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1 Introduction

The SX1231 is a single-chip integrated circuit ideally suited for today's high performance ISM band RF applications. The advanced feature set, including state of the art packet engine greatly simplifies system design whilst the high level of integration reduces the external BOM to a handful of passive decoupling and matching components. It is intended for use as high-performance, low-cost FSK and OOK RF transceiver for robust frequency agile, half-duplex bi-directional RF links, and where stable and constant RF performance is required over the full operating range of the device down to 1.8V.

The SX1231 is intended for applications over a wide frequency range, including the 433 MHz and 868 MHz European and the 902-928 MHz North American ISM bands. Coupled with a link budget in excess of 135 dB, the advanced system features of the SX1231 include a 66 byte TX/RX FIFO, configurable automatic packet handler, listen mode, temperature sensor and configurable DIOs which greatly enhance system flexibility whilst at the same time significantly reducing MCU requirements.

The SX1231 complies with both ETSI and FCC regulatory requirements and is available in a 5x5 mm QFN 24 lead package.

The SX1231-31SKB is a USB based evaluation tool designed to allow simple and easy evaluation of the suitability of the SX1231 for a given application. The low component count reference design implemented in the SM1231 reference design is illustrated below in Figure 1.

It is recommended that this user guide be read in conjunction with the SX1231 datasheet (http://www.semtech.com/images/datasheet/sx1231.pdf)

---

**Figure 1: SM1231 Application Schematic**
2 Getting Started

2.1 Evaluation Kit Contents

The SX1231-31SKB evaluation kit consists of:

- 2 x SM1231 modules
- 2 x USB bridge modules
- 2 x ¼ wave monopole antennas
- Installation CD or insert sheet
- 2 x USB cables

![Figure 2: SM1231 Module Mounted on USB Bridge](image-url)
2.2 Installation
1. Put the CDROM in your computer and browse the contents of the CD, open the "sx1231starterkitsetup.exe" manually. It can be found in the \installers sub directory of the CD-ROM
2. If the evaluation kit is supplied with an insert sheet, follow the instruction on the insert sheet and download the latest version of the software from the weblink provided
3. Follow the on-screen installation guidelines until the process is completed. Please note that .NET Framework 3.5 and the FTDI USB driver will be automatically installed if not detected on your computer
4. Connect one SX1231SKB board to the PC via the USB interface. The SM1231 module and USB bridge are powered via the USB
5. Launch "SX1231SKB" from the Start menu
6. Click on "Connect" button in toolbar or in File menu
7. SX1231SKB is now installed and ready to be used

2.3 SX1231SKB Overview
The SX1231SKB features the SM1231 reference design and is also interfaced via the FTDI USB Bridge to the USB type 'A' interface of a host PC.
Transmission and reception is indicated by a pair of LEDs on the USB Bridge.

3 SX1231 Quick Start Guide
It is recommended that this user guide is read in conjunction with the SX1231 datasheet.
1. Plug the SX1231SKB into the USB port of the computer. The USB power LED on the bridge should be illuminated
2. Run the SX1231 User Interface software: Start > All Programs > SX1231SKB > SX1231SKB
3. The SX1231SKB should connect automatically to the User Interface Software. If not, click on the USB connect button, located in the top left hand corner of the window toolbar, as illustrated in Figure 4, below
4. Once connected the SX1231SKB shows the default configuration of the SX1231 register settings upon power-up, as illustrated in Figure 3. If the EVK is not connected, the GUI screen is grayed out and an error message is displayed in the bottom left hand corner of the status bar.

4 SX1231SKB Software Description

4.1 Overview
Figure 3 illustrates the SX1231SKB graphical user interface (GUI). Each of the numbered captions corresponds to a proceeding chapter within the sections which corresponds to the description of that GUI feature.
4.2 Menu Tool Bar

The Menu toolbar contains four drop down menus, File Menu, Action Menu, Tools Menu and Help Menu.

4.2.1 File Menu

Connect / Disconnect allows for the connection or disconnection of the USB bridge from the host PC. This functionality may also be accessed through the short cut buttons of the Window Toolbar (see Section 4.3).

Open Config… allows for the opening of SX1231SKB configuration files (.cfg). This is implemented through a standard Windows file dialog box and may also be accessed through the short cut buttons of the Window Toolbar.

Save Config allows for SX1231SKB configuration files (.cfg) to be saved. This is implemented through a standard Windows file dialog box. The default file name is the last config file saved.
Save Config as… prompts for a new file name before saving, allowing for multiple configuration files to be saved and may also be accessed through the short cut buttons of the Window Toolbar.

Exit closes the application.

### Figure 4: File Menu Options

#### 4.2.2 Action Menu

*Reset* resets the SX1231 configuration registers to the recommended default values.

*Refresh* reads the status of the all registers.

*Show registers* toggles the SX1231 Registers display window and may also be accessed through the short cut buttons of the Window Toolbar. The register display window indicates the status of SX1231 configuration registers as detailed in the SX1231 datasheet. Refer to Section for further information.

*Monitor ON* allows the GUI to constantly scan the status of theIRQ registers RegIrqFlags1 and RegIrqFlags2 at addresses 0x27 and 0x28 respectively, and displays the status on the right hand side of the GUI (see Section 4.6 for further details). *Monitor OFF* disables the monitor function.

### Figure 5: Action Menu Options

#### 4.2.3 Tools Menu

*RSSI analyzer* provides a graphical representation of the signal level at the antenna port measured within the RX filter channel bandwidth, RxBw, at the programmed RF frequency. Refer to See Section 7.4 for further details.
Spectrum Analyzer provides a simple spectrum analyzer function based upon RSSI level within the programmable RX filter channel bandwidth, RxBw. Please refer to Section 7.5 for further details.

4.2.4 Help Menu

Help provides an online description of GUI commands

User’s Guide… opens a PDF version of this document.

About… provides details of the GUI revision. The latest version of the SX1231 GUI can be downloaded from the Semtech website.

4.3 Window Toolbar

The Windows Toolbar provides three buttons that provide shortcuts to some of the functions accessed from the File drop-down menu.
Open Config button opens a Windows file dialog box to allow access to a previously saved SX1231SKB configuration file (.cfg). Note that saved configuration files are designed to be a useful tool for embedded software development. The file can be opened in any text editor or within a spreadsheet to display the programmed register name, address and contents, as illustrated below in Figure 9.

![Example Configuration File Text Editor Output](image)

Figure 9: Example Configuration File Text Editor Output

Save Config button saves and will prompt if overwriting an existing configuration file.

Connect / Disconnect button allows the user to manage manually connection and disconnection of the kit.

Reset resets the SX1231 configuration registers to the recommended default values.

Refresh reads the status of all registers.

Register Window Toggle toggles the SX1231 Registers display window and may also be accessed through the short cut buttons of the Window Toolbar. The register display window indicates the status of SX1231 configuration registers as detailed in the SX1231 datasheet. Refer to Section 6 for further information.

IRQ Monitor Toggle toggles the scanning of the status of Iq registers RegIrqFlags1 and RegIrqFlags2 at addresses 0x27 and 0x28 respectively, and displays the status on the right hand side of the GUI (see Section 4.6 for further details).

Help provides an online description of GUI commands.
4.4 Status Bar
The Status Bar provides details of the SX1231 revision version and current user configuration file. For further information concerning the IC revision, please refer to the SX1231 datasheet.

![Status Bar](image)

**Figure 10: Status Bar**

4.5 Operating Modes Control Box
The Operating Mode control box allows the user to change the operating mode of the SX1231 by clicking on the radio button corresponding to the desired mode. Note that the transition between modes is applied as soon as the radio button is accessed.

When the SX1231 is configured to RX operating mode LED 2 on the USB Bridge is illuminated. When the SX1231 is configured to TX mode both LED 2 and LED 3 are illuminated.

![Operating Modes Control Window](image)

**Figure 11: Operating Modes Control Window**

4.6 IRQ Status Indicator
The IRQ Status Flag indicator provides an indication of the status of the IRQ registers. When the indicator next to the IRQ description is illuminated, the IRQ condition is true.

Please refer to the SX1231 datasheet for further information and a more detailed description of the IRQ register flags.
5 Configuration Registers Tabs

Unless otherwise stated all registers are updated as soon as they are written. It is recommended to cycle through Standby Mode when changing the contents of configuration registers.

5.1 Common Configuration Registers Tab

The Common Configuration Registers tab is illustrated on the following page in Figure 13. Please refer to the SX1231 for a full description of the configuration register functions.
Configuration register value entries can be selected from the drop down menus within the tab or entered manually within the tab fields. Note that an invalid register entry will be highlighted by an orange background and the GUI will automatically flag a warning exclamation. A valid register entry that leads to an incorrect operating setting will result in that entry to be highlighted in red. Hovering a mouse or cursor over the warning provides an explanation for the flag, as illustrated in Figure 14.

Values entered manually that do not coincide with an exact configuration will be automatically updated by the GUI to the next valid register configuration and write that value to the appropriate configuration register.

Figure 13: Common Configuration Register Tab

Figure 14: Dialog Box Error Messages
5.1.1 Modulation Mode Window
Clicking on the OOK radio button within the Modulation window will access the modulation shaping options for the OOK modulation mode.

![Modulation Mode Window](image)

5.2 Transmitter Configuration Register Tab
The Transmitter Configuration Register Tab is illustrated below in Figure 16. Please refer to the SX1231 datasheet for a full description of the configuration register functions. Configuration register value entries can be selected from the drop down menus within the tab or entered manually within the tab fields. If values are entered manually that do not coincide with an exact configuration, the GUI will automatically update the displayed value to the next valid register configuration and write that value to the appropriate configuration register.

It should be noted that the output power settings are the nominal values determined by the configuration registers and does not refer to measured output power. Please refer to the Application Information within the SX1230 datasheet for further information concerning measured output power vs. programmed power.

![Transmitter Configuration Register Tab](image)
5.3 Receiver Configuration Register Tab

The Receiver Configuration Register Tab is illustrated below. Please refer to the SX1231 for a full description of the configuration register functions.

Configuration register value entries can be selected from the drop down menus within the tab or entered manually within the tab fields. If values are entered manually that do not coincide with an exact configuration, the GUI will automatically update the displayed value to the next valid register configuration and write that value to the appropriate configuration register.

5.3.1 Rx Bandwidth

The Rx Bandwidth, RxBw, window is illustrated below. For optimum performance in FSK mode when operating with a modulation index \( > 2 \), the DCC frequency is recommended to be approximately 4% of the receiver bandwidth, RxBw. The GUI will automatically set the appropriate DCC frequency based upon the setting of RX filter bandwidth.

Figure 17: Receiver Configuration Register Tab

Figure 18: Rx Bandwidth Window
For operation with low modulation index signals, it is recommended that the user follows the recommendations for setting the correct DCC bandwidth that can be found in the SX1231 datasheet.

### 5.3.2 LNA Gain Window

The LNA gain window provides the status of the configured LNA gain. The gain can be configured automatically or manually. In automatic mode the LNA gain is set based upon the RSSI value. In manual mode, the gain should be set according to the expected signal power.

Note that the AGC reference threshold is set according to:

$$\text{AgcRef} = \left[ -174 + NF + 10 \times \log(2 \times RxBw) + \text{DemodSNR} + \text{FadingMargin} \right] \text{dBm}$$

### Figure 19: LNA Gain Window

#### 5.3.3 AFC / FEI

The AFC / FEI (Frequency Error Indicator) window is illustrated below. Note that when AFC is activated (either AFC auto “ON” or manually), the RF frequency in the General window of the Common Configuration Register Tab does not update, although a measure of frequency error can be obtained by clicking on the FEI Read button to verify correct AFC operation.

Enabling AFC low beta implements a double AFC function to offset the local oscillator of the SX1231 to ensure that the central tone at $f_0$ associated with low modulation index signals is not unduly attenuated by the cut-off frequency of the DCC.

Please refer to the optimized set up for low modulation index systems section of the SX1231 datasheet for further details.

### Figure 20: AFC / FEI Window

#### 5.3.4 RSSI

The RSSI window provides access to the RSSI timeout and timeout threshold functions and enable either automatic or manual RSSI detection threshold values to be programmed. Note that the RSSI threshold (which should not be confused with the LNA or AGC threshold) can be calculated from and equates to the effective noise floor of the receiver for a given filter bandwidth.
RSSI_{thres} = [-174 + NF + 10 \times \log(2 \times \text{RxBW}) + \text{DemodSNR}] \text{dBm}

### 5.3.5 Continuous-Time Digital AGC

The AGC dynamic range can be enhanced in V2c silicon (chip version 2.3) with the default mode of operation of DAGC enabled. Note that the DAGC mode of operation is automatically configured by the GUI depending upon whether AFC low beta is enabled (see section 5.3.3).

Please refer to the SX1231 datasheet for further information on the implementation of the continuous-time DAGC function.

### 5.4 Irq & Mapping Configuration Register Tab

The Irq & Mapping Configuration Register Tab is illustrated in Figure 23. Please refer to the SX1231 for a full description of the irq and mappings for each mode of operation of the SX1231.

Configuration register value entries can be selected from the drop down menus besides each DIO listed.

Note that when necessary the GUI will automatically re-configure DIO mappings (i.e. Packet Handler operation).

Please refer to Table 1 and Table 2, below, for the available DIO mappings of the SX1231 in continuous and packet mode, respectively.
### Table 1: Continuous Mode DIO Mappings

<table>
<thead>
<tr>
<th>Mode</th>
<th>DIOx Mapping</th>
<th>DIO5</th>
<th>DIO4</th>
<th>DIO3</th>
<th>DIO2</th>
<th>DIO1</th>
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### Table 2: Packet Mode DIO Mappings

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<td>PLLock</td>
</tr>
<tr>
<td></td>
<td>10 LowBat</td>
<td>LowBat</td>
<td>LowBat</td>
<td>LowBat</td>
<td>LowBat</td>
<td>_fifoNotEmpty</td>
<td>LowBat</td>
</tr>
<tr>
<td></td>
<td>11 ModeReady</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>ModeReady</td>
</tr>
<tr>
<td>RX</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Data</td>
<td>Dclk</td>
</tr>
<tr>
<td></td>
<td>01 Data</td>
<td>Rssi</td>
<td>Rssi</td>
<td>Data</td>
<td>_fifoFull</td>
<td>PayloadReady</td>
<td></td>
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<td>SyncAddr</td>
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</tr>
<tr>
<td></td>
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<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
</tr>
<tr>
<td>TX</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Data</td>
<td>Dclk</td>
</tr>
<tr>
<td></td>
<td>00 Clkout</td>
<td>_ModeReady</td>
<td>_fifoFull</td>
<td>fifoNotEmpty</td>
<td>fifoLevel</td>
<td>PacketSent</td>
<td></td>
</tr>
<tr>
<td></td>
<td>01</td>
<td>_ModeReady</td>
<td>_fifoFull</td>
<td>fifoNotEmpty</td>
<td>fifoLevel</td>
<td>TxReady</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 LowBat</td>
<td>LowBat</td>
<td>LowBat</td>
<td>LowBat</td>
<td>LowBat</td>
<td>fifoNotEmpty</td>
<td>LowBat</td>
</tr>
<tr>
<td></td>
<td>11 ModeReady</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
<td>PLLock</td>
</tr>
</tbody>
</table>
5.5 Packet Handler Configuration Register Tab

The Packet Handler Configuration Register Tab is shown below. Please refer to the SX1231 for a full description of the packet engine message format and operation of the SX1231.
5.5.1 Sync Word
For correct packet mode operation, the sync word needs to be set to at least one byte. Note that 0x00 cannot be set as for the first byte of the sync word. The GUI will prompt with an error message should the user attempt to set 0x00 in the first byte of the sync word.

5.5.2 AutoMode Operation
Auto Modes defines the enter conditions to start the packet handler and exit conditions to terminate packet handler operation, as defined in the SX1231 datasheet.

5.5.3 Packet Log
Clicking on the Log button within the Control Window enables the payload logging function, available in both TX and RX modes whenever the Packet Handler is enabled.

In the Packet Logger window enter the number of packets to be logged and press the Start button. Then press the Start button in the Control Window of the main Packet Handler Tab to start packet transmission or reception. When the status bar indicates full, the log can be saved by clicking on the Browse button.

The log file can be viewed in Notepad or opened in Excel as a .CSV file.

Figure 25: Packet Logger Window

Figure 26: Packet Log CSV File Format
### Packet Log Parameter Description

<table>
<thead>
<tr>
<th>Packet Log Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Local (CPU) timestamp in MM:SS.S format for TX / RX packets</td>
</tr>
<tr>
<td>Mode</td>
<td>SX1231 Packet Mode</td>
</tr>
<tr>
<td>RSSI</td>
<td>Indicated RSSI level (RX mode only)</td>
</tr>
<tr>
<td>Pkt Max</td>
<td>Number of repeated packets set in GUI Control Window (0 = infinite)</td>
</tr>
<tr>
<td>Pkt #</td>
<td>Transmitted or received packet number</td>
</tr>
<tr>
<td>Preamble Size</td>
<td>Size of transmitted or received preamble sequence</td>
</tr>
<tr>
<td>Sync</td>
<td>Sync Address</td>
</tr>
<tr>
<td>Length</td>
<td>Payload length of TX / RX packet</td>
</tr>
<tr>
<td>Node Address</td>
<td>Node Address (optional)</td>
</tr>
<tr>
<td>Message</td>
<td>Transmitted / received packet (can be viewed in GUI Message Window)</td>
</tr>
<tr>
<td>CRC</td>
<td>Transmitted / received CRC (optional)</td>
</tr>
</tbody>
</table>

**Table 3: Packet Log Descriptors**

### 5.5.4 Packet Handler GUI Limitations

When operating the packet handler via the SKB GUI, the user should be aware of the following limitations associated with the GUI:
- Minimum Preamble Size = 2 bytes
- Maximum Packet Length = 66 bytes (64 bytes of data + Length byte + Address byte)

### 5.6 Temperature Configuration Register Tab

The Temperature Configuration Register Tab is illustrated below in Figure 28. Note that user is prompted to calibrate the SX1231 temperature sensor by clicking on the Calibrate button to access the temperature calibration dialog box.

![Temperature Calibration Dialog Box](image)

**Figure 27: Temperature Calibration Dialog Box**

When the temperature sensor has been calibrate the temperature, as computed by the SX1231, will be displayed, as illustrated in Figure 28.
Figure 28: Calibrated Temperature Sensor Tab
6 Registers Display Window

As outlined in Section 4.2.3 the SX1231 GUI has a show registers utility that, when enabled from either the Menu or Windows toolbar, provides details of the status of all configuration registers that are documented in the SX1231 datasheet.

Whenever the contents of a register are changed in the main GUI window, the corresponding register displays the new contents of the register(s), highlighting changed contents in red for a period of approximately 5 seconds before reverting back to black.

The register window is displayed below in Figure 29. It can be noted that in this example, the contents of RegOpMode at Addr 0x01 have changed to 0x10, indicating that the SX1231 has been set to Receiver Mode operation.
7 Advanced Operating Modes

7.1 Packet Communications Test

To configure the SX1231 to enable a wireless packet communications transfer, follow the procedure outlined below:

7.1.1 Transmitter Mode Configuration
1. Ensure that the SX1231 is in Standby operating mode
2. Configure the SX1231 Common and Transmitter Configuration Registers
3. Configure the Packet Handler Registers for the payload you wish to transmit. The payload can be entered within the Message Window in either hexadecimal or ASCII format. Note that the packet can be configured with Address and/or Broadcast nodes enabled or disabled; DC-free mechanisms, CRC and/or AES may also be selected. The only limitation is that the maximum payload size for the purposes of GUI operation is 66 bytes
4. Click on the Transmitter radio button from within the Operating Mode Window and set the Repeat value from within the Control Window of the Packet Handler Tab. It is recommended for initial analysis that Repeat value is set to “0” (packet transmission repeat until manually stopped)
5. Click on the Start button within the Control Window of the Packet Handler Tab to start the Transmitter
6. The TX packet counter will commence to increment as the SX1231 repeatedly transmits the payload

7.1.2 Receiver Mode Configuration
1. Ensure that the SX1231 is in Standby operating mode
2. Configure the SX1231 Common and Receiver Configuration Registers. The Common configuration should be identical to that of the SX1231 configured as the transmitter. The Receiver filter BW configuration should be consistent with the signal parameters. It is recommended that the configuration of the transmitter module is used as a template
3. Configure the Packet Handler Registers for the payload you wish receive. Note that the packet can be configured with Address and/or Broadcast nodes enabled or disabled; DC-free mechanisms, CRC and/or AES may also be selected. The packet handler parameters must be identical for those selected for the transmitter for correct operation. The only limitation is that the maximum payload size for the purposes of GUI operation is 66 bytes
4. Click on the Receiver radio button from within the Operating Mode Window and set the Repeat value from within the Control Window of the Packet Handler Tab
5. Click on the Start button within the Control Window of the Packet Handler Tab to start the Receiver
6. The RX packet counter will commence to increment for each valid packet reception

7.2 Test Mode Window

The Test Mode window is accessed by depressing the <CTRL>+<ALT>+<T> keys of the PC keyboard simultaneously, and is illustrated below in Figure 30.

This window allows the user to write to and read from the contents of individual configuration register addresses. Note that address and data are entered in hexadecimal format.

The Antenna switch control dialog box enables control of the antenna diversity switch for the SX1231 antenna diversity reference design
7.3 Verification Mode

When no SX1231SKB is connected to the PC, launching the application results in the GUI display being grayed out and the user is unable to enter data.

By depressing the <CTRL>+<ALT>+<N> keys of the PC keyboard simultaneously, the user can write to the configuration registers to verify propose settings, as well as load and save configuration files (*.cfg).

7.4 RSSI Analyzer

The RSSI Analyzer can be enabled via the Menu Tool Bar. With the SX1231 configured in Receiver operating mode the RSSI analyzer displays the real-time sampled RSSI measured in the receiver channel bandwidth. The vertical axis (indicated RSSI level) can be scaled with the click-wheel of a scrolling mouse.

This data can be saved as a RSSI log file by selecting an appropriate Max sample length within the RSSI Analyzer window and clicking on the Start button. When the status bar indicates full, the log file can be saved by clicking on the Browse button and can be viewed in Notepad or opened in Excel as a .CSV file.

An example of the RSSI Analyzer display is illustrated in Figure 31, indicating a packet transmission typically 10 dB above the receiver noise floor.
7.5 Spectrum Analyzer

The Spectrum Analyzer can be enabled via the Menu Tool Bar. With the SX1231 configured in Receiver operating mode the spectrum analyzer displays the sampled spectrum based upon RSSI measured within the programmable receiver channel or “resolution” bandwidth. Center frequency, frequency span and LNA gain are all configurable. The vertical axis (Power) can be scaled with the click-wheel of a scrolling mouse.

An example of the RSSI Analyzer display is illustrated in Figure 32.

![Figure 31: RSSI Analyzer Window](image)

![Figure 32: RSSI Analyzer Window](image)
8 Compatibility with Earlier Silicon Revisions

The SX1231 GUI is backwards compatible with Rev 2.1 Silicon (SX1231 datasheet Revision 2.0). The GUI automatically detects the silicon revision number, displaying the chip version in the status bar at the bottom of the GUI.

Configuration Register Tabs are automatically updated to display register contents pertinent to the chip version.

Semtech’s policy of continual improvement may result in information contained within this User Guide not being concurrent with the revision of software included on the installation CD

The user is recommended to download the latest revision of both this document and software from the Semtech website (www.semtech.com)