DESIGN SOLUTIONS

HEALTHCARE

Train Your Fitness Monitor to Deal with Any Lighting Conditions

Introduction

With the proliferation of wearable health monitors among fitness enthusiasts, it may be worth posing the following question: Is the data being produced by these devices always accurate and reliable? In the same way that automobiles encounter real-world driving conditions vastly different from the laboratory environment used to generate performance figures on fuel economy, wearable health and fitness monitors can encounter environments not anticipated when they were originally designed. In this design solution, we consider the challenges in designing accurate, reliable wearable health and fitness monitors for a wide variety of user conditions.

We'll review the conventional approach to their design and introduce an innovative solution that enables a higher level of accuracy while consuming less power and space than has been possible until now.

Figure 1. Wrist-Worn Health and Fitness Monitor

Heart-Rate Detection

Heart-rate (or pulse) detection is an almost ubiquitous feature of wearable health and fitness monitors (Figure 1). This reading is useful because heart rate is a vital sign that provides a good indication of heart rate variability (HRV). HRV is used to assess stress levels, sleep quality, and overall well-being, among others. This measurement is based on a technique called photoplethysmography (PPG). A PPG signal is obtained by illuminating skin using a light-emitting diode (usually green) and detecting changes in the intensity of the reflected light (Figure 2) using a photodiode which generates a current proportional to the amount of received light.

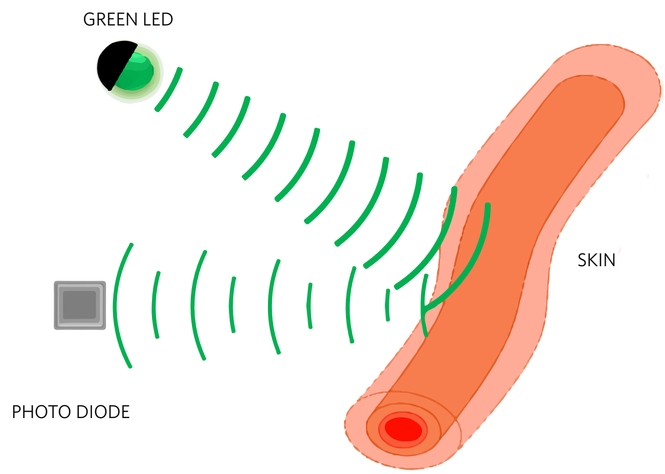

Figure 2. PPG Using LED and Photodiode

As the heart pumps blood, the amount of light returned to the photodiode from the skin registers a small change in amplitude (AC signal). This small change is superimposed on a large static amplitude (DC signal), which represents absorption through tissue along with ambient (background) lighting conditions in which the measurement is being made. The current signal is digitized and sent to a microprocessor within the device which then uses an algorithm to calculate the heart rate.

There are two major challenges in making accurate heart-rate measurements using wearable devices. The first challenge is the variation in lighting conditions the user encounters either during exercise or in normal living conditions. Rapidly varying lighting conditions can introduce "artifacts" into the measurement process. Artifacts are large changes in the received signal, which effectively mask the small AC signal, causing problems for the microprocessor to correctly calculate the pulse rate. Wearable devices must be able to compensate for large variations in ambient lighting to prevent spurious readings. While ambient light compensation is a feature of many modern health and fitness devices, the magnitude (ambient range) and quality (ambient rejection) widely varies. Currently available solutions have an ambient range of up to 25µA and an ambient rejection of up 55dB (at 120Hz).

The second challenge is the motion of the user, particularly during periods of high-intensity training, which can also cause artifacts. Currently available solutions use digital filtering techniques to attempt to compensate for motion artifacts, but these are not always successful.

Apart from the challenges associated with artifacts, wearable devices need to consume as little power as possible (to prolong battery life) in the smallest possible form factor. Available solutions use several photodiode detectors that operate sequentially at high frequency. Since the LEDs are the most power-hungry component in the device, operating them at the high frequency required for accurate readings can place a large drain on the battery powering the device. This typically consumes more than 450µW of power (at 25 samples per second).

Dual-Channel Approach

The MAX86141 optical pulse oximeter and heart-rate sensor (Figure 3) offers an alternative solution for the detection of optical heart rate, oxygen saturation (SpO_2), and muscle oxygen saturation (SmO_2 and StO_2). It uses two photodiode detectors simultaneously (instead of sequentially) which provides a two-fold advantage. First, operating two channels in parallel results in lower power consumption (184µW at 25 samples per second) since the LEDs only need to be turned on once rather than the multiple times for sequential sampling.

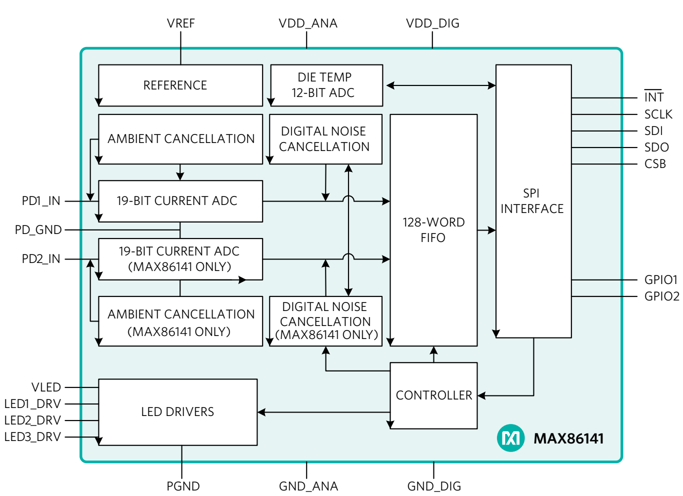

Figure 3. Functional Diagram of MAX86141

Second, the use of two photodiode detectors allows the creation of correlated (in time) differential signals. This is a new form of optical motion detection in which the signals are used by the downstream microprocessor for improved motion compensation. The MAX86141 also includes a "picket-fence" algorithm that can detect and replace rapid changes in ambient lighting such as when a car has direct sunlight exposure passing under a bridge or passing through a woodland area with alternating sunlight and shade. The ambient range is 100µA and ambient rejection is 84db (at 120Hz), far exceeding that of other solutions. It has a very low system power of 120µW and is available in a miniature 2.048mm x 1.848mm, 0.4mm pitch WLP.

Conclusion

Having considered the challenges facing designers of wearable health and fitness monitors, as well as the limitations of current solutions, we can conclude that the MAX86141 optical pulse oximeter and heart-rate sensor for wearable health provides lower power operation and higher accuracy measurements while requiring minimal space. It is well suited for use in wearable devices for fitness, wellness, and medical applications, such as those worn on the wrist, finger, and in the ear.

Glossary

LED: Light-emitting diode. A semiconductor device that emits light (usually visible or infrared) when forward-biased.

WLP: Wafer level package. WLPs allow an integrated circuit (IC) to be attached to a printed-circuit board (PCB) face down, with the chip's pads connected to the PCB pads through individual solder balls.

HRV: Heart rate variability is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval.

PPG: Photoplethysmography is the volumetric measurement of an organ.

Photodiode: A photodiode is a semiconductor device that converts light into an electrical current.

Artifact: Something observed in a scientific investigation or experiment that is not naturally present but occurs because of the preparative or investigative procedure.

Oxygen Saturation: The percentage of hemoglobin binding sites in the bloodstream occupied by oxygen.

Learn more:

MAX86141 Optical Pulse Oximeter and Heart-Rate Sensor for Wearable Health

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