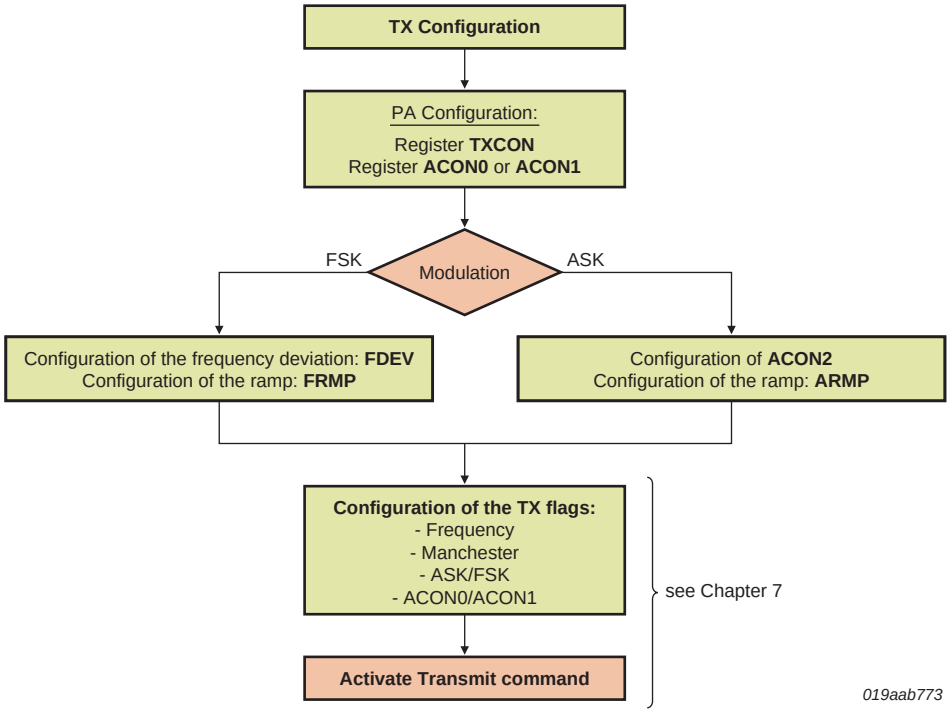



**Fig 7. TX register flow chart**

## 3.1 Power amplifier (PA) configuration

Bits PAM[1:0] in register TXCON set the voltage for the power amplifier voltage regulator. PAM0 (PAM[1:0] set to 00) is the recommended value for power amplifier operation. The Manchester encoded data requires the chip clock to be used as the transmit clock (TXCLKSEL = 1) as shown in Figure 8.

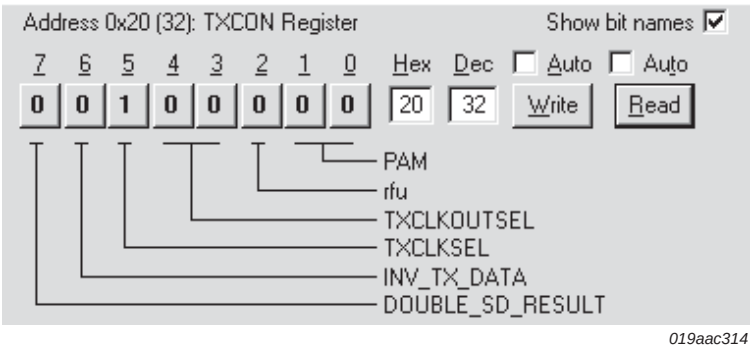



**Fig 8. PA configuration**

The output power can be trimmed by bits AMH0[4:0] in register ACON0. Setting register ACON0 as shown in Figure 9 should provide an output power of about 10 dBm.

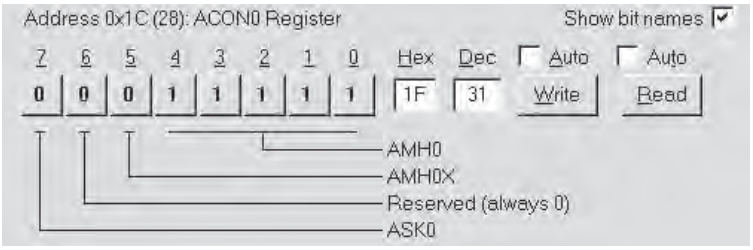



**Fig 9. Output power configuration**

## 3.2 Frequency modulation and deviation

Bit ASK0 (Figure 9) is set to logic 0 for FSK modulation. Register FDEV configures the frequency deviation, which in this example is set to 4.8 kHz as shown in Figure 10.

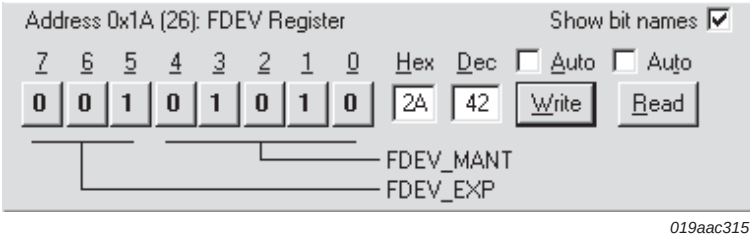



**Fig 10. Frequency deviation configuration**

$$\text{FDEV\_EXP} = min\left\{7, \max\left\{\left\lfloor \frac{1 + \text{DOUBLE\_SD\_RESULT}}{1 + \text{RF\_LO\_DIV}} \right\rfloor, \left\lfloor log2\left(\frac{FDEV}{15.75}\right) \right\rfloor\right\}\right\} \quad (5)$$

$$\text{FDEV\_MANT} = min\left\{31, \left\lfloor 0.5 + \frac{FDEV}{2^{\text{FDEV\_EXP}}} \right\rfloor\right\} \quad (6)$$

Where:

FDEV = 65536 × $f_{dev}$ / $f_{ref}$.

$f_{dev}$ = 4.8 kHz.

$f_{ref}$ = 16 MHz.

DOUBLE_SD_RESULT = 0.

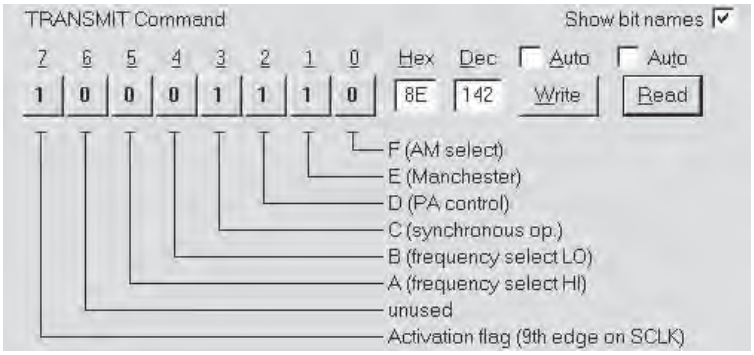
RF_LO_DIV = 0.

FDEV_EXP = 001b.

FDEV_MANT = 01010b.

## 3.3 TX flags

Transmit mode is entered by sending a transmit command to OL2381 and is activated on the 9th clock edge. Figure 11 shows the transmit command configuration for Manchester encoded data.




019aac159

Frequency channel 0 selected, FSK, Manchester encoding, synchronized mode + activation on 9th clock edge.

**Fig 11. Transmit command**

## 3.4 Results

Figure 12 and Figure 13 show spectrum analyzer displays of the transmitted signal and the demodulated signal with the transmitter settings described previously. The OL2381's registers can either be set manually using the GUI or by loading the configuration file shown in Section 4.8 on page 17.

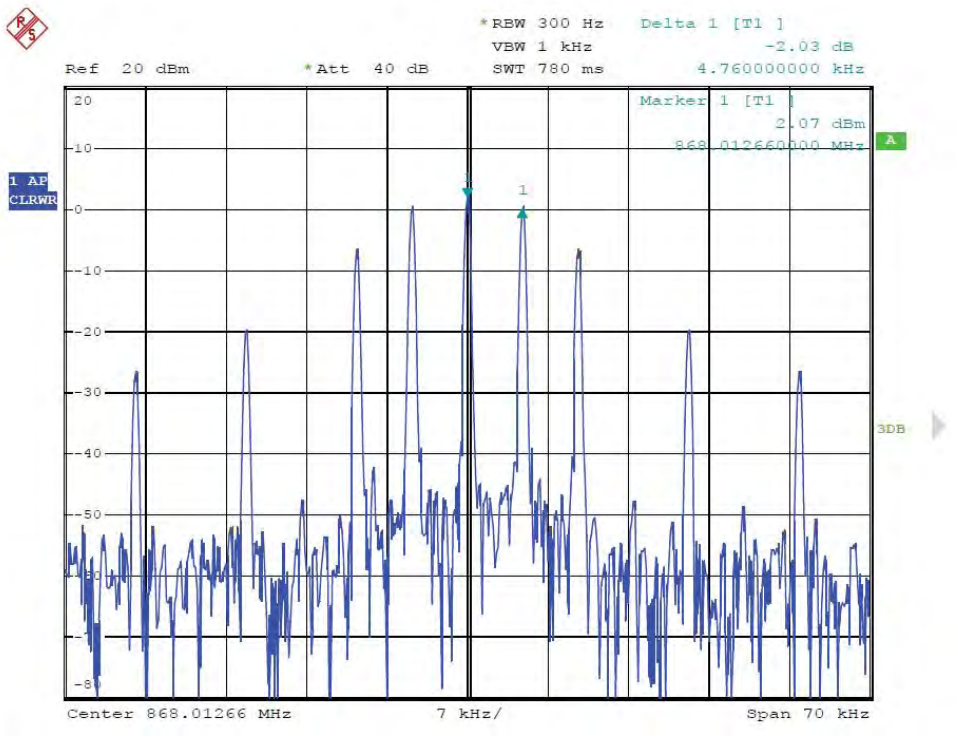



**Fig 12. Transmitted signal spectrum**

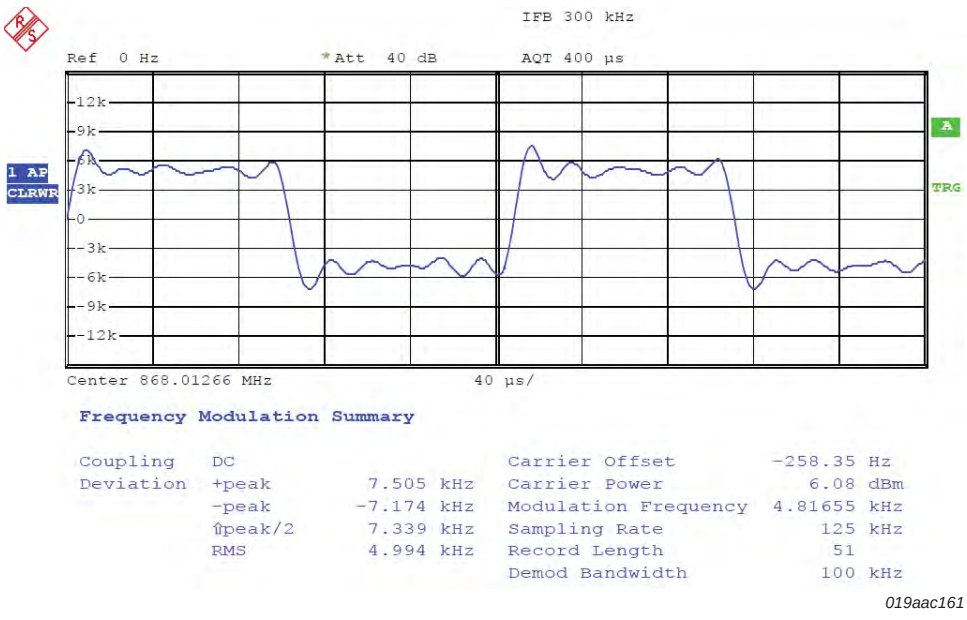



**Fig 13. Demodulated transmitted signal spectrum**

# 4. RX registers

This section describes how to set the registers used by the receiver for this application. The complete receipt flow chart is shown in Figure 14.

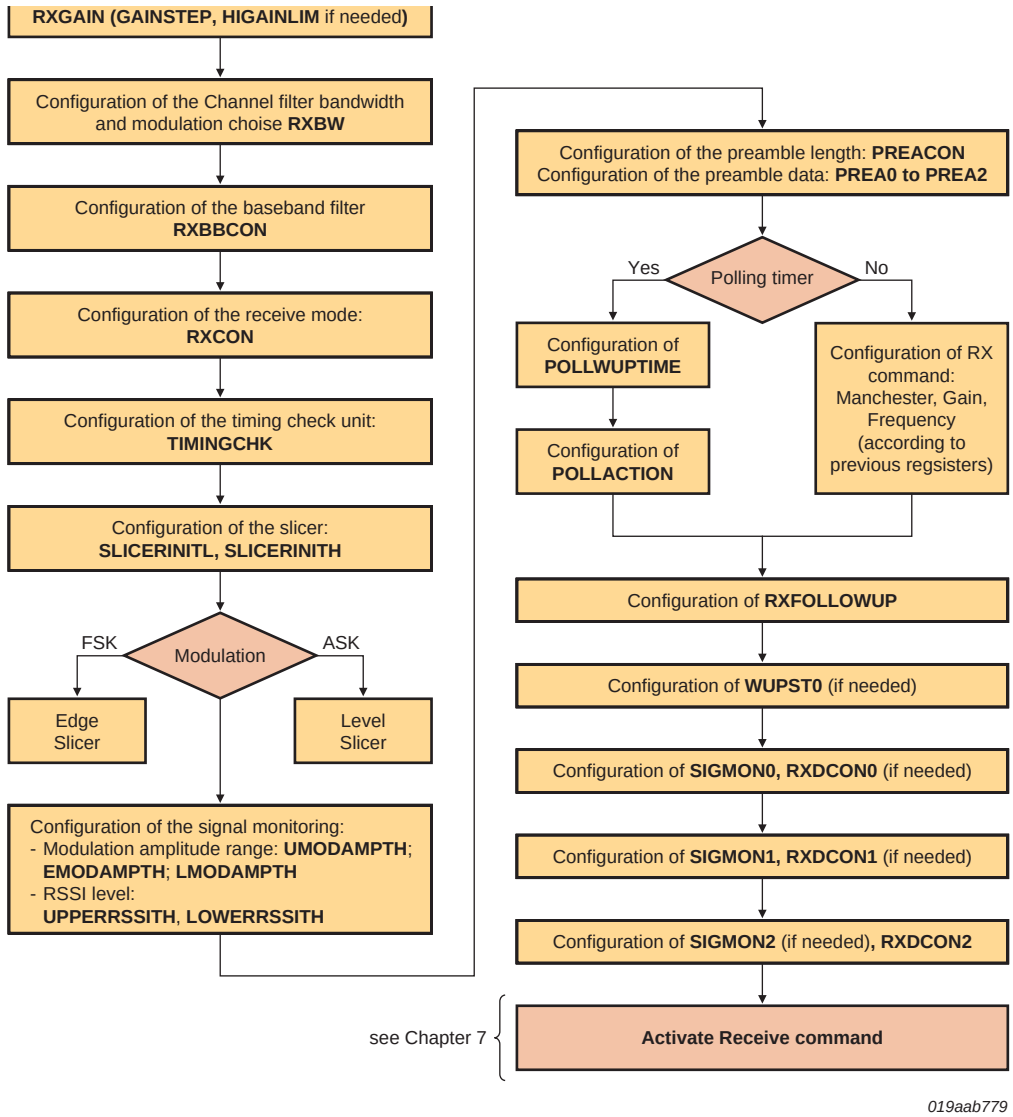



**Fig 14. RX register flow chart**

## 4.1 LNA configuration

The LNA is set to high gain mode (default value) as shown in Figure 15.

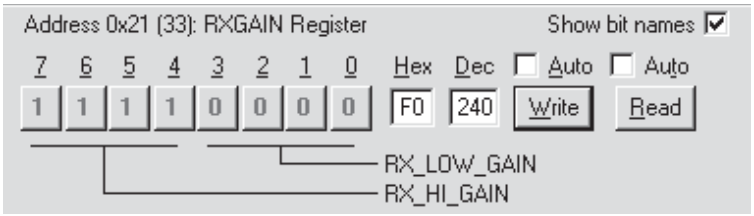



**Fig 15. LNA configuration**

## 4.2 Channel bandwidth configuration

Register RXBW sets the choice of demodulation (ASK/FSK) and channel filter (IF) bandwidth. Bit DEMOD_ASK is set to 0 for FSK modulation. Careful consideration should be given to the choice of bandwidth to optimize receiver performance. It should be close to the bandwidth occupied by the modulated signal. FSK modulation requires the bandwidth to be equal to twice the sum of the modulating frequency and frequency deviation. The frequency tolerance of the crystal oscillators used should also be taken into account.

The frequency deviation is 4.8 kHz and the modulation frequency is 4.8 kbits (4.8 kHz), which is twice the sum of the previous value of 19.2 kHz. The maximum modulation frequency of the 4.8 kbit/s Manchester encoded data is 4.8 kHz. The nearest channel bandwidth value available is 50 kHz, set by CF_BW[6:4] as shown in Figure 16.

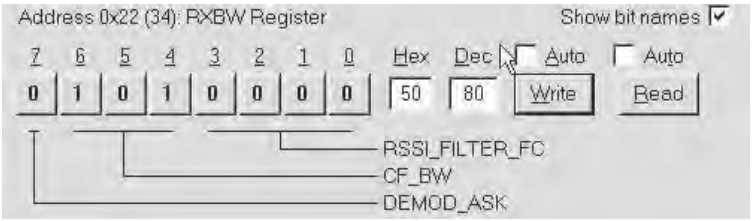
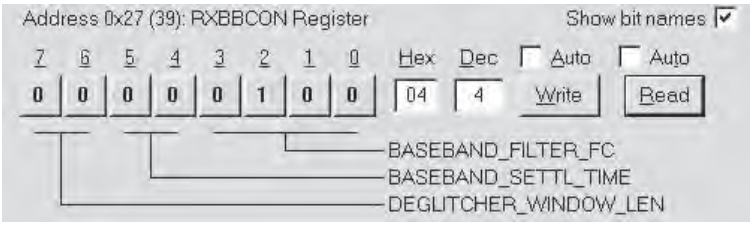



**Fig 16. Register RXBW**

## 4.3 Baseband filter configuration

Register RXBBCON sets the baseband filter cut-off frequency. It should be appropriate to use modulation. The optimum cut-off frequency at 4.8 kHz is 7.095 kHz, set by BASEBAND_FILTER_FC as shown in Figure 17.

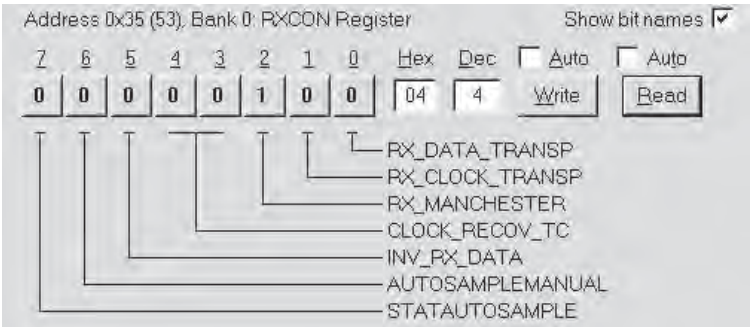



019aac352

**Fig 17. Baseband filter configuration**

## 4.4 Manchester decoder setting

The Manchester decoder should be activated by register RXCON, bit RX_MANCHESTER set to logic 1 as shown in Figure 18.

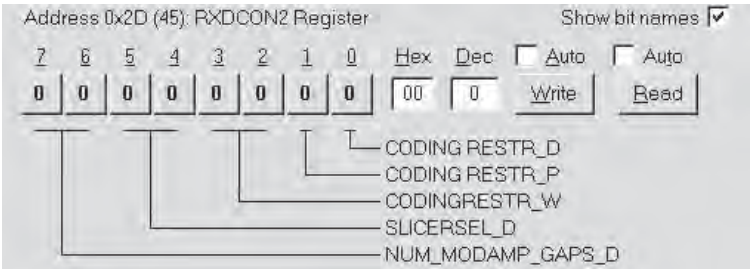



019aac317

**Fig 18. Manchester decoder**

## 4.5 Slicer configuration

The edge slicer feature is recommended for FSK modulation, SLICERSEL_D[5:4] set to 00 as shown in Figure 19.




019aac374

**Fig 19. Slicer configuration**

## 4.6 Expected modulation amplitude configuration

The expected peak modulation must be configured to set the receiver to its optimum settings. Register EMODAMPTH (Figure 20) holds the expected peak deviation value which is compared with the received baseband signal. The receiver has to know the deviation frequency of the transmitted signal to ensure correct operation.

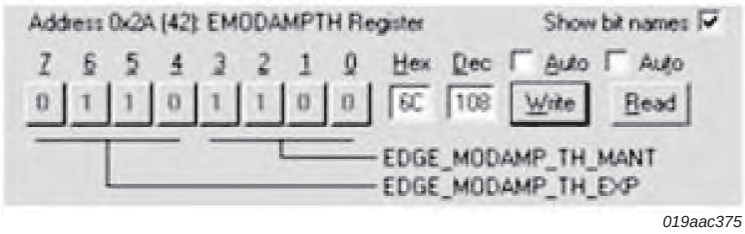



**Fig 20. Expected modulation amplitude configuration**

$$EMODAMPTH = min(32767, \text{EDGE\_MODAMP\_TH\_MANT} \times 2^{\text{EDGE\_MODAMP\_TH\_EXP}}) \quad (7)$$

$$\text{EDGE\_MODAMP\_TH\_EXP} = min\left\{15, \left\lfloor log2\left(\frac{max(15, x)}{7.75}\right)\right\rfloor\right\} \quad (8)$$

$$\text{EDGE\_MODAMP\_TH\_MANT} = min\left\{15, \left\lfloor \frac{x}{2^{\text{EDGE\_MODAMP\_TH\_EXP}}} + 0.5 \right\rfloor\right\} \quad (9)$$

Where:

x: real target value.

x = 33256 × modulation deviation / 200.

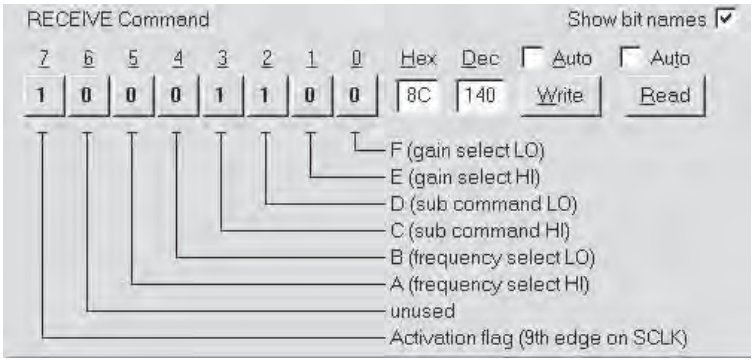
Modulation deviation = 4.8 kHz.

EDGE_MODAMPTH_TH_EXP = 0110b.

EDGE_MODAMPTH_TH_MANT = 1100b.

## 4.7 RX flags

Receive mode is entered by sending a receive command to OL2381 and is activated on the 9th clock edge. Figure 12 shows the receive command configuration when only data reception is required.



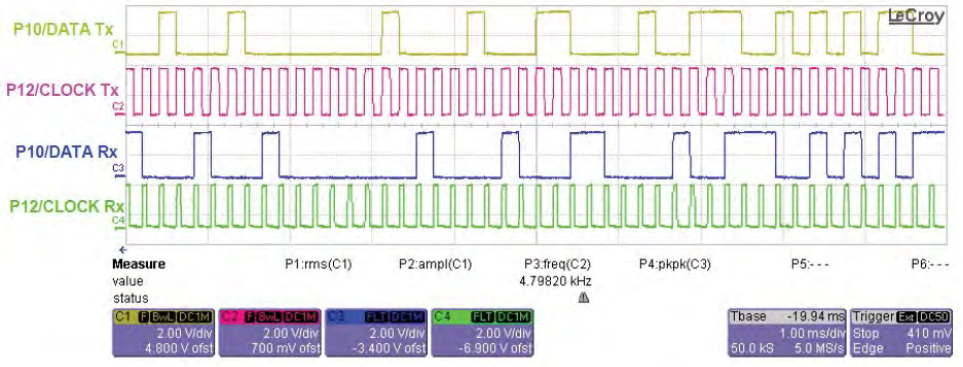

019aac162

Data reception (no WUPS and preamble), frequency channel 0 selected.

**Fig 21. Receive command**

## 4.8 Results

Figure 22 shows the transmitted and received data and clock if receiver is set as described in the previous sections. The received data and clock traces are colored blue and green respectively.




019aac164

**Fig 22. Received data**

The OL2381's pseudo-random generator is enabled for transmitting data as shown in Figure 22. Bits P10C[2:1] in register PORTCON0 are set to 10 as shown in Figure 23.

The OL2381's registers can either be set manually using the GUI or by loading the configuration file shown below.

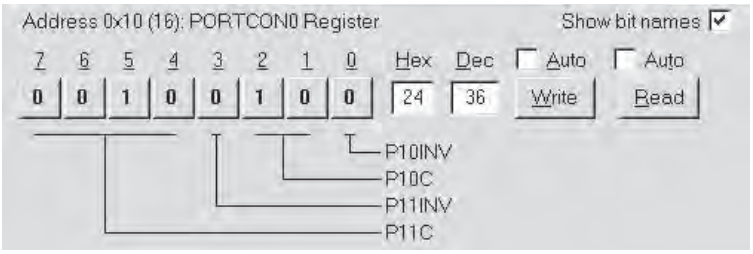



**Fig 23. Pseudo-random generator used for transmitting data**

The settings used in this application note are available in a configuration file which can be loaded into the OL2381 as shown below:

```
//Start
[LoPSTerRegisterConfiguration]
FileFormat = V2.1
NoOfConfigs = 1
ActiveConfig = 1

[PresetConfig1]
DeviceVersion = V0A
ConfigName =
UpdateTime = 04/21/09 16:14:41
;       x0 x1 x2 x3 x4 x5 x6 x7 x8 x9 xA xB xC xD xE xF
; visible in bank 0,1
01_0x = 00 00 B2 00 00 00 00 00 00 00 00 00 00 00 D5 59
01_1x = 24 24 66 00 00 00 00 00 00 00 2A 00 1F 00 00 00
01_2x = 20 F0 50 00 00 00 00 04 00 00 6C 00 00 00 -- --
01_3x = -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- 01
; visible in bank 0
0_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
0_3x  = 00 00 00 00 00 04 00 00 00 00 00 00 00 00 00 --
; visible in bank 1
1_2x  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 00 00
1_3x  = 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 --
TxRx  = -- -- -- -- -- -- -- -- -- -- -- -- -- -- 8E 8C
//Stop
```

# 5. Abbreviations

**Table 1. Abbreviations**

| Acronym | Description |
|---|---|
| AM | Amplitude Modulation |
| ASK | Amplitude-Shift Keying |
| FM | Frequency Modulation |
| FSK | Frequency Shift Keying |
| GUI | Graphic User Interface |
| LNA | Low-Noise Amplifier |
| PLL | Phase-Locked Loop |
| RF | Radio Frequency |
| RSSI | Residual Signal Strength Indicator |
| RX | Receiver |
| SPI | Serial Peripheral Interface |
| TX | Transmitter |
| VCO | Voltage-Controlled Oscillator |
| WUP | Wake UP |
| WUPS | Wake UP Search |
| XTAL | Crystal Oscillator |

# 6. Legal information

## 6.1 Definitions

**Draft —** The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

## 6.2 Disclaimers

**Limited warranty and liability —** Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

**Right to make changes —** NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

**Suitability for use —** NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors accepts no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

**Applications —** Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

**Export control —** This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

**Evaluation products —** This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer.

In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

## 6.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

# 7. Contents





For more information, please visit: http://www.nxp.com
For sales office addresses, please send an email to: salesaddresses@nxp.com

**Date of release: 5 July 2011**
**Document identifier: AN10996**