swarm bee LE V3 Data Sheet

1.0

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Contents

1. Introduction

The *swarm* bee LE V3 is a 2.4 GHz Chirp Spread Spectrum module, suitable for a variety of IoT implementations. The small 22 x 23 mm form factor, low power consumption and long-range transceiver, enable wearable and covert product designs.

Embedded accelerometer and temperature sensor, along with a low external component requirement, make the *swarm* bee LE V3 an ideal choice for personnel, equipment and asset tracking products, where in- or outdoor location sensing is critical. Accessible GPIO pins allow connection to external sensors, and the ability to receive actionable information from deployed devices in the field. Relative position is derived via the *swarm* bee's module to module direct ranging feature, without the need for additional infrastructure. *swarm* bee LE V3 based tags, when deployed with nanoANQ anchors and IoT Platform, provide the most comprehensive Real Time Location System (RTLS) on the market today.

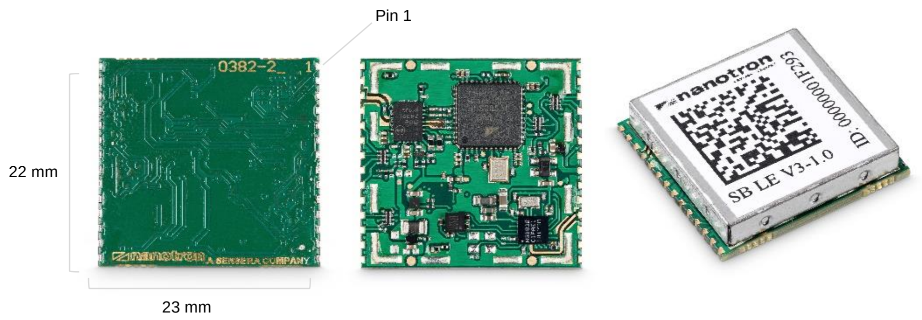


Figure 1-1: *swarm* bee LE V3 module

A complete API command set [3] eliminates the need to implement a dedicated firmware to control the module. The module can be managed via serial interface, or over the air. Higher level functions like ranging or messaging can be executed by a single API command.

Note: All differences between *swarm* bee LE V2 and V3 are summarized in section 10.

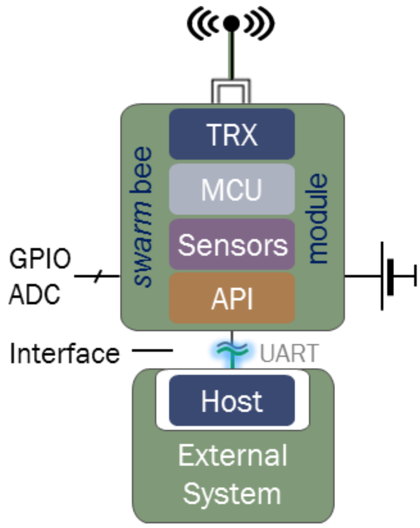


Figure 1-2: Functional diagram of *swarm* bee LE V3

2. Features

Frequency range .... ISM-band 2.4 GHz (2.4 to 2.4835)
Modulation .... Chirp Spread Spectrum (CSS)
Transmission Modes .... 80 MHz, 1 Mbps or 250 Kbps
Typical airtime per ranging cycle .... 1.8 ms
Ranging accuracy indoor .... 2 m*
Ranging accuracy outdoor .... 1 m*
RF output power .... configurable -12 to +20 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 to 1 Mbps
Tri-axial Accelerometer .... ± 2g/ ± 4g/ ± 8g/ ± 16 g
Accelerometer Sensitivity .... 0.001 to 0.192 g**
Accelerometer measurement frequency .... 1 to 5300 Hz**
Temperature measurement accuracy (module) .... ±0.5 °C
Supply voltage .... 3.3 V to 5.5 V
Maximum supply voltage ripple .... 20 mVpp
Instantaneous current consumption .... during transmission max. 230 mA
(at 20 °C, 3.3 V, in 80/1 mode +20 dBm)
Instantaneous current consumption .... during reception max. 55 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. 3 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 .... max. 3 µA
(module completely disabled)
Operating temperature range .... -30°C to +85°C
Dimensions .... 22 mm x 23 mm x 4.4 mm
Weight .... 4 grams

* 90%, 1-hour static, 10m distance, RSSI -65 dBm, 80/1 mode, no FEC
** mode dependent

3. Functional Description

The *swarm* bee LE V3 is a 2.4 GHz autonomous radio transceiver controlled by its comprehensive *swarm* API V3.0 through a host microcontroller or via the air interface. It is based on nanotron's ranging and communication transceiver chip nanoLOC, a RF frontend, a microcontroller and a triaxial acceleration sensor (MEMS) with temperature sensor. Further it can be connected to an external host controller to extend the functionality of the application.

3.1. Functional Blocks

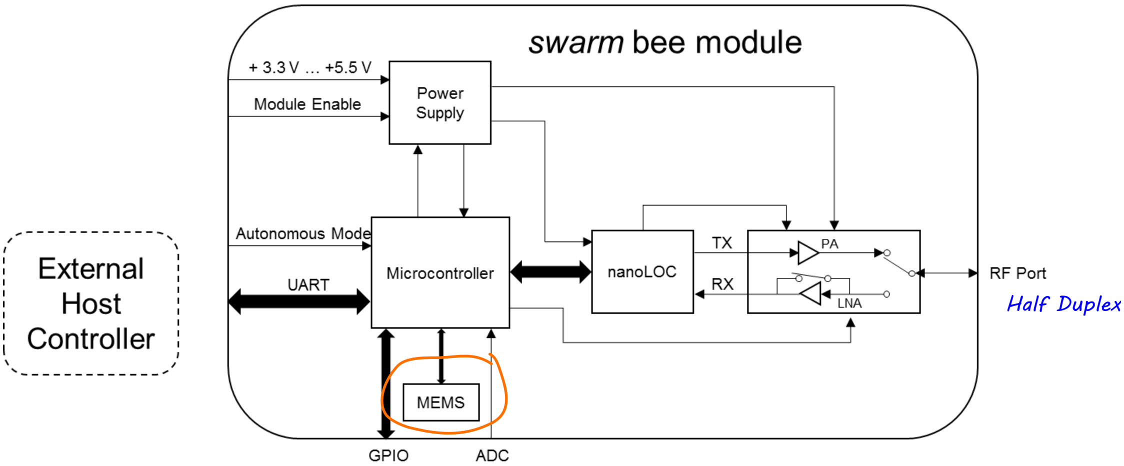


Figure 3-1: Block diagram of the *swarm* bee LE V3

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. Embedded Microcontroller

A low power, high performance microcontroller has been chosen to run the API and to control the *swarm* bee LE V3 module. Through the *swarm* API, it controls ranging functionality, power supply, the sensors 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, nap and snooze. Details can be found in [5].

3.1.4. Acceleration and Temperature 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. The temperature can be measured from -30 °C to +70 °C in steps of 1 °C. The MEMS measures accelerations of ± 4 g in steps of 0.012 g.

3.1.5. Interfaces

There are several physical interfaces on the *swarm* bee LE V3 module:

- Serial host interface
- Four GPIOs
- ADC
- 50 Ohm RF port

More details can be found in section 4.

3.2. Functions of *swarm* bee LE V3

3.2.1. Ranging, Blinking and Communication

The *swarm* bee LE V3 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 V3 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 V3 nodes or other *swarm* bee LE V2 or V1 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 V3 runs *swarm* API V3.0 (application programming interface) [3]. Starting from version API 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. Moreover, the threshold between steady and motion can be set over the air configuration process.

3.2.5. Power Management

The *swarm* bee LE V3 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.

3.2.6. Firmware Update

The *swarm* bee LE V3 allows firmware updates not only via the serial interface, but also over the air. All updating procedures are explained in AN0507 *swarm* bee LE Firmware Update [4].

4. Interface Description

The interfaces of *swarm* bee LE V3 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 1 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.

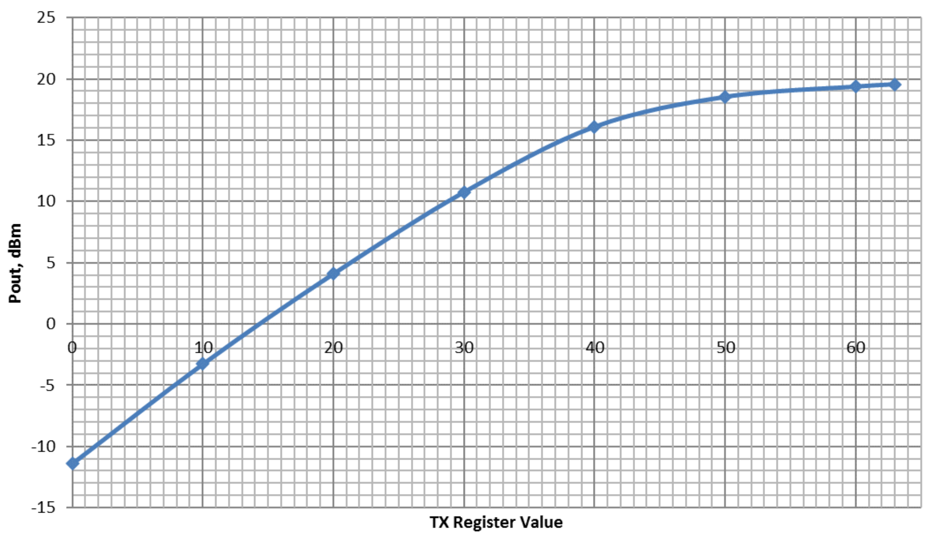
4.2. Host Control Interface

A dedicated control line MOD_EN allows the *swarm* bee LE V3 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 V3 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 V3 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.



From 0 to 63
XTXP 00
XTSP 63

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

4.4. GPIO

The module has four GPIOs (General Purpose Input Output). Each is fully programmable via the API as output or input. Latter can be configured with a pull-up, pull-down or none and optionally used as interrupt or wake-up source. See Figure 4-2. The output driving capability push-pull or open-drain can be set as well. See Figure 4-3. The electrical characteristics are explained in section 6. How to configure is explained in detail in the *swarm* API 3.0 User Guide [3] and the application note AN0513 [5].

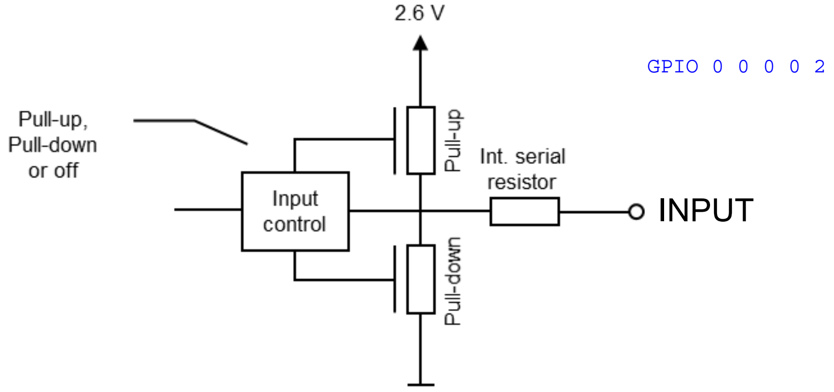


Figure 4-2: Equivalent circuit for input

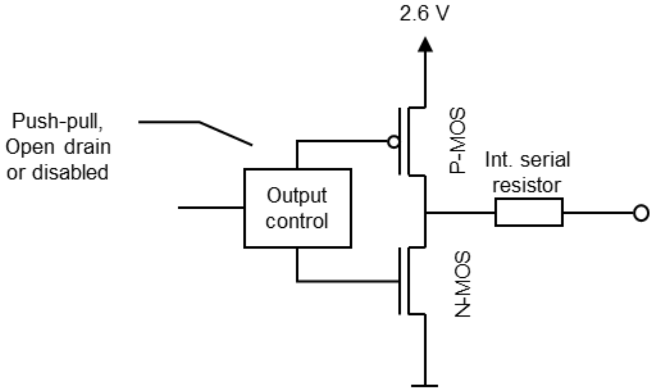


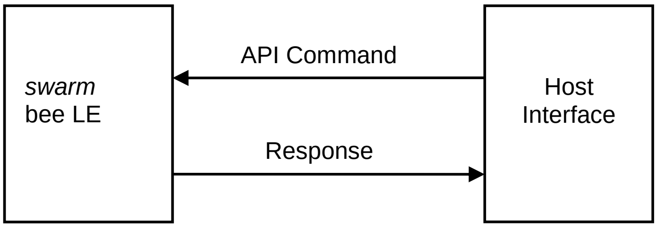
Figure 4-3: Equivalent circuit for output

5. *swarm* API

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

Figure 5-1 shows the interaction between *swarm* bee LE V3 and the host interface. A *swarm* node responds to the host after receiving an API command.

All details of the API can be found in the API V 3.0 User Guide [3].



TO enable host communication
Pull Pin9 (A_MODE) Low

Figure 5-1: *swarm* bee LE V3 is controlled through the host interface by the *swarm* API

6. Pin Information

There are 28 pins on the *swarm* bee LE V3 module. They include connections for power supply, data communication, RF interface etc. Figure 6-1 shows the *swarm* bee LE V3 pin assignment. The function of all the pins is described in Table 6-1.

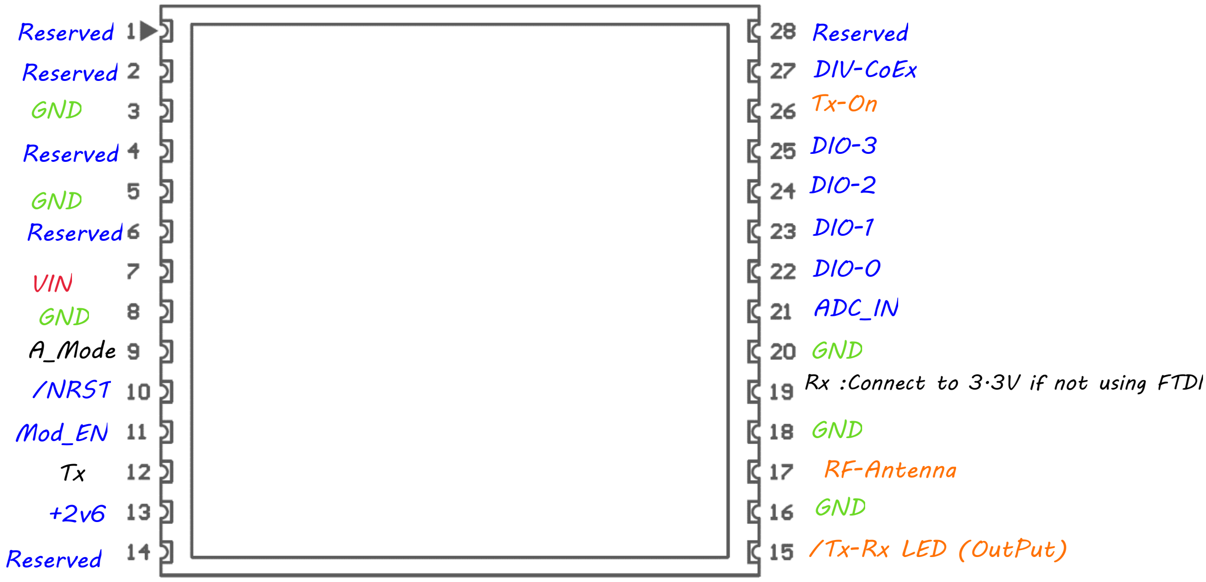


Figure 6-1: *swarm* bee LE V3 Pin Assignment (top view with shielding cap)

Connect Pin 19 to TX of Arduino or FTDI

Table 6-1: *swarm* bee LE V3 Pin Description

Pin No.	Pin Name	Pin Type	Pin Description	Electrical Conditions
1	Reserved			Must be left open
2	Reserved			Must be left open
3	GND	Power	Circuit Ground	
4	Reserved			Must be left open
5	GND	Power	Circuit Ground	
6	Reserved			Must be left open
7	VIN	Power	Power Supply	+3.3V…+5.5V
8	GND	Power	Circuit Ground	
9	A_MODE	I	Autonomous Mode	- set the *swarm* bee LE V3 into external controlled or autonomous mode; - autonomous: high level (default setting via internal pull-up 13K resistor); - external controlled: external forced low level; - internally buffered with a 1K series resistor
10	/NRST	I	Reset active low	optional, internal pull-up 10k Ohm
11	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 resistor pull-up); - module disabled: low voltage <0.4 V; - internally buffered with a 1K series resistor
12	UART1_TX	O	Serial interface transmit	internally buffered with a 1K series resistor
13	+2V6	O	2.6 V for level shifter	max. 20 mA
14	Reserved			
15	/TX_RX	O	TX/RX indicator from nanoLOC	- TX low, otherwise high; - internally buffered with a 1K series resistor.
16	GND	Power	Circuit RF Ground	
17	RF_PORT	RF	RF transmit and receive port	must be connected to a 50 R termination
18	GND	Power	Circuit RF Ground	
19	UART1_RX	I	Serial interface receive	internally buffered with a 1K series resistor
20	GND	Power	Circuit Ground	
21	ADC_IN	I	Reads out the voltage relative to 2.6 V VDD	with an external voltage divider the voltage can be read out
22	DIO_0	I/O	GPIO	internally buffered with a 1K series resistor
23	DIO_1	I/O	GPIO	internally buffered with a 1K series resistor
24	DIO_2	I/O	GPIO	internally buffered with a 1K series resistor
25	DIO_3	I/O	GPIO	internally buffered with a 1K series resistor
26	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 120 R series resistor; - recommended to be used with LED
27	DIV_COEX	O	Can be used by external applications	Refer to [6]
28	Reserved			Must be left open

*) **Note:**

Pin type

Power ->	Power Supply
I ->	Input
O ->	Output
RF ->	RF-Port

Absolute Maximum Ratings

Vin	5.5 V
All Inputs	2.9 V (except MOD_EN max. 5.5 V)
All GPIOs	2.9 V (DIO_0 to DIO_3)
RF input signal	-20 dBm (consider the use of (bandpass) filters when coexisting with certain mobile networks like LTE band 7 or band 41, or RF devices with an radiated output power greater than 100 mW)

All logic levels refer to 2.6 V VDD of the internal microcontroller

V_{OH}	min. 2.2 V
V_{OH}	max. 2.6 V
V_{OL}	max. 0.4 V
V_{IL}	max. 0.8 V
V_{IL}	min. GND
V_{IH}	min. 1.9 V
V_{IH}	max. 2.9 V

The driving or sink current in output mode is limited by the internal serial resistor ca. 2 mA
Internal pull-up or pull-down resistor in input mode typical 13 K

7. Mechanical Dimensions & Landing Pattern

7.1. Mechanical Dimensions

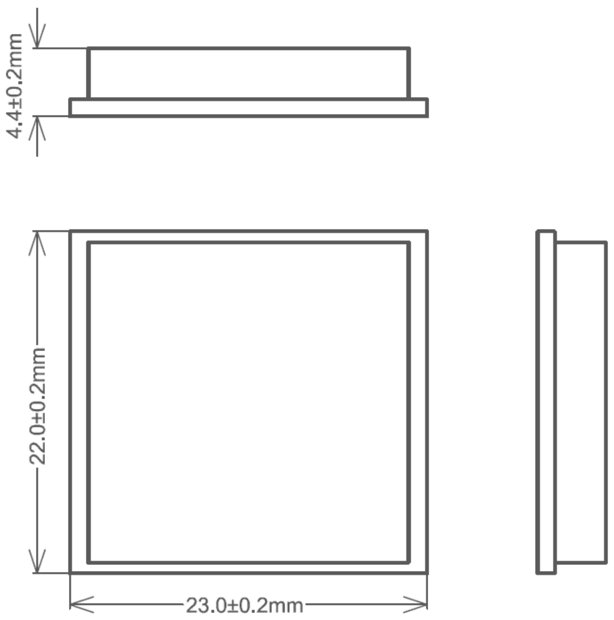


Figure 7-1: Dimension of *swarm* bee LE V3 module, top view and side view

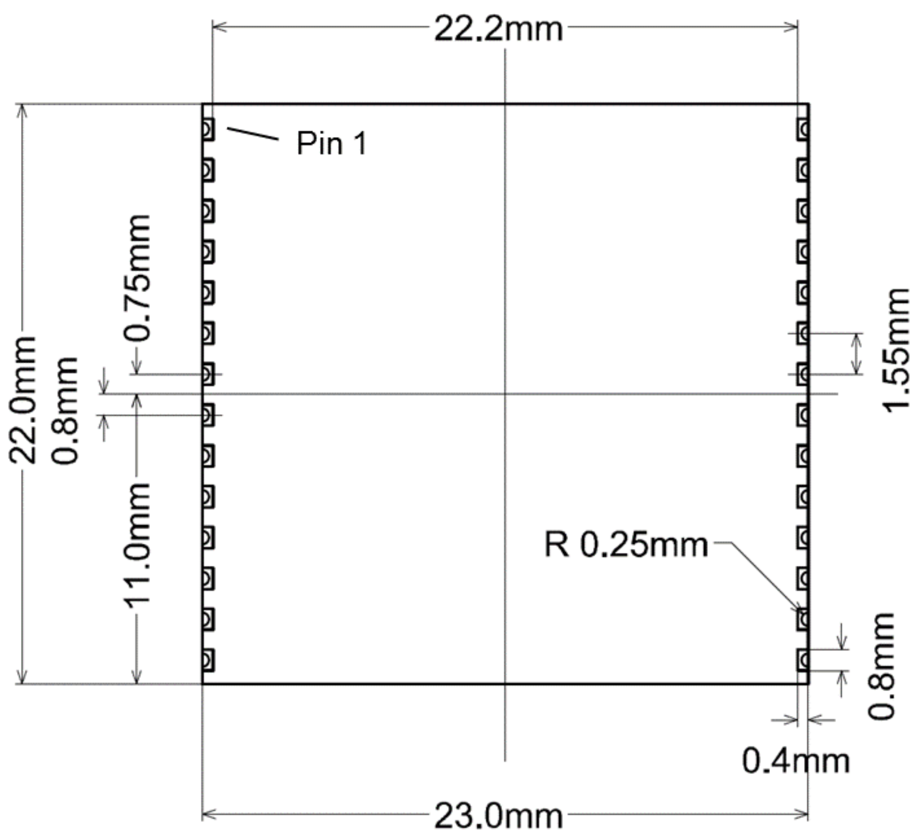


Figure 7-2: Pad dimensions of *swarm* bee LE V3 module

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 green area as shown in Figure 7-3 must be kept copper free.

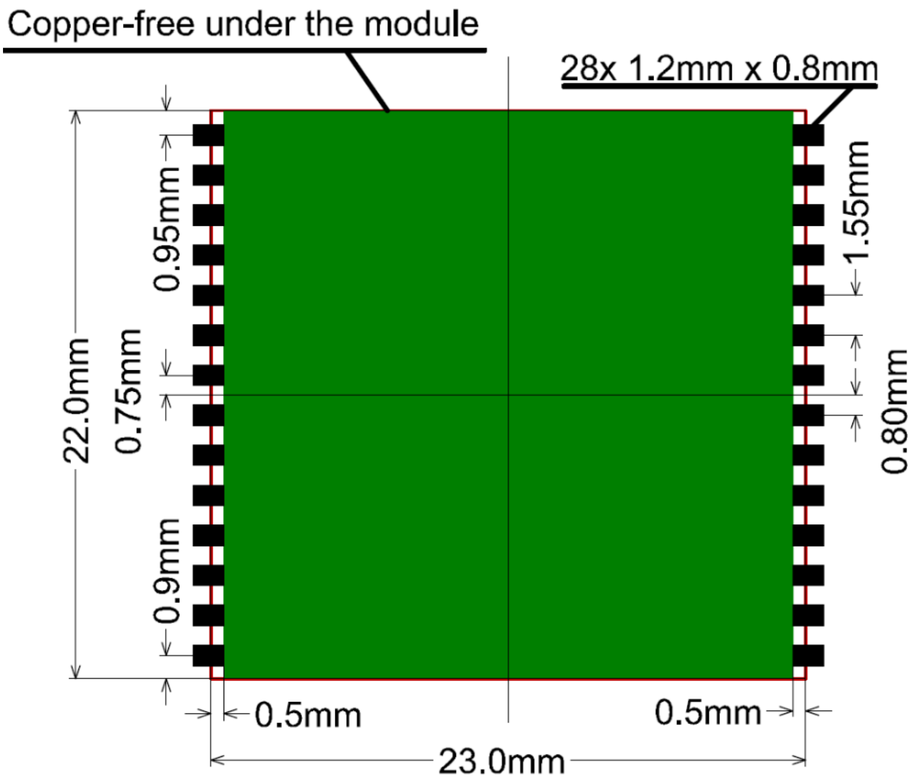


Figure 7-3: *swarm* bee LE V3 module – footprint and landing pattern (top view)

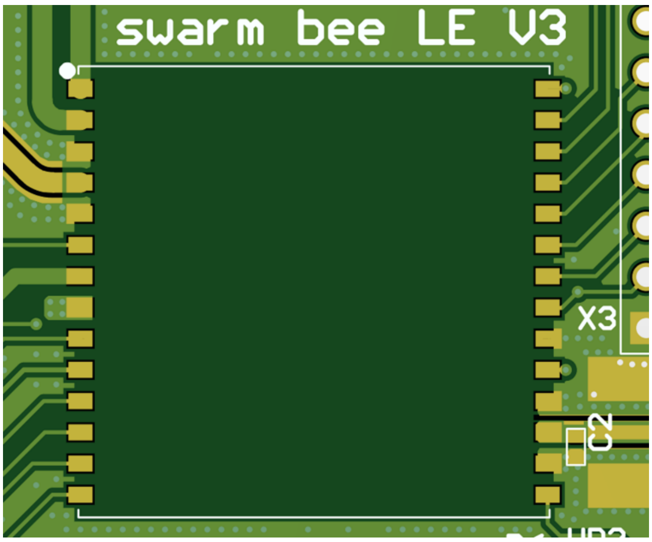


Figure 7-4: *swarm* bee LE V3 module recommended wire shielding using ground vias

8. Handling

8.1. Packaging

The *swarm* bee LE V3 modules are packaged in trays containing 50 modules each. See Figure 8-1. A box holds ten trays which is the minimum order quantity.

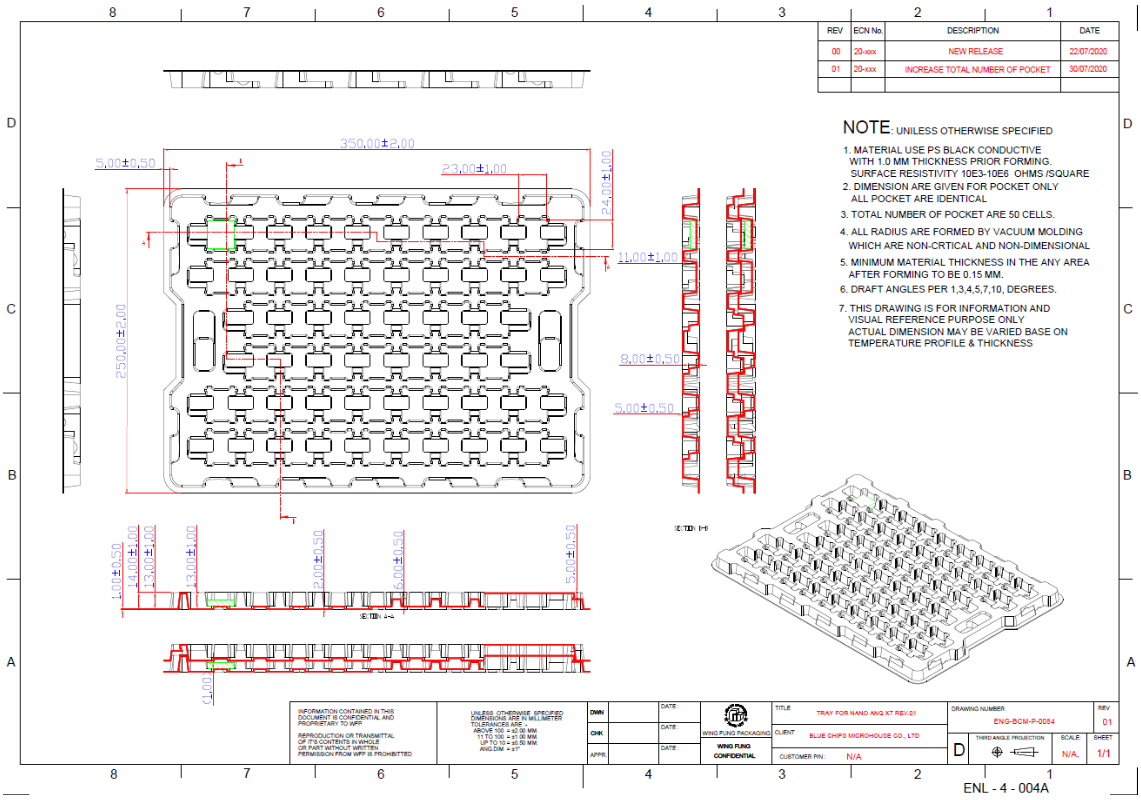


Figure 8-1: Drawing of the tray

8.2. 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.

8.2.1. 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.

8.2.2. 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”. Another LMP (Low Melting Point) solder paste with similar characteristics may also be used, if the maximum temperature mentioned below is not exceeded.

8.2.3. 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.

The max. soldering temperature of 200°C for reflow soldering must not be exceeded, if reflow temperature is exceeded this will invalidate the warranty.

8.2.4. Recommended Soldering Profile

The graph below shows the recommended temperature profile for LMP soldering

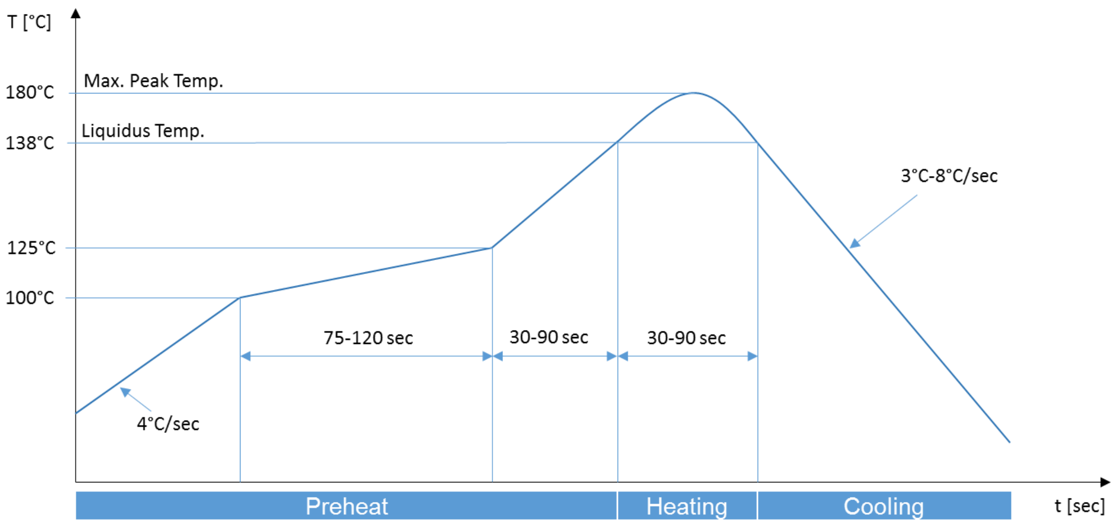


Figure 8-2: LMP soldering profile

8.2.5. 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 8-3. Take *swarm* bee LE for example, whose length is 23 mm, so bow/twist up to 0.17 mm (0.75% referred to the length) is acceptable. Please consider that the carrier board is also subject to bow and twist.

8.2.6. 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

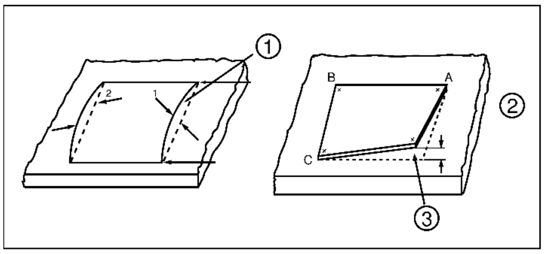


Figure 10-29
1. Bow
2. Points A, B and C are touching base
3. Twist

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 8-3: *Excerpt of IPC-A-610 "Laminate Conditions – Bow and Twist"*

8.3. Handling precautions

Standard ESD procedures according to IEC 61340 should be followed.

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 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 or over the air (FOTA), see [4] for more information. nanotron Technologies GmbH can neither be made responsible nor will accept any claims in case of incompatible firmware versions.

10. Changes between *swarm* bee LE V2 and V3

Following main modifications have been done:

- Form-factor
- Castellated pins
- Not pin to pin compatible. Simple PCB layout change.
  See *swarm* bee V2 to V3 PCB Layout Migration [7]
- Not 5 Volt Fault Tolerant FT. Max. 2.9 V on any input except MOD_EN max. 5.5 V. Refer to Note in section 6
- Increased Tx power. Ca. 20 dBm instead of ca. 16 dBm
- Addition FOTA: Firmware update Over The Air

11. Disclaimer

The products of nanotron Technologies GmbH are subject to changes and improvements. Therefore, this document may be changed or updated without further notice. nanotron Technologies GmbH can neither be made responsible nor liable for those products which are subject to changes.

12. Certification

Certification is under progress.
The *swarm* bee LE V3 is RED and FCC certified. It is only allowed to operate it within those regulations.

13. Terms And Conditions, Warranty

All related topics to the nanotron Technologies GmbH terms and conditions as well as to warranties can be seen and downloaded under the link specified in [8].

14. 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
[4] AN0507 *swarm* bee Firmware Update Doc. No. NA-14-0267-0017 V 2.0 or above
[5] AN0513 -*swarm* bee LE V1 Power Modes Doc. No. NA-15-0356-0037
[6] AN0514 How to Avoid Diversity and Coexistence Problems Doc. No. NA-16-0356-0038
[7] *swarm* bee V2 to V3 PCB Layout Migration Doc. No. NA-19-0382-0026
[8] https://nanotron.com/EN/or_termsconditions-php/

Document History

Date	Author	Version	Description
2020-10-28	MBOR	1.0	First Release

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