Technical Article

Why wearable electronics devices call for a new generation of highly integrated, smart sensor solutions

By Rob Johannigman

Director (Segment Marketing), ams AG

The electronics industry is used to riding waves of growth driven by the introduction of new categories of product. This happened with the PC in the 1980s, with networking gear in the 1990s and more recently with the smartphone. Now ‘wearable electronics’ has emerged as the next potential growth market, prompted by the success of early products such as Google Glass, a prototype wearable computer, and the Fitbit personal activity tracker.

In fact, the term ‘wearable electronics’ encompasses a huge range of device types, including the fitness and infotainment products already available, but also taking in as yet unproven concepts such as bio-sensor arrays, electronic clothing, electronic patches which may be stuck to the user’s skin, and even electronic tattoos.

As in any emerging market segment, the prospects for wearable electronics are currently clouded by uncertainty. Neither developers nor consumers know which products will hit a sweet spot, and which might flop, and product categories which today seem distinct, such as fitness monitors and medical devices, may start to merge.

There are, however, common threads running through all today’s wearable electronics products, and through the concepts in development:

- wearable devices can be kept in direct contact with the user’s body, and this supports roles in wellness, fitness and personal health monitoring
- wearable devices may readily be paired with a host computer, often a smartphone or tablet, which provides a platform for running application software and a large display screen

In fact, the broad adoption of devices running Apple’s iOS or Google’s Android operating systems, which offer access to third-party applications, was a necessary pre-cursor to the development of an ecosystem to support the wearables market.

But the very factors which make a wearable device useful to a consumer – its small size, its position near or next to the user’s skin, and the requirement for compatibility with iOS or Android – are also the factors which make the design of its electronic circuit difficult. In many wearable design concepts, the main function of the device is to sense physiological data, or data about the environment close to the user: this might be, for instance, the user’s heart rate or blood pressure; or it might be the quality of the air in the user’s vicinity.

It is hugely challenging to produce miniature, low-power sensors which interface to iOS or Android and which provide reliable and accurate data when used in real conditions. Indeed, in some ways it calls for the capabilities of sensor manufacturers to be extended. So what should the makers and designers of wearable devices be expecting from the manufacturers of sensor ICs?

Hundreds of wearable sensor types

Some of the first wearable electronics devices have used proven sensors to measure a few physiological and environmental phenomena. Products such as Nike's FuelBand and Jawbone's UP, for instance, are able to measure biological parameters and environmental phenomena such as steps taken or height climbed.

The sensors used in these devices – such as light sensors, accelerometers and barometers – were already widely used in mobile phones and tablets before 'wearable electronics' emerged as its own market segment.

But the scope for wearable devices to measure physiological and environmental phenomena goes far wider. In industrialized nations, where populations are ageing and lifestyle-related conditions such as diabetes and heart disease are prevalent, medical practitioners can dramatically enhance the effectiveness of treatment regimes if they are backed by 24/7 monitoring of parameters such as blood glucose, blood oxygen and heart rate. A wearable device's interface to a smartphone will allow the user to maintain an always-on virtual connection to a doctor or hospital, and to benefit from an app's early warning if their physical condition deteriorates dangerously.

Bio-medical sensors can also be useful to normally healthy users: for instance, a UV light sensor patch on the skin or integrated in a wearable device could trigger a smartphone app to warn the user about excessive exposure to sunlight.

Wearable devices may also measure the environment around the user. For instance, an optical sensor measuring the level of particulates suspended in the air could trigger the user's smartphone to raise an alert when air quality deteriorates below a given threshold.

Other types of sensors may be used to enable or enhance the user's operation of a wearable device. Ambient light sensors (ALS), for instance, may enable the automatic adjustment of a smart watch's display in response to changes in the brightness and color of the light the user is exposed to. Passive or active infra-red (IR) sensors may be used for gesture control in devices too small to support a useful touchscreen or buttons.

These are just a selection of the sensor types which might be used in wearable devices, and each may be deployed in isolation. Consumer device manufacturers, however, are also exploring ways in which the inputs from sensors may be combined. Samsung, for instance, has proposed SAMI (Samsung Architecture for Multimodal Interactions), an open interface for sensors enabling applications to combine inputs from multiple sensors in order, for instance, to give a more complete and insightful picture of a user's state of health than an input from a single sensor can provide.

The constraints affecting operation of a wearable sensor

It is clear, then, how the deployment of sensors near or on the body and connected to a mobile computer can – in theory – offer useful or enjoyable functions to consumers. And in all the cases described above, the fundamental technology already exists: in a laboratory, it is today possible to measure parameters such as heart rate, blood oxygen levels, air quality or proximity using a combination of LEDs and light sensors.

The challenge is to implement these functions effectively in real-world conditions.

The difficulties are of three broad types:

1) **Environment-related.** Wearable devices are worn by real people. This means they are on or near real people's skin, so they will inevitably get hot and dirty. They might be contaminated with sweat or grease. The user might unintentionally compromise their performance, for instance by subjecting them to excessive shock or vibration, by immersing them in water or by using them in the presence of excessive electro-magnetic noise.
2) **Power-related.** To be wearable, a device must be extremely small and light. So wearable devices only have space for a tiny battery power supply. Frequent recharging or replacement of batteries undermines the user's perception of the product's value. Therefore the entire electronic circuit must consume minuscule amounts of power in operation, and support deep power-down modes when not in operation.
3) **Quality-related.** First-generation fitness and wellness monitors have generally offered moderate levels of accuracy when measuring parameters such as heart rate and motion. Consumers thus far may have been content with this because of the novelty value of these pioneering devices.

   More serious uses of wearable physiological sensors will need to reach much higher standards of accuracy and reliability. For instance, wearable heart-rate or blood-oxygen sensors may be implemented in future as medical devices, and will then be subject to rigorous appraisal in the US by the Food and Drug Administration (FDA). Achieving high accuracy and reliability in a compromised environment subject to large amounts of noise will be challenging for today's sensor manufacturers.

Turning a sensor output into a useful application

The challenge in the production of wearable sensing devices, then, is to take a technique which is proven in the lab, and implement it reliably in a device which may be small, hot, dirty and electrically noisy. This is stretching the capabilities of manufacturers of analog ICs, demanding:

- greater integration and miniaturization
- lower power consumption
- higher sensitivity
- more applications expertise

An example helps to illustrate the case: gesture sensing is a function which will be commonly required in wearable devices, because it eliminates the need to accommodate buttons on the face of the product. A gesture control circuit might include two or more IR LEDs and an IR photodiode. A gesture is recognized through analysis of the IR light reflected back to the photodiode when the user's hand passes over the LEDs.

IR LEDs and IR photodiodes are common component types, and are readily available from multiple manufacturers. So what is so challenging about implementing a wearable gesture sensor? The difficulties arise in the three areas described above.

The application is environmentally challenging because the IR light sensor is subject to huge amounts of noise. Normally a wearable device will be exposed to ambient light (such as sunlight) which might include some IR luminance. In addition, the sensor's aperture on the face of the device may be obscured by contaminants such as sweat, grease from the user's skin, dust or dirt. In order to distinguish reliably between IR light attributable to ambient light (which is background noise in this application) and IR light reflected from the LEDs, the photo-sensor must be extraordinarily sensitive, calling for advanced analog semiconductor technology.

At the same time, wearable devices are tiny and light. Highly integrated semiconductor designs help achieve the miniaturization required to fit in wearable form factors. The photodiode, analog front end and processor core may be integrated on a single die, offering a complete gesture control system on a single chip.

Such a system normally requires regular operation of the LEDs to 'scan' for gestures. Intelligent power-down modes may be enabled by the implementation of power-down modes and wake-up procedures that do not require the operation of the IR LEDs.

A tiny, integrated, low-power, high-sensitivity IR sensor, then, may be able to capture and digitize accurate measurements of reflected IR light. But gesture control requires application software to provide the intelligence to interpret the raw measurements of IR light. There is a huge amount of intellectual property (IP) bound up in the analysis of IR light measurements. This analysis enables the system to:

- calculate the velocity and direction of movement of the user's hand
- measure the distance of the hand from the device
- distinguish between ambient light and light reflected from the IR LEDs
- interpret different types of movements as distinct gestures

In other words, the implementation of a gesture control system in a wearable device cannot be simply achieved by assembling IR LEDs and an IR photodiode on the device's miniature circuit board. The system requires a combination of hardware and application software. And every element of the system affects every other: for instance, the sensitivity of the photodiode affects the specification of the LEDs and the operation of the software which interprets the raw light measurements. The quality of the system – that is, its ability to recognize gestures quickly and predictably – is dependent as much on the application software as on the sensr hardware.

Manufacturers of wearable devices, then, are increasingly tending to specify sensor systems rather than sensor components. To compete in this market, analog IC manufacturers must provide application-ready algorithms and application software to support the sensor hardware.

This is as true of other wearable applications as it is of gesture control. To take another example, pulse oximetry, a light sensor measures blood oxygen levels by sensing light from LEDs after it hits the user's blood vessels. Here again, software interprets raw light measurements, converting them into accurate measurements of blood oxygen even when the sensor is contaminated by grease, dirt and sweat, and when it is subject to ambient light.

By combining application software with advanced analog hardware, the sensor manufacturer is able to provide an optimized system, saving the device manufacturer design time and effort and providing for the high performance and reliability which will be required by consumers in the next generation of wearable electronics devices.

Sensor manufacturers' new capabilities

Companies such as ams have recognized the new requirements of emerging markets such as wearable electronics, and have moved early to build the capabilities required to deliver sensor solutions rather than sensor ICs. This has involved substantial investment in software developers and applications engineering expertise. In fields such as bio-medical sensing and user interface systems, ams is able to offer device manufacturers use of valuable applications IP which it has developed over a period of years.

The highly constrained environment in which wearable sensors must operate – small, hot, dirty and noisy – tests to the limit the operation of sensor systems which nevertheless must appear faultless from the user's point of view. By offering complete solutions which deliver faultless performance of applications such as gesture control in real-world conditions, sensor manufacturers can offer the greatest possible value to makers of wearable electronics devices and help to bring to fruition a new generation of products which capture the imagination of the broad consumer market.

[ENDS]

Summary

Wearable electronics is emerging as the next big growth market in electronics. In new types of wearable devices, product developers are finding important new ways to monitor physiological and environmental data, but this calls for accurate and reliable sensing of physical phenomena.

Wearable devices are kept close to, or in contact with, the user's body, which means they are often hot, dirty and contaminated; they must also be small and light. This makes the implementation of high-performance sensing extremely challenging.

This article describes the requirements of sensors in wearable devices, and shows how a new generation of sensor solutions is combining accurate, power-efficient hardware with application software for implementing functions such as gesture control, pulse oximetry and heart-rate measurement.

It also discusses the benefits for wearable device manufacturers of specifying complete sensor solutions rather than the discrete sensor ICs traditionally supplied to the consumer electronics industry.

Biography

Mr Robert Johannigman joined ams as Director of Business Development (USA) in April 2011 and assumed the role of Acting Sales Director for the Americas in June 2011. In mid-2012, he played a key role in the integration of TAOS following its merger with ams.

In January, 2012, he took on a new role as Director, Segment Marketing and launched the Segment Marketing initiative at ams. In December 2013, he relocated to Rapperswil, Switzerland and also assumed the role of General Manager, ams International AG.

Prior to joining ams, he held various positions with Molex in Singapore and in Chicago as Director of Multinational Accounts.

Mr. Johannigman holds 2 Masters degrees from the University of Chicago: an MBA in Marketing and Finance, and an MA in Public Policy. He also holds an undergraduate degree from the University of Notre Dame.

For further information

ams AG

Otilia Ayats-Mas

Senior Marketing Communications Manager

Tel: +1 972 673-0759

otilia.ayats-mas@ams.com

www.ams.com