Theory of Operation

The product Liuwa makes use of the popular and powerful BLE standard to implement a personnel monitoring short range device. Its main purpose is to allow the user (adults here) to keep tract of the presence of the target person (usually kids here) using cell phone by having the person wearing the product. The cell phone can continuously monitoring the BLE signals send out by Liuwa and knowing the target person is nearby. If the BLE signal from Liuwa is missing for a defined time interval, then the target person is interpreted as missing and an alarm is sounded from the user cell phone to alert the user.

The BLE technology was chosen for its simple communication link between the cell phone and the device that must operate with very low power consumption, and be very low cost. It is particularly suited for those devices that need to transfer very small quantity of data, and do so within relatively short ranges. The extremely low peak and sleep mode currents of the BLE chipset (5 mA peak and 1.5 µA sleep mode) enable BLE radios to work with very small coin cell battery CR2032 for a year and more. BLE chip spend most of their time asleep, only waking up to send data. The RF transmission time lasts only 1.5 ms for every 950 ms interval. Therefore the device has a transmit to asleep duty cycle of 1 to 633 and together with its low peak power of 0 dBm, produces extremely low EMI to surrounding RF devices.

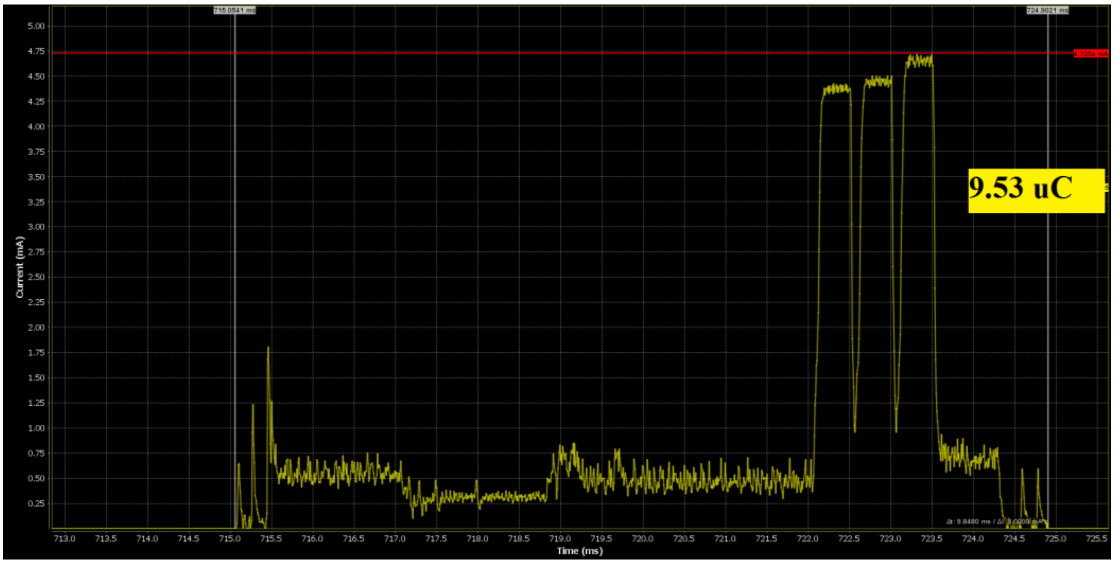

Figure 1 Transmit to asleep duty cycle in Liuwa

BLE uses only 40 channels, 2 MHz wide, (versus 79 channels in Classic Bluetooth). The 40 BLE channels are shown in figure below.

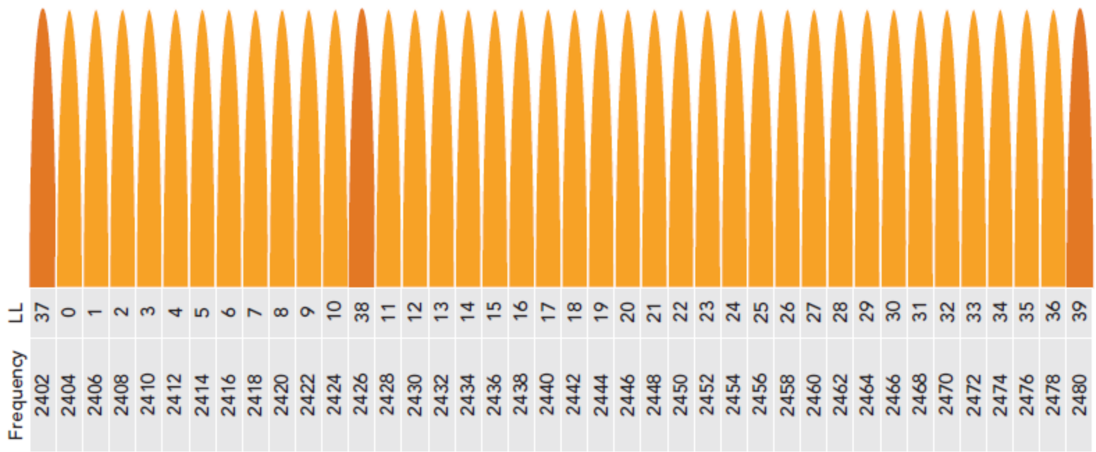

Figure 2 Channels used in BLE

Three channels, which are located exactly between the Wireless LAN channels, are used for device discovery and connection setup. These channels (2402, 2426 and 2480 channels) are used by the technology to search for other devices or promote its own presence to the cell phone that might be looking for it. These channels were chosen exactly between the non-overlapping Wireless LAN channels: so that the BLE devices will not collide with WiFi devices in these channels

Also, the modulation scheme used by BLE is the same as classic Bluetooth: both technologies use a Gaussian Frequency Shift Keying (GFSK) modulation. BLE, however, uses a modulation index of 0.5 (close to a Gaussian Minimum Shift Keying (GMSK) scheme), compared to 0.35 for Classic Bluetooth technology. This change lowers power consumption and also improves the range of BLE versus Classic Bluetooth. Thanks to an increased modulation index, BLE technology offers a somewhat improved range with respect to Classic Bluetooth: theoretically, up to 200 feet (60 m) and beyond. Key features of BLE are listed in the table below:

Frequency	2400 to 2483.5 MHz
Modulation Scheme	GFSK
Modulation Index	0.5
Number of Channels	40
Channel Bandwidth	2 MHz
Nominal Data Rate	1 Mbps
Application Throughput	< 0.3 Mbps
Security	128-bit AES
Nodes / Active Slaves	Unlimited
Tx Peak Power	0 dBm
Tx Duration	1.5 ms
Detection Range	>60 m
Antenna Type	PIFA
Antenna Gain	0dBi

Table 1 Summary of Key Features in BLE

Since BLE operates in the open, license free 2.4 GHz frequency band (just like previous versions of Bluetooth are), Liuwa can interoperate with different brand of cell phones with BLE capability in world wide applications. Like Classic Bluetooth, BLE uses fast, frequency hopping to secure a robust transmission even in the presence of other wireless technologies. This feature makes it very suitable for the crowded environment, where multiple devices using different protocols, such as WiFi, use the same 2.4 GHz spectrum in a confined space. In addition, adaptive hopping and WiFi/Bluetooth coexistence schemes enable Liuwa to be used alongside WiFi radio.

BLE is most efficient for transferring very small quantities of data. The technology supports very short data packets (8 octet minimum up to 27 octets maximum) that are transferred at 1 Mbps. All connections use advanced sniff sub-rating2 to achieve ultra-low duty cycles. These and more features make BLE a great option for Liuwa where the maximum bit rate is of just a few hundred bits-per-second.

BLE is optimized for sending small pieces of information with minimal delay (latency). The total time of sending data is generally around 1.5 ms (compared to 100 ms with Classic Bluetooth). This makes it ideal for Liuwa application where time to sound the missing signal alarm is crucial to the user.

BLE only has one fixed packet structure with two types of packets: advertising and data. The key feature of the low-energy stack is a lightweight Link Layer (LL) that provides ultra-low power idle mode operation, simple device discovery and reliable point-to-multipoint data transfer with advanced power-save and encryption functionalities. Figure below shows the LL packet format.

Preamble (1 octet)	Access Address (4 octets) **32 bits**	PDU (2 to 39 octets)	CRC (3 octets) **24 bits**

Figure 3 BLE link layer (LL) packet format

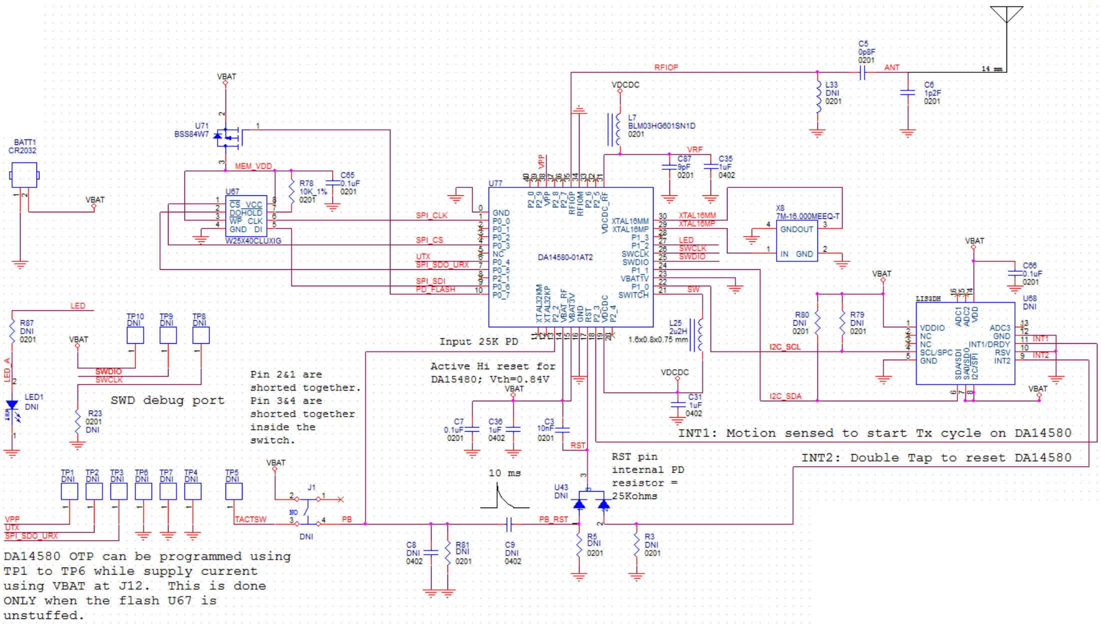

Figure 4 Schematic of Liuwa

Below is a description of the above circuit and its operation after powered up.

●U67: 4 Mbit SPI flash. Upon boot up, U77 (DA14580) will read the firmware image from the flash using SPI bus onto the on-chip RAM. It is on the RAM the firmware starts to run. Once the reading is done, U77 will cut the power off the flash using U71 which is a PMOS switch.

●X8: 16 MHz crystal +/- 10 ppm to run the application. Firmware trimming has been used to minimize frequency offset.

●C31, C35 & C36: Good filtering and decoupling of the VDCDC output (+1.4V), VDCDC_RF supply and VBAT pins is important for a good RF performance. A value of 1 µF is used for these three filtering capacitors. We use low inductance types or 0201 sized ceramic multilayer capacitors, for instance 1 µF, 6.3 V, X5R type. See the attached BOM.

●L25: An inductor with a high resonant frequency, higher than 75 MHz was chosen. This results in a lower stray capacitance and minimizes the HF noise at VDCDC_RF. An inductor value of 2.2 µH is used. See the attached BOM.

●C5 & C6: Antenna matching network that matched the PIFA antenna to 50 ohms. U77 expects a load of 50 ohms in order for a power of 0 dBm to be transmitted.

●U68, U43, J1, LED1 are currently **not** stuffed or used.

●TP2, TP3 are used for burning the firmware image onto the flash (U67) via the UART of U77.

The Beacon device uses the non-connectable advertising mode (Beacon mode) to broadcast its presence to the cell phone of the user. The period of the broadcast is 950 ms and the RF transmission lasts only 1.5 ms. In this mode, the DA14580 transmits advertising packets in all three advertising PHY channels without listening for packet reception. Avoiding the reception process results in improved power consumption compared with connectable advertising mode. Then U77 spends the rest of the time in sleep mode, conserving battery power.