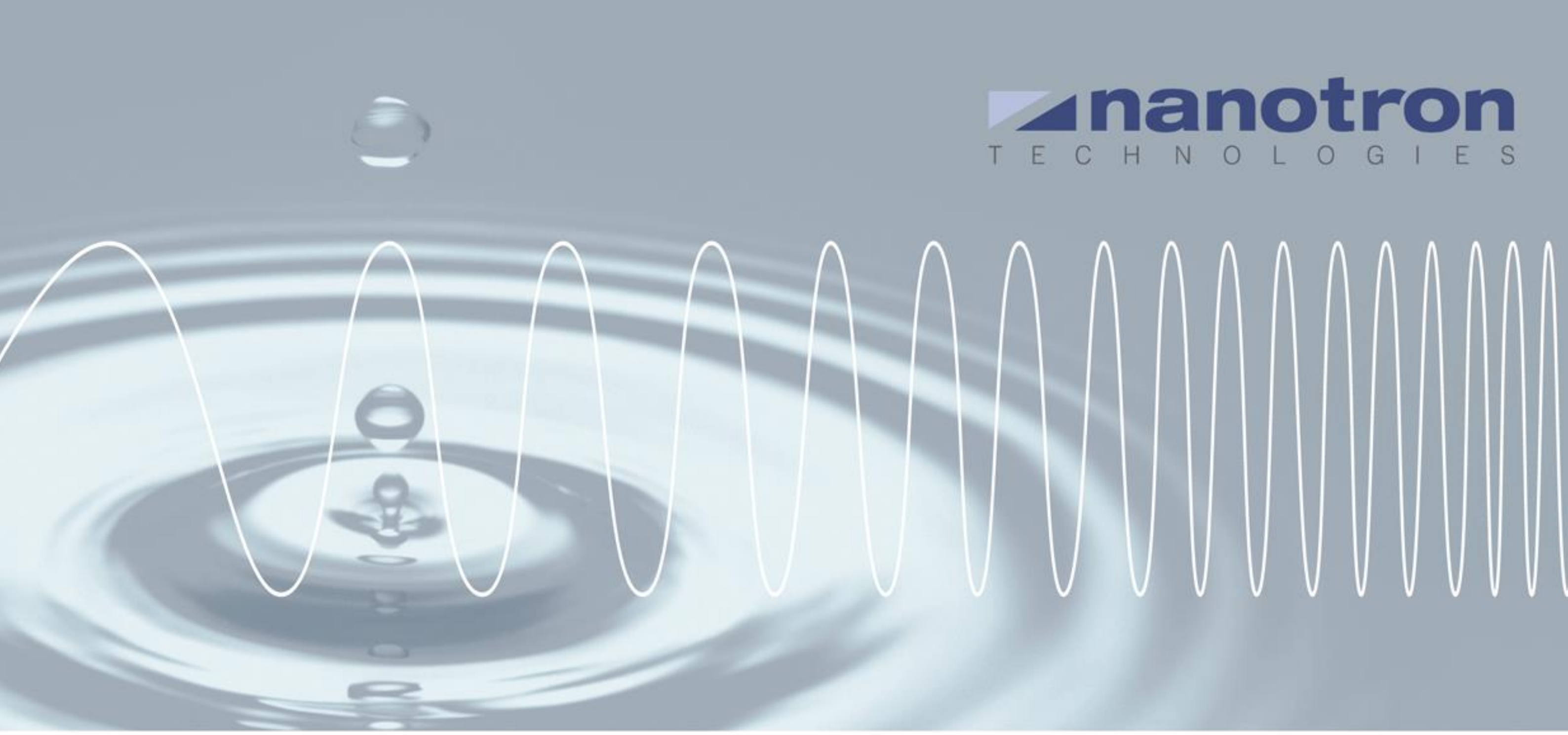

swarm bee LE V2 Data Sheet

1.7

NA-16-0364-0042

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Contents

1. Introduction

The *swarm bee LE V2* is an improved version of the swarm bee LE V2 module. It is a 2.4 GHz autonomous radio node controlled by its comprehensive *swarm* API V3.xx through a host microcontroller or via the air interface. It is based on nanotron's ranging and communication transceiver chip nanoLOC.

Figure 1-1: *swarm bee LE V2* module

With 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 set eliminates the need for lower level firmware. Higher-level functions like *Ranging* or *Messaging* can be executed with a single API command.

Note: All differences between swarm bee LE V1 and V2 are summarized in section 11.

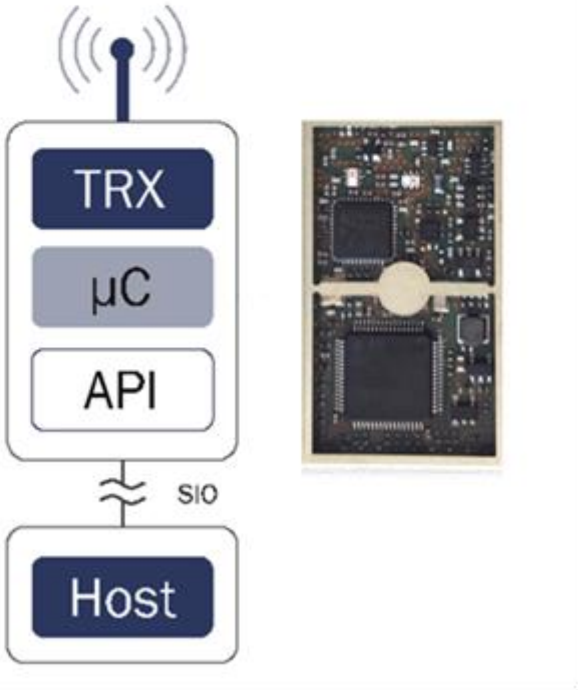

Figure 1-2: Functional diagram of *swarm bee LE V2* (inside view)

 Subject to changes without notice

2. Features

Frequency range .... ISM-band 2.4 GHz (2.4~2.4835)
Modulation .... Chirp Spread Spectrum (CSS)
Transmission Modes .... 80 MHz, 1 Mbps or 250 Kbps
ToA resolution .... < 1 ns (better than 30 cm)
Typical air time per ranging cycle .... 2 ms
RF output power .... configurable -22 to +16 dBm ± 2 dBm
RF sensitivity @ 80/1 mode .... -89 dBm typ.
RF sensitivity @ 80/4 mode .... -95 dBm typ.
RF interface .... 50 Ohm RF Port
Host interface (UART) .... 115 kbps ~ 2 Mbps
Supply voltage .... 3.3 V ~ 5.5 V
Maximum supply voltage ripple .... 20 mVpp
Active current consumption .... during transmission max. 120 mA
during reception 60 mA(at 20 °C, 3.3 V, in 80/1 mode)
Current consumption in standby mode .... 6.5 mA
(CPU stopped, all peripherals on)
Current consumption in snooze mode .... max. 6 µA
(Autonomous mode enabled, all peripherals off)
Current consumption in nap mode .... max. 20 µA*
(CPU stopped, GPIO off, UART off, MEMS alert)
Current consumption in nap mode .... max. 500 µA
(CPU stopped, GPIO alert, UART off, MEMS off)
Current consumption in deep-sleep mode .... ≤ 1 µA
(module completely disabled)
Operating temperature range .... -30°C to +85°C
Dimensions .... 40 mm x 24 mm x 3.5 mm
Weight .... 7 g

* mode dependent

3. Functional Description

The *swarm bee LE V2* module consists of a fully integrated ranging and communication transceiver, a power amplifier, a microcontroller and a triaxial acceleration sensor (MEMS) with temperature sensor.

3.1. Functional Blocks

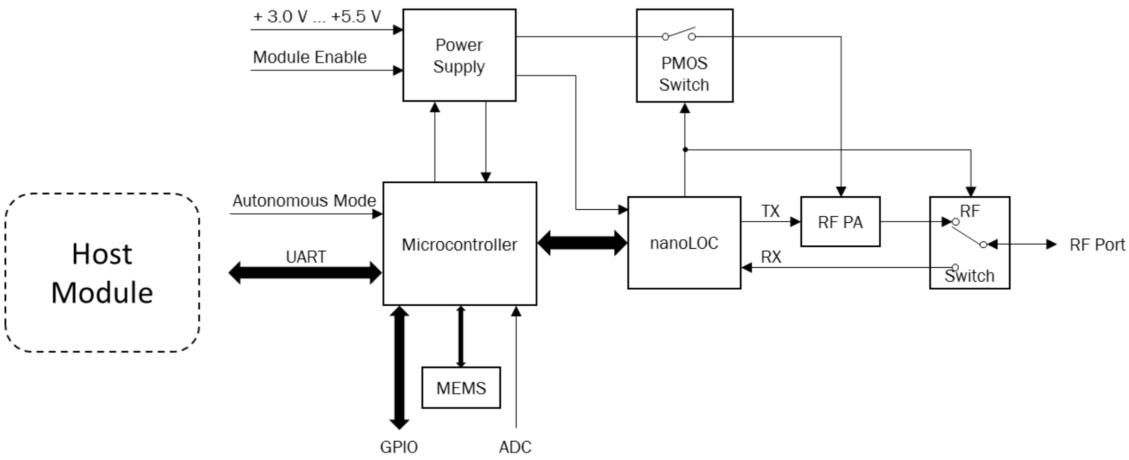

Figure 3-1: Block diagram of the *swarm bee LE V2*

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 [2] for the 2.4 GHz ISM band.

3.1.2. Microcontroller

A low power, high performance microcontroller has been chosen to run the V3.xx API of the *swarm bee LE V2* module. Through the *swarm* API, it controls ranging functionality, power supply, 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. The module has two power saving modes.

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 can detect acceleration changes like shock or movement, and is able to measure the temperature. The MEMS sensor is accessible through the *swarm* API.

3.1.5. Interfaces

There are several physical interfaces on the *swarm bee LE V2* module: a serial host interface, four GPIOs, an ADC and a 50 Ohm RF port.

3.2. Functions of *swarm bee LE V2*

3.2.1. Ranging and Communication Engine

The *swarm bee LE V2* 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 information with the targeted radio node the actual distance between the nodes is returned to the host application.

The blink that the *swarm bee LE V2* 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 V2* 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 V2* nodes.

3.2.3. *swarm* API

swarm bee LE V2 runs v3.xx *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 of the *swarm* API.

3.2.4. Movement and Temperature Detection

Movement and temperature changes can be detected by the on-board MEMS sensor, which is accessible by the host application. When the module is used with fixed location system this data is also available to the nanoLES server interface. The MEMS can further be used to save additional power by waking-up the module when detecting movements. Further the blink rate can be adjusted depending on whether the module is in movement or not.

3.2.5. Power Management

The *swarm bee LE V2* enables power saving functionality to go to sleep and only wake-up periodically for a short time in order to save battery power. As explained in section 3.2.4 the MEMS can also be used to save additional power. The underlying power management concept enables cooperation between the radios of a larger *swarm* even if they sleep most of the time.

4. Interface Description

The interfaces of *swarm bee LE V2* consist of data communication host interface and the 50 Ohm RF port.

4.1. Host Data Communication Interface

A UART interface is used for data communication. It works with a data rate from 115 kbps to 2 Mbps configurable via API. The UART settings are one start bit, 8 data bits, no parity bit and one stop bit (8, N ,1). The default bit rate is 115200 bit/s.

4.2. Host Control interface

A dedicated control line MOD_EN allows the *swarm bee LE V2* module to be toggled from its active mode into deep sleep. A second control line A_MODE toggles it between autonomous mode without host controller and the externally controlled mode.

4.3. RF Port

The RF port of *swarm bee LE V2* 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 V2* 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). The tolerance is ± 2 dBm.

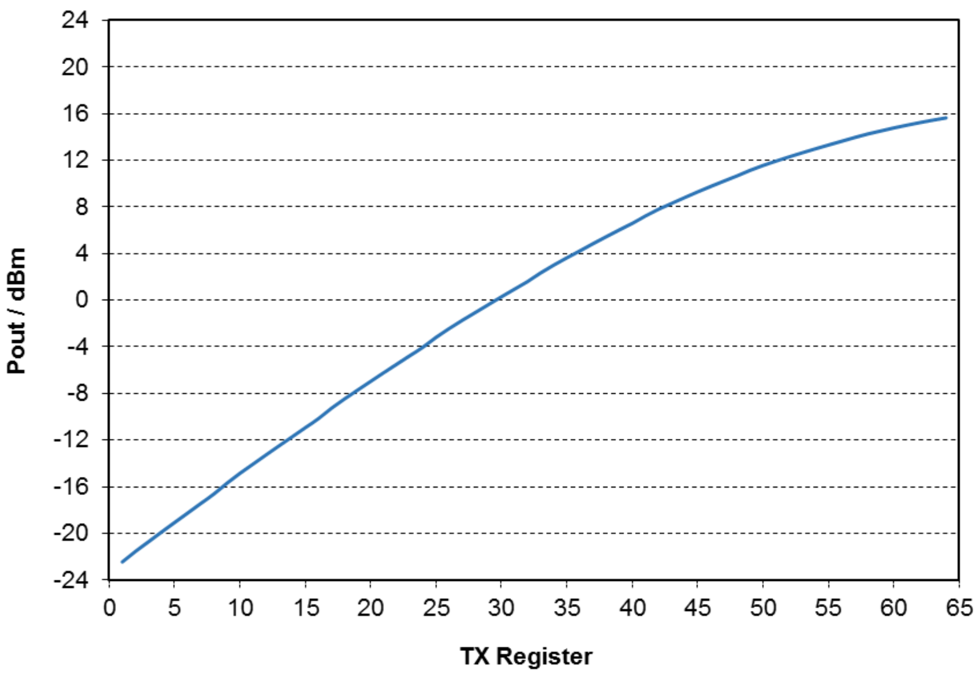

Figure 4-1: Pout as a function of TX register

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 V2* and the host interface. A *swarm* node responds after receiving an API command from the host.

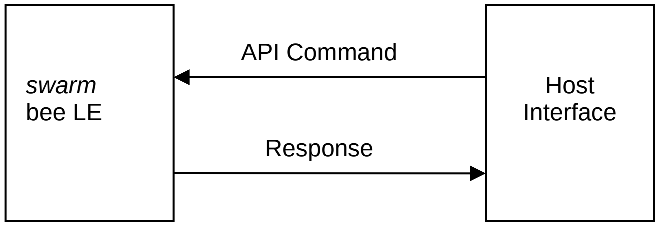

Figure 5-1: *swarm bee LE V2* is controlled through the host interface by the *swarm* API

5.1. API Command Overview

From version 2.1 onwards, the enhanced firmware *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 set please refer to [3]. The following paragraphs provide an overview of API command types.

5.1.1. *swarm* radio Setup Commands

Setup commands are used to assign the Node ID, define power saving options to be used, re-establish the factory settings etc., for example:

API Command	Function
SNID (0x00)	Sets the Node ID of a *swarm* node
For a full list of all the API commands	Refer to [3]

Note: each *swarm bee LE V2* module gets a unique node ID which is set during the module production and which can be modified.

5.1.2. Ranging Commands

Ranging commands are used to initiate ranging between *swarm* radio nodes, select which nodes to range to, enable ranging result notification etc., for example:

API Command	Function
RATO (0x12)	Initiates an elementary ranging cycle to another *swarm* node
For a full list of all the API commands	Refer to [3]

5.1.3. Data Communication Commands

This group of commands is used to activate and observe data transmission between *swarm* nodes, for example:

API Command	Function
GDAT (0x27)	Reads out transmitted data
For a full list of all the API commands	Refer to [3]

5.1.4. *swarm* radio Node Identification

The commands regarding Node Identification provide the possibility to tell if one or more *swarm* nodes are present by Node ID broadcast, for example:

API Command	Function
EBID (0x30)	Enables and disables broadcast of Node ID blink packets
For a full list of all the API commands	Refer to [3]

5.1.5. Medium Access Commands

These commands are used to control data communication mode, for example:

API Command	Function
SFEC (0x43)	Sets FEC (forward error correction) on and off
For a full list of all the API commands	Refer to [3]

5.1.6. MEMS & Temperature Sensor Commands

This category of commands enables the on-board MEMS sensor to detect acceleration and temperature changes and to transmit the values, for example:

API Command	Function
EMSS (0x50)	enables the MEMS sensor
For a full list of all the API commands	Refer to [3]

5.1.7. AIR Commands

The air commands are used to control communication of swarm nodes over the air, for example:

API Command	Function
SSTART (0x23)	Starts streaming mode until timeout or stop command
For a full list of all the API commands	Refer to [3]

6. Pin Information

There are 40 pins on the *swarm bee LE V2* module. They include connections for power supply, data communication, RF interface etc. Figure 6-1 shows the *swarm bee LE V2* pin assignment. The function of all the pins is described in Table 6-1.

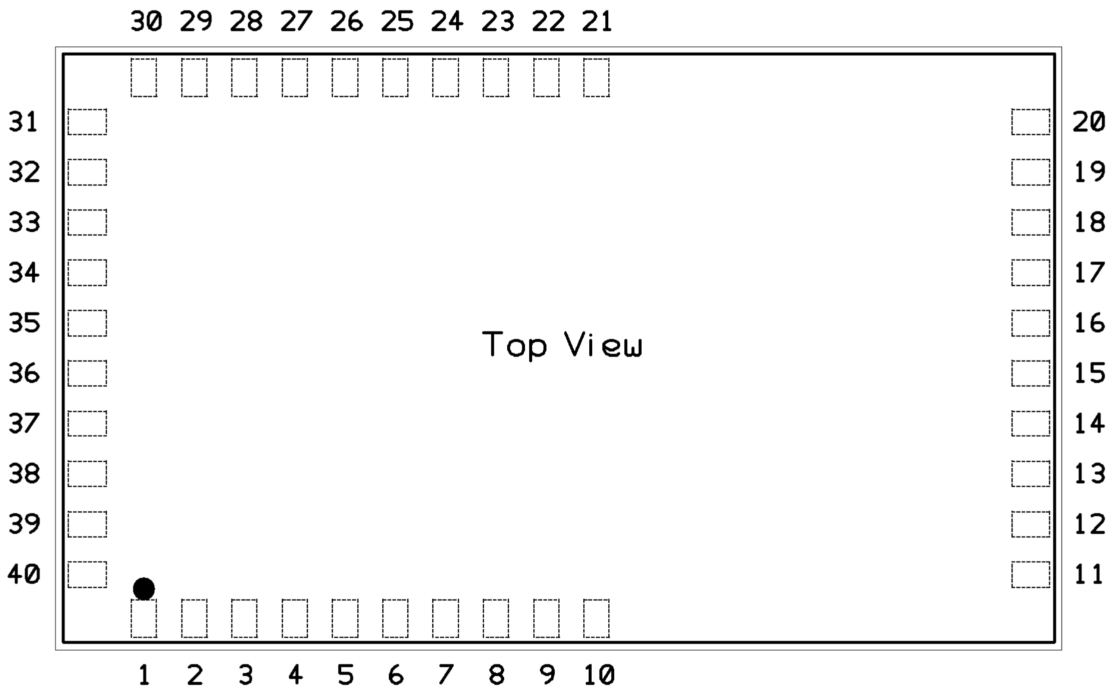

Figure 6-1: ***swarm bee LE V2*** **Pin Assignment**

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

Pin No.	Pin Name	Pin type*)	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	Autonomous Mode	- set the *swarm* bee LE into external controlled or autonomous mode - autonomous: high level (default setting via internal pull-up 45k resistor) - external controlled: external forced low level - buffered with a 1K series resistor
5	/NRST	I	Reset active low	optional
6	MOD_EN	I	disables *swarm* bee LE module	- module enabled: high voltage between +1.5 V and VIN (default setting via internal 5.6 M Ohm 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	/TX_RX	O	TX/RX indicator from nanoLOC	TX low, otherwise high. Buffered with a 1k series resistor. See also pin 35.
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 the voltage relative to 2.6 V VDD	With an external voltage divider the voltage can be read out. See [3] GBAT, SADC and GADC
25	DIO_0	I/O/FT	GPIO	buffered with a 1k series resistor
26	DIO_1	I/O/FT	GPIO	buffered with a 1k series resistor
27	DIO_2	I/O	GPIO	buffered with a 1k series resistor
28	Reserved			must be left open
29	UART_TX	O	serial interface transmit	buffered with a 1k series resistor
30	UART_RX	I / FT	serial interface receive	buffered with a 1k 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	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 buffered with a 120R series resistor. Recommended to be used with LED
36	DIV_COEX	O/FT	Can be used by external applications, see [4]	
37	Reserved			must be left open
38	Reserved			must be left open
39	Reserved			must be left open
40	Reserved			must be left open

*) **Note:**
Pin type: Power -> Power Supply
I -> Input
O -> Output
RF -> RF-Port
FT -> 5 V tolerant, max. input voltage 5.5 V

All logic levels except for 5 V 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
V_{IH} max 2.9 V (except 5 V tolerant inputs)

7. Mechanical Dimensions & Landing Pattern

7.1. Mechanical Dimensions

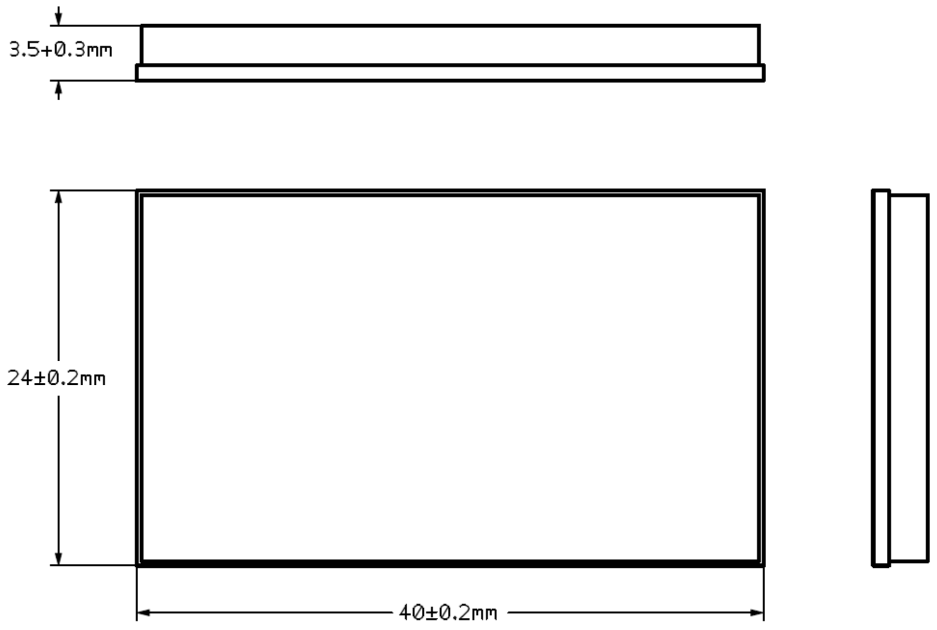

Figure 7-1: Dimension of *swarm bee LE V2* module, top view and side view

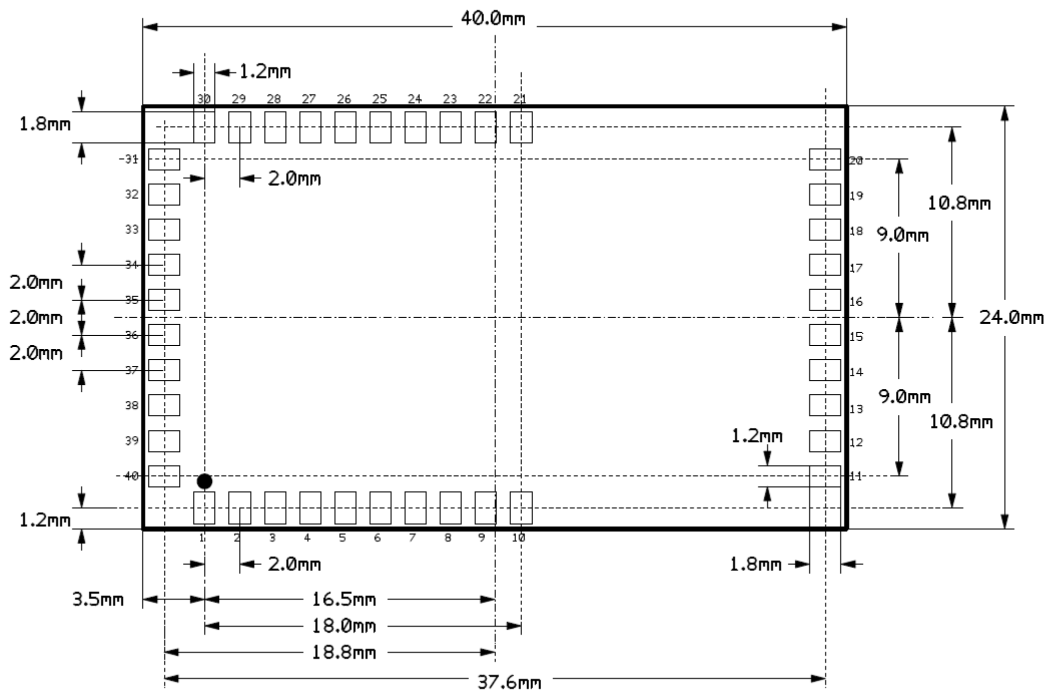

Figure 7-2: Pad dimensions of *swarm bee LE V2* module

7.2. Recommended Landing Pattern

The same dimensions for the solder paste screen are recommended, depending on the solder screen thickness. To avoid short-circuits with vias and test point of the module the shaded area as shown in Figure 7-3 must be kept copper free.

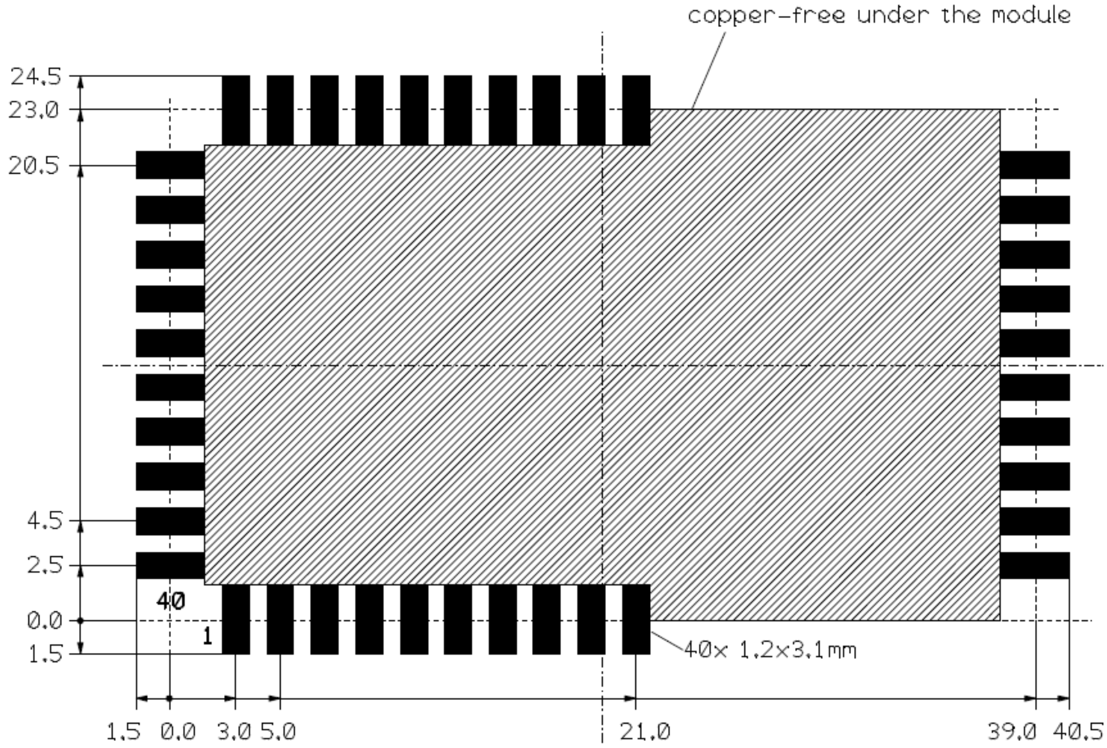

Figure 7-3: *swarm bee LE V2* module – footprint and landing pattern (top view)

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

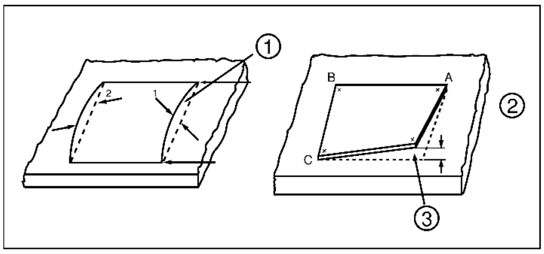

Figure 10-29
1. Bow
2. Points A, B and C are touching base
3. Twist

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. Firmware Updates

Nanotron swarm bee modules are always delivered with the latest firmware. We strongly recommend that customers check the firmware version of the delivered modules as part of the production process. If a previous version of the swarm firmware was used to develop the swarm bee application, it may be necessary to downgrade the firmware image inside the swarm bee modules in order to avoid incompatibilities.
In order to avoid such issues we recommend that the same firmware image for a given application is automatically flashed onto the swarm bee module as part of the production process. An update of the firmware is possible through the host interface, see [5] for more information. Nanotron Technologies GmbH can neither be made responsible nor will accept any claims in case of incompatible firmware versions.

10. Disclaimer

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11. Changes between swarm bee LE V1 and V2

Following main modifications have been done:

- Pins: 4, 25, 26, 27, 29, 30 serial resistor changed from 2k7 to 1K
- Pin 8: Can be used in conjunction with a level shifter
- DIO_0: Can be used in nap mode to wake-up swarm bee module to allow ultra-low power.

13. References

[1] CSS Patent, Patent No. US6404338 B1, Jun 11, 2002
[2] SDS-TWR Patent, Patent No. US7843379 B2, Nov.30, 2010
[3] Nanotron *swarm* API 3.0, NA-13-0267-0003-3.0, Mar, 2016
[4] AN0514 - How to Avoid Diversity and Coexistence Problems
[5] *swarm* bee LE Firmware Update User Guide Doc No: NA-14-0267-0011-1.0, Jul. 2014

Document History

Date	Author	Version	Description
2016-03-18	MBO	1.0 Preliminary	Initial Version
2017-01-06	MBO	1.1 Preliminary	Copper free zone of Figure 7-3 updated
2017-02-28	MBO	1.2 Preliminary	Separate sections for data and control interface 4.1 and 4.2. Added UART settings
2017-06-16	MBO	1.3 Preliminary	Rectified pull-up resistor value of pin 6 in Table 6-1 Several editorial changes from review
2018-07-06	MBO	1.4	Supply Voltage range has been changed to align with swarm bee ER. Ref. PCN 180005
2018-11-16	MBO	1.5	Added TX tolerance of ± 2 dBm in section 2 and 4.3
2019-09-13	MBO	1.7	Added Ordering Information in header

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Further Information

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