Amplifier Extends the Battery Life of Your Heart Rate Monitor

Introduction

Wearable technology for personal health monitoring is the wave of the future and potentially very big business. Every day there is a new wrist band or smart watch capable of monitoring heartbeat, workout activity (stand, move, and exercise), calories, heart rate, sleep patterns and more. In this article, we will look at the technology behind heart rate monitoring, its challenges, and ways to reduce power consumption, thereby extending the useful life of the wearable device between recharges.

Figure 1. Smart watch heart rate display

Every Microampere Counts

A 200mAh, a smart watch battery must typically support one day of usage or two weeks of stand-by time between recharges, with daily usage roughly defined as 4 hours of active operation in a 24 hour cycle. The corresponding daily allowance for the smartwatch electronics (microprocessor, memory, sensors, display and power management) is 50mA. Accordingly, a typical operational amplifier absorbing 1.5mA will claim a full 3% of the available current, corresponding to 7 minutes of usage time. Indeed, every microampere counts.

Heart Rate Monitoring

Sensing your heart beat by touching your pulse is pretty easy. The blood is pumped impulsively by the heart at the rate of roughly once per second (1Hz). A contraction of the heart muscle corresponds to a flow, a volume of blood pushed through your arteries, and a relaxation of the muscle corresponds to an ebb. As your heart beats, arteries expand in response to the incoming blood flow and contract between heartbeats. Your pulse thus sensed verifies that you are alive. What is more difficult to determine is your heart rate. This is where wearables, in the form of wrist bands and smart watches, come into play.

PPG

Reflective photoplethysmography (PPG) is a technique that uses light pulses to measure heart rate by sensing volume variations in the blood flow resulting from the heart's pumping action. Green light produces the largest modulation depth in flowing blood, with maximum absorption at flows and minimum at ebbs (more blood equals more absorption). The PPG green LED emits a short light pulse that penetrates the skin and is reflected back. The portion of the light reflected by the blood is modulated by its ebbs and flows and detected by a photodetector as an AC signal at the frequency of the heartbeat. Static portions of the targeted area reflect light as well, detected as a DC signal which will be discarded subsequently by the signal processing.

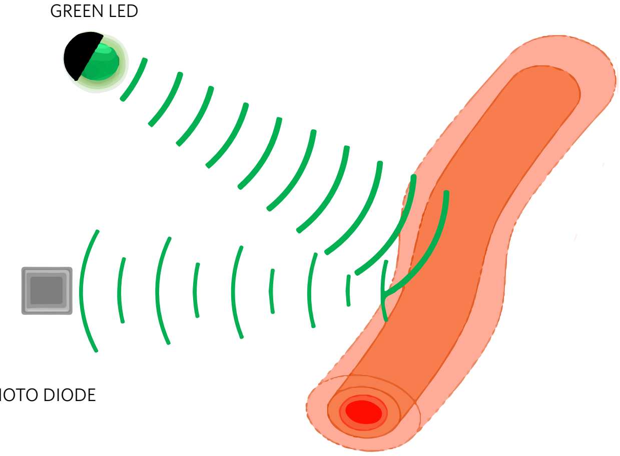

Figure 2. Green LED light modulated by artery blood ebbs and flows illustration

Signal Amplification

The current signal produced by the photo diode in response to light from the green LED is typically processed by the heart rate monitor's analog front end (AFE) circuit. At the core of the AFE is a low power operational amplifier. The op amp transimpedance configuration (Figure 3) amplifies the photodiode (PD) current I by a factor R, yielding an output voltage $V_{OUT} = I \times R$. The capacitor C implements a low pass filter of time constant RC that lets the low frequency heart rate signal pass but filters out any higher frequency noise.

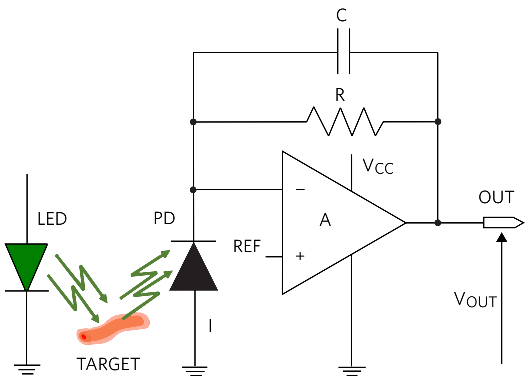

Figure 3. The transimpedance amplifer

The Ideal Amplifier for Heart Monitoring

The ideal amplifier for this application would combine high speed, low power, precision, and low-input current noise. The MAX44260 offers a unique combination of features to fit this need. Delivering 15MHz bandwidth with only 750µA supply current, the MAX44260 is extremely efficient in terms of MHz per µA and consumes very little power (50% less than typical competitive devices). Its 1.2fA/√Hz current noise density helps minimize current to voltage conversion error. The shutdown pin allows you to keep the device alive only when needed, enabling further power savings. Operation down to 1.8V also saves power and is a must have as more portable and low-power systems move to using lower voltage rails.

Signal Processing Advantages

Additional features of MAX44260 make it particularly suitable for health monitoring applications. The unique design provides excellent immunity from the RF signals present in the wearable device. The low input bias current (0.01pA typical at ambient temperature) is key when measuring high-impedance sensors or photodiodes where a high input bias current can compromise or distort the sensor reading. Finally, the combination of low voltage offset and low noise lends itself well to driving either a standalone analog-to-digital converter (ADC) or one integrated inside a microcontroller (Figure 4).

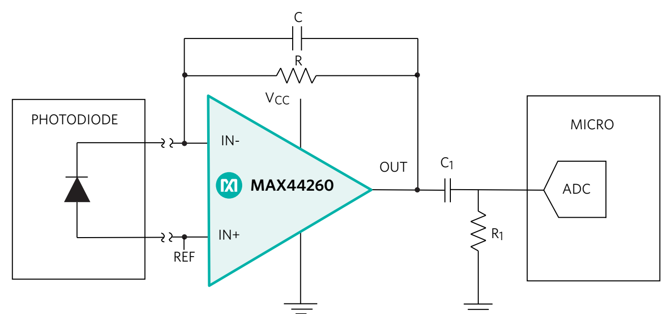

Figure 4. Signal processing

Conclusion

We have discussed the importance of minimizing power dissipation, input bias current and input noise while maximizing bandwidth and RF immunity for the op amp in a heart rate monitor's AFE circuit. MAX44260 1.8V, 15MHz Low-Offset, Low-Power, Rail-to-Rail I/O Op Amp meets all the key criteria, making it an ideal choice for demanding wearable healthcare monitoring applications.

Learn more: MAX44260 1.8V, 15MHz Low-Offset, Low-Power, Rail-to-Rail I/O Op AMP

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