Heart-Rate Monitor Wrist Band Using the MAX77651B

MAXREFDES1207

Introduction

The MAXREFDES1207 is a reference design for wearable application based on a total Maxim® solution which includes the MAX32660, MAX30112, MAX77651B, and MAX40005. This solution demonstrates how a small size, low cost, low power, high accuracy heart-rate (HR) monitor can be easily implemented. This design can monitor heart rate using two green LEDs.

The MAX30112 is an optimized pulse-oximeter and heart-rate AFE for wearable health. It has a high-resolution, optical readout signal-processing channel with built-in ambient light cancellation as well as high-current LED driver DACs to form a complete optical readout signal chain. With external LED(s) and photodiode(s), the MAX30112 offers the lowest power, highest performance heart-rate detection solution for wrist applications. The MAX77651B provides highly-integrated battery charging and power supply solutions for low-power wearable applications where size and efficiency are critical. The device features a SIMO buck-boost regulator that provides three independently programmable power rails from a single inductor to minimize total solution size. A highly configurable linear charger supports a wide range of Li+ battery capacities and includes battery temperature monitoring for additional safety (JEITA). The MAX32660 is an ultra-low-power, cost-effective, highly-integrated microcontroller unit (MCU) designed for battery-powered devices and wireless sensors. It combines a flexible and versatile power management unit with the powerful Arm® Cortex®-M4 with floating point unit (FPU). The MAX40005 is a tiny, single comparator which is ideal for a wide variety of portable electronics applications such as cell phones, media players, and notebooks that have extremely tight board space and power constraints. The design also contains an FTDI FT234 USB-to-serial UART interface. Table 1 provides an overview of the design specification.

Main features and benefits:

- Integrated solution
- Small size
- Low power
- High accuracy

Table 1. Design Specification

PARAMETER	SYMBOL	MIN	MAX
Battery Voltage	V_{BAT}	3.1V	4.6V
USB Input Voltage	V_{USB}	5V	
Standby Current	$I_{STANDBY}$	0.1mA	
Average Operation	$I_{OPERATION}$	10mA	
Pulse Width	INT	69µs	411µs
ADC Resolution		16 bits	19 bits
Sample Rate	SR	20sps	3200sps
LED Current	I_{LED}	0	50mA
Temperature Range	$T_{OPERATION}$	-40°C	+85°C

Designed–Built–Tested

This document describes the hardware shown in Figure 1 and provides a detailed systematic technical guide to designing a small-size, low-cost, low-power, high-accuracy heart-rate monitor. The design has been built and tested, details of which follow later in this document.

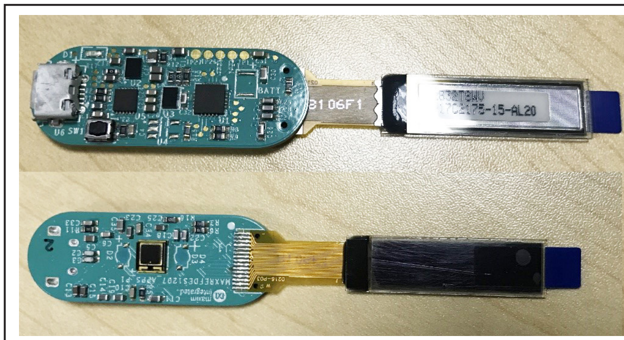

Figure 1. MAXREFDES1207 hardware.

Design Considerations

These wearable devices should have the following important characteristics and features:

- Small size –They should be designed as small as a normal watch, wrist belt, finger scanner, or similar device. And as designers try to incorporate more functions into the devices, the size of the device's individual components becomes ever more important. The number of components that can fit on a device directly determines the number of functions that the device can feature.
- Low power –They use batteries for the system power supply. Because of the limited size and energy density of the battery, low power means longer use time. The wearable devices often have two working modes: standby mode and operation mode. Most devices are in standby mode more than 90% of the time, so the standby current is very important. For a 100mAh battery, if the standby current can be limited within 1mA and operation current is 10mA, the system can work for approximately 92 hours.
- Accuracy –The devices require higher and higher accuracy, and the market only accepts the more accurate devices.

Design Procedure for the MAX77651B Power Solution

We selected the highly integrated MAX77651B as the power solution for the whole system.

Step 1: Select the Output Rails

The system requires three power rails: 3.3V, 4.5V, and 1.8V. One 3.3V rail is used for the MAX32660 MCU, the OLED panel, and the MAX40005, which use a digital power supply and require 3.3V for full operation. The MAX30112 has two rails: a 1.8V for analog and digital and a 4.5V for the LED driver. The MAX77651B has four outputs (three buck-boost regulators and one LDO) that can be configured to be 1.8V, 3.3V, or 4.5V outputs to meet the system requirements.

Step 2: Calculate the Current

The full current of the MAX32660 MCU can be calculated using the following equation:

$$I_{MCU} = 96MHz \times \frac{85\mu A}{MHz} = 8.16mA$$

where 96MHz is the maximum frequency of the MAX32660 MCU with an average of 85μA/MHz.

The MAX30112 current is determined by the LED current which ranges from 1.8mA to 10mA. For this reference design, the MAX30112 current is typically 3.2mA. The OLED panel has a maximum current of 10.8mA with full display. The MAX40005 is a nanoPower chip with a current that is less than 1mA.

The total maximum current of the reference design is less than 25mA when fully functional.

Detailed Description of Hardware

Figure 2 shows the MAXREFDES1207 block diagram. When the device is worn on the wrist or a finger is placed on the LEDs and photodiode, the sensor captures and measures the HR levels and shows the results on the OLED screen. The design includes source files for the microcontroller to enable developers to quickly evaluate and customize the design for their specific applications with minimal firmware or hardware changes. The board is designed in a compact form factor for rapid evaluation or installation.

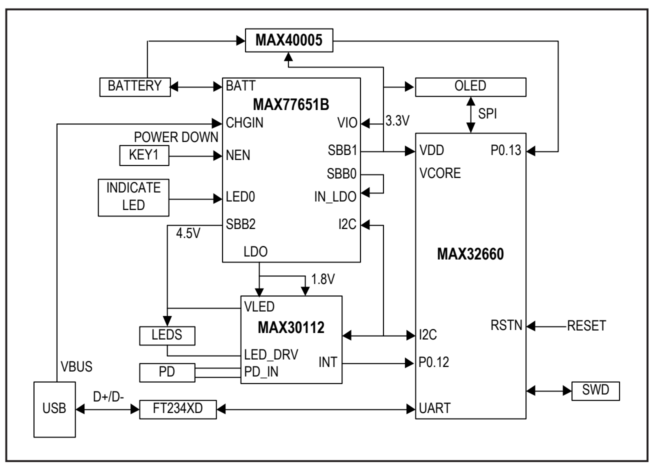

Figure 2. MAXREFDES1207 block diagram.

Microcontroller

The MAXREFDES1207 uses the MAX32660 as its MCU. This chip is dedicated for the low-power-application market to be used in wearable applications. Because the Arm Cortex-M4 is small, uses low power, and has a lot of memory, it performs to our requirements. The push button S1 can manually reset the MCU.

Optical Sensor AFE

The MAX30112 is a highly-integrated total solution for biosensors that consists of an ADC, a noise-cancellation circuit, a temperature sensor, a filter, I2C, and an LED drive. Its shutdown current is 1.4μA (typical). The MAX30112's higher accuracy allows it to be very suitable for wearable applications, like SpO2 and HR measurements for wrists, finger, ears, etc.

Power Supply

The battery must not be larger than the size of the board. A 90mAh to 120mAh Li+ battery is chosen. Usually the charge rate is 1C, which means the charge current has a maximum of 90mA to 120mA. We chose the MAX77651B as the total power solution, which also has battery charge management. The MAX77651B provides three independently programmable power rails and one 150mA LDO. In the MAXREFDES1207, the MAX77651B generates 3.3V for the MCU and analog, 4.5V for the LED driver, 1.8V for the interface. Its configurable linear charger supports the 120mA, 3.7V Li+ battery.

The MAXREFDES1207 can be supplied by both battery and USB. When the USB is present, the battery is charged and LED D1 is on. When the USB is not present, the battery supplies the system. The push button S1 can manually power down (when pressed for eight seconds) and power up the whole system.

The design also includes one MAX40005. The MAX40005 monitors the battery voltage. When the battery voltage is below 3.1V, the MAX40005 generates a rising pulse. The MAX32660 MCU can detect the pulse and give low battery voltage warning information in the OLED panel for the user. If the battery is recharged, the warning information disappears.

Detailed Description of Software

The MAXREFDES1207 software includes the MAX32660 firmware (i.e., main loop) and algorithm, the MAX30112 configure, and the MAX77651B configure.

Main Loop

The MAXREFDES1207 firmware is based on an infinite-loop design model. After power-up, the MCU configures itself, the MAX77651B, the MAX30112; and then goes into an infinite loop waiting for a data interrupt to perform measurements.

Figure 3 shows the flow of the main loop.

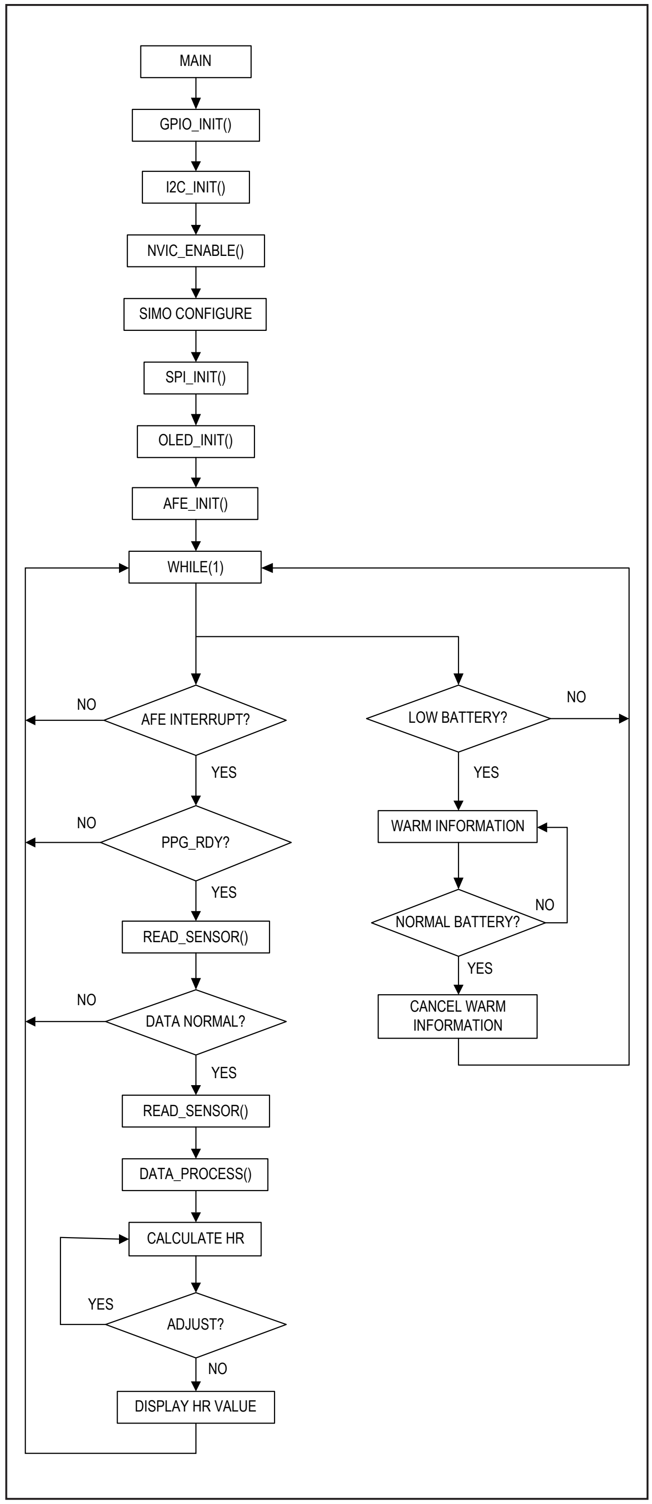

Figure 3. Main function flowchart.

MAX30112 Configuration and Measurement

The MAX30112 uses two green LEDs and a photodiode to transfer optical information directly to 16-bit to 19-bit digital current data. To be suitable for different users, the MAX30112 configuration can be automatically adjusted. The complete command sequence for HR measure is shown in Figure 4.

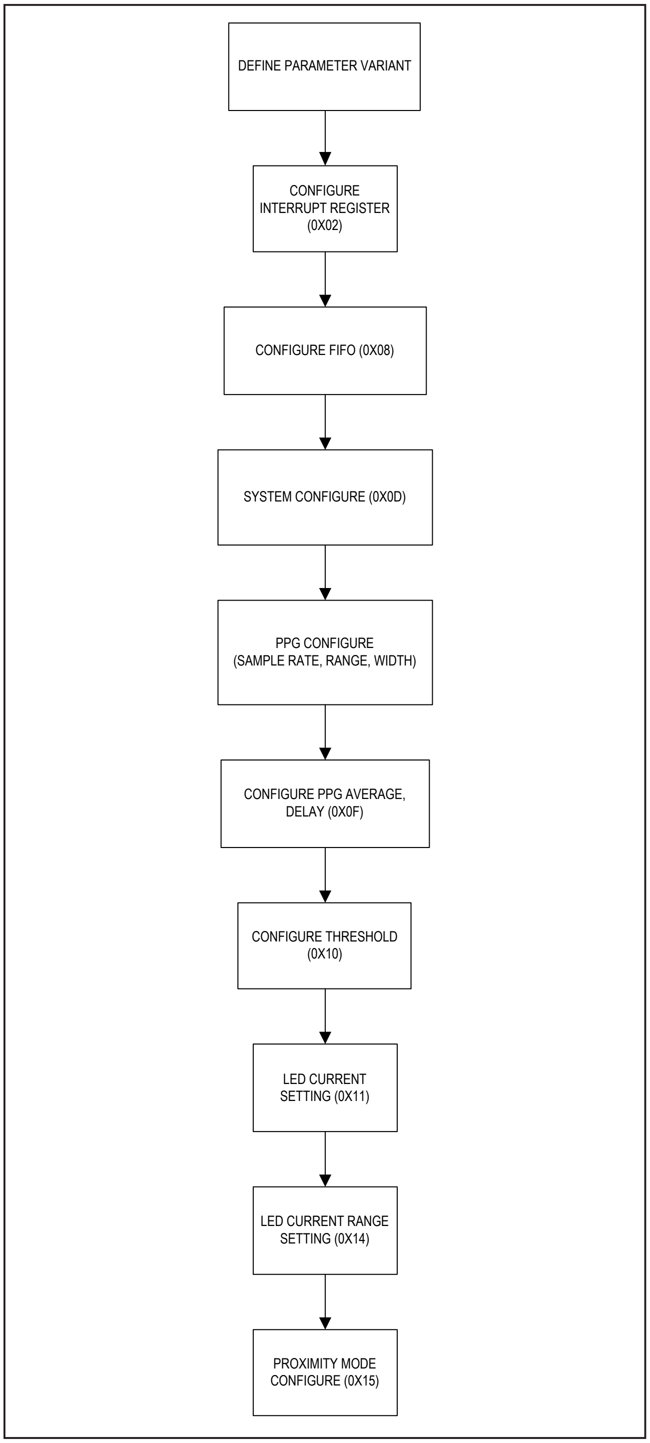

Figure 4. MAX30112 configure flowchart.

Algorithm Overview

The MAXREFDES1207 reference design board measures HR. To test the reference design, we developed a simple algorithm for the MAXREFDES1207 to calculate HR based on the PPG signal. This algorithm is only for reference and is not for commercial application.

Operation Overview

The MAXREFDES1207 operation is simple because it has no GUI and just includes operation mode selection and firmware program/download.

Power Save Mode and Operation Mode

The MAXREFDES1207 works in two modes: standby mode and operation mode. When the S1 button is pressed for 8s, the device enters power save mode. To measure HR, the device must be in operation mode.

Program Download Interface

The serial wire debug interface (SWD) is used for code loading. There are connectors (TP1,TP24 through TP27) for the SWD connection on the board.

Design Resources

Download the complete set of **Design Resources** including schematics, bill of materials, PCB layout, and test files.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	6/19	Initial release	—