TRANSITIONING FROM THE Si443X TO THE Si446X

1. Introduction

This document provides assistance in transitioning from the Si443x to the Si446x EZRadioPRO® transceivers. The Si446x radios represent the newest generation of the EZRadioPRO family with improved performance and flexibility combined with simplicity and cost efficiency. The main differences between these two transceiver families are described here. It is highly recommended that the customer read the Si446x data sheets and application notes when converting a design from the Si443x family to the Si446x family.

2. Benefits

The Si446x significantly improves performance in almost all areas compared to the Si443x transceivers. Key among these are lower current in standby and active mode, overall improved link budget to 146 dB, and improved phase noise and blocking performance. In addition, the Si446x family has a highly-configurable modem and packet handler to support various application requirements as well as legacy modes of operation. Customers will also benefit from the newer development kits and WDS improvements, which make it easier to evaluate RF performance and develop application code.

2.1. Comparison of DC Characteristics

Table 1. Si443x vs. Si446x DC Characteristics

Specification	Si443x	Si446x
Supply Voltage	1.8 to 3.6 V	1.8 to 3.6 V
Ambient Temperature	–40 to 85 °C	–40 to 85 °C
Shutdown Mode Current Consumption	15 nA	30 nA
Standby Mode Current Consumption	450 nA	50 nA
Ready Mode Current Consumption	800 µA	1.8 mA
Receive Mode Current Consumption	18.5 mA	10.7/13.7 mA
Shutdown to Receive Time	16.8 ms	15 ms
Standby to Receive Mode Time	800 µs	440 µs
Ready to Receive Mode Time	200 µs	122 µs

Both radio families work over the same range of temperatures and supply voltages. The majority of the current consumption and transition times are significantly improved in the Si446x devices. Faster turnaround times, lower active currents, and significantly lower standby current consumption make the Si446x family more desirable in battery-powered applications compared to the Si443x family.

2.2. Comparison of RF Parameters

Table 2. RF Parameters Comparison

Specification	Si443x	Si4460/61/63	Si4464
Frequency Range	240 to 480 MHz (156.25 Hz res.) 480 to 960 MHz (312.5 Hz res.)	142–175 MHz (4.7 Hz) 283–350 MHz (9.5 Hz res.) 420–525 MHz (14.3 Hz res.) 850–1050 MHz (28.6 Hz res.)	119–159 MHz (4.7 Hz) 177–239 MHz (7.1 Hz) 235–319 MHz (9.5 Hz res.) 353–479 MHz (14.3 Hz) 470–639 MHz (19.1 Hz res.) 705–960 MHz (28.6 Hz res.)
RX Channel BW	2.6 to 620 kHz	1.1 to 850 kHz	
RX Sensitivity	–108 dBm (40 kbps, GFSK, ±20 kHz dev., BER<0.1%)	–110 dBm (40 kbps, GFSK, +-20 kHz dev., BER<0.1%))	
Blocking 1 MHz Offset	–52 dBm	–75 dBm	

The wider range of operating frequencies allows the Si446x family to be used in 169 MHz European ISM Bands (proprietary, social alarm, or Wireless MBUS N mode applications). The narrower Receive channel filter, better sensitivity, and excellent blocking performance make the Si446x more valuable in narrow-band applications (FCC Part 90, ETSI Category 1, etc.).

3. Hardware recommendations

Due to the different pinout of the QFN package, it is necessary to modify the application printed circuit board when transitioning from the Si443x to the Si446x. The following sections summarize the main differences and provide guidelines for component selection.

3.1. Package and Pinout

Both Si443x and Si446x radios are in a 4 x 4 mm 20-pin QFN package. The respective pinouts of the radios are summarized in Table 3.

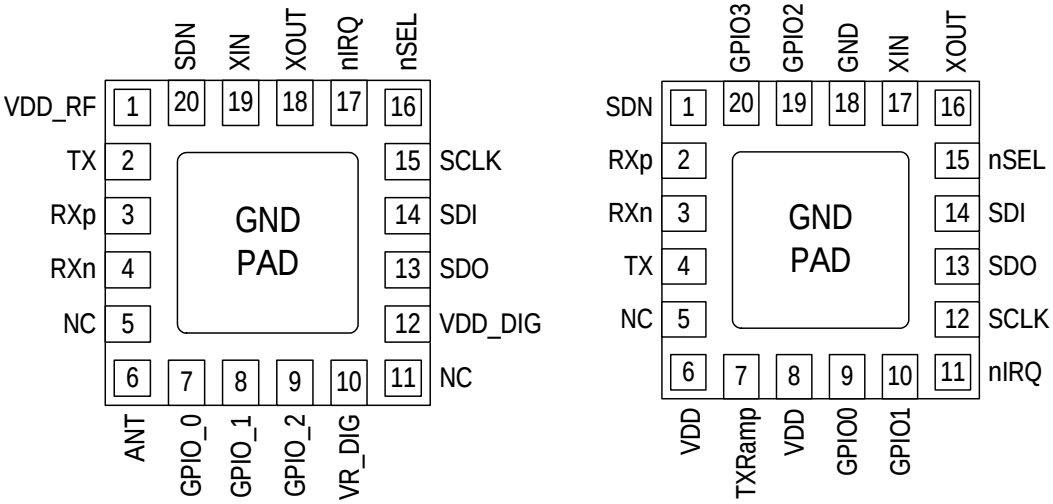


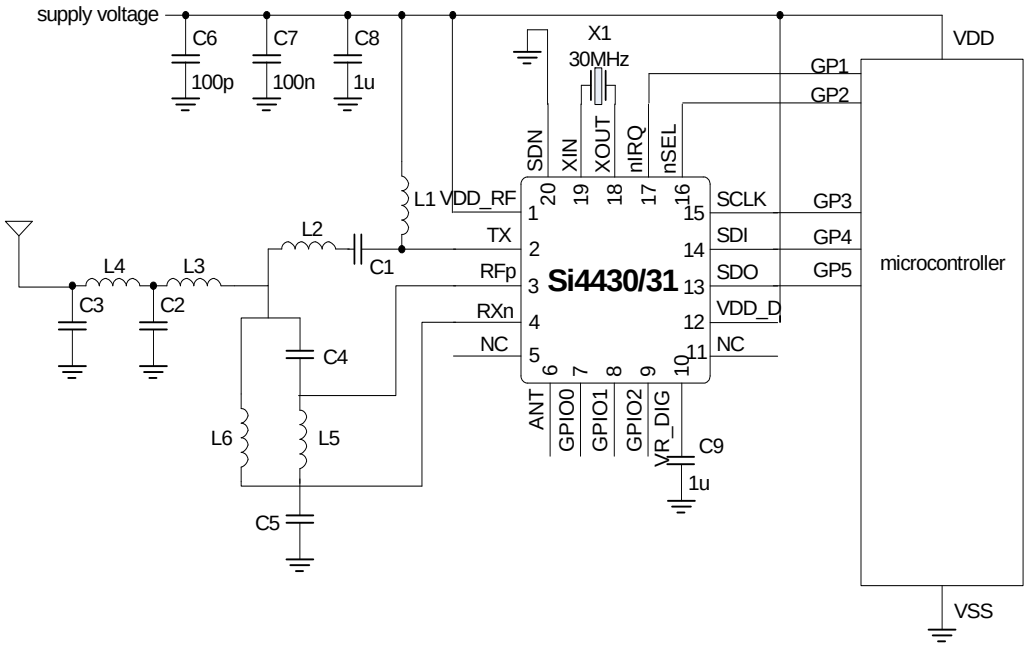
Figure 1. Pin Descriptions (Si443x and Si446x)

Table 3. Pinout Comparison

Feature	Si443x	Si446x
General Purpose IOs	3 GPIOs (digital signals or analog input for the internal ADC)	4 GPIOs (digital signals or analog input for the internal ADC)
ANT Pin	ANT pin can control the RF switch in an antenna diversity application. It helps to utilize the GPIOs for other purposes.	The RF switch control functionality is available on all 4 GPIOs. It provides flexibility for the HW designer to select GPIOs for RF switch control purposes that result in the most optimal RF layout.
TXRamp Pin	This feature is not available in the Si443x devices.	TXRamp pin can be used to control the TX ramp-up of the front end module or provide bias for the external transistor in a high-output power design.
Regulated Output Voltage of the Digital LDO	1 µF decoupling capacitor needs to be connected to VDR pin.	Internal LDO is not available externally

3.2. Reference Design and Component Selection

The typical application circuits for the Si443x and Si446x devices are shown in Figures 2 and 3.



Programmable load capacitors for X1 are integrated.

L1-L6 and C1-C5 values depend on frequency band, antenna impedance, output power and supply voltage range.

Figure 2. Si443x Application Example (Direct-Tie Application)

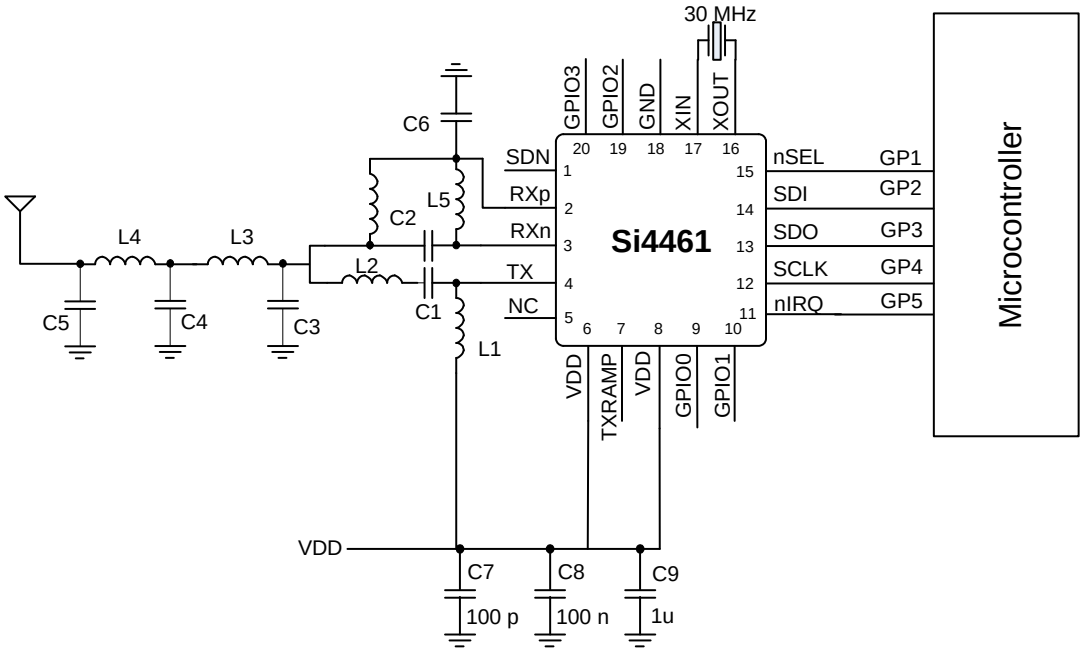


Figure 3. Si446x Application Example (Direct-Tie Application)

The architecture of the Receive and Transmit blocks of both radios are similar; therefore, the matching network topologies are the same in both application examples. Both radios can support different Tx matching network topologies. Refer to the following application notes for more details and comparisons on the different topologies:

- AN627: Si4060/Si4460/61 Low-Power PA Matching
- AN648: Si4063/4463/64 TX Matching

The Si446x can run the same crystal as the Si443x. In order to utilize a lower-cost crystal in the application, the Si446x is designed to accommodate a wide range of crystal frequencies (25–32 MHz). Refer to “AN785: Crystal Selection Guide for the Si4x6x RF ICs” for more details on crystal or TCXO selection for the Si446x devices.

4. Firmware Recommendations

4.1. Configuration Interface

Both radios can be configured through a standard SPI interface, with up to 10 MHz clock speed.

An Application Programming Interface (API) is designed for the Si446x device over the SPI interface instead of using a register configuration approach like in the Si443x. The major benefit of the API is that the radio can execute complex commands and procedures with minimal host MCU interaction. This approach helps to reduce the time-critical tasks from the host MCU and allows selection of a simpler, lower-cost MCU for the application. On the other end, the API results are as follows:

- The command execution time varies from command to command, and it may be slower than changing a simple register in the case of very basic commands.
- Retrieving status information from the chip requires the following process: issue a command that addresses what information the host MCU is looking for; wait for the radio to prepare the data (wait for the Clear To Send Signal), and read the actual status information.

For time-critical information, the host MCU can access the Fast Response Registers (RSSI, interrupt status, etc.) or use dedicated HW commands (Transmit FIFO Write, Receive FIFO Read) as well.

The complete list of commands and their descriptions are provided as an HTML document (available as the “EZRadioPRO API Documentation” zip file on the Silicon Labs web site). The HTML format helps to navigate more easily within the document. The open/collapse feature of the HTML document also helps to highlight or hide desired or undesired details for easier readability.

4.2. Power-On Sequence and Radio Configuration

After waiting for the Power-On Reset, the Si443x is ready to receive configuration commands.

There is an additional step for the Si446x since it needs to be boot up before the radio is ready to receive configuration commands. The boot-up process takes about 15 ms.

The Si443x radio can be initialized by overwriting registers that need to be different than their default value. The same approach must be followed for the Si446x. The properties of the radio need to be configured according to the desired radio parameters.

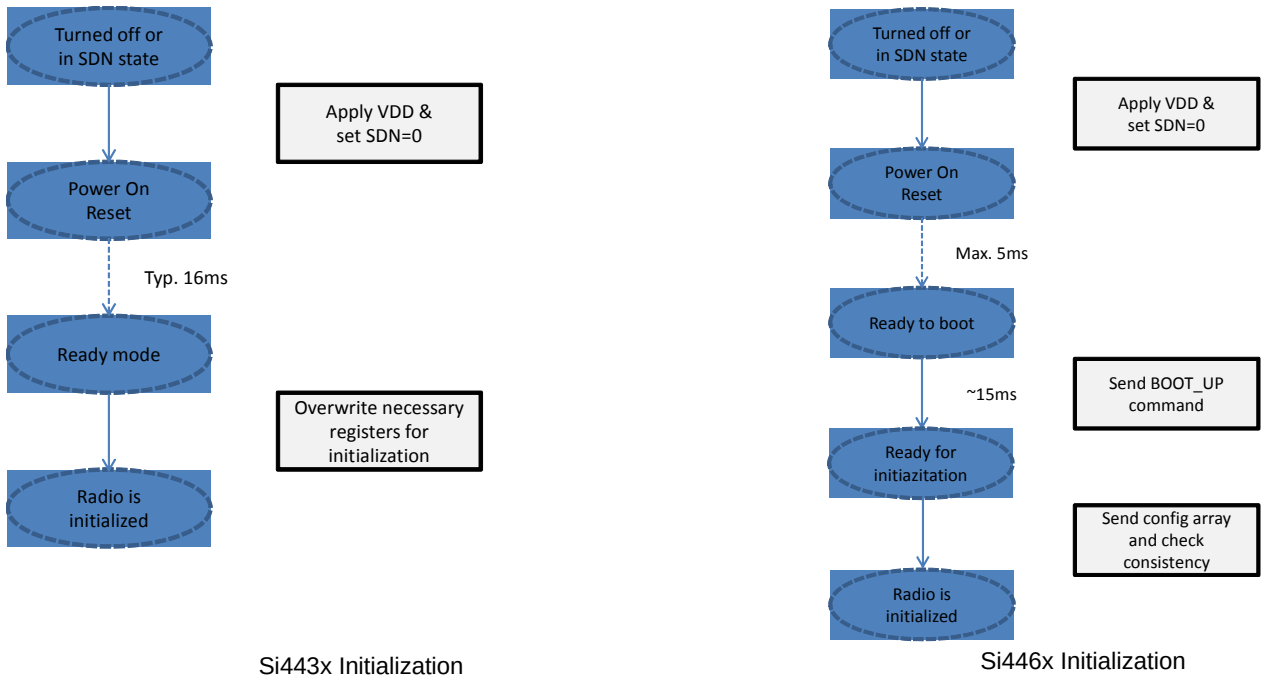


Figure 4. Initialization process for the Si4313 and Si446x Devices

The Si446x is highly-configurable. The radio has several properties that may need to be changed to achieve the desired operation. A PC GUI (WDS) is designed to help determine the necessary property settings. The user needs to set the desired configuration on a graphical user interface, and the tool provides example projects, batch files, or header files with the proper radio property configurations. For more information about the WDS and the radio configurations, refer to the following application notes:

- AN632: WDS User's Guide for EZRadioPRO® Devices
- AN633: Programming Guide for EZRadioPRO® Si4x6x Devices

4.3. Typical Use Cases

Both radios support the typical use cases: transmitting and receiving packets or transmitting and receiving data in direct mode (when the data is available or provided through a GPIO instead of via the FIFO).

Due to the API interface of the Si446x radio, realizing the typical use cases is different than for the Si443x radio. Other than the SPI low-layer driver and the application code, the rest of the application code needs to be changed. Both radios have a programming guide with example codes that summarize and show how the radio needs to be used. In addition to the radio operation, there are major improvements in the example projects and the support tools of the Si446x:.

The Si443x example codes are very basic and not partitioned; therefore, they require additional effort to change and port them to another HW platform. The Si446x example projects are built based on a driver that is well partitioned, and, beside the radio, support all major peripherals of the development board as well.

The radio configurations of the Si443x example codes need to be configured manually. WDS has a new feature for the Si446x: it can generate example projects with customized radio settings and packet configuration. The project can be saved or open in the Silicon Labs IDE for further FW development. This reduces the possibility of mis-configuration of the radio and provides a complete, tested C source code for the given use case, drastically reducing development time.

Refer to the AN633 for more details on the example project. Note that the example projects cannot be downloaded from the WEB site directly; those must be obtained from WDS with the desired radio configuration.

4.4. RX Modem

Both radios use high-performance ADCs that allows channel filtering, image rejection and demodulation to be performed in the digital domain. The Si446x has an improved digital modem; the differences are summarized in Table 4.

Table 4. RX Modem Comparison

Specification	Si443x	Si446x
Modulation Modes	2GFSK, 2FSK, OOK	2GFSK, 2FSK, 4GFSK, 4FSK, GMSK, OOK
(G)FSK Data Rate	0.123–256 kbps	0.1–500 kbps
4(G)FSK Data Rate	N/A	0.2–1000 kbps
OOK Data Rate	0.123 – 40 kbps	0.1–120 kbps
Bandwidth-Time Product	Fixed 0.5	Fixed 0.5
RX Architecture	fixed-IF (937.5 kHz)	Fixed-IF (Fxtal/64), zero-IF, scaled-IF
Image Calibration	N/A	Image calibration (IRCAL API command) is available to improve the image rejection to more than 55 dB in fixed-IF mode.

Table 4. RX Modem Comparison (Continued)

Specification	Si443x	Si446x
RSSI	Current RSSI can be read from a register.	The current RSSI is available through API call or Fast Response Registers. RSSI can be latched and stored upon a system event (preamble/synch word detection, etc.). For more accurate RSSI reading, the radio can average it for various bit timings. The radio can provide an interrupt if the RSSI si changed by a programmable amount during packet reception to detect interfering signals.
Preamble Detection	RX chain settles and detect standard preamble (“0101”).	RX chain settles and detects standard (up to 256 bytes) and custom preamble pattern (up to 4 bytes).
Automatic RX Hopping and Hop Table	N/A	This feature is intended for RX hopping where the device has to hop from channel to channel and look for packets. It is fully-configurable through the API interface, including hop table and hop conditions.
Manual RX Hopping	N/A	It provides a fast turnaround time (75 µs) from Rx-to-Rx that can be utilized for frequency scanning algorithms.

The wider data rate and modulation format support make the Si446x more future proof. The extremely-configurable RX modem makes it possible to design-in the Si446x for legacy product replacement.

Image calibration in fixed-IF mode allows the use of Si446x radios in ultra-narrow-band applications. Refer to “AN790: Image Rejection and IQ Calibration” for more details on image calibration.

4.5. Packet Handler

Both radios have built-in packet handlers that help to process the received data bits and construct the transmit packets. Utilizing this feature offloads these time-consuming tasks from the host MCU. It allows for selection of a simpler, lower-cost MCU.

The CRC and data-Whitening seeds and polynomials are more configurable in the Si446x than in the Si443x.

4.5.1. Receive Packet Handler

The Receive packet handler operation of the Si443x is very basic compared to that of the Si446x. While Si443x supports only fixed or variable packet length mode operation with optional CRC, Manchester coding, and data Whitening over the entire packet, the Si446x can be configured for a wide variety of packet configurations by introducing the FIELD feature.

FIELD is an entity within the packet where the CRC, Manchester coding, and data Whitening settings are fixed within that entity. The FIELD feature is also mandatory if 4(G)FSK modulation is used. Up to five FIELDs can be configured within a packet. One of the FIELDs cam be of variable length, where the length byte must be present in an earlier FIELD.

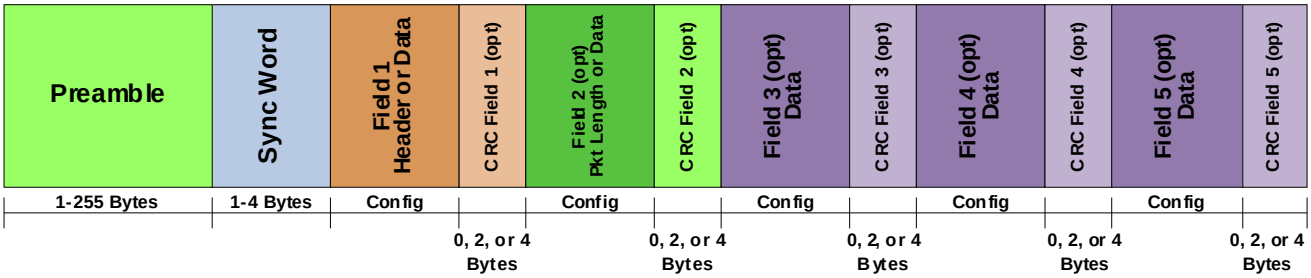


Figure 5. Packet Handler Operation of the Si446x

4.5.2. Transmit Packet Handler

The Si443x can be configured for fixed or variable-length packet transmissions. In fixed packet length mode, the radio transmits the preamble and the synch word automatically followed by the desired number of bytes from the TX FIFO. The radio also automatically applies the selected CRC calculation, Manchester coding, or data Whitening features over the entire packet.

In variable packet length mode, the operation is similar, but there is a length byte transmitted by the radio right after the synchron word that determines how many bytes will be transmitted from the FIFO.

The Si446x doesn't have dedicated variable packet length mode operation. The entire packet has to be filled into the FIFO as it desired to be transmitted, including the length byte on the proper location. Next, the START_TX command has to be called with the packet length to initiate the packet transmission. The radio transmits the preamble and the sync word automatically followed by the desired number of bytes from the FIFO (defined as packet length in the START_TX command).

If CRC calculation, Manchester coding, data Whitening, or 4(G)FSK modulation is used, then the FIELD feature needs to be used in transmit mode as well.

4.6. Auxiliary Functions

Table 5 summarizes the auxiliary functions.

Table 5. Auxiliary Functions

Function	Si443x	Si446x
Power-On Reset	Smart Reset	Simple Power On Reset.
Low Battery Detect	Battery voltage read possibility Low Battery Threshold Interrupt	Battery voltage read possibility. Low Battery Threshold Interrupt.
MCU Clock Output	Derived from the XTAL	Derived from the XTAL.
Temperature Sensor	Available through the internal ADC	Available through the internal ADC.
Wake Up Timer	Programmable, runs from the 32kHz oscillator, wakes up the radio	Programmable, runs from the 32 kHz oscillator, wakes up the radio and optionally into TX or RX mode.

The Si446x has a different power-on reset circuit that is able to reduce the Standby mode current consumption. It cannot reset the radio upon the rising edge of the supply voltage (called “smart reset” in the Si443x). Refer to the Si446x data sheet for more details on the power-on reset.

Note: If it is desired to reset the radio from the host MCU, the SDN pin is intended to be uses for that purpose.

The Wake Up Timer (waking up the radio and the host MCU regularly to complete scheduled tasks) has a new feature in the Si446x devices. It not only wakes up the radio, but it can also automatically set the radio into Receive or Transmit mode.

There is an 11-bit auxiliary ADC for measuring the battery voltage, the internal temperature sensor, or an external component over a GPIO in the Si446x. The ADC utilizes a SAR architecture and achieves 11-bit resolution. The Effective Number of Bits (ENOB) is 9 bits. This is an improvement over the 8-bit SAR architecture of the Si443x devices.

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