Manual AMB2621

Release 2.4

SW-V3.0.0

S132 V3.1.0 + SDK12.1.0

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Abbreviations and abstract

CS	Checksum	Byte wise XOR combination of the preceding fields
BLE	Bluetooth Low Energy	According to Bluetooth 4.2 specification
DTM	Direct test mode	Mode to test Bluetooth specific RF settings
LPM	Low power mode	Mode for efficient power consumption
RF	Radio frequency	Describes wireless transmission
MAC		MAC Address of the module
BTMAC		Bluetooth conform MAC Address of the module used on the RF-interface
Payload		The intended message in a frame/package
RSSI	Receive Signal Strength Indicator	The RSSI indicates the strength of the RF signal. Its value is always printed in two's complement notation.
	Soft device	Operating system used by the nRF52 chip
User settings		Settings to configure the module. Any relation to a specific entry in the user settings is marked in a special font and can be found in chapter 9.
UART	Universal Asynchronous Receiver Transmitter	Allows the serial communication with the module.
Hexadecimal	[HEX] 0xhh	All numbers beginning with 0x are hexadecimal numbers. All other numbers are decimal, unless stated otherwise.
I/O	Input/output	Pinout description

1 Summary

The AMB2621 exists in two variants, the AMB2621 with integrated PCB-antenna, and the AMB2621-1 with 50 Ohm connection to an external antenna. For the general functionality there is no difference between the variants. Beside chapter 18 and if not stated otherwise AMB2521 means both variants.

The AMB2621 module is a radio sub module/device for wireless communication between devices such as control systems, remote controls, sensors etc. On the basis of Bluetooth 4.2 (Bluetooth Low Energy, BLE) it offers a fast and secure data transmission of small data packages (up to 128 bytes) between two or more parties (point to point topology). A serial interface (UART) is available for communication with the host system.

The AMB2621 uses the BLE standard to provide general data transmission between several devices. The standard itself offers a wide range of configurations and possibilities to suit and optimize sophisticated customer applications. To fulfil the needs and specifications of such applications a tailored firmware can be developed on the basis of the AMB2621 hardware. This includes the connection and communication to custom sensors, custom BLE profiles, timing configurations as well as power consumption optimizations.

1.1 Key features

The AMB2621 offers the following key features that are described in the manual in more detail:

- SPP-like connection-based secured data transmission.

  The AMB2621 firmware implements an SPP-like BLE-profile that allows the bidirectional data transmission between several AMB2621 and/or to other BLE devices implementing the AMBER SPP profile. Connection setup can be initiated by any module in the network. Secured connections allow the transmission of encrypted data (user-defined key or pairing).

- Fast sensor data transmission via Beacons.

  The AMB2621 supports the transmission and reception of Beacons. Beacons are fast broadcast messages that allow the energy-efficient unidirectional transmission of data. Especially in sensor networks, this feature is suitable for the frequent transmission of measurement data as it removes the need for connection based communication and therefore is more energy efficient.

- Low power position sensing solutions.

  The current TX power of any AMB2621 is always transmitted with each advertising packet. With this, distance estimation and position sensing solutions can be realized conveniently by performing a passive scan.

- Fast serial interface.

  The AMB2621 offers a UART-interface to communicate with a host using a user-defined baud rate and a simple command interface.

- Latest microprocessor generation provided by Nordic Semiconductor nRF52 series.

  The heart of the AMB2621 is a BLE-chip of the nRF52 series offering high performance values combined with low power consumption. It is a 32-bit ARM® Cortex™-M4F CPU with 512kB flash + 64kB RAM and up to 4dBm output power.

- Bluetooth 4.2 stack

  The Bluetooth 4.2 stack enables fast and energy efficient data transmission using state-of-the-art technology.

- All BLE roles supported.

  The integrated BLE stack supports all BLE roles. Depending on the current state of operation the AMB2621 firmware automatically switches its role to execute the user's instructions.

- Flexible wired interfacing

  If custom hardware does not support UART communication or in case of a host less implementation, the AMB2621 is equipped with extra pins suited for custom device/sensor connection. With help of these, a tailored firmware can be developed which is optimized to the customer's needs. The pins can be configured to various functions such as UART, SPI, I^{2}C, ADC, PWM, NFC and GPIO.

- OTA firmware update

  The AMB2621 firmware provides over the air firmware update capabilities. Firmware updates can be applied using the Nordic Apps for cell phones.

- Peripheral only mode

  The AMB2621 firmware (version 3.0.0 or newer) provides the "peripheral only" operation mode (see chapter 10), that allows the easy adaption of already existing custom hardware with the BLE interface. By default, this mode offers the static passkey pairing method and a transparent UART interface. With this, custom hardware can be accessed by mobile BLE devices (like smart phones including a custom App) using an authenticated and encrypted BLE link without the need of configuring the module.

1.2 Connectivity

The BLE standard allows to setup a network with various BLE devices from different manufacturers. To be able to communicate with AMB2621 devices, the AMBER SPP-like profile must be known by all network participants. Thus arbitrary BLE devices (like iOS or Android devices) must implement this profile, too.

To do so, an application note containing the design data of the AMBER SPP-like profile is available on request.

2 Electrical parameters

T = 25°C, VCC = 3V, f = 2,44 GHz unless otherwise specified

2.1 Operational range

Description	min.	typ.	max.	unit
Supply voltage (VCC)	1.8	3	3.6	V
Supply rise time (0 V to >=1.7 V)			60	ms
Temperature range	-40	25	85	°C

The on-chip power-on reset circuitry may not function properly for rise times longer than the specified maximum.

A step in supply voltage of 300 mV or more, with rise time of 300 ms or less, within the valid supply range, may result in a system reset or erroneous behaviour.

An instable supply voltage may significantly decrease the radio performance.

2.2 Current consumption

2.2.1 Static current consumption

Continous Testmode, Transmitter only with DC/DC converter **from nRF52 data sheet**	min.	typ.	max.	unit
TX current consumption at +4 dBm		7.5*		mA
TX current consumption at 0 dBm		5.3*		mA
RX current consumption		5.4*		mA

* Current at 100% transmission/reception. Due to the BLE time slot operation, the real operating currents are reduced and depend on the user selectable advertising and connection interval settings.

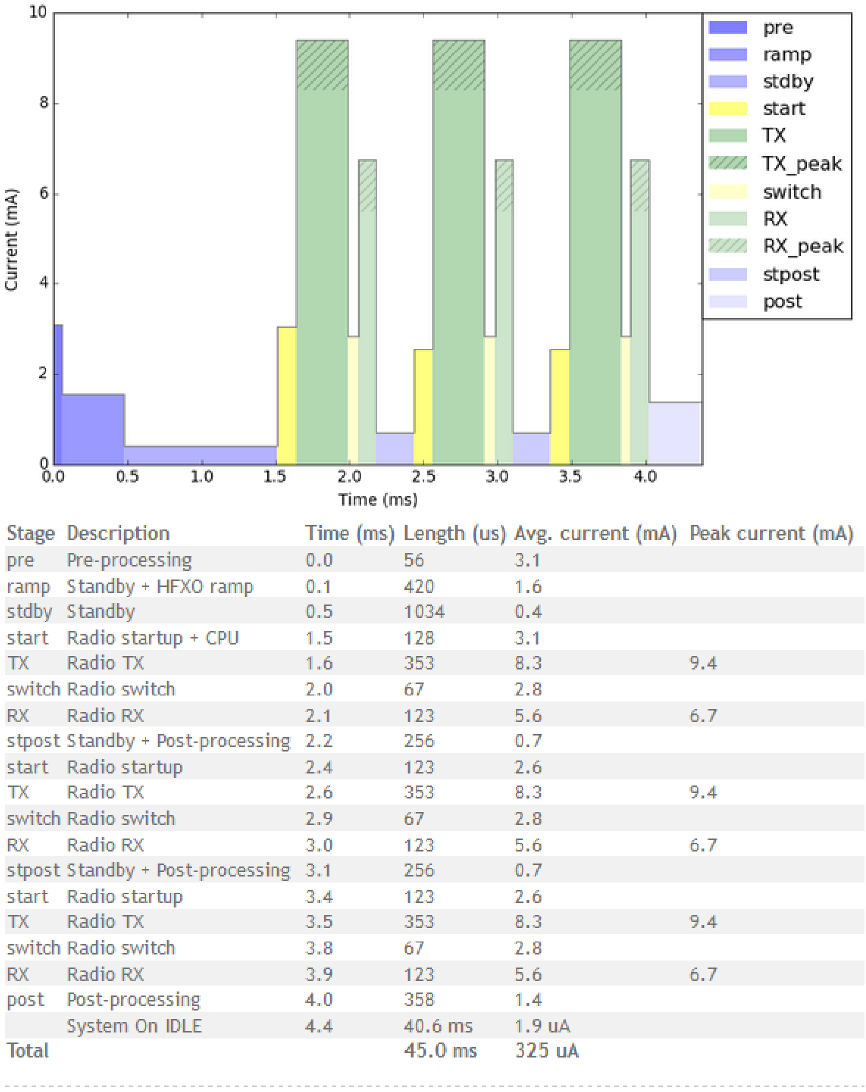
Continous Testmode	min.	typ.	max.	unit
Sleep (system off mode)		0.4		µA

Continuous Testmode overall AMB2621	min.	typ.	max.	unit
TX current consumption at +4 dBm		11		mA
TX current consumption at 0 dBm		8		mA
RX current consumption		8		mA

2.2.2 Typical current consumption

Besides the static TX, RX, IDLE and Sleep current the average current is of interest. Here an example for a typical behaviour of a peripheral device in advertising mode (see **Figure 1** and **Figure 2**). Currents and state durations are dependent on the configuration (User Settings) of the module.

In this state the module transmits the advertising packets on the 3 advertising channels.



Stage	Description	Time (ms)	Length (us)	Avg. current (mA)	Peak current (mA)
pre	Pre-processing	0.0	56	3.1	
ramp	Standby + HFXO ramp	0.1	420	1.6	
stdby	Standby	0.5	1034	0.4	
start	Radio startup + CPU	1.5	128	3.1	
TX	Radio TX	1.6	353	8.3	9.4
switch	Radio switch	2.0	67	2.8	
RX	Radio RX	2.1	123	5.6	6.7
stpost	Standby + Post-processing	2.2	256	0.7	
start	Radio startup	2.4	123	2.6	
TX	Radio TX	2.6	353	8.3	9.4
switch	Radio switch	2.9	67	2.8	
RX	Radio RX	3.0	123	5.6	6.7
stpost	Standby + Post-processing	3.1	256	0.7	
start	Radio startup	3.4	123	2.6	
TX	Radio TX	3.5	353	8.3	9.4
switch	Radio switch	3.8	67	2.8	
RX	Radio RX	3.9	123	5.6	6.7
post	Post-processing	4.0	358	1.4	
	System On IDLE	4.4	40.6 ms	1.9 uA	
Total			45.0 ms	325 uA	

Figure 1 Current consumption calculation in advertising mode with 40ms advertising interval

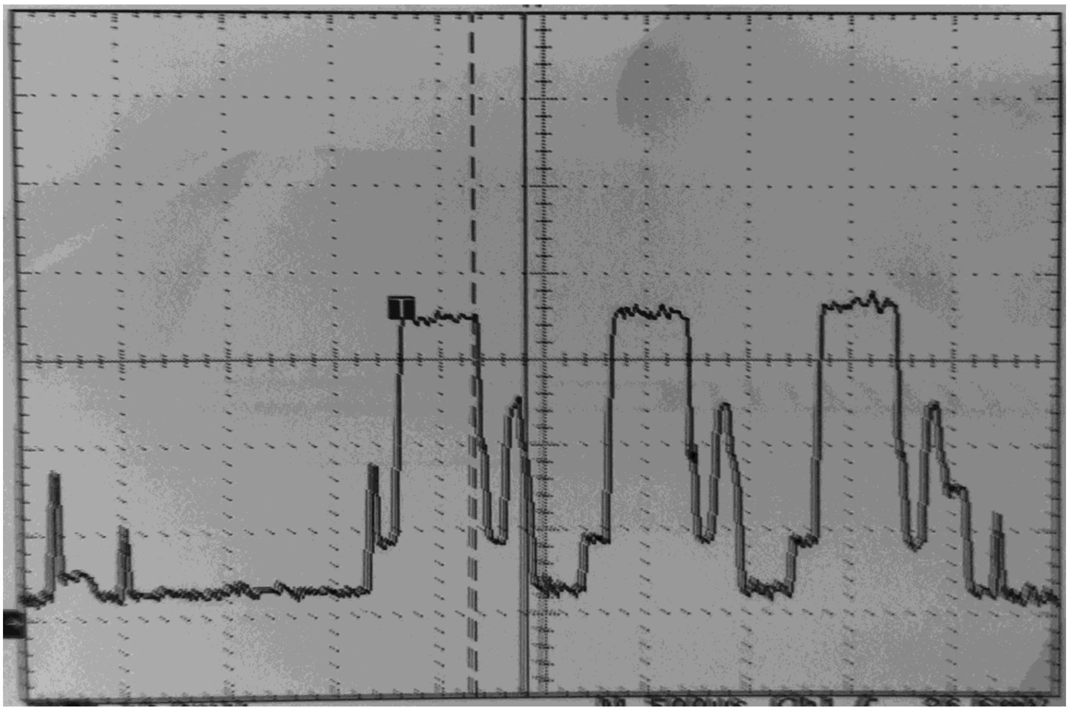


Figure 2 Transient current consumption in advertising mode with 40ms advertising interval, excerpt of 5ms

2.3 Radio parameters (nRF52 data sheet)

50 Ohm tethered.

Description	min	typ.	max.	unit
Output power	-40	+4	+6	dBm
Input sensitivity (<= 37 bytes, BER=1E-3)		-96*, -92**		dBm
RSSI accuracy valid range (± 2dB)	-90		-20	dBm
Enable TX or RX Delay		140		µs
Enable TX or RX Delay (fast mode)		40		µs
Disable TX Delay		6		µs
Disable RX Delay		0		µs

* nRF52832 Rev.1, QFN package

** nRF52832 Rev.1, with build code CIAA-B00, CSP package, in DC/DC Mode

Output power `RF_TXPower = 4`	**min**	**typ.**	**max.**	**unit**
AMB2621-1		+4		dBm
AMB2621		-2		dBm

2.4 Pin characteristics (nRF52 data sheet)

Description	**min.**	**typ.**	**max.**	**unit**
Input high voltage	0.7 * VCC		VCC	V
Input low Voltage	VSS		0.3 * VCC	V
Current at VSS+0.4 V, output set low, standard drive, VDD ≥1.7	1	2	4	mA
Current at VSS+0.4 V, output set low, high drive, VDD >= 2.7 V	6	10	15	mA
Current at VSS+0.4 V, output set low, high drive, VDD >= 1.7 V	3			mA
Current at VDD-0.4 V, output set high, standard drive, VCC ≥1.7	1	2	4	mA
Current at VDD-0.4 V, output set high, high drive, VDD >= 2.7 V	6	9	14	mA
Current at VDD-0.4 V, output set high, high drive, VDD >= 1.7 V	3			mA
Internal Pull-up resistance		13		kΩ
Internal Pull-down resistance		13		kΩ

3 Dimensions and weight

Dimensions	8 x 11 x 1.8 mm
Mass	<1 g

4 Pinout

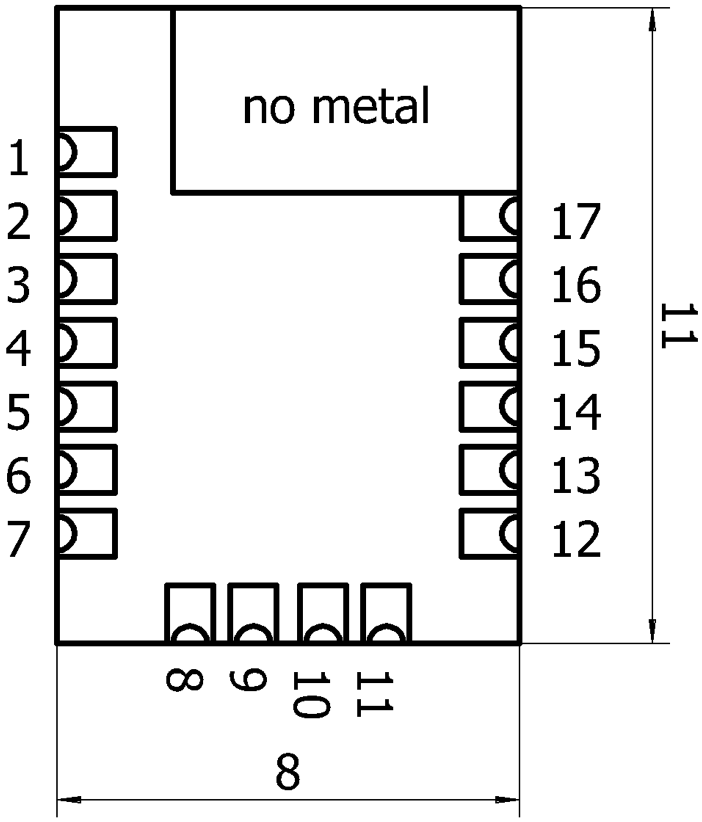


Figure 3 Pinout

The following Pinout represents the AMB2621 module pads and the corresponding µC pins as well as the function of the pad in the AMB2621 firmware. For customer specific firmware the function of a pad may vary.

Pad	µC Pin	Designation	I/O	Description
1		RF	RF	Antenna connection. Only applicable for module variant with external Antenna (e.g. ABMB2621-1). Do not connect in case of modules with internal PCB antenna (e.g. ABMB2621).
2		GND	Supply	Ground
3		SWDCLK	Input	Serial wire clock. (SWD Interface) Uses internal pulldown resistor.

Pad	µC Pin	Designation	I/O	Description
4		SWDIO	Input	Serial wire input/output. (SWD Interface) Do not connect if not needed.
5	P0.21	RESET	Input	Reset pin. A low signal resets the module. Uses internal pullup resistor.[1]
6	P0.05/AIN3	BOOT	Input	Boot pin. A low signal during and short after reset starts the module in OTA bootloader mode. Uses internal pullup resistor.[1] Do not connect if not needed.
7		VDD	Supply	Supply voltage
8	P0.10/NFC2	OPERATION MODE	Input	Operation mode pin with internal pulldown resistor[1] during start-up. Low level or open: Normal Mode. High level: Peripheral only Mode. Do not connect if not needed.
9	P0.09/NFC1	RESERVED	I/O	Do not connect.
10	P0.00/XL1	LED_1	Output	Indicates the module state (active high). Do not connect if not needed.
11	P0.01/XL2	LED_2	Output	Indicates the module state (active high). Do not connect if not needed.
12	P0.02/AIN0	UART TX	Output	UART(Transmission)
13	P0.03/AIN1	UART RX	Input	UART (Reception) Uses internal pullup resistor.[1]
14	P0.04/AIN2	RESERVED	I/O	Do not connect.
15	P0.28/AIN4	RESERVED	I/O	Do not connect.
16	P0.29/AIN5	Wake-up	Input	Wake-up will allow leaving the system-off mode or re-enabling the UART. Uses internal pullup resistor.[1] Do not connect if not needed.

[1] Internal pullup or pulldowns are configured at startup by the firmware installed in the SoC. The pullup on the Reset pin cannot be disabled by firmware.

Pad	µC Pin	Designation	I/O	Description
17		GND	Supply	Ground

Table 1 Pinout

5 Start-up and minimal configuration

5.1 Minimal configuration

In factory state the modules are immediately ready for operation; the following pins are required in the minimal configuration:

VDD, GND, UART TX, UART RX, RESET

If the module has to be connected to a PC, a converter (TTL to RS-232 or TTL to USB) has to be used. See chapter 4 for details on all pins.

Please refer to the AMB2621-EV schemes for a reference design.

Implementing the fail-save firmware update method using the SWD interface is recommended. Without having the SWD interface available a fail-save firmware update on a customer PCB cannot be guaranteed, see next chapter.

The logic level of the module is based on 3V. A 5V logic level must not be connected directly to the module.

5.2 Recommended configuration

We recommend to also have the following pins accessible in order to support a fail-safe firmware update:

SWDIO, SWDCLK, BOOT

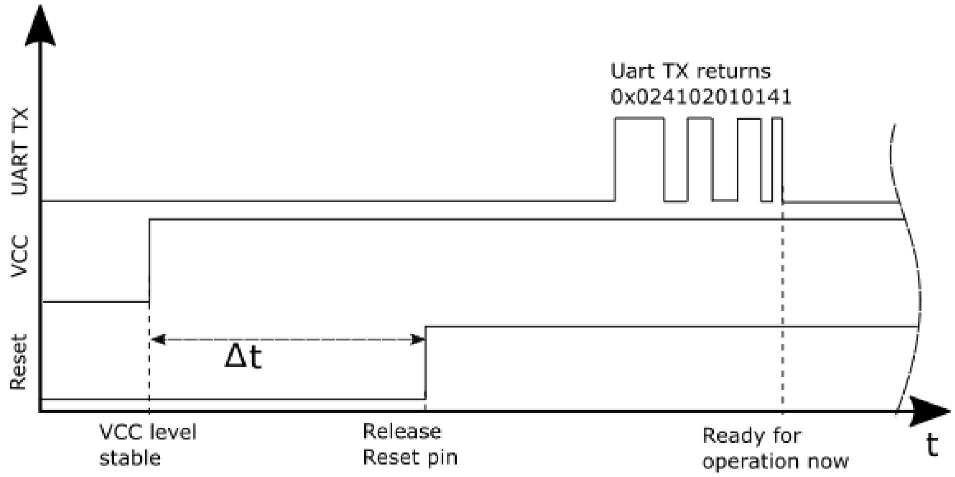
A standard socket on the customer's PCB for connecting a Flash adapter can be useful for debugging purposes (e.g. a JTAG 2*10 Pin header with 2.54mm pin-to-pin distance).

5.3 Power-up

After powering the module the Reset pin shall be hold for another Δt of 1ms after the VCC is stable to ensure a safe start-up.

The module will send "`CMD_GETSTATE_CNF`" to indicate "ready for operation" after the Reset pin was released.

Applying a reset (e.g. a host temporarily pulling the Reset pin down for at least 1ms and releasing it again) after the VCC is stable will also be sufficient.



5.4 Connecting to the AMB2621 via serial interface

To control the module the UART interface of the AMB2621 may be used. The default data rate is 115200 Baud and the data format is 8 data bits, no parity and 1 stop bit ("8n1").

Please note that every command sent to the module correctly is confirmed by the module.

If no confirmation is returned, the previously sent command was not understood. Therefore a timeout and retry algorithm has to be implemented by the host.

5.5 Quick start: Connection setup and first data transmission

This section describes how to quick start the data transmission between two AMB2621.

The goal is to setup a connection between module A and module B, transmit some data and close the connection again by the following steps.

In this section, all packet data from or to the modules is given in **hexadecimal notation**.

For quick testing a pair of AMB2621-EV is recommended.

To reproduce the following sequence, note that, the `FS_BTMAC` of every module is different, thus it has to be replaced it in the commands below. Also the XOR checksum (last byte) has to be adjusted, when adapting any command.

The command structure and checksum calculation is described in chapter 8.

Note that the module goes to ACTION_SLEEP mode if no connection is setup after `RF_AdvertisingTimeout` seconds. The module will indicate this using a `CMD_SLEEP_CNF`. Also the UART is disabled in `ACTION_SLEEP` mode.

The default value is 0s which means that it'll run forever

1. Power-up the modules and make their UARTs accessible by the host(s). After the power-up following sequence is sent from the module:

Info	Module A	Module B
◀ Response `CMD_GETSTATE_CNF` The module A started in `ACTION_IDLE` mode.	02 41 02 00 01 01 41	
◀ Response `CMD_GETSTATE_CNF` The module B started in `ACTION_IDLE` mode.		02 41 02 00 01 01 41

2. Request the `FS_BTMAC` of both modules.

Info	Module A	Module B
▶ Request `CMD_GET_REQ` with settings index 4	02 10 01 00 04 17	
◀ Response `CMD_GET_CNF` `FS_BTMAC` of module A is 0x55 0x00 0x00 0xDA 0x18 0x00	02 50 07 00 00 **55 00 00 DA 18 00** C2	
▶ Request `CMD_GET_REQ` with settings index 4		02 10 01 00 04 17
◀ Response `CMD_GET_CNF` `FS_BTMAC` of module B is 0x11 0x00 0x00 0xDA 0x18 0x00		02 50 07 00 00 **11 00 00 DA 18 00** 86

3. Connect Module A to Module B.
   Note: this example is taken from an older firmware, so in the newer firmware with the optional BT 4.2 feature “LE Packet Length Extension“ you may see other values than 0x13 for max supported payload length per packet in the opened channel (e.g. 0x80 = 128 byte max payload per packet).

Info	Module A	Module B
► Request `CMD_CONNECT_REQ` with `FS_BTMAC` of module B	02 06 06 00 **11 00 00 DA 18 00** D1	
◄ Response `CMD_CONNECT_CNF` Request understood, try to connect now	02 46 01 00 00 45	
◄ Indication `CMD_CONNECT_IND` Physical connection established successfully to module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00	02 86 07 00 00 **11 00 00 DA 18 00** 50	
◄ Indication `CMD_CONNECT_IND` Physical connection established successfully to module with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00		02 86 07 00 00 **55 00 00 DA 18 00** 14
◄ Indication `CMD_CHANNELOPEN_RSP` Channel opened successfully to module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet	02 C6 07 00 00 **11 00 00 DA 18 00 13** C3	
◄ Indication `CMD_CHANNELOPEN_RSP` Channel opened successfully to module with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet		02 C6 07 00 00 **55 00 00 DA 18 00 13** 87

4. Once the connection is active data can be sent in each direction. Let’s send a string “ABCD” from Module B to module A. Note: The RSSI values will most probably be different in your tests.

Info	Module A	Module B
► Request `CMD_DATA_REQ` Send “ABCD” to module A		02 04 04 00 **41 42 43 44** 06
◄ Response `CMD_DATA_CNF` Request received, send data now		02 44 01 00 00 47
◄ Indication `CMD_DATA_IND` Received string “ABCD” from `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xCA (-54dBm)	02 84 0B 00 **11 00 00 DA 18 00** CA **41 42 43 44** 90	
◄ Response `CMD_TXCOMPLETE_RSP` Data transmitted successfully		02 C4 01 00 00 C7

5. Reply with “EFGH” to module B.

Info	Module A	Module B
► Request `CMD_DATA_REQ` Send “EFGH” to module B	02 04 04 00 **45 46 47 48** 0E	
◄ Response `CMD_DATA_CNF` Request received, send data now	02 44 01 00 00 47	
◄ Indication `CMD_DATA_IND` Received string “EFGH” from `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xC1 (-63dBm)		02 84 0B 00 **55 00 00 DA 18 00** C1 **45 46 47 48** D7
◄ Response `CMD_TXCOMPLETE_RSP` Data transmitted successfully	02 C4 01 00 00 C7	

6. Now Module A closes the connection, so both modules will get a disconnect indication.

Info	Module A	Module B
► Request `CMD_DISCONNECT_REQ` Disconnect	02 07 00 00 05	
◄ Response `CMD_DISCONNECT_CNF` Request received, disconnect now	02 47 01 00 00 44	
◄ Indication `CMD_DISCONNECT_IND` Connection closed	02 87 01 00 16 92	
◄ Indication `CMD_DISCONNECT_IND` Connection closed		02 87 01 00 13 97

6 State overview

The AMB2621 module acts as a slave and can be fully controlled by an external host that implements the command interface. The configuration as well as the operation of the module can be managed by predefined commands that are sent as telegrams over the UART interface of the module.

The AMB2621 can operate in different states. Depending on the active state several commands of the command interface (see chapter 8) are permitted to modify the state, configure the module or transmit data over the RF-interface. An overview of the different states and the corresponding allowed commands can be found in Figure 4 on page 21.

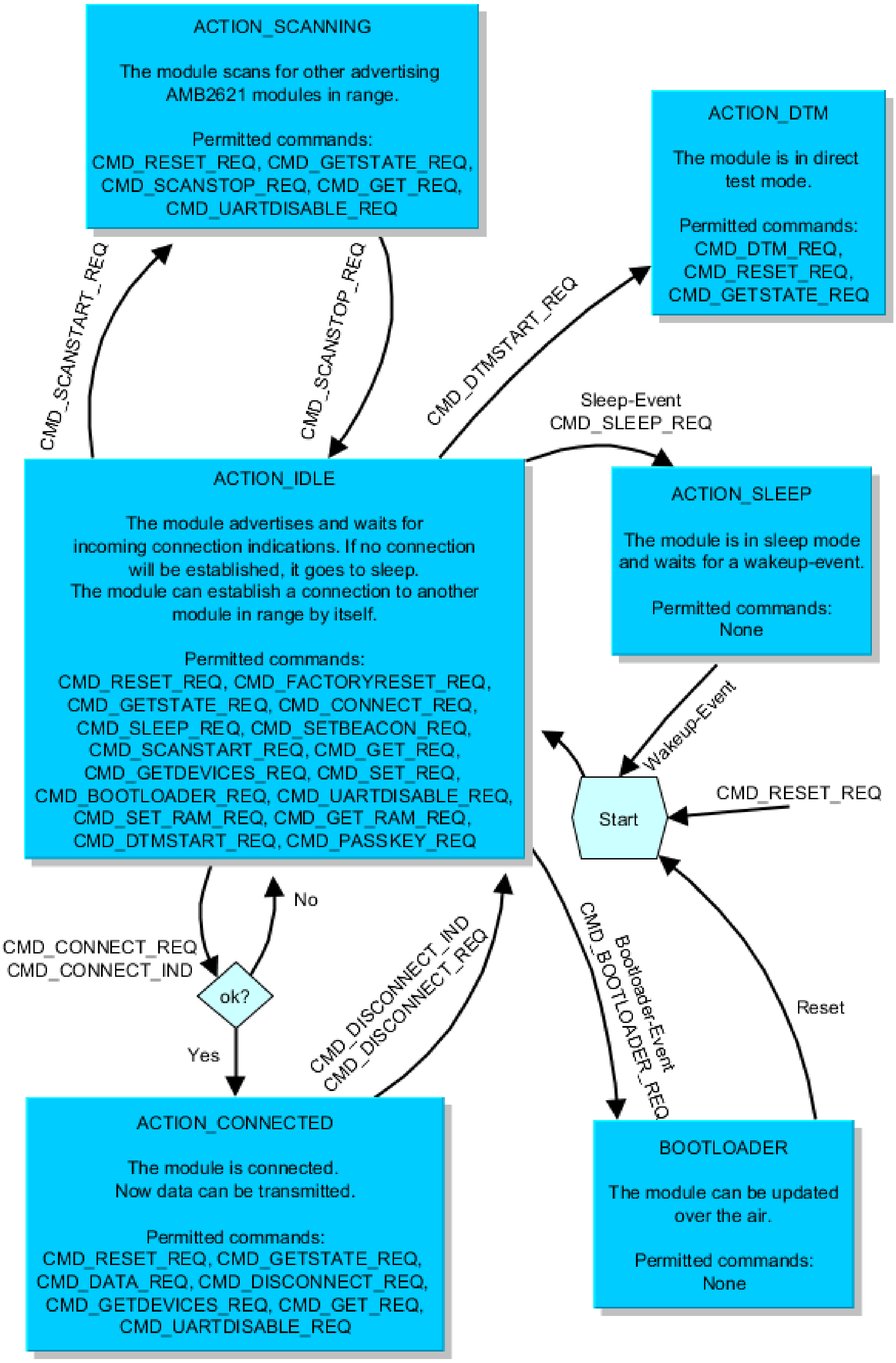
When the AMB2621 is powered up, it starts in `ACTION_IDLE` state. In this state the module advertises (BLE role “peripheral”), such that other devices in range (BLE role “central” or “observer”) can detect it and connect to it. If no connection was setup after `RF_AdvertisingTimeout` seconds, the module goes to `ACTION_SLEEP` state which will stop advertising.

The `ACTION_IDLE` state also allows to switch to `ACTION_SCANNING` state, where the module stops advertising and scans for other advertising modules in range (BLE role “central”).

When leaving the `ACTION_SCANNING` state with the corresponding command, the module is in `ACTION_IDLE` state and starts advertising again.

The `ACTION_CONNECTED` state can be entered either by getting a connection request from another module (BLE role “peripheral”) or by setting up a connection itself (BLE role “central”). In this case it stops advertising and data can be transmitted and received to/from the connected module. This state remains active as long as the module does not disconnect itself (e.g. due to a timeout), no disconnection request from the connected device is received.

When disconnecting, the module goes to `ACTION_IDLE` state und starts advertising again.



ACTION_SCANNING

The module scans for other advertising AMB2621 modules in range.

Permitted commands:
CMD_RESET_REQ, CMD_GETSTATE_REQ, CMD_SCANSTOP_REQ, CMD_GET_REQ, CMD_UARTDISABLE_REQ

ACTION_DTM

The module is in direct test mode.

Permitted commands:
CMD_DTM_REQ, CMD_RESET_REQ, CMD_GETSTATE_REQ

ACTION_IDLE

The module advertises and waits for incoming connection indications. If no connection will be established, it goes to sleep.
The module can establish a connection to another module in range by itself.

Permitted commands:
CMD_RESET_REQ, CMD_FACTORYRESET_REQ, CMD_GETSTATE_REQ, CMD_CONNECT_REQ, CMD_SLEEP_REQ, CMD_SETBEACON_REQ, CMD_SCANSTART_REQ, CMD_GET_REQ, CMD_GETDEVICES_REQ, CMD_SET_REQ, CMD_BOOTLOADER_REQ, CMD_UARTDISABLE_REQ, CMD_SET_RAM_REQ, CMD_GET_RAM_REQ, CMD_DTMSTART_REQ, CMD_PASSKEY_REQ

ACTION_SLEEP

The module is in sleep mode and waits for a wakeup-event.

Permitted commands:
None

ACTION_CONNECTED

The module is connected.
Now data can be transmitted.

Permitted commands:
CMD_RESET_REQ, CMD_GETSTATE_REQ, CMD_DATA_REQ, CMD_DISCONNECT_REQ, CMD_GETDEVICES_REQ, CMD_GET_REQ, CMD_UARTDISABLE_REQ

BOOTLOADER

The module can be updated over the air.

Permitted commands:
None

Figure 4 States of the AMB2621

6.1 State indication using the LED pins

The pins LED_1 and LED_2 of the AMB2621 can be used to determine the module state. The states described in Figure 4 result in the following pin behaviour. The pins on the AMB2621 are active high.

State	LED_1	LED_2
ACTION_IDLE	Blinking On for 200ms Off for 2800ms	Off
ACTION_SCANNING	Blinking On for 250ms Off for 750ms	Off
ACTION_CONNECTED	On	Off On (as soon as the channel was opened successfully, see CMD_CHANNELOPEN_RSP)
ACTION_SLEEP	Off	Off
ACTION_DTM	Off	Off
BOOTLOADER Waiting for connection	On	Off
BOOTLOADER Connected, firmware update running	Off	On

Table 2 LED behaviour of the AMB2621

6.2 Reset behaviour

After resetting the module a CMD_GETSTATE_CNF is sent to the serial interface as soon as the module is ready for operation. In default case the sent message (in hex notation) is 02 41 02 00 01 01 41 which indicates that the module is in ACTION_IDLE mode after having started-up successfully.

6.3 Sleep mode

Especially for battery-powered devices the ACTION_SLEEP mode (system-off mode) supports very low power consumption (<1µA). It can be entered by sending the command CMD_SLEEP_REQ to the module. If allowed (due to the current operating state) the module will then send a CMD_SLEEP_CNF and then enter the ACTION_SLEEP mode.

In ACTION_SLEEP mode the UART is disabled, so the module will not receive or transmit any data. To prevent leakage current, the host shall not pull the UART_RX to LOW level (as the module has an internal pull-up resistor enabled on this pin).

To leave the ACTION_SLEEP mode and enter ACTION_IDLE state again, the module has to be woken up by applying a low signal to the Wake-up pin for at least 5ms before releasing the signal back to high. The module then restarts completely, so that all volatile settings are set to default. A CMD_GETSTATE_CNF will be send when the module is ready for operation.

Note that the Wake-up pin has a second function. If the module is not in ACTION_SLEEP mode and the UART was disabled using the CMD_UARTDISABLE_IND, the UART can be re-enabled by applying a low signal for at least 5ms and releasing it to high again. In this case the module answers with a CMD_UARTENABLE_IND.

6.4 Identification of an AMB2621 device on the air

The AMB2621 can be identified on the RF-interface by its FS_BTMAC. This FS_BTMAC is a Bluetooth-conform MAC address, which is part of the data package sent during advertising in ACTION_IDLE mode. A FS_BTMAC has the size of 6 byte.

In ACTION_SCANNING state a module listens to the data packets of all advertising modules in range and stores their FS_BTMAC to an internal data base. With help of a FS_BTMAC a connection to the corresponding device can then be established using the CMD_CONNECT_REQ command.

To simplify the identification of AMB2621 devices on the RF-interface a short user-defined name (see RF_DeviceName) can be given to the module, which is also part of the advertising packet.

The FS_BTMAC consists of the Amber wireless company ID 0x0018DA followed by the FS_SerialNumber of the module.

6.5 Connection based data transmission, with or without security

In the BLE standard the transmission of data typically is connection based. A connection between two devices can be secured (with or without key exchange) or unsecured (default setting). In any case, each data packet transmitted is acknowledged on the link layer, such that it is resent as long as a packet is lost. The following lines describe how to run the connection setup and data transmission using the AMB2621.

If module A is supposed to setup a connection with module B, module A can use the command CMD_CONNECT_REQ including the FS_BTMAC of module B. If the FS_BTMAC of module B is unknown, a scan can be run before by module A to discover all available modules in range (see chapter 6.4).

After sending the command CMD_CONNECT_REQ, the module answers with a CMD_CONNECT_CNF to signal that the request has been understood and the module now tries to establish the connection.

If module B cannot be found on the air within a timeout, module A outputs a `CMD_CONNECT_IND` with “failed” as status. Otherwise, as soon as the physical connection has been set up successfully, module A and B print a `CMD_CONNECT_IND` with the status of the successful connection and LED_1 turns on.

Next some security and authentication messages will follow, like `CMD_SECURITY_IND`, if security is enabled.

After the physical connection has been setup successfully the modules exchange their services. As soon as this has finished successfully a `CMD_CHANNELOPEN_RSP` is given out to the UART indicating that the connection is ready for data transmission. Furthermore LED_2 turns on.

Now data can be transmitted in both directions using the command `CMD_DATA_REQ`. It is confirmed by a `CMD_DATA_CNF` (data will be processed) and a `CMD_TXCOMPLETE_RSP` (data transmitted successfully).

Each time data has been received a `CMD_DATA_IND` will be outputted containing the transmitted data.

As soon as one module closes the connection using a `CMD_DISCONNECT_REQ`, both modules will inform their host by a `CMD_DISCONNECT_IND` message that the connection is no longer open.

If one module is no longer within range the `CMD_DISCONNECT_IND` message is triggered by a timeout.

For an example on setting up an unsecured connection see chapter 5.5. See also the advanced user guide to get detailed information about the connection setup with foreign devices.

6.5.1 Further information for a secure connection setup

The `RF_SecFlags` parameter of the module determines the security mode. If a certain security mode of an AMB2621 peripheral device is set, its security level has to be met by the connecting central device to be able to exchange data. If the security level of the peripheral device is not met during connection setup, the peripheral requests for a higher security level. As soon as the defined security level is not met by the central device, no access to the peripheral’s profiles will be granted.

When connecting from an AMB2621 to an AMB2621, you shall not use different security modes.

In this case, if security is needed, we recommend to use the LTK method. It allows a quick setup of a secured connection.

To get further information about the secured connection setup, when using a foreign device (i.e. mobile phone with a custom APP), please refer to the “advanced user guide”.

6.5.1.1 Just works mode

In case of the “Just works” mode, each time a connection is established, a new random key is exchanged in advance to be used for data encryption. Since no authentication will be performed, also devices without input and output capabilities (like keyboard or display) are able to connect.

6.5.1.1.1 Example: Secured connection with LE Legacy security method “Just Works”

1. Power-up the modules and make their UARTs accessible by the host(s). After the power-up following sequence is sent from the module:

Info	Module A	Module B
◄ Response `CMD_GETSTATE_CNF` The module A started in `ACTION_IDLE` mode.	02 41 02 00 01 01 41	
◄ Response `CMD_GETSTATE_CNF` The module B started in `ACTION_IDLE` mode.		02 41 02 00 01 01 41

2. Request the `FS_BTMAC` of both modules.

Info	Module A	Module B
► Request `CMD_GET_REQ` with settings index 4	02 10 01 00 04 17	
◄ Response `CMD_GET_CNF` `FS_BTMAC` of module A is 0x55 0x00 0x00 0xDA 0x18 0x00	02 50 07 00 00 **55 00 00 DA 18 00** C2	
► Request `CMD_GET_REQ` with settings index 4		02 10 01 00 04 17
◄ Response `CMD_GET_CNF` `FS_BTMAC` of module B is 0x11 0x00 0x00 0xDA 0x18 0x00		02 50 07 00 00 **11 00 00 DA 18 00** 86

3. Configure the parameter `RF_SecFlags` to use “Just Works” pairing method for BT security

Info	Module A	Module B
►Perform `CMD_SET_REQ` with settings index 12 and value 0x02 on Module A	02 11 02 00 0C 02 1F	
◄ Response `CMD_SET_CNF` (Module will restart to adopt the new value)	02 51 01 00 00 52	
◄ Response `CMD_GETSTATE_CNF`	02 41 02 00 01 01 41	
►Perform `CMD_SET_REQ` with settings index 12 and value 0x02 on Module B		02 11 02 00 0C 02 1F
◄ Response `CMD_SET_CNF` (Module will restart to adopt the new value)		02 51 01 00 00 52
◄ Response `CMD_GETSTATE_CNF`		02 41 02 00 01 01 41

4. Connect Module A to Module B.
   Note: this example is taken from an older firmware, so in the newer firmware with the optional BT 4.2 feature "LE Packet Length Extension" you may see other values than 0x13 for max supported payload length per packet in the opened channel (e.g. 0x80 = 128 byte max payload per packet).

Info	Module A	Module B
► Request CMD_CONNECT_REQ with FS_BTMAC of module B	02 06 06 00 **11 00 00 DA 18 00** D1	
◄ Response CMD_CONNECT_CNF Request understood, try to connect now	02 46 01 00 00 45	
◄ Indication CMD_CONNECT_IND Physical connection established successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00	02 86 07 00 00 **11 00 00 DA 18 00** 50	
◄ Indication CMD_CONNECT_IND Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00		02 86 07 00 00 **55 00 00 DA 18 00** 14
◄ Indication CMD_SECURITY_IND, security mode = 1, security level = 2 (encrypted link, no MITM protection), with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00	02 88 07 00 **12 11 00 00 DA 18 00** 4C	
◄ Indication CMD_SECURITY_IND, security mode = 1, security level = 2 (encrypted link, no MITM protection), with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00		02 88 07 00 **12 55 00 00 DA 18 00** 08
◄ Indication CMD_CHANNELOPEN_RSP Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet	02 C6 07 00 00 **11 00 00 DA 18 00 13** C3	
◄ Indication CMD_CHANNELOPEN_RSP Channel opened successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet		02 C6 07 00 00 **55 00 00 DA 18 00 13** 87

5. Now Module A closes the connection, so both modules will get a disconnect indication.

Info	Module A	Module B
► Request CMD_DISCONNECT_REQ Disconnect	02 07 00 00 05	
◄ Response CMD_DISCONNECT_CNF Request received, disconnect now	02 47 01 00 00 44	
◄ Indication CMD_DISCONNECT_IND Connection closed	02 87 01 00 16 92	
◄ Indication CMD_DISCONNECT_IND Connection closed		02 87 01 00 13 97

6. You may want to perform a CMD_FACTORYRESET_REQ to restore default settings.

6.5.1.2 LTK mode

In case of the “LTK” mode, a fixed long term key (LTK) is used for encrypting the data. This key is not exchanged by the RF-interface and has to correlate on both sides of the connection. If the keys do not match, the connection will be rejected.

1. If the AMB2621 sets up a connection to another device,

   then the long term key stored in the parameter RF_PeerLTK is used. During the connection setup, it has to correlate with the key of the peer device.

   It can be modified by the CMD_SET_REQ, which writes its values into flash memory, or by the CMD_SET_RAM_REQ, which stores its value in volatile RAM.

2. If the AMB2621 requested to connect by another device,

   then the long term key stored in the parameter RF_OwnLTK is used. During the connection setup, it has to correlate with the key of the peer device.

   It can be modified by the CMD_SET_REQ, which writes its values into flash memory.

3. Consequently, if the AMB2621 connects to another AMB2621,

   then the RF_PeerLTK of the connecting device must correlate with the RF_OwnLTK of the connected device.

When consecutively connecting to several devices using the “LTK” mode, we recommend to use the CMD_SET_RAM_REQ command to update the RF_PeerLTK to the corresponding key. This saves flash cycles and thus increases the durability of the module.

6.5.1.2.1 Example: Secured connection with security method “LTK”

1. Power-up the modules and make their UARTs accessible by the host(s). After the power-up following sequence is sent from the module:

Info	Module A	Module B
◄ Response CMD_GETSTATE_CNF The module A started in ACTION_IDLE mode.	02 41 02 00 01 01 41	
◄ Response CMD_GETSTATE_CNF The module B started in ACTION_IDLE mode.		02 41 02 00 01 01 41

2. Request the FS_BTMAC of both modules.

Info	Module A	Module B
► Request CMD_GET_REQ with settings index 4	02 10 01 00 04 17	
◄ Response CMD_GET_CNF FS_BTMAC of module A is 0x55 0x00 0x00 0xDA 0x18 0x00	02 50 07 00 00 **55 00 00 DA 18 00** C2	
► Request CMD_GET_REQ with settings index 4		02 10 01 00 04 17
◄ Response CMD_GET_CNF FS_BTMAC of module B is 0x11 0x00 0x00 0xDA 0x18 0x00		02 50 07 00 00 **11 00 00 DA 18 00** 86

3. Configure the parameter RF_SecFlags to use “LTK” method for BT security

Info	Module A	Module B
►Perform CMD_SET_REQ with settings index 12 and value 0x01 on Module A	02 11 02 00 0C 01 1C	
◄ Response CMD_SET_CNF (Module will restart to adopt the new value)	02 51 01 00 00 52	
◄ Response CMD_GETSTATE_CNF	02 41 02 00 01 01 41	
►Perform CMD_SET_REQ with settings index 12 and value 0x01 on Module B		02 11 02 00 0C 01 1C
◄ Response CMD_SET_CNF (Module will restart to adopt the new value)		02 51 01 00 00 52
◄ Response CMD_GETSTATE_CNF		02 41 02 00 01 01 41

4. Connect Module A to Module B.
   Note: this example is taken from an older firmware, so in the newer firmware with the optional BT 4.2 feature “LE Packet Length Extension“ you may see other values than 0x13 for max supported payload length per packet in the opened channel (e.g. 0x80 = 128 byte max payload per packet).
   Note further: The RF_PeerLTK *of the module A coincides with the* RF_OwnLTK *of the module B. This is needed to setup successfully the connection.*

Info	Module A	Module B
► Request CMD_CONNECT_REQ with FS_BTMAC of module B	02 06 06 00 **11 00 00 DA 18 00** D1	
◄ Response CMD_CONNECT_CNF Request understood, try to connect now	02 46 01 00 00 45	
◄ Indication CMD_CONNECT_IND Physical connection established successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00	02 86 07 00 00 **11 00 00 DA 18 00** 50	
◄ Indication CMD_CONNECT_IND Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00		02 86 07 00 00 **55 00 00 DA 18 00** 14
◄ Indication CMD_SECURITY_IND, security mode = 1, security level = 3 (encrypted link, MITM protection), with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00	02 88 07 00 **13 11 00 00 DA 18 00** 4D	
◄ Indication CMD_SECURITY_IND, security mode = 1, security level = 3 (encrypted link, MITM protection), with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00		02 88 07 00 **13 55 00 00 DA 18 00** 09
◄ Indication CMD_CHANNELOPEN_RSP Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet	02 C6 07 00 00 **11 00 00 DA 18 00 13** C3	
◄ Indication CMD_CHANNELOPEN_RSP Channel opened successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet		02 C6 07 00 00 **55 00 00 DA 18 00 13** 87

5. Now Module A closes the connection, so both modules will get a disconnect indication.

Info	Module A	Module B
► Request CMD_DISCONNECT_REQ Disconnect	02 07 00 00 05	
◄ Response CMD_DISCONNECT_CNF Request received, disconnect now	02 47 01 00 00 44	
◄ Indication CMD_DISCONNECT_IND Connection closed	02 87 01 00 16 92	
◄ Indication CMD_DISCONNECT_IND Connection closed		02 87 01 00 13 97

6. You may want to perform a CMD_FACTORYRESET_REQ to restore default settings.

6.5.1.3 Static PassKey mode

In case of the "StaticPassKey" mode, a pass key has to be entered at the central side that has to match the pass key of the peripheral. Here the AMB2621 uses a static pass key in the peripheral role that is stored in the parameter RF_StaticPassKey. When using this method, the central device requests its host to enter a pass key (see CMD_PASSKEY_IND). In this case the pass key of the peripheral has to be entered on central side using the CMD_PASSKEY_REQ command. If the entered pass key is correct, the channel will be opened. Otherwise, the connection will be rejected.

6.5.1.3.1 Example: Secured connection with security method "StaticPassKey"

7. Power-up the modules and make their UARTs accessible by the host(s). After the power-up following sequence is sent from the module:

Info	Module A	Module B
◄ Response CMD_GETSTATE_CNF The module A started in ACTION_IDLE mode.	02 41 02 00 01 01 41	
◄ Response CMD_GETSTATE_CNF The module B started in ACTION_IDLE mode.		02 41 02 00 01 01 41

8. Request the `FS_BTMAC` of both modules.

Info	Module A	Module B
► Request `CMD_GET_REQ` with settings index 4	02 10 01 00 04 17	
◄ Response `CMD_GET_CNF` `FS_BTMAC` of module A is 0x55 0x00 0x00 0xDA 0x18 0x00	02 50 07 00 00 **55 00 00 DA 18 00** C2	
► Request `CMD_GET_REQ` with settings index 4		02 10 01 00 04 17
◄ Response `CMD_GET_CNF` `FS_BTMAC` of module B is 0x11 0x00 0x00 0xDA 0x18 0x00		02 50 07 00 00 **11 00 00 DA 18 00** 86

9. Configure the parameter `RF_SecFlags` to use “StaticPassKey” method for BT security

Info	Module A	Module B
►Perform `CMD_SET_REQ` with settings index 12 and value 0x03 on Module A	02 11 02 00 0C 03 1E	
◄ Response `CMD_SET_CNF` (Module will restart to adopt the new value)	02 51 01 00 00 52	
◄ Response `CMD_GETSTATE_CNF`	02 41 02 00 01 01 41	
►Perform `CMD_SET_REQ` with settings index 12 and value 0x03 on Module B		02 11 02 00 0C 03 1E
◄ Response `CMD_SET_CNF` (Module will restart to adopt the new value)		02 51 01 00 00 52
◄ Response `CMD_GETSTATE_CNF`		02 41 02 00 01 01 41

10. Connect Module A to Module B.
    Note: this example is taken from an older firmware, so in the newer firmware with the optional BT 4.2 feature “LE Packet Length Extension“ you may see other values than 0x13 for max supported payload length per packet in the opened channel (e.g. 0x80 = 128 byte max payload per packet).
    Note further: Here the `RF_StaticPassKey` *of the module B is “123123”.*

Info	Module A	Module B
► Request `CMD_CONNECT_REQ` with `FS_BTMAC` of module B	02 06 06 00 **11 00 00 DA 18 00** D1	
◄ Response `CMD_CONNECT_CNF` Request understood, try to connect now	02 46 01 00 00 45	
◄ Indication `CMD_CONNECT_IND` Physical connection established successfully to module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00	02 86 07 00 00 **11 00 00 DA 18 00** 50	
◄ Indication `CMD_CONNECT_IND` Physical connection established successfully to module with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00		02 86 07 00 00 **55 00 00 DA 18 00** 14
◄ Indication `CMD_PASSKEY_IND` to ask for the pass key	02 8D 07 00 00 **11 00 00 DA 18 00** 5B	
►Answer with the `CMD_PASSKEY_REQ` and the pass key “123123”	02 0D 06 00 **31 32 33 31 32 33** 09	
◄ Response `CMD_PASSKEY_CNF` Pass key ok	02 4D 01 00 00 4E	
◄ Indication `CMD_SECURITY_IND`, security mode = 1, security level = 3 (encrypted link, MITM protection), with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00	02 88 07 00 **13 11 00 00 DA 18 00** 4D	
◄ Indication `CMD_SECURITY_IND`, security mode = 1, security level = 3 (encrypted link, MITM protection), with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00		02 88 07 00 **13 55 00 00 DA 18 00** 09
◄ Indication `CMD_CHANNELOPEN_RSP` Channel opened successfully to module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet	02 C6 07 00 00 **11 00 00 DA 18 00 13** C3	
◄ Indication `CMD_CHANNELOPEN_RSP` Channel opened successfully to module with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet		02 C6 07 00 00 **55 00 00 DA 18 00 13** 87

11. Now Module A closes the connection, so both modules will get a disconnect indication.

Info	Module A	Module B
► Request CMD_DISCONNECT_REQ Disconnect	02 07 00 00 05	
◄ Response CMD_DISCONNECT_CNF Request received, disconnect now	02 47 01 00 00 44	
◄ Indication CMD_DISCONNECT_IND Connection closed	02 87 01 00 16 92	
◄ Indication CMD_DISCONNECT_IND Connection closed		02 87 01 00 13 97

12. You may want to perform a CMD_FACTORYRESET_REQ to restore default settings.

6.6 Unidirectional connectionless data transmission using Beacons

Besides the connection-based type of data transmission described in section 6.5 there exists a second method which uses so called Beacons. In this case, a limited amount of user data can be placed in the BLE scan response packet which is broadcasted frequently without acknowledgement and without security.

If an AMB2621 is supposed to broadcast some data, the command CMD_SETBEACON_REQ can be used to place user data in the scan response packet.

If a second AMB2621, which has its Beacon-function (see RF_BeaconFlags) enabled, is in the operating state ACTION_SCANNING, then the scan response packet is requested as soon as an advertising packet from the first module has been detected. Filtering the beacon messages can be enabled or disabled using RF_BeaconFlags.

After the reception of the scan response packet the included user data is interpreted and given out to the UART using a CMD_BEACON_IND message.

To set the module into ACTION_SCANNING mode the command CMD_SCANSTART_REQ has to be used. Enable the Beacon-function before by setting the corresponding bit in the RF_BeaconFlags parameter.

This method is very suitable for sensor networks, which frequently send their data to data collectors. Especially when using a slow RF_ScanTiming mode, data can be transmitted in a more energy efficient way.

Please check the settings RF_AdvertisingTimeout and the advertising interval in RF_ScanTiming to configure the frequency and interval of transmissions which will have an influence on the current consumption of the module.

6.6.1 Example: Unfiltered Beacons

Module A shall be the sender of beacons, module B the receiver.

Info	Module A	Module B
◄ Reset both modules using reset pin, CMD_GETSTATE_CNF	02 41 02 00 01 01 41	02 41 02 00 01 01 41
► Configure RF_BeaconFlags using CMD_SET_REQ to „beacon rx enabled, no filter"		02 11 02 00 0E 01 1E
◄ CMD_SET_CNF from module B		02 51 01 00 00 52
◄ Module B resetted such that the change in the user setting takes effect (CMD_GETSTATE_CNF)		02 41 02 00 01 01 41
► Activate scanning on module B		02 09 00 00 0B
◄ Response CMD_SCANSTART_CNF		02 49 01 00 00 4A
► CMD_SETBEACON_REQ, content "**Hallo**"	02 0C 05 00 **48 61 6C 6C 6F** 4D	
◄ CMD_SETBEACON_CNF	02 4C 01 00 00 4F	
◄ receiving multiple CMD_BEACON_IND		02 8C 0C 00 02 00 00 DA 18 00 B5 48 61 6C 6C 6F B1 02 8C 0C 00 02 00 00 DA 18 00 B1 **48 61 6C 6C 6F** B5
		⁞
► Deactivate scanning on module B, CMD_SCANSTOP_REQ		02 0A 00 00 08
◄ Response CMD_SCANSTOP_CNF		02 4A 01 00 00 49
► Reset module A (disable sending beacons), CMD_RESET_REQ	02 00 00 00 02	
◄ Response CMD_RESET_CNF	02 40 01 00 00 43	
◄ Response CMD_GETSTATE_CNF	02 41 02 00 01 01 41	

6.7 Energy-efficient distance estimation solutions

The AMB2621 advertising packet contains the TX power value of the transmitting device. This value in combination with the RSSI value of the received advertising packet can be used to estimate the distance between the modules. Using a suitable triangulation algorithm and multiple receivers or transmitters, a position can be approximated.

The advertising packets can be received by performing a passive scan that will not request the scan response. Thus only one frame, instead of three frames, is transmitted per advertising interval.

Besides the FS_BTMAC of the sending module, the RSSI value and the TX power is outputted in format of a CMD_RSSI_IND message via UART when an advertising packet of another AMB2621 has been received.

To enable this function, the corresponding bit in the RF_BeaconFlags has to be set.

6.8 Configure the module for low power consumption

Depending on the application environment of the AMB2621, the goal is to find the optimal trade-off between the module's performance and its power consumption. Therefore the main settings and operation modes that affect the current consumption are listed below:

- CMD_SLEEP_REQ: This command puts the module into ACTION_SLEEP mode, where it consumes the lowest current (<1µA). In this case both the UART and the BLE interface are shut down.
- CMD_UARTDISABLE_REQ: This command disables the UART interface. It is enabled again as soon as the module is reset/woken or when the module outputs a message e.g. when a connection request has been received or the Wake-up pin of the module was used.
- RF_TXPower: This setting can be used to configure the output power of the module. Reducing the output power saves energy.
- RF_ScanTiming and RF_ScanFactor: These settings define the timing behaviour of the module, when advertising or scanning. The less often the module sends advertising packets or scans, the less current is consumed.
- RF_ConnectionTiming: This setting defines the timing behaviour of the module during connection setup and an established connection. The less often the connected modules communicate with each other, the less current is consumed.
- The on-board nRF52 SoC is running in Debug mode. This will not occur if the pins are connected as described in this manual.

For optimum energy efficiency a user and application specific firmware may be required.

6.9 Start the direct test mode (DTM)

The direct test mode (DTM) enables the test functions described in *Bluetooth* Specification Version 4.0, Vol. 6, Part F. The purpose of DTM is to test the operation of the radio at the physical level, such as:

- transmission power and receiver sensitivity
- frequency offset and drift

- modulation characteristics
- packet error rate
- intermodulation performance

Conformance tests on the nRF52 with the DTM application as the device under test (DUT) are carried out by dedicated test equipment.

To get access to the test functions the `CMD_DTMSTART_REQ` shall be used first. This command restarts the module in direct test mode. A `CMD_GETSTATE_CNF` message (0x02 0x41 0x02 0x00 0x10 0x05 0x54) confirms that the DTM has been started successfully.

Now the `CMD_DTM_REQ` can be used to start and stop the test functions. After a test has been started, it has to be stopped before a next test can be run.

6.9.1 Example: Transmission test on channel 0 with bit pattern 0x0F

The goal of this example is to show how the DTM, and in specific the transmission/reception test, can be run. Here fore we need to connect two modules, start the transmission test on one module and start the reception test on the second module.

In this section, all packet data from or to the modules is given in **hexadecimal notation**.

All steps are described in the following:

1. First restart the modules in DTM mode.

Info	Module A	Module B
► Request `CMD_DTMSTART_REQ` to enable the DTM on module A	02 1D 00 00 1F	
◄ Response `CMD_DTMSTART_CNF` Request understood, try to start DTM now	02 5D 01 00 00 5E	
◄ Indication `CMD_GETSTATE_CNF` Restarted module with DTM enabled	02 41 02 00 10 **05** 54	
► Request `CMD_DTMSTART_REQ` to enable the DTM on module B		02 1D 00 00 1F
◄ Response `CMD_DTMSTART_CNF` Request understood, try to start DTM now		02 5D 01 00 00 5E
◄ Indication `CMD_GETSTATE_CNF` Restarted module with DTM enabled		02 41 02 00 10 **05** 54

2. Now both modules are ready for the DTM. Start the transmission test first.

Info	Module A	Module B
► Request `CMD_DTM_REQ` to start the transmission test on module A with channel 0 and bit pattern 16 times 0x0F	02 1E 04 00 02 00 10 01 0B	
◄ Response `CMD_DTM_CNF` Started test successfully	02 5E 03 00 00 00 00 5F	

3. Start the reception test.

Info	Module A	Module B
► Request `CMD_DTM_REQ` to start the reception test on module B with channel 0 bit pattern 0x0F		02 1E 04 00 01 00 00 01 18
◄ Response `CMD_DTM_CNF` Started test successfully		02 5E 03 00 00 00 00 5F

4. Stop both tests again.

Info	Module A	Module B
► Request `CMD_DTM_REQ` to stop the transmission test	02 1E 04 00 03 00 00 01 1A	
◄ Response `CMD_DTM_CNF` Stopped test successfully	02 5E 03 00 00 80 00 DF	
► Request `CMD_DTM_REQ` to stop the reception test		02 1E 04 00 03 00 00 01 1A
◄ Response `CMD_DTM_CNF` Stopped test successfully, received 0x14FE (5374$_{dec}$) packets		02 5E 03 00 00 **94 FE** 35

During the time the reception and transmission tests were running 5374 data packets have been received by module B, which were transmitted by module A.

7 Timing behaviour

7.1 Reset and sleep

After power-up, resetting the module or waking the module from sleep a `CMD_GETSTATE_CNF` is sent to the serial interface as soon as the module is ready for operation.

Description	typ.	unit
Ready after reset/sleep	4	ms

7.2 BLE timing parameters

The timing parameters for sending advertising packets or scanning are determined by the user settings `RF_ScanTiming`, `RF_ScanFactor` and `RF_AdvertisingTimeout`. Using these settings, the advertising interval, the advertising timeout, the scan interval and the scan window can be configured.

Furthermore, the user setting `RF_ConnectionTiming` allows to configure the timing parameters used during connection setup and connection retention, as well as the connection interval and the connection supervision timeout.

7.3 Connection establishment

The time needed to establish a connection sums up as the time needed to detect the selected peripheral on air and the time needed for connection parameter negotiation and service discovery.

1. Peripheral detection

   To establish a connection, the initiating device (central) waits for an advertising packet, which was sent by the peripheral to which it wants to connect to. As soon as such an advertising packet has been received, the central sends a connection request to the chosen peripheral.

   The time needed to receive this advertising packet strongly depends on the advertising interval of the peripheral as well as on the scan interval and scan window of the central (see `RF_ScanTiming`).

2. Connection parameter negotiation

   After the connection request has been sent the central and peripheral negotiate the timing and security parameters of the connection. To finish this procedure and discover the services of the peripheral several messages have to be sent, whereby only one is sent per connection interval (see `RF_ConnectionTiming`).

Connection type	Estimated number of exchanged messages	Negotiation time for a connection interval of 50ms
Unsecured connection	9-11	450-550ms
Secured connection using predefined long term keys (LTK)	16-18	800-900ms
Secured connection using the pairing method	22-24	1100-1200ms

Knowing the connection interval and the number of messages that will be sent, the time necessary to setup a connection can be estimated by multiplying the number of messages with the connection interval.

7.4 Connection based data transmission

After setting up a connection, data can be transmitted using the CMD_DATA_REQ. It buffers the data in the module and sends it with the next connection interval event. As soon as the data has been transmitted successfully a CMD_TXCOMPLETE_RSP is returned by the UART. The time needed for this coincides with the connection interval that was negotiated during connection setup. The RF_ConnectionTiming parameter defines the minimum and maximum connection interval which is supported by the module.

8 The command interface

The AMB2621 acts as a slave and can be fully controlled by an external host. The configuration as well as the operation of the module can be managed by predefined commands that are sent as telegrams over the UART interface of the module.

The commands of the command interface can be divided into 3 groups:

- Requests: The host requests the module to trigger any action, e.g. in case of the request `CMD_RESET_REQ` the host asks the AMB2621 to perform a reset.
- Confirmations: On each request the module answers with a confirm message to give a feedback on the requested operation status. In case of a `CMD_RESET_REQ`, the module answers with a `CMD_RESET_CNF` to tell the host whether the reset will be performed or not.
- Indications and Responses: The module indicates spontaneously when a special event has occurred. The `CMD_CONNECT_IND` for example indicates that a connection has been established.

All commands have to be of the format as described in Table 3.

If the command contains parameter(s) with a size of more than 1 byte in the Data section these parameters are to be transmitted LSB first, unless notified otherwise in the respective command.

Start signal	Command	Length	Data	Checksum
1 Byte	1 Byte	2 Byte, LSB first	Length Byte	1 Byte

Table 3 Telegram format in the command mode

Start signal:	0x02
Command:	One of the predefined commands
Length:	Specifies the data length in the following and is limited to 120 bytes (unless stated otherwise in the command description) in order to prevent buffer overflow. Length is a 16Bit field with LSB first.
Data:	Variable data or parameters corresponding to the value of the “Data length” field.
Checksum:	Byte wise XOR combination of the preceding fields including the start signal, i.e. 0x02 ^ command ^ Length ^ data byte 0...

If the transmission of the UART command has not finished within the packet transmission duration (depending on the currently selected UART Baud rate) + 5ms after having received the start signal, the module will discard the received bytes and wait for a new command.

This means that the delay between 2 successive bytes in a frame must be kept as low as possible.

Please note that the different commands are only valid in specific module states (see Figure 4).

If a command is not permitted in the current state, the command confirmation returns “Operation not permitted” as a response.

8.1 Scan for other modules in range

8.1.1 CMD_SCANSTART_REQ

This command starts the scan operation to find other AMB2621 in range. All found devices that fit the AMB2621 specification (i.e. devices that support AMBER SPP service UUID) are saved in an internal data base. Before outputting the data base content using the command `CMD_GETDEVICES_REQ`, the scan has to be stopped using `CMD_SCANSTOP_REQ`.

Format:

Start signal	Command	Length	CS
0x02	**0x09**	**0x00 0x00**	**0x0B**

Response (`CMD_SCANSTART_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x49**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will start scan now

0x01: Operation failed

0xFF: Operation not permitted

8.1.2 CMD_SCANSTOP_REQ

This command stops the scan operation that was started using `CMD_SCANSTART_REQ`. It stores the detected AMB2621 `FS_BTMAC` addresses in an internal database, which can be outputted using the `CMD_GETDEVICES_REQ`.

Format:

Start signal	Command	Length	CS
0x02	**0x0A**	**0x00 0x00**	**0x08**

Response (`CMD_SCANSTOP_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x4A**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will stop scan now

0x01: Operation failed

0xFF: Operation not permitted

8.1.3 CMD_GETDEVICES_REQ

This command returns the information about the devices found during the last scan operation. `#Devices` determines the number of devices that have been detected. The corresponding information will be outputted one after the other in the field behind `#Devices` in the `CMD_GETDEVICES_CNF` response. The RSSI and TXPower values are transmitted in the two's complement notation.

Format:

Start signal	Command	Length	CS
0x02	**0x0B**	**0x00 0x00**	**0x09**

Response (`CMD_GETDEVICES_CNF`):

Start signal	Command | 0x40	Length	Status	#Devices	Payload	CS
0x02	**0x4B**	**2 Byte**	**1 Byte**	**1 Byte**	**Length – 2 Byte**	**1 Byte**

The Payload sequentially lists the data of the detected `#Devices` devices. It consists of `#Devices` times the following telegram (see example below).

BTMAC	RSSI	TXPower	Device name length	Device name
6 Bytes	**1 Byte**	**1 Byte**	**1 Byte**	**Device name length bytes**

Status:

0x00: Request received

0x01: Operation failed

0xFF: Operation not permitted

If there are too many devices found to be outputted, the response of the `CMD_GETDEVICES_REQ` is split into several `CMD_GETDEVICES_CNF` messages.

If RSSI = 0x80, there is no value available.

If TXPower = 0x80, there is no value available.

If Device name length = 0, then there is no device name available.

8.1.3.1 Example 1

Request for the `FS_BTMAC` of the devices found during the last scan.

Start signal	Command	Length	CS
0x02	**0x0B**	**0x00 0x00**	**0x09**

Response:

Start signal	Command | 0x40	Length	Status	#Devices	Payload	CS
0x02	**0x4B**	**0x1E 00**	**0x00**	**0x02**	**0x11 0x00 0x00 0xDA 0x18 0x00** **0xE2** **0x04** **0x05** **0x4D 0x4F 0x44 0x20 0x31** **0x55 0x00 0x00 0xDA 0x18 0x00** **0xE5** **0x00** **0x05** **0x4D 0x4F 0x44 0x20 0x32**	**0x11**

During the last scan two devices have been detected:

- Device 1 with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00, RSSI value of 0xE2 (-30 dBm), TXPower of 0x04 (=+4 dBm) and device name of length 5 with the value of 0x4D4F442031 (“MOD 1”).
- Device 2 with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00 and RSSI value of 0xE5 (-27 dBm), TXPower of 0x00 (0 dBm) and device name 0x4D4F442032 (“MOD 2”) of length 5.

8.1.4 CMD_RSSI_IND

This telegram indicates the reception of an advertising packet sent by another AMB2621 module. It can be used to realize a position sensing application. This data can only be received, when the module is in `ACTION_SCANNING` mode (passive scan is sufficient) and the corresponding bit in the `RF_BeaconFlags` is set.

Besides the `FS_BTMAC`, the RSSI value of the advertising packet and the transmission power of the sending device are outputted. Both, the RSSI value and the TX power, are in two's complement notation.

The accuracy is ±2dB when inside the RSSI range of -90 to -20 dB.

The value of the parameter TX Power is read from the content of the received advertise packet.

Start signal	Command	Length	BTMAC	RSSI	TX Power	CS
0x02	**0x8B**	**2 Bytes**	**6 Byte**	**1 Byte**	**1 Byte**	**1 Byte**

8.2 Setup connections

8.2.1 CMD_CONNECT_REQ

This command tries to setup a connection to the AMB2621 which is identified by the `FS_BTMAC` used in the command. After the module prints a `CMD_CONNECT_CNF` to confirm that the request was received, the indication message `CMD_CONNECT_IND` follows which determines whether the connection request was accepted by the other device.

In case of enabled security features (see the setting `RF_SecFlags`) a `CMD_SECURITY_IND` is outputted in addition.

As soon as the connection setup has been completed and all services have been discovered successfully a `CMD_CHANNELOPEN_RSP` is printed by the UART. Now data may be sent using the `CMD_DATA_REQ`.

Format:

Start signal	Command	Length	BTMAC	CS
0x02	**0x06**	**0x06 0x00**	**6 Byte**	**1 Byte**

Response (`CMD_CONNECT_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x46**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, try to connect to the device with the `FS_BTMAC`

0x01: Operation failed

0xFF: Operation not permitted

8.2.2 CMD_CONNECT_IND

This telegram indicates the connection status and the `FS_BTMAC` of the connected device. This indication message is the result of a connection request (`CMD_CONNECT_REQ`).

Start signal	Command	Length	Status	BTMAC	CS
0x02	**0x86**	**0x07 0x00**	**1 Byte**	**6 Byte**	**1 Byte**

Status:

0x00: Physical connection established successfully

0x01: Connection failed, e.g. due to a timeout (as defined by `RF_ScanTiming`)

8.2.3 CMD_SECURITY_IND

This telegram indicates the security status and the `FS_BTMAC` of the connected device. This indication message is the result of a connection request (`CMD_CONNECT_REQ`).

Start signal	Command	Length	Status	BTMAC	CS
0x02	**0x88**	**0x07 0x00**	**1 Byte**	**6 Byte**	**1 Byte**

Status:

0xXY: X security mode, Y security level

- Security Mode 0 Level 0: No access permissions at all
- Security Mode 1 Level 1: No security
- Security Mode 1 Level 2: Encrypted link, no MITM protection
- Security Mode 1 Level 3: MITM protected encrypted link

8.2.4 CMD_CHANNELOPEN_RSP

This command is printed on the UART as soon as connection setup and service discovery has been completed successfully. Now data can be transmitted using the `CMD_DATA_REQ`. Next to the `FS_BTMAC` of the connected device, the maximum payload size that is supported by the link is part of this telegram.

This message is the result of a connection request (`CMD_CONNECT_REQ`).

Format:

Start signal	Command	Length	Status	BTMAC	Max payload	CS
0x02	**0xC6**	**0x08 0x00**	**1 Byte**	**6 Byte**	**1 Byte**	**1 Byte**

Status:

0x00: Success

8.2.5 CMD_DISCONNECT_REQ

This command shuts down the existing connection. Thereafter the module prints a `CMD_DISCONNECT_CNF` to confirm that the request has been received, the indication message `CMD_DISCONNECT_IND` follows which determines whether the disconnection operation has been performed successfully or not.

Format:

Start signal	Command	Length	CS
0x02	**0x07**	**0x00 0x00**	**0x05**

Response (`CMD_DISCONNECT_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x47**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, try to disconnect

0x01: Operation failed

0xFF: Operation not permitted

8.2.6 CMD_DISCONNECT_IND

This telegram indicates that the connection has shut down successfully. This indication message is the result of a disconnection request (`CMD_DISCONNECT_REQ`).

Start signal	Command	Length	Reason	CS
0x02	**0x87**	**0x01 0x00**	**1 Byte**	**1 Byte**

Reason:

0x08: Connection timeout

0x13: User terminated connection

0x16: Host terminated connection

0x3B: Connection interval unacceptable

0x3D: Connection terminated due to MIC failure
(Not able to connect due to bad link quality,
or connection request ignored due to wrong key)

0x3E: Connection setup failed

8.2.7 CMD_PASSKEY_REQ

When receiving a `CMD_PASSKEY_IND` during connection setup, the peripheral requests for a pass key to authenticate the connecting device.

To answer this request the `CMD_PASSKEY_REQ` message has to be sent to the AMB2621 central including the pass key of the peripheral.

The permissible characters of the pass key are ranging from 0x30 to 0x39 (both included) which are ASCII numbers (0-9).

Format:

Start signal	Command	Length	Pass key	CS
0x02	**0x0D**	**0x06 0x00**	**6 Bytes pass key**	**1 Byte**

Response (`CMD_PASSKEY_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x4D**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Pass key accepted and pass key request answered

0x01: Operation failed, due to invalid pass key

0xFF: Operation not permitted

8.2.8 CMD_PASSKEY_IND

Depending on the security settings of the peripheral, a pass key has to be entered on the central side to authenticate the central device. When such a pass key authentication request is received on the central side this `CMD_PASSKEY_IND` message is send to the host. In this case, the pass key has to be entered using the `CMD_PASSKEY_REQ` to successfully finish the connection procedure.

Start signal	Command	Length	Status	BTMAC	CS
0x02	**0x8D**	**0x07 0x00**	**1 Byte**	**6 Byte**	**1 Byte**

Status:

0x00: Success

8.3 Transmit and receive data

8.3.1 CMD_DATA_REQ

This command provides the simple data transfer between two connected modules. Transmission takes place to the previously connected device(s). This command is suitable for transmission for a point-to-point connection. The number of payload data bytes is negotiated during the connection phase. It can be maximal 128 bytes, but at least 19 bytes.

When the data is processed by the module a `CMD_DATA_CNF` is outputted by the UART. Additionally a `CMD_TXCOMPLETE_RSP` will follow as soon as the data has been sent.

The receiving AMB2621 will get a `CMD_DATA_IND` message containing the transmitted payload data.

Format:

Start signal	Command	Length	Payload	CS
0x02	**0x04**	**2 Bytes**	**Length Bytes**	**1 Byte**

Response (`CMD_DATA_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x44**	**2 Bytes**	**Length Bytes**	**1 Byte**

Status:

0x00: Request received, will send data now

0x01 + 0xXX: Operation failed + 0xXX maximum payload size (if it was exceeded)

0xFF: Operation not permitted

8.3.2 CMD_TXCOMPLETE_RSP

This command is outputted to the UART as soon as the data, which was requested by a `CMD_DATA_REQ` has been transmitted successfully.

Format:

Start signal	Command	Length	Status	CS
0x02	**0xC4**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Data transmitted successfully

0x01: Data transmission failed

8.3.3 CMD_DATA_IND

This telegram indicates the reception of data sent by the previously connected device. This indication message is the result of a data request (`CMD_DATA_REQ`) sent to the associated device within a connection.

The `CMD_DATA_IND` returns the `FS_BTMAC` of the sending device, the RSSI value of the received data packet and the data received via the RF-interface which can be found in the payload. The RSSI value is printed in two's complement notation.

Start signal	Command	Length	BTMAC	RSSI	Payload	CS
0x02	**0x84**	**2 Bytes**	**6 Bytes**	**1 Byte**	**Length -7 Byte**	**1 Byte**

8.3.4 CMD_SETBEACON_REQ

This command is used to place user data in the scan response packet. The data is broadcasted frequently without acknowledgement and security. No connection is needed for this mode of operation.

It can be received by any scanning AMB2621 with Beacon-function enabled (see `RF_BeaconFlags`). The receiving module will output a `CMD_BEACON_IND` indication message containing the transmitted data. See chapter 6.5.1.2 for more information.

The number of payload data bytes is limited to 19.

Start signal	Command	Length	Payload	CS
0x02	**0x0C**	**2 Bytes**	**Length bytes**	**1 Byte**

Response (`CMD_SETBEACON_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x4C**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will place data now

0x01: Operation failed

0xFF: Operation not permitted

8.3.5 CMD_BEACON_IND

This telegram indicates the reception of data bytes that have been transmitted in a beacon-packet. This data can only be received, when the module is in `ACTION_SCANNING` mode and the Beacon-function is enabled (see `RF_BeaconFlags`).

The data received via the RF-interface can be found in the payload of the `CMD_BEACON_IND` telegram. Besides this, the `FS_BTMAC` of the sending device and the RSSI value of the data packet are outputted as well. The RSSI value is outputted in two's complement notation.

Start signal	Command	Length	BTMAC	RSSI	Payload	CS
0x02	**0x8C**	**2 Bytes**	**6 Bytes**	**1 Byte**	**Length -7 Byte**	**1 Byte**

8.4 Configuring the module and modifying the device settings

It is strongly recommended to have identical settings on all devices which have to open a connection with each other or are to be used in Beacon mode.

The module's parameters are stored in flash, but have a local copy in RAM. The flash parameters can be modified by the `CMD_SET_REQ`, read by the `CMD_GET_REQ` and retain their content even when resetting the module.

Some of the RAM parameters can be modified by the `CMD_SET_RAM_REQ`, read by the `CMD_GET_RAM_REQ` and their content is replaced by the flash content when resetting the module.

The flash memory has a limited count of write cycles. For periodic modifications try to use the `CMD_SET_RAM_REQ` instead of `CMD_SET_REQ` as each `CMD_SET_REQ` command will use one write cycle.

8.4.1 CMD_SET_REQ

This command enables direct manipulation of the parameters in the module's settings in flash. The respective parameters are accessed by means of the corresponding settings index which can be found in Table 8.

Parameters of 2 or more bytes have to be transferred with the LSB first unless noted differently in the corresponding description.

ℹ The modified parameters only take effect after a restart of the module. This may be done by a `CMD_RESET_REQ` if the module does not restart automatically.

ℹ The flash memory used to store these settings has a limited count of write cycles. Try to avoid performing periodic `CMD_SET_REQ` as each command will use one write cycle.

! Caution: The validity of the specified parameters is not verified. Incorrect values can result in device malfunction!

! To save the parameters in the flash memory of the module, the particular memory segment must first be flushed entirely and then restored from RAM.
If a reset occurs during this procedure, the entire memory area may be corrupted (e.g. due to supply voltage fluctuations).

Recommendation: First verify the configuration of the module with `CMD_GET_REQ` and only then apply a `CMD_SET_REQ` if required to avoid unnecessary flash cycles.

Format:

Start signal	Command	Length	Settings index	Parameter	CS
0x02	**0x11**	**2 Bytes**	**1 Byte**	**Length - 1 Byte**	**1 Byte**

Response (`CMD_SET_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x51**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, settings set successfully

0x01: Operation failed due to invalid parameter

0x04: Serious error, when writing flash. Try to factory reset or reflash the device

0xFF: Operation not permitted

8.4.1.1 Example 1

Setting the advertising time `RF_AdvertisingTimeout` to 180 seconds.

Start signal	Command	Length	Settings index	Parameter	CS
0x02	**0x11**	**0x03 0x00**	**0x07**	**0xB4 0x00**	**0xA3**

Response:

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x51**	**0x01 0x00**	**0x00**	**0x52**

Setting was set successfully.

8.4.1.2 Example 2

Setting the local long term key `RF_OwnLTK` to 0x52 0x63 0x43 0x44 0x34 0x73 0x45.

Start signal	Command	Length	Settings index	Parameter (Length – 1 Byte)	CS
0x02	**0x11**	**0x08 0x00**	**0x05**	**0x52 0x63 0x43 0x44 0x34 0x73 0x45**	**0x2A**

Response:

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x51**	**0x01 0x00**	**0x00**	**0x52**

Long Term Key (LTK) was set successfully.

8.4.2 CMD_GET_REQ

This command can be used to query individual setting parameters in flash. The respective parameters are accessed by means of the corresponding settings index which can be found in Table 8.

Parameters of 2 or more bytes have to be transferred with the LSB first unless noted differently in the corresponding description.

Read access to the memory area outside the setting is blocked.

Format:

Start signal	Command	Length	Settings index	CS
0x02	**0x10**	**0x01 0x00**	**1 Byte**	**1 Byte**

Response (`CMD_GETS_CNF`):

Start signal	Command | 0x40	Length	Status	Parameter	CS
0x02	**0x50**	**2 Bytes**	**1 Byte**	**Length -1 Byte**	**1 Byte**

Status:

0x00: Request received, read out of setting successful

0x01: Operation failed

0xFF: Operation not permitted

8.4.2.1 Example 1

Request the current long term key `RF_OwnLTK`. The size of the key can be up to 16 byte:

Start signal	Command	Length	Settings index	CS
0x02	**0x10**	**0x01 0x00**	**0x05**	**0x16**

Response: The current `RF_OwnLTK` in flash is “AMB_DEFAULT_KEY” (0x41 0x4D 0x42 0x5F 0x44 0x45 0x46 0x41 0x55 0x4C 0x54 0x5F 0x4B 0x45 0x59).

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 Byte)	CS
0x02	**0x50**	**0x10 0x00**	**0x00**	**0x41 0x4D 0x42 0x5F 0x44 0x45 0x46 0x41 0x55 0x4C 0x54 0x5F 0x4B 0x45 0x59**	**0x10**

8.4.3 CMD_SET_RAM_REQ

This command enables direct manipulation of the parameters in the module's settings in RAM. The available parameters are accessed by means of the corresponding settings index which can be found in Table 8.

Parameters of 2 or more bytes have to be transferred with the LSB first unless noted differently in the corresponding description.

❗ Caution: The validity of the specified parameters is not verified. Incorrect values can result in device malfunction!

Format:

Start signal	Command	Length	Settings index	Parameter	CS
0x02	**0x21**	**2 Bytes**	**1 Byte**	**Length - 1 Byte**	**1 Byte**

Response (`CMD_SET_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x61**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, settings set successfully

0x01: Operation failed due to invalid parameter

0xFF: Operation not permitted

8.4.3.1 Example 1

Setting the `RF_PeerLTK` to 0x78 0x56 0x45 0x37 0x78 0x7A 0x41.

Start signal	Command	Length	Settings index	Parameter	CS
0x02	**0x21**	**0x08 0x00**	**0x06**	**0x78 0x56 0x45 0x37 0x78 0x7A 0x41**	**0x32**

Response:

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x61**	**0x01 0x00**	**0x00**	**0x62**

Setting was set successfully.

8.4.4 CMD_GET_RAM_REQ

This command can be used to query individual setting parameters in RAM. The respective parameters are accessed by means of the corresponding settings index which can be found in Table 8.

Parameters of 2 or more bytes have to be transferred with the LSB first unless noted differently in the corresponding description.

Read access to the memory area outside the setting is blocked.

Format:

Start signal	Command	Length	Settings index	CS
0x02	**0x20**	**0x01 0x00**	**1 Byte**	**1 Byte**

Response (`CMD_GETS_CNF`):

Start signal	Command | 0x40	Length	Status	Parameter	CS
0x02	**0x60**	**2 Bytes**	**1 Byte**	**Length -1 Byte**	**1 Byte**

Status:

0x00: Request received, read out of setting successful

0x01: Operation failed

0xFF: Operation not permitted

8.4.4.1 Example 1

Request the `RF_PeerLTK`. The size of the key can be up to 16 byte:

Start signal	Command	Length	Settings index	CS
0x02	**0x20**	**0x01 0x00**	**0x06**	**0x25**

Response: The current key in RAM is 0x78 0x56 0x45 0x37 0x78 0x7A 0x41 .

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 Byte)	CS
0x02	**0x60**	**0x08 0x00**	**0x00**	**0x78 0x56 0x45 0x37 0x78 0x7A 0x41**	**0x75**

8.5 Manage the device state

8.5.1 CMD_GETSTATE_REQ

This command returns the current state of the module.

Please refer to chapter 6 for details on the states of the module.

Format:

Start signal	Command	Length	CS
0x02	**0x01**	**0x00 0x00**	**0x03**

Response (`CMD_GETSTATE_CNF`):

Start signal	Command | 0x40	Length	Module role	Module action	More info (optional field)	CS
0x02	**0x41**	**2 Bytes**	**1 Byte**	**1 Byte**	**Length - 2 bytes**	**1 Byte**

Module role:

0x00: No role

0x01: Peripheral

0x02: Central

0x10: Direct test mode (DTM)

Other: reserved

Module action:

0x00: No action

0x01: Idle (advertising)

0x02: Scanning

0x03: Connected (*More info* is the 6-bytes `FS_BTMAC` address of the connected device)

0x04: Sleep (system-off mode)

0x05: Direct test mode

8.5.1.1 Example 1

Get the current state of the module.

Start signal	Command	Length	CS
0x02	**0x01**	**0x00 0x00**	**0x03**

Response:

Start signal	Command | 0x40	Length	Module role	Module action	More info (Length - 2 byte)	CS
0x02	**0x41**	**0x08 0x00**	**0x02**	**0x03**	**0x11 0x00 0x00 0xDA 0x18 0x00**	**0x99**

The module is connected to another module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00.

8.5.2 CMD_RESET_REQ

This command triggers a software reset of the module.

Format:

Start signal	Command	Length	CS
0x02	**0x00**	**0x00 0x00**	**0x02**

Response (`CMD_RESET_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x40**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will perform reset now

0x01: Operation failed

0xFF: Operation not permitted

8.5.3 CMD_SLEEP_REQ

This command is used to start the system-off mode (`ACTION_SLEEP`). After entering this mode, the module has to be woken up using the Wake-up pin (apply a low signal at this for at least 5ms and release it to high again) before any other action can be performed. The UART interface as well as the BLE interface are shut down in this mode. For more details please see also chapter 6.3.

Format:

Start signal	Command	Length	CS
0x02	**0x02**	**0x00 0x00**	**0x00**

Response (CMD_SLEEP_CNF):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x42**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will go to sleep now

0x01: Operation failed

0xFF: Operation not permitted

Please note that the Wake-up pin has a second function. If the module is not in ACTION_SLEEP mode and the UART was disabled using the CMD_UARTDISABLE_REQ, the UART can be re-enabled by applying a low signal at this for at least 5ms and releasing it again to high. In this case the module answers with a CMD_UARTENABLE_IND.

8.5.4 CMD_SLEEP_IND

This indication is send by the module when the RF_AdvertisingTimeout has expired without a connection to the module.

Indication (CMD_SLEEP_IND):

Start signal	Command | 0x80	Length	Status	CS
0x02	**0x82**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Advertising Timeout detected, will go to sleep now

8.5.5 CMD_FACTORYRESET_REQ

This command triggers a factory reset of the module. First the default User Settings are restored, then the module is reset.

Format:

Start signal	Command	Length	CS
0x02	**0x1C**	**0x00 0x00**	**0x1E**

Response (`CMD_FACTORYRESET_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x5C**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will perform reset now

0x01: Operation failed

0xFF: Operation not permitted

To save the parameters in the flash memory of the module, the particular memory segment must first be flushed entirely and then restored from RAM.
If a reset occurs during this procedure (e.g. due to supply voltage fluctuations), **the entire memory area may be destroyed**.

During start-up of the device, the user settings memory is checked for consistency. In case of inconsistency (e.g. the memory was erased) the device will perform a factory reset.

8.5.6 CMD_UARTDISABLE_REQ

This command disables the UART of the module. It will be re-enabled when the module has to send data to the host (e.g. data was received via RF or a state is indicated) or if the Wake-up pin is used (hold at least 5ms low before releasing). In this case either the received data or a `CMD_UARTENABLE_IND` is transmitted by the module. Afterwards the UART will stay active until another `CMD_UARTDISABLE_REQ` or `CMD_SLEEP_REQ` or a timer triggered sleep event occurs.

Format:

Start signal	Command	Length	CS
0x02	**0x1B**	**0x00 0x00**	**0x19**

Response (`CMD_UARTDISABLE_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x5B**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will disable UART now

0x01: Operation failed

0xFF: Operation not permitted

We insistently recommend to disable the UART using this command only, if it is foreseeable that there will be no UART communication for several seconds! Use cases could be during advertising phase to wait for connecting BLE devices or when broadcasting data via Beacons.

Disabling the UART peripheral of the module results in a reduction of current consumption of about 1,15mA.

Please note that the Wake-up pin has a second function. If the module is in `ACTION_SLEEP` mode, this pin wakes up the module by applying a low signal at this for at least 5ms and releasing it again to high. In this case the module answers with a `CMD_GETSTATE_CNF`.

8.5.7 CMD_UARTENABLE_IND

This indication is shown when the UART of the module is re-enabled (after performing a `CMD_UARTDISABLE_REQ` followed by using the Wake-up pin). After receiving this message the UART can be used for any operation again.

Indication:

Start signal	Command	Length	Status	CS
0x02	**0x9B**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: UART has been re-enabled successfully

8.5.8 CMD_BOOTLOADER_REQ

This command resets the module and starts the OTA bootloader.

Use this command with caution. Please refer to chapter 10 on how to use the bootloader for a firmware update.

Please note that you can only exit the bootloader mode by performing a hardware reset using the respective pin.

❗ The bootloader mode will also be enabled if the firmware image is marked “invalid” or if the BOOT pin logic level (set by the host) is set to start the bootloader during start-up of the module.

Format:

Start signal	Command	Length	CS
0x02	**0x1F**	**0x00 0x00**	**0x1D**

Response (`CMD_BOOTLOADER_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x5F**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will start bootloader now

0x01: Operation failed

0xFF: Operation not permitted

8.6 Run the Bluetooth test modes

The test modes “DTM” as specified by the Bluetooth SIG are defined in the Bluetooth Core specification v4.0 Volume 6.

8.6.1 CMD_DTMSTART_REQ

This command restarts the module in direct test mode (DTM). When starting in DTM mode, a `CMD_GETSTATE_CNF` message (0x02 0x41 0x02 0x10 0x05 0x54) follows which indicates that the test mode has been enabled successfully. Now the `CMD_DTM_REQ` can be used to start and stop various test modes.

As soon as the module is reset, the DTM will be left again and normal operations can be performed.

Performing a reset will leave the DTM and restart the module in the IDLE state.

Format:

Start signal	Command	Length	CS
0x02	**0x1D**	**0x00 0x00**	**0x1F**

Response (`CMD_DTMSTART_CNF`):

Start signal	Command | 0x40	Length	Status	CS
0x02	**0x5D**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x00: Request received, will enable DTM now

0x01: Operation failed

0xFF: Operation not permitted

8.6.2 CMD_DTM_REQ

This command starts and stops various test modes. To be able to run these test modes, the DTM has to be enabled first using the `CMD_DTMSTART_REQ`. After a test has been started, it has to be stopped first before a next test can be run.

The default TXPower value is 0 dBm (0x00), the allowed range is from -40 up to +4 dBm in steps of 4dB (see chapter 9.1.18).

The valid range for Channel (or Vendor option in case of Vendor Command = Carrier Test) is 0…39 (0x00 to 0x27).

Format:

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**1 Byte**	**1 Byte**	**1 Byte**	**1 Byte**	**1 Byte**

Command code:

0x00: DTM reset (note: this command does not perform a module reset.

0x01: Start RX test

0x02: Start TX test

0x03: Stop last test

Payload:

0x00: Bit pattern PRBS9

0x01: Bit pattern 0x0F

0x02: Bit pattern 0x55

0x03: Vendor specific

Payload ≠ Vendor specific (0x00, 0x01 or 0x02)	Payload = Vendor specific (0x03)
Length / Vendor Command: Length of the packet to send	**Length / Vendor Command**: 0x00: Carrier test 0x02: Set transmission power
Channel: Frequency = (2402 + Channel * 2) MHz to be used for RX/TX	**Vendor option:** (dependant on used “Vendor command”) Frequency = (2402 + [Vendor option] * 2) MHz or [Vendor option] := TXPower (in two’s complement notation) in steps of 4dB

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**2 Bytes**	**1 Byte**	**0-2 Byte**	**1 Byte**

Status:

0x00: Request received

0x01: Operation failed

0x03: Busy

0xFF: Operation not permitted

Result:

0x0000: Test success

0x0001: Test error

0x8000 + n: Received n packets during RX test

See example in chapter 6.9.1.

8.6.2.1 Example: Transmission, 16 times 0x0F, channel 0

Start the transmission test on channel 0 (2402 MHz). The packets consist of 16 times 0x0F:

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**0x02**	**0x00**	**0x10**	**0x01**	**0x0B**

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**0x03 0x00**	**0x00**	**0x00 0x00**	**0x5F**

Test started successfully.

Stop the test again:

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**0x03**	**0x00**	**0x00**	**0x01**	**0x0B**

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**0x03 0x00**	**0x00**	**0x80 0x00**	**0xDF**

Test stopped successfully and received 0 packets.

8.6.2.2 Example: Receiver, 0x0F, channel 0

Start the reception test on channel 0 (2402MHz) with bit pattern 0x0F:

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**0x01**	**0x00**	**0x00**	**0x01**	**0x18**

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**0x03 0x00**	**0x00**	**0x00 0x00**	**0x5F**

Test started successfully.

In between we started the transmission test (see chapter 8.6.2.1) on a second module. When we stop RX test now, we can count the received packets from the transmitting module.

Stop the test again:

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**0x03**	**0x00**	**0x00**	**0x01**	**0x0B**

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**0x03 0x00**	**0x00**	**0x0E 0x67**	**0x36**

Test stopped successfully and received 0x0E67 (3687_{dec}) packets.

8.6.2.3 Example: Transmission, carrier test, channel 0

Start the carrier test on channel 0 (2402MHz). We need to use a vendor specific command:

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**0x02**	**0x00**	**0x00**	**0x03**	**0x19**

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**0x03 0x00**	**0x00**	**0x00 0x00**	**0x5F**

Test started successfully.

See example 8.6.2.1 to stop the test again.

8.6.2.4 Example: Set TXPower to -4 dBm

Set the TXPower to -4dBm (0xFC in two’s complement notation):

Start signal	Command	Length	Command code	Channel / Vendor option	Length / Vendor command	Payload	CS
0x02	**0x1E**	**0x04 0x00**	**0x02**	**0xFC**	**0x02**	**0x03**	**0xE7**

Response (`CMD_DTM_CNF`):

Start signal	Command | 0x40	Length	Status	Result	CS
0x02	**0x5E**	**0x03 0x00**	**0x00**	**0x00 0x00**	**0x5F**

Set value successful.

8.7 Other messages

8.7.1 CMD_ERROR_IND

This indication is shown when the module entered an error state.

Indication:

Start signal	Command	Length	Status	CS
0x02	**0xA2**	**0x01 0x00**	**1 Byte**	**1 Byte**

Status:

0x01: `UART_COMMUNICATION_ERROR`

The UART had a buffer overflow. Thus UART TX and RX was aborted and UART has restarted. Please restart module if UART is still malfunctioning.

8.8 Message overview

Start signal	CMD	Message name	Short description	Chapter
Requests				
0x02	0x00	CMD_RESET_REQ	Reset the module	8.5.2
0x02	0x01	CMD_GETSTATE_REQ	Request the current module state	8.5.1
0x02	0x02	CMD_SLEEP_REQ	Go to sleep	8.5.3
0x02	0x04	CMD_DATA_REQ	Send data to the connected device	8.3.1
0x02	0x06	CMD_CONNECT_REQ	Setup a connection with another device	8.2.1
0x02	0x07	CMD_DISCONNECT_REQ	Close the connection	8.2.5
0x02	0x09	CMD_SCANSTART_REQ	Start scan	8.1.1
0x02	0x0A	CMD_SCANSTOP_REQ	Stop scan	8.1.2
0x02	0x0B	CMD_GETDEVICES_REQ	Request the scanned/detected devices	8.1.3
0x02	0x0C	CMD_SETBEACON_REQ	Place data in scan response packet	8.3.4
0x02	0x0D	CMD_PASSKEY_REQ	Respond to a pass key request	8.2.7
0x02	0x10	CMD_GET_REQ	Read the module settings in flash	8.4.2
0x02	0x11	CMD_SET_REQ	Modify the module settings in flash	8.4.1
0x02	0x1B	CMD_UARTDISABLE_REQ	Disable the UART	8.5.6
0x02	0x1C	CMD_FACTORYRESET_REQ	Perform a factory reset	8.5.5
0x02	0x1D	CMD_DTMSTART_REQ	Enable the direct test mode	8.6.1
0x02	0x1E	CMD_DTM_REQ	Start/stop a test of the direct test mode	8.6.2
0x02	0x1F	CMD_BOOTLOADER_REQ	Switch to the bootloader	8.5.8
0x02	0x20	CMD_GET_RAM_REQ	Read the module settings in RAM	8.4.4
0x02	0x21	CMD_SET_RAM_REQ	Modify the module settings in RAM	8.4.3
Confirmations				
0x02	0x40	CMD_RESET_CNF	Reset request received	8.5.2
0x02	0x41	CMD_GETSTATE_CNF	Return the current module state	8.5.1
0x02	0x42	CMD_SLEEP_CNF	Sleep request received	8.5.3
0x02	0x44	CMD_DATA_CNF	Data transmission request received	8.3.1
0x02	0x46	CMD_CONNECT_CNF	Connection setup request received	8.2.1
0x02	0x47	CMD_DISCONNECT_CNF	Disconnection request received	8.2.5
0x02	0x49	CMD_SCANSTART_CNF	Scan started	8.1.1
0x02	0x4A	CMD_SCANSTOP_CNF	Scan stopped	8.1.2
0x02	0x4B	CMD_GETDEVICES_CNF	Output the scanned/detected devices	8.1.3
0x02	0x4C	CMD_SETBEACON_CNF	Data is placed in scan response packet	8.3.4
0x02	0x50	CMD_GET_CNF	Return the requested module flash settings	8.4.2
0x02	0x51	CMD_SET_CNF	Module flash settings have been modified	8.4.1
0x02	0x5B	CMD_UARTDISABLE_CNF	Disable UART request received	8.5.6
0x02	0x5C	CMD_FACTORYRESET_CNF	Factory reset request received	8.5.5
0x02	0x5D	CMD_DTMSTART_CNF	Enable the direct test mode now	8.6.1
0x02	0x5E	CMD_DTM_CNF	Test of direct test mode started/stopped	8.6.2
0x02	0x5F	CMD_BOOTLOADER_CNF	Will switch to bootloader now	8.5.8
0x02	0x60	CMD_GET_RAM_CNF	Return the requested module RAM settings	8.4.4
0x02	0x61	CMD_SET_RAM_CNF	Module RAM settings have been modified	8.4.3
Indications				

0x02	0x82	CMD_SLEEP_IND	State will be changed to ACTION_SLEEP	8.5.4
0x02	0x84	CMD_DATA_IND	Data has been received	8.3.3
0x02	0x86	CMD_CONNECT_IND	Connection established	8.2.2
0x02	0x87	CMD_DISCONNECT_IND	Disconnected	8.2.6
0x02	0x88	CMD_SECURITY_IND	Secured connection established	8.2.3
0x02	0x8B	CMD_RSSI_IND	Advertising package detected	8.1.4
0x02	0x8C	CMD_BEACON_IND	Received Beacon data	8.3.5
0x02	0x8D	CMD_PASSKEY_IND	Received a pass key request	8.2.8
0x02	0x9B	CMD_UARTENABLE_IND	UART was re-enabled	8.5.7
0x02	0xA2	CMD_ERROR_IND	Entered error state	8.7.1
0x02	0xC4	CMD_TXCOMPLETE_RSP	Data has been sent	8.3.2
0x02	0xC6	CMD_CHANNELOPEN_RSP	Channel open, data transmission possible	8.2.4

Table 4 Message overview

9 User settings

The settings described in this chapter are stored permanently in the module's flash memory. Depending on their corresponding permissions, their current values can be read out by the `CMD_GET_REQ` command or modified by the `CMD_SET_REQ` command. To do so the corresponding settings index is used, which can be found in the primary table of each setting description.

This settings cannot be accessed (read, write) from the *Peripheral only mode* introduced in a fallow-up chapter.

❗ The validity of the specified parameters is not verified. Incorrect values can result in device malfunction.

❗ After the modification of the non-volatile parameters, a reset will be necessary for the changes to be applied.

9.1.1 FS_DeviceInfo: Read the chip type and OS version

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
15	`FS_DeviceInfo`	-	-	read	Flash	12

This setting contains information about the chip type and the OS version. The value of `FS_DeviceInfo` is composed of the following 4 sub parameters (ordered by appearance in the response):

OS version	Build code	Package variant	Chip ID
2 Byte	4 Byte	2 Byte	4 Byte

OS version:

0x0081 : Softdevice S132 2.0.0

0x0088 : Softdevice S132 2.0.1

0x008C : Softdevice S132 3.0.0

0x0091 : Softdevice S132 3.1.0

Build code:

ASCII coded (see following Table nRF52832 IC revision overview)

Package variant:

0x2000 : QF

0x2002 : CI

Chip ID:

0x00052832 : nRF52832

nRF52832 IC revision overview				
Packet variant	Build code	Package	Flash size	RAM size
QF	AAB0	QFN48	512 kB	64 kB
QF	ABB0	QFN48	256 kB	32 kB
CI	**AABA**	**WLCSP**	**512 kB**	**64 kB**

9.1.1.1 Example 1

Request the device info of the module using `CMD_GET_REQ` with settings index 15

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x0F	0x1C

Response `CMD_GET_CNF`: Successfully read out the device info (with byte order changed to MSB first):

OS version = **0x0088** (Softdevice S132 2.0.1)

Build code = 0x41414241 (AABA)

Package variant = **0x2002** (CI)

Chip ID = 0x00052832

Please note that LSB is transmitted first in case of parameters with more than one byte length.

Start signal	Command | 0x40	Length	Status	Parameter (Length - 1 byte)	CS
0x02	0x50	0x0D 0x00	0x00	**0x88 0x00** 0x41 0x42 0x41 0x41 **0x02 0x20** 0x32 0x28 0x05 0x00	0xE9

9.1.2 FS_FWVersion: Read the firmware version

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
1	FS_FWVersion	-	-	read	Flash	3

This setting contains the firmware version of the module.

9.1.2.1 Example 1

Request the firmware version of the module using CMD_GET_REQ with settings index 1.

The firmware version consists of a 3 byte parameter.

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x01	0x12

Response CMD_GET_CNF: Successfully read out the firmware version, for this example it is 0x000001 so “1.0.0” (with the parameter reverted to MSB first).

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 Byte)	CS
0x02	0x50	0x04 0x00	0x00	0x00 0x00 0x01	0x57

9.1.3 RF_DeviceName: Modify the device name

This parameter is using MSB first notation.

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
2	`RF_DeviceName`	See description	“A2621”	read/write	Flash	1-5

This parameter determines the name of the module which is used in the advertising packets to identify the module on air. The permissible characters are in the range of 0x20 – 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

The maximum size of this setting is 5 byte (due to packet size restrictions of BLE advertise packets a longer name does not fit).

9.1.3.1 Example 1

Set the device name of the module to 0x4D 0x4F 0x44 0x20 0x31 = “MOD 1” using `CMD_SET_REQ` with settings index 2.

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x06 0x00	0x02	0x4D 0x4F 0x44 0x20 0x31	0x40

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.3.2 Example 2

Request the device name of the module using `CMD_GET_REQ` with settings index 2

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x02	0x11

Response `CMD_GET_CNF`: Successfully read out the module name

0x41 0x32 0x36 0x32 0x31 = “A2621”

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x06 0x00	0x00	0x41 0x32 0x36 0x32 0x31	0x12

9.1.4 FS_MAC: Read the MAC address

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
3	FS_MAC	-	-	read	Flash	6

This setting contains the unique MAC address of the module.

9.1.4.1 Example 1

Request the MAC address of the module using CMD_GET_REQ with settings index 3

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x03	0x10

Response CMD_GET_CNF: Successfully read out the MAC address 0x55 0x93 0x19 0x6E 0x5B 0x87

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x07 0x00	0x00	0x55 0x93 0x19 0x6E 0x5B 0x87	0x38

9.1.5 FS_BTMAC: Read the BLE conform MAC address

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
4	FS_BTMAC	-	-	read	Flash	6

This setting contains the BLE conform MAC address of the module. The FS_BTMAC is introduced and used to find the respective device on the RF-interface. It consists of the Amber wireless company ID 0x0018DA followed by the FS_SerialNumber of the module. Please note that LSB is transmitted first in all commands.

9.1.5.1 Example 1

Request the Bluetooth-conform MAC of the module using CMD_GET_REQ with settings index 4

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x04	0x17

Response CMD_GET_CNF: Successfully read out the BLE conform MAC address

0x11 0x00 0x00 **0xDA 0x18 0x00**.

Accordingly, the FS_SerialNumber of this module is 0x000011 (17 decimal).

Start signal	Command | 0x40	Length	Status	Parameter (Length - 1 byte)	CS
0x02	0x50	0x07 0x00	0x00	0x11 0x00 0x00 0xDA 0x18 0x00	0x86

9.1.6 FS_SerialNumber: Read the serial number of the module

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
16	`FS_SerialNumber`	-	-	read	Flash	3

This setting contains the serial number of the module.

9.1.6.1 Example 1

Request the serial number of the module using `CMD_GET_REQ` with settings index 16

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x10	0x03

Response `CMD_GET_CNF`: Successfully read out the serial number, it is 0.0.11

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x04 0x00	0x00	0x11 0x00 0x00	0x57

9.1.7 RF_OwnLTK: Modify the security key of the current device

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
5	`RF_OwnLTK`	See description	“AMB_ DEFAULT _KEY”	read/write	Flash	7-16

This setting determines the long term key of the current module. In security mode “LTK” (see `RF_SecFlags`), this key is used, when another device sets up an encrypted connection to the current module. The key used by the peer device must coincide with the `RF_OwnLTK` to setup an encrypted connection. Otherwise, the connection request is refused.

The permissible characters are ASCII characters ranging from (hexadecimal) 0x21 to 0x7E (both included) which are special characters, alphabetic characters (a-z and A-Z) and numbers (0-9).

Please refer to your preferred ASCII table for reference of all allowed characters and use 0x21 and 0x7E to find the allowed range of characters.

9.1.7.1 Example 1

Set the own long term key of the module to 0x78 0x56 0x45 0x37 0x78 0x7A 0x41 = “xVE7xzA” using `CMD_SET_REQ` with settings index 5

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x08 0x00	0x05	0x78 0x56 0x45 0x37 0x78 0x7A 0x41	0x01

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.7.2 Example 2

Request the own long term key of the module using `CMD_GET_REQ` with settings index 5

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x05	0x16

Response `CMD_GET_CNF`: Successfully read out the key as 0x41 0x4D 0x42 0x5F 0x44 0x45 0x46 0x41 0x55 0x4C 0x54 0x5F 0x4B 0x45 0x59 = “AMB_DEFAULT_KEY”

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x10 0x00	0x00	0x41 0x4D 0x42 0x5F 0x44 0x45 0x46 0x41 0x55 0x4C 0x54 0x5F 0x4B 0x45 0x59	0x10

9.1.8 RF_PeerLTK: Modify the security key to setup connections

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
6	`RF_PeerLTK`	See description	"AMB_DEFAULT_KEY"	read/write	Flash / RAM	7-16

This setting determines the long term key that is used to setup an encrypted connection to another device, when security mode "LTK" (see `RF_SecFlags`) was selected. The key used by the peer device must coincide with the `RF_PeerLTK` to setup an encrypted connection. Otherwise, the connection request is refused.

The permissible characters are ASCII characters ranging from (hexadecimal) 0x21 to 0x7E (both included) which are special characters, alphabetic characters (a-z and A-Z) and numbers (0-9).

Please refer to your preferred ASCII table for reference of all allowed characters and use 0x21 and 0x7E to find the allowed range of characters.

9.1.8.1 Example 1

Set the peer long term key of the module to 0x78 0x56 0x45 0x37 0x78 0x7A 0x41 = "xVE7xzA" using `CMD_SET_REQ` with settings index 6

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x08 0x00	0x06	0x78 0x56 0x45 0x37 0x78 0x7A 0x41	0x02

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.8.2 Example 2

Request the peer long term key of the module using `CMD_GET_REQ` with settings index 6

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x06	0x15

Response CMD_GET_CNF: Successfully read out the key as 0x41 0x4D 0x42 0x5F 0x44 0x45 0x46 0x41 0x55 0x4C 0x54 0x5F 0x4B 0x45 0x59 = "AMB_DEFAULT_KEY"

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x10 0x00	0x00	0x41 0x4D 0x42 0x5F 0x44 0x45 0x46 0x41 0x55 0x4C 0x54 0x5F 0x4B 0x45 0x59	0x10

9.1.9 RF_StaticPasskey: Modify the static pass key to setup connections

Setting s index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
18	`RF_StaticPasskey`	See description	“12312 3”	read/write	Flash / RAM	6

This setting determines the static pass key of the peripheral device used for authentication. If the static pass key security mode is enabled by the peripheral, this key must be entered in the central device. In case of an AMB2621 central, the command to enter this pass key during connection setup is the `CMD_PASSKEY_REQ`.

The permissible characters are ranging from 0x30 to 0x39 (both included) which are ASCII numbers (0-9). This is due to the fact that mobile phones prefer numbers only for the passkey.

9.1.9.1 Example 1

Set the static pass key of the module to 0x31 0x32 0x33 0x34 0x35 0x36 = “123456” using `CMD_SET_REQ` with settings index 18

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x07 0x00	0x12	0x31 0x32 0x33 0x34 0x35 0x36	0x01

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.9.2 Example 2

Request the static pass key of the module using `CMD_GET_REQ` with settings index 18

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x12	0x01

Response `CMD_GET_CNF`: Successfully read out the key as 0x31 0x32 0x33 0x34 0x35 0x36 = “123456”

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x07 0x00	0x00	0x31 0x32 0x33 0x34 0x35 0x36	0x52

9.1.10 RF_SecFlags: Modify the security settings

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
12	`RF_SecFlags`	See description	0	read/write	Flash	1

This 8-bit field configures security settings of the module. Chapter 6.5.1 contains further information about secure connections.

ℹ When connecting from an AMB2621 to another AMB2621, be sure that the same security mode is used.

ℹ When connecting from a foreign device to an AMB2621, the peripheral (AMB2621) determines the minimum security level needed for communication. So configure the `RF_SecFlags` of the peripheral to set the desired security level.

<table>
<tr><th>Bit no.</th><th colspan="3">Description</th></tr>
<tr><td rowspan="6">2 : 0</td><td colspan="3">Security mode configuration. Depending on its value, different modes are chosen when setting up a secure connection.
In firmware version 2.1.0 and newer the peripheral decides which is the minimum security level to access its data.</td></tr>
<tr><td>0x0</td><td>No security</td><td>Data is transmitted without authentication and encryption.</td></tr>
<tr><td>0x1</td><td>LTK
Level 1.3</td><td>A fixed long term key (LTK) is used for encrypting the data. This key is not exchanged by the RF-interface and has to correlate on both of the connected devices. If the keys do not match, the connection will be rejected.
This mode is only available/recommended for the connection between two AMB2621 modules. When communicating to a foreign device, please use another security mode.</td></tr>
<tr><td>0x2</td><td>Just works
Level 1.2</td><td>Each time a connection is established, new random keys are exchanged in advance to use them for data encryption. This mode uses the “just works” method.</td></tr>
<tr><td>0x3</td><td>Static pass key
Level 1.3</td><td>For authentication the `RF_StaticPasskey` is used. If the peripheral uses this method, the central device must enter the correct pass key to finalize the connection.</td></tr>
<tr><td>others</td><td></td><td>Reserved</td></tr>
<tr><td>15 : 3</td><td colspan="3">Reserved</td></tr>
</table>

Table 5 Security configuration flags

9.1.10.1 Example 1

Set the security flags to 0x01, to use the long term key for transmission encryption, using `CMD_SET_REQ` with settings index 12

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x02 0x00	0x0C	0x01	0x1C

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.10.2 Example 2

Request the security flags of the module using `CMD_GET_REQ` with settings index 12

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x0C	0x1F

Response `CMD_GET_CNF`: Successfully read out the value 2, which means that the pairing mode is enabled.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x02	0x52

9.1.11 RF_SecFlagsPerOnly: Modify the security settings (Peripheral only mode)

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
44	`RF_SecFlags`	See description	3	read/write	Flash	1

Please refer to the setting `RF_SecFlags` for more details.

This setting is only used in peripheral only mode.

9.1.11.1 Example 1

Set the security flags to 0x02 to use the just works pairing, using `CMD_SET_REQ` with settings index 12

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x02 0x00	0x2C	0x02	0x3F

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.11.2 Example 2

Request the security flags of the module using `CMD_GET_REQ` with settings index 44

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x2C	0x3F

Response `CMD_GET_CNF`: Successfully read out the value 2, which means that the pairing mode is enabled.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x02	0x52

9.1.12 RF_ScanFlags: Modify the scan behaviour

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
13	`RF_ScanFlags`	See description	0	read/write	Flash	1

This 8-bit field configures the scan behaviour of the module. To use multiple settings, add the bit numbers and choose the result as value for `RF_ScanFlags`.

Bit no.	Description
0	If this bit is set, an active scan is performed when using `CMD_SCANSTART_REQ`. In this case, after receiving an advertising packet a scan request is send to the advertising module that returns a scan response containing additional information. For the communication of AMB2621 modules, active scanning is only needed when using Beacons. In this case, it is enabled automatically by the firmware. Please note that active scanning increases the current consumption.
15 : 1	Reserved

Table 6 Scan configuration flags

9.1.12.1 Example 1

Set the scan flags to 0x01 to enable active scanning using `CMD_SET_REQ` with settings index 13

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x02 0x00	0x0D	0x01	0x1D

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.12.2 Example 2

Request the scan flags of the module using `CMD_GET_REQ` with settings index 13

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x0D	0x1E

Response `CMD_GET_CNF`: Successfully read out the value 0, which means that active scan is disabled.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x00	0x50

9.1.13 RF_BeaconFlags: Interpret the advertising data

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
14	`RF_BeaconFlags`	See description	0	read/write	Flash	1

This 8-bit field enables/disables the reception of Beacons. To use multiple settings, add the bit numbers and choose the result as value for `RF_BeaconFlags`.

<table>
<tr><th>Bit no.</th><th>Description</th></tr>
<tr><td>1 : 0</td><td>Enable/disable the reception of Beacons. To avoid too much traffic on the UART, we recommend to use the filtered version.
<table>
<tr><td>00</td><td>0x0</td><td>Reception of Beacons disabled.</td></tr>
<tr><td>01</td><td>0x1</td><td>Receive all Beacons from AMB2621 devices in range. Each received packet is interpreted and outputted by the UART.
In this case, active scanning is performed which increases the current consumption.
To decrease the work load of the receiving module, use a sufficiently high UART baud rate at the receiving device and slow advertising intervals at the sending devices.</td></tr>
<tr><td>11</td><td>0x3</td><td>Same as ‘01’ plus additional filter. This filter discards redundant packets that contain the same content.</td></tr>
</table>
</td></tr>
<tr><td>2</td><td>If this bit is set, a <code>CMD_RSSI_IND</code> message is outputted each time when an advertising packet with AMBER UUID is received. This feature can be used to realize a position sensing application, since the <code>CMD_RSSI_IND</code> contains the current TX power level and the current RSSI value besides the <code>FS_BTMAC</code> of the sending device.
To decrease the work load of the receiving module, please use a sufficiently high UART baud rate at the receiving device and slow advertising intervals at the sending devices.</td></tr>
<tr><td>15 : 3</td><td>Reserved</td></tr>
</table>

Table 7 Beacon configuration flags

ℹ The internal database of the module may host the advertising data of 25 different devices. If the data base is full, the oldest entry is removed.

ℹ To avoid too much traffic the usage of slow advertising intervals is recommended.

9.1.13.1 Example 1

Set the Beacon flags to 0x04 using `CMD_SET_REQ` with settings index 14. Thus when an advertising packet with AMBER UUID is received, a `CMD_RSSI_IND` message is printed.

Start signal	Command	Length	Settings index	Parameter	CS
0x02	0x11	0x02 0x00	0x0E	0x04	0x1B

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.13.2 Example 2

Request the Beacon flags of the module using `CMD_GET_REQ` with settings index 14

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x0E	0x1D

Response `CMD_GET_CNF`: Successfully read out the value 3, which means that the reception of Beacons is enabled and double packets are filtered by the module.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x03	0x53

9.1.14 RF_AdvertisingTimeout: Modify the advertising timeout

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
7	RF_AdvertisingTimeout	0 (infinite) 1 – 65535	0	read/write	Flash	2

This parameter defines the time in seconds after which the advertising of the module stops. If no peer connects before this timeout, advertising stops and the module goes to system-off mode.

If the RF_AdvertisingTimeout is set to 0, the module advertises infinitely.

To ensure that the module sends a sufficient amount of advertising packets per RF_AdvertisingTimeout, please also check the RF_ScanTiming parameter, which defines the frequency of advertising packets.

9.1.14.1 Example 1

Set the advertising timeout parameter to 0x00 0xB4 (180s) using CMD_SET_REQ with settings index 7.

Start signal	Command	Length	Settings index	Parameter	CS
0x02	0x11	0x03 0x00	0x07	0xB4 0x00	0xA3

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.14.2 Example 2

Request the advertising timeout of the module using CMD_GET_REQ with settings index 7

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x07	0x14

Response CMD_GET_CNF: Successfully read out the value 0x00 0x00 = 0s, which indicates indefinite advertising.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x03 0x00	0x00	0x00 0x00	0x51

9.1.15 RF_ScanFactor: Modify the scan factor

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
10	`RF_ScanFactor`	1 – 10	2	read/write	Flash	1

This parameter defines the factor between the scan window and the scan interval. See `RF_ScanTiming` for more information.

Example: Let's assume that the scan window is 50ms, the `RF_ScanFactor` is 3, then the module scans for 50ms on a fixed channel, enters a suspend mode (system-on mode) for 100ms (3•50ms - 50ms), switches the channel, again scans for 50ms and so on.

The larger the `RF_ScanFactor`, the less time the module scans and thus the less power is consumed, but also the more difficult it is to detect other BLE devices on air.

9.1.15.1 Example 1

Set the scan factor to 0x03 using `CMD_SET_REQ` with settings index 10.

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x02 0x00	0x0A	0x03	0x18

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.15.2 Example 2

Request the scan factor of the module using `CMD_GET_REQ` with settings index 10

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x0A	0x19

Response `CMD_GET_CNF`: Successfully read out the value 2.

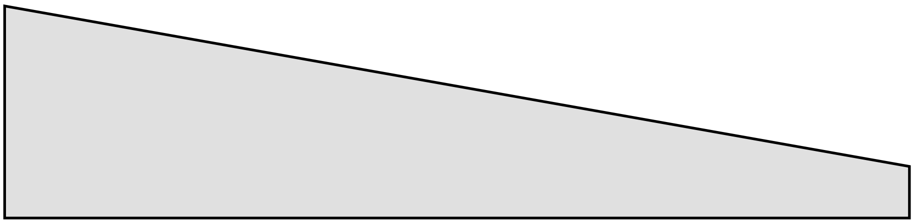
Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x02	0x52

9.1.16 RF_ScanTiming: Modify the scan timing settings

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
9	RF_ScanTiming	0 – 5	1	read/write	Flash	1

The RF_ScanTiming enables the possibility to configure the timing behaviour of the module's RF interface during advertising and scanning state. Using this parameter several predefined configurations can be chosen, which include timing parameters, such as the frequency of advertising packets and the length of a scan window.

The choice of the RF_ScanTiming primarily affects the latency of device detection on air as well as the current consumption. The lower the RF_ScanTiming, the faster the modules can find each other for communication, but also the more power will be consumed.

RF_ScanTiming	0	1	2	3*	4*	5*
Advertising interval [ms]	20	40	250	1000	5000	10240
Scan window [ms]	25	50	312	1250	6250	10240
Scan interval [ms]	Defined by the RF_ScanFactor.					
Connection setup timeout [s]	1	2	2	5	20	35
Current consumption						

*Mainly suitable for transmitting data using Beacons without consuming much energy.

Further information:

- In ACTION_SCANNING mode, the scan interval defines the time after which the module switches channel to detect other BLE devices in range. See also RF_ScanFactor.
- In ACTION_SCANNING mode, the scan window defines the section of the scan interval, where the module is scanning. During the remaining time, the module enters a suspend mode (system-on mode). See also RF_ScanFactor.

- In ACTION_IDLE mode, the advertising interval defines the time after which the module periodically sends its advertising packet. In between, the module enters a suspend mode (system-on mode).
- The connection setup timeout defines the time after which a connection request has to be answered by the peripheral.

Please ensure that all members of a network support the same advertising and scan timing parameters.

To ensure that the module is allowed to send a sufficient amount of advertising packets, please also check the RF_AdvertisingTimeout parameter.

To connect to an Android or iOS device, please first review their supported settings [1].

9.1.16.1 Example 1

Set the scan timing parameter to 0x00 using CMD_SET_REQ with settings index 9.

Start signal	Command	Length	Settings index	Parameter	CS
0x02	0x11	0x02 0x00	0x09	0x00	0x18

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.16.2 Example 2

Request the scan timing parameter of the module using CMD_GET_REQ with settings index 9

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x09	0x1A

Response CMD_GET_CNF: Successfully read out the value 4.

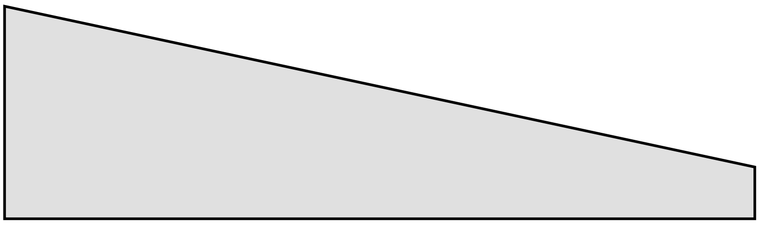
Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x04	0x54

9.1.17 RF_ConnectionTiming: Modify the connection timing settings

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
8	`RF_ConnectionTiming`	0 – 6	1	read/write	Flash	1

The `RF_ConnectionTiming` enables the possibility to configure the timing behaviour of the module's RF interface during an established connection. Using this parameter several predefined configurations can be chosen, which include the minimum and maximum connection interval, as well as the connection supervision timeout.

The choice of the `RF_ConnectionTiming` primarily determines how rapidly the connection is established and data is transmitted. The lower the `RF_ConnectionTiming`, the more frequently the connected devices communicate with each other and thus, the more power is consumed.

`RF_ConnectionTiming`	0	1	2	3	4	5	6
Minimum connection interval [ms]	8	20	50	200	750	2000	8
Maximum connection interval [ms]	30	75	250	1000	2250	4000	8
Connection supervision timeout [s]	4	4	4	8	15	25	4
Maximum throughput* [kB/s]	Up to 3.97	Up to 1.7	Up to 0.51	-	-	-	Up to 4.5
Current consumption							

*Measured with 230400 baud UART baud rate and payload size of 128Bytes between two AMB2621 modules.

More information:

- The minimum and maximum connection interval parameters specify the borders of the connection interval as determined in the negotiation procedure between the central and the peripheral during connection setup. The connection interval defines the frequency of communication during connection setup and data transmission.

If an AMB2621 module A (central) connects to an AMB2621 module B (peripheral), the connection interval settings of the central are used for connection setup. If both modules have different connection interval settings the peripheral requests the central to accept the peripheral's settings after 5s. The central accepts these settings, and thus the peripheral's connection interval is used.

If now another BLE device (e.g. a smart phone) connects as central to an AMB2621 module (peripheral) and the connection interval settings do not coincide, the AMB2621 requests the smart phone to accept its settings after 5s. If the cell phone does not accept the settings, it will be requested a further 3 times with a delay of 10s. If the peripheral's settings request have been rejected in all cases the connection will be shut down. If the smart phone itself requests to update the connection interval of the AMB2621, the module accepts the request.

Reversely, if an AMB2621 (central) connects to another BLE device (peripheral) and the connection interval settings do not coincide, the AMB2621 accepts all requests of the peripheral to update the connection parameter settings.

- The connection supervision timeout defines the time after which an already established connection is considered as lost, when no further communication has occurred.

ℹ Please ensure that all members (AMB2621s, cell phones and other BLE devices) of a network use the same connection timing parameters to avoid connection problems and changes of the connection interval during an opened connection.

ℹ To connect to an Android or iOS device, please first review their supported settings [1].

The minimal value of the minimum connection interval that is supported by iOS is 30ms!

9.1.17.1 Example 1

Set the connection factor to 0x00 using `CMD_SET_REQ` with settings index 8.

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x02 0x00	0x08	0x00	0x19

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.17.2 Example 2

Request the connection timing parameter of the module using `CMD_GET_REQ` with settings index 8

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x08	0x1B

Response `CMD_GET_CNF`: Successfully read out the value 1.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x01	0x51

9.1.18 RF_TXPower: Modify the output power

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
17	`RF_TXPower`	See description	4	read/write	Flash	1

This setting determines the output power in dBm of the module. The value has to be entered in hexadecimal and as two's complement. The permissible values are listed in the following table.

Permissible values									
Decimal [dBm]	-40	-30	-20	-16	-12	-8	-4	0	+4
Two's complement, hexadecimal	0xD8	0xE2	0xEC	0xF0	0xF4	0xF8	0xFC	0x00	0x04

9.1.18.1 Example 1

Set the output power of the module to -8 dBm, which is 0xF8 in two's complement notation, using `CMD_SET_REQ` with settings index 17

Start signal	Command	Length	Settings index	Parameter	CS
0x02	0x11	0x02 0x00	0x11	0xF8	0xF8

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.18.2 Example 2

Request the output power of the module using `CMD_GET_REQ` with settings index 17

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x11	0x02

Response `CMD_GET_CNF`: Successfully read out the value 0x04 = 4dBm

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x04	0x54

9.1.19 UART_BaudrateIndex: Configure the UART speed

Settings index	Designation	Permissible values	Default value	Permissions	Stored in	Number of bytes
11	`UART_BaudrateIndex`	See description	3	read/write	Flash	1

This parameter defines the baud rate used by the module's UART.

Possible values are:

`UART_BaudrateIndex`	0	1	2	3	4
Rate [Baud]	9600	19200	38400	115200	230400

ⓘ After changing the baud rate using the `CMD_SET_REQ` the module restarts using the new baud rate. Therefore don't forget to update the baud rate of the connected host to be able to further use the module's UART.

ⓘ Please note that due to the HF-activity of the chip, single bytes on the UART can get lost, when using a very fast UART data rate. In case of corrupted UART communication the module cannot interpret the sent request and thus does not return a confirmation.

9.1.19.1 Example 1

Set the baud rate index to 0x04 (230400 Baud) using `CMD_SET_REQ` with settings index 11.

Start signal	Command	Length	Settings index	Parameter (Length -1 byte)	CS
0x02	0x11	0x02 0x00	0x0B	0x04	0x1E

Response `CMD_SET_CNF`: Successfully modified the setting.

Start signal	Command | 0x40	Length	Status	CS
0x02	0x51	0x01 0x00	0x00	0x52

9.1.19.2 Example 2

Request the baud rate index of the module using `CMD_GET_REQ` with settings index 11

Start signal	Command	Length	Settings index	CS
0x02	0x10	0x01 0x00	0x0B	0x18

Response `CMD_GET_CNF`: Successfully read out the value 0x03, which equals 115200 Baud.

Start signal	Command | 0x40	Length	Status	Parameter (Length -1 byte)	CS
0x02	0x50	0x02 0x00	0x00	0x03	0x53

9.2 List of user settings

Settings index	Designation	Summary	Permissible values	Default value	Permissions	Stored in	Number of bytes
1	`FS_FWVersion`	Version of the firmware	-	-	read	Flash	3
2	`RF_DeviceName`	Name of the module	See description	"A2621"	read/write	Flash	1-5
3	`FS_MAC`	MAC address of the module	-	-	read	Flash	6
4	`FS_BTMAC`	BLE conform MAC address of the module	-	-	read	Flash	6
5	`RF_OwnLTK`	Long term key used when it is connected by another device	See description	"AMB_DEFAULT_KEY"	read/write	Flash	7-16
6	`RF_PeerLTK`	Long term key used to connect to another device	See description	"AMB_DEFAULT_KEY"	read/write	Flash / RAM	7-16
7	`RF_AdvertisingTimeout`	Time [s] after advertising stops. LSB first	0 (infinite) 1 – 65535	0	read/write	Flash	2
8	`RF_ConnectionTiming`	Module connection timing configuration	0 – 6	1	read/write	Flash	1
9	`RF_ScanTiming`	Module advertising and scanning timing configuration	0 – 5	1	read/write	Flash	1
10	`RF_ScanFactor`	Factor between scan interval and scan window	1 – 10	2	read/write	Flash	1
11	`UART_BaudrateIndex`	Baud rate of the UART	See description	3	read/write	Flash	1
12	`RF_SecFlags`	Security settings of the module	See description	0	read/write	Flash	1
13	`RF_ScanFlags`	Scan settings of the module	See description	0	read/write	Flash	1
14	`RF_BeaconFlags`	Beacon settings of the module	See description	0	read/write	Flash	1
15	`FS_DeviceInfo`	Information about the chip	-	-	read	Flash	12
16	`FS_SerialNumber`	Serial number of the module	-	-	read	Flash	3
17	`RF_TXPower`	Output power [dBm] Two's complement	See description	4	read/write	Flash	1

Settings index	Designation	Summary	Permissible values	Default value	Permissions	Stored in	Number of bytes
18	`RF_StaticPasskey`	6 digit pass key	See description	“123123”	read/write	Flash	6
44	`RF_SecFlagsPerOnly`	Security settings of the module (peripheral only mode only)	See description	3	read/write	Flash	1

Table 8 Table of settings

10 Peripheral only mode

The version 3.0.0 of the AMB2621 implements a new feature, that allows the easy integration of the AMB2621 BLE module to an already existing host. The peripheral only mode offers a plug and play installation without previous configuration of the AMB2621. It is tailored for easy communication with mobile BLE devices like smart phones.

10.1 What the peripheral only mode is

The peripheral only mode is a special operation mode, that uses the user settings and the peripheral functions of the normal mode described in the previous chapters.

It has to be enabled during the module start-up and contains the following key features:

- Peripheral only functions: The AMB2621 only contains the functions of a peripheral. Thus it is advertising until another BLE devices connects to it. In this case the UART of the AMB2621 is enabled, the LED_2 pin shows that the channel is open and bidirectional data transmission can start. As soon as the connection is closed, the UART is disabled again to save power.

  Since all central functions are no longer valid, the module cannot initiate any connection or run scans.

- Transparent UART interface: The serial interface of the AMB2621 is no longer driven by commands. This means, when the UART of the module is enabled (i.e. only when a channel is open, indicated by both LEDs active), data sent to the UART is transmitted by the AMB2621 to the connected BLE device. On the other hand, all data received by RF is send from the AMB2621 to the connected host without additional header bytes.

  Please have in mind that the connecting smart phone must support and initiate larger MTU sizes when payload sizes of more than 19 Byte shall be used. Additional bytes will be discarded without notice to the host.

  The data sent to the UART is buffered in the AMB2621 up to a maximum payload depending on of the current channel MTU. When no new byte was received for 20ms, the data will be transmitted by RF to the connected BLE device.

  The UART is only running, when a channel is open. Thus power is saved during the advertising period.

  Depending on the configured connection interval, only one packet per interval is allowed to be transmitted.

  Since the commands of the command interface are no longer valid, a AMB2621 cannot be configured when running in peripheral only mode.

- Pairing: The default security mode is the static passkey pairing method (see `RF_SecFlagsPerOnly`), with the default key “123123”.

10.2 Reasons to use the peripheral only mode

The AMB2621 peripheral only mode equips custom applications with a BLE interface (to be accessible by other BLE devices) without installation effort.

To setup a connection to the AMB2621 in peripheral only mode the central device has to insert the AMB2621’s static passkey. As soon as the channel to a connected BLE central device is open, the LED_2 pin switches on to signalize that data can be exchanged now. When the connection was shut down by the BLE central device, the LED_2 pin switches off again.

Due to the transparent UART interface, data can be exchanged without additional headers.

Furthermore, the peripheral only mode allows an energy efficient operation of the BLE interface, since the UART is only enabled when it is really used.

10.3 How to use the peripheral only mode

The peripheral only mode is enabled, when a high signal is present on the OPERATION MODE pin during device start-up or reset.

No configuration of the module is needed for this operating mode. The module shall be set to factory settings if reconfigured before so it uses the default user settings. In this case the UART uses 115200Baud 8n1 and static passkey pairing is used as authentication method.

If a configuration of the module is still needed (e.g. when another UART baud rate needs to be chosen), the module has to be started in normal mode and the `CMD_SET_REQ` may be used to update the user settings.

The user shall not change any other of the user settings but the following two parameters:

- `RF_UARTBaudrateIndex` (change the UART baud rate, default value “115200”)
- `RF_StaticPasskey` (change the default static passkey, default value “123123”)

Only changes (in comparison to the factory settings) in the two parameters `RF_UARTBaudrateIndex` and `RF_StaticPasskey` are allowed.

In case the module has been configured with other non-default user settings, while the command mode was used, a `CMD_FACTORYRESET_REQ` is mandatory before activating the peripheral only mode.

On the central side (e.g. smart phone), the AMBER SPP like profile has to be implemented in a customer application. For more information, see the “AMB2621 Advanced developer guide” and the application note *AMB2621_AN003* that explains the general connection.

10.4 More information

- The maximum payload supported by an open channel depends on the connected central device. The AMB2621 supports up to 128 Byte payload (corresponding to a MTU of 132 Byte), which may be negotiated by the central device (using a MTU request). If no MTU request is requested by the connecting central device the value of 19 Bytes payload per packet and connection interval as given by the BT 4.0 standard is used (compatibility mode to BLE 4.0 devices). Data received by the AMB2621’s UART, that exceeds the maximum payload size of the open channel, is discarded. In peripheral only mode, (due to the deactivated commands) the AMB2621 cannot inform its host about the maximum payload size or of payload discarding.
- The connecting device could implement a function to inform the host behind the AMB2621 which MTU the channel is capable of. Until this message is received, the host shall assume a payload capability of up to 19 Byte.

- Only in peripheral only mode, the name of the device is now longer the 5-digit `RF_DeviceName` that is saved in the user settings. The new 8-digit device name is "A-**123456**" in case of the module has the `FS_BTMAC` 0x0018DA**123456**. This is a workaround for iOS which does not allow access to the BT-MAC for received BT frames.
- The content of the advertising packet was changed in peripheral only mode. The TX power information block was removed, as the device name was extended to 8 digits.

11 Firmware update

The AMB2621 offers two possibilities of updating its firmware, namely wired or wireless.

The firmware of the AMB2621 consists of 3 parts, the OTA-bootloader, the Softdevice and the application. Ensure that after updating the firmware all parts are still existent.

11.1 Firmware update using the SWD interface

To update the firmware of the AMB2621 the SWD interface of the module and a supported flasher hardware (such as SEGGER J-Link plus) can be used. Therefore the pins GND, VCC, RESET, SWDIO and SWDCLK of the module have to be accessible and connected to the flasher hardware accordingly (corresponding documentation of flasher has to be read for further information). After the connection of a flash adapter to this SWD interface, the new firmware can be flashed using the corresponding PC software *nrfjprog.exe* available directly from Nordic Semiconductor.

```
nrfjprog.exe --family NRF52 --chiperase --program  AMB2621.hex
```

For this reason a .hex-file can be provided, which contains all firmware parts (bootloader, Softdevice, application). The name of the hex file has to be adopted accordingly in the command line above.

This is the only method by which the module could be recovered in the event of a serious software fault or corrupted memory. This method is fail-safe.

11.2 Firmware update using the AMB2621 OTA bootloader

The second method offers a possibility to update the firmware over the air (OTA). Therefore, the *Nordic nRF52 BLE DFU Bootloader* is integrated into the AMB2621's firmware, which will communicate over the BLE interface.

The OTA bootloader mode is a distinct operating mode besides the normal operating modes mentioned before.

For this reason, a .zip-file can be provided, which contains all (bootloader, Softdevice, application) parts of the firmware in an encrypted and authenticated package.

To start the bootloader, one of the following two conditions has to be satisfied:

1. send the command `CMD_BOOTLOADER_REQ` to the module to restart in bootloader mode
2. during a reset and while restarting, a low signal has to be present on the BOOT pin of the module to start it in bootloader mode

The bootloader mode has started successfully if LED_1 has turned on.

After the bootloader has started successfully, the module goes into the advertising mode using the name “DFU2621”. Now, any BLE device hosting an application that understands the commands of the *Nordic nRF52 BLE DFU Bootloader* can connect in order to update the AMB2621 firmware.

The DFU application of the AMB2621 Toolbox App is such an application. For more details, please refer to the AMB2621 Toolbox Quick Start Guide. As an alternative the plain apps from Nordic Semiconductor “nRF Toolbox” can be used.

Version of the firmware before the update	Version of the new firmware	Version of the AMB2621 Toolbox App (Android)
1.0.0 – 1.1.0	1.0.0 – 1.1.0	1.16.2, 1.18.4
1.0.0 – 1.1.0	2.1.0	Not supported due to S132 update and BL changes
2.1.0	2.1.0	1.18.4
2.1.0, 3.0.0	3.0.0	1.18.4 or Nordic nRF Toolbox 2.2.1

Table 9 Compatibility matrix

As soon as a connection has been set up, LED_1 turns off again and LED_2 turns on.

The implemented *Nordic nRF52 BLE DFU bootloader* uses a dual bank method to update the firmware. Thus the old firmware is only replaced once the new firmware has been transferred successfully. This prevents the module from being flashed with a faulty firmware.

An OTA firmware update will take several minutes to be performed, the duration is also dependant how much of the firmware shall be updated (application only or complete update).

The max connection interval of the update service is set to 30ms. Please check whether your mobile supports this speed.

This method is only applicable if the AMB2621 still contains an intact bootloader. In order to be able to recover a faulty module, we recommend to have access to the relevant JTAG pins required to perform a wired firmware update (see chapter 11.1).

12 Hardware integration

12.1 Footprint

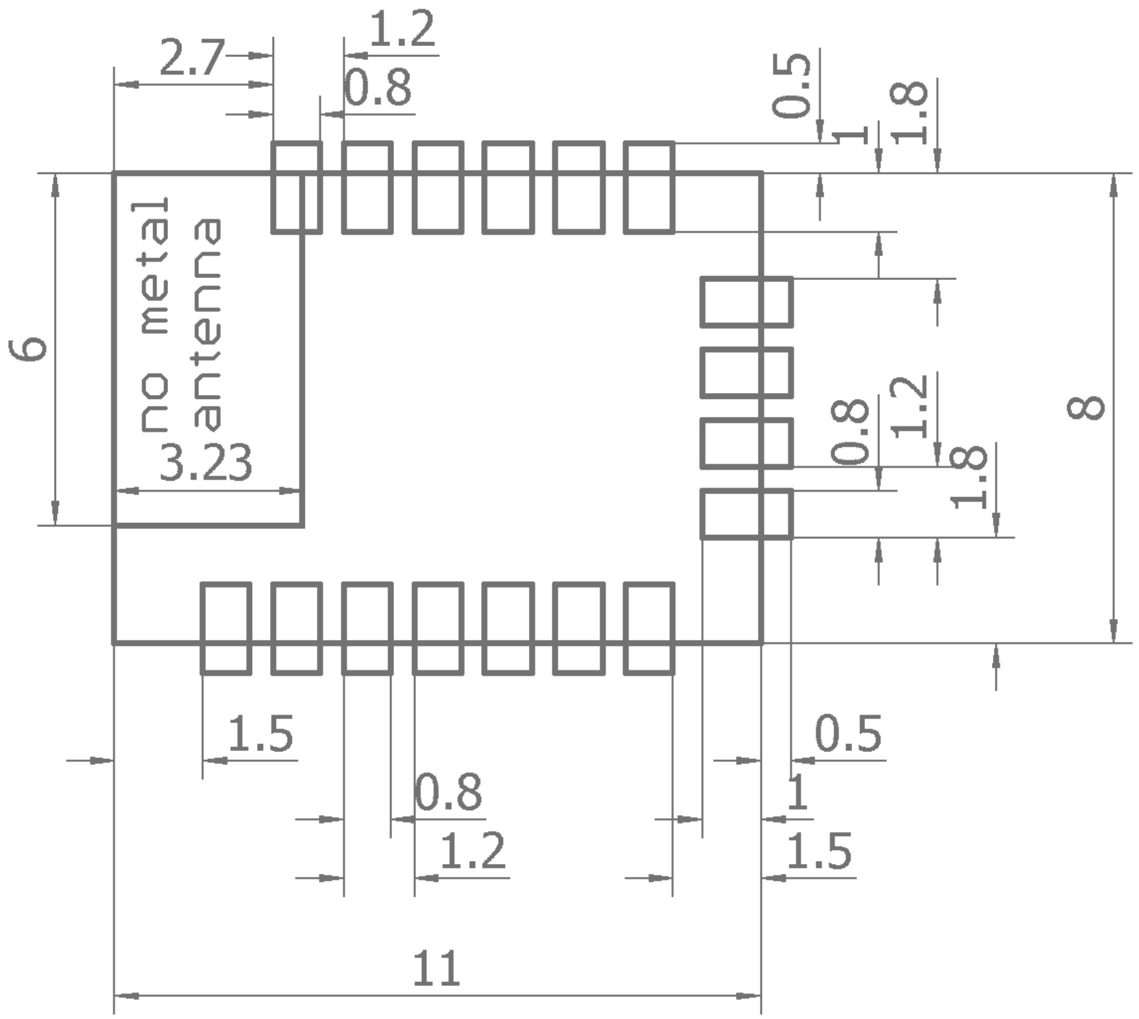


Figure 5 Footprint

Dimensions in mm.

12.2 General advice for schematic and layout

For less experienced RF users it is advisable to closely copy the relating evaluation board with respect to schematic and layout, as it is a proven design. The layout should be conducted with particular care, because even small deficiencies could affect the radio performance and its range or even the conformity.

The following general advice should be taken into consideration:

Radio performance parameters, such as sensitivity, may be affected by high frequency digital I/O with large sink/source current close to the radio, power supply and antenna pins.

- A clean power supply is strongly recommended. Interference, especially oscillation can severely restrain range and conformity.
- Variations in voltage should be avoided.
- LDOs, properly designed in, usually deliver a proper regulated voltage.
- Blocking capacitors and a ferrite bead in the power supply line can be included to filter and smoothen the supply voltage when necessary.

No fixed values can be recommended, as these depend on the circumstances of the application (main power source, interferences etc.).

- Elements for ESD protection should be placed on all Pins that are accessible from the outside and should be placed close to the accessible area. For example, the RF-Pin is accessible when using an external antenna and should be protected.
- ESD protection for the antenna connection must be chosen such as to have a minimum effect on the RF signal. For example, a protection diode with low capacitance such as the LXES15AAA1-100 or a 68 nH air-core coil connecting the RF-line to ground give good results.
- Placeholders for optional antenna matching or additional filtering are recommended.

Again, no fixed values can be recommended, as they depend on the influencing circumstances of the application (antenna, interferences etc.).

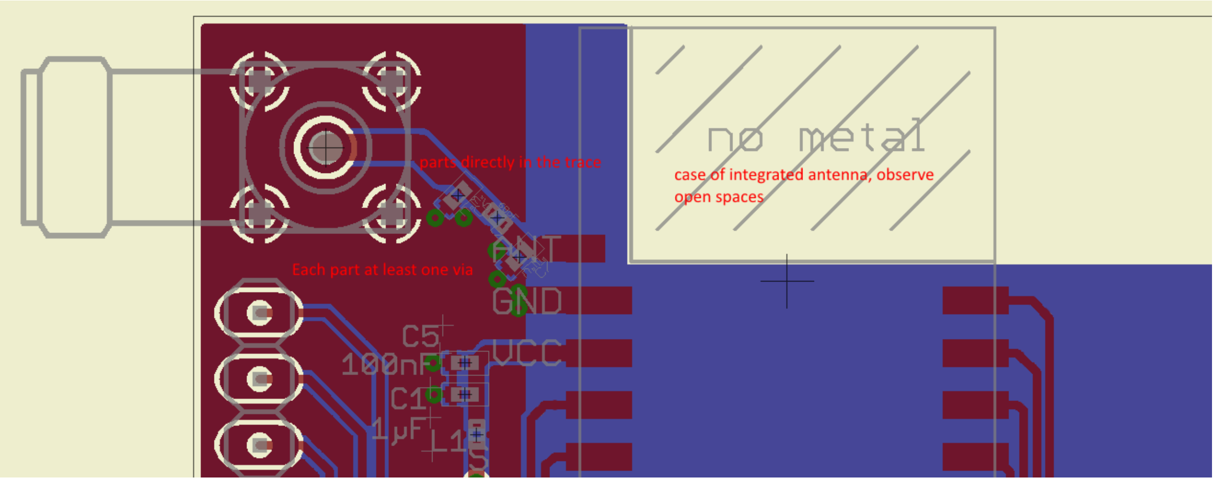

no metal
parts directly in the trace
case of integrated antenna, observe open spaces
ANT
Each part at least one via
GND
C5
100nF
VCC
C1
1µF
L1

Figure 6: Layout

- To avoid the risk of short circuits and interference there should be no routing underneath the module on the top layer of the printed circuit board.
- On the second layer, a ground plane is recommended, to provide good grounding and shielding to any following layers and application environment.
- In case of integrated antennas, it is required to have areas free from ground. This area should be copied from the evaluation board (respectively Figure 5).
- The area with the integrated antenna must overlap with the carrier board and should not protrude, as it is matched to be placed directly on top of a PCB.
- Modules with integrated antennas should be placed with the antenna at the edge of the main board. It should not be placed in the middle of the main board or far away from the edge. This is to avoid tracks being placed beside the antenna.

- Filter and blocking capacitors should be placed directly in the tracks without stubs, to achieve the best effect.
- Antenna matching elements should be placed close to the antenna/connector and blocking capacitors close to the module.
- Ground connections for the module and the capacitors should be kept as short as possible and with at least one separate through hole connection to the ground layer.
- ESD protection elements should be placed as close as possible to the exposed areas.

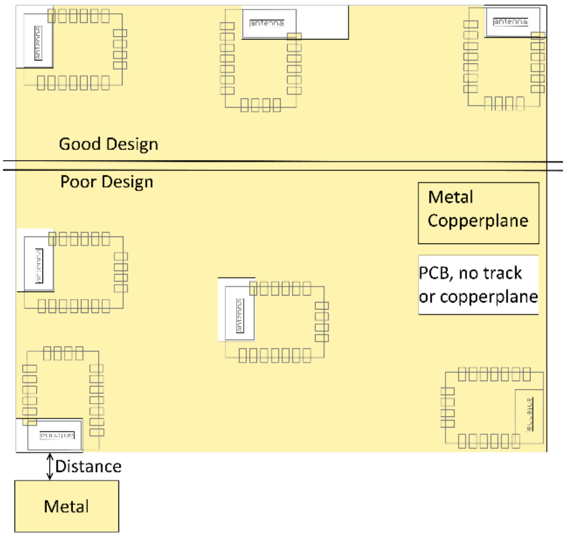


Figure 7: Placement of the module

12.3 Dimensioning of the 50 Ohm micro strip

The antenna track has to be designed as a 50 Ohm feed line.

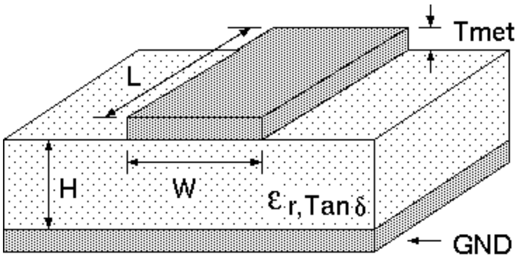


Figure 8 Dimensioning the antenna feed line as micro strip

The width W for a micro strip can be calculated using the following equation:

$$W = 1.25 \cdot \left(\frac{5.98 \cdot H}{e^{\frac{50 \cdot \sqrt{\varepsilon_r} + 1.41}{87}}} - T_{met} \right)$$

Equation 1 Parameters of the antenna feeding line

Example: a FR4 material with ε_r = 4.3, a height H = 1000 µm and a copper thickness of T_{met}= 18 µm will lead to a trace width of W ~ 1.9 mm. To ease the calculation of the micro strip line (or e.g. a coplanar) many calculators can be found in the internet.

- As rule of thumb a distance of about 3 x W should be observed between the micro strip and other traces / ground.
- The micro strip refers to ground, therefore there has to be the ground plane underneath the trace.
- Keep the feeding line as short as possible.

12.4 Antenna solutions

There exist several kinds of antennas, which are optimized for different needs. Chip antennas are optimized for minimal size requirements but at the expense of range, PCB antennas are optimized for minimal costs, and are generally a compromise between size and range. Both usually fit inside a housing. Range optimization in general is at the expense of space. Antennas that are bigger in size, so that they would probably not fit in a small housing, are usually equipped with a RF connector. A benefit of this connector may be to use it to lead the RF signal through a metal plate (e.g. metal housing, cabinet).

As a rule of thumb a minimum distance of λ /10 (3.5 cm @ 868 MHz, 1.2 cm @ 2.44 GHz) from the antenna to any other metal should be kept. Metal placed further away will not directly influence the behaviour of the antenna, but will never the less produce shadowing.

Keep the antenna away from large metal objects as far as possible to avoid electromagnetic field blocking.

In the following chapters, some special types of antenna are described.

12.4.1 Lambda/4 radiator

An effective antenna is a λ/4 radiator. The simplest realization is an 8.6 cm long piece of wire for 868 MHz, respectively a 3.1 cm long piece of wire for 2.44 GHz. This radiator needs a ground plane at its feeding point. Ideally, it is placed vertically in the middle of the ground plane. As this is often not possible because of space requirements, a suitable compromise is to bend the wire away from the PCB respective to the ground plane. The λ/4 radiator has approximately 40 Ohm input impedance, therefore matching is not required.

12.4.2 Chip antenna

There are many chip antennas from various manufacturers. The benefit of a chip antenna is obviously the minimal space required and reasonable costs. However, this is often at the expense of range. For the chip antennas, reference designs should be followed as closely as possible, because only in this constellation can the stated performance be achieved.

12.4.3 PCB antenna

PCB antenna designs can be very different. The special attention can be on the miniaturization or on the performance. The benefits of the PCB antenna are their minimal (if PCB space is available) costs, however the evaluation of a PCB antenna holds more risk of failure than the use of a finished antenna. Most PCB antenna designs are a compromise of range and space between chip antennas and connector antennas.

12.4.4 Antennas provided by AMBER

12.4.4.1 AMB1926

The AMB1926 is a 2.4 GHz antenna with SMA connection and swivel base.

13 Manufacturing information

- The assembly contains moisture sensitive devices of the MSL classification 3. Only the dry packed Tape & Reel devices (AMB2621-TR) are suitable for the immediate processing in a reflow process.
- Further information concerning the handling of moisture sensitive devices, (e.g. drying) can be obtained from the IPC/ JEDEC J-STD-033.
- Recommendations for the temperature profile for the soldering furnace cannot be made, as it depends on the substrate board, the number and characteristics of the components, and the soldering paste used (consult your EMS).

Figure 9 shows a soldering curve that had been used for a 31 cm² carrier board for single-side assembly.

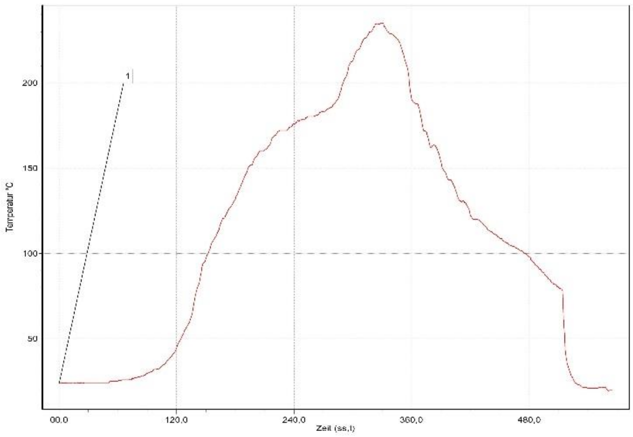


Figure 9 Example of a temperature profile

Caution: Must be adjusted to the characteristics of the carrier board!

To ensure the mechanical stability of the modules it is recommended to solder all pads of the module to the base board, even if they are not used for the application.

Caution! ESD sensitive device.

Care should be taken when handling the device in order to prevent permanent damage.

MSL 3

Caution! This assembly contains moisture sensitive components.

Care should be taken when processing the device according to IPC/JEDEC J-STD-033.

Since the module itself is not fused the voltage supply shall be fed from a limited power source according to clause 2.5 of EN 60950-1.

14 References

[1] Bluetooth Core Specifications 4.0 and 4.2

Source: https://www.bluetooth.com/specifications/adopted-specifications

[2] Nordic Semiconductor Infocenter

Source: http://infocenter.nordicsemi.com

15 Firmware history

Version 0.x.x

- Pre-Release for test run

Version 1.0.0

- First production release
- New command interface with 2 Byte length field
- using Softdevice 2.0.1 + SDK 11.0
- SPP-Like Protocol
- Known issues: CMD_SET_REQ does not run with parameter `RF_AdvertisingTimeout`

Version 1.0.1

- Fixed issues:
    - CMD_SET_REQ does not run with parameter `RF_AdvertisingTimeout`
- UART checks for max buffer size
- Known issues: None

Version 1.1.0

- Fixed issues:
    - DCDC enabled for lowest power consumption
- Known issues: None

Version 2.1.0

- Change notes:
    - Using Softdevice 3.0.0 and SDK 12.1.0
    - Remove UART baud rates faster than 230400 baud to prevent lost bytes
    - due to DMA usage the UART current is increased (without DMA the UART data rate must be decreased further below 230400 baud)
    - Introduced `CMD_ERROR_IND` message indicating internal error states
    - Introduced support for transmission of large BLE packets (19 bytes payload → 128Bytes payload). This is a non-mandatory BLE 4.2 feature. Use `CMD_DATA_REQ` command to send long packets if it is indicated by the `CMD_CHANNELOPEN_RSP`.
    - Modified the `CMD_CHANNELOPEN_RSP` indication the max. supported payload size
    - `CMD_DATA_REQ` returns maximum supported payload size if it was exceeded
    - Modified `RF_ConnectionTiming` profile 0 and added profile 6
    - Modified the `CMD_SECURITY_IND` message
    - DTM uses max packet size for TX test packets (255 bytes)
    - Parameter `RF_SecLTK` replaced by `RF_OwnLTK` and `RF_PeerLTK`
    - Added commands `CMD_SET_RAM_REQ` and `CMD_GET_RAM_REQ` to set/get volatile RAM parameter values (only `RF_PeerLTK` at the moment)
    - Moved the settings index of parameter `RF_TXPower`
    - New OTA bootloader
    - AMB2621 Toolbox App version 1.18.4 must be used to update the firmware
    - `CMD_DATAEX_REQ` removed due to incompatibilities with foreign BLE devices
    - Added new security concept. Now the peripheral decides whether the security level is sufficient.
    - Added new security mode in `RF_SecFlags` (Static pass key method was added)
    - New user setting `RF_StaticPasskey` added
    - New commands `CMD_PASSKEY_REQ` and `CMD_PASSKEY_IND` added
- Known issues:
    - OTA update from version 1.1.0 to 2.1.0 not supported
    - Compatibility of version 2.1.0 to older versions only given when no security mode is enabled

Version 3.0.0

- Change notes:
  - Using Softdevice 3.1.0 and SDK 12.1.0
  - Changed default value of user setting parameter `RF_AdvertisingTimeout` from 180s to 0s. This means, that in default configuration the module does not go to sleep after 180s as in the previous firmware versions.
  - Function of LED_2 has changed. Now it indicates whether a channel is open or not.
  - Introduced new operation mode “Peripheral only mode” with special behaviour
    - Introduced new Advertise format containing the LSBs of the MAC address (only for Peripheral only mode)
    - Introduced PIN “`OPERATION MODE`“ to enable the Peripheral only mode, as an internal pull-down is used the “do not connect if not needed” still applies for normal mode operation
    - Introduced a transparent UART interface (only available for this mode)
    - Introduced a new user setting `RF_SecFlagsPerOnly`
- Known issues:
  - OTA update from version 1.x.x to 3.0.0 not supported

16 License information

The AMB2621 firmware contains the following software or software-parts provided by Nordic Semiconductor:

- „S132 Softdevice“ which is the actual BLE 4.2 Stack in a binary format
- nRF5 SDK containing drivers, library's and source code example projects

Those software parts are allowed to be used only on Nordic Semiconductor hardware.

For complete license information (“NORDIC SEMICONDUCTOR STANDARD SOFTWARE LICENSE AGREEMENT“) please refer to the corresponding documents of Nordic Semiconductors (e.g. S132 Softdevice 3.1.0 or nRF5 SDK 12.1.0).

All other firmware components are property of AMBER wireless GmbH.

17 Bluetooth SIG listing & qualification

Each product containing intellectual property of the Bluetooth SIG must be listed and qualified by the Bluetooth SIG. Due to the qualification of the AMB2621 as end product no further Bluetooth tests are required.

Please refer to the testing laboratory of your choice for further more detailed information regarding the listing of your product.

17.1 AMB2621 listing details

Declaration ID: D033500

QD ID: 90212

Specification Name: 4.2

Project Type: End product

Model Number: AMB2621

17.2 nRF52832 listing details

Nordic Bluetooth low energy QD ID: 80428 (nrf52832 CIAA using Softdevice S132 v3.x.x)

18 Regulatory compliance information

18.1 Important notice

The use of RF frequencies is limited by national regulations. The AMB2621 has been designed to comply with the R&TTE directive 1999/5/EC and the RED directive 2014/53/EU of the European Union (EU).

The AMB2621 can be operated without notification and free of charge in the area of the European Union. However, according to the R&TTE / RED directive, restrictions (e.g. in terms of duty cycle or maximum allowed RF power) may apply.

Conformity assessment of the final product

The AMB2621 is a subassembly. It is designed to be embedded into other products (products incorporating the AMB2621 are henceforward referred to as "final products").

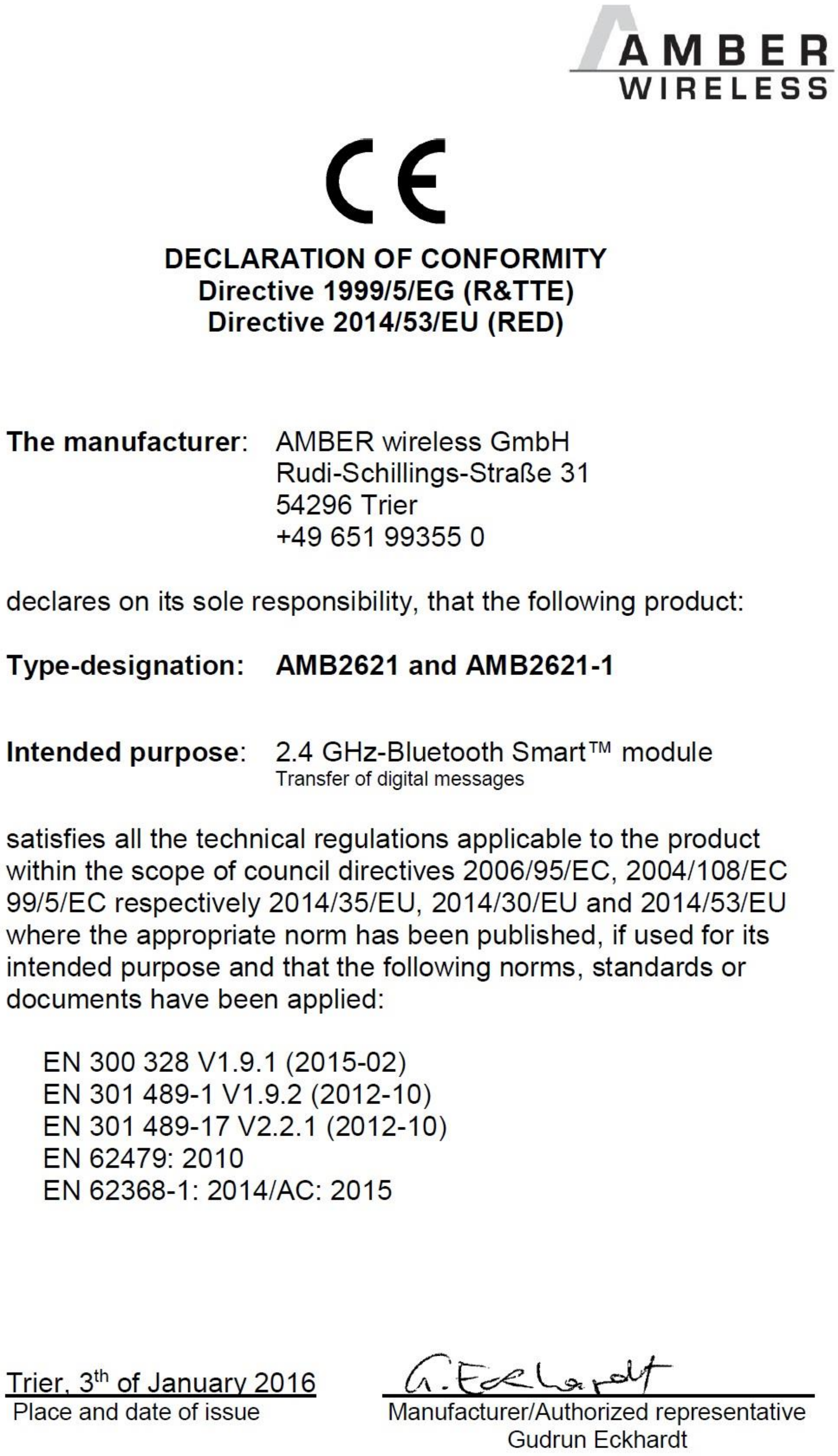
It is the responsibility of the manufacturer of the final product to ensure that the final product is in compliance with the essential requirements of the European Union's Radio & Telecommunications Terminal Equipment (R&TTE) directiveor rather the Radio Equipment Directive (RED).

The conformity assessment of the subassembly AMB2621 carried out by AMBER wireless GmbH does not replace the required conformity assessment of the final product in accordance to the R&TTE or rather the RED.

Exemption clause

Relevant regulation requirements are subject to change. AMBER wireless GmbH does not guarantee the accuracy of the before mentioned information. Directives, technical standards, procedural descriptions and the like may be interpreted differently by the national authorities. Equally, the national laws and restrictions may vary with the country. In case of doubt or uncertainty, we recommend that you consult with the authorities or official certification organizations of the relevant countries. AMBER wireless GmbH is exempt from any responsibilities or liabilities related to regulatory compliance.

18.2 Declaration of conformity



DECLARATION OF CONFORMITY
Directive 1999/5/EG (R&TTE)
Directive 2014/53/EU (RED)

The manufacturer: AMBER wireless GmbH
Rudi-Schillings-Straße 31
54296 Trier
+49 651 99355 0

declares on its sole responsibility, that the following product:

Type-designation: AMB2621 and AMB2621-1

Intended purpose: 2.4 GHz-Bluetooth Smart™ module
Transfer of digital messages

satisfies all the technical regulations applicable to the product within the scope of council directives 2006/95/EC, 2004/108/EC 99/5/EC respectively 2014/35/EU, 2014/30/EU and 2014/53/EU where the appropriate norm has been published, if used for its intended purpose and that the following norms, standards or documents have been applied:

EN 300 328 V1.9.1 (2015-02)
EN 301 489-1 V1.9.2 (2012-10)
EN 301 489-17 V2.2.1 (2012-10)
EN 62479: 2010
EN 62368-1: 2014/AC: 2015

Trier, 3th of January 2016
Place and date of issue

Manufacturer/Authorized representative
Gudrun Eckhardt

18.3 FCC Compliance statement AMB2621

FCC ID: R7TAMB2621

This device complies with Part 15 of the FCC Rules.

Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and

(2) this device must accept any interference received, including interference that may cause undesired operation.

(FCC 15.19)

Modifications (FCC 15.21)

Caution: Changes or modifications for this equipment not expressly approved by AMBER wireless may void the FCC authorization to operate this equipment.

18.4 IC Compliance statement AMB2621

Certification Number: 5136A-AMB2621

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

19 Important information

19.1 Exclusion of liability

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