

## **Bluetooth Classic and BLE Modules for a Noncontact Vital Sign Monitoring System**

### **Introduction**

By accurately measuring someone's vital signs without physical contact, a noncontact vital sign monitoring system could provide great advantages in home health care, biomedical monitoring, and search and rescue applications. To conveniently provide results to a consumer, however, it is necessary for there to be a way for the system to wirelessly communicate health information in real time to a partner application on a mobile device. This communication must not only be fast and reliable (to provide meaningful results in real time), but also secure (to comply with the Health Insurance Portability and Accountability Act). Of the available wireless communication protocols, Bluetooth Classic and Bluetooth Low Energy (BLE) accomplish all of this and are popular choices for close-distance communication. Since the microcontroller unit (MCU) that interfaces with the system is not guaranteed to have a built-in Bluetooth module, a separate module is needed to provide this functionality. This paper provides an overview of these two protocols, reviews some commercially available Bluetooth and BLE modules that can be integrated into a MCU, and describes how these modules can interface with Android applications.

### **Close-Distance Wireless Communication Protocols**

Bluetooth Classic (sometimes referred to as simply Bluetooth) is a secure protocol for sending and receiving data through a 2.4GHz wireless link. This protocol and its associated hardware can be used to substitute a physical communication interface, such as UART (Universal Asynchronous Receiver / Transmitter), with a wireless connection. Before beginning communication, two devices capable of using Bluetooth must first establish a secure connection through a pairing process. Once a connection is formed using this information, the two devices can begin transmitting and receiving data as if they had a direct serial connection with a data throughput from 0.7 to 2.1 Mbps and an inter-device range of 100 m. [1]

BLE is a distinctive feature of Bluetooth 4.0 developed for short-range communication as a low-power solution for applications that do not require a large communication bandwidth [2]. Compared with Bluetooth Classic, BLE provides a smaller typical data throughput of 0.27 Mbps. BLE's maximum working range is around 50 meters in ideal conditions, though the typical range tends to be around 10 m due to factors such as antenna orientation, transmit power on the sending node, competing traffic in the same 2.4GHz bandwidth, and obstacles between end points. For applications that do not require the range and bandwidth of Bluetooth Classic, BLE has the advantage of a very low power consumption rate and an expected battery life of several months [1].

### **Commercially Available Bluetooth Classic and BLE Modules**

#### *Bluetooth Classic*

The LM400 is an integrated Class 1 Bluetooth module with an onboard IC antenna that offers low latency, a maximum bandwidth of 2.25 MBps, and a connectivity range of 100 m. The module uses a UART interface and can be plugged into a 12-pin-socket, meaning it can interface directly with an MCU's serial ports or fit onto another printed circuit board assembly. The operating voltage is between 3.0 V and 3.6 V, and the power consumption of

the module peaks at 110 mA. The module is 30 mm by 27 mm by 14 mm, weighs 4.91 g, and is priced at \$32.29 [3]. The Bluegiga WT11u is a Class 1 Bluetooth module with an onboard antenna, Bluetooth radio, and iWRAP Bluetooth stack. The module can use a UART or a USB interface to communicate with an MCU, and 6 software programmable IO pins are available. A transmit power of +17 dBm allows for a maximum connectivity range of 350 meters. The operating voltage is between 2.7 V and 3.6 V, and the average power consumption is 114 mA. The module is 35.75 mm by 14.50 mm by 2.6 mm and is priced at \$22.00 [4].

#### *Bluetooth Light Energy*

The following two modules provide encrypted connections and can be powered using Lithium-ion batteries due to the low amount of power required. The Bluefruit LE UART Friend is a multi-function module that provides BLE connectivity to MCUs with a data transfer rate of 84 kbps. Under ideal conditions, the BLE module and the communicating Android device can maintain reliable communication from up to 6 feet apart with a maximum output power of about 2.5 mW. The module is 21 mm by 32 mm by 5 mm, weighs 3.4 g, and is priced at \$17.50 [5]. The Bluetooth Mate Silver is a modem with a built-in antenna that provides BLE connectivity to an MCU and is designed to work directly with Arduino Pro and LilyPad Arduino systems while providing a data transfer limit of 115 kbps. The operating voltage is between 3.3 V and 6 V, and the average power consumption is 25 mA. The module is 44.45 mm by 16.5 mm and is priced at \$24.95 [6].

#### **Module Implementation and Communication with Android Applications**

In order for a Bluetooth or BLE module to communicate with an MCU through hardware serialization, the Bluetooth module, which has a serial communication interface, must be connected to the MCU using the MCU's serial pins or USB interface. A connection through the MCU's serial pins will require attaching the MCU's transmit (Tx) pin to the module's receive (Rx) pin and vice versa [7]. A connection through a USB interface, on the other hand, will require software serialization and the use of control flow signals (such as RTS/CTS) [5].

In order for an Android device to communicate with a Bluetooth Classic or BLE supporting module, the device needs to have a built-in Bluetooth adapter which will need to be enabled by the user of the Android device [8]. For developers, a Bluetooth API is provided that contains classes that manage Bluetooth functionality and supports both Classic Bluetooth and BLE. This API allows Android applications to do things such as scan for Bluetooth/BLE devices, establish RFCOMM communication, and transfer data to and from connected devices. To make use of the Bluetooth APIs, Bluetooth Classic requires Android version 2.0 or later to be running [9] while BLE requires at least Android version 4.3 [10]. This is not often an issue since, currently, more than 96.7% of all active Android devices use version 4.3 or later [11]. In addition to Bluetooth permissions from the Android device, BLE requires "location services" to also be enabled, meaning that a device without GPS functionality will be unable to interface with a BLE module [8].

Due the different requirements of the two protocols, a developer must take into consideration the tradeoffs between the desired data bandwidth, connectivity range, power consumption, and price that the two protocols and their associated modules offer early on in the development process.

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