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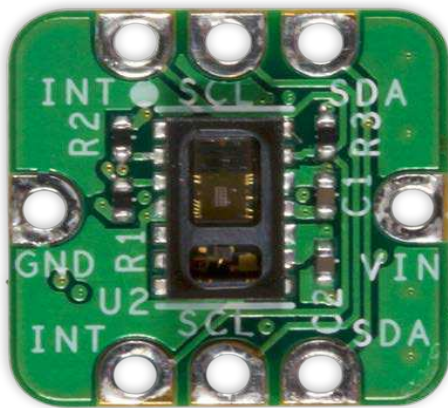
System Board 6300
# MAXREFDES117#: Heart-Rate and Pulse-Oximetry Monitor

The MAXREFDES117# reference design is a low power, optical heart-rate module complete with integrated red and IR LEDs, and a power supply. This tiny board, perfect for wearable projects, may be placed on a finger or earlobe to accurately detect heart rate. This versatile module works with both Arduino and mbed platforms for quick testing, development and system integration. A basic, open-source heart-rate and SpO$_2$ algorithm is included in the example firmware.

The board features 8 sewing tap pads for attachment and quick electrical connection to a development platform.

MAXREFDES117# System Board   MAXREFDES117# Reference Design Block Diagram
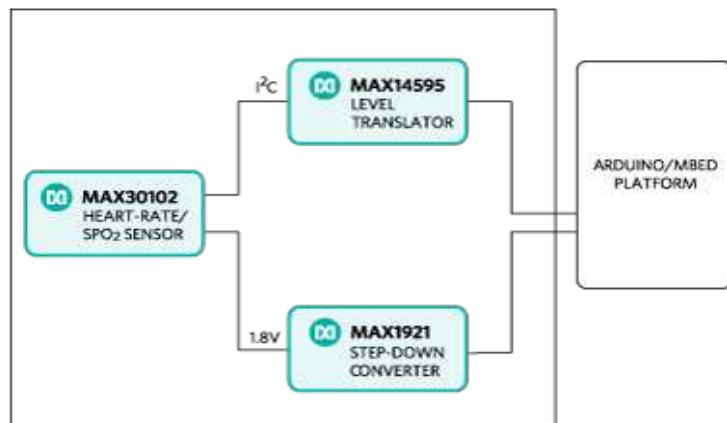
Features
Optical Heart-Rate Monitor and Pulse Oximetry Solution
Tiny 12.7mm x 12.7mm (0.5in x 0.5in) Board Size
Low Power
Device Drivers
Free Algorithm
Example C Source Code For Arduino And mbed Platforms
Test Data

Competitive Advantages
Highly-integrated, small-size sensor
Non-chest based heart-rate/SpO$_2$ detection
Ultra-low power consumption

Applications

Wearables

Heart-rate monitor

Pulse oximeter

Introduction

Wearable devices hold the potential to transform health and medical monitoring. Heart rate, specifically, provides tremendous insight into heart function and health, during both activity and rest. Innovation and development of both optical semiconductors and lower-power integrated circuits makes the transition to wearables possible. Until now, only large organizations, with deep development budgets, could deliver such advanced products.

MAXREFDES117# delivers the promise of wearable devices to all developers. This unique design measures both heart rate and pulse oximetry. MAXREFDES117# features the MAX30102 with integrated red and IR LEDs for heart-rate and SpO$_2$ detection. This configuration ideally detects heart rate and pulse ox on a person's fingertip, earlobe, or other fleshy extremity. The small board size of 12.7mm x 12.7mm (0.5in x 0.5in) is ideal for wearable applications and may be stitched into fabric for immediate prototyping. Firmware is available for both Arduino and mbed platforms, enabling users to develop with virtually any platform. User needs to provide a 2V to 5.5V supply at the power input, perfect for virtually any battery or Arduino and mbed form-factor board.

The MAXREFDES117# design utilizes the heart-rate/SpO$_2$ sensor (MAX30102), an efficient, low-power step-down converter (MAX1921), and an accurate level translator (MAX14595). The entire design typically operates at less than 5.5mW when using with the example firmware. A block diagram of the system is shown in **Figure 1**.
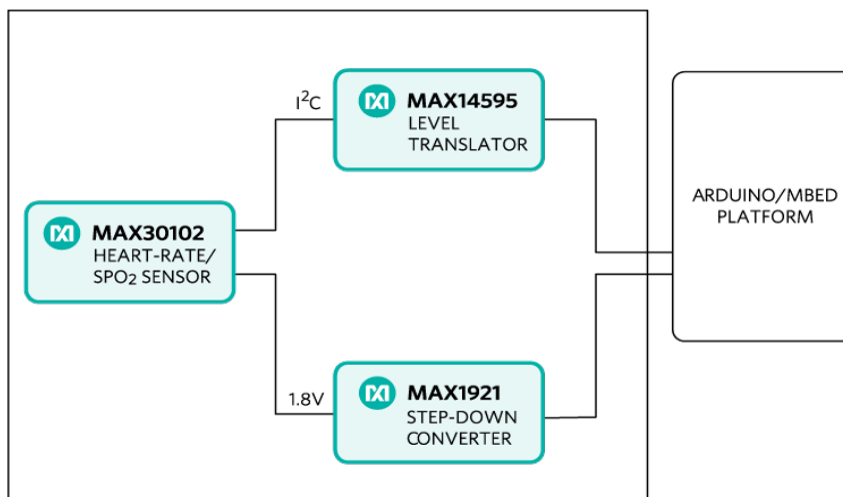
System Diagram

Figure 1. MAXREFDES98# reference design block diagram.

The power requirement is shown in **Table 1**.

Table 1. Power Requirement for the MAXREFDES117# Reference Design

Input Voltage (V) 2V to 5.5V

Input Current (mA, typ) 1.5mA (3.3V input)

Note: Controller board is powered separately

The MAXREFDES117# reference design is a PPG-based heart-rate and SpO2 monitor subsystem. The circuit utilizes the MAX30102 heart-rate/SpO2 sensor with integrated red and IR LEDs. The step-down converter MAX1921 converts the 2V to 5.5V supply input and generates the 1.8V rail for the heart-rate sensor. The MAX14595 level translator provides an interface between the heart-rate/SpO2 sensor and the controller board, which generally use a different logic level.

Detailed Description of Firmware

The MAXREFDES117# can be used with virtually any microcontroller that has I_2C interface. The Arduino and mbed example firmware have been tested on the following development platforms:

mbed:
  Maxim Integrated MAX32600MBED#
  Freescale FRDM-K64F
  Freescale FRDM-KL25Z

Arduino:
  Adafruit Flora
  Lilypad USB
  Arduino UNO

Users may read sampled data, calculated heart rate and SpO_2 through a terminal program, allowing analysis on excel or any third-party software. The simple process flow is shown in **Figure 2**.
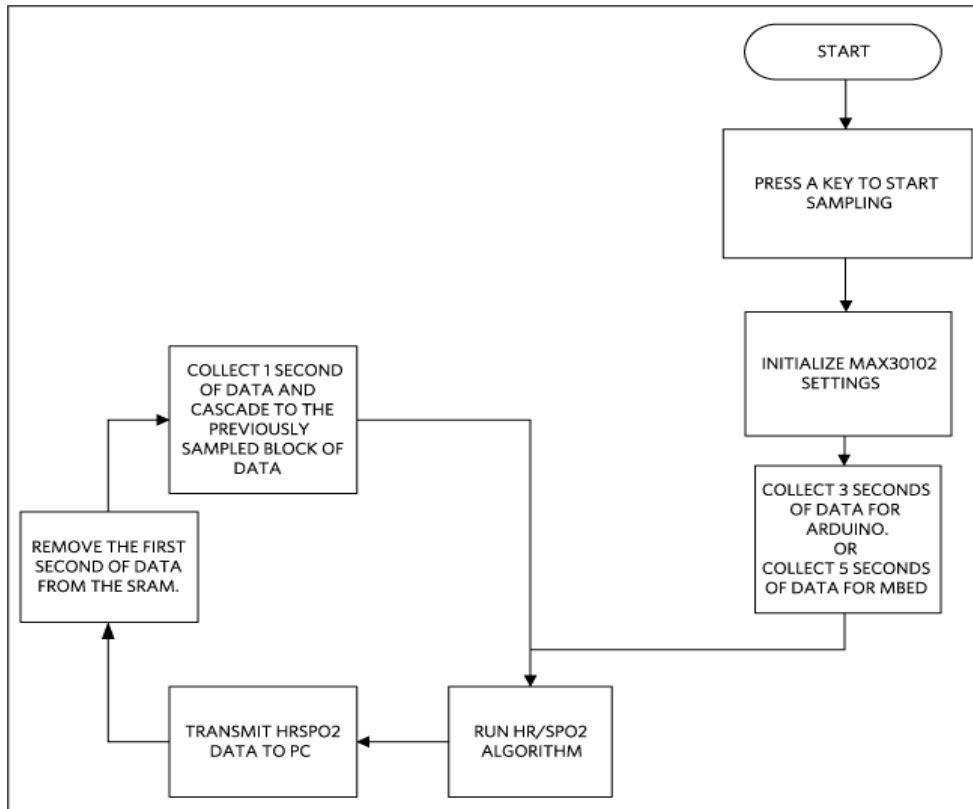
Figure 2. The MAXREFDES117# firmware flowchart.

Figure 2. The MAXREFDES117# firmware flowchart.

The complete source code, including the heart rateheart-rate/SpO$_2$ algorithm, is provided to accelerate development. Code documentation can be found in the corresponding firmware platform files.

Heart rateHeart-rate accuracy varies depending on the chosen platform. The tested mbed platforms give more accurate heart-rate/SpO$_2$ calculations than the tested Arduino platforms because the mbed platform controllers have more SRAM than the Arduino platform controllers. For the example firmware, mbed platforms store 5 seconds of samples collected at 100sps, while the Arduino platforms store 4 seconds of samples collected at 25sps.

SpO$_2$ calculation is based on the equation shown below. However, determining the constants (C_1, C_2, and C_3) requires a comprehensive clinical study of pulse pulse-oximetry data from a statistically significant population set using this hardware. Such a clinical study is beyond scope of this design. Therefore, the calculated SpO$_2$ value may havecan have an error.

$$SpO_2 = C_1 \times AverageRatio_2 + C_2 \times AverageRation + C_3$$

Where AverageRatio is the average ratio of IR and red LED readings. C_1, C_2, and C_3 are constants.

Quick Start

Required equipment:

- Windows PC with a USB port
- MAXREFDES117# board
- 5 cables that can be used to connect the MAXREFDES117# with the controller board
- One of the supported mbed or Arduino controller boards listed above
- One USB cable that is compatible with the selected controller board

Download, read, and carefully follow each step in the appropriate MAXREFDES117# quick Start Guide:

▲ MAXREFDES117# mbed Quick Start Guide

Quick Start

Required equipment:

- Windows PC with a USB port
- MAXREFDES117# board
- 5 cables with grabber clips on both ends.
- One of the three supported controller boards (Adafruit Flora, Lilypad USB, or Arduino UNO board)
- One micro USB cable (for Lilipad or Flora)
- One A to B USB cable (for Arduino UNO) Procedure

The reference design is fully assembled and tested. Follow the steps below to verify board operation:

1. If Arduino IDE is not installed on the PC follow the getting started guide to install the Arduino IDE on the PC.
2. If Adafruit Flora board is selected as the controller board:
    ◦ Follow the Adafruit Windows Driver installation guide to install the driver.
    ◦ Follow the "Adafruit Arduino IDE setup guide" to install the Arduino IDE and support files for Adafruit Flora board.
3. Download the source code RD117_ARDUINO.zip file and unzip it in a desired location.
4. Double click the RD117_ARDUINO.ino to open the project in Arduino IDE.
5. Connect the MAXREFDES117 to the controller board: For Flora

Flora port	MAXREFDES117 port
SDA	SDA
SCL	SCL
D10	INT
3.3V	VIN
GND	GND

For Lilypad USB

Lilypad USB port	MAXREFDES117 port
2	SDA
3	SCL
10	VIN
+	VIN
-	GND

For Arduino UNO

Arduino UNO port	MAXREFDES117 port
SDA	SDA
SCL	SCL
10	INT
3.3V	VIN
GND	GND

6. Connect the controller board to the PC with a USB cable.
7. In the Arduino IDE, click on the **Tools** menu and make sure the appropriate board is selected.
8. Select the proper communication port in the **Tools** menu.
9. Press the **Upload** menu item in the **Sketch** menu to upload the firmware to the Flora board.

10. Open Hyperterminal or a similar terminal program on the PC. Find the appropriate COM port and configure the connection for 115200, 8-N-1 with no flow control.
11. Put a finger on top of the U1 on the MAXREFDES117#, contact with an earlobe is also sufficient. Constant pressure yields the best result.
12. Press any key on the terminal program and the system will start the conversion.


```
COM14 (Adafruit Flora)                                    [ - ] [ □ ] [ X ]
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[✓] Autoscroll                    No line ending ▾    115200 baud ▾
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13. From left to right, the first two column shows the data for red and IR LED receiver. Third and fifth columns show the calculated heart rate and SpO2 values. And the fourth and sixth columns show the validities of the heart rate and SpO2 calculations.

▲ MAXREFDES117# Arduino Quick Start Guide

Quick Start: Required equipment:

- Windows PC with a USB port
- MAXREFDES117# board
- 5 pieces of wires to connect the MAXREFDES117# to the controller board
- One of the three supported controller boards (Maxim Integrated MAX32600MBED#, Freescale FRDM-KL25Z, or Freescale FRDM-K64F)
- One micro USB cable (for MAX32600MBED# and FRDM-K64F)
- One mini USB cable (for FRDM-KL25Z) Procedure

The reference design is fully assembled and tested. Follow the steps below to verify board operation:

1. Create an account on http://developer.mbed.org to use their online compiler.
2. Import the demo program from https://developer.mbed.org/teams/Maxim-Integrated/code/RD117_MBED/
3. Connect the MAXREFDES117 to the controller board: For MAX32600MBED#

MAX32600MBED# port	MAXREFDES117 port
P26 SDL	SDA
P27 SCL	SCL
P20 SCK RX	INT
3.3V	VIN
GND	GND

For FRDM-K64F

FRDM-K64F port	MAXREFDES117 port
E25	SDA
E24	SCL
D1	INT
P3V3	VIN
GND	GND

For FRDM-KL25Z

FRDM-KL25Z port	MAXREFDES117 port
E0	SDA
E1	SCL
D1	INT
3.3V	VIN
GND	GND

4. Connect the controller board to the PC with a USB cable.
5. In the MBED compiler, click the button at the upper right hand corner to select the appropriate controller board.
6. Compile and download the resulting binary to your mbed platform.
7. Press the Upload menu item in the Sketch menu to upload the firmware to the Flora board.

8. Open Hyperterminal or a similar terminal program on the PC. Find the appropriate COM port and configure the connection for 115200, 8-N-1 with no flow control.
9. Put a finger on top of the U1 on the MAXREFDES117#, contact with an earlobe is also sufficient. Constant pressure yields the best result.
10. Press any key on the terminal program and the system will start the conversion.
11. From left to right, the first two column shows the data for red and IR LED receiver. Third and fifth columns show the calculated heart rate and SpO2 values. And the fourth and sixth columns show the validities of the heart rate and SpO2 calculations.

Lab Measurements
Equipment used:

- MAX32600MBED#
- Adafruit Flora
- Adafruit BlueFruit
- Polar H7 Bluetooth Smart Heart RateHeart-Rate Sensor
- Android tablet

Figure 3 and **Figure 4** show how the MAXREFDES117 calculated heart rate compared to the Polar H7 chest strap. The data in Figure 3 were taken while the person was sitting still for 20 minutes. And the data in Figure 4 were taken while the person was walking at a normal speed for 20 minutes.
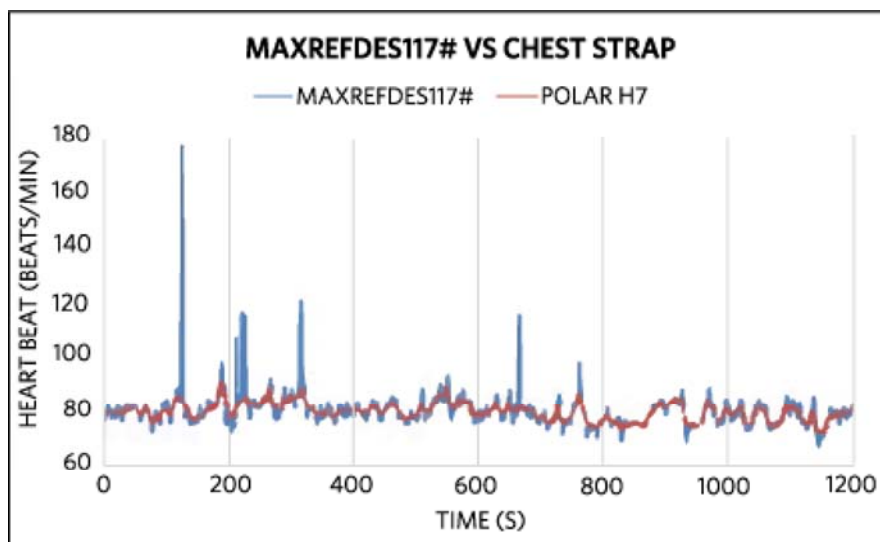

Figure 3. For sedentary test, over 99% of the mbed + MAXREFDES117# heart heart-rate data are less than 5 beats/min delta from the Polar H7 chest strap.
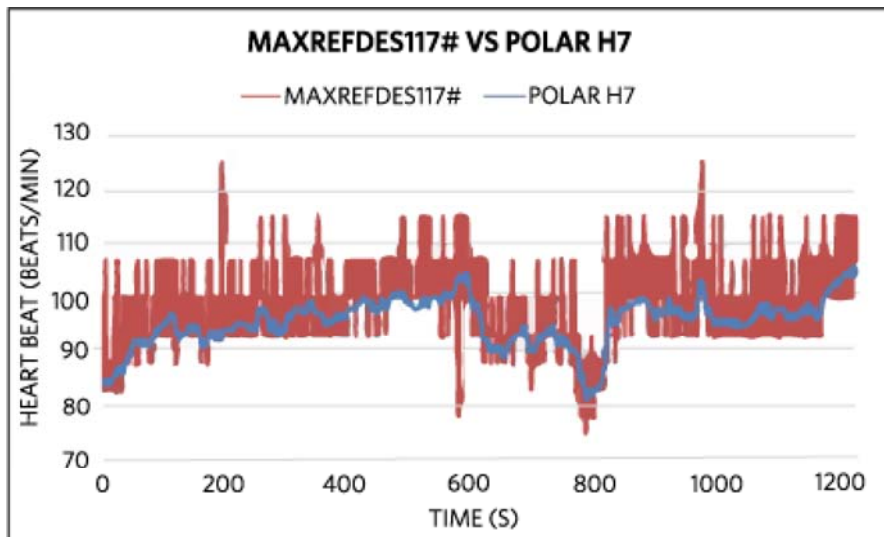
Figure 4. For moving test, over 92% of the Arduino + MAXREFDES117# heart- rate data are less than 10 beats/min delta from the Polar H7 chest strap.