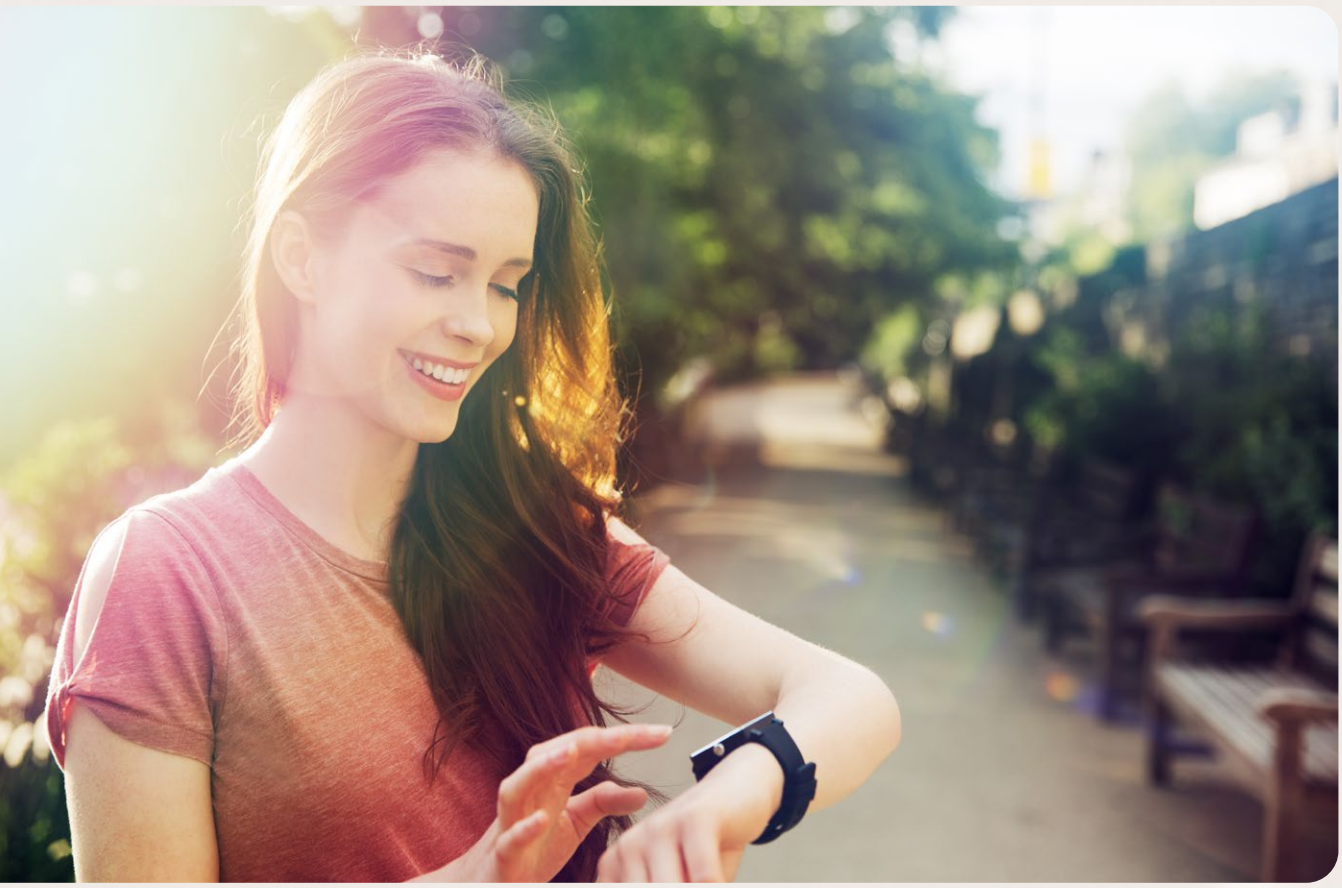
White Paper



# Faster implementation and lower development risk

**How the comprehensive ams OSRAM portfolio of innovative light-emitting and optical sensor technology for vital signs monitoring supports mobile medical and wearable device manufacturers**

ams OSRAM

## Technology for a healthier life

Vital signs monitoring functions performed by wearable devices such as earbuds can give consumers the information they need to live a healthy lifestyle.

When a medical professional assesses a patient, monitoring of their vital signs often provides the first and most useful indicator of their state of health. These vital signs include the heart rate, blood pressure, blood oxygenation, and body temperature.

In a clinical environment, measurement of vital signs generally informs diagnosis of a particular condition or disease. But the absolute values of a person's vital signs, and the changes in those values over time, can indicate a great deal about a person's state of health, even when they are not presenting to a medical professional with an illness or complaint.

Now the development of chip-scale sensors and digital technologies has made it possible to implement vital signs monitoring functions in portable and wearable devices which can operate 24/7/365. When accurate vital signs monitoring is performed continuously and as part of a person's normal life – rather than occasionally in an artificial clinical environment – it can provide valuable insights into their physical condition, and the effect of lifestyle on their health.

Patients could, for example, see whether they are consuming unhealthy amounts of sugar, and need to change their diet. Patients suffering with heart disease could more easily monitor the effectiveness of their treatment. Intelligent algorithms will warn users if, for instance, blood pressure is about to reach a dangerous level, or if heart rate variability has become abnormal, triggering potentially life-saving interventions.

Collaborative health systems could even use millions of data sets to detect outbreaks of pathogens before a pandemic occurs. There is good reason to think that millions of people could be protected from serious illnesses by adopting wearable vital signs monitoring equipment.

Embedded in mobile and wearable devices such as smart watches, smart rings, or earbuds, this new monitoring functionality can help people enjoy healthier lives with less incidence of serious illness. Equally, the availability of data to support preventive health measures could help to reduce demand for conventional medical treatments, potentially saving national healthcare systems billions of dollars in operating and capital expenses.

## Semiconductor technology for wearable form factors

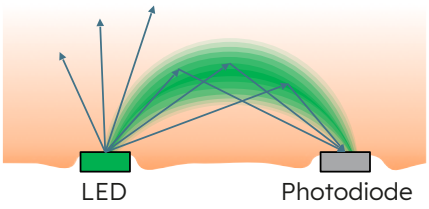
In a medical setting for one-time-only measurements of vital signs such as blood pressure or heart rate, the equipment used is extremely accurate, reliable, and long-lasting. But a device such as a conventional cuffed blood pressure monitor is also bulky, expensive, and uncomfortable to wear.

Now various technological advances have made it possible to implement vital signs monitoring in a device as small as a ring or wristband. These advances are based on special semiconductor sensors and signal processors, tiny chips which perform complex optical or electrical operations.

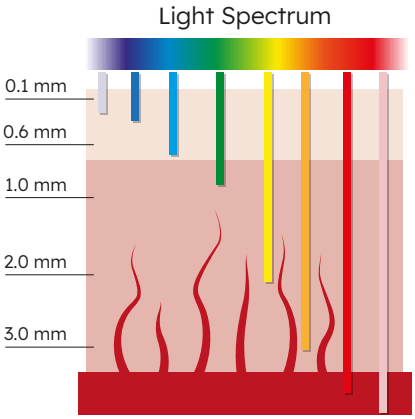
While the implementation of vital signs monitoring at chip scale is new, the principles of the techniques which these chips use to measure vital signs are well established and understood.

Photoplethysmography (PPG) is an optical technology. Light is projected into the body, passing through the skin to reach an artery. A photodiode (light sensor) measures the amount of light reflected from or passing through the blood vessels. When the heart pulses, the artery is forced to expand and fill with blood, so more light is absorbed. The photodiode detects the periodic rise and fall in reflected/transmitted light levels. This optical signal can be converted into a measurement of heart rate and heart rate variability. Very sensitive and accurate optical systems can also use PPG signals to measure blood pressure. For heart rate measurements, wearable devices generally use a green light emitter.

A PPG optical system measures the heart rate by tracking the changes in the amount of light absorbed by the blood as vessels expand and contract with each heart beat








The same principle is used to measure blood oxygen saturation ($SpO_2$), since oxygenated hemoglobin has a distinctly different pattern of light absorption than unoxygenated hemoglobin. $SpO_2$ systems use red and infrared (IR) emitters.

Electrocardiography (ECG) measures the pattern of electrical activity as the heart's muscles contract and expand to pump blood around the body. This electrical sensing technique may be used to monitor sleep patterns, or to detect abnormal or irregular heart activity.

Galvanic skin response measurement is another electrical sensing technique which tracks the activity of sweat glands. The outputs from a galvanic skin response sensor may be used to monitor the user's emotional state.

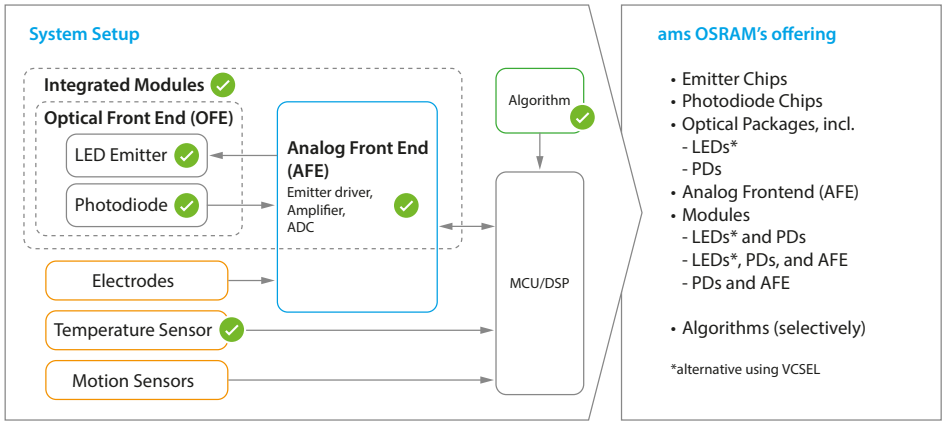
Both ECG and galvanic skin response may be implemented with a combination of electrodes and signal processing circuitry.

The implementation of PPG is more complex, since a PPG system consists of multiple components:

- An optical front end – multiple LEDs and one or more photodiodes. The emitters and photodiodes require a precisely manufactured package which ensures that the emitters' light output is efficiently coupled to the user's body. There should be minimal leakage of ambient light, which interferes with the optical signal. The optical assembly must be designed in such a way as to minimize crosstalk between the emitters and photodetectors.
- An analog front end - a driver to operate the emitters, an amplifier circuit to boost the low-current photodiode output, and an ADC to digitize the sensor signals.
- A temperature sensor to enable compensation to be applied to temperature-sensitive components such as the emitters, and to measure body temperature.
- Algorithms to convert the raw measurement signals into useful outputs such as a heart rate measurement, an $SpO_2$ measurement or a blood pressure reading.

The challenge with the design of a compact PPG system is the integration of these multiple components – and this is where the portfolio of products and services available from ams OSRAM comes into play.

A simplified block diagram of a PPG system, showing the components (green ticks) which are available from ams OSRAM



## Size, power, accuracy: the challenges in system implementation

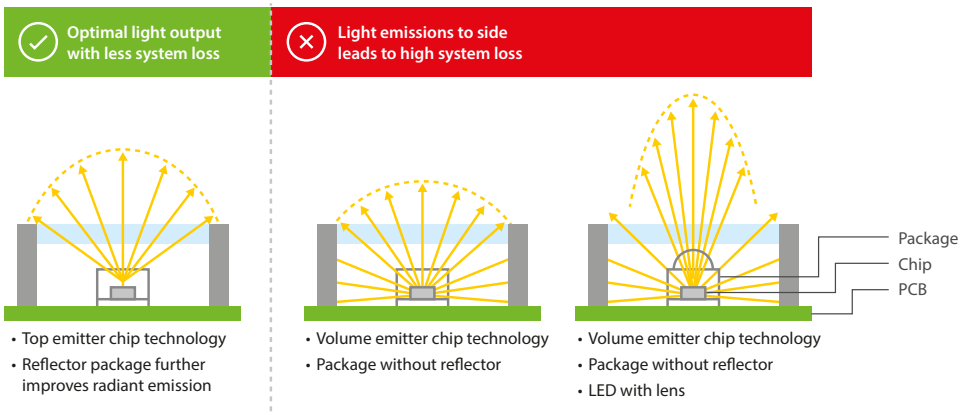
The principles underlying the operation of PPG might be well understood, but their implementation in a space-constrained wearable device such as a smart watch or smart ring gives rise to various design and production difficulties.

The optical system needs to balance accuracy of measurement with low power consumption – a wearable device's power supply is a small battery. A high-power optical system which drains power from the battery at a fast rate requires more frequent recharging, compromising the user experience.

But in a PPG system, only a small fraction of the emitted light is scattered back to the photodetector. The weaker the signal, the lower the signal-to-noise ratio (SNR), and the less reliable is the heart rate or $SpO_2$ measurement derived from it. A more powerful emitter which produces a higher light output will result in a higher SNR – but also consumes more power.

The SNR problem is exacerbated if the optical assembly suffers from excessive crosstalk or interference from ambient light sources.

Component selection and the design of the optical assembly have a substantial effect on the performance of a PPG system




This means that optimization of the design of the optical assembly is an essential function of a PPG system design. So is pairing emitters and photodetectors to maximize sensitivity to the emitter's peak wavelength.

There are other ways in which design choices about one component affect the performance of another part of the system. For instance, the number of emitters and their position relative to the photodiode(s) affects the optical signal strength and quality: more emitters can produce a stronger signal, but will consume more power and occupy more space.

Wearable device manufacturers can choose to eliminate some of the design complexity by selecting a modular optical front end, which integrates emitters and photodetectors, lenses and cover glass into a single unit.

But even when using an optical module, a PPG system still requires integration of the analog front end, and a microcontroller to run measurement algorithms.

So, the question which system designers will face when troubleshooting a prototype design or working to refine its performance is: where is the source of the problem or performance shortfall? Which element of the system is limiting the overall performance?

And if the bill-of-materials features emitters, photodiodes, an analog front end and algorithms from different suppliers, which supplier is going to assume responsibility for the problem?

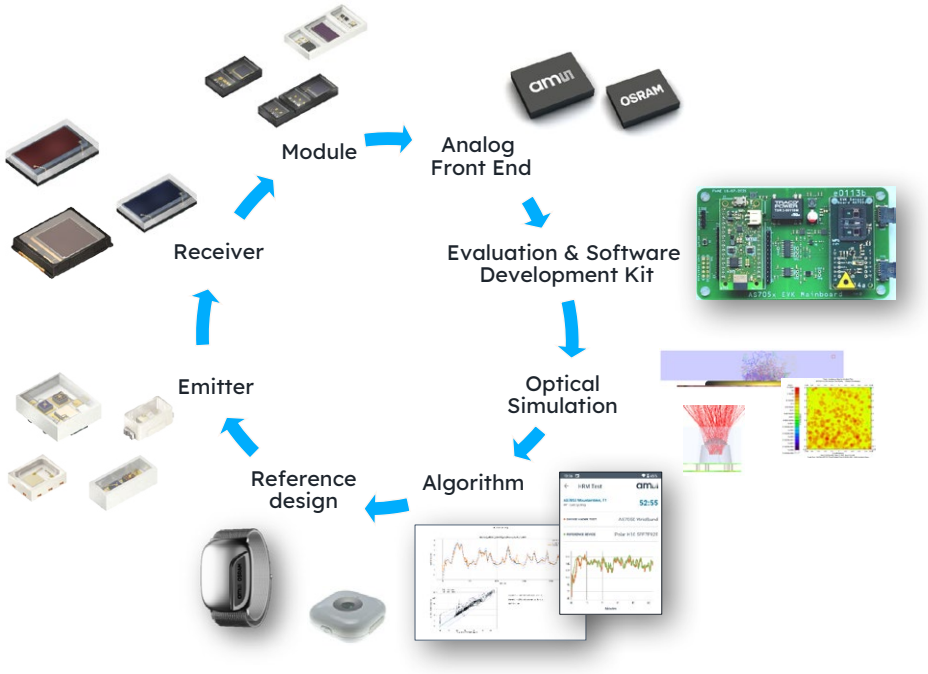
It's a common scenario – but one which is avoided if the device OEM works with ams OSRAM, a one-stop-shop for PPG components and systems.

## The ams OSRAM advantage: a one-stop shop

ams OSRAM is unique in offering a comprehensive portfolio of products for implementing PPG systems in portable and wearable devices. It is a single source for:

- Discrete LED and VCSEL emitters in infrared and all required wavelengths in the visible light spectrum
- Photodiodes which offer peak sensitivity matched to the range of LED and VCSEL emitters
- Modular optical front ends which combine emitters and photodiodes in a single optical assembly
- Analog front ends which combine drivers for emitters, an amplifier circuit and ADC
- Ultra-accurate temperature sensors
- Algorithms for converting raw measurement inputs to values for heart rate, blood pressure or $SpO_2$

A complete hardware and software solution for PPG in mobile and wearable applications is available from ams OSRAM




Backed by deep application-level expertise, this complete offering means that device manufacturers can work with ams OSRAM to optimize the optical, electrical and mechanical aspects of their product designs.

As a one-stop shop for PPG components, ams OSRAM can provide:

- Guidance on product selection to ensure a design combines components which are well matched with each other
- A single point of contact for the resolution of problems or difficulties in the development of the PPG function in a vital signs monitoring product
- Expert design advice to ensure flawless acquisition of accurate and reliable optical signals in challenging wearable or hearable formats
- A quicker route to design completion thanks to the provision of ready-made algorithms and firmware for vital signs monitoring

## Conclusion

The optoelectronics market supports various manufacturers of emitters, photodiodes and signal-processing components which can be used in PPG systems. But when choosing other manufacturers' products, an OEM design team will need to combine products which might not be perfectly matched. Problems which are discovered at the prototype stage might be hard to diagnose because each supplier will find it difficult to know how its component interacts with other suppliers' components in a complex optical assembly.

By contrast, ams OSRAM can work with customers to optimize the arrangement of components in an optical assembly, including the size, shape, and position of passive elements such as optical barriers between emitters and photodiodes, and the position, material, and thickness of the cover glass.

The result of drawing on the application expertise and comprehensive portfolio of ams OSRAM is faster design completion, reduced design risk, and a streamlined development process.

## Learn more about ams OSRAM expertise and resources

The ams OSRAM website provides links to the product portfolio for PPG and ECG systems.

Visitors to the ams OSRAM website can also find information, technical guidance and video content on specific aspects of the design of a vital signs monitoring device:

Mobile & Wearables - Vital Sign Monitoring | ams OSRAM

Video: heart rate monitoring in mobile devices

Video: pulse oximetry in mobile devices

The ams OSRAM blog site also includes articles about vital signs monitoring, and on using a digital temperature sensor to monitor body temperature.

OSRAM Application Note AN147 provides a detailed technical guide to the implementation of PPG systems in wearable and mobile devices.

## Biography

Florian Lex, Product Marketing Manager at ams OSRAM, is an expert for Vital Sign Monitoring. He has international expertise in general sensing applications, project and communication management, emitter and detector technologies and product and marketing management. His background is in broad application support, 3D sensing application, communication management and application engineering. He graduated with a Bachelor of Science in Biomedical Engineering from OTH Regensburg.

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