SMART MODULES

GENERALITIES & TECHNOLOGIES

DECEMBER 2019
- COMPANY OVERVIEW
- BLUETOOTH LOW ENERGY
- LoRa
- UWB
Experts in RF System-in-Package (SiP) and Antenna-in-Package (AiP) in response to ultra miniature wireless solution demand

- **Established in 2005**
  - Founded by actual CEO and CTO
  - Core team of PhD and MSc from National Semiconductor
  - Electromagnetic simulation, antenna design and µW & RF circuit theory skills
  - Unique set of design techniques & industrialization expertise
  - 25 people engineering and fabless company

- **Locations**
  - Europe – HQ & Technical team in Sophia-Antipolis
  - North America – Subsidiary in Denver
  - Asia – Sales office in Tokyo
  - Global network of distributors
  - Manufacturing – Taiwan and Philippines
Company Profile

- Modules are manufactured in several plants and partners, in Taiwan and Philippines
  - Production level greater than 1M modules

- Quality standards in production
  - ISO9000 standards and several other equivalent certifications
  - OHSAS18001 – Health and Safety management
  - ISO13485 – Medical requirements
  - AS9100 – Aerospace requirements
  - QS9000 – Automotive requirements

- All modules fully tested before delivery
  - IOs, Radio and Flash/RAM writing
  - Possibility to offer Pre-programming service
**Technology Benefits**

- **SiP approach consists of integrating several different components into a single miniaturized module**
  - From different semiconductor and passive technologies
    - Organic substrates (BT, FR4...)
    - Multi-layer ceramic substrates (LTCC, HTCC, Thick film...)
    - Thin film IPD on silicon or glass
  - Unique ability to embed functions within the package
  - RF know-how
  - Extremely rapid and low cost development cycles

- **Insight SiP focus on AiP – Antenna in Package – products with the addition of ultra-miniature antennas in the SiP**
  - Insight SiP’s long term fundamental research program
  - Combining electromagnetic simulations and circuit level optimization
  - Based on a user extendable library of physical objects
  - R&D work implemented in several Wireless Connectivity products
Technology Benefits

- Ready to Go
  - No need for RF knowledge
  - Design effort for RF design is very often underestimated
  - Minimum electronic skills for digital connection
  - Module is certified, avoiding lengthy and expensive certification process

- Fast Time to Market
  - Time to market reduced by 3 to 6 months

- Smaller
  - Small and integrated solution
  - Single component replaces many, supply chain simpler

- Improved performance
  - Optimized antenna performance
  - BLE function concentrated in one single component

- Application development is focused on customer’s added value
**Technology Benefits**

- Designed by RF specialist with leading chipset manufacturer
- Offers fully embedded connectivity solutions

1. **SoC Inside**
   - WLCSP wireless SoC and multiple analog and digital functions

2. **Both crystals included**
   - Radio & Synchronization
   - Reduced power consumption

3. **Power supply decoupling**
   - For both DC-DC enable or disable operating mode

4. **Antenna matching circuit**

5. **Integrated Antenna**
   - Proprietary integrated antenna
   - Offering best reproducibility and best in class performance
   - Relatively insensitive to environment

6. **Integrated shielding avoiding external metallic covers**
   - Reduces height and size
Insight SiP is addressing a wide area of market segments that require state of the art wireless and IoT solutions.

- Mobile Computing
- Healthcare and Wellness
- Industry 4.0
- Cellular Connectivity
- IoT and M2M
- Defence
- Smart Secure
- Mobility
- Avionics and Space
MARKET & CUSTOMERS

LOW POWER NETWORKING

- BLE
- BT 5 Long Range & Mesh
- Moderate Power Moderate Cost
- LTE-M & NB-IoT
- LoRa 800/900 MHz & LoRa 2.4 GHz
- Very Low Power Very Low Cost
- Low Power Low Cost

Data Rate (Kbps) vs. Range (m)
Positioning

- BLE
- BT 5.1
- LoRa 2.4 GHz
- LTE-M
- UWB

Accuracy (cm)

Range (m)
<table>
<thead>
<tr>
<th>Positioning Modules</th>
<th>Wide Area Modules</th>
<th>Short Range Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Range UWB Security Bubble</td>
<td>iSP45 LoRa 800/900 Europe Japan &amp; USA</td>
<td>iSP09 BLE 4.0</td>
</tr>
<tr>
<td>iSP19 BT 5.1 Direction Finding Low Cost</td>
<td>iSP09 BLE 4.1</td>
<td>iSP13 BLE 4.1</td>
</tr>
<tr>
<td>iSP19 BT 5.1 Direction Finding High Temp</td>
<td>iSP15 BLE 4.2 ANT+</td>
<td>iSP15 BLE 4.2 ANT+</td>
</tr>
<tr>
<td>iSP18 BT 5.0 ANT+ Thread Zigbee</td>
<td>iSP18 BT 5.0 ANT+ Thread Zigbee</td>
<td>iSP18 BT 5.0 ANT+ Thread Zigbee</td>
</tr>
<tr>
<td>iSP30 Long Range UWB</td>
<td>iSP19 BT 5.1 ANT+ Thread Zigbee</td>
<td>iSP19 BT 5.1 ANT+ Thread Zigbee</td>
</tr>
<tr>
<td>iSP60 NB-IoT</td>
<td>iSP19 BT 5.1 Direction Finding High Temp</td>
<td>iSP70 BLE Secure</td>
</tr>
<tr>
<td>2009</td>
<td>2018</td>
<td>2019 NEW MODULES</td>
</tr>
<tr>
<td>PLAN FOR 2020+</td>
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</tbody>
</table>
Bluetooth Low Energy
Insight SiP offers Built-in Antenna BLE Modules with Concentrated Performances for IoT Applications

- **Tiny module size**
  - SIP package = smallest solution on the market for antenna integrated module

- **Proven available high performance**
  - Outstanding antenna performance verified by major companies
  - Hardware support for standard application: Sensor demo, Beacon Demo
  - Very high quality hardware support from true RF experts: possible RF and range simulation of customer design

- **Based on Nordic Semiconductor chipset**
  - Established player in BLE for many years
  - Proven and well supported protocol stack, with huge firmware library

- **Fully certified**
  - BT SIG, CE, FCC, IC, TELEC
- **Bluetooth SIG**
  - The Bluetooth Special Interest Group was formed in 1998
  - This is now a community of over 30000 members

- **Bluetooth Classic**
  - V2.0  Bluetooth Classic released in 2004
  - V3.0  Bluetooth High Speed adopted in 2009, dedicated to audio application

- **Bluetooth Low Energy (BLE)**
  - V4.0  First Bluetooth Low Energy concept adopted in 2010
  - V4.1  Multirole capabilities: Master & Slave on the same chip
  - V4.2  Enable IPv6 for Bluetooth: Improve speed, security and privacy
  - V5.0  Adopted end 2016: 2X speed, 4X range, 8X throughput
  - V5.1  Last generation enabling Direction Finding

  - In parallel, Bluetooth Mesh was introduced as new connectivity capabilities, independent of BLE versions
Insight SiP offers BLE modules from V4.0 up to V5.1

- No Bluetooth Classic or Dual Mode available

Bluetooth Low Energy

- Allows for short bursts of long-range radio connection
- Doesn’t require continuous connection
- Depends on long battery life
- Makes it ideal for Internet of Things (IoT) applications

Bluetooth Classic

- Establishes a relatively short-range
- Continuous wireless connection
- Makes it ideal for use cases such as streaming audio

Dual-Mode

- Available to support single devices such as smartphones or tablets
- Need to connect to BR/EDR devices (such as audio headsets)
- Also need to connect to LE devices (such as wearables or retail beacons)
BLE Specifications

- **Frequency range**
  - In the globally unlicensed ISM 2.4 GHz band: 2400–2483.5 MHz
  - Bluetooth uses a radio technology called frequency-hopping spread spectrum (FHSS)
  - It usually performs 1600 hops per second
  - The transmitted data are divided into packets and each packet is transmitted on one of the 79 channels (or 40 channels for Bluetooth Low Energy)

- **Modulation**
  - Originally, Gaussian frequency-shift keying (GFSK) modulation was the only modulation scheme available, said to be operating in basic rate (BR) mode where an instantaneous data rate of 1 Mbit/s was possible
  - Since the introduction of Bluetooth 2.0, DQPSK and 8DPSK modulation may also be used between compatible devices, described as enhanced Data Rate (EDR), each giving 2 and 3 Mbit/s respectively

- **Data rate**
  - Enhanced rate with V3.0
  - Reduced for V4.0 to save energy

<table>
<thead>
<tr>
<th>Version</th>
<th>Data rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>1 Mbits/s</td>
</tr>
<tr>
<td>2.0 + EDR</td>
<td>3 Mbits/s</td>
</tr>
<tr>
<td>3.0 + HS</td>
<td>24 Mbits/s</td>
</tr>
<tr>
<td>4.0</td>
<td>1 Mbits/s</td>
</tr>
<tr>
<td>5.0</td>
<td>2 Mbits/s</td>
</tr>
</tbody>
</table>
**Bluetooth Low Energy is designed for Low Power Applications**

- Where aim is long battery life
- Months / years off coin cell
- Occasional data exchange

**Principle of Bluetooth LE solution**

- BLE chip saves power by being in “sleep mode” most of the time
- Power consumption is strongly related to data rate
- Bluetooth low energy is designed to enable connectivity of power-sensitive devices operating on primary cells for long periods of time ranging from months to potentially several years
- One cannot look at peak RX or TX current to assess overall power consumption since the time in low power “sleep” mode dominates overall power consumption
BLE Architecture

- **Core Architecture: Host**
  - ✓ Generic Access Profile (GAP) works in conjunction with GATT to define procedures and roles related to the discovery of Bluetooth devices
  - ✓ Generic Attribute Profile (GATT) groups services and defines procedures and formats of services including discovering, reading, writing, notifying
  - ✓ Attribute Protocol (ATT) defines the client/server protocol for data exchange once a connection is established
  - ✓ Security Manager defines the protocol and behavior that manages pairing integrity, authentication and encryption
  - ✓ Logical Link Control and Adaptation Protocol (L2CAP) transmits packets to the HCI

- **Core Architecture: Controller**
  - ✓ Link Layer defines packet structure/channels, discovery/connection and sends/receives data
  - ✓ Direct Test Mode allows testers to instruct the PHY layer
  - ✓ The Physical Layer (PHY) controls 2.4Ghz radio
The Bluetooth stack is commonly integrating the Host

Application Profiles & Services

- A device must interpret certain profiles, which are definitions of possible applications and specify general behaviors that devices use to communicate with other devices.

- There are a wide range of Bluetooth profiles that describe many different types of applications or use cases for devices.

Central role (Client) & Peripheral role (Server)

- Bluetooth is a packet-based protocol with a client-server structure. One client may communicate with several servers, all devices share the client’s clock.
BLE Mesh is a recent extension of Bluetooth technology
  ✓ It extends the capabilities and potential uses of Bluetooth in many applications
  ✓ Particularly suited to smart building and home automation applications

BLE Mesh is available from V4.2 Bluetooth version
  ✓ It uses the same radio and physical transport as existing BLE
  ✓ It adds a networking layer that allows multiple Bluetooth devices to work together
  ✓ Messages from one device to another is sent via one or more intermediate nodes
  ✓ In other words the network or “mesh” allows two devices to communicate that are too far apart to make a direct point to point Bluetooth connection
  ✓ In practical terms, a direct point to point Bluetooth connection is limited to around 50m (direct line of sight), or 200m for Bluetooth 5 long range.

Ability to extend the effective communication distance

Allows devices to be put into groups and message to be sent to one device or a group of devices
### Relay nodes

- Receive and forward messages to other nodes
- Can also be connected to a device (light, thermostat ...)
- Act themselves on a message or generate one
- A relay node receiving a message will look at it, decode and act it (e.g. switch the light on or off), or broadcast the message onward
- Relay nodes are not “low-energy nodes”
Friend nodes
- Friend nodes enable to connect a low energy device to a mesh network
- The low energy device is linked to a friend node
- The friend device can operate in Low Energy mode, and the associate friend node will store a message, and send it on when the friend device is awake
- In the other direction, the friend device sends data when it wants, and the associated friend node is ready and waiting
- Friend nodes cannot act to relay messages in the mesh, they are “end point”

Proxy Nodes
- Smartphone or tablet don’t need to be updated to run mesh
- As of today no phones run Bluetooth Mesh
- Proxy node acts as a bridge between a standard BT4+ dual mode and the mesh
- Proxy node runs both the Mesh and the standard BLE stacks, and can thus receive a message from a phone, and send it on to the mesh
Direction Finding is the main new feature of Bluetooth 5.1
✓ Former BT location systems was based on RSSI only, with poor precision
✓ It will offer enhance location services for Real Time Location Systems (RTLS)

Bluetooth direction finding is using AoA or AoD to detect tag location
✓ Angle of Arrival (AoA) and Angle of Departure (AoD) makes use of the angular phase-shifts that occur between antennas as they receive or transmit RF signals
✓ This full system is made of anchor units positioned in line of sight manner
✓ Antenna arrays at both side of the communication link are providing phase shift data, determining AoA or AoD
✓ Position of tagged items are calculated by triangulation from different anchors

Allows for use of very simple and low cost tags to determine their location

Perfectly suited for asset tracking in warehouses and buildings or ID location of people and staff
BLE Main Applications

- BLE typically used for

✓ Connected sensors for medical devices, healthcare, sport, fitness, industrial devices ...
✓ IoT applications: connected objects like bracelet, watches ...
✓ Wearable technology
✓ Phone/laptop accessories
✓ Home automation
✓ Beacons
✓ Localize indoors to medium accuracy
✓ Wireless charging
✓ Led lighting
✓ Toys
Insight SiP offers LoRa Low Power solution platform for Longer Range Networking applications

- Insight SiP is LoRa Alliance member since 2018

- **LoRa section based on Semtech transceiver**
  - Europe: based on Semtech SX1261, 867-869 MHz and +14dBm
  - US: based on Semtech SX1262, 902-928 MHz and +20dBm
  - Japan: based on Semtech SX1261, 920-925 MHz and +14dBm

- **BLE section based on Nordic nRF52 chipset**
  - Providing over the air configuration of LoRa through smartphone or tablet
  - Also offering low energy rough location indication

- **Dual antenna integration**
  - New and unique concept developed by Insight SiP with 2 embedded antennas in package

- **Certifications**
  - BT SIG, CE, FCC, IC, TELEC based on versions
LoRa is a Low-Power Wide Area Network (LPWAN) standard

- Aimed at low data rate – low power applications (like BLE)
- Uses Adaptive Data Rate (ADR) to maximize combination of range/data/rate power
- Thus one cannot quote a max range or data rate like BLE, but the following table (Source: Orange) indicates capability (probably under ideal conditions)
The following table defines the frequencies used by LoRa in key regions:

LoRa uses unlicensed spectrum.

<table>
<thead>
<tr>
<th>Region</th>
<th>Supported</th>
<th>Band [MHz]</th>
<th>Duty cycle</th>
<th>Output power</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>Y</td>
<td>868</td>
<td>&lt;1 %</td>
<td>+14 dBm</td>
</tr>
<tr>
<td>EU</td>
<td>Y</td>
<td>433</td>
<td>&lt;1 %</td>
<td>+10 dBm</td>
</tr>
<tr>
<td>US</td>
<td>Y</td>
<td>915</td>
<td>&lt;2 % (BW&lt;250 kHz) or &lt;4 % (BW&gt;=250 kHz) Transmission slot &lt; 0.4 s</td>
<td>+20 dBm</td>
</tr>
<tr>
<td>CN</td>
<td>N</td>
<td>779</td>
<td>&lt;0.1 %</td>
<td>+10 dBm</td>
</tr>
</tbody>
</table>
LoRaWAN refers to a standard Network protocol, allowing different LoRa devices to communicate with each other in a standard way

✓ A private point to point network could use LoRa technology, but not LoRaWAN (although it could)

✓ A public network would normally use LoRaWAN

LoRaWAN is defined and maintained by the LoRa Alliance (this roughly corresponds to the BT SIG)

✓ LoRa Alliance members include chip companies, Network operators, system integrators

✓ LoRaWAN evolving – currently on 1.0.2, 1.1 coming (roaming protocol)
LoRa Basics

- **Insight SiP module is focused on Class A devices, this is the mode used in most battery driven nodes, as it is the lowest power mode**

- **There are two types of LoRa node: Gateway and Device**

- **Gateways have a different hardware for the radio** – thus a device module cannot be used as a Gateway

- **Devices can be three classes**
  - **Class A** – Transmits only when ready - Downlink follows uplink, but there is no way for the Gateway to initiate a downlink
  - **Class B** – Has a regularly scheduled downlink window
  - **Class C** – Is always listening
Insight SiP is also offering new range of innovative IoT Location System based on UWB technology

- **Dual antenna integration**
  - New and unique concept developed by Insight SiP with 2 embedded antennas

- **Ultra precise Location Systems powered by Decawave DW1000**
  - Insight SiP decided to improve ISP1510, still using Decawave DW1000, but offering a 50 meters optimal range and an embedded intelligent power supply to operate on coin cell battery
  - New chipset generation are in progress with much lower power consumption, better sensitivity and longer range

- **BLE section based on Nordic nRF52 chipset**
  - Providing friendly configuration of UWB through smartphone or tablet
  - Also offering low energy rough location indication
- **Ultra Wide Band in the age**
  - UWB is more than 100 Years old technology
  - In the 2000’s, WiMedia was intended for short-range multimedia file transfers and was promoted for personal computers, consumer electronics, mobile devices ...

- **UWB Impulse Radio (IR-UWB)**
  - Finally, UWB spectrum was opened for commercial use in 2005 by the FCC for pulse-based transmission in the 3.1 to 10.6 GHz frequency range targeting sensor data collection, precision locating and tracking applications
  - UWB conforms with IEEE 802.15.4 technical standard which defines the operation of low-rate wireless personal area networks (LR-WPANs). It specifies the physical layer and media access control for LR-WPANs which focuses on low-cost, low-speed ubiquitous communication between devices
Frequency range
✓ Insight SiP module uses UWB channel 5 center frequency 6489.6 MHz
✓ UWB channel bandwidth 499.2 MHz

802.15.4-2011 Standard

Coded pulse train
✓ Binary Position Modn
✓ Binary Phase Shift Key
✓ Symbol = 2 bits 1 BPM 1 BPSK

UWB consumes very little power
✓ Low regulatory limit for transmission strength
✓ Very short pulse train in the range of nano-seconds

Built-in scalability
✓ Communication link can be adjusted in terms of data bandwidth, sensitivity, recurrence, etc.
For applications where precise positioning is necessary, UWB offer the best performances over other technologies

- WiFi and Bluetooth using RSSI method, sensitive to Multipath, to Interference, to relative position antenna: offers precision in the 10 meters range
- UWB using Time of Flight method, unsensitive to Multipath and Interference offers precision in 10 cm range

- Unsensitivity to Noise & Interference of other systems
  - RF pulse straight edges give precise determination of arrival time

- Unsensitivity to Multi-Path Reflection Interference
  - Short pulses avoid combination with reflected signals
### 2-Way Ranging

- **Anchor**

- **Tag**

- Simple measurement of time of flight

#### Time Difference of Arrival (TDOA)

- Location determined by a multi-lateration algorithm

- Need to have all Anchors perfectly synchronized
UWB MAIN APPLICATIONS

- **Consumer**
  - ✓ Building Control
  - ✓ Retail
  - ✓ Home Robots
  - ✓ Access Control

- **Automotive**
  - ✓ Smart Car Entry
  - ✓ Secure Bubble
  - ✓ Automated Valet

- **Industrial**
  - ✓ Building Control
  - ✓ Healthcare
  - ✓ Agriculture
  - ✓ Safety Security
  - ✓ Factory Automation
  - ✓ Robotics
  - ✓ Mining
ANY QUESTION

... FEEL FREE TO CONTACT US
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