Freescale Semiconductor, Inc.
User's Guide

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KW40 Heart Rate Monitor Using Bluetooth Low Energy

User's Guide

1. Introduction

This document explains the features and usage of the Bluetooth® Low Energy (BLE) Heart Rate Monitor reference design which uses the KW40Z device. It does not contain software or hardware descriptions. See the Reference Manual (document BLEHRMRDUG) or Design Guide (document KW40HRMRDUG) for software and hardware descriptions.

1.1. Audience

The manual is intended for any person interested in understanding the functionality of the BLE Heart Rate Monitor reference design.

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2. Overview of reference design

The BLE Heart Rate Monitor reference design demonstrates the implementation of a wireless electrocardiogram (ECG) acquisition system. It features the Freescale MKW40 system on chip (SoC) which includes an ARM® Cortex™ M0+ processor together with a 2.4 GHz radio for BLE and 802.15.4.

The ECG signal is obtained from the finger tips and processed by the MKW40 SoC. Then, the user's heart rate is calculated and transmitted to a smartphone application using BLE. Figure 1 shows a general block diagram of the system implementation.

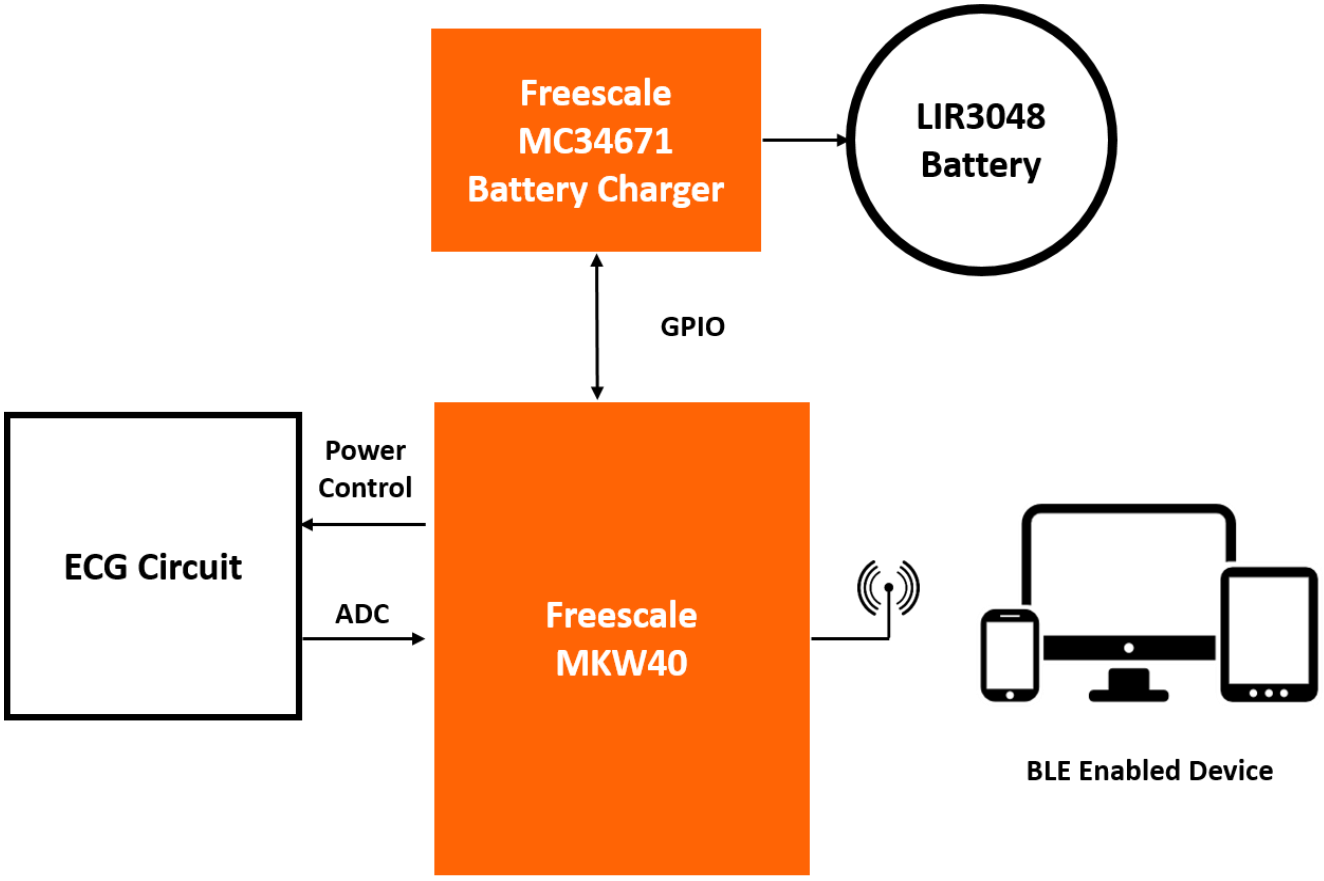

Figure 1. Application block diagram

A Li-Ion coin-cell battery is also included. The LIR3040 is a 3.6V 200mA/h rechargeable. The Freescale MC34671 is included provide a battery charger solution for the device.

2.1. Get to know the BLE Heart Rate Monitor

Figure 2 highlights the most relevant parts of the hardware.

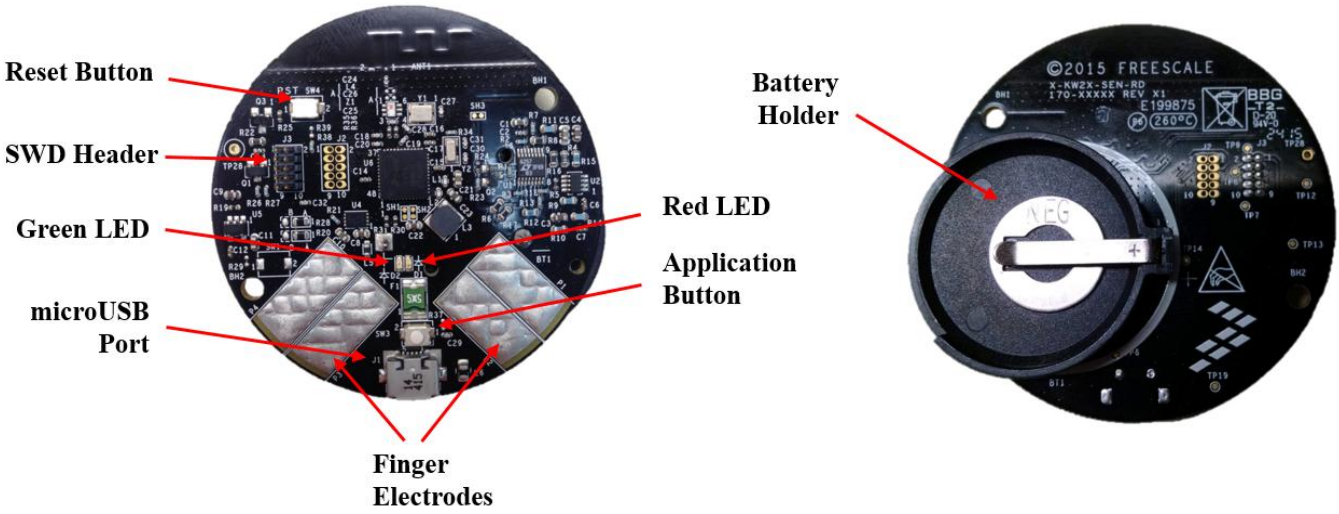

Figure 2. BLE heart rate monitor board

3. Unboxing

The demo kit contains two items: the main board and a LIR3048 coin-cell battery. The coin-cell battery must be placed in the main board's battery holder before you use the device. Figure 3 shows position of the battery.

Figure 3. Battery placement

After you have inserted the battery, the device will enter a battery retention mode. It can now interact with the user interface components.

4. Functional description

This chapter describes the device behavior across all its functional phases. It comprises all the required information to fully understand the application's functionality.

4.1. Battery Retention State

The battery retention state consists of turning off all the board indicators and program the KW40Z SoC to be in a low power state for battery saving.

The device can only exit from this state by connecting the battery charger or by entering the device in Advertising State (see the next section, 4.2).

The device enters in this state if a connection is not established during the advertising state or by pressing the application button either when the device is advertising or connected.

4.2. Advertising State

When the device is in advertising state, presence reports are transmitted over the air so the BLE devices nearby can be aware of the device's availability for connection.

To enter the advertising phase, the device must be in Battery Retention State (see section 4.1) and the application button must be pressed. The green LED will start blinking to indicate that the device is in the Advertising State (see Figure 4).

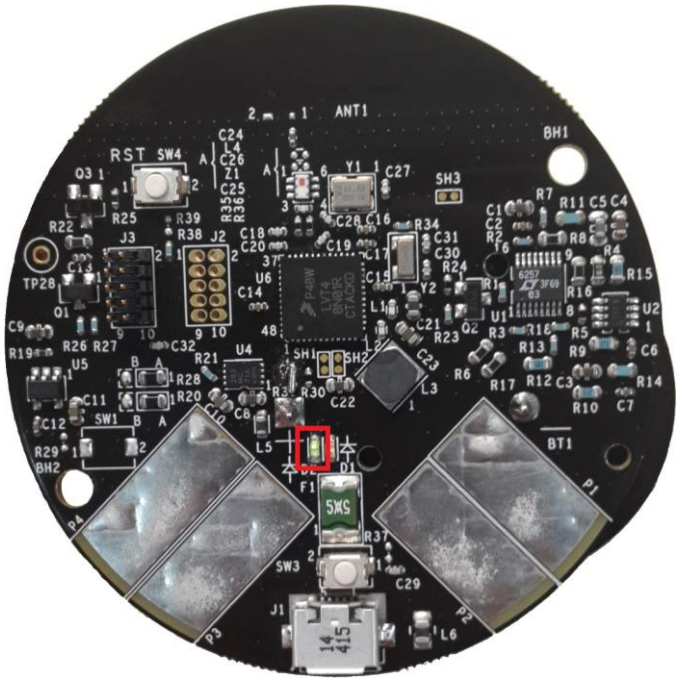

Figure 4. Device advertising

The device will advertise for 30 seconds. If a connection is not detected during that time interval, the device enters the battery retention state.

4.3. Connection with a smartphone

During the Advertising State, any BLE enabled smartphone can attempt to establish communication with the device. The following steps must be performed on the smartphone side:

1. Enable Bluetooth on the smartphone and scan for devices. See the smartphone's user documentation to learn how to do this.
2. Search for device "FSL_HRS_RD" and attempt a connection with it.

Figure 5. Device report name

3. When the passkey is requested, type 123456.
4. After connection is established, open the Freescale BLE Toolkit application in the smartphone. Any BLE heart rate application can be used as well.
5. Heart rate and battery level measurements will be reported in the application.

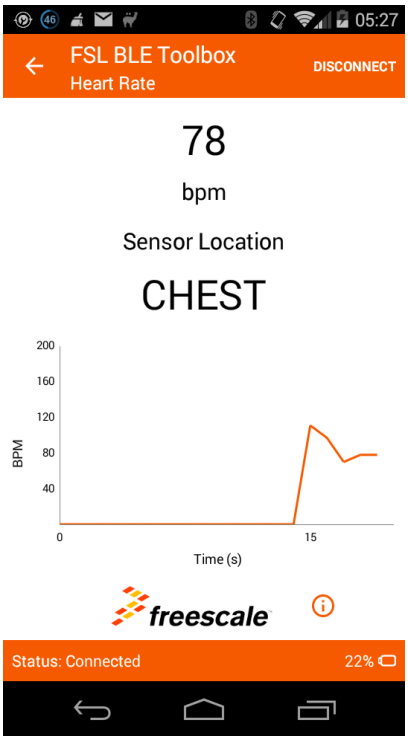

Figure 6. Application showing the reported measurements

4.4. Operation

After the device is connected, two types of measurements are reported to the smartphone application, heart rate and battery level.

4.4.1. Battery level

The battery level reports the percentage of the remaining charge in the device battery. This value is updated every 10 seconds in the smartphone application.

When the battery level reaches 0%, the device automatically enters the Battery Retention State and the device cannot be used until the battery has enough energy. Any attempt to begin using the device with a low battery will result in the red LED blinking three times indicating low battery level. See section 4.6 for instructions on how to properly charge the battery.

4.4.2. Heart rate measurements

When the device is connected to a heart rate application, it begins to report the acquired measurements. The ECG is obtained from the fingertips by placing them in the on-board electrodes. You must carry out the following steps to ensure accurate measurements.

1. Place your thumbs on the on-board firmware electrodes (see Figure 7). Avoid pressing too hard to prevent muscular noise interference.

Figure 7. Fingers position

2. Wait for at least 10 seconds for the signal to stabilize. The red LED will blink every time a heartbeat is detected.

NOTE

PCB electrodes might not always acquire the ECG signal immediately. If this happens and the reported heart rate is shown as zero, remove your fingers from the PCB electrodes and repeat steps 1 and 2.

3. See the results on the smartphone screen. The results are updated every 2 seconds.

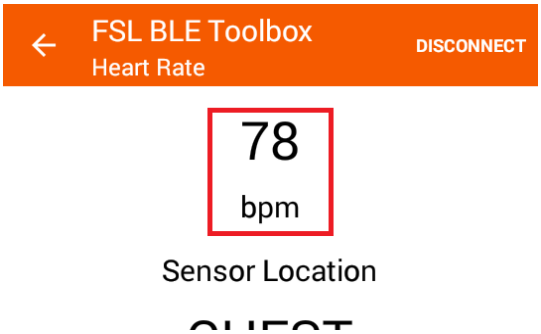

Figure 8. Heart rate report

4.5. Disconnecting from the application

A connection can end for three main reasons:

1. The connection is lost.
2. The connection is explicitly terminated by the smartphone.
3. The connection is explicitly terminated by the device.

When the connection is lost or explicitly terminated by the smartphone, the device enters the Advertising State during 30 seconds. If the connection is not re-established during that time, the device enters the Battery Retention State.

When the connection is explicitly terminated by the device by pressing the application button, it enters the Battery Retention State.

4.6. Charging the battery

The BLE Heart Rate Monitor includes a rechargeable coin-cell battery and a battery charger. The device actively reports the current battery level every 10 seconds when connected to a smartphone.

The included coin-cell battery is recharged by connecting a USB battery charger to the microUSB port in the board (see Figure 2).

4.6.1. Device operation when charging

Immediately after the battery charger is connected the red LED will start blinking indicating that the battery is being charged.

During charging, all BLE communications and analog processing is disabled. Any established connection is terminated immediately after the charger is connected. Any advertising or connection attempts are rejected during the time the charger is connected.

NOTE

To ensure user safety, the analog acquisition circuit is disabled during the charge of the battery. Heart rate measurements are unavailable during that time.

After the battery is fully charged, the red LED will remain on to indicate that the battery charger can be disconnected.

5. User Interface Description

In the BLE Heart Rate Monitor, the user interface is composed of two LEDs and one push button. Functionality for each element is described below.

5.1. Red LED

Table 1 shows the possible indications for the red LED and its meaning.

Table 1. Red LED indications

LED Status	Indicated action
LED off	No action
LED fade	Battery charging
LED on	Battery fully charged
LED flash	Heartbeat detected

5.2. Green LED

Table 2 shows the possible indications for the green LED and its meaning.

Table 2. Green LED indications

LED Status	Indicated Action
LED off	No action
LED blink	Device advertising
LED fade	Device connected

5.3. Application Button

Table 3 shows the action performed by the application button depending on the actual state.

Table 3. Application button actions

Device state	Action performed
Battery Retention State	Enter Advertising state
Advertising State	Enter Battery Retention State
Connected	Enter Battery Retention State
Charging	None

6. Loading firmware

If a firmware update is required, a new version can be downloaded using a J-link programmer. This chapter explains the firmware download process for the device.

6.1. Prerequisites

The following list details the required elements for the download process:

1. Download and install J-Link software v5.02 or higher from www.segger.com.
2. J-Link or J-Link Pro debugger.
3. heart_rate_sensor.bin file with the latest firmware.

6.2. Download process

The following steps explain the downloading process for the firmware.

1. Copy the heart_rate_sensor.bin file to the J-Link software installation folder. It is typically located in C:\Program Files\SEGGER for 32-bit systems and C:\Program Files (x86)\SEGGER for 64-bits systems.
2. Make sure that the battery is inserted properly (see Figure 3).
3. Connect the J-Link debugger to the SWD header in the board as shown in the following.

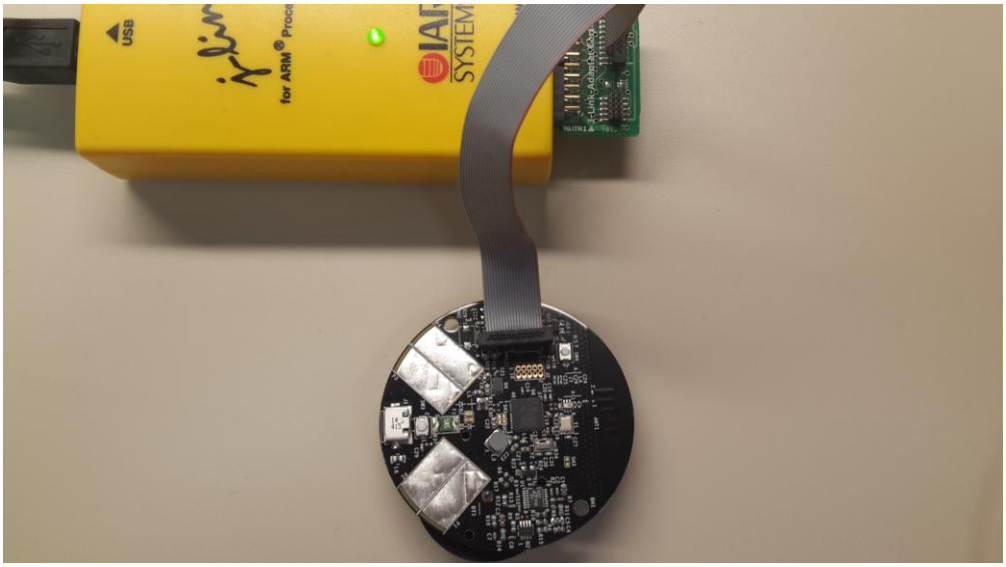

Figure 9. J-Link connection

4. In the J-Link software installation folder, execute the program JLink.exe. A terminal window will open (see Figure 10).

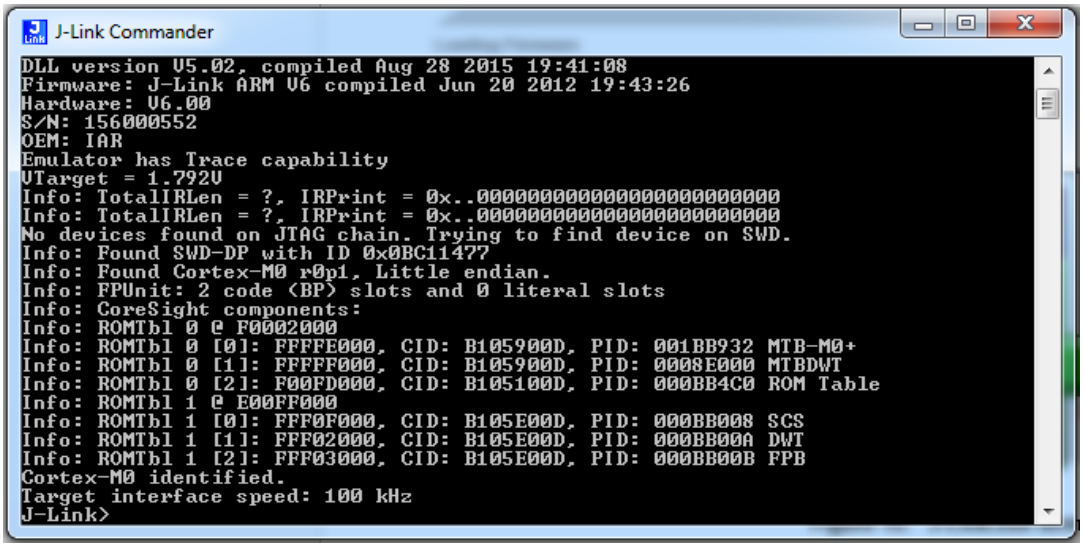

Figure 10. J-Link.exe terminal

5. Type the following instructions and press the enter key.
   - unlock kinetis
   - device MKW40Z160xxx4
   - loadbin heart_rate_sensor.bin 0
6. Wait for the board to flash (see Figure 11).

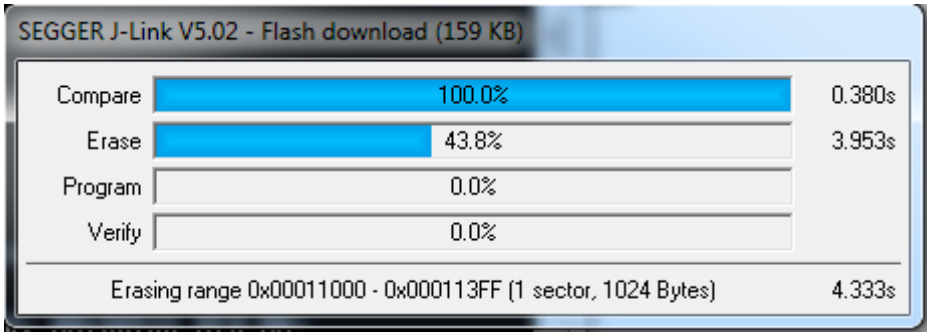

Figure 11. Board flashing

7. Remove the battery and insert it again to begin using the device.

7. Revision history

Table 4. Revision history

Revision number	Date	Substantial changes
0	10/2015	Initial release

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