

Si4010 KEY FOB DEMO KIT WITH AES CAPABILITY USER'S GUIDE

1. Purpose

Thank you for your interest in Silicon Laboratories' Si4010 SoC RF key fob demo kit with AES capability. The Silicon Laboratories Si4010 key fob demo kit with AES capability contains everything you need to familiarize yourself with and evaluate the Si4010 RF SoC. The kit has two versions, one for the 434 MHz band and one for the 868 MHz band. The key features of the development platform are as follows:

- The key fob demo board has five push buttons and one LED output, a PCB antenna, and a battery in a plastic case.
- The key fob uses hardware-accelerated 128-bit advanced encryption standard (AES) encryption and rolling counter for RKE application.
- The receiver demo board has a graphic LCD to display received key fob commands.
- The provided software pack contains all the documentation and files needed to develop a user application. The kit supports the use of Silicon Laboratories' Integrated Development Environment (IDE) for software debugging and the use of the Keil C compiler, assembler, and linker toolchain.
- Contains demo applications using API functions and the key fob demo application.

2. Kit Contents

The kit contains the following items:

Qty	Part Number	Description
	4010-DAAKF_434	Si4010 Key Fob Demo Kit with AES Capability 434 MHz
1	4010-DAPB_434	Si4010 Universal Key Fob 434 MHz
1	4313-DACB_ANY	Si4313 LCD FSK/OOK Receiver any band
1	MSC-AT50-434	434 MHz Antenna
1	MSC-PLPB_1	Key Fob Plastic Case (translucent grey)
1	CRD2032	CR2032 3 V coin battery
1	MSC-DKSW1	Wireless Development Suite disc
	4010-DAAKF_868	Si4010 Key Fob Demo Kit with AES Capability 868 MHz
1	4010-DAPB_868	Si4010 Universal Key Fob 868 MHz
1	4313-DACB_ANY	Si4313 LCD FSK/OOK Receiver any band
1	MSC-AT50-868	868 MHz Antenna
1	MSC-PLPB_2	Key Fob Plastic Case (translucent red)
1	CRD2032	CR2032 3 V coin battery
1	MSC-DKSW1	Wireless Development Suite disc

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Figure 1. Si4010 Universal Key Fob and Plastic Case (P/N 4010-DAPB 868 and MSC-PLPB_1)



Figure 2. Si4313 LCD FSK/OOK Receiver Any-Band (P/N 4313-DACB ANY) with 434 MHz Antenna (P/N MSC-AT50-434)

3. Key Fob Demo with AES Capability

The 4010-DAPB RKE key fob transmitter and the Si4313 FSK receiver are the transmit and receive devices used in this key fob demo. This transmit/receive pair can be used to evaluate the capabilities of the Si4010 transmitter and the Si4313 receiver.

3.1. Operation of the Demo

The Si4313 demo receiver board uses the following RF parameters:

- 9.6 kbps
- FSK modulation
- 433.92 MHz or 868.3 MHz center frequency (menu selectable)
- ± 70 kHz deviation

If any push button is pressed on the key fob, it sends a message to the receiver. The demo uses Silicon Labs' general EZMacPRO protocol.

Table 1. General EZMacPRO Extended Packet Configuration Used by Demo Key Fobs

Preamble	Synch Word	MAC Header					MAC Payload		CRC
Min.13 bytes	2 bytes	5 bytes					0...64 bytes		2 bytes
0xAA...0xAA	0x2DD4	CTRL	CID	SID	DID	PL	NHDR	NWK payload	CRC

3.2. Association

To enable the receiver to react to the button presses on the key fob(s), they have to be paired (i.e., the key fob has to be associated to the receiver by pressing the left and right buttons simultaneously on the key fob).

Table 2. The MAC Payload Field of the “Associate Request from TX only Device” Packet

MAC Payload					
NHDR	NWK Payload				
1 byte	1 bytes	1 byte	1 byte	4 byte	4 byte
0x47	0x05	0x01	AES	Address	Rolling Counter

3.2.1. Meanings of the Different Fields

- **AES**—Defines whether the transmitter is using AES-128 encryption or not. It is set to 0x01; then, the Rolling counter field of the packets is extended to 16 bytes length (12 dummy bytes are appended) and is encoded by AES-128. Other fields of the packet are not affected by the encryption.
- **Address**—4 bytes of key fob address. The four byte random number factory burned in the Si4010 is used as the address.
- **Rolling Counter**—The transmitter increments a 4 byte counter after every packet transmission. This counter is stored in the MTP memory of the Si4010.

If the receiver accepts the association, it registers the Address, Master Key, and Rolling Counter value of the requesting key fob.

The Master accepts the association if it is in pairing mode and there is a free slot for a key fob (i.e., if there are fewer than four key fobs associated to the receiver).

After power up, the Receiver board is in pairing mode automatically. After pairing, it goes to normal packet reception mode. The Pairing mode can be invoked by pressing the push button, PB3, on the Receiver Board. This button needs to be pressed before the second and any subsequent pairing. If the PB is pressed for more than one second, the receiver disassociates all key fobs.

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3.3. Button is Pressed on the Key Fob

If any single button or button combination (except association combination) is pressed on the key fob, then it transmits a key fob data packet showing the button number in the button field.

Table 3. The MAC Payload Field of the “Key Fob Data” Packet

MAC Payload						
NHDR	NWK payload					
1 byte	1 byte	4 bytes	1 byte	2 bytes	1 byte	4 byte
0x04	AES	Address	Button	TEMP	Battery	Rolling Counter

3.3.1. Meaning of the Different Fields

- **AES**—Defines whether the transmitter is using AES-128 encryption. It is set to 0x01, then Button, Temp, Battery, and Rolling counter fields of the packets are extended to 16 bytes length all together and are encoded by AES-128. Other fields of the packet are not affected by the encryption.
- **Address**—4 bytes of key fob address. The four-byte random number factory burned in the Si4010 is used as the address.
- **Button**—Each bit of this byte corresponds to the status of a push button on the key fob. If the bit is set, the given button is pressed. If the bit is cleared, the button is released.
- **TEMP**—The temperature is encoded as a signed 16-bit integer. Each incremental bit of temperature reading represents 0.1 °C. If the temperature function is not implemented in the key fob, this field is set to 0xFFFF.
- **Battery**—1 byte unsigned char showing the actual power supply status of the key fob. It must be interpreted as follows:

1 bit	1 bit	1 bit	5 bits
Lbd Available	LBD Status	Battery Voltage Available	Battery Voltage[4:0]

- **LBD Available Bit**—If set, the LBD status bit shows the actual status of the battery.
- **LBD Status**—Shows whether the actual battery voltage is above the LBD limit (set if the actual voltage is below the threshold). The LBD limit is configurable in the key fob program.
- **Battery Voltage Available**—If set, the battery voltage information is available.
- **Battery Voltage**—It shows the actual battery voltage of the key fob. Each increment of the battery voltage bit corresponds to 50 mV. However, 0 represents 1.7 V.
- **Rolling Counter**—The transmitter increments a 4 byte counter after every packet transmission. This counter is stored in the MTP memory of the Si4010.

Since AES is used by the key fob, the receiver board decrypts the encrypted portion of the packet and discards the dummy bytes. Then, the receiver board checks the sync counter value against its own copy of the sender key fob's counter. If the key fob sync counter value minus the copy counter value is more than zero and less than a configurable window value (default value is 10), the master increments the copy.

3.4. Key Handling

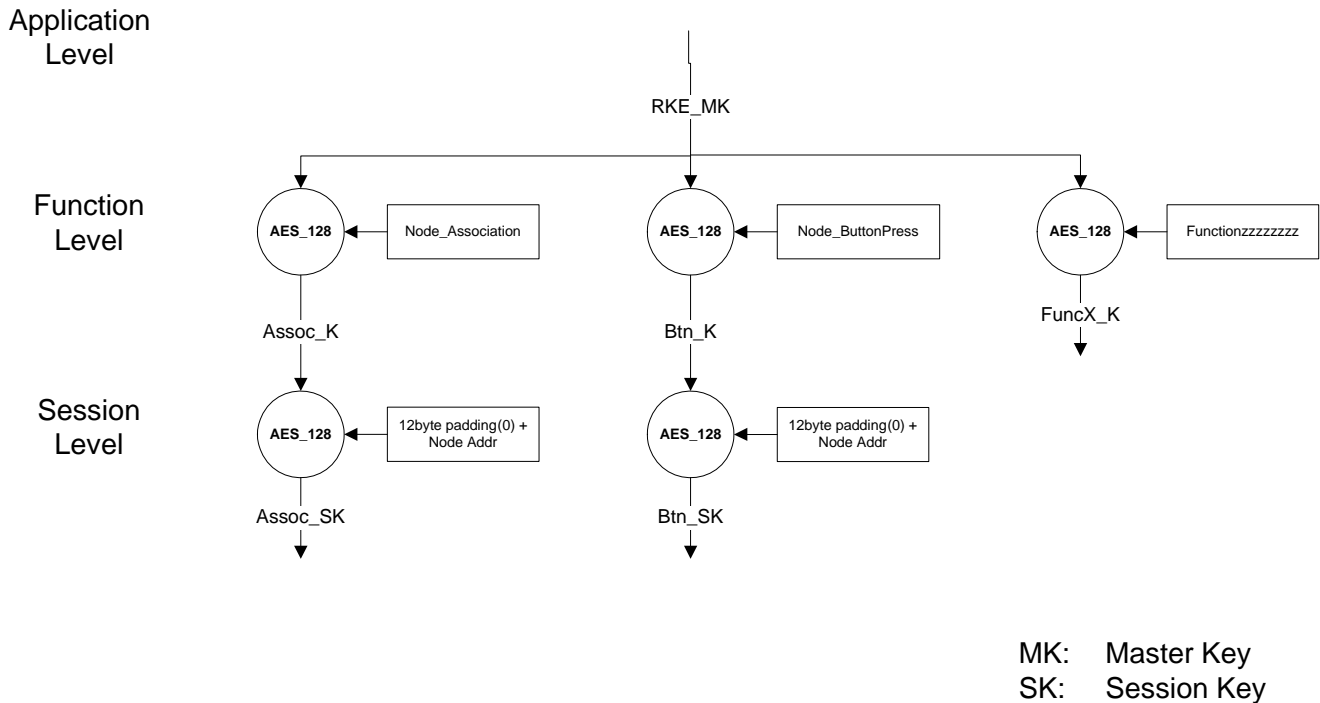


Figure 3. SRW AES128 Applications Key Hierarchy

AES keys used in the demos are generated according to the hierarchy shown in Figure 3. Only the Application level keys are stored on the receiver board. The function level keys are calculated at power-up. The Session level keys are calculated at their first use.

In the key fobs Function level, keys are not generated but only stored to save power. The Session level keys are calculated at each power up.

The Assoc_SK is used for association packets, and the Btn_SK is used for encrypting the messages generated by a button press.

3.5. Key Fob Firmware Description

The complete project of the program used in the demo key fob can be found in the Si4010 documentation kit in the "rke_demo" folder.

The key fob wakes up for button push or battery insert. If the battery was inserted, the `vSys_FirstPowerUp()` API function is called, which shuts down the chip after 600 ms. This is for safe startup in case of battery contact bouncing. Upon button push wakeup, the system variables and hardware control registers are initialized first, and the session keys used in the AES encoding are generated from the function keys and the device address. Then, button debouncing is made.

If a valid button push is detected, first a packet is assembled and transmitted six times for the LED receiver demo board used in the Si4010 Simplified Key Fob Demo Kit (see details in "AN516: Si4010 Simplified Key Fob Demo Quick Start Guide"). Then, a packet is assembled according to the description in the previous chapters. It is transmitted in FSK modulation for the Si4313 receiver board (part of this kit), and then also in OOK modulation. The next step is to increment the sync counter stored in the MTP memory.

If there is no valid button push detected for 3.2 s, the program shuts down the chip.

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3.5.1. Key Fob Firmware Flowchart

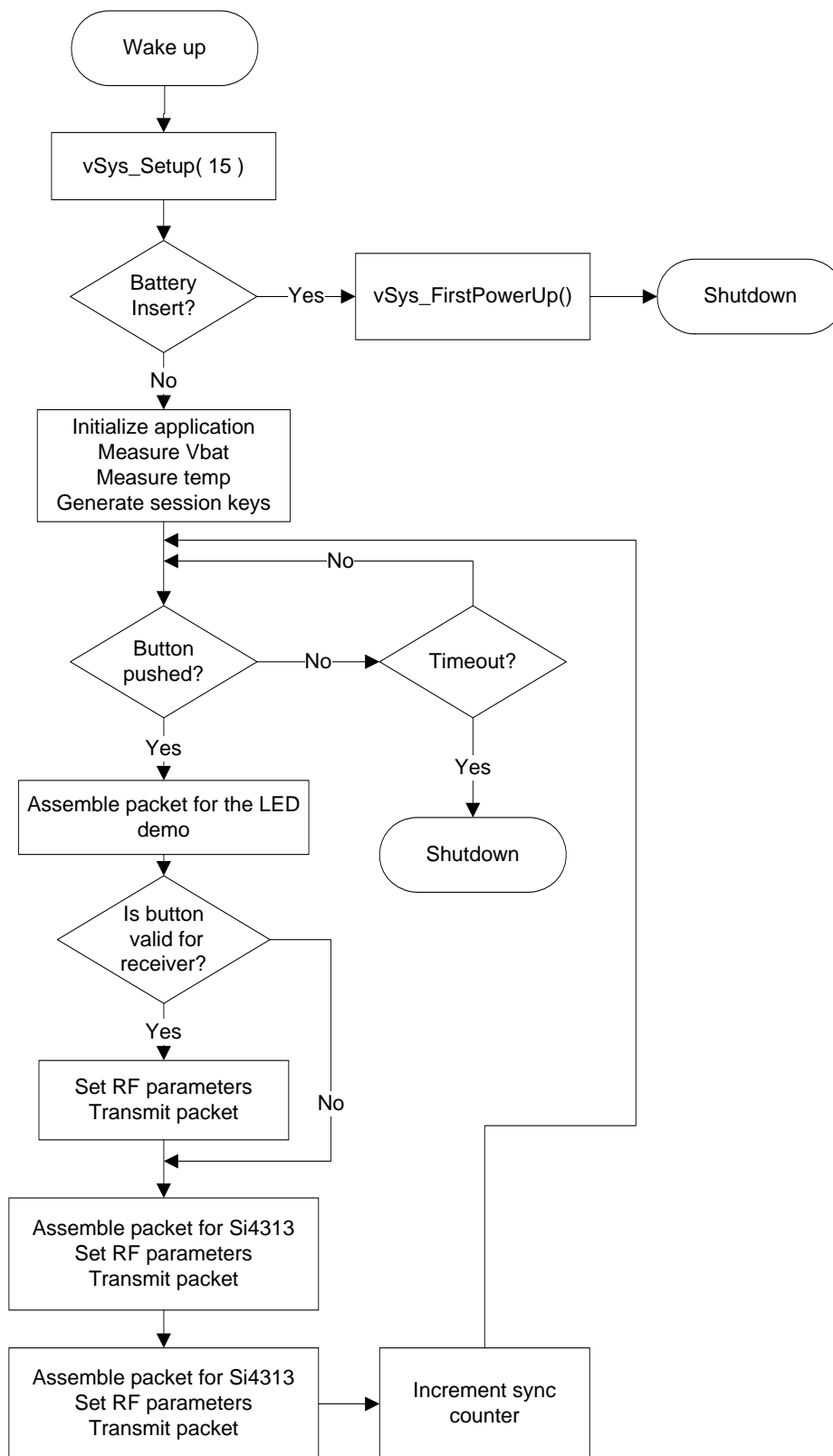


Figure 4. Key Fob Firmware Flowchart

3.6. Receiver Board Firmware Description

The Si4313 RX board receives the packets from the Si4010 key fob, and, by the packet headers, it decides what kind of packet was received. Two packet types can be received: association packets or button press packets. The Si4313 RX board has two operation modes: Association mode and Button press mode. *A key fob can only associate when the Si4313 RX board is in Association mode. If the Si4313 is in Button press mode, then the association packet will be discarded.* During the first power up, the Si4313 RX board goes into Association mode, and, after every key fob association, the firmware goes into Button press mode. The board can go back to Association mode if the PB button is pressed. After an Si4010 key fob associates to the Si4313 RX board, the RX board can receive the button press packets. At every packet reception, the firmware updates the LCD and sends an indication message to the PC via the UART interface. The LCD displays the associated key fob serial numbers and the number of the last button pressed on the key fob. However, the firmware stores more information about each associated key fob, such as AES keys, temperature, battery level, etc. Figure 5 shows a flow chart of the receiver board firmware.

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3.6.1. Receiver Board Firmware Flowchart

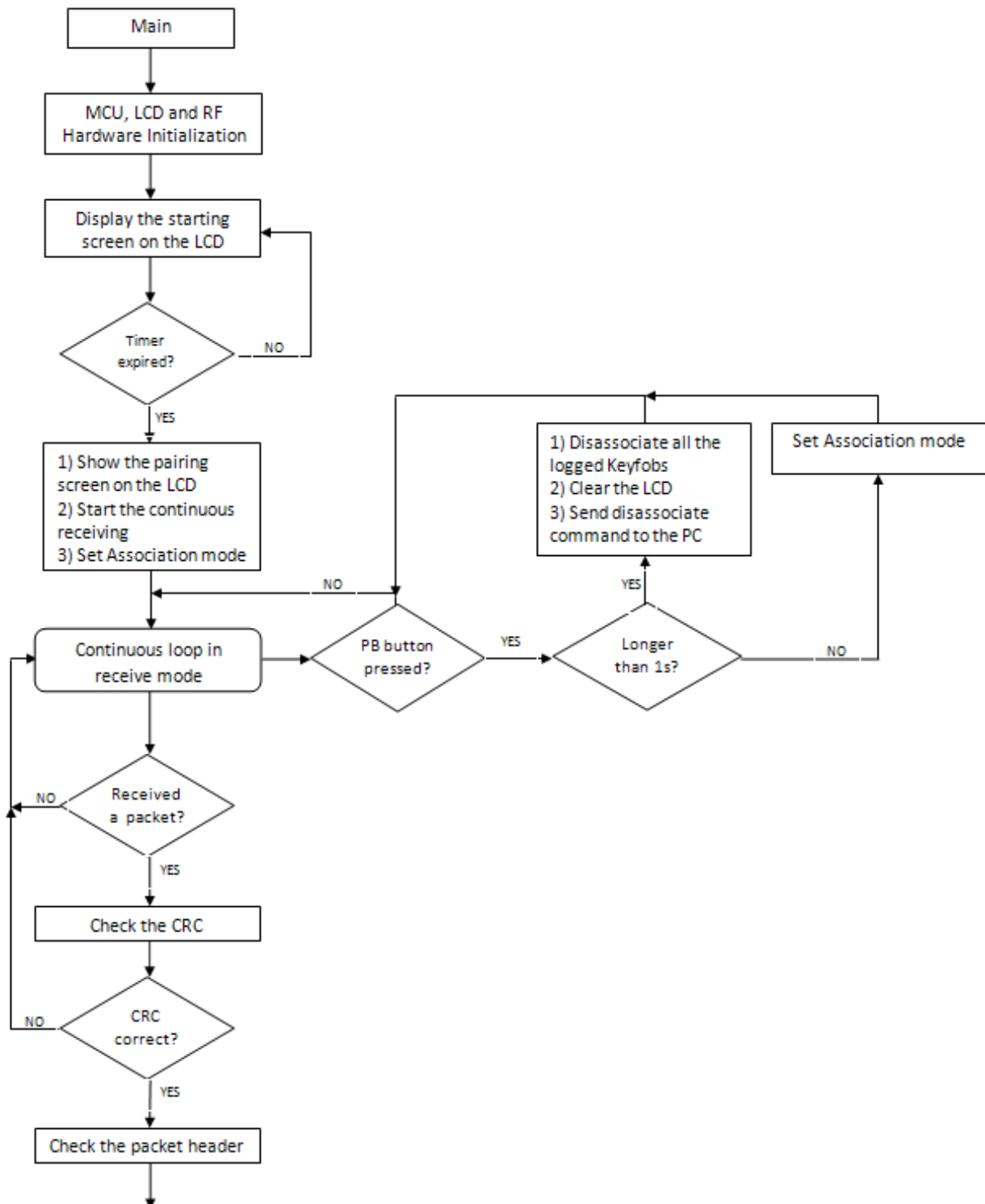


Figure 5. Basic Program Structure Block Diagram (1 of 2)

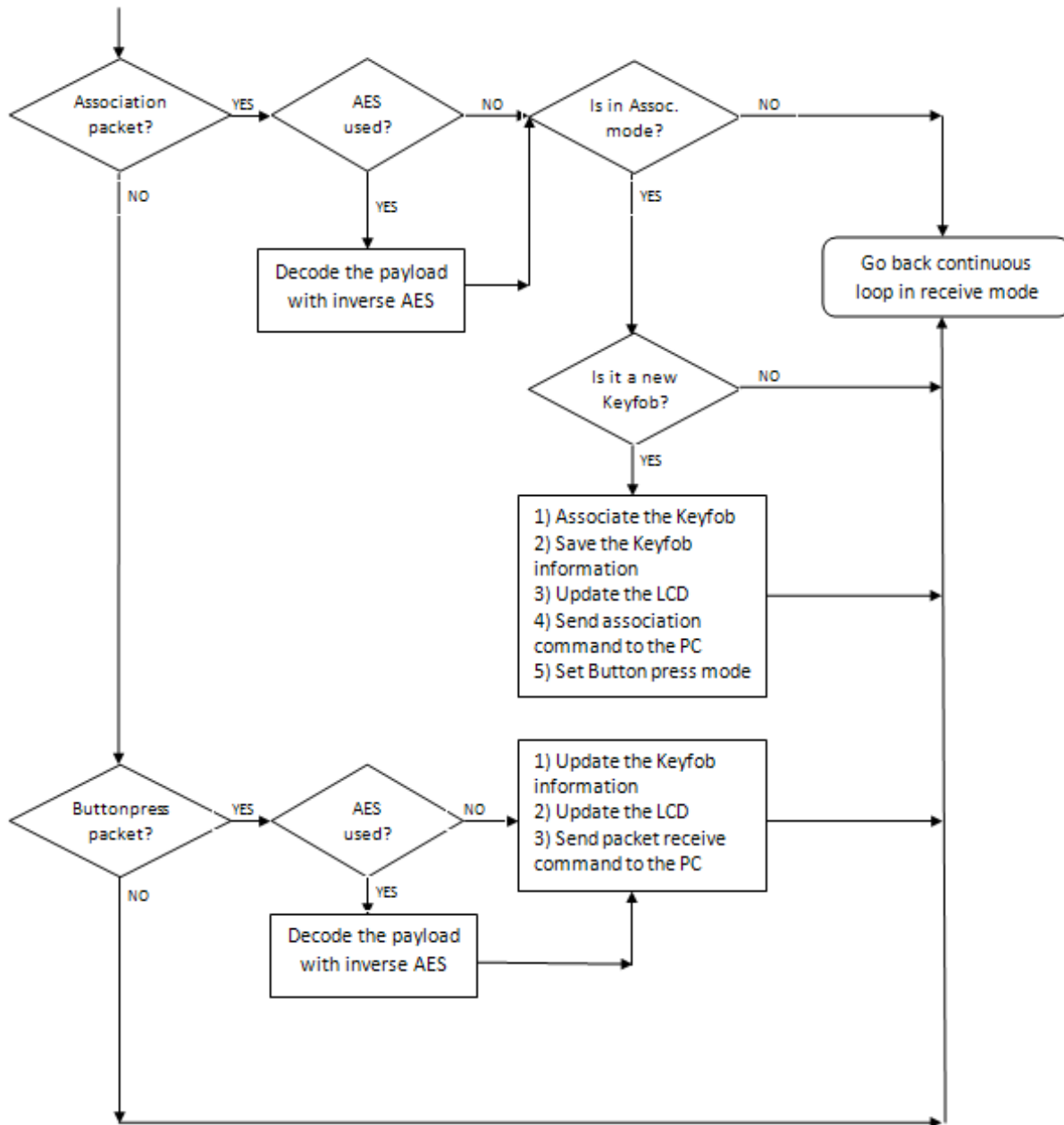


Figure 6. Basic Program Structure Block Diagram (2 of 2)

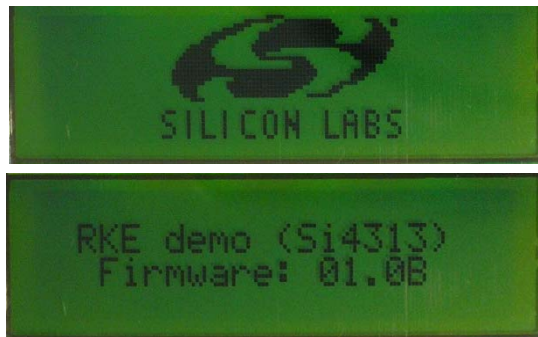
For details on how to program the Si4010, see the following documentation:

- Si4010 Data Sheet
- AN370: Si4010 Software Programming Guide
- Si4010 Development Kit User's Guide

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4. Demo Quick Start Guide

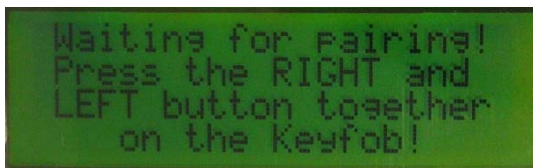
1. The first step is to insert the CR2032 battery into the key fob demo board and then place the board with the battery into the plastic key fob case. Pushing any key will flash the LED on the key fob.
2. Connect the antenna into the SMA connector of the 4313-DACB_ANY receiver board.
3. Power up the Si4313 Receiver board by connecting it to the PC's USB port or by inserting batteries (3xAA) at the back side of the board.
4. Switch the "S1" power supply switch to the proper position. If the board is supplied from the USB port, switch to the "USB" state, or, if the board is supplied from the batteries, switch to the "Bat." state.
5. After switching on the board, the LCD shows the Silicon Laboratories logo and the firmware version information. The demo shows this information three times during the startup. This startup process can be skipped if any of the PB1–PB3 button is pressed on the board.



6. On the next screen set the desired receive frequency using PB1 (+) and PB2 (–) buttons. Then step to the next screen by pushing the PB3 (GO) button.



7. Wait until the following screen appears.



8. Pair the key fob with the Receiver board by pressing the LEFT and the RIGHT buttons together on the key fob. If the key fob can be associated to the receiver board, then the serial number of the key fob appears on the display.

Note: Only four key fobs can be associated at the same time to the receiver board. The PB3 button on the receiver board has to be pressed shortly before every key fob association.

9. When the key fob is associated to the RKE receiver board, press any button on the key fob. The LCD screen shows the number of the depressed button.

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10. If the PB3 button is pressed for longer than 2 s and then released, the RKE receiver board disassociates all associated key fobs. If you want to use the key fob again then it is required to be paired again. Refer to Step 7 for instructions on how to perform the pairing. In this case, the key fobs should associate again.

The code used in the transmitter of this key fob demo application can be found in the documentation kit in the \Si4010 projects\rke_demo folder.

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5. Software Installation

The provided software pack contains all the documentation and files needed to develop a user application. It also contains example applications using API functions and the key fob demo application.

The directory structure of the software examples is as follows:

```
+--Si4010_projects
|
|  +--aes_demo
|  |   |--bin          .. Keil uVision and SiLabs IDE files
|  |   |--out          .. output directory for Keil toolchain
|  |   |--src          .. aes_demo source code
|  |
|  +--common
|  |   |--lib          .. Si4010 additional API functions library
|  |   |--src          .. Si4010 required files
|  |
|  +--fcast_demo      .. frequency casting (tuning) demo
|  |   |--bin
|  |   |--out
|  |   |--src
|  |
|  +--fstep_demo      .. frequency two step tuning demo
|  |   |--bin
|  |   |--out
|  |   |--src
|  |
|  +--tone_demo       .. continuous wave (tone) demo
|  |   |--bin
|  |   |--out
|  |   |--src
|  |
|  +--keyfob_demo     .. simple keyfob demo
|  |   |--bin
|  |   |--out
|  |   |--src
|  |
|  +--rke_demo        .. advanced keyfob demo with AES
|  |   |--bin
|  |   |--out
|  |   |--src
```

Copy the directory structure in a directory of your choice. It is recommended to keep the structure of the Si4010_projects folder to allow the compiler to find the Si4010 common files. Each project has a *.wsp project file in the bin folder that contains all the settings of the IDE for the project, including the relative path of the common files.

6. SiLabs IDE Run

Download the SiLabs IDE (Integrated Development Environment) from <http://www.silabs.com/products/mcu/Pages/SiliconLaboratoriesIDE.aspx> and install it on your computer. To run the Silicon Labs IDE, open the *.wsp project file.

7. Keil Toolchain Integration

The project files in examples assume that the Keil toolchain is installed to C:\Keil directory. The location of the Keil toolchain can be easily changed in the SiLabs IDE in the Project—Tool Chain Integration menu. An evaluation version of the Keil toolchain can be downloaded from the Keil web site, <http://www.keil.com/>. This free version has 2 kB code limitation and starts the code at 0x0800 address. The Keil free evaluation version can be unlocked to become a 4k version with no code placement limitation by following the directions given in application note “AN104: Integrating Keil 8051 Tools into the Silicon Labs IDE”, which covers Keil toolchain integration and license management. Unlock code can be found on the WDS CDROM in the root folder in the Keil_license_number.txt file. Contact your Silicon Laboratories sales representative or distributor for application assistance.

For the complete development platform containing debug adapter and development boards, see Silicon Laboratories' Key Fob Development Kit (P/N 4010-DKKF_434 or 4010-DKKF_868).

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