NO MORE CABLES

THE BLUETOOTH WIRELESS STANDARD

AND ATMEL CORPORATION'S

INSTANT TIME-TO-MARKET BLUETOOTH SOLUTION

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THE TETHERED AGE

The information age might as well be called the tethered age because every apparatus that supplies us with information is tethered to something by myriad cables. Take a look at the back of your desktop computer and you will find cables. Lots of cables - mouse cables, printer cables, video cables, scanner cables, joy stick cables, keyboard cables, network cables, phone lines, speaker cables. There are also occasional cables to transfer data to or from digital cameras, portable Zip drives, and portable computers. It's messy. It's ugly and it's not fun.

Although computers are gross offenders, they are not the only tethered devices around us. Home entertainment systems have lots of cables between the settop box, VCR, DVD, stereo audio system, speakers and TV. We hide them under carpets and molding and we still occasionally trip over them. Your wireless phone needs a cable if you are to have hands-free operation. Automobiles and boats are full of cables connecting the climate control, braking, engine control, emission control, and other systems.

Nor is there any single kind of cable. There are PCMCIA cables, RS-232 cables, parallel cables, USB cables, and so on. As the information age expands, we can only expect to have other types of applications with even more cables.

There is hope, however, that we may soon be freed of many of these cables. A new technology is emerging that promises to eliminate them. Called Bluetooth, the technology consists of a specification for the wireless communication of voice and data using a short range radio. Bluetooth is an open, global standard, meaning that, unlike cables, there will only be one kind of Bluetooth and any Bluetooth-certified device will be able to communicate with any other Bluetooth-certified device.

The Bluetooth Special Interest Group (SIG) was founded by Ericsson, IBM, Intel, Nokia and Toshiba to develop an open specification for short-range wireless connectivity. Originally conceived to enable the design of universal wireless connections for laptops computers to cellular telephones. It quickly became apparent that there were many other applications for the Bluetooth standard.

The idea behind the Bluetooth standard is that any Bluetooth-certified device can interact with any other nearby Bluetooth-certified device, anywhere in the world. Thus, a Bluetooth-certified PDA or cell phone would work with any PC, equipped with a Bluetooth-certified card, regardless of the manufacturer of either. A person could buy any brand of PDA, cell phone or mouse that worked with the Bluetooth standard, take it home and begin using it with a Bluetooth equipped PC immediately, without any special effort. Application software that is unique to a mobile phone, PDA or mouse could be automatically downloaded from the device to the PC, using the Bluetooth connection.

Bluetooth can replace cables currently being used with laptops, PDAs, mobile phones, and digital cameras, to name a few. Bluetooth supports voice as well as data transmission, so headsets used within the office or home could also become wireless. Bluetooth might even be used to replace the control cables in automobiles, boats and industrial control systems. Since Bluetooth is a global standard and uses universally available unlicensed radio frequency spectrum, any Bluetooth-certified devices would interact in the same way in any part of the world.

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 0dBm. At 0dBm, 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 one megabit (Mb) per second, maximum. But communication protocol overhead limits the practical data rate to a little over 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 $1/1600^{th}$ of a second (625 µ sec) for the next frequency hop and re-transmits 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, de-compressed 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 connection-less (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 µ sec 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 the PDA, 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 Bluetooth-certified devices 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 CORPORATION'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, PDA's, headsets and mice, all of this functionality must fit in a very small package and should consume as little power as possible.

Atmel Corporation of San Jose California 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. The company's TEMIC Semiconductors subsidiary (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 Corporation has an extensive library of intellectual property in the areas of DSP, programmable logic, microcontrollers, analog and non-volatile memory, plus application specific IP for media access controller/basebands for 802.11, 802.11B and Voice-over-IP telephones.

Atmel has chip fab facilities in Colorado Springs, CO, 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. TEMIC Semiconductors is one of only two companies in the world, in volume production, with a Silicon-Germanium (SiGe) process. Atmel is currently developing a

Silicon Germanium BiCMOS (SiGe-BiCMOS) process that should enable it to offer one of the industry's first single chip Bluetooth solutions. Atmel's initial Bluetooth solution will consist of a pre-certified Bluetooth reference design based on a multi-chip module that includes the radio, baseband and flash memory in a BGA package, external discrete components and an integrated antenna, all assembled on a small PCB. 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 - TEMIC Semiconductors' 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 -80dBm, linearity of SFDR 50 dB, and VCO phase noise of -89 dBc/Hz at 500 kHz. Transmit/receive turn around time is100µs.

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 transmit data modulates the VCO by switching the charge pump in tristate while the Phase Lock Loop (PLL) is in "open-loop mode". This causes frequency drift. TEMIC Semiconductors has developed a modulation compensation circuit (MCC) that makes it possible

to use "closed-loop modulation" of the VCO

There are several advantages of TEMIC Semiconductors ’s "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. TEMIC Semiconductor ’s 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’s TEMIC Division was the first RF company 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 draw back 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. TEMIC´s image rejection mixer is capable of up to 35 dB image rejection.

Bluetooth RF Front End - ATMEL's TEMIC Semiconductors subsidiary is also developing a SiGe-BiCMOS front end T7024 transceiver which will include 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 will boost the range of Atmel's Bluetooth system much beyond 100 meters.

Bluetooth Baseband - Atmel's single-chip AT76C551 Bluetooth Controller performs the Bluetooth Link Management and Control (baseband) protocols. The AT76C551 controller, available in several options, integrates an ARM 7TDMI 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 or UART standard interface. Dedicated hardware in the AT76C551 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 AT76C551's USB interface supports up to six endpoints each with double buffered FIFOs. Multiple clock frequencies are supported for interface to GSM, CDMA, TDMA telephones and pagers, eliminating the need for an additional crystal.

Flash Memory - Atmel's Bluetooth solution includes one megabit of low voltage flash memory for the storage of firmware and data

Product Road Map - Initially, Atmel will provide a pre certified Bluetooth reference design based on a multi-chip module that includes the radio, baseband and flash memory in a BGA package, external discrete components and an integrated antenna, all assembled on a small PCB.

In 2000, Atmel will develop a more integrated version that integrates the external flash memory and the T2901 RF transceiver onto the Bluetooth processor. This design will also eliminate the SAW filter and implement the analog to digital and digital to analog conversion in the baseband processor, resulting in a single chip complete solution.

Atmel expects to introduce the true single chip Bluetooth solution in early 2001, based on the company's SiGi-BiCMOS process technology.

Pre-Certified Reference Design With HCI Software - Atmel will make available a complete Bluetooth reference design that provides virtually instant time-to-market for Bluetooth-enabled products. It consists of a very small printed circuit board populated with a multi-chip module that includes the T2901 Bluetooth transceiver, the AT76C551 Bluetooth baseband processor, and one Mbit of flash memory in a BGA package. In

addition to the multi-chip module, the PCB has a small antenna and all other necessary components for a complete plug-and-play Bluetooth solution. The Atmel solution also includes 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.