A Customizable ECG Monitor You Can Call Your Own

It's possible that as you read this you're one of the many people wearing a health or fitness monitor (Figure 1). Wearable devices, whether worn on the wrist or on the chest, have proliferated in recent years almost to the point of ubiquity. Wearables offer many features (calorie count, heart rate, pedometry, etc.) that have become broadly homogenous, with an equally indistinct range of software applications available to perform custom analysis and interpretation.

Figure 1. Wrist- and Chest-Worn Health and Fitness Monitors

However, serious health and fitness enthusiasts, seeking to improve physical performance, are continuously looking for new ways to measure and understand how their bodies function under extreme duress. One such measurement, the electrocardiogram (ECG), has the potential to offer this type of insight. In this design solution, we review the challenges encountered when attempting to accurately measure and record ECG signals during intense training, and the limitations they impose on design. We then introduce a new type of chest-worn device, which not only accurately measures ECG, but also provides a hardware platform for quick development of high-end health and fitness products and apps.

Measuring ECG

Biopotential measurements require placing two or more electrodes in contact with the skin of a patient's body to detect the small electrical signals generated by the heart. The signals are then conditioned and sent to a microprocessor for storage, calculation and/or display. Two important cardiac parameters which can be recorded using this technique include ECG and R-R intervals. An electrocardiogram (ECG or EKG) is the measurement and graphical representation, with respect to time, of the electrical signals associated with the heart muscles. The R-R interval is the time between the peak amplitudes of the heart's periodic electrical signal, also known as R peaks (Figure 2).

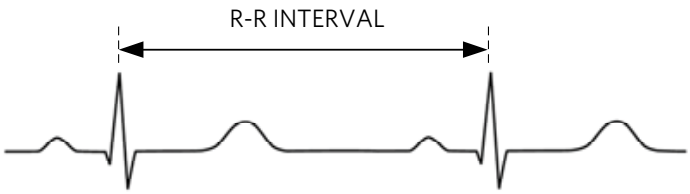

Figure 2. R-R Interval in a Typical ECG Waveform

ECG waves and R-R intervals are used by healthcare professionals to interpret the overall cardiac health of the person under observation. As such, having the ability to continuously measure and record this information, for later analysis by a clinician, provides potential benefits to both patients and high-performance athletes.

Design Challenges for Fitness Wearables

Designers of wearable devices who wish to measure and record ECG waves and R-R intervals are faced with several conflicting challenges. While their device must be capable of accurately recording, storing, and processing the desired measurements, it needs to be as small as possible to make it portable and comfortable without compromising functionality. To maximize portability and comfort of the device, a key design goal is to reduce the number of electrodes to a minimum, ideally no more than two. This becomes a major challenge as ECG measurement typically requires several pairs of channels (as anyone who has ever had an ECG measurement in a hospital will know).

Also, since portable devices must be powered by batteries with a finite charge, they must consume as little current as possible to maximize the time interval between battery recharge or replacement. The device should also be able to detect if an electrode has become detached, which could possibly happen during periods of intense activity, potentially causing spurious measurements.

Clearly, hardware developers with substantial resources at their disposal have an advantage when it comes to successfully overcoming these challenges. Even then, the product development cycle can still be on the order of months to years. Similarly, software developers who want to develop ECG data processing apps and algorithms are constrained by the fact there are very few "off-the-shelf" wearable ECG solutions available, and these do not provide access to the raw, sample-by-sample data that they require for analysis.

"White Box" Product

Wearable health and fitness product developers looking to include ECG functionality now have an alternative option in the form of a fully functional, evaluation and development platform (Figure 3). This is a complete wearable ECG monitor, based on an ultra-low-power, clinical-grade biopotential analog front-end (MAX30003).

Figure 3. The MAX-ECG-MONITOR Evaluation and Development Platform

Requiring only two electrodes (single-channel), the ECG monitor is attached to the wearer's chest using a strap or two adhesive patches. Controlling the device requires pairing it with a smart mobile device (e.g., smartphone, tablet or smart watch) using a wireless Bluetooth® connection. Once paired, the mobile device app is used to begin monitoring and recording the ECG signal. An on-board memory function means it can continue measuring and recording, even when connection to the controlling smart device has been lost. This feature, combined with the fact that it is waterproof, means that it can be used while swimming. In addition to ECG signals, the device also measures heart rate, R-R intervals, and calorie consumption while also being able to detect if an electrode has become detached. The maximum recording time depends on the intensity of the recorded activity. However, due to its low current consumption, it typically records 3.5 hours of activity with an average heart rate of 120bpm.

Development Platform

For cloud application developers who wish to create custom applications and algorithms, the open application program interface (API) is used to develop unique in-device apps for various ECG-based use cases when the heart is at rest or after exercise has begun. Additional on-board sensor inputs are available, such as an accelerometer, a gyroscope and a magnetometer, for increased customization.

A "white box" licensing agreement is available for companies who want to incorporate this product into their own line, potentially saving months of development time. In particular, this arrangement may be of interest to high-end sports clothing and equipment manufacturers who wish to integrate an ECG monitor without devoting additional resources to developing the technology themselves.

Summary

Today's serious fitness enthusiasts and high-performance athletes require wearable devices capable of measuring and recording ECG and R-R information during intense training sessions. We have presented a new type of closed reference design that not only records accurate ECG measurement using a single pair of electrodes, but also provides the raw data required for development of custom algorithms. Apart from health and fitness applications, it is suitable for use in devices providing remote medical monitoring.

Glossary

ECG: Electrocardiography (ECG or EKG) involves measuring and recording the electrical activity of the heart over a time interval using electrodes placed on the skin. This is useful for diagnostic purposes.

AFE: Analog front-end. The analog portion of a circuit which precedes analog-to-digital conversion.

CMRR: Common-mode rejection ratio. The ability of a differential amplifier to not pass (reject) the portion of the signal common to both the + and – inputs.

Biopotential: An electrical voltage produced by living tissue

Bluetooth: A technology that allows voice and data connections between a wide range of mobile and stationary devices through a short-range digital two-way radio. For instance, it specifies how mobile phones, wireless information devices (WIDs), computers, and PDAs interconnect with each other, with computers, and with office or home phones.

Learn more:

MAX-ECG-MONITOR Wearable ECG and Heart Monitor Evaluation and Development Platform

MAX30003 Ultra-Low Power, Single-Channel Integrated Biopotential (ECG, R to R Detection) AFE

Design Solutions No. 133

Rev 0; June 2018

Visit the Maxim Support Center

Find More Design Solutions

Maxim Integrated
160 Rio Robles
San Jose, CA 95134 USA
408-601-1000

maximintegrated.com/design-solutions