Tuesday, February 28, 2006

# SmartStep™ – V2.1.1-A2

## Operational Description

SmartStep™ System:

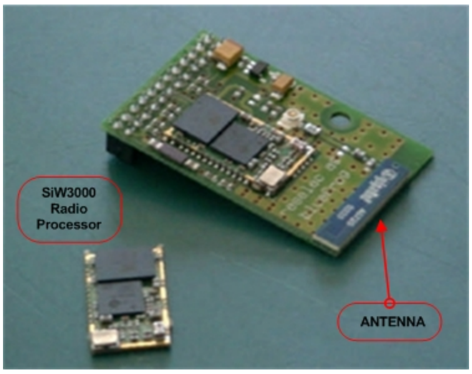
SmartStep™ is a feedback training device designed to help assess accurately patient status and enhance recovery of lower limb problems.
The system is consisting of a wireless control unit that communicates with the SmartStep™ system PC software through a Bluetooth USB dongle (BToes from MSI, FCC ID: PANBT330E).

The Control Unit:

The SmartStep™ control unit has two PCB. The Bluetooth module board is connected to the main board through 24 Pin socket connector.
The main board microcontroller (PIC16F876) is connected to the Bluetooth module UART.
The Bluetooth module is power from the main board voltage supply.

The Bluetooth Module:

The following image shows the Bluetooth module:




The Bluetooth module is a class 2 (0 dBm) module. The module based on the RF Micro Devices SiW3000™ Radio Processor which combines the ARM7TDMI processor for Bluetooth wireless technology.
The Bluetooth module is consisting of a 2.4 GHz SMD Antenna from gigaAnt.
The antenna is located on the board inside the control unit box.

- *For full specification of the Bluetooth module, please refer to the SiW3000™ Radio Processor and the antenna data sheets.*

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The following information is based on the:
BLUETOOTH SPECIFICATION Version 1.2 [vol 2].

## Frequency Hop Synchronization

FHSS Description:

During typical operation a physical radio channel is shared by a group of devices that are synchronized to a common clock and frequency hopping pattern. One device provides the synchronization reference and is known as the master. All other devices are known as slaves. A group of devices synchronized in this fashion form a piconet.
Devices in a Bluetooth piconet use a specific frequency hopping pattern, which is algorithmically determined by certain fields in the Bluetooth address and clock of the master according to the Bluetooth specification. The basic hopping pattern is a pseudo-random ordering of the 79 frequencies in the ISM band. The basic Bluetooth piconet physical channel is characterized by a pseudo-random hopping through all 79 RF channels. The frequency hopping in the piconet physical channel is determined by the Bluetooth clock and BD_ADDR of the master. When the piconet is established, the master clock is communicated to the slaves. Each slave add an offset to its native clock to synchronize with the master clock. Since the clocks are independent, the offsets must be updated regularly. All devices participating in the piconet are time-synchronized and hop-synchronized to the channel.

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## Sample hopping list:

Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence):
CLK start: 0x0000010
0x00000000

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|---|---|---|---|---|---|---|---|---|
| 0x0000010: | 08 66 | 10 70 | 12 19 | 14 23 | 16 01 | 18 05 | 20 33 | 22 37 |
| 0x0000030: | 24 03 | 26 07 | 28 35 | 30 39 | 32 72 | 34 76 | 36 25 | 38 29 |
| 0x0000050: | 40 74 | 42 78 | 44 27 | 46 31 | 48 09 | 50 13 | 52 41 | 54 45 |
| 0x0000070: | 56 11 | 58 15 | 60 43 | 62 47 | 32 17 | 36 19 | 34 49 | 38 51 |
| 0x0000090: | 40 21 | 44 23 | 42 53 | 46 55 | 48 33 | 52 35 | 50 65 | 54 67 |
| 0x00000b0: | 56 37 | 60 39 | 58 69 | 62 71 | 64 25 | 68 27 | 66 57 | 70 59 |
| 0x00000d0: | 72 29 | 76 31 | 74 61 | 78 63 | 01 41 | 05 43 | 03 73 | 07 75 |
| 0x00000f0: | 09 45 | 13 47 | 11 77 | 15 00 | 64 49 | 66 53 | 68 02 | 70 06 |
| 0x0000110: | 01 51 | 03 55 | 05 04 | 07 08 | 72 57 | 74 61 | 76 10 | 78 14 |
| 0x0000130: | 09 59 | 11 63 | 13 12 | 15 16 | 17 65 | 19 69 | 21 18 | 23 22 |
| 0x0000150: | 33 67 | 35 71 | 37 20 | 39 24 | 25 73 | 27 77 | 29 26 | 31 30 |
| 0x0000170: | 41 75 | 43 00 | 45 28 | 47 32 | 17 02 | 21 04 | 19 34 | 23 36 |
| 0x0000190: | 33 06 | 37 08 | 35 38 | 39 40 | 25 10 | 29 12 | 27 42 | 31 44 |
| 0x00001b0: | 41 14 | 45 16 | 43 46 | 47 48 | 49 18 | 53 20 | 51 50 | 55 52 |
| 0x00001d0: | 65 22 | 69 24 | 67 54 | 71 56 | 57 26 | 61 28 | 59 58 | 63 60 |
| 0x00001f0: | 73 30 | 77 32 | 75 62 | 00 64 | 49 34 | 51 42 | 57 66 | 59 74 |
| 0x0000210: | 53 36 | 55 44 | 61 68 | 63 76 | 65 50 | 67 58 | 73 03 | 75 11 |
| 0x0000230: | 69 52 | 71 60 | 77 05 | 00 13 | 02 38 | 04 46 | 10 70 | 12 78 |
| 0x0000250: | 06 40 | 08 48 | 14 72 | 16 01 | 18 54 | 20 62 | 26 07 | 28 15 |
| 0x0000270: | 22 56 | 24 64 | 30 09 | 32 17 | 02 66 | 06 74 | 10 19 | 14 27 |
| 0x0000290: | 04 70 | 08 78 | 12 23 | 16 31 | 18 03 | 22 11 | 26 35 | 30 43 |
| 0x00002b0: | 20 07 | 24 15 | 28 39 | 32 47 | 34 68 | 38 76 | 42 21 | 46 29 |
| 0x00002d0: | 36 72 | 40 01 | 44 25 | 48 33 | 50 05 | 54 13 | 58 37 | 62 45 |
| 0x00002f0: | 52 09 | 56 17 | 60 41 | 64 49 | 34 19 | 36 35 | 50 51 | 52 67 |
| 0x0000310: | 38 21 | 40 37 | 54 53 | 56 69 | 42 27 | 44 43 | 58 59 | 60 75 |
| 0x0000330: | 46 29 | 48 45 | 62 61 | 64 77 | 66 23 | 68 39 | 03 55 | 05 71 |
| 0x0000350: | 70 25 | 72 41 | 07 57 | 09 73 | 74 31 | 76 47 | 11 63 | 13 00 |
| 0x0000370: | 78 33 | 01 49 | 15 65 | 17 02 | 66 51 | 70 67 | 03 04 | 07 20 |
| 0x0000390: | 68 55 | 72 71 | 05 08 | 09 24 | 74 59 | 78 75 | 11 12 | 15 28 |
| 0x00003b0: | 76 63 | 01 00 | 13 16 | 17 32 | 19 53 | 23 69 | 35 06 | 39 22 |
| 0x00003d0: | 21 57 | 25 73 | 37 10 | 41 26 | 27 61 | 31 77 | 43 14 | 47 30 |
| 0x00003f0: | 29 65 | 33 02 | 45 18 | 49 34 | 19 04 | 21 08 | 23 20 | 25 24 |

In absence of data, the system continues to hop.
Repeating of a packet has no influence on the hopping sequence. The hopping sequence generated by the master of the connection will be followed any case. That means, a repeated packet will not be send on the same frequency. It is send on the next frequency of the hopping sequence.

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## Receiver input bandwidth and Synchronization

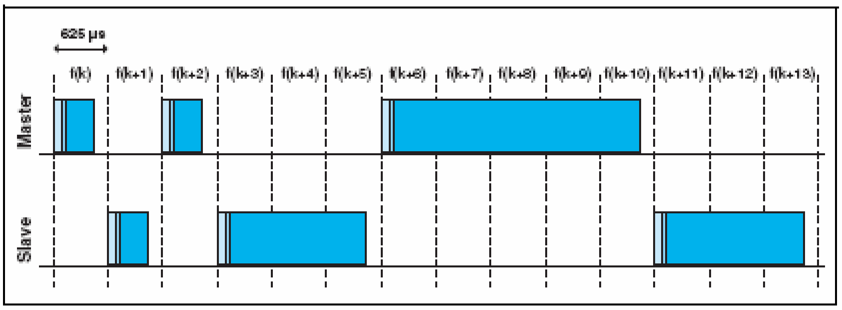
The receiver has input bandwidth of 1 MHz.

In every connection one Bluetooth device is the Master and the other is the Slave. The master determines the hopping sequence. The slave follows this sequence. Both devices shift between RX and TX time slot according to the clock of the master. Additionally the type of connection (e.g. single or multislot packet) is set up at the beginning of the connection. The master adapts its hopping frequency and its RX/TX timing according to the packet type of the connection. Also the salve of the connection will use these settings.

The basic piconet physical channel is characterized by a pseudo-random hopping through all 79 RF channels. The frequency hopping in the piconet physical channel is determined by the Bluetooth clock and BD_ADDR of the master. When the piconet is established, the master clock is communicated to the slaves. Each slave add an offset to its native clock to synchronize with the master clock. Since the clocks are independent, the offsets must be updated regularly. All devices participating in the piconet are time-synchronized and hop-synchronized to the channel.

The basic piconet physical channel is divided into time slots, each 625 µs in length. The time slots are numbered according to the most significant 27 bits of the Bluetooth clock CLK28-1 of the piconet master. The slot numbering ranges from 0 to 227-1 and is cyclic with a cycle length of 227. The time slot number is denoted as k. A TDD scheme is used where master and slave alternatively transmit, see Figure <Below>. The packet start shall be aligned with the slot start.

Packets may extend over up to five time slots.





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Access Code:

In the Bluetooth system all transmissions over the physical channel begin with an access code. Three different access codes are defined:

• device access code (DAC)
• channel access code (CAC)
• inquiry access code (IAC)

All access codes are derived from the LAP of a device address or an inquiry address.
The device access code is used during page, page scan and page response substates and is derived from the paged device's BD_ADDR.
The channel access code is used in the CONNECTION state and forms the

beginning of all packets exchanged on the piconet physical channel. The channel access code is derived from the LAP of the master's BD_ADDR.
Finally, the inquiry access code is used in the inquiry substate.
The access code indicates to the receiver the arrival of a packet. It is used for **timing synchronization** and offset compensation. The receiver correlates against the entire synchronization word in the access code, providing very robust signaling.
Given that the number of RF carriers is limited and that many Bluetooth devices may be operating independently within the same spatial and temporal area there is a strong likelihood of two independent Bluetooth devices having their transceivers tuned to the same RF carrier, resulting in a physical channel collision. To mitigate the unwanted effects of this collision each transmission on a physical channel starts with an access code that is used as a correlation code by devices tuned to the physical channel. This channel access code is a property of the physical channel. The access code is always present at the start of every transmitted packet. Whenever a Bluetooth device is synchronized to the timing, frequency and access code of a physical channel it is said to be 'connected' to this channel.
Every packet starts with an access code. This access code is used for **synchronization**, DC offset compensation and identification. The access code identifies all packets exchanged on a physical channel: all packets sent in the same physical channel are preceded by the same access code. In the receiver of the device, a sliding correlator correlates against the access code and triggers when a threshold is exceeded. This trigger signal is used to determine the receive timing.
When two Bluetooth devices establish contact for the first time, one device sends an inquiry access code. The other device is scanning for this inquiry access code. If two devices have been connected previously and want to

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connect again, a similar procedure takes place. The only difference is use of other access code derived from the BD_ADDRESS of the paged device. This

access code is sent by the master of this connection. Due to the fact that both units have been connected before (inquiry procedure), the paging unit has timing and frequency information about the page scan of the paged unit. For this reason the time for establish the connection is reduced.

***The same theory of operation applies for all Bluetooth operation modes: Inquiry mode, Connection mode.***

Summary:

The SiW3000_RMOD is a class 2 (0 dBm) module for Bluetooth Wireless Technology. The module based on the RF Micro Devices SiW3000™ Radio Processor.
The SiW3000™ Radio Processor is qualified for Bluetooth protocol and complies with the Bluetooth protocol specification.