Atmel *Bluetooth*™ Solution Backgrounder

No More Cables – The *Bluetooth* Wireless Standard and Atmel's Instant Time-to-Market *Bluetooth* Solution

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How Does It Work?

There are four basic parts to any *Bluetooth* system: a radio (RF) that receives and transmits data and voice, a baseband or link control unit that processes the transmitted or received data, link management software that manages the transmission and supporting application software.

Bluetooth **Radio** – The *Bluetooth* radio is a short distance, low-power radio operating in the unlicensed spectrum of 2.4 gigahertz (GHz) and using a nominal antenna power of 0 dBm. At 0 dBm, the range is ten meters, meaning equipment must be within 10 meters of each other (about 33 feet) to communicate using the *Bluetooth* standard. Optionally, a range of 100 meters (about 328 feet) may be achieved by using an antenna power of 20 dBm. Data is transmitted at a rate of up to 1 megabit (Mb) per second, maximum. But communication protocol overhead limits the practical data rate to 721 Kbits per second.

Radio communication is subject to noise and interference. For example, when you use your portable telephone near your printer or microwave, it is common to get a scratchy signal because of interference from the other device. The 2.4 GHz frequency is shared by other types of equipment, microwave ovens, wireless local area networks (LANs), industrial, security and medical applications. As a result, at first blush, interference with *Bluetooth* devices might seem extremely likely. However, the *Bluetooth* specification has solved this problem by employing what is called spectrum spreading, in which the *Bluetooth* radio hops among different frequencies very quickly. There are 79 hops starting at 2.402 GHz and stopping at 2.480 GHz, each of which is displaced by 1 MHz. *Bluetooth* avoids interference by hopping around these 79 frequencies 1,600 times per second. If the transmission encounters interference it waits 1/1600th of a second (625 µsec) for the next frequency hop and retransmits on a new frequency. Frequency hopping also provides data security because two packets of data are never sent over the same frequency consecutively and the changing frequencies are unpredictable.

Baseband – In wireless communications, the baseband is the hardware that turns the radio signals (transmit/receive) into a digital form that can be processed by the host application. In other words, it can convert the digital or voice data into a form that can be transmitted using a radio signal, according to a protocol that allows it to be decoded once it is received.

Since a *Bluetooth* mobile phone, *Bluetooth* PDA and *Bluetooth* PC can simultaneously send and receive signals, there must be some way to differentiate all the transmissions from each other. The computer needs to know if a transmission is from the PDA or the mobile phone and visa versa. Virtually all wireless communication accomplishes this feat by putting the data into packets.

Each packet contains a pre-determined amount of data. It also contains information about where it is coming from and where it is going. Thus, packets from the PDA have a unique identifier, while packets from the mobile phone have another unique identifier. Packets also contain information on how the data was compressed, the order in which they were transmitted and information that is used to verify the correctness of the transmission. When the data is received, it is checked for accuracy, un-packetized, reassembled, decompressed and possibly filtered in some way.

The baseband processor handles all the tasks described above. It takes care of converting data from one form to another (e.g. voice to digital data), compressing it, putting it into packets, taking it out of packets, assigning identifiers and error correction information and then reversing the process for data that is received. In *Bluetooth*, the baseband function is called the Link Controller.

Links – The *Bluetooth* link is the method of data transmission to be used. The *Bluetooth* standard supports two link types, Synchronous Connection Oriented (SCO), used primarily for voice communications and Asynchronous Connectionless (ACL) links for packet data. Each link type supports sixteen different packet types that are used based on the application. Any two devices in a *Bluetooth* system may use either link type and may change link types during a transmission.

Link Management – The Link Manager is software that runs on a microprocessor and manages the communication between *Bluetooth* devices. Each *Bluetooth* device has its own Link Manager that discovers other remote link managers and communicates with them to handle link setup, authentication, configuration and other protocols.

Link Controller – The Link Controller is a supervisory function that handles all the *Bluetooth* baseband functions and supports the Link Manager. It sends and receives data, requests the identification of the sending device, authenticates the link, sets up the type of link (SCO or ACL), determines what type of frame to use on a packet-by-packet basis, directs how devices will listen for transmissions from other devices or puts them on hold. Each packet uses a single 625 µsec slot, but can be extended to cover up to five slots. *Bluetooth* supports an asynchronous data channel, three synchronous voice channels at 64K bits per second, or simultaneous asynchronous data and synchronous voice channels. The asynchronous channel can support an asymmetric link of 721K bits per second in either direction and 57.6K bits per second in the return direction, or a 432.6K bits per second symmetric link.

Application Software – The application software is the software embedded in the device that operates the *Bluetooth* application. This is the software that makes PDAs, mobile phone or keyboard do its job. All *Bluetooth* devices are required to have compatible sections in the application software, so that any *Bluetooth* device will work with any other one.

All devices certified with *Bluetooth* must have the components described above, operating according to the *Bluetooth* standard. The standard and certification procedures guarantee global interoperability between devices regardless of the vendor and regardless of the country in which it is used.

Atmel's *Bluetooth* Solution

The hardware implementation of a *Bluetooth* system requires radio frequency (RF) technology, analog-to-digital and digital-to-analog conversion, a processor to manage the communication links and implement the *Bluetooth* baseband functions, memory to store programs and data, and host interfaces to current communications standards including USB, PCMCIA and UART. Systems that will use voice control or transmit voice, such as mobile phones, will require voice recognition and speech synthesis capabilities as well. Since many *Bluetooth* applications will be small, battery powered portable devices, like mobile phones, digital cameras, PDAs, headsets and mice, all of this functionality must fit in a very small package and should consume as little power as possible.

Atmel is one of the world's few suppliers that has all the technology and expertise to provide a single-source *Bluetooth* solution to the developers of *Bluetooth* end-products. Atmel Wireless & Microcontrollers (Heilbronn, Germany) is one of the world's premier providers of RF devices, having developed numerous radio frequency applications for the GSM and DECT wireless telephony standards, as well as others. Atmel has an extensive library of intellectual property in the areas of DSP, programmable logic, microcontrollers, analog and nonvolatile memory, plus application specific IP for media access controller/baseband for 802.11, 802.11B and Voice-over-IP telephones.

Atmel has chip fab facilities in Colorado Springs, Colorado, in Rousset, France and Heilbronn, Germany and has extensive experience refining its process technologies to achieve the system-level integration of all the components of the *Bluetooth* standard. Atmel Wireless & Microcontrollers is one of only two companies in the world, in volume production, with a Silicon Germanium (SiGe) process. Atmel's initial *Bluetooth* solution will consist of a pre-certified *Bluetooth* reference design based on a Printed Circuit Board (PCB) multi-chip module that includes the radio, baseband, Flash memory, external discrete components and an integrated antenna, all assembled on a small PCB. Initially, the three actives (baseband, RF and Flash) will be packaged. Later, packages will be eliminated by a process called "Flip-chip." Flip-chip will allow a lower cost better performance and a smaller form factor. Atmel will also provide all *Bluetooth* software through the Host Controller Interface (HCI) and develop software through the Logical Link Control Adapter Protocol (L2CAP) level for qualified customers.

Because Atmel's *Bluetooth* solution is pre-certified, OEM manufacturers can get products to market immediately, without engaging in the certification process themselves.

***Bluetooth* RF Transceiver** – Atmel Wireless & Microcontrollers T2901 is a highly-integrated radio that includes transceiver, synthesizer and voltage controlled oscillator. Operating at the 2.4 GHz ISM band, it has a sensitivity of -80 dBm, linearity of SFDR 50 dB and VCO phase noise of -89 dBc/Hz at 500 kHz. Transmit/receive turn-around time is 100 µsec.

The T2901 IC is completely compliant with the *Bluetooth* RF standard, including a 1 megabit per second symbol rate that fully exploits the maximum channel bandwidth; spread spectrum of 79 frequencies with hopping occurring 1,600 times per second. Since 2.4 GHz electronics must run at high current levels, the air interface is tailored to minimize current consumption. The T2901 *Bluetooth* radio employs proprietary technologies that enhance its reliability.

Closed Loop Modulation – In most RF systems the transmitted data modulates the VCO by switching the charge pump in tri-state while the Phase Lock Loop (PLL) is in "open-loop mode". This causes frequency drift. Atmel Wireless & Microcontrollers has developed a modulation compensation circuit (MCC) that makes it possible to use "closed-loop modulation" of the VCO.

There are several advantages of Atmel Wireless & Microcontrollers "closed loop modulation" approach:

- There is no frequency drift as in open-loop modulation, so demodulation in the receiver is easier and collocation of several timeslots increases the effective data rate.
- Closed loop modulation is insensitive to tolerances and noise influences, resulting in better performance.

Most RF chips use IQ modulation in which I and Q signals are transmitted by the baseband to the RF during the mixer stage to stabilize the frequency. However, this increases complexity of the interface between RF and baseband. Atmel Wireless & Microcontrollers advanced closed-loop voltage modulation scheme keeps the VCO frequency stable while providing a more reliable, more highly-integrated and less-expensive solution.

No Mechanical Tuning – Many RF implementations require mechanical tuning. However, the elimination of mechanical tuning is part of the *Bluetooth* standard and is required for certification. Atmel Wireless & Microcontrollers Division was the first RF in the world to create a DECT transceiver that does not require mechanical tuning by isolating the VCO from the other components on the RF chip.

This method was adapted to the *Bluetooth* chipset. It avoids cross talk and keeps the frequency very stable so that all adjustments to the transceiver can be handled electronically by the baseband.

Image Rejection Mixer – All superheterodyne radios tend to receive two frequencies, the signal frequency and the image frequency. An unwanted signal at the image frequency must be suppressed to avoid interference with the wanted. Usually image rejection is accomplished by using an off-chip passive filter. However, this filter is expensive and having it off-chip limits increases system size – a drawback for many small, portable *Bluetooth* applications. Atmel has developed an image rejection mixer that handles image rejection on the *Bluetooth* transceiver IC without expensive external components. The image rejection mixer also cuts power consumption by converting the frequency down to 111 MHz, a frequency for which many low cost filters are available. Atmel Wireless & Microcontrollers image rejection mixer is capable of up to 35 dB image rejection.

***Bluetooth* RF Front End** – Atmel Wireless & Microcontrollers has also developed a SiGe-BiCMOS front end T7024 transceiver which includes a power amplifier and low noise amplifier as well as the drivers of a PIN diode switch. The T7024, in conjunction with T2901, provides a 20 dBm solution that boosts the range of Atmel's *Bluetooth* system much beyond 100 meters.

***Bluetooth* Baseband** – Atmel's single-chip AT76C55X *Bluetooth* controller performs the *Bluetooth* Link Management and control (baseband) protocols. The AT76C55X controller, available in several options, integrates an ARM7TDMI™ core and dedicated *Bluetooth* baseband block. Options include a voice Codec utilizing log PCM or continuous variable slope delta (CVSD) coding and a USB, PCMCIA and UART standard interface. Dedicated hardware in the AT76C55X handles *Bluetooth*'s frequency hopping algorithm, channel access code generation, forward error correction (FEC), scrambling, header error check, CRC, encryption/decryption and authentication processing accelerations as required by the *Bluetooth* standard.

Voice data is coded using the Continuous Variable Slope Delta (CVSD) algorithm or log-PCM. A dedicated bus is used to transfer voice data to minimize jitter and dedicated FIFOs are used to store SCO voice packets.

The AT76C55X's USB interface supports up to six endpoints each with double buffered FIFOs. Multiple clock frequencies are supported, eliminating the need for an additional crystal.

Flash Memory– Atmel's *Bluetooth* solution requires 1 megabit of low-voltage Flash memory for the storage of firmware and data.

Product Road Map – Initially, Atmel will provide pre-certified *Bluetooth* reference designs based on a PCB multichip module that includes the radio, baseband and Flash, external discrete components and an integrated antenna.

In 2001, Atmel will reduce the size and cost of their PCB modules by a process called "Flip-chip." By bumping wafers, Atmel is able to assemble bare die directly to the PCB. This process, known as Flip-chip, allows for lower cost, smaller board designs and increased performance.

Atmel expects to introduce a true single-chip *Bluetooth* solution in early 2002, based on one of the company's process technologies.

Pre-certified Reference Design with HCI Software – Atmel will make available a complete *Bluetooth* reference design that provides virtually instant time-to-market for products enabled with *Bluetooth*. It consists of a very small printed circuit board populated with the T2901 transceiver, the AT76C55X baseband processor and 1 megabit of Flash memory. The PCB also will have a small antenna and all the other necessary components for a complete plug-and-play *Bluetooth* solution. The Atmel solution will include all the *Bluetooth* software through the host controller interface.

Atmel's reference design is pre-certified, so any product it is plugged into automatically meets the *Bluetooth* certification standard.

Custom Software Available – Atmel has extensive experience in the development of communications systems that it will apply to the development of custom application software through the Logical Link Control Adapter Protocol (L2CAP) level for qualified *Bluetooth* customers. The company has successfully developed similar communications products for the 802.11 and 802.11b wireless LAN markets.

Atmel does not develop or market *Bluetooth* end-products for itself and therefore does not have a conflict of interest with any of its customers.

Turn-key Solution – Atmel's *Bluetooth* solution contains all required *Bluetooth* functionality including firmware, functional compliance and regulatory certification. Atmel's *Bluetooth* certification is inherited by Atmel customers, so there is no need for Atmel customers to go through the entire certification process.

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