FEATURING

A Dream Technology That Connects All Types of Equipment

Ultraminiature Next-Generation Bluetooth™ Module

- **Next-generation wireless data transmission standard**
- **General-purpose full HCI module: CXN1000**
- **Built-in high-frequency passive device PWB**
- **Compact, low power, and low cost**

* Bluetooth is a trademark of Bluetooth SIG Inc. (USA) and is licensed to Sony Corporation.

Origin of the Bluetooth Name

The Bluetooth is named for Harald Bluetooth, the 10th century Viking king who united Norway and Denmark. Since Harald united Norway not with military might but with consultation and cooperation, Bluetooth was seen as an appropriate technology that would unite the computer and telecom industries. Harald was actually called Blatand, but that becomes Bluetooth when rendered in modern English.

What Is Bluetooth?

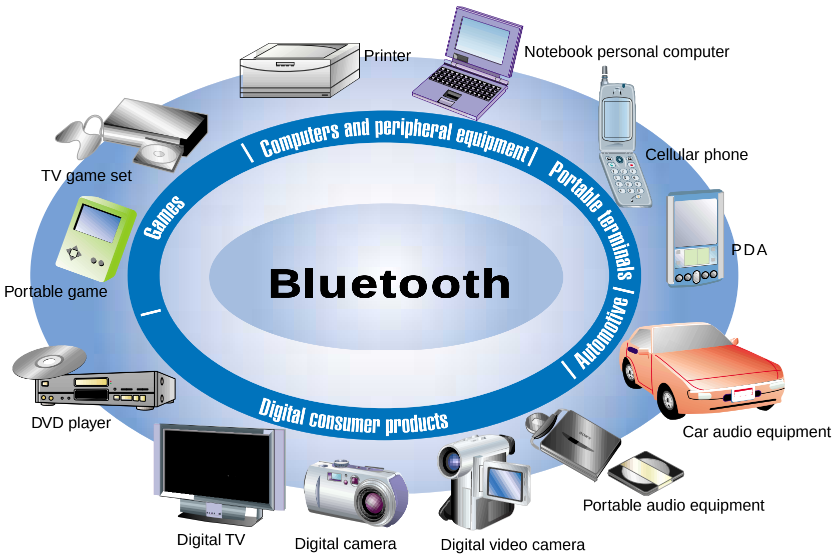
Bluetooth is the codename for a new data transmission technology that connects, using wireless transmission, equipment such as PCs, PDAs, cellular phones, AV equipment, and general household appliances. Bluetooth uses a 2.45 GHz radio frequency and is capable of communication over distances from 10 to 100 meters. Since Bluetooth performs connection and communication operations automatically between multiple devices, it provides users with data exchanges between devices that are wireless, transparent, and unconstrained in space or time. For example, Bluetooth can easily implement wireless use of a cellular phone as a modem for a notebook personal computer or purchase of items from vending machines from a cellular phone.

The Bluetooth SIG (Special Interest Group), which has over 2000 corporate members, is now researching and developing Bluetooth technology, and Bluetooth is taking root as a global wireless standard.

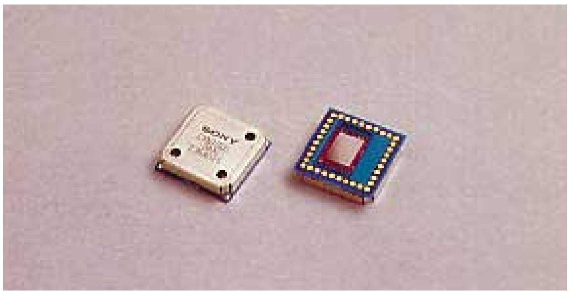
Sony Bluetooth Efforts

Bluetooth equipment is about to enter a period of increasingly widespread use. To respond to the needs of this growing market, Sony Semiconductor is now proceeding with the development and release of module products that strive for small sizes and high mounting densities by going beyond the IC/LSI framework and combining Sony's high mounting density technologies with Sony's semiconductor process and assembly technologies to achieve the highest performance as well as low cost and low power consumption, which are Bluetooth's major features. Furthermore, to respond to customer requests, Sony is also developing application software at the same time to provide even higher value-added solutions.

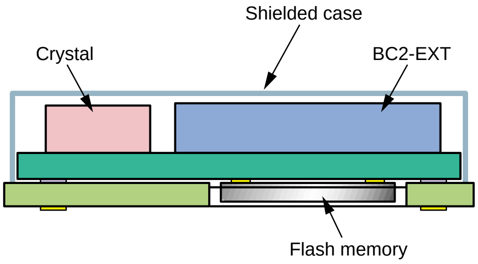
Sony's product lineup in this area starts with general-purpose modules that support normal data communication, and extends to a module, currently under development, that includes an audio codec to support audio communication. This article introduces these Bluetooth technologies from Sony Semiconductor.



■ **Figure 1 Bluetooth Connections for a Wide Range of Equipment**



■ **Photograph 1 CXN1000 General-Purpose Bluetooth Module**



■ **Figure 2 CXN1000 Device Structure**

General-Purpose Bluetooth Module: CXN1000

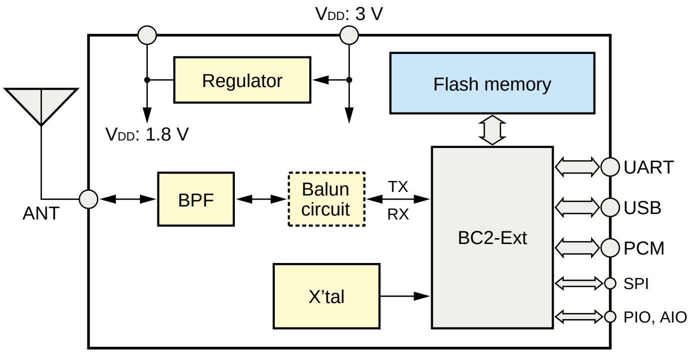
Here we present a general-purpose full Bluetooth HCI level module that includes both RF and baseband circuits. The CSR BC2-EXT Version B, which supports the Bluetooth specifications version 1.1 is adopted as the core chip, and the transmission output level is class 2. (See photograph 1.)

■ CXN1000 Features

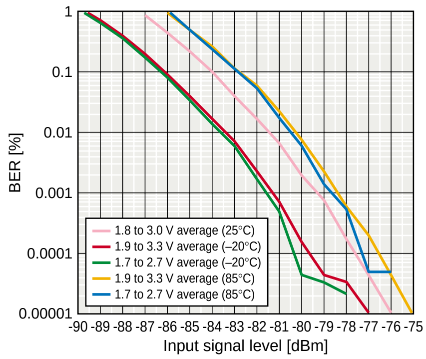
The features of the CXN1000 are due to its structure. (See figure 2.) It consists of two 4-layer 0.33 mm thick PWBs. The upper PWB is for circuits, and the lower PWB is for pin leads. This increases the degrees of freedom in designing the pin layout and allows the maximum possible amount of space to be allocated to flash ROM on the circuit board. As a result, the pin layout can be customized, the flash ROM capacity can be selected (4 or 8 Mb), and the device can support a wide range of interface types, including UART, USB, PCM, and SPI.
We will now briefly explain the flash ROM capacities provided by this module.
When system controller is provided by the end product in which this module is embedded, the module only needs to perform communication under control of that system. In this case, only the firmware required for control of the module itself needs to be installed, and a flash ROM capacity of 4 Mb is sufficient. In contrast, in cases, such as headset applications, where the module's own controller controls the whole application, it is necessary to install the application software in the module. In these cases, users can select the 8 Mb capacity.
We also briefly describe the power supply system used. This module requires two internal power supplies 3 V and 1.8 V. Basically, however, since this module includes a built-in 1.8 V regulator, it can be operated from just a single 3 V external power supply. However, in the case that a system power supply is present in the end product that includes the module, users can select a version that does not include the 1.8 V regulator and get all power supply from the end product.
Thus Sony provides optimal CXN1000 modules according to the particular conditions of the system in which the module will be used.

■ Circuit Miniaturization

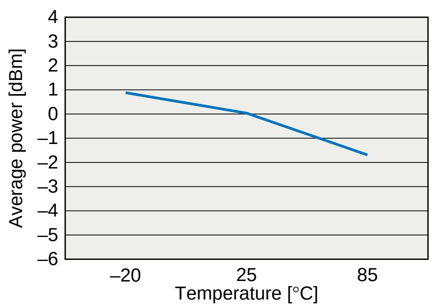
Sony has adopted the following techniques to achieve even further miniaturization in the CXN1000 circuits. Bumps are formed on the pad sections of the bare die, and the die is mounted directly on the PWB using ACF (anisotropic conductive film) joining, an LC phase circuit is used in the RF output balanced to unbalanced conversion block to eliminate the need for a balun, and the crystal is miniaturized. (See figure 3.) As a result, Sony has achieved the compact size of 11.0 × 11.0 × 2.3 mm without using special PWB materials such as LTCC.



■ **Figure 3 CXN1000 Block Diagram**



■ **Figure 4 CXN1000 Reception Sensitivity Characteristics**



■ **Figure 5 CXN1000 Transmission Output Temperature Characteristics**

Built-in High-Frequency Passive Device PWB

With its eye on future System in Package products for communication applications, Sony has developed PWBs that incorporate high-performance passive devices. This PWB technology uses semiconductor thin-film technology to enable inductors (L), capacitors (C), and resistors (R) to be integrated on organic PWBs. Figure 6 presents an overview of this technology. This technology provides many advantages, including the following five.

(1) It allows the formation of passive devices that have extremely high Q values (the inverse of the loss component) and high resonant frequencies by using an organic substrate which is an insulator.

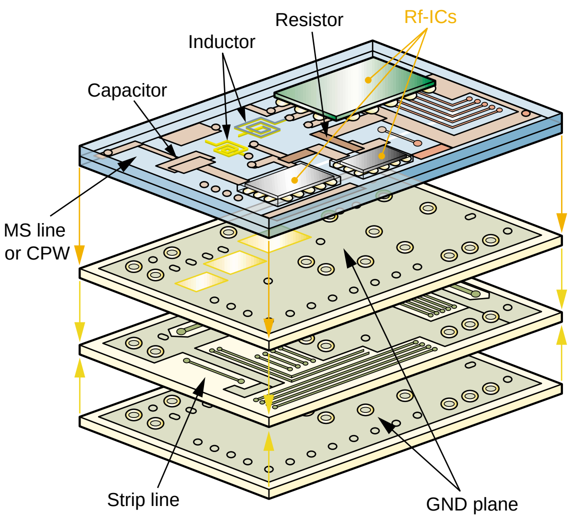
(2) It allows the formation of circuit structures that completely isolate both the thin-film wiring sections and the multi-layer PWB sections that form the base, for example, isolating the high-frequency signal lines from the power supply and control signal lines.

(3) The manufacturing precision in the thin-film wiring sections is extremely high, with a minimum line width (and line spacing) of 10 µm. This allows high-precision impedance control for high-frequency signals, and allows a previously unknown level of high-density wiring for digital signals.

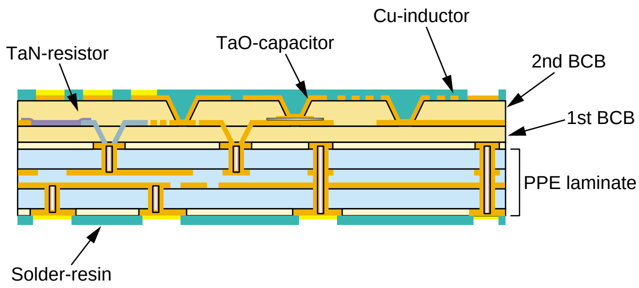
(4) Furthermore, functional components such as band-pass filters (BPF), baluns, and duplexers can be formed extremely compactly by combining passive devices in the thin-film section with strip lines in the base section.

(5) Since a multi-layer organic substrate is used and that substrate itself can perform the role of a BGA or LGA package, the whole module can be formed at low cost.

Figure 7 shows the cross section of this newly-developed PWB. Polyphenyl ethylene (PPE) is used for the organic PWB which forms the base in this structure, and after the flattening layer above the base, there are two BCB (benzo cyclo butane)/ Cu plating layers. Of the passive devices, the resistors and capacitors are acquired by using a sputtering technique to form TaN resistors on the first BCB layer as shown in the figure, and then using anodic oxidation of this TaN to form Ta2O5 capacitors. Inductors are usually formed using the Cu plating lines in the second layer for spiral and meander form inductors. Although not shown in the figures, smaller capacitors can be formed using the BCB dielectric film itself. While the range of values of passive devices that can be formed depends, of course, on the area, if we assume a size of about 1 mm^2 or less, then BCB capacitors have values from 0.5 pF to 3 pF, TaO capacitors have values from 3 pF to 1000 pF, TaN resistors have values from 2 Ω to 2k Ω, and inductors have values from 0.5 nH to 20 nH. The Q value for inductors of about 3 nH is in the range 40 to 60 and the self-resonant frequency is over 15 GHz. Figure 8 presents an example of a band-pass filter formed by combining the integrated constant devices and distributed constant devices mentioned above as feature (4). In this case, capacitors are used both for the strip line resonator in the base PWB and for the capacitive load that shortens the effective length of that resonator. In contrast with the conventional planar strip line filter, whose size is approximately λ/4 or about 30 mm on a side, the size of the device in this case can be reduced to approximately 3 mm□. Figure 9 shows an actual example of a Bluetooth module fabricated using this built-in high-frequency passive device PWB technology. In addition to the Class 1 specification, CSR radio IC, this module also includes external flash ROM, power amplifiers, and other circuits. This prototype device includes 16 capacitors and 2 inductors, and furthermore uses bare chip mounting for the RF IC to achieve a package diagonal of under 11.8 mm and a height of under 1.6 mm. This device is literally the world's smallest in its class and achieves a maximum rate of 700 kbps.



■ **Figure 6** PWB with Internal High-Frequency Passive Devices Overview



■ **Figure 7** PWB with Internal High-Frequency Passive Devices Cross Section

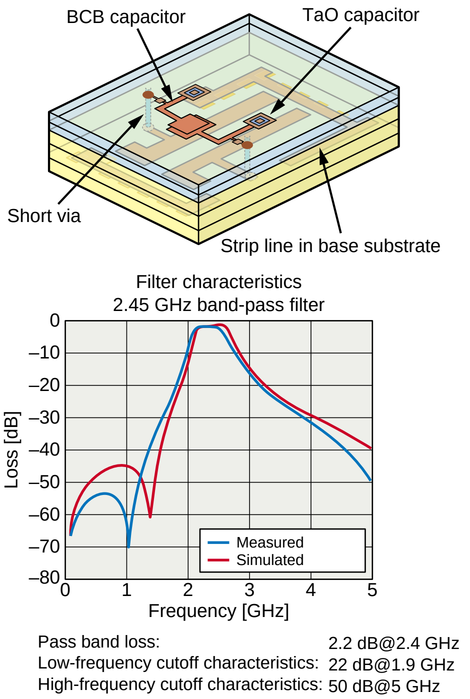
The communication field is expected to see a large number of wireless communication systems existing simultaneously, and thus it is expected that there will be an increasing necessity for technologies that can support multiple frequency bands and multiple operating modes, that is multiband technologies. Sony plans to add MEMS switch and other technologies to the built-in high-frequency passive device PWB technology described here and is investigating the possibility of creating reconfigurable (as well as adjustable, for example using tunable antennas and band-pass filters) RF and communication modules. In the future, Sony plans to apply these technologies to miniaturization of wireless communication modules, which are the information portal for mobile products.

Software Efforts

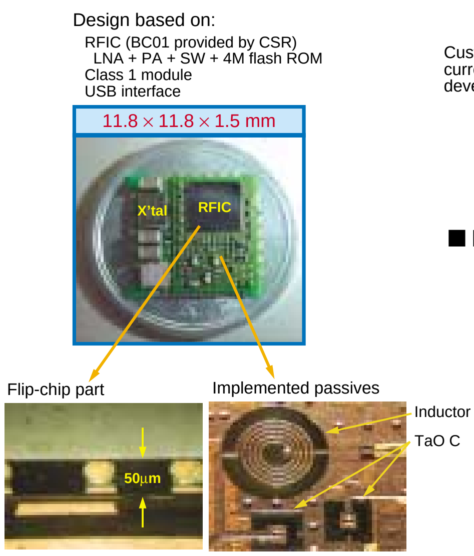
Since Bluetooth is a technology in which software plays a crucial role, demands for software support are rapidly becoming stronger. To respond to these needs, Sony can develop modules that include the software needed by the user.
Sony is currently developing a module specialized for headset applications, and development is close to complete. This headset module is being designed so that the user application can be executed with just the processor provided by the Bluetooth module, and thus without the need for any other processor. In addition to the development of the software desired by the user, these modules also provided the added value of miniaturization and low cost. Sony is committed to providing the most complete possible support from the software side as well to develop modules that will please our customers.

Future Developments

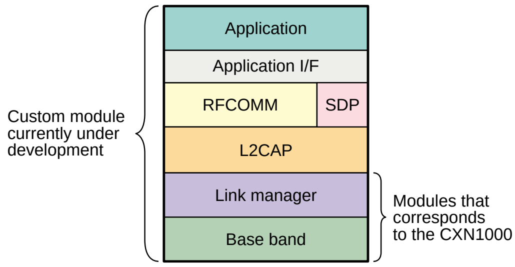
Currently, the module being developed as the first phase in this effort is positioned as an entry-level model in our product line that includes Bluetooth technology. In the second phase, we will aim for even further miniaturization and lower costs by using Sony's unique ultrahigh density mounting technology. We are also considering creating modules that combine the Bluetooth technology with other wireless communication technologies as the third phase. Sony also plans to proceed with the development of high value-added Bluetooth modules that go beyond the framework of wireless communication technology.
Keep your eye on Sony's Bluetooth modules.



■ Figure 8 Band-Pass Filter Implementation Example



■ Figure 9 Actual Bluetooth Module (Power Class 1) Example



■ Figure 10 Bluetooth Stack Structure