The high penetration of smart phones in many mature markets, combined with the wide availability of lower cost MEMS sensors, has led to the rise of a new category of electronics known as wearable devices. A wearable is a highly portable device that is worn or otherwise attached to the body, and is capable of measuring/capturing information via one or more sensors. *Figure 1* shows a generic information flow diagram of a wearable device.
Wearable devices can be broadly classified based on the market segment they serve or the body part on which they are intended to be worn. Table 1 shows the common classifications of wearable devices and their typical use cases.

Figure 1: Wearable Device – Information flow
<table>
<thead>
<tr>
<th></th>
<th>Sports/Fitness/Wellness</th>
<th>Infotainment/Gaming</th>
<th>Healthcare/Medical</th>
<th>Lifestyle</th>
<th>Industrial/Military</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EYE</strong></td>
<td>Smart glasses</td>
<td>Smart glasses</td>
<td>Bionic contact lens</td>
<td>–</td>
<td>Heads up display</td>
</tr>
<tr>
<td></td>
<td>Light emit glasses</td>
<td>Heads up display</td>
<td></td>
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<td></td>
<td></td>
<td>Music glasses</td>
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<td></td>
<td></td>
<td>Imaging devices</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Virtual reality headsets</td>
<td></td>
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<tr>
<td><strong>NECK</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>USB necklacet</td>
<td>–</td>
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<tr>
<td></td>
<td></td>
<td>–</td>
<td>–</td>
<td>Collar headphones</td>
<td>–</td>
</tr>
<tr>
<td>BODY*</td>
<td>Smart clothing</td>
<td>Tactile vest (Gaming)</td>
<td>Glucose monitor</td>
<td>ECG monitor</td>
<td>Muscle fatigue monitor</td>
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<tr>
<td>WRIST</td>
<td>Sports watches</td>
<td>Smart watches</td>
<td>Gesture control band</td>
<td>Pulse oximeters</td>
<td>Blood pressure monitor</td>
</tr>
<tr>
<td>FOOT</td>
<td>Smart socks</td>
<td>—</td>
<td>Smart shoes</td>
<td>Pedometer</td>
<td>Insole sensors</td>
</tr>
</tbody>
</table>

* BODY: Includes Arm, Torso & Leg
Most wearable devices are equipped with one or more sensor(s), a processor, storage, connectivity link (i.e., radio controller), display and battery. Figure 2 shows a block diagram for an activity monitor.

Since these devices are to be worn on the body, there are additional aspects that must be considered which govern the acceptance of these devices:

- Communication mode supported
- Average battery life
- Low cost
- Size and weight of the product

These aspects are discussed in detail in the next few sections.
Communication Modes

There are various communication protocols available for use in wearables, including standards like Bluetooth Classic, ZigBee and Wi-Fi, as well as proprietary interfaces developed by silicon vendors. Standard protocols like Bluetooth classic, ZigBee and Wi-Fi have not been designed with low power as the primary design consideration. For this reason, many OEMs chose to use a proprietary protocols focused on energy efficiency. The use of a proprietary protocol imposes many limitations on the flexibility of these wearable products by restricting their interoperability to only devices using the same proprietary protocol.

"These devices not only have a controller but also integrate analog and digital subsystems which can be used to implement the basic analog front end and other digital functionality."

To address the restrictions, the Bluetooth Special Interest Group (SIG) has introduced Bluetooth Low Energy (BLE), specifically designed to achieve the lowest possible power for short-range communication. Just like Bluetooth classic, BLE continues to operate in 2.4 GHz ISM band with a bandwidth of 1 Mbps. Some of the salient features of BLE are:
BLE’s low data rate makes for an ideal fit for applications where only state information has to be exchanged.

The protocol is optimized to burst transmit small blocks of data at regular intervals, thus enabling the host processor to maximize the amount of time it can operate in a low power mode when information is not being transmitted.

The protocol is optimized to reduce the time required for connection setup to data exchange to within a few milliseconds.

Each layer of the architecture has been optimized to reduce power consumption:
- The physical layer’s modulation index is increased as compared to Bluetooth classic, therefore helping reduce transmit and receive current.
- The link layer is optimized for quick reconnections, thereby reducing power.
- The controller implements various key tasks like establishing the connection and ignoring duplicate packets, which enables the host processor to stay in low power modes for an extended duration.

BLE has a robust architecture similar to Bluetooth classic supporting Adaptive Frequency Hopping with a 32-bit CRC.

It supports only broadcaster mode, so wearable communications do not have to undergo a connection procedure.

Since it is a different technology, a BLE device is not compatible with standard Bluetooth radio. However, Bluetooth dual mode devices do support both BLE and classic Bluetooth. Due to the adoption of Bluetooth Smart Ready host (dual-mode devices), BLE eliminates the need for a dongle for its operation as compared to proprietary protocols.
The BLE protocol is a perfect fit for wearable devices for the following reasons:

- Protocol optimized for ultra-low power
- Low power consumption helps reduce the size of battery, thus reducing the cost, size and weight of the product
- Easy adoption because of BLE Smart Ready host available in smartphones
- Wearable devices exchange small burst of information over long period intervals

However, the communication protocol is only one part of wearable devices. Wearable devices include many other blocks like sensors, an analog front end to process sensor signals, a digital signal processing to filter out any noise picked up from the environment, storage in which to log information, a processor to implement high-level system-related functionalities, a battery charger and other subsystems.

Take, for example, the typical implementation of an optical heart rate monitor wristband. An optical heart rate monitor works on the principle of PPG where an optical technique is used to detect the change in volume of blood. In this technique, an LED is used to illuminate the tissue; and the reflected signal, which carries information related to the change in volume of blood, is measured using a photo diode.

A Trans-Impedance Amplifier (TIA) is used to convert the photo current into a voltage. This voltage signal is then converted into a digital signal using an ADC. This digital signal is then processed in firmware to remove DC offset and high frequency noise and thus detect heart
beats. Filtering can also be performed in the analog domain using active filters.

Heartbeat information is sent to the BLE controller and then transmitted to a BLE-enabled device using Bluetooth link. In some optical heart rate monitors, an independent controller is used to perform heart rate processing before communicating this data to the main processor via an I²C/SPI/IART interface.

"BLE’s low data rate makes for an ideal fit for applications where only state information has to be exchanged."

In such systems, the use of multiple discrete components makes system design more complex in terms of the different parts being electrically compliant with each other and increasing testing complexity. In addition, there is a significant impact on power consumption (due to lack of control over the AFE when it is not in use), BOM cost and the size of the PCB.

Building a Bluetooth IoT Device – Considerations

To address these issues, multiple vendors have released devices based on a System-on-Chip (SoC) architecture. These devices not only have a
A controller, but also integrate analog and digital subsystems which can be used to implement the basic analog front end and other digital functionality. One such controller is the PSoC 4 BLE based on Cypress’s Programmable System on Chip (PSoC) architecture.

Increasing adoption of Bluetooth Smart Ready in smart phones, tablets and other portable devices has led to Bluetooth Low Energy as a popular choice for the communication protocol in wearable products. To support the power requirements of these applications, various silicon vendors have developed BLE controllers and SoCs supporting BLE. SoCs with BLE help to reduce system power consumption, BOM and size of products to make the wearables market even more attractive and promising.


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