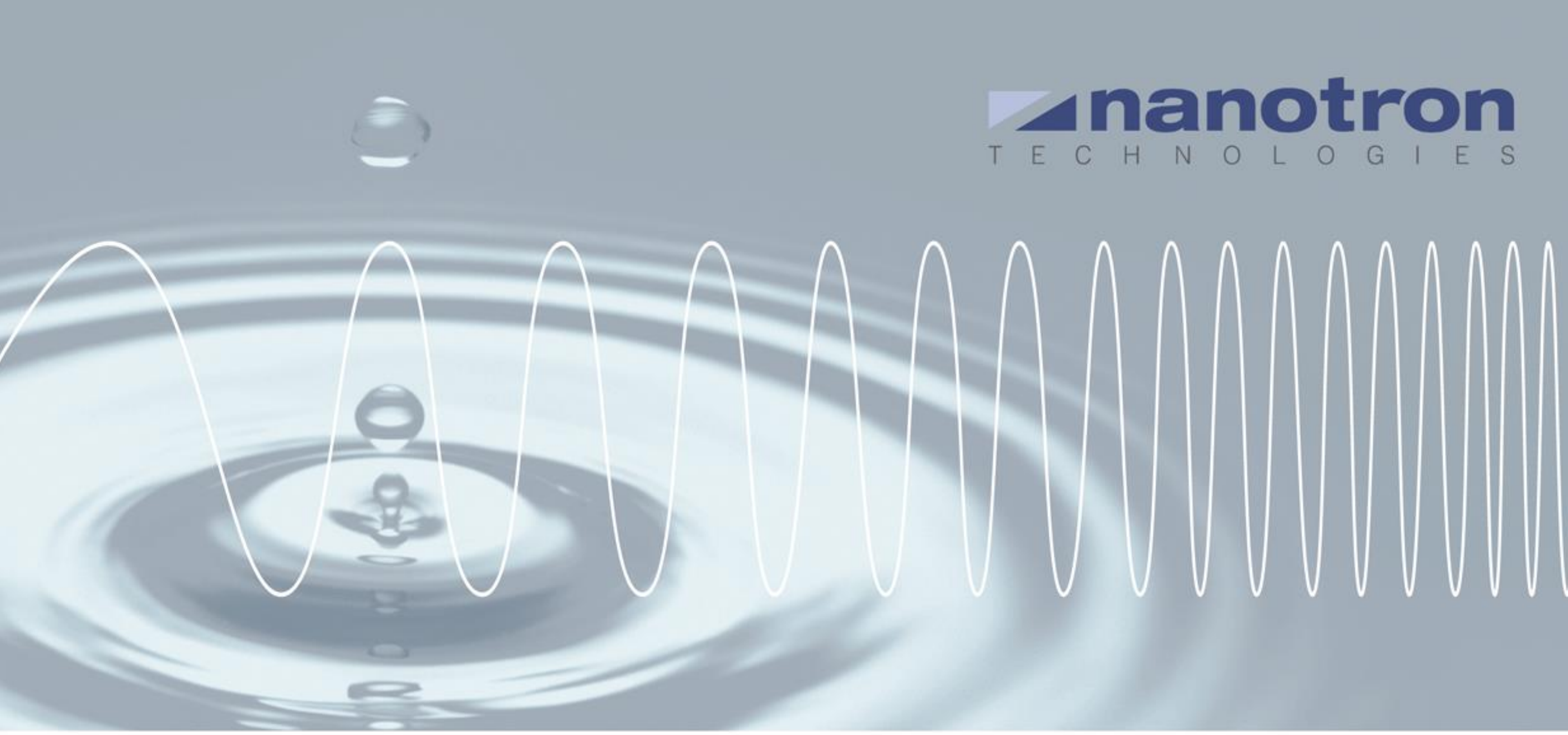

swarm bee LE
Data Sheet

1.3

NA-14-0267-0002-1.3

Contents

Figures

Tables

1. Introduction

The *swarm* bee LE module is a 2.4 GHz autonomous radio node controlled by its comprehensive *swarm* API through a host microcontroller. It is based on nanotron's second generation ranging and communication transceiver chip nanoLOC.

Figure 1-1: *swarm* bee LE module

Using a host microcontroller, an antenna and a battery as the only external components customers are able to create fully functional low power radio nodes in a very short period of time. A comprehensive API command language eliminates the need for lower level firmware. Higher-level functions like *Ranging* or *Messaging* can be executed with a single API command.

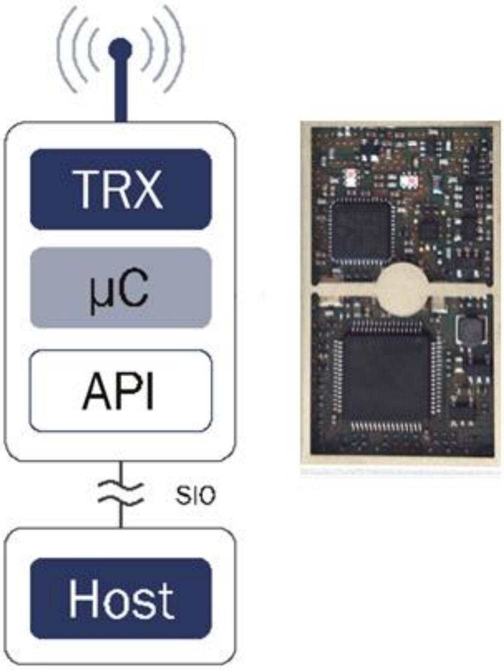

Figure 1-2: Functional diagram of *swarm* bee LE (inside view)

2. Features

Frequency range ………………….…………………….……..….... ISM-Band 2.4 GHz, 2.4000 ~ 2.4835 GHz

Modulation …………………….…………………………………..….……………. Chirp Spread Spectrum (CSS)

Transmission Modes ……………………………………………………………….... 80 MHz, 1 Mbps or 250 Kbps

ToA capture accuracy …...…. < 1 ns (better than 30 cm)

Typical air time per ranging cycle ………………………….……………………………………………………1.8 ms

RF output power ……………………………….……….……………….……………………………. –22 ~ 16 dBm

RF sensitivity ……………………………………………………………………………….….. -89 dBm @80/1 Mode
-95 dBm @80/4 Mode

RF interface ……………………………………………………………………………….………………. 50 Ohm RF Port
(for external antenna)

Host interface (UART) ……………………………………………………………………..…….…. 500 bps ~ 2 Mbps

Supply voltage ………….…………………………….………………………….…………………………. 3.0 ~ 5.5 V

Supply voltage ripple (max.) …………………………………………….……………………………… 20 mVpp

Active power consumption* …..………………………....…………………..…. max. 120 mA during transmission,
60 mA during receive @80/1 Mode

Power consumption in sleep mode* ……………..……...……….………………………………………… 5.5 mA
(transceiver disabled, all peripherals on)

Power consumption in snooze mode* …………………..…….…………………………..………………… 4.5 µA
(transceiver disabled, all peripherals off, wake-up by timer)

Power consumption in nap mode** ………..…………….……………..……………………………… 4.5 ~ 600 µA
(transceiver disabled, UART off, wake-up by interrupt)

Power consumption in deep-sleep mode* ………………………….....…………………………………… ≤ 1 µA
(device completely disabled)

Operating temperature range ……..………………………………………………………..……..... –30 ~ 85 °C

Dimensions ………………...…………………………….……...…...……………….. 40 mm × 24 mm × 3.5 mm

Weight …… 7 g

* Power consumption in all modes is measured at 20 °C, 3.3 V.

** Power consumption in nap mode depends on interrupt sources (GPIO pins or MEMS or both). Refer to [4] for more information.

3. Functional Description

The *swarm* bee LE module consists of a fully integrated ranging and communication transceiver, a power amplifier, a microcontroller and a MEMS and temperature sensor.

3.1. Functional Blocks

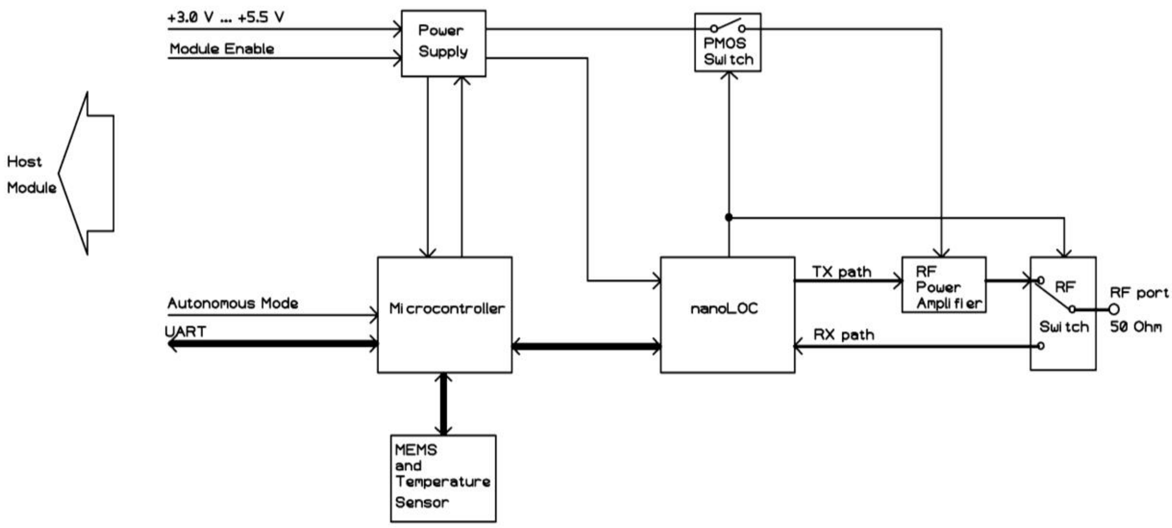

Figure 3-1: Block diagram of *swarm* bee LE

3.1.1. Fully Integrated Ranging and Communication Transceiver

The on-board single chip nanoLOC integrated transceiver offers robust wireless communication and ranging capabilities. It utilizes Chirp Spread Spectrum (CSS), the unique wireless communication technology patented by nanotron [1] for the 2.4 GHz ISM band.

3.1.2. Microcontroller

A low power, high performance microcontroller is chosen to run *swarm* API (from V2.1 onwards). The *swarm* API controls ranging functionality, power supply, power modes, the sensor and the data communication functions.

3.1.3. Power Supply

A single 3.3V supply voltage is required to operate the radio. Supply voltage tolerances allow for direct connection to a 3.6 V LiPo battery or 5V USB. Different power modes are implemented to optimize power consumption.

3.1.4. Sensor

The on-board MEMS sensor is an ultra-small, triaxial, low-g acceleration sensor with digital interfaces for low-power applications. It detects acceleration changes like shock or movement and measures temperature of the module. The MEMS sensor is accessible through the *swarm* API.

3.1.5. Interfaces

There are two physical interfaces on the *swarm* bee LE module: a serial host interface and a 50 Ohm RF port.

3.2. Functions of *swarm* bee LE

3.2.1. Ranging and Communication Engine

The *swarm* bee LE features a low power, yet powerful ranging and communication engine. It automates the necessary sequence of steps for Symmetrical Double-Sided Two Way Ranging (SDS-TWR) patented by nanotron [2]. After time of flight measurements (TOF) including an exchange of informaton with the targeted radio node the measured distance between the nodes is returned to the host application.

The blink that the *swarm* bee LE sends out in broadcast mode is detected and utilized by nanotron's RTLS platform solution to determine the physical location of the module.

Communication between *swarm* bee LE nodes or other *swarm* radios is possible during ranging or independent of ranging.

3.2.2. RSSI Detection

A received signal strength indicator (RSSI) allows to estimate the signal strength of incoming chirp spread spectrum signals from other *swarm* bee LE nodes.

3.2.3. *swarm* API

swarm bee LE runs *swarm* API (application programming interface). Starting from version v2.0 this interface has been streamlined for high throughput and is no longer compatible with previous versions.

3.2.4. Movement and Temperature Detection

Movement and temperature changes can be detected by the on-board MEMS sensor, which is accessible through the host application. When the module is used with the fixed location system developed by nanotron this data is also available to the nanoLES server interface.

3.2.5. Power Management

In order to give users more flexibility for using *swarm* bee LE and to optimize power consumption at the same time, a dedicated power management concept is developed and several power modes are implemented. All power modes are available with *swarm* API from version 3.0 onwards. These modes are: active, sleep, snooze and nap. The user can select from these modes according to application requirements. Please refer to [3] and [4] for more information.

4. Interface Description

The interfaces of *swarm* bee LE consist of a host interface for data communication and a 50 Ohm RF port.

4.1. Host Interface for Data Communication

A UART interface is used for data communication. The data rate is selectable from 500 bps to 2 Mbps. A dedicated control line allows the *swarm* bee LE module to be toggled from its active mode into deep sleep (Pin 6 MOD_EN, see Table 6-1 for detailed explanation). A second control line toggles it between autonomous mode and the externally controlled mode (Pin 4 A_MODE, see Table 6-1 for detailed explanation).

4.2. RF Port

The RF port of *swarm* bee LE is single-ended and has an impedance of 50 Ohm. It is decoupled from DC. This RF port must be connected to an external antenna. Different types of 2.4 GHz antenna can be used.

The RF output power of the *swarm* bee LE can be configured through its API. The command to set TX register values STXP is described in [3]. In Figure 4-1 the output power Pout is shown as a function of TX register value (0…63) according to measurements at room temperature (25 °C).

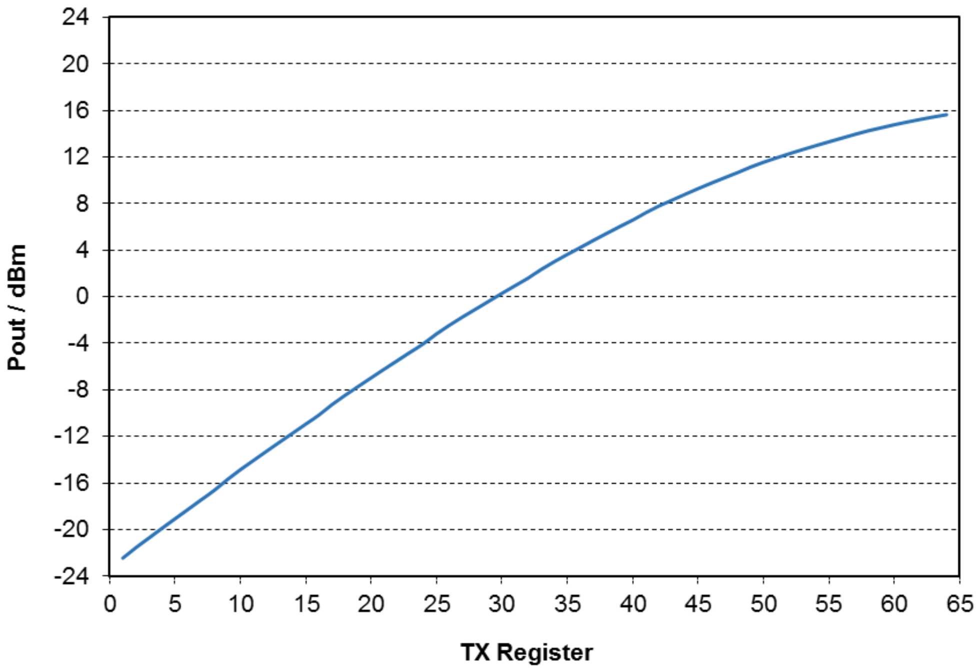

Figure 4-1: RF output power as a function of TX register

5. *swarm* API

A hardware independent Application Programming Interface (API) is used to realize the low level ranging and communication functionality of a *swarm* radio.

Figure 5-1 shows the interaction between *swarm* bee LE and the host interface. A *swarm* node responds after receiving an API command from the host.

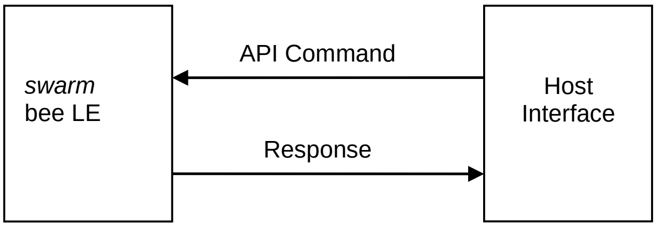

Figure 5-1: *swarm* bee LE is controlled by host interface through *swarm* API

5.1. API Command Overview

From version 2.1 onwards, the enhanced *swarm* API supports three protocols – ASCII, BINARY and AIR - for direct communication between host and *swarm* radios as well as for reconfiguration of remote *swarm* radio nodes over the air.

Using API commands, MEMS sensor data, RSSI value, battery level etc. of *swarm* radios can be accessed. For detailed information about the *swarm* API command language please refer to [3]. The following paragraphs provide an overview of API command groups.

5.1.1. *swarm* radio Setup Commands

SNID (0x00) **S**et the **N**ode **ID** of *swarm* node

GNID (0x00) **G**et **N**ode **ID** of the node connected to host

SSET (0x01) **S**ave **SET**tings; saves all settings including Node ID permanently to EEPROM

RSET (0x02) **R**estore **SET**tings from EEPROM (node configuration)

GSET (n.a.) **G**et current **SET**tings (node configuration)

SFAC (0x03) **S**et node configuration to **FAC**tory default settings

SPSA (0x04) **S**et **P**ower **S**aving **A**ctive; sets power management mode on/off

STXP (0x05) **S**ets transmission (**TX**) **P**ower of the node

SSYC (0x06) **S**et the PHY **SY**n**C**word of *swarm* node

BLDR (0x07) **B**oot**L**oa**D**e**R**, switch to bootloader.

SBIN (n.a.) **S**et/**S**elect **BIN**ARY mode/interface

GFWV (0x08) **G**et the **F**irm**W**are **V**ersion of the swarm Node

GUID (0x09) **G**et **U**nique **ID** of swarm Node

SUAS (0x0a) **S**et **UA**RT **S**peed

EAIR (0x0c) **E**nable **AIR** interface

5.1.2. Ranging Commands

EPRI (0x10) **E**nable **PRI**vacy mode**;** Enables and disables automatic response to received ranging requests.

SPBL (0x11) **S**ets **P**rivacy **B**lack**L**ist; handles the privacy black list used to block ranging operation with specified node IDs; maximum number of entries is 19.

GPBL (0x11) **G**et **P**rivacy **B**lack**L**ist.

RATO (0x12) **RA**nge **TO**; initiates an elementary ranging cycle to another *swarm* node

BRAR (0x13) **B**roadcast **RA**nging **R**esults; enabled (or disabled) the broadcasting of ranging results after each successful ranging operation.

SROB (0x14) **S**elects **R**anging **O**peration **B**links; sets which classes of devices the node will initiate a ranging operation with upon reception of a node blink ID packet.

SRWL (0x15) **S**ets **R**ange **W**hite **L**ist; Handles the list of node IDs the node should range to. Maximum number of entries is 19.

GRWL (0x15) **G**et **R**anging **W**hite **L**ist.

ERRN (0x16) **E**nables (or disables) **R**anging **R**esult **N**otification

SROF (0x17) **S**ets **R**ange **OF**fset (in ms), this is fixed delay before ranging to autonomous devices

5.1.3. Data Communication Commands

EDAN (0x20) **E**nables and disables **DA**ta **N**otification

SDAT (0x21) **S**ends **DAT**a to node ID

GDAT (0x27) **G**ets received **DAT**a

BDAT (0x22) **B**roadcasts **DAT**a

FNIN (0x28) **F**ill data into **N**ode **I**D **N**otification packets.

FRAD (0x2A) **F**ills the **RA**nging data buffer. This data will be transmitted with the next RATO operation.

EIDN (0x26) **E**nables and disables Node **ID** Broadcast **N**otification

5.1.4. *swarm* radio Node Identification

EBID (0x30) **E**nable **B**roadcast **ID.** Enables and disables broadcast of Node ID blink packets

SBIV (0x31) **S**ets the **B**roadcast **I**nterval **V**alue (or blinking rate)

NCFG (0x32) **N**otification **C**on**F**i**G**uration is used to define which information is visible after receiving *RRN or *NIN type of notifications.

5.1.5. Medium Access Commands

SRXW (0x40) **S**ets reception, **RX, W**indow during which the receiver listens after its ID Broadcast.

SRXO (0x41) **S**ets **RX** Window **O**ccurrence; sets whether the receives listens after every blink, after every 2 blink,.. It will listen after every SRXO

SDCL (0x42) **S**ets the **D**evice **CL**ass of the node (1…8).

SFEC (0x43) **S**witches **F**orward **E**rror **C**orrection (FEC) on and off.

SDAM (0x44) **S**ets **DA**ta **M**ode and air communication speed (80/1 and 80/4 mode).

CSMA (0x45) Switches **CSMA** mode on and off and determines back-off factor for CSMA.

5.1.6. MEMS & Temperature Sensor Commands

EMSS (0x50) **E**nables the **M**EMS **S**ensor

EBMS (0x51) **E**nable **B**roadcast **M**EM**S** within Node ID Blink packets.

SMRA (0x52) **S**ets **M**EMS' **RA**nge

SMTH (0x53) **S**ets the **M**EMS' **TH**reshold for the slope interrupt.

SMBW (0x54) **S**ets **M**EMS' filter **B**and**W**idth of the MEMS.

SMSL (0x55) **S**ets **M**EMS' **SL**eep time of the sensor

SMDT (0x56) **S**ets **M**EMS' **D**ead**T**ime. It's the minimum time between two possible interrupts.

GMYA (0x57) **G**ets **MY A**cceleration; acceleration value of the node connected to the host

GMYT (0x58) **G**ets **MY T**emperature; temperature of the node connected to the host

GBAT (0x59) **G**ets **BAT**tery status of the node connected to the host

GPIO (0x5A) Configure **GPIO** pins.

SPIN (0x5B) **S**ets GPIO **PIN**s.

GPIN (0x5B) **G**ets GPIO **PIN** status.

ICFG (0x5C) **I**nterrupt **C**on**F**i**G**uration**.**

SMAI (0x5D) **S**ets **M**EMS' **A**lternative blink **I**nterval.

5.1.7. AIR Commands

SSTART (0x23) **S**treaming **START** until timeout or stop command.

SEXTEND (0x24) **S**treaming **EXTEND** refresh timeout from start command.

SSTOP (0x25) **S**treaming **STOP**.

MRATO (0x18) **M**ultiple **RA**nge **TO**; request allows a remote swarm to perform several ranging requests to the same or different nodes.

6. Pin Information

There are 40 pins on the *swarm* bee LE module. They include connections for power supply, data communication, RF interface etc. Figure 6-1 shows the *swarm* bee LE pin assignment. The function of all the pins is described in Table 6-1.

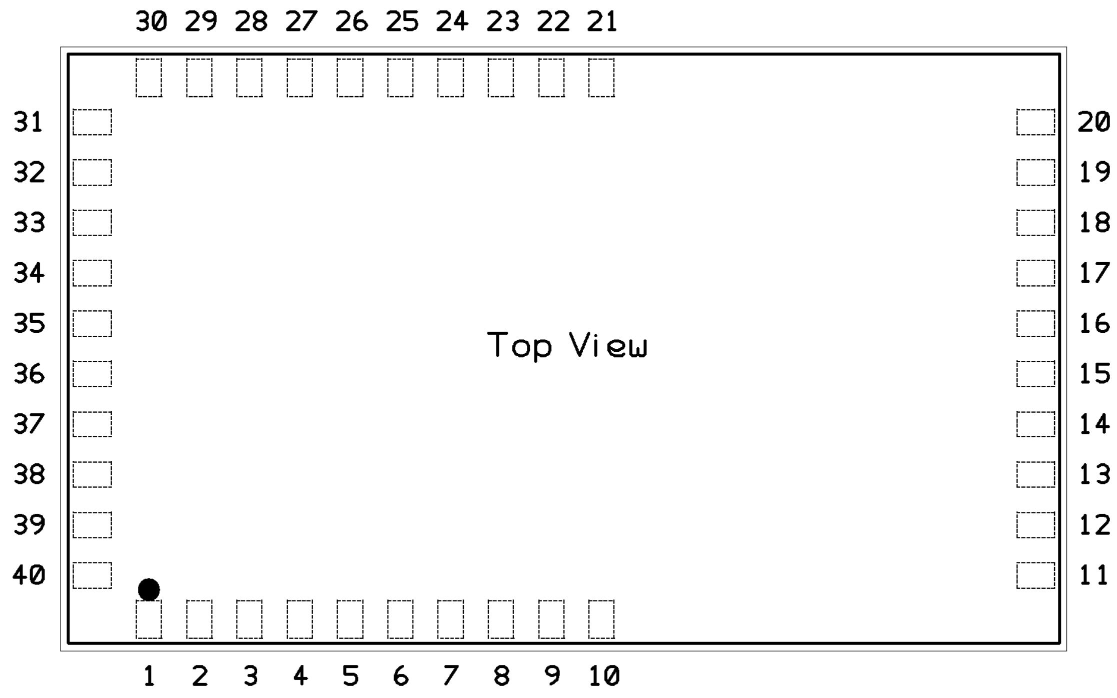

Figure 6-1: *swarm* bee LE Pin Assignment

Table 6-1: *swarm* bee LE Pin Description

Pin No.	Pin Name	Pin type[1)]	Pin Description	Electrical Conditions
1	Reserved			must be left open
2	VIN	Power	Power Supply	+ 3.0 V … + 5.5 V, max. 120mA @3.3V
3	GND	Power	Circuit Ground	
4	A_MODE	I / FT[2)]	Autonomous Mode	- set the *swarm* bee LE into external controlled or autonomous mode - autonomous: high level[3)] (default setting via internal pull-up 45k resistor) - external controlled: external forced low level[3)] - buffered with a 2k7 series resistor
5	/NRST	I	Reset active low	
6	MOD_EN	I	disables *swarm* bee LE module	- module enabled: high voltage between +1.5 V and VIN (default setting via internal 220k resistor) - module disabled: low voltage <0.4 V - buffered with a 1k series resistor
7	Reserved			must be left open
8	+2V6	O	2.6 V for level shifter	Max. 20 mA
9	Reserved			must be left open
10	GND			
11	Reserved			must be left open
12	GND		RF Ground	
13	RF_PORT	RF	RF transmit and receive port	must be connected to a 50 Ohm termination
14	GND		RF Ground	
15	GND			
16	GND			
17	GND			
18	GND			
19	GND			
20	GND			
21	GND			
22	GND			
23	Reserved			must be left open
24	ADC_IN	I	Reads out battery voltage level of the module	must be connected to a voltage divider with two resistors of 2.7 M Ohm (to battery voltage) and 2.2 M Ohm (to GND).
25	DIO_0	I/O/FT[2)]	GPIO	buffered with a 2k7 series resistor
26	DIO_1	I/O/FT[2)]	GPIO	buffered with a 2k7 series resistor
27	DIO_2	I/O	GPIO	buffered with a 2k7 series resistor
28	Reserved			must be left open
29	UART_TX	O	serial interface transmit	buffered with a 2k7 series resistor
30	UART_RX	I / FT[2)]	serial interface receive	buffered with a 2k7 series resistor
31	Reserved			must be left open
32	Reserved			must be left open
33	Reserved			must be left open
34	DIO_3	I/O/FT[2)]	GPIO	buffered with a 1k series resistor
35	TX_ON	O	Transmission indicator (max.50 ms high after TX)	Max. pin current 25 mA, not more than 10 mA recommended
36	DIV_COEX	O/FT[2)]	Can be used by external applications, see [5].	
37	Reserved			must be left open
38	Reserved			must be left open
39	Reserved			must be left open
40	Reserved			must be left open

[1] Pin type: Power – Power Supply; I – Input; O – Output; RF – RF port
[2] FT : 5 V tolerant, max. input voltage 5.5V
[3] all logic levels except for 5V tolerant inputs refer to 2.6 V VDD of the internal microcontroller: V_{OH} min 2.15 V; V_{OL} max 0.45 V; V_{IL} max 0.7 V

7. Mechanical Dimensions & Landing Pattern

7.1. Mechanical Dimensions

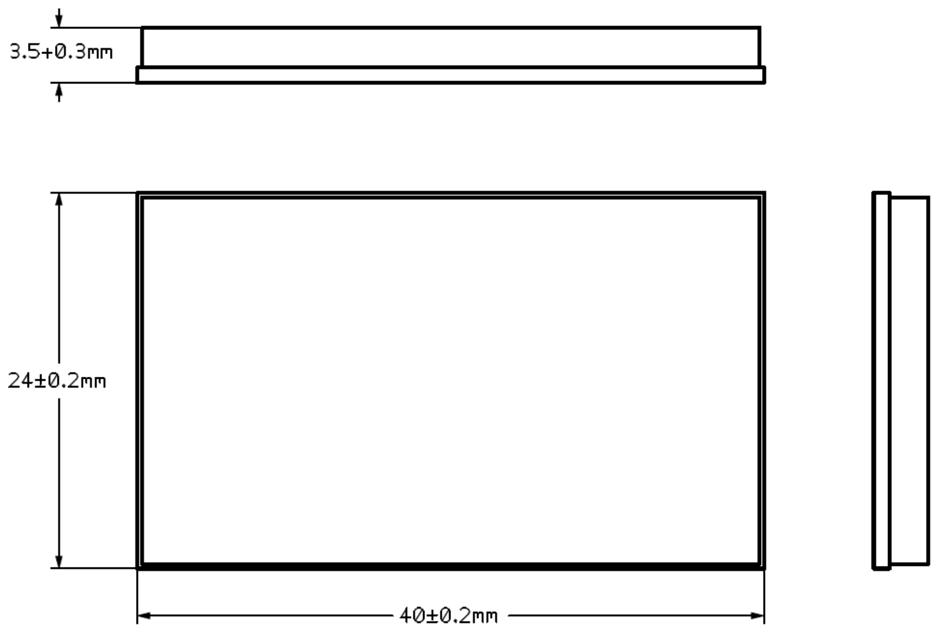

Figure 7-1: Dimension of *swarm* bee LE module, top view and side view

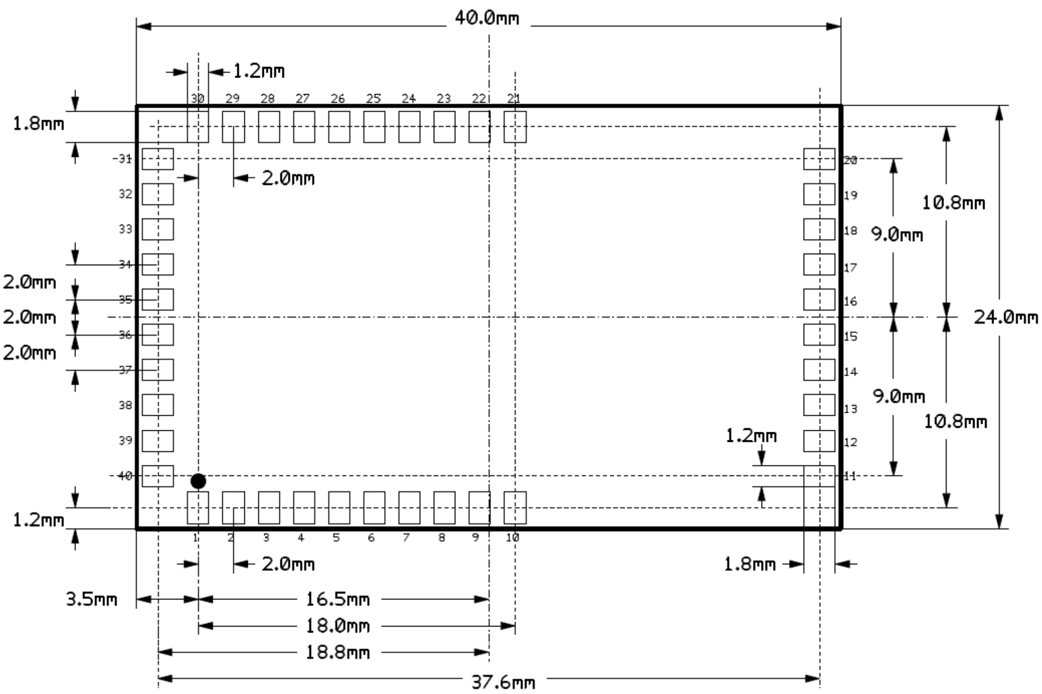

Figure 7-2: Pad dimensions of *swarm* bee LE module

7.2. Recommended Landing Pattern

The same dimensions for the solder paste screen are recommended, depending on the solder screen thickness.

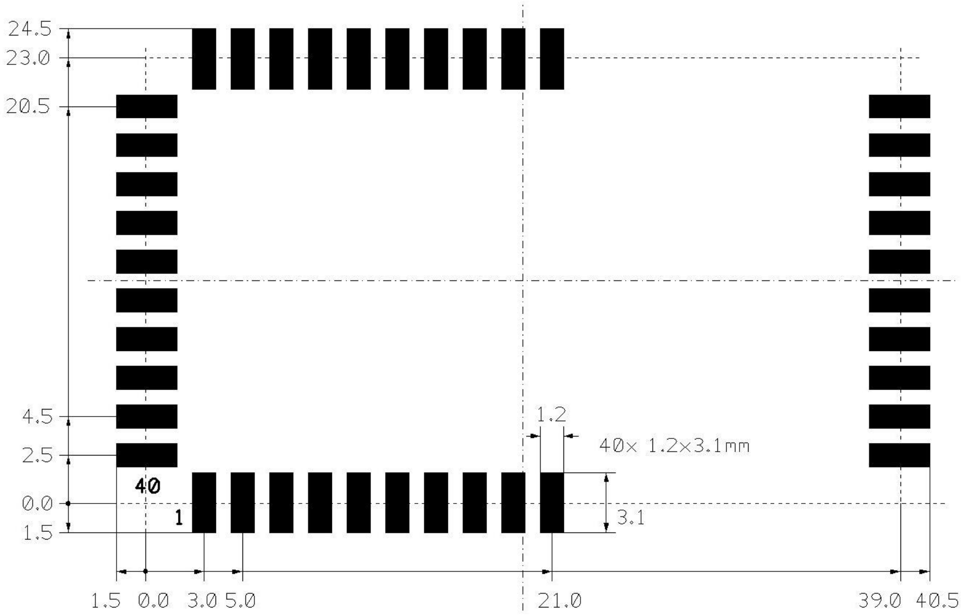

Figure 7-1 *swarm* bee LE module – footprint and landing pattern (top view)

8. Soldering *swarm* bee LE on a Carrier Board

The following information on reflow soldering (module on carrier board) is based on recommendations from our manufacturing partner.

8.1. Allowed Soldering Process

The *swarm* bee LE module is designed for ONE-TIME reflow soldering on a carrier board or ONE-TIME wave soldering (passive soldering process where soldering is realized by contacting the solder wave on the BOTTOM side). More-than-one-time soldering may cause intergranular changes to layer composition of the pads, which may lead to changes of the bonding stability in the long run. In this case, impacts on the function of the module cannot be excluded.

8.2. Soldering Paste

Our manufacturing partner has good experience in reflow soldering (module on carrier board) and recommends the soldering paste „ ALPHA CVP520 LOW TEMPERATURE SOLDER PASTE".

8.3. Max. Soldering Temperature

The max. soldering temperature of 200 °C for reflow soldering must not be exceeded, so that the solder points on the module do not melt again. Melting (when temperature is higher than 200 °C) may cause damages to the soldered connections. If melting happens, it is recommended to carry out optical and electrical tests after the reflow process.

8.4. Laminate Conditions - Bow and Twist

The *swarm* bee LE module is manufactured according to the standard „IPC-A-610D Norm Class 2". In chapter 10.2.7 "Laminate Conditions – Bow and Twist" it is stated: "Bow/twist after solder should not exceed 1.5% for through-hole and 0.75% for surface mount printed board applications", see Figure 8-1. Take *swarm* bee LE for example, whose length is 40 mm, so bow/twist up to 0.3 mm (0.75% referred to the length) is acceptable. Please consider that the carrier board is also subject to bow and twist.

8.5. Avoiding Bow and Twist

It is recommended to take the following two measures to avoid bow and twist:

1) Temper both components (*swarm* bee LE module and carrier board) before reflow in order to minimize humidity and stress.
2) Increase the paste thickness in module pads using a solder paste stencil with partial thickness to achieve better co-planarity.

10 Printed Circuit Boards and Assemblies

10.2.7 Laminate Conditions – Bow and Twist

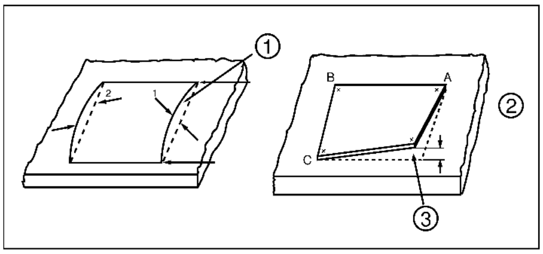

Figure 10-29
1. **Bow**
2. **Points A, B and C are touching base**
3. **Twist**

Acceptable - Class 1,2,3

- Bow and twist does not cause damage during post solder assembly operations or end use. Consider ''Form, Fit and Function'' and product reliability.

Defect - Class 1,2,3

- Bow and twists causes damage during post solder assembly operations or end use.

Note: Bow and twist after solder should not exceed 1.5% for through-hole and 0.75% for surface mount printed board applications (See IPC-TM-650, 2.4.22).

Figure 8-1: Excerpt of IPC-A-610 "Laminate Conditions – Bow and Twist"

9. References

[1] CSS Patent, Patent No. US6404338 B1, Jun 11th, 2002
[2] SDS-TWR Patent, Patent No. US7843379 B2, Nov.30th, 2010
[3] *swarm* API User Guide V3.0, NA-13-0267-0003-3.0, Apr. 15th, 2016
[4] AN0513 – swarm bee Power Modes, NA-15-0356-0037, Feb. 3rd, 2016
[5] AN0514 – How to Avoid Diversity and Coexistence Problems, NA-16-0356-0038, Feb. 5th, 2016

Document History

Date	Authors	Version	Description
2014-02-27	JDI	1.0	Initial version.
2015-01-13	JDI	1.1	Key features updated. GPIO pins added.
2015-04-10	JDI	1.2	RF output power added. Description of Pin 24 corrected. Function of Pin 35 added. More API command groups added according to *swarm* API V2.1.
2016-05-15	JDI	1.3	Chapter 2 Features updated (UART speed, power consumption etc.). Chapter 3.2.5 Power Management updated. Chapter 4.1 Host Interface for Data Communication amended. Chapter 5.1 API Command Overview updated according to *swarm* API V3.0. Table 6-1: *swarm* bee LE Pin Description updated (new function added to pin 5, 8 and 36). Chapter 7.3 replaced with 8 providing more detailed information on reflow soldering.

Life Support Policy

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Nanotron Technologies GmbH customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify nanotron Technologies GmbH for any damages resulting from such improper use or sale.

About nanotron Technologies GmbH

Today nanotron's ***embedded location platform*** delivers location-awareness for safety and productivity solutions across industrial and consumer markets. The platform consists of chips, modules and software that enable precise real-time positioning and concurrent wireless communication. The ubiquitous proliferation of such platforms is creating the location-aware Internet of Things.

Further Information

For more information about products from nanotron Technologies GmbH, contact a sales representative at the following address:

nanotron Technologies GmbH
Alt-Moabit 60
10555 Berlin, Germany
Phone: +49 30 399 954 – 0
Fax: +49 30 399 954 – 188
Email: sales@nanotron.com
Internet: www.nanotron.com