Application Note No. AN088

OSRAM
Opto Semiconductors

LEDs for wearable applications

Application Note

Valid for:
Firefly E1608

Abstract

Light of an LED can be used for heart rate monitoring in wearable applications. OSRAM Opto Semiconductors offers LEDs especially designed for the use in fitness tracking, health monitoring or similar applications such as the Firefly E1608.

This application note provides a short introduction into the general use of LEDs for wearable applications, with a focus on heart rate monitoring. Furthermore, it contains information on how to handle and process the Firefly E1608 for an appropriate implementation of the LED.

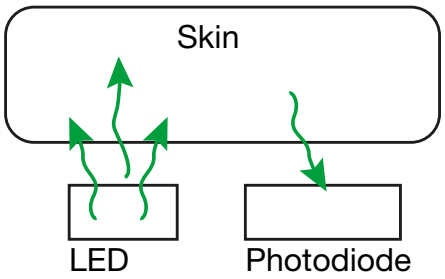
Author: Retsch Stefanie / Schmidt Katharina

Table of content

A. LEDs as a light source for heart rate monitoring

With each cardiac cycle, the heart pumps blood through the circulatory system of the human body. Arteries periodically dilate and constrict as blood flows through and the arteries increase or decrease in volume with every heartbeat. To detect this change in volume caused by the pressure pulse, the skin is illuminated with an LED and the amount of light either transmitted or reflected to a photodetector is measured afterwards (Figure 1).

Figure 1: The functional principle of an LED as a light source for heart rate monitoring.



For the system setup, integrated solutions (emitters and detectors integrated in a single package) are available and represent a compact alternative to discrete

components. However, while both discrete components and integrated solutions are equally efficient and capable of delivery precise and accurate photoplethysmography (PPG) sensing, discrete components (single LEDs and photodetectors) offer more design freedom, because various geometries can be selected and different components can be combined depending on the system requirements.

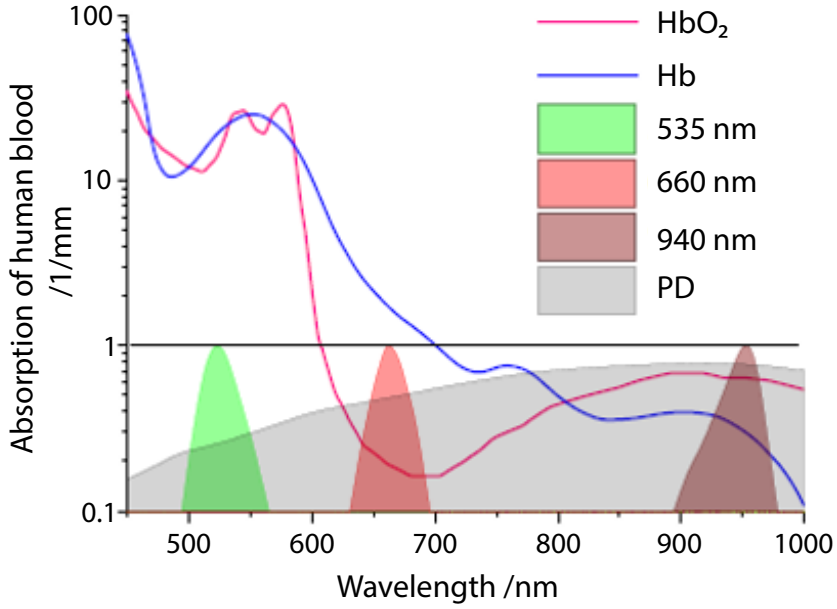
Using discrete components for heart rate monitoring, OSRAM Opto Semiconductors recommends the Firefly E1608 due to its compact size. This small LED package provides major benefits for the customer because it enables flexible product design. It allows to combine different wavelengths and typical brightness levels, all matching the application.

Optical barriers between the LED and the photodiode are fundamental to avoid direct cross talk between emitters and detectors. Both integrated solutions and discrete components provide this option in order to achieve high-quality measurements.

The impact of wavelength

Absorption in human blood mainly depends on hemoglobin. Figure 2 shows the absorption spectra of hemoglobin (Hb) and oxyhemoglobin (HbO_2). Short wavelengths (from blue to yellow) are strongly absorbed, while for longer wavelengths (from red to infrared) this absorption decreases at least an order of magnitude. Green is therefore the best choice for the application, although red and infrared can be used successfully in body locations with a higher concentration of arterial blood (e.g. fingertips, ears, and forehead).

Figure 2: Absorption of human blood (hemoglobin (Hb) and oxyhemoglobin (HbO_2)) versus wavelength of light. Also includes spectral responsivity of the photodiode (PD)



Finding an appropriate photodiode

OSRAM Opto Semiconductors provides not only LEDs for heart rate monitoring, but also appropriate photodiodes. For example, an SFH 2240 diode can be used for the detection of the reflected light. This SMT pin photodiode was developed for bio monitoring and features a high linearity and fast switching time. The SFH 2440 photodiode is a good alternative. Both provide an IR Cut filter. However, in contrast to the SFH 2240 the SFH 2440 has a leaded package. For this reason the SFH 2240 enables a more compact system assembly.

In addition, the SFH 2200, a broadband photodiode without an IR filter, can be used. When using this photodiode, it must be considered that infrared ambient light is also detected.

Table 1 provides an overview of all the photodiodes mentioned above, but please note that this is only a small extract of the portfolio offered by OSRAM Opto Semiconductors.

Table 1: Overview of possible photodiodes

Photodiode	Properties
SFH 2240	developed for bio monitoring fast switching time leadless package
SFH 2440	developed for bio monitoring fast switching time leaded package
SFH 2200	broadband photodiode no filter leadless package

Application set-up notes

Since no standards exist with regard to the skin tolerability of LEDs, the system must be set up with a glass cover between the monitoring application and the skin. This glass cover also protects the assembly against dust and water. However, it may affect the measurement quality.

At least 2 LEDs should be used in order to achieve reliable measurement results. Depending on the application, 2 to 6 LEDs may be used. These should be installed at a distance of less than 3.5 mm to the photodiode. The ideal distance for a good AC / DC signal depends on the application system and must be evaluated for the specific application.

The best measurement results can be achieved if the heart rate monitoring system is placed as closely as possible to the skin. Furthermore, it is essential that the spot chosen for the measurement exhibits good blood circulation. Good circulation results in a noticeable change of the blood volume within the arteries increasing the accuracy and stability of the measurement results.

B. The Firefly E1608

The Firefly E1608 was developed for use in wearable applications, and especially heart rate monitoring. The following part provides handling and assembly information.

ESD stability

Although there is no additional ESD protection included, the LED provides ESD stability of up to 2 kV. It is assigned to the “Class 2 HBM” category in accordance with ANSI / ESDA / JEDEC JS-001. With this class the Firefly E1608 can be considered as uncritical for processing and assembly by state of the art SMT equipment aligned with ESD precautions. To achieve higher ESD protection on the system level, additional ESD protection must be applied.

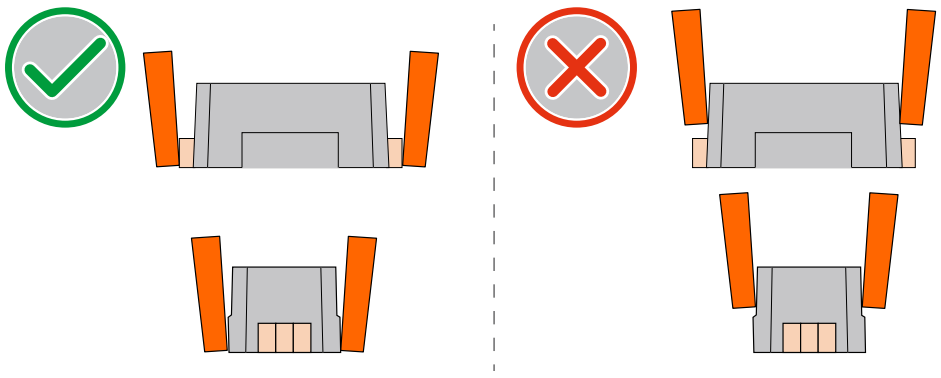
As is the case for all LEDs from OSRAM Opto Semiconductors, the Firefly E1608 also fulfills the current RoHS guidelines (European Union and China) and therefore contains no lead or other defined hazardous substances.

Pick and place

Although manual handling and assembly is possible, automatic placement is recommended.

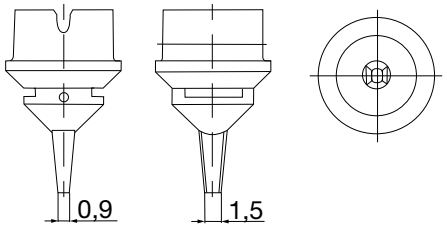
Special care must be taken if the Firefly E1608 is handled manually. The LED must not be lifted from the top, because high forces can cause damage to the surface. In addition, it is recommended to hold the LED package as shown in Figure 3 by using a tweezer and applying the force equally to the entire LED package.

Figure 3: Recommended manual handling



An automatic assembly process is recommended. The SIPLACE nozzle 911 shown in Figure 4 is recommended for the automated placement machines.

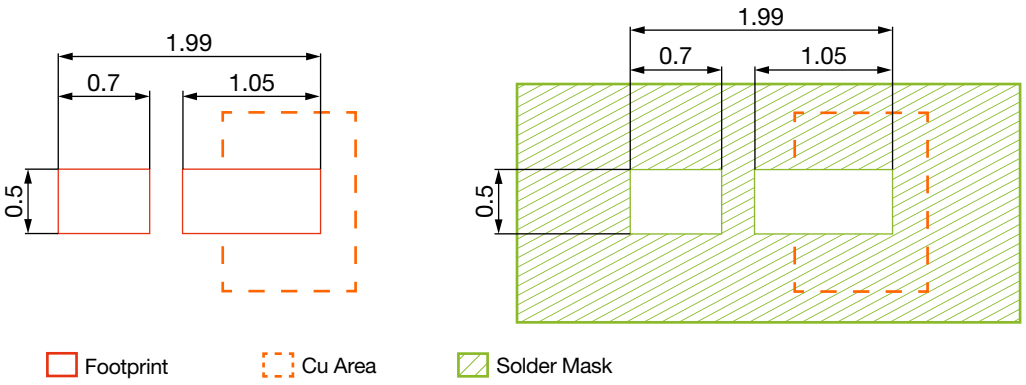
Figure 4: Recommended SIPLACE nozzle 911



Solder pad design

PCBs not only serve as a mechanical substrate and electrical contacting element for the components. In addition, modern circuit boards should also ensure stable characteristics within the circuitry. As the solder pad creates the direct contact between the LED and the circuit board, the design of the solder pad significantly determines the performance of the solder connection. The design influences the reliability of the solder and the heat dissipation. It is therefore recommended to use the solder pad shown in Figure 5, because it is individually adapted to the properties and conditions of the LED. The corresponding solder pad can also be found in the datasheet of each LED.

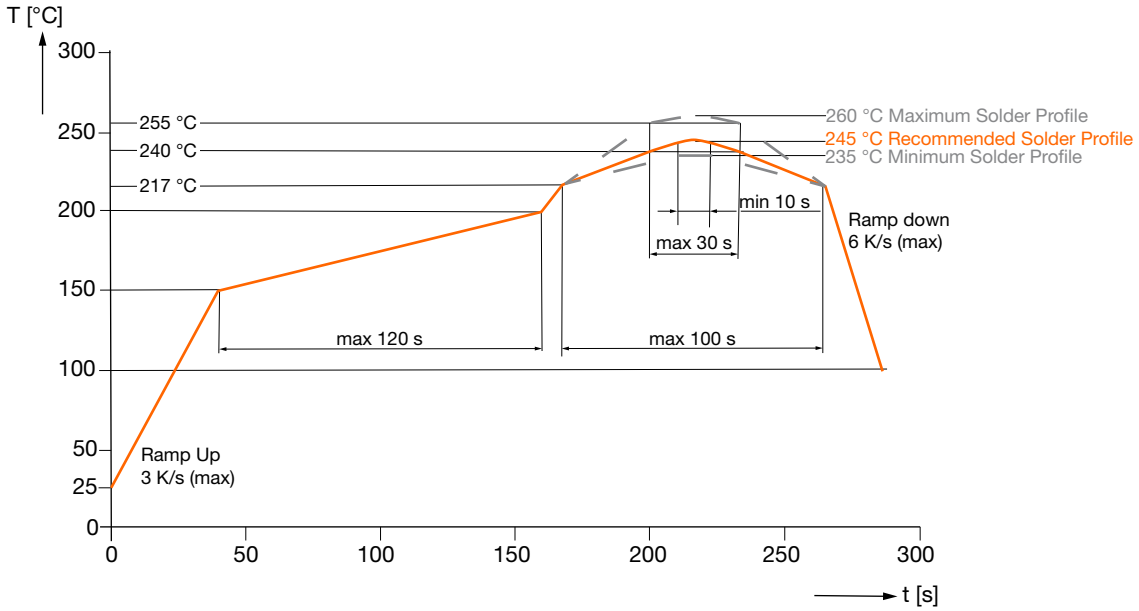
Figure 5: Recommended solder pad design



Assembly process

Since the Firefly E1608 is compatible with existing industrial SMT processing methods, state-of-the-art standard techniques can be used for mounting. The component is qualified for a standard Pb-free (lead-free) reflow soldering process with a maximum peak temperature of 260 °C (see Figure 6). For an optimized alignment it is recommended to check the profile on all new PCB materials and designs. The recommended temperature profile of the solder paste manufacturer can serve as a good starting point. The assemblies should be allowed to return to room temperature after soldering before subsequent handling or the next process step.

Figure 6: Temperature profile for lead-free reflow soldering according to JEDEC JSTD-020E



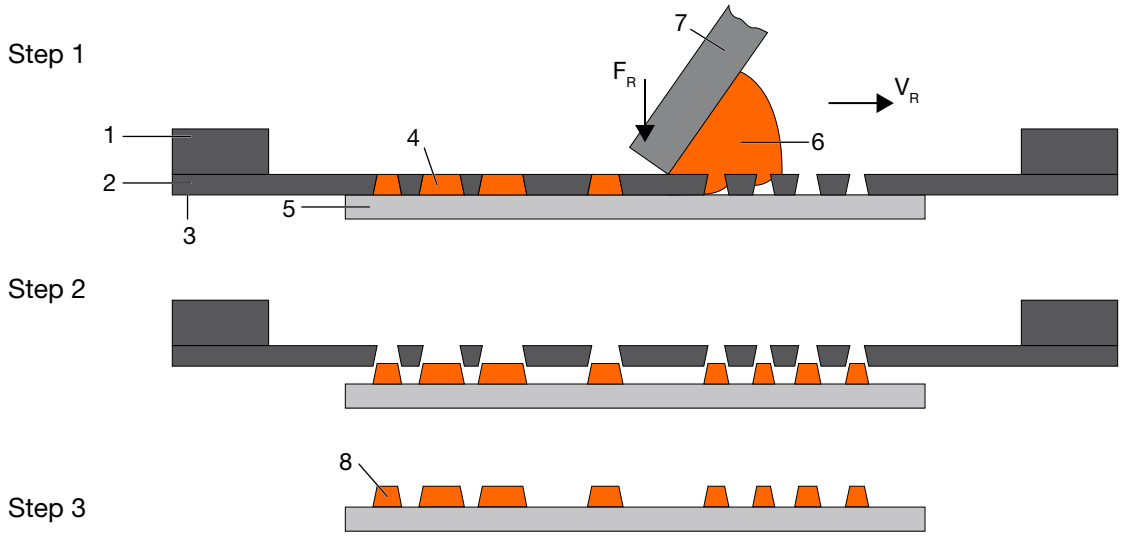
For more detailed information concerning the general processing of SMD LEDs refer to the following application note "AN036_Processing of SMD LED".

Solder quality

Uniform thickness of the solder joint is essential in order to produce reliable solder joints and achieve an appropriate optical alignment of the Firefly E1608. To achieve optimum solder joint connectivity results, soldering with a standard nitrogen atmosphere is recommended.

The design of the printing stencil and an accurate working process have a significant influence on the solder quality of the component. The solder paste printing process is the most critical process in the entire process chain, as most failures occur during the SMT assembly process. In industry, commonly laser cut stencils usually made from stainless steel (CrNi) or electroformed stencils (Ni), are used. Aperture sidewalls are typically trapezoidal (5°) to ensure a uniform release of the paste and to reduce solder smearing or so called edge tears. Figure 7 shows a schematic diagram of the solder paste printing process.

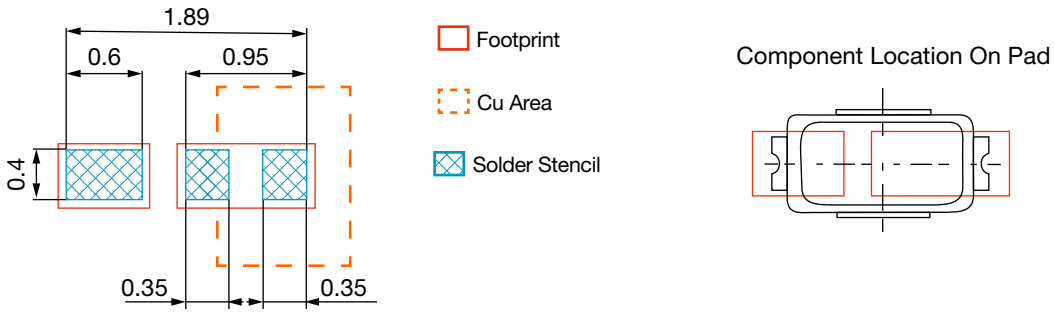
Figure 7: Solder paste printing process



1 Printing Plate	5 Substrate
2 Stencil	6 Solder Paste
3 Stencil Mounting	7 Spreader
4 Printing Patter	8 Printed Pattern
V_R Spreader Speed	F_R Spreader Force

In order to achieve a high quality in the solder process, the solder paste must be applied in the exact position, geometry and precise volume as required. The volume of the printed solder paste is determined by the stencil aperture (opening of the stencil) and the stencil thickness. Figure 8 shows the geometry recommended for the solder stencil.

Figure 8: Recommended solder stencil geometry



The solder joint thickness (standoff height) of the Firefly E1608 electrical leads should be typically between 50 µm to 75 µm, which is directly influenced by the amount of solder paste that is printed on the center thermal pad (heat slug) area. The stencil thickness used in industry SMT assembly processes varies in a range from 100 µm to 150 µm (0,004 in to 0,006 in). For the Firefly E1608 a stencil thickness of 120 µm is recommended. However, the actual stencil thickness depends on the other SMD components on the PCB.

Cleaning

From today's perspective any direct mechanical or chemical cleaning of the Firefly E1608 is forbidden. Isopropyl alcohol (IPA) can be used if cleaning is mandatory. Other substances, and especially the ultrasonic cleaning should be avoided, as they can damage the LED. For more information on correct cleaning refer to the application note "AN017_Cleaning of LEDs".

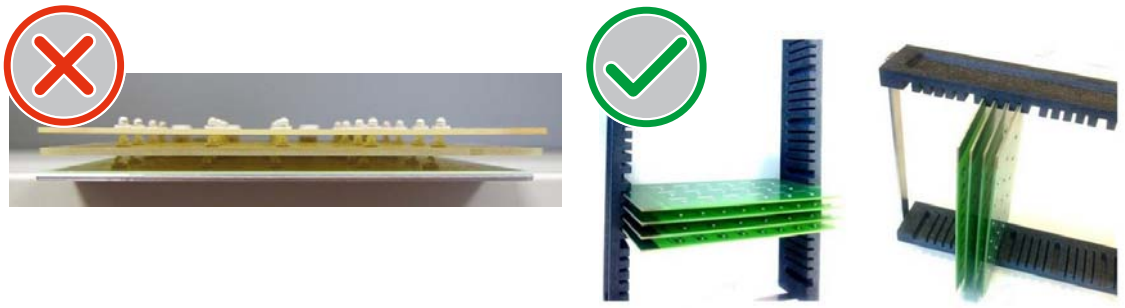
Dusty LEDs can be cleaned by means of using pure compressed air (e.g. central supply or spray can). In any case, all materials and methods should be tested in advance.

Storage

Since the Firefly E1608 is generally supplied in tape with a dry pack, it should be factory-sealed when stored. The hermetically sealed package should only be opened immediately before mounting and processing, after which the remaining LEDs should be repacked according to the moisture level in the datasheet (see JEDEC J-STD-033 - Moisture Sensitivity Levels).

Assembled LED boards should not be stacked on top of each other and a correct storage system should be used (Figure 9). To avoid the risk of damage to the assembled LEDs, make sure that they are not exposed to compression forces of any kind. Furthermore, the LED of the assemblies must also not be touched directly.

Figure 9: Correct storage



Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

www.ledlightforyou.com

ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, Munich, Germany is one of the two leading light manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. Osram Opto Semiconductors has production sites in Regensburg (Germany), Penang (Malaysia) and Wuxi (China). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. Osram Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

DISCLAIMER

PLEASE CAREFULLY READ THE BELOW TERMS AND CONDITIONS BEFORE USING THE INFORMATION SHOWN HEREIN. IF YOU DO NOT AGREE WITH ANY OF THESE TERMS AND CONDITIONS, DO NOT USE THE INFORMATION.

The information provided in this general information document was formulated using the utmost care; however, it is provided by OSRAM Opto Semiconductors GmbH on an “as is” basis. Thus, OSRAM Opto Semiconductors GmbH does not expressly or implicitly assume any warranty or liability whatsoever in relation to this information, including – but not limited to – warranties for correctness, completeness, marketability, fitness for any specific purpose, title, or non-infringement of rights. In no event shall OSRAM Opto Semiconductors GmbH be liable – regardless of the legal theory – for any direct, indirect, special, incidental, exemplary, consequential, or punitive damages arising from the use of this information. This limitation shall apply even if OSRAM Opto Semiconductors GmbH has been advised of possible damages. As some jurisdictions do not allow the exclusion of certain warranties or limitations of liabilities, the above limitations and exclusions might not apply. In such cases, the liability of OSRAM Opto Semiconductors GmbH is limited to the greatest extent permitted in law.

OSRAM Opto Semiconductors GmbH may change the provided information at any time without giving notice to users and is not obliged to provide any maintenance or support related to the provided information. The provided information is based on special conditions, which means that the possibility of changes cannot be precluded.

Any rights not expressly granted herein are reserved. Other than the right to use the information provided in this document, no other rights are granted nor shall any obligations requiring the granting of further rights be inferred. Any and all rights and licenses regarding patents and patent applications are expressly excluded.

It is prohibited to reproduce, transfer, distribute, or store all or part of the content of this document in any form without the prior written permission of OSRAM Opto Semiconductors GmbH unless required to do so in accordance with applicable law.

OSRAM Opto Semiconductors GmbH

Head office:

Leibnizstr. 4
93055 Regensburg
Germany
www.osram-os.com